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AN INVESTIGATION OF SOME CONTEMPORARY PROBLEMS IN ASTRONOMY AND ASTROPHYSICS BY WAY OF EARLY ASTRONOMICAL RECORDS

BY

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Kevin K. C. Yau

ABSTRACT

Early astronomical records of comets, supernovae, novae, sunspots and aurorae from Far Eastern dynastic histories together with records from Babylonians cuneiform tablets are compiled and analysed. The present investigation gives new insight into the three following topics in current astronomy and astrophysics.

(1) Halley's Comet

Past orbits of Halley's Comet since 240 BC are studied in detail using mainly early Chinese observations. The date of perihelion passages are deduced for each return. The only gap in the Chinese records, for the return of 164 BC, is now filled by the discovery of two records on Babylonian tablets. This discovery improves the date of perihelion, which is established as within one week of Nov 16 in 164 BC. We are now confident that every return of Halley's Comet from 240 BC onwards has been recorded.

(2) Supernovae and Novae

A catalogue of historical supernovae and novae is compiled. Descriptions regarding the position of the eight well known supernovae SN 185, 386, 393, 1006, 1054, 1181, 1572 and 1604 are re-evaluated in term of recent studies. The spurious supernova SN 1408 is discussed in detail and found that there is insufficient evidence supporting a supernova interpretation. The positions of 26 well recorded historical novae are discussed in depth and their coordinates are deduced.

(3) Solar Variability

Catalogues of naked-eye sunspots and aurorae are compiled from Far Eastern sources. Analysis of these records suggests an average period of about 10 years for the basic solar cycle. Observational factors such as variation with the phases of the Moon are also discussed. A comparison of these data with other proxy indicators like ^{14}C and ^{10}Beshows a similar trend in the behaviour of the Sun over the last two thousand years.

CONTENTS

Preface

The work presented in this thesis was carried out by the author while he was a research student under the supervision of Dr F. R. Stephenson at the department of Physics, University of Durham, between April 1984 to May 1987. Some of the work presented here have already been published or in press.

Publication List

1. "Oriental Tales of Halley's comets", 1984, *New Scientist*, **103**, 30-32. (with F.R. Stephenson)
2. "Records of Halley's comet on Babylonian tablets", 1985, *Nature*, **314**, 587-592. (with F.R. Stephenson and H. Hunger)
3. "Far Eastern Observations of Halley's Comet: 240 BC to AD 1368", 1985, *J. Brit. Interplanetary Soc.*, **38**, 195-216. (with F.R. Stephenson)
4. "Halley's Comet and Babylon", 1985, *Spaceflight*, **27**, 360. (with F.R. Stephenson)
5. "The New Star of AD 1408 - A Spurious Supernova", 1986, *Q.Jl.R. astr. Soc.*, **27**, 559-568. (with F.R. Stephenson)
6. "Some New Light on Historical Novae and Supernovae", 1986, *Bull. AAS,* **18**, 1043. (with F.R. Stephenson)
7. "Four Korean 'Guest Stars' observed in AD 1592", 1987, *Q.Jl.R. astr. Soc.,* **28**, 431-444. (with F.R. Stephenson)
8. "A Revised Catalogue of Far Eastern Observation of Sunspots (165 BC to AD 1918)", June 1988, *Q.Jl.R. astr. Soc.,* **29**, in press. (with F.R. Stephenson)
9. "Seasonal and Secular Variations of the Oriental Sunspot Sightings", 1988, (with D.M. Willis, C.M. Doidge, M.A. Hapgood and F.R. Stephenson). In *Secular Solar and Geomagnetic Variations in the Last 10,000 Years*, ed. F.R. Stephenson and A.W. Wolfendale, Reidel, Holland (in press).
10. "Analysis of Pre-telescopic and Telescopic Sunspot Observations", 1988, In *Secular Solar and Geomagnetic Variations in the Last 10,000 Years*, ed. F.R. Stephenson and A.W. Wolfendale, Reidel, Holland (in press).

Books

Halley's Comet in History, 1985, British Museum Publications Ltd. (with H. Hunger, F.R. Stephenson and C.B.F. Walker)

CHAPTER 1

INTRODUCTION

Celestial events like the sudden darkness due to a total solar eclipse, the awesome appearance of comets, the shooting stars across the sky and the moving planets along the ecliptic must have evoked two basic human characteristics, curiosity and fear, amongst early man. Occasionally, one of these strange phenomena in the sky might have coincided with tragedies like the death of a prominent person or ruler, or a natural calamity like a drought or pestilence. It must have been natural for human experience to relate an unusual sky phenomenon in the present with a similar terrestrial misfortune in the past. It appears that the ability to interpret celestial omens and predict their likely outcome would have been the principal motive behind a constant watch of the sky since time immemorial. Another reason might possibly be due to social development. In order for early man to achieve a relatively more organised agricultural society, the ability to keep time and maintain an accurate calendar in step with the seasons seemed prerequisite. There were no better devices than the rising and setting of the Sun in the day and changing positions of the Moon, planets and stars in the night.

Before writing had been developed, astronomical knowledge was circulated and passed down in an oral form and is still to be found from legends and folklores of many cultures. Beginning with the first inscriptions made on rocks or animal bones and followed much later on clay tablets, bamboo strips and eventually paper, today we have access to a wealth of astronomical records resulting from many generations of diligent astronomers. It is based on this wealth of astronomical data that I have carried out my investigation and analysis which I present in this thesis.

1.1 An Overview on Previous Investigations

The use of ancient observations to help solve contemporary problems in astronomy is by no means new. The subject can at least be traced back to Hipparchus (2nd century BC) and Ptolemy (2nd century AD), both of whom used ancient Babylonian observations to improve lunar and planetary ephemerides. However, the modern study of historical records was started – as with many other astronomical foundations – by Johannes Kepler (1571–1630). In one of Kepler's book *Ad Vitellionem Paralipomena, quibus Astronomiae Pars Optica traditur* of 1604, he mentioned that the duration and degree of obscuration of solar eclipses deduced from records found in ancient literature did not match those calculated from contemporary theory. He hoped to correct the sizes and mutual distances of the Sun, Moon and Earth from comparisons with ancient eclipses. Edmond Halley (1656–1742) in 1695 also investigated eclipse observations from antiquity and inferred that the mean motion of the Moon was being accelerated (Halley, 1695). As is well known, Halley was the first to analyse cometary records and successfully predicted the return of a comet in 1758 which now bears his name (Halley, 1705).

Not very much progress in the field was made in the 18th century, perhaps the most noteworthy achievement being that of Richard Dunthorne (1749), who managed to fix the acceleration of the Moon (as about 10 arcsec/century^2) from early eclipse records. In the 19th century, not only historical solar eclipse and cometary records were sought by astronomers, sunspot records were also employed to study the solar cycle. Wolf (1856, 1868) investigated records of sunspots back to the first telescopic sighting in 1610. He was able to trace the cycle throughout much of this time. Sporer (1887,

1889) and later Maunder (1890, 1894) suggested from the deficiency of sunspot records in the 17th century that the activity of Sun varied on a long time scale.

In 1843, Biot (1843a,b) made an extensive translation of Chinese astronomical records of both comets and new stars. It helped astronomers like Laugier (1843, 1846) and Hind (1850) to identify earlier returns of Halley's Comet. Later in the same century, Newcomb (1878) discussed and extended the theory on the rate of rotation of Earth from early eclipses.

The present century saw an increased interest in early astronomical records. Lundmark (1921) published a listing of Chinese guest stars and associated them with suspected novae. However, it was Hubble (1928) who gave the first positive identification of the guest star observed by Chinese astronomers in AD 1054 as the supernova outburst which produced the remnant in the Crab Nebula. Interest in the study of historical supernovae has been continued during the following decades, notably by Baade (1943, 1945), and culminated with the *The Historical Supernovae*, a classic work by Clark and Stephenson (1977).

While progress was also being made in the area dealing with the rate of Earth's rotation. Fotheringham (1915, 1920) obtained solutions for the acceleration of both the Moon and Sun in Classical time from a study of ancient eclipses. Later Spencer Jones (1939) showed that the apparent solar acceleration and part of the lunar acceleration merely due to the real deceleration of the Earth's rate of axial rotation. This set the scene for studying changes in the Earth's rotation rate in the past by Newton (1970, 1972), Stephenson and Morrison (1984).

The 1910 return of Halley's Comet stimulated Cowell and Cromelin (1907d,1908b–e) to investigate its past orbit. They claimed to have established identifications with records as early as 240 BC. A detailed examination of Chinese records of Comet Halley by Kiang (1972) showed discordances in only a few cases with the results of Cowell and Crommelin. This provided the basis for a further study by Yeomans and Kiang (1981). Significant progress was made in the 1970s with the study of the solar activity cycle. Eddy (1976) made a lengthy evaluation of the telescopic sunspot records and reaffirmed the existence of the Maunder Minimum (AD 1645–1715).

As the study of ancient observations requires competence in both astronomy and history, the field has never been overcrowded. The main objective of this field, which is now usually known as *Applied Historical Astronomy* coined by F.R. Stephenson (private communication), is to deduce from historical records a solution of some outstanding present day problems in astronomy where modern data is inadequate. This is effectively an extension backwards in time of modern observational studies. The present investigation aims especially to collect early astronomical data and perfect some techniques of analysis in the rising field of Applied Historical Astronomy.

Most naked-eye observations achieved an accuracy of no better than a large fraction of a degree, but they have a distinct advantage. Namely, they cover a very long time span. As a result their application in the study of long term variational problems is indispendable. The four major areas of interest in the application of early astronomical records are in the study of the past orbit of Halley's Comet, historical novae and supernovae, solar variability problems – which are the main topics in astronomy and astrophysics – and the rate of Earth's rotation in the field of geophysics. These four subjects are by no means the only problems in which early astronomical records can be applied. A wide varieties of other disciplines across many fields like chronological dating, studies of calendrical methods and early astronomical instrumental techniques also find the use of early astronomical records.

However, the present thesis will consist only three parts from an investigation of the three main themes in astronomy and astrophysics. Part I will be a study of comets with a special emphasis on Halley's Comet. In Part II, a study of 'guest stars' and their relationship to supernovae and novae will be presented. The final part will be concerned with a study of solar variability by way of early records of naked-eye sunspots and aurorae.

1.2 A General Survey of World Data

Prior to any data analysis, the acquisition of data will be the initial step. (Either an experiment is performed and data obtained there afterwards or the data will have to be collected by some other means). The data for the present study is collected entirely from a variety of historical texts belonging to different cultures. It seems that a survey of both the source and quantity of these materials is a prerequisite. However, it will have to be stressed that this is not meant to be a detailed survey of the world astronomical development through history; this would have occupied many volumes and in any case is not the primary concern here. I shall emphasize only the contribution of the early observational data from the various astronomical cultures and leave out information relating to observational techniques or theories, and calendrical or instrumental methods.

The development of astronomy prior to about 700 BC may be regarded as elementary and our knowledge of this period is very incomplete. Before written records were kept, primitive cultures left some pre-literate astronomical records in the form of stone monuments and cave paintings. Astronomical development since the first extant written records may be divided into the following four periods: (i) Semi-Legendary Period (c.2000 BC to c.700 BC); (ii) Ancient Period (c.700 BC to c.AD 750); (iii) Medieval Period (c.AD 750 to c.1500) and (iv) Modern Period (c.1500 to present).

The Semi-Legendary Period begins approximately with the first extant astronomical record and ends with the first series of astronomical observations recorded on Babylonian tablets and in the Chinese chronicle *Ch'un Ch'iu* ('Spring and Autumn Annals') around 700 BC. Due to the fragmentary nature of the records, only an exiguous understanding of this period can be made and perhaps one or two glimpses into its activity. For instance, the earliest datable astronomical observation is a lunar eclipse from Sumeria, dated 25 July 2095 BC (Huber, 1982).

The ancient period extends right through the times of Antiquity to the beginning of the Islamic astronomical inheritance. The Medieval period signals the height of both Chinese and Islamic astronomy. This period closes on the decline of these two centres and begins with the upsurge of astronomical ideas in Europe. Lastly, the modern period initiates with the astronomical revolution in the Renaissance Europe and invention of the telescope right up to present day astronomy. The intertwining nets of astronomical development (Fig. 1.1) and rise and fall of its centres throughout the world are complex. The overall picture may appropriately be divided into four branches: (1) the Western Heritage; (2) the Middle Eastern Connection; (3) the Far Eastern Traditions; and (4) the Lost Mesoamerican Civilisations.

1.2.1 The Western Heritage

(1) Egyptians

The ancient Egytians are known to have employed a lunistellar calendar from which developed a system of a 365-day year. Each year has three seasons of four 30-day months with an extra 5 days added at the end. The division of the 30 day month into three 10 day 'weeks' is dependent on the visibility of certain stars known as decans rising at nightfall (Neugebauer, 1955). It is generally believed that we have inherited from the Egytians the 24 hour day and calendar year of 365 days. Apart from perhaps

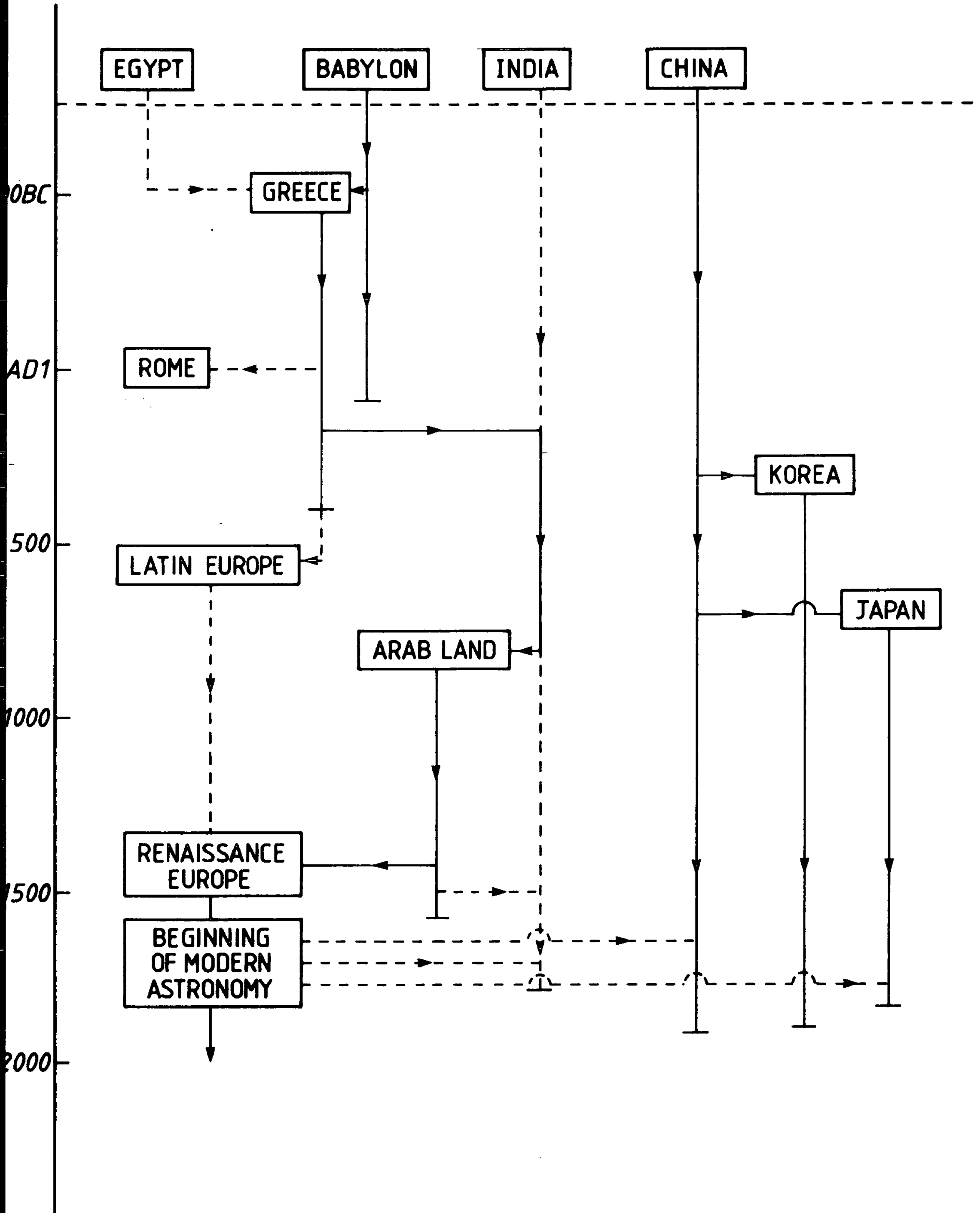


Fig. 1.1 A schematic diagram showing the principal routes of transmission of astronomical knowledge between the various cultures.

the well known observations of Sirius there is not very much else known about Egytian astronomy. Diodorus Siculus writing in the 1st century BC mentioned that the positions and motions of stars and planets were the subject of careful observation among the Egyptians (Diodorus Siculus, *Bibliotheca* I, 81). However, there is no evidence of a technical vocabulary or written record to suggest that the movements of the Moon and planets were systematically observed and recorded as they were in Babylonia. On the contrary, modern researchers believed that astronomy in Egypt was only implied (Parker, 1974).

Through the long ancient Egyptian history, there is only a single questionable record of an eclipse (Neugebauer, 1957). It is not until the third century B.C. that the earliest account mentioning the work of any Egyptian astronomer was found; an attribution inscribed on the statute of an astronomer named Harkhebi (Neugebauer and Parker, 1969). However by that time, external influence had already overshadowed any, if there were any, accomplishments which might be credited to early Egypt.

None the less, there are many references in ordinary texts mentioning the Sun, Moon and stars, especially Ṣirius (*Sothis* in Egyptian). The main sources of these references are from inscriptions on the inside of coffin lids and ceilings of tombs and temples. Of particular interest are 12 star clocks on coffin lids ranging from the Ninth to the Twelfth Dynasties. Also there are 81 monuments (majority are tomb ceilings) inscribed with celestial figures and may be grouped into families: the Senmut family, the Seti IA family and the Seti IC family, all three of rising decans. The Seti IB family are the transitting decans. Also the Tanis family which is a family with uncertain classification.

Ever since Jean Francois Champollion made the first successful attempt at decoding of the hieroglyphics in the early 19th century, there had been many attempts to collect astronomical information from hieroglyphic inscriptions. One of the notable collection was by Karl Richard Lepsius who led an expedition between 1842–45. A German called Heinrich Brugsch also edited many inscriptions into a *Thesaurus Inscriptions Inscriptionus Aegyptiacarum* contained in 5 volumes. The vol 1 in the series, *Astronomical and Astrological Inscriptions on Ancient Egyptian Monuments* was published in Leipzig in 1883. But these inscriptions related to religious symbols rather than anything else. It seems that astronomy was regarded as a lightweight science in ancient Egypt and limited to what is found in temples and burial grounds.

(2) Babylonians

We inherited from the Babylonians the sexagesimal number system, that is 360° in a circle, 60 minutes to the hour and 60 seconds to the minute. The predecessors to the Babylonians were the Sumerians who occupied Mesopotamia, in the present day southern Iraq. Mesopotamian astronomy probably began at about 2000 BC and not much is known before this date. Around 2000 BC, some of the earliest recorded observations of lunar eclipses which possibly occurred in 2095 and 2053 BC were found (Huber, 1982). Little was known about Babylonian astronomy apart from brief references found in Classical writings; a small selection of late Babylonian eclipse observations was quoted by Ptolemy dates from 721 BC to AD 136.

It was not until the mid-1870s that an archive of clay tablets from Babylon was accidentally uncovered by inhabitants of the nearby town of Hillah looking for baked bricks for re-use in buildings. The majority of these tablets was acquired by the British Museum through the dealer Spartali and Co. in Baghdad between 1876 and 1882, and only isolated pieces have gone to museums in other parts of the world, e.g. Berlin and Chicago. As no record of archeological context were kept, the original site could not be traced. It seems that the large portion of these tablets are from a single site in Babylon with possibly others from sites in Uruk, Borsippa and Sippar. Also, some tablets were added to the British Museum's collection through its own excavations at Babylon led by Rassam in the early 1880s (Hunger, Stephenson, Walker and Yau, 1985).

Drawings of most of the tablets which contained astronomical observations known by the name of astronomical diaries have been published by Sachs (1955) in *Late Babylonian Astronomical and Related Texts*. The work is essentially a compilation of about 1600 Babylonian astronomical texts hand-copied in the 1890s by T.G. Pinches and Father J.N. Strassmaier. Their work remained hidden in the British Museum archives for 60 years before they were rediscovered by Sachs. It was hoped that the total of 2000 or so known texts would be translated and published by Sachs – who spent 30 years editing and translating them. However, since Sachs' death in 1983, the task of publication is now left in the hands of Hermann Hunger of Vienna University and is in an advanced state of completion.

Apart from a short list of Venus sightings in the reign of King Ammizaduqa around 1700 BC, the earliest known Babylonian astronomical observation is a lunar eclipse whose date corresponds to BC 721 March 19. From this date to about 40 BC, we have a large number of fragments of astronomical diaries from extensive daily observations of naked-eye astronomical phenomena (see Section 1.3.1 below). The bulk of the observations is concerned with the movements of the Moon and planets. The observers held to a fairly strict observational schedule which concentrated on prediction processes in order to improve existing theory. There are very few records of observation of comets and no known sightings of new stars or sunspots. The absence of sunspot sightings is possibly due to the clear sky over that area. Even so, the Babylonians used to time the sunrise and sunset and watched for eclipses so must have watched the Sun regularly.

Babylonian observations of the sky are believed to have been carried out by astronomers in the city of Babylon (15 km north of present day Baghdad: Lat 32°33′N and Long 44°26′E) using as observatory the Ziggurrat of Marduk (Diodorus Siculus, *Bibliotheca* II, 9). The tradition of keeping astronomical records on clay tablets was probably started sometime in the 8th century BC. Ptolemy referenced in the *Almagest* that the earliest astronomical observations available to him were from the time of the Babylonian King Nabonassar (747–734 BC). The main objective of keeping a record of observation of celestial events on tablets was astrological; a regular and permanent record of astronomical events would facilitate better predictions. In recent times however, Babylonian records proved to be one of the important sources of astronomical data. Notable records are the observation of Halley's Comet in 164 BC and 87 BC (see section 3.5). The many accurately timed eclipses also proved to be the main source of ancient data in tracking the rate of Earth's rotation back in the past (Stephenson and Morrison, 1984).

(3) Hellenistic and Roman Period

Early Greek astronomy mainly concerned with practical problems like keeping the time and regulating the calendar. From about the 5th century BC, astronomical traditions developed in three different ways accordingly described in the literary, philosophical and scientific works. Of special interest are some of the early philosophical speculations in astronomy. For instance, Pythagoras first proposed the idea of a round Earth and his student Philolaus attempted to explain its motion in the celestial globe.

Both Plato and Aristotle had written on astronomy. Yet Plato himself regarded the profession of astronomy as a lowly occupation and consequently paid no seriously attention in the subject. Little original astronomical work came from Aristotle, he merely edited the works of other authors before him. He gave sound proofs that the

Earth is a sphere, but this achievement was somewhat overshadowed by Aristotle's erroneous demonstration of the absolute immobility of the Earth (4th century BC).

Among the early Greeks, one notable scientific development was found in the work by Hipparchus (2nd century BC). He was able to derive some useful results from a series of observations regarding the movement of planets. He was also credited with the first accurate measurement of the distance of the Moon and the first known catalogue of stars. Another important development was in the measurement of the circumference of Earth by Eratosthenes.

We have to come down to the 2nd century of our era to find any observational record. The principal source is in the *Almagest*, the work of the great Hellenistic astronomer Claudius Ptolemy who was born in Alexandria and believed to be a descendant of the Egyptian royal family. The exact dates of his birth and death are not known. However, we could deduce from his astronomical observations, the earliest on AD 127 and latest AD 151, that he lived and worked around the 2nd century AD.

His monumental piece of work the *Mathematike Syntaxis* which is now known by its Arabic name as *Almagest* ('the Greatest'), contains the most important theory on the geocentric motion of the planets and a catalogue of 48 constellations and 1050 stars. It also preserved a small collection of accurately dated Babylonian and Greek observations on the Moon and planets. However, these were cited as illustrative examples which included measurements of equinoxes. The few Greek observations of lunar eclipses and conjunctions of the Moon with stars have only approximate times; because of their low precision they are practically of no value in modern applications.

There is little in the way of useful records from the Romans, apart from a few observations by Menelaus (c.100 AD) listed by Ptolemy. It is probable that due to a strong indulgement of this great nation in materialistic excellence, that they have abandoned the formulating of the heavens to the gods. It was true that astrology was practised on a large scale and sky worship was one of the Roman religious activities, but they left no day to day observational records.

The little other astronomical information survives today from ancient Europe confined to the histories, both Greek and Roman, by authors such as Herodotus, Thucydides, Livy and Dion Cassius, also in the *Historia Naturalis* of Pliny and *Quaestiones Naturales* of Seneca. The astronomical records contained in these works are vague and of limited scientific value. They were recorded on account of their spectacular appearances – for instance, large solar eclipses and bright comets. Very often, only the approximate date and place of observation are given. With the superior series of data from both Babylon and China, the observations from ancient Europe will not be considered further.

(4) Medieval Europe

The final years of Greek astronomy were probably upheld by two writers Pappos (c.320 AD) and Theon of Alexandria (c.380 AD) who wrote extensive commentaries on the *Almagest* but contributed nothing new. Theon may have been one of the last members of the Alexandria Museum, an institution for advance learning which was built near the royal palace around 280 BC. It was destroyed by Theophilos, the bishop of Alexandria in the 5th century, after which the centre of Greek astronomy was for a short time centred at Athens. However, this met its end in 529 when Justinian closed all the schools of rhetoricians and philosophers, confiscated their properties and forbade any pagan to teach (Pannekoek, 1961).

Although astronomical writings continued to be copied, circulated and studied, there was no one in Europe competent enough to penetrate the technical details of the

Almagest. Astronomy was cultivated for the sake of practical applications and astrology. Greek astronomy was effectively at an end after Claudius Ptolemy.

With the downfall of the Roman Empire in the 5th century, Europe was in turmoil and sunk into the long Dark Ages. There were only a few scattered intellectual centres within the monasteries, which were inhabited by learned scholar monks. It was mainly due to the importance of astronomy in fixing religious dates especially the date of Easter, that its study was permitted. The monks also kept chronicles in which they included any phenomena which were thought of as acts of God. Around AD 800, these annals were from only a few centres but by AD 1100 they were widespread in most European countries from Iceland to Russia. The chroniclers usually wrote in Latin but several works are in the vernacular. For the earlier period between the 6th and 10th century, we also have the histories of Bede, Gregory of Tours, Cedrenus, Syncellus and Theophanes.

Around AD 1000, European commercial centres began to recover from the Dark Ages. Prosperity was such that new towns and monastries began to be constructed. Under the umbrella of the church, some form of intellectual activities were allowed in monastries in association with productive labour. At this time, not only numerous monasteries kept chronicles, some towns had their own chronicles too. These annals are the main sources of medieval European astronomical records before the Renaissance. Generally, the chronicles are concerned only with local affairs, in many ways similar to the Chinese local histories (see later). Usually only recordings of natural disasters and accounts of spectacular celestial phenomena like large eclipses and bright comets (Newton, 1972 and Schove, 1985) were made. In some cases, accounts of the same event are recorded independently in different chronicles. Occasionally, aurorae, meteor showers and even occultations were also reported. These observations were made only as simple eyewitness reports; technical information like the timing of an eclipse or the constellations in which a comet passed through was usually lacking. Hence, these records are in many respects an inferior source of information, although the careful descriptions of total eclipses are of value in Earth's rotation studies.

The European chronicles were at the height of their popularity between about AD 1100 and 1300, after which there was a gradual decline in their numbers. Medieval European dates are usually exact, although some chronicles give no more than the year of occurrence. The calendar which was most commonly adopted was the Julian Calendar, with dates expressed in terms of the Calends, Nones and Ides rather than the days of the month. The Calends was always the 1st day of the month, the 5th (or the 7th in a month of 31 days) was known as Nones, the 13th (15th of the months which contained 31 days) as Ides.

There are extensive compilations of these mediaeval chronicles made in the last century. Some of the well known chronicles included the *Rerum Britannicarum Medii Aevi Scriptores* (Longman, 1850), *Recueil des Historiens des Gaules et de la France* (Bouquet, 1869), *Monumenta Germaniae Historica Scriptores* (Pertz, 1826), and *Rerum Italicarum Scriptores* (Muratori, 1723). All these are multi-volume works containing chronicles almost entirely before AD 1250.

After the Middle Ages, during the Renaissance, writers like John of Sacrobosco, Ristoro d'Arezzo, St Thomas Aquinas and Nicole Oresme wrote extensively on cosmological speculation. However, their works contained few records of actual observation. We shall stop this survey after the Renaissance as we have come to the modern era.

1.2.2 The Middle East

(1) Indian Astronomy

Hindu astronomy in the early periods tended to mingle mythological cosmogony and fabled legends with true astronomy. Coupled with an unreliable chronology, it is regretted that no great reliance can be placed upon any conjecture and conclusion deduced from Hindu writings by various investigators. From an early time, Indian astronomy was already influenced by the Babylonians and Greeks. Forbes (1977) suggested that the main lines of transmission from cuneiform, demotic and papyri sources had already occurred prior to the mid-second century AD.

Hindu astronomy flourished during the Gupta Dynasty (c.AD 300–500). A series of astronomical texts known as *Siddhantas* were written by Brahmagupta and his contemporaries. The contents of these books were based on early Greek ideas like the spherical Earth and epicyclic planetary orbits. One of the best known astronomical works written in Sanskrit is that of the *Surya Siddhanta* which preserved the Egyptian 365-day year from Hellenistic Egypt (Neugebauer, 1975). Later the Egyptian system went through a complete cycle of transmission into Western Europe by way of the Arabs. However, the main part of the work is only a compilation of rules in brief technical terms as an instruction to observers.

The final phase of classical astronomy in India probably began by Sawai Jai Singh II who built for his king Muhammad Shah five well equipped observatories between 1728 and 1734 at Jaipur, Delhi, Benares, Ujayyin and Malhura (Sayili, 1960). So far, there do not seem to be observational records of any kind from India.

(2) Islamic Inheritance

Medieval Arabian astronomy developed from a mingling of three sources: Sasanian Iranian, Indian Sanskrit and Hellenistic in roughly this order of incidence and influence. During the 'Days of Ignorance' and the first 150 years of Islam, the Arabs already possessed some knowledge of astrological and practical astronomy. Astronomy as a science began with the founding of Baghdad by Al-Mansur, the second of the Abbasid caliphs (AD 762). During this reign, at about AD 773 the Hindu astronomer Mansa was presented at the court of Caliph Al-Mansur by the astronomer Al-Fazari (Dreyer, 1906). Mansa brought with him a copy of the Siddhanta of Brahmagupta and translated it into Arabic. It stimulated further translation of astronomical works especially from the Greeks. The first reliable translation of Ptolemy's *Syntaxis* (or *Almagest*) was made in AD 827 during the Caliphate of Al-Ma'mun and this time can be regarded as the commencement of the hey days of Islamic astronomy, culminating in the building of an observatory at Baghdad.

For about a hundred years the bulk of this activity was carried on in Baghdad (or the second capital, Samarra), although several series of observations were made from Dayr Maran, on a mountain overlooking Damascus. By the beginning of the tenth century, observers were busy in centres stretching from Egypt through Central Asia. Among them the works of Ibn Yunis at Cairo and al-Biruni at Ghazna (in modern Afghanistan) were outstanding.

The types of phenomena observed were quite varied, encompassing from solar and lunar eclipses, planetary conjunctions and transits of the Sun and stars. Meridian transits of the sun were used to determine the lengths of the seasons and the characteristics of the solar motion. Both the transits of fixed stars and the Sun were used to deduce terrestrial latitudes of important localities. Planetary positions especially conjunctions between a pair of planets, between a fixed star and a planet, were employed to correct the mean motion parameters inherited from the Greek and Indian sources.

With the break up of the vast empire of the Caliphs during the 10th century AD, Baghdad ceased to be a major astronomical centre. Its role was taken over firstly by Cairo. Here Ibn Yunis established a well equipped observatory some time around AD

977 where observations very similar to those made at Baghdad were continued. After the death of Ibn Yunis (AD 1009), Spain became the leading astronomical centre, and it held this position for over two centuries. The Christian King Alfonso X of Castille (AD 1252–1284) followed the example of the Caliphs and employed Arabic astronomers to assist in the preparation of the renowned *Alfonsine Tables*, which remained a standard work for some 3 centuries. Islamic astronomy experienced its last flush of glory at Samarkand under the protection of the Sultan Ulugh Beg, between AD 1420 and 1449.

There are a profusion of astronomical documents left from the Great Islamic Age (8th to 12th century). However, not many have survived from the early days of the Islamic Age and hundreds of scientific works which are known to have existed have since disappeared. Take the case of Al-Biruni, according to Kennedy (1970) he alone wrote over a hundred and forty-eight books and treatises, of which less than a third are extant. Only about half of these have been published (in their original language). The great bulk of the available manuscript sources have not been read in modern times, much less edited or studied.

One of the notable treatises by Ibn Yunis written in the 11th century records 25 solar and lunar eclipses with accurately measured first and last contacts. The times of these were determined by measuring the altitude of the Sun and Moon. These observations were carried out at Baghdad and Cairo between AD 829 and 1004. In recent times, Goldstein (1965) compiled a list of sightings of the new star of AD 1006 from a search through Arabic chronicles, treatises on astrology and other lesser known sources. From the few observations other than those cited by Ibn Yunis – which have been found and translated, it seems that Arabic records tend to be generally vague. As in the European chronicles, which were roughly contemporary, most of the observations were recorded as a result of their spectacular nature than being systematically observed.

1.2.3 The Far Eastern Traditions

(1) Chinese Astronomy

The beginning of Chinese astronomy has been lost in the mists of time. Legends from the earliest times told that people used to tie knots on rope and pile up stones in order to keep records. With the development of writing we find today the earliest incriptions on shells of tortoises and animal shoulder blade bones known as *scapulimancy* or *oracle bone inscriptions*. The first of these oracle bones were uncovered at the end of the last century near An-yang. They were identified to have come from the later years of the Shang Dynasty (c.1500 to 1050 BC). The amount of astronomical information preserved on the Shang oracle bones is very sketchy. Partly due to difficulties in deciphering and partly due to the contents which emphasize on the outcome of divination than anything else. However, mention of both solar and lunar eclipses, planets and stars have been found (D.N. Keightly, private communication).

The Chou Dynasty (1055–256 BC) succeeded the Shang. We find in this period carvings on bronze vessels noting a few of the 'lunar mansions'. The capacity to keep more records came with the beginning of writing on bamboo slips which was probably began sometime in the Spring and Autumn Period (722 to 481 BC). The earliest Chinese books were simply formed by stringing bamboo slips together by leather thongs. Contemporary to the bamboo books are the costly silk books which are just inscribed scrolls of silk. It was not until the 1st century AD that paper was invented and printing began sometime in the Sui Dynasty (AD 589–618).

The first datable celestial records from China is contained in the work *Ch'un Ch'iu* ('Spring and Autumn Annals') which gives its name to this period. The *Ch'un Ch'iu* chronicle covers the period form 722 and 481 BC, is alleged to have been compiled by

Confucius from the Lu state annals. The work lists 37 accurately dated solar eclipses and a few reports of comets and meteors, but there are no lunar and planetary records.

Following the Ch'un Ch'iu period, comes the Warring States Period (403 and 221 BC). Although not many astronomical records have survived from these times, there is an important star catalogue which supposedly contained observations by astronomers from three of the states by name of Kan Te, Shih Shen and Wu Hsien. The original catalogue is no longer extant but parts have been preserved in later texts. From these later sources we know that a total of 1464 stars were mapped in 283 groups. It appears that by the Warring States Period there was a fair deal of astronomical knowledge. It is unfortunate that few astronomical observations have been preserved from this era down to the beginning of the Han Dynasty at 206 BC. Probably this circumstance is due to the infamous 'Burning of the Books' at the command of Emperor Ch'in Shih-huang in 213 BC and the subsequent sacking of the Chinese capital of Hsien-yang in 206 BC.

The main motive behind a constant watch of the sky was astrology. The Chinese viewed the heaven above as a mirror imaging the state of earthly beings. It is no surprise that most of the Chinese asterisms have names which were commonly found in daily life of ancient China. Chinese rulers in the past had always placed an importance on strange happenings of the celestial vault; they regarded them as signs of their state of governing the country. Since Han times (206 BC to AD 8) and possibly earlier, the rulers of China had appointed civil servants to keep a constant records of the sky day and night, and report any astrological interpretations. The observations were carried out in observatories situated near the imperial palace inside the capital city. The organisation of the astronomical bureau through the centuries remained virtually the same apart from the number and titles of the astronomers. Fig. 1.2 shows the organisation of a typical astronomical bureau from the Ming Dynasty (AD 1368–1644).

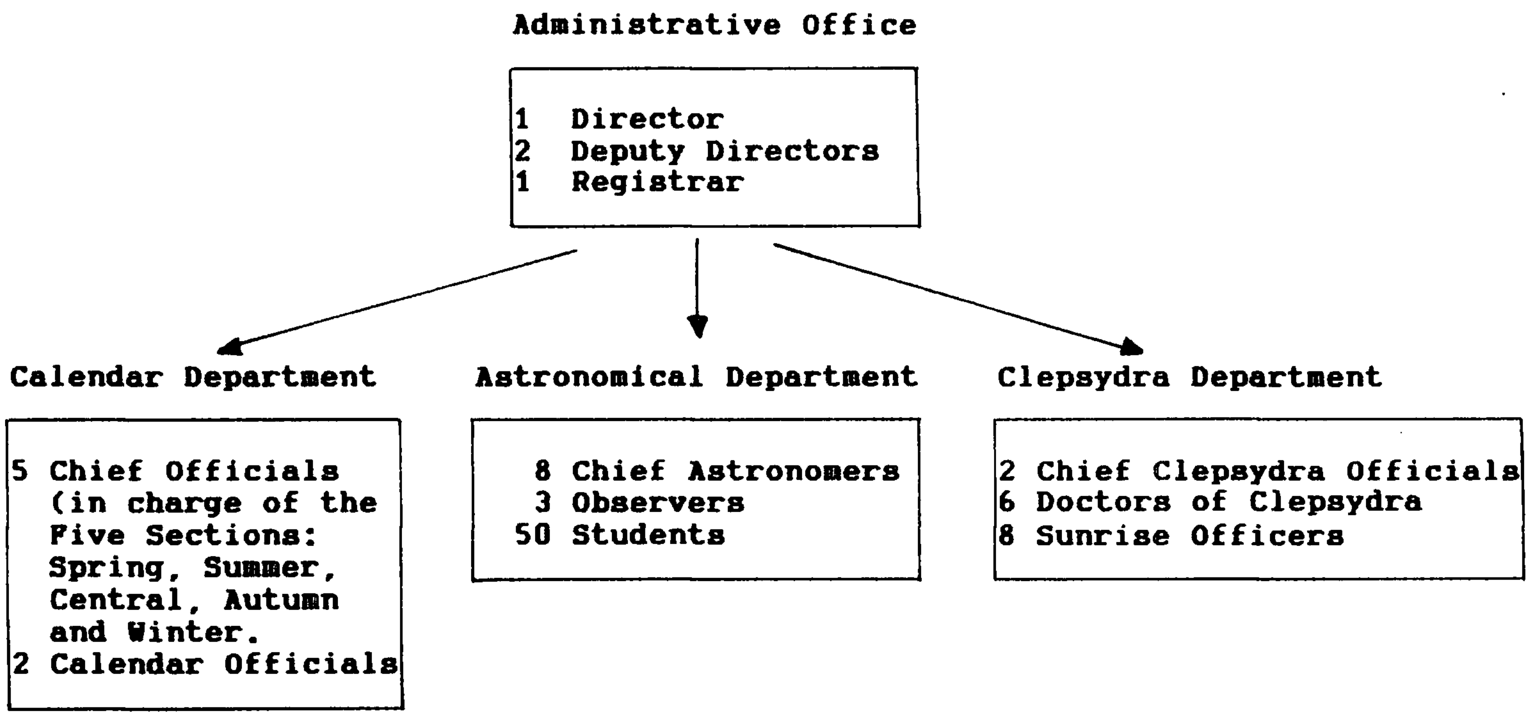


Fig. 1.2 The organisation of a typical astronomical bureau from the Ming Dynasty period (see details in Ho Peng Yoke, 1969).

It seems that although Chinese astronomy had already reached a high level of attainment by the Han Dynasty, further progress was slow. The zenith was probably reached during the Sung and Yuan Dynasties (AD 960–1368). The standard of astronomical instruments in these two periods might have rivalled that of anywhere else in the world. For instance, Su Sung's astronomical clock-tower (p.363, Needham, 1959) was probably the best indication of Chinese achievement in astronomical techniques. The traditional Chinese astronomy started a gradual decline in the succeeding Ming Dynasty (AD 1368–1644) and was soon overtaken by Renaissance astronomy from Europe. Western celestial techniques were introduced at the end of Ming Dynasty by Jesuit astronomers such as Matteo Ricci and Adam Schall von Bell. Still, the systematic watch of the heavens in the traditional style continued unchanged down to the end of the last dynasty of Ch'ing (AD 1644–1911).

From the Han Dynasty onwards until the last dynasty of Ch'ing are preserved many thousands of records of such diverse phenomena as solar and lunar eclipses, sunspots, conjunctions of the Moon with planets and stars, planetary conjunctions, comets, 'guest stars' (novae and supernovae), meteors and aurora borealis. One of the factors contributing to the preservation of Chinese observational records is her tradition of compiling dynastic histories. As a rule, after the fall of a dynasty, its history would usually be written under an official decree by the new dynasty. In a few cases, these were compiled privately by scholars who had access to the Imperial archives of the old dynasty. Most of the 26 standard dynastic histories (Table 1.1) have a section known as *Astronomical Treatise* (Han, 1955). It is in these treatises that most of the astronomical records are contained.

The first of the 26 dynastic histories of China is the *Shih-chi* (*Historical Records*), which was compiled by the Grand Historian and Astronomer Ssu-ma Ch'ien (145–87 BC). Two chapters of this work have been devoted to the discussions on astronomy

Table 1.1 The Twenty-six Chinese Dynastic Histories
- Edited from Han (1955)

Book Title	Translated Title	Chief Editor	Date of Compilation
1. Shih-chi	Historical Records	Ssuma Ch'ien	104-87 BC
2. Han-shu	History of the Former Han Dynasty	Pan Ku and Pan Chao	AD 58-76
3. Hou-han-shu	History of the Later Han Dynasty	Fan Yeh	AD 398-445
4. San-kuo-chih	History of the Three Kingdoms	Ch'en Shou	AD 285-297
5. Chin-shu	History of the Chin Dynasty	Fang Hsuan-ling	AD 635
6. Sung-shu	History of the (Liu) Sung Dynasty	Shen Yueh	AD 492-493
7. Nan-ch'i-shu	History of the Souther Ch'i Dynasty	Hsiao Tzu-hsien	AD 489-537
8. Liang-shu	History of the Liang Dynasty	Yao Ssu-lien	AD 629-636
9. Ch'en-shu	History of the Ch'en Dynasty	Yao Ssu-lien	AD 629-636
10. Wei-shu	History of the (Northern) Wei Dynasty	Wei Shou	AD 551-554
11. Pei-ch'i-shu	History of the (Northern) Ch'i Dynasty	Li Te-lin	AD 627-636
12. Chou-shu	History of the (Northern) Chou Dynasty	Ling-hu Te-fen	AD 636

13. Nan-shih	History of the Southern Dynasties	Li Yen-shou	AD 630-650
14. Pei-shih	History of the Northern Dynasties	Li Yen-shou	AD 630-650
15. Sui-shu	History of the Sui Dynasty	Wei Cheng	AD 629-636
16. Chiu-t'ang-shu	Old History of the T'ang Dynasty	Liu Hsu	AD 940-945
17. Hsin-t'ang-shu	New History of the T'ang Dynasty	Ou-yang Hsiu Sung Ch'i	AD 1060
18. Chiu-wu-tai-shih	Old History of the Five Dynasties	Hsueh Chu-cheng	AD 973-974
19. Hsin-wu-tai-shih	New History of the Five Dynasties	Ou-yang Hsiu	AD 1036-1053
20. Sung-shih	History of the Sung Dynasty	T'o-t'o and Ou-yang Hsuan	AD 1343-1345
21. Liao-shih	History of the Liao Dynasty	T'o-t'o and Ou-yang Hsuan	AD 1343-1345
22. Kin-shih	History of the Kin Dynasty	T'o-t'o and Ou-yang Hsuan	AD 1343-1345
23. Yuan-shih	History of the Yuan Dynasty	Sung Lien	AD 1369-1370
24. Hsin-yuan-shih	New History of the Yuan Dynasty	K'o Shao-min	AD 1890-1920
25. Ming-shih	History of the Ming Dynasty	Chang T'ing-yu	AD 1672-1755
26. Ch'ing-shih-kao	Drafted History Ch'ing Dynasty	K'o Shao-min	AD 1914-1927

and calendrical methods. However, most of the astronomical records are contained in the chapters of chronological tables and biographies of the emperors. After the *Historical Records*, comes the *Han-shu* ('History of the Former Han Dynasty'). This is the first dynastic history to adopt a standard format in which all celestial events are collected together to form the *T'ien-wen-chih* (or *Astronomical Treatise*). Only excerpts of the original observations made by the imperial astronomers are now preserved in the astronomical treatises. It is worth noting that the *Han-shu Astronomical Treatise* is the earliest work to have included the first detailed account of the motion of Halley's Comet (12 BC). A similar format in compiling the astronomical treatise was followed by the compilers of later dynastic histories.

(2) Japanese Astronomy

Astronomy in the Chinese style was imported into Japan through a Buddhist monk Mim who was sent to China to study Buddhism as well as astronomy. Mim went to T'ang China in 608 and returned to Japan in 632 with texts on Buddhist teaching as well as on various astronomical writings and techniques. At the same time he acquired the technique of interpreting astrological portents. It was under his guidance that the first Japanese observatory was built at Asuka (the then Japanese capital) in the 4th year of Emperor Temmu (AD 675). The astronomical bureau was organised in a similar way to that in China. The same structure was preserved even when the capital and observatory moved to other sites during later centuries (Nakayama, 1969).

The first recorded astronomical observation from Japan was made in the early decades of the 7th century AD, and after that date we have almost an unbroken series of observations of celestial events in essentially the same style of reporting as in China. Hence records of numerous eclipses, comets, meteors, supervovae, aurorae etc. are found today. Most of these early data from the period beginning in the 7th century down to AD 1600 have been compiled by Kanda (1934, 1935).

(3) Korean Astronomy

Korean astronomy also imitated the style of astronomy in China. One of the original three kingdoms, Silla, built an observatory at Kyungju between AD 632 and 647. This is the earliest observatory which still extant today. The dynasty of Koryo inherited the tradition from Silla and borrowed elements from T'ang China. The astronomical organisation was succeeded by the Yi Dynasty more or less intact in 1392 when the new dynasty was established (Rufus, 1936). The organisation of the astronomical bureau was similar to those in China and Japan.

In the earlier centuries most of the astronomical records contained in Korean histories are copied directly from Chinese sources. It is not until the 11th century AD that systematic Korean astronomical records began. The same pattern of recording as that of China was employed - and was written in Classical Chinese. It is important to note that the state of preservation of Korean materials in the later centuries is better than in China and hence the records are much more detailed.

1.2.4 The Lost Meso-American Civilisations

All Mayan books except three were destroyed by Bishop Diego de Landa at Mani in 1562. The three Mayan codices that have luckily escaped the burning were already despatched as souvenirs to Europe. Presently, the three books are in three different European libraries in Dresden, Madrid and Paris and by whose name they are now known. The main source of information on astronomy is in the *Dresden Codex* (Thompson 1974) written in the 11th century, made of tree bark, lime coated and painted in hieroglyphics. Although it contains tables on the calculated dates for solar eclipses and Venus synodical revolutions, it does not preserve any observational record. In addition, there are three further sources on astronomical information: (i) monumental inscriptions on pillars or stelae, (ii) ethnographic reports of ancient practice dating from the Spanish colonial period and (iii) alignments of buildings and cities according to astronomical measurements. However, none of this information concerns actual observational records.

1.2.5 A Summary

From the survey given above we can say that there are four main sources of material which contain early astronomical data, these are from (i) the Babylonian astronomical cuneiform tablets, (ii) Chinese and other Far Eastern astronomical treatises and annals, (iv) Islamic texts, and (iv) European records from both the Greek and Roman Classics and the Medieval Monastic Chronicles. Of the four sources cited, only the Chinese and to a lesser extent, Babylonian materials provide a long, systematic and continuous series of data. Early astronomical records from Europe and Arabic chronicles are often random and lack observational details, and covers shorter time spans.

Fig. 1.3 shows the coverage of source materials over the twenty-seven centuries since 700 BC. The major part of astronomical data selected for analysis in the present study comes mostly from the Chinese texts and Babylonian tablets. I shall examine below these two longest series of data in details.

1.3 Observational Records from the Two Principal Series

1.3.1 Records on Babylonian Cuneiform Tablets

By excluding non-observational astronomical records like schematic calendric astronomy or lists of names of constellations, Sachs (1948, 1955 and 1974) divided the astronomical tablets from Babylon into two series separated by a gap of about a thousand

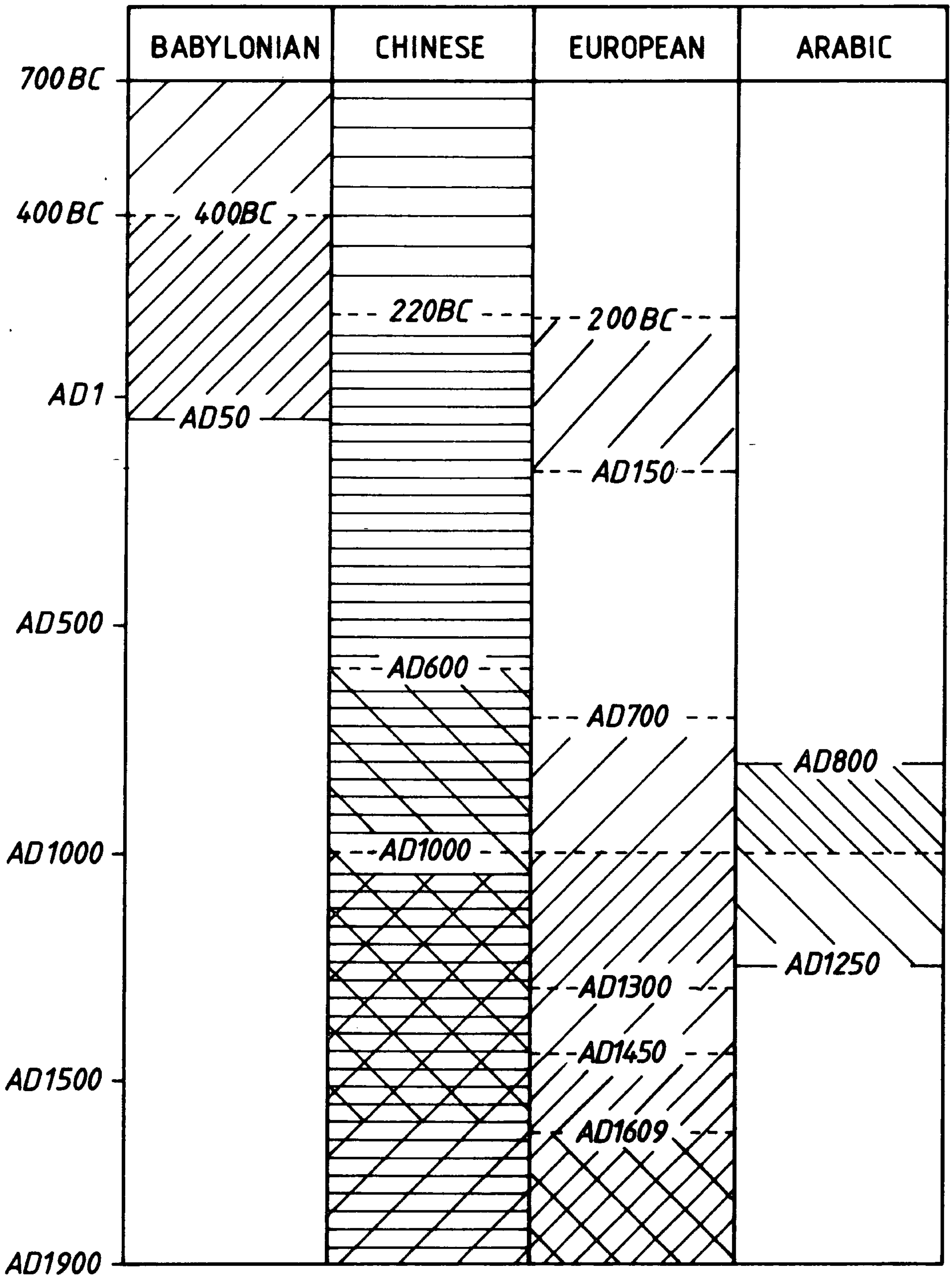


Fig. 1.3 The period of coverage provided by the four principal sources of astronomical records.

years. Further, the second series may be divided into four classes: (i) Astronomical diaries; (ii) Goal year text (iii) Almanacs and (iv) Mathematical astronomical texts.

The first series only consists of the Venus Tables which are a list of dates for the first and last appearance of Venus as an evening star and as a morning star for whole of the 21st year of King Ammisaduqa's reign of the First Dynasty of Babylon. There are several extant later copies of the same tablet made in the 8th century BC which is long since lost (Sachs, 1974).

The most important class of the second series is the astronomical diaries. There are a total of about 1600 fragments in variant sizes and state of preservation of which only about one third have been dated. Drawings of most of these are contained in the *Late Babylonian Astronomical Texts* of Sachs (1955). Fig. 1.4 shows the distribution of the dated diaries over seven centuries as given in the *Late Babylonian Astronomical Texts* – most of which exist as mere fragments. After the earliest datable tablet from the year 652 BC, records for the following three centuries are very few and far between. From the 4th century onwards to the end of the series the numbers become numerous with the greatest density in the 2nd century BC. Babylonians seem to have reached the heyday of their astronomy in the Seleucid period after about 300 BC. They were able to deduce the planetary and lunar periods, and detect any apparent discord in their data by comparing them with earlier figures.

From about 250 BC on and for two centuries, there are a large number of *goal-year texts*. These texts contains information extracted by the Babylonian astronomers from astronomical diaries of previous years and were used for predicting both lunar and planetary phenomena in the coming year know as the goal year. The almanacs contain astronomical data in consecutive years listing data concerning all kinds of phenomena

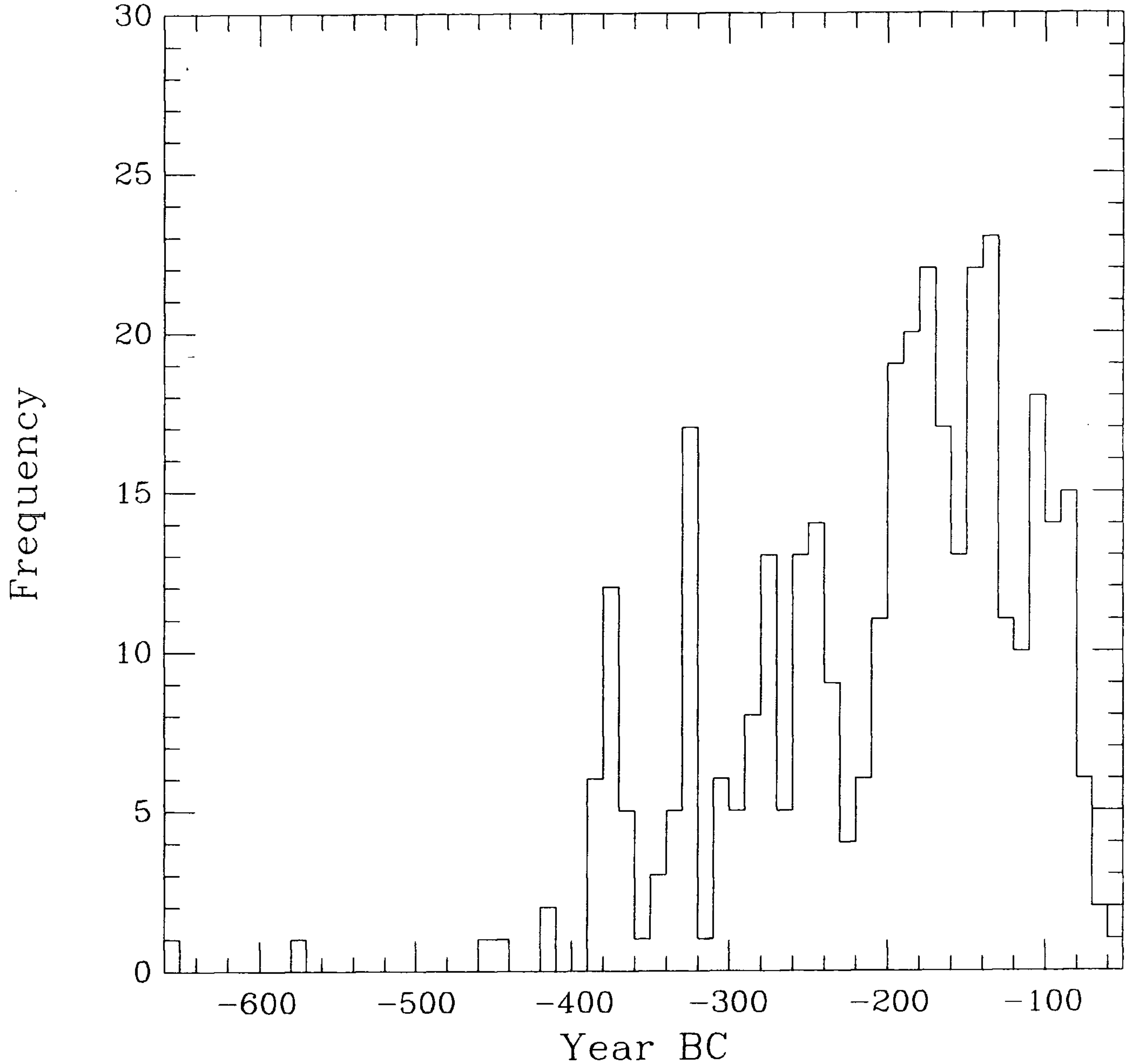


Fig. 1.4 **The decade distribution of Babylonian dated astronomical diaries (660 BC to 50 BC).**

from planetary positions, length of month, lunar eclipses. Also the mathematical astronomical texts containing information on the calculation of movements of the Sun, Moon and planets.

1.3.1.1 Contents of Astronomical Diaries

The diary cuneiform texts are written across from left to right – not in columns like some other texts. Each side of a whole tablet has been estimated to have originally contained about 40 lines (Hunger, Stephenson, Walker and Yau, 1985). The form of the writing on the tablets indicates that the scribes used a kind of wedge-shaped reeds. A diary usually contains the first six or seven months of a Babylonian year. First entry of each monthly record gives the date of first sighting of the crescent moon which is either on the 30th or 31st evening. The intervals between the rising and setting of the Sun and Moon which are used for fixing the date of the beginning of next month are recorded three times at the beginning, middle and end of the month.

The basic pattern of recording in a diary is as follows: (i) at the beginning of each month, a statement about the length of the previous month (either 29 or 30 days) and the measured time between sunset and moonset of the first visibility of the lunar crescent; (ii) in the middle of each month around full moon, two pairs of time intervals either from moonset to sunrise and sunrise to moonset or moonrise to sunset and sunset to moonrise; (iii) at the end of each month, the time interval is given between moonrise and sunrise in the morning of last visible crescent.

In between are the observational records which included both lunar and solar eclipses, the dates of first and last visibility of the planets. Also conjunctions of the Moon and each of the five planets with some thirty *normal stars* along the zodiacal belt. All sorts of meteorological events are reported, particulary in the rainy winter season but good weather is never mentioned. The computed dates for equinoxes and solstices, and dates of appearance of the star Sirius are also given. At least one event is reported for every day of the month. After the last astronomical or meteorological events of the month, a summary of the main astronomical events is given. This is followed by a statement about the commodity prices of daily necessities like barley, dates, sesame. Change of river level at Babylon (in the course of the month) are also noted together with a report of secular affairs.

1.3.1.2 Dating Astronomical Diaries

The calendar adopted in Babylon was luni-solar, with regular intercalation of a 13th lunar month to keep the calendar roughly in step with the seasons. From about 250 BC a standardised scheme of intercalation was adopted based on the 19-year lunar cycle. The Babylonian astronomers began each month with the first visibility of the young crescent Moon. The day commenced at sunset, roughly 6 hours in advance of the civil day.

Before 305 BC the dates of diaries were expressed relative to the beginning of the regnal year of the current king on the throne. From 305 BC onwards, the Seleucid Era was used. Seleucus I Nicator (one of Alexander the Great's generals) became the sole king of Babylon in 305 BC. However the Era was post-dated by the Babylonians so SE I = 311/310 BC. In 171 BC the Parthians occupied Babylonia, and the texts may also be dated by the Arsacid Era (named after Arsaces I the founder of the Parthian Dynasty, which begun in 247 BC).

If the tablets do happen to carry a preserved date the conversion from the Babylonian calendars to the Julian calendar is relatively straightforward; the tables of Parker and Dubberstein (1956) may be used. However, dating the texts is not always easy since the tablets are broken into pieces. In such case, dating a piece of tablet is indirect, relying on the lunar and planetary information which it contains. For example, the dates for the 164 BC and 87 BC returns of Halley's Comet were deduced in such a way (Stephenson, Yau and Hunger, 1985). So far, only about one-third of the available 1600 fragments have been dated largely by Sachs (1955). The other tablets are virtually all undatable due to the small size and insufficient astronomical contents to enable a date to be deduced.

1.3.2 Chinese Texts

The early chronicles of the three countries in the Far East – China, Japan and Korea – may conveniently be placed under one title as the Chinese texts. All three countries used classical Chinese, a common form of written language of the early periods. The annals of these three countries combined to provide a systematic record of astronomical observations that is unparalleled elsewhere.

(1) From China

The bulk of records from China is contained in the astronomical treatises of the 26 official dynastic histories (see Table 1.1). In nearly all of the dynastic histories, a special section is devoted to astronomy. Apart from discussing astronomy in all aspects, the treatises preserve observational records of all kinds. These are classed under different headings. The general classification is to place records in two main categories, the day phenomena and night phenomena. The diurnal phenomena are solar eclipses, sunspots, solar haloes and the related atmospheric changes in the vicinity of the Sun. Also the occasional sightings of Venus and Jupiter in the daytime. The bulk of naked-eye astronomical records belongs to the category of night phenomena. The main nocturnal events observed included lunar eclipses, lunar haloes, conjunction of Moon with planets and stars, conjunction of planets with with one another and stars along the ecliptic, comets, guest stars, meteors and meteor showers and aurorae.

In Fig. 1.5, the decade distribution for all records contained in the astronomical treatises of the principal dynastic histories, beginning with the Han down to the Ch'ing dynasties, is shown. One of the most striking features shown is the uneven distribution of data. Some periods have many more preserved records than others. I assume that these features reflect only the state of preservation of records rather than the varying interests of the imperial courts and their astronomers. The two centuries before and after our era (ie. the time of the Former and Later Han dynasties) records are poorly preserved. It is not until the 4th century that we see an obvious increase in the number of records. There is a strong peak in the 5th century corresponding to the times of the late Chin and the first two short southern dynasties of the North-Southern Dynasty period. It has to be stressed here that whenever there are two contemporary dynastic histories, only records from the traditionally recognised mainstream dynasty are counted, to avoid any repeated counting.

The next 500 years is a poor period for astronomical records. However, records are very well preserved in the astronomical treatise of the *Sung-shih.* It is no wonder that we find 3 supernova records in this period. The Northern Sung period (AD 960–1127) seems to have many more records than the Southern Sung period (AD 1127–1279). The sudden drop in the number of records between two consecutive dynasties is clearly illustrated by the end of the Sung Dynasty and beginning of the Yuan Dynasty (AD 1279–1368). The number of records preserved in the astronomical treatise of the *Ming-shih* is fairly disappointing. It appears there should be many more astronomical records than these as can be judged from the number of records preserved in the *Ming-shih-lu* ('Veritable History of the Ming Dynasty'). The very strong feature in the Ch'ing period (AD 1644–1911) is solely due to records from the reign of emperor Ch'ien-lung (reigned from AD 1736 to 1795). One other important finding is that no astronomical records are found after AD 1800 in the *Ch'ing-shih-kao.*

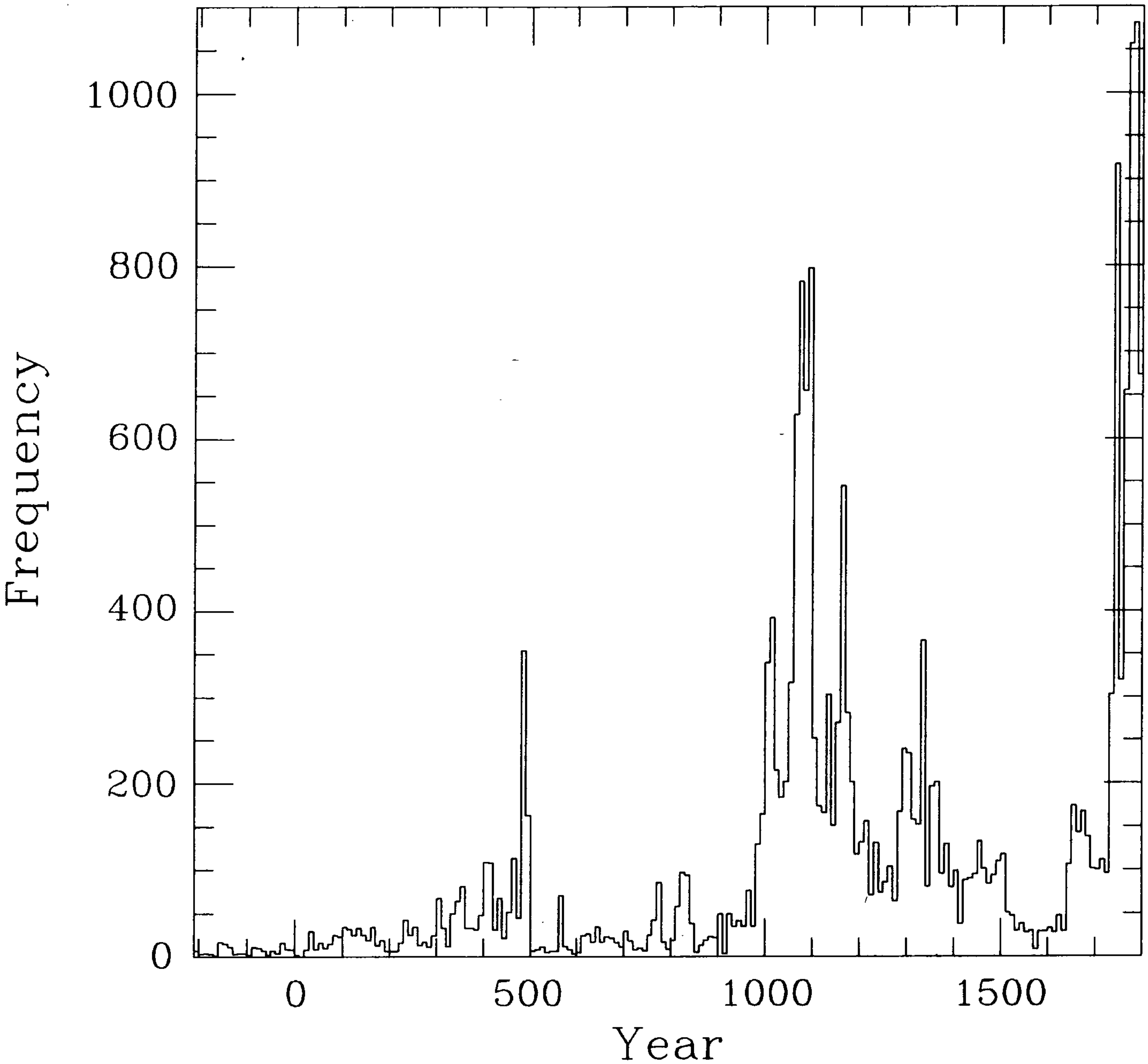


Fig. 1.5 The decade distribution of astronomical records from China for the period 210 BC to AD 1800.

Also the *Fang-chih* ('Local histories' or 'gazettes') have recently come into prominence, in particular relating to new records of sunspots. The local gazettes were formerly a kind of 'local guides' with maps and brief explanations of a region. However in later centuries especially during the periods of the Ming and Ch'ing Dynasties, they evolved to become thorough regional chronicles. These contain a variety of local affairs which range from the history of the region to notable events or persons of that area. It is in one of the sections known as *chang-i* ('strange phenomena') that we expect to find any, if there are any, celestial phenomena. However, the quality of these records is generally poorer than those from the official histories and the records tend to be fairly random.

(2) From Japan

The earliest history of Japan is the *Nihongi* or *Nihon Shoki* which was edited in AD 720 under the supervision of Supreme Prince Toneri. It records Japanese history from earliest times up to the year 697. After that, there have been many histories covering short periods of history of Japan. The Japanese astronomical sources are not contained systematically in any Japanese history as in China. Rather the various astronomical records scattered in chronicles, personal diaries of courtiers, records in temples and shrines, family archives, and various biographies. Luckily, Kanda Shigeru went through over 700 sources, collected all astronomical information and edited them in *Nihon Temmon Shiryo* (Kanda, 1935). For Japanese records, Kanda's collection still serves as the primary reference.

Kanda divided the records into 8 sections: (i) solar eclipses, (ii) lunar eclipses, (iii) conjunction of the Moon with planets, (iv) conjunction of the planets with each other and with stars, (v) sighting of stars or planets in daytime, (vi) comets and guest stars (novae or supernovae), (vii) meteors, and (viii) miscellaneous phenomena which included partial eclipses, both solar and lunar haloes, the star of *Lao-jen* ('Canopus'), aurorae and plus other unclassifiable events. Each section is listed separately in chronological order from 15 BC to 1600. The first chapter of each section covers the period from 15 BC to AD 800, the remaining 13 chapters cover the period up to AD 1600. There is a total of about 2700 records in all. The decade distribution of all records from AD 628 to 1600 as listed in Kanda (1934) is given in Fig. 1.6. The distribution shows many peaks and troughs. These are presumably due to the various periods of coverage of Kanda's source materials, many of these were personal diaries.

(3) From Korea

Table 1.2 shows the principal histories of Korea. The *Samguk Sagi* records events from earliest times to the unification under the Koryo King T'aejo in AD 918. This less reliable work is followed by the very reliable *Koryo-sa* which has a format identical to a standard Chinese dynastic history. All the astronomical records in the *Koryo-sa* are contained in a section under the title of *Astronomical Treatise*. Fig. 1.7 shows the yearly distribution of records from the *Koryo-sa Astronomical Treatise*. I have used the yearly distribution rather than the decade distribution here to emphasize another point, that the unevenness of the underlying distribution is even more ragged. I suspect that the mang peaks and troughs are due to selection methods of the compilers of the history than actual observations. This is a caution one has to bear in mind when dealing with records supposed to have periodic features, eg. sunspots and aurorae.

The longest of all Korean dynasties is that of the Choson (or Yi) Dynasty (AD 1392–1910) which was found in 1392 by general Yi Songgye. The basic histories of this dynasty are the detailed *Sillok* ('Veritable Records') of each king. In addition, the *Sungjong-won Ilgi* ('Records of the Royal Secretariat'), the extant 126 volumes covering the period from King Injo 1 (AD 1623) to King Ch'oljong 14 (AD 1863), is an extremely detailed work. Thus between 1623 to 1863, the *Sungjong-won Ilgi* provides much more

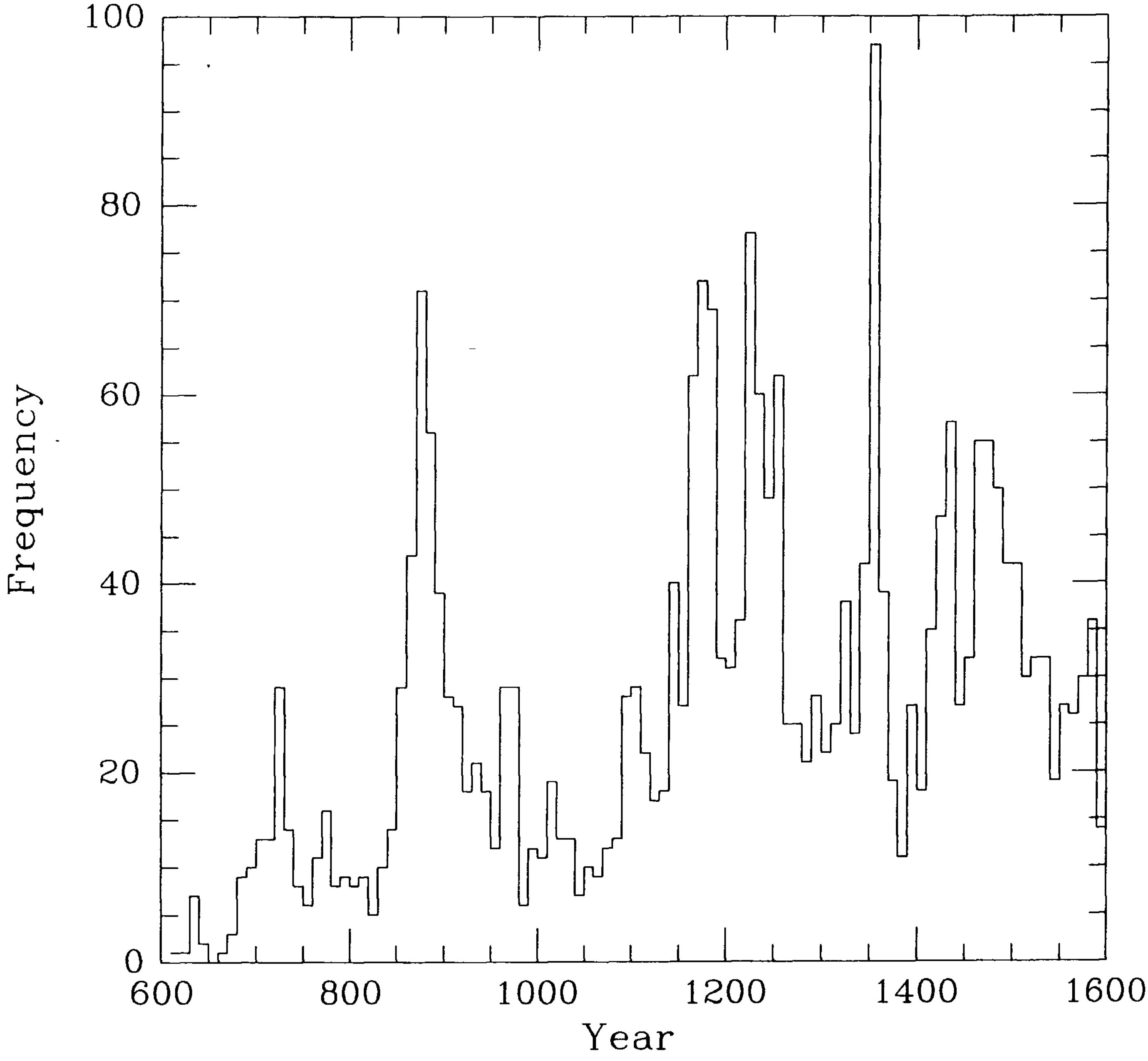


Fig. 1.6 The decade distribution of astronomical records from Japan for the period AD 600 to 1600.

Table 1.2 Principal Korean Histories

	Book Title	Translated Title	Chief Editors	Date of Compilation
1.	Samguk Sagi	History of the Three Kingdoms	Kim Pu-sik	1145
2.	Koryo-sa	History of the Koryo Dynasty	Chong In-ji	1451
3.	Choson Wangjo Sillok	Veritable Records of the Yi Dynasty	Veritable Records Office	1413-1865
4.	Sungjongwon Ilgi	Diary of the Royal Secretariat	Royal Secretariat	1623-1894
5.	Chungbo Munhon Pigo	Abridged encyclo-paedia		1908

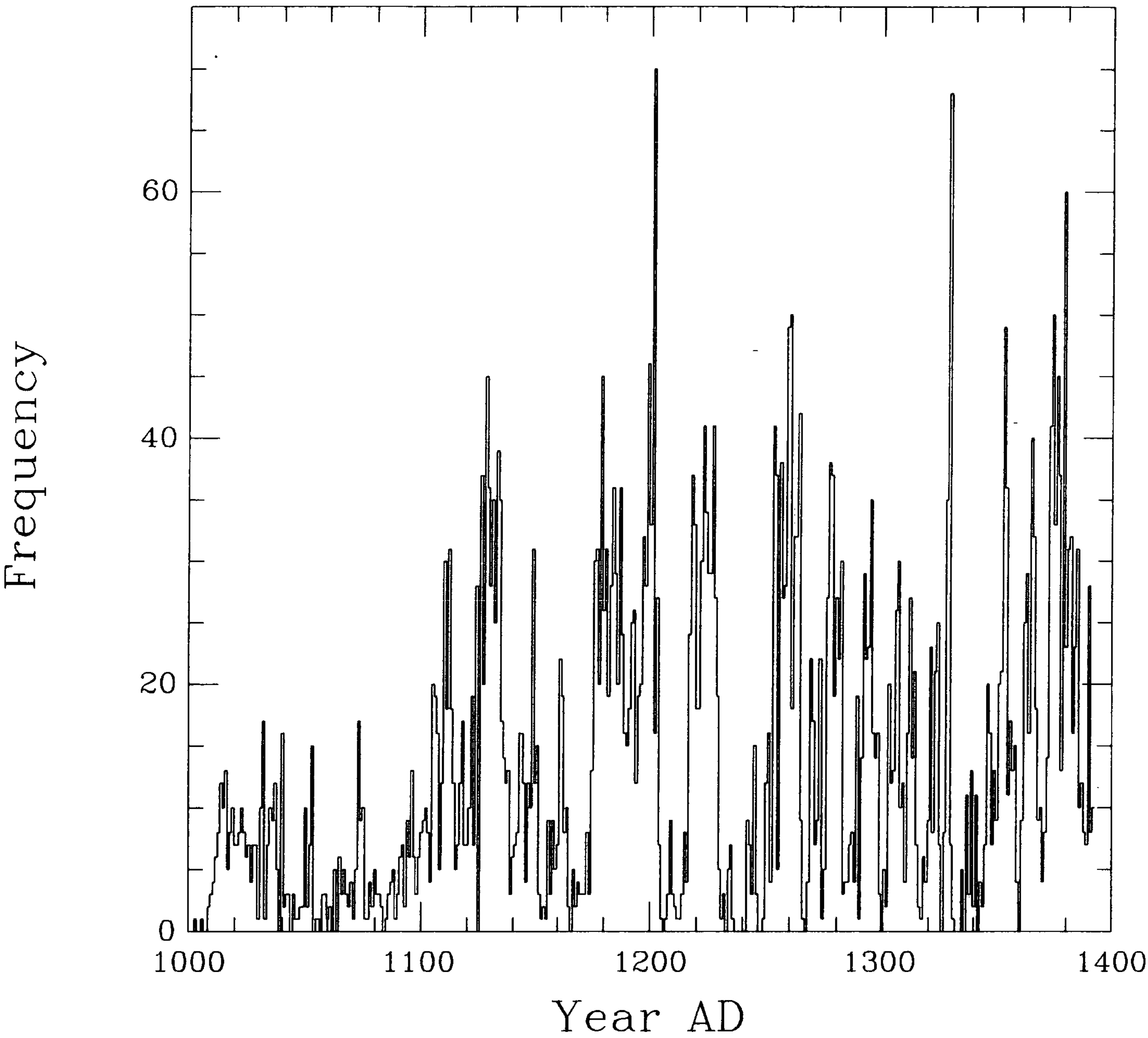


Fig. 1.7 The yearly distribution of astronomical records from the Korean history *Koryo-sa* for period AD 1000-1390.

extensive astronomical information than the *Sillok* (Park, 1980). It is unfortunate that the previous 230 years have been destroyed.

Since the detailed works of the *Sillok* and *Ilgi* do not have an easy and direct access to the astronomical records they contained, an encyclopaedia, the *Chungbo Munhon Pigo*, has often been consulted to begin with. The abstracted entries in this work do serve as a good index to the much more detailed records in both the *Sillok* and *Ilgi*. However, there are several drawbacks to the *Chungbo Munhon Pigo*, these included omissions of records and errors in dates, mainly the result of careless copying. For instance, the sunspot records in the 21st and 25th years of King Injo were omitted and the alleged guest star records of AD 1600 and 1664 (see chapter 5) were in fact part of the records of Kepler's supernova (SN 1604).

1.3.2.1 Method of Date Conversion in the Present Investigation

After extracting records from the sources the foremost step is to deduce the dates of observation and convert them into western dates. Since the date of observation is one of the most important parameters in applied historical astronomy, accurate dating is an essential part of the present investigation.

The calendar employed in China, which was later followed by Japan and Korea, was luni-solar. Hence in order to keep the year in step with the seasons, an intercalary month was occasionally inserted. Although there have been many refinements to the calendar over the years, essentially the same system was employed at all periods down to the end of the last dynasty (AD 1644–1911).

The usual format for the date in a Far Eastern source is first the year number in the reign period of the particular emperor or king on the throne. This is then usually followed by the lunar month and the day number of the sexagenary cycle – a cycle of

60 days independent of both Moon and Sun (Table 1.3). Various standard tables are available for Chinese date conversions, notably those by Hsueh and Ou-yang (1956) and Ch'en (1962). Furthermore, we have developed and employed successfully a computer program which converts all Chinese dates into the Western calendar. Prior to 15 Oct 1582 dates are expressed in terms of the Julian calendar, after which all dates are given in the Gregorian calendar.

1.3.2.2 Adopted System of Transliterations

For Chinese transliterations, the Wade-Giles System has been used throughout this thesis except in cases of personal names, where the authors are best known by their Pinyin equivalents. For Korean names, the method of transliteration adopted is that of Reischauer and for Japanese names the system employed is known as the Hepburn system.

1.3.3 Reliability of Records Investigated

After the dates have been checked and before performing an analysis, the reliability of the records needs to be established. Firstly, the various meanings and minor details given in the description often require attention before the record may be properly interpreted and elucidated. Secondly, where necessary the authenticity of the records has to be checked by analysing neighbouring data of eclipses, lunar occultations and planetary conjunctions. These are easily carried out by comparing with modern data of eclipses and conjunctions. The quality and authenticity of the records can often be established in this way.

Finally, before assuming my study in depth, a note on computing facilities. The data analysis for this thesis was carried out using the Starlink VAX 11/750 at the Durham node.

Table 1.3 The sexagenary cycle in a tabulated form. The cyclic numbers are formed from the combination of two series of elements. The first series of elements is known as the celestial stems consisting of 10 elements. the second is known as the earthly branches consisting of 12 elements.

	TZU	CH'OU	YIN	MAO	CH'EN	SZU	WU	WEI	SHEN	YU	HSU	HAI
CHIA	CHIA-TZU 1		CHIA-YIN 51		CHIA-CH'EN 41		CHIA-WU 31		CHIA-SHEN 21		CHIA-HSU 11	
I		I-CH'OU 2		I-MAO 52		I-SZU 42		I-WEI 32		I-YU 22		I-HAI 12
PING	PING-TZU 13		PING-YIN 3		PING-CH'EN 53		PING-WU 43		PING-SHEN 33		PING-HSU 23	
TING		TING-CH'OU 14		TING-MAO 4		TING-SZU 54		TING-WEI 44		TING-YU 34		TING-HAI 24
WU	WU-TZU 25		WU-YIN 15		WU-CH'EN 5		WU-WU 55		WU-SHEN 45		WU-HSU 35	
CHI		CHI-CH'OU 26		CHI-MAO 16		CHI-SZU 6		CHI-WEI 56		CHI-YU 46		CHI-HAI 36
KENG	KENG-TZU 37		KENG-YIN 27		KENG-CH'EN 17		KENG-WU 7		KENG-SHEN 57		KENG-HSU 47	
HSIN		HSIN-CH'OU 38		HSIN-MAO 28		HSIN-SZU 18		HSIN-WEI 8		HSIN-YU 58		HSIN-HAI 48
JEN	JEN-TZU 49		JEN-YIN 39		JEN-CH'EN 29		JEN-WU 19		JEN-SHEN 9		JEN-HSU 59	
KUEI		KUEI-CH'OU 50		KUEI-MAO 40		KUEI-SZU 30		KUEI-WEI 20		KUEI-YU 10		KUEI-HAI 60

PART I. A STUDY OF COMETS – WITH SPECIFIC APPLICATION TO HALLEY'S COMET

CHAPTER 2
COMETS IN THE PAST

2.1 Introduction

The frequency of appearance of bright comets is about one every five years according to Ho's (1962) naked-eye cometary catalogue. Before the telescopic era, numerous fainter comets below the threshold of visibility to the naked-eye must have gone unnoticed. Historical records of comets are available for the last two and a half millennia and are largely due to astronomers of the Far East. So far, Halley's Comet is the only bright periodic comet identified from the medley of early records, although there is no reason to suggest that there should not be another comet like Comet Halley. By tracing the dynamical history of a short period comet such as Halley's Comet backwards in time, it is hoped that one may just be able to catch a glimpse of its long life history. For instance, how did it evolve inside the solar system since it was supposedly captured by Jupiter (Everhart, 1972 and Fernandez, 1981). As was stressed by Yabushita (1983), 'dynamical evolution provides the basis for discussing theories of cometary origin'.

Another phenomenon closely associated with comets is the meteor shower. Some of these interrelations have been discussed by McIntosh and Hajduk (1983); Williams (1985). In addition, the question of terrestrial mass extinctions suggested by Alvarez *et al.* (1980) has initiated a series of papers (e.g. Raup and Sepkoski, 1984; Rampino and Stothers, 1984; Davis *et al.*, 1984; Alvarez and Muller, 1984; Sekanina and Yeomans, 1984) on the possibility of cometary impacts on Earth causing the disappearance of whole species from the surface of the Earth.

Although attempts have been made to identify and calculate orbits for a small number of naked-eye comets (Hasegawa, 1979), the present study is concentrated on the investigation of one particular comet, namely Comet Halley. The identification of early records of P/Halley (the prefix denoting the periodic nature of the comet) serves two main purposes. Firstly, records of ancient and medieval returns provide constrains on the motion of the comet in the past. Secondly, the records enable a direct verification of the accuracy of current theories of the long-term motion of the comet. It is hoped that a detailed understanding of the dynamical history of a comet, in this case Halley's Comet, will be a model for further investigations.

2.2 An Overview of Cometary Research

2.2.1 Early Philosophical Ideas

The early Greek philosopher Aristotle (d.322 BC) believed that comets were no more than exhalations raised into the upper regions of the air above the Earth. Here they caught fire and blazed for a time, thus becoming visible (*Meteorologica*). In the Roman period, the historians and naturalists Pliny and Seneca wrote detailed commentaries on comets. The view held by Seneca seems to indicate that he had a better grasp of the nature of comets than even Aristotle. He believed comets were not a sudden fire in the atmosphere, but eternal works of nature that moved outside the zone of the zodiac (*Quaestiones Naturales*). However Aristotle's fashion of thinking seemed to have persisted until the age of the Renaissance in Europe. In the more distant past, comets were more commonly regarded as harbingers of bad news than necessitating celestial theories. No Babylonian or Egyptian accounts of the nature of comets are known. The early Chinese view seems to have been fairly sophisticated, for example, the second century BC writer Ching Fang believed that comets originated from planets (Loewe, 1980). In the astronomical treatise of the *Chin-shu* ('History of the Chin Dynasty', compiled in AD 635) the first reference to the tail of a comet always pointing away from the Sun is found.

During the period of revival of science in Europe, various authorities had their own views as to the nature of comets. Some held on to Aristotelian notion that comets were sub-lunar objects, that is they resided between the Moon and the Earth. It was Tycho Brahe (1588) who 'smashed' the so-called crystal celestial spheres and established comets to be objects beyond the Moon's orbit by calculating the parallax for the comet of 1577 (Hellman, 1944).

From the time of Renaissance (c.1450), improved instrumental techniques enabled positions to be measured to within a few arc minutes. European astronomers began to hypothesize regarding the configuration of their orbits. However, most were without success; even the great Kepler himself figured that cometary orbits were little more than a straight line (Kepler, 1619). Although both Kepler's teacher Michael Mastlin and master Tycho Brahe assigned circular paths to comets, he adhered to his own view that comets were ephemeral objects and hence would follow a rectilinear path. Using Kepler's method, Hevelius attempted a calculation for the orbits of ten comets (Hevelius, 1668).

It was not until the publication of the *Principia* by Newton (1687), that a tool was then available for further progress. In order to illustrate his law of Universal Gravitation, Newton gave in the *Principia* (book III, Cor 7, Prop 16, Lib I) an example of a solution to the orbit of the 1680-1 comet. The theory of Newton was based on the assumption that comets followed a parabolic motion which was a fair approximation for most comets near perihelion. By adapting Newton's techniques, Halley was able to calculate orbital elements for a number of comets in the past in his now famous investigation (Halley, 1705).

2.2.2 The First Predicted Return

By Halley's time, about 400 cometary sightings were known to be recorded in European literature. Of these only 24 had been observed well enough to enable their orbits to be calculated. At this time the great wealth of Far Eastern cometary records was virtually unknown. Halley scoured well documented sightings between 1337 and 1698 and it was estimated that he took about twenty weeks to complete the calculations (Hughes, 1985a). His calculations were not published until March 1705 in *A Synopsis of the Astronomy of Comets* (Halley, 1705). In this monumental work, he noted that three sets of elements relating to comets seen in 1531, 1607 and 1682 were so similar that it was difficult to consider them coincidental (Table 2.1). This led him to propose that they related to one and the same comet. All other values in his table are random. The probability of accidental accord between three sets of data is minute. He rather courageously anticipated the return of this object "circa finem anni 1758 vel initium proximi", even though he knew that he would not live long enough to see it. The prediction proved to be remarkably accurate and sixteen years after Halley's death, the comet which now known after him was first sighted by the farmer and amateur astronomer Johann Palitzsch on the night of Christmas day in 1758. The return of Halley's Comet reinforced Newton's Law of Universal Gravitation as demonstrated in the *Principia* and thus defeating proponents of Cartesian vortices.

In addition, Halley suggested that comets observed in Europe in AD 1456, 1380 and 1305 may have represented earlier apparitions of this same object. However, here he merely assumed an interval of about 75 years between successive returns, although in the case of the 1456 comet he noted that it passed between the Earth and Sun in a retrograde direction – an indication of its identity. We now know that although Halley's identification of the comet of AD 1456 was sound, the sightings in AD 1380 and 1305

Table 2.1 The orbital elements of the 24 comets calculated by Halley (1705).

Note the similarity in the orbital elements for comets 1531, 1607 and 1682.

MOTUUM COMETARUM IN ORBE PARABOLICO ELEMENTA ASTRONOMICA.

Cometæ Anni.	Nodus Ascend. ° ' "	Inclin. Orbitæ. ° ' "	Perihelion. ° ' "	Distantia Perihelia à Sole.	Logarithmus Distantiæ Perihelia à Sole.	Logarithmus Medii Motus Diurni.	Temp. Æquat. Perihel. D. H. '	Perihel. à Nodo. ° ' "	
1337	♊ 24 21 0	32 11 0	♉ 7 59 0	40666	9 609236	0 546274	*Junii* 2 6 25	46 22 0	Retrog.
1472	♑ 11 46 20	5 20 0	♉ 15 33 30	54273	9 734584	0 358252	*Feb.* 28 22 23	123 47 10	Retrog.
→ 1531	♉ 19 25 0	17 56 0	♒ 1 39 0	56700	9 753583	0 329754	*Aug.* 24 21 18	107 46 0	Retrog.
1532	♊ 20 27 0	32 36 0	♋ 21 7 0	50910	9 706803	0 399924	*Oct.* 19 22 12	30 40 0	Direct.
1556	♍ 25 42 0	32 6 30	♑ 8 50 0	46390	9 666424	0 460492	*Apr.* 21 20 3	103 8 0	Direct.
1577	♈ 25 52 0	74 32 45	♌ 9 22 0	18342	9 263447	1 064958	*Oct.* 26 18 45	103 30 0	Retrog.
1580	♈ 18 57 20	64 40 0	♋ 19 5 50	59628	9 775450	0 296953	*Nov.* 28 15 0	90 8 30	Direct.
1585	♉ 7 42 30	6 4 0	♈ 8 51 0	109358	0 038850	9 901853	*Sept.* 27 19 20	28 51 30	Direct.
1590	♍ 15 30 40	29 40 40	♏ 6 54 30	57661	9 760882	0 318805	*Jan.* 29 3 45	51 23 50	Retrog.
1596	♒ 12 12 30	55 12 0	♏ 18 16 0	51293	9 710058	0 395041	*Julii* 31 19 55	83 56 30	Retrog.
→ 1607	♉ 20 21 0	17 2 0	♒ 2 16 0	58680	9 768490	0 307393	*Oct.* 16 3 50	108 5 0	Retrog.
1618	♊ 16 1 0	37 34 0	♈ 2 14 0	37975	9 579498	0 590881	*Oct.* 29 12 23	73 47 0	Direct.
1652	♊ 28 10 0	79 28 0	♈ 28 18 40	84750	9 928140	0 067918	*Nov.* 2 15 40	59 51 20	Direct.
1661	♊ 22 30 30	32 35 50	♋ 25 58 40	44851	9 651772	0 482470	*Jan.* 16 23 41	33 28 10	Direct.
1664	♊ 21 14 0	21 18 30	♌ 10 41 25	102575½	0 011044	9 943562	*Nov.* 24 11 52	49 27 25	Retrog.
1665	♏ 18 2 0	76 5 0	♊ 11 54 30	10649	9 027309	1 419164	*Apr.* 14 5 15	156 7 30	Retrog.
1672	♑ 27 30 30	83 22 10	♉ 16 59 30	69739	9 843476	0 194914	*Feb.* 20 8 37	109 29 0	Direct.
1677	♏ 26 49 10	79 3 15	♌ 17 37 5	28059	9 448072	0 788020	*Apr.* 26 0 37	99 12 5	Retrog.
1680	♑ 2 2 0	60 56 0	♐ 22 39 30	00612½	7 787106	3 279469	*Dec.* 8 0 6	9 22 30	Direct.
→ 1682	♉ 21 16 30	17 56 0	♒ 2 52 45	58328	9 765877	0 311313	*Sept.* 4 7 39	108 23 45	Retrog.
1683	♍ 23 23 0	83 11 0	♊ 25 29 30	56020	9 748343	0 337614	*Julii* 3 2 50	87 53 30	Retrog.
1684	♐ 28 15 0	65 48 40	♏ 28 52 0	96015	9 982339	9 986620	*Maii* 29 10 16	29 23 0	Direct.
1686	♓ 20 34 40	31 21 40	♊ 17 0 30	32500	9 511883	0 692304	*Sept.* 6 14 33	86 25 50	Direct.
1698	♐ 27 44 15	11 46 0	♑ 0 51 15	69129	9 839660	0 200638	*Oct.* 8 16 57	3 7 0	Retrog.

related to different comets; the latter two dates were in error by respectively two and four years.

2.2.3 Subsequent Predictions for the Perihelion Passage

Since Halley's epoch making calculation of cometary orbits and his subsequent prediction of a comet which now bears his name, the subject of comets passed under the scrutiny of many skillful orbital calculators. Among these might be mentioned de Pontecoulant and Hind in the last century and culminating with one of the most extensive calculations of the orbit by Cowell and Crommelin in the years preceding its return in 1910.

The action of Jupiter was found to retard the motion of the comet by 518 days and that of Saturn by 100 by Clairaut (1758). He used a modified version of his analytic lunar theory to compute the perturbations by Jupiter and Saturn on the comet's orbital period over the interval AD 1531–1759. He predicted a perihelion date for Halley's Comet of 1759 Apr 13 and pointed out that the uncertainty in the masses of the great planets and other unknown members of the solar system could alter the date by a whole month. The actual date of perihelion passage for the 1759 apparition was Mar 13, thus asserting Clairaut's prediction.

All subsequent work following Clairaut to 1910 is based on the variation of elements technique first developed by Lagrange (1783). The various methods differed only in the number of planets used in perturbation calculations, how many orbital parameters were varied and how many times per revolution the reference ellipse was rectified by adding the perturbations in elements. For the 1835 return, Rosenberger (1835) in Germany started with the 1682 perihelion passage time and took into account perturbations by Mars, Earth and Venus in addition to those of the major planets. He arrived at two possible dates for the 1835 return: November 3 on the assumption that the comet passed through a resisting medium, and November 11 without it. Lehmann (1835), also from Germany, carried the calculation from the 1607 apparition, observed by Kepler, and obtained November 26.73 as the likely date of perihelion (see Table 2.2 for a comparison).

For the return of 1910, Pontecoulant (1864) had previously calculated a perihelion passage time of May 24.36 from a consideration of the perturbations by Jupiter, Saturn and Uranus. Cowell and Crommelin began their initial investigation by examining the accuracy of Pontecoulant's predicted date. In a series of papers (Cowell and Crommelin, 1907a–c, 1908a), they worked out the perturbations due to the planets from Venus to Neptune, except Mars, using the variation of elements technique. They arrived at a perihelion passage time of Apr 8.5. Cowell and Crommelin (1910) then used a new method of analysis, now known as numerical integration, to obtain directly the perturbed rectangular coordinates at each time step. They integrated the orbit of Comet Halley forward from the 1835 apparition to 1910 by calculating the various perturbations from Venus through Neptune. They predicted P/Halley would return in 1910 with a perihelion passage time of Apr 17.11. Earlier, Ivanov (1909) investigated Comet Halley with a set of initial elements based upon the 1835–36 observations. He integrated the equations of motion forward to Dec 1909, taking into considerations the appropriate perturbations from the planets Mercury to Neptune and obtained a perihelion passage time of Apr 22.91. The actual date of perihelion was Apr 20.18, 1910.

For the 1986 return of P/Halley, Yeomans (1977) calculated a perihelion passage time of 1986 Feb 9.66 from considering both the non-gravitational forces caused by the outgassing jet effect of a water-ice cometary nucleus and perturbations induced by the nine known planets. A decade earlier, Brady and Carpenter (1967) derived a perihelion passage time of Feb 5.37 from fitting the observations obtained during the 1835 and 1910

Table 2.2 A Comparison Between the Predicted and Observed Dates of Perihelion of Halley's Comet.

Observed Date of Perihelion	Predicted Date of Perihelion	References
1759 Mar 13.06	1758/59	Halley (1705)
	1759 Apr 13	Clairaut (1758)
1835 Nov 16.44	1835 Nov 17.15	Damoiseau (1820)
	Nov 4.81	Damoiseau (1829)
	Nov 7.5	de Pontecoulant (1830)
	Nov 13.1	de Pontecoulant (1834)
	Nov 10.8	de Pontecoulant (1835)
	Nov 12.9	de Pontecoulant (1835)
	Nov 12.0	Rosenberger (1835)
	Nov 26.73	Lehmann (1835)
1910 Apr 20.18	1910 May 24.36	de Pontecoulant (1864)
	Apr 8.5	Cowell and Crommelin (1907)
	Apr 22.91	Ivanov (1909)
	Apr 17.11	Cowell and Crommelin (1910)
1986 Feb 9.45	1986 Feb 5.37	Brady and Carpenter (1967)
	Feb 9.39	Brady and Carpenter (1971)
	Feb 9.66	Yeomans (1977)
	Feb 9.42	Rasmusen (1981)

Apart from the 1986 return, all data for the observed perihelion passages are taken from Yeomans and Kiang (1981). The 1986 value is taken from Yeomans (1986).

apparitions by a trial and error technique. Brady and Carpenter (1971) later added an empirical secular term in the radial component of the comet's equations of motion and produced a date of perihelion of Feb 9.39. Rasmusen (1981) also calculated a perihelion passage time of Feb 5.46, 1986 from a fit to the observations in 1835 and 1910, and then adding +3.96 days. The actual perihelion passage time for the 1986 return was Feb 9.45.

2.3 Cometary Orbital Motion

The motion of a comet about the Sun to a first approximation can be regarded simply as a two-body problem representable by the following equations of relative motion:

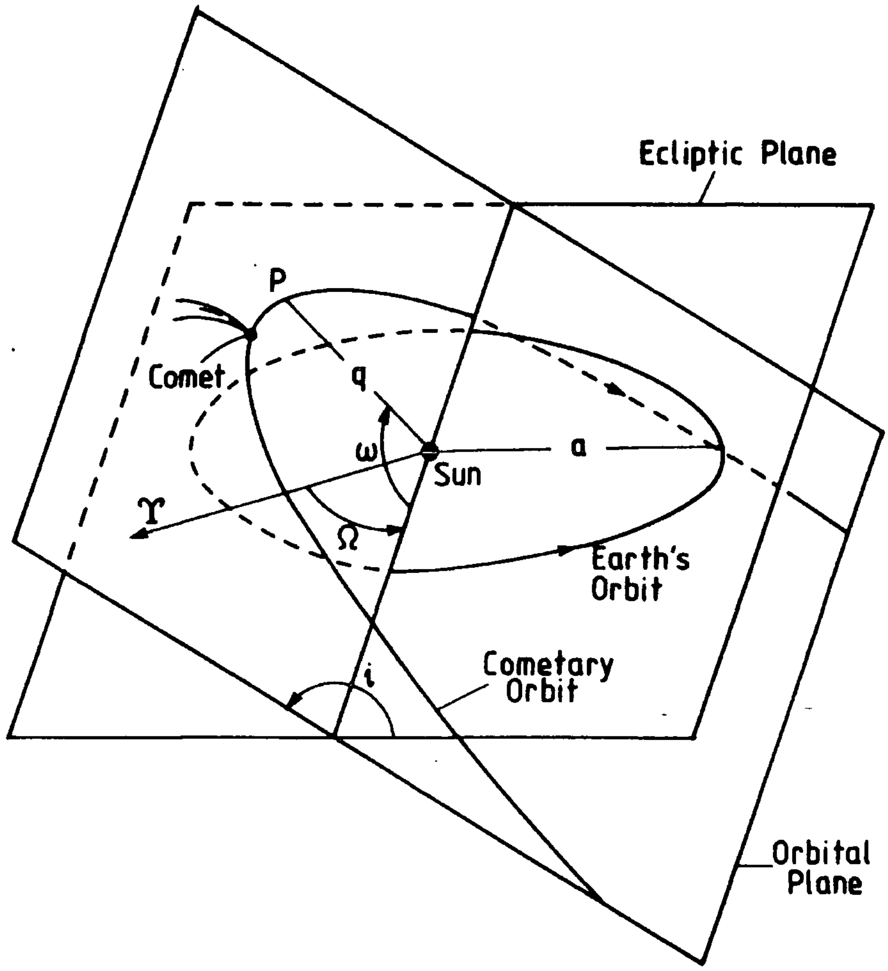
$$\frac{d^2\mathbf{r}}{dt^2} = -\mu\frac{\mathbf{r}}{r^3}$$

where $\mu = G(m_1 + m_2)$

Essentially these are three second-order differential equations solvable by developing the various integrals of these equations. The integration of these equations of motion introduces a set of six mutually independent constants usually referred as the orbital elements.

The six elements of a cometary orbit by convention are: the longitude of ascending node Ω, inclination i, longitude of perihelion w, perihelion distance q, eccentricity e, and time of perihelion passage T (Fig. 2.1). The first three elements define the orientation of the orbit in space with respect to a chosen origin, i.e. the Sun, the next two elements define the size and shape of the orbit and the last defines the position of the body at a certain instant along the orbit.

In the case of short period comets, in addition to the perturbations from the nine planets, there is a non-gravitational term due to the rocket-like effects of outgassing



Ω = longitude of ascending node

ω = longitude of perihelion

i = angle of inclination

a = semimajor axis

e = eccentricity

p = position of perihelion

q = perihelion distance

♈ = first point of Aries

Fig. 2.1 The elements of a cometary orbit.

volatiles from an icy-conglomerate nucleus. A model that has taken into account these non-gravitational accelerations was given by Marsden *et al.* (1973). They obtained the following cometary equations of motion:

$$\frac{d^2\mathbf{r}}{dt^2} = -\mu\frac{\mathbf{r}}{r^3} + \frac{\partial R}{\partial \mathbf{r}} + A_1 g(r)\hat{\mathbf{r}} + A_2 g(r)\hat{\mathbf{T}}$$

where r is the heliocentric distance, μ is the product of the gravitational constant G and solar mass $M_\odot$, and R is the planetary perturbing function. The nongravitational acceleration term $g(r)$ is modelled on a water-iced nucleus with $A_1 g(r)$ as the radial acceleration and $A_2 g(r)$ the transverse acceleration. It is given by:

$$g(r) = \alpha\left(\frac{r}{r_o}\right)^{-m}\left[1 + \left(\frac{r}{r_o}\right)^n\right]^{-k}$$

For water ice r_o = 2.808 AU and the normalizing constant α = 0.111262. The components m, n and k equal 2.15, 5.093 and 4.6142 respectively. The unit vector $\hat{\mathbf{r}}$ is defined outward along the Sun-comet radius vector. The transverse unit vector $\hat{\mathbf{T}}$ is directed in the direction of the comet's motion and normal to $\hat{\mathbf{r}}$ in the orbital plane. The success of this model relies on a constant outgassing rate which is in general true for most comets (Yeomans, 1977).

With these equations, one can then solve for the six initial orbital elements and the two non-gravitational parameters A_1 and A_2. Using observations from 1607 to 1911, Yeomans (1977) solved these equations by employing a least-square differential correction procedure. He successfully integrated the orbit of Halley's Comet backward in time to AD 837. In addition, he was able to make a very close prediction for the date of perihelion for the 1986 return of Comet Halley. The value of the two non-gravitational parameters, A_1 and A_2, used to construct the 1986 orbit of Halley's Comet were 0.0858 and 0.0155 respectively (Yeomans, 1986).

For the purpose of the present study, we are more concerned with the geometrical configuration of the comet's path through the celestial sphere in the relatively short period of time near perihelion. The short arc can be adequately represented by the Keplerian elliptic orbit. In orbital work, one often encounters two problems, one is to obtain the position and velocity of the body, given the six elements and the time; the other is to obtain the elements of the orbit, given the position, velocity and the time. The present investigation with Halley's Comet involves the first instance. I shall describe briefly below the procedure employed in obtaining the positions of Halley's Comet from orbital elements.

We begin by solving Kepler's equation:

$$M = E - e \sin E$$

where M is the mean anomaly, E is the eccentric anomaly and e is the eccentricity. The mean anomaly is related to the mean motion of the comet n and date of perihelion T for a given epoch t_0 by:

$$M = n(t_o - T)$$

The mean motion, n,can be obtained directly from the period P as follows:

$$n = \frac{2\pi}{P} = \frac{2\pi}{a^{3/2}}$$

where a is the semi-major axis and is related to the perihelion distance q and eccentricity e by $a = \frac{q}{1-e}$. Once the eccentric anomaly E is found, we can obtain the true anomaly ν from:

$$tan(\frac{\nu}{2}) = (\frac{1+e}{1-e})^{1/2} tan(\frac{E}{2})$$

Further, let us define a right-handed orthogonal set of unit vectors **P, Q, W** for the orbital plane, where **P** is directed toward the perihelion, **Q** is perpendicular to **P** in the direction of motion of the comet in the orbital plane and **W** is perpendicular to the orbital plane (see p.45–51, Herrick, 1971). The respective axes for this set of unit vectors are x_w, y_w, z_w. In the two-body problem $z_w = 0$. Then the coordinates of the comet with respect to this set of axes are given by:

$$x_w = r\cos\nu = a(\cos E - e)$$

$$y_w = r\sin\nu = a\sqrt{1-e^2}\,\sin E$$

where $r = a(1 - e\cos E)$

The rectangular coordinates of the comet (x, y, z) can then be written:

$$\mathbf{r} = x_w\mathbf{P} + y_w\mathbf{Q}$$

or

$$x = x_w P_x + y_w Q_x$$

$$y = x_w P_y + y_w Q_y$$

$$z = x_w P_z + y_w Q_z$$

where

$$\mathbf{P} = \mathbf{I}(\cos\omega\cos\Omega - \sin\omega\sin\Omega\cos i) + \mathbf{J}(\cos\omega\sin\Omega + \sin\omega\cos\Omega\cos i) + \mathbf{K}\sin\omega\sin i$$

$$\mathbf{Q} = \mathbf{I}(-\sin\omega\cos\Omega - \cos\omega\sin\Omega\cos i) + \mathbf{J}(-\sin\omega\sin\Omega + \cos\omega\cos\Omega\cos i) + \mathbf{K}\cos\omega\sin i$$

$$\mathbf{W} = \mathbf{I}(\sin\Omega\sin i) + \mathbf{J}(-\cos\Omega\sin i) + \mathbf{K}\cos i$$

Here the elements ω, Ω and i are the argument of perihelion, the longitude of the ascending node and orbital inclination respectively.

If the geocentric distance of the comet is denoted by ρ with coordinates ξ, η, ζ and the geocentric equatorial rectangular coordinates of the Sun are X, Y, Z. Then we can write

$$\rho = \mathbf{r} + \mathbf{R}$$

or

$$\xi = x + X$$
$$\eta = y + Y$$
$$\zeta = z + Z$$

with

$$\rho^2 = \xi^2 + \eta^2 + \zeta^2$$

Thus the equatorial position of the comet (α, δ) can be found from:

$$\tan\alpha = \frac{\eta}{\rho}$$

$$\sin\delta = \frac{\zeta}{\rho}$$

2.4 Orbital Characteristics of Comets

2.4.1 Classification

By convention, comets are classified according to their periods; those with periods less than 200 years are known as short period comets and those greater than 200 years as long period comets. So far, accurate orbits have been deduced for a total of 748 comets (Marsden, 1986). The number of comets in the pre-telescopic era with orbital elements calculated is fairly small, only 66, while the number since AD 1610 is 682. Table 2.3 gives the general classification of known cometary orbits.

2.4.2 Long Period Comets

Fig. 2.2 shows the distribution of the various orbital elements of all known long period comets as listed in Marsden (1986). The visibility of long-period comets is influenced

Table 2.3 A Statistical Table of Comets
- data from Marsden (1986).

I.	Short period comets (period < 200 yrs)		135
	Only one appearance	50	
	More than one appearance	85	
II.	Long period comets (period > 200 yrs)		613
	Elliptical orbits (e < 1)	179	
	Hyperbolic orbits (e > 1)	112	
	Parabolic orbits (e = 1)	322	

For orbits classified as parabolic, the eccentricity e is inmeasurably different from unity.

by selection effects. Everhart (1967) studied the discovery positions of 337 long period comets. He found that whereas 69% of the retrograde comets were actually seen in the morning sky, 81% of all comets were discovered in the morning sky. He thus confirmed the so called Holetschek Effect, that is comets which arrive at perihelion when the Earth is on the other side of the Sun are not as likely to be discovered.

The direction of perihelion in space is a relatively stable feature and has been used for studying the problem of comet groups. The famous Kreutz group of sungrazing comets is evident around longitude of perihelion at 280° (Fig. 2.2). The distribution of the longitude of ascending nodes of comets is what would be expected from random fluctuation. The median of orbital inclination is 94° and median of perihelion distance is 0.85 AU. The distribution of eccentricity is clustered around 1, this implies that most of the long period comets have very elongated orbits. The random distribution of orbital inclinations is what one would expect from Oort's theory of comets, namely they enter the solar system from all directions.

Long period comets can have periods up to tens of millions of years. It is well known that if the osculating orbits are traced back to when the respective comets were well beyond the circuit of Neptune, if the orbits are then referred to centre of mass of the Sun and planets, these 'original orbits' invariably turn out to be elliptical. Fig. 2.3 shows the distribution of the reciprocal semimajor axes $1/a$ of these original orbits as calculated by Marsden *et al.* (1978) and, Everhart and Marsden (1983). Most of these long period comets have very small positive values of $1/a$ between 1 and 10×10^{-5} AU^{-1}, which suggest that they have very long aphelion distances. A positive $1/a$ value also indicates that the comet was originally bound to the solar system. On the other hand, an original orbit with a negative $1/a$ value would imply that the comet follows a hyperbolic orbit and comes from interstellar space. The few small negative $1/a$ values shown in Fig. 2.3 may be explained by nongravitational forces (Marsden *et*

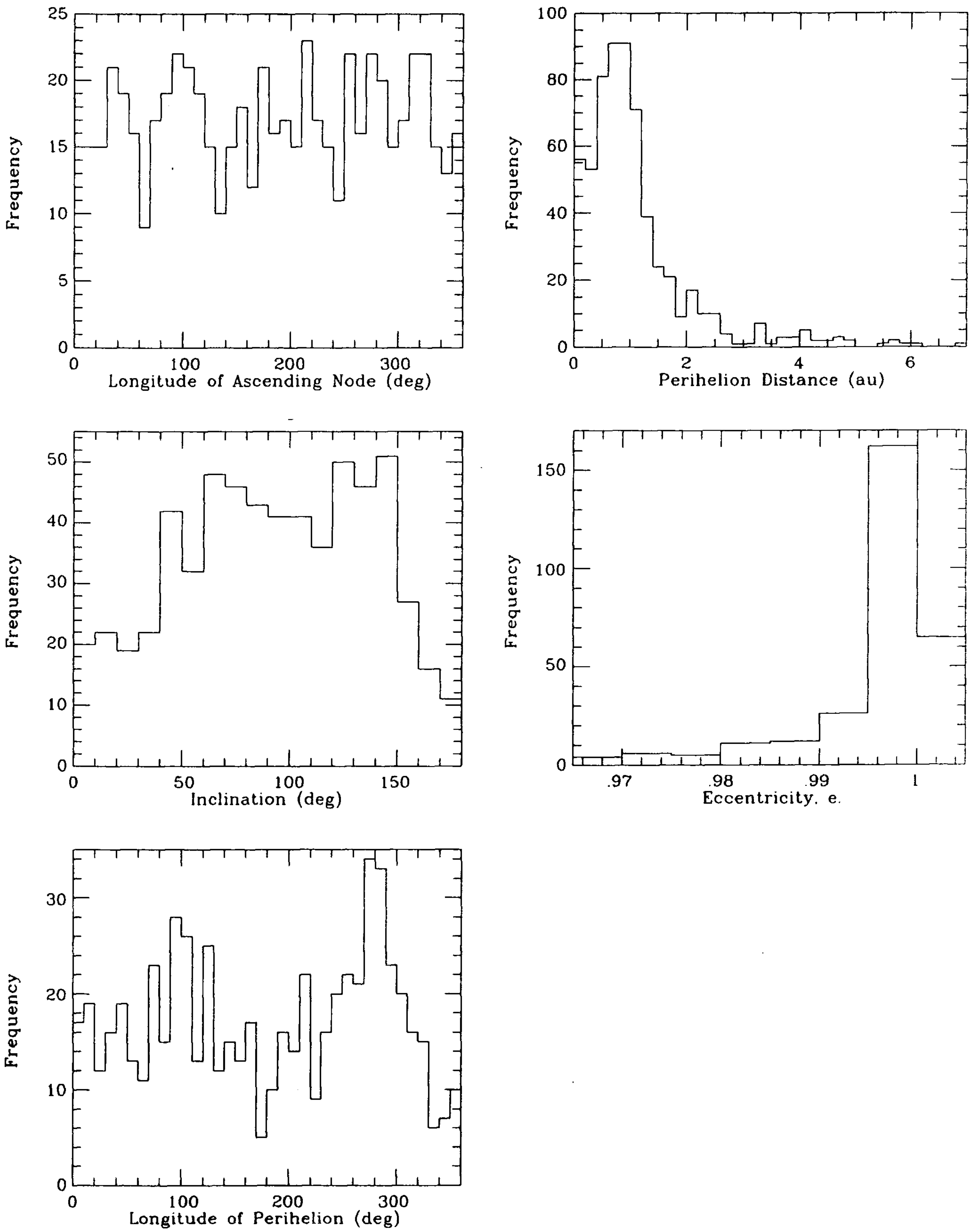


Fig. 2.2 Distributions obtained from five of the orbital elements of long period comets.

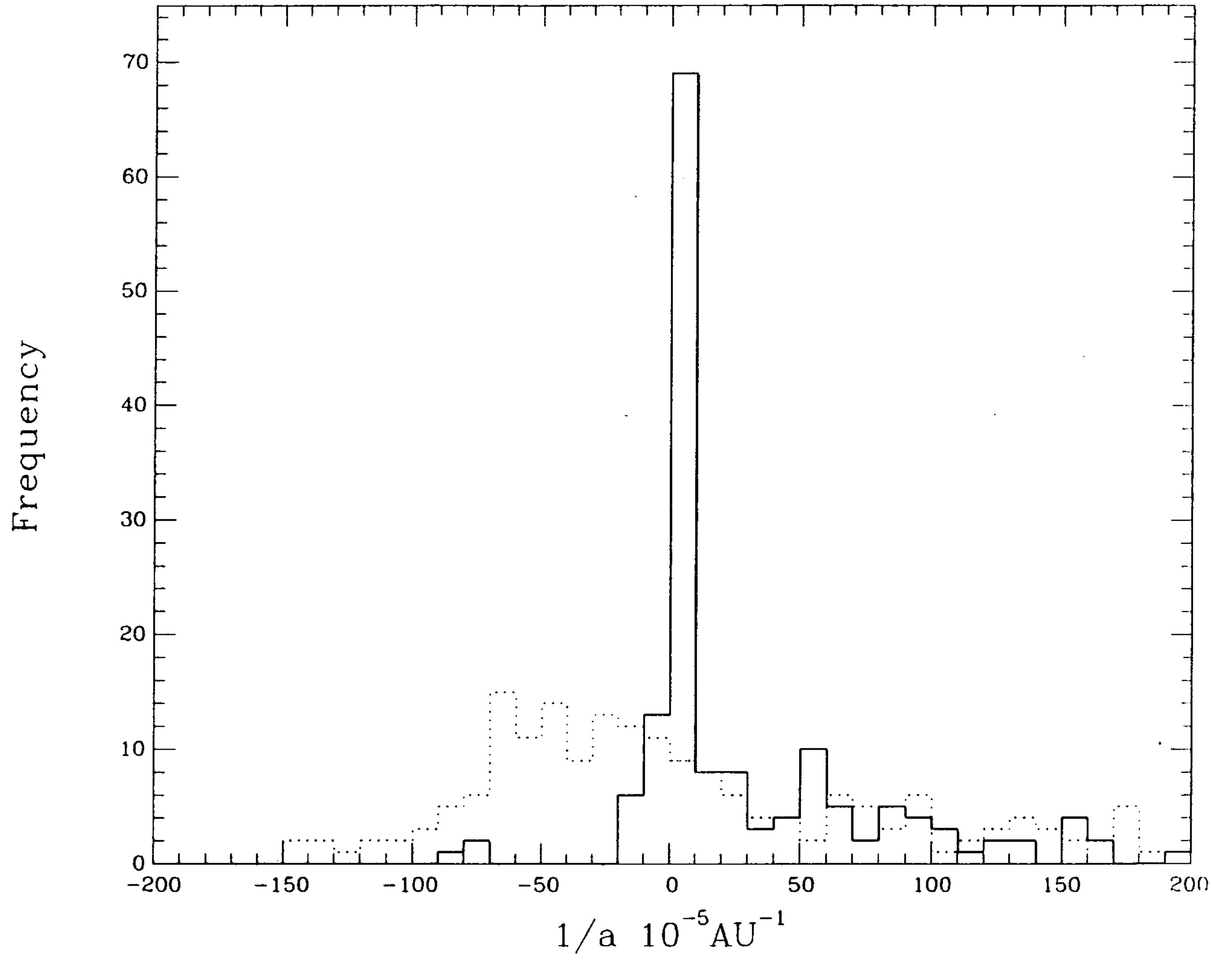


Fig. 2.3 Distributions of the reciprocal semimajor axes, 1/a, of the long period comets. The solid line represents original orbits and dotted line is for osculating orbits.

al., 1978). Fig. 2.3 also shows the distribution of the $1/a$ values derived directly from osculating elements as given in Marsden's cometary catalogue (Marsden, 1986). The two distributions differed in that the calculation of the original orbits had taken into account planetary perturbations.

The sharp peak shown by the original $1/a$ distribution, plus the fact that comets eject material in the form of tails means that they possess a finite life span comparatively shorter than those more durable members of the solar system such as the planets and their satellites. These two factors provide the key to the theory of cometary origin. Nearly two centuries ago, Laplace (1805) who attempted to explain a theory of the solar formation, found difficulties in accommodating comets. This led him to suggest that comets were interstellar objects. Whether comets have an interstellar or a solar system origin is a subject long debated.

The now favoured hypothesis is that comets were formed at the same time as the solar system, which has an estimated age ranging from 5 to 10×10^9 years. They were probably formed in a low density region of the pre-solar nebula where there were not enough materials to build kilometric scale structures. The model also requires that the region be sufficiently far from the protosun to facilitate the ice conglomerates to grow, possibly at distances similar to that of Saturn or Uranus. These smaller bodies would be expelled later from the inner solar system by planetary perturbations. Some would leave the solar system and never to return, but most of them would gradually acquire very elongated orbits.

When their aphelia extended to a distance some 30,000 AU from the Sun, planetary perturbations are no longer important, but perturbations from the surrounding stars and gas clouds might render their orbits permanently outside the inner part of the solar system. Then they would have been released from the gravitational influences of the planets and acquired a quasi-stationary state. At this stage, they are confined to a spherically thick shell whose inner radius is 30,000 AU from the Sun with its outer surface extending some 100,000 AU from the solar system (Fig. 2.4). At the outer extent, the number of comets decreases with the distance from the Sun due to the increase likelihood of 'evaporation' by stellar perturbations. This model of cometary origin was first proposed by Opik (1932) and investigated in detail by Oort (1950).

After their capture by the spherical cloud or Oort Cloud as it is now known, comets will be released again over a long time-scale. They are progressingly randomized by the continuing stellar perturbations. Eventually, their motion can either be retarded towards the Sun or accelerated away from the cloud to unknown destinations. The Oort Cloud model was further strengthened by Whipple (1950, 1951) who was able to explain the high cometary loss rate by his icy-conglomerate model.

Alternatively, comets may have joined the solar system at a relatively recent date. As explained by Laplace (1805), comets were small condensations of the nebulous material (cosmic dust particles and gases) which happened by chance to wander within the gravitational attraction of the Sun. Lyttleton (1948) suggested that the solar system may have transversed several such cosmic gas and dust clouds in its circuits of the galaxy. Each time an accretion stream of cometary condensations would fall inward on hyperbolic orbits until it was retarded by planetary perturbations. A detailed review on the origin of comets may be found in Bailey *et al.* (1986).

2.4.3 Short Period Comets

The majority of short period comets have periods between 5 and 9 years (Fig. 2.5). The dotted line regions represent comets with only one recorded apparition. The origin of short period comets is an important problem of cometary research. The transition

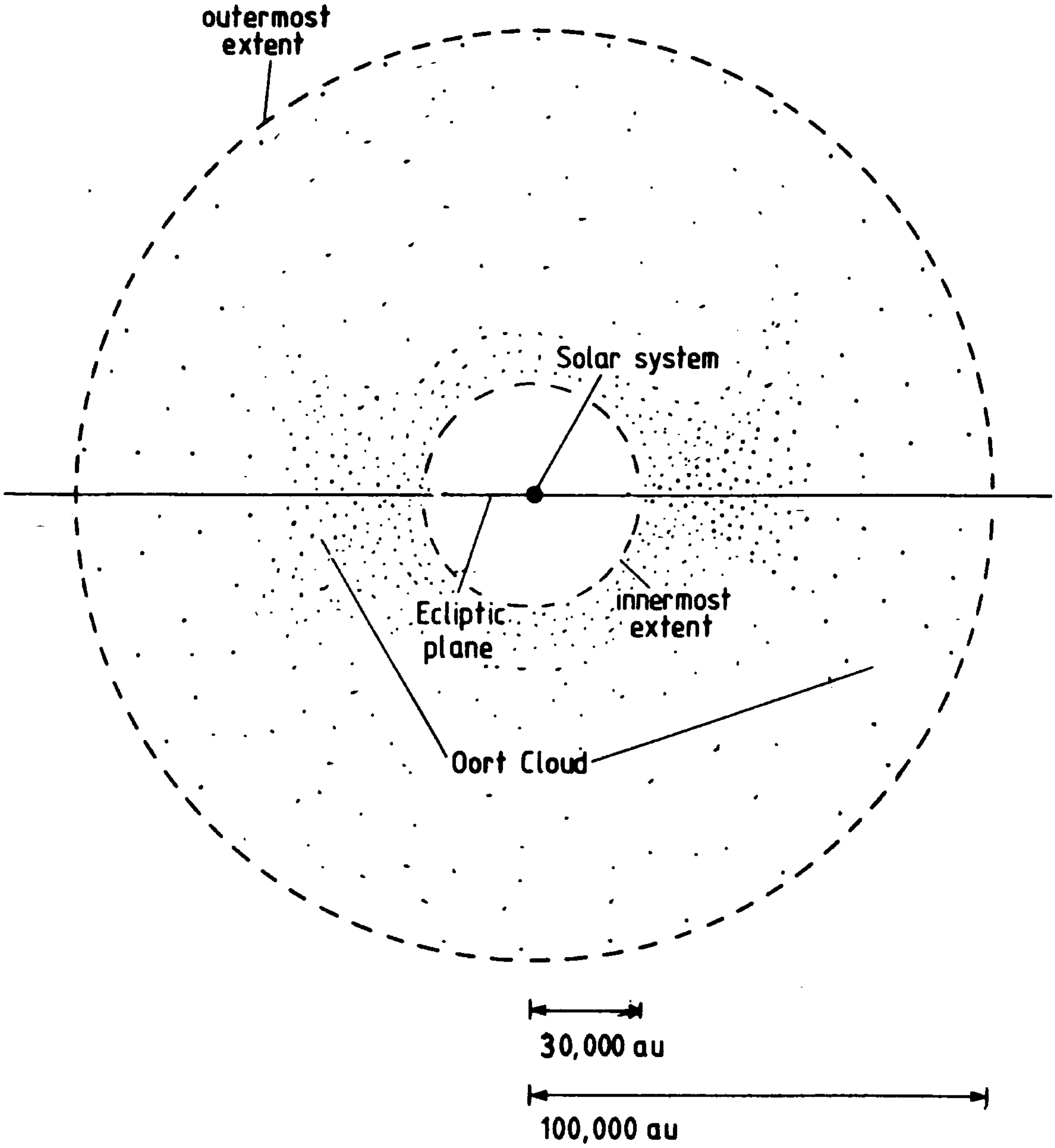


Fig. 2.4 A schematic diagram of the Oort Cloud in relation to the solar system.

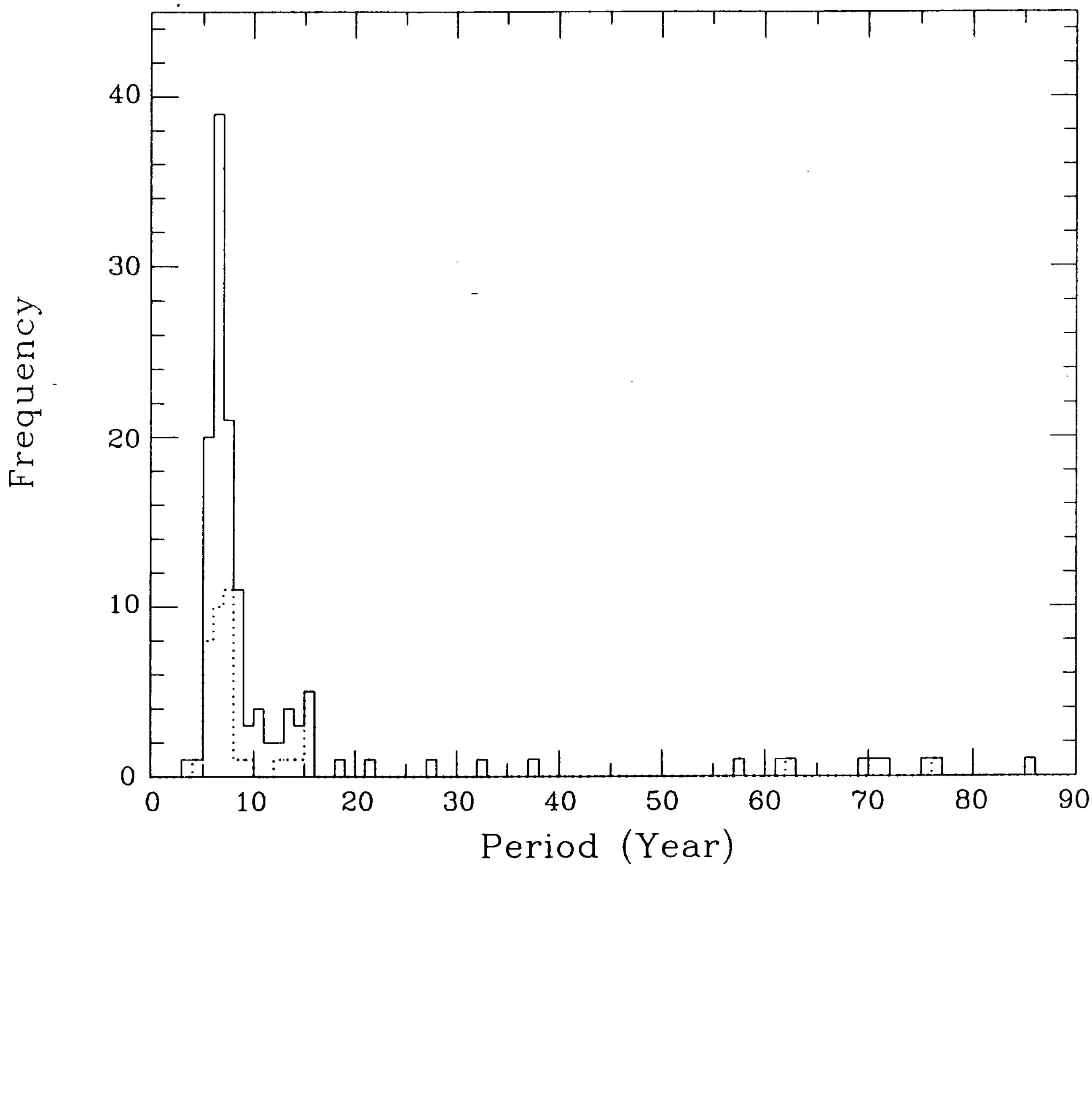


Fig. 2.5 The distribution of the periods of short period comets; the dotted line represents comets with only one recorded apparition.

from long period to short period comets has been discussed by several authors (Hughes, 1985b), one of the suggested mechanisms being the capture by the gravitational field of Jupiter (Everhart, 1972 and Fernandez, 1981). The orbital evolution of Halley's Comet is not properly understood. Several researchers used past records to show that there has been no substantial change in brightness over two millennia (Stephenson and Yau, 1984; Bortle and Morris, 1984; Hughes, 1985c). This suggests that the evaporation rate is very slow over periods of millennia. According to Hughes (1987) Halley's Comet was captured by Jupiter into its present orbit some 200,000 years ago and will have disappeared in about 300,000 years time when all of its materials decayed into the associated meteoroid stream.

Fig. 2.6 shows the distributions of the various orbital elements of short period comets as listed in Marsden (1986). A large proportion of the short period comet has an average period of 7 years and a typical perihelion distance of 1.5 AU. There are twice as many short period comets with longitude of perihelion in the semicircle centred on Jupiter's perihelion (longitude $\sim 15°$) as in the opposite semicircle. The distribution of the eccentricity shows clustering around $e = 0.55$ which means they describe well defined elliptical orbits. The remarkable concentration of orbital inclinations at lower values is interesting. This suggests that only those comets entering the solar system at a low inclination angle to the ecliptic plane are captured whereas those with high inclination angles pass through the solar system without being perturbed significantly.

2.5 Catalogues of European sightings of Comets

The standard cometary catalogues of Pingre (1783–4) has served many purposes as a good collection of European observations before the 18th century. Other well known later collections of European source materials included those by Lersch (1883), Chambers (1909) and Baldet (1949). The usefulness of European source materials is hindered

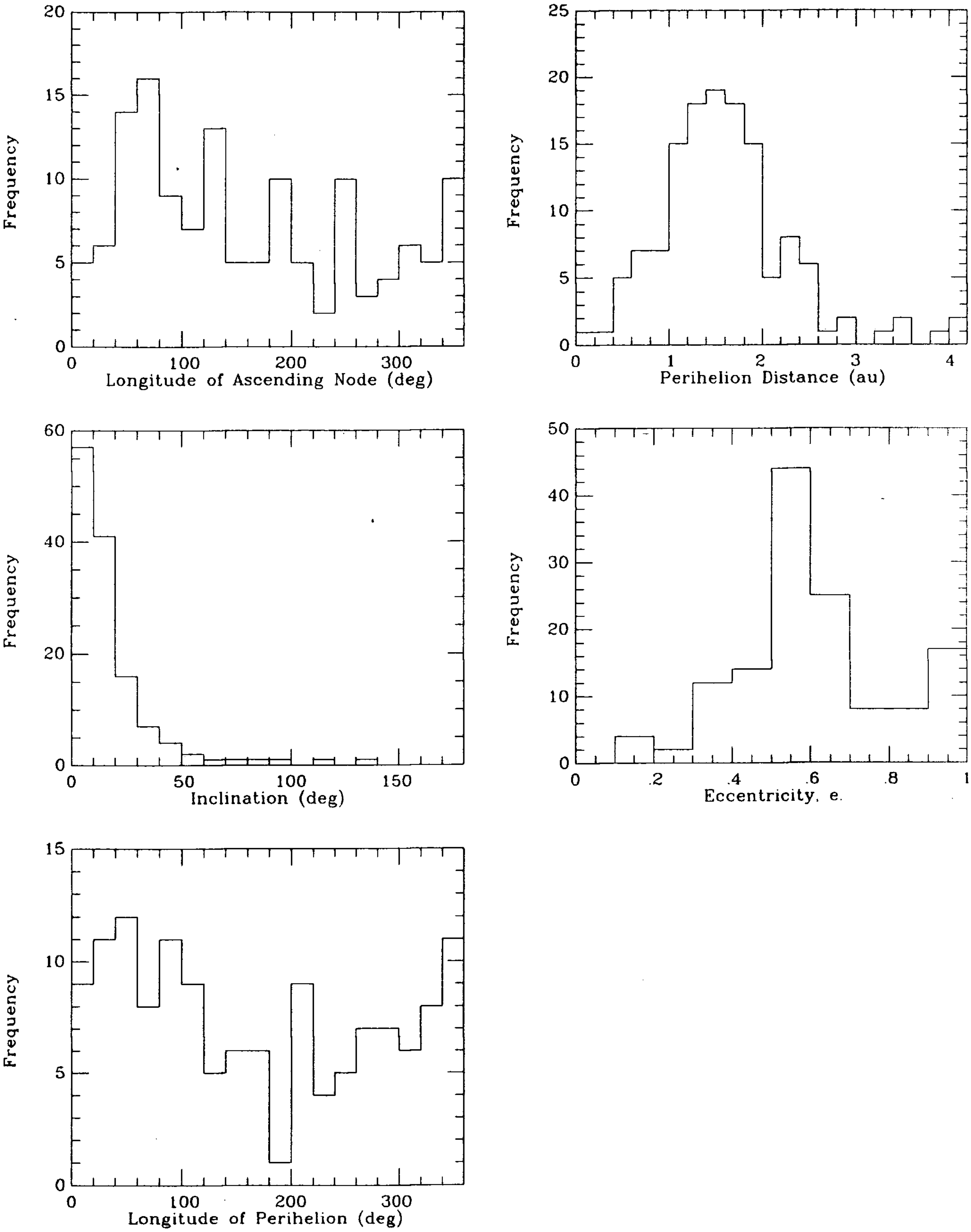


Fig. 2.6 Distributions obtained for five of the orbital elements of short period comets.

by their brevity and the positional information given is usually too general for an orbit to be ascertained. Both Greek and Roman material have been assembled from a disparate collection of sources ranging from historical and philosophical to ecclesiastical. Often the reference to the comet is quite incidental, mentioned only as a portent of some great historical event (Barrett, 1978). The medieval chronicles suffered similar fate and confusion. Venerable Bede observing near Durham in AD 729, reported in the *Historia Ecclesiastica* the observation of two comets. In fact these were one and the same comet appearing both in the morning and evening sky.

The first reliable catalogue of calculated cometary orbits was compiled by Galle (1894). This was widely used by comet researchers in the early decades of the present century. As commented by Marsden (1986), it is a remarkably accurate catalogue which is by no means superseded by even his own compilation for pre-1894 comets. The most up to date and complete catalogue on cometary orbits is due to Marsden (1986). The Marsden catalogue is now in its sixth edition and originated from the catalogues of Porter (1961) and its supplement by Marsden (1966). The catalogue of Marsden provides orbital elements for a total of 1187 cometary apparitions from 240 BC up to the end of December 1985. The main list in Marsden's catalogue gives for each cometary orbit the whole set of standard orbital elements and important osculation epochs. This is followed by statistical tables for various categories of orbits. Fig. 2.7 shows the decade distribution of comets in the telescopic era with the thicker line representing comets recorded in Far Eastern sources. It seems that the gradual increase in the number of comets reported since 1610 corresponds with the increased number of interested observers and observatories (Fig. 2.8).

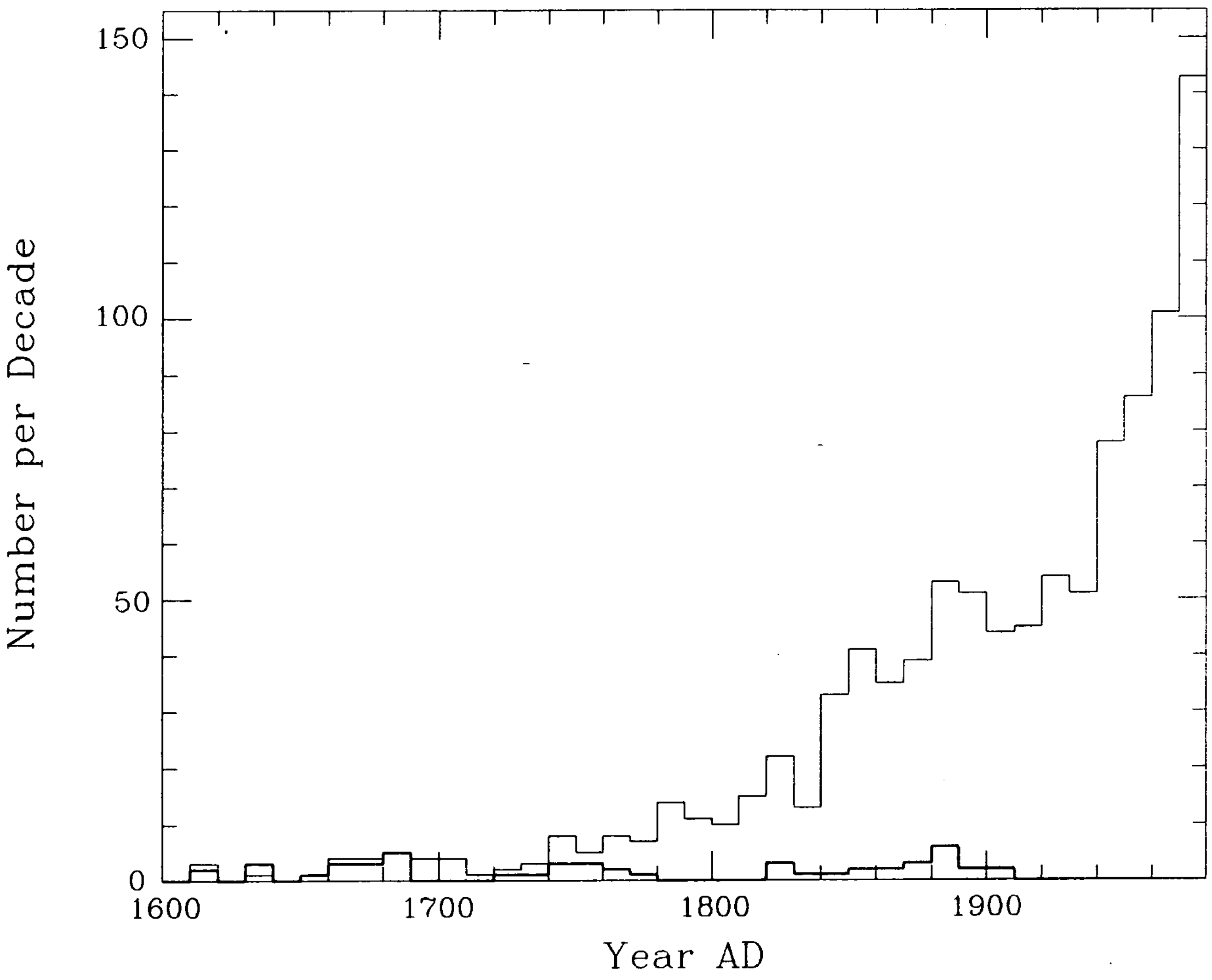


Fig. 2.7 The decade distribution of comets in the telescopic era. The thicker line represents naked-eye comets recorded in Far Eastern sources.

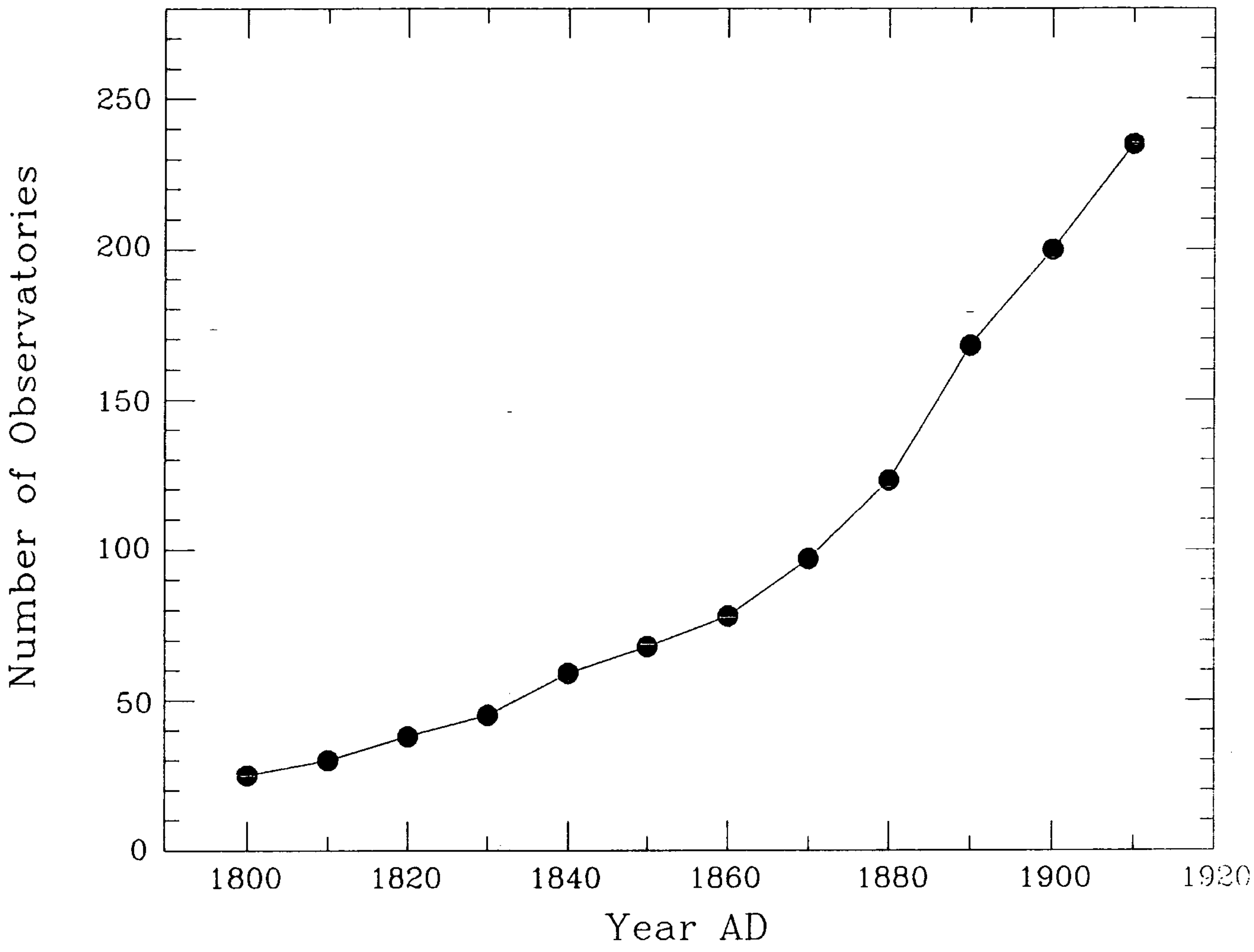


Fig. 2.8 The increase in the number of observatories during AD 1800 to 1910. (After Herrmann, 1984).

2.6 Far Eastern Catalogues

Ancient and medieval cometary records with sufficient details for studying the past orbits of comets are mainly found in Far Eastern sources. The earliest datable observation of a comet is recorded in the Chinese chronicle *Ch'un Ch'iu* for the year 613 BC. In the following five centuries only intermittent records are to be found. Sadly, not only cometary records, but astronomical records in general prior to the second century BC are scarce. As already discussed in chapter 1, this could possibly be due to the 'Burning of Books' in 213 BC.

The most complete catalogue of cometary records from the Far East is by Ho Peng Yoke (1962) and its supplement (Ho Peng Yoke and Ang Tian-se, 1970). Before Ho's catalogues, western astronomers relied on two 19th century compilations by Biot (1843a, b) and Williams (1871). These two works derived their sources mainly from the *Wen-hsien T'ung-k'ao* ('Historical Investigation of Public Affairs') which was completed by Ma Tuan-lin in AD 1254 and also its supplement *Hsu Wen-hsien T'ung-k'ao* (compiled in AD 1747). These older catalogues are now more or less obsolete.

The catalogues of Ho list about 500 naked-eye observations of comets. A distribution of the naked-eye comets by centuries is given in Fig. 2.9. If comets do appear in groups then striking features would be expected. However, the features of this distribution is statistically insignificant to account for such a hypothesis. Thus it may be concluded that they occurred randomly through the past 2000 years. Any cyclic reappearance of groups of comets can not be supported.

It would be a daunting task if one were to search for Halley's Comet among the numerous ancient and medieval cometary records without detailed knowledge of its orbital motion. Recently, Hasegawa (1980) published a revised version of Ho's catalogues

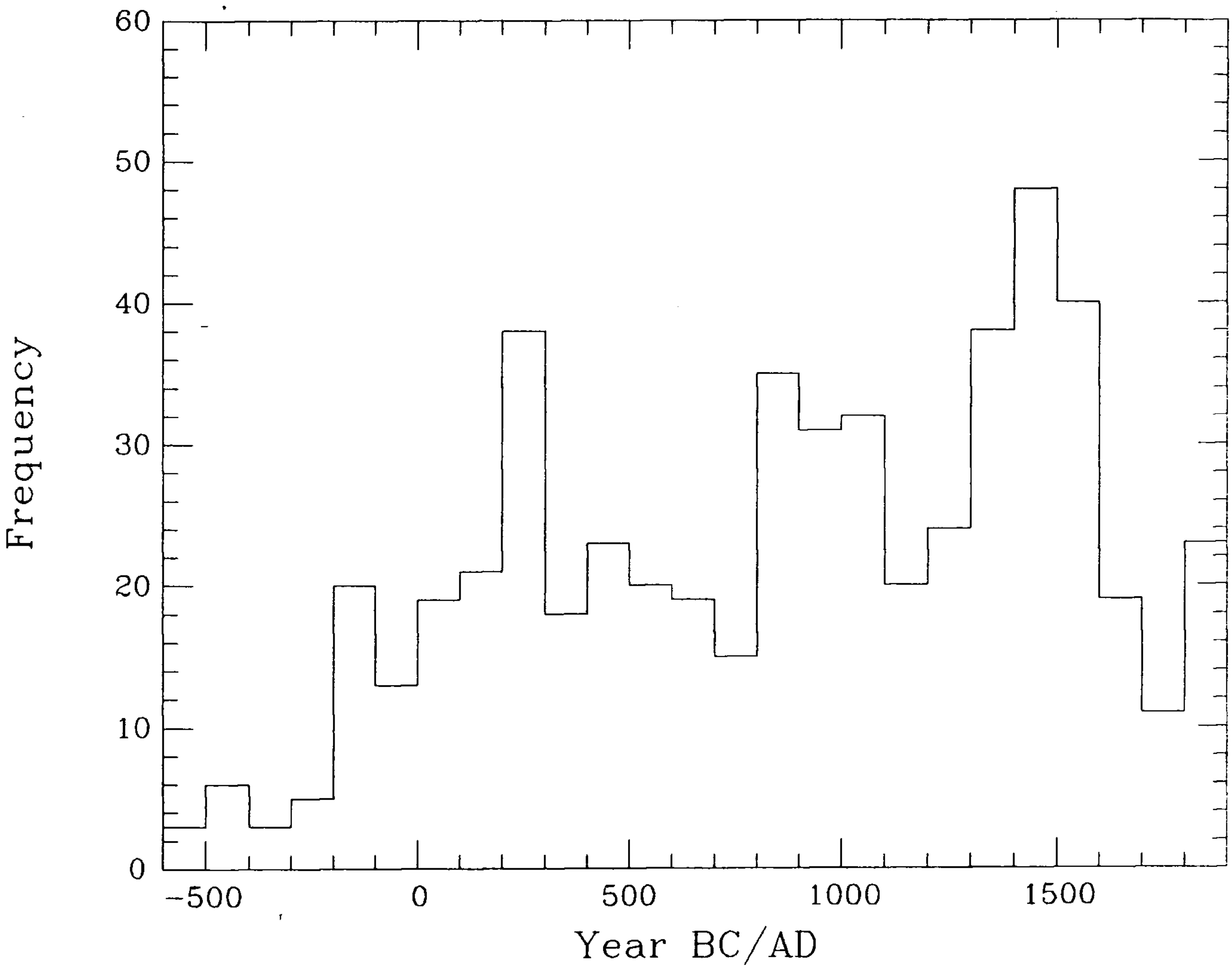


Fig. 2.9 The distribution of naked-eye comets by centuries.

of Far Eastern sightings of comets together with European observations since ancient times. However, this gives no additional observational details.

2.6.1 Terminology

In order to make full use of the East Asian records it is necessary to know first the various terms used to describe comets. There are two standard names used for comets in Far Eastern texts, the *hui-hsing* ('broom star') and *po-hsing* ('bushy star'). However, in addition to these two terms other names were also used. For example, during the Han Dynasty (206 BC to 208 AD), the following terms were often employed by the astronomers: *ch'ang-hsing* ('long star'), *t'ien-ch'an* ('celestial gondolier'), *p'eng-hsing* ('luxuriant star'), *chu-hsing* ('candle star'), and sometimes even as *k'o-hsing* ('guest star'). In later dynasties, the term *hui-hsing* was commonly used for tailed comets and *po-hsing* for tailless comets. The term *po-hsing* was also used at all periods to describe stellar outbursts. Since the nucleus of a comet often resembles a bright star some confusion is inevitable. A lack of reference to movement may indicate a stellar nature – see chapter 4.

2.6.2 Relative Position and Time Measurements

The versatility to determine accurate positions from descriptions given in the text renders Far Eastern records considerably superior to those from other sources. The Chinese have from a very early period used the equatorial system to define celestial positions. Any given celestial location of an object is referenced from two points. The right ascension is given with respect to how many *tu* ('degrees of 365.25 to a circle') eastward of the appropriate determinant star of one of the 28 *Hsiu* ('Lunar Mansion') which roughly lie along the ecliptic (Fig. 2.10) – see also Table 2.4. The declination is given as so many degrees from the north celestial pole.

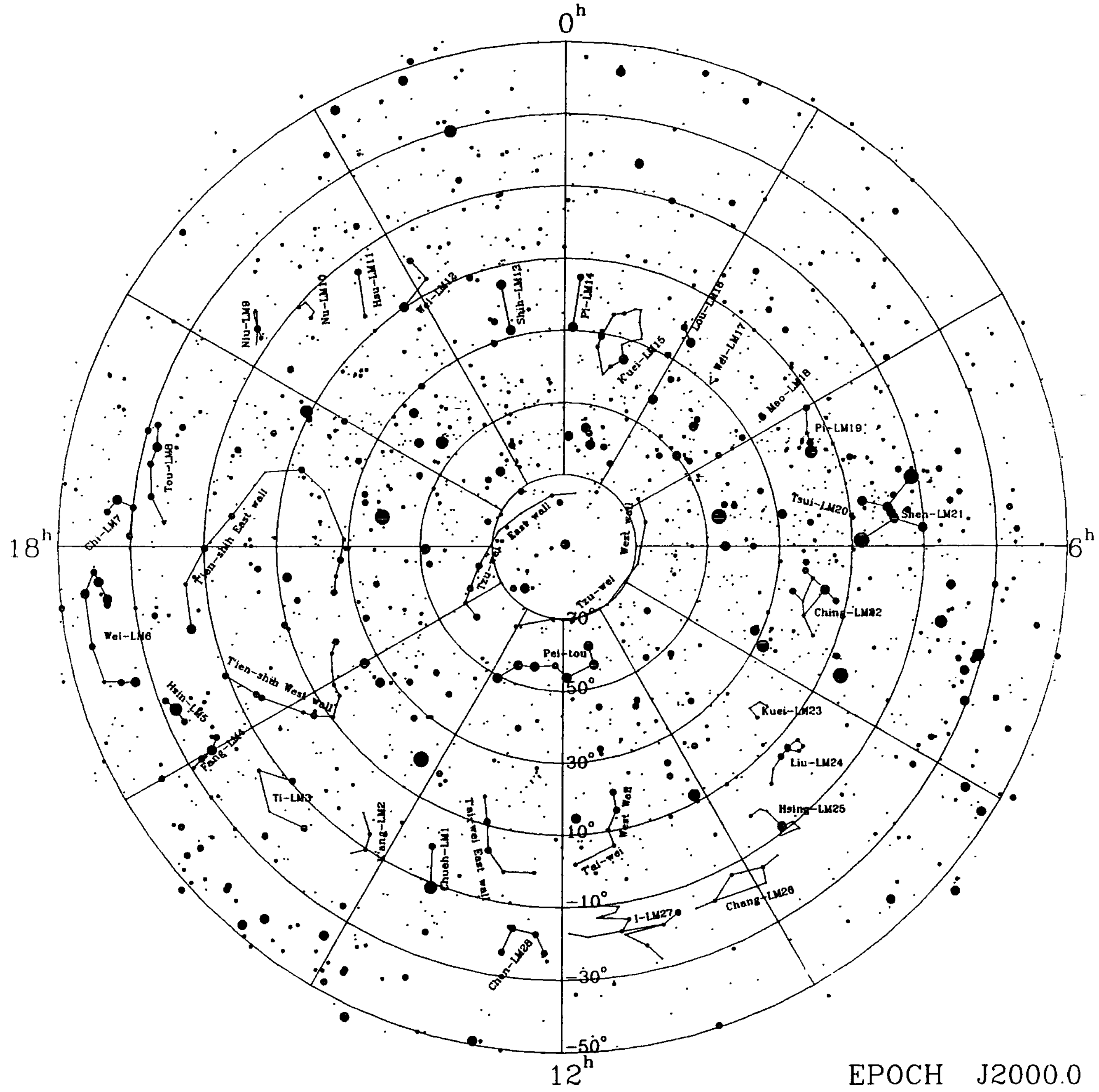


Fig. 2.10 A star map showing the 28 Lunar Mansions.

Table 2.4 Identification of the determinant stars of the 28 Lunar Mansions with the Yale Bright Star catalogue.

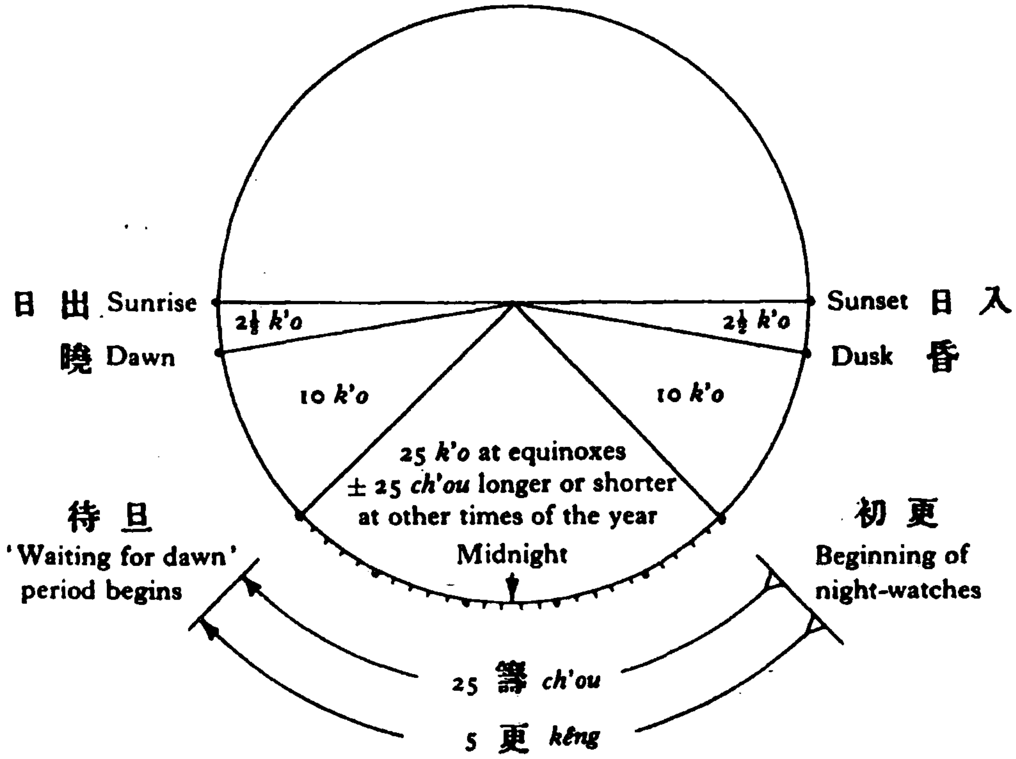
LM	Name	HR	HD	Star name	VAR	R.A.(J2000.0)	Dec.	VMAG	CLASS
1	Chueh	5056	116658	67 α VIR	01 VIR	13 25 11.5	-11 9 41	0.98	B1
2	K'ang	5315	124294	98 κ VIR		14 12 53.7	-10 16 25	4.19	K3
3	Ti	5531	130841	9 α^2 LIB	VAR?	14 50 52.6	-16 2 31	2.75	A3
4	Fang	5944	143018	6 π SCO	102782	15 58 51.0	-26 6 51	2.89	B1
5	Hsin	6084	147165	20 σ SCO	18 SCO	16 21 11.2	-25 35 34	2.89	B2
6	Wei	6247	151890	μ^1 SCO	121 SCO	16 51 52.1	-38 2 51	3.08	B1
7	Chi	6746	165135	10 γ^2 SGR	101708	18 5 48.4	-30 25 27	2.99	K0
8	Tou	7039	173300	27 ϕ SGR		18 45 39.3	-26 59 27	3.17	B8
9	Niu	7776	193495	9 β CAP		20 21 0.6	-14 46 53	3.08	F8
10	Nu	7950	198001	2 ϵ AQR		20 47 40.5	- 9 29 45	3.77	A1
11	Hsu	8232	204867	22 β AQR		21 31 33.4	- 5 34 16	2.91	G0
12	Wei	8414	209750	34 α AQR		22 5 46.9	- 0 19 11	2.96	G2
13	Shih	8781	218045	54 α PEG	102226	23 4 45.6	+15 12 19	2.49	B9
14	Pi	39	886	88 γ PEG	03 PEG	0 13 14.1	+15 11 1	2.83	B2
15	K'uei	271	5516	38 η AND		0 57 12.4	+23 25 4	4.42	G8
16	Lou	553	11636	6 β ARI	100146	1 54 38.3	+20 48 29	2.64	A5
17	Wei	801	16908	35 ARI		2 43 27.0	+27 42 26	4.66	B3
18	Mao	1142	23302	17 TAU		3 44 52.5	+24 6 48	3.70	B6
19	Pi	1409	28305	74 ϵ TAU		4 28 36.9	+19 10 49	3.53	G9
20	Tsui	1879	36861	39 λ ORI	100542	5 35 8.2	+ 9 56 3	3.66	O8
21	Shen	1852	36486	34 δ ORI	04 ORI	5 32 0.3	- 0 17 57	2.23	B0
22	Ching	2286	44478	13 μ GEM	12 GEM	6 22 57.6	+22 30 49	2.88	M3
23	Kuei	3357	72094	31 θ CNC		8 31 35.7	+18 5 40	5.35	K5
24	Liu	3410	73262	4 δ HYA		8 37 39.3	+ 5 42 13	4.16	A1
25	Hsing	3748	81797	30 α HYA	101049	9 27 35.2	- 8 39 31	1.98	K3
26	Chang	3903	85444	39 υ^1 HYA		9 51 28.6	-14 50 48	4.12	G7
27	I	4287	95272	7 α CRT		10 59 46.4	-18 17 56	4.08	K0
28	Chen	4662	106625	4 γ CRV	101250	12 15 48.3	-17 32 31	2.59	B8

The Chinese day begins at dawn and ends at dawn (Kiang, 1981). The length of the day is divided into 12 Chinese double-hours represented by the 12 earthly branches. In addition, the length of the night is divided into 5 watches (*keng*) corresponding approximately to the period between sunset and sunrise (Fig. 2.11). Although nearly all Chinese records can be accurately dated, the time of the night during which the observation was carried out is not often specified. However, we can estimate the time that a comet would be visible to observers in a particular locality. By calculating both the time of the beginning and end of twilight, and the time of rise and set of the comet, the UT of observation can be deduced to within a few hours on either side of the true value.

2.7 Determination of the Date of Perihelion of a Comet

At the perihelion passage of a comet, perturbations from the major planets often influence its orbit significantly such that theoretical modelling alone may not be sufficient to trace accurately its motion into the past. It is fair to say that no modern integration techniques so far developed could represent accurately the orbit of a comet into the past without taken into account historical observations (Yeomans, 1988). We have adopted the following method of correction to the date of perihelion of cometary orbits, with Halley's Comet being our principal object of investigation.

The method is essentially based on an empirical fitting of observed cometary positions by a trial and error technique. We employed a simple one parameter fit by varying only the date of perihelion and keeping the other five elements fixed to an already existing set of osculating elements determined by other researchers. By changing the date of perihelion T, we in effect change the relative configuration and motion of a comet through the constellations as seen by observers on Earth. A small change in the date of perihelion T by an amount ΔT will result in a corresponding change in the



1	Tzu	子	11 p.m.–1 a.m.	*yeh pang*	夜半	rat
2	Ch'ou	丑	1 a.m.–3 a.m.	*chi ming*	雞鳴	ox
3	Yin	寅	3 a.m.–5 a.m.	*p'ing tan*	平旦	tiger
4	Mao	卯	5 a.m.–7 a.m.	*jih ch'u*	日出	hare
5	Ch'en	辰	7 a.m.–9 a.m.	*shih shih*	食時	dragon
6	Ssu	巳	9 a.m.–11 a.m.	*yü chung*	隅中	snake
7	Wu	午	11 a.m.–1 p.m.	*jih chung*	日中	horse
8	Wei	未	1 p.m.–3 p.m.	*jih tieh*	日昳	sheep
9	Shen	申	3 p.m.–5 p.m.	*pu shih*	晡時	monkey
10	Yu	酉	5 p.m.–7 p.m.	*jih ju*	日入	cock
11	Hsü	戌	7 p.m.–9 p.m.	*huang hun*	黃昏	dog
12	Hai	亥	9 p.m.–11 p.m.	*jen ting*	人定	boar

Fig. 2.11 The first part shows the scheme of the time-divisions of the night in ancient and medieval China. A night was divided into five 'watches' (*keng*), each watch subdivided into five *ch'ou*. The night watches began at the hour of *hsu* (7-9 p.m.) and end at *yin* (3-5 a.m.). The second part shows the day and night 'double-hours'. A full day (from midnight to midnight) was divided into a total of 12 double-hours. One double-hour was equivalent to about 8 *k'o* (quarters). (After Needham, Ling and Price, 1960)

positional coordinates α and δ (the right ascension and declination respectively) by $\Delta\alpha$ and $\Delta\delta$ (Fig. 2.12). The success of the technique relies on the fact that the relative celestial position of a comet is very sensitive to small variations in the time of perihelion passage. Whereas a small change in any of the other five elements produced virtually negligible effect on the position of a comet along that short section of observable arc near perihelion.

The constraint on the date of perihelion is provided solely by observational data. For example, in the investigation of P/Halley, we first calculated an initial orbit based on the elements of Yeomans and Kiang (1981). We then altered this orbit by varying the date of perihelion until its path through the constellations fits the historical descriptions. In this way, the dates of perihelion obtained from a numerical integration may be rectified. In addition, the method facilitated the identification of the apparition of Halley's Comet in 164 BC from historical records. The investigation of P/Halley is presented in the next chapter.

2.8 Summary

Short period comets are the older portion of the cometary population which have orbits around the Sun inside the solar system. The nature as to how these comets acquired their present orbits is not yet clear. As already shown by Fig. 2.5, the majority of these have periods between 5 and 9 years which are much shorter than the 76 year period of Comet Halley. The rarity of the species of comets with similar periods to that of Comet Halley may be one of the reasons contributing to its uniqueness among comets. It is possible that Halley's Comet belongs to an intermediate group of comets undergoing a transition from long periods of more than 200 years into very short periods of 5 to 9 years. The small number of comets with periods between 50 and 200 years may suggest that the transitional rate between long and very short period comets is very rapid.

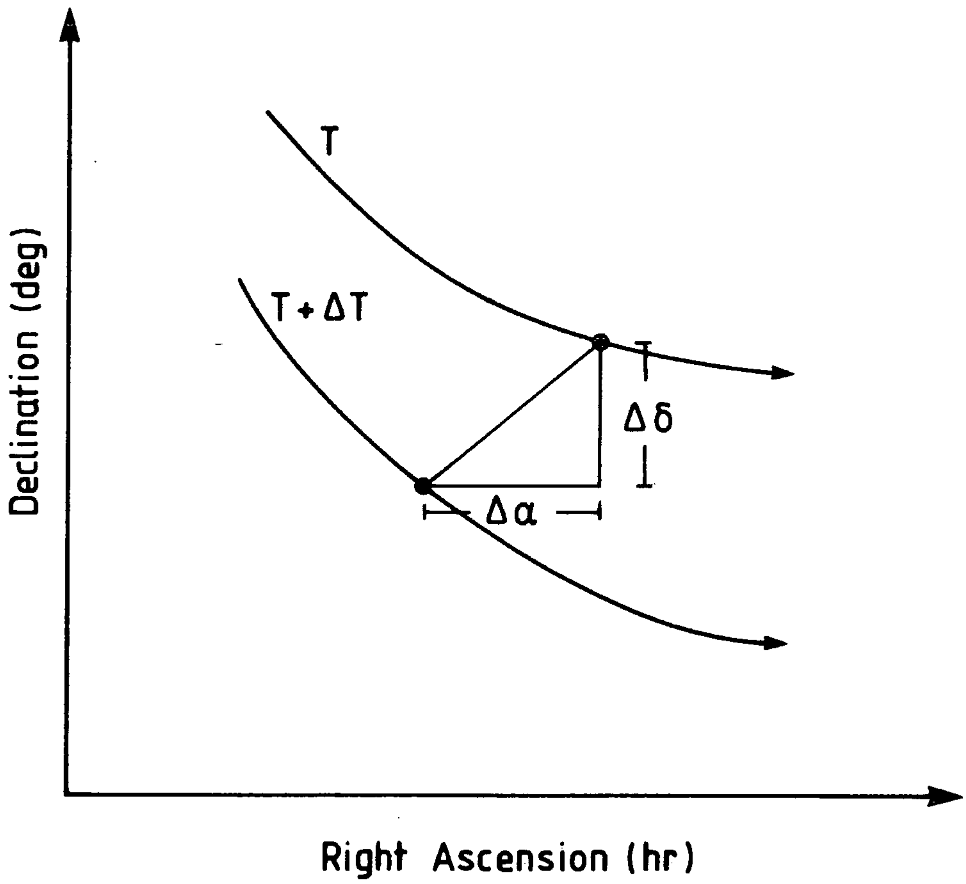


Fig. 2.12 A diagram showing the small change in right ascension, $\Delta\alpha$, and declination, $\Delta\delta$, as a result of varying the time of perihelion passage of a cometary orbit from T to $T + \Delta T$

Perhaps after a long period comet is captured by Jupiter into an orbit inside the solar system, it will swiftly undergo the intermediate phase to become a very short period object. An understanding of the past orbit of the intermediate group of comets may assist us in elucidating this delicate transitional process. It is hoped that the past orbit of Halley's Comet in the last 2500 years will help us grasp this knowledge.

CHAPTER 3

THE PAST ORBIT OF HALLEY'S COMET

3.1 Introductory Remarks

One of the reasons why Halley's Comet is unique among comets is that it is the only bright periodic comet visible to the naked-eye. It is also the only comet which has an extensive history – covering more than two millennia. Although the comet has probably never been bright enough to be seen in full daylight (unlike some brilliant long-period comets), nevertheless it attracts widespread attention at its return to the inner part of the solar system every 76 years or so. Apart from having a larger mass than most members of its group of short period comets, Halley's Comet is a fairly ordinary middle-aged comet (Hughes, 1985c). Table 3.1 gives a list of some of its physical characteristics together with some of its basic orbital parameters, including results from recent observations made by spacecraft flybys.

The number of recorded observations of P/Halley which has been chronicled so far (including the 1986 apparition) is as many as 30. The records of Halley's Comet may be categorised into three groups starting with the latest observation in 1986 as follows: (i) The period from the present to AD 1456; (ii) the period from AD 1378 to 240 BC; and (iii) the ancient period prior to 240 BC.

By the apparition in AD 1456, European measurements had surpassed the traditional-style observations of the imperial astronomers of the Far East. Beginning with this return, accurate measurements from Europe are available for studying the past orbit of Halley's Comet, although the first telescopic observation of P/Halley was not made until the return of 1682. Various attempts have already been made by researchers

TABLE 3.1 Some Physical and Orbital Characteristics of P/Halley

(a) Physical Characteristics

Parameters	Values	References
Size	Long principal axis: 14 km Short principal axis: 7.5 km	Sagdeev, *et al.* (1986)
Shape	Potato-shaped rigid body	Sagdeev, *et al.* (1986)
Mass	2.2×10^{17} g	Hughes (1985c)
Density	~1 g cm^{-3}	Hughes (1985c)
Temperature	300-400 K	Sagdeev, *et al.* (1986)
Rotation period	~53 hr (2.2 days)	Sagdeev, *et al.* (1986)
Free-precessional period	14.8 days	Wilhelm (1987)
Spectra	OH, NH, CN, C_3, CH, C_2, NH_2	Krasnopolsky, *et al.* (1986)
Surface albedo	~0.04	Sagdeev, *et al.* (1986)
Absolute magnitude change per revolution	9×10^{-4} mag	Hughes (1985c)
Estimated number of previous returns	2300	Hughes (1985c)

(b) Calculated Orbital Characteristics

Location of orbit pole		$\lambda=328.14°$, $\beta=-72.24°$
Location of perihelion		$\lambda=305.31°$, $\beta=16.45°$
Heliocentric distance of nodes		1.80 AU, 0.85 AU
Distance from Sun at perihelion		0.587 AU
Distance from Sun at aphelion		35.3 AU
Orbital velocity at	Perihelion	54.4 km s^{-1}
	Venus	49.1 km s^{-1}
	Earth	41.6 km s^{-1}
	Mars	33.4 km s^{-1}
	Jupiter	17.1 km s^{-1}
	Aphelion	0.91 km s^{-1}
Time within orbit of	Mars	150 days
	Earth	80 days
	Venus	40 days

to utilise these observational data for the purpose of calculating the orbital elements, the latest being that of Landgraf (1986).

In much of period (ii), although some European observations of P/Halley are also found, as already discussed in the last chapter, the quality of these is insufficient to aid orbital analysis. As to the Arabic astronomical records, undoubtedly these have not been adequately exploited in the search for medieval references to P/Halley; so far, few translations of the appropriate texts have ever been published. Still, from the few records that have been translated the information is fairly general with no measurement of positions. It would appear that throughout much of period (ii) observations from the Far East, are consistently superior to those from any other part of the world. One exception is for the 164 BC return; here the recent discovery of the Babylonian records fills in the gap (see below).

At the present, no identifiable records of Comet Halley have been found from period (iii). Cometary records or astronomical records in general from any part of the world during this period are few and far between so that effective use must be made of whatever material is still extant. For this early time, only a few Chinese observations of comets are available. As yet none of these comets has been firmly established to be the sighting of P/Halley. The earliest recorded sighting of a comet from Babylon dates from 234 BC (H. Hunger, private communication).

The present investigation will concentrate on period (ii) and (iii), the orbital history of Comet Halley in the medieval and ancient times.

3.2 The Search for Early Observations of P/Halley

Ever since the pioneering investigation of Halley (1705) and the subsequent recovery of the comet predicted by him to return in the year 1758, many attempts have been made by researchers to identify earlier returns of this comet. In 1783, the French astronomer Pingre compiled a comprehensive catalogue of European cometary sightings extending to ancient times. By then, orbital elements were available for five previous returns of Comet Halley. Pingre (1783–84) was able to demonstrate with reference to additional material in his own catalogue that the AD 1456 comet was an apparition of Halley's Comet; this had been suspected by Halley (1705). Pingre also calculated approximate orbits for comets seen in 1301 and 837, but he failed to recognise them as Comet Halley.

The apparition of Halley's Comet in the summer of AD 1456 is especially notable for the careful measurements of its position made by the Italian astronomer Paolo Toscanelli (Celoria, 1885). Between Jun 8 and Jul 8 in that year, Toscanelli made almost daily measurements of the celestial co-ordinates (ecliptic longitude and latitude) of the nucleus of the comet to within a fraction of a degree. There are in all, positions on 24 days. These represented the first accurate measurements of the motion of the comet ever made in Europe; previously the astronomers of the Orient had been unrivalled. By investigating Toscanelli's measurements of star positions, Celoria (1885) deduced a mean correction of only $+26'$ to Toscanelli's longitudes and $+24'$ to his latitudes. Toscanelli watched the comet travelled through several constellations, covering an angular distance of more than 90 degrees in a single month.

After Pingre's work, little significant progress was made in the study of the past history of Halley's Comet for full 60 years. In the intervening time, J.C. Burckhardt (1804) investigated observations of a comet recorded in AD 989 in both the Anglo-Saxon Chronicle and Chinese annals, the latter containing enough information to enable him to calculate an orbit. Burckhardt noted that this orbit resembled that of P/Halley. This recognition of an isolated return illustrated for the first time the great importance of the Chinese accounts of Halley's Comet in tracing its early history.

Further impetus was given by the French sinologue Edouard Biot – a former railway worker – who in 1843 made an extensive translation of Chinese Cometary records (Biot, 1843a, b). This was based largely on the compilation by the 13th century scholar Ma Tuan-lin in his great historical encyclopaedia, the *Wen-hsien T'ung-k'ao.* The French astronomer Laugier (1843, 1846) made almost immediate use of Biot's work and successfully identified records of the apparitions of P/Halley in AD 1378, 760 and 451. Laugier essentially followed the method of investigation adopted by Pingre in studying the 1456 return. The AD 1378 apparition was the last occasion when Far Eastern observations have proved of any real value in the analysis of the past motion of Halley's Comet. With the onset of Renaissance, they were superseded by careful European measurements made with accurate instruments.

It was in the mid-19th century that the most significant work on the identification of records of Comet Halley was made by Hind (1950). Like Laugier, his chief source of data was once again Biot's translation of extracts from the Chinese annals. Taking Laugier's date of 1378 as a starting point, Hind simply stepped backwards in time in a semi-empirical manner at intervals of 76–77 years. Around each selected date he examined cometary records for descriptions which might correspond to the motion of P/Halley. Where possible, he derived an approximate date of perihelion passage from the observations and suggested a positive identification if orbital elements similar to those of Halley's Comet could satisfy the record. Since Hind worked backwards only one step at a time, on each occasion deriving a new starting date from which to measure his next interval, the technique which he utilised was self-rectifying; otherwise his earlier dates might have been many years in error.

Although he made one or two incorrect identifications, he revolutionized the whole question of the early history of Halley's Comet. The comet was now recognised to be unique in having made regular visits to the inner solar system for about two thousand years, a significant portion of human history. Selecting one particular example, it was now for the first time realised that the comet depicted on the famous Bayeux Tapestry, portraying the Norman Conquest of England in AD 1066, was in fact P/Halley. Hind's analysis was to provide the basis for improvement by Cowell and Crommelin (1907d, 1908b–e). By integrating the motion of the comet backwards in time, they were able to rectify several errors of identification made by Hind and also suggested that comets seen by the Chinese in both 87 and 240 BC might be references to Halley's Comet. However, at the earlier epoch they had to assume an error of some 18 months in their calculated date of perihelion.

3.2.1 Investigations Inspired by the 1910 Return

Hind's method of investigation was quite satisfactory for his purpose, which was simply to identify as many returns of Halley's Comet as possible from historical records. However he was unable to prove beyond doubt that each of his identification was truly a record of Halley's Comet. Present day astronomers are more demanding in this respect; they require independent evidence. The then imminent 1910 return of Comet Halley was one of the impetuses for a better method to be developed.

Cowell and Crommelin (1907d, 1908b–e) were responsible for developing the modern technique of numerical integration of the motion of the comet backwards in time. They took into account only the perturbations by the large planets, the lighter planets of Mercury and Mars were ignored. The existence of Pluto was then unknown; in any case, its gravitational perturbations on the motion of the comet would be completely negligible as its mass was so small. Cowell and Crommelin began by regarding only dates back to AD 1378 as reliably established. From their integrated orbital elements, they were able to show that right back to 12 BC only two of Hind's dates (AD 1223 and

608) were seriously in error due to misidentifications; both dates were wrong by about a year.

The accuracy of the calculations of Cowell and Crommelin was fairly satisfactory. Back to AD 760, they were never more than about 20 days in error in their computed dates of perihelion passage, while errors did not exceed about 50 days right down to 87 BC. However, further back in time, the values obtained by Cowell and Crommelin were inaccurate. In order to accommodate the return of 240 BC they had to assume a discrepancy of some 18 months in their calculations. Nevertheless, this was a dramatic progress and put the past history of Halley's Comet on a sure foundation. Table 3.2 lists the dates of perihelion of P/Halley back to 240 BC as obtained by Cowell and Crommelin, and later investigators.

3.2.2 Recent Investigations

In the more recent times, Kiang (1972) made a renewed attempt at calculating the orbital elements of Comet Halley backwards in time. He used extensively any accurately observed apparitions of the comet by Far Eastern astronomers to constrain the motion of the comet into the past. His approach was proved to be a fruitful one and considerably refined the solution of Cowell and Crommelin. The calculation of Kiang (1972) was accurate to 12 BC, but before that date he was able to make little progress; the available observations proved to be vague and of doubtful reliability. Kiang gave some support to Cowell and Crommelin's identification of the Chinese records in 87 and 240 BC but he could find no trace of the intermediate apparition, the calculated date of which is 164 BC. The recent discovery of Babylonian sightings of Halley's Comet in 164 and 87 BC as discussed below, as well as directly extending the history of the comet by two further returns, has also enabled much more confidence to be placed in the Chinese observation of 240 BC.

Table 3.2 Dates of perihelion of P/Halley back to 240 BC obtained by various investigators since Cowell and Crommelin.

YEAR	YK	LANDGRAF	BRADY	CHANG	KIANG	CC
1910	4 20.18	4 20.18	4 19.68	4 19.0	4 20.18	5 6.3
1835	11 16.44	11 16.44	11 15.94	11 11.0	11 16.44	11 15.94
1759	3 13.06	3 13.05	3 12.55	3 7.0	3 13.05	3 12.57
1682	9 15.28	9 15.28	9 14.79	9 9.0	9 15.27	9 14.81
1607	10 27.54	10 27.52	10 26.80	9 27.0	10 27.56	10 26.87
1531	8 26.24	8 26.32	8 25.59	7 19.0	8 25.8	8 25.8
1456	6 9.63	6 9.67	6 8.97	4 28.0	6 9.1	6 8.21
1378	11 10.69	11 11.05	11 10.87	10 7.0	11 9.02	11 8.77
1301	10 25.58	10 26.00	10 26.40	10 17.0	10 23.38	10 22.7
1222	9 28.82	9 28.82	9 29.12	11 7.0	10 1.5	9 10
1145	4 18.56	4 17.96	4 17.86	6 18.0	4 22.0	4 19
1066	3 20.93	3 19.80	3 19.52	5 4.0	3 23.8	3 27
989	9 5.69	9 4.04	9 2.99	10 9.0	9 9.0	9 2.0
912	7 18.67	7 17.48	7 16.59	7 8.0	7 9.5	7 20
837	2 28.27	2 28.48	2 27.88	1 6.0	2 27.5	3 1
760	5 20.67	5 20.71	5 21.78	4 19.0	5 22.5	1 11
684	10 2.77	10 2.16	10 6.73	9 27.0	9 28.5	11 6
607	3 15.48	3 14.77	3 18.20	4 2.0	3 13.0	3 20
530	9 27.13	9 26.57	9 26.89	10 18.0	9 25.2	11 15
451	6 28.25	6 27.83	6 25.79	6 29.0	6 24.5	7 3.5
374	2 16.34	2 15.87	2 12.56	1 21.0	2 16.0	2 13
295	4 20.40	4 20.53	4 22.54	3 18.0	4 20.5	4 7
218	5 17.72	5 17.38	5 27.56	3 8.0	5 17.5	4 6
141	3 22.43	3 21.33	4 10.24	2 13.0	3 20.0	3 25
66	1 25.96	1 23.28	2 19.97	12 23.0	1 26.5	1 26
-11	10 10.85	10 8.21	10 8.64	9 27.0	10 5.5	10 8.8
-86	8 6.46	8 5.49	7 10.40	8 15.0	8 2.5	8 15
-163	11 12.57	11 8.29	6 22.38	*1 20.0	10 5.5	*5 20
-239	5 25.12	5 24.42	#11 30.64	8 2.0	3 30.5	5 15

N.B. * the year is -162
the year is -240
YK Yeomans and Kiang
CC Cowell and Crommelin

In the decade preceding the 1986 return, several sets of orbital elements have been produced by various researchers. Chang (1979) obtained the orbital elements for P/Halley from a straightforward integration of the equations of motion of the comet backward in time to BC 1057. The major deficiency in his calculations was that he did not use any observational constraints. In addition, he did not take into account the non-gravitational forces which would have significantly altered the orbit over the time span under his consideration.

Yeomans and Kiang (1981) – here abbreviated to YK and independently Brady (1982) have numerically integrated the orbit into the distant past – respectively 1404 BC and 2647 BC. Their techniques differ in one important detail. In AD 837, Halley's Comet made a very close approach to the Earth, 0.03 AU, (see Fig. 3.1) and this significantly disturbed the motion of the comet. As a result, YK felt that in investigating all earlier returns, it was necessary to constrain the computed motion by incorporating in their solution some unusually accurate Chinese observation made in AD 837 and also in AD 374 and 141. (It is interesting to note also the close approaches to Venus made by Halley's Comet in the same diagram – Fig. 3.1). However, Brady preferred a continuous integration without recourse to observations. In addition, YK made a small but systematic correction for the non-gravitational 'rocket effect' caused by outgassing of the comet's nucleus.

Differences between the results of YK and Brady for the various orbital elements apart from the date of perihelion passage are trivial at all returns. Up to and including 87 BC, discrepancies in the date of perihelion amount to no more than 20 days, suggesting that the motion of Comet Halley is well represented by either solution for fully two millennia. This is confirmed by observation in a number of examples; accurate dates of perihelion may be deduced from the observational record at every return back to AD 989 and in four further cases as far as AD 141. However, at all apparitions before 87 BC

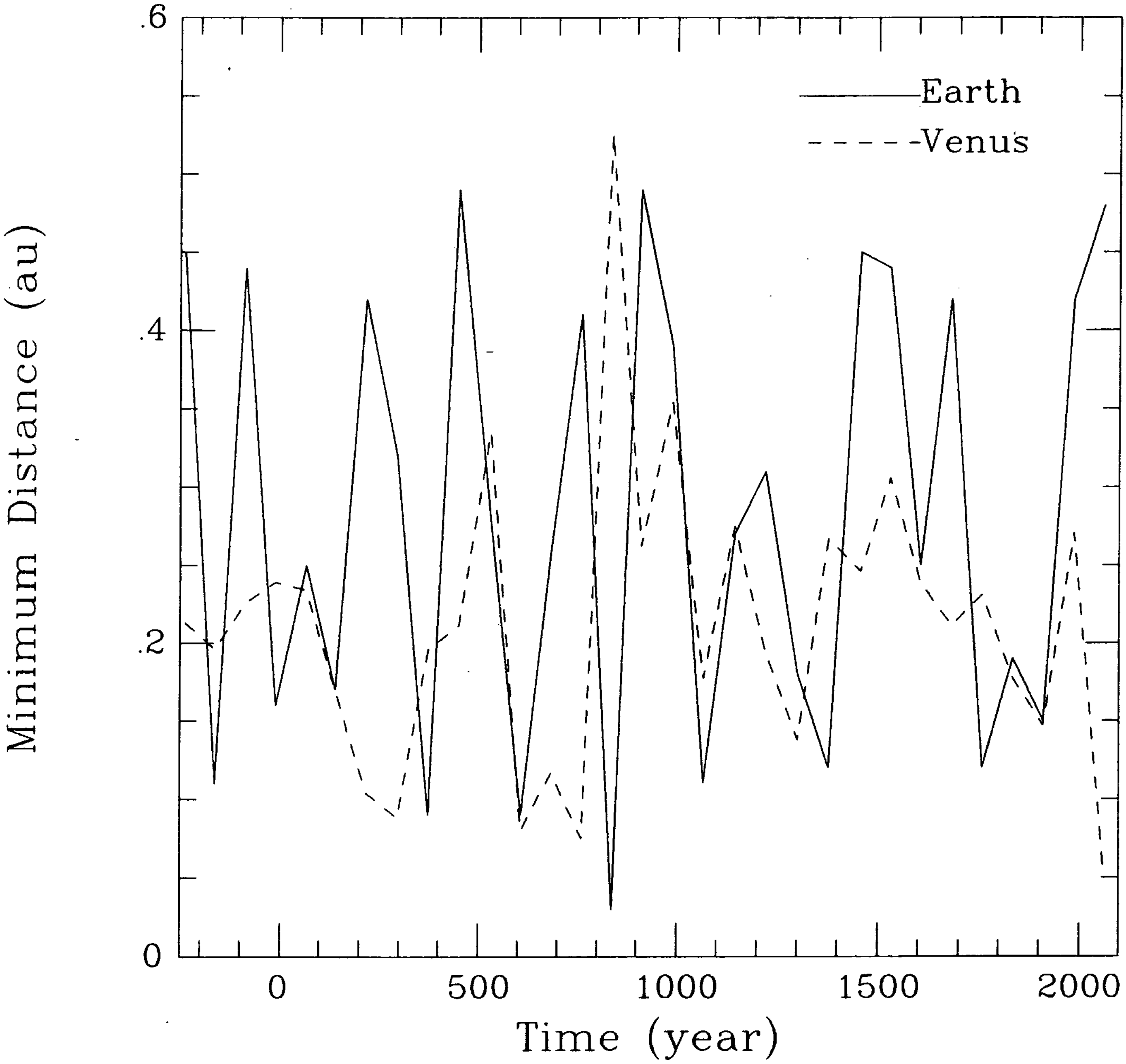


Fig. 3.1 The close approaches of Halley's Comet to the Earth and Venus during the period 240 BC to AD 2061.

the two sets of computed dates of perihelion disagree by at least 5 months – increasing to several years before 500 BC.

By using two different orbital solutions, Landgraf (1984) integrated the motion of Comet Halley from AD 2284 to 2317 BC. For the time span AD 2284 to AD 837, his initial orbital elements were obtained from a solution to the observational arc 1607–1984. For the interval from AD 837 to 2317 BC, he integrated backwards employing an initial solution to the interval AD 1607–1983 and a correction to the perihelion passage time in AD 837. His results were similar to those of YK back to 87 BC, but the two sets of predicted perihelion passage times diverged rapidly prior to 87 BC. Recently, Landgraf (1986) has improved his earlier orbit determinations of P/Halley. This time, he stopped his integration after 466 BC. The discrepancy in the times of perihelion passages between YK and Landgraf (1986) is now very small, seldom exceeding a single day.

3.3 Orbital Characteristics of P/Halley

Fig. 3.2 shows the long term variations of the six orbital elements of P/Halley as calculated by Yeomans and Kiang (1981). The date of perihelion is simply a monotonic function of time. The variations in the longitude of perihelion and ascending node show a similar linear behaviour with time with only minute changes between two returns of the comet. The inclination varies from one return to the next and follows a somewhat semicircular pattern of variations with time. This can be explained by vibrations of the orbital plane about the line of nodes. However the amplitude of variation never exceeds a degree over more than 3 millennia.

The perihelion distance has its lowest value of 0.5727 AU in AD 1301 and its highest value of 0.6342 AU in 1266 BC; the change is only about 0.062 AU. Similarly the overall change in the eccentricity is only 0.005 over the last three thousand years

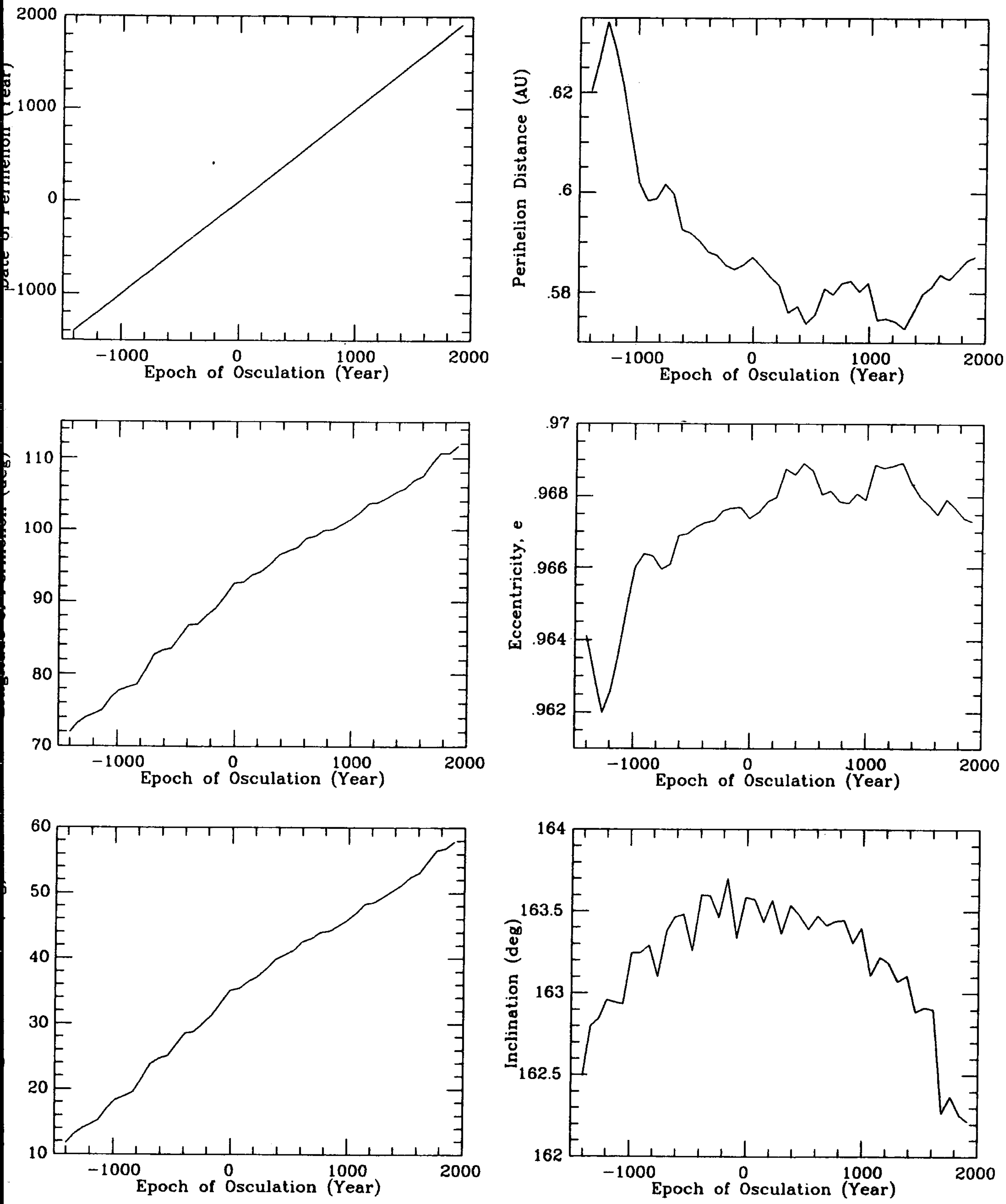


Fig. 3.2 The long term variations of the six orbital elements of P/Halley.

or so which is very small indeed. It can be seen that the pattern of behaviour in the perihelion distance is reflected inversely in the eccentricity. The wayward behaviour of both the perihelion distance and eccentricity from about 500 BC backwards is likely due to the instability induced by the long term numerical integration of the motion of Halley's Comet (Milani and Nobili, 1985).

The perihelion distance together with the eccentricity are directly responsible for the size and shape of the orbit, and the times between two perihelion passages – the orbital period. Fig. 3.3 shows the variations in the orbital period of Comet Halley during the last 3000 years or so. The behaviour in the orbital period follows a similar trend in the eccentricity (Fig. 3.3). The period, P, is related to the perihelion distance, q, and eccentricity, e, by $P = [q/(1-e)]^{3/2}$. The variations in these parameters are the results of gravitational perturbations by the planets. Hughes (1987) commented that the peaks near AD 374 and AD 1145 are due to a 2:13 commensurability between the orbital periods of the comet and Jupiter.

In the investigation of the past orbital history of Halley's Comet, we have adopted the elements calculated by Yeomans and Kiang (1981) as the standard. We have used only one parameter fit to the observed positions, namely by varying the date of perihelion only and keeping the other five elements fixed. The validity of this approach depends on the almost invariance of five of the orbital elements: the perihelion distance, eccentricity, longitude of perihelion, longitude of ascending node and inclination of the orbit. Fig. 3.4 shows the deviation of each of the six orbital elements calculated by Chang (1979), Brady (1982) and Landgraf (1986) from an arbitrary standard set of elements calculated by that of Yeomans and Kiang (1981). As can be seen from Fig. 3.4, apart from the date of perihelion, the deviations between the various values of the other orbital elements obtained by different researchers are trivially small. Hence we are quite confident of our method. The following represent detailed contributions to the investigation of Halley's

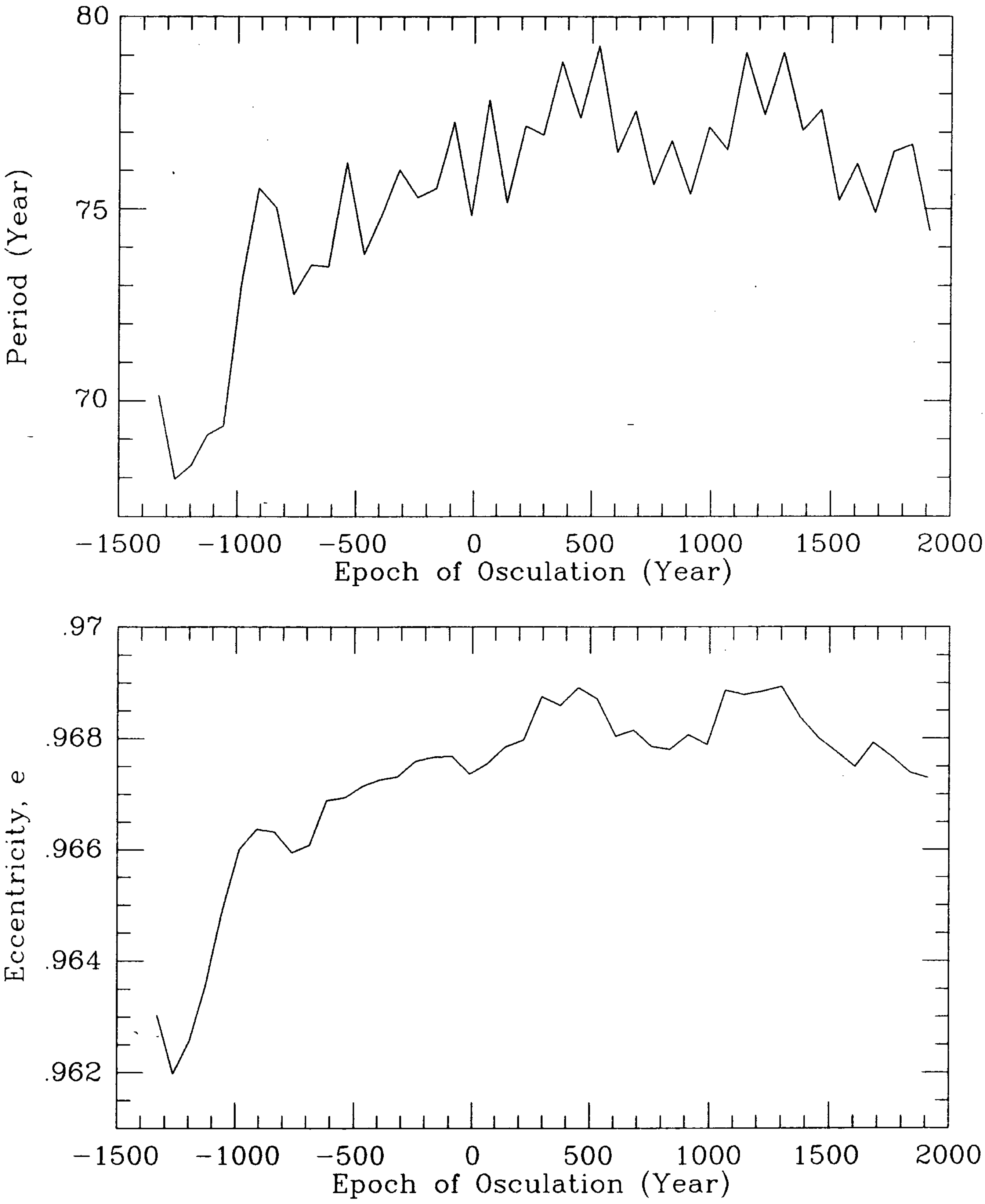


Fig. 3.3 The behaviour of the orbital period and eccentricity of P/Halley shows a similar trend in variations with respect to time.

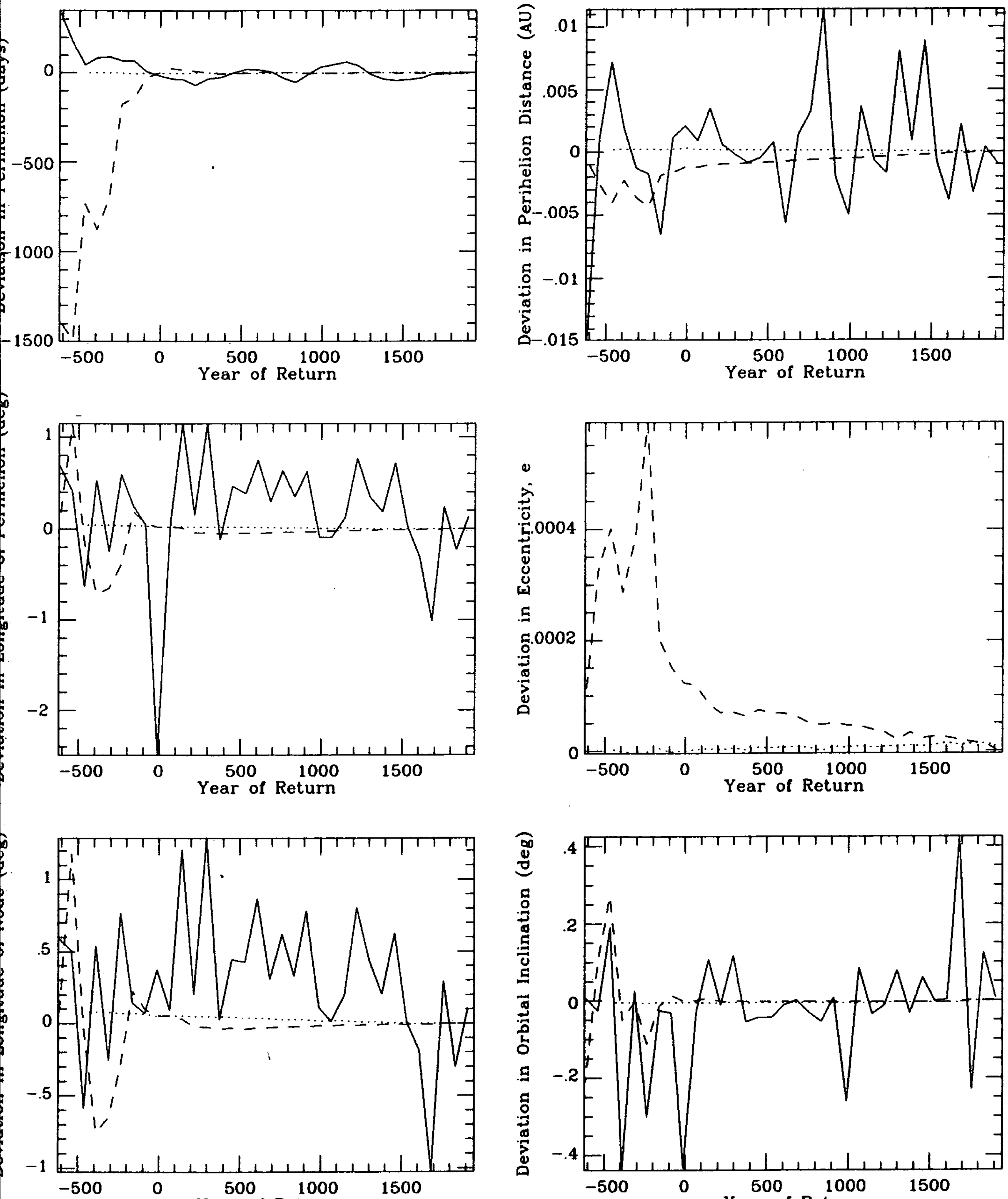


Fig. 3.4 The deviation of the various elements due to Chang (1979) - solid line, Brady (1982) - dashed line, and Landgraf (1986) - dotted line, from an arbitrary standard set of elements calculated by Yeomans and Kiang (1981).

Comet from AD 1378 back to 240 BC, as published in major journals (I also made extensive contributions to the book *Halley's Comet in History* – see a photocopy of the title page below).

HALLEY'S COMET IN HISTORY

by
Hermann Hunger
F. Richard Stephenson
Christopher B. F. Walker
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edited by
F. R. Stephenson
and C. B. F. Walker

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3.4 Far Eastern Observations of Halley's Comet: 240 BC to AD 1378

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FAR EASTERN OBSERVATIONS OF HALLEY'S COMET: 240 BC to AD 1368

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Halley's comet has been observed at every return since 12 BC and may possibly be traced as far back as 240 BC. The observations by the ancient astronomers of China, Japan and Korea are a valuable contribution to the understanding of the past history of this famous comet. A collection of oriental records of the comet from earliest times down to the period when detailed European observations became available is presented here. Although our main objective has been to assemble a comprehensive catalogue, the reliability and accuracy of each individual observation are also discussed, often in some detail. In addition, a number of comparisons between the dates of perihelion passage derived from observations and those calculated from various theories are made. At most returns, the prominent asterisms through or near which the comet passed were usually recorded by these ancient astronomers. In every case, where the asterisms have been recorded, we have identified and tabulated them along with the equivalent Western names of the principal stars. The apparent path of Halley's comet changes considerably from one apparition to the next. Diagrams showing the computed path at all of the returns discussed here are presented.

1. INTRODUCTION

Ancient observations of Halley's comet are currently proving to be of considerable importance. It is, of course, interesting merely to read the early descriptions, noting such details as general appearance, length of tail, duration of visibility, etc. However, the early positional data are particularly valuable in studying the long-term motion of the comet, as for instance Kiang [1] and Yeomans and Kiang [2] have shown. During the past two millennia, Halley's comet has made several very close approaches to the Earth, notably in AD 837 when it passed by only about 0.03 AU away (not much more than 10 times the Moon's distance). Such encounters severely perturb the motion of the comet. It is thus impractical to numerically integrate the orbit over the historical period without making use of some of the more precise ancient observations. In particular, Yeomans and Kiang [2] incorporated unusually accurate observations in AD 141, 374 and 837 in their calculation of the motion of the comet.

Accurate European positional measurements of Halley's comet began at the AD 1456 apparition with the work of Toscanelli (see Ref. 3). From that date onwards, the Far Eastern observations have little more than curiosity value. However, at all previous returns the oriental observations are far superior to their occidental counterparts. In recent years, the main source of oriental observations has been the catalogue of cometary and nova records compiled by Ho Peng Yoke [4, 5] in two extensive linked papers. As part of this work, Ho translated most of the available Far Eastern accounts of Halley's comet from earliest times down to the 19th century. However, he attached no special significance to this comet and at each appropriate entry made only passing comments regarding its identification.

As far as we are aware, the oriental sightings of Halley's comet have not as yet been assembled *in extenso* and it is our purpose here to try to remedy this omission, at least down to AD 1368. In what follows we have compiled what we believe to be a comprehensive catalogue of ancient and medieval sightings of Halley's comet in the Far East. Throughout, we have restricted our attention almost entirely to the most original of the extant sources, principally the dynastic histories. With only a single exception, late works such as historical encyclopaedias have been disregarded. We have made full use of the material in the compilations of Ho [4, 5] and Kanda [6], the latter being concerned only with Japanese records. Nevertheless, all translations are our own.

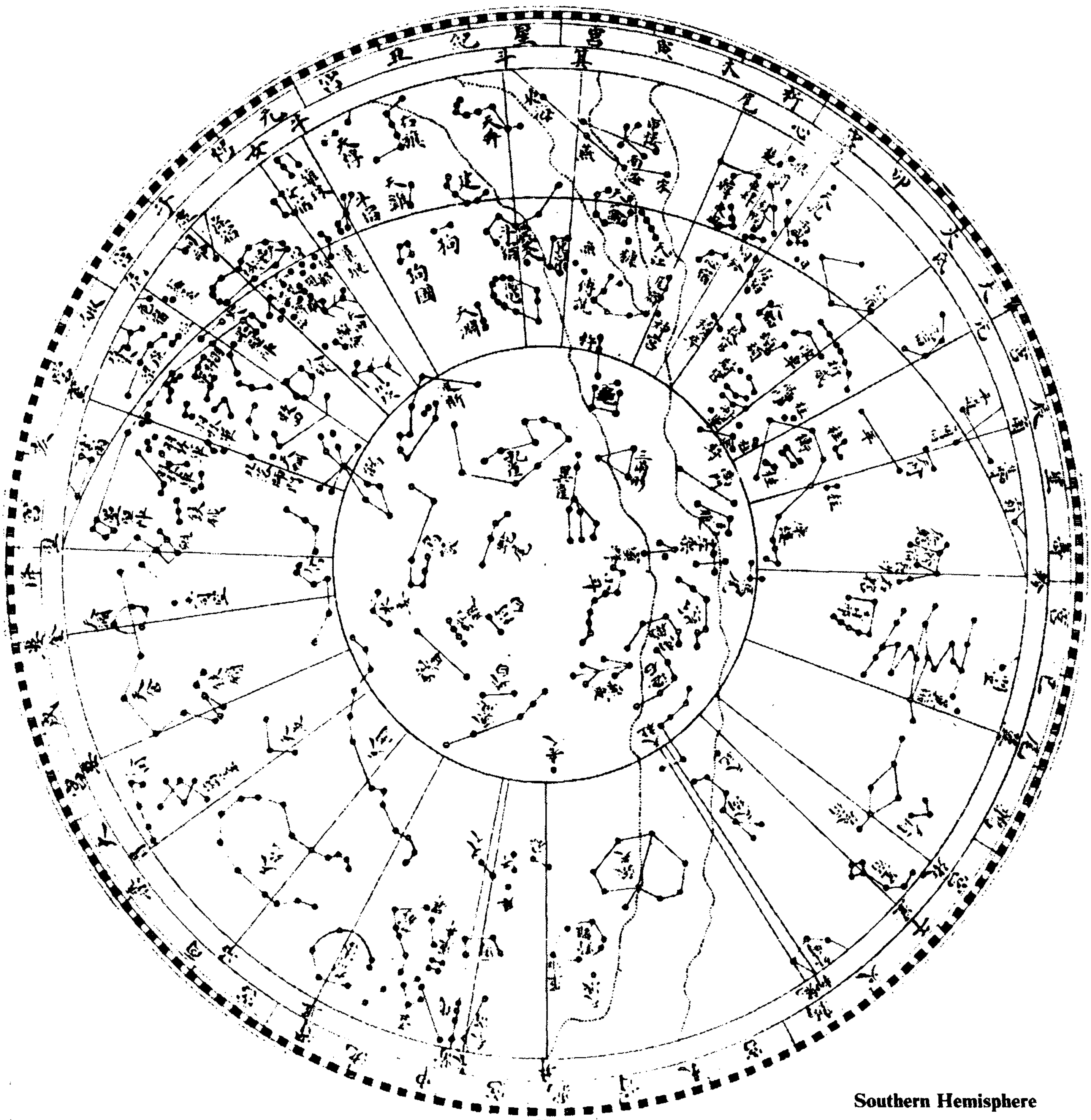
It was our original intention merely to list the various observations with the minimum of commentary. However, because of frequent textual errors – especially with regard to date – and the occasional appearance of more than one comet in the same year, a fairly full discussion has become necessary. For each apparition we have carefully compared the observed motion with that calculated on the basis of the osculating orbital elements derived by Yeomans and Kiang [2], discussing any discrepancies in the date of perihelion. It is our hope that this presentation will add further interest to the forthcoming return of this most famous of all comets.

2. SOURCES OF ORIENTAL ASTRONOMICAL RECORDS

Oriental historical sources have been discussed in some detail by Clark and Stephenson [7]. The earliest systematic astronomical records are from China, beginning around 200 BC. Not long afterwards, Korean astronomical records are occasionally to be found. However, these do not become fully independent or reliable until as late as AD 1000. The earliest Japanese astronomical observations date from the 7th century AD. Both Korea and Japan modelled their astronomy (in common with much of their culture) on that of China. Hence after about AD 1000 it is not uncommon to find three independent descriptions of the same astronomical phenomenon. As the written language of Korea and Japan was Classical Chinese until late medieval times, the translation of astronomical records from both countries is much simplified.

The Chinese were assiduous observers of the sky from a very early period, possibly before 1000 BC. The main motive was political astrology; it was believed that there was a direct correspondence between celestial and state events. Throughout much of Chinese history, the astronomers were civil servants employed by the ruler to observe and interpret celestial omens.

Unfortunately, very few records of astronomical phenomena survive from before 200 BC, probably on account of the infamous "Burning of the Books" in 213 BC at the command of the first emperor of China. In later centuries, astronomical records of all kinds are to be found and these



Southern Hemisphere

Fig. 1 continued.

Other primary works which we have referenced are:

(i) the *Shih-chi* ("Historical Record"), a history of China from earliest times to 122 BC;

(ii) the *T'ang-hui-yao* ("Collection of the Essentials of T'ang History");

(iii) the *Ming-shih-lu* ("Annals of the Ming Dynasty"), a detailed day to day chronicle.

We have found it necessary to consult only two Korean historical works. The earlier of these is the *Samguk Sagi* ("History of the Three Kingdoms"), a semi-legendary work which covers the period from ancient times down to AD 936. Its successor, the normally very reliable *Koryo-sa* ("History of Koryo"), continues down to the fall of the Koryo Dynasty in AD 1392. Both works are modelled on a typical Chinese dynastic history. Japanese sources are

TABLE 2. Asterisms Other Than Lunar Mansions Mentioned in the Observations of Halley's Comet.

Name of Asterisms (Wade-Giles)	(Pinyin)	Equivalent Western Name of Stars (Principal Stars)
Ch'ang-ch'iu*	Changqiu	η Leo (same as Hou)
Chi-hsing*	Jixing	The Pole Star
Chi-shui*	Jishui	ο Gem
Chien-hsing	Jianxing	ξ Sgr
Chou-ting	Zhouding	β CrB
Ch'u*	Zhu	ε Oph
Ch'uan-she	Chuanshe	10 Cas
Chung-t'ai	Zhongtai	λ UMa, μ UMa
Fei*	Fei	γ Leo
Fen-mu	Fenmu	ζ Aqr
Ho-shu	Heshu	α Cmi, α Gem
Hou*	Hou	η Leo
Hsia-t'ai*	Xiatai	λ UMa
Hsuan-yuan	Xuanyuan	α Leo
Kuan-so	Guansuo	α CrB
Liang*	Liang	δ Oph
Ling-t'ai	Lingtai	59 Leo
Nan-ho*	Nanhe	α CMi
Nei-chieh	Neijie	π^2 UMa
Nei-wu-chu-hou	Niewuzhuhou	θ Gem
Pa*	Ba	ε Ser
P'ing-hsing	Pingxing	ν Vir
Pei-ho	Beihe	α Gem, β Gem
Pei-chi	Beiji	γ UMi
Pei-tou	Beidou	The Plough
San-kung	Sangong	24 CVn
San-t'ai	Santai	ι UMa
Shang-hsiang*	Shangxiang	δ Leo
Shang-t'ai*	Shangtai	ι UMa
Shao-tsai*	Shaozai	η Dra
She-t'i	Sheti	η Boo and ζ Boo
Shu*	Shu	α Ser
Sung*	Song	η Oph
Szu-fu	Sifu	4 stars near N Pole
Ta-chueh	Dajiao	α Boo
Ta-huo	Dahuo	α Sco
Ta-ling	Daling	β Per
T'ai-wei	Taiwei	Large group (see note)
T'ai-yang*	Taiyang	χ UMa
Ti-tso	Dizuo	β Leo
T'ien-chi*	Tianji	γ UMa
T'ien-ho	Tianhe	The Milky Way
T'ien-pien	Tianbian	λ Aql
T'ien-p'ou	Tianpou	ι Her
T'ien-shih	Tianshi	Large group (see note)
T'ien-yo	Tianyo	4 Sgr
Ts'ang-lung	Canglong	Fang (LM4) and Hsin (LM5)
Tuan-men	Duanmen	β Vir, η Vir
Tz'u-fei	Cifei	α Leo
Tzu-wei	Ziwei	Large group (see note)
Wen-ch'ang	Wenchang	18 UMa
Wu-ch'e	Wuche	α Aur
Wu-chu-hou	Wuzhuhou	θ Gem
Wu-ti-tso	Wudizuo	β Leo
Yu-chih-fa*	Youzhifa	β Vir
Yu-she-t'i	Yousheti	η Boo

Notes:
T'ai-wei: a large area in Coma Bernices, Leo and Virgo.

T'ien-shih: a large area main in Hercules, Ophiuchus, Serpens Caput and Serpens Cauda.

Tzu-wei: a well-defined region of sky within about 25 deg of the N Celestial pole.

* Denotes reference to a single star only.

everyday units of length rather than in angular measure. These units were *chang, chih* and *ts'un*, where 1 *chang* = 10 *chih* = 100 *ts'un*. Very roughly, 1 *chih* was equivalent to 1 deg, the other two units representing 10 deg and 0.1 deg respectively. Kiang [7], from an analysis of some 7th century positional measurements, deduced that at this period 1 *chih* was equivalent to 1.50 ± 0.24 deg. Because of the length of time covered by our investigation, we have preferred to equate *chih* directly, if somewhat crudely, with deg. In our translations, where a measurement is given in *tu* we have affirmed this by a note in parenthesis; otherwise no such remark is made.

Some remarks are necessary on the subject of date conversion. The Chinese calendar, like many ancient calendars, was luni-solar. Years were not numbered continuously from some standard epoch; instead, they were counted from the beginning of each individual reign or reign period (a subdivision of a reign). Since the foundation of the Empire in 221 BC, there have been several hundred reign periods, some lasting less than a year. As a result, careful consultation of chronological tables is necessary to obtain the correct year BC or AD.

New Year's Day usually occurred about a month after the winter solstice. Individual years were either of 12 or 13 months duration. As a common year of 12 lunar months contained about 354 days, in order to keep the calendar roughly in step with the seasons an extra month was intercalated roughly every two and a half years or so. Although somewhat complex, the precise rules for intercalation are well known so that date conversion is highly reliable.

Lunar months contained either 29 or 30 days, the average length being close to the mean synodic month of 29.5306 days. However, in expressing individual dates the day of the month was not used regularly. From a very early period – well before 1000 BC – an independent 60-day cycle having close parallels with our much shorter week was employed. Dates are thus normally specified in terms of (i) year of reign or reign period; (ii) lunar month and (iii) cyclical day. The use of cyclical days considerably simplifies conversion to the Western calendar.

The Chinese calendar was adopted with minor modifications in both Japan and Korea. Both countries numbered years in terms of their own rulers or reign periods but otherwise there is almost exact calendar correspondence. Chinese dates may be fairly readily expressed in terms of the Julian or Gregorian calendar using the chronological tables of Ch'en [8] and Hsueh and Ou-yang [9]. For Korean dates, the tables of the Chindan Hakhoe [10] are very useful. Kanda [6] transformed all dates of Japanese astronomical observations which he catalogued directly to the Western

6. THE RECORDS

In what follows, returns are numbered from the forthcoming apparition, i.e. 1986 = return 0. For each return the title gives us the following information:

(i) P = date of perihelion as computed by Yeomans and Kiang [2], regarding this work as the standard investigation;

(ii) d = minimum computed distance of Halley's comet from the Earth in astronomical units (AU) – this is followed by the date of closest approach;

(iii) the country or countries of origin of the available records of the comet (Far East only).

6.1 Return -29. 240 BC (P = May 25.1; d = 0.45 AU on Jun 3). China

As already stated, the records of the broom star which appeared in this year represent probably the earliest known sightings of Halley' comet in the Far East. Although the two accounts in the *Shih-chi* are extremely brief, they are nevertheless sufficient to identify the comet with fair confidence.

(i) "During this year (i.e. 240 BC), a broom star first appeared at the E direction; it was then seen at the N direction. In the month May 24 to Jun 23 it was seen at the W direction... The broom star was again seen at the W direction for 16 days." (*Shih-chi*, Annals).

(ii) "During this year a broom star was seen at the N direction and then at the W direction. During the summer the Empress Dowager died." (*Shih-chi*, Chronological Tables).

The record in the Chronological Tables is probably no more than a summary of that in the Annals. There is no mention of the comet in the Astronomical Treatise.

Calculation based on the orbital elements of Yeomans and Kiang [2] shows that Halley's comet would probably become visible in mid-May and would be seen before dawn in the E sky. By the end of the month when it made its closest approach to the Earth the declination would be so high (close to +40 deg) that it might have been seen in a roughly N direction (NNE) before dawn. Following conjunction with the Sun around Jun 2, the comet would be seen in the W sky after dusk and would be particularly well placed for observation in mid-June. The reported duration of 16 days at the W is quite in keeping with calculation; towards the end of June, Halley's comet would have faded considerably. According to Brady [13], the date of perihelion was Nov 30, which would imply that the comet seen in 240 BC was not Halley's. However, the agreement between observation and the expected motion on the basis of the theory of Yeomans and Kiang [2] is impressive.

6.2 Return -28. 164 BC (P = Nov 12.6; d = 0.11 AU on Sep 28). No Record

This return does not seem to have been noted in China and no report would be expected from elsewhere in the Far East at such an early period. In the *Ch'ien-han-shu*, the official history of the time, neither the Astronomical Treatise nor the Treatise on the Five Elements mentions any strange star appearing during this year or the immediately preceding and following years. Although around this time few astronomical records of any kind are preserved, the lack of reference to Halley's comet is still rather surprising. On the elements of Yeomans and Kiang [2], this object should have been fairly bright and well placed for observation in China for a full month – between about Sep 20 and Oct 20. The Astronomical Treatise of the *Ch'ien-han-shu* mentions the sighting of what may have been a comet on a date corresponding to Feb 6 in 162 BC, but this is much too late for Halley's comet. Brady [13], like Yeomans and Kiang [2] calculates that perihelion passage occurred in 164 BC, although he differs by some five months in the precise date.

6.3 Return -27. 87 BC (P = Aug 6.5; d = 0.44 AU on Jul 26). China

"In autumn during the month Aug 10 to Sep 8 a star emerged (po) at the E." (*Chien-han-shu*, Annals). This text is not found in any other early source. As Kiang [1] pointed out, if this star indeed refers to Halley's comet then either the month or the direction must be in error. Halley's comet should have been visible in the E for much of July – up to about Jul 25. Following conjunction with the Sun around Jul 27 it would reappear in the W sky after dusk. As the comet would be fading by Aug 10 (the beginning of the 7th lunar month), an error in the month seems to be the most likely possibility. Reading 6th month for 7th (although the characters for 6 and 7 are dissimilar) would put the observation at some time between Jul 9 and Aug 8. This would fit in well with the calculated dates of visibility in the E. However, on the basis of Brady's calculations [13], a *two* month error would have to be assumed.

6.4 Return -26. 12 BC (P = Oct 10.8; d = 0.16 AU on Sep 9). China

After the disappointing observations at previous apparitions, it is encouraging to some across such a detailed account of the motion of Halley's comet, which has followed for as long as 56 days.

"On Aug 26 a star emerged (*po*) at Tung-ching (LM 22); it was treading on Wu-chu-hou. It appeared to the N of Ho-shu and passed through Hsuan-yuan and T'ai-wei. Later it travelled at more than 6 deg (*tu*) daily. In the morning it appeared at the E direction. On the evening of the 13th day (Sep 7) it was seen at the W direction. It trespassed against Tz'u-fei, Ch'ang-ch'iu, (Pei-) Tou and Saturn. Its "swarming flames" again penetrated within Tzu-wei, with Ta-huo (= Antares) right behind. It reached T'ien-ho (the Milky Way), sweeping the region of Hou and Fei. It moved S, crossing and trespassing against Ta-chueh (= Arcturus) and She-t'i. When it reached T'ien-shih it moved slowly at a regular pace. Its "flames" entered T'ien-shih. After a further ten days it went towards the W. On the 56th day (Oct 20) it went out of sight together with Ts'ang-lung." (*Ch'ien-han-shu*, Treatise on the Five Elements). There is a brief mention of the comet in the Annals of the *Ch'ien-han-shu*, but this provides no independent details.

In the above text, it is unfortunate that so few precise dates are given. More dates of conjunction with asterisms would have rendered the record of great value. One of the more interesting observations is the date of first visibility in the W sky (Sep 7). Unfavourable weather could have delayed this sighting by one or more days, but a useful limit on the date of perihelion passage is still provided. In order for Halley's comet to have been visible in the W on the evening of Sep 7 (roughly at 15h ET), perihelion must have been at early for Halley's comet, i.e. roughly six months before the calculated dates of perihelion passage and closest approach to the Earth. Some other object must be referred to here.

Considering now the report in the Astronomical Treatise of the *Hou-han-shu*, the observed passage of the comet by way of Wu-che, Tung-ching (LM 22), Wu-chu-hou, Hsuan-yuan and T'ai-wei is well supported by calculation. Wen-chang, however, lay more than 20 deg to the N of the computed path, although – as Kiang [1] has pointed out – the tail of the comet may well have reached this asterism. The calculated date of conjunction with the Sun is May 28. Hence, as the comet was seen for "more than 20 days" at the E, a discovery date in the first few days of May is implied. The last reported position was at T'ai-wei, which Halley's comet should have reached by about Jun 15. A duration of at least 40 days is thus indicated. This is the last occasion for which there is a significant discrepancy between the dates of perihelion as computed by Yeomans and Kiang [2] and Brady [13] – in this case ten days. At all subsequent returns the deviation is less than five days.

6.8 Return -22. AD 295 (P = Apr 20.4; d = 0.32 AU on May 11). China

Once again, only the lunar month of first sighting is noted. Precisely the same report is to be found in the Astronomical Treatise of both the *Chin-shu* and the *Sung-shu*. The Annals of the *Chin-shu* provide additional details (there is no mention of the comet in the *Sung-shu* Annals).

(i) During the month May 1 to May 30 there was a star emerging (*po*) at K'uei (LM 15). It reached Hsuan-yuan and T'ai-wei. It passed San-t'ai and Ta-ling." (*Chin-shu* and *Sung-shu*, Astronomical Treatises).

(ii) "During the month May 1 to May 30 a broom star was seen at the W direction. It emerged (*po*) at K'uei (LM 15) and reached Hsuan-yuan." (*Chin-shu*, Annals).

The above records, such as they are, are deficient in a variety of ways. Conjunction with the Sun, the expected date of which is about May 8, is not alluded to and only occasional asterisms near which the comet passed are named. The date of first sighting is surprisingly late. Halley's comet should have been well placed for observation by about Apr 20; it would then be close to perihelion and rapidly approaching the Earth. Possibly adverse weather delayed discovery. Whatever the explanation of this delay, calculation indicates that the comet would be more or less stationary just below K'uei (LM 15) for several weeks until towards the end of April. However, by about May 2 it would have moved into the range of RA covered by the next lunar mansion (Lou, LM 16). Hence if we interpret the record literally, the discovery date indicated is the very beginning of May (the start of the 4th lunar month). The computed path approached very close to Ta-ling and crossed Hsuan-yuan but it was never within 10 deg of San-t'ai and T'ai-wei. The tail could well have reached San-t'ai and might later have extended as far as T'ai-wei, but by the time the comet reached the vicinity of this latter asterism it would be very faint. Possibly the report in the *Chin-shu* Annals is naming the asterisms near which the head of the comet first appeared and finally disappeared.

6.9 Return -21. AD 374 (P = Feb 16.3; d = 0.09 AU on Apr 1). China

Around the time of this extremely close approach to the Earth, Halley's comet would be almost in opposition to the Sun. It must have been a spectacular sight, but the brief records which have come down to us do not convey this impression in any way. The descriptions in the Astronomical Treatises of both the *Chin-shu* and *Sung-shu* are identical except that the former text also reports a later sighting (on Apr 2) which is not mentioned in the *Sung-shu*. The Annals of the *Chin-shu* carry only two short notices regarding the comet, but the first of these has considerable value in correcting a dating error in both Treatises. These give an impossible date for the first detection of the comet: the lunar month (1st) and cyclical day (*ting-szu*) are at variance. However, the Annals place this event on the same day in the 2nd month, which corresponds to Mar 4. There seems no reason to doubt the date given in the Annals, for the sighting of the comet is reported along with non-astronomical events in strict chronological sequence.

(i) "On Mar 4 there was a star emerging (po) at Nu (LM 11). It passed Ti (LM 3), K'ang (LM 2), Chueh (LM 1), Chen (LM 28), I (LM 27) and Chang (LM 26). On Apr 2 a broom star was seen at Ti (LM 3). On Nov 19 a star emerged (*po*) at T'ien-shih." (*Chin-shu*, Astronomical Treatise).

(ii) "On Mar 4 there was a star emerging (*po*) at Nu (LM 10) and Hsu (LM 11)... On Apr 2 a broom star was seen at Ti (LM 3)... On Nov 19 there was a star emerging (*po*) at T'ien-shih." (*Chin-shu* Annals).

It would appear that as far as compilers of the *Chin-shu* were concerned, the broom star which was reported on Apr 2 was independent of the star which was first seen on Mar 4. Nevertheless, an observation of Halley's comet at Ti (LM 3) on Apr 2 would be consistent with a location between Nu (LM 10) and Hsu (LM 11) a month earlier. On the contrary, the object appearing at T'ien-shih on Nov 19 could have no connection with Halley's comet, which by this date would have long since ceased to be visible to the unaided eye, and in any case would be more than 60 deg away from T'ien-shih.

The calculated path of Halley's comet agrees well with the list of lunar mansions from Nu (LM 10) to Chang (LM 26) given in (i). However, only the observation at Ti (the date of which is confirmed in the Annals) is useful for establishing the date of perihelion; in early March the comet would be almost stationary near Nu and Hsu. The equivalent RA of Ti at epoch is in the range of 13h 24m and 14h 24m. Also, the ET of the observation on Apr 2 can be readily shown to be between 13h and 22h. A date of perihelion of Feb 17.3 $\pm$ 0.5 is then implied. This single recorded position is particularly valuable since at the time the motion would be as much as 1 deg per hour.

6.10 Return -20. AD 451 (P = Jun 28.2; d = 0.49 AU on Jun 29). China

Three records of this apparition are to be found in separate histories. The most detailed accounts are contained in the Astronomical Treatises of the *Sung-shu* and *Wei-shu*, the latter providing dates not specified in the former. A third report in the *Nan-shih* Annals gives additional information. The *Nan-shih* and *Wei-shu* texts are translated below.

(i) "On Jun 10 a broom star was seen at Mao (LM 18)... On Jul 13 the broom star was seen within T'ai-wei facing Ti-tso." (*Nan-shih*, Annals of the Sung Dynasty).

(ii) "During the month Jun 15 to Jul 14 a broom star errors to those already discussed. Reading 2nd month for 1st month and cyclical day *ping-wu* for *ping-tzu* (again quite likely errors) gives the date of first sighting as Mar 30. The computed location on this day (and for a few days before and after) would be very close to Tung-pi (LM 14). Roughly 20 days of visibility in the E would then be available before conjunction with the Sun. By mid-April, Halley's comet would be so close to the Earth that the tail may have extended across a considerable portion of the sky.

As Cowell and Crommelin [14] remarked, "The observations of 607 are in a decided tangle." True though this remark is, it should be emphasised that no matter in which way we interpret the records it would be surprising if what must have been a spectacular apparition of Halley's comet escaped notice.

6.13 Return -17. AD 684 (P = Oct 2.8; d = 0.26 AU on Sep 6). China and Japan

In this year we find the earliest Japanese record of Halley's comet. Unfortunately, both this and the Chinese accounts are disappointingly brief. Not a single positional description is given – only vague indications as to direction. The situation is complicated by the appearance of at least one other comet around the same time.

(i) China. "On the evening of Sep 6 there was a broom star at the W direction. It was more than 10 deg in length. On Oct 9 it was not seen. On Nov 11 a star like the half Moon was seen at the W." (*Hsin-t'ang-shu*, Astronomical Treatise).

(ii) Japan. "On Sep 7 a broom star appeared at the W direction; it was more than 10 deg in length. During the month Dec 12 to Jan 10 a star emerged (po) at the zenith; it moved along with the stars of Mao (LM 18). At the end of the month it disappeared." (*Nihon Shoki*).

The Astronomical Treatise of the *Chiu-t'ang-shu* and the *T'ang-hui-yao* both contain essentially the same records as (i), but these differ as to the duration of visibility. The former specifies 49 days while the latter asserts 42 days. The duration implied in (i) is confirmed by the brief notice in the Annals of the *Chiu-t'ang-shu*, which states that after 33 days the broom star was extinguished.

There is no doubt that only the broom star sightings can refer to Halley's comet. The objects seen in China on Nov 11 and in Japan more than a month later appeared too long after perihelion and furthermore were in the wrong part of the sky. By Nov 11 Halley's comet would already be very faint and its proximity to the Sun (only 15 deg away) would mean that it would never be above the horizon in a dark sky. If visible at all, it would be seen only at dawn in the E. By mid-December, the comet would be far below the unaided eye limit and almost 180 deg from Mao (LM 18). Possibly the first object was no more than a bright meteor. The later star, which remained visible for several days, could either have been a comet or a nova.

Coming now to the broom stars reported in both China and Japan, the similarity between the separate accounts is noteworthy – apart from the discrepancy of one day in the date of discovery. However, the terminology is sufficiently general to suggest that the Japanese record may be independent. Regardless of this, the observations are quite compatible with the calculated motion of Halley's comet. The expected date of conjunction with the Sun is about Sep 7. However, because of its high declination (+40 deg), the head of the comet should have been visible for the first time in the W (better the NW) on the previous evening, which agrees exactly with the date of the first Chinese sighting. Following the motion of the comet over the succeeding weeks, it should have been favourably placed for viewing until around Oct 10. After then, because of the gradual decrease in both the declination and the elongation from the Sun, it would be soon lost in the twilight glow. A duration of 33 days thus seems more appropriate than 42 days or more.

It is worth pointing out that Halley's comet seems to have escaped notice before conjunction with the Sun, although it would be well placed in the NE sky before dawn during late August and early September. Possibly overcast weather prevailed around this time.

6.14 Return -16. AD 760 (P = May 20.7; d = 0.41 AU on Jun 2). China

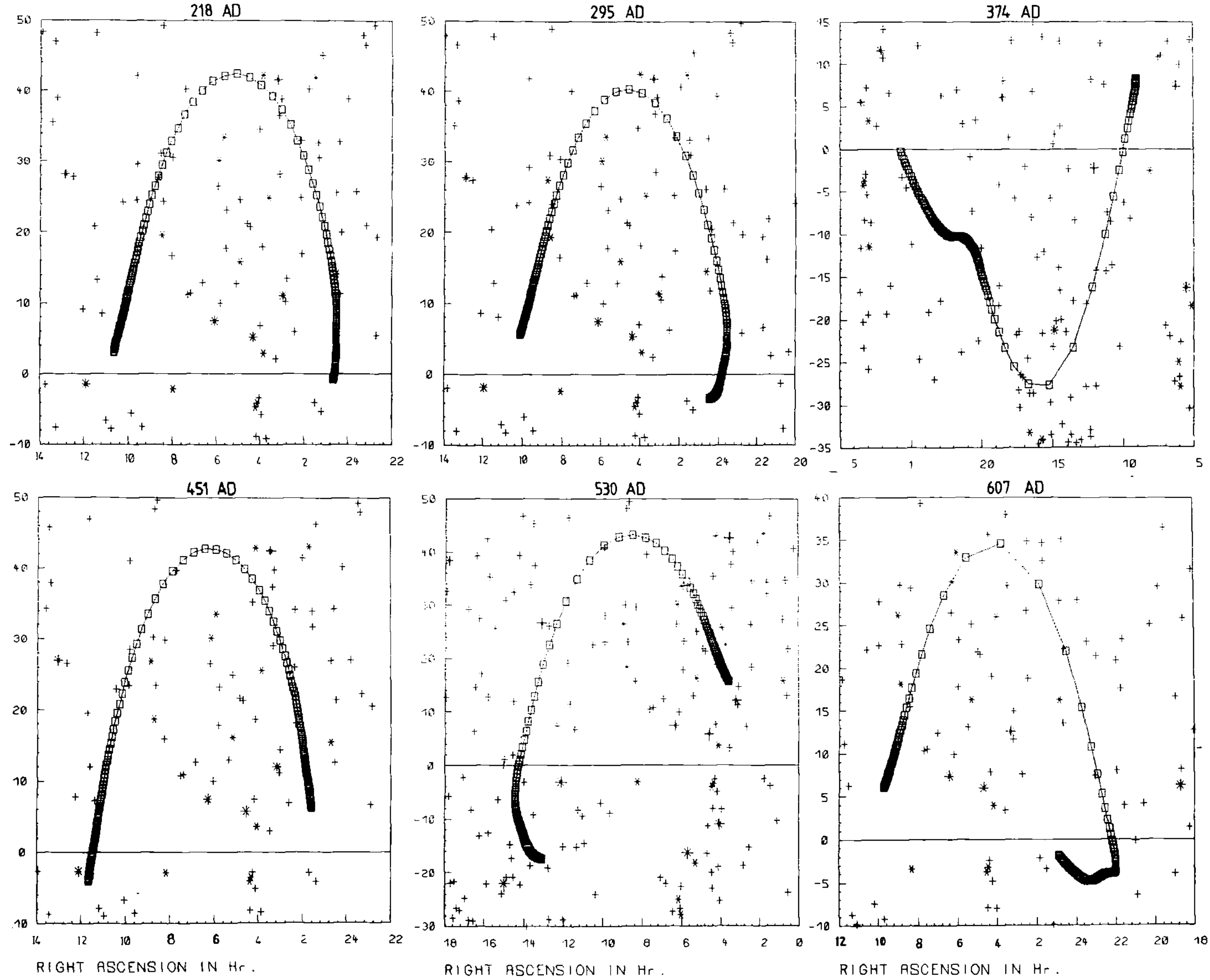
The Japanese sources are silent regarding this return. The following description in the *T'ang-hui-yao* is fairly representative of the most detailed Chinese sources.

"On May 16 a broom star was seen at the E direction; it was between Lou (LM 16) and Wei (LM 17). Its colour was white and its length was 4 deg. It moved rapidly towards the NE. It passed Mao (LM 18), Pi (LM 19), Tsai (LM 20), Shen (LM 21), (Tung-) Ching (LM 22), (Yu-) Kuei (LM 23), Liu (LM 24) and Hsuan-yuan. It reached the W of T'ai-wei, 7 deg to the W of Yu-chih-fa and was extinguished. It lasted for a total of more than 50 days. On May 20 an ominous star was seen at the W direction. It was several tens of degrees in length. During the month Jun 18 to Jul 16 it was extinguished." (*T'ang-hui-yao*).

The Astronomical Treatises of both the *Chiu-t'ang-shu* and the *Hsin-t'ang-shu* contain much the same entry. However, there are small fundamental differences. The former work gives the approximate time of night at which the broom star first appeared – during the 5th watch. It also implies that this star was last seen when only 0.7 deg to the W of Yu-chih-fa and states that the ominous star appeared at the S rather than at the W. The *Hsin-t'ang-shu* Astronomical Treatise gives no estimate of the minimum distance from Yu-chih-fa. However, it describes the second object as a broom star and confirms the direction assigned to it in the *T'ang-hui-yao*. This Treatise further discusses the disastrous astrological implications of two separate broom stars appearing simultaneously.

Although the Annals of both the *Chiu-t'ang-shu* and the *Hsin-t'ang-shu* supply no additional information, they each affirm that the later object was a broom star and that it was seen at the W. It is interesting to note that both Annals specify the date of discovery of the earlier object as May 17 instead of May 16. Presumably these sources are concerned with only the civil dates of events whereas the previously mentioned works use the astronomical day. This may be inferred from the remark in the *Chiu-t'ang-shu* Astronomical Treatise that the broom star was seen during the final watch of the night – roughly the last two hours before dawn. The civil date would have changed to May 17 at midnight but the astronomers would await sunrise before altering their calendar.

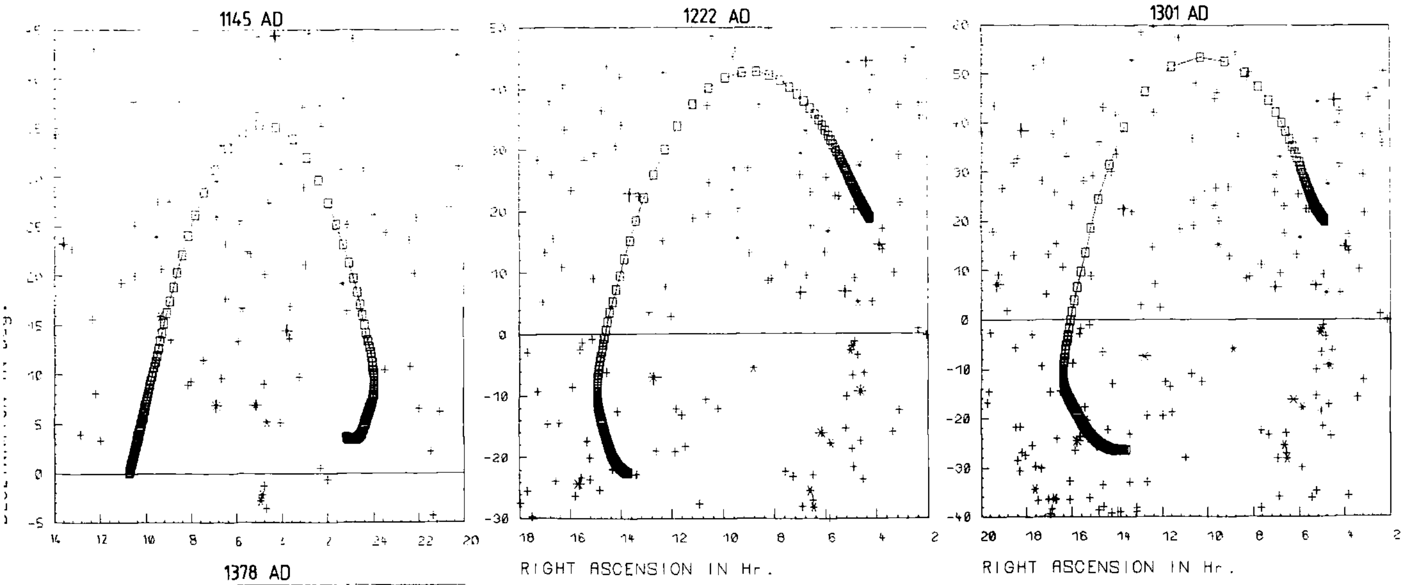
It seems well established from the various records cited above that two distinct comets appeared at much the same time in AD 760. The first of these objects was sighted at the E before dawn on the morning of May 17 and the second was seen at the W or S only four days later. From the calculated motion of Halley's comet at this apparition, only the first star need be considered further. During the whole of the latter half of May, Halley's comet would be rising at the E before dawn and could not be seen in either the W or S. Its motion would follow closely the path described from Lou (LM 16) and Wei (LM 17) to Hsuan-yuan. In particular, the observed position between Lou and Wei on the



asterisks denoting stars brighter than mag +1.5. Markers in the form of small squares indicate the position of the comet's nucleus at daily intervals for 100 days before and after perihelion. (In AD 837 and 1378, the motion of the comet was so rapid that around closest approach to the Earth positions at 6-hourly intervals are shown).

again pointed W. On the night of Mar 29 the broom (star) was 8 deg (*tu*) in Wei (LM 12). On the night of Apr 5 it was 3.5 deg (*tu*) in Hsu (LM 11). On the night of Apr 6 the length of the broom (star) was more than 10 deg. It moved W in a straight line, pointing slightly S. It was 1.5 deg (*tu*) in Hsu (LM 11). On the night of Apr 7 its length was more than 20 deg and its width was 3 deg. It was 9 deg (*tu*) in Nu (LM 10). On the night of Apr 8 it increased in both length and width; it was 4 deg (*tu*) in Nu (LM 10). On the night of Apr 9 its length was more than 50 deg. It branched into two tails, one pointed towards Ti (LM 3) and the other concealing Fang (LM 4). It was 10 deg (*tu*) in (Nan) Tou (LM 10). On the night of Apr 11 the length of the broom (star) was 60 deg. The tail was without branches and it pointed N. It was 7 deg (*tu*) in K'ang (LM 2). The Emperor summoned the Astronomer Royal and asked him the reason for these star changes... That same night (i.e. still Apr 11) the length of the broom (star) was 50 deg and its width was 5 deg. It was moving towards the NW and pointing E. On the night of Apr 13 the length of the broom (star) was more than 80 deg. It was (still) moving NW and pointing E; it was 14 deg (*tu*) in Chang (LM 26)... (A general amnesty was declared)... On the night of Apr 28 the broom (star) was 3 deg in length. It appeared to the right of Hsuan-yuan and was pointing E. It was 7 deg (*tu*) in Chang (LM 26)... On Sep 9 a broom (star) appeared at Hsu (LM 11) and Wei (LM 12)." (*Chiu-t'ang-shu*, Astronomical Treatise).

(ii) China. "On Mar 22 there was a broom star at Wei (LM 12). Its length was more than 7 deg and it pointed W towards Nan-tou (LM 8). On Mar 24 it was at the SW of Wei (LM 12); its rays had increased in brightness and had grown. On Mar 29 it was situated at Hsu (LM 11). On Apr 6 its length was more than 10 deg; it moved W and pointed slightly towards the S. On Apr 7 it was at Wu-nu (LM 10). Its length was now



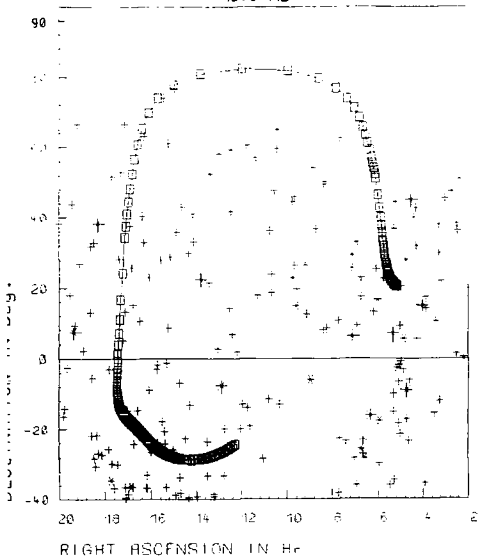


Fig. 2. continued.

objects remained fixed.

Considering only the observations between Mar 22 and Apr 28, the *Chiu-t'ang-shu* obviously gives more precise details than the *Hsin-t'ang-shu*. However, there are significant discrepancies. The most important of these are as follows:

(a) On Mar 29, the *Chiu-t'ang-shu* (which we shall abbreviate to *CTS*) gives the position as 8 deg in Wei (LM 12) whereas the *Hsin-t'ang-shu* (*HTS*) gives a location at Hsu (LM 11). The *CTS* in fact records two positions at Hsu but both are several days later – Apr 5 and Apr 6.

(b) There is deviation of one day between the two sources over the date when the tail of the comet became temporarily branched (*CTS* Apr 10, *HTS* Apr 9). Nevertheless, both works agree on a location at Nan-tou (LM 8) on Apr 9.

(c) The *CTS* contains no entry for Apr 12. Comparing with the *HTS* entry for that date, it seems likely that the text beginning "That same night..." should be transferred from Apr 11 to Apr 12. This would avoid the occurrence of two evidently independent observations on the same date.

(d) There is disagreement between the *CTS* and the *HTS* as to which day the tail of the comet reached its maximum length of 80 deg. It thus seems likely that the date when the RA was 14 deg in Chang (LM 26) could either be Apr 13 or Apr 14.

On the points (a), (b) and (d) above, both the Annals of the *CTS* and the *T'ang-hui-yao* (*THY*) support the *CTS* Astronomical Treatise. However, neither of these works offers any information which would help in resolving (c).

The various RA measurements are clearly of great value in fixing the precise date of perihelion passage. Both Kiang [1] and Yeomans and Kiang [2] recognised and put to good use the tremendous potential of this material. In Table 4 we have assembled the data from all four sources which is relevant to the determination of the date of perihelion. The Japanese observation is too general to be of service here while the Annals of the *HTS* note little more than the date of discovery. The first column of Table 4 gives the equivalent Julian date in AD 837, while columns 2 to 5 list the positions reported in the Astronomical Treatise of the *CTS* (column 2), the Astronomical Treatise of the *HTS* (column 3), the Annals of the *CTS* (column 4) and the *THY* (column 5). It should be noted that the Astronomical Treatise of the *HTS* normally does not concern itself with precise locations for the comet. Otherwise, the RA is usually given as so many degrees (*tu*) in a particular lunar mansion. Only for the first observation (Mar 22) is an ordinal numeral used, i.e. the 1st deg in Wei (LM 12).

Table 5 summarises the reduction of the data in Table 4. In general, we have discarded the rough *HTS* positions – except where these are apparently independent of the measurements recorded elsewhere (as on Mar 29 and Apr 14). The individual columns of Table 5 contain the following details: (i) and (ii) the Ephemeris Date and estimated ET of the observation, the ET and associated uncertainty being based on the calculated length of time that the comet was above the horizon during the hours of darkness; (iii) the observed RA of the nucleus, expressed to the nearest 0.01

ley's comet would reach the W of Chang (LM 26) and pass quite close to Ling-t'ai in the days immediately after conjunction with the Sun (c. Jul 15). The positional information thus seems quite sound; it appears likely that the brief records (i) and (ii) may refer to the earliest sightings in China (presumably there were no pre-conjunction observations, as in Japan). Nevertheless, if we are to interpret the records as indeed referring to Halley's comet, we must assume errors in both the month (reading 6th month for 4th month) and cyclical days. Although neither of these corrections would normally be easily explained, there is evidence that chronology during this period was rather unreliable.

Analysis of the three other astronomical observations made in the same year recorded in the Astronomical Treatise of the *Hsin-wu-tai-shih* is helpful. A near approach of Mars to β Sco is reported on Feb 7 and close approaches of the Moon to Antares are dated Feb 19 and Apr 25 – the latter being described as an occultation. Only the first of these dates is roughly correct; calculation indicates Feb 4 rather than Feb 7. On the two later dates the Moon was on each occasion some 90 deg from Antares. The corrected dates are Mar 10 and May 4, the only two conjunctions of the Moon with Antares visible in China during the first nine months of AD 912. The various amendments cannot be explained in terms of simple copying errors, a remark which may just as well apply to the cometary records. At some stage between making the observations and their final summarisation in the official histories, serious mistakes must have occurred. There is thus no need to assume unusual behaviour on the part of Halley's comet in AD 912.

6.17 Return -13. AD 989 (P = Sep 5.7; d = 0.39 AU on Aug 20). China, Japan, Korea.

On this occasion, we find several short but useful records from China and to a lesser extent Japan. A Korean text may also refer to Halley's comet, but only if we assume an error in the date of observation.

(i) China. "On Aug 12 a guest star appeared to the NW of the stars of Pei-ho. It became slightly dimmer. It had short rays and a broom which pointed SW." (*Sung-shih*, Astronomical Treatise – section on Guest Stars).

(ii) China. "On Aug 13 a broom star appeared at Tung-ching (LM 22) to the W of Chi-shui. Its colour was pale blue (i.e. "bluish white"). Its rays gradually lengthened. In the morning it was seen at the NE for 10 days. In the evening it was seen at the NW. It passed Yu-she-ti. After a total of 30 days it reached K'ang (LM 2) and disappeared.' ' (*Sung-shih*, Astronomical Treatise – section on Broom Stars and Bushy Stars).

(iii) China. "On Aug 13 a broom star was seen at Tung-ching (LM 22)... On Sep 10 it was not seen." (*Sung-shih*, Annals).

(iv) Japan. "On Jul 16 a broom star was seen at the E and W. Between Aug 14 and Aug 23 on successive nights a broom star was seen at the E and W." (*Nihon Kiryaku*, a chronicle covering the period from earliest times to the 11th century).

(v) Japan. "On Aug 16 a broom star was seen at the E direction for several nights. Its length was about 5 deg." (*Shodo Kambun*).

(vi) Korea. "On Oct 18 a broom star was seen." (*Koryo-sa*, Astronomical Treatise).

In China the broom star was regared as the forerunner of a drought which occurred in the autumn, while in Korea a general amnesty was declared.

Kiang [1] pointed out that (i) and (ii) almost certainly related to the same object – despite the fact that they are included in separate sections of the *Sung-shih* Astronomical Treatise. The asterisms Pei-ho and Chi-shui are less than 10 deg apart. Text (iii) presumably implies that the broom star was not seen after Sep 9. Combining this date with that of the earliest sighting (Aug 12) gives a period of visibility of 29 days, which closely confirms the duration mentioned in (ii).

The celestial locations described in the Chinese sources are in good agreement with the calculated positions. The most critical observation is that made on Aug 13 – see (ii) – since a fairly well defined range of RA is indicated. Chi-shui is a single star (o Gem), whose RA in AD 989 was 6h 12m. The location at Tung-ching lunar mansion is consistent with an RA in excess of 5h 20m so that the true value must have been between these extremes. In order to satisfy these observations, it is necessary to delay the tabular date of perihelion by at least three days.

The earliest Japanese observation – on Jul 6 – cannot relate to Halley's comet unless there is a mistake in the recorded date. On Jul 6 the comet would be still nearly 2 AU from the Earth and thus well below the unaided eye threshold. There is some confusion here. However, the remaining observations are in good agreement with those from China. It is noteworthy that although the date of discovery in Japan (Aug 14) is only two days later than in China, both dates are perhaps two weeks later than expected, Halley's comet should have been observable from about the beginning of August. The statement in (iv) that the broom star "was seen at the E and W" presumably means that it was observed both before and after conjunction with the Sun. As already noted, the Chinese observations support a delay in the date of perihelion by at least three days. However, if this date is altered by more than four days, the comet would not be seen at the W until after Aug 23. Hence a final correction of between three and four days may be inferred, corresponding to an amended date of perihelion passage of around Sep 9.

Lastly we come to the very brief Korean account. By Oct 18 Halley's comet would be very faint and once more in conjunction with the Sun. The simplest inference is probably a two month error in the recorded date, but, as the direction in which the broom star appeared is not specified, even this is no more than speculation. We must wait until AD 1066 before we find the first reasonably reliable Korean observation of Halley's comet.

6.18 Return -12. AD 1066 (P = Mar 20.9; d = 0.11 AU on Apr 23). China, Japan, Korea

This famous apparition of Halley's comet was carefully recorded in China, where it was observed for a total of 67 days. There are only brief records from Japan and a probable sighting in Korea, the date of which is in doubt.

(i) China. "On Apr 3 a broom star appeared at Ying-shih (LM 13). In the morning it was seen at the E direction. Its length was about 7 deg. It pointed SW towards Wei (LM 12) and reached Fen-mu. Gradually it increased its speed, moving E, and when near the Sun it disappeared. On the evening of Apr 24 it was seen at the SW. In the N there was a star without rays or broom, advancing in an E direction. There was another white vapour about 3 deg in width. It penetrated Tzu-wei and the Pole Star (Chi-hsing), joining

Fang (LM 4) lunar mansion. Its head and tail went below the horizon. It advanced E, passed Wen-chang and Pei-tou and penetrated Wei (LM 6). On Apr 25 the star again had its rays and broom. Its length was more than 10 deg and its width more than 3 deg; it pointed NE. It passed Wu-che. The white vapour became branched and stretched across the sky. It penetrated Pei-ho, Wu-chu-hou, Hsuan-yuan and also Wu-ti-tso and Nei-wu-chu-hou of T'ai-wei. It reached Chueh (LM 1), K'ang (LM 2), Ti (LM 3) and Fang (LM 4) lunar mansions. On Apr 26 the length of the broom (star) was 15 deg. The star had a broom-like vapour and resembled a one-tenth peck measure. It passed from Ying-shih (LM 13) lunar mansion to Chang (LM 26), a total of 14 lunar mansions. After a total of 67 days the star, vapour and 'bushiness' (*po*) all vanished." (*Sung-shih*, Astronomical Treatise).

(ii) China. "On Apr 3 a broom star was seen in the morning at (Ying-) Shih (LM 13)... On Apr 24 the broom (star) was seen in the morning at Mao (LM 18). It was like Venus; it was 15 deg in length. On Apr 25 it emerged (*po*) at Pi (LM 19). It was like the Moon... On Jun 7 the broom star reached Chang (LM 26) and disappeared." (*Sung-shih*, Annals).

(iii) N. China. "On Apr 24 a broom star was seen at the W." (*Liao-shih*, Annals).

(iv) Japan. "On the morning of Apr 3 a broom star was seen at the E direction. Its length was 7 deg. On Apr 27 between 5 and 7 p.m. the broom star was seen at W direction." (Composite translation based on serveral sources which Kanda [6] consulted).

(v) Japan. "During the month Mar 29 to Apr 26 a broom star was seen at the E direction. After twenty days its was no longer seen. Later is was seen at the W direction." (*Sankaiki*).

(vi) Korea. "On Apr 19 a star appeared at the NW direction. It was as large as the Moon. Suddenly it changed into a 'comet' (*hui-po*)." (*Koryo-sa*, Astronomical Treatise).

The details in (ii) are also to be found in the biographical section of the *Sung-shih*.

The first Chinese report is rather complex. Seemingly, as far as the observers were concerned, the "white vapour" seen on Apr 24 and 25 was quite independent of the broom star. However, Kiang [1] pointed out that this vapour must be understood to refer to the tail of the comet – which would appear greatly elongated on account of its proximity to the Earth. Otherwise, the Chinese and Japanese descriptions are in excellent accord with the calculated motion of Halley's comet at this return. Almost certainly the Korean astronomers also saw this comet, but the date and direction given in the *Koryo-sa* are somewhat at variance with the details noted in China and Japan. It is interesting that both the Chinese and Korean observers drew attention to the large angular size of the coma – similar to the Moon – when near the Earth.

Discovery seems to have been simultaneous in both China and Japan – i.e. on Apr 3. This is roughly the date which might have been expected, on account of its low declination and small elongation from the Sun, Halley's comet would be poorly placed until the end of March. However, the fact that the comet was followed until as late as Jun 6 in China is surprising. Although then well placed in the W sky after dark, it would be more than 1.5 AU from both Earth and the Sun and thus extremely faint.

The date of disappearance in the E before conjunction with the Sun cannot be established precisely. Only text (v) provides direct information, but this is rather vague. Assuming that the date of first sighting was Apr 3, as in (iv), the date of last visibility in the E would be Apr 22. However, we cannot be sure that the "20 days" is more than a round number. In China the comet seems to have been carefully observed both before and after conjunction. The date of reappearance seems firmly identified as Apr 24 and this is verified by the brief entry in the *Liao-shih* (iii). The *Sung-shih* Annals indicate that after conjunction the comet was still a morning object but this must be a mistake. Apart from the conflicting evidence in the Astronomical Treatise of the same history (i), the statement that the broom star was at Mao (LM 18) on Apr 24 proves that it was by then an evening object. On this day, the Sun (RA 2h 30m) was to the W of Mao so that only an evening observation would be possible.

For the purpose of better dating perihelion passage, the most valuable observations are the locations within the lunar mansions Mao (LM 18) and Pi (LM 19) on Apr 24 and Apr 25 respectively. Halley's comet was then moving very rapidly – at nearly 1 deg per hour. As the observations are reported in the *Sung-shih* Annals, it is fortunate that the comet was then an evening object since both the civil and astronomical dates would be identical and there is no possibility of confusion. Having just passed conjunction, the most suitable time for viewing would be around 8-9 p.m., corresponding to about 13h-14h ET. For the nucleus to be in the required ranges of RA (2h 51m to 3h 35m on Apr 24 and 3h 35m to 4h 44m on Apr 25) implies perihelion on Mar 23.5 + 0.3, some 2.5 days later than the tabular date. This is in reasonable agreement with the observed reappearance after conjunction on Apr 24.

6.19 Return -11. AD 1145 (P = Apr 18.6; d = 0.27 AU on May 12). China, Japan, Korea

Although this apparition was observed throughout the Far East, the most intriguing record is to be found in a non-astronomical work. For nearly two months the Japanese courtier Fujiwara no Yorinaga, then aged 25, kept a regular account of the appearance and motion of the comet in his diary, the *Taiki*. Although written in non-technical language, this is the most systematic report of the comet which we possess for AD 1145. Because of its length we have summarised the main points. As usual, we shall begin with the Chinese sources.

(i) China. "On Apr 26 a broom star was seen at the E direction. On May 14 it was again seen in the degrees of Shen (LM 21). On Jun 4 it changed into a guest star. Its colour was pale blue (i.e. "bluish-white"). On Jun 14 it was beside Chang (LM 26) and guarded it. On Jul 6 it dispersed. (*Sung-shih*, Astronomical Treatise).

(ii) S. China. "On Apr 26 a broom star was seen at the E direction. On May 5 there was a general amnesty on account of the broom (star). On May 11 the broom star disappeared. On Jun 3 a guest star was seen. On Jul 6 the guest star disappeared." (*Sung-shih*, Annals).

(iii) N. China. "On May 14 a broom star appeared at the NW. It was more than 10 deg in length. On Jun 14 it was extinguished." (*Kin-shih*, Astronomical Treatise).

(iv) Japan. "On May 3 the Professor of Astronomy said that a star had emerged (*po*) at K'uei (LM

What would appear to be the most careful description of the comet's position is given in text (iii). The *Chin-shu* states that on Sep 10 it was situated within K'ang lunar mansion between Yu-she-ti and Chóu-ting. There is a discrepancy here for the two latter asterisms – only some 10 deg apart – are to the W of K'ang and more nearly in Chueh (LM 1). Possibly the lunar mansion was only roughly estimated; the text is quite specific that the comet was between Yu-she-ti and Chou-ting. On this assumption, the correction to the adopted date of perihelion is about +1.5 ± 1.5 days, making Sep 30.5 ± 1.5 day. This result is confirmed by the statement in the *Koryo-sa* that the broom star appeared within San-t'ai on Oct 3. The implied date of perihelion here is no later than Oct 1. Hence the two observations combined give an accurately defined date of perihelion passage.

The observations from S. China are less useful. By Sep 25 Halley's comet would be almost stationary within Ti (LM 3). This accords with text (ii), but no information regarding the date of perihelion can be deduced. The details in text (i) are somewhat dubious. The comet could never have reached as far as Fang (LM 4) and Hsin (LM 5) since it commenced to retrograde at Ti. The assertion that the comet was seen at Yu-she-ti on Sep 25 is at variance with the independent observations reported in (ii), (iii) and (v). Very probably, this entry in the Astronomical Treatise of the *Sung-shih* became garbled when it was condensed by the compilers of the history – an all too frequent occurrence.

Our final comments concern the duration of visibility of the comet. Discovery – by the Korean astronomers on Oct 3 – was perhaps 10 days later than might have been expected. Nevertheless, this is still a few days before conjunction. In order for the comet to be seen again in the NW (i.e. after conjunction) on Sep 6, a date of perihelion no later than Oct 1 is again required. Last visibility in Japan was on Oct 5 and in N. China on Oct 8. Both dates are quite likely for after about Oct 10 Halley's comet would be too close to the Sun for further observation. The dates of final disappearance implied in (i) and (ii) – i.e. two months after Sep 25 and Oct 23 – are impossible. The comet would not again emerge from the solar glare until about mid-November, by which time it would be invisible to the unaided eye on account of its great distance from the Earth (more than 2 AU).

6.21 Return -9 AD 1301 (P = Oct 25.6; d = 0.18 AU on Sep 23). China, Japan, Korea

At the time of this return, China was part of the vast Mongol Empire, which had its capital at Ta-tu (i.e. Pei-ching or Peking). The astronomers of this period have furnished us with what is ostensibly the most accurate of all Far Eastern measurements of the position of the nucleus.

(i) China. "From Sep 16 to Oct 31 a broom star appeared at 24.4 deg (*tu*) within (Tung-) Ching (LM 22). It was like the large star of Nan-ho (i.e. Procyon). Its colour was white and its length was 5 deg. It formed a straight line towards the NW. Later it passed Wen-chang and the head of (Pei) Tou. It swept to the S ofT'ai-yang and then swept Pei-tou, T'ien-chi, the wall of Tzu-wei, San-kung and Kuan-so. The length of the star was more than 10 deg. It reached the E of Pa-shu at the T'ien-shih wall, (continued to) the S of Liang and Chu and above the star Sung. Its length was rather more than 1 deg. After a total of 46 days it was extinguished." (*Yuan-shih*, Astronomical Treatise).

(ii) Japan. "On Sep 15 between 3 and 5 a.m. a broom star appeared at the E direction. Its rays were more than 3 deg (in length). On the morning of Sep 16 the broom star appeared at the E direction. On the night of Sep 23 between 7 and 9 p.m. the broom star again appeared at the NW. Its rays were more than 10 deg in length." (Composite translation based on two of the sources consulted by Kanda).

(iii) Korea. "On Sep 14 a broom star was seen at Pei-tou and Tzu-wei. On Sep 18 it was seen at Pei-tou. On Oct 1 it was seen at Shang-t'ai and entered the wall of T'ien-shih... On Oct 9 the broom star was seen at the wall of T'ien-shih." (*Koryo-sa*, Astronomical Treatise).

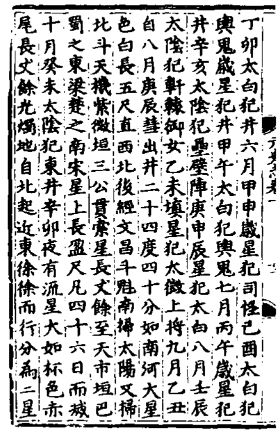


Fig. 4. *Yuan-shih, Astronomical Treatise*, description of Halley's comet in AD 1301.

Most of the above observations agree well with the calculated motion of Halley's comet. Kiang [1] pointed out that although the head of the comet could not have passed close to Wen-chang and Tzu-wei, the tail would probably have done so. In the Korean text (iii) there is an obvious error regarding the Oct 1 location. Shang-t'ai and the (W) wall of T'ien-shih are more than 90 deg apart. Although both asterisms lay close to the calculated path, the comet would take some two weeks to travel between them.

Only the precise Chinese measurements of 24.4 *tu* (= 24.0 deg) in Tung-ching (LM 22) is relevant to the determination of the date of perihelion. It seems reasonable to suppose that this observation was made on the day of discovery itself (i.e. Sep 16) since it is the first recorded location. However, this is not distinctly stated. The equivalent RA is 7hr 17m at epoch. On Sep 16, Halley's comet would be fairly high in the sky between midnight and dawn so that the ET of the observation may be deduced as 19 ± 2.5 hr on this day. For the computed and observed RA to agree, the tabular date of perihelion must be advanced by 0.9 ± 0.1 day, corresponding to Oct 24.7 ± 0.1. The reliability of this result is somewhat diminished since no other observation is sufficiently accurate to provide useful independent confirmation.

During the later stages of its motion, the Chinese astronomers followed the comet for almost as long as it was possible to do so with the unaided eye. By Oct 31, the last reported sighting, it would be very close to the Sun and only above the horizon for a short time at dusk.

6.22 Return -8. AD 1378 (P = Nov 10.7; d = 0.12 AU on Oct 3). China, Japan, Korea

With this return, we reach the last of the apparitions of

3.5 Records of Halley's Comet on Babylonian Tablets

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Records of Halley's comet on Babylonian tablets

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The late Babylonian texts in the British Museum are shown to contain probable observations of Halley's comet at both its 164 BC and 87 BC apparitions. These texts have important bearing on the orbital motion of the comet in the ancient past.

HALLEY'S comet returns to the inner Solar System every 75–80 years, the precise interval depending appreciably on perturbations in its orbit induced by various planets. The comet is unique in being the only known periodic comet that regularly becomes bright enough to attract the attention of the unaided eye. As a result, no other comet has a comparable history. Since the pioneering work of Halley[1], the orbital motion has been investigated carefully and observations of every apparition as far back as 12 BC have been identified confidently[2].

Despite this impressive record, the history of Halley's comet before 12 BC is relatively obscure. At this early period, Chinese records, so detailed in later centuries, are comparatively poor, although there are two possible references in 87 BC and 240 BC[2,3]. Greek and Latin sources mention several comets occurring in ancient times, but scant attention is paid to information such as celestial location and exact date of observation. Identification of P/Halley (the prefix denotes the periodic nature of the comet) among such diverse material is very difficult, if not impossible.

A neglected source of cometary observations is the late Babylonian astronomical texts. These inscribed clay tablets were discovered about a century ago and are now mainly in the British Museum[4]. Here we present for the first time two separate Babylonian records of P/Halley from 164 BC (the only extant records of this apparition in the world) and one from 87 BC. It is hoped that these records will enable a more definite orbit of P/Halley to be traced into the ancient past and a deeper understanding of the evolution of cometary orbits to be made with respect to the recent interest in cometary catastrophism.

Orbital parameters

According to Ho Peng Yoke's[5] catalogue of oriental records of comets and guest stars, some 500 naked-eye comets have been observed over the past 2,200 years (that is, an average of one comet approximately every five years). On the basis of these statistics, there is a significant probability of another bright comet appearing in the same year as P/Halley itself; in fact several such double events are known to have occurred, most recently in 1910. Thus, it is evident that to investigate the most ancient apparitions of Halley's comet, a highly reliable orbital theory is required or an incorrect identification may well be made. Recently, four independent sets of osculating orbital elements have been derived for P/Halley by Chang[6], Yeomans and Kiang[7], Brady[8] and Landgraf[9]. All the solutions cover more than three millennia and are based on a numerical integration of the equations of motion of the comet backwards in time.

The apparent motion of a comet across the celestial sphere is only weakly dependent on small changes in orbital parameters such as eccentricity, inclination and perihelion distance. The slight differences in these parameters deduced by the various authors can safely be neglected. On the other hand, the relative motion with respect to the Earth is very sensitive to variations in the precise date of perihelion passage (T). Hence a question of prime concern is the reliability of values of T as calculated by the authors of refs 6-9.

Both telescopic and pre-telescopic measurements of the position of P/Halley enable the dates of every perihelion passage back to AD 989 to be determined accurately[2,3,7]. On only two occasions during this period do observational uncertainties exceed 0.5 day (1.5 days in AD 1222 and 0.8 days in AD 1145).

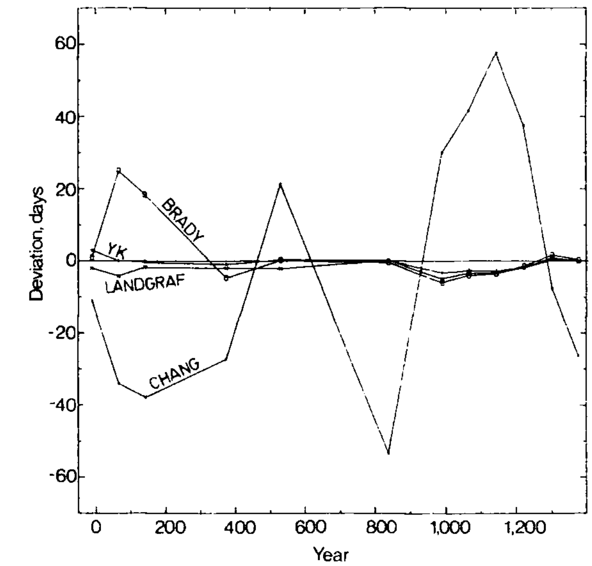


Fig. 1 Plot of the deviations between the calculated and observed dates of perihelion passage for Halley's comet between 12 BC and AD 1378 for the investigations in refs 6-9. YK, Yeomans and Kiang.

Further back in time the precision of observation is generally low but there are several notable exceptions. In AD 837, 530, 374 and 141, careful measurements of the RA of the comet by Chinese astronomers enable values of T to be deduced with uncertainties between 0.1 and 0.5 days. Finally, Chinese observations in AD 66 and 12 BC, although less accurate, still have tolerably small uncertainties of $\sim$2 days.

Over the earlier part of this time range, the results of a comparison between observation and theory for the four investigations cited are summarized in Fig. 1. This diagram emphasizes the high accuracy of Yeomans and Kiang[7], Brady[8] and Landgraf[9] in representing observations as far back as AD 374; discrepancies in T do not exceed $\sim$5 days at any perihelion passage since that date. Similar consistency for the three most ancient well-observed apparitions (AD 141, AD 66 and 12 BC) is obtained in refs 7, 9. However, Brady's[8] results for T are somewhat discordant in both AD 141 ($\sim$20 days error) and AD 66 ($\sim$25 days), although the accuracy is again high in 12 BC (discrepancy $\sim$1 day). The relatively low precision of Chang's[6] solution is evident; errors of a month in T are not unusual.

The mutual discrepancies in the dates of perihelion passage as calculated in refs 6-9 back to 700 BC are shown in Fig. 2. Here, Yeomans and Kiang's data[7] have been adopted arbitrarily as the standard from which to measure deviations. From Fig. 2 it is apparent that for any apparition of P/Halley back to 87 BC the agreement between refs 7-9 is good; the maximum discord amounts to less than a month. In 164 BC and 240 BC, refs 7 and 9 still tend to support one another, discrepancies being about 15 and 40 days, respectively. However, Brady[8] deviates from these solutions by some 150 days in both cases. Beyond 240 BC, even the precise years of apparition are in dispute. The apparent lack of useful observational data before 12 BC is a serious handicap to further progress. It is hoped that our discovery uš (that is, 23.7° or ~95 min). (2) Attention has already been drawn to the observation on about the 12th of the following month when Venus was 2 fingers above γ Cap.

On the reverse of both tablets there are several identical pairs of observations, both covering two successive months: (1) On the 7th of the second month cited, both texts state that at the beginning of the night the Moon was 2/3 cubit behind β Gem. (2) On the 9th, both texts assert that at the beginning of the night the Moon was 6.5 cubits below ε Leo. (3) On the 15th, in each case the interval between sunrise and moonset is given as 5,30 uš (that is, 5.5° or 22 min). (4) As well as the above, on about the 15th of the month a lunar eclipse is reported. The two texts give few overlapping details but a separate tablet giving fuller information (BM 34037) shows that they represent portions of the same eclipse record.

The evidence is thus conclusive that the two tablets represent copies, albeit with slight variants, of the same astronomical diary. Many similar duplicate and some triplicate texts are known.

(2) 87 BC

BM 41018 rev. 8′-10′ (unpublished)
[...GE$_6$]13(?) 8 ME muš USAN ^{d}ṣal-lam-mu-ú
[...] šá ITU.ŠU u$_4$-mu al-la u$_4$-mu 1 KUŠ
[...] x bi-rit SI u MAR mi-ši-iḫ-šú 4 KÙŠ

On the 13th(?), the interval between moonrise and sunset was 8 degrees, measured; first part of the night, a comet [...] which in month IV day beyond day, one cubit [...] between north and west its tail 4 cubits [...]

As indicated by the brackets, the test is fragmentary. The gaps at the beginning of each line may be rather long. The passage quoted is from the 13th(?) (the number is damaged, but certainly it is at least the 12th) day of a month. Although, as before, neither the month nor the year are preserved, both may be derived uniquely from other astronomical data recorded on the same tablet. This information includes: (1) 3rd day of the same month, the Moon was 2 cubits east of Venus; (2) on about the 4th day, Mercury set in the east in Leo; (3) some time between the 4th and 12th Mars was 6 fingers above δ Cnc; (4) 13th day, a lunar eclipse which "passed by", that is, a predicted eclipse which was invisible in the longitude of Babylon; (5) some time between the 13th and 19th, Venus was 1 cubit below α Lib.

The reverse of the text mentions the capital city of Seleucia, founded in 274 BC, which sets a useful time limit. The only astronomically acceptable date is the lunar month beginning on 12 August in 87 BC, that is, month V of the year SE 225. This date is confirmed by the retrospective entry relating to month IV in the account of the comet. Calculation of the time interval between moonrise and sunset on the evening of the cometary observation (that is, 8° or 32 min) determines the date as 24 August, corresponding to the 13th of the lunar month[13]. The fact that the entry for a specific day summarizes observations going back to the previous month strongly suggests that on this day the comet had either reappeared after a period of invisibility or had been seen for the last time.

Because of the gaps in the text, one cannot be definite about certain points of syntax. Thus 'one cubit' may refer to the average daily motion of the comet or it may relate to a verb in the missing part of the next line. However, given the standard presentation of Babylonian observations in which the time reference precedes statements of position or movement, it seems probable that the present passage describes the average daily movement of the comet. The term mishu, which occasionally refers to some luminous phenomenon associated with stars, here seems to indicate the tail of the comet; passages in other texts show that it is usual to specify its direction, as indicated here.

The 'cubit', mentioned in two of the three texts, was used in Babylonian astronomy as an angular unit. It is usually estimated to be ~2° (ref. 14). From an analysis of some 20 Babylonian observations of conjunctions of the Moon with stars contained in a diary dating from SE 60 (= 252 BC)[14], we have arrived at the result that 1 cubit = 2.5 ± 0.5° (s.d. per observation). The analysis also indicates that the term ina IGI ('in front of') used

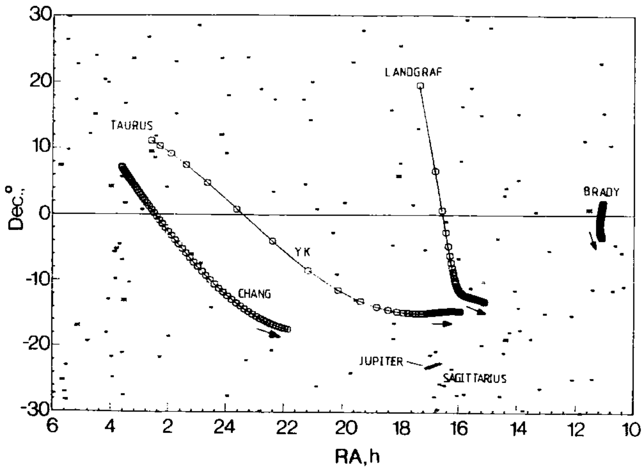


Fig. 3 The computed motion of Halley's comet in 164 BC between 22 Sep and 19 Nov for the dates of perihelion passage deduced by Brady[8] (164 BC 22 June), Landgraf[9] (164 BC 30 Oct), YK (Yeomans and Kiang)[7] (164 BC 12 Nov) and Chang[6] (163 BC 20 Jan). Positions are at daily intervals. Background stars down to mag +3.5 are shown.

in the second of the 164-BC texts was a standard expression meaning 'to the west of', implying an earlier meridian transit.

The Babylonians divided the sky into three regions of declination named after gods: Enlil, Anu and Ea[15]. Of these, Anu was the equatorial region, extending between about +17° and −17°. The entire sky further north was known as Enlil, whereas that to the south was Ea. The limiting declination was based on the well known text ^{mul}APIN (possibly composed ~1000 BC), which states that the Sun spent exactly one quarter of a year in each of these regions before moving on to the adjacent one. However, it would perhaps be unwise to assume too precise a definition of Anu and Ea in analysing the motion of the comet.

Analysis of 164 BC observation

There is a brief Chinese record of a comet on a date equivalent to 6 February 162 BC (ref. 5), but this is much too late for Halley's comet. The dates of perihelion for P/Halley as computed in refs 6-9 all lie between June 164 BC and January 163 BC. The salient points of the two Babylonian accounts are as follows: (1) First appearance in the east in the Taurus region, some time before month VIII (21 October to 19 November). (2) Further appearance in the west in Sagittarius during month VIII. (3) As the difference in RA between Taurus and Sagittarius is as much as 14 h in the direct sense, it seems probable that the motion of the comet was retrograde. (4) The position relative to Jupiter (then in Sagittarius, according to calculation) was recorded at some time between 21 October and 19 November (the Babylonian month VIII). The fact that a difference in longitude (some 2.5°), as well as latitude is mentioned, indicates that this is not a record of closest approach. The reason for recording this rather careful measurement is obscure.

Figure 3 is a chart of the sky in the range of RA from 10 to 6 h and dec. from +30° to −30° at the epoch 164 BC. The region of Taurus (where the comet seems to have been first observed) and Sagittarius (where it was later observed) are marked. The range of positions computed from the JPL Ephemeris DE102 (ref. 16) for Jupiter during month VIII is indicated by crosses. The four roughly vertical tracks (composed of small squares) denote the computed motion of Halley's comet during months VII and VIII (22 September-19 November) on each of the dates of perihelion passage deduced by Brady (22 June), Landgraf (30 October), Yeomans and Kiang (12 November), all in 164 BC, and Chang[6] (20 January 163 BC). In each case the general direction of travel is from north to south, the individual squares representing positions of the comet at daily intervals. Only on the solution of Yeomans and Kiang[7] does the computed path approximate to the observational record. It is evident that merely

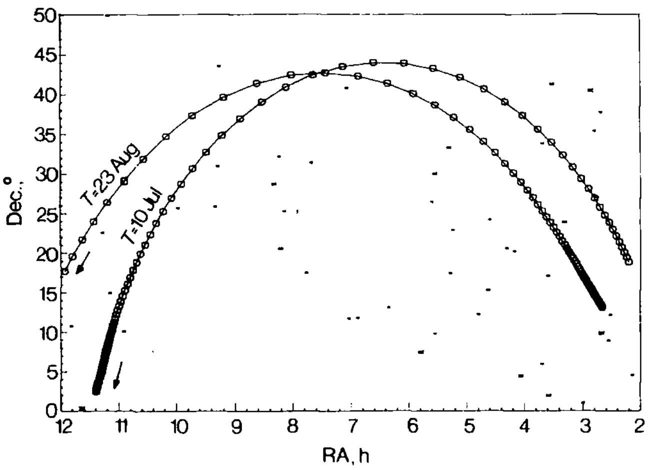


Fig. 5 The computed motion of Halley's comet in 87 BC for both the lower and upper limits of the theoretical *T*, that is 10 Jul (ref. 8) and 23 Aug (ref. 9) over the time range 13 Jun to 9 Sep (months III–V).

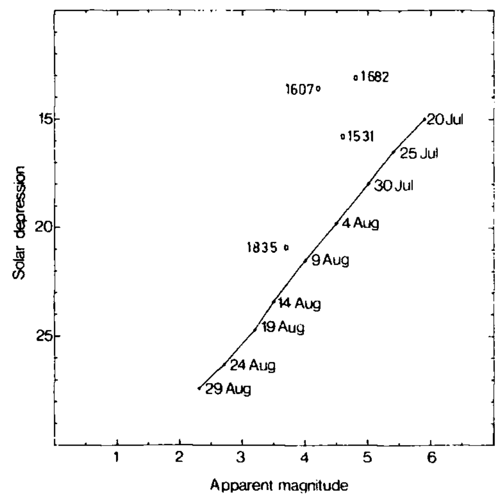


Fig. 6 Plot of the solar depression as a function of the calculated apparent magnitude of P/Halley on the evening of 24 Aug in 87 BC for dates of perihelion between 20 Jul and 29 Aug with, for comparison, the circumstances at the last recorded visibility (in Korea) in AD 1531, 1607, 1682, 1835.

observation reported on 24 August represented either reappearance or last visibility. Such a circumstance is unlikely to result from unfavourable weather, for during the summer months the skies are almost cloudless in this part of the world. (2) The comet was seen 'day beyond day' (u_4-mu al-la u_4-mu) during the 4th lunar month (14 July–11 August), which seems to imply a lengthy period of visibility during this month. (3) We add that the probability of our text referring to P/Halley, rather than some other comet, is high. The various computed dates of perihelion passage lie in the range 10 July–23 August. Calculation shows that on any of these solutions, Halley's comet would be well placed for northern observers during the summer of 87 BC (Fig. 5) and fairly bright, approaching 0 mag according to the formula of Morris and Green[17].

Figure 5 shows the computed motion of Halley's comet in a general easterly direction during months III, IV and V (13 June–9 September) in 87 BC on the dates of perihelion computed by Brady[8] (10 July) and Landgraf[9] (23 August). These represent the extreme calculated dates; Yeomans and Kiang[7] deduced 6 August, whereas Chang[6] gave 15 August. For any of these values of *T*, the comet never approached very close to the Earth (minimum distance ~0.45 AU) so that the motion was unusually regular. The calculated daily motion, indicated by small squares on the diagram, was always >1° and <6° for at least a month. As both of these values are within about a factor of two of 1 cubit, this seems to explain the reference to this quantity in the text, that is, 'day beyond day one cubit'.

As the displacement in the position of P/Halley in response to a change in *T* was fairly linear, it is possible to summarize the main characteristics of the apparent motion almost independently of the precise date of perihelion. On any of the four solutions cited, the comet would first reach the estimated limiting discovery brightness (+4 mag) while some 45° west of the Sun. It would then be fairly high in the eastern sky before dawn. Moving quickly eastwards, the comet would pass conjunction with the Sun approximately 10–15 days later, now becoming an evening object. Gradually diminishing in speed, it would reach a maximum elongation of only ~35° east of the Sun after a further 15 days or so. Some time later the comet, approaching a second conjunction with the Sun and growing progressively fainter, would probably set heliacally, being lost to view in the evening twilight.

From the above outline, it is apparent that the Babylonian record indicates observations both before and after the first conjunction with the Sun. The tail could only have pointed north-west before this conjunction. However, on 24 August, the date of the preserved diary entry, the comet was said to be visible in the "first part of the night" and thus to the east of the Sun. (The Babylonian astronomers divided the interval between sunset and sunrise into three roughly equal parts.) On the basis of brightness considerations, it can be deduced that by 24 August Halley's comet was probably well past conjunction with the Sun. For the comet to have been just emerging after conjunction would require an estimated discovery date (+4 mag) no earlier than about 13 August. As month IV ended on 11 August and the computed magnitude was changing by about 0.2 daily, there would seem to be no possibility of observation 'day beyond day' during this month under these circumstances. Thus, we infer that the most probable interpretation of the observation on 24 August is final visibility.

Before analysing the 24 August observation, we note that it is possible to fix useful limits on the date of perihelion in 87 BC from the additional information supplied in the Babylonian record. For *T* before about 20 July, the tail of Halley's comet could only have pointed north-west earlier than month IV, but such an early date does not seem to be implied in the text. If *T* was after about 30 August, the period of visibility in month IV would probably be too short to be described as 'day beyond day'. These limits may be narrowed further on the assumption of last sighting on 24 August.

Figure 6 illustrates the circumstances relating to the visibility of P/Halley on the evening of 24 August in 87 BC for dates of perihelion between 20 July and 29 August. The abscissa gives the apparent magnitude of the comet as deduced from the empirical formula of Morris and Green[17]. The ordinate is the depression of the Sun below the western horizon at the moment when the nucleus of the comet set (refraction being ignored). For the earlier dates of perihelion, the comet would set in strong twilight. The best time for observation would then be roughly midway between sunset and the setting of the comet itself, when the effects of the twilight glow and atmospheric absorption were optimized (although the tail would then be pointing in a roughly vertical direction, it would be very short on account of the comet's considerable distance from the Earth, some 1.5 AU for *T* before about 1 August).

The precise date of heliacal setting for a celestial body depends on various factors (largely of atmospheric origin) and is therefore best treated empirically. To provide some parallel data, we have analysed several dates of the last sighting of P/Halley as reported in far Eastern history. Such information is fairly regularly available over the past two millennia but before ~AD 1400 only summary records are now extant. Thus, there is a distinct possibility of copying errors, but for later centuries detailed chronicles are available from both China and Korea. The Korean works are particularly useful for our purpose because they contain day-to-day reports of astronomical phenomena, usually

3.6 Comparisons Between Computed and Observed Dates of Perihelion

The corrections to the dates of perihelion of Yeomans and Kiang (1981) as deduced from the investigations above are collected together in Table 3.3 for comparisons. Also listed in Table 3.3 are the dates of first and last sightings of Comet Halley as deduced from Far Eastern observations, and also from Babylonian observations in the case of the 164 BC return.

Using the observed dates of perihelion, and other orbital elements from Yeomans and Kiang (1981) I have produced for each return an ephemeris at two day intervals (see Appendix II). I have found this invaluable in the investigation of the past observations of Halley's Comet. Further, the observed path of Comet Halley through some of the principal Chinese asterisms (the 28 Lunar Mansions, the three Walls of *Tzu-wei*, *T'ai-wei* and *T'ien-shih*, and also *Pei-tou*) is depicted for each of the return between AD 1378 and 240 BC (Fig. 3.5 a–f). This is the first set of comprehensive orbital maps listing path by path the motion of Halley's Comet at each of its known returns. These maps summarise the results of a long and detailed study on both orbital motion of Comet Halley and Chinese star maps. It is hoped that this set of orbital maps together with the ephemeris will assist researchers in refining their orbital calculations with reference to early observations.

3.7 Identification of Halley's Comet Preceding 240 BC

3.7.1 Babylonian Cometary Observations

Apart from the records of Halley's Comet in 164 BC and 87 BC, 7 additional records of comets are now known among the late Babylonian texts (private communication from H. Hunger). The observations were made in the years 234, 210, 163, 157, 138, 120, and

TABLE 3.3 First and last sightings of Comet Halley and corrections to the dates of perihelion of Yeomans and Kiang (1981).

Year	Observed Arc First Sighted	Observed Arc Last Sighted	Date of Perihelion	Correction (day)
1378	Sep 26	Nov 9	Nov 10.7	+0.0±0.1
1301	Sep 15	Oct 31	Oct 25.6	-0.9±0.1
1222	Sep 3	Oct 23	Sep 28.8	+1.7±1.5
1145	Apr 26	Jul 6	Apr 18.6	+2.8±0.8
1066	Apr 3	Jun 7	Mar 20.9	+2.6±0.5
989	Aug 12	Sep 9	Sep 5.7	+3.3±1
912	Jul 19	Jul 28	Jul 18.7	-
837	Mar 22	Apr 28	Feb 28.3	+0.0±0.1
760	May 16	Jul 1	May 20.7	-
684	Sep 7	Oct 9	Oct 2.8	-
607	Apr 18	Jul ?	Mar 15.5	-
530	Aug 29	Sep 27	Sep 27.1	-0.4±0.2
451	Jun 10	Aug 15	Jun 28.3	-
374	Mar 4	Apr ?	Feb 16.3	+1±0.5
295	May 1	May 30	Apr 20.4	-
218	May 1	Jun 15	May 17.7	-
141	Mar 7	Apr 30	Mar 22.4	+0.4±0.5
66	Jan 31	Apr 10	Jan 26.0	-
-11	Aug 26	Oct 20	Oct 10.9	-
-86	Jul 14	Aug 24	Aug 6.5	-
-163	Sep 22	Nov 16	Nov 12.6	+4±1
-239	May 24	Jun 23	May 25.1	-

N.B. The corrections to the date of perihelion between AD 141-1378 are similar to those listed in Table 1 of Yeomans and Kiang (1981). Since these two sets of results have been deduced independently from the same set of crucial observations, this emphasizes again the importance and reliability of these early Chinese records.

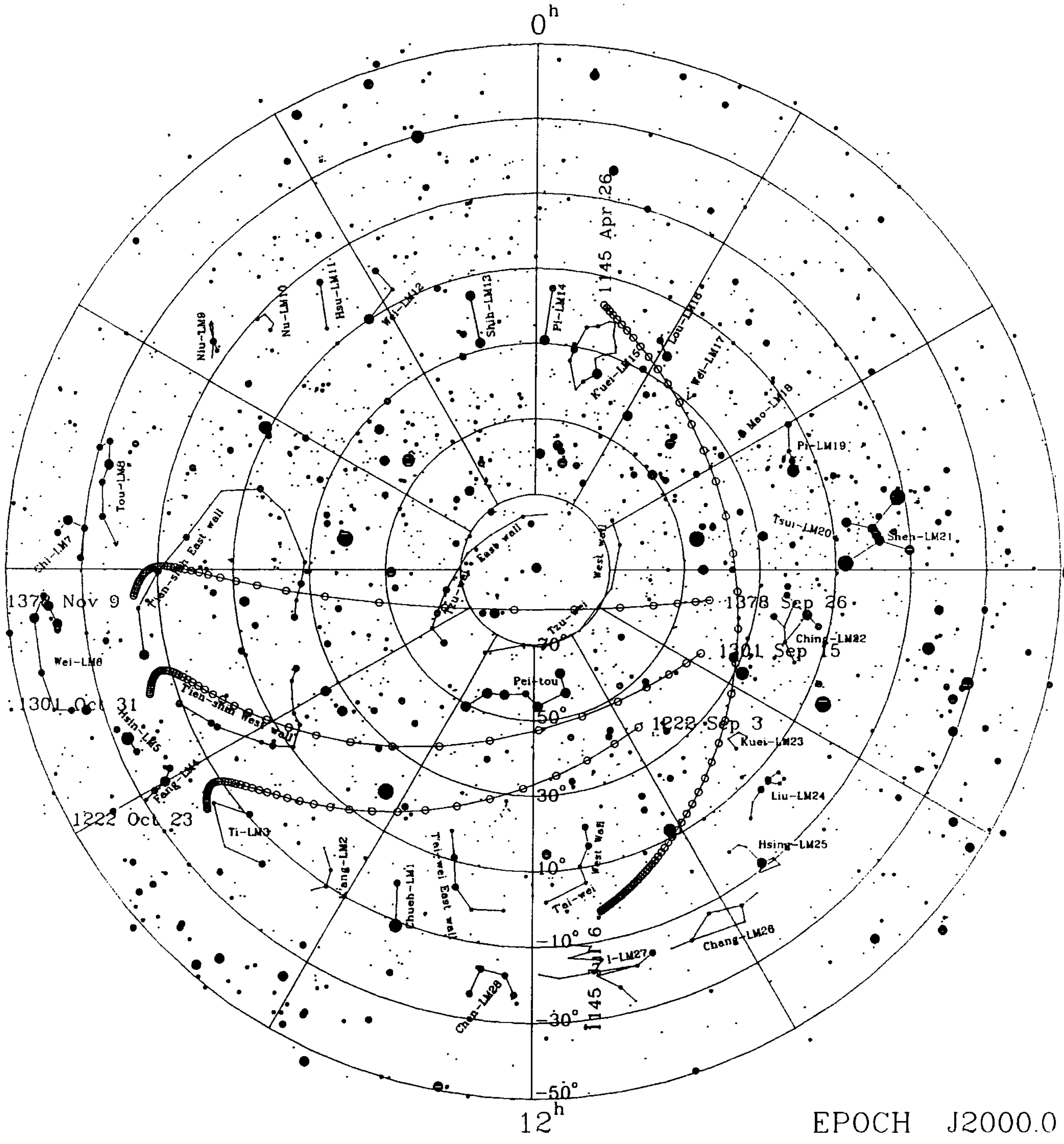


Fig. 3.5a The observed orbital arc of Comet Halley through some of the principal Chinese asterisms (the 28 Lunar Mansions, Walls of Tzu-wei, T'ai-wei and T'ien-shih, and Pei-tou) at the return in AD 1378, 1301, 1222 and 1145.

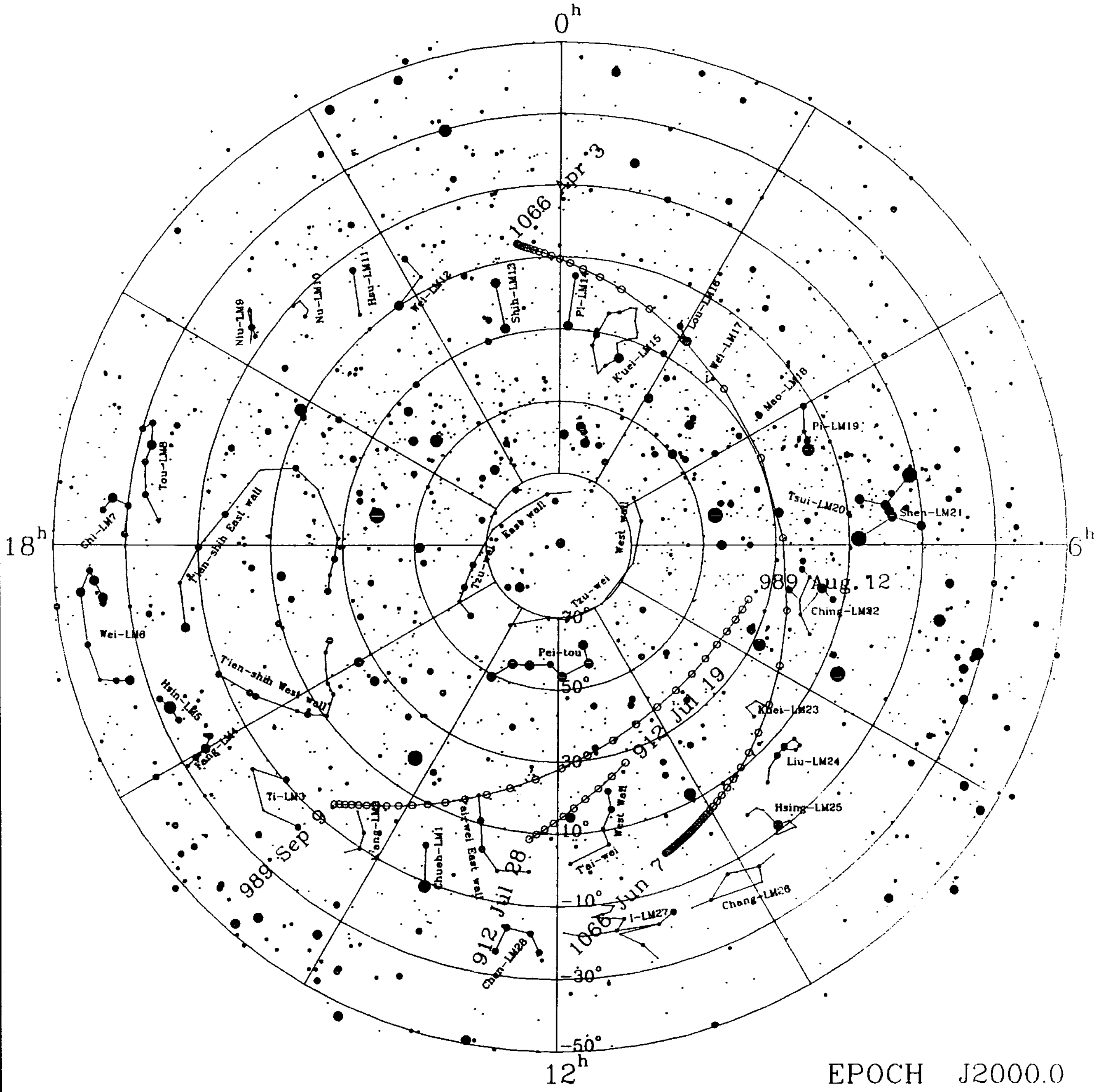


Fig. 3.5b The observed orbital arc of Comet Halley through some of the principal Chinese asterisms (the 28 Lunar Mansions, Walls of Tzu-wei, T'ai-wei and T'ien-shih, and Pei-tou) at the return in AD 1066, 989 and 912.

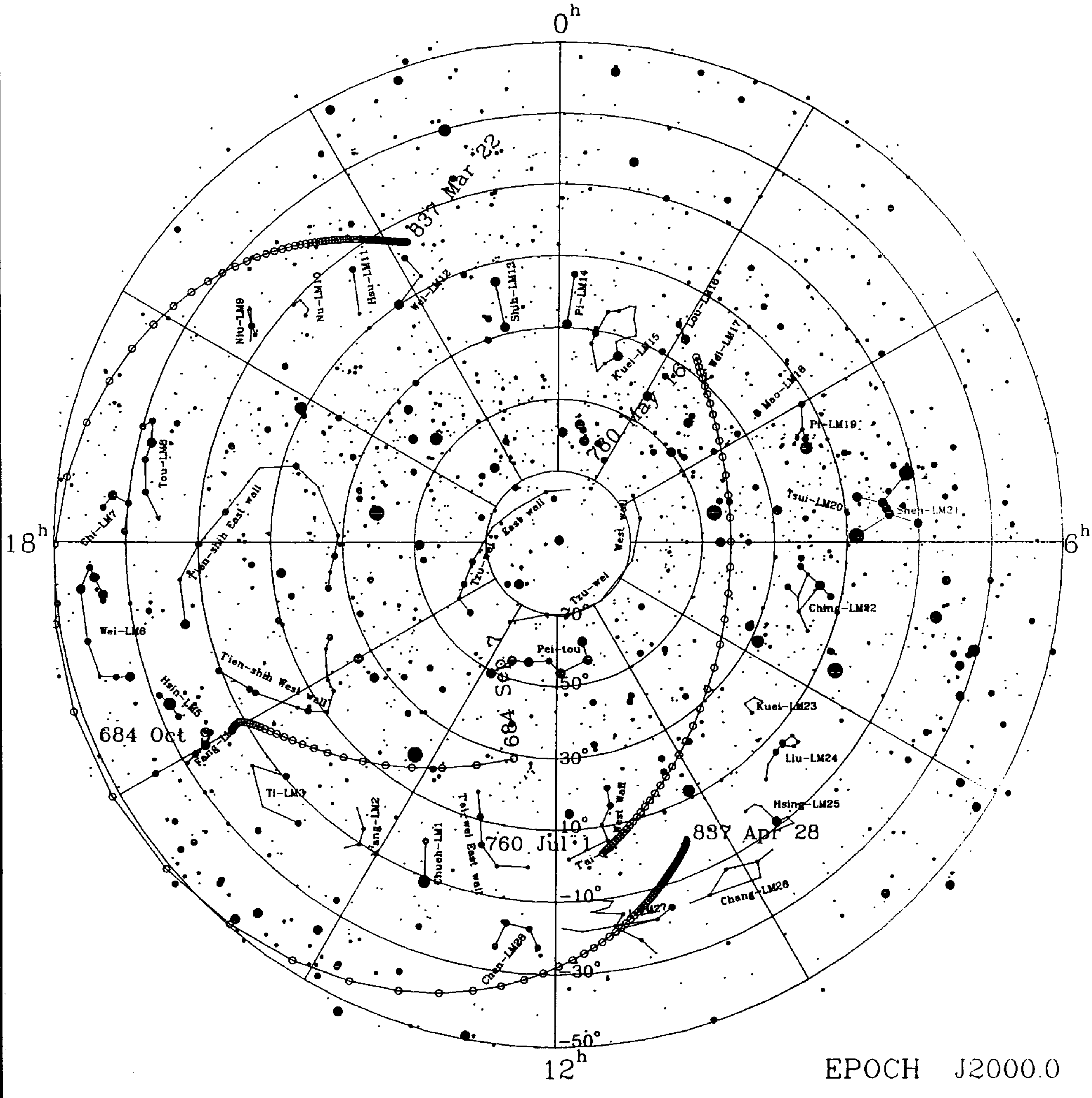


Fig. 3.5c The observed orbital arc of Comet Halley through some of the principal Chinese asterisms (the 28 Lunar Mansions, Walls of Tzu-wei, T'ai-wei and T'ien-shih, and Pei-tou) at the return in AD 837, 760 and 684.

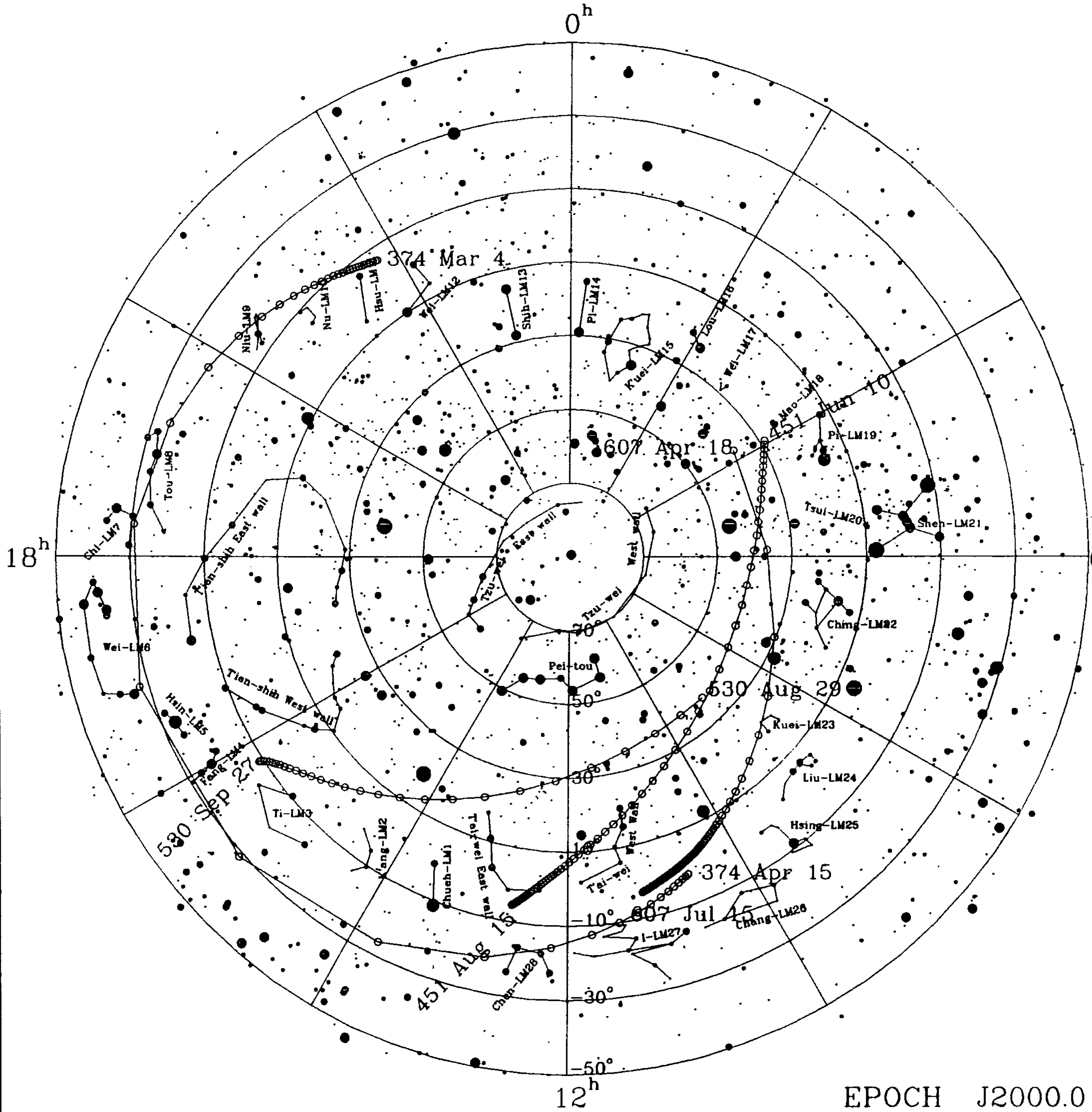


Fig. 3.5d The observed orbital arc of Comet Halley through some of the principal Chinese asterisms (the 28 Lunar Mansions, Walls of Tzu-wei, T'ai-wei and T'ien-shih, and Pei-tou) at the return in AD 607, 530, 451 and 374.

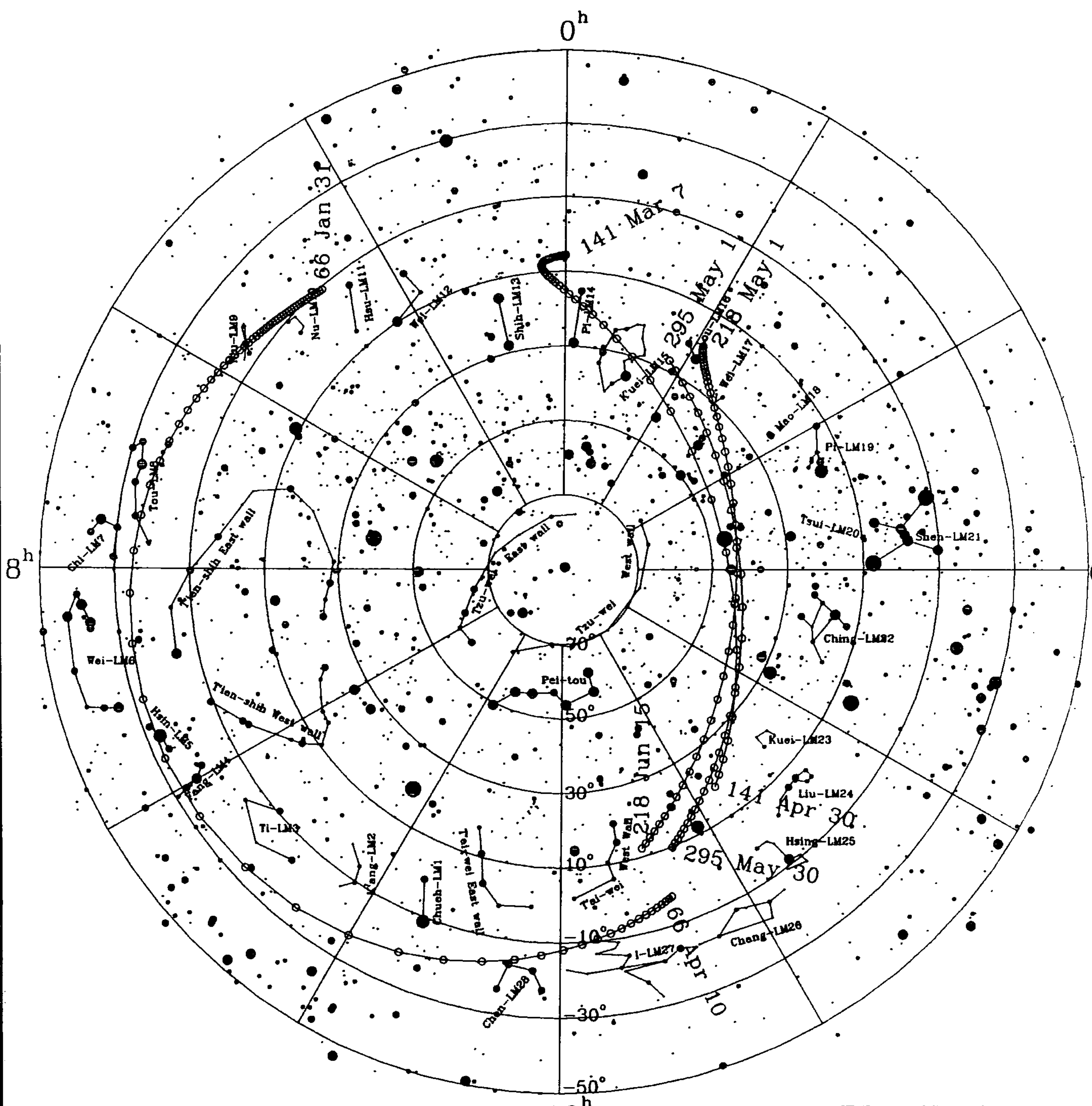


Fig. 3.5e The observed orbital arc of Comet Halley through some of the principal Chinese asterisms (the 28 Lunar Mansions, Walls of Tzu-wei, T'ai-wei and T'ien-shih, and Pei-tou) at the return in AD 295, 218, 141 and 66.

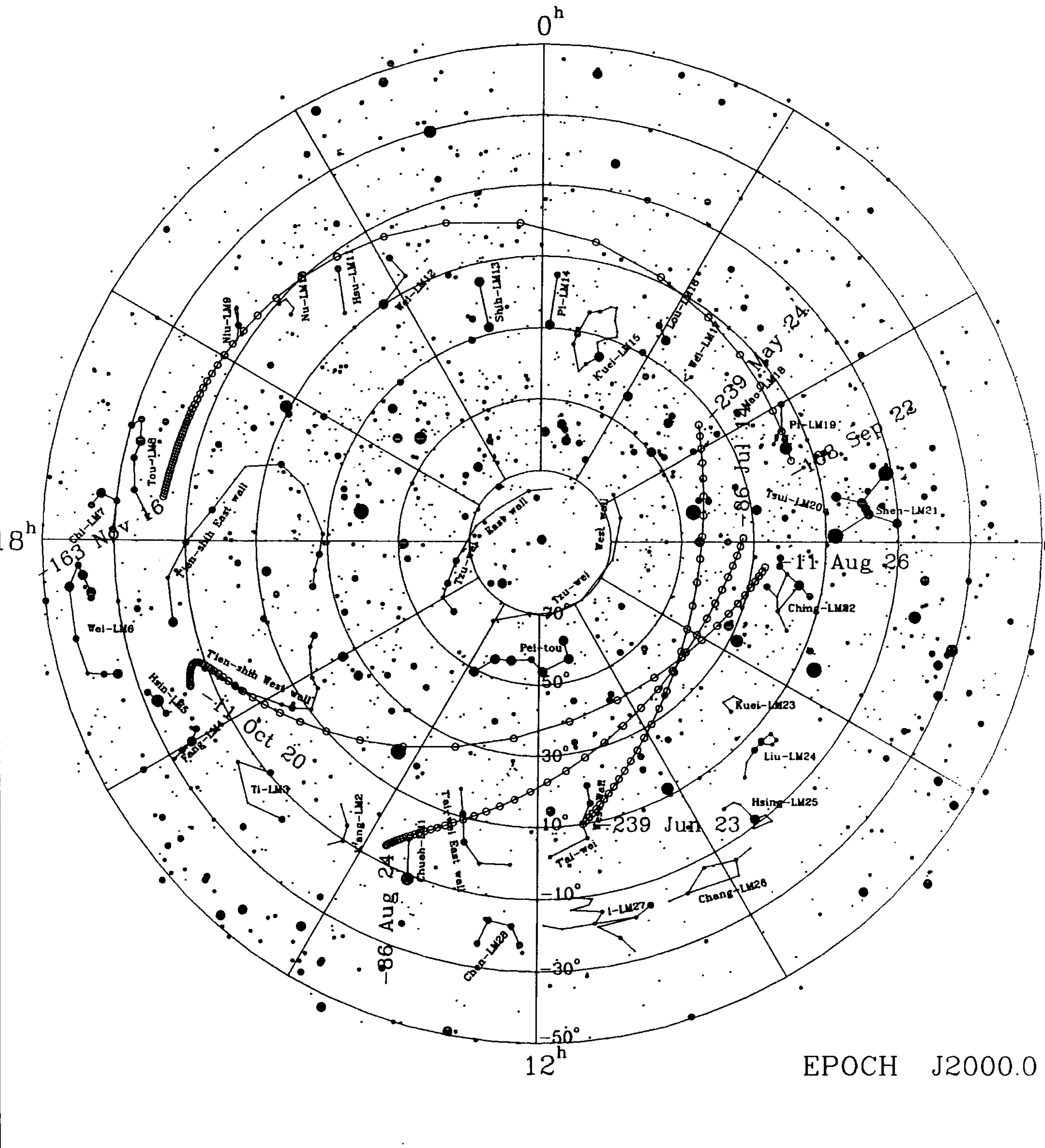


Fig. 3.5f The observed orbital arc of Comet Halley through some of the principal Chinese asterisms (the 28 Lunar Mansions, Walls of Tzu-wei, T'ai-wei and T'ien-shih, and Pei-tou) at the return in 12, 87, 164 and 240 BC.

110 BC. It seems quite likely that cometary records initially extended much further back in time, possibly to around 750 BC (the likely starting date of the diaries). According to Diodorus Siculus that the Chaldeans followed the practice of the Egyptians in keeping a long series of observations of the stars and planets. As a result they were able to have prior knowledge of the risings of the comets and other natural causes. (Diodorus Siculus, *Bibliotheca*, I, 81). However, if these were so, all earlier texts are now lost.

Table 3.4 gives a summary of all extant Babylonian cometary records (except records of 164 and 87 BC) together with contemporary Chinese cometary records for comparison. From these existing fragmentary records, one may still catch a glimpse of some of the characteristic features of a typical Babylonian cometary account. Whether in the daily reports or the monthly summaries, records of comets apparently entered only on the following dates: (i) first sighting; (ii) heliacal setting; (iii) heliacal rising; (iv) any stationary points; and (v) last visibility. On each of these dates – apart from the first – it was customary to provide a retrospective summary, for reference.

It is clear that the Babylonian astronomers recognised that the same comet could be visible both before and after conjunction with the Sun. However, in view of the fragmentary nature of the texts and also the generally poor quality of ancient Chinese cometary records, it is impossible to assign priority for this discovery to either civilisation.

The paths of comets were described by Babylonian astronomers with reference to three regions of sky: Enlil, Anu and Ea. Enlil represented the northern sky, Anu the equatorial zone and Ea the southern sky. That these divisions, which are never found in planetary records, were used to describe the locations of comets suggest that the Babylonians were well aware of the highly wayward movements of comets. Detailed measurements of the locations of comets are given with respect to one of the twelve

Table 3.4 A comparison of Babylonian Cometary Records with those from China.

Date	Babylonian Records	Chinese Records
234 BC Jan/Feb	77 SE "[Month XI (Jan 23-Feb 20)...] last part of the night, a comet in the east .... of Capricorn 10 fingers; the 25th, it was overcast .... around the 17th, Mercury set in the east in Aquarius; Saturn was in Cancer; Mars .... 3 cubits below the Corona became visible(?); towards Sun...."	Ch'in Shih-huang, 13th year, 1st month (Feb/Mar) "A broom star was seen at the East." (*Shih-chi*, 6)
210 BC Jun/Jul	102 SE "[Month IV (Jun 24-Jul 22)...] its tail directed to the east; night of the 13th, moonrise to sunset, 6 degrees. .... which had become visible in the path of Ea in the area of Scorpius .... the disk, its tail (directed) to the east"	Not Observed in China.
163 BC Aug-Oct	149 SE "[Month V (Aug 12-Sep 10)...] the 25th, first part of the night, a comet ... 2/3 cubits above the Corona, its tail directed to the south ... Month VI (Sep 11-Oct 9), the 1st (of which followed the 30th of the preceding month), sunset to moonset: 13.30 degrees; measured. Night of the 1st, first part of the night, a comet behind(?) .... the comet ... cubits above the Corona, its tail .... night of the 30th(?) when the comet came out .... Corona"	Not Observed in China.

157 BC Oct/Nov	155 SE "[Month VIII (Nov 2-Dec 1)...] the 14th the comet which before on the 16th of month VII (Oct 19)...."	Emperor Wen-ti, Hou reign-period, 7th year, 9th month (8 Oct-5 Nov). "A bushy (*po*) star appeared in the West. Its body laid straight across both the *Wei* and *Chi* (Lunar Mansions) and its tail pointed towards the *Hsu* and *Wei* (Lunar Mansions). It measured over 1 *chang* (10 deg) and reached the Milky Way (*T'ien-han*). It went out of sight after 16 days." (*Han-shu*, 27)
138 BC May/Jun	174 SE "[Month II (May 9-Jun7)...] that month the comet which had set in Libra reappeared on the night of the 20th in the west in the area of...."	Emperor Wu-ti, Chien-yuan reign-period, 3rd year, 3rd month (9 Apr-7 May). "A bushy (*po*) star appeared at the *Chang* (Lunar Mansion). It passed the *T'ai-wei* (Enclosure), trespassed against the *Tzu-wei* (Enclosure) and reached the Milky Way." (*Han-shu*, 26) Chien-yuan reign-period, 3rd year, 4th month (8 May-6 Jun), a bushy (*po*) star appeared at *T'ien-chi* (in Hercules) and went as far as *Chih-nu* (Vega).
120 BC Apr/Jun	192 SE "[Month I, the 29th (May 18)...] a comet in the path of .... 2 cubits ... fell, was seen. The 29th, solar eclipse; when watched for, not seen." "[Month II (May 20-Jun 17) beginning] .... when the comet became stationary towards the east ...." "[Month III (Jun 18-Jul 17)...] night of the 26th (Jul 13), beginning of the night, the comet which had set in the east, on the 29th [of the previous month (Jun 17) in Aries in the path of Anu ...."	Yuan-shou reign-period, 3rd year, spring. "A bushy (*po*) star was seen in the East."

	"[Month I (Apr 20-May 19)] night of the 29th (May 18) .... cubits low to the south .... its tail (directed) towards the south. I heard(?) .... solar eclipse, when watched for, not seen.	
	"[Month II, day 14 (Jun 16) ....] a comet was seen, its tail (directed) towards the south; 6 degrees in front of the upper star of .... (follows total lunar eclipse)"	
110 BC Nov/Dec	202 SE "[Month IX, day 1 (Nov 23) a comet....] in the east, and its tail towards the west in the path of.... [Day 10 to 12 (Dec 2 to Dec 4)] .... the comet which on the 1st had appeared in the path of Enlil to the north...."	Not observed in China.

constellations of the Zodiac. In addition, positions were given in relation to nearby planets. In Babylonian astronomy, positions of eclipses and planets were normally determined with respect to a set of 31 reference stars along the ecliptic known as the 'Normal Stars' (Fig. 3.6). It is possible that the positions of comets might have also been given in this way as well. It seems that the direction of the tail (*mishu*) of a comet was frequently cited, there are several descriptions in the extant records (Table 3.4).

Comparing the computed dates of perihelion of P/Halley (Table 3.5) with the list of Babylonian cometary observations given in Table 3.4, it is apparent that any Babylonian records of the 12 BC, the 240 BC and earlier returns are now lost. However, as is already discussed in section 3.5, accounts of the apparitions in both 164 and 87 BC are still preserved, the former on two separate tablets.

3.7.2 Ancient Chinese Records

Prior to the Former Han Dynasty (206 BC–AD 8), Chinese cometary records are in general infrequent and deficient in detail as has already been mentioned in the previous chapter. Before 240 BC, only 13 cometary observations have survived with the earliest in the year 613 BC, near the beginning of the Ch'un-ch'iu period. It is probable that originally there was much more material, as is evident from a silk manuscript discovered recently in a Han tomb dating from 168 BC (Xi Ze-zong, 1984). This shows 29 separate drawings of cometary tails, each with a separate astrological interpretation; unfortunately all are undated. In addition, the manuscript contains hitherto unknown records of planetary phenomena.

Fig. 3.7 shows the decade distribution of astronomical records from China from 720 BC to 1 BC; the years of expected apparitions of P/Halley are also indicated. The number of records preserved from this period is very small, only one or two in

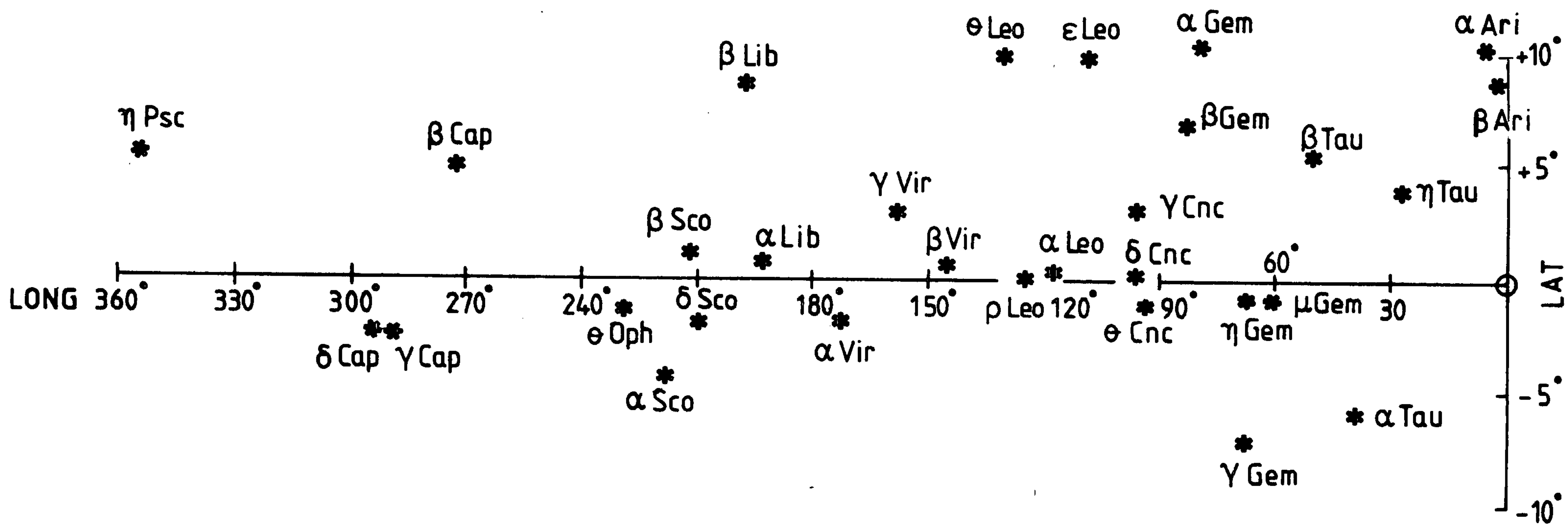


Fig. 3.6 The Babylonian reference stars for epoch 150 BC.

Table 3.5 A list of calculated dates of perihelion of P/Halley in the BC period by various investigators.

Yeomans and Kiang (1981)	Landgraf (1986)	Brady (1982)	Chang (1979)
-11 10 10.85	-11 10 8.21	-11 10 8.64	-11 9 27.0
-86 8 6.46	-86 8 5.49	-86 7 10.40	-86 8 15.0
-163 11 12.57	-163 11 8.29	-163 6 22.38	-162 1 20.0
-239 5 25.12	-239 5 24.42	-240 11 30.64	-239 8 2.0
-314 9 8.52	-314 9 9.00	-316 10 15.78	-314 12 6.0
-390 9 14.37	-390 9 15.17	-392 4 22.19	-390 12 8.0
-465 7 18.24	-465 7 17.90	-467 7 16.05	-465 9 2.0
-539 5 10.83	-	-543 4 10.57	-539 11 1.0
-615 7 28.50	-	-619 10 5.17	-614 7 1.0

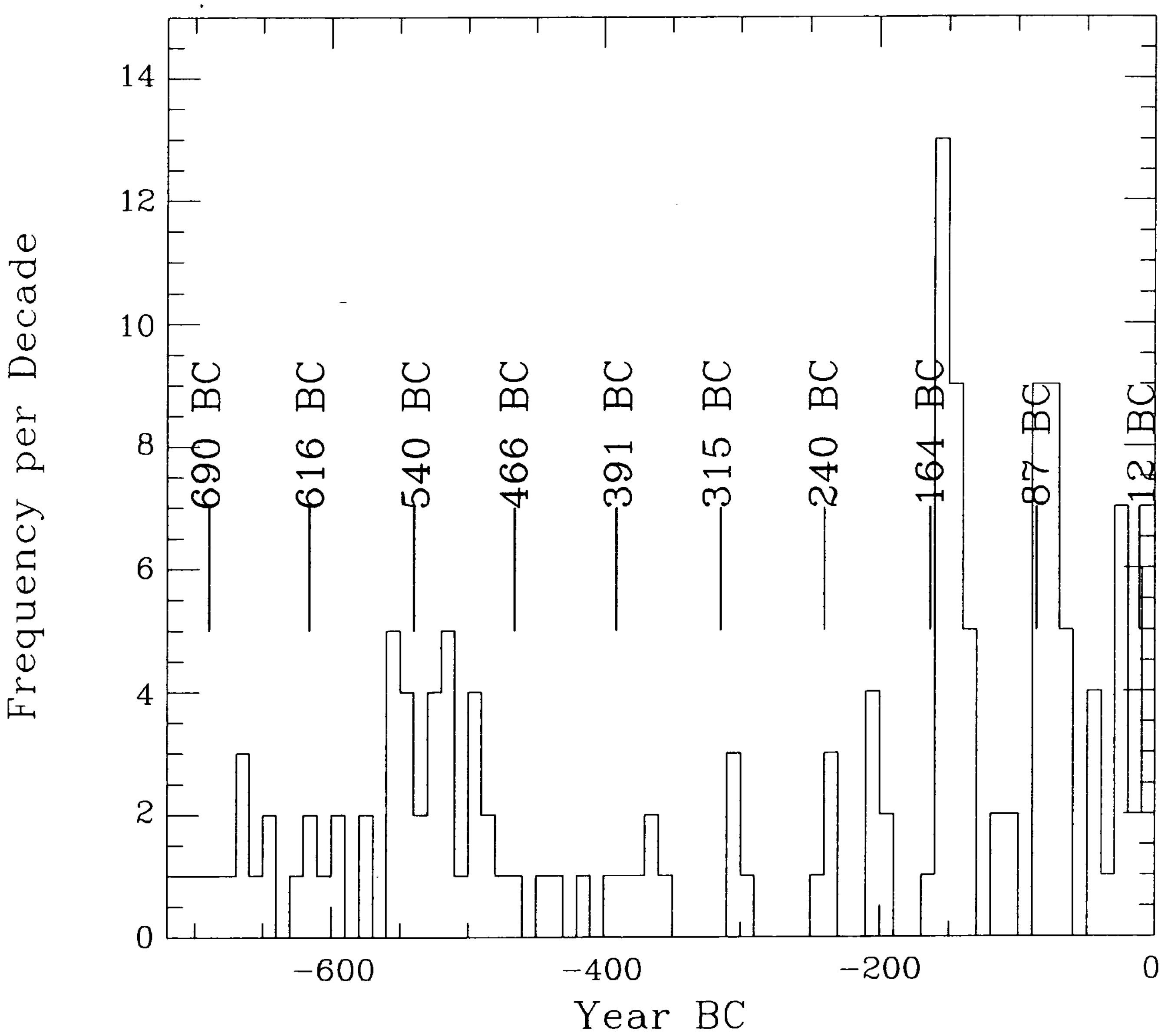


Fig. 3.7 The decade distribution of Chinese astronomical records for the period 720 BC to 1 BC; the calculated years of return of P/Halley by Yeomans and Kiang (1981) are also marked.

a decade. Undoubtedly, numerous ancient astronomical records were lost both at the systematic 'Burning of the Books' in 213 BC at the command of the first emperor, Ch'in Shih-huang. This was a deliberately act devised to purge both historical and literature writings of those former rival states now under the control of Ch'in Shih-huang. The decree as drafted by Li Ssu and approved by the Emperor is extracted here from a translation by Fitzgerald (1935):

> "... Your subject proposes that the histories [of the feudal states], with the exception of that of Ch'in, shall all be burnt. With the exception of those holding the rank of 'Scholars of Great Learning', all men in the entire empire who possess copies of the *Shu Ching*, the *Shih Ching*, and the works of the Hundred Schools, must all take these books to the magistrates to be burnt. Those who dare to discuss and comment the *Shu Ching* and *Shih Ching* shall be put to death and their bodies exposed in the market place. Those who praise ancient institutions to decry the present regime shall be exterminated with all the members of their families. Officials who condone breaches of this law shall themselves be implicated in the crime. Thirty days after the publication of this decree, all who have not burnt their books will be branded and sent to forced labour on the Great Wall. Those books which shall be permitted are only those which treat of medicine, divination, agriculture and arboriculture. As for those who wish to study law and administration, let them take the governing officials as their masters."

A few years later the capital was subsequently sacked by rebels (207 BC) who were overthrowing the harsh Ch'in government. Possibly this later disaster was even more serious since most of the remaining copies of the proscribed books, which had been carefully preserved in the imperial library, now perished (Dubs, 1938).

Apart from the silk manuscript referred to above, virtually all of the extant astronomical records from the Warring States Period (403–221 BC) are found in the *Shih-chi* ('Historical Record') compiled by the Grand Historian Szu-ma Ch'ien between 104 and

87 BC. These are mainly located in the *Piao* ('Chronological Tables') and consist almost exclusively of comets and solar eclipses. It is the style of the *Piao* to give only brief summaries of major historical events so that Szu-ma Ch'ien may have even further condensed the meagre astronomical information which he had access to from this period. Practically all of the observations which he cited are from the history of the state of Ch'in, which ultimately – in 221 BC – became the ruling house. In addition to the *Shih-chi*, there is also the chronicle *Ch'un-ch'iu* ('Spring and Autumn Annals'), reputedly to have been compiled by Confucius. This work, the only survivor of the ancient state chronicles, covers the period from 722 to 481 BC, often known synonymously as the Ch'un-Ch'iu Period after this famous history of the state Lu.

Table 3.6 summarises all extant cometary records prior to 240 BC. A further comet, whose date is equivalent to 433 BC, is cited in the medieval work *Wen-hsien T'ung-k'ao*. Apparently due to a copying error of the date, this record is misplaced in a different reign year, it should really be the comet observed in 361 BC. Out of the observations in Table 3.6, only in one example is even the month given and in several instances we known nothing whatever about the position or motion of the object.

According to calculation, in the time range covered by the table P/Halley should have appeared around the years 315, 391 and 466 BC (Table 3.5). There is nothing to suggest that the two previous returns were noted and we must go back to 466 BC to have any prospects of a further identification. The comet which was seen in – or near – 468 BC has been frequently linked with P/Halley (Chang, 1979; Brady, 1982 and Landgraf, 1986). However, apart from the complete lack of any descriptive details which might offer confirmatory evidence, it is difficult to establish the exact date of observation. Taking into consideration the fact that the various numerical integrations yield dates of perihelion ranging between 468 Jul and 466 Jul BC for the return of

Table 3.6 Observation of comets in China in the ancient period prior to 240 BC.

Year/BC	State	Ruler	Year	Month	Observational Records	Sources
613	LU	Wen-kung	14	-	A 'po' star entered the Plough.	Ch'un-ch'iu
532	CHIN	P'ing-kung	26	spring	A star appeared in Wu-nu (10th lunar mansion).	Ch'un-ch'iu
525	LU	Chao-kung	17	winter	A star emerged ('po') at Ta-ch'en (Antares); (its rays) reached the Milky Way in the W.	Ch'un-ch'iu
516	CH'I	Ching-kung	32	-	A broom star appeared in the NE, the divisions of Ch'i.	Shih-chi
500	CH'IN	Hui-kung	1	-	A broom star was seen	Shih-chi
482	LU	Ai-kung	13	11	A star emerged ('po') in the E.	Ch'un-ch'iu
481	LU	Ai-kung	14	winter	There was a 'hsing-po' ('bushy star').	Han-shu
471	CH'IN	Li-kung	7	-	A broom star was seen	Shih-chi
468	CH'IN	Li-kung	10	-	A broom star was seen	Shih-chi
361	CH'IN	Hsiao-kung	1	-	A broom star was seen at the W.	Shih-chi
305	CH'IN	Chao-wang	2	-	A broom star was seen	Shih-chi
303	CH'IN	Chao-wang	4	-	A broom star was seen	Shih-chi
296	CH'IN	Chao-wang	11	-	A broom star was seen	Shih-chi

P/Halley around this time, there can be no firm conclusions regarding the nature of the comet recorded in the *Shih-chi.*

Going back still further in time, comets were seen in the years corresponding to 481, 482, 500, 516, 525, 532 and 613 BC (Table 3.6). As the computed dates of return for Halley's Comet in this period are close to 540 and 616 BC, all of these observations must relate to other objects. Nevertheless, the 613 BC record deserves special mention as probably the earliest reliable sighting of a comet from anywhere in the world. The *Ch'un-ch'iu* gives a relatively more detailed account of this event – as it does for the comets of 532 and 525 BC.

The *Ch'un-ch'iu* contains few astronomical records other than solar eclipses but there are as many as 37 solar eclipse observations, the dates of which can be checked easily using modern calculation. I have computed a list of solar eclipses (Table 3.7) observable at Ch'u-fu, the capital of the state Lu, during the Ch'un-ch'iu period. The asterisk marks those eclipses that have been recorded. Fig. 3.8 shows a histogram comparing the number of calculated and observed eclipses. It seems likely that partial eclipses with magnitudes less than 0.8 were only occasionally detected. Partial eclipses with 0.8 magnitudes and over were detected in about half of the cases. Total eclipses were apparently always detected due to their striking appearance. Of all eclipse records in the *Ch'un-ch'iu*, apart from 5 cases which could possibly due to copying errors, the observations are all correct.

Before 613 BC, Ho Peng Yoke (1962), who made a careful search of the available literature, could trace no more than three allusions to comets; all of these are of dubious reliability and are cited only in late works. The oracle bone fragments from the Shang Dynasty – c. 1500 to 1050 BC – contain several references to eclipses but so far nothing which might relate to a comet has been identified (D. N. Keightly, personal communication).

Table 3.7 A computed table of solar eclipses observable at Ch'u-fu, the capital city of the state Lu. An asterisk represents an eclipse actually observed.

LOCATION LAT, LONG: 35.53 -117.02

YR	MN	DY	JD	CYC DAY	CDN	DELTA T	LHR	ALT	MAG	
-721	10	9	1457994.	TING-WEI	44	20642.0	8.35	25.93	0.174	
-719	2	22	1458496.	CHI-SZU	6	20619.5	7.04	4.83	0.441	*
-717	7	27	1459381.	CHIA-YIN	51	20579.8	16.13	34.62	0.273	
-715	6	6	1460061.	CHIA-HSU	11	20549.4	16.98	24.47	0.129	
-712	9	29	1461272.	I-YU	22	20495.2	5.27	-8.61	0.109	
-711	9	18	1461626.	CHI-MAO	16	20479.4	9.85	47.44	0.361	
-708	7	17	1462659.	JEN-CH'EN	29	20433.3	15.59	41.81	1.057	*
-707	12	31	1463191.	CHIA-SHEN	21	20409.6	7.56	3.64	0.672	
-701	3	5	1465081.	CHIA-YIN	51	20325.4	17.91	-4.03	0.625	
-700	8	17	1465612.	I-SZU	42	20301.7	9.60	52.55	0.630	
-696	6	6	1467001.	CHIA-YIN	51	20240.0	5.72	9.16	0.486	
-694	10	10	1467857.	KENG-WU	7	20202.0	15.92	22.43	0.551	*
-684	3	26	1471312.	I-SZU	42	20049.0	6.91	10.59	0.060	
-682	3	5	1472021.	CHIA-WU	31	20017.7	17.84	-3.22	0.141	
-681	8	18	1472552.	I-YU	22	19994.2	4.89	-3.64	0.452	
-680	1	13	1472700.	KUEI-CH'OU	50	19987.7	11.52	31.42	0.158	
-679	1	1	1473054.	TING-WEI	44	19972.1	12.21	30.85	0.553	
-678	6	17	1473586.	CHI-HAI	36	19948.6	14.61	53.92	0.600	
-677	11	1	1474088.	HSIN-YU	58	19926.5	13.43	38.16	0.063	
-675	4	15	1474619.	JEN-TZU	49	19903.1	17.70	7.70	0.698	*
-674	4	5	1474974.	TING-WEI	44	19887.5	7.57	20.79	0.682	
-672	8	8	1475830.	KUEI-HAI	60	19849.8	4.52	-6.16	0.546	
-668	5	27	1477218.	HSIN-WEI	8	19788.8	10.20	61.54	0.903	*
-667	11	10	1477750.	KUEI-HAI	60	19765.5	10.50	34.81	0.737	*
-665	3	27	1478252.	I-YU	22	19743.4	7.47	17.39	0.723	
-663	8	28	1479137.	KENG-WU	7	19704.6	15.53	37.24	0.847	*
-658	11	1	1481028.	HSIN-CH'OU	38	19621.9	6.37	-2.71	0.131	
-657	10	21	1481382.	I-WEI	32	19606.4	9.06	29.81	0.352	
-655	4	5	1481914.	TING-HAI	24	19583.1	7.69	22.28	0.040	
-654	8	19	1482415.	WU-SHEN	45	19561.2	14.81	47.49	0.926	*
-653	8	9	1482770.	KUEI-MAO	40	19545.8	5.32	2.75	0.341	
-652	2	2	1482947.	KENG-TZU	37	19538.0	7.33	4.35	0.932	
-650	6	7	1483803.	PING-CH'EN	53	19500.7	18.84	2.97	0.687	
-650	12	2	1483981.	CHIA-YIN	51	19492.9	6.80	-2.89	0.201	
-647	4	6	1484837.	KENG-WU	7	19455.6	17.88	3.56	0.270	*
-646	9	19	1485368.	HSIN-YU	58	19432.5	8.97	37.95	0.310	
-640	11	11	1487613.	PING-HSU	23	19335.0	17.56	-4.05	0.620	
-635	2	23	1489178.	HSIN-MAO	28	19267.1	17.37	0.45	0.840	
-628	4	6	1491777.	KENG-HSU	47	19154.6	17.11	13.08	0.499	
-627	9	19	1492308.	HSIN-CH'OU	38	19131.7	5.62	-2.05	0.402	
-625	2	3	1492810.	KUEI-HAI	60	19110.0	12.60	35.38	0.793	*
-624	7	19	1493342.	I-MAO	52	19087.1	8.31	40.46	0.675	
-623	12	3	1493844.	TING-CH'OU	14	19065.4	16.60	3.40	0.140	
-621	5	18	1494375.	WU-CH'EN	5	19042.6	15.70	37.95	0.239	
-620	5	7	1494730.	KUEI-HAI	60	19027.3	6.43	13.59	0.337	
-614	6	29	1496974.	TING-HAI	24	18930.8	4.56	-2.36	0.935	
-613	6	18	1497328.	HSIN-SZU	18	18915.6	9.57	56.11	0.092	
-613	12	13	1497506.	CHI-MAO	16	18907.9	13.41	28.34	0.950	
-611	4	28	1498008.	HSIN-CH'OU	38	18886.4	6.55	13.43	0.861	*
-609	9	30	1498893.	PING-HSU	23	18848.4	16.81	14.47	0.675	

-606	7	30	1499927.	KENG-TZU	37	18804.1	17.75	14.67	0.066	
-605	7	19	1500281.	CHIA-WU	31	18789.0	18.54	6.56	0.565	
-604	12	3	1500784.	TING-SZU	54	18767.5	7.77	7.30	0.590	
-603	11	22	1501138.	HSIN-HAI	48	18752.4	9.23	22.82	0.040	
-602	5	18	1501315.	WU-SHEN	45	18744.8	16.27	31.06	0.534	
-601	5	8	1501670.	KUEI-MAO	40	18729.6	6.07	9.27	0.402	
-600	9	20	1502171.	CHIA-TZU	1	18708.2	15.73	29.53	0.877	*
-599	9	10	1502526.	CHI-WEI	56	18693.1	5.65	0.34	0.846	
-598	3	6	1502703.	PING-CH'EN	53	18685.5	6.02	-4.59	0.688	*
-596	7	9	1503559.	JEN-SHEN	9	18649.0	13.32	68.97	0.319	
-590	9	30	1505833.	PING-YIN	3	18552.2	17.49	6.09	0.151	
-581	3	28	1508934.	TING-WEI	44	18420.6	2.03	44.75	0.306	
-580	3	16	1509288.	HSIN-CH'OU	38	18405.6	15.78	23.79	0.152	
-578	7	20	1510144.	TING-SZU	54	18369.3	20.32	-12.23	0.725	
-574	5	9	1511533.	PING-YIN	3	18310.6	14.73	48.27	0.952	*
-573	10	22	1512064.	TING-SZU	54	18288.2	7.86	16.80	0.663	*
-571	3	7	1512566.	CHI-MAO	16	18267.0	11.04	44.70	0.860	
-570	8	21	1513098.	HSIN-WEI	8	18244.6	4.89	-4.39	0.186	
-569	8	10	1513452.	I-CH'OU	2	18229.7	4.79	-3.48	0.587	
-561	3	17	1516228.	HSIN-SZU	18	18112.8	5.55	-7.92	0.237	
-559	7	20	1517084.	TING-YU	34	18076.9	5.85	10.93	0.381	
-558	1	14	1517262.	I-WEI	32	18069.4	15.08	17.50	0.605	*
-557	5	31	1517764.	TING-SZU	54	18048.4	4.90	-0.73	0.368	*
-551	8	20	1520037.	KENG-HSU	47	17953.2	14.50	50.64	0.696	*
-549	1	5	1520540.	KUEI-YU	10	17932.1	8.88	16.39	0.880	*
-548	6	19	1521071.	CHIA-TZU	1	17909.9	14.00	61.29	1.076	*
-547	6	9	1521426.	CHI-WEI	56	17895.1	3.90	-10.00	0.811	
-546	10	23	1521927.	KENG-CH'EN	17	17874.2	18.15	-7.32	0.822	
-545	10	13	1522282.	I-HAI	12	17859.4	7.29	12.47	0.918	*
-543	3	27	1522813.	PING-YIN	3	17837.2	1.40	49.55	0.151	
-541	7	31	1523669.	JEN-WU	19	17801.6	15.48	41.97	0.081	
-534	3	18	1526091.	CHIA-CH'EN	41	17700.8	14.37	38.78	0.365	*
-532	1	27	1526771.	CHIA-TZU	1	17672.6	9.86	26.64	0.038	
-526	4	18	1529044.	TING-SZU	54	17578.4	11.97	62.88	0.885	*
-524	8	21	1529900.	KUEI-YU	10	17543.0	17.46	14.72	0.842	*
-520	6	10	1531289.	JEN-WU	19	17485.6	10.33	64.62	0.614	*
-519	11	23	1531820.	KUEI-YU	10	17463.7	11.61	34.85	0.596	*
-517	4	9	1532322.	I-WEI	32	17443.0	8.20	29.40	0.581	*
-511	6	30	1534596.	CHI-CH'OU	26	17349.4	20.51	-12.87	0.755	
-510	11	14	1535098.	HSIN-HAI	48	17328.7	10.13	31.29	0.581	*
-509	5	10	1535275.	WU-SHEN	45	17321.5	16.86	22.77	0.052	
-507	4	18	1535984.	TING-YU	34	17292.4	4.47	-13.33	0.604	
-505	8	22	1536840.	KUEI-CH'OU	50	17257.2	4.22	-12.10	0.773	
-504	2	16	1537018.	HSIN-HAI	48	17249.9	14.96	24.77	0.394	*
-502	6	21	1537874.	TING-MAO	4	17214.9	19.35	-1.63	0.774	
-500	11	23	1538760.	KUEI-CH'OU	50	17178.6	12.61	34.35	0.237	
-497	9	22	1539793.	PING-YIN	3	17136.4	11.46	56.63	0.883	*
-496	9	10	1540147.	KENG-SHEN	57	17121.9	17.29	12.87	0.200	
-495	2	6	1540296.	CHI-CH'OU	26	17115.8	8.98	22.00	0.853	
-494	7	22	1540827.	KENG-CH'EN	17	17094.1	11.83	76.13	0.523	*
-491	11	14	1542038.	HSIN-MAO	28	17044.7	9.94	29.89	0.213	
-487	3	9	1543249.	JEN-YIN	39	16995.4	13.53	42.65	0.024	
-487	9	1	1543425.	WU-HSU	35	16988.3	13.84	54.77	0.339	
-480	4	19	1545847.	KENG-SHEN	57	16889.9	0.79	61.42	0.840	*

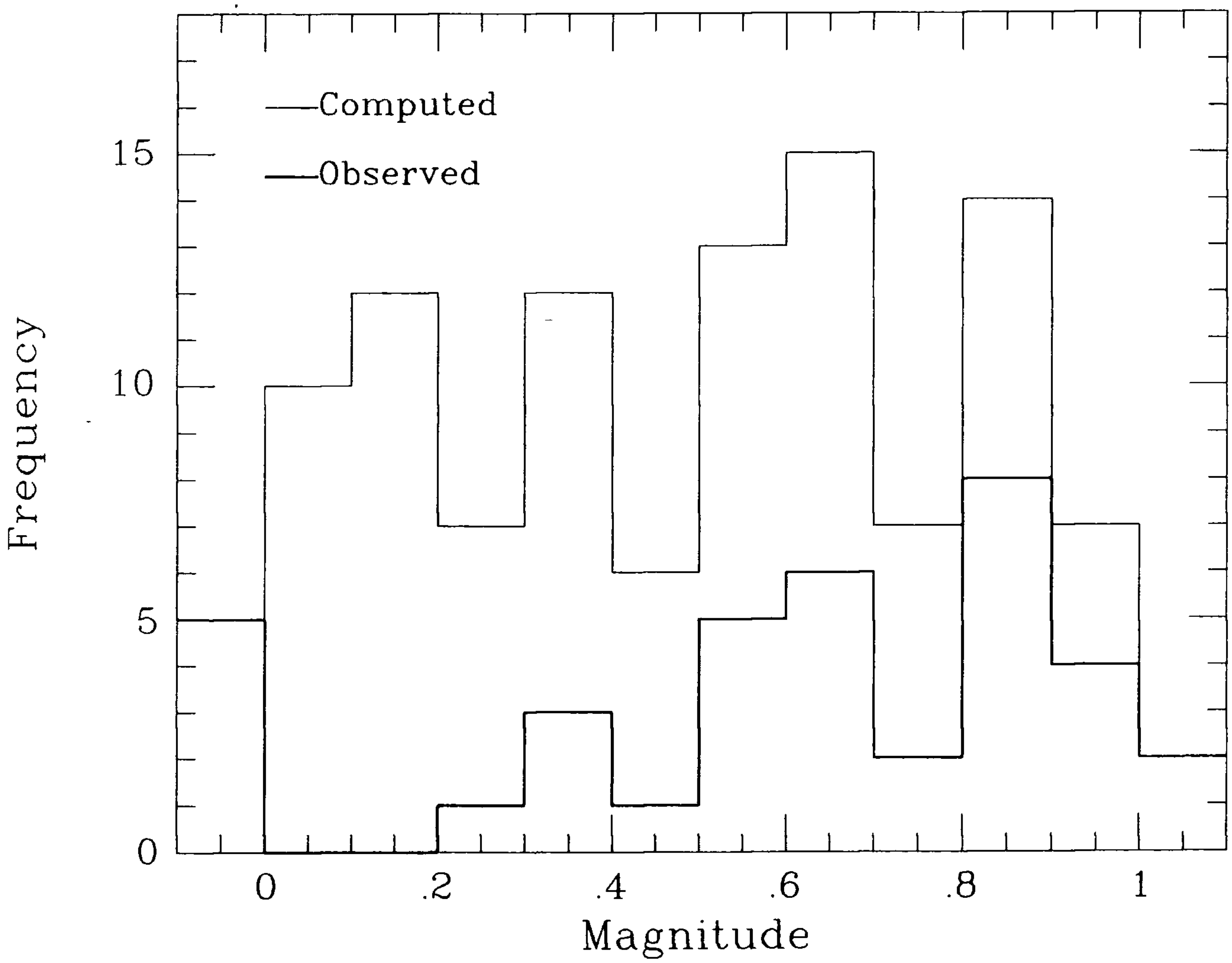


Fig. 3.8 A comparison between the number of observed and calculated solar eclipses during the Ch'un-ch'iu period (722 to 481 BC).

3.8 Conclusions

Hind (1850) concluded that, "Previous to the year 11 BC the accounts of comets become so vague that it would be vain to attempt to carry the inquiry into more remote antiquity." This statement by Hind may have underestimated the skills of later investigators. Not only did the 12 BC (Hind said 11) return identify, all returns back to 240 BC are now positively confirmed, the latest addition is the 164 BC apparition which was recorded on Babylonian tablets. We may now claim to have brought the total number of recorded apparitions of P/Halley to 30 extending from AD 1986 to 240 BC.

Into the 'remote antiquity', as Hind put it, there is no recorded sighting of Comet Halley as far as we know, although we cannot rule out unexpected discovery in the future. Without any observational constraints, it is unlikely that numerical integrations could improve upon existing investigations. As Chirikov and Vecheslavov (1986) pointed out that because of the chaotic nature of its highly eccentric orbit, it is unlikely that the motion of P/Halley can ever be accurately integrated outside the observed interval.

I hope the present investigation would serve as a good reference to the study of the past orbit of Comet Halley. On the next return of this famous comet in the year AD 2061, hopefully that this work will still be of value to researchers even then. The ability to follow closely the motion of Halley's Comet facilitates the predictions of its orbit past and future, a problem compliments each other. The proposed plans to put space probes in orbits around comets (Yeomans, 1985) will no doubt bring us further understanding to these ancient bodies as old as our solar system.

PART II. INVESTIGATION OF HISTORICAL NOVAE AND SUPERNOVAE

CHAPTER 4
A SURVEY OF NEW STARS

4.1 Introduction

Among the various phenomena in the night sky, the appearance of a *stella nova* or 'new star' must have captured the focus of attention of many early observers. New stars were defined by Newton in his *Principia* (book III, last proposition) as "fixed stars that suddenly appear, at first shine brilliantly and then gradually fade away." Newton's definition held its own for more than two hundred years before spectroscopic observations in the latter half of the 19th century began to throw new light on the meaning of novae. There had been many curious ideas in the early decades of the present century before the full realisation of the nova phenomena. One notable example was given by Hagen (1921) who stated that: "A nova is a cometary nebula brought temporarily into close proximity or contact with a bright star."

Probably the first nova eruption to be observed after the introduction of the telescope was that of CK Vul in 1670 (Payne-Gaposchkin, 1957; Shara *et al.*, 1985). The next was observed by the comet genius Halley himself, who observed the eruption of η Carinae in 1677 at 4th magnitude (Muller and Hartwig, 1918). Since then there have been many more observations of nova outbursts especially during the present century. The latest catalogue of classical novae by Bode *et al.* (1988) contains information on more than 200 objects (Table 4.1). Fig. 4.1 shows the distribution of these novae in galactic coordinates which I have produced from this catalogue. The fairly isotropic

Table 4.1 A catalogue of classical novae - compiled from data given in Bode et al (1988).

No	Name	RA (J2000.0) (h m s)	Dec (o ' ")	Long (o	Lat o)	m(max)	m(min)	Class	Year
1	LS And	0 31 44	+41 58 12	119.1	-20.75	11.7	20.5	VF	1971
2	DO Aql	18 31 26	- 6 29 50	24.9	1.45	8.7	16.5	VS	1925
3	EL Aql	18 56 1	- 3 19 18	30.6	-2.54	6.4	20	F	1927
4	EY Aql	19 34 44	+15 1 52	51.3	-2.48	10.5	21	F?	1926
5	V356 Aql	19 17 13	+ 1 43 21	37.5	-4.95	7.7	17.7	S	1936
6	V368 Aql	19 26 34	+ 7 36 13	43.8	-4.27	5.0	15.4	F	1936
7	V500 Aql	19 52 27	+ 8 28 46	47.7	-9.47	6.5	17.8	F	1943
8	V528 Aql	19 19 19	+ 0 37 53	36.8	-5.91	7.2	18.1	F	1945
9	V603 Aql	18 48 54	+ 0 35 2	33.2	0.82	-1.1	12.0	VF	1918
10	V604 Aql	19 2 6	- 4 26 45	30.3	-4.40	7.6	21	VF	1905
11	V606 Aql	19 20 23	- 0 8 1	36.2	-6.51	6.7(4.4)	17.3	S?	1899
12	V841 Aql	19 7 39	+10 29 43	44.2	1.21	11.5	17.5	S?	1951
13	V1229 Aql	19 24 44	+ 4 14 47	40.6	-5.44	6.7	19.4	M	1970
14	V1301 Aql	19 17 55	+ 4 47 18	40.3	-3.68	10.3	21	F	1975
15	V1370 Aql	19 23 21	+ 2 29 26	38.9	-5.95	6.0	19.5 (Ve)	VF	1982
16	Nova Aql 1984	19 16 35	+ 3 43 19	39.2	-3.88	10	21		1984
17	OY Ara	16 40 50	-52 25 51	334.0	-3.94	6.0	17.5	M	1910
18	SU Ari	2 47 51	+17 21 55	158.7	-37.30	9.5(Ve)	14.5(Ve)	?	1854
19	SV Ari	3 25 4	+19 49 53	165.5	-30.08	12.0	22	?	1905
20	T Aur	5 31 59	+30 26 45	177.2	-1.69	4.2	15.2	M	1891
21	QZ Aur	5 28 34	+33 18 21	174.4	-0.73	6.0(5.0)	18.0	F	1964
22	T Boo	14 14 1	+19 4 3	14.3	69.40	9.7	18.5	VF	1860
23	CG CMa	7 4 4	-23 45 35	235.7	-7.98	13.7	15.9	VF?	1934
24	RS Car	11 8 6	-61 56 14	291.2	-1.46	7.2(5.0)	22	F	1895
25	V365 Car	11 3 16	-58 27 27	289.2	1.49	10.1	22	VS	1948
26	Nova Car 1953	10 31 19	-59 58 25	286.3	-1.73	14.5	19	?	1953
27	Nova Car 1971	10 39 47	-63 14 7	288.8	-4.05	13?	?	?	1971
28	Nova Car 1972	10 38 22	-63 8 28	288.6	-4.05	13?	?	?	1972
29	BC Cas	23 51 17	+60 18 10	115.6	-1.70	10.7	17.4	M	1929
30	MT Cen	11 44 0	-60 33 39	294.8	1.23	8.5(8.2)	22	F	1931

31	V359 Cen	11 58 15	-41 46 8	292.5	20.01	13.8	21	F	1930
32	V812 Cen	13 13 54	-57 40 44	306.0	5.06	11(9)	18	?	1973
33	IV Cep	22 4 36	+53 30 23	99.7	-1.64	7.5	17.1	F	1971
34	RR Cha	13 26 23	-82 19 43	304.2	-19.54	7.1	19.3	M	1953
35	X Cir	14 42 40	-65 11 36	314.3	-4.80	6.5(6.2)	23	S?	1926
36	AI Cir	14 49 31	-68 51 35	313.3	-8.40	10.9	23	S?	1914
37	AR Cir	14 48 9	-60 0 26	317.1	-0.37	10.3	15?	VS	1906
38	V394 CrA	17 59 33	-39 0 35	352.8	-7.58	7.5	22	F?	1949
39	V655 CrA	18 24 44	-36 59 43	356.9	-11.06	13.0(8.0)	17.6	?	1967
40	V693 CrA	18 41 57	-37 31 13	357.9	-14.40	7.0(Ve)	23	F	1981
41	AP Cru	12 31 20	-64 26 24	300.8	-1.65	10.7(9.1)	21.7	F?	1935
42	V404 Cyg	20 24 3	+33 52 3	73.2	-2.09	12.5(11.0)	20.5?	M	1938
43	V450 Cyg	20 58 47	+35 56 27	79.2	-6.46	7.8(7.0)	16.3	M	1942
44	V465 Cyg	19 52 37	+36 33 52	72.0	4.76	8.0(7.3)	16.7(Ve)	S	1948
45	V476 Cyg	19 58 24	+53 37 6	87.4	12.42	2.0	15.6	VF	1920
46	V1330 Cyg	21 11 36	+48 9 2	89.9	-0.07	9(7.5)	18.1	F	1970
47	V1500 Cyg	21 11 36	+48 9 2	89.9	-0.07	2.2	21.5	VF	1975
48	V1668 Cyg	21 42 35	+44 1 55	90.9	-6.76	6.7	20.0	F	1978
49	Q Cyg	21 41 43	+42 50 27	90.0	-7.55	3.0(Ve)	15.6(Ve)	VF	1876
50	Nova Cyg 1986	19 54 37	+35 42 16	71.4	3.98	8.7(Ve)	?		1986
51	HR Del	20 42 20	+19 9 40	63.5	-13.97	3.5(Ve)	12.0(Ve)	VS	1967
52	DM Gem	6 44 12	+29 56 41	185.2	11.73	4.8(Ve)	16.7	F	1903
53	DN Gem	6 54 54	+32 8 28	184.1	14.72	3.5	15.8	F	1912
54	DQ Her	18 7 30	+45 51 31	73.2	26.44	1.3(Ve)	14.5(Ve)	M	1934
55	V360 Her	17 16 38	+24 26 47	46.6	30.95	6.3	?	?	1892
56	V446 Her	18 57 21	+13 14 29	45.5	4.70	3.0	15.5	F	1960
57	V533 Her	18 14 20	+41 51 21	69.3	24.27	3.0	15.8	F	1963
58	CP Lac	22 15 41	+55 37 1	102.2	-0.84	2.1(Ve)	16.6	VF	1936
59	DI Lac	22 35 48	+52 42 35	103.2	-4.86	4.6(Ve)	14.9	F	1910
60	DK Lac	22 49 46	+53 17 18	105.3	-5.35	5.9(5.0)	15.5	F	1950
61	GW Lib	15 19 55	-25 0 25	340.8	26.76	9	18.5	?	1983
62	HR Lyr	18 53 24	+29 13 37	59.7	12.47	6.5	15.8	M	1919
63	BT Mon	6 43 47	- 2 1 13	213.9	-2.62	8.5(4.5)	15.5var	F?	1939
64	GI Mon	7 26 47	- 6 40 29	223.0	4.75	5.6(5.2)	18	F	1918
65	KT Mon	6 24 43	+ 5 26 33	205.1	-3.42	10.3(9.8)	21	F	1942

66	GQ Mus	11	52	2	-67	12	20	297.3	-5.00	7.2(Ve)	22	M	1983
67	IL Nor	15	29	23	-50	35	0	326.9	4.81	7.0	18?	M	1893
68	IM Nor	15	39	26	-52	19	20	327.2	2.48	9.0	22	S?	1920
69	V341 Nor	16	13	44	-53	19	7	330.5	-1.61	9.4(Ve)	17?	?	1983
70	BB Oph	17	24	30	-24	48	6	1.0	6.19	11.3	21	S?	1897
71	V553 Oph	17	42	53	-24	51	33	3.2	2.64	11.2(10.8)	19?	F?	1940
72	V794 Oph	17	38	6	-22	50	42	4.4	4.64	11.7	18	S	1939
73	V840 Oph	16	54	43	-29	37	28	353.2	8.72	6.5(5.5)	20?	F	1917
74	V841 Oph	16	59	30	-12	53	26	7.7	17.77	4.2(2)(Ve)	13.5(Ve)		1848
75	V849 Oph	18	14	7	+11	36	42	39.3	13.48	7.4(7.2)	17	S	1919
76	V906 Oph	17	26	3	-21	52	40	3.7	7.51	8.4	13?	?	1952
77	V908 Oph	17	28	11	-27	45	25	359.0	3.86	9.0(7.5)	?	?	1954
78	V972 Oph	17	34	43	-28	10	36	359.4	2.43	8.0	17	S?	1957
79	V1012 Oph	17	41	34	-23	23	33	4.3	3.67	13.8	22	?	1961
80	V2024 Oph	17	42	6	-24	59	24	3.0	2.73	11.0(9.5)	18	F?	1967
81	V2104 Oph	18	3	25	+11	47	56	38.3	15.92	8.8(5.3)	20.5(Ve)	?	1976
82	V2109 Oph	17	24	16	-24	36	50	1.1	6.34	10.8	18	?	1969
83	V2110 Oph	17	43	32	-22	15	36	5.5	3.88	12.0	20	S?	1950
84	Nova Oph 1938	17	37	40	- 3	14	39	21.4	14.79	15.6(10?)	?	?	1938
85	GR Ori	5	21	35	+ 1	10	8	201.2	-19.31	11.5	(21)	?	1916
86	V Per	2	1	53	+56	44	4	132.6	-4.82	9.0(8.8)	18.5	S?	1887
87	GK Per	3	31	11	+43	54	16	151.0	-10.10	0.2(Ve)	14var	VF	1901
88	V400 Per	3	7	38	+47	7	39	145.7	-9.64	7.8	20	F	1974
89	RR Pic	6	35	36	-62	38	23	272.4	-25.67	1.0	11.9	M	1925
90	CP Pup	8	11	45	-35	21	5	253.0	-0.83	0.5(Ve)	15.0	VF	1942
91	DY Pup	8	13	48	-26	33	57	245.9	4.36	7.0	20	S	1902
92	HS Pup	7	53	24	-31	38	51	247.8	-2.11	8.0	20.5	M	1963
93	HZ Pup	8	3	22	-28	28	29	246.2	1.39	7.7	18	M	1963
94	Nova Pup 1673	7	58	59	-43	49	23	258.9	-7.42	3(Ve)	20?	?	1673
95	SS Sge	19	39	8	+16	42	39	53.3	-2.58	11.75	16.0	VS?	1916
96	WY Sge	19	32	43	+17	44	54	53.4	-0.74	6.0(Ve)	19.5	?	1783
97	HS Sge	19	39	22	+18	7	53	54.5	-1.93	7.0	20.5	F	1977
98	AT Sgr	18	3	30	-26	28	28	4.2	-2.18	11.0(8.7)	19	F	1900
99	BS Sgr	18	26	46	-27	8	20	6.1	-7.07	9.2	18?	VS	1917
100	FL Sgr	18	0	30	-34	36	15	356.8	-5.60	8.3	20	F	1924

101	FM Sgr	18	17	4	-23	38	28	8.2	-3.51	8.6	20.5	F	1926
102	GR Sgr	18	22	10	-25	34	50	7.0	-5.44	11.4	16.6	S?	1924
103	HS Sgr	18	28	3	-21	34	25	11.2	-4.79	11.5(10)	17	VS?	1901
104	KY Sgr	18	1	8	-26	24	39	4.0	-1.68	10.6(7.2)	20	F?	1926
105	LQ Sgr	18	28	28	-27	55	19	5.5	-7.76	13.0	21	?	1897
106	V363 Sgr	19	11	10	-29	50	0	7.7	-17.06	8.8(7.9)	20	M	1927
107	V441 Sgr	18	22	8	-25	28	54	7.1	-5.38	8.7(8.0)	?	M	1930
108	V522 Sgr	18	48	0	-25	22	22	9.8	-10.57	12.9(12.8)	17	VF?	1931
109	V630 Sgr	18	8	48	-34	20	21	357.8	-6.97	4.5(Ve)	18	VF	1936
110	V726 Sgr	18	19	33	-26	53	19	5.5	-5.52	10.8	19	M	1936
111	V732 Sgr	17	55	14	-27	22	25	2.5	-1.02	6.5	?	M	1936
112	V737 Sgr	18	7	8	-28	44	51	2.6	-3.99	10.3(10.0)	19	M?	1933
113	V787 Sgr	17	59	17	-30	30	33	0.2	-3.36	9.8	21	M	1937
114	V909 Sgr	18	25	23	-35	1	29	358.8	-10.32	6.8	20	VF	1941
115	V927 Sgr	18	7	11	-28	6	52	3.2	-3.69	8.0(7.3)	20	VF	1944
116	V928 Sgr	18	18	14	-28	6	4	4.3	-5.83	8.9(8.5)	20.5	S	1947
117	V949 Sgr	18	40	14	-28	9	31	6.5	-10.19	15.7	?	?	1914
118	V990 Sgr	17	57	10	-28	19	7	1.9	-1.87	11.1	?	F	1936
119	V999 Sgr	17	59	14	-27	33	17	2.8	-1.88	8.0	16.5	S	1910
120	V1012 Sgr	18	6	14	-31	44	25	359.9	-5.26	8.0	20	F	1914
121	V1014 Sgr	18	6	45	-27	36	4	3.6	-3.36	10.9(10.3)	20	M?	1901
122	V1015 Sgr	18	9	2	-32	28	31	359.5	-6.13	7.1(6.5)	21?	F	1905
123	V1016 Sgr	18	19	57	-25	11	14	7.1	-4.81	8.5(8.4?)	17	S?	1899
124	V1059 Sgr	19	1	50	-13	9	42	22.4	-8.23	4.9(2.0)	16.5	VF?	1898
125	V1148 Sgr	18	8	12	-25	59	10	5.1	-2.86	8.0	?	?	1943
126	V1149 Sgr	18	18	30	-28	17	17	4.2	-5.97	7.4	21	S	1945
127	V1150 Sgr	18	18	54	-24	5	30	8.0	-4.09	13.3(12)	22?	VS	1946
128	V1151 Sgr	18	25	23	-20	11	59	12.1	-3.60	11.1(10.5)	20	S	1947
129	V1172 Sgr	17	50	23	-20	40	30	7.7	3.33	9.0	18	F?	1951
130	V1174 Sgr	18	1	13	-28	44	27	2.0	-2.85	12.0	?	?	1951
131	V1175 Sgr	18	14	14	-31	7	7	1.2	-6.47	7.0	?	?	1952
132	V1274 Sgr	17	48	55	-17	51	54	10.0	5.06	10.5	?	?	1954
133	V1275 Sgr	17	59	6	-36	18	40	355.1	-6.19	7.0	18?	VF	1954
134	V1310 Sgr	18	34	16	-30	4	25	4.1	-9.84	11.7	?	VS	1935
135	V1431 Sgr	18	1	17	-30	6	3	0.8	-3.53	17.2	19.4	?	1945

136	V1572 Sgr	18 5 17	-31 37 43	359.9	-5.03	11.0	?	?	1955
137	V1583 Sgr	18 15 26	-23 23 18	8.2	-3.06	8.9	21	F	1928
138	V1905 Sgr	18 33 42	-25 20 36	8.4	-7.65	9.1(8.0)	19	VS?	1932
139	V1944 Sgr	18 0 36	-27 17 17	3.2	-2.01	13(7.5?)	?	?	1960
140	V2415 Sgr	17 53 11	-29 34 18	0.4	-1.75	13.0	?	?	1951
141	V2572 Sgr	18 31 36	-32 25 57	1.7	-10.35	6.5	18?	M	1969
142	V3645 Sgr	18 35 49	-18 41 45	14.6	-5.10	12.6(8.0?)	18	VS?	1969
143	V3888 Sgr	17 48 41	-18 45 36	9.2	4.65	9.0(7.5)Ve	16	VF?	1974
144	V3889 Sgr	17 58 21	-28 21 42	2.0	-2.12	8.4(Ve)	21	VF	1975
145	V3890 Sgr	18 30 42	-24 0 58	9.3	-6.45	8.4(4.8)	17var	?	1962
146	V3964 Sgr	17 49 42	-17 23 35	10.5	5.14	9(6)	?	F	1975
147	V4021 Sgr	18 38 14	-23 22 47	10.6	-7.70	8.8(7.5)Ve	?	M	1977
148	V4027 Sgr	18 2 29	-28 45 20	2.1	-3.10	11.0(8.5)	21	?	1968
149	V4049 Sgr	18 20 38	-27 56 25	4.7	-6.22	12.0	?	S?	1978
150	V4065 Sgr	18 19 7	-24 43 43	7.4	-4.43	8.6(Ve)	?	VF	1980
151	V4077 Sgr	18 35 39	-26 25 58	7.6	-8.52	8.0(Ve)	14.4(22)	M	1982
152	Nova Sgr 1953	18 5 12	-29 57 40	1.3	-4.20	10.5	?	?	1953
153	Nova Sgr 1963	17 54 13	-28 41 43	1.2	-1.50	13	?	?	1963
154	Nova Sgr 1983	18 7 54	-28 49 27	2.6	-4.17	9.5(Ve)	21	?	1983
155	Nova Sgr 1984	17 53 42	-29 2 8	0.9	-1.57	10.5(Ve)	?	?	1984
156	Nova Sgr 1985	17 56 34	-31 49 31	358.8	-3.51	10.5(Ve)	?	?	1985
157	T Sco	16 17 2	-22 59 30	352.7	19.45	6.7(Ve)	?	F	1860
158	KP Sco	17 44 16	-35 43 24	354.1	-3.30	9.4	21	F	1928
159	V382 Sco	17 51 56	-35 25 5	355.2	-4.48	9.5	22	VF?	1901
160	V384 Sco	18 1 43	-35 39 27	356.0	-6.33	12.3(9.3)	18.5	F?	1893
161	V696 Sco	17 53 11	-35 50 15	355.0	-4.91	7.5	19.5	VF	1944
162	V697 Sco	17 51 21	-37 24 55	353.4	-5.39	10.2(8)	17	F?	1941
163	V707 Sco	17 48 26	-36 37 54	353.8	-4.49	9.9(9.6)	20	M	1922
164	V711 Sco	17 54 6	-34 21 16	356.3	-4.33	9.7	19	S?	1906
165	V719 Sco	17 45 43	-34 0 54	355.7	-2.67	9.8	20.5	F	1950
166	V720 Sco	17 51 58	-35 23 22	355.2	-4.47	7.5	?	F	1950
167	V721 Sco	17 42 28	-34 40 41	354.8	-2.44	10.1(8)	?	F?	1950
168	V722 Sco	17 48 22	-34 57 51	355.2	-3.62	9.5(9.4)	?	F	1952
169	V723 Sco	17 50 1	-35 23 53	355.0	-4.14	9.8	?	F	1952
170	V728 Sco	17 38 44	-45 28 46	345.2	-7.50	5(Ve)	20?	?	1862

171	V729 Sco	17 22 2	-32 5 49	354.7	2.54	14.0	22	?	1936
172	V744 Sco	17 53 18	-31 13 35	359.0	-2.61	13.3	21	?	1935
173	V745 Sco	17 55 17	-33 14 29	357.4	-3.99	11.2	?	?	1937
174	V825 Sco	17 49 53	-33 32 13	356.6	-3.16	12(8)	19.0	M?	1964
175	V902 Sco	17 25 31	-39 4 27	349.3	-1.98	11.0	20.0	S	1949
176	Nova Sco 1952	17 46 22	-33 11 31	356.5	-2.36	11.0	?	?	1952
177	Nova Sco 1954	17 53 15	-30 45 36	359.4	-2.36	13.8	?	?	1954
178	Nova Sco 1985	17 56 34	-31 49 36	358.8	-3.51	10.5(Ve)	16var	?	1985
179	EU Sct	18 56 13	- 4 12 30	29.8	-2.98	8.4	16	F	1949
180	FS Sct	18 58 16	- 5 24 4	29.0	-3.98	10.1	18	M	1952
181	FV Sct	18 34 51	-12 55 26	19.6	-2.26	12.5(7)	?	?	1960
182	V366 Sct	18 29 42	-12 18 54	19.6	-0.86	15.4	21	?	1961
183	V368 Sct	18 45 43	- 8 33 1	24.7	-2.63	6.9(Ve)	19	F	1970
184	V373 Sct	18 55 26	- 7 43 5	26.6	-4.40	7.1(Ve)	18.5	M	1975
185	X Ser	16 19 17	- 2 29 29	10.9	31.87	8.9	18.3	VS?	1903
186	CT Ser	15 45 39	+14 22 32	24.6	47.56	8.0(5)Ve	16.6	S?	1948
187	DZ Ser	18 0 58	-10 33 51	17.8	6.16	14.0(8)	21	?	1960
188	FH Ser	18 30 46	+ 2 36 51	33.0	5.78	4.5(Ve)	16.2	M	1970
189	LW Ser	17 51 15	+14 42 25	39.8	19.82	8.3(Ve)	21	M	1978
190	MU Ser	17 55 52	-14 1 17	14.1	5.55	7.7(Ve)	21	VF	1983
191	XX Tau	5 19 24	+16 43 0	187.2	-11.65	5.9	18.5	F	1927
192	UW Tri	2 45 17	+33 31 26	148.7	-23.60	?			1972
193	RW UMi	16 47 52	+77 2 10	109.7	33.15	6.0(2)	21	S?	1956
194	CN Vel	11 2 38	-54 23 9	287.5	5.18	10.2	17?	VS	1905
195	CQ Vel	8 58 51	-53 20 17	272.4	-4.89	9.0(8.9)	21	M	1940
196	CK Vul	19 47 37	+27 18 39	63.5	0.99	2.6(Ve)	20.7?	S?	1670
197	LU Vul	19 45 35	+28 35 29	64.3	2.02	9.5	21	F	1968
198	LV Vul	19 48 0	+27 10 19	63.4	0.84	4.7(Ve)	16.9	F	1968
199	NQ Vul	19 29 14	+20 28 0	55.4	1.29	6.0(Ve)	18.5	M	1976
200	PW Vul	19 26 5	+27 21 58	61.2	5.19	6.4(Ve)	17	M	1984
201	Nova Vul 1984	20 26 46	+27 50 43	68.6	-6.03	5.6(Ve)	?	?	1984
202	LMC (Numerous)	5 23 38	-68 13 14	278.7	-33.15	-	-	-	-
203	SMC (Numerous)	0 52 43	-71 1 16	302.8	-46.11	-	-	-	-
204	M31 (Numerous)	0 42 44	+41 16 9	121.2	-21.57	-	-	-	-
205	M33 (Numerous)	1 33 52	+30 39 14	133.7	-31.33	-	-	-	-

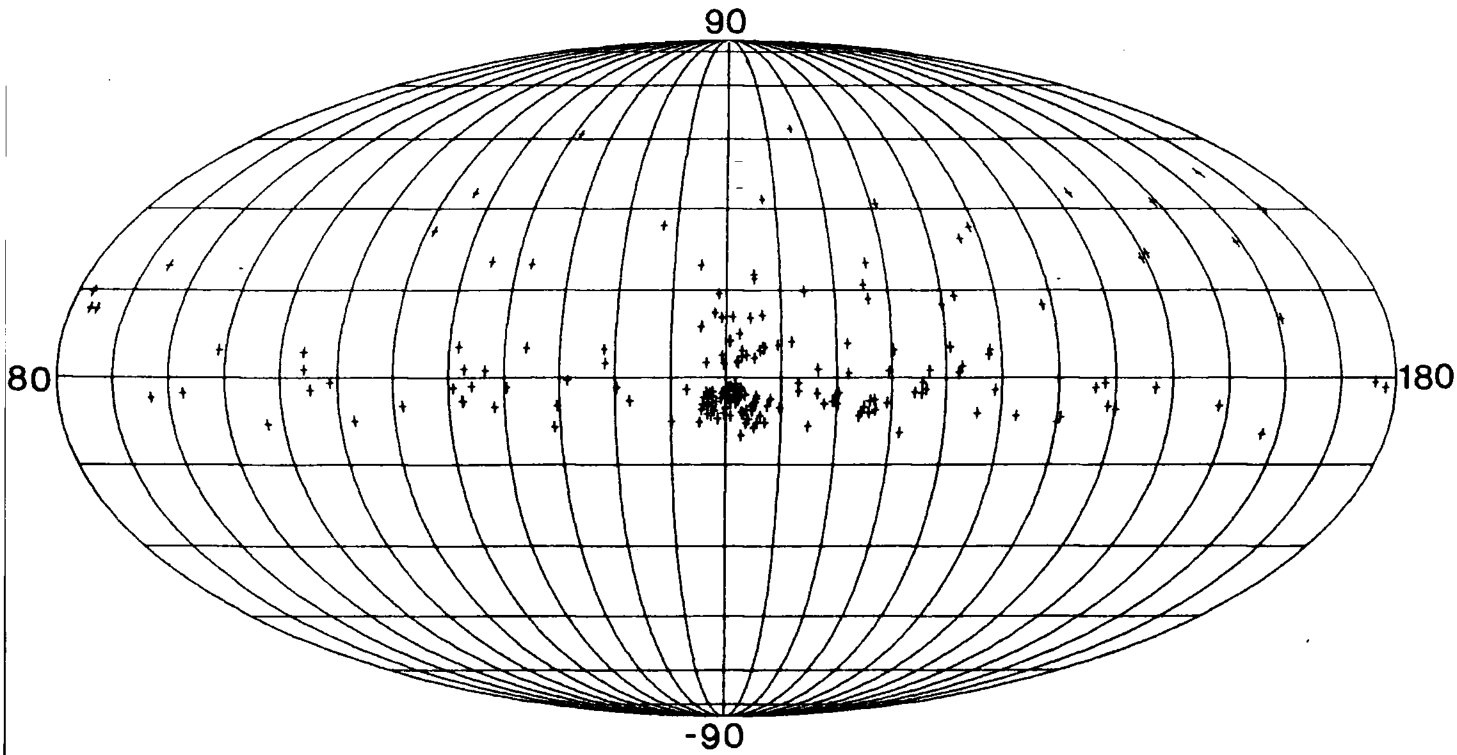


Fig. 4.1 The galactic distribution of novae.

distribution may be explained by the close proximity of novae to the solar system (typically a few hundred pc away). The large clustering of novae near the galactic centre may due to the particular attention paid to this region by earlier nova surveys.

The brighter relatives of the novae, the supernovae, have only in the last half century or so been recognised as a separate class of objects. The term supernova (SN) was first applied by Baade and Zwicky (1934) to describe those extraordinarily brilliant novae whose apparent brightness at maximum was comparable with their own galaxies. At present, approximately 150 galactic supernova remnants (SNRs) have been catalogued (Table 4.2), mainly on the basis of radio observations (Green, 1987). So far, only a few of the progenitors to these SNRs have ever been seen at their outburst stages; the most recent example is the supernova SN 1987a which appeared in the Large Magellanic Cloud (Shelton, *et al.*, 1987). However, the last supernova definitely seen in our galaxy goes back more than three centuries to AD 1604, five years before the advent of the telescope. There is nothing in the intervening time except a possible outburst around AD 1658 which is alleged to have produced the SNR in Cas A (Ashworth, 1980); however, there is no definite record of its detection. Fig. 4.2 shows the distribution of SNRs in our galaxy which I have produced based on the data in Green's catalogue. As can be seen, nearly all of the SNRs lie closely to the galactic plane which means that they are certainly galactic features situating at a long distance from the Earth. The low discovery rate of supernovae (SNe) in our galaxy seems likely to be a result of the large interstellar absorption along the plane of the Milky Way, in which the solar system is situated.

The nova phenomenon represents an important stage in the evolution of low mass binary stars. Direct observations of nova outbursts may provide valuable clues to the evolutionary status of these stars. Before the telescopic period, such data are mainly found in Far Eastern chronicles. At the same time, valuable information gained from

Table 4.2 A Catalogue of Supernova Remnants (after Green (1987) with RA and Dec converted to epoch J2000.0)

No.	l	b	RA (J2000.0) (h m)	Dec (° ′)	Size (′)	Alpha	Flux (1 GHz)	Type	Other Names
1	33.6	+0.1	18 52.717	+ 0 40.72	10	0.5	22	S	Kes 79, 4C00.70, HC13
2	34.7	-0.4	18 56.037	+ 1 21.95	30	0.32	250	S	W44, 3C392
3	39.2	-0.3	19 4.044	+ 5 27.52	6.5x6	0.5	19	?	3C396, HC24, NRAO 593
4	39.7	-2.0	19 11.971	+ 4 57.07	120x60	0.45	100	?	W50, SS433
5	40.5	-0.5	19 7.191	+ 6 29.74	22	0.5	11	S	Flo
6	41.1	-0.3	19 7.596	+ 7 7.77	3.5	0.5	19	S	3C397
7	41.9	-4.1	19 22.451	+ 6 5.80	160?	0.5	20	S?	PKS 1920+06, (CTB 72)
8	43.3	-0.2	19 11.059	+ 9 6.01	3.5	0.50	38	S	W49B
9	46.8	-0.3	19 18.170	+12 9.51	15	0.5	14	S	(HC30)
10	47.6	+6.1	18 57.262	+15 34.05	80?	0.5?	12	S	CTB 63
11	49.2	-0.7	19 23.801	+14 5.89	25?	0.25?	160	?	(W51)
12	53.6	-2.2	19 38.748	+17 14.90	28	0.55	8	S	3C400.2, NRAO 611
13	54.1	+0.3	19 30.544	+18 52.35	1.5	0.1	0.5	F	
14	54.4	-0.3	19 33.380	+18 51.55	40?	0.5?	27	S	(HC40)
15	55.7	+3.4	19 21.313	+21 43.73	23	0.6	1.3	S	
16	57.2	+0.8	19 34.985	+21 56.65	12	0.5?	1.8	S?	(4C21.53)
17	65.3	+5.7	19 34.975	+29 56.66	260x200	0.6	53	S?	
18	65.7	+1.2	19 52.174	+29 25.79	18	0.6	6	F?	DA 495
19	69.0	+2.7	19 53.429	+32 52.87	40	varies	120	?	CTB 80
20	73.9	+0.9	20 14.216	+36 12.18	25?	0.3	9	?	
21	74.0	-8.5	20 51.077	+30 41.29	190	0.5	210	S	Cygnus Loop
22	74.9	+1.2	20 16.028	+37 12.29	8x6	0.24	9	F	CTB 87
23	78.2	+2.1	20 20.788	+40 24.57	60	0.7	340	S	DR4, gamma Cygni
24	82.2	+5.3	20 19.299	+45 29.49	95x65	0.7	120	S	W63
25	84.2	-0.8	20 53.294	+43 27.41	20x16	0.5	11	S	
26	89.0	+4.7	20 44.541	+50 35.95	120x90	0.40	220	S	HB21
27	93.3	+6.9	20 52.386	+55 21.38	27x20	0.54	9	S	DA 530, 4C(T)55.38.1
28	93.7	-0.2	21 29.056	+50 53.17	70?	0.34	65	S	CTB 104A, DA 551, NRAO 662
29	94.0	+1.0	21 24.839	+51 52.98	30x25	0.44	17	S	3C434.1
30	109.1	-1.0	23 1.423	+58 54.14	26	0.50	20	S	CTB 109

31	111.7	-2.1	23 23.429	+58 48.48	5	0.77	2700	S	Cassiopeia A, 3C461
32	112.0	+1.2	23 16.160	+61 46.38	30	0.6	6	S?	
33	114.3	+0.3	23 37.347	+61 56.61	95x65	0.3	5	S	
34	116.5	+1.1	23 53.488	+63 16.69	80x60	0.8	11	S	
35	116.9	+0.2	23 59.210	+62 26.70	34	0.5	9	S	CTB 1
36	117.4	+5.0	23 54.988	+67 46.70	60x80	0.5	35	S?	
37	119.5	+10.2	0 6.645	+72 46.70	80	0.30	40	S	CTA 1
38	120.1	+1.4	0 25.300	+64 8.61	8	0.61	56	S	Tycho, 3C10, SN1572
39	123.2	+2.9	0 54.626	+65 46.26	43	0.5	7	S?	S183
40	126.2	+1.6	1 21.849	+64 15.69	70	0.9	9	S?	
41	127.1	+0.5	1 28.371	+63 10.52	45	0.6	13	S	R5
42	130.7	+3.1	2 5.691	+64 49.33	9x5	0.10	33	F	3C58, SN1181
43	132.7	+1.3	2 17.763	+62 43.85	70	0.5	55	S	HB3
44	152.2	-1.2	4 9.178	+48 43.88	110	0.7	25	S?	
45	160.9	+2.6	5 0.696	+46 34.40	120	0.44	130	S	HB9
46	166.0	+4.3	5 26.584	+42 54.56	36	0.4	7	S	VRO 42.05.01
47	166.2	+2.5	5 19.043	+41 53.10	90x70	0.6	10	S	OA 184
48	179.0	+2.7	5 53.733	+31 5.57	70	0.3	7	S	
49	180.0	-1.7	5 39.139	+27 31.63	180	0.5	64	S	S147
50	184.6	-5.8	5 34.509	+22 0.96	6x4	0.30	1000	F	Crab Nebula, 3C144, SN1054, Taurus A
51	189.1	+3.0	6 17.024	+22 34.87	40	0.36	155	S	IC443, 3C157
52	192.8	-1.1	6 9.409	+17 19.42	78	0.55	20	S	
53	205.5	+0.5	6 38.687	+ 6 27.29	220	0.5	160	S	Monoceros Nebula
54	206.9	+2.3	6 48.686	+ 6 26.57	45	0.45	6	S?	PKS 0646+06
55	211.7	-1.1	6 45.573	+ 0 32.79	70	0.5	15	S?	
56	240.9	-0.9	7 43.090	-25 13.19	95?	0.1?	20?	S?	
57	260.4	-3.4	8 22.886	-42 59.70	55	0.5	130	S	Puppis A, MSH 08-44
58	261.9	+5.5	9 3.942	-38 41.96	44	0.4	10	S	
59	263.9	-3.3	8 34.669	-45 45.39	260	0.3	1800	C?	Vela XYZ
60	287.8	-0.5	10 46.961	-59 39.84	3	?	?	S?	Carina Nebula
61	290.1	-0.8	11 3.063	-60 56.17	12	0.5	45	S	MSH 11-61A
62	291.0	-0.1	11 12.145	-60 38.33	10	0.2	16	S?	(MSH 11-62)
63	292.0	+1.8	11 24.600	-59 16.49	12x8	0.2	15	F?	MSH 11-54
64	293.8	+0.6	11 35.002	-60 53.60	9?	0.6	5	F?	
65	296.1	-0.5	11 51.471	-62 33.69	33?	0.55	7	S	

66	296.5	+10.0	12	9.614	-52	26.69	80	0.5	60	S	PKS 1209-51/52
67	296.8	-0.3	11	58.537	-62	34.70	12	0.5	10	S	1156-62
68	298.5	-0.3	12	12.669	-62	51.68	4?	0.4	5	?	
69	298.6	-0.0	12	13.677	-62	36.68	8?	0.3	4	?	
70	299.0	+0.2	12	17.714	-62	28.66	11?	?	9	S?	
71	302.3	+0.7	12	45.714	-62	8.39	15	0.4	6	S	
72	304.6	+0.1	13	5.990	-62	42.05	7?	0.5	14	S?	Kes 17
73	308.7	+0.0	13	41.450	-62	15.15	17x7	0.4	12	F?	
74	309.2	-0.6	13	46.517	-62	53.99	9?	0.4	7	S	
75	309.8	+0.0	13	50.517	-62	4.86	20	0.5	17	S	
76	311.5	-0.3	14	5.632	-61	57.33	4?	0.5	4	?	
77	312.4	-0.4	14	13.011	-61	43.04	36x27	0.28	44	S	
78	315.4	-2.3	14	42.938	-62	29.75	40	0.6	46	S	RCW 86, MSH 14-63, SN185
79	315.4	-0.3	14	35.954	-60	36.07	15x10	0.4	10	S?	
80	316.3	-0.0	14	41.628	-59	59.81	15	0.3	28	S	(MSH 14-57)
81	320.4	-1.2	15	14.445	-59	9.15	30	0.3?	70?	C	MSH 15-52, RCW 89
82	321.9	-0.3	15	20.643	-57	33.81	25	0.3	13	S	
83	322.3	-1.2	15	27.120	-58	5.45	10?	0.9	6	?	Kes 24
84	323.5	+0.1	15	28.704	-56	21.35	9	0.4	3	S	
85	326.3	-1.8	15	52.962	-56	8.91	35	0.4	150	C	MSH 15-56
86	327.1	-1.1	15	54.416	-55	8.82	12	?	8	S?	
87	327.4	+0.4	15	48.832	-53	49.16	20	0.6	35	C	Kes 27
88	327.6	+14.6	15	2.770	-41	55.75	30	0.6	19	S	SN1006, PKS 1459-41
89	328.0	+0.3	15	53.332	-53	28.89	6	0.55	3	?	
90	328.4	+0.2	15	55.497	-53	16.75	5	0.2	15	F?	(MSH 15-57)
91	330.0	+15.0	15	8.220	-39	11.47	180	0.5	280	S?	Lupus Loop
92	330.2	+1.0	16	1.106	-51	34.40	10	0.3?	7	S?	
93	332.0	+0.2	16	13.279	-50	54.62	10	0.5	10	S	
94	332.4	-0.4	16	17.546	-51	2.35	8	0.5	28	S	RCW 103
95	332.4	+0.1	16	15.276	-50	42.49	15	0.5	25	S	MSH 16-51, Kes 32
96	335.2	+0.1	16	27.725	-48	46.67	17	0.5	18	S	
97	336.7	+0.5	16	32.177	-47	19.37	10	0.5	6	S	
98	337.0	-0.1	16	35.695	-47	36.13	10	0.5	17	S?	(CTB 33)
99	337.2	-0.7	16	39.462	-47	50.88	4?	0.7	2	?	
100	337.3	+1.0	16	32.650	-46	36.34	12	0.49	16	S	Kes 40

101	337.8	-0.1	16	39.010	-46	58.91	10?	0.5	16	?	Kes 41
102	338.1	+0.4	16	37.986	-46	23.98	10	0.4	1.3	S?	
103	338.3	-0.0	16	40.997	-46	33.77	8?	0.7	7	S?	
104	338.5	+0.1	16	41.155	-46	18.76	12?	0.3	27	?	
105	340.4	+0.4	16	46.602	-44	39.38	6	0.4	6	S	
106	340.6	+0.3	16	47.601	-44	35.31	5	0.4	5	S	
107	341.9	-0.3	16	54.924	-44	0.81	6	0.5	3.4	S	
108	342.0	-0.2	16	54.836	-43	52.81	9	0.4	3.5	S?	
109	344.7	-0.1	17	3.853	-41	38.18	7	0.5	3	S?	
110	346.6	-0.2	17	10.311	-40	9.72	8	0.50	10	S	
111	348.5	+0.1	17	13.596	-38	32.48	10	0.3	65	S	CTB 37A
112	348.7	+0.3	17	13.918	-38	11.46	18	0.3	24	S	CTB 37B
113	349.7	+0.2	17	17.982	-37	26.17	2.5	0.5	20	S?	
114	350.0	-1.8	17	26.768	-38	24.54	30?	0.5	30	S?	
115	350.1	-0.3	17	21.068	-37	26.95	4?	0.7	6	?	
116	351.2	+0.1	17	22.364	-36	10.85	6	0.4	6	S	
117	352.7	-0.1	17	27.670	-35	7.47	5?	0.6	6	S?	
118	355.9	-2.5	17	45.970	-33	43.14	14	0.5	8	S	
119	357.7	-0.1	17	40.394	-30	57.54	3x8?	0.4	37	?	MSH 17-39
120	357.7	+0.3	17	38.553	-30	41.68	24	0.4	12	S	
121	359.1	-0.5	17	45.535	-29	56.17	24	0.4	15	S	
122	0.0	+0.0	17	45.678	-29	0.16	3	0.8	100	S	Sag A East
123	1.9	+0.3	17	48.749	-27	9.93	1.2	0.7	0.6	S	
124	4.5	+6.8	17	30.663	-21	29.24	3	0.64	20	S	Kepler, SN1604, 3C358
125	5.4	-1.2	18	1.579	-24	55.00	35	0.2	32	S	Milne 56, A4
126	6.4	-0.1	18	1.043	-23	20.03	45	0.4	320	C	W28
127	7.7	-3.7	18	17.558	-24	3.83	18	0.3	10	S	1814-24
128	9.8	+0.6	18	5.139	-20	13.73	13	0.5	4	S	
129	10.0	-0.3	18	8.727	-20	25.47	8	0.3	2	S?	
130	11.2	-0.3	18	11.455	-19	26.27	4	0.55	22	S	
131	11.4	-0.1	18	10.697	-19	5.33	7	0.6	5	S?	
132	12.0	-0.1	18	12.104	-18	37.23	5?	0.7?	3	?	
133	15.9	+0.2	18	18.944	-15	1.72	5	0.6	5	S?	
134	16.8	-1.1	18	25.354	-14	46.26	?	?	<5	?	
135	18.8	+0.3	18	23.973	-12	23.36	15	0.4	30	S	Kes 67

136	18.9	-1.1	18	30.148	-12	52.91	24?	0.4	40	?	
137	20.2	-0.2	18	28.122	-11	35.06	10	0.0	10	F	
138	21.5	-0.9	18	33.518	-10	34.67	1.2	0.1	7	F	
139	21.8	-0.6	18	32.760	-10	7.72	20	0.6	70	S	Kes 69
140	22.7	-0.2	18	33.241	- 9	12.68	25	0.6	32	S?	
141	23.3	-0.3	18	34.731	- 8	42.58	22	0.5	60	S?	W41
142	23.6	+0.3	18	33.055	- 8	11.70	7?	0.3	8?	?	
143	24.7	+0.6	18	34.366	- 7	5.60	30x15	0.2	20	F	
144	24.7	-0.6	18	38.708	- 7	32.29	15	0.5	7	S?	
145	27.4	+0.0	18	41.324	- 4	56.10	4	0.7	5	S?	(Kes 73), 4C-04.71
146	27.8	+0.6	18	38.645	- 4	17.29	50x30	0.3	30	F?	
147	29.7	-0.3	18	46.453	- 2	58.73	2.5	0.7	10	C	Kes 75
148	30.7	+1.0	18	44.759	- 1	31.85	18	0.4	6	S?	
149	31.9	+0.0	18	49.414	- 0	55.52	6	0.6	24	S	3C391
150	32.0	-4.9	19	5.617	- 2	55.37	60?	0.5?	20	S?	3C396.1
151	32.8	-0.1	18	51.399	- 0	8.38	17	0.3	11	S?	Kes 78
152	33.2	-0.6	18	53.732	- 0	8.21	15	0.7	4	S	

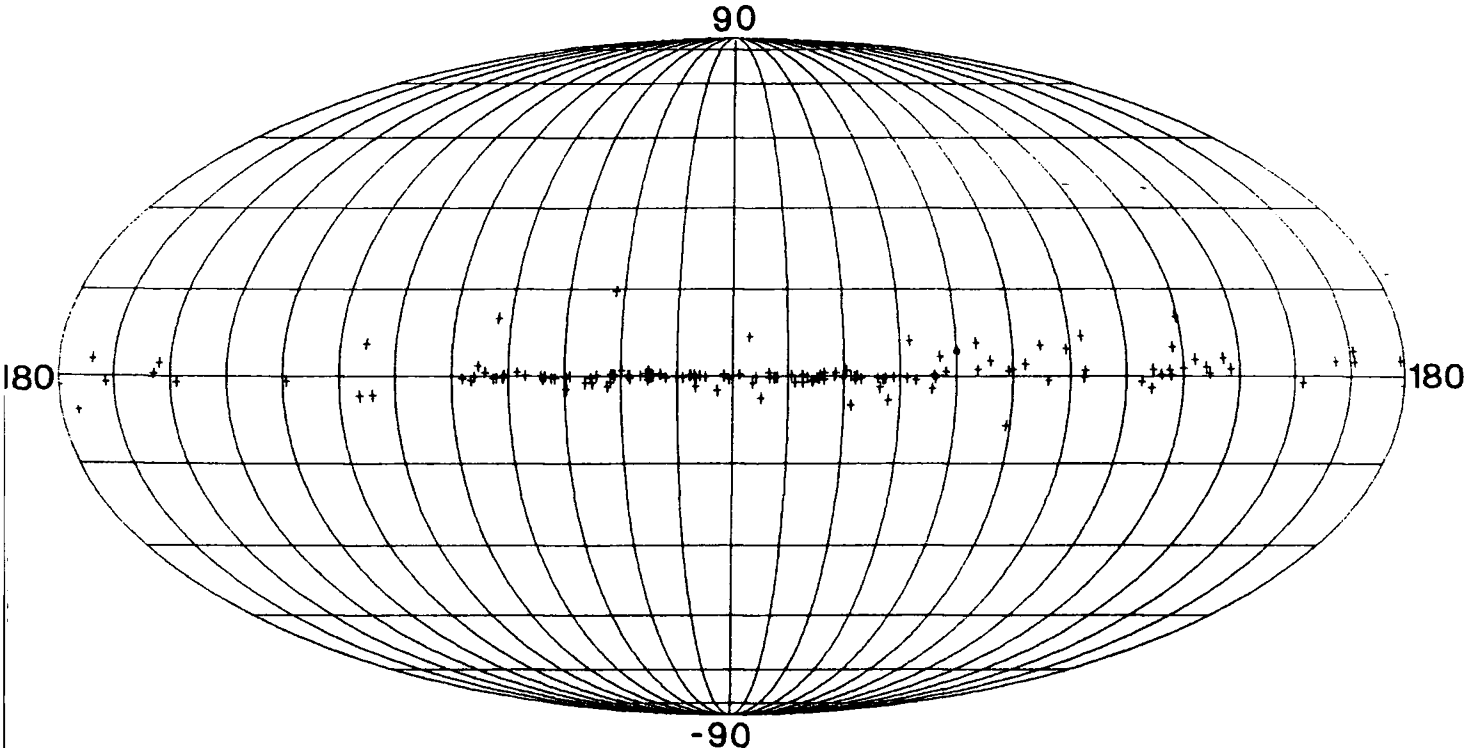


Fig. 4.2 The galactic distribution of SNRs.

historical records of SNe may lead us to solve some of the problems concerning the final stages in the life of a more massive star. As well, supernova explosions have long been known to leave behind remnants which are responsible for many rich and varied astrophysical processes in the interstellar medium and also act as major sources of galactic cosmic rays – as first suggested by Baade and Zwicky (1934).

Some of these SN explosions may have left behind rotating neutron stars or pulsars, which act as powerful galactic discrete sources of synchrotron radiation and strong emitters across most of the electromagnetic spectrum – from radio to gamma-ray frequencies. Furthermore, the study by Cini-Castagnoli *et al.* (1982) on thermoluminescence in marine sediments even suggested that traces of gamma-ray bursts from several galactic supernovae during the historical past may be detected. It is obvious that the time span covered by telescopic data on novae and SNe is limited, early historical observations are thus of considerable importance in filling the observational gaps prior to the telescope.

4.2 Classification of Novae and SNe

4.2.1 Nova Types, Light Curves and Magnitudes

The first attempted classification was that by McLaughlin (1945). He grouped novae into very fast, fast, average, slow and RT Serpentis in a convenient fashion rather than based on any physical parameters. It is now customary to divide novae into 3 groups: (i) Classical novae (Ne); (ii) Recurrent novae (RNe) and (iii) Dwarf novae (DNe).

(i) Classical Novae

In general, the speed class may be defined in terms of the rate of decline in magnitudes per day of the visual light curve down to 2 magnitudes from maximum brightness. The classification scheme adopted here is similar to that of Payne-Gaposchkin (1957) which is also the scheme used by Bode *et al.* (1988) in their catalogue (Table 4.1). The subdivided groups are: (a) Very Fast (VF), (b) Fast (F), (c) Moderately Fast (MF), (d) Slow (S), and (d) Very Slow (VS) according to the rate of decline of the optical light curves (Table 4.3).

Fig. 4.3 shows two typical light curves of classical novae: Nova Aquilae 1918 (a fast nova) and Nova Herculis 1934 (a slow nova). It appears that the brightness of a fast nova at maximum is generally brighter than a slow nova. Fig. 4.4 shows the distributions of the visual brightness of classical novae at maximum and minimum light which I have constructed from the data given in Table 4.1. The majority of these novae seems to have apparent magnitudes at maximum between 6 and 12, and at minimum between 16 and 20. It may be inferred from Fig. 4.4 that a small portion of the classical novae (especially those in the fast speed classes) should be observable by the naked-eye.

(ii) Recurrent Novae

The basic definition of a recurrent nova is that it has shown at least one repeated brightness eruption. A recurrent nova brightens by a similar magnitude to that of classical novae but the time between two eruptions is relatively shorter. The brightness of recurrent novae during outburst changes by about 7 magnitudes in only a few days. After maximum its brightness slowly fades and returns to its pre-outburst magnitude in about 100 days. The top part of Fig. 4.5 shows the composite light curves of the recurrent nova RS Oph. So far, there are 7 recurrent novae known. Two of these have been fairly well observed: RS Oph with outbursts in 1898, 1933, 1958, 1967, 1985 and T Pyx with outbursts in 1890, 1902, 1920, 1944, 1967. The others are VY Aqr, TCrB, V616 Mon, U Sco and V1017 Sgr.

(iii) Dwarf Novae:

Dwarf novae have two subgroups: one subgroup shows characteristics of Z Cam type

Table 4.3 The speed classes of classical novae (after Payne-Gaposchkin, 1957)

Speed Class	Time for Decline of 2 mag	Rate of Decline mag/day
Very Fast	< 10 days	> 0.20
Fast	11 to 25 days	0.18 to 0.08
Moderately Fast	26 to 80 days	0.07 to 0.025
Slow	81 to 150 days	0.024 to 0.013
Very Slow	151 to 250 days	0.013 to 0.008

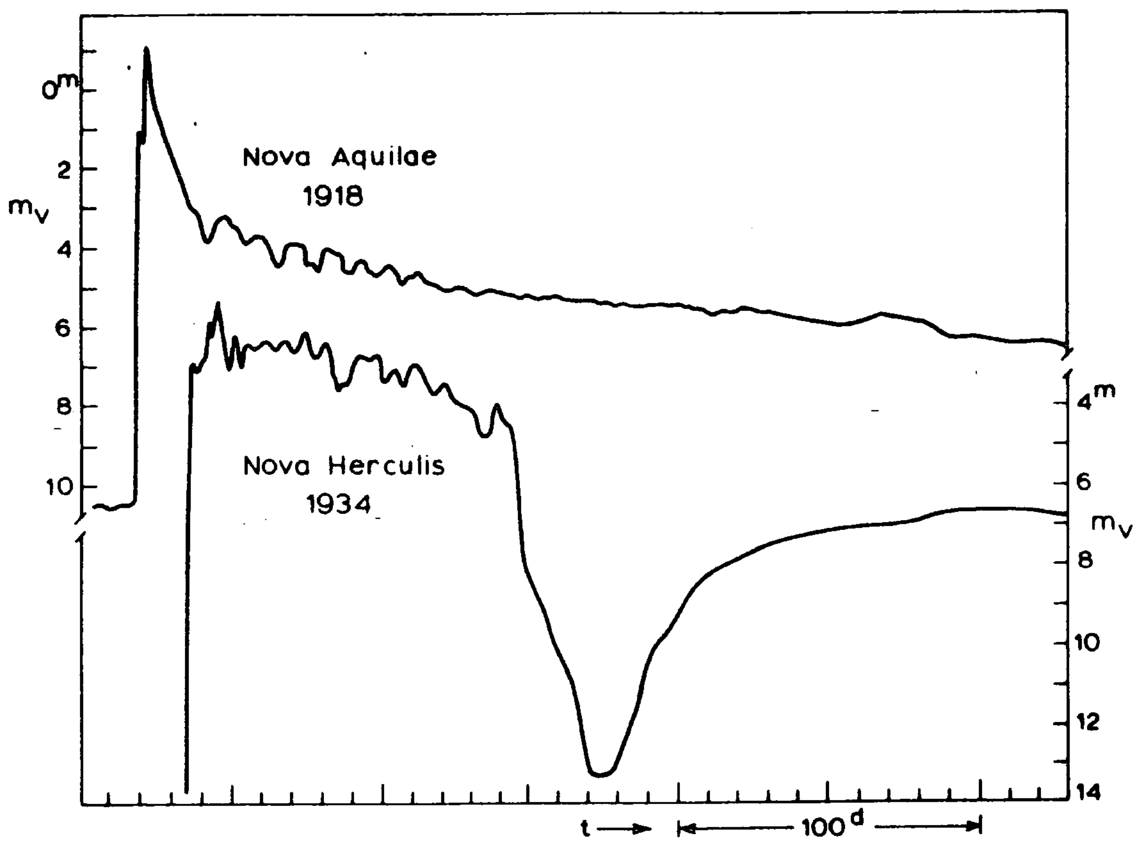


Fig. 4.3 The light curves of classical novae, a fast nova (Nova Aquilae 1918) and slow nova (Nova Herculis 1934).

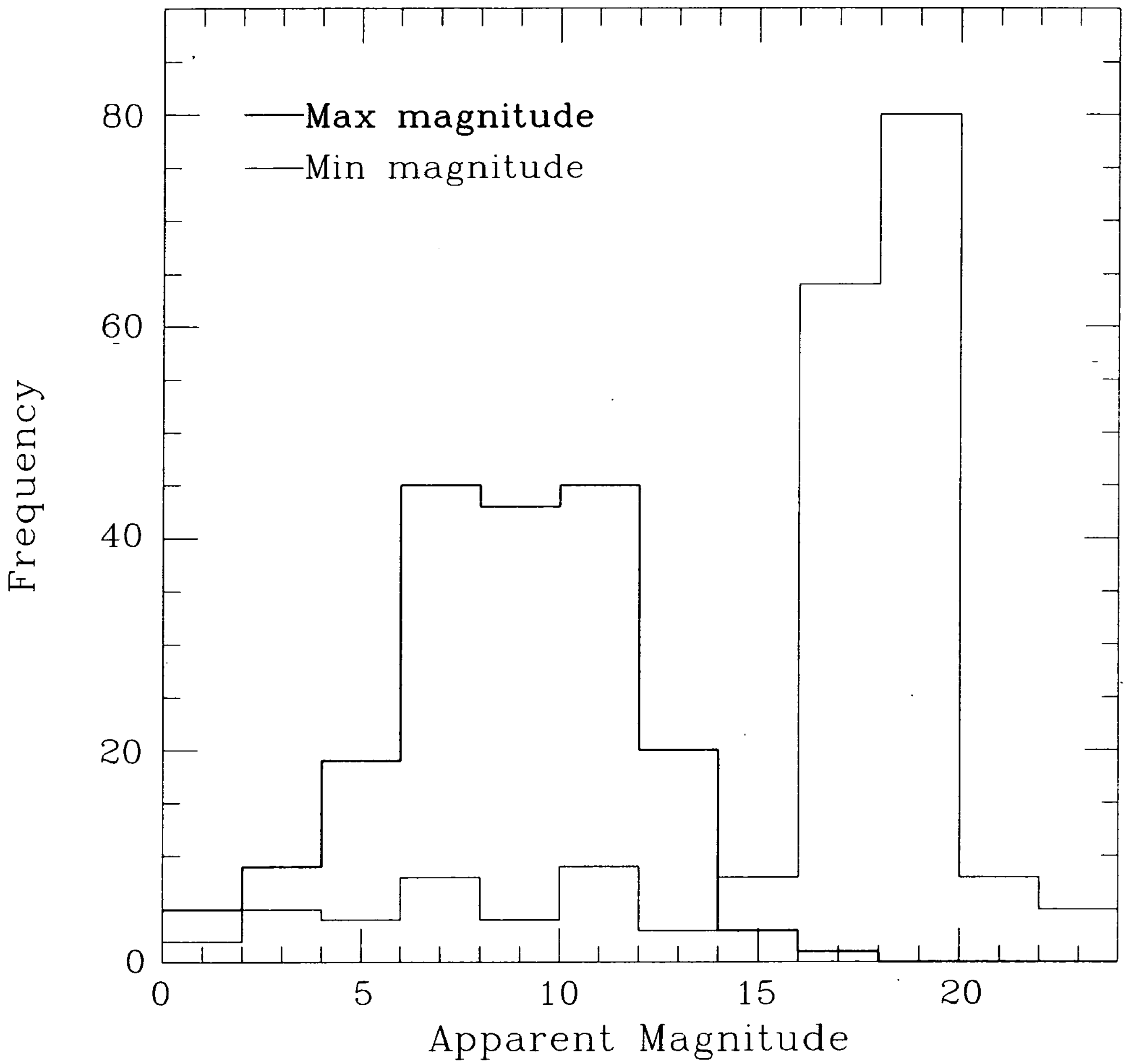
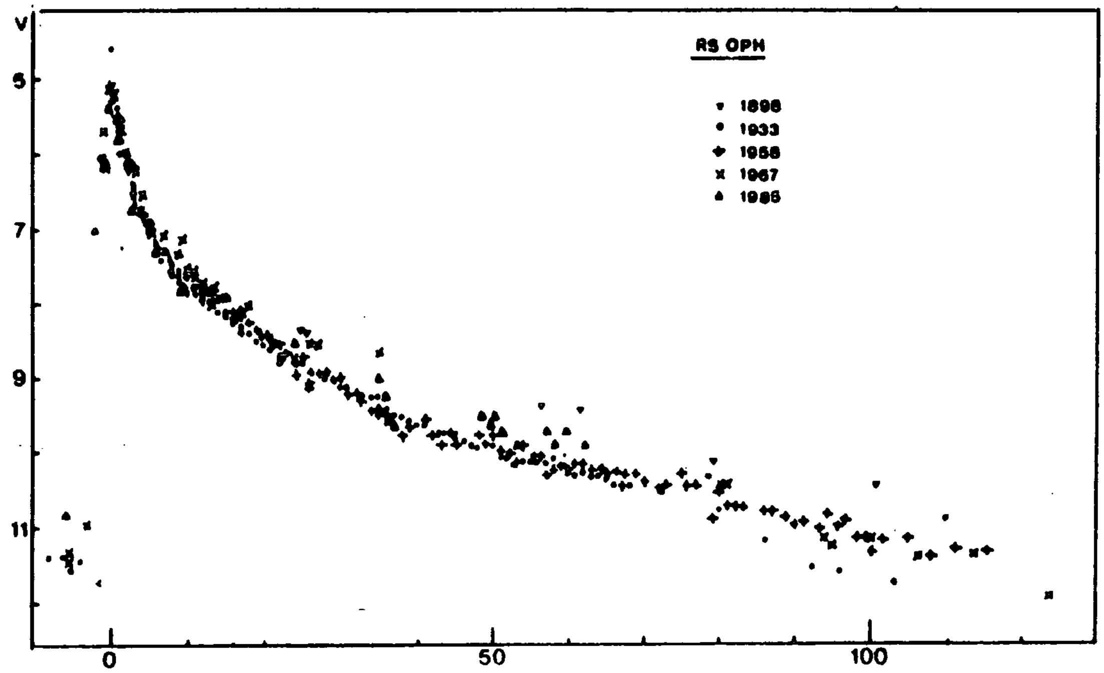
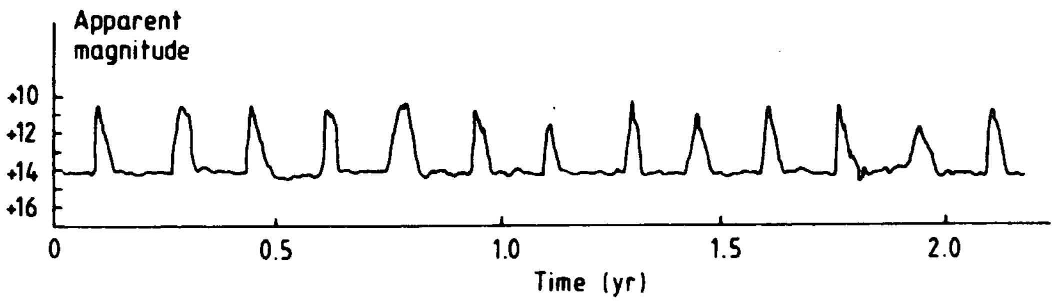


Fig. 4.4 The distribution of the magnitudes of novae at maximum and minimum light.





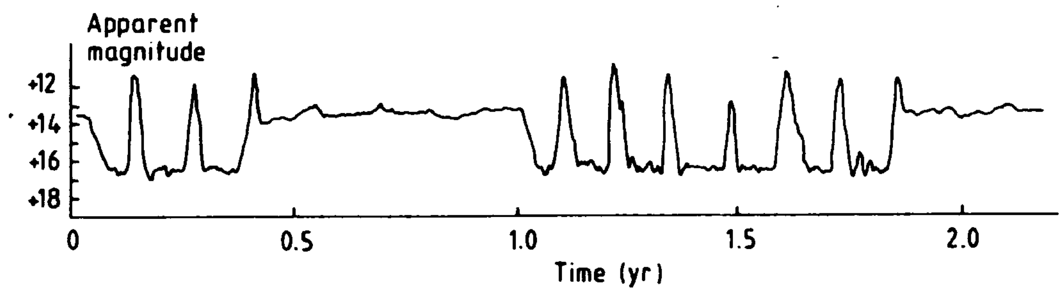


Fig. 4.5 (a) shows the five superposed light curves of RS Oph (a recurrent nova). (b) and (c) show the light curves of two dwarf novae: U Gem and Z Cam type stars. After Rosino (1987) and Kitchin (1987).

stars and the other behaves like U Gem (or SS Cyg) stars. This type of novae periodically brightens by only a few magnitudes (Fig. 4.5). As their brightness at maximum is below the threshold of visibility to the naked-eye, I shall not consider them further in connection with early records of new stars.

Nowaday, it is usual to investigate nova magnitudes and light-curves via extra-galactic systems – e.g. M31 – than in our own Galaxy. Anything from 21 to 33 per year (Ford, 1978) are discovered in M31. They have the advantage that in an external galaxy all novae are essentially at the same distance from us and are more readily discovered than in our own galaxy since they are all concentrated in a relatively small region of the sky. In recent years, amateurs have contributed significant efforts in the discovery of novae, e.g. Alcock discovered two novae – Delphinus 1967 and Vulpecula 1967 after years of persistent searches of the sky. Nova Cygni 1975 was discovered by Kentaro Osada (29 Aug 1975); it was a fast nova which faded by about 7 mag in two and half months (70 days).

4.2.2 SN Types, Light Curves and Magnitudes

Galactic supernovae may be broadly divided into Type I and Type II (with the less well defined peculiars of types III, IV and V (Zwicky, 1965)). The classification was made originally on the basis of spectral criteria. Minkowski (1941) had defined type II to be those SNe with spectra exhibiting the lines of the Balmer series and all other as type I. The modern classification is mainly based on the shapes of the light curves. Also, the presence in the spectra of strong lines due to H2 emission is a good indication of Type II, as Type I do not show this characteristic. Type II SNe are observed only in the spiral arms of the more open spiral galaxies (types Sb and Sc) whereas Type I SNe are found in all types of galaxies. From their distributions in galaxies, Type I SNe are thought to originate from population II type stars and Type II SNe from population

I type stars. In addition, Type I SNe produce a shell type remnant without a pulsar; whereas Type II SNe leave behind a filled centre (or plerionic) remnant and possibly a pulsar.

(i) Type I Light Curves:

The light curve consists of a small broad peak with a rapid rise followed by a slow exponential decline. The initial rise in brightness is rather rapid at a rate of 0.25 to 0.5 magnitudes per day. It takes about one to two months to reach a peak absolute magnitude of about −19. Table 4.4 lists some values of the absolute photographic magnitudes of both types of supernovae at maximum. After remaining at its maximum brightness for approximately a week, it starts to decline initially at a rate of about one magnitude per week, and gradually slows down to about one magnitude in 10 weeks. The time it takes to decline about 20 magnitudes may take up to a year or more. Type I light curves (Fig. 4.6) seem to follow a regular pattern, such that even fragmentary observations may be extrapolated to determine the apparent magnitude at maximum.

(ii) Type II Light Curves:

In contrast to the regular pattern observed in Type I SN light curves, Type II light curves behave in a rather irregular fashion, each with its own peculiar pattern (Fig. 4.7). The rate of initial rise is similar to Type I, available data shows that on average an increase of 0.2 to 0.5 mag per day. However, the peak brightness of Type II is slightly lower than that of Type I, they may reach absolute magnitudes of about −17.5. After remaining at their maximum brightness for a few weeks they decline slowly, initially at some 3 or 4 magnitudes over the first 100 days and afterwards roughly one magnitude per 50 days.

Table 4.4 Absolute photographic magnitudes of supernovae at maximum (after de Jager, 1980).

Type I	Type II	References
−19.9	−18.0	Kowal (1968), Sandage and Tammann (1976)
−19.1	−17.2	Tammann (1977a,b)
−19.6±0.6		Branch (1977a,b, 1979)
−19.0		Wyckoff and Wehinger (1977)
−19.45[a]		Van den Bergh and Kamper (1977)
−21.3	−18.3	Pskovskii (1977, 1978)
−19.8±0.2	−18.7±0.2	Tammann (1978)
	−18.8	Barbon (1978)
	−16.45[b]	Barbon *et al.* (1979)

[a] Derived from the communicated $M_v = -19.3$, and $B-V = -0.15$, at t_{max} (Pskovskii, 1971).

[b] Assuming a Hubble constant of 100 km s^{-1} Mpc^{-1}.

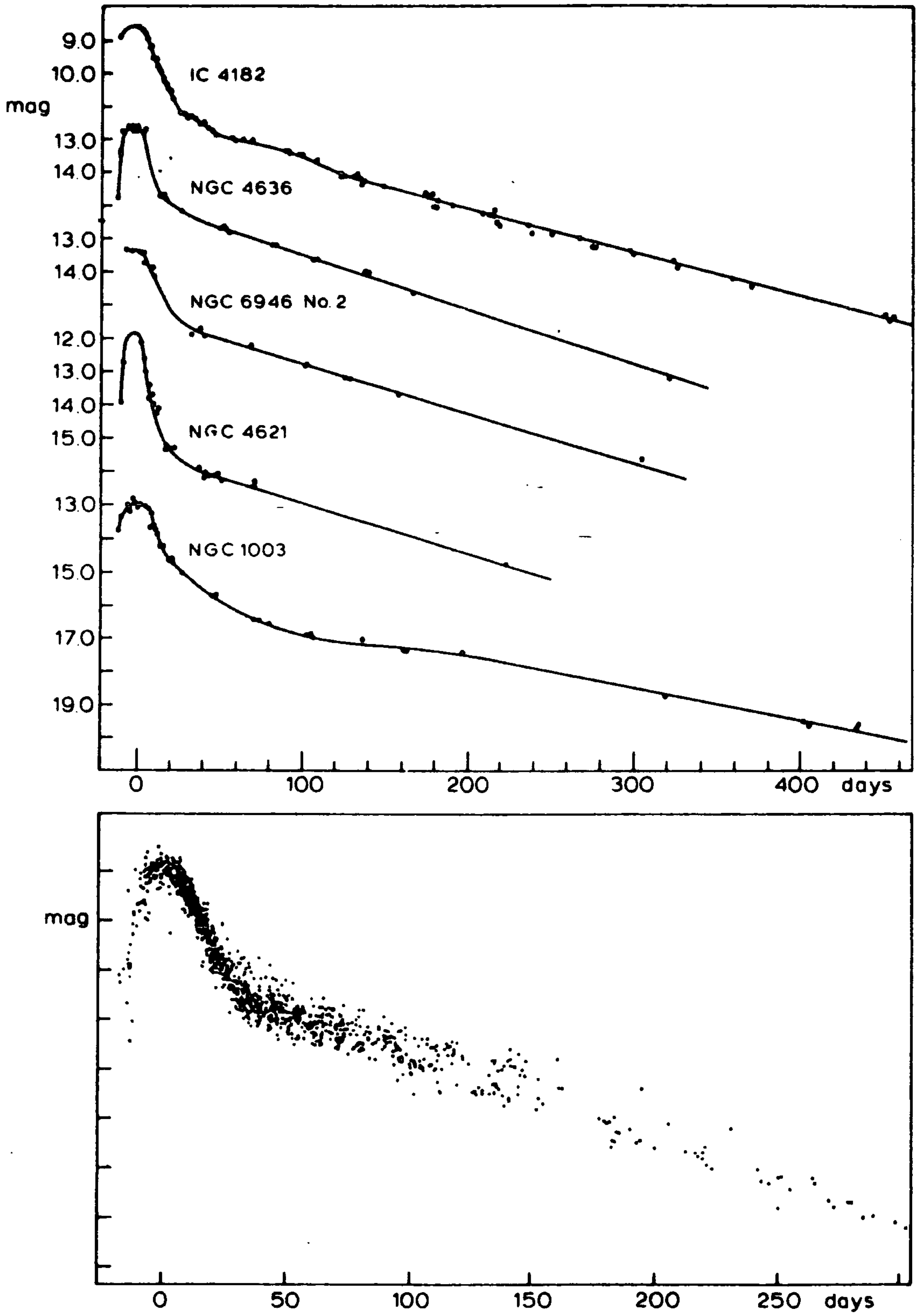


Fig. 4.6 Typical Type I SN light curves (after Arp, 1974 and Barbon *et al.*, 1974a).

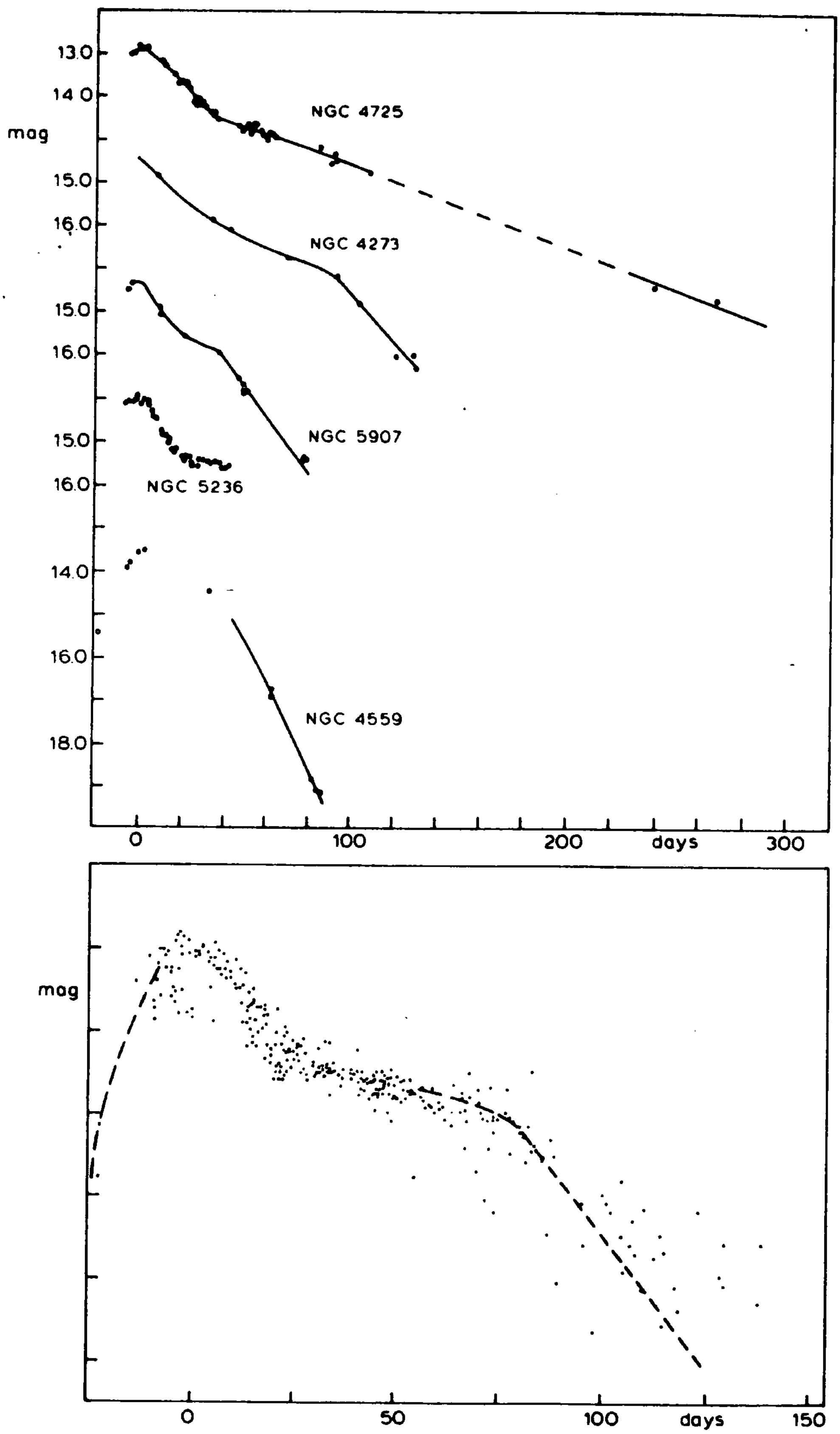


Fig. 4.7 Typical Type II SN light curves. (after Arp, 1974 and Barbon *et al.*, 1974b).

4.3 Theoretical Summary

4.3.1 Nova Models

Out of the three groups of novae mentioned above, only the classical and recurrent novae are of direct interest in the study of early records of new stars. Both classical and recurrent novae are subsets of the class of stars commonly known as cataclysmic variables. Both phenomena have been predicted to be the result of an interaction between the stars of a close binary system. The canonical model proposed by Kraft (1963) established that classical novae as well as recurrent novae are semi-detached binaries. The components of the binary system consist of a cool companion of low mass ($\sim 1M_{\odot}$) and a more compact hot white dwarf. For classical novae, the companion star to the white dwarf is a late type main sequence star (probably a red dwarf); whereas for recurrent novae the companion star is a red giant.

The mechanism of the outburst are similar for all types of novae. A number of reviews on this subject may be found in Warner (1976); Gallagher and Starrfield (1978); and Bath (1978). Essentially, after filling its Roche lobe, the cool companion loses mass by transferring hydrogen-rich material through the Lagrangian point along a stream onto the accretion disk of the white dwarf (Fig. 4.8). This material is eventually accreted onto the degenerate white dwarf, forming a hydrogen-rich envelope. Continuing the accretion process increases the temperature at the base of the hydrogen envelope and consequently increases the thermonuclear energy generation. As the material is degenerate it does not expand and so the temperature continues to rise and a nova explosion results.

Classical novae undergo outbursts with peak luminosities $\sim 5 \times 10^{37} - 5 \times 10^{38}$ erg s^{-1}; whereas the peak luminosity of recurrent novae is about 10^{37} erg s^{-1}. For classical

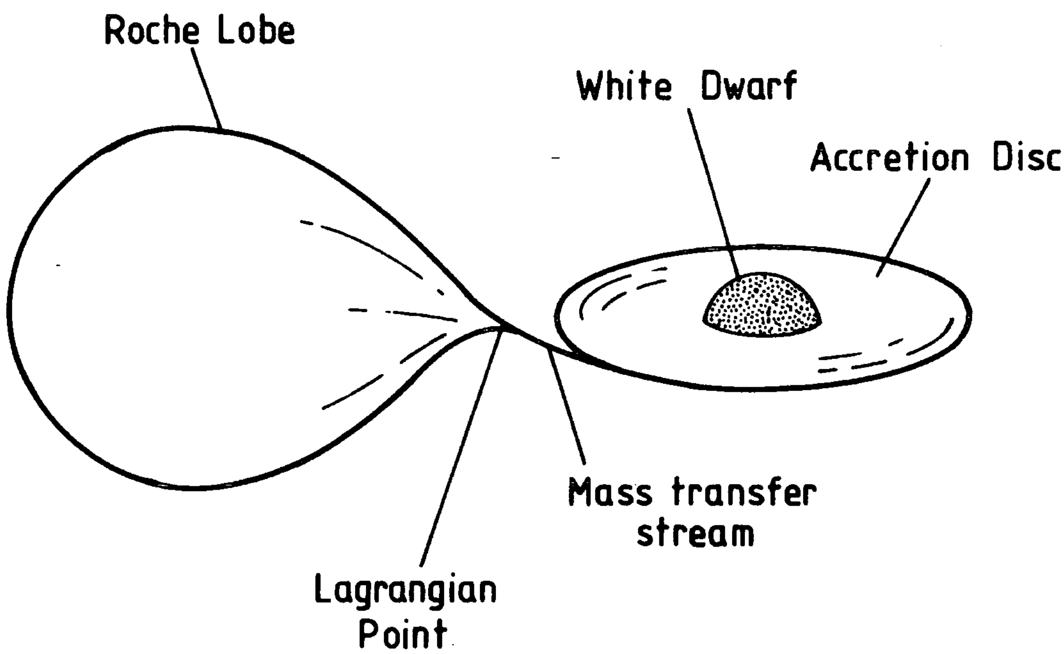


Fig. 4.8 A diagram showing the binary system proposed for the nova outburst mechanisms.

novae, around $10^{-5} - 10^{-4} M_\odot$ of material is ejected at velocities typically 1,000 km s^{-1} at outburst with a recurrence time of $10^4 - 10^5$ years. Recurrent novae eject only 10^{-8} to $10^{-5} M_\odot$ at velocities typically 5,000 km s^{-1} at outburst with a recurrence time of about 30 years. Orbital periods are normally found to be in the range 3–10 hr with cataclysmic variable orbits generally of low eccentricity (Bath, 1978).

4.3.2 Supernova Models

A SN is an irreversible process – transforming almost all of the mass of a star into a gaseous remnant and possibly forming a tiny neutron star in the centre. Type I and Type II supernovae do not seem to have much in common, the only similarity that seems to exist is the amount of energy released during the explosive phase which is about 10^{51} erg. The average SN formation rate was initially given as something like 1 per 80 years by Caswell and Lerche (1979). But according to Tammann (1982), the occurrence rate of Type I SNe is one every 36 years and Type II SNe is one every 44 years. This is compatible with a recent estimate of the rate of birth of pulsars of 1 per 30–40 years by Lyne (1985).

Various models have been proposed to explain the mechanisms of both types of supernova phenomena, a number of outstanding issues still remain to be resolved. There are already many good reviews on the current thinking of these subjects, eg Trimble (1982, 1983); Rees and Stoneham (1982) and recently Woosley and Weaver (1986). I shall only give a brief summary here.

(i) Mechanisms of Type I SN

From the many suggested mechanisms, the thermonuclear model first proposed by Hoyle and Fowler (1960) seems to have won the approval of workers in this field. The central system consists of a nova-type close binary (Fig. 4.8) made up by a fairly massive white dwarf and a large late type main sequence star. The progenitor to the supernova explosion, the white dwarf, is thought to have a mass between 1 to 8 $M_\odot$, containing a developed core of carbon-oxygen and a helium mantle (Wheeler, 1978). The absence of hydrogen in Type I SN spectra seems to suggest that the precursor had already expelled its hydrogen envelope sometime ago. The accreting white dwarf is provoked into thermonuclear instability by the accumulation of a critical mass. If the Chandrasekhar limit (1.4 $M_\odot$) is exceeded before all transferred materials were consumed then the white dwarf could become degenerate.

Under extremely degenerate conditions, carbon or helium begins to ignite and burns a substantial mass to nuclear statistical equilibrium. About 0.2 to 1 $M_\odot$ of ^{56}Ni is synthesized during the burning of the carbon and oxygen. The energy from the burning disrupts the star at a high velocity. The radius of the exploding shell of materials is about 10^{15} cm at maximum light and moving away from the centre at a velocity of 11,000 km s^{-1}. The energy released by the explosion is $\sim 10^{51}$ erg and the total ejected mass is $1.5 \pm 0.5 M_\odot$.

The rise to peak luminosity of Type I SN light curves may be interpreted simply in terms of the energy ($\sim 10^{51}$ ergs) released during the explosion. Attempts have been made to explain the observed decline in the light curve by way of the decay of ^{56}Ni. It is generally believed that further energy input was required to sustain the slow decline of the light curve about 50 days after the explosion. The radioactive decay of 0.25–1 $M_\odot$ of ^{56}Ni to ^{56}Co with a 6 day half life, and then to ^{56}Fe with a 77 day half life seems to fit the observation. The energy released by the decay provides the power for the later stages of the SN emissions leading to the observed 50 to 80 days for the decline of the light curve after the first few weeks. Most of the mass of the precursor is thrown out into space as a hot gas cloud leaving behind only a tenuous remnant. No neutron star or black hole is expected from a Type I explosion.

(ii) Mechanisms of Type II SN

Type II SNe occur mostly in young and massive population I stars in the arms of spiral galaxies. The precursor is thought to have a mass $\sim 8M_{\odot}$, the highest mass in which a white dwarf can form. Various models predict a large initial radius greater than about 10^{13} cm for the precursor. This criterion indicates that the likely candidate is a red supergiant which would have evolved from a OB star earlier. Models for these stars also suggest (i) a large envelope of unburned hydrogen; (ii) a zone of helium produced in hydrogen burning; (iii) a layer of oxygen produced in helium burning; (iv) a silicon rich zone with byproducts of oxygen burning, e.g. sulphur, argon and calcium; and (v) an iron core.

The massive stars with mass of 15–100 $M_{\odot}$ will evolve relatively quickly in $\sim 10^6$ yr to the point, where in the central regions the silicon burning shell creates a core of iron group elements. As the binding energy per nucleon reaches a maximum at iron, no further fusion is expected to be possible. An unstable core of iron-group elements will form with a mass of $\sim 1.5M_{\odot}$. At this point the central temperature is $\sim 3 \times 10^9$ K and the density $\sim 4 \times 10^{12}$ kg m^{-3}. Under these conditions the nucleus begins to fragment through photodissociation back to lighter elements, mostly helium. As the pressure drops collapse will then follow. For the lighter stars with masses between 8 to 12 $M_{\odot}$, a similar collapse begins when the degenerate electrons are captured just before the oxygen burning stage.

Fig. 4.9 shows schematically the various stages of the Type II outburst mechanism. At the stage when the degenerate iron core exceeds the Chandrasekhar limit, it can no longer supports itself the core collapses under its own gravitational attraction. The energy of the collapse provides outgoing momentum to the envelope material via a shock reflected from the core as it reaches nuclear densities or from coupling to the neutron flux from the core. There have been theoretical difficulties in achieving this coupling

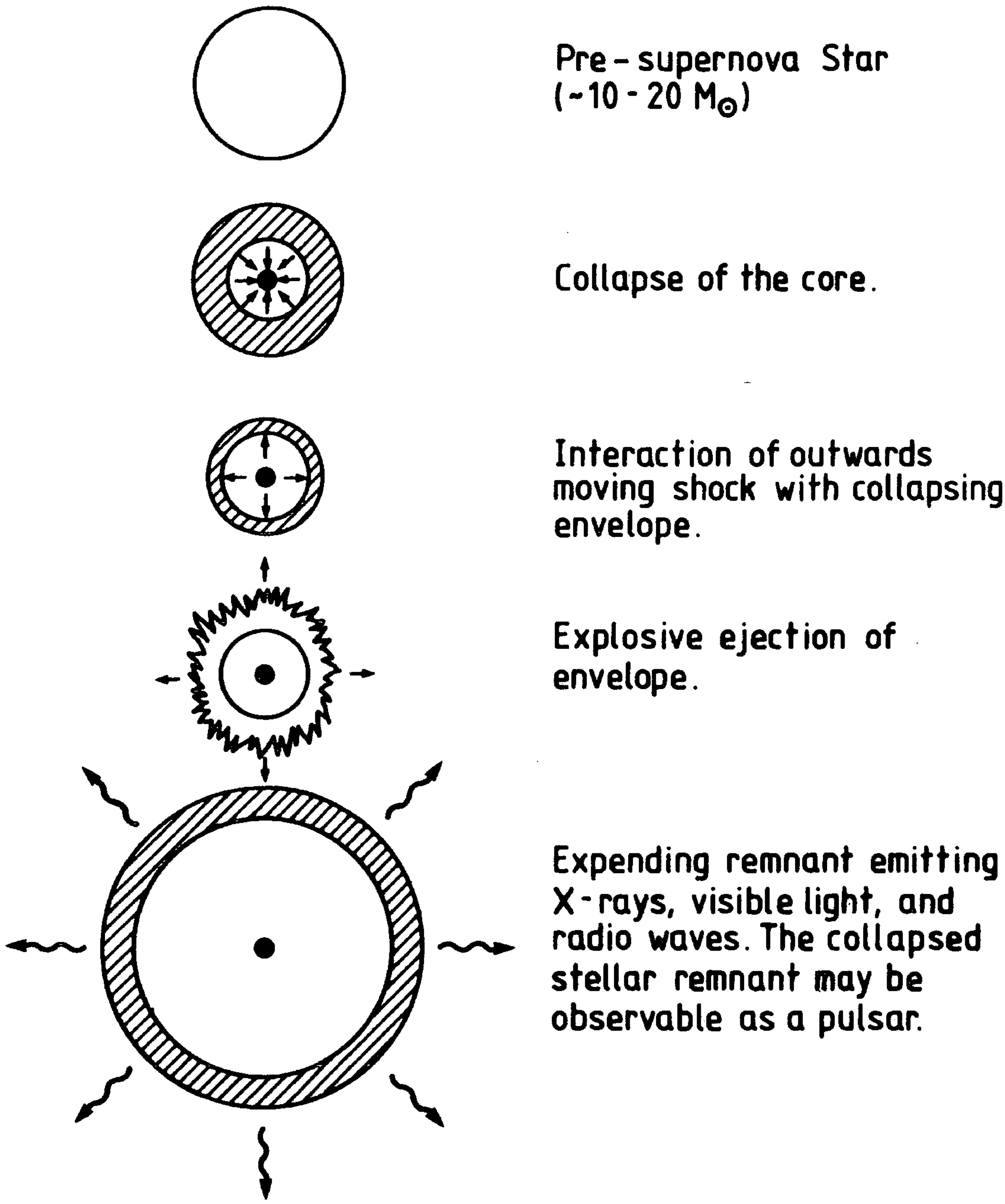


Fig. 4.9 A diagram showing the stages of a Type II SN explosion.

(Hillebrandt, 1982) and the only models in which most of the envelope is ejected are those in which the star is rapidly rotating (Bodenmeimer and Woosley, 1983). An equatorial ring of ejecta is predicted in this case. Recent observational evidences for expanding rings have been seen in a number of SNRs, e.g. CAS A (Markert *et al.*, 1983).

The hydrogen envelope which was also falling towards the centre will then interact with these shock waves spreading out from the core. It is suggested that the shock waves will create an explosive ejection of the envelope. The remnant that left behind after the explosion will continue to emit X-rays, visible light, and radio waves. The collapsed stellar core is expected to form a neutron star and sometime may be observed as a pulsar. The energy released by the explosion is about 10^{51} erg which had been predicted earlier by Zwicky back in 1938.

The shapes of Type II light curves can be explained by an initial input of $\sim 10^{51}$ erg which pushes the total light to maximum. The smooth continuum observed at maximum may hide the most interesting events of SN II but it dose allow the photospheric temperatures to be determined rather well. The decline in the light curve has been suggested as an indication of ^{56}Co decay.

With this kind of model, but unlike Type I, the observations of the outburst do not provide support for any particular version of the nuclear turmoil in the core. The observations confirm that type II SNe have substantial hydrogen-rich envelopes but there is no way to see far enough to determine the nuclear burning stages of the exploded star. The observed oxygen over abundances in optical filaments (typical features of Type II) is consistent with models of Type II events.

4.4 Significance of New Star Records

(i) In the Study of Nova

Since the recovery of two of the oldest known remnants: CK Vul (Nova 1670) (Shara *et al.*, 1985) and WY Sag (Nova 1783) (Shara *et al.*, 1984), and also Nova 1901 (Reynolds and Chevalier, 1984), interest in the possibility of recovering further nova remnants has been enlivened. The two oldest objects noted above (CK Vul and WY Sag) exhibit a low mass-transfer rate $\sim 10^{-1} M_{\odot} yr^{-1}$ resembling dwarf novae rather than classical novae observed in the past 100 years or so. The space density of cataclysmic variables (most of which are classical novae) is found to be incompatible with that of the white dwarfs by Patterson (1984). He estimated that about 1–3% of all white dwarfs are formed in systems that become cataclysmic variables. However, only 0.06% have so far been observed. It appears that there should be a large population of extinct classical novae to account for the inferred rate of eruption in the Galaxy.

Our current observational knowledge extends only about three centuries which is only a fraction of the recurrence time for a classical nova. This fact, coupled with the difficulty in determining how classical novae evolve during the long interval between their cataclysmic outbursts renders Far Eastern new star records of importance. In comparison with that expended in studies of historical SNe, very little effort has been made by researchers in locating nova remnants or identifying possible recurrent outbursts of an old nova amongst novae observed in modern times.

Recent improvement in determining absolute magnitude of novae at maximum has been attempted by a number of researchers. By analysing a large amount of new observational data of nova shells Cohen (1985) was able to obtain improved parameters for the distance-magnitude relation:

$$M_{V(max)} = -10.70(\pm0.30) + 2.41(\pm0.23)\log t_2$$

where $M_{V(max)}$ is the absolute magnitude of a nova at maximum, and t_2 is the time in days for a nova to decline 2 mag from maximum light. This formula has been calibrated using novae of known distances and absolute magnitude. It should provide a useful tool for measuring distances to nearby galaxies in which novae are observed.

(ii) In the Study of SN

Visual estimates of the brightness from historical observations may be used to estimate the distance of a SN. The distance-magnitude relation of a star is given by the following well known relation:

$$5log_{10}(d/10) = M_{V(max)} - m_{V(max)} + A_V$$

where d is the distance to SN (pc), $M_{V(max)}$ is the absolute magnitude of 'type I' SN, $m_{V(max)}$ is the apparent magnitude of the SN estimated from historical observations, and A_V is the optical extinction – see Green (1984) for a detailed discussion.

In the search for the remnant of a suspected historical supernova, distance estimates are often required in the identification process. There are two techniques commonly employed for SNR distance determination. One uses the absorption of the continuum radio emission from the SNR by the neutral interstellar hydrogen (HI) along the line of sight. HI measurements in the direction of certain SNRs exhibit well defined minima; these are interpreted as due to HI clouds in the spiral arms along the line of sight. The position of the intervening spiral arms for a particular SNR may be determined from a reference profile slightly displaced from the direction of the SNR. The absorption feature corresponding to the most distant cloud then gives the minimum distance to the SNR (Clark and Stephenson, 1977). Another technique employs a relationship between the radio surface brightness $\sum$ and the outer diameter of the SNR shell D. Clark and Caswell (1976) found a linear relationship between $\sum$ and known distances of SNRs. Thus, the distance of any SNR may be obtained from the measurement of its shell diameter.

Further, a small diameter and a high surface brightness may suggest that the object is a young remnant left behind by a recent SN explosion and could have been recorded by early observers. Clark and Caswell (1976) derived empirically from a study of radio remnants the following relationship:

$$D \sim 0.9t^{2/5}$$

where D is the remnant diameter in pc and t is the time in years since the explosion. They estimated that an age of 2000 years would correspond to a remnant diameter of about 20 pc.

4.5 Observation of New Stars in Europe

Prior to the observation of new stars in the year AD 1604 (by Kepler and others) and AD 1572 (by Tycho Brahe), there are only a few allusions to the sighting of new stars in Europe. The most notable of these is that cited by Pliny. He asserted that the appearance of a new star in the year around 130 BC was the motivation behind the construction by Hipparchus of his famous catalogue of stars (Pliny, *Historia Naturalis* II). Fotheringham (1919) showed this was probably a comet of 134 BC observed in China. There are also three other new stars mentioned to have appeared during the year AD 390, about the year AD 945 and also in the year AD 1264 (Grant, 1852;

Humboldt, 1851). However, the nature of none of these stars has been established with any degree of reliability. Newton (1972) listed 16 events between AD 334 and 1283 which are described as appearances of a *stella* ('star') in Medieval chronicles; these would seem to be possible nova appearances. However, some of these objects are listed as comets in Far Eastern sources (Ho Peng Yoke, 1962). Most others are included neither in the catalogues of new stars of Ho (1962) nor Xi and Bo (1965), so that they may be spurious. The most reliable sightings of new stars in ancient and medieval history relate to the brilliant SN of AD 1006. The monastic chronicles of St Gallen gives a fairly detailed description and there is a brief mention in the chronicle of Beneventani (Clark and Stephenson, 1977).

4.6 Observation of 'Guest Stars' in the Far East

The Aristotelian dogma of a supposed perfect heaven as held by early philosophers may have contributed to the dearth of new star records from Mediaeval Europe. In the Far East however, there was no such belief in an incorruptible heaven (Needham, 1959). On the contrary, heaven was thought to reflect the changes in daily earthly affairs. The belief that new stars were omens prevailed through much of Far Eastern history. It is no wonder that today we find numerous sightings of the so called 'guest stars' (*k'o-hsing*) – stars seemingly appearing from nowhere, residing temporarily within a particular asterism and disappearing after an elapse of time – just like one's guests coming and going.

It seems unavoidable that apart from relatively modern times, records from China, Japan and Korea provide the vast bulk of data on new stars. Only the brilliant new star of SN 1006 attracted interest in Europe and the Arabic world. However, the identification of a nova or SN candidate from the large number of Far Eastern records is often difficult. This is mainly due to the many different terms used in the historical texts.

4.6.1 Terminology and Criteria for Identification

The general term used to describe new stellar objects by Far Eastern astronomers is that of *k'o-hsing* ('guest star'). This term first appeared in the dynastic history *Shi-chi* and already was used to indicate the specific appearance of new stars. However, Far Eastern astronomers do not make any distinction between novae and SNe – and sometimes tailless comets or even meteors are described as guest stars. Also, it is not uncommon to find records of moving guest stars (Ho Peng Yoke, 1962). Apart from the term *k'o-hsing*, various other names like *Chou-po* and *Lou-tzu* were used. The most ambiguous term is *hsing-po* ('a star emerged'), which can mean either the appearance of a tailless comet or a stellar object.

Nevertheless, some obvious exclusion of records can be made, for instance, if the description of a guest star record indicates: (i) motion through the sky; (ii) a tail or trail; and (iii) a pale blue colour. If a star identified as a guest star has a slow motion or tail, obviously it is a comet. On the other hand, we can confidently identify rapid moving 'guest stars' as meteors especially if the record mentions a trail. Or if the record includes a description of a pale blue colour and a comparison with one of the large objects which would imply a large angular diameter, then it is probable a comet without a tail. For example, fairly bright comets similar to IRAS-Araki-Alcock in 1983 have little trace of a tail. A typical comet does not develop a tail until it is within the orbit of Mars (Brandt and Chapman, 1981), at which the heat from the Sun starts to vaporize its conglomerate icy core (Whipple, 1951). As a comet approaches the Sun from the depth of space, its tailless appearance resembles that of a new star.

After ruling out obviously erroneous records, a positive identification of SN outbursts from among the medley of new star records is possible if the following set of criteria have also been established:

(i) a fixed position in the sky; (ii) a long duration of visibility; (iii) a low galactic latitude; and (iv) identifiable in position with a known SNR of corresponding age.

In some cases, a comet may only be visible for a few days and then be lost to view on account of close conjunction with the Sun or unfavourable weather. An abridged record may thus give a false impression of immobility over the few days that the comet was observed. On the other hand, if a comet was observed for a considerable period of time, the movement of the comet through the asterisms is usually described in East Asian texts. It seems that if an object is observed for a long duration without any mention of movement, we can confidently interpret it to be of a stellar nature.

Low galactic latitude is another useful indicator of SN nature. Novae which are bright enough to attract the attention of naked-eye observers are usually only a few hundred parsecs from the Earth and hence their distribution in galactic latitude (like that of comets) is fairly isotropic (Fig. 4.10). This is quite opposite to the observed distribution of SNe, whose distance is typically several kpc. As can be seen from Fig. 4.10, the majority of the SNRs are within 1 deg of the galactic equator.

If a new star of fixed position and long duration appears in close proximity to the site of a currently observed SNR, a possible association between the two objects may well be worth considering in detail. However, it is essential that a fairly accurate location for the star be obtained in order to obviate an accidental agreement in position.

In the case of nova identification, criteria (ii) and (iii) will have to be relaxed. The major differences between the identification of novae and supernovae are the length of visibility and their proximity to the galactic equator. A typical nova would be visible

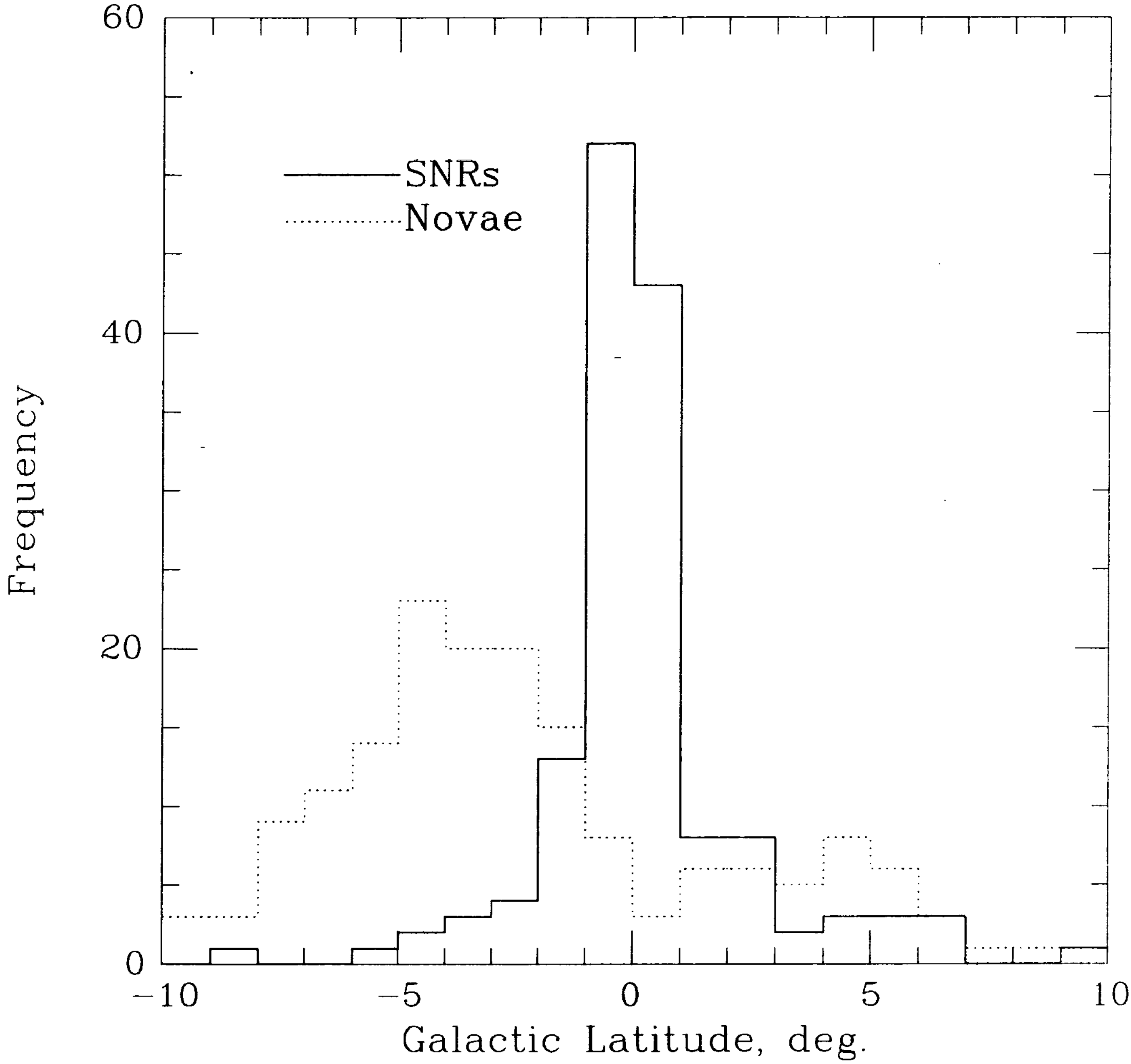


Fig. 4.10 A comparison between the galactic distribution of SNRs and novae.

to the naked eye for a period ranging from a few days to several months. The period of visibility for SNe is usually longer than for novae ranging from 6 to 24 months. The well established SN of 1604 was only about as bright as Jupiter and yet it was kept in view by both European and Chinese astronomers for a full year. The significantly brighter SN of AD 1572 was followed for some 15 months. The comparatively short distance between novae and Earth may render their apparent brightness similar to that of SNe. During the present century, three novae (in 1901, 1918 and 1942) have attained zero magnitude or brighter.

4.7 A Catalogue of Possible Novae and Supernovae

Ever since the French scholar Biot (1846a, b) put forth his incomplete list of guest stars, there have been many revisions since. Humbolt (1851) and Zinner (1919) constructed incomplete listings from Biot. The first attempted identification of new stars with novae was by Lundmark (1921) of Sweden. The Lundmark new star list was revised first by Hsi Tse-tsung (1958) and later enlarged by Xi and Bo (1965). There are also two catalogues by Ho Peng Yoke (1962) and, Ho Peng Yoke and Ang Tian-se (1970) which listed both comets and guest stars. A comprehensive table of SN and novae appeared in Clark and Stephenson (1977).

The present catalogue is a revision of three previous catalogues by Ho Peng Yoke (1962), Xi and Bo (1965), and Clark and Stephenson (1977). The aims of the compilation were to weed out dubious records and add any details that have been missed by previous catalogues. The catalogues of Ho Peng Yoke (1962) and, Ho Peng Yoke and Ang Tian-se (1970) have been the major sources for studying guest stars for the last two decades. However these catalogues are not specifically concerned with records of guest stars; they include numerous cometary records as well. The version of the catalogue of

Xi and Bo which is available to Western scholars has its limitations. There are many seemingly obvious omissions and mistakes introduced as a result of translation. The Clark and Stephenson catalogue only gives a comprehensive listing, it does not contain the original records.

In compiling the present catalogue of new stars, the set criteria for identification listed above has been followed. Also every effort has been made to consult the most original sources, as secondary sources may have been corrupted. I have omitted records that are ambiguous in meaning and vague in contents. For every entry, primary sources that are extant today have been consulted. This is to avoid any corruption or superfluous characters that could have been introduced during the compilation of secondary sources. Those records that only indicate a general direction without mentioning the nearest asterism are omitted. Sometimes it is much more difficult to deal with ambiguous records as we can neither prove or disprove the information given by the records. It is always dangerous to make any tacit assumption. It is hoped that the present catalogue will eliminate any omission and mistakes in previous such catalogues of new stars. The complete Catalogue of New Stars is placed in Appendix III and a summary listing is presented here under Table 4.5.

The first column of the table is the numbering of the list. The second column gives the date of first sighting of new stars. If the duration is mentioned in the record, this is given in the third column. The next few columns give the location of the guest star with errors. Both RA and Dec are given for epoch J2000.0. The following two columns are the corresponding approximate galactic latitudes and longitudes of the guest stars. The column following galactic coordinates indicates the category of records. I have adapted the following general rules in dividing the records. Category 1, are records in which the term *k'o-hsing* ('guest star') is specified, together with an indication of both a relatively accurate position and a long duration. Category 2 are those records in which either a

No.	Date	Duration	Location RA (h m)	Err (m)	Dec (deg)	Err (deg)	Approx Long (deg)	Lat (deg)	Cat	Comments on Record	Position	Other Cat.
1	532 BC spring	-	21 10	±22	-10	±25	40	-35	3	Very brief	Poor	XB2, CS1, H06
2	134 BC Jun/Jul	-	16 10	±12	-26	±15	349	+19	3	Very brief	Poor	XB4, CS3, H040
3	110-105 BC	-	7 40	±32	+30	±8	190	+23	3	Very brief	Poor	XB5, - H045
4	104-101 BC	-	14 30	±12	+39	±3	69	+66	3	Very brief	Good	- - H046
5	77 BC Oct/Nov	-	11 4	±6	+76	±1.5	131	+39	2	Brief	Good	XB6, CS4, H050
6	48 BC May/Jun	-	19 23	±4	-28	±1	10	-19	2	Brief	Good	XB7, CS5, H057
7	4 BC Apr/May	-	19 51	±20	+9	±5	48	-09	3	Very brief	Poor	XB9, - H064
8	AD 29	-	17 15	±4	+14	±1	35	+28	3	Very brief	Poor	XB10, - H067
9	AD 70 Dec/ 71 Jan	48 dy	9 46	±72	+24	±18	207	+48	2	Brief	Poor	- CS11,H079
10	101 Dec 30	-	10 17	±4	+23.4	±1	210	+55	2	Brief	Good	- CS13,H088
11	107 Sep 13	-	6 30	±32	-40	±8	248	-21	2	Brief	Fair	XB12,CS14,H090
12	125 Dec/ 126 Jan	-	17 30	±100	+10	±25	33	+23	3	Very brief	Poor	XB13,CS15,H094
13	158 Mar/Apr	-	12 30	±12	+55	±6	130	+62	3	Very brief	Poor	XB14, - H0104
14	185 Dec 7	20 mn	14 22	±18	-60.6	±.2	314	+0.3	1	Detailed	Good	XB15,CS17,H0109
15	200 Nov 6	-	3 45	±40	+24	±10	166	-24	3	Very brief	Poor	XB16, - H0115
16	207 Nov 10	-	11h -> 13.5h				-	-	3	Very brief	Poor	XB17, - H0119
17	213 Jan/Feb	-	6 50	±20	+34	±5	182	+15	3	Very brief	Poor	XB18, H0120
18	222 Nov 4	-	12 31	±11	-1.1	±0.4	292	+61	2	Brief	Very good	- CS18,H0123
19	269 Oct/Nov	-	0	±12h	+90	±25	122	+26	3	Very brief	Poor	XB19, - H0145
20	275 Jan/Feb	-	12 50	±36	-18	±9	303	+45	3	Very brief	Poor	XB20, - H0146
21	290 Apr/May	-	0	±12h	+90	±25	122	+26	3	Very brief	Poor	XB21,CS20,H0155
22	304 Jun/Jul	-	4 29	±4	+19	±1	178	-20	3	Very brief	Poor	XB22,CS21,H0163
23	305 Nov 21	-	12 30	±50	+55	±6	130	+62	3	Very brief	Poor	- - H0165
24	329 Aug/Sep	23 dy	12 30	±50	+55	±6	143	+51	2	Brief	Poor	XB23,CS22,H0165
25	340 Mar 25	-	12 15	±60	+10	±11	275	+71	3	Very brief	Poor	- - H0169
26	369 Mar/Apr	~5 mn	8	±6h	+70	±5	145	+30	1	Quite detailed	Fair	XB24,CS23,H0174
27	386 Apr/May	~3 mn	19 30	±48	-25	±12	14	-19	1	Quite detailed	Fair	XB25,CS24,H0177
28	393 Feb/Mar	~7 mn	17 18	±27	-40	±4	350	-02	1	Quite detailed	Fair	XB26,CS25,H0179
29	396 -	>50 dy	4 28	±4	+24	±6	178	-20	1	Detailed	Fair	XB27,CS26,H0182
30	415 Jul 20	-	3 45	±20	+20	±5	169	-27	3	Very brief	Poor	XB28, - H0187

31	419	Feb 17	-	11 20	±20	+10	±10	247	+62	3	Very brief	Fair	XB29, - H0192
32	421	Jan/Feb	-	11 38	±40	-18	±15	279	+41	3	Very brief	Poor	XB30,CS28,H0194
33	436	Jun 21	-	16 10	±3	-26	±10	349	+19	3	Very brief	Poor	XB31, - H0199
34	437	Feb 26	-	6 40	±28	+20	±9	194	+07	2	Detailed	Fair	XB32,CS29,H0200
35	541	Feb/Mar	-	0	±12h	+90	±25	122	+26	3	Very brief	Poor	XB33,CS32,H0220
36	561	Sep 26	-	11 38	±40	-18	±15	279	+41	3	Very brief	Poor	XB34,CS33,H0224
37	575	Apr 27	-	14 16	±20	+19	±5	15	+69	3	Very brief	Poor	XB35, - H0231
38	588	Nov 22	-	20 34	±13	-15	±10	30	-29	3	Very brief	Poor	XB36, - H0235
39	642	Aug 9	-	16 36	±	-19	±	359	+19	3	Very brief	Good (Moon)	- - H0247
40	708	Jul 28	-	3 14	±31	+27	±5	158	-26	3	Very brief	Fair	XB39, - H0262
41	709	Sep 16	-	0	±12h	+90	±25	122	+26	3	Very brief	Poor	XB40, - H0263
42	722	Aug 19	5 dy	1 24	±80	+57	±10	127	-6	2	Brief	Fair	XB41,CS36,H0266
43	725	Feb 11	-	1 32	±52	+70	±5	125	+07	3	Very brief	Poor	XB42, - H0267
44	745	Jan 8	-	2 5	±30	+42	±9	137	-19	3	Very brief	Poor	XB44, - H0271
45	829	Nov/Dec	-	10 52	±12	+22	±3	217	+62	3	Very brief	Poor	- CS37,H0288
46	837	Apr 29	23 dy	6 51	±27	+13	±3	200	+06	1	Detailed	Fair	XB45,CS38,H0291
47	837	May 3	46 dy	(12 15, 0; 12 3,+6; 11 45,+6; 11 57, 0)				275	+63	1	Detailed	Good	XB46,CS39,H0291
48	837	Mar 22	-	18 2	±10	-24.5	±3.5	6	-01	2	Brief	Fair	- CS40,H0291
49	891	May 11	-	16 31	±2	-16.6	±0.5	0.2	+21	2	Brief	Good	XB49,CS42,H0313
50	902	Mar	~1 yr	2 43	±78	+77	±7	130	+15	2	Brief	Poor	XB50,CS43,H0320
51	911	May/Jun	-	17 15	±4	+14.4	±1	36	+28	3	Very brief	Good	XB51,CS44,H0324
52	1006	Apr 3	16 mn	15 3	±0.5	-42	±1	328	+14	1	Very detailed	Good	XB53,CS45,H0356
53	1011	Feb 8	-	19 16	±9	-28	±3	10	-17	3	Very brief	Fair	XB54,CS46,H0358
54	1054	May 20	2 yr	5 38	±5	+21	±1.5	186	-06	1	Very detailed	Good	XB57,CS48,H0375
55	1065	Aug 1	-	-		-		-	-	3	Very brief	No	XB58, - H0379
56	1065	Sep 11	-	9 20	±40	-25	±5	254	+17	3	Very brief	Uncertain	XB58,CS49,H0379
57	1070	Dec 25	-	2 45	±40	+4	±8	169	-49	3	Very brief	Poor	- CS51,H0382
58	1073	Oct 9	-	0 35	±22	+5	±10	118	-43	2	Brief	Fair	XB59,CS52,H0383
59	1074	Aug 19	-	0 35	±22	+5	±10	118	-43	2	Brief	Fair	- - H0384
60	1082	Aug 4	-	0	±12h	+90	±5	122	+26	2	Brief	Fair	- - -

61	1113 Aug 15	-	23 39 ±34	+15 ±20	98	-44	3	Brief	Fair	XB60, - H0394
62	1123 Aug 11	-	12 30 ±12	+55 ±6	130	+62	3	Very brief	Poor	XB61, - H0395
63	1138 Jun/Jul	-	2 19 ±24	+20 ±10	150	-38	3	Very brief	Poor	XB62,CS54,H0403
64	1139 Mar 23	-	14 32 ±19	-10 ±20	340	+46	3	Very brief	Poor	XB63,CS55,H0404
65	1163 Aug 10	-	17 34 ±5	-21.5±0.5	5	+06	2	Very brief	Good (Moon)	- CS56,H0411
66	1175 Aug 10	6 dy	(16 40,+57; 15 30,+57; 16 40,+50; 15 30,+42)		78	+50	1	Detailed	Good	XB64,CS57,H0413
67	1181 Aug 6 -1182 Feb 6	185 dy	(0 57,+62; 1 55,+62; 0 57,+67; 1 15,+67)		128	+02	1	Very detailed	Good	XB65,CS58,H0415
68	1203 Jul 28	10 dy	17 29 ±36	-38 ±5	350	-02	1	Detailed	Fair	XB66,CS59,H0419
69	1220 Dec/ 1221 Jan	-	12 30 ±60	+55 ±6	130	+62	3	Very brief	Poor	XB67, - H0424
70	1224 Jul 11	-	17 29 ±36	-38 ±5	350	-02	3	Brief	Poor	XB68,CS60,H0427
71	1240 Aug 17	-	17 29 ±36	-38 ±5	350	-02	3	Very brief	Poor	XB70,CS61,H0433
72	1356 May 3	-	5 51 ±3	+27.8±.5	182	+0.3	2	Very brief	Good (Moon)	- CS62,H0460
73	1399 Jan 5	-	18 52 ±2	-20.1±.5	15	-08	2	Very brief	Good (Moon)	- CS64 -
74	1399 Oct 7	-	-	-	-	-	3	Very brief	Very poor	- - H0486
75	1408 Jul 14	-	-	-	-	-	3	Extremely brief	No	- - H0492
76	1408 Oct 24	-	19 54 ±21	28.5±3.5	65	+0.4	2	Detailed	Fair	- CS65,H0490
77	1430 Sep 3	26 dy	(7 26,+10; 7 31,+11; 7 47, +7; 7 41, +5)		211	+13	1	Detailed	Good	XB74,CS66,H0501
78	1437 Mar 11	14 dy	16 53 ±2	-41.9±0.5	343	+1.3	1	Detailed	Very good	XB75,CS68,H0508
79	1460 Feb/Mar	-	11 38 ±38	-18.3±25	280	+41	3	Very brief	Poor	XB77,CS69 -
80	1572 Nov 8	18 mn	0 35 ±10	+63 ±2	121	+0.2	1	Extensive	Good	XB79,CS70,H0565
81	1584 Jul 11	-	16 10 ±11	-26 ±25	349	+19	3	Very brief	Poor	XB80,CS71,H0572
82	1592 Nov 28	15 mn	1 51 ±2	-10.4±.5	166	-68	1	Extensive	Very good	XB81,CS72,H0577
83	1592 Nov 30	4 mn	0 57 ±2	+59.9±.5	124	-03	1	Extensive	Very good	XB83,CS74,H0577
84	1592 Dec 4	3 mn	0 09 ±4	+59.1±1	118	-03	1	Very detailed	Good	XB83,CS74,H0577
85	1592 Dec 12	1 mn	1 0 ±20	+42 ±5	125	-21	2	Brief	Poor	XB83,CS74,H0577
86	1604 Oct 10	1 yr	17 35 ±10	-17 ±5	7	+07	1	Extensive	Very Good	XB85,CS75 -
87	1690 Sep 29	2 dy	18 35.5±.2	-34.1±.1	0.5	-12	1	Detailed	Very Good	XB90 - -

N.B. Values given inside brackets for the location are the coordinates of the error box.

relatively good position or a duration of more than two days is mentioned. Category 3 records are generally very brief, sometime ambiguously stated with few details. In addition, those records mention only a *po* star was seen without any further comments have been placed in category 3.

4.8 Preliminary Analysis

In this section only a preliminary analysis of the data listed in Table 4.5 is given; a more detailed treatment of those well observed new stars will be given in the next chapter. The temporary stars selected in this catalogue are based principally on their reliability and fairly well defined positions. The accuracy of individual positions of new stars is given with errors. These positions have been deduced after a careful examination of the original records. Very often, the positions are not specified accurately in the records, only a rough location is given with respect to the nearest asterism. It is unavoidable that the errors associated with these positions are very large.

Fig. 4.11 shows a galactic distribution of all new stars from the present catalogue together with the distributions of novae and SNRs for comparison. The histogram of new stars shows a fairly isotropic galactic distribution, though there is some slight concentration towards the galactic equator – these are the SN candidates.

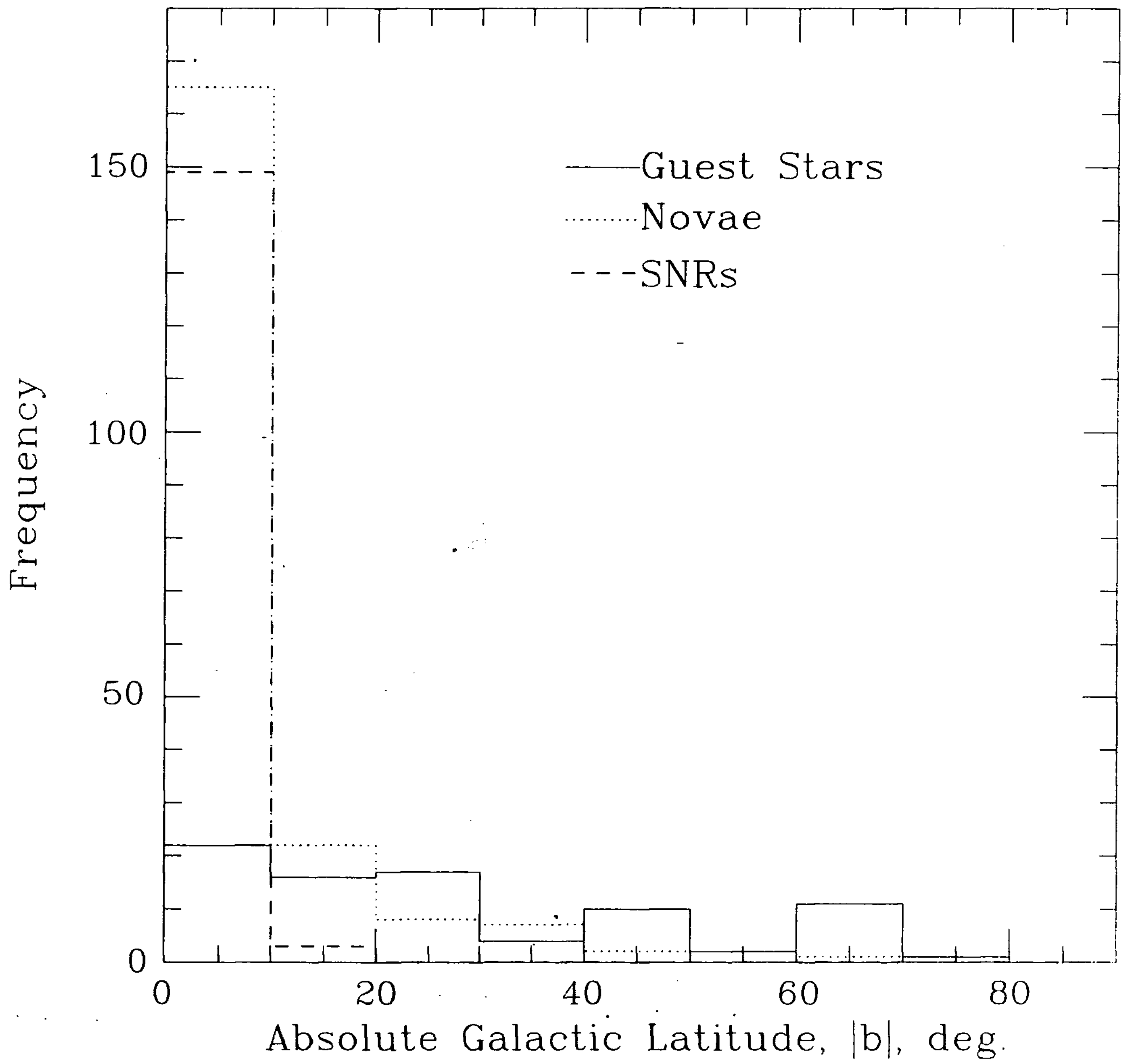


Fig. 4.11 The galactic distribution of new stars from Far Eastern sources together with the distributions for SNRs and novae.

CHAPTER 5

POSITION OF NOVA AND SUPERNOVA CANDIDATES

5.1 Introduction

Of the eight likely supernovae of AD 185, 386, 393, 1006, 1054, 1181, 1572 and 1604 that have been discussed in detail by Clark and Stephenson (1977), only four of them are claimed to be positively identified; the other four are still regarded as only possible or probable events (Table 5.1). Whereas in the case of historical novae, there is not yet a single positive identification of pre-telescopic new star sightings with any remnants.

In the past decade, progress in the investigation of historical novae and supernovae is mainly built upon the definitive work of Clark and Stephenson (1977). Notable efforts made by recent researchers tend to concentrate more on re-examining existing records than on reporting new ones (Stephenson and Yau, 1986; Huang, 1986). The foremost problem now facing researchers is in the quest for a better determination of the location of these outbursts. Only recently, Huang and Moriarty-Schieven (1987) proposed that the location of the AD 185 'guest star' as deduced by Clark and Stephenson (1977) was in error and that the identification of its associated remnant is incorrect.

In view of the amount of information that has been accumulated during the last decade or so on these subjects, there is now an urgent need for a closer look at some of these outstanding issues. The present investigation will place emphasis on the positional accuracy of new stars. I will first discuss the records of the SNe and then those of the novae. The order of this chapter follows more or less chronologically the order of appearance of the new stars. Only those well recorded new stars with a reasonably good position are analysed. In each case I have studied other astronomical records in the same

Table 5.1 Historical galactic supernovae and their remnants.

Supernova	Duration	Mag	SN Type	Remnant	l (°)	b (°)	Size (′)	α	Flux (1 GHz)	Shell type	Distance kpc
SN 185	20 mn	-8	II	RCW 86	315.4	-2.3	40	0.6	46	S	2.5
SN 386	3 mn	+1	-		11.2	-0.3	4	0.55	22	S	>5
SN 393	7 mn	-1	-	CTB 37A	348.5	+0.1	10	0.3	65	S	>6
			-	CTB 37B	348.7	+0.3	18	0.3	24	S	>6
SN 1006	16 mn	-9	I?	PKS 1459-41	327.6	+14.6	30	0.6	19	S	~1.2
SN 1054	24 mn	-4	I/II?	Crab	184.6	-5.8	6x4	0.30	1000	F	2.0
SN 1181	185 dy	0	II?	3C58	130.7	+3.1	9x5	0.10	33	F	8
SN 1572	18 mn	-4	I	Tycho's SN	120.1	+1.4	8	0.61	56	S	3
SN 1604	12 mn	-2.5	I	Kepler's SN	4.5	+6.8	3	0.64	20	S	~8
SN 1667?	?	?	II	Cas A	111.7	-2.1	5	0.77	2700	S	2.8

historical source in considerable detail in order to interpret the record in question with more reliability.

5.2 Guest Stars of the First Millennium AD

5.2.1 SN 185

The new star which appeared in AD 185 Dec 7 is regarded as a SN and was associated with the remnant G315.4–2.3 (RCW 86) by Clark and Stephenson (1977). Huang and Moriarty-Schieven (1987) however suggested that the remnant RCW 86 is not related to the guest star of AD 185 and the visible duration is only of 7 months instead of 20 months. They argued also that the location of the guest star should be between β and υ Cen, rather than between α and β Cen as deduced by Clark and Stephenson (1977).

The record of the new star of AD 185 is given in chapter 20 of the *Hou Han-shu*: "On day *kuei-hai*, the 10th month of the 2nd year of the Chung-p'ing reign-period (AD 185 Dec 7). A guest star appeared within *Nan-men*. It was as large as a half of a mat and had a scintillating variegated colour. It became smaller and disappeared in the 6th month of the 'following year' (*hou-nien*)."

I have translated the term *hou-nien* here as 'the following year' instead of 'the year after next' as given in Clark and Stephenson. Huang and Moriarty-Schieven (1987) quite rightly pointed out that the usage of *hou-nien* could simply be a shortened form of *hou-i-nien* (one year later) from examination of the usage in the same text – the *Hou-han-shu Astronomical Treatise*. Nevertheless, a 7 month duration of visibility is still characteristic of a SN. I however do not support the interpretation by Huang and Moriarty-Schieven (1987) of the location of the new star as between β and υ Cen. The asterism *Nan-men* (Fig. 5.1) should have been fairly prominent in the southern sky observable from Lo-yang – the capital city of the Later Han Dynasty. From a study of

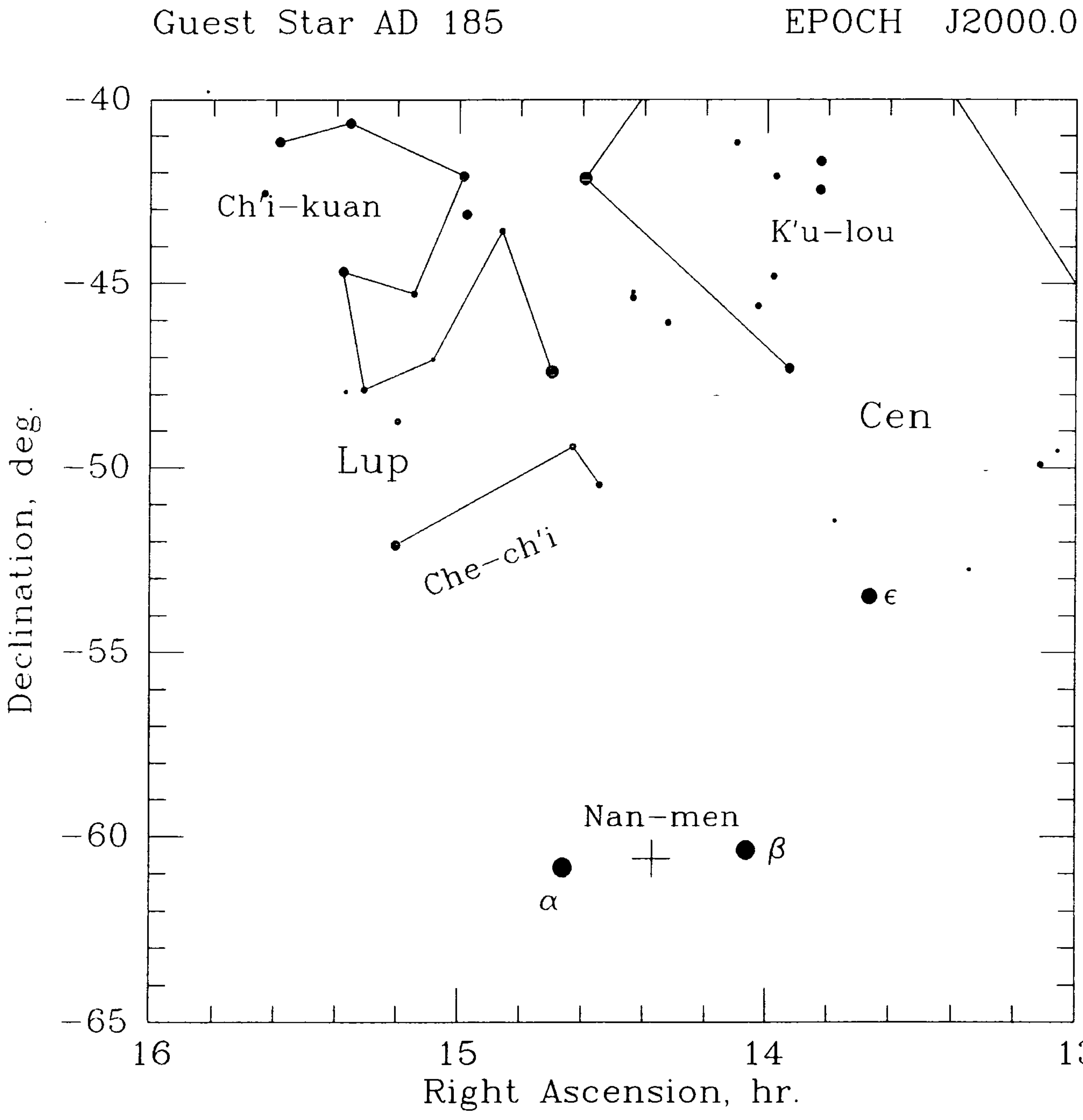


Fig. 5.1 A star map showing the region of sky in the vicinity of the guest star AD 185, the cross indicates the approximate location of the guest star.

early star maps – e.g. the Suchow Star Map – the location of the two stars designated as *Nan-men* always have a similar declination. Further, the brightness of the two stars is depicted by the same symbol representing brightness in the star charts of the *Ku-Chin T'u-shu Chi-ch'eng* (a Chinese Empirical Encyclopaedia of the early 18th century). If the two were of dissimilar brightness as in the case between β and υ Cen, the markers for the two stars should have been different.

The analysis given by Clark and Stephenson (1977) is particularly careful on this issue. A location between alpha and beta Cen seems to be the correct interpretation. So far, the remnant G315.4–2.3 (RCW 86) is still the best candidate for the new star of AD 185. Albeit other candidates have also been proposed, Webster (1978) suggested the AD 185 new star to be the expulsion of the shell in the unusual planetary nebula He 2–111.

5.2.2 SN 386

The AD 386 guest star occurred sometime in the 3rd month (Apr 15 to May 14) of the 11th year of the T'ai-yuan reign-period. The text reads, "A guest star was at (*tsai*) *Nan-tou*. It lasted until the 6th month (Jul 13 to Aug 10) and then disappeared." The entry is found both in chapter 13 of the *Chin-shu* and chapter 25 of the *Sung-shu*.

The record for the new star of AD 368 is a relatively poor one compared with some of the records in Table 4.5. Apart from a longish duration of some three months, there is not much of a clue to confirm a SN sighting. Even the position of the star is subject to interpretation of the record. The preposition *tsai*, used to indicate place, can mean either as 'at' or 'in' *Nan-tou*. *Nan-tou* is the 8th Lunar Mansion (see Table 2.4) between the *Chi* and *Niu* Lunar Mansions. It is an easily recognised asterism and there is no problem of identifying its constituent stars. Whether the description meant a position near the asterism *Nan-tou* or somewhere in the range of R.A. defined by the Lunar Mansion of *Nan-tou* is however uncertain and open to interpretation.

Take the first case, if the new star of AD 386 was meant to have a position somewhere near the asterism of *Nan-tou*, then the radio/X-ray source G11.2–0.3 would be a highly probable remnant of the new star as suggested by Clark and Stephenson (1977). On examining VLA radio maps of G11.2–0.3, Ann Downes (1984) noted that it was a very nearly circular remnant – and presumably young. She hence claimed that the source was a strong candidate for the 386 guest star. On the other hand, if the position was intended as somewhere within the Lunar Mansion of *Nan-tou* then the location of the new star is too vague for a deduction of the position to be made.

5.2.3 SN 393

The guest star of AD 393 is also reported both in chapter 13 of the *Chin-shu* and chapter 25 of the *Sung-shu*. The text says that during the 2nd month (Feb 27 to Mar 28) of the 18th year of the T'ai-yuan reign-period, "A guest star was seen within *Wei* (LM6). It lasted until the 9th month (Oct 22 to Nov 19), and then it was extinguished."

The record gives a period of visibility of about 8 months and although the description is rather brief, no movement of any kind is implied. The region described as within *Wei* corresponds to the southern part of the constellation of Scorpius (Fig. 5.2). It so happens the galactic equator passes through this region of *Wei* thus making the record that much more interesting. (We may recall from the previous chapter that SNe occur fairly close to the galactic equator). There are 7 SNRs catalogued within this area of the constellation of Scorpius. Some of these remnants are of low surface brightness and large angular diameter which suggest old age. I agree with the deduction by Clark and

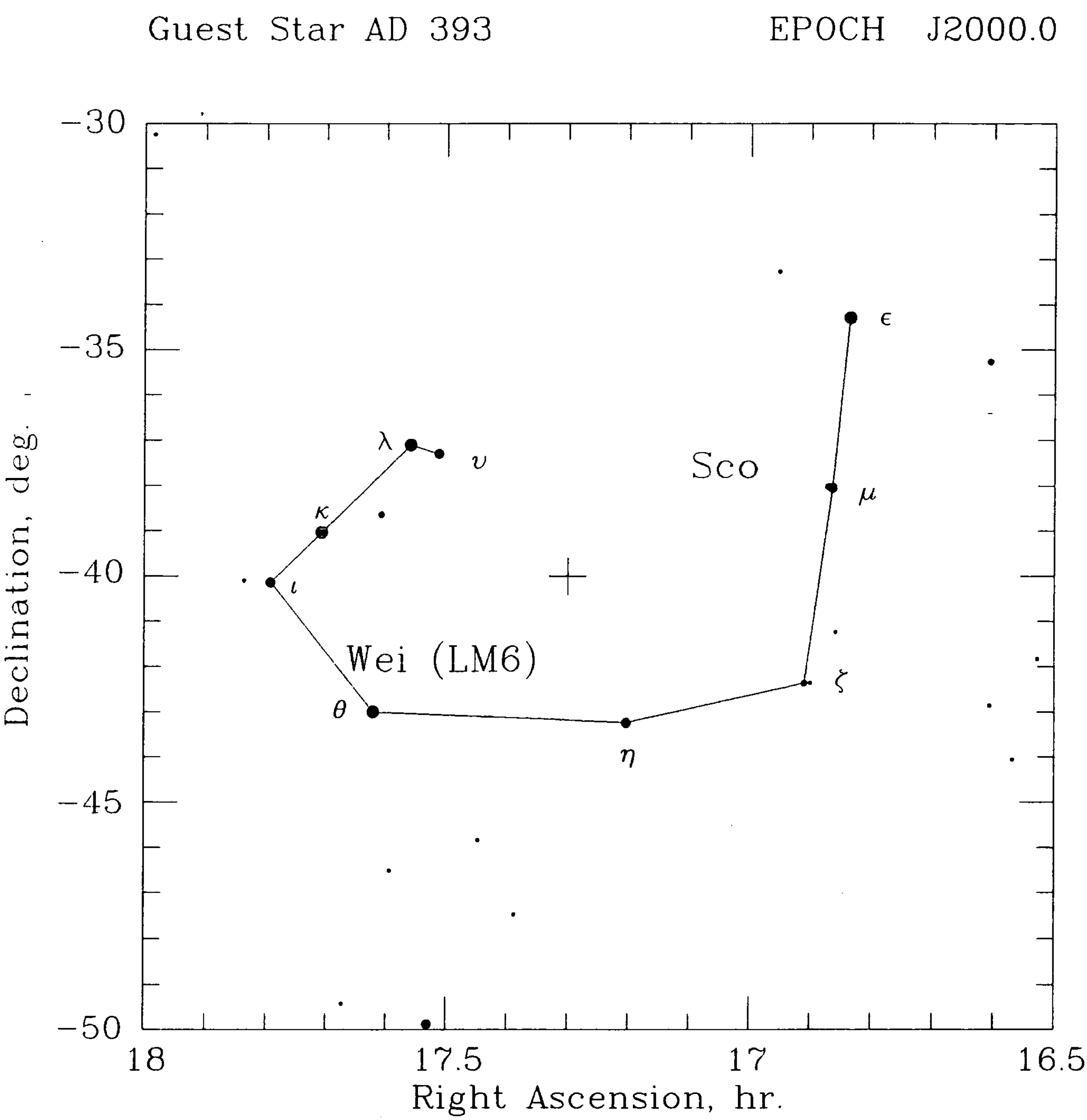


Fig. 5.2 A star map showing the region of sky in the vicinity of the guest star AD 393, the cross indicates the approximate location of the guest star.

Stephenson (1977) that one of the two likely sources G348.5+0.1 and G348.7+0.3 could be the remnant to the new star of AD 393.

5.3 The Sung Dynasty Guest Stars

By the Sung Dynasty (AD 960–1279) Chinese astronomy was at one of her highest stages of development with teams of skillful observers working in a relatively well organised astronomical bureau. It is thus no coincidence that three of the best recorded new stars: AD 1006, AD 1054 and AD 1181 should have been observed and recorded by astronomers of this period. I shall examine here some of the issues attending to the three SNe from this period.

5.3.1 SN 1006

Before discussing SN 1006, the records for the new star are first given below:

> (a) 1006 May 6 – 1007 Sep (China)
> Ching-te reign-period, 3rd year, 4th month, day *wu-yin*. "A *Chou-po* star appeared 1° west of *Ch'i-kuan* to the south of *Ti* (Lunar Mansion). Its shape was like a half Moon and it had horned rays. It was glittering so intensely such that one could see things in detail. It was continually at the east of *K'u-lou*, and in the 8th month it followed the celestial sphere and entered the horizon. In the 11th month, it was again seen at *Ti* (Lunar Mansion). Thereafter it was frequently seen in the 11th month in the morning in the SE direction and in the 8th month, it entered the horizon at the SW. (*Sung-shih*, 56)
>
> (b) 1006 May 30 – Nov 26 (China)
> Ching-te, 3rd year, 5th month, day *jen-yin*. "A *Chou-po* star was seen. 11th month, day *jen-yin*, the *Chou-po* star was again seen." (*Sung-shih*, 7)
>
> (c) 1006 May 1 (China)
> Ching-te reign-period, 3rd year. "The Director of the Astronomical

Bureau reported, 'Previously in the 2nd day of the 4th month, at the 1st watch of the night, a large star was seen. Its colour was yellow and it appeared east of *K'u-lou* and west of *Ch'i-kuan*. Gradually, it increased its brightness; it was measured 3 degrees (*tu*) from *Ti*.' " (*Sung-hui-yao*)

(d) 1006 May 1 (Japan)
Kanko reign-period, 3d year, 4th month, 2nd day, *kuei-yu*. "At nightfall, there was a large guest star within *Ch'i-kuan*. It was like Mars and its light was scintillating. For consecutive nights it was seen in the S direction. Or it was said that the *Ch'i-ch'en Chiang-chun* star had changed its body and increased its brightness." (*Meigetsuki*, 3)

(e) 1006 Apr 28 (Japan)
Kanko reign-period, 3d year, 3rd month, day *wu-tzu* (read *keng-wu*). "A guest star entered *Ch'i-(kuan)*. Its colour was whitish-blue. The astronomical doctor Abe Yoshimasa reported it." (*Ichidai Yoki*)

In addition to the Far Eastern sources, there are five Arabic and six European records. The Islamic chronicles examined by Goldstein (1965) give an important positional information. The most accurate position is described by Ali ibn Ridwan of Fustat (Egypt), in a commentary on Ptolemy. He regarded the star as a bad omen and blamed it for the 'calamity and destruction' which persisted many years afterwards. He stated that, "the star was in the 15th degree of Scorpius" and added, "This spectacle was a large circular body $2\frac{1}{2}$ to 3 times as large as Venus (the brightest of the planets). The sky was shining because of its light. The intensity of its light was a little more than a quarter of that of moonlight."

The six European records known to contain information on the AD 1006 new stars are: (i) *Annales Beneventani*, (ii) *Annales Sangallenses Maiores*, (iii) *Annales Laubienis*, (iv) *Iohannis Chronicon Venetum*, (v) *Alpertus de Diversitate Temporum*, Lib.I, (vi) *Annales Mosomagenses* (Porter, 1974; Clark and Stephenson, 1977). These Latin chronicles are all from the compilation of chronicles *Monumenta Germaniae Historica*

(Pertz, 1826 onwards). Apart from a definitive statement regarding position given in the *Annales Sangallenses Maiores* from St Gallen in Switzerland, nothing else was added by the other five chronicles.

The quotation given in record (c) comes from the *Sung-hui-yao*, the earliest of the Chinese sources. It stated that the position reported by the Director of the Astronomical Bureau as 3 degrees (*tu*) into *Ti* (Fig. 5.3). A system of 365.25° in a circle was used in Chinese measurement. Hence the *tu* is slightly less than 1° (0.9856°). As already mentioned in chapter 3, the two reference coordinates in the Chinese system of referencing star positions were: (i) RA was obtained by measuring eastwards from one of the nearest determinant stars of the 28 lunar mansions and (ii) Dec was obtained by measuring the angular distance from the North Celestial Pole. The distance of 3 degrees from *Ti* is equivalent to 11.8^m from the determinant star. The determinant star of *Ti* Lunar Mansion is α^2 Lib which has RA: $14^h50.88^m$ (see Table 2.4). Hence the expected right ascension of SN 1006 is $15^h2.7^m$ (epoch J2000.0). Only two SNRs are situated near the location indicated by the various observers, these are the Lupus Loop and PKS14-59. The position of PKS14–59 is RA: $15^h2.77^m$ and Dec: $-41°55.8'$. I am confident that PKS14–59 is the remnant to the guest star 1006.

5.3.2 SN 1054

(a) 1054 Jul 4 – 1056 Apr 6 (China)
Chih-ho reign-period, 1st year, 5th month, day *chi-ch'ou* (26). "A guest star appeared about several ts'un SE of *T'ien-kuan*. After more than a year it gradually disappeared." (*Sung-shih*, 56)

(b) 1056 Apr 6 (China)
Chia-yu reign-period, 1st year, 3rd month, day *hsin-wei* (8). "The director of the Astronomical Bureau reported, 'Since the 5th month

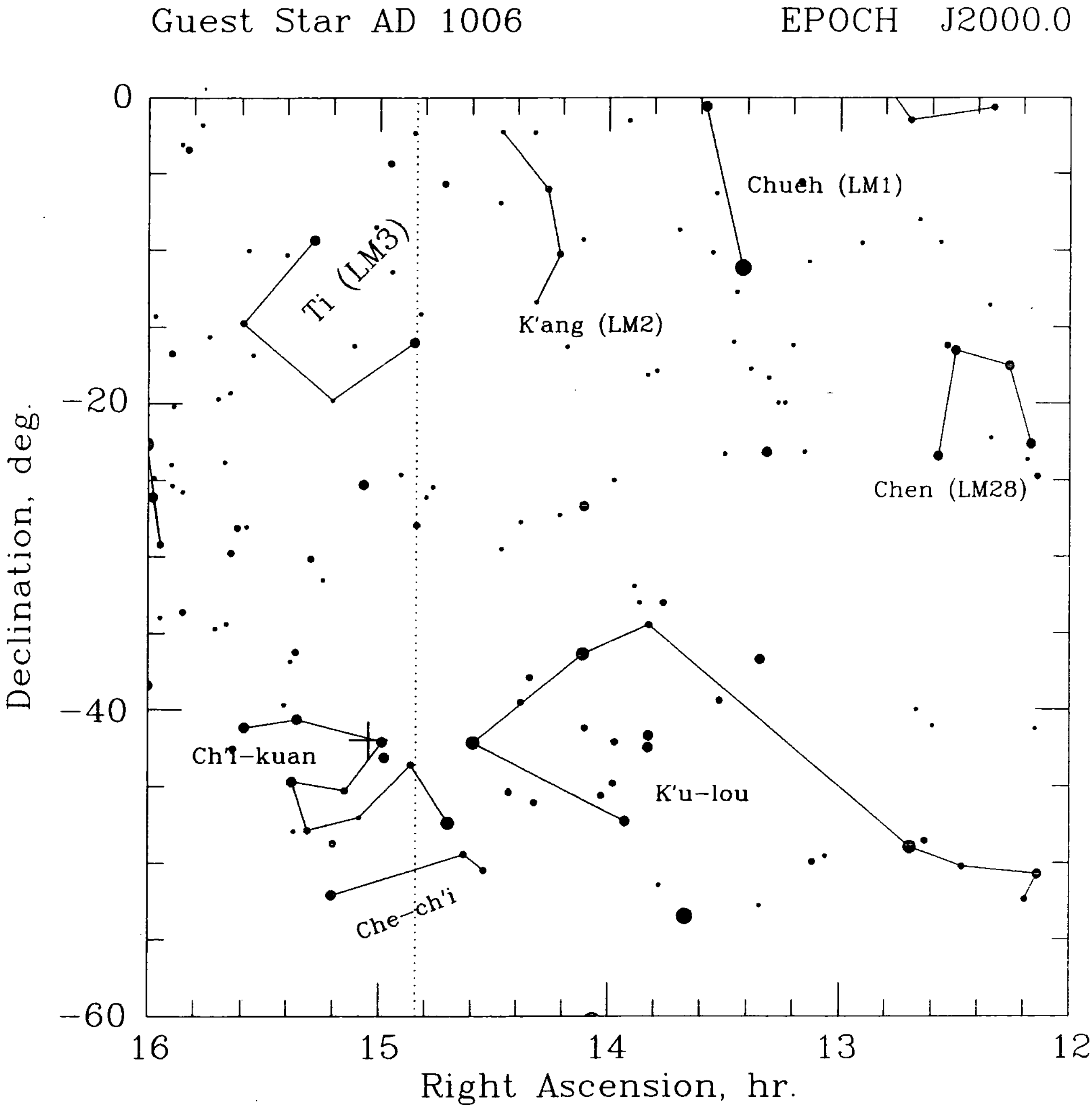


Fig. 5.3 A star map showing the region of sky in the vicinity of the guest star AD 1006, the cross indicates the approximate location of the new star.

of the 1st year of the Chih-ho reign-period, a guest star has appeared in the E direction. It guarded *T'ien-kuan* ever since and now it has disappeared." (*Sung-shih*, 12)

(c) 1054 Aug 27 (China)

Chia-yu reign-period, 1st year, 3rd month. "The Director of the Astronomical Bureau said, 'The guest star had disappeared; an omen for a guest leaving. Early in the 5th of the 1st year of Chih-ho reign-period, (the guest star) appeared in the E direction in the morning, and guarded *T'ien-kuan*. It was seen during day-time like Venus with horned rays in all directions. It had a reddish-white colour and lasted for a total of 23 days." (*Sung-hui-yao*)

(e) 1054 Jul 4 (China)

Chih-ho reign-period, 1st year, 5th month, day *i-ch'ou*. "A guest star appeared about several *ts'un* (1 *ts'un* $\sim 0.1^\circ$) SE of *T'ien-kuan*." (*Hsu-tzu-chih T'ung-chien Ch'ang-pien*, 176)

(f) 1054 May 20 – 29 (Japan)

Tengi reign-period, 2nd year, 4th month. "After the middle decade (of the month), at the hour of *ch'ou* (1–3 a.m.), a guest star appeared in the degrees of *Tsui* and *Shen* Lunar Mansions. It was seen in the E direction and emerged (*po*) at the *T'ien-kuan* star. It was as large as Jupiter." (*Meigetsuki*, 12)

(g) 1054 May 1? – 29 (Japan)

Tengi reign-period, 2nd year, 4th month. "A guest star appeared in the degrees of *Tsui* and *Shen* Lunar Mansions. It was seen in the E direction and emerged (*po*) at the *T'ien-kuan* star. It was as large as Jupiter." (*Ichidai Yoki*, 1)

The ambiguity in position of the AD 1054 guest star has long been the centre of discussion – ever since it was first pointed out by Dujvendak *et al.* (1942). The contradictions in position even led Ho Peng-Yoke *et al.* (1970) to doubt whether the object of AD 1054 was related to the Crab Nebula. The discrepancy in position is due to a statement in one of the records that the guest star was "about several *ts'un* SE of

T'ien-kuan". However the position of the Crab Nebula based on modern measurement is clearly to the north-west of *T'ien-kuan*.

First, a few words about the distance of "about several *ts'un*". The unit of *ts'un* was a linear measure in daily usage, however in astronomical usage, it was taken to mean a subdivision of the angular unit *tu*. Various authors have discussed and analysed planetary data in order to establish whether an exact relation existed (Stephenson, 1971a; Kiang, 1972). The general consensus is that 1 ts'un is about 0.1°. Hence "about several *ts'un*" can be taken to mean about 0.5°. I have calculated the separation between *T'ien-kuan* and the Crab Nebula and found them separated by 1.2°. Despite the difference between the two results, we may just tolerate that they are roughly of the same magnitude. The important issue here is not the separation but the wrong direction.

The report of an erroneous direction first appeared in Li Tao's well known work the *Hsu-tzu-chih T'ung-chien Ch'ang-pien* – completed in AD 1168. This mistake was copied unaware by the compilers of the *Sung-shih Astronomical Treatise* (completed AD 1345) and *Wen-hsien T'ung-k'ao* (completed AD 1307) (Wang, 1977 and Bo *et al.* 1978). Whereas an earlier work the *Sung-hui-yao* (completed AD 1081) containing direct observational records of the imperial astronomers does not make this mistake. Although it is not known where Li Tao obtained his information, it is unlikely to be the original records kept by the court astronomers. For the capital city of the Northern Sung Dynasty – Kai-feng – has already fallen to the Kin Tartars in AD 1127 and any archives would presumably have remained behind. Since the guest star was close to *T'ien-kuan* it would have been difficult for an amateur to distinguish which was the guest star and which was *T'ien-kuan* without knowing before hand the position of *T'ien-kuan*.

In spite of the above argument, the detail given in the *Sung-hui-yao* alone is sufficient to establish the nature of the AD 1054 guest star. I strongly believe that the Crab Nebula was the remnant of the AD 1054 guest star.

5.3.3 SN 1181

(a) AD 1181 Aug 6 to 1182 Feb 6 (China)
Shun-hsi reign-period, 8th year, 6th month, day *chi-szu* (6). "A guest star appeared in the *K'uei* Lunar Mansion. It invaded *Ch'uan-she.* Until day *kuei-yu* (10) in the 1st month of the next year, after a total of 185 days, then it was extinguished." (*Sung-shih*, 56)

(b) AD 1181 Aug 6 (China)
Shun-hsi reign-period, 8th year, 6th month, day *chi-szu.* "A guest star appeared in the *K'uei* Lunar Mansion. It invaded *Ch'uan-she.* On day *chia-hsu*, the guest star guarded the 5th star of *Ch'uan-she.* On day *kuei-yu* in the 1st month of the 9th year (of the Shun-hsi reign-period) the guest then was not seen. From day *chi-szu* in the 6th month of the previous year until now after a total of 185 days it finally disappeared." (*Wen-hsien T'ung-k'ao*)

(c) AD 1181 Aug 11 (Northern China)
Ta-ting reign-period, 21st year, 6th month, day *chia-hsu* (11). "A guest star was seen at *Hua-kai.* After a total of 156 days it was extinguished." (*Kin-shih*, 20)

(d) AD 1181 Aug 7 (Japan)
Jisho reign-period, 5th year, 6th month, 25th day, *keng-wu* (7). "At the hour of the *hsu* (7–9 p.m.), a guest star was seen in the N direction near *Wang-liang* and guarding *Ch'uan-she.*" (*Meigetsuki*, 3)

(e) AD 1181 Aug 7 (Japan)
Jisho reign-period, 5th year, 6th month, 25th day, *keng-wu* (7). "At the hour of the *hsu* (7–9 p.m.), a guest star was seen in the NE direction.

It was like Saturn. Its colour was bluish-red and it had horned rays."
(*Azuma Kagami*)

This star was only visible for about 6 months and possibly did not reach zero magnitude but there is a close correspondence in position between it and the SNR catalogued as 3C 58. There are two independent Chinese accounts (from the Sung and Kin Empires) and of the several Japanese reports. The important record concerning the position of the guest star contained in the *Wen-hsien T'ung-k'ao* was overlooked by Clark and Stephenson (1977). It stated that the guest star "guarded the 5th star of *Ch'uan-she*". Recently, Liu (1983) has discussed in some detail this particular issue. He deduced that the 5th star of *Ch'uan-she* was GC2379 (i.e. BD+63 265) and thus provided evidence that 3C58 was the remnant to the guest star 1181.

Huang (1986) suggested that the physical properties of the filled centre remnant 3C 58 implied that it may be a relatively old remnant unrelated to AD 1181 event. His reexamination of Chinese and Japanese records indicates that the location is probably nearer HD 9030 than 3C 58. His interpretation is that the guest star could have been a distant SN or a nearby slow nova.

I have re-examined the relevant details given by the various records above. The only accurate position is given by record (b) which indicates that the guest star was guarding the 5th star of *Ch'uan-she.* If the 5th star of *Ch'uan-she* is well established, then record (b) alone will be sufficient to provide us the location of the guest star. However, the exact components of the *Ch'uan-she* asterism remains uncertain due to difficulties in identifying some of its faint components.

I have deduced an error box encompassing all the details given by the above records (Fig. 5.4). Record (a) states that the guest star occurred in the *K'uei* Lunar Mansion which provides a useful left hand side limit for the error box. Record (c) states that the

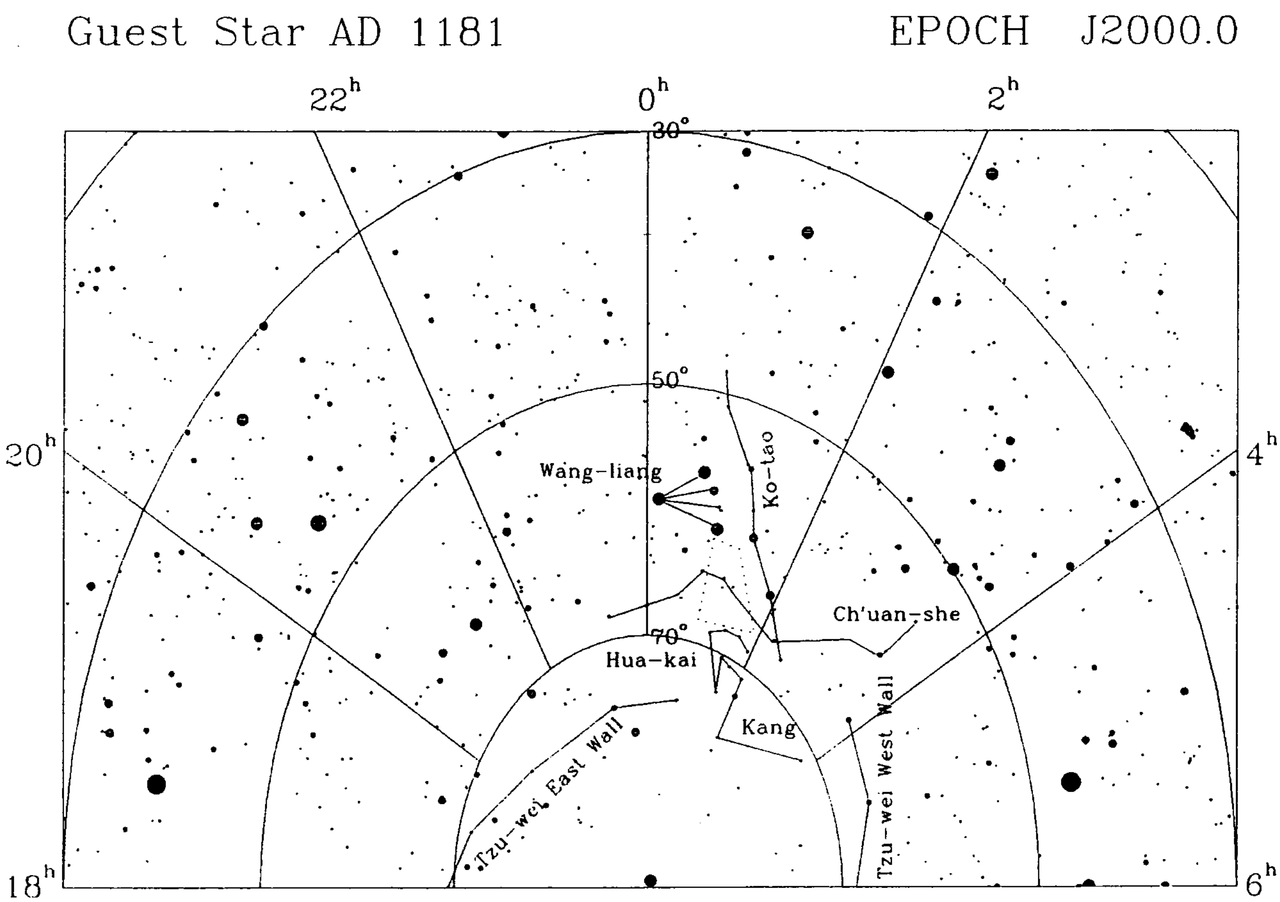


Fig. 5.4 A star map showing the region of sky in the vicinity of the guest star AD 1181, the dotted region represents the error box encompassing the uncertainty in the position of the new star.

guest star was seen at *Hua-kai*, this gives an indication of the bottom side limit of the error box. Record (d) gives the location that the guest star was near *Wang-liang*; this provides the limit on the top side of the error box. The right hand side limit is governed by the boundary separating the *K'uei* Lunar Mansion and the next lunar mansion of *Lou*. No mention of the guest star being close to the *Ko-tao* asterism may suggest that the guest star was not near to it. However the error box deduced here does not include the supposed remnant to the guest star 3C 58; it lies just outside the error box. The remnants which I find in Green's catalogue (1987) situating inside the error box are G126.2+1.6 and G127.1+0.5 respectively.

5.4 The Supernovae of Tycho (SN 1572) and Kepler (SN 1604)

The new stars that occurred in the year AD 1572 and AD 1604 are now very well established. The position recorded for these two new stars by Far Eastern astronomers are far less accurate than their European counterparts, especially the observations of Tycho for AD 1572 and Kepler for AD 1604. I discuss here briefly a few points regarding the positions of these two new stars.

5.4.1 SN 1572

(a) AD 1572 Nov 8 (China)
Lung-ch'ing reign-period, 6th year, 10th month, day *ping-ch'en*. "A guest star was seen in north-eastern direction like a pellet. It appeared beside *K'o-tao* in the degrees of the *Pi* Lunar Mansion (LM14). Gradually, it had short bright rays. On the 19th day (*jen-shen*), at night, the above mentioned star was reddish-yellow in colour. It was as large as a cup and its rays were shooting in all directions. Editor: 'It was not until the 2nd month of the 1st year of the Wan-li reign-period that the brightness of this star then gradually began to dim. In the 4th month

of the 2nd year it was then disappeared. A memorandum from the Department of Rites: ... from the 10th month, a guest could be seen in the day, it was extraordinarily brilliant .... " (*Ming-shih-lu*)

(b) AD 1572 Nov/Dec (Korea)
King Sonjo, 5th year, 10th month. "A guest star was seen at (*yu*) *T'se-hsing*. It was larger than Venus." (*Sonjo Sillok*)

This star, which appeared in Cassiopeia, was also seen in daylight by Tycho Brahe. It was sighted in both China and Korea but the European observations – in particular those of Tycho Brahe – are vastly superior. The descriptions given in Far Eastern sources follow the traditional style, developed over many centuries. On the other hand, Tycho Brahe measured the position of the object with remarkable precision (1 arc min) and his estimates of its changing brightness allow a fairly reliable light curve to be drawn.

Discovery took place in Europe on Nov 6 and only two days later the star was sighted in China. (Observers in both regions noted its visibility in daylight). Astronomers in Europe and Korea separately estimated that at maximum the star rivalled Venus – then around magnitude −4.5. Over the succeeding 15 months, Tycho followed its declining brightness, comparing it first with Jupiter and subsequently in turn with stars in each of the then adopted 6 magnitude classes. Fig. 5.5 shows a sketch of the new star ('stella nova') by Tycho in his famous work *De Nova Stella* Fig. 5.6 shows a section of the Cassiopeia plate in Bevis's star atlas, c.1750. The prominent object at bottom centre is the Tycho's star of 1572.

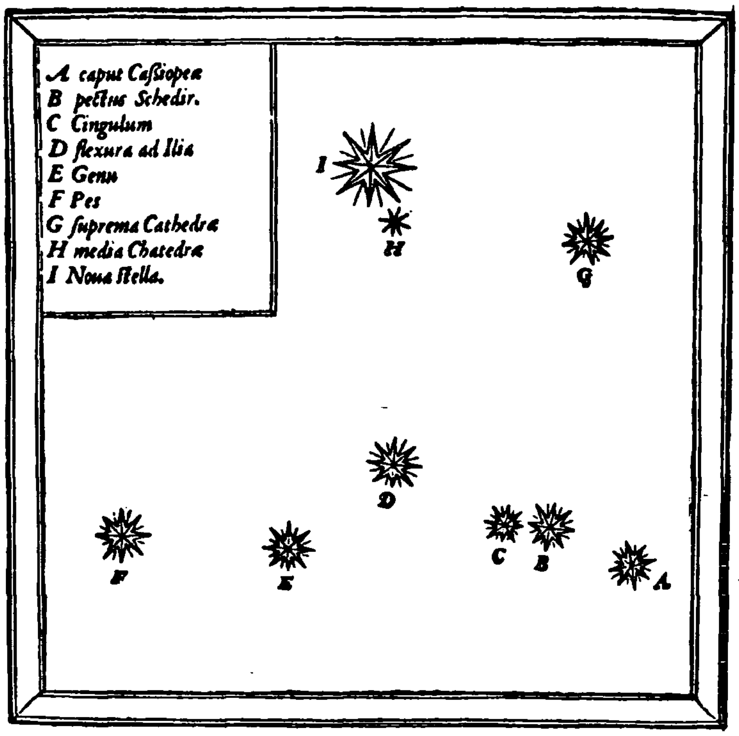


Fig. 5.5 The position of SN 1572 as drawn by Tycho Brahe (from *De Nova Stella*).

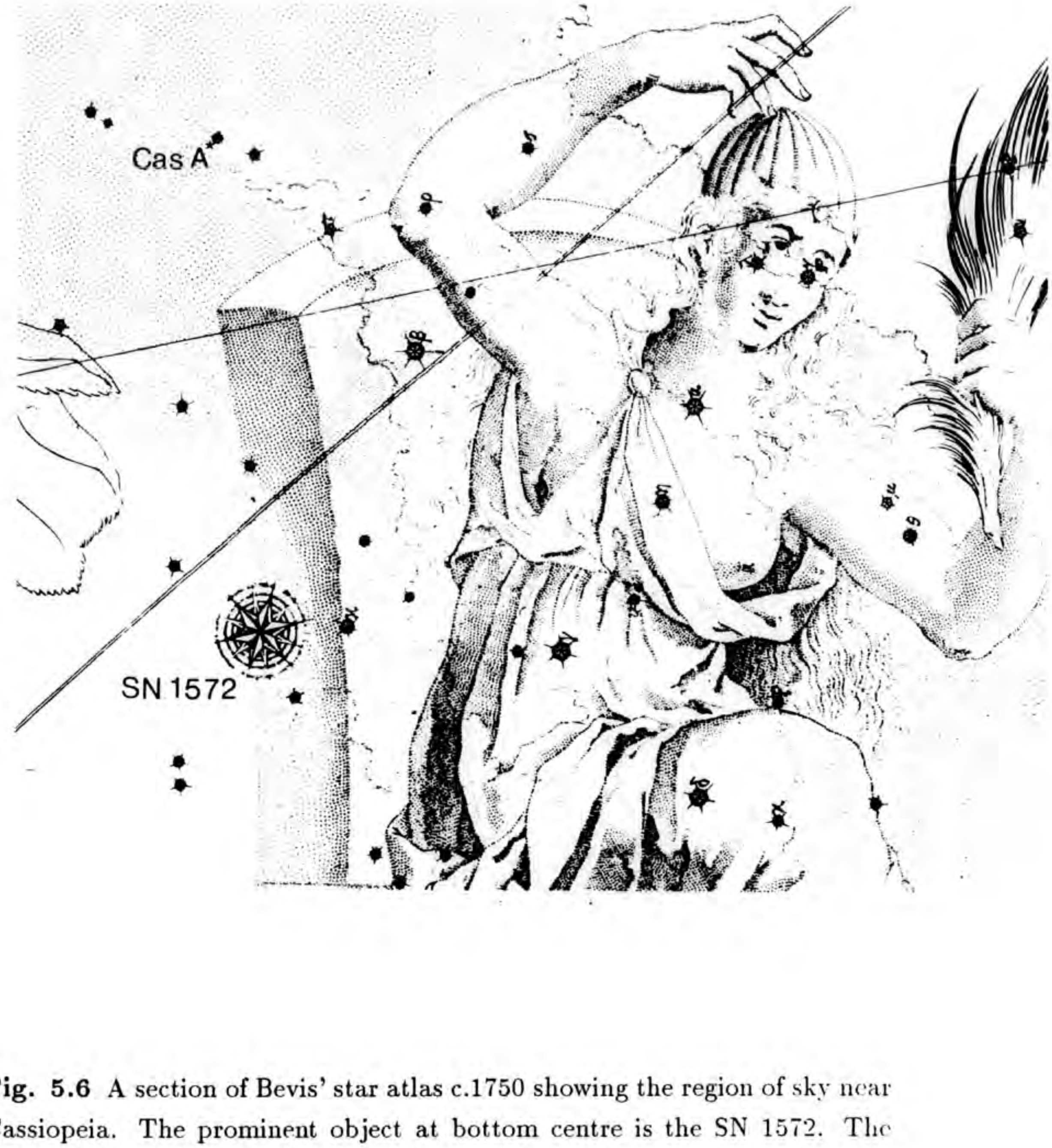


Fig. 5.6 A section of Bevis' star atlas c.1750 showing the region of sky near Cassiopeia. The prominent object at bottom centre is the SN 1572. The position of Cas A is also shown.

5.4.2 SN 1604

(a) AD 1604 Oct (China)

Wan-li reign-period, 32th year, 9th month, day *i-ch'ou* (2). "At night, in the SW direction there produced a strange star. It was as large as a pellet and its body was reddish-yellow in colour. Its name was known as *k'o-hsing*." (*Ming-shih-lu*)

(b) AD 1605 Jan (China)

Wan-li reign-period, 32th year, 12th month, day *hsin-yu* (58). "Tonight, the guest star followed the sky and changed its position, it was now seen in the SE direction. It was as large as a pellet with a yellow colour but its bright rays were becoming small. It situated in the *Wei* Lunar Mansion (LM6)." (*Ming-shih-lu*)

(c) AD 1605 Sep (China)

Wan-li reign-period, 33rd year, 8th month, day *ting-mao* (4). "At night, the guest star was not seen. From the 33rd year, 9th month, the guest star was seen at the division of *Wei* (LM6). At the hours of the 1st watch, it was (always) seen appearing in the SW direction. It followed the motion of the heaven and appeared in the W. In the 10th month, it set in the evening and could not be seen. In the 11th month, in the 5th watch, it was frequently appearing in the SE direction. This year, in the 2nd month, its brightness was dimming gradually. Now, it has extinguished." (*Ming-shih-lu*)

(d) AD 1604 Oct 13 (Korea)

The guest star was first observed on day *wu-ch'en*, in the 9th month of the 37th year of King Sonjo (AD 1604 Oct 13): "In the first watch of the night a guest star was in the 10th degree of *Wei* Lunar Mansion and distant 110 degrees from the pole. Its form was slightly smaller than Jupiter. Its colour was yellowish-red (orange) and it was scintillating. In the 5th watch there was a mist." (*Sonjo Sillok*)

The following night, the position was adjusted to "the 11th degree of *Wei* and distant 109 degrees from the pole" and the details "above

T'ien-chiang" was added. Thereafter on every clear night up to Nov 26, the guest star was reported in this pattern, retaining the revised position, with only occasional changes to the brightness of the star. Between Oct 28 and Nov 5, the guest star was compared with Venus in brightness, and from Oct 28 to 31 the description "its ray emanations were very resplendent" was added which could have suggested that it was at maximum brilliance near this period. After Nov 26, the guest star was not seen for a few days due 'dense clouds'. There are no records of the star between Nov 30 and Dec 3, and by Dec 4 the star would have already set heliacally. The record on this date says: "The guest star was close to the sun. Before dusk, it sank in the west, and could not be observed." The precise date of heliacal setting is uncertain, but it must have been sometime between Nov 27 and Dec 3.

The star reappeared on Dec 27. The record mentions that, "At daybreak, the guest star was seen in the east above the stars of *T'ien-chiang*. It was within the 11th degree of *Wei* and distant 109 degrees from the pole. Its form was larger than Antares. Its colour was orange and it was scintillating". Until Apr 5, a similar record (with minor textual variations) to that of Dec 27 was given on almost every night except when the brightness of the Moon hindered the observation. From Apr 6 onwards, there are only a few reports of the guest star, possibly due to some of the repetative records had been left out by the compilers. The record on Apr 23 follows the same pattern as before, and on May 2 the record states that, "at the 4th watch the guest star was faintly visible through rifts in the clouds". Only three more records were found after this date. Two of these concerned the astrological significance of the guest star. The last reference of the guest star was given on September 15; the record reads: "there were dense clouds and the guest star was not seen." It seems likely that the guest star continued to be observed for a further length of time than given here, maybe comparable with that in China and Europe (i.e. for almost a full year).

Of the Far Eastern observations, only the Korean measurements provide a useful indication of the location of the new star. However, the European measurements by Kepler and Fabricius (Baade, 1943) are so accurate (better than 1 arcmin) that the

Korean measurements are of no more than historical interest. The right ascension (in the 11th degree of *Wei* Lunar Mansion) is fairly accurate but the polar distance (109 degrees from the pole) is nearly 4 deg in error. On Jan 20, AD 1605 (37th year of King Sonjo, 12th month, day *ting-wei*) a remarkable conjunction between Venus and the guest star was noted. Thus, even based on the Korean positional information alone, it is still possible to identify the remnant of the explosion of 1604. In addition, the Korean records help in establishing the optical light curve – see Clark and Stephenson (1977).

5.5 The New Star of AD 1408 – A Spurious Supernova

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(co-authored with F.R.Stephenson)

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The New Star of AD 1408 – A Spurious Supernova?

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SUMMARY

This article discusses via a new reference found from an Imperial Encyclopaedia of AD 1726 the suspected supernova explosion in 1408. The new evidence suggests that temporary stars observed in AD 1408 by the astronomers of China and Japan do not relate to a supernova, as has been claimed. In addition, the historical evidence presented here does not support the linking of these objects with either Cygnus X-1 or CTB 80.

INTRODUCTION

The search of historical astronomical records for events which can be interpreted as supernova explosions has been a continuing theme in recent years. In particular the likelihood of a supernova occurring in AD 1408 has been considered in a number of papers. The initial suggestion was made by Li Qi-bin (1), who discussed several Chinese records of temporary stars seen during the year in question. Li Qi-bin was of the opinion that these related to the same object – a supernova (SN) appearing in Cygnus – and this author further proposed the contemporary object Cygnus X-1 as its remnant. Additional historical records from Japan were examined by Imaeda & Kiang (2), who confirmed that a SN interpretation seemed likely. Following the investigation by Strom *et al.* (3), the radio source CTB 80, rather than Cygnus X-1, has found more general favour as the remnant (4–7). Here we reconsider the historial evidence for a supernova in AD 1408.

FAR EASTERN OBSERVATIONS OF 'NEW STARS' IN AD 1408

Li Qi-bin (1) and Imaeda & Kiang (2) demonstrated that three independent groups of records from Japan, S.W. China (Szechuan province) and the Chinese capital (Nanking) describe new or temporary stars (we make no distinction between these terms) appearing in AD 1408. The dates of these correspond to July 14, September 10 and October 24, respectively. Durations of visibility are not specified and no other reports of new stars appearing in AD 1408 are known to be cited in the literature of China, Japan and Korea. The various descriptions are listed below in chronological order, together with a brief commentary. The key texts are assigned identifying letters (a–d) for further reference.

(1) July 14

Using historical sources listed by Kanda (8) in his catalogue of Japanese astronomical records, Imaeda & Kiang (2) located the following entry in the diary of a Japanese courtier named Noritoki (the *Noritoki Kyo Ki*). The date is specified as the day *wu-hsü*, the 21st day of the 6th month of the 15th year of the Ohei reign period (i.e. AD 1408 July 14):

> (a) 'A 'guest star' (*k'o-hsing*) appeared. The astronomical doctors commented on eight reasons for the evil omen and reported it to the throne; it was an alarming occurrence'.

A later compilation, the *Zokushi Gusho*, summarizes Noritoki's account without providing any additional information. The *Noritoki Kyo Ki* makes no further mention of the star.

(2) September 10

As shown by Li Qi-bin (1), as many as six *Fang-chih* (local gazettes or histories) from Szechuan province contain almost identical records of an unusual star visible during the autumn. The principal local history, the *Szŭ-chuan T'ung-chih*, contains records from much of Szechuan province whereas the other five are concerned with the following areas of Szechuan: Hsü-chow; Ma-pian-t'ing; Ya-chow; Nei-kiang; P'ing-chow.

The *Szŭ-chuan T'ung-chih* and two other histories agree on an exact date. Of the remaining works, one gives the wrong day of the month and two give only the season (autumn) and month (8th). The date given by the three corroborating sources is the day *ping-shen* in the 8th month of the 6th year of the Yung-lo reign period (i.e. AD 1408 September 10). In the fourth case the day is given as *ping-ch'en*, which is presumably an error for *ping-shen* (there was no *ping-ch'en* day in the 8th month). Apart from these minor discrepancies in date, the texts are identical; it is evident that they share a common origin. A translation of the description of the star is as follows:

> (b) 'At night there was a star as large as a cup (*chan*); its colour was pale blue (i.e. bluish-white) and it was bright. It appeared in the W direction'.

Li Qi-bin gives the direction of the star described in the local gazettes as east but in the original texts this is specified as west.

None of these sources provide any record of position or duration and make no subsequent reference to the object. However, the present authors have found that the *Ku-chin T'u-shu Chi-ch'êng* (Book 4 Shu-chêng Tien, chapter 55), an Imperial Encyclopaedia of AD 1726, abstracts from an early version of the *Szŭ-chuan T'ung-chih* and gives additional details as follows:

> (c) 'According to the *Szŭ-chuan T'ung-chih*, 'In the 6th year of the Yung-lo reign period, 8th month, day *ping-shen*, at night there was a star like a large cup. Its colour was pale blue and it had a bright trail (*wei-chi*). It appeared in the W direction and travelled south, entering the horizon''.

In the above account, a transposition of two characters (*ju-ta*) would render the appropriate part of the description 'as large as a cup', i.e. identical with that in the sources consulted by Li Qi-bin.

(3) *October 24*

The *Ming-shih-lu* ('Veritable records of the Ming Dynasty'), a detailed day to day chronicle of China based on the 'Diaries of Activity and Repose' of the Ming Emperors, contains the following report on the day *kêng-ch'en* of the 10th month of the 6th year of the Yung-lo reign period (i.e. AD 1408 October 24):

> (d) 'At night, in the zenith, at the south-east of *Nien-tao* (an asterism in Cygnus and Lyra), there was a star as large as a cup (*chan*). It was yellow in colour and its light had a sheen (*jun*). It emerged (*ch'u*), but it did not move. It was a *Chou-po* ('Earl of *Chou*'), a virtuous star'.

There is no further mention of the star in the chronicle. The above account is copied in the astronomical treatise of the *Ming-shih*, the official history of the Ming Dynasty, compiled during the 17th and 18th centuries. However, this work gives an erroneous year (the 2nd year of the Yung-lo reign period, i.e. AD 1404). In this form the record has found its way into the catalogues of Hsi Tse-tsung (**9**), Ho Peng Yoke (**10**) and Clark and Stephenson (**11**). Other early works which abstract from the *Ming-shih-lu* – e.g. the 17th century *Kuo-chüeh* ('National Archives') and the 18th century *Hsü Wen-hsien T'ung-k'ao* (an historical encyclopaedia) – do not make this mistake. Hence, there is no reason for doubting that the correct year is indeed AD 1408.

INVESTIGATION OF THE RECORDS

In this section, we discuss each of the three sightings – in Japan, SW China and the Chinese capital – separately. Possible links between the various stars will be examined in the following section.

(1) *Japanese Records*

The star seen in Japan on July 14 is described in text (a) as a 'guest star'. This is the general Far Eastern term for a temporary star-like object, usually – but not necessarily – fixed. It is somewhat surprising that several other Japanese sources which report astronomical events around this time, (**8**), make no mention of this or any other new star in AD 1408. Similar remarks also apply to the detailed Korean chronicle of the time – the *T'aejong Sillok* ('Annals of the reign of King T'aejong'). The reign of King T'aejong was a period of considerable interest in portents – Park (**12**). This suggests that the star, whatever its nature, only remained visible for a short period.

(2) *Records from Chinese Local Gazettes*

In each of the six local histories from Szechuan, the reference to the star of September 10 is found in a chapter devoted to ominous phenomena – both celestial and terrestrial. It is in this section that we might expect to find any records of new stars – if noted at all. Although events are usually widely spaced in time, an average interval being perhaps a decade, this does not necessarily imply that only unusual observations were reported. Material included in this chapter varies from the banal to the bizarre. There can be little doubt that such records represent merely a random collection of portents; they are vastly inferior to the much more systematic observations reported in the imperial chronicles and dynastic histories. Mutual comparison between the content of these sections in the individual local gazettes under consideration shows that the material is practically identical; there must have been a single common source for most of the various records.

It is important to point out that both Ho Peng Yoke (10) and Li Qi-bin render the term *chan*, found in the September 10 (b and c) and October 24 (d) records above, as 'lamp', suggesting unusual brightness. However, these renderings are apparently based on a misapprehension. In colloquial usage, *chan* is a numerary adjunct connecting a number to lamps (*têng*), e.g. *i-chan-têng* meaning one lamp – and so on for larger numbers. However, when not coupled with *teng*, *chan* retains its normal meaning – 'a cup'. Reference to the numerous meteor records in the *Ming-shih-lu* around this time shows that the apparent sizes of these objects were usually compared with four everyday objects – bowls (*wan*), cups, hen's eggs (*chi-tzŭ*) and crossbow pellets (*t'ang-yuan*). Comparison with cups was by far the most common; of the 17 meteors noted in the *Ming-shih-lu* during AD 1408, 12 are described in this way. The angular equivalents of these various estimates are obscure. For rather similar descriptions of sunspots see Clark & Stephenson (13).

Even without the additional information regarding motion in the text (c), the record in (b) is so similar to that of a typical meteor in the *Ming-shih-lu* that an alternative interpretation would have seemed unlikely. Thus we find in the *Ming-shih-lu* meteor descriptions of the following format on six occasions during AD 1408:

> 'At night there was a star as large as a cup; its colour was pale blue and it was bright. It appeared ... (there follows an account of the location and motion)'.

The extra details found in (c), which describe both the trail of the object and its movement across the sky would seem to render a meteor interpretation unavoidable. Hence we are left with only two possible references to temporary stars in AD 1408 – on dates corresponding to July 14 and October 24.

(3) *The 'Official' Chinese record*

By the 'official' record is here meant that contained in the *Ming-shih-lu*. In view of the close concern of this work with imperial affairs, there are sound reasons for believing that the bulk of the astronomical records contained in it are compiled from the nightly observations of the imperial astronomers – see also Clark & Stephenson (11). The *Ming-shih-lu*, which we shall subsequently abbreviate to MSL, does not contain a special section devoted to astronomical phenomena; these are reported alongside more mundane events purely in chronological order.

Several of the expressions used in text (d) require comment. The description 'as large as a cup' has already been discussed above. Based on his erroneous interpretation of the meaning of *chan*, Li Qi-bin (1) inferred that the temporary star reported in the MSL was 'as bright as a well-lit lamp'. He additionally suggested that since the star was located not far from Vega and yet no brightness comparison was made, it must have far outshone Vega. He concluded that at maximum, 'this star was brighter than magnitude −3'. We cannot endorse these claims. A study of a wide variety of Far Eastern records of new stars (both novae and SN) – e.g. in the extensive catalogue compiled by Ho Peng Yoke (**10**) – shows that brightness comparisons between these objects and fixed stars are fairly rare. Presumably much depended on the whim of the observers. For example, in describing the SN of AD 1572 and 1604, the Chinese astronomers made no brightness comparisons, as reported in the MSL (**11**). However, the court astronomers of Korea likened the AD 1572 star to Venus, while in 1604 they made regular estimates of the changing brightness of the SN in relation to five standard objects (Venus, Jupiter, Mars, Antares and τ Sco). It is thus not possible to make any estimate of the brightness of the star of AD 1408 October 24 merely by default; indeed, the record gives no details which enable the apparent magnitude to be estimated.

The appellation *Chou-po* was probably applied because of the colour of the star. From ancient times, bright yellow stars which were of a temporary nature were occasionally described in this way; these were normally regarded as auspicious omens. The term *jun* (here rendered 'sheen') normally refers to the appearance of a polished surface. Its usage in an astronomical text is rather uncommon, but there are several instances in the MSL (e.g. in AD 1406) where a meteor is alluded to in the same way. However, we feel that the choice of this particular expression is no guide as to the true nature of the star.

If the temporary star of 1408 was a long-lived stellar object, it is surprising that the MSL gives no indication of its duration of visibility. This contrasts markedly with the large majority of other records of temporary stars (both comets and novae, etc.) as reported in the MSL. The chronicle tends to avoid day to day repetition of entries for those astronomical phenomena which remained visible for several days or more. In such cases, only a single entry is normally given – for the day of discovery – and this specifies the duration. A typical entry, relating to a probable nova observed in AD 1430, is as follows. It is found under day *kêng-yin* in the 8th month of the 5th year of the Hsüan-tê reign period (AD 1430 September 9):

> 'At night a guest star was seen beside *Nan-ho* (in Canis Minor). It was as large as a crossbow pellet and its colour was dark blue (i.e. 'blue-black'). After a total of 26 days it was extinguished'.

As no motion is alluded to, it seems reasonable to suppose that the new star of AD 1430 remained fixed for the 26 days of visibility.

The lack of a recorded duration for the object recorded by the Chinese in AD 1408 thus strongly suggests that it was seen only on a single night by the astronomers of the Ming court. In late October, the asterism *Nien-tao*, near which the star appeared, would be nearly overhead in the early evening. Hence, there should have been ample opportunity for observation in a dark sky until around midnight – when *Nien-tao* would set. The report in the MSL quoted earlier (d) asserts that the star did not move. However, we feel that if this remark is indeed based on only a few hours of observation at most, it does not even establish the stellar nature of the object with any degree of confidence. In such a short time a comet might well appear stationary.

DISCUSSION

From the above investigation, all that can be ascertained regarding temporary stars in AD 1408 is that (i) on July 14 a 'guest star' was observed in Japan for an unknown length of time and in an unspecified part of the sky, and that (ii) more than three months later (October 24) a 'Chou po' star was seen in China in the Cygnus region. There is no direct evidence to relate these two objects.

Imaeda & Kiang (2) argued that the probability of the Chinese and Japanese records relating to different events was very small on account of the low frequency of observation of guest stars in both countries – only once every 15 years on the average. However, this argument is of doubtful validity since the Chinese record in AD 1408 does not refer specifically to a 'guest star' and its stellar nature cannot be established from the text itself.

On the assumption that the star sighted by the Japanese on July 14 had indeed been identical with that observed in China, it is difficult to explain how it could have remained undiscovered by the official astronomers of China for more than three months – and not noticed at all by the Korean astronomers. *Nien-tao* would be better placed for observation in mid-July (when it was some 90 degrees to the east of the Sun) than in late October (when it was near conjunction, although much to the north of the Sun). Further, if the star seen in Japan was a SN its brightness would have faded by some 3 mag by October 24, so that we would have to conclude that the Chinese observers overlooked it until it was well on the decline. There is evidence that the Chinese astronomers were watching the sky during July. The MSL notes observations of meteors on July 16, 25 and 29 (and several more between August and October). Interestingly enough, the recorded paths of two of these (on July 25 and 29) passed close to *Nien-tao* – see Fig. 1. This would give the Chinese astronomers an added opportunity to discover a new star in that vicinity – and yet none is reported in the MSL until October 24.

In this context, it is interesting to note that of the five established SN which have appeared since AD 1000 (i.e. in the years 1006, 1054, 1181, 1572 and 1604) four were detected independently in different parts of the Far East or Europe over a span of 5 days or less (11). Further, in the case of the stars of AD 1006, 1054, 1572 and 1604, the records affirm directly that the star remained fixed for a year or more. The AD 1181 observations suggest a fixed position for about 6 months. Such long durations of visibility are quite characteristic of a SN – Barbon *et al.* (14). Such positive evidence contrasts markedly with the vague situation existing in AD 1408.

Further difficulties are encountered when we consider the accuracy with which the celestial position of the star reported in (d) can be deduced. The positions of the five SN noted above can all be determined within a very few square degrees, thus allowing a confident identification with a contemporary SN remnant. Similar precision cannot be obtained in AD 1408. An investigation of oriental star maps enables the constituent stars of the asterism *Nien-tao* to be reliably deduced as: R Lyr, η Lyr, θ Lyr, 4 Cyg and 17 Cyg. Fig. 2 represents the area of sky in the vicinity of *Nien-tao*, with co-ordinates shown for the epoch 1950. Towards the SE of *Nien-tao* there are few even moderately bright stars – hence the absence of oriental asterisms in this region. The

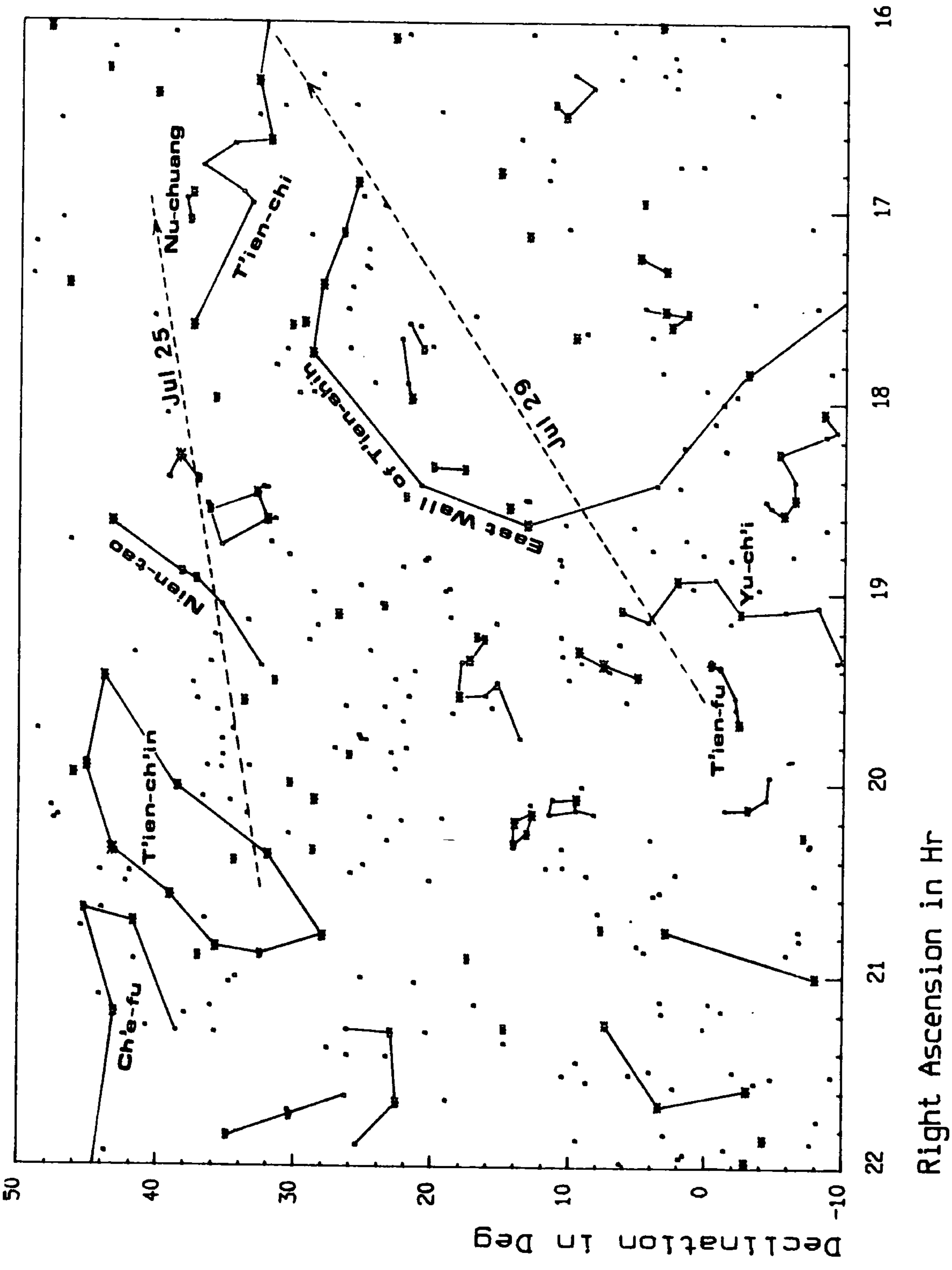

FIG. 1. Chart of the *Nien-tao* region (epoch AD 1408) showing the observed paths of meteors on the nights of July 25 and 29 in AD 1408.

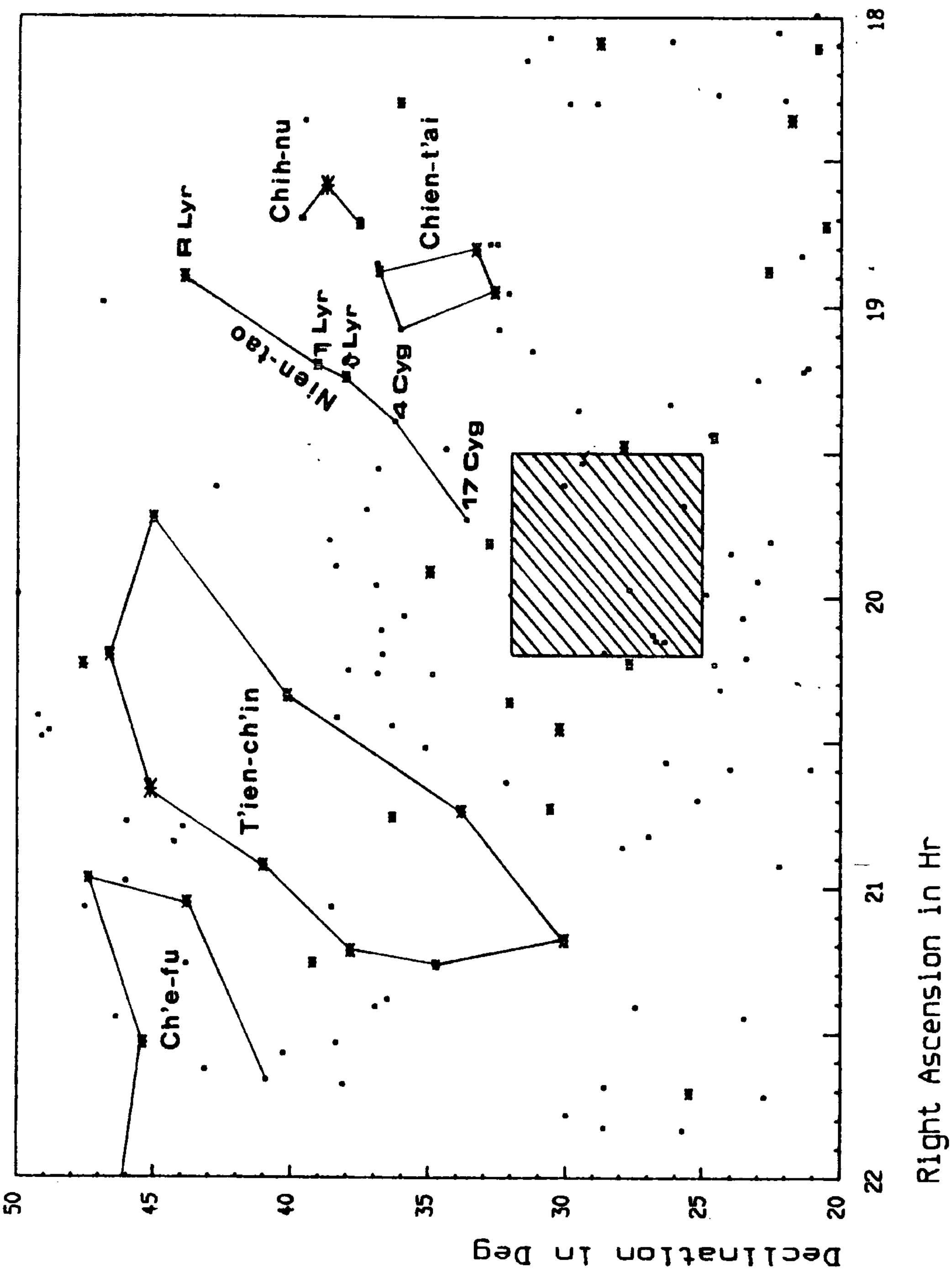

FIG. 2. The region of *Nien-tao* (epoch 1950) showing the estimated error box for the position of the star of AD 1408 October 24.

hatched square seems a reasonably conservative estimate of the area of sky answering the MSL positional record. This area occupies about 50 square degrees, more than an order of magnitude larger than the search areas for any of the established historical supernovae which have occurred since AD 1000 (11). Hence even if we could be fairly confident that the star of AD 1408 was a supernova, any agreement in position with that of a SN remnant might well be only coincidental.

CONCLUSIONS

From our investigation, it seems clear that the AD 1408 new star records do not provide enough evidence to justify a supernova interpretation. Either of the objects seen on July 14 and October 24 could have been fast novae appearing only for a few nights, but even a cometary explanation cannot be ruled out. The position of the star seen on July 14 is unknown whereas that of the October 24 object is very uncertain. In view of these considerable difficulties, it seems misguided to consider the possible links between either of these stars and known SN remnants.

To summarize, the following statements may be made about the AD 1408 temporary stars:

(1) Only the 'official' Chinese record (October 24) gives even a rough position and indication of a fixed nature. The Chinese local histories (September 10) clearly refer to a meteor. Although the Japanese record (July 14) uses the term 'guest star', the object was of unknown duration and position.

(2) There is no direct evidence to suggest that the records from China and Japan relate to the same object.

(3) In view of the poor positional description of the October 24 object (anywhere within an area of about 50 square degrees) and its uncertain duration, attempts at identifying it with CTB 80 or any other known SN remnant seem to be quite unwarranted.

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5.6 False Sightings of New Stars in AD 1600 and 1664

There are two seemingly fairly detailed records of new star in chapter 6 of the *Chungbo Munhon Pigo* (an 18th century Korean historical compendium). One is listed under the year AD 1600 (Ho Peng Yoke, 1962 and Xi and Bo, 1965) and the other in AD 1664 (Xi and Bo, 1965).

The AD 1600 record is found on day *i-yu* in the 11th month of the 33rd year of King Sonjo, the year *keng-tzu* (AD 1600–1):

> "A guest star was seen at *Wei* (Lunar Mansion). It was larger than *Huo-hsing* of the *Hsin* Lunar Mansion (i.e. Antares). Its colour was yellowish-red (orange) and it was scintillating. On day *ting-wei* (44) in the 12th month, the guest star trespassed against Venus at *Wei*."

Neither of the cyclical days quoted (i.e. *i-yu* and *ting-wei*) occurred during the appropriate months so that the dates cannot be accurately converted to the Gregorian Calendar. The Sonjo Sillok (see section 5.9) contains detailed astronomical records for the period but it makes no mention of any guest star under the 33rd year of King Sonjo. However, reference in this same work to the same dates under the 37th year of Sonjo (AD 1604–5) reveals almost identical entries to those cited above, in particular the close conjunction with Venus (equivalent date AD 1605 Jan 21). Hence the apparent record of a new star visible for possibly several weeks in AD 1600 is false. It owes its origin to two observations of Kepler's SN misplaced by 4 years.

A similar entry is found in the 9th month of the 5th year of King Hyonjong (1664):

> "A guest star was seen above *T'ien-chiang*; it was as large as Jupiter. Its colour was yellowish-red (orange) and it was scintillating. It was

seen again in the E direction until the 5th month of the following year, then it was extinguished".

A new star visible for some 8 months and lying very close to the galactic equator (as is true for *T'ien-chiang* – in Ophiuchus) would normally be an obvious SN candidate. However, there is no trace of the record of the guest star in the *Hyonjong Sillok* (the official annals of the reign of King Hyonjong) nor is there any note of it in the much more extensive *Sungjong-won Ilgi*, which is based on the daily records of the Royal Secretariat. Both of these works cite numerous other astronomical observations. Reference once more to the Korean observations of Kepler's SN, as reported in the *Sonjo Sillok* demonstrates that the account quoted above is merely a summary of observations made during the corresponding months of AD 1604 and 1605. A misplacement by exactly 60 years is easy to explain since in the Far East a 60-year (and 60-day) cycle was in regular usage. Both the years AD 1604–5 and 1664–5 share the same cyclical signs *chia-ch'en*.

Wang Jian-min (1980) claimed there are two cases of re-explosions of supernovae, one in 1664 for SN 1604 and another in 1016 for SN 1006. From the above analysis we know that the record for 1664 is false, hence the first case can be safely dismissed. Whereas in the second case the record of a guest star in 1016 is questionable. There is only a brief mention of a *Chou-po* star in Li Tao's monumental work, the *Hsu-tzu-chih T'ung-chien Ch'ang-pien*. There is no mention of a position of the 'guest star' in question. An association of this record to a supposed outburst of the same star in 1006 is rather dangerous. Besides, on physical ground alone the possibility of re-explosions of supernovae is ruled out.

In summary, so far as is known, no new star appeared in either AD 1600–1 or 1664–5. In both cases careless filing of material and abridgement by the compiler of the *Chungbo Munhon Pigo* was presumably to blame for the false entries under these years.

5.7 Cas A SN

Not counting the current SN 1987a, the previous supernova observable with the naked-eye was believed to be Cas A, a supernova that is suspected to have occurred around AD 1670. Van den Bergh and Dodd (1970) measured 27 fast moving knots on all plates taken with the 200-inch Mount Wilson telescope between 1951 and 1969 and from proper motions they obtained that the SN explosion took place around 1667. Whereas direct measurements of the optical expansion rate give a likely date for the original outburst of AD 1658±3 (Van den Bergh and Kamper, 1978). Although astronomy with the telescope was fairly well established in Europe by this epoch, there is no direct observational record of a new star appearing near the site of the SNR around this time. This could either because the age estimate is incorrect or possibly due to heavy interstellar absorption rendering the outburst escaped notice.

It was suggested by Brosche (1967) that a possible link between Cas A and one of the three new stars observed by the Koreans in AD 1592–3 (see section 5.9). The object in question was observed in the vicinity of "the 1st star of Wang-liang (β Cas)" and was observed for 3 months. However Cas A is some 5° from beta Cas, which scarcely fits the Korean record. The proposed association between new star and suggested remnant should be regarded as very subjective.

From statistical investigation of the motion of the optical filaments Van den Bergh (1971) deduced that the distance of Cas A from the Earth to be about 3 kpc, which is fairly typical of the remnants of the historical SN discussed above. However Van den Bergh and Dodd (1970) pointed out that the original SN may have been as faint as 2nd magnitude due to the high interstellar absorption of light in the direction of Cas A.

The catalogue of Flamsteed (1725) contained a certain 6th magnitude star '3 Cas', of whose existence there is now no trace. Flamsteed produced his catalogue of stars around August of AD 1680, and has been suggested by Ashworth (1980) that Flamsteed may have observed the SN itself although the date of his observation (i.e. AD 1680 or a little earlier) seems rather late. The discrepancy in position between '3 Cas' and the Cas A SN is about 10 arcmin which is fairly large for telescopic observations. Further we have no information on any change in brightness of 3 Cas. Whether the outburst of the SN which produced Cas A was actually noticed is thus a very debatable issue.

5.8 Investigation of Some Nova Candidates

Table 5.2 summarises those records that hold real possibility of being records of nova outbursts. I have chosen only those records which have been categorised as either 1 or 2 for analysis. For each entry in the table the available information is briefly discussed. For the four guest stars of AD 1592, which were observed by the Korean court astronomers, details are presented in section 5.9. The latest classical nova catalogue by Bode *et al.* (1988) – see Table 4.1 – is used to identify some of these possible nova outbursts in the past, on the assumption that they were long period recurrent novae!

(i) 77 BC

The first of the nova candidates to be considered here is the new star of 77 BC. In chapter 26 of the *Han-shu*, the following record is found in the 9th month (Oct/Nov) of the 4th year of the Yuan-feng reign-period (77 BC), "A guest star was situated within *Tzu-kung* ('the Purple Palace') between the Pole Star and *Tou-shu* ('alpha UMa')."

This record gives only the position without any mention of a duration. Although the record gives a fairly accurate location – Fig. 5.7 – (RA: $11^h4 \pm 6^m$, Dec: $+76 \pm 1.5°$)

Table 5.2 A Table of Possible Novae from Far Eastern Sources

Entry	Date	Duration	Location RA (h m)	Err (m)	Dec (deg)	Err (deg)	Approx Long (deg)	Lat (deg)	Cat	Comments on Record	Position
i	77 BC	-	11 4	±6	+76	±1.5	131	+39	2	Brief	Good
ii	48 BC	-	19 23	±4	-28	±1	10	-19	2	Brief	Good
iii	AD 70	48 dy	9 46	±72	+24	±18	207	+48	2	Brief	Poor
iv	AD 101	-	10 17	±4	+23.4	±1	210	+55	2	Brief	Good
v	AD 222	-	12 31	±11	-1.1	±0.4	292	+61	2	Brief	Very good
vi	AD 329	23 dy	12 30	±50	+55	±6	143	+51	2	Brief	Poor
vii	AD 369	~5 mn	8	$\pm 6^h$	+70	±5	145	+30	1	Quite detailed	Fair
viii	AD 396	>50 dy	4 28	±4	+24	±6	178	-20	1	Detailed	Fair
ix	AD 437	-	6 40	±28	+20	±9	194	+07	2	Detailed	Fair
x	AD 722	5 dy	1 24	±80	+57	±10	127	-6	2	Brief	Fair
xi	AD 837a	23 dy	6 51	±27	+13	±3	200	+06	1	Detailed	Fair
xii	AD 837b	46 dy	($12^h 15^m$ 0°, $12^h 3^m$ +6° $11^h 45^m$ +6°, $11^h 57^m$ 0°)				275	+63	1	Detailed	Good
xiii	AD 837c	-	18 2	±10	-24.5	±3.5	6	-01	2	Brief	Fair
xiv	AD 891	-	16 31	±2	-16.6	±0.5	0.2	+21	2	Brief	Good
xv	AD 902	~1 yr	2 43	±78	+77	±7	130	+15	2	Brief	Poor
xvi	AD 1073	-	0 35	±22	+5	±10	118	-43	2	Brief	Fair
xvii	AD 1074	-	0 35	±22	+5	±10	118	-43	2	Brief	Fair
xviii	AD 1082	-	0	$\pm 12^h$	+90	±5	122	+26	2	Brief	Fair
xix	AD 1163	-	17 34	±5	-21.5	±0.5	5	+06	2	Very brief	Good (Moon)
xx	AD 1175	6 dy	($16^h 40^m$ +57°, $15^h 30^m$ +57° $16^h 40^m$ +50°, $15^h 30^m$ +42°)				78	+50	1	Detailed	Good
xxi	AD 1203	10 dy	17 29	±36	-38	±5	350	-02	1	Detailed	Fair
xxii	AD 1356	-	5 51	±3	+27.8	±.5	182	+0.3	2	Very brief	Good (Moon)
xxiii	AD 1399	-	18 52	±2	-20.1	±.5	15	-08	2	Very brief	Good (Moon)
xxiv	AD 1430	26 dy	($7^h 26^m$ +10°, $7^h 31^m$ +11° $7^h 47^m$ +7°, $7^h 41^m$ +5°)				211	+13	1	Detailed	Good
xxv	AD 1437	14 dy	16 53	±2	-41.9	±0.5	343	+1.3	1	Detailed	Very good
-	AD 1592a	15 mn	1 51	±2	-10.4	±.5	166	-68	1	Extensive	Very good
-	AD 1592b	4 mn	0 57	±2	+59.9	±.5	124	-03	1	Extensive	Very good
-	AD 1592c	3 mn	0 09	±4	+59.1	±1	118	-03	1	Very detailed	Good
-	AD 1592d	1 mn	1 0	±20	+42	±5	125	-21	2	Brief	Poor
xxvi	AD 1690	2 dy	18 35.5	±.2	-34.1	±.1	0.5	-12	1	Detailed	Very Good

N.B. Values given inside brackets for the location are the coordinates of the error box.

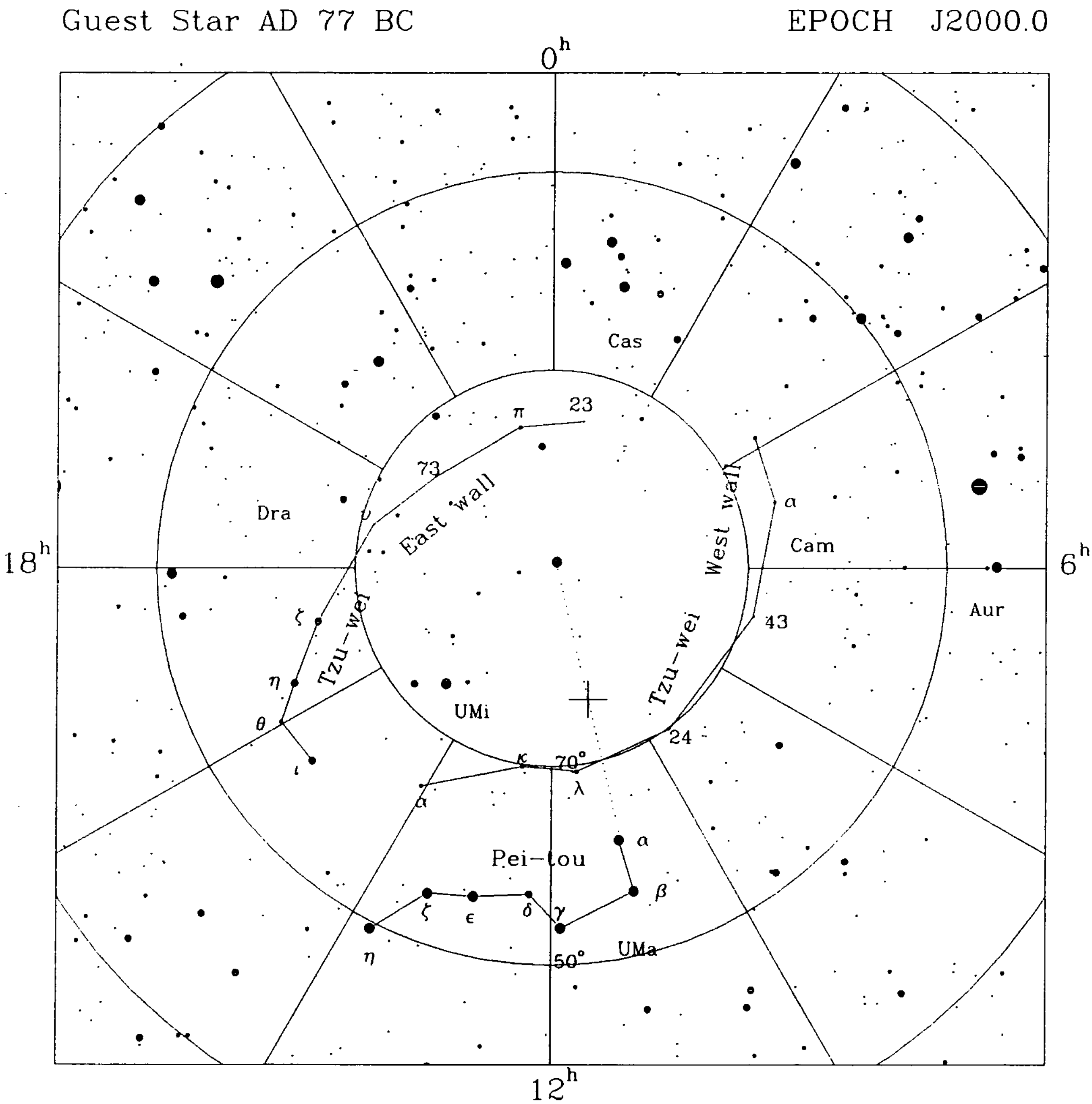

Fig. 5.7 A star map showing the region of sky in the vicinity of the guest star 77 BC, the cross indicates the approximate location of the new star.

no identification is possible with novae listed in Table 4.1. The high galactic latitude rules out a SN identification. However, YY Dra has been suggested to be associated with this temporary star of 77 BC (Hertzog, 1986).

(ii) 48 BC

The record for the 48 BC guest star is also found in chapter 26 of the *Han-shu* under the 4th month (May/June) of the 1st year of the Ch'u-yuan reign-period (48 BC) as follows, "A guest star as large as a melon with a colour of bluish-white was situated about 4 *ch'ih* ($\sim 4°$) to the E of the 2nd star of *Nan-tou* (τ Sgr)."

The position of this guest star is reasonably good (Fig. 5.8). I have deduced the RA to be $19^h 23 \pm 4^m$ and Dec $-28 \pm 1°$. V363 Sgr with RA $19^h 10^m$ and Dec $-29.9°$ is listed in Table 4.1 and is inside the error box. Nova V363 Sgr had its last outburst in 1927 with a maximum photographic magnitude of ~ 8. Wang *et al.* (1986) identified the 48 BC guest star with the filled centred remnant G21.5–0.9 (RA: $18^h 33.5^m$, Dec: $-10°34.7'$) in their list of SNR identifications. I reckon G21.5–0.9 is much too far away from the error box to warrant a claim of association.

(iii) AD 70

The record for the AD 70 guest star is contained in chapter 83 of the *Hou Han-shu* during the 11th month (70 Dec – 71 Jan) of the 13th year of the Yung-p'ing reign-period, "A guest star appeared at *Hsien-yuan* for 48 days." Although the duration for this new star is specific, the position is not. The *Hsien-yuan* asterism is occupying a large part of the constellation Leo together with the constellation Lynx. The region of sky covered by the *Hsien-yuan* asterism is very large $\gg$20 square degrees (or more). I am of the opinion that (unless more information is forthcoming) the exact location of this may never be known.

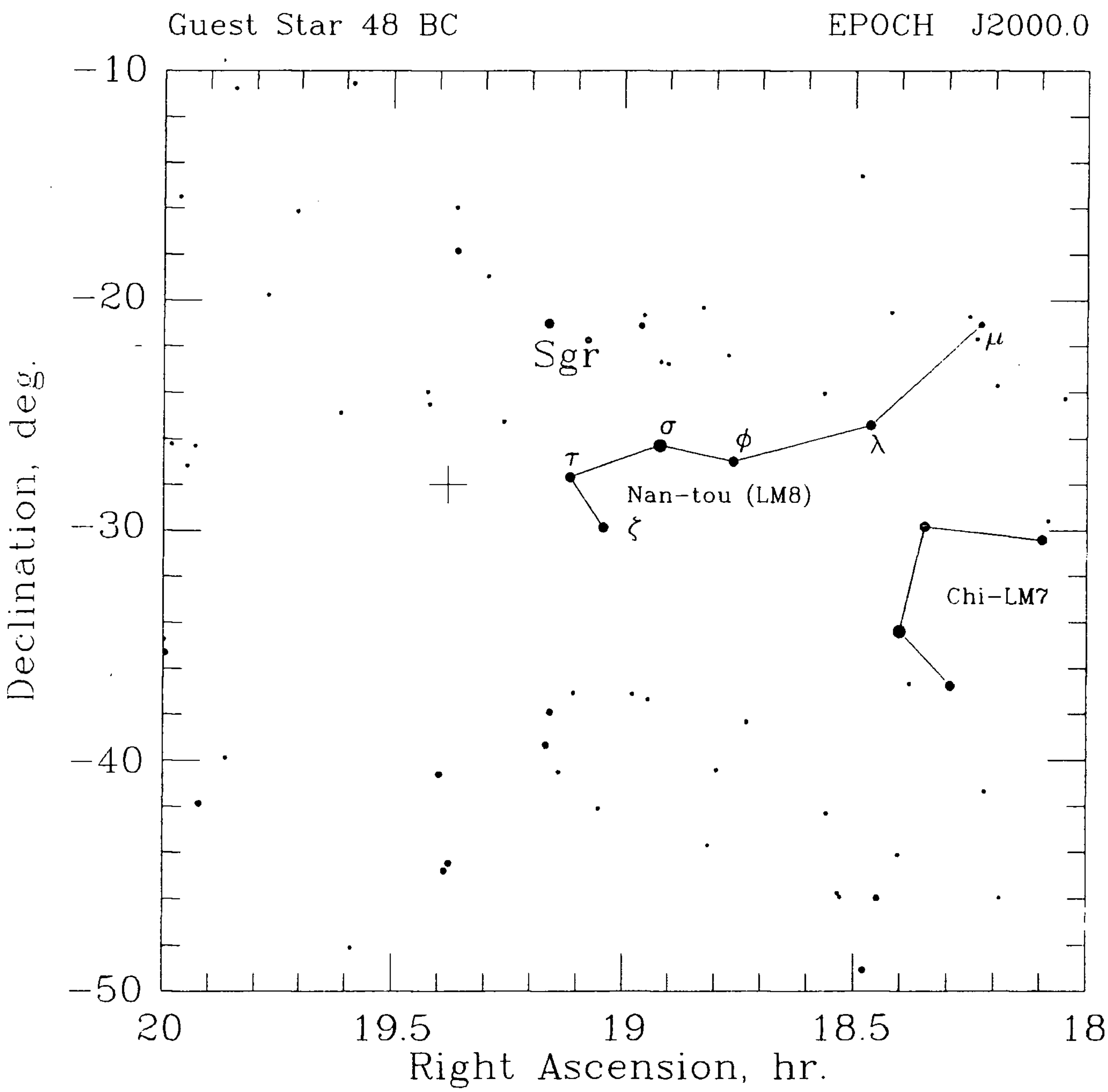

Fig. 5.8 A star map showing the region of sky in the vicinity of the guest star 48 BC, the cross indicates the approximate location of the new star.

(iv) AD 101

The second of the *Hou Han-shu* records is listed under the 13th year of the Yung-yuan reign-period (AD 101). The entry for day *i-ch'ou* of the 11th month (Dec 30) is as follows: "A small guest star appeared at the fourth star of *Hsien-yuan*. It was bluish-yellow in colour."

The position implied by the record is fairly accurate but the length of visibility is not given. The fourth star of *Hsien-yuan* I have taken to be ζ Leo (Fig. 5.9). Liu (1986) analysed some Chin Dynasty planetary occultations of stars and found that the first star of *Hsien-yuan* to be α Leo and second star to be ηLeo. It follows, working in sequence, that the fourth star of *Hsien-yuan* was zeta Leo. I have taken it for granted that there was no significant change in the usage of terms between the Later Han and Chin periods.

I have arrived at a position of RA: 10^h17^m and Dec: +23.4°; no corresponding recent nova is found in Table 4.1. However, Hertzog (1986) proposed that the remnant of the AD 101 guest star was PG 0917+342, which was a nova occurred in the constellation Lyncis in AD 101.

(v) AD 222

The guest star of AD 222 is mentioned both in Chapter 13 of the *Chin-shu* and chapter 23 of the *Sung-shu* under the 3rd year of the Huang-ch'u reign-period. On day *chia-ch'en* (Nov 4) in the 9th month the text reads, "A guest star was seen inside the *Tso-i-men* of the *T'ai-wei* (Enclosure)."

The record gives a good position but does not mention any duration. The asterism indicated by *Tso-i-men* consisted of 2 stars (γ and η Vir) forming part of the *T'ai-wei*

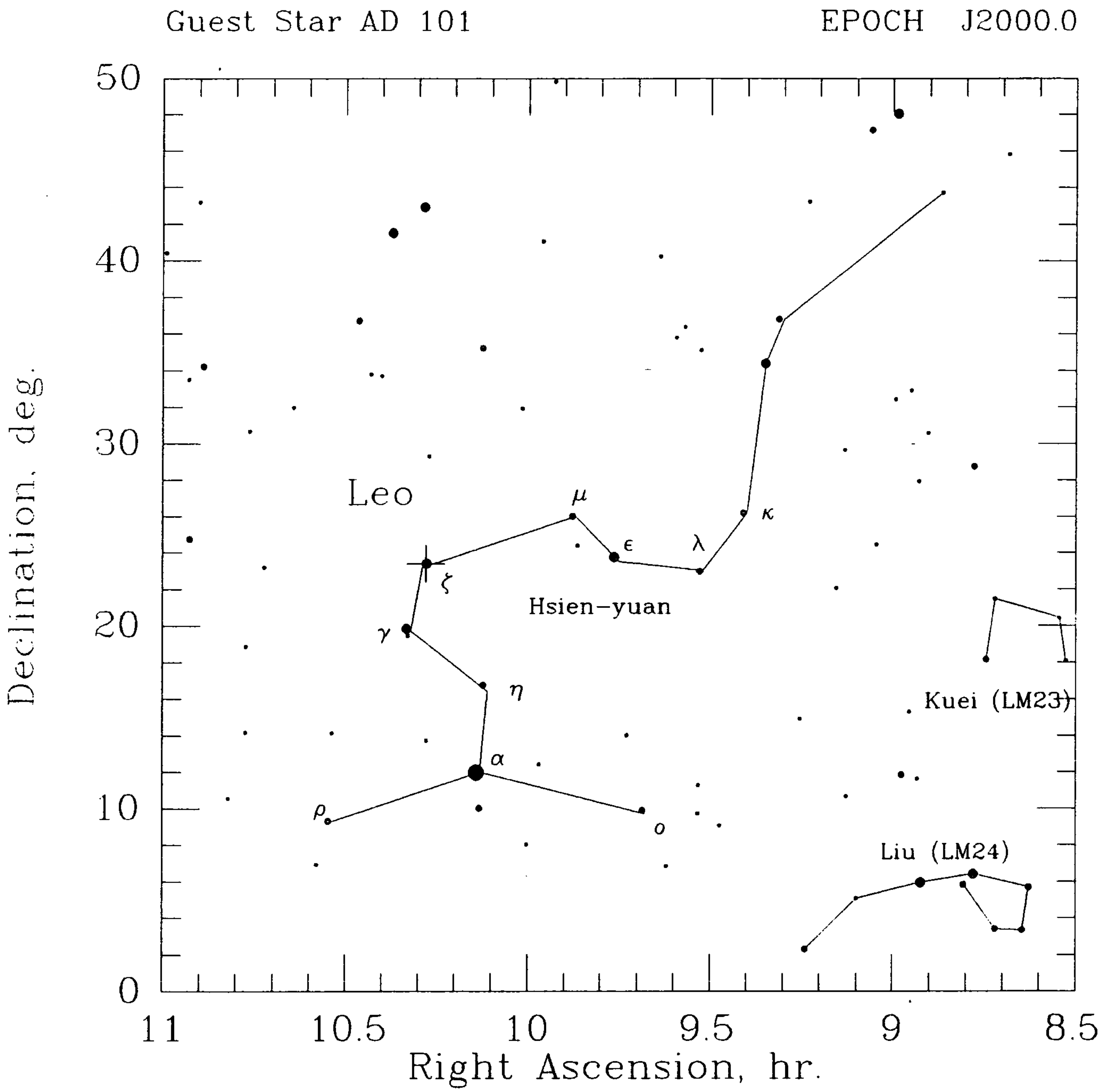

Fig. 5.9 A star map showing the region of sky in the vicinity of the guest star AD 101, the cross at ζ Leo indicates the approximate position of the new star.

east wall (Fig. 5.10). No corresponding nova of recent centuries is found from Table 4.1.

(vi) AD 329

In chapter 13 of the *Chin-shu*, and chapter 24 of the *Sung-shu* under the 4th year of the Hsien-ho reign-period the following record is found. The text says that, "During the 7th month (Aug 11 to Sep 9), a star emerged (*po*) at the NW. It invaded (*fan*) *(Pei-)tou* and after 23 days it was extinguished."

Although a duration of 23 days is given for this star, the positional information is vague. The term *fan* is mentioned in the text; it is one of the several terms used in Far Eastern astronomy to indicate the nature of a close approach between two heavenly bodies. The meaning of *fan* is such that one body comes close to another in the sky to within about 7 *ts'un* (1 ts'un $\sim 0.1^\circ$) (See p.168 of Clark and Stephenson (1977) for a verification). Since the asterism *Pei-tou* (the 'Dipper') covers a large region of sky and the record does not indicate which of the stars was 'invaded' by the temporary star, the error in position is unavoidably large. I have deduced a position with RA: $12^h30 \pm 50^m$ and Dec: $+55 \pm 6^\circ$ and searched without success for any novae in Table 4.1. Hertzog (1986) suggested that UX UMa was related to the new star of AD 329. However this can only be viewed with scepticism because of the uncertainty in the position.

(vii) AD 369

In the same text as the last entry the record of another guest star is also found under the 4th year of the T'ai-ho reign-period. Some time in the 2nd month (Mar 24 to Apr 22) in the spring, "A guest star was seen at the West Wall of *Tzu-kung* (i.e. *Tzu-wei* Enclosure). It lasted until the 7th month (Aug 19 to Sep 17) and then it was extinguished."

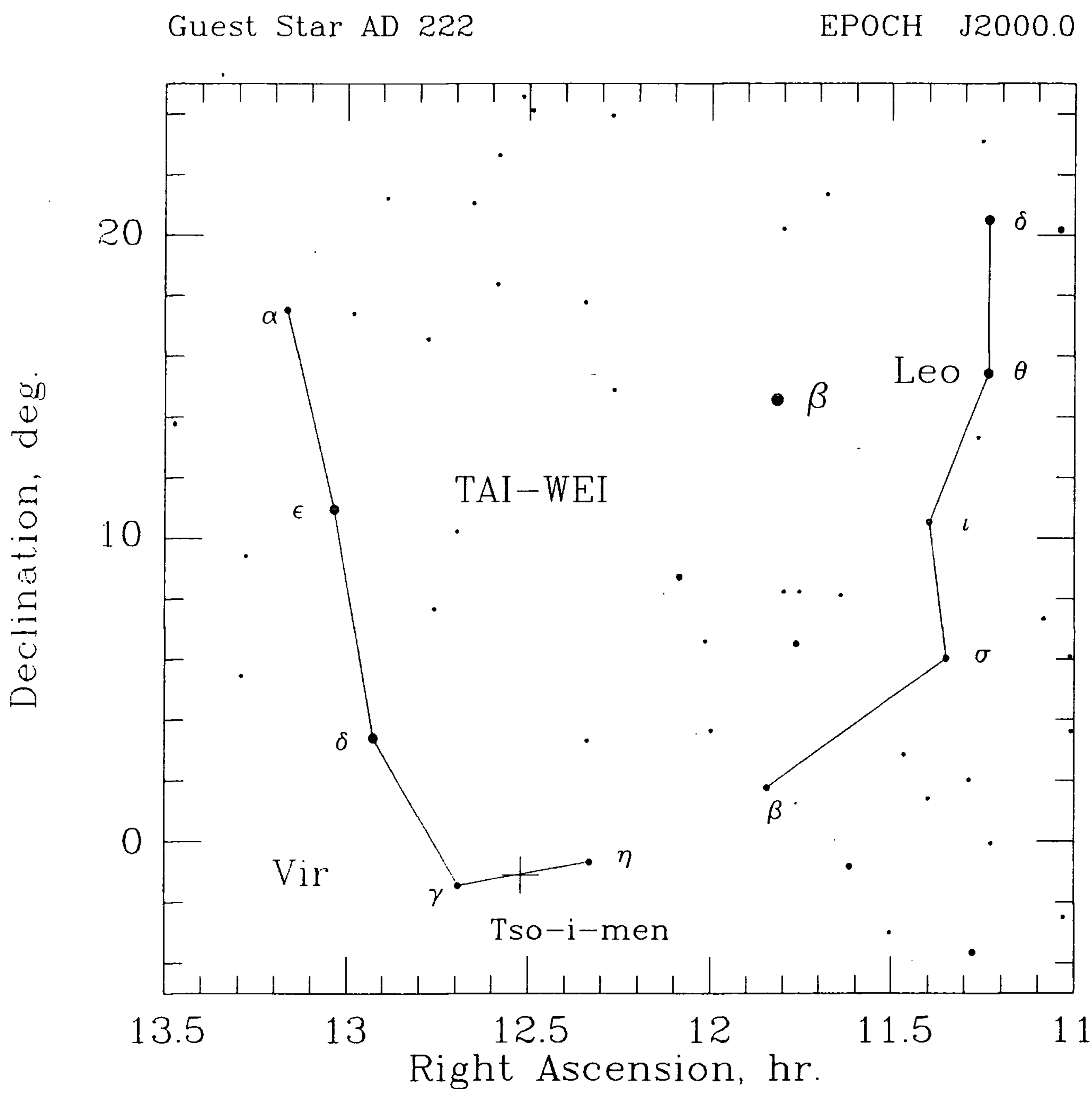

Fig. 5.10 A star map showing the region of sky in the vicinity of the guest star AD 222, the cross between γ and η Vir indicates the approximate location of the new star.

Apart from a fairly lengthy visibility of some 5 months, the position is only indicated approximately. The location described in the text is not accurate enough for a good position to be deduced. The RA alone ranges from 3.5^h to 14^h is too large to warrant a search be carried out. Only NGC 6543 has been linked to this event by Webster (1978) but without foundation. No other candidates (SN or nova) have been found.

(viii) AD 396

Under the 1st year of the Huang-shih reign-period in chapter 105 of the *Wei-shu* the guest star of AD 396 is listed, "A large yellow star appeared at the boundary between *Mao* and *Pi* (Lunar Mansions) for more than 50 days. In the 11th month (Dec/Jan) the yellow star was again seen."

This is a fairly good record with both the position and duration given. The translation here does not include an irrelevant commentary following the record which had been wrongly incorporated in Hsi (1958) by the translator as part of the record. The wrongly translated record implied that the star was "without peer under the sky". In fact the commentary referred to an astrological prediction to some warfare. Fig. 5.11 indicates approximately where the guest star was situated; somewhere along the boundary separating the *Mao* and *Pi* (Lunar Mansions). The binary system V471 Tau has been suggested by Hertzog (1986) as a possible remnant. Though I have found no modern nova or SNR remnant associating with the star.

(ix) AD 437

In chapter 105 of the *Wei-shu* and chapter 26 of the *Sung-shu*, the entry of a guest star is contained under the 3rd year of the T'ai-yen reign-period. It reads on day *jen-wu* (Feb 26) of the 1st month that, "A star was seen at the NE in daytime before the hour

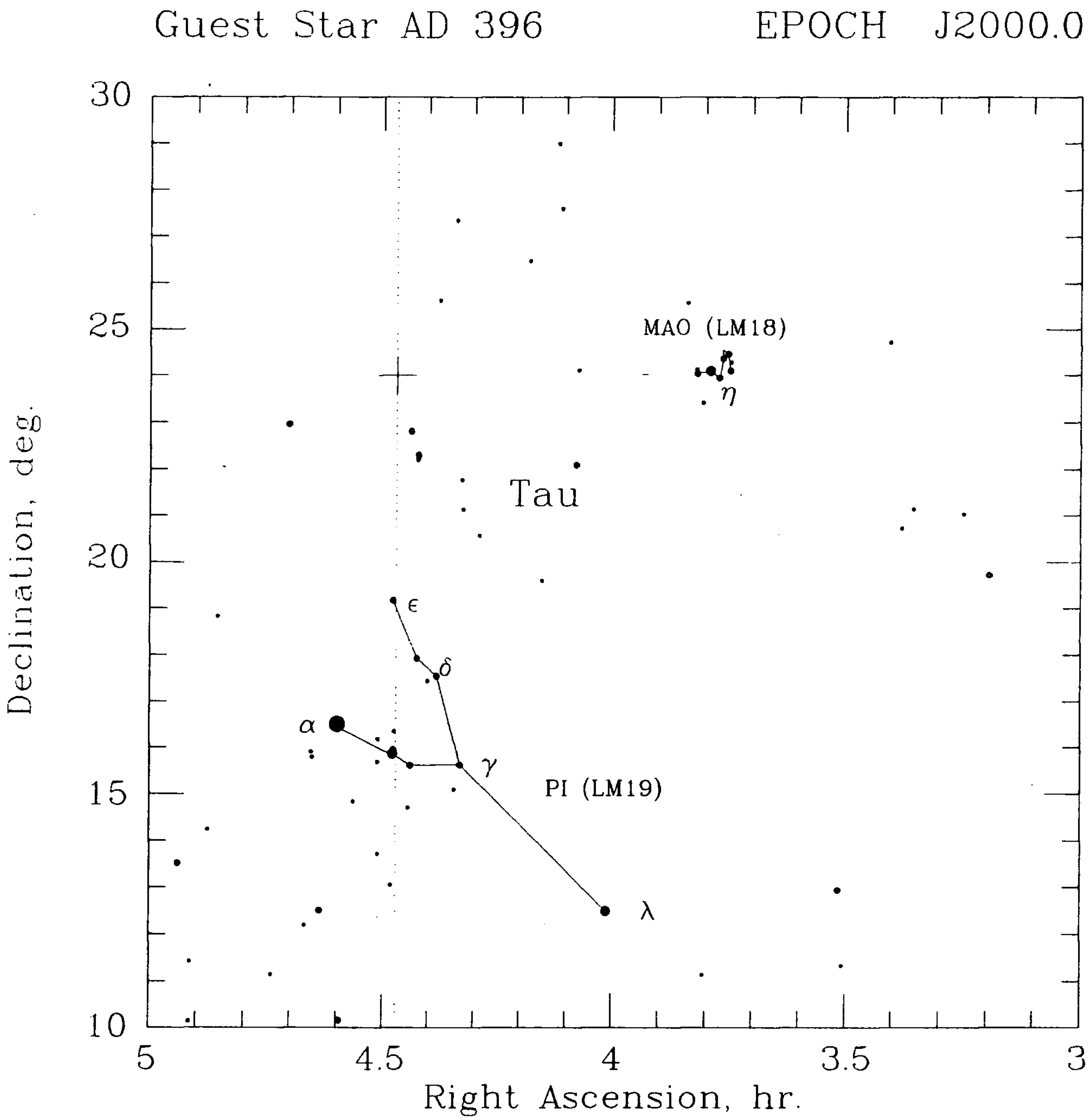

Fig. 5.11 A star map showing the region of sky in the vicinity of the guest star AD 396, the cross indicates the approximate location of the new star.

of *pu* (3–5 p.m.). It was near *Ching* (Lunar Mansion 22), yellowish-red (i.e.orange) in colour and as large as a tangerine."

The record indicated that the star was visible during daytime which would imply a substantial brightness. The position is only fair, but no duration is given. I have deduced a position of RA: $6^h 40 \pm 28^m$ and Dec: $20 \pm 9°$. There are two novae within the error box, DM Gem and DN Gem and two SNRs G189.1+30 and G192.8–1.1. Bignami *et al.* (1984) identified the AD 437 guest star as the Geminga. This is only true if positional coincidence and a much more precise temporal coincidence is established

(x) AD 722

The first Japanese entry contained in Table 5.2 is for the guest star of AD 722. The record is found in chapter 478 of the *Temmon Shiryo* (Kanda, 1935). The text reads on day *jen-shen*, the 3rd day in the 7th month of the 6th year of the Yoro reign-period (AD 722 Aug 19) that, "A guest star was seen by the side of *Ko-tao* for a total of 5 days."

This is a brief record with only a fair position and relatively short duration. I found one nova corresponding with this position, V Per. There are also six SNRs in the vicinity. However, one is the remnant of SN1181 and the other is SN1571; the others are all extremely old.

(xi) AD 837a

In chapter 32 of the *Hsin T'ang-shu* a guest star visible for nearly a month is found under day *chia-shen* in the 3rd month of the 2nd year of the K'ai-ch'eng reign-period (AD 837 Apr 29), "A guest star appeared below *T'ung-ching*. In the 4th month, day *ping-wu* (May 21) the guest star below *T'ung-ching* disappeared."

This is the first of the three AD 837 guest stars. Only a relative position is given as below the asterism *T'ung-ching* (Fig. 5.12). I have found only one nova, KT Mon, inside the error box of the position deduced by me (RA: $5^h50^m \pm 30$ and Dec: $14 \pm 3°$). Also there are 4 SNRs in this region.

(xii) AD 837b

The second of the AD 837 guest stars is found on day *wu-tzu* of the 3rd month (May 3). The text says that, "Another guest star appeared within *Tuan-men* near *P'ing-hsing*. In the 5th month, day *kuei-yu* (Jun 17), the guest star within *Tuan-men* disappeared."

The position indicated by this record is very precise, between η and β Vir (Fig. 5.13). However no remnants of any kind is found for this location.

(xiii) AD 837c

The last of the AD 837 guest star is an entry on day jen-wu (Mar 22) in the 5th month. It mentioned that, "A guest star like a (*po*) was in between *Nan-tou* and *T'ien-yo*."

Although no duration is mentioned, the position is reasonably good. The area of sky between *Nan-tou* and *T'ien-yo* occupies part of the constellation Sagittarius is a particularly interesting region. The Milky Way passes through the region with the galactic equator intersecting the ecliptic equator. Numerous remnants lie in the error box of the search position (RA: $18^h2 \pm 10^m$, Dec: $-24.5 \pm 4°$). A positional association may not be practical because of the number of remnants (whether supernova or nova). However Hertzog (1986) suggested that 9 Sgr was the remnant to the guest star.

(xiv) AD 891

A Japanese record for the guest star of AD 891 is as follows, "On day *chi-mao*, the 29th

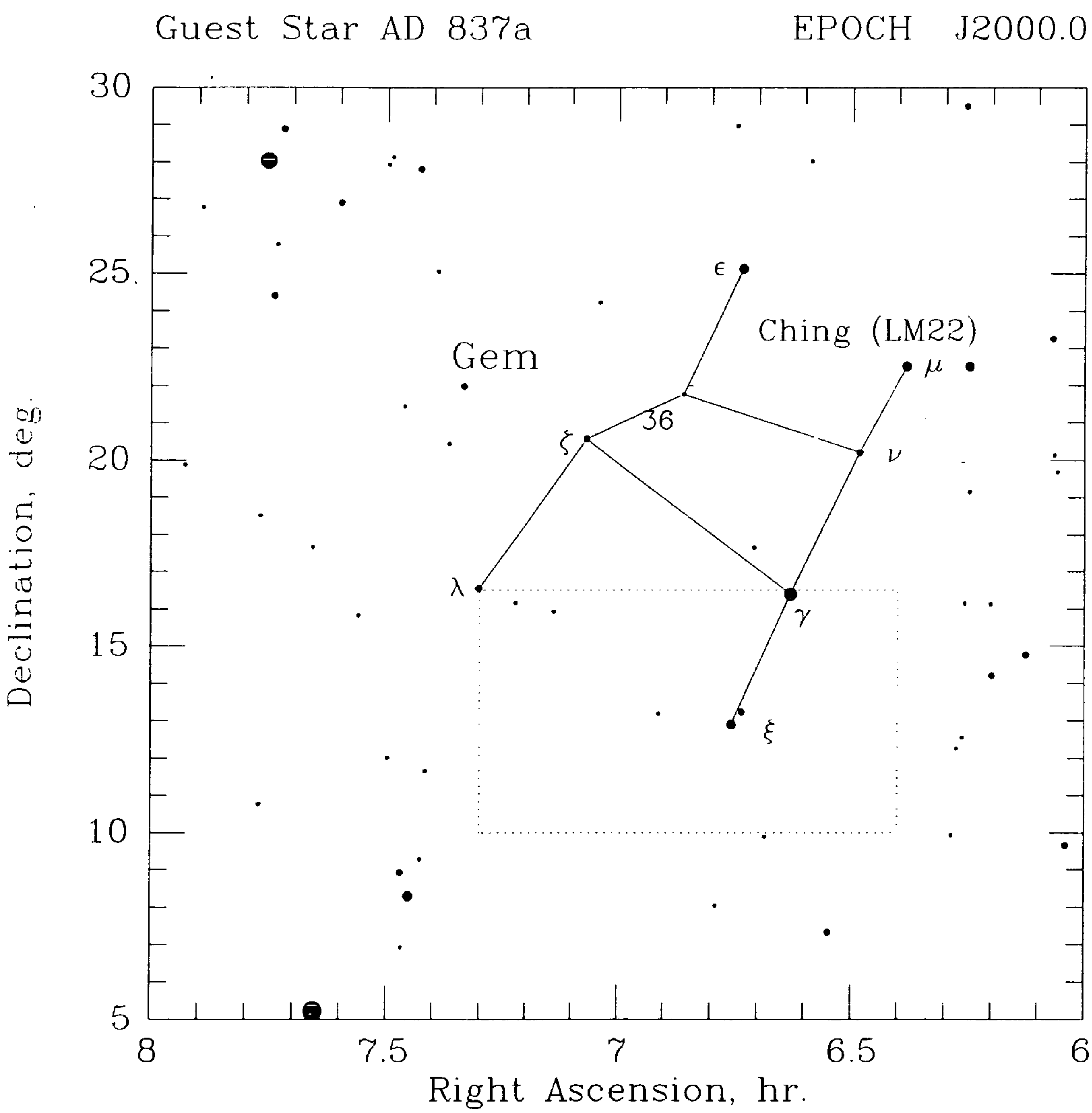

Fig. 5.12 A star map showing the region of sky in the vicinity of the guest star AD 837a, the dotted error box indicates the approximate location of the new star.

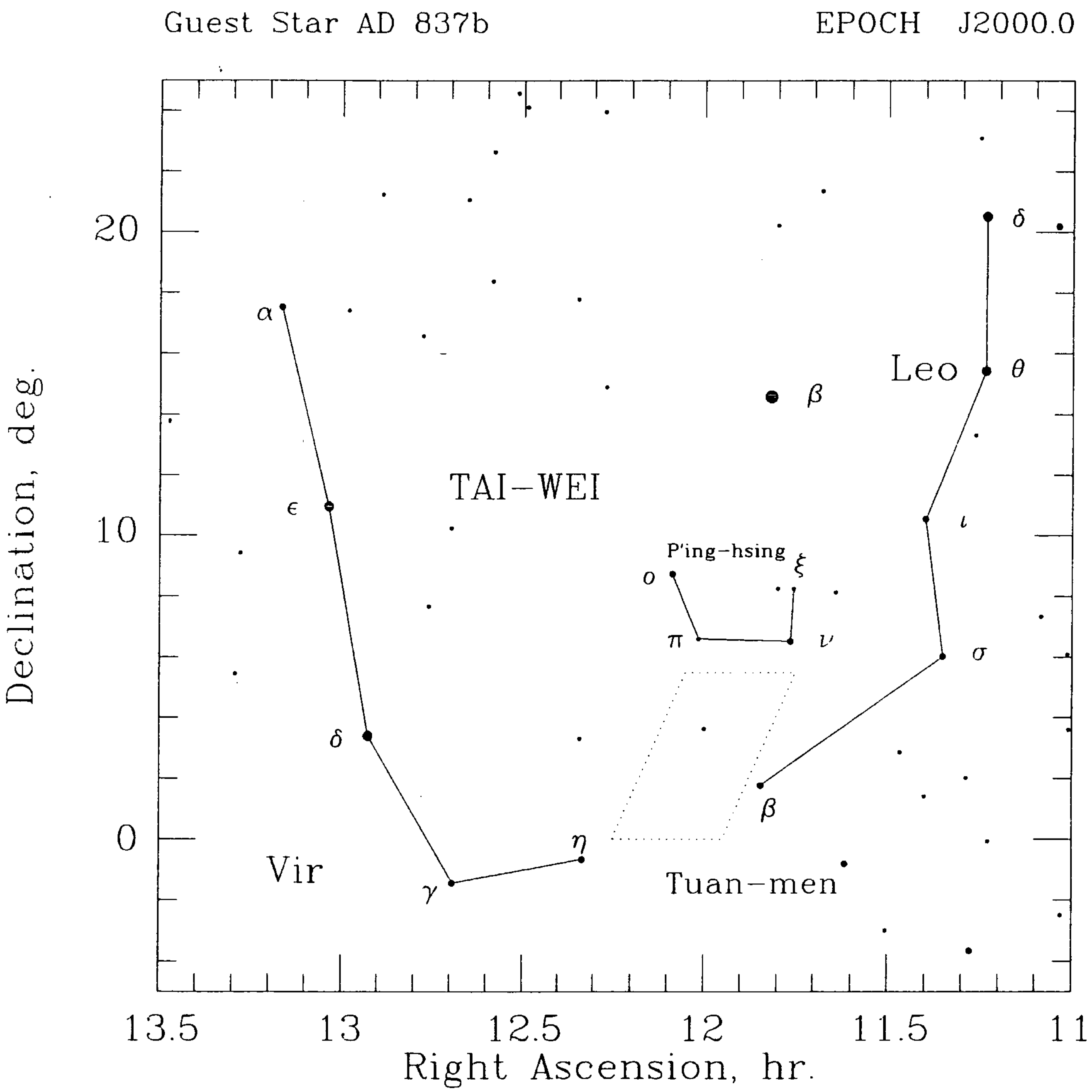

Fig. 5.13 A star map showing the region of sky in the vicinity of the guest star AD 837b, the dotted error box indicates the approximate location of the new star.

day of the 3rd month of the 3rd year of the Kempyo reign-period (May 11), at the hour of *hai* (9–11 p.m.), a guest star was at the east of the star of *Tung-hsien* and separated from it by about one *t'sun* ($\sim 0.1°$)." (*Temmon Shiryo*, 484)

The record described a particular careful measurement of a guest star but without an indication of its duration. The asterism *Tung-hsien*, consistsof ϕ, χ, ω and ψ Oph, is in the Lunar Mansion *Hsin* (LM 5). As the text do not say which star of *Tung-hsien* I have used a relatively large error box to encompass any uncertainty in the position. The coordinates for the deduced position are RA: $16^h 35 \pm 5^m$ and Dec: $-19 \pm 3°$. I searched the area for any corresponding modern nova in Table 4.1. Despite using a large error box I have found no remnant in the region east of the asterism *Tung-hsien*.

(xv) AD 902

Another record from the *Hsin T'ang-shu* says that, "On day chi-szu in the 1st month of the 2nd year of the T'ien-fu reign-period (AD 902 Mar 4), a guest star was at *Kang* and guarded it. The next year (AD 903) it was still there."
The length of visibility of the guest star is at least a year as implied by the record. This would have been a strong SN candidate if the position was a little precise. The asterism *Kang* is in the circumpolar region occupying part of the constellation Cassiopiae. Although the constituent stars are faint, there is no problem of their identification. No remnant is found within the error box.

(xvi) AD 1073

The record for the guest star of AD 1073 is in chapter 47 of the Korean history *Koryo-sa*, it lists on day *ting-ch'ou* in the 8th month of the 27th year of King Munjong (Oct 9) that, "A guest star was seen at the south of *Tung-pi* (LM14)."

The lunar mansion *Tung-pi* consists of only two stars, α And to the north and γ Peg to the south. I have assigned a search position with RA: $0^h35 \pm 20^m$, Dec: $5 \pm 10°$ and found no corresponding nova in Table 4.1. Li Jing (1985) suggested that the variable star R Aqr is associated with the guest star. He inferred from the rate of expansion of its nebulosity that R Aqr had undergone an outburst some 550–1100 years ago. However R Aqr (RA: $23^h41.2^m$, Dec: $-15°33.7'$) is a long way from *Tung-pi* and because the large uncertainty in the age of the outburst of R Aqr, a claim of identification does not seen justifiable.

(xvii) AD 1074

A similar record to (xvi) above is also found in the *Koryo-sa*. On day *keng-shen* in the 7th month of the 28th year of King Munjong (AD 1074 Aug 19), "A guest star as large as a papaya was seen south of *Tung-pi*."

The brief record is almost verbatim in description to the previous record. One may naturally suspect that the same guest star was seen again. The only difference between the two texts is an additional description of the size of the apparent guest star in the latter record – 'as large as a papaya' (the term 'papaya' may suggest a significant angular size). If the two records were of one and the same object, the implied duration of visibility is some eleven months. From the consideration in chapter 4, a duration of this length would suggest a SN interpretation. However the position is a considerable distance from the galactic equator (RA: $0^h35 \pm 20^m$ and Dec: $5 \pm 10°$ with galactic latitude approximately $-40°$). I would incline to think that these two Korean records (in AD 1073 and 1074) are not related. So far, no remnant of any kind has been suggested for the guest star.

(xviii) AD 1082

The record of the AD 1082 guest star is in chapter 47 of the *Koryo-sa.* The record says that, "On day *ting-hai* in the 7th month of the 36th year of King Munjong (AD 1082 Aug 4), a star appeared in *Tzu-wei* (Enclosure) and invaded (*fan*) Polaris."

This is one of the few guest star records that Ho (1962) has overlooked. The description suggests that the star was very close to Polaris from the meaning of the term *fan* (see discussion given in the AD 329 record above). I searched with an error box $\pm 5°$ in declination and for all ranges of right ascension centred on Polaris for any modern nova. I have found no corresponding candidate in Table 4.1.

(xix) AD 1163

Another entry from the *Koryo-sa* says that on day *wu-hsu* in the 7th month of the 17th year of King Uijong (Aug 10), "A guest star trespassed against the Moon."

This is the first of the three records concerning the occultation of a guest star by the Moon. I have adopted a mean position for the guest star with its corresponding error box as follows, RA: $17^h34 \pm 5^m$ and Dec: $-21.5 \pm 0.5°$ (See Stephenson (1971b) for a detail analysis of the position). I have found only one nova from Table 4.1 with a similar position, namely V794 Oph with RA: $17^h38.1^m$ and Dec: $-22.8°$. This was a slow nova which had its outburst in 1939. If these two novae were the same, the astrophysical implication would be profound. Could a periodic outburst with a period of about 800 years be a realistic mechanism for these objects? However it has to be pointed out that the position of the guest star is very close to Kepler's SN as well.

(xx) AD 1175

The AD 1175 guest star is reported in chapter 56 of the *Sung-shih.* On day *hsin-ch'ou* in the 7th month of the 2nd year of the Shun-hsi reign-period (AD 1175 Aug 10), "A star emerged at the NW. It was situated outside the Wall of the *Tzu-wei* Enclosure and above *Ch'i-kung*. It was as small as Mars and burst out luxuriously with rays in all directions. It lasted until day *ping-wu* (Aug 15) and then it was dispersed."

The record for this guest star is reasonably detailed. The text indicates a duration of about 6 days with a deduced position RA: $16^h05 \pm 35^m$ and Dec: $+50 \pm 7°$. The short duration given by the text could imply that the object was a fast nova. However, no corresponding candidate is found in Table 4.1.

(xxi) AD 1203

Another record from chapter 56 of the *Sung-shih* says that, "On day *i-mao* in the 6th month of the 3rd year of the Chia-t'ai reign-period (AD 1203 Jul 28), a guest star appeared at the SE, inside the *Wei* Lunar Mansion. Its colour was bluish-white and it was as large as Saturn. On day *chia-tzu* (Aug 6), it guarded *Wei*."

The position of the guest star is not accurately stated in this record. The position was initially given as somewhere in the *Wei* Lunar Mansion. In a latter statement the record gives a refined position saying that the guest star "guarded *Wei*". I have taken the latter statement to mean the guest star was in the vicinity of the *Wei* asterism. I have assigned a search area with RA: $17^h30 \pm 35^m$ and Dec: $-38 \pm 5°$. Unfortunately, in this region of sky, the large number of possible nova candidates preclude a positive identification. Unless a finer position can be obtained for this guest star, we may never reach a conclusion.

(xxii) AD 1356

From chapter 47 of the *Koryo-sa*, on day *kuei-ch'ou* in the 4th month of the 5th year of King Kongmin Wang (May 3). "A guest star trespassed against the Moon."

Based on the analysis of Stephenson (1971b), I have assigned a position with RA: $5^h 50.5 \pm 2.5^m$ and Dec: $27.8 \pm 0.5°$ for the guest star. No corresponding candidate is found in Table 4.1. The accurate position merits a careful search to be made for the remnant of this guest star.

(xxiii) AD 1399

A similar entry: "a guest star trespassed against the Moon" is found in the *T'aejo Sillok* on day *keng-tzu* in the 11th month of the 7th year of King T'aejo (Jan 5).

If the guest star is truly a nova outburst then its position is very well defined. I have deduced a position of the guest star based on Stephenson's (1971b) analysis with RA: 18h51.5±1.5m and Dec: $-20.1 \pm 0.5°$. No corresponding nova outburst in modern time coinciding in position is found in Table 4.1. As was pointed out by Stephenson (1971b), the Moon passed within about half a degree of Saturn on the morning of 1399 Jan 6. The possibility that Saturn was mistaken for a guest star by the Korean astronomers is very small at this period, for planetary records show that a careful watch was kept on the planets.

(xxiv) AD 1430

A detailed record of a star with a fixed nature is listed under the 5th year of the Hsuan-te reign-period (AD 1430) in the *Ming-shih-lu.* On day *chia-shen* in the 8th month (Sep 3) the record reads, "At night, a guest star was seen more than a *ch'ih* ($\sim 1°$) NE of *Nan-ho.* Its colour was bluish-black. On day *keng-yin* (Sep 9), a guest star as large as a pellet was seen beside *Nan-ho.* Its colour was bluish-black. It extinguished after a total of 26 days."

The error in position is fairly small for this guest star (see Fig. 5.14). No corresponding nova candidate is found in Table 4.1.

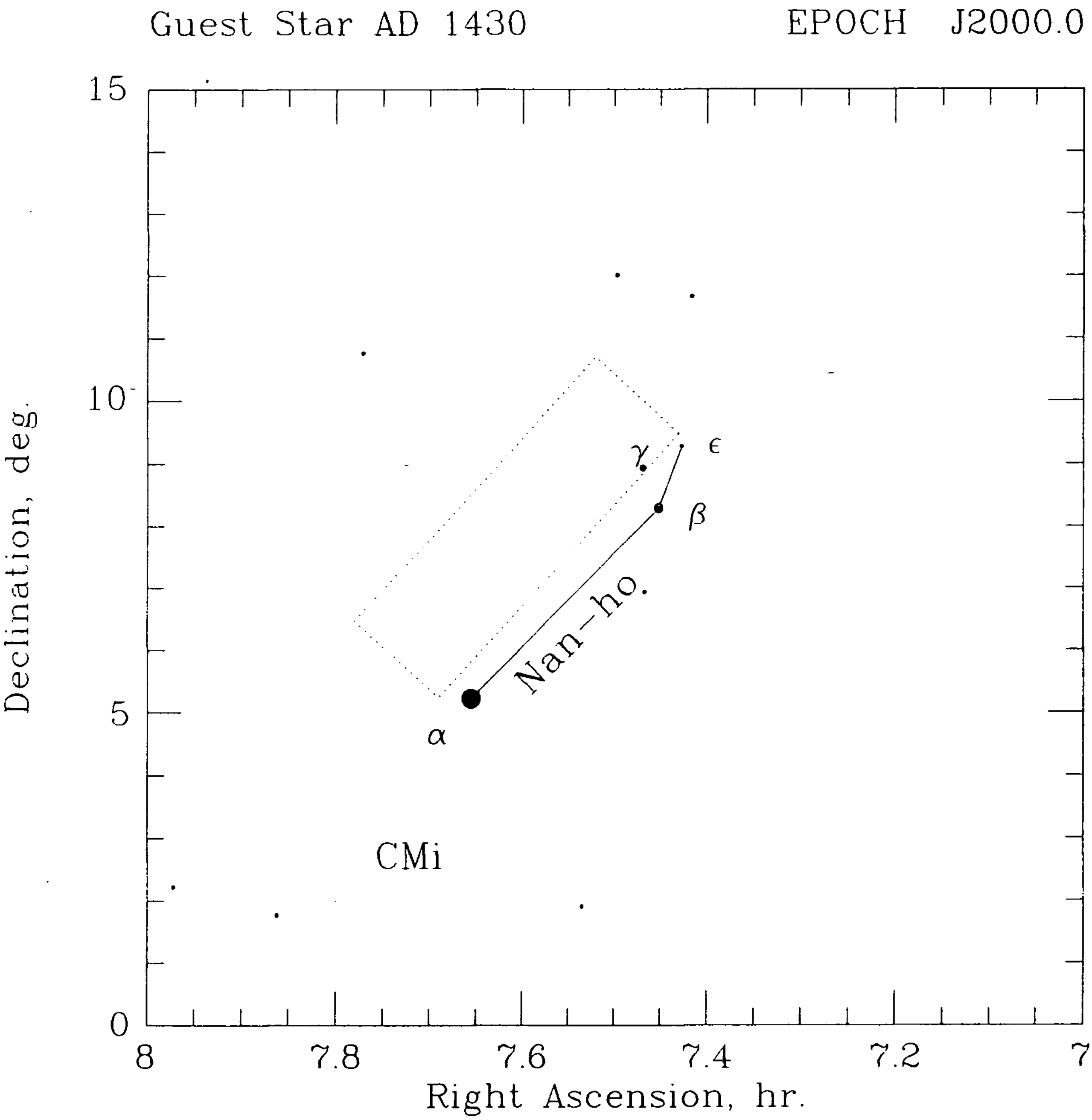

Fig. 5.14 A star map showing the region of sky in the vicinity of the guest star AD 1430, the dotted region represents the error box encompassing the uncertainty in the postion of the new star.

(xxv) AD 1437

The guest star record of AD 1437 is a detailed Korean entry listed under the 19th year of King Sejong in the *Sejong Sillok.* On day *i-ch'ou* in the 2nd month (Mar 11), "A guest star was seen between the 2nd and 3rd stars of the *Wei* Lunar Mansion. It was nearer to the 3rd star and separated by about half of a *ch'ih* (1 *ch'ih* is $\sim 1°$). It was there for a total of 14 days."

This is a particularly good record, mentioning an accurate position and a duration of 14 days. The position specified the guest star was near the 3rd star of *Wei*. The star was probably a fast nova. *Wei* is the tail of the Scorpion. Modern star maps designate the 2nd star of *Wei* as ε Sco and the 3rd star as ζ Sco. However these are not adjacent – they are separated by μ Sco. If the numbering is from the top right the sequence fits (see Fig. 5.2). In any case the important 3rd star is ζ Sco. A position of "about half of a *ch'ih*" ($\sim 0.5°$) north of ζ Sco seems to be a reasonably deduction. I have assigned a position for the guest star with RA: $16^h53 \pm 2^m$ and Dec: $-41.9 \pm 0.5°$. No corresponding nova candidate is found in Table 4.1. Hertzog (1986) has suggested that HR 6272 is associated with the guest star.

(xxvi) AD 1690

The last entry in table 5.2 is for the guest star of AD 1690. There are two records, one from the *Ching-shih-k'ao* ('A Drafted History of the Ch'ing Dynasty') (a) and another from the original report presented to the emperor by the Astronomical Bureau (b). The latter was included in the catalogue of Xi and Bo (1965) but has not attracted the attention it deserves because of an incomplete translation.

(a) K'ang-hsi reign-period, 29th year, 8th month, day *i-yu* (Sep 29). "An unusual star was seen at *Chi* (LM7). Its colour was yellow and it lasted for a total of 2 nights."

(b) K'ang-hsi reign-period, 29th year, 8th month, 27th day, *i-yu* (Sep 29). "At the hour of *hsu* (7–9 p.m.), it was observed that to the east of the 3rd star of the *Chi* Lunar Mansion (LM7) in the S direction, there appeared an unusual star. It was yellow in colour and without a ray tail. By using an instrument, it was measured 3 *tu*, 18 *fen* from *Ch'ou-kung* and south 'latitude' (declination) 34 *tu*, 20 *fen*. On the 28th day (Sep 30), it was observed that this guest star was still at the E of the 3rd star of the *Chi* Lunar Mansion (LM7). It was yellow in colour and without a ray tail. By using an instrument it was measured that it did not move." (*Astronomical Bureau Report*)

The position of this guest star is carefully measured. No associated nova candidate is found for the guest star from Table 4.1. I recommend that a search should be made for the remnant of this particularly accurately measured guest star of AD 1690.

5.9 Four Korean 'Guest Stars' Observed in AD 1592

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Four Korean 'Guest Stars' observed in AD 1592

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SUMMARY

During the year 1592, four 'guest stars' were sighted by the Korean court astronomers. We present here an evaluation of the suitability of these stars as potential novae or supernovae. Our investigation shows that three of the stars are strong nova candidates. Two of these objects appeared in the constellation of Cassiopeia and one in Cetus.

1 INTRODUCTION

Apart from the brilliant supernovae of AD 1572 and 1604, the temporary stars which appeared in AD 1592 were more extensively recorded than any other similar objects in the whole of the pre-telescopic period. These stars were apparently only sighted in Korea, but the chronicle in which they were reported – the *Sonjo Sillok* ('Veritable Records of the Reign of King Sonjo') – contains many detailed astronomical records. In recent years, this and other related chronicles of Korea have proved valuable sources of information on matters as diverse as the light curve of the supernova of AD 1604 (Clark & Stephenson 1977) and auroral frequency (Dai & Chen 1980).

In AD 1592, the Korean court astronomers discovered as many as four temporary stars. Three of these objects were systematically observed for periods ranging from three months to more than a year. Although the stars have appeared as entries in a variety of modern catalogues of probable novae and supernovae (Ho Peng Yoke 1961; Xi & Bo 1966; Chu Sun-il 1968; Clark & Stephenson 1977), an extensive investigation of them has never been made. It is our aim here to remedy this omission.

2 HISTORICAL OUTLINE

All four stars appearing in AD 1592 were sighted within a period of only about a month but it seems likely that the discovery of the first object led to a search for others. The day to day records in the *Sonjo Sillok* show that these stars – which are described as 'guest stars' (*k'o-hsing*) – remained visible for periods ranging from about five weeks to 15 months. The usual interpretation of the term guest star in East Asian history is a nova or supernova – especially if, as here, the duration of visibility is fairly long and there is no evidence of motion. Although it must be conceded that the probability of four separate novae/supernovae appearing within such a short interval of time is extremely low, the detailed Korean records of the guest stars appear genuine and are deserving of careful study.

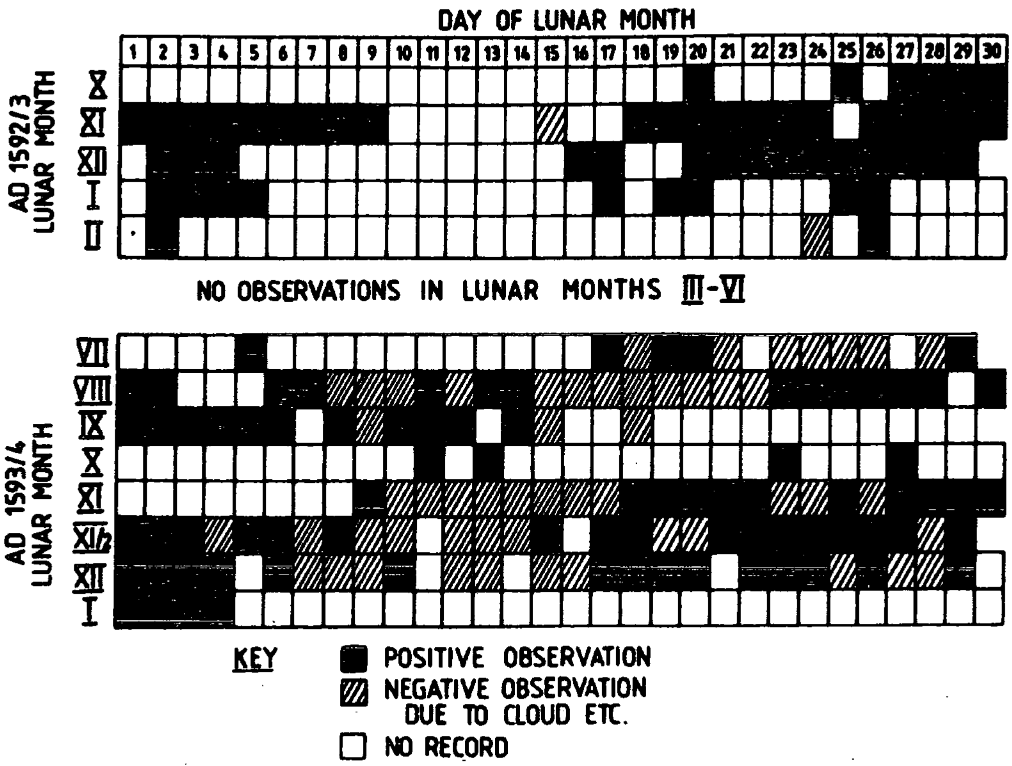

FIG. 1. A statistical chart of the guest star records in the *Sonjo Sillok* for the years 1592 to 1594.

There is no known reference to any of these stars in Chinese history but the degree of preservation of astronomical records from China around this time is much poorer than from Korea. It is more difficult to account for the apparent absence of any observations in Europe – e.g. there are no allusions to the stars in the systematic compilation of cometary and related sightings by Pingré (1783–4). However, examination of the European observations of the supernovae of AD 1572 and 1604 suggests that these stars were mainly noticed on account of their unusual brilliance. As soon as significant fading occurred, only a few astronomers continued to observe them systematically (Clark & Stephenson 1977). There is nothing in the Korean records to indicate that the stars appearing in 1592 were particularly bright; in fact any brightness comparisons which were made rather imply the converse. If the records of these objects are indeed reliable, we would seem to have evidence of a diligent observing team whose members were well versed in the constellation patterns.

The *Sonjo Sillok*, in which the guest star observations are reported, is a detailed day to day chronicle of major events of all kinds which concerned the Korean court during the long reign of King Sonjo (AD 1567–1608). Similar compilations are available for every other reign from the beginning of the Yi dynasty (AD 1392) down to AD 1864. These form the *Choson Wangjo Sillok* ('Veritable Records of the Yi Dynasty in Korea'). Because of the political importance of astrology throughout this period, the kings of Korea, like the emperors of China and Japan, employed official astronomers to maintain a systematic watch of the sky. Only a few specimens of the original reports of these astronomers survive (Il-Seong Nha 1981), but fairly detailed summaries are found in the *Choson Wangjo Sillok*. The chronicle is thus a valuable source of astronomical (and also meteorological) data.

Although there are several obvious gaps in the records of the new stars of AD 1592 in the *Sonjo Sillok*, the general picture is one of impressive consistency, as illustrated in Fig. 1. This diagram summarizes the day-to-day record of the stars over the entire period of visibility from November 1592 (the 10th lunar month in the 25th year of King Sonjo) to March 1594 (the first lunar month in the 27th year). In Fig. 1, a black square denotes a positive observation of at least one of the new stars and a hatched square an abortive sighting on account of cloud or bright moonlight. A blank square indicates a missing record.

Three of the guest stars were sighted within a few days of 1592 December 1 and over the next three months there are extant reports on almost 60 per cent of days. (Little interest was apparently shown in the fourth star; there are only two observations of it separated by about 5 weeks.) Most of the accounts tend to be very repetitive but the slight differences give an impression of authenticity; as do the occasional allusions to overcast weather preventing or interrupting observation. The three principal stars were seen regularly until 1593 March, but during this month or soon afterwards they were apparently all lost to view. However, one of them was recovered later in the year (1593 August) following conjunction with the Sun. This star was then kept under observation for a further six months, until February 1594. For much of the time these later records are even more systematic than those before conjunction; this is especially true for unsuccessful sightings due to unfavourable weather or bright moonlight.

The consistency of the various guest star accounts is all the more remarkable when we consider the tense political situation which existed in Korea around this time. At the instigation of the Shogun of Japan, Toyotomi Hideyoshi, a large force of Japanese troops had invaded Korea in 1592 May and by the following month had captured the capital of Hansong (Seoul). As the *Sonjo Sillok* tells us, King Sonjo and his court fled northwards towards the Chinese border, where they remained until 1593 October. The invaders devastated much of Korea, including the capital, and the royal observatory was destroyed. Peace was not finally restored until 1598. Under such difficult circumstances, there must have been many occasions when the court astronomers were unable to perform their normal duties of nightly observing; in addition, it is probable that some of their existing records would be lost. Yet during the relatively calm period later in the reign of King Sonjo when the supernova of AD 1604 appeared, the records of this brilliant object are scarcely more complete.

As a cultural satellite of China, Korea adopted the Chinese luni-solar calendar – with its parallel 60-day cycle – at an early period. However, years are numbered from the accession of Korean kings rather than using the appropriate Chinese reign period. Dates are readily and accurately reducible to the Gregorian Calendar (or Julian Calendar in AD 1582 or before) using the tables of Chindan Hakhoe (1959). Korea also followed the traditional Chinese division of the sky into more than 250 small star groups or asterisms. Throughout the period of visibility of the guest stars, the time of night at which they first appeared is usually given in terms of the five 'watches' (*keng*), which equally divided the period between twilight and dawn. The length of these watches thus varied with the seasons. Since the astronomical day normally began at sunrise in East Asia (Stephenson 1971; Kiang 1971), the recorded date of an observation made after midnight should be one day behind the civil date. However, to avoid possible confusion we have ignored this difference and converted all recorded Korean dates directly to the Gregorian Calendar (without regard for the precise time of night).

In common with almost all Korean literary works composed before the present century, the *Sonjo Sillok* is written in Classical Chinese. In quoting the names of star groups, days of the sexagenary cycle, etc. we have followed the fairly standard practice of using Mandarin Chinese (rather than Korean) transliterations, adopting the Wade–Giles system of romanization.

In summarizing the records of the four guest stars below, we shall divide them into two separate groups – (i) observations made between 1592 November and 1593 March and (ii) those between 1593 August and the final disappearance of the last star in 1594 February. For reference, the stars will be identified as 1592A, B, C or D (in order of discovery).

3 SUMMARY OF THE RECORDS – FIRST PHASE (1592 NOVEMBER TO 1593 MARCH)

The first direct reference in the *Sonjo Sillok* to any of the guests stars of AD 1592 occurs on a date corresponding to November 23. This entry reads as follows, the Korean date being the day *ping-wu* in the 10th month of the 25th year of King Sonjo:

> [1] In the first watch of the night, a guest star was seen beside (*yu*) the stars of *T'ien-ts'ang*.

T'ien-ts'ang was a star group in Cetus. There is no further mention of the star until November 28, when the above entry is repeated. On November 29 there is no record, but by November 30 an additional star (1592B) had appeared, this time in Cassiopeia – in much the same right-ascension as Cetus:

> [2] In the first watch of the night, a guest star was seen beside the stars of *T'ien-ts'ang*. A guest star was seen at the east of *Wang-liang*.

This latter entry is repeated on the following three nights. However, on December 4 three stars are now reported and the position of 1592A is a little more specific:

> [3] A guest star was seen within (*nei*) the stars of *T'ien-ts'ang*. A guest star was seen at the east of *Wang-liang*. A guest star was seen beside (*yu*) the first star from the west.

The context must be understood to imply that the third guest star (1592C) appeared near *Wang-liang* rather than *T'ien-ts'ang*, although this is never directly stated. There are regular entries similar to [3] above over the next few days down to December 11, the time of night usually being given as the first watch. Linguistic variations are trivial except that 1592C is now regularly described as 'within' (*nei*) the first star from the west (of *Wang-liang*). The meaning of *nei* in this context will be discussed in section 5.

On December 12 is given the first of only two allusions to a fourth guest star (1592D). This star, which is not mentioned again until January 18, appeared to the north of *K'uei*, a 'lunar mansion' in Andromeda and Pisces. The full entry reads as follows:

> [4] In the first watch of the night, a guest star was seen at the east of *T'ien-ts'ang*. One was also seen at the east of *Wang-liang*. One was also seen within the first star from the west. One was also seen above the stars of *K'uei*.

After five days when no observations are reported we find a reference to unfavourable weather (December 18):

> [5] At night there was thin cloud. Where the guest stars were situated could not be observed. In the fourth and fifth watches the Moon was eclipsed.

We calculate that on December 19 (civil date), a partial lunar eclipse would be visible in Korea between about 2.10 and 4.20 a.m. – roughly between the fourth and fifth watches. At maximum phase, the Moon would be about one-third in shadow. Since the next astronomical day did not begin until sunrise, the recorded date is exactly correct. The observation is thus fully reliable.

Between this last date and January 6 there is a report of the guest stars 1592A, B and C (1592D is ignored) on almost every night. These descriptions have an almost stereotyped format:

> [6] In the first watch of the night a guest star was seen within the stars of *T'ien-ts'ang*. One was also seen at the east of *Wang-liang*. A guest star was also seen within the first star from the west.

Astronomical entries are absent on every subsequent day until January 18, when we find the last reference to 1592D in a statement almost identical to [4] above. There is nothing to indicate that the guest star was now becoming dim, which suggests that it may possibly have remained visible for a further length of time. Hence we can only set a lower limit on its duration of visibility.

Between January 19 and February 5 of AD 1593, reports of the three stars 1592A, B and C now continue on a regular basis, usually with no significant alteration. However, on both January 25 and January 30 a particularly careful description of the position of 1592B is given – 'at *Wang-liang* between the first and second stars from the east'. Systematic records cease after February 5; no further observations are noted for 11 days and only six between February 17 and March 4. These later descriptions still follow the customary pattern set in [6] above. The March 4 entry (the day *ting-hai* in the 2nd month of the 26th year of King Sonjo) contains the last direct allusions to both 1592A and 1592C and reads as follows:

> [7] At night a guest star was seen within the stars of *T'ien-ts'ang*. One was also seen at the east of *Wang-liang*. A guest star was also seen within the first star from the west.

After this date there is a further long gap – devoid of any astronomical observations – until March 26, the entry on this day being concerned only with adverse weather:

> [8] In the first watch of the night it was cloudy. Where the guest star(s) were situated could not be observed. In the fourth and fifth watches it was foggy.

As there is no distinction between singular and plural in Classical Chinese, it is not possible to tell whether more than one star was still visible by this date. Unlike *Wang-liang*, which was circumpolar, *T'ien-ts'ang* would set heliacally in mid-March so that the March 4 record must represent one of the last possible sightings of 1592A. There is no astronomical record on March 27 but the next entry on March 28 (the day *hsin-hai* in the 2nd month of the 26th year of the King Sonjo) notes the visibility of only 1592B. Presumably 1592C had now faded below the unaided eye limit. The March 28 report repeats the more accurate position of 1592B, as reported twice in late January:

> [9] A guest star was seen at *Wang-liang* between the first and second stars from the east.

After this entry there are no further astronomical records of any sort in the *Sonjo Sillok* until August 1, when 1592A was rediscovered. 1592B must have disappeared at some time during this interval and – like 1592C and D – was apparently never seen again. Investigation of all four temporary stars will follow after discussion of the second phase of entries.

4 SUMMARY OF THE RECORDS – SECOND PHASE (AUGUST 1593 TO FEBRUARY 1594)

After the lapse of more than four months, the guest star 1592A was recovered before dawn on August 1 (civil date August 2) in AD 1593. This was the day *ting-szu* in the 7th month of the 26th year of King Sonjo). The new entry is partly retrospective:

> [10] In the fifth watch of the night, the stars of *T'ien-ts'ang* were seen at the eastern direction. The guest star was still at the east of *T'ien-ts'ang*. From last year *jen-ch'en* 11th month, 22nd day [i.e. AD 1592 December 25] until this year 2nd month [some time between March 3 and April 1 in AD 1593] it was often seen.

This sighting is much later than might have been expected since *T'ien-ts'ang* should have risen heliacally towards the end of May. Possibly the political situation was not conducive to serious observation during the summer. The date indicated in the above text corresponding to 1592 December 25 is not the original discovery date. It merely notes the fact that the star was frequently seen from late December (perhaps on account of improved weather). The actual discovery date was on day *ping-wu* of the 10th month (1592 November 23) – see section 3 above.

After August 1, there is no further mention of the guest star until August 13 but on August 6 the discovery of a comet is reported. The motion of this object, mainly in the north circumpolar region, was followed until September 18. The comet was also noticed independently in both Europe and China. The principal European observer – situated in Germany – was de Ripen, a student of Tycho Brahe (Pingre 1783/4). Tycho himself seems to have shown little interest in the object. De Ripen measured the position of the comet's head to a fraction of a degree on several nights between August 4 and September 1. He also noted that it passed directly across ε Cep on August 31 – a particularly careful observation. From these valuable measurements, Marsden (1986) calculated the orbital elements of the comet. The Chinese

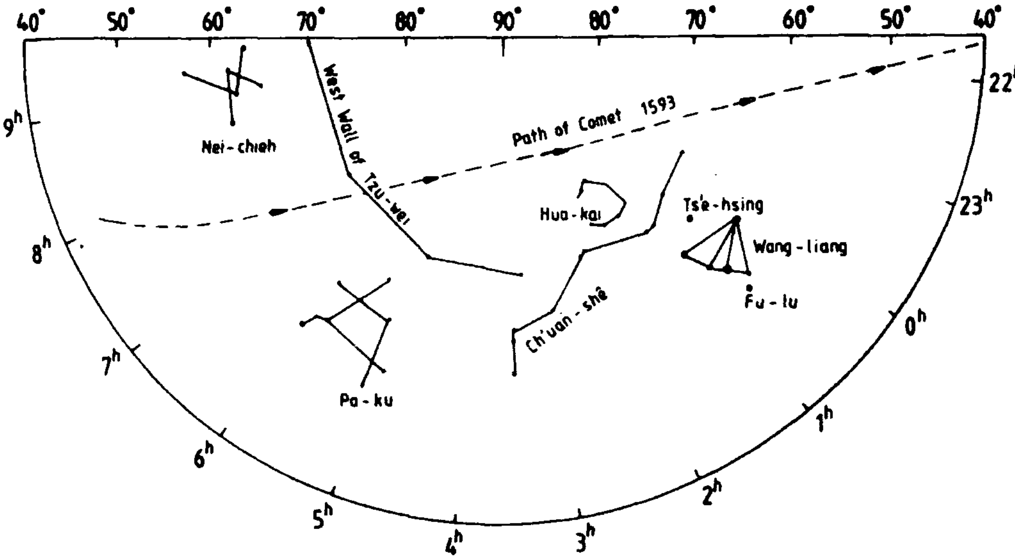

FIG. 2. Chart for the epoch J2000.0 showing the path of the comet of AD 1593 through the various Chinese asterisms in the north circumpolar region.

observations are reported briefly in the official chronicle of the time – the *Ming-shih-lu*. Only two rough positions are noted – on July 30 and August 19.

Figure 2 shows the path of the comet relative to the epoch J2000.0, as computed from the orbital elements of Marsden, together with the asterisms near which this object passed as reported by the Korean astronomers. (For reference, we have also shown *Wang-liang* and *Ts'e-hsing*, near which both 1592B and C appeared). Apart from three incorrectly dated entries in late August and early September, the positional agreement is satisfactory, giving additional credibility to the guest star accounts.

On August 13, the *Sonjo Sillok* gives a detailed account of both comet and guest star:

[11] In the fifth watch of the night, the broom star (i.e. comet) was situated below the stars of *Pa-ku*. Its shape and form were gradually becoming faint. Its colour was pale blue. Its rays were overshadowed by the moonlight. Where it was pointing or how long it was could not be observed. The guest star was at *T'ien-ts'ang*, within (*nei*) the third star from the east and about 3 *ts'un* away. Its colour and form were less (conspicuous) than the stars of *T'ien-ts'ang*.

We have here a useful estimate of both the position and brightness of the guest star. As the six stars of *T'ien-ts'ang* are all in the narrow magnitude range 3·5–4, 1592A must have been somewhat fainter than magnitude 4. Since it remained visible for another 6 months, its average rate of decline was rather slow.

For more than a month, comet and guest star are frequently reported. The comet passed only about 10 deg from *Wang-liang*, the site of outburst of both 1592B and C. The lack of any allusion to these guest stars suggests that they were definitely no longer visible. The various descriptions of 1592A are virtually identical with that in the second part of [11] above. On a number of occasions the chronicle states that cloud or bright moonlight prevented observation of both guest star and comet, sometimes for only part of the night.

Other observations made around this time include several bright meteors and lunar haloes. A conjunction between the Moon and Jupiter ('they shared the same degree') is reported in the second watch on September 5 and a similar observation involving Saturn and Venus is noted in the fourth watch on September 19. The entrance of the Moon into the lunar mansion *Tung-ching* (in Gemini) is also noted in the fourth watch on September 18. Both of the lunar observations – including dates and approximate times – are well supported by modern calculation. The conjunction between Venus and Saturn is actually recorded 5 days too early but around this time the relative motion of the two planets was fairly slow.

After the comet was lost to view (September 18), the guest star was regularly observed over the next three weeks. Mostly the location is described simply as 'at the east of *T'ien-ts'ang*' but on other occasions the more precise position – 'at *T'ien-ts'ang*, within the third star from the east and about 3 *ts'un* away' – is given. Where the brightness of the star is reported, this is identical with the estimate in [11] above. The almost full Moon prevented the guest star from being seen on October 8 and 9 while on October 12 the main item of interest was a spectacular thunder storm during the third and fourth watches in which houses were burnt and several people killed. Between now and November 15, astronomical records occur on only two days (November 3 and 5). This lapse may possibly be attributed to the journey of King Sonjo and his court back to the ruined capital of Hansong, where they arrived on October 27. The November 3 and 5 entries follow the now standard pattern found in [11]. On the former day, in the fifth watch it was also observed that 'Venus entered the wall of *T'ai-wei*, inside the Main Gate' and this event is closely confirmed by calculation.

At some time between November 15 and 19 (the intervening observations are missing) the guest star seems to have faded noticeably. On November 15 we find the usual comparison with the stars of *T'ien-ts'ang* but only four days later the entry reads as follows:

> [12] From the first watch to the fifth watch, the guest star was at *T'ien-ts'ang*, within the third star from the east and about 3 *ts'un* away. Its form and body were very small.

This description is duplicated in almost every record of the star until its final sighting in the following February (AD 1594). There are no extant records from November 20 to 30 but between December 1 and February 23 references to the star are made on all but seven nights – remarkable consistency indeed. Throughout this time it is often reported that cloud or bright moonlight interfered with observation but almost fifty separate positive sightings of the star are on record. As usual, these descriptions are highly stereotyped, the guest star typically being described as 'at *T'ien-ts'ang*, within the third star from the east and about 3 *ts'un* away'. However, it is possible to follow the changing pattern of visibility as the guest star approached its second conjunction with the Sun. Thus the star was observed between the first and fourth watches in most of December but towards the end of the month it could only be seen between the first and third watches. Visibility was further reduced to the first and second watches by mid-January.

In passing, we note that a solar eclipse is briefly reported in the *Sonjo Sillok* on November 23 in AD 1593. Calculation shows that this observation is reliably recorded; the eclipse would be visible in Korea just before sunset on the stated day. Hence, we may conclude that the various solar, lunar and planetary observations made while the guest stars were visible all prove to be reliably recorded in the chronicle – apart from a single minor dating error, the planetary conjunction in September of 1593. Thus there seems to be no valid reason for doubting the veracity of the guest star reports.

The last extant reference to the star 1592A occurs on February 23 in AD 1594. On the previous night 'its form and brightness were very small' – the customary description – but now there is no mention of brightness. This entry, on the day *kuei-wei* in the first month of the 27th year of King Sonjo (i.e. 1594 February 23), may be translated as follows:

> [13] From the first watch of the night to the second watch, the guest star was at *T'ien-ts'ang*, within the third star from the east and about 3 *ts'un* away.

As in the previous year, *T'ien-ts'ang* would set heliacally in mid-March. Hence although the February 23 entry may not necessarily represent the final disappearance of the guest star, it could not have been seen for many more days. There is no record of the recovery of the guest star during the summer of AD 1594 (or on any subsequent occasion) so that by this time we may suppose that it had faded below the unaided eye limit.

5 ANALYSIS OF THE GUEST STAR RECORDS

Of the four new stars discovered by the Korean astronomers in AD 1592, the object which we have labelled here as 1592D is by far the weakest nova/supernova candidate. There are only two references to this star in the *Sonjo Sillok* – more than a month apart (on December 12 in 1592 and January 18 in 1593). In both cases the recorded location is vague – 'above the stars of *K'uei*'. The indicated position is within perhaps 5 deg of the point with present day (J2000.0) coordinates: R.A. $1^h\ 0^m$, dec. +42 deg. The probable location at epoch AD 1593 is shown in Fig. 3. If the records are indeed reliable, a cometary nature seems unlikely in view of the absence of any change in location over 37 days. However, the positional description is much too imprecise to justify a search for its remnant. Fortunately, the locations of the other three new stars were more precisely described.

The guest star 1592A was regularly observed at a fixed position – near *T'ien-ts'ang* in Cetus – for more than a year so that it was undoubtedly of stellar rather than cometary nature. The fact that the star was not discovered in Europe would suggest that its brightness never attained first magnitude – otherwise it would have been easy to detect. There are no useful indications of brightness in the *Sonjo Sillok* until mid-August in AD 1593, some nine months after the star was first sighted. As indicated in section 4 above, the magnitude was by now rather fainter than +4. Later, around mid-November, a further fall in brightness was noted. A supernova identification would seem to be ruled out by the very high galactic latitude (−70 deg) of

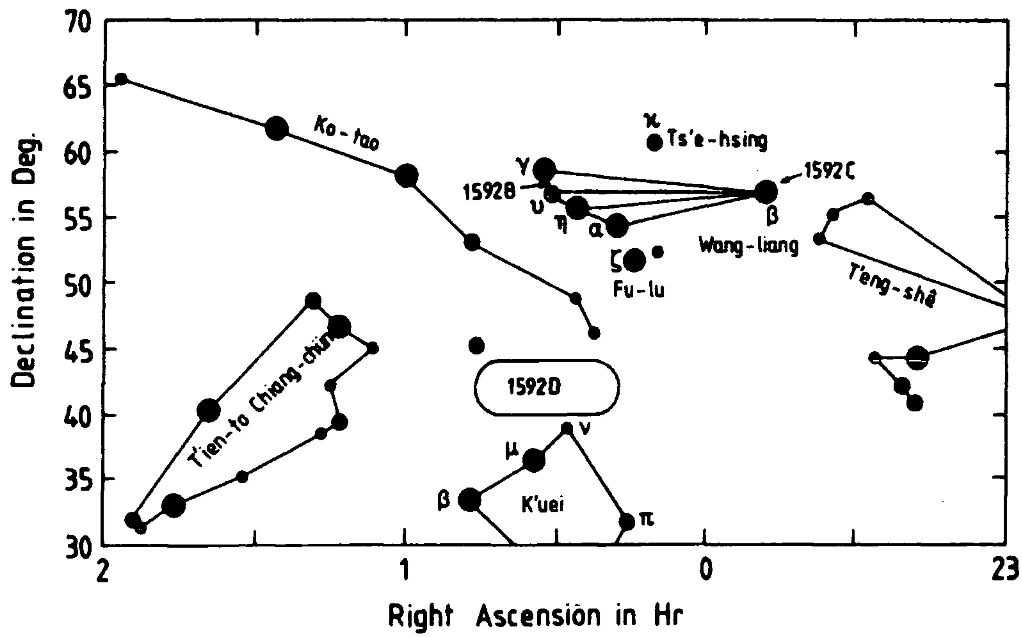

FIG. 3. A star map showing the Cassiopeia region for epoch 1593 with some of the principal stars marked by Bayer and Flamsteed designations. The guest stars 1592B, C and D are referenced relative to the Chinese asterisms *Wang-liang* and *K'uei*.

T'ien-ts'ang; no supernova remnants (SNR) are known to be more than about 15 deg from the galactic equator (Green 1984). Most probably, the object was a slow nova.

From ancient times, *T'ien-ts'ang* ('Celestial Granary') was regarded as consisting of six stars (Ho Peng Yoke 1966) and it is represented in this way on a variety of early star charts from both China and Korea. Useful selections of these charts are published by Needham (1959) and the Institute of Archaeology, Beijing (1978). According to de Schlegel (1875) and I Shih-t'ung (1982), the constituents of *T'ien-ts'ang* were ι, η, θ, ζ, τ and υ Cet. Wylie (1897), the principal source of Ho Peng Yoke's (1966) star catalogue and atlas, agrees with most of these identifications but replaces υ Cet by the nearby star 57 Cet, less than 0·5 deg away. However, this is clearly a mistake; the latter star (mag +5·4) is much fainter than υ Cet (mag +4·0). Measurements which we ourselves have made on a number of early star maps support the identifications of Schlegel and I Shih-t'ung. Although all six stars are rather faint – magnitudes ranging from +3·5 to +4 – the asterism is well defined since the surrounding sky is somewhat deficient in naked-eye stars. The vicinity of *T'ien-ts'ang* at epoch AD 1593 is shown in Fig. 4.

The guest star 1592A was brought into association with Mira Ceti by Brosche (1967). This well known long-period variable was discovered in Europe by David Fabricius in 1596 and it would have been most interesting if the discovery date could have been extended back (albeit by only four years) using Korean observations. However, as is apparent from Fig. 4, Mira was at least 10 deg from *T'ien-ts'ang* and rather close instead to the asterism *T'ien-chun*. The characters *ts'ang* and *chun* are quite dissimilar and it would seem that the proximity of 1592A to Mira is no more than coincidental.

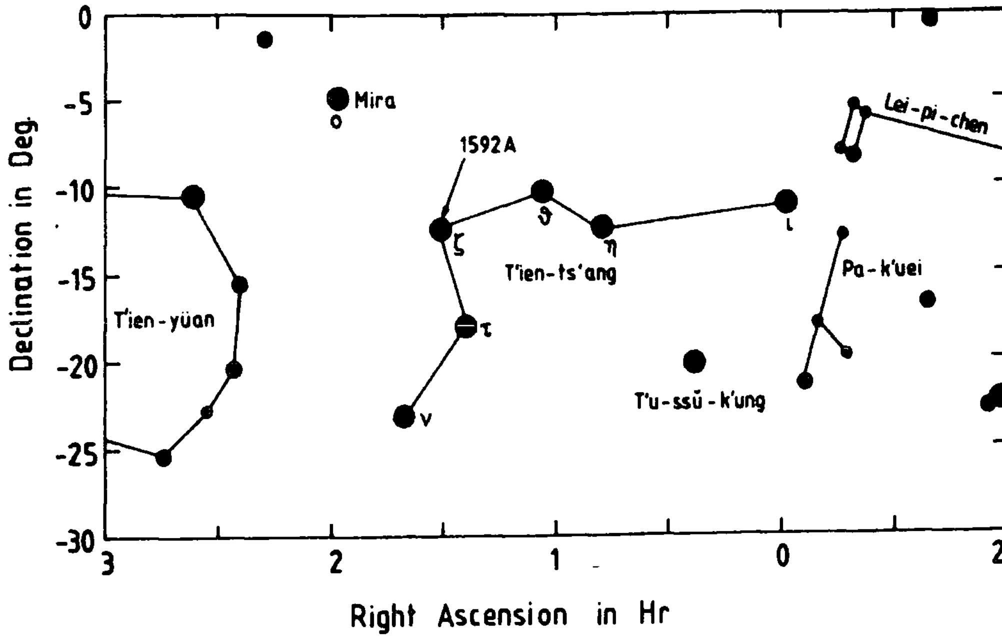

FIG. 4. A star map showing the Cetus region for epoch 1593 with some of the principal stars marked by Bayer and Flamsteed designations. The guest star 1592A is indicated with respect to the Chinese asterism *T'ien-ts'ang*.

The most accurate position of 1592A – frequently reported in the period after the guest star was recovered following conjunction with the Sun – was 'at *T'ien-ts'ang*, within the third star from the east, and about 3 *ts'un* away'. In Korea, as in China, numbering of the stars within each asterism followed two separate schemes. The more arbitrary method simply assigned each star within a group a separate number – e.g. 'the fifth star of *Nan-tou* (part of Sagittarius)'. Obviously, unless careful records were kept, it would be difficult to maintain the continuity of such a scheme down the centuries. The other method (fortunately used in describing the location of the three guest stars 1592A, B and C) was more specific since it involved direction. Thus a text might refer to 'the first star from the south of *Fang* (in Scorpius)' or the 'third star from the west of *Pi* (in Taurus)'. Descriptions of this kind are often found in records of close conjunctions of the Moon and planets with stars. We have computed the detailed circumstances of a number of Korean and Chinese observations of such conjunctions and have found that with very few exceptions the star identified by calculation matches that in the record itself.

As is evident from Fig. 4, the 'third star from the east of *T'ien-ts'ang*' is clearly ζ Cet. Hence the indicated site for 1592A is 'within 3 *ts'un*' of ζ Cet. Investigations of ancient and medieval Chinese records of planetary conjunctions which use the term *ts'un* by Kiang (1971) indicate that this unit (actually a linear unit in normal usage) was probably equivalent to about 0·15 deg. Accordingly, we recommend searches for a post nova, the likely remnant of 1592A, within about 0·5 deg of ζ Cet. The approximate coordinates of ζ Cet at epoch J2000.0 are R.A. $1^h\ 51^m$, dec. $-10{\cdot}4$ deg. (galactic coordinates $l = 167$ deg, $b = -68$ deg). Although post-novae are much more difficult to detect than SNR, recent successes such as those achieved by Reynolds & Chevalier (1984) and Shara, Moffatt & Webbink (1985) promise some hope of recovery. Reynolds and Chevalier detected the radio remnant of the outburst of Nova Persei (GK Per), which occurred in 1901, while Shara *et al.* recovered the optical (H alpha) remnant of Nova Vulpecula, which was observed in AD 1670.

Both 1592B and 1592C appeared for at least 3 months and their positions, which are rather carefully described in relation to *Wang-liang* (an asterism in Cassiopeia), remained fixed. Hence, both objects must represent stellar outbursts. The galactic latitude is very low – close to zero in each case – so that there is a possibility that either of the stars were supernovae. No information is given on the brightness of 1592B but the apparent failure of Western astronomers to notice it suggests, as for 1592A, that it was fainter than first magnitude. Beyond that we cannot judge. The only brightness estimate for 1592C is that it rivalled Praesepe (i.e. 5th magnitude) soon after discovery. Unless the star subsequently brightened considerably, it is remarkable that such an unimpressive object remained visible for so long.

From ancient times, *Wang-liang* (named after a famous charioteer), was regarded as consisting of five stars – representing the charioteer himself and his four horses – while a neighbouring star *Ts'e-hsing* ('Whip Star'), represented his whip (Ho Peng Yoke 1966). A wide variety of pre-Jesuit oriental star maps show *Wang-liang* as consisting of five stars, with connecting lines radiating from the westernmost member of the group. *Ts'e-hsing* is shown as a single star a little to the north of *Wang-liang*. Wylie (1897) and I Shih-t'ung (1982) indicate that the constituents of *Wang-liang* were α, β, η, κ and λ Cas, with β Cas representing the charioteer himself and γ Cas his whip. Schlegel (1875) agrees with these identifications except that he replaces λ Cas by μ Cas. Measurements made by Clark & Stephenson (1977) on a number of early star maps indicate that the members of *Wang-liang* were α, β, γ, η and υ Cas (regarding the two rather close components of υ Cas as a single star) while κ Cas was *Ts'e-hsing*. Additional measurements which we have made confirm these identifications – see Fig. 3.

Studies of medieval Chinese star lists by Pan & Wang (1981) support our identification of κ Cas as *Ts'e-hsing*. Direct evidence that κ Cas was regarded as *Ts'e-hsing* by the Korean astronomers around the time that the guest stars appeared is found in the *Sonjo Sillok* itself. The supernova of AD 1572 is described in this work as 'beside' (*yu*) *Ts'e-hsing*. Using the very accurate measurements of Tycho Brahe, the supernova was only 1·5 deg from κ Cas (to the northwest of this star) but as much as 5 deg from γ Cas. Hence we identify the constituents of *Wang-liang* as α, β, γ, η and υ Cas.

The most accurate position reported for the guest star 1592C was '(at *Wang-liang*) within the 1st star from the west'. This clearly indicates a site close to β Cas. As is apparent from Fig. 3, the other four members of *Wang-liang* are all considerably to the east of β Cas. Just how close 1592C was to β Cas depends on the interpretation of the term *nei*. The literal meaning is 'within' or 'inside' but the astronomical equivalent is not clear. However, judging from the description of 1592A – i.e. 'at *T'ien-ts'ang*, within the third star from the east, and about 3 *ts'un* away' – a close approach of less than a degree seems indicated. The approximate coordinates

TABLE I

Guest star	Region of occurrence	Visibility: First sighted	Visibility: Last sighted	Duration (months)	Positions (J2000.0): R. A. h	Positions (J2000.0): R. A. min	Positions (J2000.0): Dec. (deg)	Error (deg)
1592A	Cetus	1592 November 28	1594 February 23	15	1	51	−10.4	±0.5
1592B	Cassiopeia	1592 November 30	1593 March 28	4	0	57	+59.9	±0.5
1592C	Cassiopeia	1592 December 4	1593 March 4	3	0	09	+59.1	±1
1592D	Andromeda	1592 December 12	1593 January 18	1	1	00	+42	±5

of β Cas at epoch J2000.0 are R.A. 0^h 09^m, dec. +59·1 deg, (galactic coordinates $l = 118$ deg, $b = -3$ deg) and we suggest a search within about 1 deg of this site.

With regard to the location of 1592B, the best description is 'at *Wang-liang* between the first and second stars from the east'. Judging from Fig. 3, a position between γ and υ Cas seems the most likely (η and α Cas are significantly further to the west). The coordinates of γ and υ Cas at epoch J2000.0 are respectively R.A. 0^h 57^m, dec. +60·7 deg and R.A. 0^h 57^m, dec. +59·1 deg (galactic coordinates $l = 124$ deg, $b = -3$ deg). The position of 1592B should be roughly on a direct line between these two stars, which are about 1·6 deg apart.

The extensive catalogue of SNRs by Green (1984) does not contain any young SNR (i.e. of small angular extent and high surface brightness) in the vicinity of either 1592B or 1592C – apart from 3C10, the remnant of Tycho's supernova. On this basis, we infer that both temporary stars were probably novae. We recommend a search for post-novae in both regions of Cassiopeia indicated above. Brosche (1967) and Chu Sun-il (1968) were of the opinion that 1592C was linked with the powerful radio source Cas A. However, whether an age for this SNR of as much as almost 400 years is acceptable or not, the positional agreement is poor. Cas A lies some 6 deg to the west of β Cas – hardly warranting the description 'within' that star.

For reference, we have summarized in Table I the positions and durations of visibility of all four new stars.

CONCLUSIONS

We have identified from Korean chronicles four guest stars appearing in AD 1592 which exhibit close resemblance to the type of 'new stars' seen at the time of nova or supernova explosions. Although the likelihood of four such outbursts occurring within a short period of time is undeniably very small we have presented evidence that the descriptions given in the texts seem to be genuine observations made by the Korean court astronomers of that time. Of the four guest stars discussed above, 1592D is a relatively poor candidate, on account of both its uncertain nature and rough location. However, the remaining three stars are clearly viable nova (although evidently not supernova) candidates. From our analysis of the information given in the texts the positions of 1592A, B and C are fairly accurately known – within about a square degree. Hence a search for the post-novae would seem well worthwhile. It is hoped that optical and radio astronomers will act on our suggestions.

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5.10 Conclusions and Future Prospect

In this chapter I have investigated in detail the positions of those historical SNe and novae which are well recorded, and attempted to identify the corresponding modern counterparts of some of the nova candidates. It is possible that the remnants of one or two novae mentioned here may be observed some time in the future (possible recurrent of these). With regard to historical records of new stars, the dynastic histories of China, Korea and Japan have already provided some of the most important documental evidence for the outbursts of the remnants observed today. However, the prospect of finding new reports from these dynastic annals is not very great. Any additional observational detail may possibly come from diaries and biographies of astronomers or court officials that so far have been overlooked. Another source may be the local Chinese histories (*fang-chih*). However, these records are generally vague and lack technical details such as positional measurements; only a layman's description is normally given. It would appear that scope for future development in the field of historical novae and supernovae lies mainly in the reinterpretation of records.

Another concern is for radio and X-ray astronomers to search for the remnants of those new stars which had been recorded but as yet were without a possible remnant. Palumbo *et al.* (1981) attempted a survey at 610 MHz for radio remnants of ancient Far Eastern 'guest stars' with the Westerbork telescope but found no such remnants. Seven positions of new stars listed by Xi and Bo (1965) were searched in $1.5° \times 1.5°$ fields. The failure of their survey is due to two principal factors. The first is due to selecting unsuitable candidates with only poorly established positions. The second is that the search area was too small and too specific to cover the error in position. It is hoped that using the positions deduced from the present catalogue (Table 5.2) researchers will be able to search the area of the sky much closer to the true position.

PART III. SOLAR VARIABILITY

CHAPTER 6
SUNSPOTS

6.1 Introduction

The earliest alleged reference to a sunspot in Western literature is found around 350 BC; it was seen by Theophrastus of Athens, who was a pupil of Aristotle (Bray and Loughhead, 1964). The Aristotelian view of a perfect Sun without blemish plus the Orthodox Christian theological teaching about an uncorruptable heaven in the Middle Ages prevented the potential recognition of sunspots in Europe. Most of the few accounts of European sightings of sunspots that are known were due to misidentification of other phenomena than a specific observation of sunspots. One of the well known examples is found in Einhard's *Life of Charlemagne*, in which a spot on the Sun around AD 807 was wrongly interpreted to be a transit of Mercury (Goldstein, 1969). A 14th century Russian chronicle – the Niconovsky Chronicle – recorded descriptions of dark spots on the Sun as seen through the haze of forest fires in the years 1365 and 1371 (Vyssotsky, 1949). Also the Carraras (father and son) in Italy were known to have observed sunspots in 1457. However the doctrine of a perfect Sun persisted down to the dawn of telescopic observation. Even Johannes Kepler himself mistook a spot he had seen on May 18, 1607 to be a transit of Mercury (Sarton, 1947).

In the Islamic world, Abu-l-Fadl Ja'far ibn al-Muktafi (AD 906–977) recorded that the philosopher al-Kindi observed a spot on the Sun in May 840, which was mistaken for a transit of Venus (Goldstein, 1969). There was also Ibn Rushd who mentioned the sighting of a spot on the Sun in 1196. However, these are only isolated events. In East Asia, one finds a long series of sightings of sunspots – almost exclusively from China and Korea – going back two millennia with the earliest recorded spot in 165 BC from China. As with most of the other types of astronomical records, these sightings are preserved in various astronomical treatises of the official histories.

It seems that before the invention of telescope in 1609, the existence of sunspots was virtually unknown in Europe. It was largely due to the publication in 1613 by Galileo of his telescopic sunspot observations in *Istoria e Dimonztrazioni intorno alle Macchie Solari e loro Accidenti* (Mascardi, Rome, 1613) that they gradually started to attract a wide interest. Although contemporary observations had also been made by Harriot in England, Scheiner in Germany and Goldsmid in Holland, Galileo was credited with the discovery that the spots were phenomena associated with the surface of the Sun (which he thought to be similar to clouds on Earth). On the contrary, others like Scheiner initially thought they were due to the passage of planets across the Sun's disc or small satellites of the Sun.

Before the full understanding of sunspot phenomena about a century ago, there had been much speculation about the nature of sunspots. When a spot is situated near the limb of the Sun, the penumbra on the side nearest to the limb becomes more comparatively stretched out than the side furthest from it, an effect due to perspective and foreshortening. This led Wilson (1774) to suspect sunspots to be depressed regions on the solar surface. His idea was generalised by Herschel (1795) who preferred them to be openings in the luminous solar cloud and from which one could glimpse the exposed cool surface of a solid Sun.

The existence of the sunspot cycle was not known until Schwabe of Dessau in 1843 showed from 17 years observations of sunspots a periodicity of approximately 10 years (Schwabe, 1843). About twenty years later, Carrington (1863) derived an accurate rate of rotation of the Sun with a mean length of 27.2753 days from the apparent motions of sunspots. Thereafter, the Sun's synodic rotation has been numbered with the

Carrington Rotation Number which began on November 9th 1853. Carrington later also demonstrated the variation of sunspot latitude and distribution over the solar surface during the course of a spot cycle. It is possible that the quasi-random distribution of spots on the surface of the Sun was one of the major causes for not recognising their periodic nature earlier. As sunspot records are the only direct indicators of the long term behaviour of solar activity, their importance in our understanding of the Sun need not be more emphasized.

6.2 The Formation of Sunspots

After the discovery of the differential rotation of the Sun by Carrington it was generally accepted that this effect was largely attributed to a greater acceleration of convection currents at the solar equator. In the following years many attempts were made to interpret the process of sunspot formation. Faye (1865) regarded sunspots to be places where the ascending currents of gas were particularly strong – such that they blew away the particles forming the photosphere, thus exposing the deep interior of the Sun. As the gases were too hot to emit any visible radiation, this resulted in a dark spot. In the same year, De la Rue *et al.* (1865) reckoned that the currents of gas were descending as opposed to ascending into the solar interior and cooler than the surroundings. Other interpretation of sunspots was largely based on terrestrial analogy. For example, Herschel believed some spots were due to meteoritic collisions while De la Rue *et al.* (1865) hypothesized that the frequency of formation was due to an alignment of two or more planets.

However, from spectroscopic observation Lockyer (1886) was able to show that currents of gas were descending inside sunspots and different spectral lines appeared in them were resulted from a lower temperature. This led to suggestions that sunspots were caused by eruption of material from the solar surface. The material was thrown up from the edge of a ring, cooled and fell back into the middle of the ring forming a central depression. (Secchi, 1870 and Schaeberle, 1890)

At the end of the 19th century, the only common consensus among researchers was that sunspots were depressions in a gaseous solar surface. Further progress was not possible without one essential element, namely the magnetic field. In 1908, George Hale proved spectroscopically the existence of a magnetic field within sunspots and measured its field strength via the Zeeman effect (Hale, 1908). He was able to show that the magnetic fields of sunspots were intense and that the north and south sunspot belts were in opposite sense to each other and further were reversed with each 11-year cycle. Also shortly afterwards, systematic motions of the material within sunspots were observed by Evershed (1909).

Sunspots possess magnetic fields of about 300 mT for medium to large size spots, which is much larger than the average solar magnetic field of 0.1 mT. (cf geomagnetic field $\sim$ 0.05 mT). It can be shown empirically that the sunspot magnetic field, B, can be approximated by (Bray and Loughhead, 1964):

$$B = \frac{370A}{A + 60} \qquad \mathrm{mT}$$

where A is the mean area of sunspots in millionths of the Sun's hemisphere. Most spots exist in pairs of opposite polarities, with the larger, preceding spots (or leader spots) moving a few degrees in latitude closer to the solar equator. It has been shown from an analysis of the Mount Wilson white light plates, for the years 1917–1983, that leader spots rotate faster than the follower spots by $\sim 0.1°$ per day (Gilman and Howard, 1985). Individual sunspot magnetic fields are a part of a more fundamental region in the photosphere known as the bi-polar magnetic region. Sometimes, a single spot occurs instead of a pair; however its associated bi-polar magnetic region of opposite polarity can still be identified.

The principal energy transfer at the solar visible surface is believed to be by way of convection columns. When these columns of plasma carrying the energy from within the Sun rise to the surface, they spread outwards before falling back to the surface again. The appearance of a localised strong magnetic region like a sunspot apparently inhibits this process, as first pointed out by Biermann (1941). Under the influence of a strong magnetic field, a plasma can still move freely along the field lines but only diffuses slowly across them. As a result, the rising plasma of the individual convection columns is constrained from moving across the sunspot field lines. However, the motion of the plasma along the radial sunspot field lines is unaffected. The effective energy transfer due to convection is then suppressed because the horizontal flow of the plasma is hindered. It is now generally accepted that the coolness or darkness of a sunspot is resulted from a reduction in the amount of energy convected upwards from the solar interior. The temperature of umbrae is about 4300 K and penumbrae about 5700 K, as compared with the photospheric temperature of about 6050 K (Allen, 1976).

So far, the origin of the intense sunspot magnetic field is not yet fully understood despite many attempts at a theoretical solution. Cowling (1934) was the first to put the magnetic field of a sunspot in magnetohydrodynamic terms. The classic model of Babcock (1961) suggested that the differential rotation of the Sun intertwined its own field lines to such an intensity as to create a significant magnetic pressure within the plasma near the surface. This upsets the hydrostatic equilibrium and reduces the normal gas pressure within the plasma at that intense flux region. As the plasma density is reduced, it rises like a 'bubble' carrying field lines which have been frozen into the plasma. Eventually the subsurface tube of field lines penetrates the surface at the centre of activity and forming an arch above the surface with its two ends still embedded in the photosphere (Fig. 6.1). Often a loop prominence will form along these field lines, and the two ends linking the photosphere are the pair of sunspot regions. Parker (1979) explained that the subsurface magnetic field of a sunspot is consisted of a dynamical clustering of many separate flux tubes. At the visible surface, this loose cluster of flux tubes are pressed together to form a single large flux tube.

For the complex sunspot groups, the mechanism is much more complicated by the processes of compressing, breaking and reconnecting of magnetic field lines. There have been many theories proposed to explain the formation of sunspots or the underlying solar activity (see reviews by Parker, 1979; Moore and Rabin, 1985). The formation of sunspots or the cause of the sunspot cycle is still not clearly known; what is certain is the interplay between three factors – a large-scale relatively weak poloidal solar magnetic field beneath the photosphere, differential rotation and convection.

6.3 Telescopic Observations

Following Galileo's telescopic rediscovery of sunspots in AD 1610, European astronomers took an enthusiastic interest in observing this phenomenon. However, there do not seem to have been many observational records from the second half of that century. The lack of reports of sightings can possibly be attributed to a real scarcity of sunspots during this period – the Maunder Minimum (Eddy, 1976). It was not until the early 18th century that fairly frequent observations are to be found again.

Since AD 1818, almost daily sunspot records are available but prior to that date little more than monthly means (between 1749 and 1817) or even annual means (1700 to 1748) can be deduced. Before AD 1700, data are relatively scarce and much more difficult to interpret. In Table 6.1, I have compiled a list of some of the principal observers of sunspots since Galileo and their respective period of observations. The list

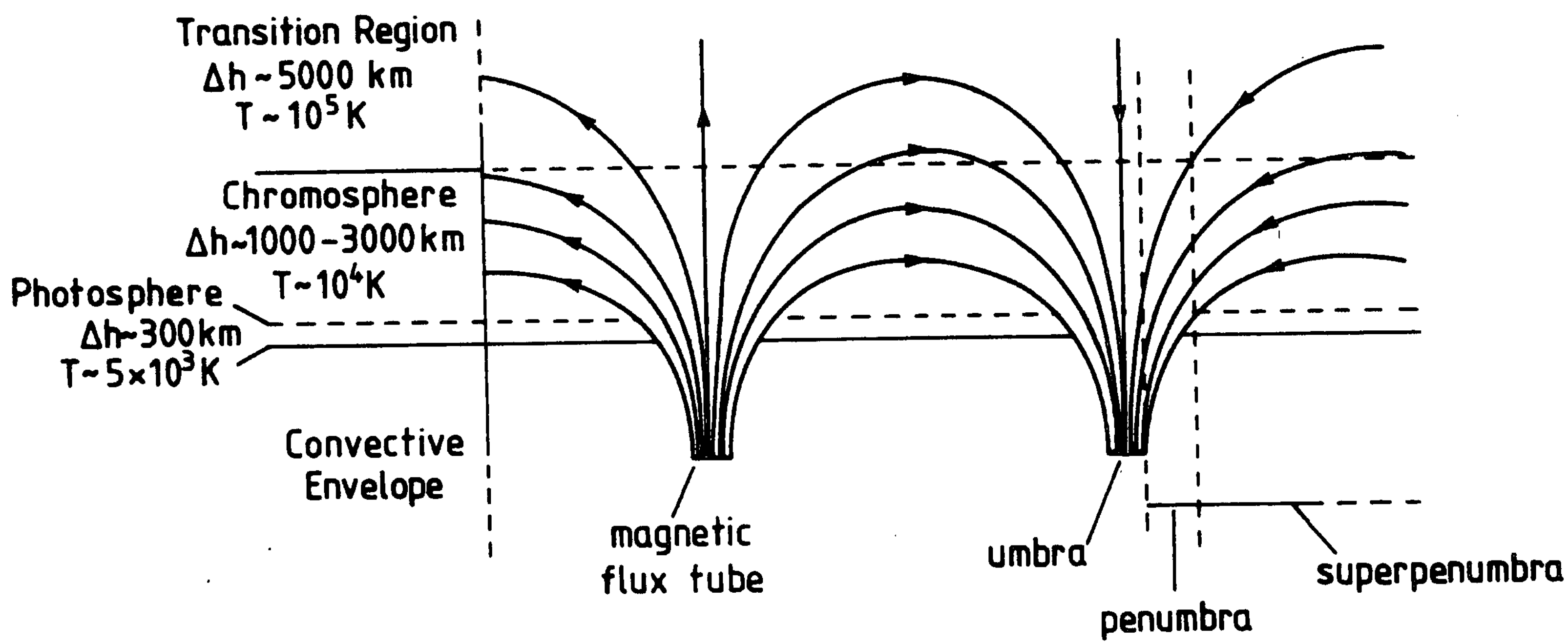

Fig. 6.1 A diagram showing the surface layers of the Sun and the sunspot magnetic field configurations.

TABLE 6.1 Some of the principal observers of sunspots since Galileo and their respective period of observations

Observer	Period	References
G. Galileo	1611-12	Opera (1615) daily drawings ~ 4" diameter
C. Scheiner	ca 1625-1627	Rosa Ursina (1630) in Latin - daily drawings ~ 8" diameter
J. Hevelius	1642 - 44	Selenographia (c.1647) in Latin - daily drawings ~ 8 inches in diameter
C.H. Adams	1819 - 23	
S.H. Schwabe	1825 - 67	39 Vols (MN, xxxvi, 297-99; xli, 180)
R. Wolf	1610-1715	Historical Reconstructions (1856)
T.J. Hussey	1826 - 37	
H. Lawson	1831 Aug - 1832 Aug	
J. Herschel	1836 Dec - 1837 Oct 1826, 1836 1856 - 58 1865 - 71	176 diagrams
C. Shea	1847 - 65	5 Vols
T. Chevallier	1847 - 49	2 Vols
J.H. Griesbach	1850 - 65	
R.C. Carrington	1853 - 61 1870	3 Vols (MN, xxxvi, 249-50)
F. Howlett	1859 - 92	8 Vols (MN, xxxvi, 297; xxxvii,364; lv, 73-6)
G.L. Bernaerts	1870 - 79	13 Vols

covers the period down to the 1890s. In 1874, RGO began a daily photographic patrol of sunspots and results were annually published as *Greenwich Photoheliographic Results.*

The most extensive compilation of the RGO series of observations covering 1874–1954 is summarised in *Sunspot and Geomagnetic Storm Data 1874–1954* (RGO, 1955), compiled under the direction of Sir Harold Spencer Jones. The original data were recorded by the photo-heliograph on glass plates with 4" solar diameters which are now preserved in the plate archives at RGO in Herstmonceux. The RGO photo-heliographic plate measurements terminated after 1976 and the observatory at Debrecen in Hungary agreed to continue this work but have not yet published any data. The 1955–1976 series is only available in annual databooks.

Conventionally, the sunspot number is arbitrary defined by an index, R, as follows:

$$R = k(10g + f)$$

where g is the number of groups of spots, f is the number of individual spots and k is a correction factor taking into account the different sizes of telescopes and observing conditions. The index R was first established by Wolf at Zurich (1856). Appropriately, the international sunspot number index used to come from the Swiss Federal Observatory at Zurich, it was responsible for normalising measurements from various observatories and with the determination of the subjective correction factor k. Since 1981 the Sunspot Index Data Centre in Brussels has taken over the task for world wide distribution of sunspot numbers.

6.4 Far Eastern Naked-eye Sunspot Catalogues

For the pre-telescopic period several compilations of Far Eastern naked-eye sunspot sightings have appeared in various journals over the years. The earliest of these catalogues was compiled by Williams (1873) and was followed by Turner (1889). The more extensive compilations of the present century include the catalogues of Kanda (1933), Schove (1950), Keimatsu (1976), Yunnan Observatory (1976), Clark and Stephenson (1978), and Chen and Dai (1982). Recently, Wittmann and Xu (1987) have compiled a list numbering some 235 entries including a few observations from European sources. For the period since 1610, naked-eye observations were first brought to note by Xu and Jiang (1979) who argued against the existence of the Maunder Minimum. In addition, there is also a list of naked-eye sunspots from Chinese local gazettes given in a book by Chen (1984), which is extracted from the yet unpublished *A Union Table of Ancient Chinese Records of Celestial Phenomena*. Table 6.2 gives a comparison of the above mentioned catalogues.

Despite the numerous attempts at a complete compilation, these catalogues suffered in one form or another, most often by omissions, dating errors or the inclusion of apparently spurious data. I have compiled a new catalogue of naked-eye sunspots which aims at correcting the mistakes made in earlier catalogues and incorporates several new records. This investigation is based on a detailed study of dynastic histories and other sources. For the period from earliest times to the late 14th century I have consulted principally records contained in the *Astronomical Treatises* of the various official Far Eastern dynastic histories. The use of late secondary sources for this period is restricted as most of these works copied records directly from the earlier dynastic histories.

For the period from the late 14th to mid-17th century I have consulted astronomical records in the *Ming-shih-lu* ('Veritable Records of the Ming Dynasty') for sunspots observed in China. This has been made easier by a recent compilation of all astronomical records in the *Ming-shih-lu* by Ho and Chiu (1986). For the period since 1644, no dynastic record of sunspots from China is found. From the late 14th century onwards up to about the mid-18th century, there are a number of Korean sightings of sunspots from the *Sillok* ('Veritable Records') of the Korean Kings. Throughout the time span

Table 6.2 A comparison of the various sunspot catalogues.

Authors	Period Covered	Total Number of Entries
Kanda (1933)	28 BC - AD 1743	142
Yunnan Group (1976)	43 BC - AD 1638	112
Clark and Stephenson (1978)	28 BC - AD 1604	139
Xu and Jiang (1979)	AD 1603 - AD 1684	33
Chen and Dai (1982)	165 BC - AD 1648	162
Chen (1984) (i)	28 BC - AD 1640	125
(ii)	165 BC - AD 1918	109
Xu and Wittmann (1987)	165 BC - AD 1684	235
The Present Work	165 BC - AD 1918	235

(165 BC – AD 1918) under consideration, there are only three Vietnamese and one Japanese records of sunspots.

The present catalogue also extends into relatively modern times; the last entry is in AD 1918. The majority of the more recent data (since the 17th century) come from the Chinese Local Gazettes, of which Durham Oriental Library has a sizeable collection, which have not so far appeared in any Western literature. The total number of entries contained in the present catalogue is 235 with 157 from the pre-telescopic era and 78 from the post-telescopic period. Table 6.3 is a summary list of the present catalogue. The main body of the catalogue is in Appendix IV.

6.5 Investigation of Telescopic Data

6.5.1 Sunspot Cycles Since 1610

I have reconstructed annual mean sunspot numbers (Fig. 6.2) based on Eddy (1976) and Waldmeier (1961) for the period 1610 to 1931 and the UK World Data Centre series for the period 1932 to 1986. As can be seen, the nominal 11-year cycle is clearly depicted since 1700. Prior to the 18th century, the 11-year period is obscure. Eddy (1976) claimed this was due to a period of suppressed solar activity between 1645 and 1715, which following the original suggestion by Maunder (1890) he called the 'Maunder Minimum'.

Several contemporary astronomers had commented on the paucity of sunspots during this period. Concerning a sunspot in 1684, Flamsteed comments: "These appearances, however frequent in the days of Scheiner and Galileo, have been so rare of late that this is the only one I have seen in his face since December, 1676" (Maunder, 1894). In 1705, Cassini and Maraldi recorded that they had never seen a spot in the northern hemisphere of the Sun.

TABLE 6.3 A SUMMARY TABLE OF FAR EASTERN OBSERVATION OF SUNSPOTS (165 BC TO AD 1918)

DATE RANGE	NO OF DAYS VISIBLE	COUNTRY	SOURCE TYPE	CATALOGUE NUMBER
-164 Jan/Feb- Mar/Apr	1	C	L	CD1,WX
-42 May 5 - Jun 3	1	C	O	CD2
-31 Mar 8 - Apr 5	1	C	O	CD3,WX
-27 May 10?	1	C	O	CS1,K1,CD4,WX
+15 Mar 10 - Apr 7	1	C	O	CD5,WX
20 Mar 17	1	C	O	CS2,K2,CD6,WX
187 Mar/Apr?	1	C	O	CS3,K3,CD7,WX
188 Feb 15 - Mar 15	>1 month?	C	O	CS4,K4,CD8,WX
240	1	C	L	CD9,WX
299 Feb 17 - Mar 18	?	C	O	CS6,K5,CD11,WX
301 Jan 19	1	C	O	CS7,K6,CD13,WX
301 Oct 20	1	C	O	CS8,K7,CD14,WX
302 Dec 6 - 303 Jan 4	1	C	O	CS9,K8,CD15,WX
304 Dec 14 - 305 Jan 11	1	C	O	CS10,K9,CD16,WX
311 Apr 7	1	C	O	CS11,K10,CD18,WX
321 May 7	1	C	O	CS12,K11,CD20,WX
322 Nov 6	1	C	O	CS13,K12,CD21,WX
342 Mar 7 - Mar 11	5	C	O	CS14,K13,CD22,WX
352	5	C	O	CS15,K14,CD23,WX
354 Nov 7	1	C	O	CS16,K15,CD24,WX
355 Apr 4	1	C	O	CS17,K16,CD25,WX
359 Nov 7	1	C	O	CS18,K17,CD26,WX
369 Nov 27?	1	C	O	CS19,K18,CD27,WX
370 Mar 29	1	C	O	CS20,K19,CD28,WX
373 Jan 28?	1	C	O	CS21,K20,CD29,WX
373 Dec 26	1	C	O	CS22,K21,CD30,WX
374 Apr 6	1	C	O	CS23,K22,CD31,WX
375 Jan 10	1	C	O	CS24,K23,CD32,WX
388 Apr 2	1	C	O	CS25,K24,CD33,WX
389 Jul 17	1	C	O	CS26,K25,CD34,WX
395 Dec 13	1	C	O	CS27,K26,CD35,WX
400 Dec 6	1	C	O	CS28,K27,CD36,WX
499 Jul 4?	1	C	O	CS29,K28,CD39,WX
500 Jan 29 to Jan 30	2	C	O	CS30/31,K29,CD40,WX
501 Sep 4	1	C	O	CS32,K30,CD41,WX
502 Feb 8, Feb 11, Feb 12	3	C	O	CS33,K31,CD42,WX
502 Mar 26?	1	C	O	CS34,K32,CD43,WX
505 Jan 4	1	C	O	CD44
510 Mar 17	1	C	O	CS35,K33,CD45,WX
511 Dec 16	1	C	O	CS36,K34,CD46,WX
513 Apr 17	1	C	O	CS37,K35,CD47,WX
566 Mar 29	1	C	O	CS38,K36,CD48,WX
567 Dec 10 to Dec 18	9	C	O	CS39,K37,CD49,WX
577 Dec 30?	1	C	O	CS40,K38,CD50
579 Apr 3 to Apr 6	4	C	O	CS41,K39,CD51,WX

826	May 7	1	C	0	CS42,K41,CD52,WX
826	May 24?	1	C	0	CS43,K41,CD53,WX
832	Apr 21	1	C	0	CS44,K43,CD55,WX
837	Dec 22	1	C	0	CS45,K45,CD57,WX
841	Dec 30	1	C	0	CS46,K46,CD58,WX
851	Dec 2	1	J	0	CS47,K47,CD59,WX
865	Jan 31 - Feb 28	1	C	0	CS48,K48,CD60,WX
874		1	C	0	CS49,K49,CD61,WX
875		1	C	0	CS50,K50,CD62,WX
904	Feb 19	1	C	0	CS51,CD64,WX
927	Mar 9	1	C	L	CS52,K52,CD66,WX
947	Nov 26	1	C	0	CD67,WX
974	Mar 3	1	C	0	CS53,K53,CD68,WX
1077	Mar 7 to Mar 21	15	C	0	CS54,K54,CD69,WX
1077	Jun 7	1	C	0	CS55,K55,CD70,WX
1078	Mar 11 to Mar 29	19	C	0	CS56,K56,CD71,WX
1079	Jan 11 to Jan 22	12	C	0	CS57,K57,CD72,WX
1079	Mar 20 to Mar 29	10	C	0	CS58,K58,CD73,WX
1105	Dec 6	1	C	0	CS59,K59,CD74,WX
1112	May 2	1	C	0	CS60,K60,CD75,WX
1118	Dec 17	1	C	0	CS61,K61,CD76,WX
1120	Jun 7	1	C	0	CS62,K62,CD77,WX
1122	Jan 10	1	C	0	CS63,K63,CD78,WX
1129	Mar 22 to Apr 14	24	C	0	CS64,K64,CD79,WX
1131	Mar 12 to Mar 14/15	3/4	C	0	CS65,K65,CD80,WX
1136	Nov 23 to Nov 27	5	C	0	CS66/67,K66,CD81,WX
1137	Mar 1 to Mar 10	10	C	0	CS68,K67,CD82,WX
1137	May 8 to May 22/later	>15	C	0	CS69,K68,CD83,WX
1138	Mar 16 or Mar 17	1	C	0	CS70,K69,CD84,WX
1138	Nov 26	1	C	0	CS71,K70,CD85,WX
1139	Mar 3 - Mar 31	> 1 mn	C	0	CS72,K71,CD86,WX
1139	Nov 20	1	C	0	CS73,K72,CD87,WX
1145	Jun/Jul?	2	C	0	CS74,K73,CD88,WX
1151	Mar 21, Mar 31, Apr 1	3	K	0	CS75,K74,CD89/90,WX
1160	Feb 28 to Mar 1	3	K	0	CS76,K75,CD91
1160	Sep 26	1	NC	0	CS77,K76,CD92,WX
1160	Sep 29	1	K	0	CS78,K76,CD93,WX
1171	Oct 20	1	K	0	CS79,K77,CD94,WX
1171	Nov 16	1	K	0	CS80,K78,CD95,WX
1183	Dec 4 to Dec 5	2	K	0	CS81,K79,CD96,WX
1185	Feb 10, 11	2	SC, K	0	CS82/83,K80,CD97,WX
1185	Feb 15 to Feb 27	13	SC	0	CS84,K80,CD98,WX
1185	Mar 27	1	K	0	CS85,K81,CD99,WX
1185	Apr 18 to Apr 19	2	K	0	CS86,K82,CD100,WX
1185	Nov 14	1	K	0	CS87,K83,CD101,WX
1186	May 23 to May 27	5	SC	0	CS88,K84,CD102,WX
1193	Dec 3 to Dec 12	10	SC	0	CS90,K85,CD103,WX
1200	Sep 19	1	K	0	CS91,K86,CD104,WX
1200	Sep 21 to Sep 26	6	SC	0	CS92,K86,CD104,WX

1201 Jan 9 to Jan 29	21	SC	O	CS93,K87,CD105,WX
1201 Apr 6	1	K	O	CS94,K88,CD106,WX
1202 Aug 23	1	K	O	CS95,K89,CD107,WX
1202 Dec 19 to Dec 31	13	SC	O	CS96,K90,CD108,WX
1204 Feb 3 to Feb 5	3	K	O	CS97,K91,CD109,WX
1204 Feb 21	1	SC	O	CS98,K92,CD110,WX
1205 May 4	1	SC	O	CS99,K93,CD111,WX
1238 Dec 5	1	SC	O	CS100,K94,CD112,WX
1258 Sep 15 to Sep 16	2	K	O	CS101,K95,CD113,WX
1276 Feb 17	1	SC	O	CS102,K96,CD114,WX
1276 Mar 17 - Apr 15	1	V	O	
1278 Aug 31	1	K	O	CS103,K97,CD115,WX
1356 Apr 4 to Apr 5	2	K	O	CS104,K98,CD116,WX
1361 Mar 16	1	K	O	CS105,K99,CD117,WX
1362 Oct 5	1	K	O	CS106,K100,CD118,WX
1365 1st half of year	1	C	O,L	CH36,WX
1368	1	C	L	CH37
1368 Jul/Aug-Oct/Nov	1	C	L	CH38,WX
1369 Dec 30 - 1370 Jan 27	1	C	L	CH39,WX
1370 Jan 1	1	C	O	CS107,K101,CD119,WX
1370 Jan 28 to Feb 3	7	C	O	
1370 Frequently seen	?	C	O	CS112,K105,CD125,WX
1370 Apr 25	1	C	L	CH41
1370 Oct 2	1	C	O	CS108,K102,CD121,WX
1370 Oct 21	1	C	O	CS109,K103,CD122,WX
1370 Dec 7	1	C	O	CS110,K104,CD123,WX
1370 Dec 19	1	C	L	CH42
1371 Jan 2	1	K	O	CS111,K105,CD124,WX
1371 Mar 31	1	C	O	CS113,K106,CD126,WX
1371 Jun 13 to Jul 12	30	C	O	CS114,K107,CD127,WX
1371 Oct/Nov?	1	K	O	CS116,K109,CD128,WX
1371 Nov 6	1	C	O	CS115,K108,CD129,WX
1372 Feb 6	1	C	O	CS117,K110,CD130,WX
1372 Apr 3	1	C	O	CS118,K111,CD131,WX
1372 May 8	1	K	O	CS119,K112,CD132,WX
1372 Jun 19	1	C	O	CS120,K113,CD133,WX
1372 Aug 25	1	C	O	CS121,K114,CD134,WX
1373 Apr 26, 27	2	K	O	CS122,K115,CD135,WX
1373 Oct 23	1	K	O	CS123,K116,CD136,WX
1373 Nov 15	1	C	O	CS124,K117,CD137,WX
1374 Mar 27 to Mar 31	5	C	O	CS125,K118,CD138,WX
1375 Mar 20 to Mar 22	3	K, C	O	CS126/7,K119,CD139,WX
1375 Oct 21	1	C	O	CS128,K120,CD140,WX
1376 Jan 19	1	C	O	CS129,K121,CD141,WX
1381 Mar 22 to 25	4	C, K	O	CS130/1,K122,CD142,WX
1382 Mar 9 to Mar 11	3	K	O	CS132,K123,CD143,WX
1382 Mar 21	1	C	O	CS133,K124,CD144,WX
1383 Jan 10	1	C	O	CS134,K125,CD145,WX
1387 Apr 15	1	K	O	CS135,K126,CD146,WX
1402 Nov 15	1	K	O	CS136,K127,CD147,WX

1520 Mar 9	1	K	O	CS137,K128,CD148,WX
1556 Apr 17	1	K	O	CD149,WX
1562	1	C	L	CH47,WX
1566 Jan 21 - Feb 19	5	C	L	CH48,WX
1567 Feb/Mar- Apr/May	1	C	L	CH49,WX
1569 Jan 17	>1	C	L	CH50
1573 - 1619	1	C	L	CH51
1590 May 4 - Jun 1	1	C	L	CH52,WX
1593 Jan 3	1	V	O	CD150,WX
1603 Apr 4 - May 10	1	V	O	CD152,WX
1603 Apr 16	1	K	O	CS138,K129,WX
1604 Oct 24 to Oct 25	2	K	O	CS139,K130,CD153,WX
1608 May 10	1	K	O	CD154,WX
1613 Mar 30	1	C	L	CH53,XJ3,WX
1616 Oct 10	1	C	O	K131,CD155,XJ4,WX
1617 Jan 11	1	C	L	CH54,XJ6,WX
1617	1	C	L	CH55,K132,XJ7,WX
1618	1	C	L	CH56
1618 Apr 25 - May 23	1	C	L	XJ8,WX
1618 May 24 - Jun 21	1	C	L	CH57,XJ9,WX
1618 Jun 20 to Jun 22	3	C	O	K133,CD156, WX
1618 Jun 22	1	C	L	CH58,XJ11,WX
1620 Oct 15 - Oct 24	1	C	O	
1621 May 23	1	C	O	CD157,XJ12,WX
1622 Jun 9 - Jul 7	1	C	L	
1624 Mar 17 to Mar 20	4	C	O	K134,CD158,XJ13,WX
1624 May/Jun?	1	C	O	K136,CD159,XJ15,WX
1625 May/Jun- Jul/Aug	1	C	L	CH59,XJ16,WX
1626 Jun 29	1	C	L	CH60,XJ17,WX
1631 Feb 25	1	C	L	CH61,XJ18,WX
1635 Feb 17 - Mar 18	1	C	L	XJ19,WX
1637	1	C	L	XJ20,WX
1638 Sep 8 - Oct 6	1	C	L	XJ22,WX
1638 Dec 9	1	C	O	K137,CD160,XJ23,WX
1639 Oct 26	1	C	L	XJ26,WX
1643 Jun 16 - Jul 15	1	C	L	CH64,XJ27,WX
1643 Jul 2	1	K	O	CD161,WX
1647	1	C	L	CH65,XJ28,WX
1648 Jan 16	1	K	O	CD162,WX
1648 May/Jun- Jul/Aug	1	C	L	WX
1650 Oct 25	1	C	L	XJ29,WX
1655 Apr 30	1	C	L	CH66,XJ30,WX
1656 Jan/Feb- Mar/Apr	1	C	L	CH67,XJ31,WX
1665 Feb 15 - Mar 16	1	C	L	WX
1665 Feb/Mar- Apr/May	1	C	L	WX
1665 Feb 20	1	C	L	CH68,XJ32,WX
1665 Aug 27	1	C	L	WX
1684 Mar 16 to Mar 18	3	C	L	CH69,XJ33,WX
1709	1	C	L	CH70
1720 Jun 1	1	K	O	

1726 Oct 20 to Oct 21	2	K	O	
1732 May 11	1	C	L	CH71
1743 Oct 19 to 21	3	K	O	
1757 Jun 16 - Jul 15	1	C	L	CH72
1792	1	C	L	CH73
1799 Feb 5	1	C	L	CH74
1819 Aug 21 - Sep 18	1	C	L	CH75
1848 May 3 - May 15	13	C	L	CH76
1851 Feb - Apr	1	C	L	CH77
1851 Dec 25	1	C	L	CH78
1852 Jan 19	1	C	L	CH79
1852 Mar 22	1	C	L	CH80
1852 Apr 2	1	C	L	CH81
1852 Dec 29	1	C	L	CH82
1853 Feb 8 - Mar 9	1	C	L	CH83
1853 May 17	1	C	L	CH84
1853 Jun 7 - Jul 5	1	C	L	CH85
1853 Aug 5 - Sep 2	1	C	L	CH86
1855 Jan 20	1	C	L	CH87
1856 Feb 8	1	C	L	CH88
1856 Aug 30 - Sep 28	1	C	L	CH89
1860 Dec 4	1	C	L	CH90
1861 Mar 30 to Apr 10	12	C	L	CH91
1861 Nov 24	1	C	L	CH92
1863 Mar 19	1	C	L	CH93
1865 Mar 27 - Apr 24	1	C	L	CH94
1865 Jul 18	1	C	L	CH95
1873 Feb 23 to Feb 24	2	C	L	CH96
1874 Feb/Mar- Apr/May	1	C	L	CH97
1874 Dec 9	1	C	L	CH98
1883 Dec 26	1	C	L	CH99
1885 Jul 5	1	C	L	CH100
1900 Feb 15	1	C	L	CH101
1904 Feb 16	1	C	L	CH102
1905	1	C	L	CH104
1905 Feb 4	1	C	L	CH103
1905 Oct 31	1	C	L	CH105
1911 Jan 30	1	C	L	CH106
1916 Jul/Aug- Sep/Oct	1	C	L	CH107
1917 Feb 11	1	C	L	CH108
1918 Feb 11	1	C	L	CH109

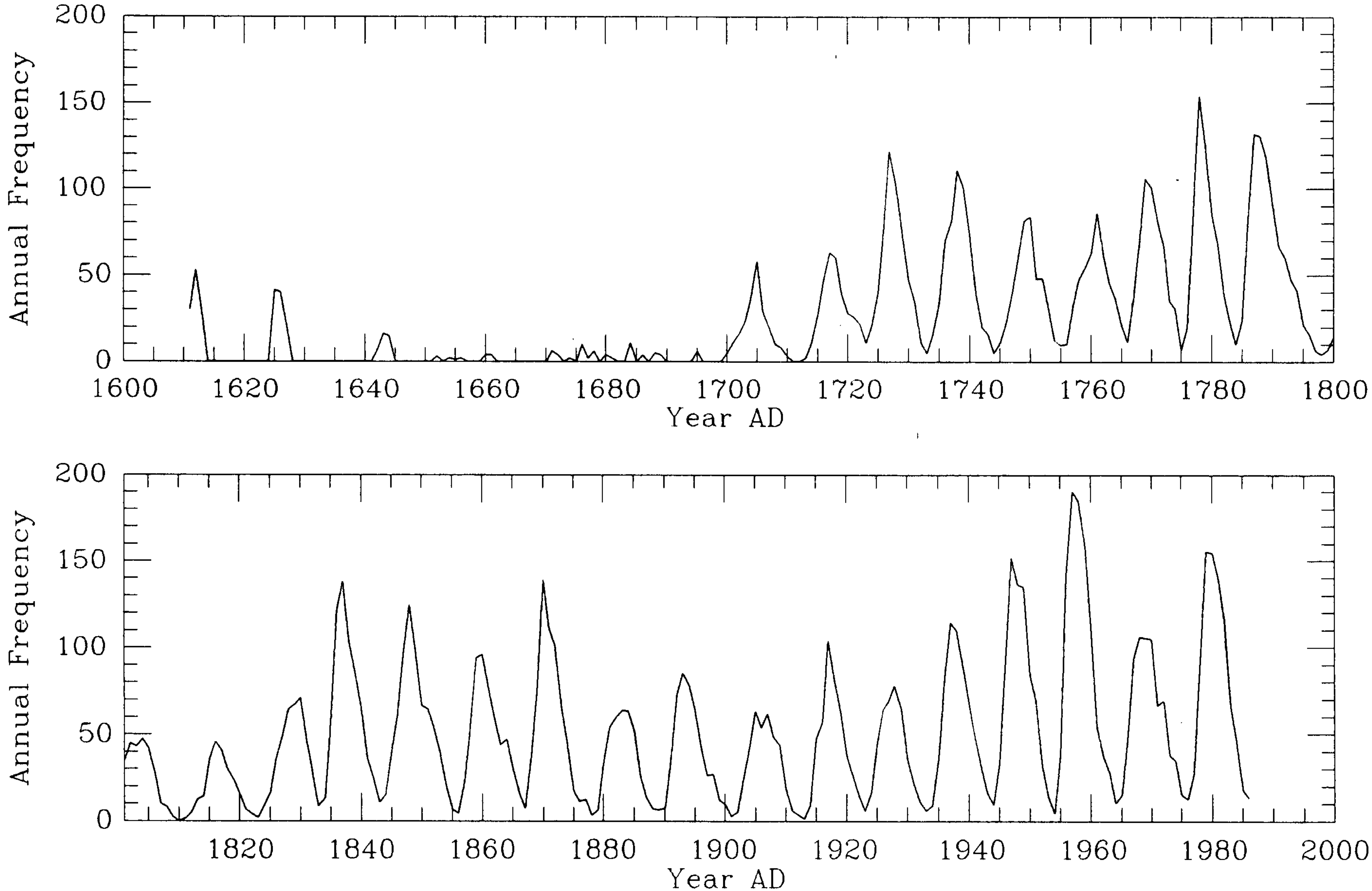

Fig. 6.2 The annual mean sunspot numbers from AD 1610 to 1986.

It seems difficult to quantify the level of solar activity during the Maunder Minimum on account of data selection effects. Stephenson (1988) expected that imperfect sampling would cause spurious trends in addition to real solar fluctuations. He illustrated this by the sudden increase in the number of reports of occultations and eclipses in the second half of the 17th century (Fig. 6.3). Apart from more observers, more astronomers communicated observations to the newly established research journals, whereas formerly much material was scattered in unpublished papers or books having a limited circulation.

As is evident from Fig. 6.2 the sunspot record since the early 18th century shows some indication of modulation on the centennial time-scale. This is the so-called 'Gleissberg Cycle' of about 80 years (Gleissberg, 1965). It is tempting for one to interpret the Maunder Minimum as a continuation of this pattern. However, the problems relating to data selection have already been noted. In addition, the reality of the Gleissberg Cycle is still in doubt, particularly because of its obviously variable length. It is likely that these long term cycles are caused by the random fluctuations of the 11-year cycles.

The amount of solar activity may vary considerably between two consecutive sunspot cycles. As can be seen from Fig. 6.2, the onset and termination of one cycle can be markedly different from the rest. The rise time to the sunspot maximum is approximately 4 or 5 years and the time for the cycle to decline is about 6 or 7 years.

The phase of the sunspot cycle also closely determines the mean heliographic latitude of all groups. At minimum the first groups of the new cycle appear at $\pm 30°$ to $\pm 35°$. Thereafter the latitude range moves progressively towards the equator, until by the next minimum the mean latitude is around $\pm 7°$. Then, while the equatorial groups are fading, those of the succeeding cycle begin to appear in their characteristically higher latitudes. Groups are seldom seen farther than 35° or closer than 5° from the equator. This latitude-time relation for the progression of sunspots was first illustrated by Sporer

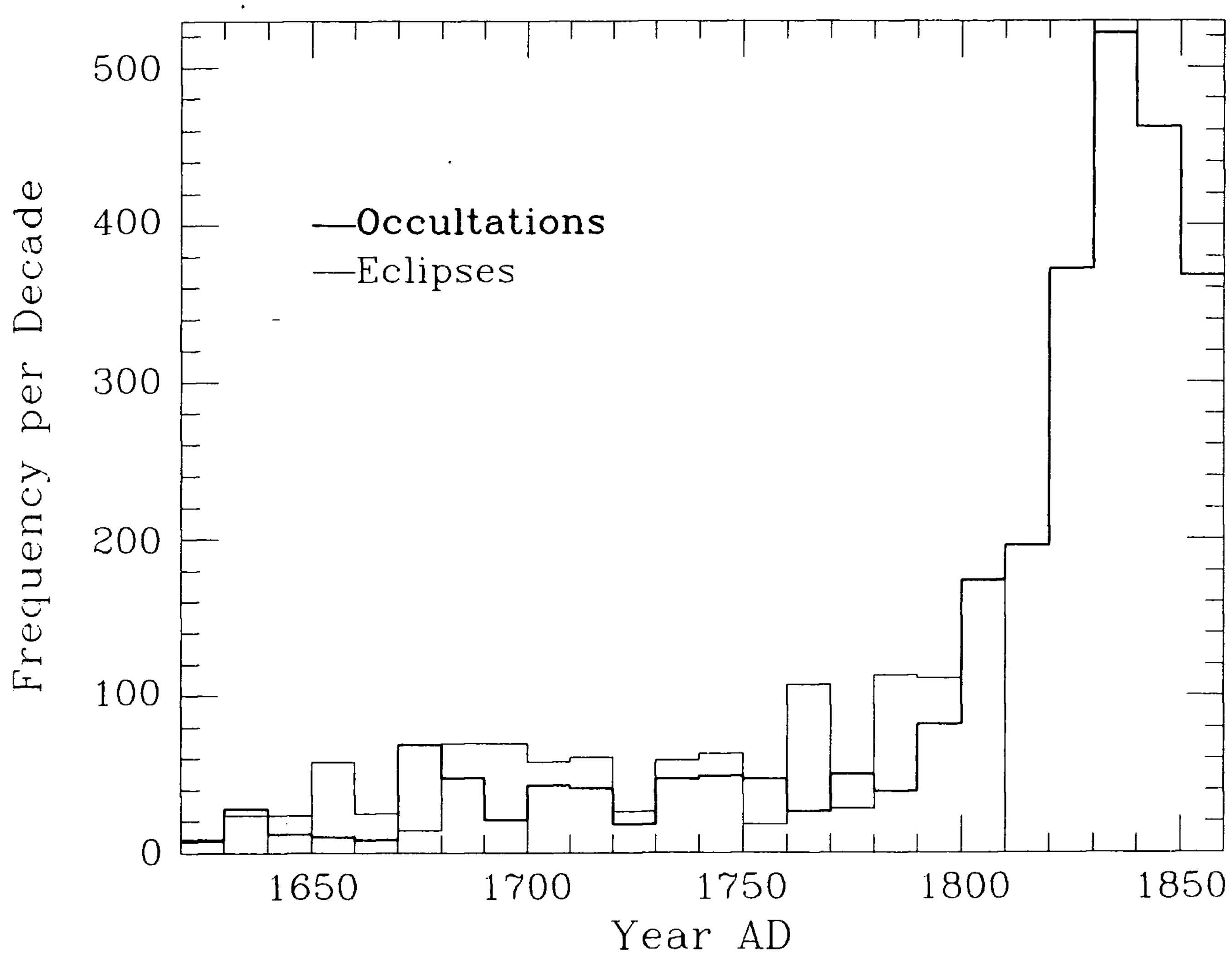

Fig. 6.3 The decade distribution of the number of reports of solar eclipses (between AD 1620 to 1810) and occultations (AD 1620 to 1860).

(1889) and subsequently became known as Sporer's Law. A graphical representation of this law is depicted by the 'butterfly diagram' which is obtained by plotting the mean heliographic latitude of individual groups of sunspots against time.

6.5.2 Asymmetric Distribution of Spot Areas

The size of a sunspot or sunspot group is conventionally measured in units of millionths of the area of the Sun's visible hemisphere. Sunspots may be morphologically classified into one of nine classes of the Zurich system of classification (Bray and Loughhead, 1964). The typical lifetime of a spot in days is approximately 1/10th of the spot's maximum area in millionths of the solar hemisphere. In order to show the distribution of relative sunspot sizes, I have analysed the sunspot areas given per rotation in the RGO series covering the 80 year period between 1874–1954. Fig. 6.4 shows the distribution of of sunspot areas for both the northern and southern hemispheres of the Sun. Of all of the sunspot group areas in this period, about 22% have an average area greater than 500 millionths of the Sun's hemisphere. It can be seen from Fig. 6.5a that sunspot areas for the two hemispheres were not equally represented. I have calculated the anisotropy index, A_s, for the two hemispheres by:

$$A_s = \frac{N - S}{N + S}$$

where N is the total mean areas in the northern hemisphere and S is the total mean areas in the southern hemisphere. It is worth noting the marked deviation between the hemispheres around the minima of sunspot cycles (Fig. 6.5b). In contrast, around the maximum the two hemispheres are relatively equally covered by sunspots. The deviation can be taken to signify that at least on the century time-scale there is a systematic difference between the magnetic fluxes from the two hemispheres during

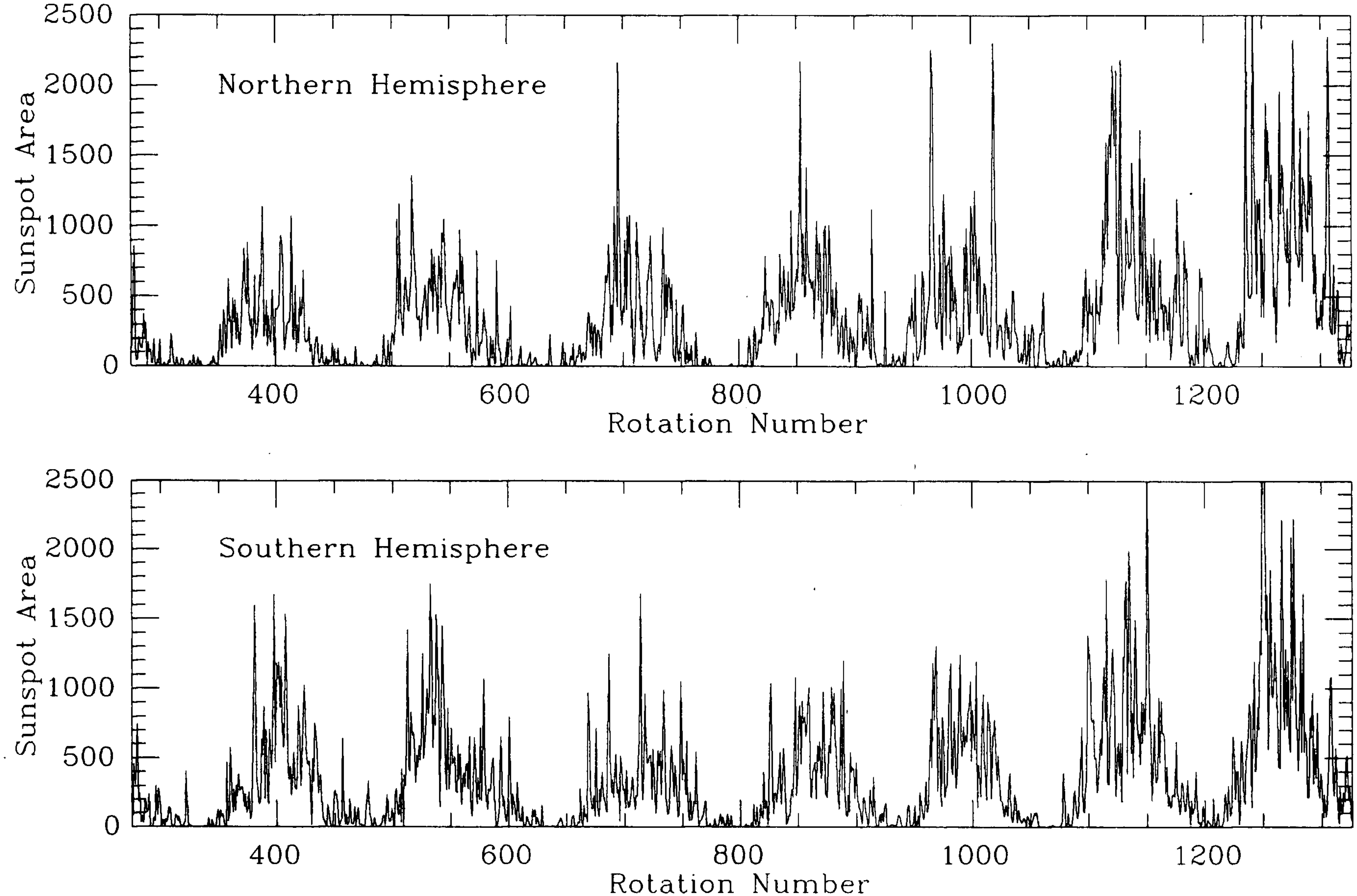

Fig. 6.4 The distributions of the sunspot areas per rotation from AD 1874 to 1954 for the northern and southern hemisphere.

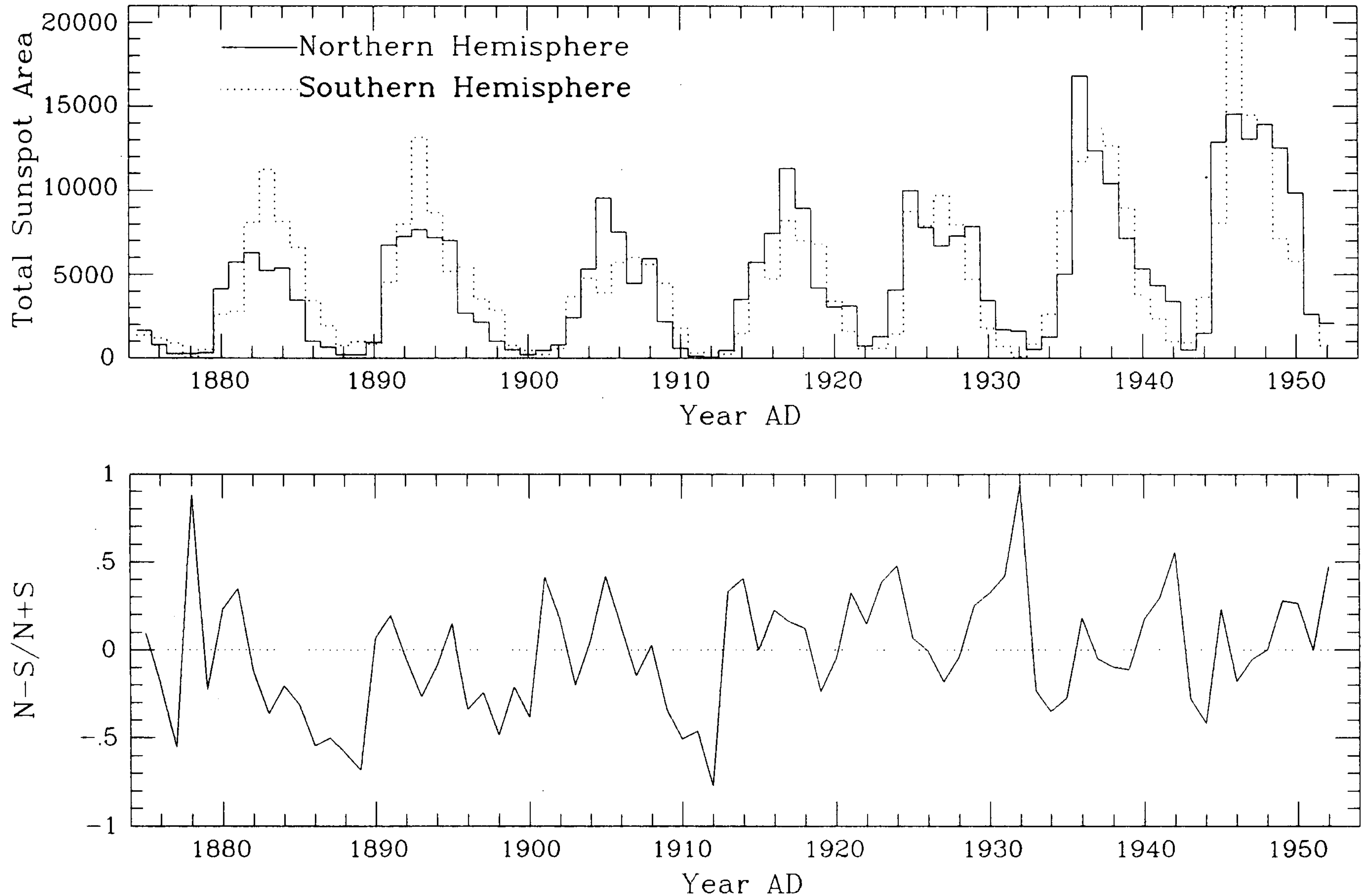

Fig. 6.5 (a) A comparison between the total sunspot areas per year of the northern and southern solar hemispheres. (b) The area asymmetric index, N-S/N+S, calculated from the asymmetry between the areas in the northern and southern hemispheres.

sunspot minimum, whereas near maximum the magnetic fluxes are nearly balanced between the two hemispheres.

6.6 Investigation of Naked-eye Sunspot Records

Watching the Sun was a regular practice in China which may be traced back in time to the pre-Han period (prior to 220 BC). It is generally believed that the mythology of depicting a crow on a reddened Sun may have originated from earlier sightings of unusually large sunspots. Solar observation is likely to have been carried out routinely by astronomers of the Imperial Astronomical Bureau. Throughout the entire Chinese history down to the fall of the last dynasty in AD 1911, watching the Sun for unusual occurrence was vigorously practised. In later centuries, the same tradition was adhered to by astronomers in Korea and Japan. The type of phenomena noted by these astronomers seems to include virtually anything on or near the Sun. These phenomena range from sunspots, solar haloes, parhelia to 'auspicious vapours' in the vicinity of the Sun (Ho Peng Yoke, 1966). They were regarded as portents and it thus can be understood that the Sun played an important role in astrological prognostications.

The general description of a sunspot record from the Far East is that of "a black spot (*hei-tzu*) or vapour (*hei-ch'i*) within the Sun". Some of the spots are compared with the shape of common objects like hen's eggs, plums, chestnuts and so on (Table 6.4). It can be seen that the comparison of spots with such objects is very much period dependent on and subject to the observers of that time. Beside the comparison of the shapes of spots, the duration of visibility of a spot was sometime mentioned.

6.6.1 Observational Criteria

In order for the eye to look at the Sun directly, it is necessary for the brightness of Sun to be sufficiently dimmed. Adequate dimming of the Sun's brightness may be

Table 6.4 A comparison of sunspot shapes described in Far Eastern texts.

Period		Flying Magpie	Flying Swallow	Crow	Melon	Pear	Goose' Egg	Duck's Egg	Hen's Egg	Cup	Peach	Plum	Date	Chestnut	Coin	Dipper	Pellet	Star
CHINA																		
Former Han	206 BC-AD 9														1		1	1
Later Han	25-220	1			1													
Western Chin	265-317		2															
Eastern Chin	317-420			1				1	3		1	4						
Ch'en	557-589			1														
Northern Wei	386-535						2				2							
Northern Chou	557-581			1					1	1								
T'ang	618-906		1						2	1						1		
Later T'ang	923-935								1									
Later Han	947-950								1									
Norther Sung	960-1126											6	2	1				
Southern Sung	1127-1279											3	5					
KOREA																		
Uijong	1147-1170								2									
Myongjong	1171-1197					2					2							
Sinjong	1198-1204					1						2						
Kojong	1214-1259								1									
Ch'ungnyol -wang	1275-1308								1									
Sinu	1375-1388								1									
Myongjong	1546-1567								1									
Sonjo	1568-1608								1									
Kwanghae-gun	1609-1623					1												

gained in several ways: natural aids include atmospheric haze, dust or sand storms, severe atmospheric absorption near sunrise or sunset and reflection from still waters. In addition, artificial aid may be used. Needham (1959) thought that Far Eastern astronomers used pieces of semi-transparent jade, mica or smoky rock crystal for looking at the Sun, but there does not seen to be any early literature supporting this claim. On the other hand, there are mentions that solar eclipses were observed by looking at the reflection of the Sun in a basin of water blackened with Chinese ink (Chu Wen-hsin, 1934; Wang and Siscoe, 1980). In addition, I have found a quote in the 12th century encyclopedia the *Wen-Hsien T'ung-k'ao* saying that a basin of oil was used for observing an eclipse in the Sung Dynasty (AD 960–1279).

Provided viewing conditions are favourable, a large whole spot or compact spot group of area 500 millionths of the Sun's hemisphere (about one arc minute) when near the centre of the solar disk should be just visible to the naked-eye (Newton, 1955). There are larger spots with areas up to six times this size but they are less frequent. A spot with a mean area of 1500 millionths of the Sun's hemisphere is regarded as a 'giant spot' and should be readily observable by the naked-eye under suitable conditions. Fig. 6.6 shows the distribution of the larger sunspots (areas greater than 500 millionths of the Sun's hemisphere) together with the mean annual sunspot numbers in the interval 1874–1954. It is clear that the larger sunspots do follow closely the pattern exhibited by the 11-year cycles. Hence it may be readily deduced that the probability of sighting a naked-eye sunspot during the peak years of a sunspot cycle is much higher than at any other times within that cycle.

If the astronomers of the Far East kept a consistent watch of the sky, the extremely small sample of extant naked-eye sunspot records (about one per decade) is not easily explained. According to the RGO (1955) catalogue, there was a total of 761 large whole spots or compact spot groups (areas greater than 500 millionths of the Sun's

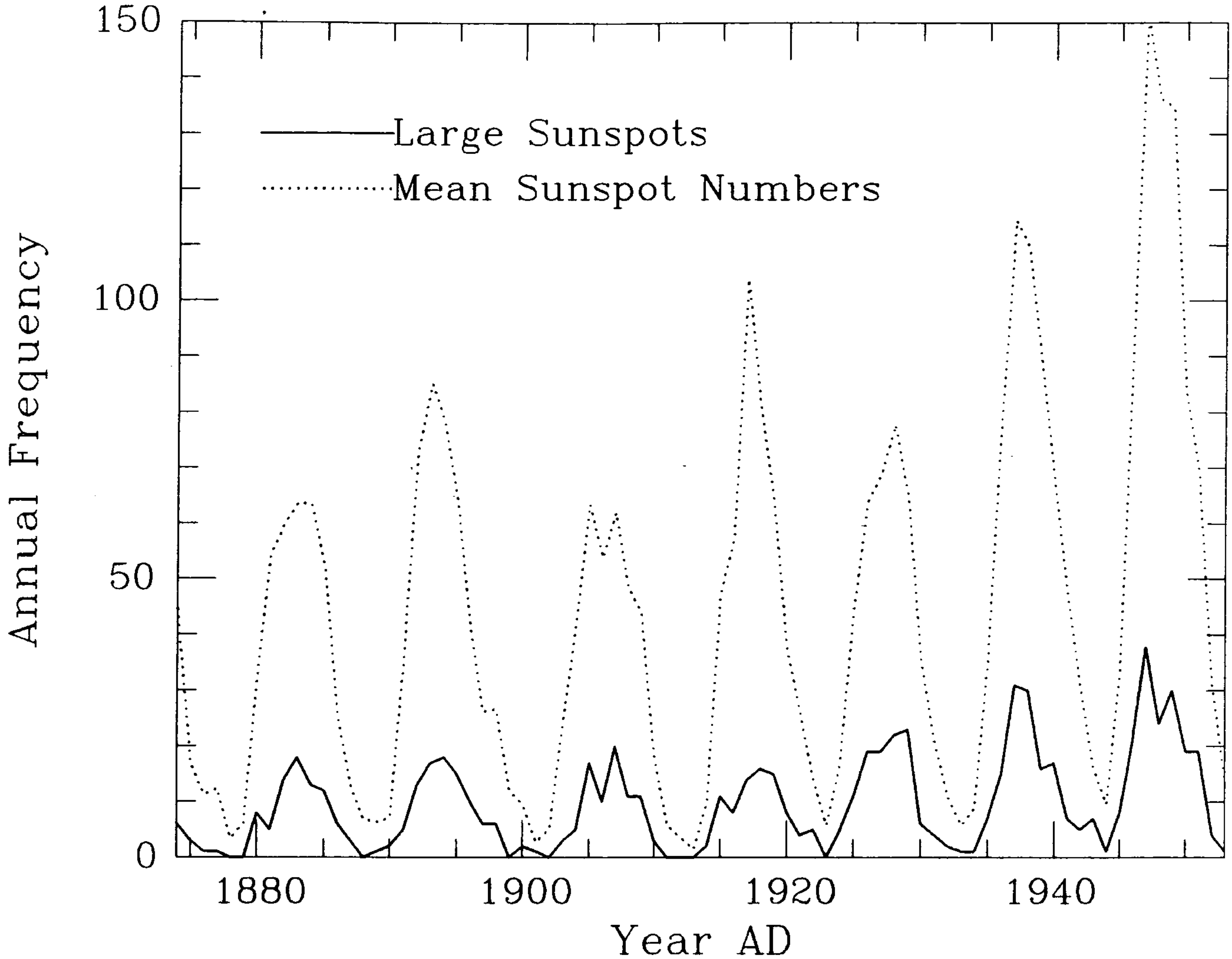

Fig. 6.6 A comparison between large sunspots (with area greater than 500 millionths of the Sun's hemisphere) and yearly mean sunspot numbers.

hemisphere) observed during the 80 years from 1874 to 1954. Based on these statistics, one can readily inferred that approximately 100 spots per decade should be visible to the naked-eye during normal solar activity. Comparing the number of naked-eye sunspots with modern observations, it seems that only about 1% of the theoretically observable sunspots were observed. Even if all occasions unfavourable for observing sunspots in the past were allowed for we would still have expected many more sightings. One may argue that this was due to inattention on the part of astronomers or due to some kind of astrological selection factors. Other reasons may be due to the attitude of the imperial court, both the rulers and their astronomers. A possible explanation is that these astronomers tended to observe at a specific time. Fig. 6.7 shows a plot of the frequency of sunspots against the lunar age. The single marked peak on the first day of the month can be understood as due to accidental sightings when the Sun was being examined for possible eclipses. Hence it seems likely that the court astronomers did not keep a regular watch for spots; otherwise we would have a lot more records today. Sunspots observed on days other than the first were purely on a casual basis.

6.6.2 Seasonal Variation

Far Eastern sunspot sightings show a marked seasonal variation. The cause of this is the general climatic conditions over much of central China and Korea. During the late winter and whole of the spring, both dust and sand storms originating from the Takla Makan, Gobi and Ordos Deserts and the Chinese loesslands frequently dim the Sun considerably. As a result, these natural geographical factors provide a favourable viewing condition and enable direct observation of the Sun to be made readily. Consequently, there would have been a higher probability of observing sunspots during the spring and winter times than any other seasons. On the other hand, the chance of directly looking at the Sun in summer is limited due to a prevalent clear sky.

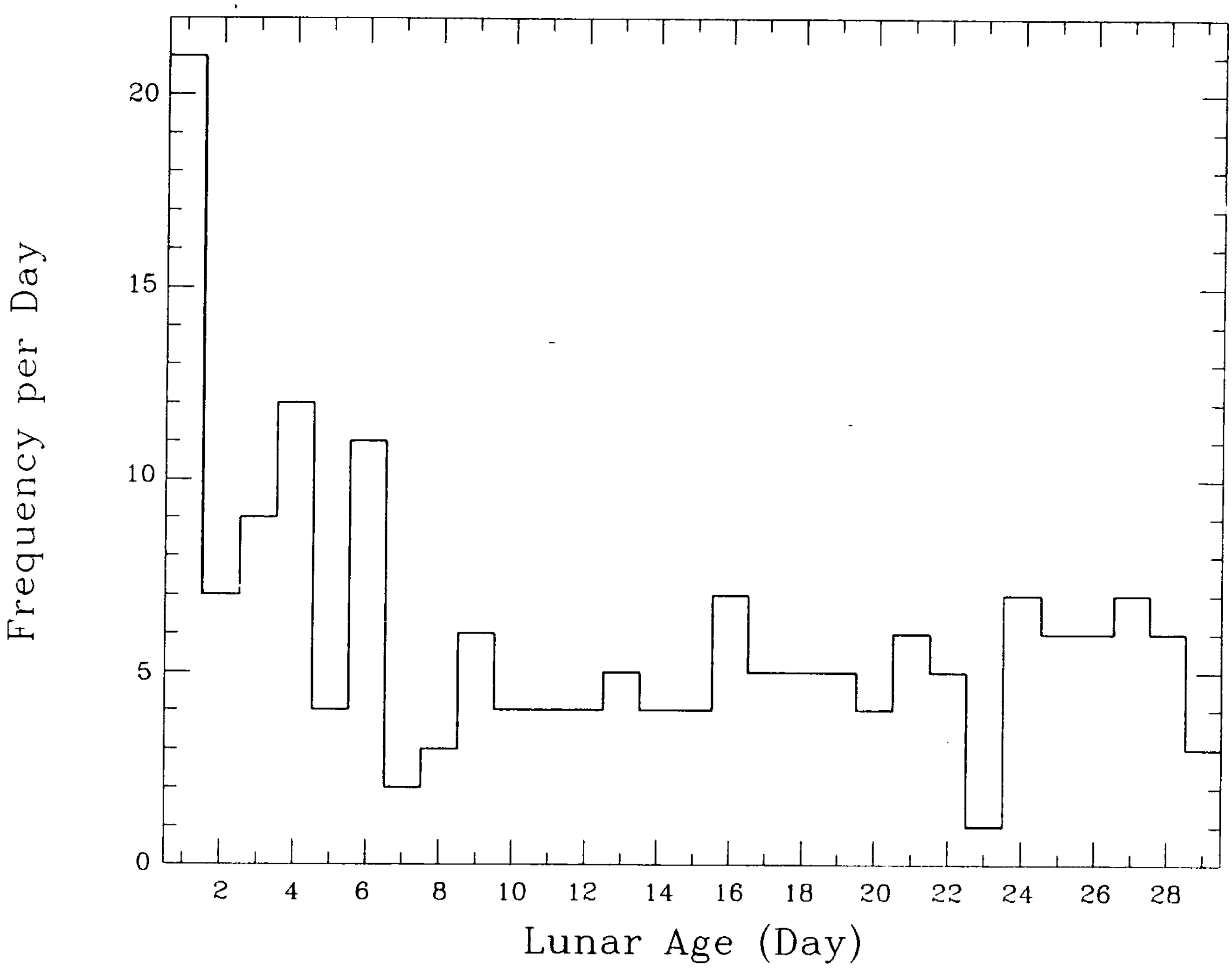

Fig. 6.7 The frequency of naked-eye sunspots plotted against lunar age.

The variation of sunspots with seasons was first suggested by Kanda (1933) and was brought into attention again by Clark and Stephenson (1978). A subsequent detailed analysis by Willis *et al.* (1980) demonstrated the existence of a marked seasonal variation in the Far Eastern sunspot records. With the help of satellite photographs they were able to show the large extent of dust storms over much of East Asia. Fig. 6.8 shows the seasonal variation of sunspot sightings with the addition of all new data from the present catalogue. The histogram clearly indicates a marked variation of sunspots with seasons; furthermore the characteristic seasonal variation as shown by Willis *et al.* (1980) has been retained.

6.6.3 Secular Variation

By studying early naked-eye sunspot observations, it is hoped that one may be able to obtain an indication to the long term activity levels of the Sun in the past. It is assumed that a close correlation between the appearance of large sunspots and a higher level of solar activity existed. Due to the small number of recorded naked-eye sunspots, it is very much doubted that if one could ever retrace accurately the 11-year cycle. Furthermore, the 11-year cycle may well be described as 'quasi-regular' since the actual interval between successive maxima may vary by several years. It seems likely that at best, one might just be able to recover longer trends similar to that of the Maunder Minimum type of long depression intervals. It is difficult now to assess the true scale of the sunspot cycle before the telescopic period from the scanty naked-eye sunspot data alone.

Fig. 6.9 shows a histogram of the decade distribution of naked-eye sunspot records from Far Eastern histories covering the period 165 BC to AD 1918. For the first millenium AD only a few features can be seen. Due to the preservation of the records, one can at most claim that these peaks confirm the Sun was active to a certain degree

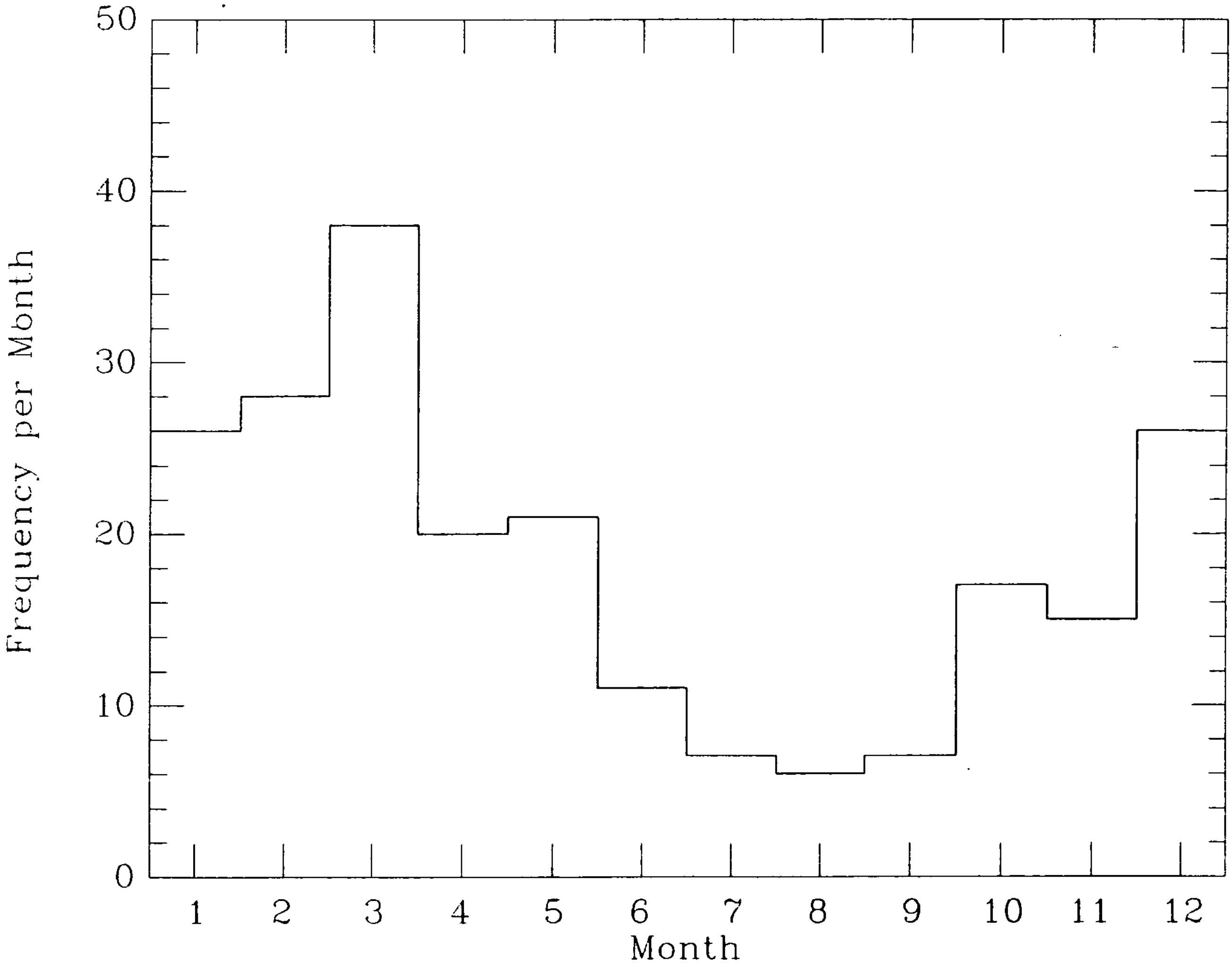

Fig. 6.8 The seasonal variation of naked-eye sunspots.

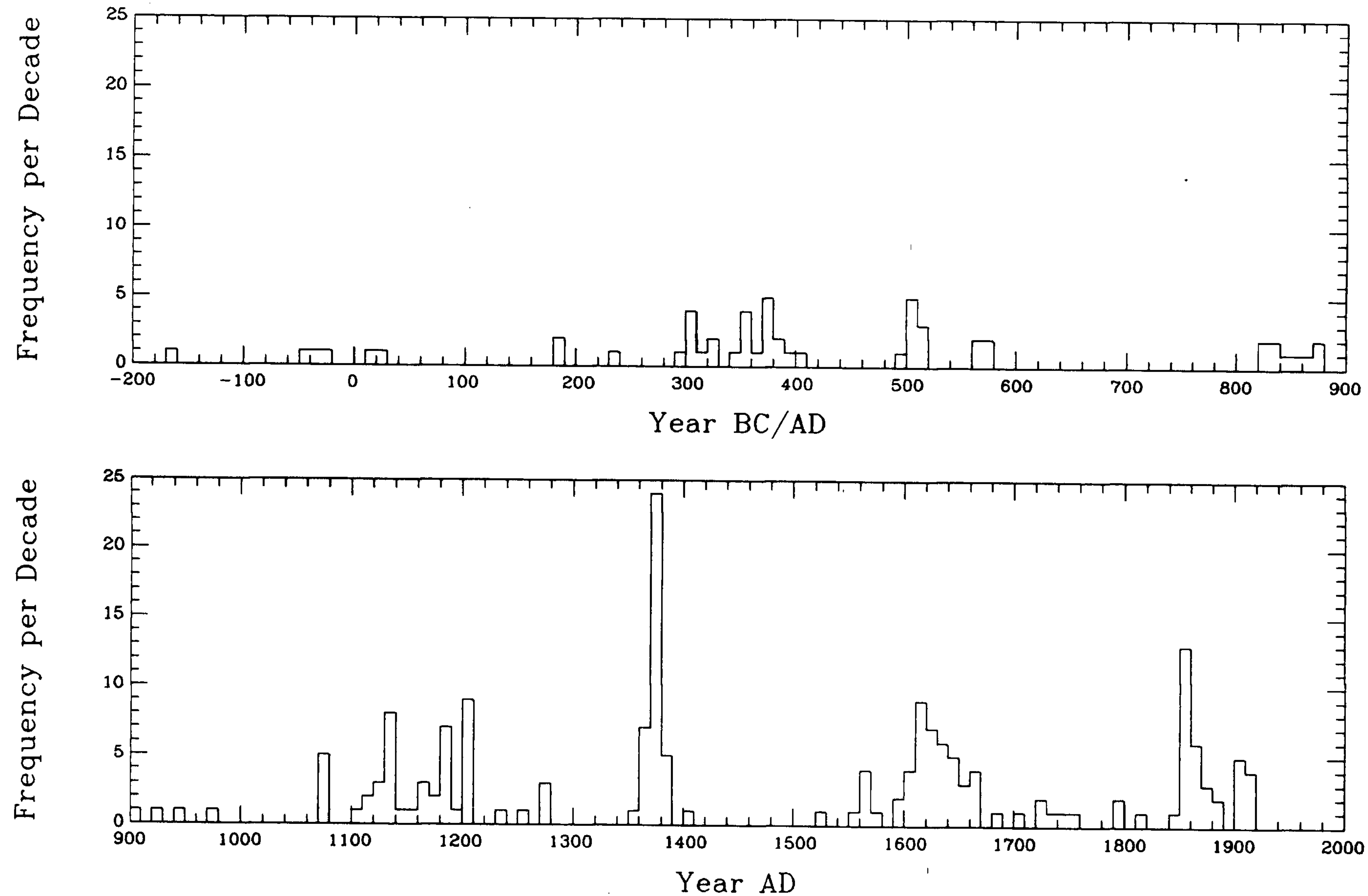

Fig. 6.9 The decade distribution of naked-eye sunspots from 165 BC to AD 1918.

during these periods. Whereas the absence of sunspot records do not necessarily mean the Sun was inactive due to the problem with data gaps.

Some of the gaps exhibited by historical records may be attributed to the chaos caused by the downfall of a dynasty in China, or wars in Korea or Japan (see Fig 1.6, 1.7 and 1.8). Presumably, during these difficult times, the astronomers were hindered from carrying out their normal observational routines. In addition, it is also difficult to distinguish between the changing attitudes towards the value of celestial portents and the amount of preserved materials available today. The problem can best be illustrated by a comparison with other solar related phenomena, e.g. the solar haloes (Fig. 6.10). The various peaks shown in this figure are likely due to random fluctuations caused by the varying number of preserved records. The peaks appeared in the distribution around the 12th century may be similarly explained. The strongest peak of the distribution is at around 1370's, it is plausible that this represents a period of relatively higher solar activity judging from the size of the feature.

For the post-telescopic period, the features at the first half of the 17th century could be due to selection effects. The lack of naked-eye sunspot records in the telescopic period prompted researchers to look for sightings recorded in other sources than the official dynastic histories. Sunspot records in the *Fang-chih* ('local gazettes') were first drawn to attention by Xu and Jiang (1979). They compiled a list of 21 records in the 17th century from these local gazettes. Based on these records Xu and Jiang proposed that the Sun did not lower its sunspot production during the Maunder Minimum period as favoured by Eddy (1976). They believed that the 11-year sunspot cycles were present at these times and the Maunder Minimum was due to a deficiency in the data.

In a reassessment of the Maunder Minimum, Eddy (1983) pointed out that only six of the Chinese sightings actually occurred during this interval, and some of these

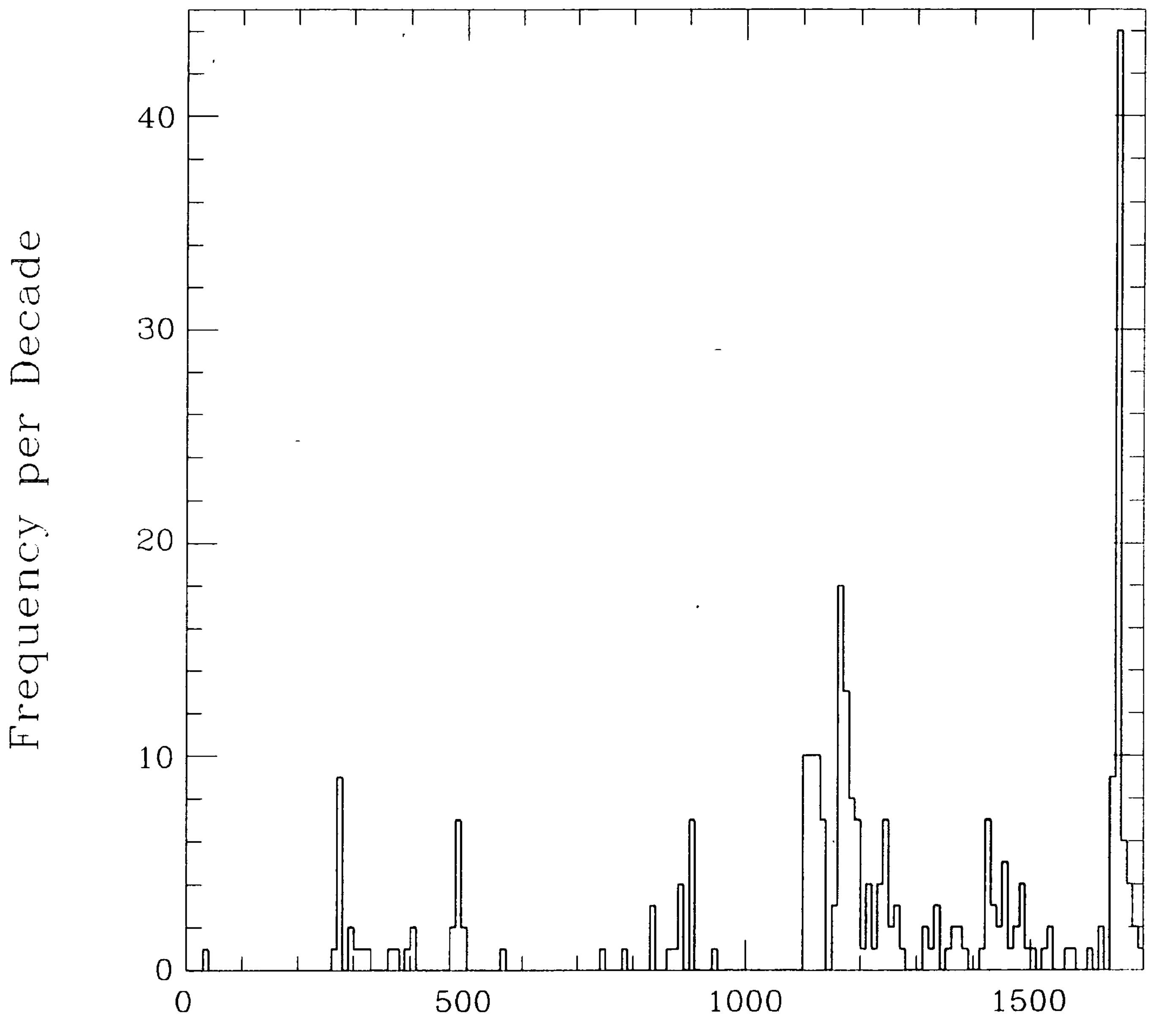

Fig. 6.10 The decade distribution of solar haloes from AD 1 to 1700.

coincided with spots reported in Europe at the time. Hence these isolated occurrences – only a tip of a large iceberg – represent only a minute fraction of the total number of sunspots seen telescopically in Europe at this period.

The lack of naked-eye sunspot records during the last three centuries in China had been interpreted as either the Chinese astronomers were not interested in sunspots or the records were simply lost. It is possible that the introduction of the telescope around the mid-17th century into China might have brought an end to the omen value of sunspots. Cullen (1980) argued that sunspot records could have been lost at the time when the Peking Observatory was occupied by Allied troops during the Boxer Uprising in 1900. However, from the state of preservation of other astronomical records in the early Ch'ing period down to AD 1800, Cullen's conclusion may not be entirely correct. During this period, there is a profusion of other records such as eclipses, planetary conjunctions and so on. If sunspots were recorded they would have been preserved together with other contemporary astronomical records at least until AD 1800.

The absence of Japanese sunspot records in the Maunder Minimum period and other times is curious. Only one sighting in the year AD 851 is reported for the entire period since the first Japanese observation in the 7th century. It is possible that they too, like their European counterparts, believed in an unblemishable Sun. It is of interest to note that the insignia of Japan is none other but the Sun.

Fig. 6.11 compares the distributions of telescopic and naked-eye sunspots for the period from AD 1600 to 1920. The naked-eye records for this period originated mainly from local gazettes. Due to incomplete telescopic data, not much can be inferred from the distributions before about AD 1700. But from about AD 1700 onwards, a number of interesting features are shown by the distributions. It can be seen that most of the naked-eye sunspots lie within the maximum envelopes of the 11-year cycle. Only in a few cases did the naked-eye sunspots coincide with the cycle minima. Thus, the

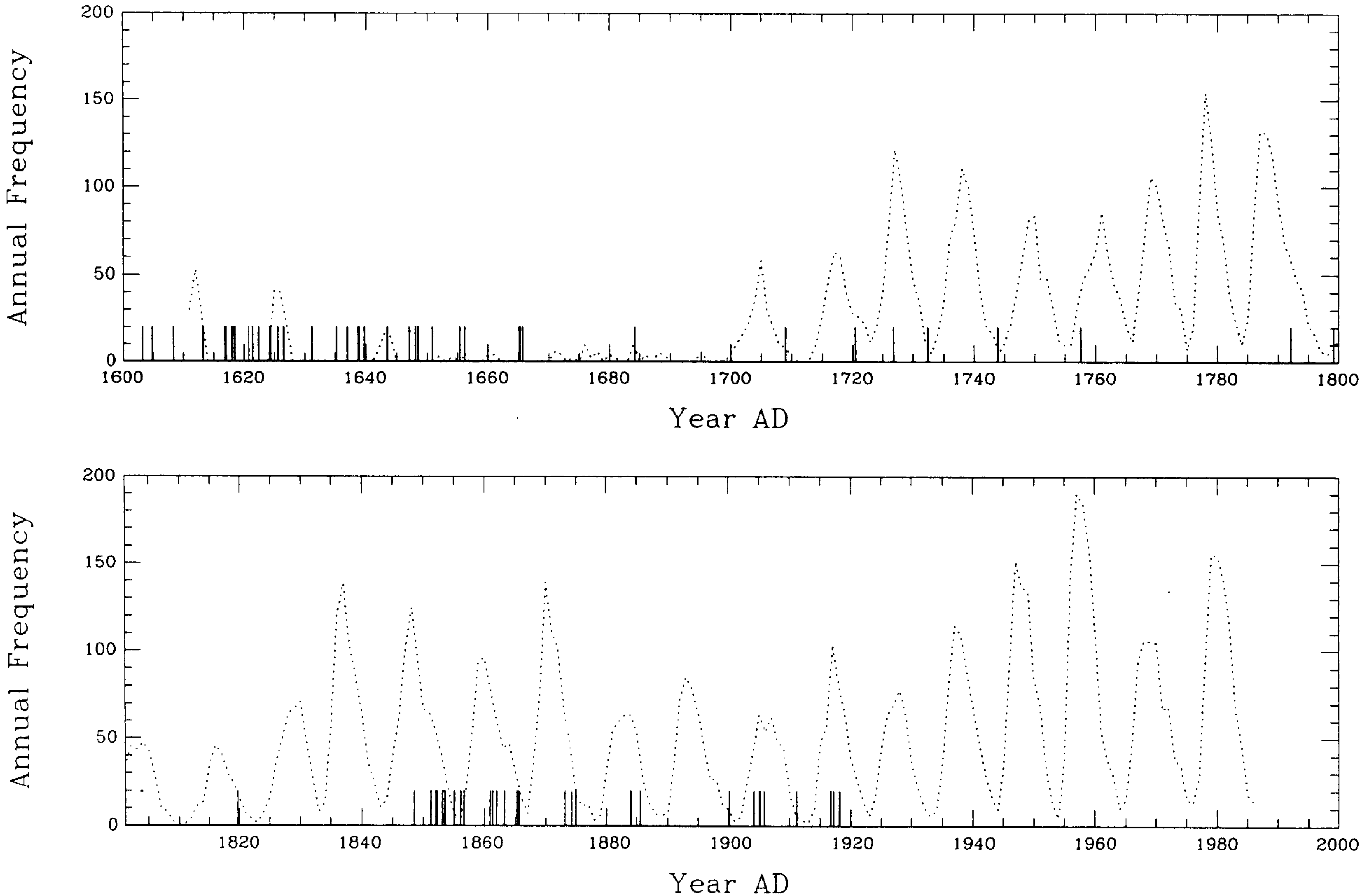

Fig. 6.11 A comparison between the number of naked-eye and telescopic sunspots for the period AD 1600 to 1920.

assumption that the observations of naked-eye sunspots represent times when the solar activity is at a higher level appears essentially correct.

6.6.4 Period Search on Naked-eye Sunspot Records

(1) Methods of Period Analysis

One of the reasons for studying early sunspot data is to see whether the 11-year sunspot cycle persisted in the pre-telescopic past. Several available methods can be performed which will search for the underlying periodicities of the data. One of the better known methods is that of power spectral analysis. This type of analysis has already been performed on the telescopic sunspot series by a number of researchers (Cole, 1973; Cohen and Lintz, 1974; Wittmann, 1978; Otoalo and Zenteno, 1983). Although there is a considerable disparity in the periods obtained, from 5 to 180 years, there seems to be a general agreement on the existence of an 11-year period. Beside the power spectral method and its variant methods - see details in Berry (1987), two other methods worth mentioning are the cyclogram method (Attolini and Cecchini, 1984) and epoch folding method (Wittmann and Xu, 1987).

The criteria for using the above methods vary considerably. For instance, both the power spectral analysis and the cyclogram method assume that the input data are equally spaced, continuous and homogeneous; whereas the epoch folding method requires a relatively large sample and fairly accurate knowledge of the search period. I have initially analysed the naked-eye sunspot data (and the telescopic data as a check) for periodicities by the power spectral analysis employing a Parzen lag window (NAG, 1984 and Bloomfield, 1976). Fig. 6.12a shows the results of the power spectral analysis on the telescopic sunspot data. It seems that in addition to the primary period of 11 years, there is a secondary period of 10 years. At lower periods the spectrum becomes noisy, it is difficult to draw any concrete conclusion on the existence of other periods.

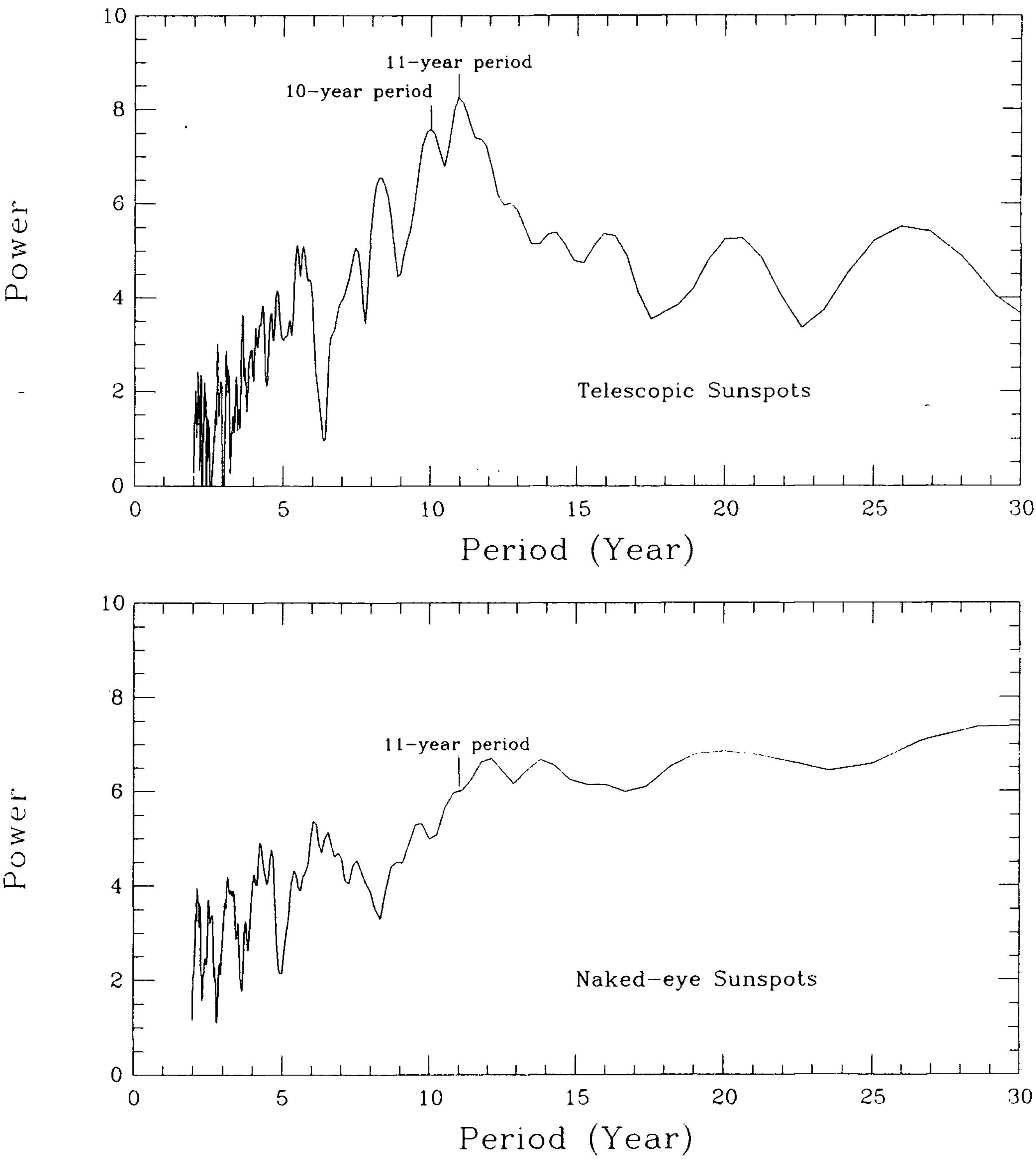

Fig. 6.12 (a) The spectrogram obtained from a power spectral analysis of the telescopic sunspot data. (b) The spectrogram obtained from a power spectral analysis of the naked-eye sunspot data.

The results of the analysis on the naked-eye sunspot records is shown in Fig. 6.12b; no obvious feature is present at either the 11 or 10 year period.

In order to examine the data in another fashion to see whether it is the power spectral method that failed to pick out the underlying periods or the 10/11-year cycles are really absent from the naked-eye observations, I have adopted a different approach. The method I have selected here, which I shall call the pseudo-spectral method, is based on a similar method used by Stothers (1979) in the investigation of the Greco-Roman records of aurorae.

(2) Pseudo-Spectral Method

Several peculiarities of the naked-eye sunspot records need to be taken into considerations when selecting a suitable method of period analysis. The naked-eye sunspot records: (i) have large data gaps; (ii) are not expected to coincide exactly with the maximum of the 11-year cycles and (iii) constitute only a relatively small sample for each 11-year cycle. In addition, the naked-eye sunspot data set is not expected to follow a true sinusoidal pattern as can be inferred from the irregular 11-year cycles exhibited by the telescopic data. The ability to incorporate large data gaps and not to involve a sine wave term are intrinsic features of the pseudo-spectral method which makes it more suitable for the purpose of analysing naked-eye data than methods like the power spectral, cyclogram or epoch folding.

First a suitable array of trial periods is set up. Then a continuous sequence of predicted times of maximum for each combination of trial period and trial epoch is calculated from:

$$t_{max} = t_0 + nP$$

where t_{max} is the time of the nth maximum, t_0 is the initial epoch and P is the trial period. Both P and t_0 are to be determined simultaneously. The residual index R_{index}

is then estimated from:

$$R_{index} = \frac{\sigma_c - \sigma}{P}$$

where the rms residual σ is calculated for each sequence by:

$$\sigma = \left(\sum_{i=1}^{N} \frac{d_i^2}{N}\right)^{\frac{1}{2}}$$

Here d_i ($i = 1, 2, ..., N$, for N observations) is the difference between the predicted maximum and the observed time. The expected rms residual σ_c assuming a rectangular distribution is given by:

$$\sigma_c = \frac{P}{N}\left(\frac{N^2 - 1}{12}\right)^{\frac{1}{2}}$$

Fig. 6.13a shows the results of a search for periodicities in the naked-eye sunspot records. There is only one broad peak at a period of about 10 years. The results obtained here is compatible with the secondary feature seen in the telescopic data (Fig. 6.12a). It appears that the early sunspot cycles were more like 10 years rather than the dominant 11-year cycles seen in recent times. If this interpretation is correct, it would be worth looking at the mechanisms that caused the slow down of the sunspot cycle. Fig. 6.13b shows the resulting spectrum of a similar search carried out on the solar halo records. As is expected, no visible peak is seen in this case.

6.7 Summary

In this chapter, an analysis of the available sunspot records from both the pre-telescopic and telescopic periods has been carried out. The results obtained are in general agreement with previous investigations. For the telescopic period, the analysis on sunspot

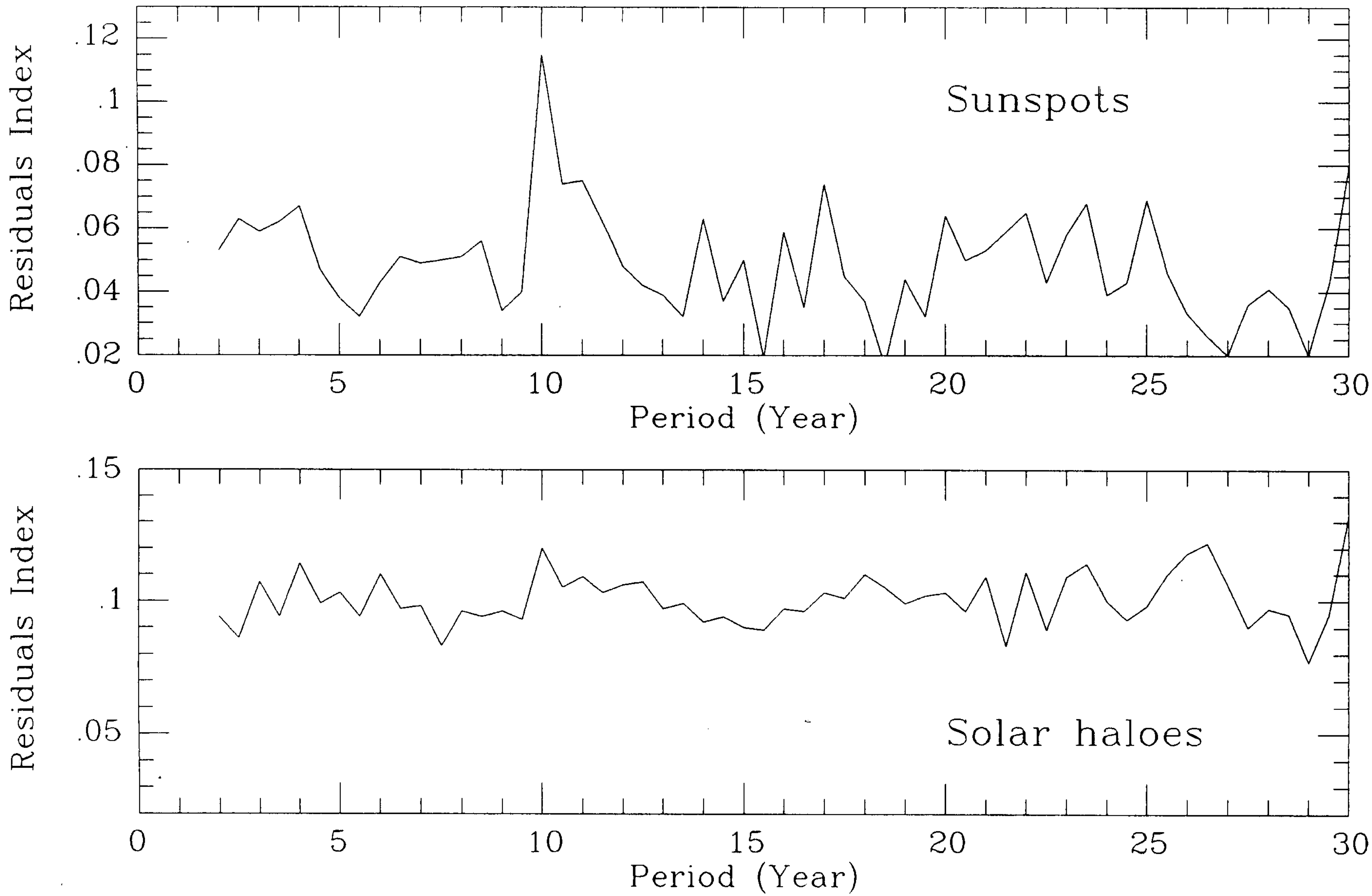

Fig. 6.13 (a) The spectrogram obtained for the naked-eye sunspot data using the pseudo-spectral method.
(b) The spectrogram obtained for the solar halo data using the same method.

areas from the RGO series showed an asymmetric distribution between the areas north and south of the solar equator. The variability of magnetic flux especially during sunspot minima is inferred. The results obtained here should provide another parameter for constraining future models on the cyclic variation of the Sun.

The Far Eastern historical records of sunspots have been updated and revised to include some 77 records from local Chinese histories. The period search performed on the naked-eye data yielded a mean period of about 10 years. It is hoped that a few more naked-eye sunspots will be recovered from other Far Eastern sources like the biographies of astronomers and diaries of court officials. At the present, the time for the onset and termination of the Maunder Minimum is only arbitrarily determined. It is worth pursuing in depth these two limits if we are to obtain improvements on current models of protracted periods of low solar activity. Foremost to our understanding of the variations in the sunspot cycles is that the observation of sunspots should be continued.

CHAPTER 7
AURORAE

7.1 Introduction

The earliest reliable description of an aurora from Europe is generally accepted as that given by Aristotle (c. 330 BC). He used terms like 'chasms', 'trenches', and 'blood-red colours' to describe aurorae in one of his master works, the *Meteorologica* (I, 5). Amongst the various terms mentioned by later Latin writers, the term 'chasmata' (Latin word for chasm) seems to be the most commonly employed (Seneca, *Quaestiones Naturales*, I, 14 and Pliny, *Historia Naturalis*, II, 26–27). The origin given to aurorae at this early time was similar to that given to meteors and comets. The occurrence of aurorae was regarded as when a large quantity of dry air in the atmosphere caught fire and burned. Even though these ideas were primitive by modern standards, it is interesting that aurorae were recognised as atmospheric phenomena, although of course we now know that they occur high in the Earth's ionosphere. Fig. 7.1 shows the position of the aurora in relation to other natural phenomena occurring in the various strata of Earth's atmosphere. Stormer (1955) determined using a photographic method that most aurorae occur at heights between 90 and 150 km above sea level (Fig. 7.2).

The occurrence of aurorae depends on the geomagnetic latitudes of the place of observation. Aurorae are frequently reported from places situated in high geomagnetic latitudes like the countries of Northern Europe. Many accounts of these phenomena have been found in Scandinavian literature going back to the Viking era (Brekke and Egeland, 1983). Auroral records from countries in low geomagnetic latitudes, however, are much rarer. Nonetheless, about a thousand auroral records are known to exist in Far Eastern dynastic histories. These low latitude aurorae are usually associated with energetic particles originating from intense flares which occur in the vicinity of large

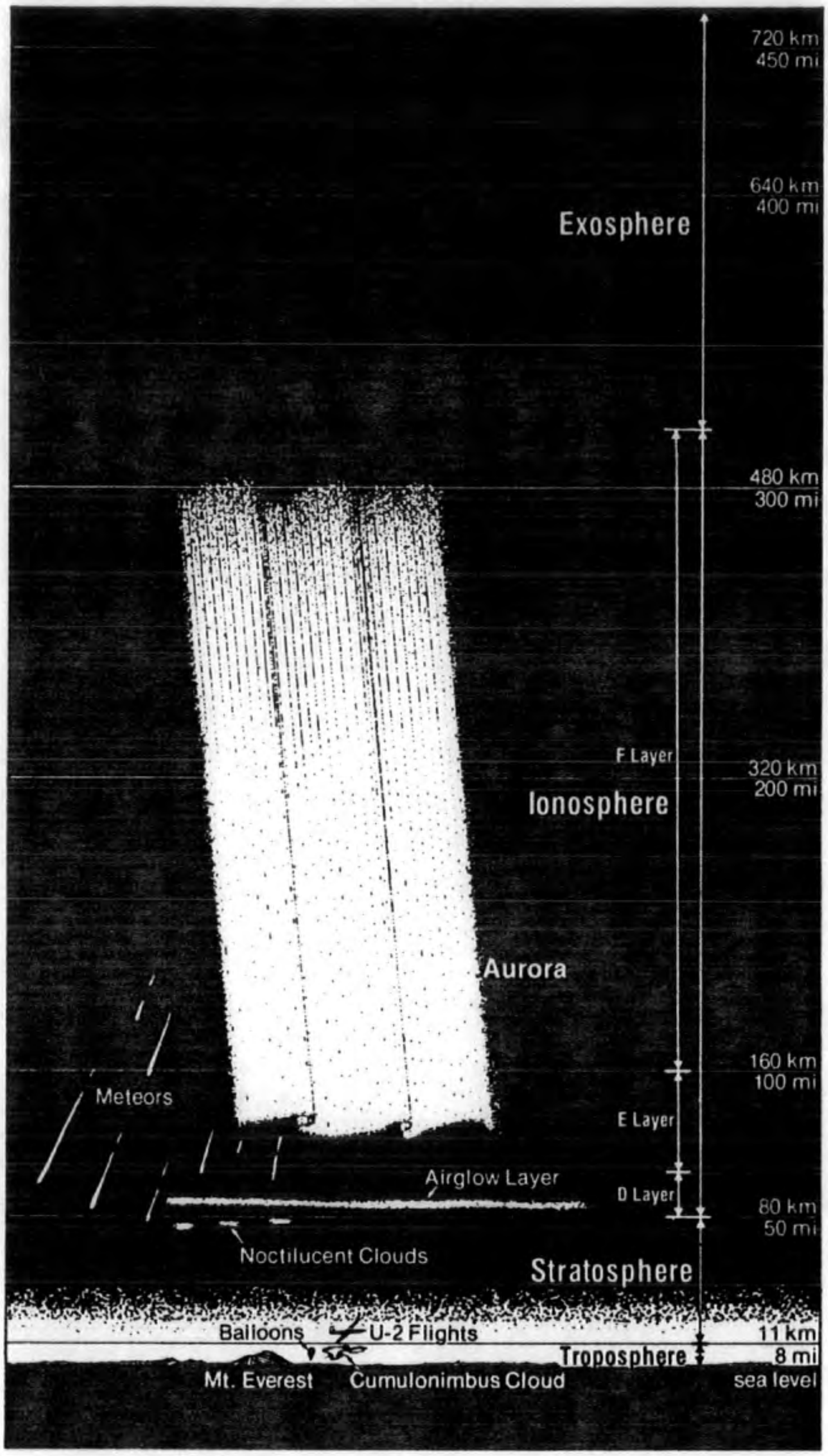

Fig. 7.1 The height of occurrence of aurorae and other phenomena in the Earth's atmospheric layers (after Akasofu, 1979).

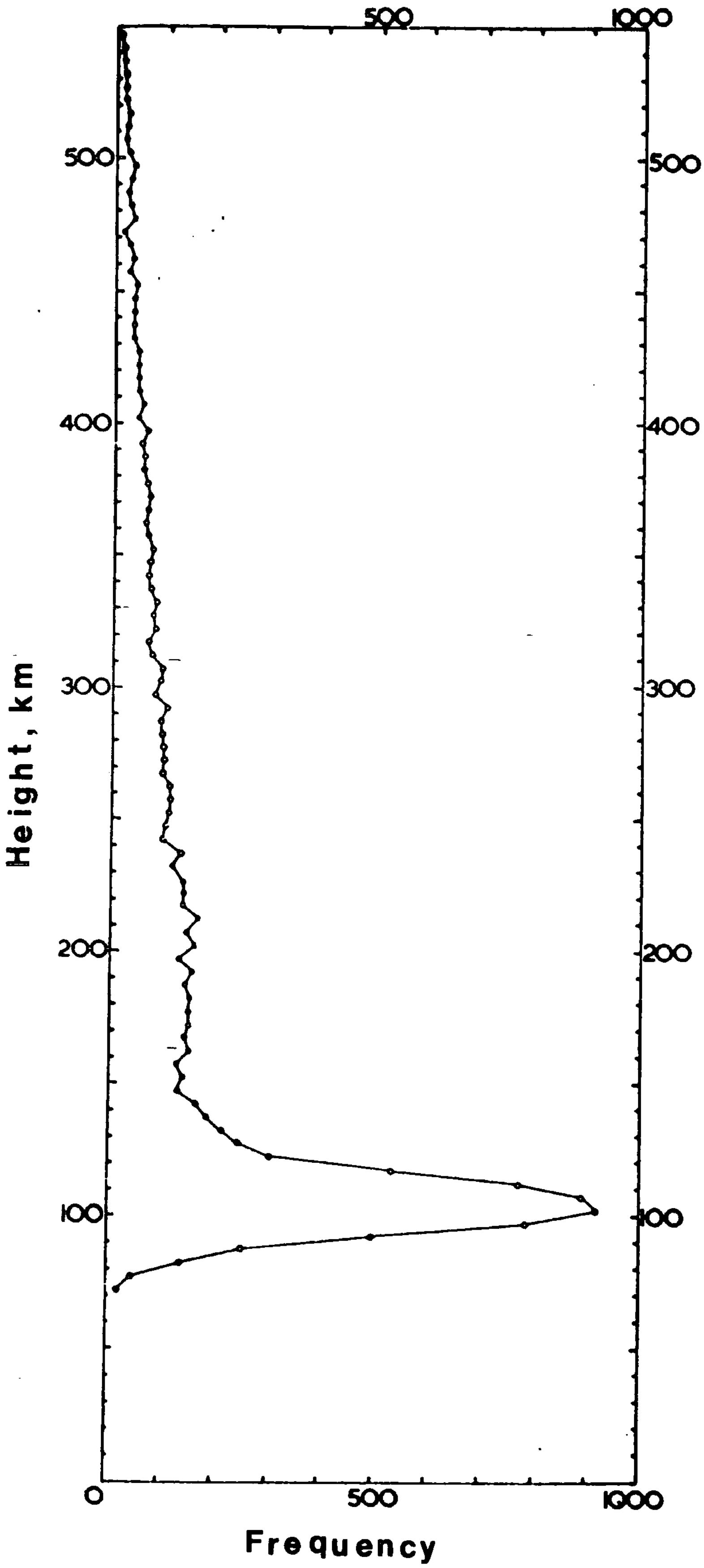

Fig. 7.2 The frequency of aurorae as a function of its height in the atmosphere (after Stormer, 1955)

sunspots. It has been shown that the occurrence of low latitude aurorae follow the rise and fall of the sunspot cycle (Meinel *et al*, 1954). In contrast, aurorae observed at places in high geomagnetic latitudes are usually induced by particles coming from coronal holes which are not directly related to sunspots.

European records of aurorae exist in a number of different sources and have already been compiled by several authors (e.g. Link, 1962; 1964). However, European records suffer from the non-uniformity of their sources and places of observation being in a high geomagnetic latitude. Far Eastern records, on the other hand, are based on systematic observations by astronomers stationed in capital cities situated in low geomagnetic latitudes. Thus, Far Eastern auroral records seem to be more suited for the study of the solar cycle than their European counterparts. It is hoped that the investigation of the frequency of occurrence of these low geomagnetic latitude aurorae will improve our understanding of the long term variations in solar activity.

7.2 An Overview of Auroral Research

One of the essential ingredients in the understanding of the auroral phenomenon which the early philosophers had been unaware of was of course the magnetic field of the Earth. Although magnetic compasses for navigation purposes were in use very early in China (Needham, 1962), the fact that the Earth possesses a magnetic field was not fully realised until about AD 1600. In that year, William Gilbert wrote in his great treatise entitled *De Magnete* that, 'magnus magnes ipse est globus terrestris' (the terrestrial globe itself is a great magnet). A little more than a century later, Edmond Halley, best known for his studies of the comet which bears his name (chapter 2), was able to depict the Earth's magnetic field as an ideal dipole (Halley, 1716). When Halley saw a fine auroral display over London the next year, he postulated that the 'Effluvia of the Magnetical Matter' of the Earth was the driving force behind the production of luminous aurorae (Halley, 1717). A few years later, Graham discovered the transient magnetic variations by observing the movement of a compass needle with the help of a microscope in London in 1722 (Graham, 1724). He was able to distinguish magnetically quiet days from the days that were disturbed.

In 1733, De Mairan published a book entitled *Traite Physique et Historique de l'Aurore Boreale*, in which he rejected the idea that the aurora was related to the zodiacal light and suspected that aurora was due to the interaction between the Sun and the atmosphere of Earth. His work stimulated further researches by European workers into the origin of the aurora. The same year Anders Celsius discussed in detail the auroral phenomenon based on a series of observations made in Sweden from 1716–1732. Celsius later introduced his brother-in-law Olof Hiorter to the possible correlation between the aurora and the position of the compass needle. In 1741, Hiorter made a total of 6638 readings – mainly at hourly intervals – in Uppsala and established the close connection between the movement of the magnetic needle and the appearance of the northern lights (Hiorter, 1747).

Wilcke, well known for making one of the first world-wide magnetic inclination charts, was able to show in 1777 that aurorae aligned themselves in the same direction as the geomagnetic field lines. Lomonosov (1747) demonstrated experimentally the light-emitting electrical nature of aurorae. He put forth the concept of rising and sinking air streams near the pole, generating tensions of friction and discharging themselves, becoming luminous as aurorae. The height of the aurora was measured by Bergman (1764). He found that it was situated far above the clouds at a height between 380 and 1300 km from the Earth's surface.

At the beginning of the 19th century, the question as to whether the aurora was reflected sunlight or not was finally answered by Jean Biot who found no trace of polarization with a polarimeter in 1817. The work of Hansteen (1825) showed conclusively that aurorae were related to magnetic phenomena. In 1867, Anders Angstrom examined the aurora with a spectrometer and showed it to consist of gases instead of water molecules as had been supposed. There was a huge magnetic storm and the largest auroral display near the beginning of September 1859. At low latitude areas such as Puerto Rico (latitude 18° N) the aurora was observed even in the zenith. This was coincident with a white-light flare seen by Carrington on 1 Sept 1859 when he was drawing sunspots as projected by the telescope. The observation of this flare was to be the landmark of auroral research.

Soon after the discovery of the Schwabe 11-year sunspot cycle, Lamont (1852) found from observations of the terrestrial magnetic field in Germany over a 15-year interval that in addition to a variable daily amplitude, there was a period of $10\frac{1}{3}$ years. However, he failed to notice that there was an association between his findings and the sunspot cycle. It was Sabine (1852) who demonstrated a near 10 year cycle in the magnetic storms from an analysis of geomagnetic observations from Canada. He also recognised the connection with Schwabe's sunspot period, which was consequently confirmed by Wolf (1852) and Gautier (1852). By 1885, Tromholt firmly established the correlation between solar activity and the aurora. He noted that the visibility of the aurora was dependent on the position of the observers relative to the auroral ring (Tromholt, 1885). By the beginning of the present century, the association between the appearance of aurorae and the sudden-commencement type of storms originating from solar flares was fairly well established (Maunder, 1904; Newton, 1943).

7.3 Solar-Terrestrial Environment

7.3.1 The Magnetosphere

Birkeland (1896) showed that if a stream of electrons was projected onto a magnetised sphere it would be deflected towards the poles by the magnetic field. Similarly, a stream of charged particles from the Sun would be deflected by the geomagnetic field towards the poles to produce the aurora. However a very high density of charged particles would be required to produce both magnetic storms and aurorae. As charged particles of one sign would mutually repel one another, they would not be stable enough to have reached the Earth. Lindemann (1919) suspected that such a stream of particles from the Sun would be ionized and electrostatically neutral. Chapman and Ferraro (1933) found that the consequences of an interaction between such a stream of particles and the geomagnetic field would create a magnetic cavity in the stream. A term to describe this hollow region, which confined the whole Earth and its extended magnetic field lines, was later coined by Gold (1959) as the *magnetosphere* (Fig. 7.3). It is here in this region of the Earth's upper atmosphere that lies the key to the whole of solar-terrestrial relationships.

The steady plasma flow out of the Sun was not known until Biermann (1951) inferred its existence from cometary observations. Parker (1958) suggested that the source might be a hydrodynamic expansion of the ionized gas in the solar corona. This stream of plasma emitted from the Sun, now known as the *solar wind*, consists mostly of electrically charged particles (protons and electrons). The supersonic speed at which the Earth moves through the solar wind (at a relative velocity of about 400 kms^{-1}) creates a shock wave, known as the bow shock, at a distance of about 10 Earth radii in front of the Earth under normal solar activity. Subjected to the action of a magnetised solar wind, the magnetosphere is forced into an open configuration (Dungey, 1961 and Stern, 1977). Thus, the geomagnetic field lines on the dayside are compressed and nightside stretched into a tail, known as the *magnetotail*, extending far beyond the Moon's orbit (Fig. 7.3).

The boundary of the magnetosphere, the *magnetopause*, marks the limit within which the influence of the geomagnetic field can still be regarded as effective. Beyond

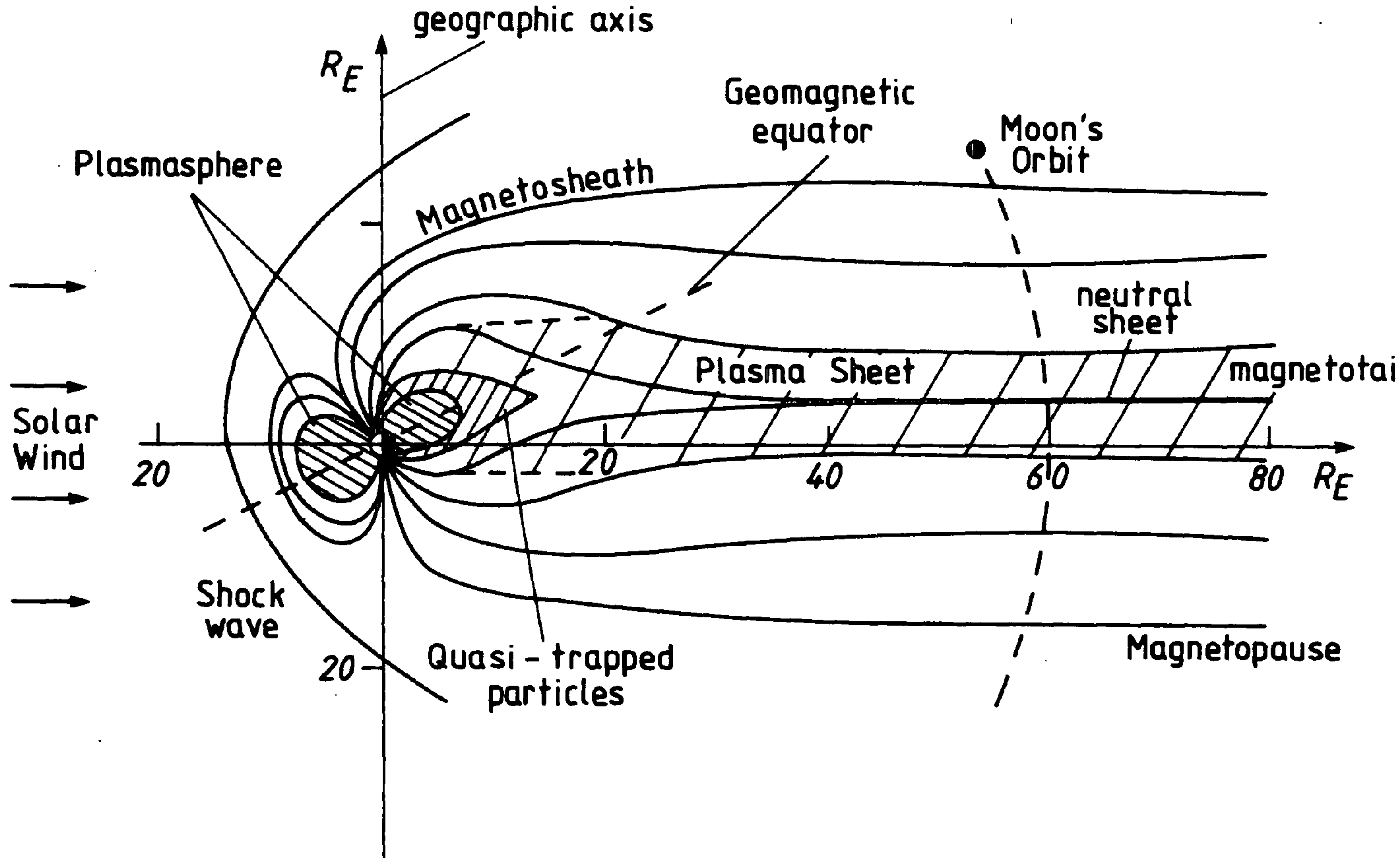

Fig. 7.3 A diagram showing the magnetosphere of the Earth.

the magnetopause, the interplanetary magnetic field becomes dominant. Some of the geomagnetic field lines are almost always interconnected with the interplanetary magnetic field (IMF) lines across the magnetopause. The intermediate region between the shock wave and magnetopause is known as the *magnetosheath.* The magnetic field lines in the *plasma sheet* connect back to the Earth around the polar region or *polar cap* in both hemispheres. A small fraction of the solar wind particles that impinge on the magnetosphere are captured into the plasma sheet in the magnetotail. The *plasmasphere*, in the form of a doughnut, contains mostly charged particles from the Earth's ionosphere. The plasmasphere is simply the extension of the Earth's ionosphere into space. Within the plasmasphere there are two trapped radiation belts or Van Allen belts in which particles can orbit the Earth in relatively stable configurations. However, particles in the region near the boundary of the plasmasphere called the *plasmapause* are only quasi-trapped.

The interaction of the solar wind and the magnetosphere gives rise to a solar wind-magnetosphere dynamo (Akasofu, 1981). The aurora is thought to result from an electrical discharge process powered by this dynamo. The power generated by this dynamo is transmitted to the convective motion of the plasma in the plasma sheet. The main part of the convective flow originates from the magnetopause and is directed toward the *neutral sheet* in the magnetotail. The neutral sheet consists of oppositely directed magnetic flux regions (Lui, 1984). Auroral displays are produced when particles in the plasma sheet are accelerated to energies of a few keV onto the polar upper atmosphere along field lines; an enhanced reconnection of these flux regions in the neutral sheet then takes place. A complex magnetospheric current system driven by the solar wind-magnetosphere dynamo is believed to be behind the acceleration mechanism (see reviews by Williams, 1983 and Akasofu, 1984). At present, the generation process of these currents is not yet fully understood.

7.3.2 The Auroral Oval

The auroral oval is a permanent feature of the planet Earth; its form is dependent on the horizontal component B_z of the interplanetary magnetic field. The definition of the auroral oval differs from that of the auroral zone. The auroral oval is simply an instantaneous belt of aurorae, whereas the auroral zone is an annular region with its centre-line on the geomagnetic latitude circle of 67°. The radius of the oval is about 2000 km with a width of the order of a few hundred kilometres (Akasofu, 1981). The auroral oval is not strictly circular and it is eccentric with respect to the geomagnetic pole. However, the auroral zone is concentric with respect to the geomagnetic pole. In other word, the auroral zone is simply the locus of the midnight part of the auroral oval.

The position of the auroral oval is dependent upon magnetic activity; under normal conditions it comes within $\sim 12°$ of the geomagnetic poles on the sunward side and $\sim 22°$ on the dark side (Fig. 7.4). The poleward boundary of the auroral belt is simply the mapping of the plasma sheet onto an annular region of the polar upper atmosphere. Similarly, the equatorward boundary is the mapping of the border of the plasmasphere onto the polar region. At times of high solar activity, the earthward edge of the plasma sheet moves closer to the Earth, corresponding to an equatorward motion of the aurora. However, the earthward motion of the plasma sheet is limited by the extent of the plasmasphere.

The size of the auroral oval is controlled by the IMF B_z component. The oval contracts poleward as the B_z component becomes positive (northward directed) and expands towards the equator as the B_z component becomes negative (southward directed). The average size of the oval requires that the B_z component to have a negative value

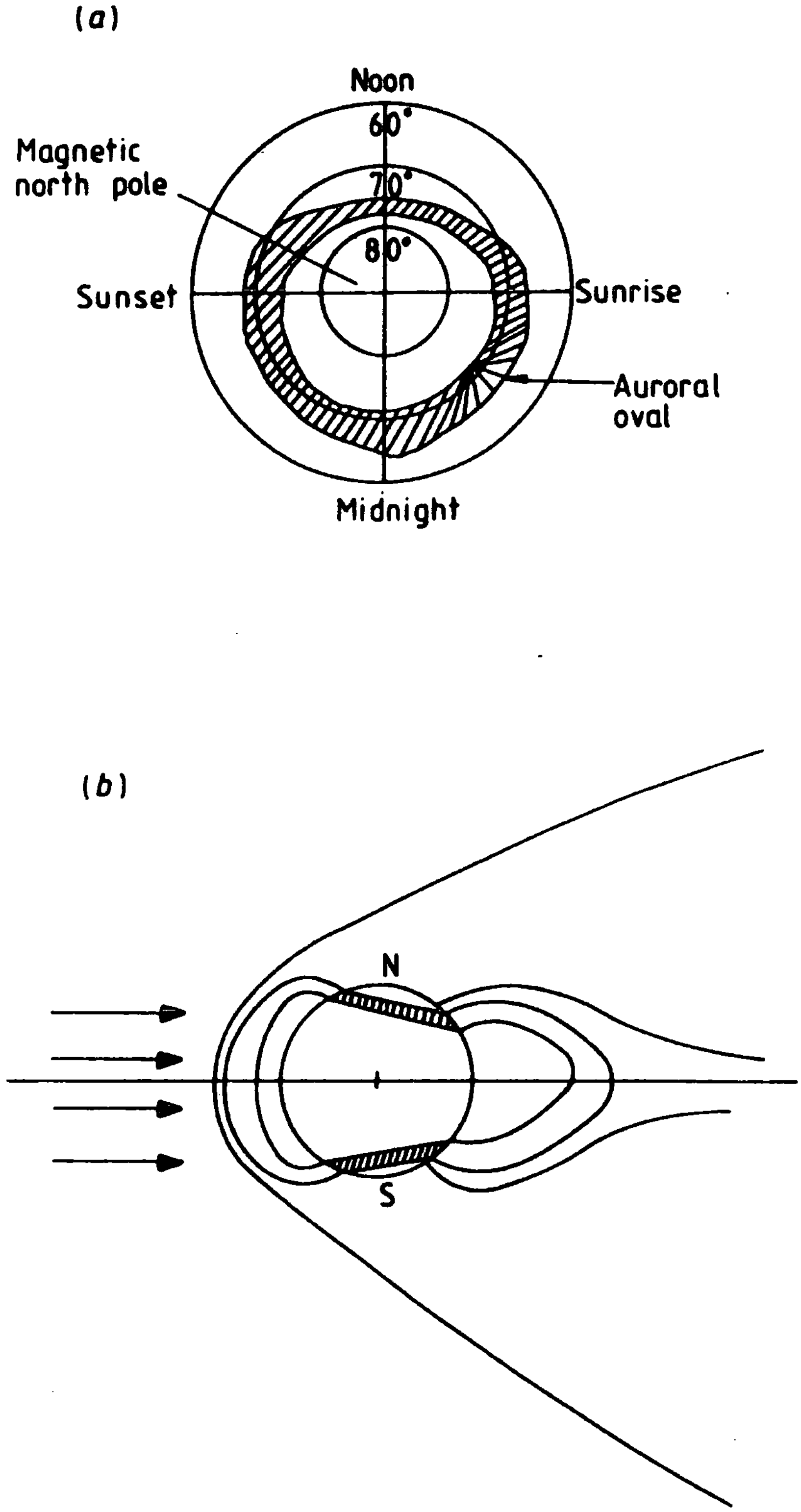

Fig. 7.4 (a) shows both the noon and midnight sectors of the auroral oval, and (b) shows the distortion of the auroral oval by the solar wind (after Seymour, 1986).

$B_z \sim -2\gamma$. Perreault and Akasofu (1978) deduced that the energy coupling between the solar wind and the magnetosphere is governed by:

$$\epsilon = \frac{vB^2 sin^4\theta}{2l_o^2}$$

where v is the solar wind speed, B is the magnitude of the IMF, θ is the polar angle of the IMF, projected on the y-z plane and l_o is a constant (~7 Earth radii). The aurora becomes visible when the dynamo power is $\sim 10^{18}$ erg/sec. During a major storm, the power may exceed $\sim 10^{19}$ erg/sec. Under this condition, aurorae are expected to be visible in low latitude areas.

7.4 Low Latitude Aurorae

The different types of aurorae can be broadly divided into two groups according to the two types of magnetic storms. Those in the first group are associated with the slow-start type of magnetic storm which is produced by solar wind streams originating in coronal holes (Sheeley, *et al.*, 1976; Nolte *et al.*, 1976) observable only in soft X-rays. This type of magnetic storm has a life time of one to two hundred days and shows a 27 days recurrence. The second group of aurorae is related to the sudden-commencement type of magnetic storm which is produced by solar flares (Gopasyuk, 1961; Sheeley, 1978) in connection with the appearance of sunspots.

It is expected that the frequency of group II aurorae is closely correlated with the sunspot cycle whereas group I aurorae are very much independent of the appearance of sunspots. As group I aurorae are produced by less energetic charged particles, they are mainly observable at high geomagnetic latitudes in the circular auroral zone near the geomagnetic pole. Group I aurorae are more frequently occur during the declining phase of the sunspot cycle than group II, when coronal holes tend to develop. The formation of a sunspot group below a coronal hole suppresses the high-speed streams flowing out of it. As a result, during the peak years of the sunspot cycle, the only auroral activity is expected to come from solar flares (Akasofu, 1982). Those aurorae seen in low geomagnetic latitude areas are normally induced by an intense solar flare originating near a large sunspot group.

7.5 Observational Status

7.5.1 European Sightings

The first detailed bibliography of historical auroral data was compiled by Schoning (1760). This was followed by the catalogues of Frobesius (1739), Fritz (1873), Schove (1948) and Link (1962, 1964). Among the 19th century catalogues, the one by Fritz is worth a special mention. Although it had its limitations and contained many false sightings, it was the most complete list available to researchers before Link's detailed catalogues. The first of Link's catalogues covers the period from ancient times to AD 1600. His second catalogue covers the interval from AD 1600 to 1700. In addition, two smaller lists of European sightings have appeared. Dall'Olmo (1979) compiled a list covering the interval from AD 450 to AD 1466; this is a supplement to Link's two catalogues. Stothers (1979) also compiled a catalogue from Greek and Roman sources.

Fig. 7.5 shows the distribution of European sightings of aurorae per decade based on the catalogues of Link (1962, 1964), Dall'Olmo (1979) and Stothers (1979). A few researchers have demonstrated that certain features closely resembled that of the solar cycle, e.g. the Maunder Minimum (Eddy, 1980 and Siscoe, 1980). During this period, there seems to be a considerable reduction in the number of observations of aurorae in Europe. However it is difficult to quantify the mean level of solar activity during this period based on auroral records alone. Before about AD 1500, European data are very inhomogeneous as they were extracted from a wide variety of chronicles, each covering

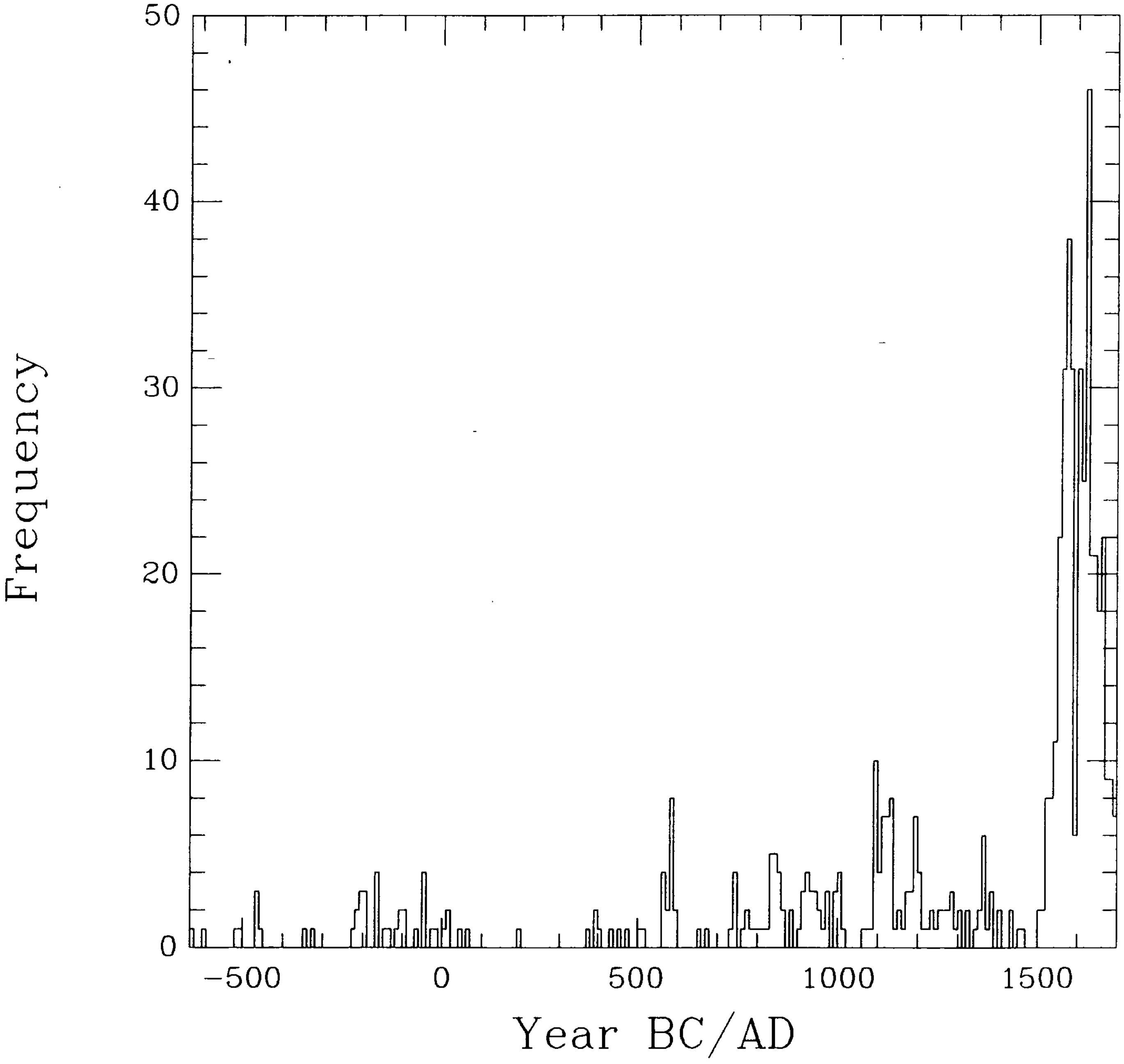

Fig. 7.5 The decade distribution of European sightings of aurorae.

its own individual time-span. The strong feature exhibited by the data around the 16th and early 17th century may be due to a general increase in the number of interested observers and reports of aurorae available from this period (Stephenson, 1988). However, there seems to be a general decline in the number of aurorae in the 2nd half of the 17th century.

7.5.2 East Asian Records

As was mentioned earlier (see section 7.1), the advantage of East Asian records is that the observers were located at a lower geomagnetic latitude. Thus the observations will be a much more representative of the solar cycle than European sightings. However, the opportunity of observing aurorae at low geomagnetic latitudes is very much reduced. According to the frequency distribution map (Fig. 7.6) published by Fritz (1881), less than one aurora per decade is expected from latitudes where most of the Far Eastern capitals are situated (Lat. 30°-40°). Therefore, it is rather surprise to find some one thousand records of aurorae in Far Eastern texts spanning almost two millennia.

The only catalogue of East Asian auroral observations readily accessible to Western scholars today is that by Keimatsu (1970–76) in a series of papers. However, this compilation is fairly incomplete and is contaminated with phenomena which are clearly not aurorae – e.g. records of meteor showers were included. Another defect of this catalogue is the obvious omission of good data. These two factors alone are sufficient to have considerably undermined the quality of Keimatsu's catalogue.

The catalogue due to Dai and Chen (1980), available only in Chinese, lists 929 entries extending from the legendary period to AD 1747. Some of the accounts are very brief and the nature of the phenomenon described is thus open to question. On the other hand, many descriptions are quite vivid and clearly related to aurorae. The compilation

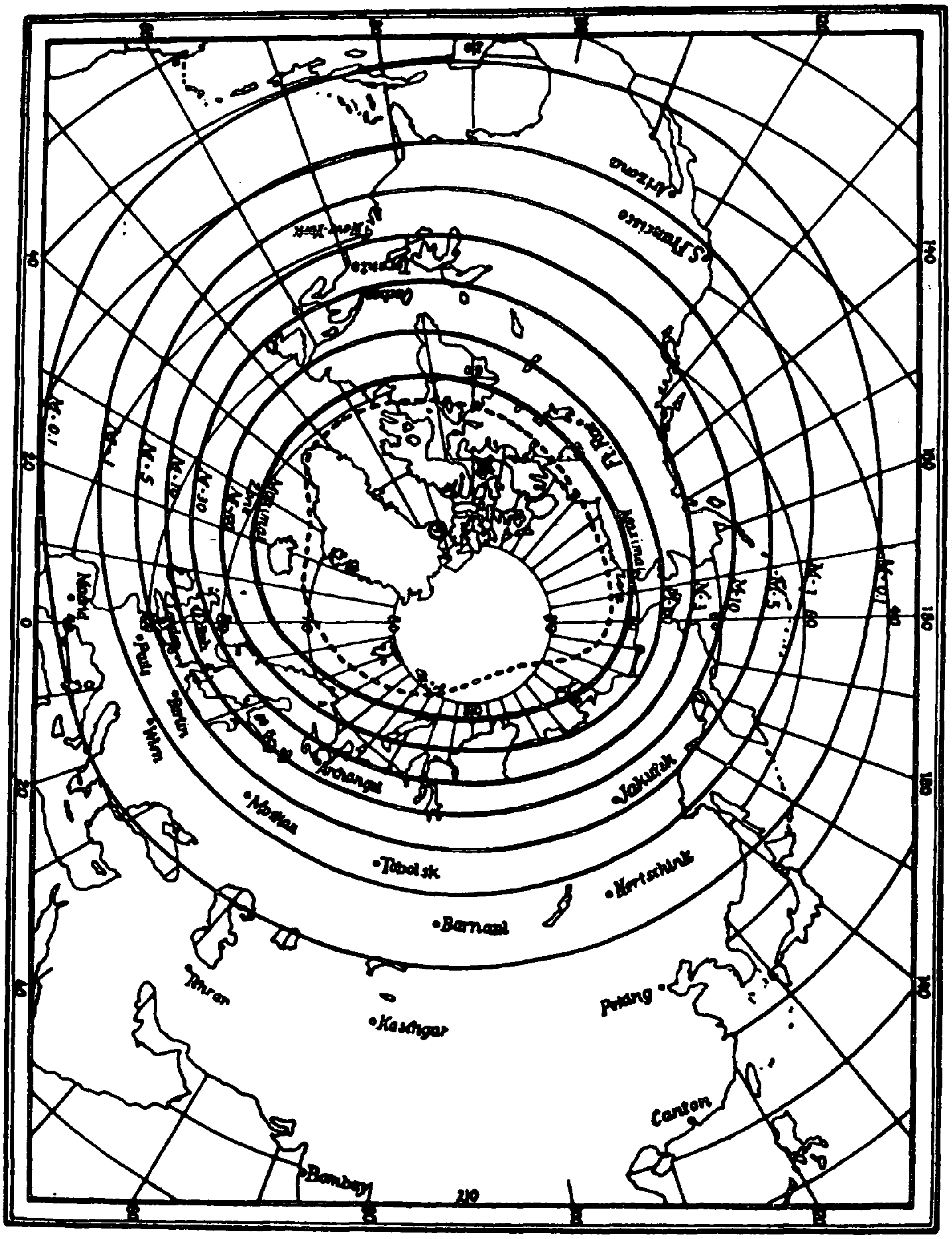

Fig. 7.6 A map showing the geographical distribution of aurorae as a function of latitude by Fritz (1881). The isometric lines, called isochasms by Fritz, indicate the places where aurorae are observed with equal frequency. M is the mean number of days per year in which aurorae are seen.

of Dai and Chen contains far fewer false entries than that of Keimatsu (1976). One of the obvious errors in the catalogue by Dai and Chen is the inclusion of some 15 Chinese sightings of *Lao-jen* (the 'Longevity Star'), which is well known to be the bright star Canopus.

In the light of difficulties with these two catalogues of East Asian aurorae, I have compiled a revised list. The present catalogue contains a total number of 847 entries covering the period 193 BC to AD 1770 (see Appendix V). Over this entire interval, only on two occasions that the aurora was reported from two different countries on the same day. One was reported from both China and Korea on 1138 Oct 6, and the other from China and Japan on 1363 Jul 30. Thus the number of independent reports is 849 in total (Table 7.1). I have produced this auroral catalogue mainly based upon the work of Dai and Chen (1980), but included additional materials they overlooked. The catalogue of Keimatsu (1976) has also been used for checking omissions and dates.

7.6 Analysis of East Asian Records

7.6.1 Types and Colours

The earliest attempt at classifying the aurora into shapes, movements and colour was by Barhow (1751). Since then many classification schemes have been made. The basic system of classifying the aurora into about 15 different forms employed before about 1950 was based largely on the diligent work of Stormer and co-workers. From the late 1950's onwards, with simultaneous ground and satellite observations it is now possible to classify the various types of aurorae into four primary forms (Brekke and Egeland, 1983): (i) Homogeneous quiet arcs and bands; (ii) Active aurorae with ray structure; (iii) Diffuse spots and surfaces and (iv) Spiral structure (Fig. 7.7).

Table 7.1 East Asian auroral records per century

	China	Korea	Japan	Total
200- 101	5	0	0	5
100- 1 BC	3	0	0	3
AD 1- 100	2	0	0	2
101- 200	4	1	0	5
201- 300	7	0	0	7
301- 400	8	0	0	8
401- 500	20	1	0	21
501- 600	15	0	0	15
601- 700	3	0	1	4
701- 800	11	0	0	11
801- 900	8	0	5	13
901-1000	13	1	4	18
1001-1100	19	14	3	36
1101-1200	43	51	13	107
1201-1300	12	18	9	39
1301-1400	17	31	6	54
1401-1500	7	16	8	31
1501-1600	11	295	4	310
1601-1700	25	105	0	130
1701-1800	4	26	0	30
Total	237	559	53	849

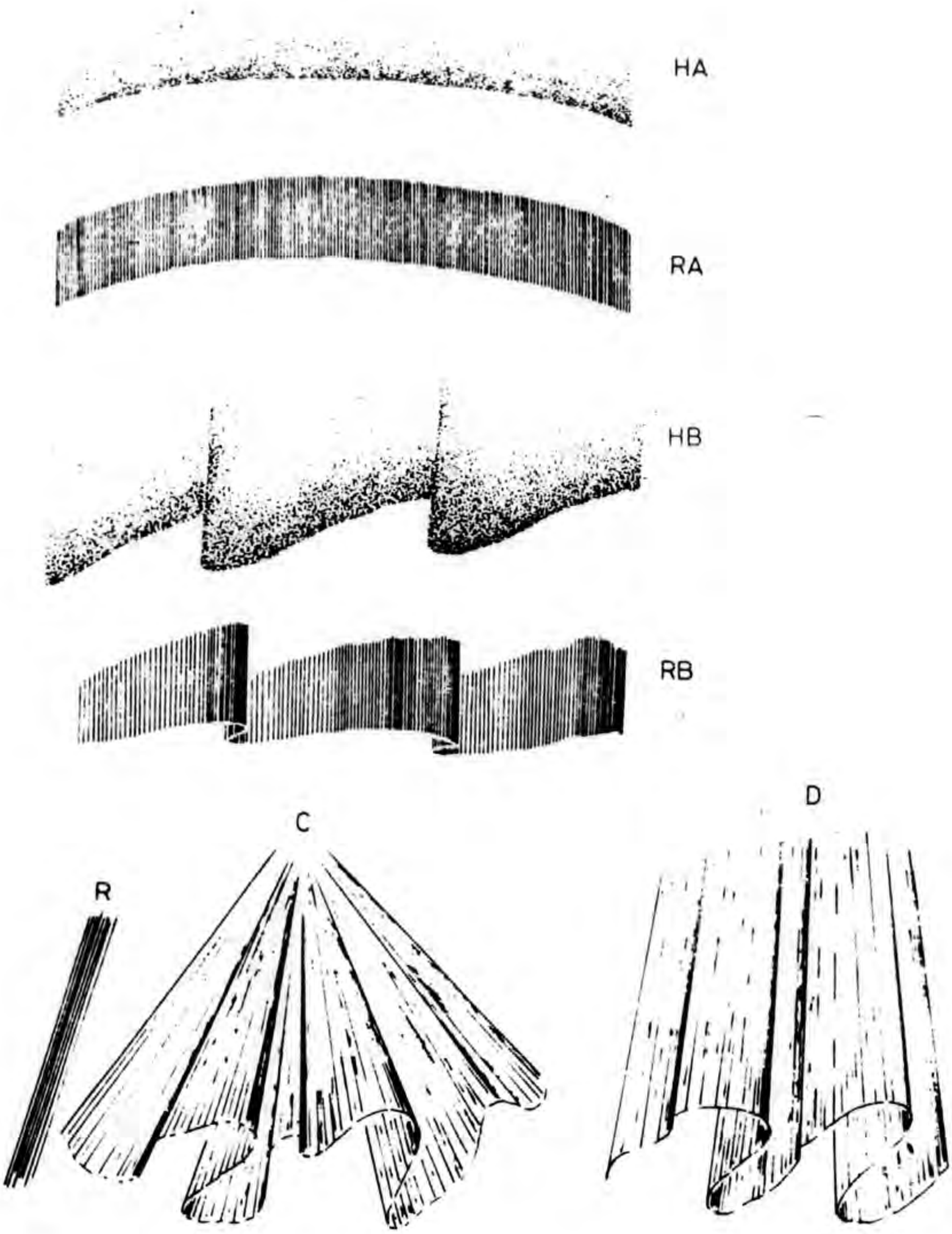

Fig. 7.7 The morphological structure of the basic forms of aurorae. HA - homogeneous arc; RA - arc with ray structure; HB - homogeneous band; RB - band with ray structure; R - rays; C - corona and D - draperies (after Brekke and Egeland, 1983).

East Asian aurorae are typically classified under the 'cloudy vapours' section of the *Astronomical Treatises* of the official histories. However, this broad category probably also includes other phenomena such as airglow, zodiacal light, lunar haloes and rainbows, extended twilight and so on. From the often vague descriptions given to aurorae in Far Eastern texts, it is extremely difficult to make a reliable identification of auroral structural features according to modern classification. The general description of an aurora recorded in Far Eastern annals is that of a coloured vapour. In simple forms, only the colours of the vapour are mentioned. If they are of complicated form, some very splendid descriptions can be found e.g. a moving snake, the marching of lances and spears or even a vibrating tree.

The light in the auroral displays is produced by excitation and ionization of the upper atmosphere at high latitudes by an influx of electrons with energies about 10 keV. The colour of aurorae at low latitudes is normally red due to the emission of ionised oxygen [OI] 630 nm at high altitude (Meinel and Meinel, 1983; Tinsley, 1984) – See Fig. 7.8. About 70% of the aurorae given in the present catalogue are described as having a red colour, the rest of them mainly have colours ranging from green to violet. In addition, a few aurorae were described as white, presumably because of low intensity rendering their colour undetectable.

7.6.2 Observability – Phases of the Moon

The visibility of the aurora under a dark sky can vary from a feeble glow to a brightness that outshines the stars at times of intense solar activity. The intensity of the aurora can vary over four orders of magnitude and at maximum it is comparable with that of the illumination on the ground of the moonlight. The brightest aurorae are about an order of magnitude above the colour threshold for the human eye and hence can exhibit vivid colour.

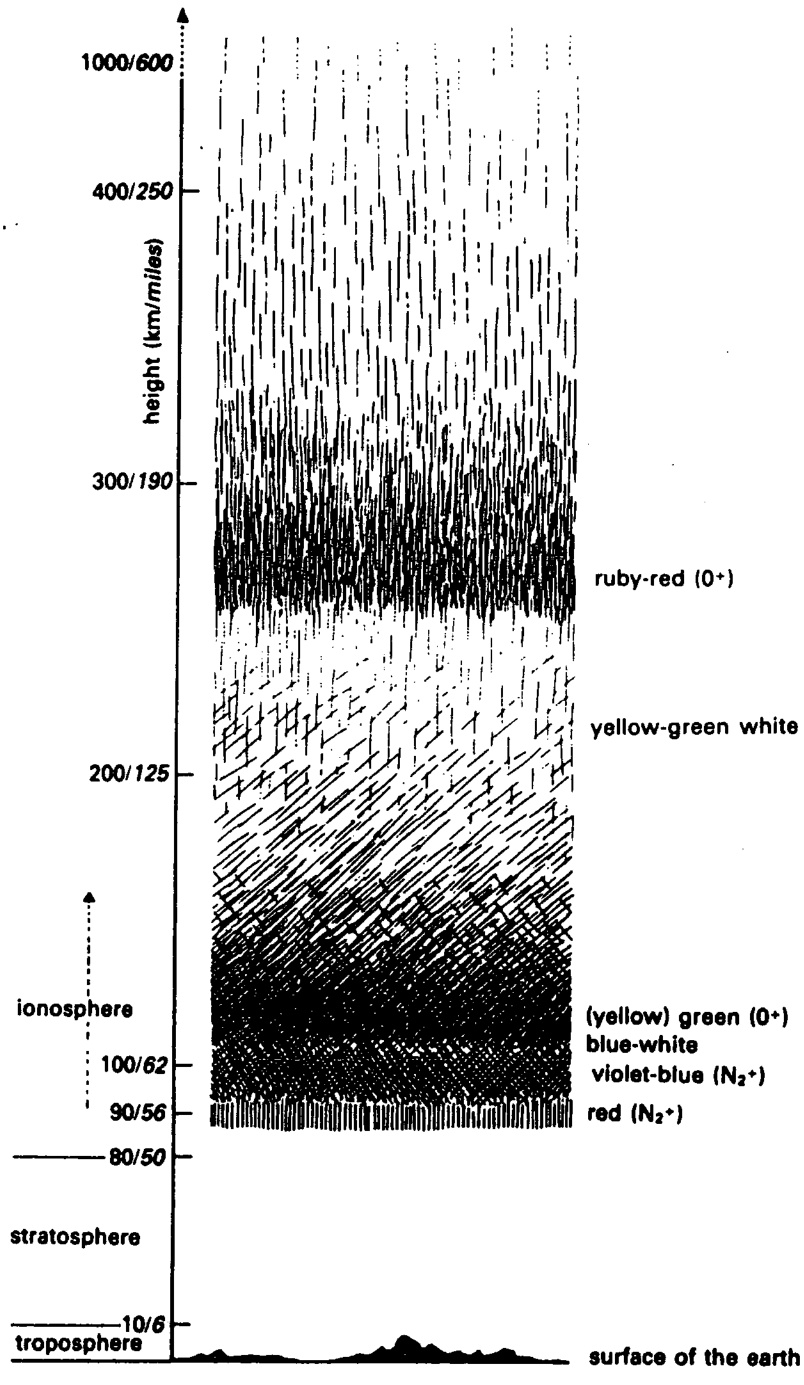

Fig. 7.8 The colour of aurorae in relation to atomic elements of the various atmospheric layers (after Falck-Ytter, 1985).

Fig. 7.9 shows the distribution of East Asian aurorae taken from the present catalogue against the age of the Moon. It appears that the frequency of aurorae follows closely the phases of the Moon. This may be explained simply by the moonlight reducing the visibility of aurorae to the naked-eye.

7.6.3 Seasonal Variation

The seasonal variation of the geomagnetic storms is well known (Chapman and Bartels, 1940, p.367). This variation is explained by the motion of the Earth around the Sun during the course of a year with the subsequent changing declination of the Sun. The apparent passage of the Sun across the equatorial plane of the Earth occurs around Mar 22 and Sep 22 (the equinoxes). A similar seasonal variation in the auroral records with maxima in the spring and autumn was already noticed by Mairan (1754) back in the mid-18th century. According to Stormer (1955), the seasonal variation of the aurora was related to the latitude of the place of observation. He noticed that for places between the northern and southern auroral zones, the two maxima in the monthly distribution should be fairly conspicuous in the months of Septembet or October and March or April. He further noted the same seasonal variation in data obtained within the auroral zone, but the distribution showed a deep summer minimum as aurorae were not easily observed during the summer nights in the polar region.

Fig. 7.10 (a) shows the seasonal variation of East Asian aurorae. A distinct maximum near the spring equinox can be seen whereas the maximum at the autumn equinox is less evident. This is to be compared with Fig. 7.10 (b), the monthly frequency distribution of aurorae obtained by Meinel *et al.* (1954) from an analysis of a 55-year series of auroral records from Yerkes Observatory (lat. 42.6° N, long. 88.6° W). The seasonal distribution of the Yerkes Observatory records shows a considerably larger autumn maximum than the spring. This was suggested by Meinel *et al.* (1954) as due

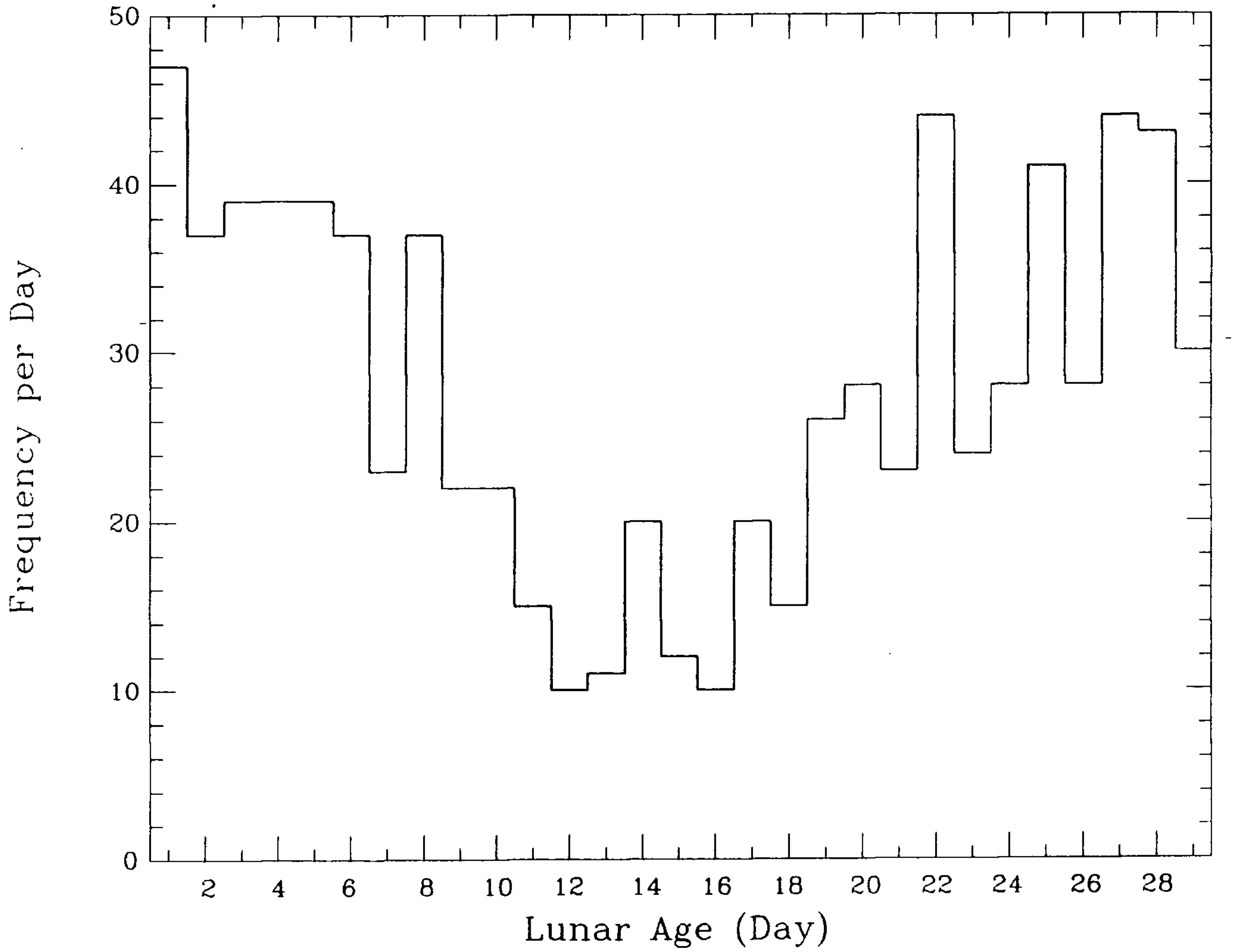

Fig. 7.9 The distribution of East Asian aurorae as a function of the lunar age.

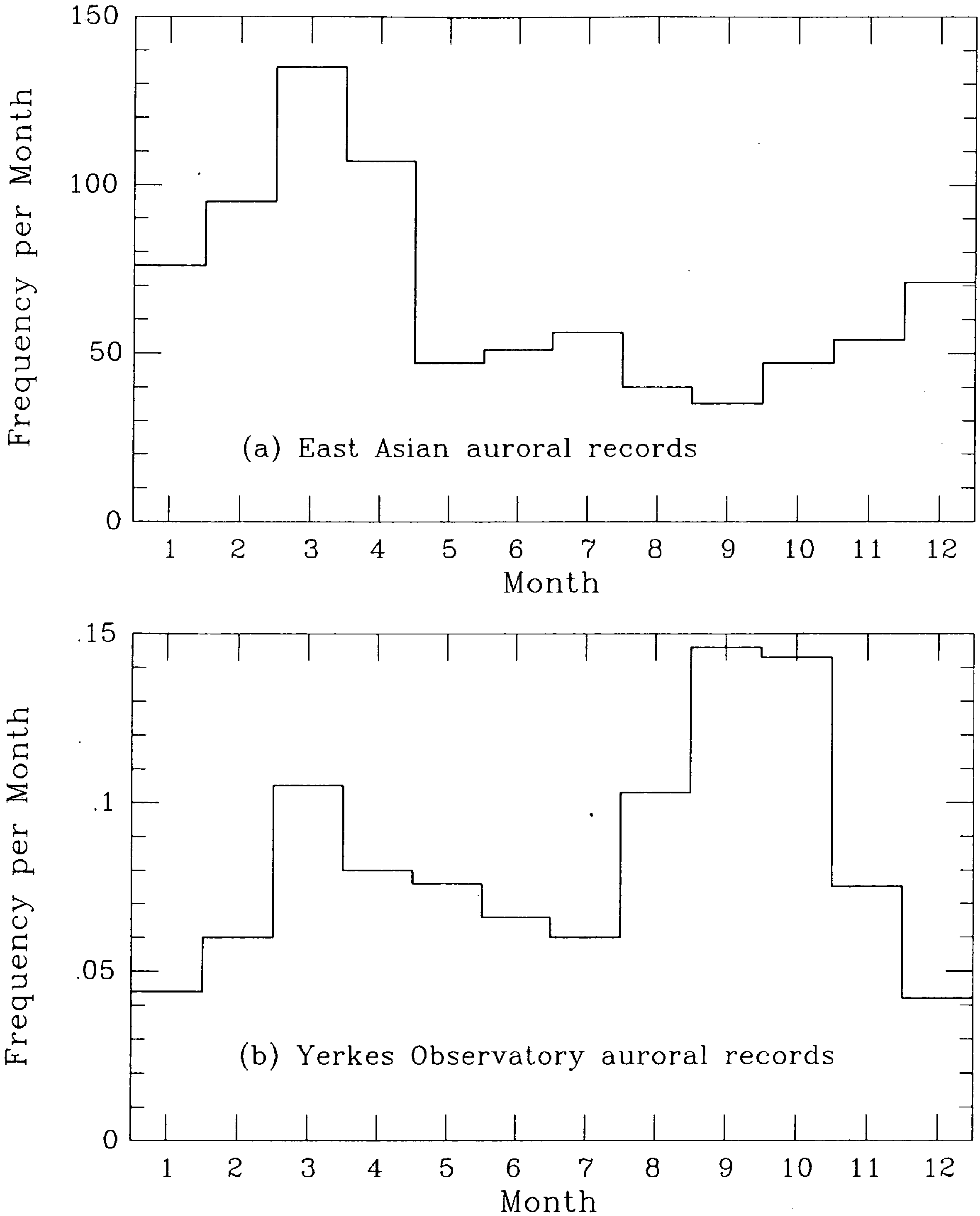

Fig. 7.10 (a) The monthly distribution of East Asian aurorae. (b) Fraction of all aurorae observed in each calendar month at Yerkes Observatory (after Meinel, *et al.*, 1954).

to cloudiness and the different number of dark hours in each month. Hultqvist (1967) pointed out that if the auroral seasonal variation was really due to the earth being at highest heliographic latitudes in March and September, then the angular diameters of the solar plasma beams would not exceed $\sim 5°$ as seen from the Sun. However, this is certainly not true in the case of a very intense flare.

7.6.4 Secular Variation

Fig. 7.11 shows the decade distribution of East Asian aurorae from 193 BC to AD 1770 as contained in the present catalogue. Before AD 1000 there are only a few records from Japan and Korea; the majority of the observations are from China. Only a few relatively large features can be seen around AD 300, 460, 760, 820, 1000 in the first millenium. After about AD 1000, in addition to the Chinese data, there are also contributions from Korea and Japan. A number of comparatively large peaks are present in the distribution after about AD 1000. Apart from the unusual excess in the 16th and first part of the 17th century (see section on Korea excess below), there are peaks at AD 1130, 1180, 1260, 1370, 1410 and 1730.

Based on the present configuration of the geomagnetic field, the number of aurorae seen in mid-latitude area is only about one per decade. The number per decade of aurorae observed after AD 1000 is in general higher than what would have been expected. Two reasons may be put forth to explain these unusually large features. One is that the general improvement in the amount of preserved materials not only from China but also Korea and Japan. Another reason is that the north geomagnetic pole was situated nearer to East Asia than at present. Keimatsu *et al.* (1968) attempted tracing the secular variation of the geomagnetic field in historical times from auroral records. After comparing the number of coincidental occurrence of aurorae in both Europe and Far East, they inferred that the geomagnetic dipole axis might have been inclined towards

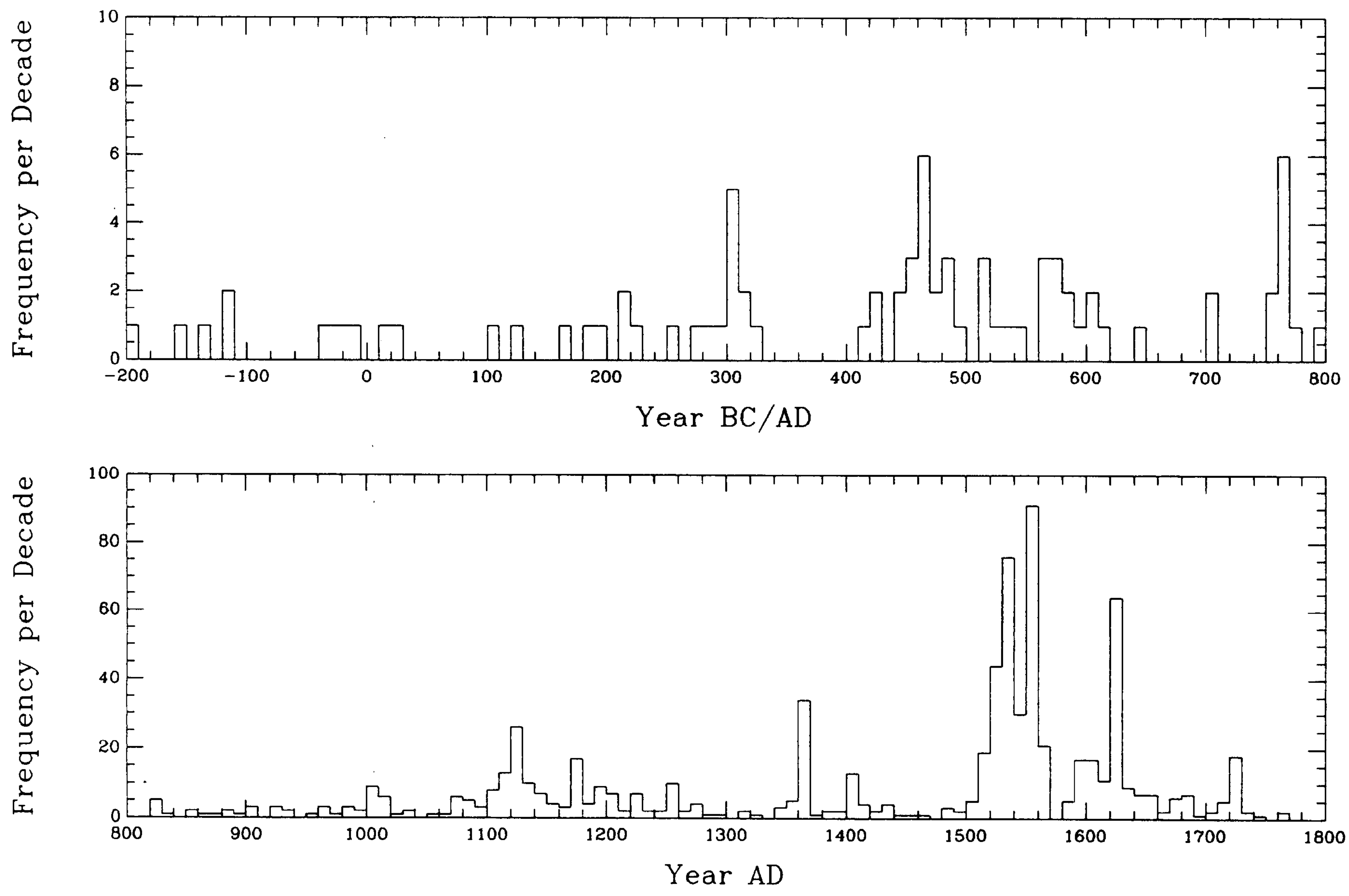

Fig. 7.11 The decade distribution of East Asian aurorae from AD 1 to 1770 as contained in the present catalogue.

China around the 11th and 12th century (see reviews in Stephenson and Wolfendale, 1988). However, the reliability of a number of their records is questionable.

Fig. 7.12 compares the number of aurorae seen in Europe and Far East. Only a few coincidences between European and Far Eastern data are evident. The most interesting coincidence is around AD 1100; there is a general excess of aurorae seen both in Europe and East Asia. This has been suggested by Eddy (1977) as a period of unusually high solar activity which he called the Medieval Maximum.

Fig. 7.13 shows the result of a search for periodicity in the East Asian auroral data using the pseudo-spectral method described in the last chapter. A large feature at the period of 10 years can be seen. This is in close correspondence with a similar feature observed in the spectral analysis of the naked-eye sunspot data.

7.6.5 The Korean Excess

The large excess of East Asian sightings of aurorae in the 16th century – between about AD 1515 and 1560 and also for the period around AD 1625 (Fig. 7.11) – is due mostly to the quantity of Korean observations (Table 7.1). The Korean records for this period are contained in the *Sillok* ('Veritable Records') of individual kings. This set of histories covers the period from AD 1392 to the end of the last century. The frequency of unexpected reports of aurorae has puzzled researchers. Although there are a few detailed descriptions of aurorae, the general contents of the auroral records for this period is very brief. The two general forms are: (i) "At night in the ... direction there was a vapour like fire", and (ii) "At night in the ... direction there was a red vapour". In addition, the direction and time of night of observation are often given.

No satisfactory explanation has yet been offered, the most likely inference being either a deliberately falsification of records for astrological purposes or an alternative

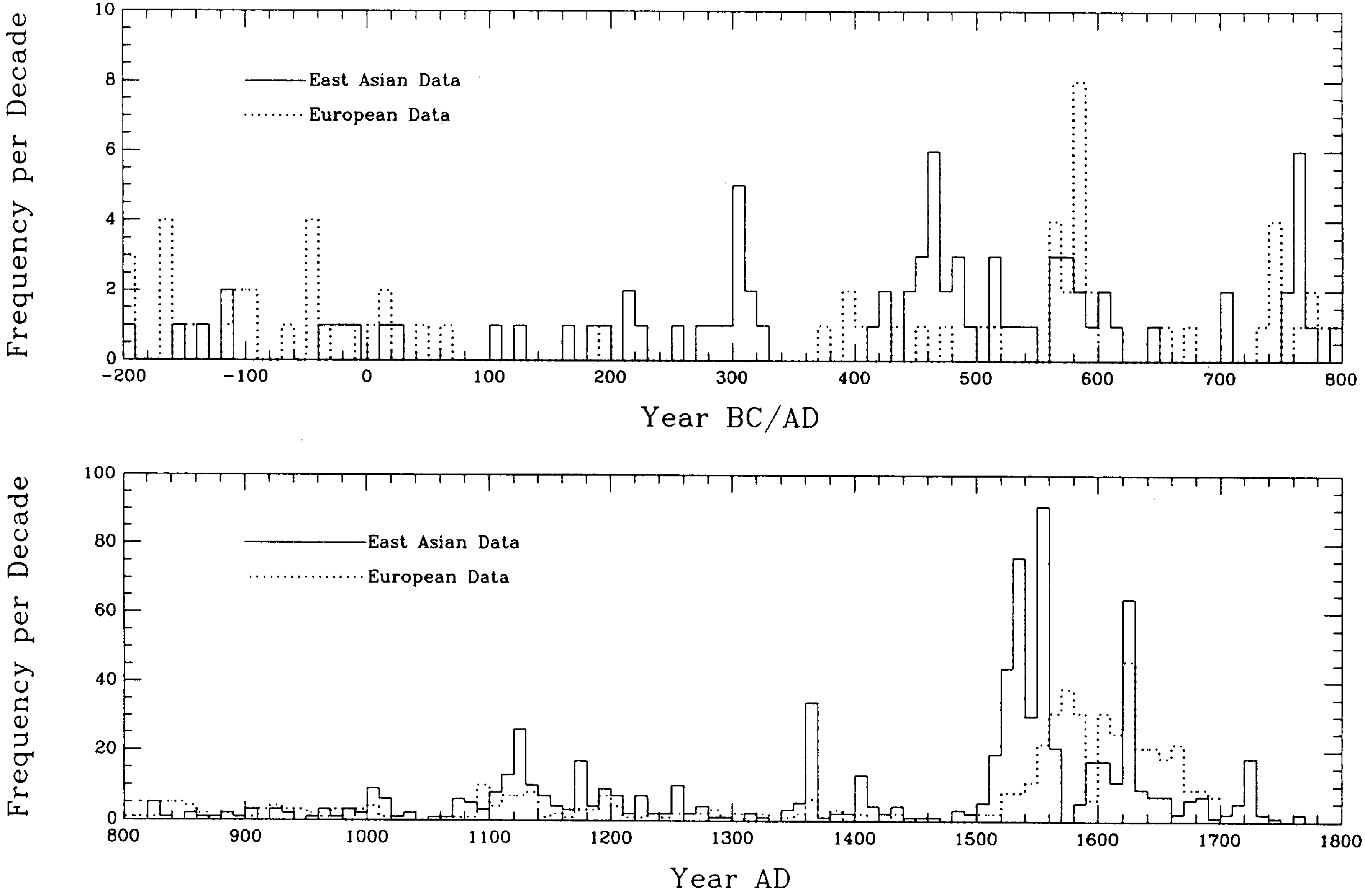

Fig. 7.12 A comparison between the number of European and East Asian sightings of aurorae from 200 BC to AD 1800.

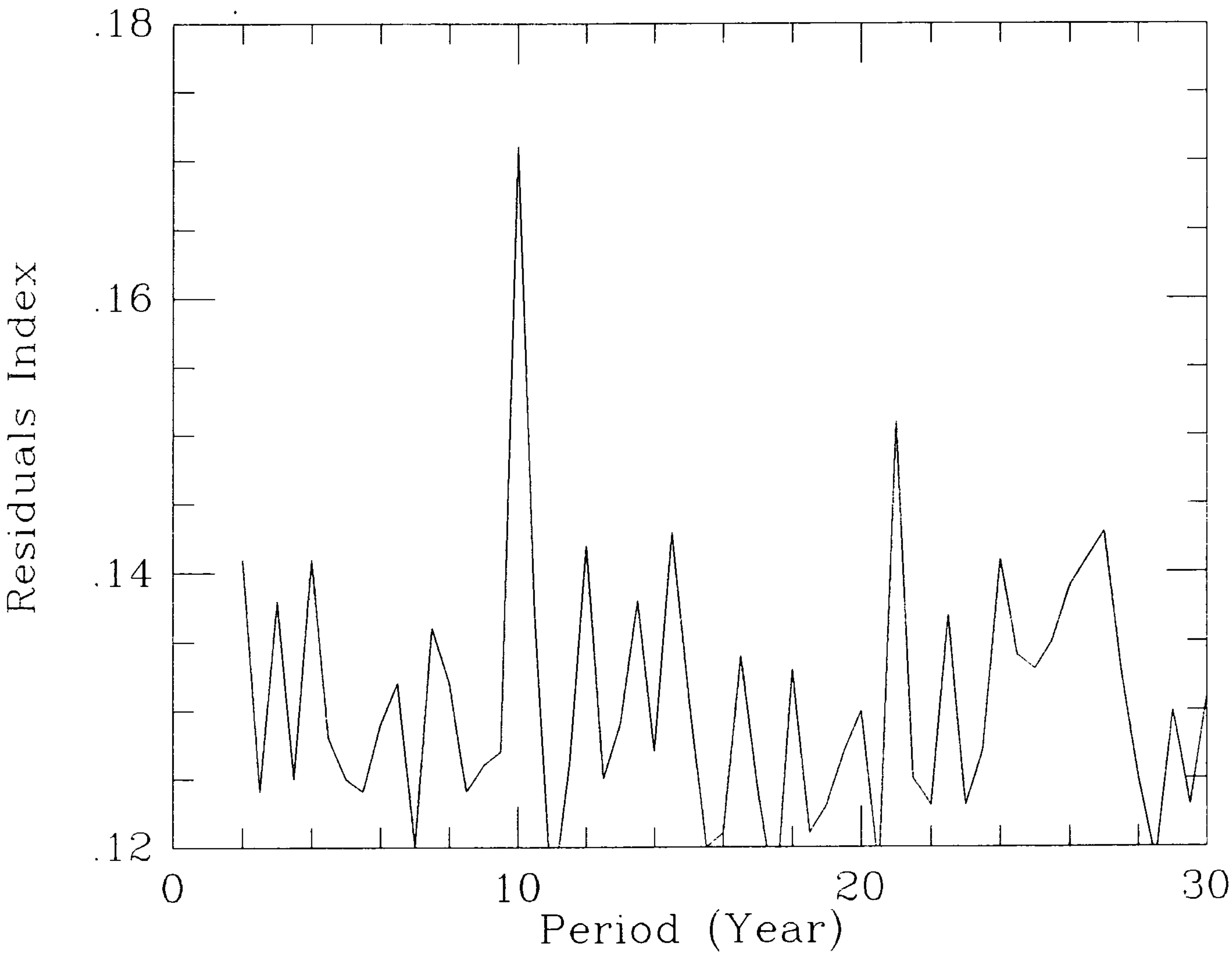

Fig. 7.13 The spectrogram obtained from a pseudo-spectral analysis of the East Asian auroral data.

atmospheric effect. Deliberately falsification of records does not seem to be the case. The high quality of records (both in accuracy and detail) of other astronomical observations seems to rule out the possibility of falsification. See for example the records of the Korean guest stars of AD 1592 (Chapter 5).

It has been suggested that these Korean auroral records were of atmospheric origin. Volcanic eruptions might have contributed to a reddening of the sky at night. This was described by Keen (1983) as an extended twilight at the western horizon. However, many of the descriptions clearly stated 'a vapour of fire' was seen, which are dissimilar to reports of the kind of glow due to volcanic aerosols. Also the direction of occurrence the extended twilights disagrees with directions given in most of the Korean records.

Other explanations also have been put forth, Zhang (1985) suggested that the Korean auroral observations referred to stable auroral arcs (SAR). However, the detectability of the SARs is below the threshold of visibility of the naked-eye (Roach and Gordon, 1973). Out of the principal components of the light of the night sky (Table 7.2), the only remaining alternative seems to be the airglow. Airglow displays are produced by photochemical reactions between the various species at heights of 90–100 km in the upper atmosphere (Roach and Gordon, 1973). The principal effect is the dissociation of the O_2 molecule into two O atoms by the solar UV radiation. The brightness of the airglow, although weaker than most aurorae, is comparable with that of the Milky Way. It is possible that the Korean observations were related to unusual bright airglow displays.

7.7 Summary

The investigation on the frequency of auroral records from East Asia has revealed an underlying period of about 10 years. This result is in good agreement with that

Table 7.2 Components of the light of the night sky (after Roach and Gordon, 1973)

Component	Function of		Physical origin
	Position in sky	Other	
Integrated starlight	b, l;[a] galactic coordinates		Stars of our Galaxy
Zodiacal light	β, $\lambda - \lambda_{\odot}$; ecliptic coordinates		Sunlight scattered by interplanetary dust
Airglow	Z, A; horizon coordinates	Local time Latitude Season Solar activity Wavelength Height	Ambient excitation (usually photo-chemical) of upper-atmosphere atoms and molecules
Aurora		Magnetic latitude Season Solar activity Magnetic activity Wavelength	Excitation of upper-atmosphere atoms and molecules by energetic particles
Diffuse galactic light	b, l		Scattering of starlight by interstellar dust
Integrated cosmic light	b, l	Cosmological red shift Cosmological model	

[a] b = galactic latitude; l = galactic longitude; β = ecliptic latitude; λ = ecliptic longitude; $\lambda_{\odot}$ = ecliptic longitude of Sun; Z = zenith angle; A = azimuth.

obtained for the naked-eye sunspot data (chapter 6). It is a good indication that both set of data have a common origin; in which the governing body was the solar cycle. At present, the Korean excess remains a mystery. It is possible that the north geomagnetic pole was somewhat further to the Eastern Hemisphere during the the 15th century, but to explain the observations would require a major shift by $\sim 90°$. Barraclough (1974) showed that the geomagnetic dipole axis had drifted westward at an averaged rate of about 11° in longitude per century between AD 1650 and 1850, but subsequently slowed to about 4°. Hence, unless the motion of the geomagnetic pole prior to AD 1650 was particularly rapid, a shift of $\sim 90°$ seems to be unlikely.

As a secondary index of solar activity, produced in the Earth's upper atmosphere by the interaction of the solar wind, aurorae are a poor substitute for sunspots in recent centuries. Aurorae as a proxy of solar activity are often taken all too indiscriminately as a direct indicator of solar activity and even as a simple gauge of sunspot numbers. There are many reasons why a lack of an auroral report does not mean the Sun was not active. On the other hand, flares originating near the limb of the Sun often miss as small a target as the Earth. The likelihood of observing an aurora at low geomagnetic latitudes is also diminished by moonlight, unfavourable weather conditions, etc. It should be borne in mind that the probability of using auroral data to trace the basic detail solar cycle is very small; the main emphasis should be on studying long-term patterns.

CHAPTER 8
SOLAR-CYCLE VARIATIONS

8.1 Solar Activity Cycle

The origin of the solar activity cycle is far from understood. One of the main difficulties is a lack of data relevant to the numerous theories proposed to explain the cycle. Nevertheless, significant advances have been made in modelling the sunspot cycle (Sonett, 1983; Bracewell, 1986), but detailed agreement awaits to be elaborated. A theory that is accountable for all parameters is a complex problem encompassing magnetohydrodynamic theory coupled with observationally elusive constraints like the quantitative description of the solar convective zone.

Popular theories based on two contrasting assumptions suggest either the cycle originates from a coherent magnetically controlled solar global oscillation (Gough, 1986; Stenflo and Vogel, 1986) or from some dynamo process that is essentially confined to the turbulent region of the convection zone (Yoshimura *et al.*, 1984). The first of the two models, although it can explain the 22-year Hale magnetic cycle, requires that there is a large-scale internal magnetic field whose intensity is similar to that observed in sunspots. Dynamo theories have the attraction that they can simulate the observed sunspot cycle by adjusting the statistical properties of the turbulence; however they have so far failed to explain the migration of the sunspot belts towards the equator. Whatever form a model may take, the basic criteria must be its ability to reproduce the variations in the long-term solar activity cycle. Before any accurate model of the solar cycle can be made, a thorough understanding of the solar cycle from existing observational data needs to be pursued.

The fundamental solar cycle so far recognised from sunspot observations, having a mean period of 11 years, was first noticed by Schwabe (1843) and later confirmed by Wolf (1856). The 11-year Schwabe or sunspot cycle is not strictly periodic; time intervals between maxima varying from 8 to 15 years are exhibited in the sunspot records since AD 1700 (Eddy, 1977). Otoalo and Zenteno (1983) also showed that there are other resolved peaks between 9 and 12 year. Further, the polarity of the magnetic field within sunspot groups in both the northern and southern hemispheres reverses sign at the beginning of a new sunspot cycle to produce the 22-year Hale magnetic cycle (Hale and Nicholson, 1925). Longer periods have also been noted, one of the better known is the 80-year Gleissberg cycle (Gleissberg, 1944). Also, Cohen and Lintz (1974) identified a period of 90 years and Kuklin (1976) a period of 190 years.

A peculiar characteristic of the solar cycle is the occasional prolonged intervals of suppressed activity, an abnormality first reported by Sporer (1887) from the examination of early telescopic sunspot records. The careful investigation by Maunder (1894) of European sunspot observations since Galileo's time demonstrated that during the period, now known as the Maunder Minimum (1645-1715), there was an obvious deficiency in sunspot numbers. Eddy (1976) has since re-examined in much detail some of the evidence, especially the sunspot data back to 1610, for the reality of the Maunder Minimum. He assertively confirmed the existence of a prolonged minimum in the solar cycle for the period from 1645 to 1715. Similar periods of low activity of differing lengths have also been proposed at earlier epochs: the Sporer (AD 1420–1530), Wolf (AD 1280–1340) and Oort (AD 1010–1050) Minima (Eddy, 1977).

The appearance of sunspots (chapter 6) on the surface of Sun is the most direct indication of the activity cycle of the sun. Less effective are auroral records (chapter 7) which can only serve as an indirect pointer dependent on the modulation of the geomagnetic field. Apart from these two indices, modern researchers also found the following proxy indicators of the past activity cycle of the Sun: (i) Carbon-14; (ii) Beryllium-10; (iii) Variations in Solar Diameter; (iv) Solar Corona; (v) Cometary tail lengths; and (vi) Sedimentary Varves.

I shall first make a survey of the various proxy indicators as listed above. A comparison is then made of these indicators with the results obtained from the previous two chapters on the investigation of sunspot and auroral records.

8.2 Carbon-14 Record from Tree Rings

Natural atmospheric ^{14}C fluctuations, apart from recent artificial perturbations such as due to the burning of fossil fuel and testing of atomic weapons, are either resulting from reservoir changes or changes in the production rate of ^{14}C. The effects of reservoir changes are generally small as pointed out by Damon (1970). Any changes in atmospheric ^{14}C are supposedly due to changes in the production rate of ^{14}C. This production rate is dependent on the flux of galactic cosmic rays injected at the upper atmosphere, which is itself modulated by two components. The first is due to variations in solar wind magnetic properties and the second to variations in the geomagnetic dipole moment.

As was first indicated by Stuiver (1961), the observed variations in the atmospheric ^{14}C concentration on time-scales of a few hundred years or less superimposed on the long-term trend could be attributed to solar activity. Whereas long-term variations over several thousand years or more are generally attributed to changes in the geomagnetic dipole moment (Merrill and McElhinny, 1983). The resultant changes in the atmospheric ^{14}C level are recorded in tree rings through the mechanism of photosynthesis.

From tree-ring ^{14}C measurements, the atmospheric ^{14}C record may be derived and any changes in the production rate of ^{14}C in the upper atmosphere may be calculated.

By using a carbon reservoir model describing terrestrial carbon exchange between the biosphere, atmosphere and oceans. Stuiver and Quay (1980) calculated the production rate changes, Q_M, in atoms cm^{-2} Earth surface sec^{-1}. After removing the long term trend due to changes in the geomagnetic field, the percentage deviation from the steady state ^{14}C production rate, ΔQ_M, is calculated. This should reflect solar modulation of the cosmic ray flux and correlate with solar activity levels indicated by the historical sunspot records.

Stuiver and Quay (1980) identified from the ΔQ_M record three periods of abnormality in the solar cycle similar to those proposed by Eddy (1977): AD 1654 to 1714 (Maunder minimum), 1416 to 1534 (Sporer minimum), and 1282 to 1342 (Wolf minimum). They also noted a less precisely defined minimum occurred near AD 1040. A strong correlation was found between the observed sunspot numbers since AD 1645 and their ^{14}C record. In a later paper, they extended their calculation to AD 300 (Stuiver and Quay, 1981). They identified two general types of periodicities, the Maunder type lasting 120–140 year and the Sporer type lasting 130–200 year (Fig. 8.1). However they did not identify the 80-year Gleissberg cycle. As good resolution of the sunspot cycle could not be obtained from the small sample of pre-telescopic sunspots, it is difficult to say whether a definite correlation existed between the two set of data.

8.3 Beryllium-10 in Deep Ice Cores

Beryllium is produced in the upper atmosphere (stratosphere and troposphere) in the ratio of 1/3 by galactic cosmic rays and 2/3 by neutron spallation. ^{10}Be produced in the upper atmosphere is precipitated in polar ice, surface ocean, deep ocean, continent decay and lake sediments. As was mentioned in the last section, variations in the production rate of cosmogenic nuclides are caused by changes in the primary cosmic ray

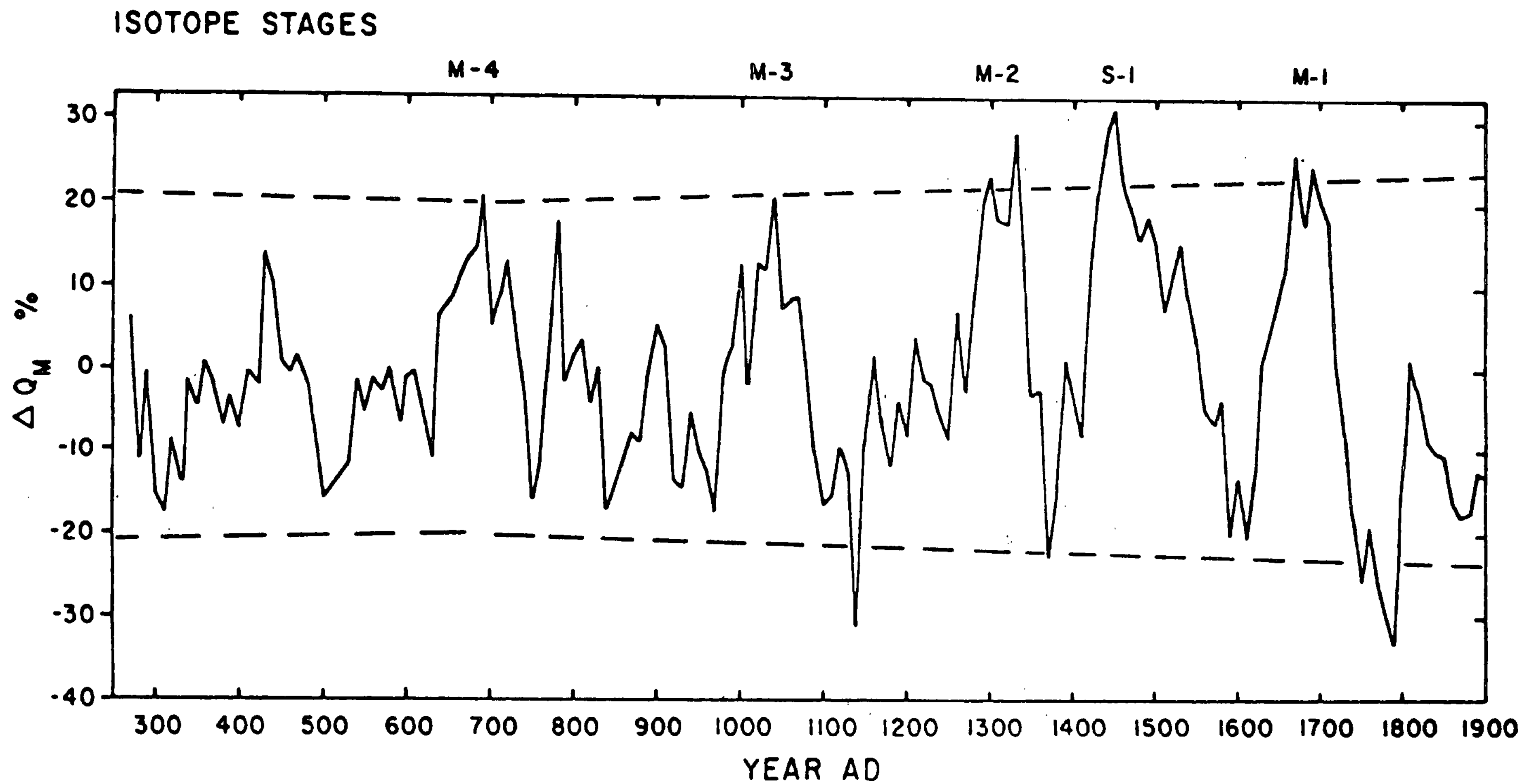

Fig. 8.1 The C-14 curve back to AD 300 showing the Maunder and Sporer types of variations (after Stuiver and Quay, 1981)

intensity, the geomagnetic field intensity and solar activity (modulating influence of the solar wind).

To date, concentration profiles of cosmogenic ^{10}Be in deep ice cores from Antarctica have been examined (Raisbeck, *el al.* 1981, 1987). Raisbeck *el al.* (1981) showed that ^{10}Be concentration in these deep ice cores from Antarctica exhibited variations similar to the solar cycle and an enhanced ^{10}Be concentration about the time of the Maunder Minimum (AD 1645 to 1715) (see Fig. 8.2). Recently, Raisbeck *et al.* (1987) extended their data further back in time and confirmed a ^{10}Be peak lasting 1000$\sim$2000 years at $\sim$60,000 year BP and a similar peak at 35,000 year BP.

8.4 Variations in the Solar Diameter

The possibility of a variation in the luminosity of the Sun due to structural changes and the accompanied change in the solar diameter was pointed out by Sofia *et al.* (1979). Various attempts have since been made to measure the variation in the solar diameter using different methods. For examples, meridian transits (Sofia *et al.*, 1979; Eddy and Boornazian 1979), Mercury transits (Shapiro, 1980; Parkinson *et al.*, 1980) and timing the duration of solar eclipses Parkinson *et al.* (1980). Recently, Ribes *et al.* (1987) inferred that the solar diameter was larger and rotation rate was slower during the Maunder Minimum period from an analysis of a 53-year record of regular observations of the solar diameter at meridian transits by Picard and La Hire in 17th century. Some of the measurements on the solar diameter are summarised in Table 8.1. The large uncertainties associated with most of the measurements preclude a positive conclusion to be drawn on the variation of the solar diameter. However, the general trend seems to indicate that the solar diameter is decreasing very slowly with time – i.e. much slower than first proposed by Eddy and Boornazian (1979).

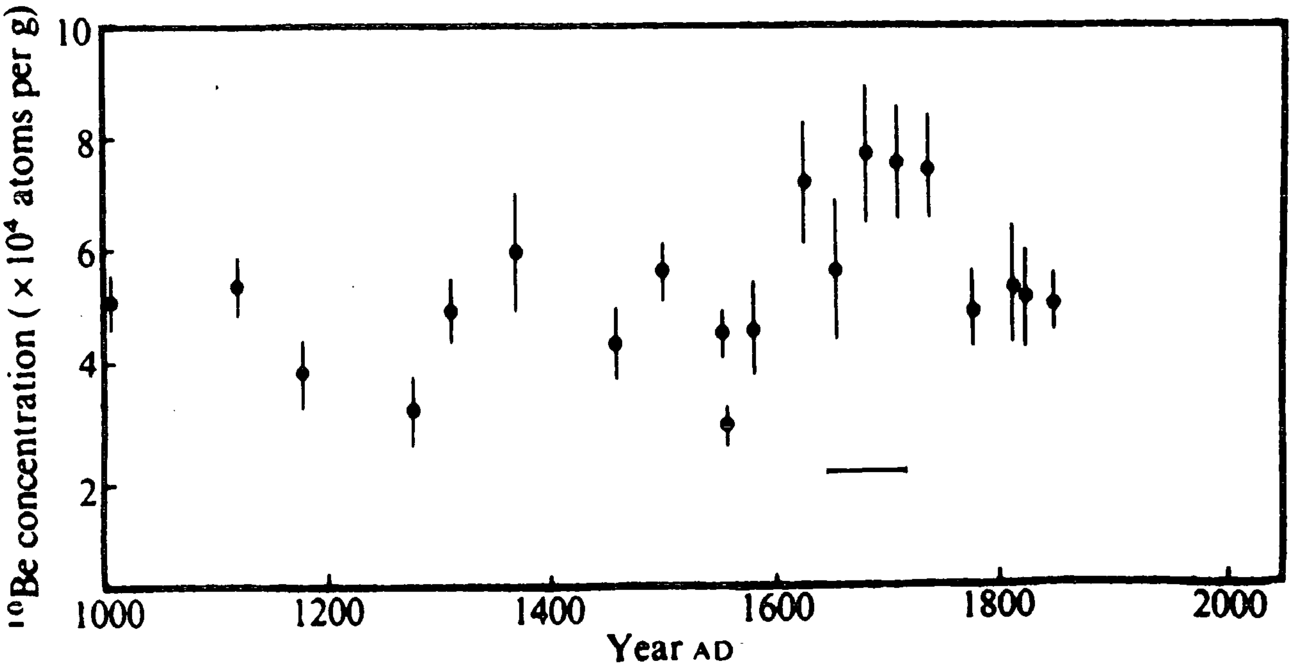

Fig. 8.2 Be-10 concentration near the Maunder Minimum (1645 to 1715) (after Raisbeck, 1981).

Table 8.1 A summary of the measurements on the solar radius.

Time Range	dR/dt (arcsec/cy)	Method	Reference
1836-1953	-0.38 to -1.15	Meridian transit	Eddy and Boornazian (1979)
1758-1974	+0.05±0.07	"	Wittman (1980)
1640-1981	0.0 ±0.1	"	Wittman *et al.* (1981)
1834-1887	-0.5 ±0.5	"	Smith and Messina (1981)
1666-1719	-0.09±0.06	"	Ribes *et al.* (1987)
1715-1979	-0.13±0.08	Total eclipse	Sofia *et al.* (1980)
1715-1966	-0.08±0.07	"	Parkinson *et al.* (1980)
1925-1979	-0.94±0.44	"	Dunham *et al.* (1981)
1750-1973	+0.02±0.07	Mercury transit	Shapiro (1980)
1723-1973	-0.14±0.08	"	Parkinson *et al.* 1980)
1974-1980	+0.2 ±1.6	Telescopic image size	LaBonte and Howard (1981)

8.5 Observation of the Solar Corona at Eclipse

One of Eddy's supporting evidences for the Maunder Minimum (1645–1715) was the absence of solar corona at total eclipse during that period (Eddy, 1976). It is generally believed that the form of the corona seen at a total eclipse is closely related to the level of activity of the Sun. At periods of normal solar activity the corona seen at eclipse is a mixture of the true corona (or K corona) and the weaker glow of the zodiacal light (or F corona). An active Sun however, has a bright and well developed K corona with numerous tapered streamers. At times of low solar activity, the K corona is almost absent of coronal streamers and so dim that the only visible feature is due to the much fainter F corona.

Reports of coronal sightings in Europe are very rare in the period before the 18th century. One of the main reasons is that total eclipses during the interval between the Renaissance and the end of the 17th century happened to be invisible to observers in the astronomical centres of Europe. Consequently, Eddy (1976) found only four European descriptions of the corona from the eclipses of 1652, 1698, 1706 and 1708. Although these were largely amateur accounts, Eddy believed they were descriptions of the F corona, thus suggesting the absence of the brighter K corona and hence an indication of a low level of solar activity. Only four other accounts of coronal sightings at eclipses of AD 968, 1567, 1605 and 1652 have been noted (Stephenson, 1988). However, the sparseness of the sightings does not enable the activity of the Sun to be ascertained.

So far no datable account on the sighting of the solar corona from Far Eastern histories is known to the author. Wang and Siscoe (1980) attempted to list five alleged Chinese references to observation of the corona. However these reports seem to suggest unusual atmospheric changes attaching to the Sun than anything else and in any case are not datable. It thus seems that the usefulness of early observations of the corona is very limited and cannot help reconstructing the variations in long-term solar activity.

8.6 Length of Cometary Tails

Eddy (1980) mentioned that by measuring cometary tail lengths it may be possible to get a qualitative measurement of the level of activity of the Sun. In order to test whether this relationship between the strength of solar wind and length of cometary tails, I have extracted from the cometary catalogue of Ho Peng Yoke (1966) all measurements of the angular tail length and plotted them as a function of time in Fig. 8.3. Obviously, the tail length of a comet depends on several factors, for example, the size of its nucleus, the distances from the Sun and Earth, and of course the action of the solar wind. It would have been desirable to normalise the tail length to a reference distance – say 1 au from the Sun. However, nearly all of these naked-eye comets recorded in Far Eastern annals have no calculated orbital elements. Thus the necessary normalisation is not possible and hence the recorded tail length is only a rough approximation to the true length.

8.7 Sedimentary Varves

Sedimentary varves are layers deposited in peri-glacial lakes resulting from annual rapid spring-summer melting and sediment transport. In between the spring-summer layers there is the quiet winter settling of silt layer. The most well known of the varves is the Elatina sedimentary varves from the late Precambrian period (c. 680 to 2500x10^6 years old) which had been deposited in a peri-glacial lake in Australia (Williams, 1981). These varves have been suggested to record climatic changes having periods similar to the solar cycle thus reflecting the activity of the Sun (Sonnett and Williams, 1985). The regularity of the bandings with periods ranging from 9 to 14 year and averaging 11.2

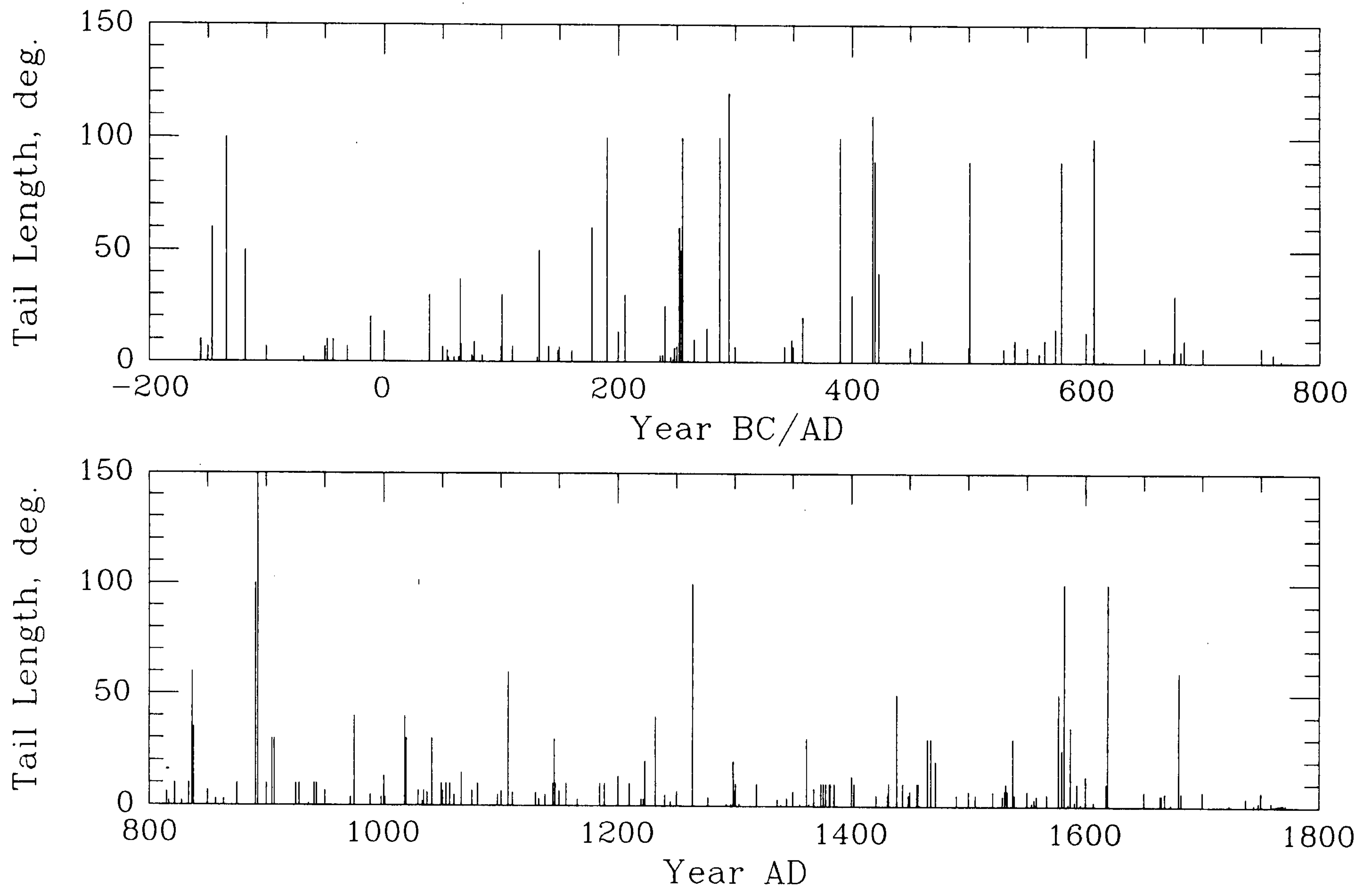

Fig. 8.3 The distribution of the angular length of cometary tails.

year over a 20,000 year sequence suggest that the solar cycle dates back to at least 700 million years ago.

Recently, Sonett and Trebisky (1986) have attempted a derivation from ancient varves and the present-epoch sunspot index the secular changes in solar activity. They suggested that the pattern seen in the periods of varves and sunspot cycle have a common forcing mechanisms affecting both the luminosity and the solar dynamo periods. Since sedimentary varve data are only indexed by integers hypothesized to correspond to solar years and because of the paucity and special qualities of these data, so far no conclusive interpretation can be drawn. It needs to be stressed here that present day varves do not record the solar cycle. In addition, Castagnoli and Bonino (1984) claimed to have found a 11-year cycle in the thermoluminescence profile of sea sediments.

8.8 A Comparison of the Proxy Indicators

Of the proxy indicators discussed above, only the telescopic sunspot records exhibit a cyclic pattern of about 11 years. As already mentioned above, the 11-year cycle is not strictly periodic; its length may vary from 5 to 13 years. However, the analysis on both naked-eye sunspot and auroral data seems to suggest a mean period of only about 10 years. Apart from the historical sunspot records, no other proxy indicators can demonstrate such an unambiguous behaviour of the solar cycle. Attempts have already been made to simulate the sunspot cycle with modulated sinusoidal waves. The investigation by Bracewell (1986) showed that the sunspot cycle can be modelled by random noises. So far, a comprehensive model that can describe all aspects of the 11-year sunspot cycle is still lacking.

Superposed upon the 11-year cycle is the suspected Gleissberg cycle of 80 years. None of the proxy indicators discussed above provides sufficient evidence to support its existence. However, prolonged periods of suppressed solar activity do occur. The most striking long term variations of the solar cycle is observed during the Maunder Minimum Period (AD 1645–1715). This period of low solar activity has already been discussed in full by Eddy (1976). Beside a reduced number of sunspot sightings during this period, a few other proxy indicators also provide evidence supporting this period of abnormal activity of the Sun. The production rate of ^{14}C during this period (about AD 1600 to 1750) was abnormally higher than normal, this was taken to be evidence for a decrease in the mean solar activity (Stuiver and Quay, 1980, 1981). The evidence given by the ^{14}C data seems to be fairly convincing. In addition to this abnormal period, other intervals of abnormal ^{14}C production have also been noted (Fig. 8.1). The ^{10}Be data analysed by Raisbeck *et al.* (1981) also show some degrees of deviation in the concentration level of ^{10}Be during the Maunder Minimum period.

Due to the fragmentary nature of both naked-eye sunspot and auroral data from East Asia, only a tentative support for a period of suppressed solar activity in the second half of the 17th century can be achieved. Whereas evidence provided by the remaining proxy indicators is even less conclusive. Although variations in the solar diameter during the Maunder Minimum period has been reported (e.g. Ribes *et al.*, 1987), the evidence is far from convincing. The evidence provided by solar corona, cometary tail lengths and sedimentary varves can only be taken as suggestive. These indicators can only provide a secondary support to the claim of a period of depressed solar activity in the 16th century. Up to now, the best indicator of the solar activity level is still the Wolf sunspot numbers.

8.9 Conclusions

The existence of the solar activity cycle since about AD 1700 is now fairly well established from records of sunspots observed with the telescope. The quality of sunspot data before AD 1700 deteriorates backwards in time. For the century before AD 1700, records of sunspots can only trace a general pattern of the solar activity cycle. Whereas the pre-telescopic records of sunspots are deficient for a conclusive picture to be drawn on the behaviour of the Sun in the two millennia prior to the telescopic observation of the Sun. Even when complemented by the records of aurorae (a less direct indicator) the available data are still inadequate for a detailed study of the variations in the solar cycle. The problem lies with the relatively small number of extant observations which could possibly have been contaminated by large spurious trends due to data artifacts, thus masking any real evidence of long-term solar variability. The spurious peaks seem to suggest that the possibility exists of an artificial periodicity being induced by random fluctuations.

Recognition of the contribution of the geomagnetic factor to the variations in the solar cycle in the mid-19th century has stimulated other proxy indicators to be investigated especially with the study of aurorae. In the last decade or so the existence of long periods of depression in the cycle of the Sun such as the Maunder Minimum has been reaffirmed (Eddy, 1976). Other proxy indicators currently being pursued such as ^{14}C, ^{10}Be and so on (as discussed above) have also been investigated by researchers. The general pattern confirms the results obtained from the study of sunspots.

The solar type of activity cycle is not solely confined to the Sun; stars like the RS Canum Venaticorum and BY Draconis variables also show similar behaviour (Baliunas and Vaughan, 1985). Perhaps observations of stellar activity cycles, the counterparts of the sunspot cycle on other stars, may illuminate theoretical studies of the solar cycle. Although, there are so many unknown parameters in our jigsaw puzzle of the activity of the Sun, it seems the central element to a full understanding relies on solving the physics of the solar magnetic field.

CHAPTER 9
EPILOGUE

The investigations presented in this thesis have a common theme in that they all relied on early astronomical observations. In Part I, the author has attempted to demonstrate the value of early cometary records in the investigation of past cometary orbits. An example is provided by the investigation of the past orbit of Halley's Comet. The method of analysis developed was employed successfully in obtaining corrections to the perihelion passage times of Comet Halley in a number of its past returns and recovering early records of its apparitions in 164 BC and 87 BC.

In Part II, a list of possible novae and supernovae from from Far Eastern sources was compiled. These records of new stars were investigated in detail with a specific concern for positional accuracy. The records of the five established historical supernovae were re-examined and positional information was discussed. Of the suspected nova candidates, twenty-six of the well observed fixed stars of short duration were investigated in detail. Positions with associated errors are deduced for each candidate, which should serve as a good guide for radio astronomers looking for nova remnants.

In the final part of the thesis, the author has studied the long term variability of solar activity cycles. An analysis of telescopic sunspot data from AD 1874 to 1954 indicated that the distribution of sunspot areas in the northern and southern hemispheres were asymmetric. It was thus inferred that an apparent asymmetry exists in the sunspot magnetic flux between the two hemispheres. A catalogue of Far Eastern sightings of sunspots was compiled which extended into the telescopic era. The data were analysed for any apparent cyclicity; a 10-year (rather than 11-year) cycle seems to exist in the naked-eye sunspot records. A secondary index, that of the observation of aurorae, was also examined. Again a 10-year cyclicity seems to exist.

One question that has been asked often is the following: are we putting too much faith in old and sometime sketchy records? The quality of results obtained in this thesis seems to suggest otherwise. In contrast, early astronomical records can, if carefully interpreted and investigated yield important and sometime surprising results. A good example is the case of Halley's Comet. It is my hope that the work described here is an important contribution to knowledge and valuable reference. The present study has been highlighted with the discovery of records of Comet Halley on Babylonian tablets in 164 BC and 87 BC.

One of the foremost difficulties in investigating historical records of astronomical phenomena is the interpretation of the description given in a record. A serious misidentification can lead to unnecessary wastage of effort on the part of other researchers. Any worker in the field of applied historical astronomy should bear in mind that once a misinterpreted record gets a footing in scientific journals it dies hard. One recent example is the enigma of the colour of Sirius (Schlosser and Bergmann, 1985), which has actually misled researchers in proposing a theoretical solution to an unfounded problem. The mistaken colour change of Sirius from red to white led Bruhweiler (1986) to propose that the white dwarf (Sirius B) of the Sirius binary star system had undergone a recent thermonuclear runaway event. It was alleged that Sirius B expanded in size to mimic a red-giant and this was the reason for the supposedly colour change of Sirius. Van Gent (1987) made a strong case for observations which had been interpreted as referring to Sirius actually relating to Arcturus.

Another example is the spurious SN of AD 1408 which had attracted much attention since it was first suggested by Li Qi-bin in 1978. The searches for its remnant in the last decade had produced fruitless and with contradicting results. When I was checking a record of something totally unrelated to 'new stars' in the *Ku-chin T'u-shu Chi-ch'eng* (an 'Imperial Encyclopaedia' compiled in AD 1726), I accidentally came upon a record under the 6th year of the Yung-lo reign-period. It gave the description of a meteor travelling across the sky with a tail. When I later checked against the various entries of new stars in AD 1408 recorded in local gazettes (the various local gazettes give slightly different entries but relating to a single star) given by Li Qi-bin (1978), I found that they referred to the same object, but with the extra details regarding motion and trail. This confirmed that they were records of meteors. The information provided us firm support for our long suspicion that the interpretation of the 1408 star as a SN explosion was incorrect (Stephenson and Yau, 1986) – see chapter 5.

I believe it is our duty as both astronomers and historians of science that every care should be taken not to mislead colleagues into misplaced efforts. Although the present state of knowledge still has many gaps, in a way is limited by the contents of those few sources that have so far been exploited. Astronomical records incorporated into the dynastic histories must represent only a fraction of the original reports presented by the court astronomers. Fig. 9.1 shows a comparison between the number of records in the *Astronomical Treatise* of the *Ming-shih* (one of the twenty-six dynastic histories) and the *Ming-shih-lu* (almost daily records of the Ming emperors). The number of astronomical records in the *Ming-shih* only amounts to about 30 per cent of the total records in the much detailed work of the *Ming-shih-lu.* As can be seen from Fig. 9.1, even the number of astronomical records contained in the *Ming-shih-lu* is far from complete, the number seems to fluctuate with the reigns of individual emperors. The sudden drop in the number of astronomical records preserved in the *Ming-shih-lu* after about AD 1530 is very curious. Since the Ming Dynasty did not end until more than a hundred years later in AD 1644, the notion that some of the records got lost during the chaos associated with the end of a dynasty is not likely. Most probably the situation is related to the general neglect of the imperial court and decline in the standard of astronomy in that period.

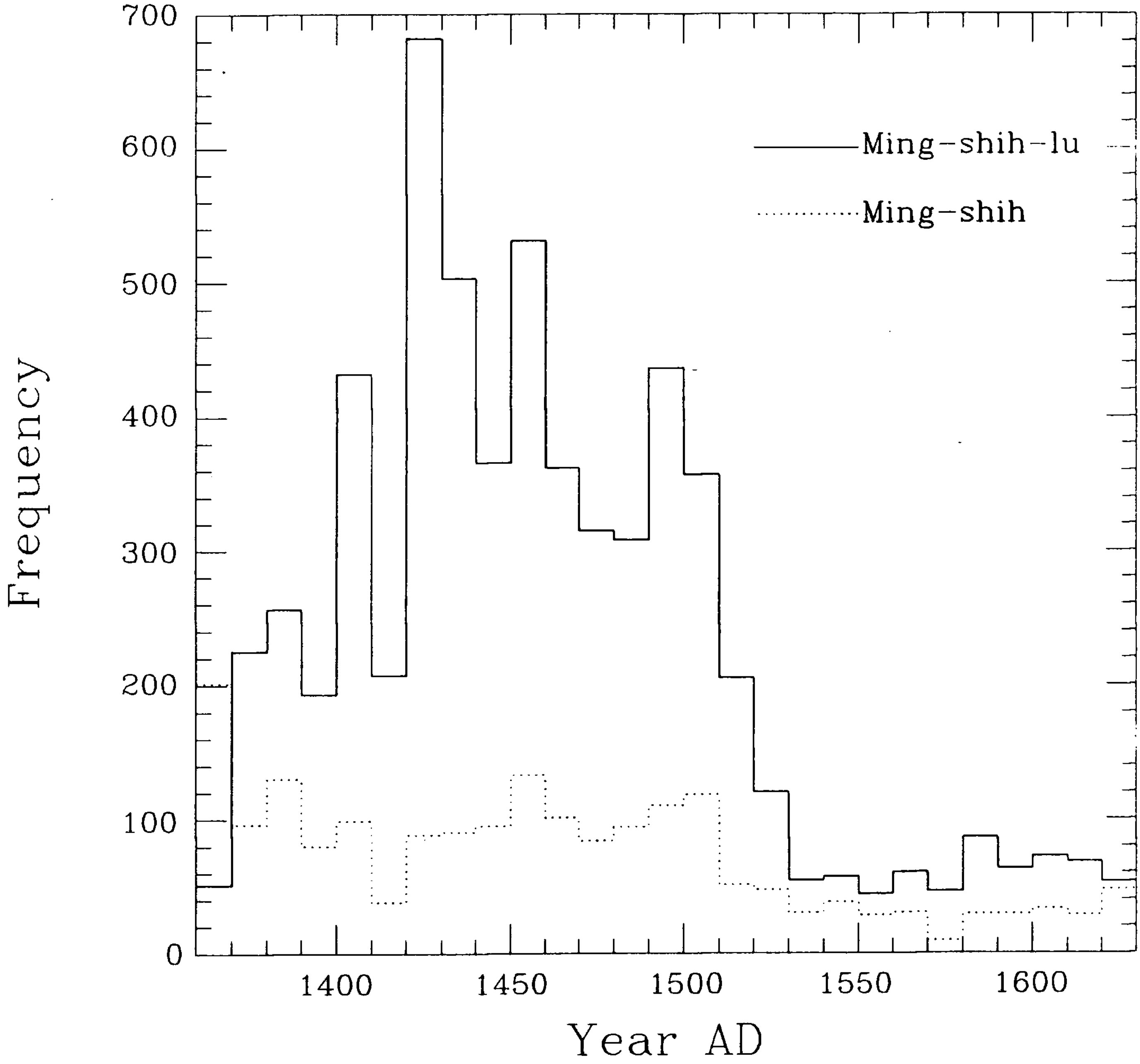

Fig 9.1 A comparison between the number of astronomical records in the Ming-Shih-lu and the Ming-shih for the period AD 1360 to 1630.

A substantial amount of archival sources are still waiting to be exploited. For instance, the very extensive Korean chronicles, the *Sungjong-won Ilgi* ('Court Diaries') – which is available in the library of the School of Oriental and African Studies in London – and cover the period AD 1623 to 1863 is virtually untapped. There are also the many thousands of diaries, monastery records, trading company records, expedition reports, and ship logs for more recent centuries. Even in the modern era, newspaper reports on seemingly casual sightings like the aurora can help researchers establish the extent of the auroral oval during periods of high solar activity. In my opinion, chasing historical records of astronomical phenomena in early annals and chronicles has in itself as much merit as compiling modern day observations. Without doubt, the field of Applied Historical Astronomy will continue to play an important role in our understanding of this ever changing cosmos.

APPENDICES

APPENDIX I CHRONOLOGICAL TABLES

(a) Chinese Chronological Table

Dynasty	Period rise	Period fall	Capital City	Modern Name	Lat deg min	Long deg min
Shang or Yin	c.1523 BC	1028 BC	An-i	An-yang	36 04	-114 20
Western Chou	1066 BC	770 BC	Hao-ching	Sian	34 16	-108 54
Eastern Chou	770 BC	256 BC	Lo-i	Lo-yang	34 45	-112 35
Lu	722 BC	481 BC	Ch'u-fu	Ch'u-fu	35 40	-117 01
Ch'in	221 BC	206 BC	Hsien-yang	Hsien-yang	34 22	-108 42
Former Han	206 BC	AD 9	Ch'ang-an	Sian	34 16	-108 54
Hsin (Wang Mang)	AD 9	AD 23	Ch'ang-an	Sian	34 16	-108 54
Later Han	25	220	Lo-yang	Lo-yang	34 45	-112 35
THREE KINGDOMS PERIOD						
Wei	220	265	Lo-yang	Lo-yang	34 45	-112 35
Shu	221	264	Ch'eng-tu	Ch'eng-tu	30 37	-104 06
Wu	222	280	Chien-Yeh	Nanking	32 03	-118 47
Western Chin	265	317	Lo-yang	Lo-yang	34 45	-112 35
Eastern Chin	317	420	Chien-k'ang	Nanking	32 03	-118 47
SOUTHERN DYNASTIES						
Sung	420	479	Chien-k'ang	Nanking	32 03	-118 47
Ch'i	479	502	Chien-k'ang	Nanking	32 03	-118 47

Liang	502	557	Chien-k'ang	Nanking	32 03	-118 47
Ch'en	557	589	Chien-k'ang	Nanking	32 03	-118 47
NORTHERN DYNASTIES						
Northern Wei	386	535	P'ing-ch'eng	Ta-t'ung	40 12	-113 12
Western Wei	535	556	Ch'ang-an	Sian	34 16	-108 54
Northern Chou	557	581	Ch'ang-an	Sian	34 16	-108 54
Eastern Wei	534	550	Yeh	Lin-chang	36 19	-114 33
Northern Ch'i	550	577	Yeh	Lin-chang	36 19	-114 33
Sui	581	618	Ta-hsing -ch'eng	Sian	34 16	-108 54
T'ang	618	906	Ch'ang-an	Sian	34 16	-108 54
FIVE DYNASTY PERIOD	(907-960)					
Later Liang	907	922	Pien	K'ai-feng	34 47	-114 20
Later T'ang	923	935	Lo-yang	Lo-yang	34 45	-112 35
Later Chin	936	946	Pien	K'ai-feng	34 47	-114 20
Later Han	947	950	Pien	K'ai-feng	34 47	-114 20
Later Chou	951	960	Pien	K'ai-feng	34 47	-114 20
Norther Sung	960	1126	K'ai-feng	K'ai-feng	34 47	-114 20
Southern Sung	1127	1279	Lin-an	Hangchow	30 18	-120 07
Liao	907	1124	Lin-huang	Han-sum	44 36	-119 59
Hsi Hsia	960	1126	Hsing-ch'ing	Yin-ch'uan	38 30	-106 19
Kin	1115	1234	Yen-ching	Peking	39 55	-116 26
Yuan	1280	1368	Ta-tu	Peking	39 55	-116 26

Ming	1368	1644	Shun-t'ien	Peking	39 55	-116 26
Ch'ing	1644	1911	Peking	Peking	39 55	-116 26

(b) Korean Chronological Table

Dynasty	Period rise	Period fall	Capital City	Modern Name	Lat deg min	Long deg min
Koryo	936	1232	Kaesong	Kaesong	37 58	-126 34
(From 1232-1270 and 1290-1292)			Kangwha	Kangwha	37 44	-126 29
Choson Kingdom	1392	1910	Hanyang	Seoul	37 33	-126 58

(c) Japanese Chronological Table

Dynasty	Period rise	Period fall	Capital City	Modern Name	Lat deg min	Long deg min
Nippon	710	784	Nara	Nara	34 41	-135 49
	784	794	Nagaoka	Nagaoka	37 27	-138 50
	794	1868	Kyoto	Kyoto	35 02	-135 45
	1868		Yedo	Tokyo	35 40	-139 45

APPENDIX II

AN EPHEMERIS FOR COMET HALLEY AT EACH OF THE RETURN BETWEEN AD 1378 AND 240 BC

The ephemeris is constructed in a way such that each return occupies one page of output. The length of time covers by the ephemeris is approximately 100 days, about 50 days before and 50 days after perihelion. The following gives an explanation of the symbols used in the table:

YR = Year

MH = Month

DY = Day

JD = Julian day number

RA(DATE)DEC = Right ascension and declination at the date

RA(J2000.0)DEC = Right ascension and declination at the equinox J2000.0

TWE = Altitude of comet at end of twilight

9PM = Altitude of comet at 9 p.m.

MN = Altitude of comet at midnight

3AM = Altitude of comet at 3 a.m.

TWB = Altitude of comet at beginning of twilight

R = Heliocentric distance in AU

DEL = Geocentric distance in AU

ELONG = Elongation of comet

TMAG = Total (nucleus plus coma) magnitude of comet

NMAG = Nuclear magnitude of comet

YR	MH	DY	JD	RA(DATE)DEC		RA(J2000.0)DEC		TWE	9PM	MN	3AM	TWB	R	DEL	ELONG	TMAG	NMAG
1378	9	17	2224632.25	5.6965	29.443	6.3565	29.420	-22.	-9.	22.	58.	80.	1.233	0.617	-97.	5.4	13.5
1378	9	19	2224634.25	5.7243	31.013	6.3927	30.960	-20.	-7.	23.	59.	83.	1.202	0.542	-98.	5.0	13.2
1378	9	21	2224636.25	5.7576	33.076	6.4374	32.988	-18.	-5.	25.	61.	85.	1.171	0.468	-100.	4.6	12.8
1378	9	23	2224638.25	5.8006	35.908	6.4970	35.774	-15.	-2.	27.	62.	87.	1.139	0.394	-101.	4.1	12.4
1378	9	25	2224640.25	5.8632	40.018	6.5858	39.815	-11.	1.	30.	63.	85.	1.108	0.322	-102.	3.5	11.9
1378	9	27	2224642.25	5.9716	46.440	6.7417	46.118	-6.	6.	32.	63.	79.	1.077	0.252	-103.	2.8	11.3
1378	9	29	2224644.25	6.2276	57.442	7.1093	56.839	4.	13.	34.	58.	67.	1.045	0.187	-102.	2.0	10.6
1378	10	1	2224646.25	7.6954	77.056	8.9867	75.055	22.	24.	32.	42.	47.	1.014	0.137	-97.	1.2	9.8
1378	10	3	2224648.25	16.4009	65.336	16.4833	63.960	47.	33.	17.	10.	13.	0.983	0.119	-23.	0.8	9.4
1378	10	5	2224650.25	17.1351	34.384	17.5112	33.774	55.	29.	-2.	-20.	-18.	0.953	0.147	50.	1.1	9.8
1378	10	7	2224652.25	17.3190	16.597	17.7813	16.190	49.	21.	-14.	-37.	-35.	0.922	0.203	55.	1.6	10.5
1378	10	9	2224654.25	17.3988	6.951	17.9012	6.634	43.	15.	-21.	-46.	-43.	0.892	0.269	55.	2.1	11.0
1378	10	11	2224656.25	17.4402	1.198	17.9656	0.929	39.	11.	-26.	-52.	-47.	0.862	0.340	54.	2.4	11.4
1378	10	13	2224658.25	17.4621	-2.566	18.0026	-2.809	35.	7.	-29.	-56.	-49.	0.833	0.413	53.	2.7	11.8
1378	10	15	2224660.25	17.4721	-5.211	18.0233	-5.440	32.	4.	-32.	-59.	-50.	0.804	0.486	51.	2.9	12.1
1378	10	17	2224662.25	17.4739	-7.176	18.0330	-7.399	30.	1.	-35.	-61.	-50.	0.776	0.560	49.	3.0	12.3
1378	10	19	2224664.25	17.4691	-8.698	18.0345	-8.923	28.	-1.	-37.	-63.	-50.	0.749	0.634	47.	3.1	12.5
1378	10	21	2224666.25	17.4588	-9.920	18.0293	-10.152	26.	-3.	-40.	-65.	-49.	0.723	0.708	45.	3.2	12.6
1378	10	23	2224668.25	17.4436	-10.929	18.0183	-11.173	24.	-6.	-42.	-66.	-47.	0.699	0.781	43.	3.2	12.8
1378	10	25	2224670.25	17.4239	-11.784	18.0021	-12.044	22.	-8.	-44.	-67.	-46.	0.675	0.853	41.	3.2	12.9
1378	10	27	2224672.25	17.3998	-12.524	17.9812	-12.805	21.	-10.	-47.	-67.	-44.	0.654	0.923	39.	3.3	13.0
1378	10	29	2224674.25	17.3716	-13.177	17.9558	-13.482	19.	-13.	-49.	-67.	-42.	0.635	0.993	36.	3.3	13.1
1378	10	31	2224676.25	17.3395	-13.764	17.9261	-14.096	17.	-15.	-51.	-67.	-40.	0.618	1.060	34.	3.3	13.2
1378	11	2	2224678.25	17.3036	-14.299	17.8926	-14.662	15.	-17.	-53.	-67.	-38.	0.603	1.126	31.	3.3	13.3
1378	11	4	2224680.25	17.2643	-14.793	17.8554	-15.191	13.	-20.	-56.	-66.	-36.	0.592	1.189	29.	3.3	13.3
1378	11	6	2224682.25	17.2219	-15.255	17.8150	-15.690	11.	-22.	-58.	-65.	-34.	0.583	1.249	26.	3.4	13.4
1378	11	8	2224684.25	17.1768	-15.690	17.7717	-16.166	9.	-25.	-60.	-64.	-31.	0.578	1.307	23.	3.4	13.5
1378	11	10	2224686.25	17.1295	-16.105	17.7262	-16.622	7.	-27.	-62.	-62.	-29.	0.576	1.361	21.	3.5	13.6
1378	11	12	2224688.25	17.0806	-16.503	17.6790	-17.062	5.	-30.	-64.	-61.	-26.	0.578	1.411	18.	3.9	13.7
1378	11	14	2224690.25	17.0305	-16.886	17.6305	-17.489	3.	-32.	-66.	-59.	-24.	0.583	1.457	15.	4.0	13.7
1378	11	16	2224692.25	16.9798	-17.256	17.5813	-17.904	1.	-35.	-68.	-57.	-22.	0.591	1.500	13.	4.1	13.8
1378	11	18	2224694.25	16.9290	-17.615	17.5319	-18.308	-2.	-37.	-70.	-55.	-19.	0.603	1.539	10.	4.2	13.9
1378	11	20	2224696.25	16.8784	-17.965	17.4828	-18.702	-4.	-40.	-71.	-53.	-17.	0.617	1.573	7.	4.3	14.0
1378	11	22	2224698.25	16.8285	-18.307	17.4342	-19.087	-6.	-43.	-73.	-51.	-14.	0.634	1.604	4.	4.4	14.1
1378	11	24	2224700.25	16.7794	-18.641	17.3864	-19.464	-8.	-45.	-73.	-49.	-12.	0.653	1.631	2.	4.6	14.2
1378	11	26	2224702.25	16.7313	-18.968	17.3396	-19.833	-11.	-48.	-74.	-47.	-10.	0.675	1.654	-1.	4.7	14.3
1378	11	28	2224704.25	16.6843	-19.290	17.2938	-20.195	-13.	-50.	-74.	-45.	-8.	0.698	1.674	-4.	4.9	14.4
1378	11	30	2224706.25	16.6384	-19.607	17.2491	-20.552	-15.	-53.	-74.	-42.	-5.	0.722	1.690	-6.	5.0	14.5
1378	12	2	2224708.25	16.5935	-19.919	17.2055	-20.902	-18.	-55.	-73.	-40.	-3.	0.748	1.703	-9.	5.1	14.6
1378	12	4	2224710.25	16.5496	-20.228	17.1627	-21.249	-20.	-57.	-72.	-38.	-1.	0.775	1.713	-11.	5.3	14.7
1378	12	6	2224712.25	16.5066	-20.533	17.1208	-21.591	-22.	-60.	-71.	-36.	1.	0.803	1.721	-14.	5.4	14.8
1378	12	8	2224714.25	16.4643	-20.837	17.0796	-21.931	-25.	-62.	-69.	-34.	3.	0.832	1.725	-17.	5.5	14.9
1378	12	10	2224716.25	16.4224	-21.138	17.0388	-22.268	-27.	-64.	-67.	-32.	5.	0.861	1.727	-19.	5.6	15.0
1378	12	12	2224718.25	16.3809	-21.439	16.9984	-22.603	-30.	-67.	-65.	-29.	6.	0.891	1.727	-22.	5.7	15.0
1378	12	14	2224720.25	16.3395	-21.738	16.9581	-22.937	-32.	-69.	-63.	-27.	8.	0.921	1.724	-24.	5.8	15.1
1378	12	16	2224722.25	16.2981	-22.037	16.9176	-23.271	-35.	-71.	-61.	-25.	10.	0.951	1.719	-27.	6.0	15.2
1378	12	18	2224724.25	16.2562	-22.336	16.8768	-23.604	-37.	-73.	-59.	-23.	11.	0.982	1.712	-29.	6.0	15.2
1378	12	20	2224726.25	16.2139	-22.635	16.8354	-23.939	-40.	-75.	-57.	-21.	13.	1.013	1.703	-32.	6.1	15.3
1378	12	22	2224728.25	16.1707	-22.935	16.7932	-24.274	-42.	-76.	-55.	-19.	14.	1.044	1.693	-35.	6.2	15.3
1378	12	24	2224730.25	16.1264	-23.236	16.7499	-24.612	-45.	-78.	-53.	-17.	16.	1.076	1.680	-37.	6.3	15.4
1378	12	26	2224732.25	16.0808	-23.537	16.7052	-24.951	-47.	-78.	-51.	-14.	17.	1.107	1.667	-40.	6.4	15.4
1378	12	28	2224734.25	16.0337	-23.840	16.6589	-25.292	-50.	-79.	-49.	-12.	19.	1.138	1.651	-42.	6.5	15.5
1378	12	30	2224736.25	15.9846	-24.144	16.6107	-25.636	-53.	-79.	-46.	-10.	20.	1.169	1.634	-45.	6.5	15.5
1379	1	1	2224738.25	15.9333	-24.449	16.5602	-25.982	-55.	-78.	-44.	-8.	21.	1.201	1.616	-48.	6.6	15.5

YR	MH	DY	JD	RA(DATE)	DEC	RA(J2000.0)	DEC	TWE	9PM	MN	3AM	TWB	R	DEL	ELONG	TMAG	NMAG
1301	8	31	2196491.25	5.6240	27.144	6.3525	27.156	-26.	-19.	9.	45.	64.	1.231	0.895	-81.	6.2	14.3
1301	9	2	2196493.25	5.6925	28.012	6.4257	27.952	-26.	-17.	11.	46.	65.	1.200	0.820	-82.	5.9	14.1
1301	9	4	2196495.25	5.7734	29.045	6.5124	28.900	-25.	-16.	12.	47.	67.	1.168	0.745	-82.	5.6	13.8
1301	9	6	2196497.25	5.8720	30.295	6.6179	30.045	-23.	-15.	12.	47.	68.	1.137	0.669	-83.	5.2	13.5
1301	9	8	2196499.25	5.9962	31.836	6.7508	31.457	-22.	-14.	13.	48.	69.	1.106	0.594	-83.	4.8	13.2
1301	9	10	2196501.25	6.1598	33.781	6.9252	33.230	-20.	-12.	14.	48.	69.	1.074	0.520	-83.	4.4	12.8
1301	9	12	2196503.25	6.3868	36.291	7.1661	35.506	-18.	-11.	14.	47.	69.	1.043	0.447	-83.	3.9	12.4
1301	9	14	2196505.25	6.7242	39.597	7.5209	38.470	-15.	-9.	14.	46.	67.	1.012	0.376	-81.	3.4	12.0
1301	9	16	2196507.25	7.2714	43.948	8.0866	42.292	-11.	-7.	13.	42.	62.	0.981	0.309	-77.	2.8	11.5
1301	9	18	2196509.25	8.2520	49.176	9.0679	46.680	-5.	-5.	9.	34.	53.	0.950	0.249	-69.	2.2	11.0
1301	9	20	2196511.25	10.0535	52.598	10.7771	49.038	4.	-2.	2.	21.	38.	0.919	0.205	-53.	1.6	10.5
1301	9	22	2196513.25	12.4216	46.968	12.9699	43.143	16.	1.	-8.	1.	16.	0.889	0.187	-25.	1.3	10.2
1301	9	24	2196515.25	14.0953	32.955	14.5995	29.776	25.	3.	-19.	-19.	-6.	0.859	0.203	5.	1.3	10.3
1301	9	26	2196517.25	14.9914	19.905	15.5209	17.345	28.	3.	-26.	-34.	-22.	0.829	0.247	24.	1.5	10.7
1301	9	28	2196519.25	15.4895	10.768	16.0479	8.622	29.	2.	-30.	-44.	-32.	0.800	0.307	34.	1.8	11.0
1301	9	30	2196521.25	15.7912	4.632	16.3719	2.759	28.	1.	-33.	-50.	-39.	0.772	0.375	38.	2.1	11.4
1301	10	2	2196523.25	15.9864	0.386	16.5836	-1.303	26.	-1.	-36.	-55.	-42.	0.745	0.447	40.	2.3	11.7
1301	10	4	2196525.25	16.1177	-2.680	16.7274	-4.242	25.	-2.	-38.	-58.	-44.	0.719	0.522	41.	2.5	12.0
1301	10	6	2196527.25	16.2074	-4.986	16.8268	-6.459	23.	-4.	-40.	-60.	-45.	0.694	0.599	41.	2.6	12.2
1301	10	8	2196529.25	16.2682	-6.783	16.8953	-8.195	22.	-6.	-42.	-62.	-45.	0.671	0.676	40.	2.7	12.4
1301	10	10	2196531.25	16.3076	-8.226	16.9410	-9.597	20.	-8.	-44.	-63.	-45.	0.650	0.753	39.	2.8	12.5
1301	10	12	2196533.25	16.3306	-9.414	16.9692	-10.761	19.	-10.	-46.	-64.	-44.	0.630	0.829	38.	2.8	12.7
1301	10	14	2196535.25	16.3404	-10.415	16.9835	-11.751	17.	-12.	-48.	-65.	-43.	0.613	0.905	36.	2.9	12.8
1301	10	16	2196537.25	16.3395	-11.274	16.9863	-12.609	16.	-14.	-50.	-65.	-42.	0.599	0.979	34.	3.0	12.9
1301	10	18	2196539.25	16.3296	-12.025	16.9797	-13.367	14.	-16.	-52.	-65.	-40.	0.588	1.051	32.	3.0	13.1
1301	10	20	2196541.25	16.3121	-12.690	16.9652	-14.048	13.	-18.	-54.	-65.	-38.	0.579	1.122	30.	3.1	13.2
1301	10	22	2196543.25	16.2885	-13.287	16.9442	-14.666	11.	-20.	-56.	-64.	-36.	0.574	1.190	28.	3.2	13.3
1301	10	24	2196545.25	16.2599	-13.830	16.9179	-15.235	9.	-22.	-58.	-63.	-34.	0.573	1.254	25.	3.6	13.4
1301	10	26	2196547.25	16.2272	-14.328	16.8873	-15.763	7.	-25.	-60.	-62.	-32.	0.575	1.316	23.	3.7	13.5
1301	10	28	2196549.25	16.1915	-14.789	16.8535	-16.257	5.	-27.	-62.	-61.	-30.	0.580	1.374	21.	3.8	13.6
1301	10	30	2196551.25	16.1537	-15.220	16.8174	-16.723	4.	-29.	-64.	-60.	-28.	0.589	1.429	18.	3.9	13.7
1301	11	1	2196553.25	16.1145	-15.625	16.7799	-17.164	2.	-32.	-65.	-58.	-25.	0.601	1.480	16.	4.1	13.8
1301	11	3	2196555.25	16.0747	-16.008	16.7415	-17.583	0.	-34.	-67.	-57.	-23.	0.615	1.527	13.	4.2	14.0
1301	11	5	2196557.25	16.0347	-16.373	16.7029	-17.984	-2.	-36.	-69.	-55.	-21.	0.633	1.570	10.	4.4	14.1
1301	11	7	2196559.25	15.9950	-16.721	16.6645	-18.369	-4.	-39.	-70.	-53.	-19.	0.652	1.609	8.	4.5	14.2
1301	11	9	2196561.25	15.9559	-17.056	16.6266	-18.740	-6.	-41.	-71.	-51.	-16.	0.674	1.645	5.	4.7	14.3
1301	11	11	2196563.25	15.9175	-17.380	16.5894	-19.097	-8.	-43.	-72.	-49.	-14.	0.697	1.677	3.	4.9	14.4
1301	11	13	2196565.25	15.8801	-17.693	16.5531	-19.444	-10.	-46.	-73.	-47.	-12.	0.722	1.705	0.	5.0	14.6
1301	11	15	2196567.25	15.8436	-17.998	16.5177	-19.781	-12.	-48.	-73.	-45.	-10.	0.748	1.731	-2.	5.2	14.7
1301	11	17	2196569.25	15.8081	-18.295	16.4832	-20.110	-14.	-50.	-73.	-43.	-7.	0.776	1.753	-4.	5.3	14.8
1301	11	19	2196571.25	15.7735	-18.585	16.4496	-20.432	-16.	-53.	-72.	-41.	-5.	0.804	1.772	-7.	5.5	14.9
1301	11	21	2196573.25	15.7397	-18.871	16.4167	-20.746	-18.	-55.	-72.	-39.	-3.	0.833	1.788	-9.	5.6	15.0
1301	11	23	2196575.25	15.7066	-19.151	16.3846	-21.056	-20.	-57.	-71.	-37.	-1.	0.862	1.802	-12.	5.7	15.1
1301	11	25	2196577.25	15.6741	-19.427	16.3530	-21.361	-22.	-59.	-70.	-35.	1.	0.892	1.813	-14.	5.9	15.1
1301	11	27	2196579.25	15.6421	-19.700	16.3219	-21.661	-25.	-61.	-68.	-33.	3.	0.923	1.821	-17.	6.0	15.2
1301	11	29	2196581.25	15.6104	-19.970	16.2910	-21.959	-27.	-64.	-67.	-31.	5.	0.953	1.828	-19.	6.1	15.3
1301	12	1	2196583.25	15.5789	-20.238	16.2603	-22.253	-29.	-66.	-65.	-29.	7.	0.984	1.832	-21.	6.2	15.4
1301	12	3	2196585.25	15.5473	-20.503	16.2295	-22.546	-31.	-68.	-63.	-27.	8.	1.015	1.833	-24.	6.3	15.4
1301	12	5	2196587.25	15.5156	-20.767	16.1986	-22.837	-33.	-70.	-61.	-25.	10.	1.047	1.833	-26.	6.4	15.5
1301	12	7	2196589.25	15.4835	-21.029	16.1672	-23.126	-36.	-71.	-59.	-23.	12.	1.078	1.831	-29.	6.5	15.6
1301	12	9	2196591.25	15.4508	-21.290	16.1353	-23.414	-38.	-73.	-58.	-21.	13.	1.109	1.827	-31.	6.6	15.6
1301	12	11	2196593.25	15.4175	-21.549	16.1027	-23.702	-40.	-75.	-55.	-19.	15.	1.141	1.822	-33.	6.7	15.7
1301	12	13	2196595.25	15.3832	-21.808	16.0691	-23.989	-43.	-76.	-53.	-17.	16.	1.172	1.814	-36.	6.8	15.7
1301	12	15	2196597.25	15.3479	-22.065	16.0344	-24.276	-45.	-77.	-51.	-15.	18.	1.203	1.805	-38.	6.8	15.8

YR	MH	DY	JD	RA(DATE)	DEC	RA(J2000.0)	DEC	TWE	9PM	MN	3AM	TWB	R	DEL	ELONG	TMAG	NMAG
1222	8	7	2167612.25	5.0681	25.282	5.8678	25.884	-29.	-26.	-2.	32.	45.	1.238	1.283	-64.	7.0	15.1
1222	8	9	2167614.25	5.1283	25.841	5.9315	26.373	-29.	-25.	-1.	33.	47.	1.207	1.210	-65.	6.8	14.9
1222	8	11	2167616.25	5.1954	26.464	6.0025	26.918	-28.	-24.	0.	34.	48.	1.175	1.137	-66.	6.5	14.7
1222	8	13	2167618.25	5.2710	27.163	6.0826	27.530	-27.	-23.	1.	35.	49.	1.144	1.063	-67.	6.3	14.5
1222	8	15	2167620.25	5.3578	27.956	6.1743	28.222	-27.	-22.	2.	36.	51.	1.113	0.988	-68.	6.0	14.3
1222	8	17	2167622.25	5.4590	28.863	6.2813	29.010	-26.	-22.	3.	36.	52.	1.081	0.913	-68.	5.6	14.1
1222	8	19	2167624.25	5.5796	29.909	6.4084	29.916	-25.	-21.	3.	37.	53.	1.050	0.838	-68.	5.3	13.8
1222	8	21	2167626.25	5.7264	31.127	6.5628	30.964	-24.	-20.	4.	37.	53.	1.019	0.764	-68.	5.0	13.6
1222	8	23	2167628.25	5.9097	32.557	6.7548	32.181	-22.	-18.	4.	37.	53.	0.988	0.689	-68.	4.6	13.3
1222	8	25	2167630.25	6.1455	34.242	7.0002	33.596	-21.	-17.	4.	36.	53.	0.957	0.616	-67.	4.2	13.0
1222	8	27	2167632.25	6.4586	36.219	7.3233	35.218	-19.	-16.	4.	35.	51.	0.926	0.545	-65.	3.8	12.6
1222	8	29	2167634.25	6.8887	38.474	7.7616	37.002	-16.	-15.	3.	32.	49.	0.896	0.478	-62.	3.3	12.3
1222	8	31	2167636.25	7.4972	40.841	8.3703	38.741	-13.	-14.	0.	28.	44.	0.866	0.415	-57.	2.9	11.9
1222	9	2	2167638.25	8.3641	42.735	9.2157	39.845	-9.	-12.	-3.	21.	37.	0.836	0.362	-49.	2.4	11.5
1222	9	4	2167640.25	9.5319	42.811	10.3240	39.103	-3.	-10.	-8.	12.	27.	0.807	0.323	-38.	2.0	11.2
1222	9	6	2167642.25	10.8700	39.379	11.5770	35.139	4.	-8.	-15.	-1.	14.	0.779	0.304	-22.	1.7	11.0
1222	9	8	2167644.25	12.0837	32.405	12.7285	28.100	10.	-6.	-22.	-14.	-1.	0.752	0.309	-6.	1.5	10.9
1222	9	10	2167646.25	12.9985	24.119	13.6218	20.041	14.	-5.	-28.	-26.	-14.	0.726	0.338	9.	1.6	11.0
1222	9	12	2167648.25	13.6348	16.613	14.2605	12.833	17.	-4.	-32.	-36.	-24.	0.701	0.385	20.	1.7	11.3
1222	9	14	2167650.25	14.0725	10.597	14.7089	7.088	18.	-4.	-35.	-43.	-31.	0.677	0.445	27.	1.8	11.5
1222	9	16	2167652.25	14.3776	5.967	15.0261	2.676	18.	-4.	-37.	-48.	-36.	0.655	0.514	31.	2.0	11.7
1222	9	18	2167654.25	14.5937	2.410	15.2534	-0.713	18.	-5.	-39.	-52.	-39.	0.636	0.587	33.	2.1	12.0
1222	9	20	2167656.25	14.7481	-0.361	15.4175	-3.356	17.	-7.	-41.	-55.	-41.	0.618	0.664	35.	2.3	12.2
1222	9	22	2167658.25	14.8583	-2.559	15.5360	-5.459	16.	-8.	-43.	-57.	-42.	0.603	0.743	35.	2.4	12.4
1222	9	24	2167660.25	14.9360	-4.335	15.6206	-7.167	15.	-10.	-44.	-58.	-43.	0.591	0.822	35.	2.5	12.5
1222	9	26	2167662.25	14.9888	-5.798	15.6793	-8.581	14.	-11.	-46.	-59.	-42.	0.582	0.901	34.	2.6	12.7
1222	9	28	2167664.25	15.0225	-7.022	15.7181	-9.773	13.	-13.	-48.	-60.	-42.	0.577	0.979	33.	2.8	12.9
1222	9	30	2167666.25	15.0414	-8.061	15.7412	-10.795	11.	-15.	-50.	-61.	-41.	0.574	1.056	31.	2.9	13.0
1222	10	2	2167668.25	15.0486	-8.957	15.7521	-11.682	10.	-17.	-52.	-61.	-40.	0.575	1.130	30.	3.4	13.2
1222	10	4	2167670.25	15.0468	-9.737	15.7535	-12.463	8.	-19.	-54.	-61.	-38.	0.580	1.202	28.	3.5	13.3
1222	10	6	2167672.25	15.0382	-10.426	15.7476	-13.158	7.	-21.	-55.	-60.	-37.	0.588	1.271	26.	3.7	13.5
1222	10	8	2167674.25	15.0244	-11.041	15.7362	-13.783	5.	-23.	-57.	-60.	-35.	0.599	1.338	24.	3.9	13.6
1222	10	10	2167676.25	15.0069	-11.594	15.7208	-14.351	4.	-25.	-59.	-59.	-33.	0.613	1.400	22.	4.0	13.8
1222	10	12	2167678.25	14.9869	-12.098	15.7026	-14.871	2.	-27.	-61.	-58.	-31.	0.630	1.460	20.	4.2	13.9
1222	10	14	2167680.25	14.9652	-12.560	15.6826	-15.352	1.	-29.	-62.	-57.	-29.	0.649	1.516	17.	4.4	14.1
1222	10	16	2167682.25	14.9425	-12.987	15.6614	-15.798	-1.	-31.	-64.	-56.	-27.	0.670	1.568	15.	4.6	14.2
1222	10	18	2167684.25	14.9194	-13.386	15.6397	-16.216	-2.	-33.	-65.	-54.	-25.	0.693	1.617	13.	4.8	14.3
1222	10	20	2167686.25	14.8963	-13.761	15.6178	-16.611	-4.	-35.	-66.	-53.	-23.	0.717	1.663	11.	4.9	14.5
1222	10	22	2167688.25	14.8734	-14.116	15.5961	-16.984	-6.	-37.	-68.	-52.	-20.	0.743	1.705	9.	5.1	14.6
1222	10	24	2167690.25	14.8509	-14.453	15.5748	-17.340	-7.	-39.	-69.	-50.	-18.	0.770	1.744	6.	5.3	14.7
1222	10	26	2167692.25	14.8290	-14.775	15.5539	-17.680	-9.	-41.	-69.	-49.	-16.	0.798	1.780	4.	5.4	14.9
1222	10	28	2167694.25	14.8076	-15.085	15.5335	-18.008	-10.	-43.	-70.	-47.	-14.	0.827	1.813	2.	5.6	15.0
1222	10	30	2167696.25	14.7869	-15.384	15.5137	-18.323	-12.	-45.	-70.	-45.	-12.	0.856	1.844	0.	5.8	15.1
1222	11	1	2167698.25	14.7667	-15.674	15.4944	-18.629	-14.	-47.	-71.	-44.	-10.	0.886	1.871	-3.	5.9	15.2
1222	11	3	2167700.25	14.7471	-15.955	15.4756	-18.927	-15.	-49.	-70.	-42.	-8.	0.916	1.896	-5.	6.0	15.3
1222	11	5	2167702.25	14.7280	-16.230	15.4573	-19.217	-17.	-51.	-70.	-40.	-6.	0.947	1.919	-7.	6.2	15.4
1222	11	7	2167704.25	14.7093	-16.498	15.4394	-19.500	-19.	-53.	-70.	-38.	-4.	0.978	1.939	-9.	6.3	15.5
1222	11	9	2167706.25	14.6908	-16.761	15.4217	-19.777	-21.	-55.	-69.	-37.	-2.	1.009	1.956	-11.	6.4	15.6
1222	11	11	2167708.25	14.6726	-17.018	15.4043	-20.049	-22.	-57.	-68.	-35.	0.	1.040	1.972	-14.	6.5	15.7
1222	11	13	2167710.25	14.6546	-17.272	15.3869	-20.317	-24.	-59.	-67.	-33.	2.	1.071	1.985	-16.	6.7	15.7
1222	11	15	2167712.25	14.6366	-17.521	15.3696	-20.581	-26.	-61.	-66.	-31.	4.	1.102	1.996	-18.	6.8	15.8
1222	11	17	2167714.25	14.6184	-17.767	15.3522	-20.841	-28.	-63.	-64.	-29.	6.	1.134	2.005	-20.	6.9	15.9
1222	11	19	2167716.25	14.6001	-18.010	15.3345	-21.098	-30.	-65.	-63.	-27.	8.	1.165	2.013	-22.	7.0	16.0
1222	11	21	2167718.25	14.5816	-18.250	15.3165	-21.352	-31.	-66.	-61.	-26.	9.	1.196	2.018	-25.	7.1	16.0

YR	MH	DY	JD	RA(DATE)	DEC	RA(J2000.0)	DEC	TWE	9PM	MN	3AM	TWB	R	DEL	ELONG	TMAG	NMAG
1145	2	25	2139325.25	0.5032	4.858	1.2409	9.496	11.	-15.	-45.	-45.	-24.	1.236	2.063	25.	8.1	16.1
1145	2	27	2139327.25	0.4871	4.976	1.2248	9.618	9.	-17.	-46.	-44.	-23.	1.205	2.058	23.	7.9	16.1
1145	3	1	2139329.25	0.4713	5.097	1.2090	9.743	7.	-18.	-46.	-43.	-22.	1.173	2.050	21.	7.8	16.0
1145	3	3	2139331.25	0.4556	5.220	1.1932	9.871	5.	-20.	-47.	-42.	-21.	1.142	2.041	19.	7.7	15.9
1145	3	5	2139333.25	0.4399	5.347	1.1775	10.002	3.	-21.	-48.	-40.	-20.	1.111	2.030	16.	7.5	15.9
1145	3	7	2139335.25	0.4242	5.477	1.1618	10.135	1.	-23.	-48.	-39.	-19.	1.079	2.017	14.	7.4	15.8
1145	3	9	2139337.25	0.4084	5.609	1.1459	10.271	-1.	-24.	-48.	-38.	-17.	1.048	2.001	12.	7.2	15.7
1145	3	11	2139339.25	0.3923	5.744	1.1299	10.410	-3.	-26.	-49.	-36.	-16.	1.017	1.984	10.	7.0	15.6
1145	3	13	2139341.25	0.3760	5.882	1.1135	10.552	-6.	-27.	-49.	-35.	-15.	0.986	1.964	8.	6.9	15.5
1145	3	15	2139343.25	0.3592	6.022	1.0967	10.696	-8.	-28.	-49.	-34.	-14.	0.955	1.942	6.	6.7	15.4
1145	3	17	2139345.25	0.3421	6.165	1.0795	10.843	-10.	-30.	-49.	-32.	-13.	0.924	1.918	4.	6.5	15.3
1145	3	19	2139347.25	0.3244	6.311	1.0618	10.993	-12.	-31.	-49.	-31.	-11.	0.894	1.891	1.	6.3	15.2
1145	3	21	2139349.25	0.3063	6.460	1.0435	11.147	-14.	-32.	-48.	-29.	-10.	0.864	1.861	-1.	6.1	15.1
1145	3	23	2139351.25	0.2875	6.613	1.0247	11.304	-16.	-33.	-48.	-28.	-9.	0.835	1.829	-3.	5.9	15.0
1145	3	25	2139353.25	0.2682	6.771	1.0052	11.465	-18.	-35.	-48.	-26.	-8.	0.806	1.794	-5.	5.7	14.9
1145	3	27	2139355.25	0.2483	6.933	0.9852	11.631	-20.	-36.	-47.	-24.	-6.	0.778	1.756	-7.	5.5	14.8
1145	3	29	2139357.25	0.2280	7.101	0.9648	11.803	-22.	-37.	-47.	-23.	-5.	0.751	1.715	-9.	5.3	14.6
1145	3	31	2139359.25	0.2073	7.277	0.9439	11.983	-23.	-38.	-46.	-21.	-4.	0.725	1.671	-12.	5.0	14.5
1145	4	2	2139361.25	0.1864	7.462	0.9229	12.172	-25.	-39.	-45.	-19.	-2.	0.700	1.623	-14.	4.8	14.4
1145	4	4	2139363.25	0.1657	7.659	0.9021	12.373	-27.	-40.	-44.	-18.	-1.	0.676	1.573	-16.	4.6	14.2
1145	4	6	2139365.25	0.1455	7.871	0.8817	12.588	-29.	-41.	-43.	-16.	0.	0.655	1.518	-18.	4.3	14.1
1145	4	8	2139367.25	0.1264	8.102	0.8625	12.823	-30.	-41.	-42.	-14.	2.	0.635	1.461	-20.	4.1	13.9
1145	4	10	2139369.25	0.1091	8.359	0.8451	13.082	-32.	-42.	-41.	-12.	3.	0.618	1.400	-22.	3.9	13.8
1145	4	12	2139371.25	0.0946	8.647	0.8306	13.372	-33.	-43.	-40.	-11.	4.	0.603	1.336	-24.	3.7	13.6
1145	4	14	2139373.25	0.0840	8.976	0.8200	13.703	-34.	-43.	-39.	-9.	6.	0.591	1.268	-26.	3.5	13.5
1145	4	16	2139375.25	0.0789	9.358	0.8151	14.086	-36.	-43.	-38.	-7.	7.	0.582	1.198	-28.	3.3	13.3
1145	4	18	2139377.25	0.0812	9.808	0.8178	14.535	-36.	-43.	-36.	-5.	8.	0.577	1.124	-30.	3.1	13.2
1145	4	20	2139379.25	0.0933	10.345	0.8305	15.070	-37.	-43.	-35.	-4.	10.	0.575	1.048	-31.	2.9	13.0
1145	4	22	2139381.25	0.1183	10.994	0.8564	15.715	-37.	-43.	-34.	-2.	11.	0.576	0.970	-33.	3.0	12.8
1145	4	24	2139383.25	0.1600	11.787	0.8996	16.501	-38.	-42.	-32.	-1.	12.	0.581	0.890	-34.	2.9	12.7
1145	4	26	2139385.25	0.2237	12.766	0.9655	17.469	-37.	-42.	-31.	1.	13.	0.589	0.810	-34.	2.7	12.5
1145	4	28	2139387.25	0.3167	13.991	1.0620	18.674	-36.	-40.	-30.	2.	14.	0.600	0.729	-34.	2.6	12.3
1145	4	30	2139389.25	0.4498	15.541	1.2003	20.190	-35.	-39.	-28.	3.	14.	0.615	0.649	-34.	2.4	12.1
1145	5	2	2139391.25	0.6392	17.521	1.3979	22.113	-33.	-37.	-27.	3.	14.	0.631	0.570	-32.	2.2	11.9
1145	5	4	2139393.25	0.9108	20.073	1.6827	24.562	-30.	-34.	-26.	3.	13.	0.650	0.495	-30.	2.0	11.6
1145	5	6	2139395.25	1.3072	23.351	2.1010	27.646	-26.	-30.	-25.	2.	12.	0.672	0.424	-25.	1.8	11.4
1145	5	8	2139397.25	1.8972	27.417	2.7274	31.332	-19.	-24.	-24.	0.	9.	0.695	0.362	-18.	1.5	11.1
1145	5	10	2139399.25	2.7782	31.886	3.6634	35.054	-11.	-16.	-22.	-4.	3.	0.719	0.314	-7.	1.3	10.9
1145	5	12	2139401.25	4.0143	35.294	4.9572	37.134	1.	-6.	-20.	-10.	-4.	0.745	0.285	7.	1.2	10.7
1145	5	14	2139403.25	5.4539	35.472	6.4090	35.558	13.	6.	-16.	-17.	-13.	0.772	0.282	23.	1.3	10.8
1145	5	16	2139405.25	6.7352	32.232	7.6489	30.770	24.	15.	-12.	-23.	-21.	0.800	0.305	38.	1.6	11.0
1145	5	18	2139407.25	7.6699	27.667	8.5329	25.178	31.	22.	-9.	-27.	-27.	0.829	0.349	49.	2.0	11.4
1145	5	20	2139409.25	8.3067	23.400	9.1316	20.290	35.	26.	-8.	-30.	-31.	0.858	0.406	56.	2.5	11.8
1145	5	22	2139411.25	8.7446	19.907	9.5439	16.416	37.	28.	-7.	-32.	-34.	0.888	0.471	61.	2.9	12.2
1145	5	24	2139413.25	9.0562	17.149	9.8385	13.413	37.	29.	-7.	-33.	-36.	0.918	0.541	64.	3.3	12.6
1145	5	26	2139415.25	9.2867	14.972	10.0572	11.070	37.	29.	-7.	-35.	-38.	0.949	0.614	66.	3.7	12.9
1145	5	28	2139417.25	9.4632	13.231	10.2253	9.210	36.	28.	-8.	-36.	-40.	0.979	0.688	67.	4.1	13.2
1145	5	30	2139419.25	9.6027	11.815	10.3587	7.705	35.	27.	-9.	-37.	-41.	1.010	0.763	67.	4.4	13.5
1145	6	1	2139421.25	9.7159	10.641	10.4673	6.464	34.	26.	-10.	-39.	-42.	1.042	0.838	67.	4.7	13.8
1145	6	3	2139423.25	9.8101	9.653	10.5578	5.422	33.	25.	-11.	-40.	-43.	1.073	0.914	67.	5.0	14.1
1145	6	5	2139425.25	9.8901	8.807	10.6349	4.532	32.	24.	-12.	-41.	-44.	1.104	0.989	67.	5.2	14.3
1145	6	7	2139427.25	9.9594	8.073	10.7017	3.761	31.	23.	-13.	-42.	-45.	1.136	1.064	66.	5.5	14.5
1145	6	9	2139429.25	10.0202	7.427	10.7606	3.085	29.	22.	-15.	-43.	-46.	1.167	1.138	65.	5.7	14.7
1145	6	11	2139431.25	10.0746	6.852	10.8133	2.483	28.	20.	-16.	-44.	-47.	1.198	1.211	64.	6.0	14.9

YR	MH	DY	JD	RA(DATE)	DEC	RA(J2000.0)	DEC	TWE	9PM	MN	3AM	TWB	R	DEL	ELONG	TMAG	NMAG
1066	1	27	2110441.25	23.6953	-0.466	0.4916	4.733	28.	-5.	-40.	-55.	-34.	1.240	1.789	42.	7.8	15.8
1066	1	29	2110443.25	23.6605	-0.444	0.4567	4.756	26.	-7.	-42.	-55.	-33.	1.209	1.800	39.	7.7	15.8
1066	1	31	2110445.25	23.6268	-0.417	0.4229	4.783	23.	-9.	-43.	-54.	-31.	1.178	1.810	37.	7.5	15.7
1066	2	2	2110447.25	23.5940	-0.387	24.3900	4.813	21.	-11.	-45.	-53.	-30.	1.146	1.818	34.	7.4	15.7
1066	2	4	2110449.25	23.5619	-0.354	24.3578	4.846	19.	-13.	-46.	-52.	-28.	1.115	1.825	32.	7.3	15.6
1066	2	6	2110451.25	23.5304	-0.318	24.3261	4.882	16.	-15.	-47.	-51.	-27.	1.084	1.829	29.	7.2	15.6
1066	2	8	2110453.25	23.4993	-0.280	24.2948	4.919	14.	-17.	-49.	-50.	-25.	1.052	1.832	27.	7.0	15.5
1066	2	10	2110455.25	23.4683	-0.240	24.2638	4.957	12.	-19.	-50.	-49.	-24.	1.021	1.833	25.	6.9	15.5
1066	2	12	2110457.25	23.4375	-0.200	24.2328	4.995	9.	-21.	-51.	-48.	-22.	0.990	1.832	22.	6.7	15.4
1066	2	14	2110459.25	23.4066	-0.160	24.2018	5.033	7.	-23.	-52.	-47.	-21.	0.959	1.829	20.	6.6	15.3
1066	2	16	2110461.25	23.3755	-0.121	24.1705	5.070	5.	-24.	-53.	-45.	-19.	0.929	1.824	17.	6.4	15.2
1066	2	18	2110463.25	23.3440	-0.083	24.1389	5.105	2.	-26.	-53.	-44.	-18.	0.898	1.816	15.	6.2	15.2
1066	2	20	2110465.25	23.3120	-0.046	24.1068	5.138	0.	-28.	-54.	-42.	-16.	0.868	1.806	13.	6.1	15.1
1066	2	22	2110467.25	23.2794	-0.012	24.0740	5.169	-3.	-30.	-54.	-41.	-15.	0.839	1.794	10.	5.9	15.0
1066	2	24	2110469.25	23.2461	0.019	24.0406	5.196	-5.	-32.	-55.	-39.	-14.	0.810	1.778	8.	5.7	14.9
1066	2	26	2110471.25	23.2120	0.046	24.0062	5.219	-7.	-33.	-55.	-37.	-12.	0.782	1.760	5.	5.5	14.8
1066	2	28	2110473.25	23.1769	0.070	23.9710	5.237	-10.	-35.	-55.	-36.	-11.	0.754	1.739	3.	5.3	14.7
1066	3	2	2110475.25	23.1409	0.089	23.9348	5.250	-12.	-37.	-55.	-34.	-9.	0.728	1.715	0.	5.1	14.6
1066	3	4	2110477.25	23.1039	0.103	23.8977	5.258	-15.	-38.	-55.	-32.	-8.	0.703	1.688	-2.	4.9	14.5
1066	3	6	2110479.25	23.0660	0.112	23.8596	5.260	-17.	-40.	-54.	-31.	-6.	0.679	1.657	-5.	4.7	14.4
1066	3	8	2110481.25	23.0273	0.116	23.8207	5.257	-19.	-41.	-54.	-29.	-5.	0.657	1.623	-7.	4.5	14.2
1066	3	10	2110483.25	22.9879	0.116	23.7812	5.248	-22.	-43.	-53.	-27.	-4.	0.637	1.585	-10.	4.3	14.1
1066	3	12	2110485.25	22.9482	0.112	23.7413	5.235	-24.	-44.	-53.	-25.	-2.	0.620	1.543	-12.	4.1	14.0
1066	3	14	2110487.25	22.9084	0.105	23.7014	5.219	-27.	-46.	-52.	-23.	-1.	0.605	1.498	-15.	3.9	13.9
1066	3	16	2110489.25	22.8691	0.097	23.6619	5.201	-29.	-47.	-51.	-21.	1.	0.592	1.448	-17.	3.7	13.8
1066	3	18	2110491.25	22.8309	0.090	23.6235	5.184	-31.	-48.	-50.	-19.	2.	0.583	1.395	-20.	3.6	13.7
1066	3	20	2110493.25	22.7944	0.088	23.5869	5.172	-33.	-49.	-49.	-18.	4.	0.577	1.338	-22.	3.5	13.5
1066	3	22	2110495.25	22.7605	0.095	23.5528	5.168	-35.	-51.	-48.	-16.	5.	0.575	1.278	-25.	3.3	13.4
1066	3	24	2110497.25	22.7300	0.114	23.5222	5.178	-37.	-51.	-46.	-14.	6.	0.575	1.214	-27.	3.5	13.3
1066	3	26	2110499.25	22.7038	0.152	23.4958	5.208	-39.	-52.	-45.	-12.	8.	0.580	1.147	-29.	3.4	13.2
1066	3	28	2110501.25	22.6830	0.215	23.4749	5.264	-41.	-53.	-44.	-10.	9.	0.588	1.078	-32.	3.3	13.1
1066	3	30	2110503.25	22.6687	0.311	23.4604	5.355	-43.	-53.	-42.	-9.	10.	0.598	1.006	-34.	3.2	13.0
1066	4	1	2110505.25	22.6622	0.449	23.4536	5.491	-44.	-54.	-41.	-7.	11.	0.612	0.933	-36.	3.2	12.9
1066	4	3	2110507.25	22.6650	0.641	23.4561	5.684	-45.	-54.	-40.	-5.	12.	0.629	0.857	-38.	3.1	12.8
1066	4	5	2110509.25	22.6791	0.904	23.4699	5.952	-46.	-54.	-39.	-4.	13.	0.647	0.781	-39.	3.0	12.6
1066	4	7	2110511.25	22.7073	1.259	23.4978	6.316	-47.	-54.	-37.	-3.	14.	0.668	0.703	-41.	2.8	12.5
1066	4	9	2110513.25	22.7537	1.739	23.5438	6.809	-47.	-53.	-36.	-1.	15.	0.691	0.626	-42.	2.7	12.3
1066	4	11	2110515.25	22.8246	2.392	23.6143	7.483	-47.	-53.	-35.	0.	15.	0.716	0.547	-42.	2.5	12.1
1066	4	13	2110517.25	22.9307	3.301	23.7202	8.419	-47.	-52.	-34.	0.	16.	0.741	0.469	-43.	2.3	11.8
1066	4	15	2110519.25	23.0907	4.604	23.8806	9.756	-46.	-50.	-34.	1.	16.	0.768	0.392	-42.	2.0	11.5
1066	4	17	2110521.25	23.3415	6.563	24.1334	11.750	-43.	-48.	-34.	0.	15.	0.796	0.316	-39.	1.7	11.1
1066	4	19	2110523.25	23.7630	9.697	0.5620	14.892	-39.	-45.	-34.	-2.	12.	0.825	0.243	-34.	1.2	10.6
1066	4	21	2110525.25	0.5524	15.015	1.3755	20.050	-30.	-37.	-34.	-6.	7.	0.854	0.177	-23.	0.7	10.0
1066	4	23	2110527.25	2.1910	23.196	3.0908	27.203	-10.	-20.	-32.	-16.	-5.	0.884	0.130	0.	0.1	9.4
1066	4	25	2110529.25	4.9082	27.215	5.8832	28.035	20.	8.	-19.	-27.	-23.	0.914	0.123	35.	0.1	9.3
1066	4	27	2110531.25	6.9833	22.238	7.9046	20.318	41.	28.	-6.	-30.	-33.	0.944	0.162	61.	0.8	10.0
1066	4	29	2110533.25	7.9994	17.261	8.8736	14.164	49.	37.	0.	-29.	-35.	0.975	0.224	74.	1.6	10.8
1066	5	1	2110535.25	8.5268	14.068	9.3765	10.437	51.	40.	3.	-29.	-36.	1.006	0.294	80.	2.3	11.5
1066	5	3	2110537.25	8.8392	12.004	9.6754	8.088	51.	41.	4.	-29.	-36.	1.037	0.368	83.	2.9	12.0
1066	5	5	2110539.25	9.0444	10.588	9.8723	6.498	51.	41.	4.	-29.	-37.	1.069	0.443	85.	3.4	12.5
1066	5	7	2110541.25	9.1898	9.561	10.0122	5.354	50.	40.	4.	-30.	-37.	1.100	0.519	85.	3.8	12.9
1066	5	9	2110543.25	9.2990	8.780	10.1176	4.489	49.	40.	3.	-30.	-38.	1.131	0.595	85.	4.2	13.2
1066	5	11	2110545.25	9.3849	8.163	10.2005	3.807	48.	39.	2.	-31.	-39.	1.163	0.671	85.	4.6	13.6
1066	5	13	2110547.25	9.4551	7.658	10.2684	3.252	47.	38.	1.	-32.	-39.	1.194	0.747	84.	4.9	13.9

YR	MH	DY	JD	RA(DATE)	DEC	RA(J2000.0)	DEC	TWE	9PM	MN	3AM	TWB	R	DEL	ELONG	TMAG	NMAG
989	7	17	2082488.25	4.2969	23.036	5.3163	24.768	-32.	-31.	-11.	23.	32.	1.239	1.548	-53.	7.5	15.5
989	7	19	2082490.25	4.3448	23.516	5.3681	25.178	-31.	-30.	-9.	24.	34.	1.208	1.478	-54.	7.2	15.4
989	7	21	2082492.25	4.3967	24.038	5.4245	25.623	-31.	-29.	-8.	25.	35.	1.176	1.407	-55.	7.0	15.2
989	7	23	2082494.25	4.4536	24.608	5.4862	26.110	-30.	-29.	-7.	26.	37.	1.145	1.335	-56.	6.8	15.0
989	7	25	2082496.25	4.5166	25.237	5.5545	26.645	-30.	-28.	-6.	27.	38.	1.114	1.263	-57.	6.5	14.8
989	7	27	2082498.25	4.5873	25.934	5.6312	27.237	-29.	-27.	-5.	28.	39.	1.083	1.190	-58.	6.2	14.7
989	7	29	2082500.25	4.6677	26.713	5.7182	27.895	-28.	-26.	-4.	29.	41.	1.052	1.116	-59.	6.0	14.4
989	7	31	2082502.25	4.7603	27.589	5.8185	28.632	-27.	-25.	-3.	30.	42.	1.021	1.041	-60.	5.7	14.2
989	8	2	2082504.25	4.8690	28.583	5.9358	29.462	-26.	-24.	-2.	31.	43.	0.990	0.967	-60.	5.3	14.0
989	8	4	2082506.25	4.9989	29.719	6.0756	30.401	-25.	-23.	-1.	31.	43.	0.960	0.892	-60.	5.0	13.8
989	8	6	2082508.25	5.1573	31.026	6.2454	31.467	-24.	-22.	-1.	32.	44.	0.929	0.817	-60.	4.7	13.5
989	8	8	2082510.25	5.3548	32.533	6.4558	32.674	-22.	-20.	0.	31.	44.	0.899	0.743	-59.	4.3	13.2
989	8	10	2082512.25	5.6071	34.270	6.7226	34.028	-21.	-19.	0.	31.	43.	0.870	0.671	-58.	3.9	12.9
989	8	12	2082514.25	5.9380	36.243	7.0682	35.505	-19.	-18.	-1.	29.	42.	0.841	0.601	-55.	3.5	12.6
989	8	14	2082516.25	6.3823	38.396	7.5245	37.006	-16.	-16.	-2.	27.	39.	0.812	0.535	-52.	3.1	12.3
989	8	16	2082518.25	6.9881	40.508	8.1321	38.272	-13.	-14.	-4.	22.	35.	0.784	0.475	-47.	2.7	12.0
989	8	18	2082520.25	7.8058	42.022	8.9268	38.753	-9.	-12.	-6.	16.	29.	0.757	0.425	-39.	2.3	11.6
989	8	20	2082522.25	8.8418	41.924	9.9012	37.577	-4.	-10.	-11.	8.	20.	0.732	0.390	-29.	1.9	11.4
989	8	22	2082524.25	9.9869	39.164	10.9565	33.982	2.	-8.	-16.	-2.	9.	0.707	0.373	-17.	1.7	11.2
989	8	24	2082526.25	11.0439	33.770	11.9350	28.195	7.	-5.	-21.	-13.	-3.	0.684	0.378	-3.	1.5	11.2
989	8	26	2082528.25	11.8838	27.100	12.7312	21.493	11.	-4.	-26.	-23.	-13.	0.662	0.405	9.	1.5	11.2
989	8	28	2082530.25	12.5001	20.628	13.3324	15.164	14.	-3.	-29.	-31.	-22.	0.643	0.450	18.	1.6	11.4
989	8	30	2082532.25	12.9410	15.087	13.7732	9.812	15.	-3.	-32.	-38.	-29.	0.626	0.508	25.	1.7	11.6
989	9	1	2082534.25	13.2563	10.596	14.0948	5.503	15.	-3.	-34.	-43.	-34.	0.611	0.575	29.	1.9	11.8
989	9	3	2082536.25	13.4833	7.019	14.3300	2.079	15.	-4.	-37.	-47.	-38.	0.599	0.649	32.	2.1	12.0
989	9	5	2082538.25	13.6475	4.166	14.5026	-0.651	14.	-5.	-38.	-50.	-40.	0.590	0.726	33.	2.2	12.3
989	9	7	2082540.25	13.7664	1.868	14.6291	-2.853	14.	-7.	-40.	-52.	-41.	0.584	0.804	34.	2.4	12.5
989	9	9	2082542.25	13.8517	-0.005	14.7213	-4.653	13.	-8.	-42.	-54.	-42.	0.582	0.884	34.	2.6	12.7
989	9	11	2082544.25	13.9119	-1.552	14.7875	-6.148	11.	-10.	-44.	-55.	-42.	0.583	0.963	33.	3.1	12.8
989	9	13	2082546.25	13.9532	-2.849	14.8340	-7.407	10.	-11.	-46.	-56.	-42.	0.587	1.042	32.	3.3	13.0
989	9	15	2082548.25	13.9802	-3.948	14.8654	-8.481	9.	-13.	-47.	-57.	-41.	0.595	1.118	31.	3.5	13.2
989	9	17	2082550.25	13.9964	-4.893	14.8854	-9.410	8.	-15.	-49.	-57.	-40.	0.605	1.193	30.	3.6	13.4
989	9	19	2082552.25	14.0044	-5.714	14.8968	-10.222	6.	-17.	-51.	-57.	-39.	0.619	1.265	28.	3.9	13.6
989	9	21	2082554.25	14.0064	-6.436	14.9017	-10.941	5.	-19.	-52.	-57.	-38.	0.635	1.334	26.	4.1	13.7
989	9	23	2082556.25	14.0040	-7.077	14.9019	-11.584	4.	-21.	-54.	-56.	-36.	0.654	1.401	25.	4.3	13.9
989	9	25	2082558.25	13.9985	-7.654	14.8986	-12.164	2.	-22.	-56.	-56.	-35.	0.674	1.464	23.	4.5	14.1
989	9	27	2082560.25	13.9908	-8.176	14.8929	-12.692	1.	-24.	-57.	-55.	-33.	0.697	1.524	21.	4.6	14.2
989	9	29	2082562.25	13.9816	-8.655	14.8856	-13.178	0.	-26.	-58.	-54.	-31.	0.721	1.581	19.	4.8	14.4
989	10	1	2082564.25	13.9716	-9.096	14.8772	-13.627	-2.	-28.	-60.	-54.	-29.	0.746	1.636	17.	5.0	14.5
989	10	3	2082566.25	13.9610	-9.507	14.8682	-14.047	-3.	-30.	-61.	-53.	-27.	0.772	1.687	15.	5.2	14.7
989	10	5	2082568.25	13.9503	-9.892	14.8588	-14.440	-4.	-32.	-62.	-51.	-26.	0.800	1.735	13.	5.4	14.8
989	10	7	2082570.25	13.9395	-10.255	14.8494	-14.812	-6.	-34.	-63.	-50.	-24.	0.828	1.780	11.	5.6	14.9
989	10	9	2082572.25	13.9289	-10.599	14.8400	-15.165	-7.	-35.	-64.	-49.	-22.	0.857	1.823	9.	5.7	15.1
989	10	11	2082574.25	13.9186	-10.927	14.8308	-15.501	-8.	-37.	-65.	-48.	-20.	0.886	1.863	7.	5.9	15.2
989	10	13	2082576.25	13.9085	-11.242	14.8218	-15.824	-10.	-39.	-66.	-46.	-18.	0.916	1.900	5.	6.0	15.3
989	10	15	2082578.25	13.8987	-11.544	14.8131	-16.134	-11.	-41.	-66.	-45.	-16.	0.946	1.935	3.	6.2	15.4
989	10	17	2082580.25	13.8893	-11.836	14.8046	-16.434	-13.	-43.	-67.	-44.	-14.	0.977	1.967	1.	6.3	15.5
989	10	19	2082582.25	13.8800	-12.119	14.7964	-16.724	-14.	-44.	-67.	-42.	-12.	1.008	1.997	-1.	6.5	15.6
989	10	21	2082584.25	13.8711	-12.394	14.7883	-17.006	-15.	-46.	-67.	-41.	-10.	1.039	2.024	-3.	6.6	15.7
989	10	23	2082586.25	13.8623	-12.661	14.7805	-17.280	-17.	-48.	-67.	-39.	-8.	1.070	2.050	-5.	6.7	15.8
989	10	25	2082588.25	13.8537	-12.922	14.7727	-17.548	-18.	-50.	-67.	-38.	-6.	1.101	2.073	-7.	6.8	15.9
989	10	27	2082590.25	13.8451	-13.178	14.7650	-17.810	-20.	-51.	-66.	-36.	-4.	1.132	2.094	-9.	7.0	16.0
989	10	29	2082592.25	13.8366	-13.428	14.7573	-18.067	-21.	-53.	-66.	-35.	-2.	1.163	2.113	-11.	7.1	16.1
989	10	31	2082594.25	13.8280	-13.673	14.7495	-18.319	-23.	-55.	-65.	-33.	0.	1.194	2.130	-14.	7.2	16.1

YR	MH	DY	JD	RA(DATE)	DEC	RA(J2000.0)	DEC	TWE	9PM	MN	3AM	TWB	R	DEL	ELONG	TMAG	NMAG
912	5	25	2054311.25	2.7617	17.202	3.7948	21.163	-30.	-35.	-32.	-5.	3.	1.231	2.082	-24.	8.1	16.1
912	5	27	2054313.25	2.7841	17.556	3.8198	21.489	-31.	-35.	-31.	-4.	4.	1.200	2.029	-26.	7.9	16.0
912	5	29	2054315.25	2.8074	17.928	3.8459	21.832	-31.	-35.	-30.	-2.	5.	1.169	1.973	-27.	7.7	15.9
912	5	31	2054317.25	2.8318	18.320	3.8733	22.192	-32.	-35.	-29.	-1.	7.	1.137	1.916	-29.	7.5	15.8
912	6	2	2054319.25	2.8576	18.735	3.9022	22.573	-32.	-35.	-28.	1.	8.	1.106	1.858	-30.	7.3	15.7
912	6	4	2054321.25	2.8849	19.175	3.9329	22.978	-32.	-35.	-27.	2.	10.	1.075	1.797	-32.	7.1	15.5
912	6	6	2054323.25	2.9141	19.645	3.9657	23.409	-32.	-35.	-26.	4.	11.	1.044	1.735	-33.	6.9	15.4
912	6	8	2054325.25	2.9456	20.148	4.0012	23.870	-32.	-34.	-25.	5.	13.	1.013	1.672	-34.	6.6	15.2
912	6	10	2054327.25	2.9799	20.690	4.0398	24.367	-32.	-34.	-23.	7.	14.	0.982	1.606	-36.	6.4	15.1
912	6	12	2054329.25	3.0175	21.278	4.0822	24.904	-32.	-34.	-22.	8.	16.	0.952	1.539	-37.	6.2	14.9
912	6	14	2054331.25	3.0595	21.918	4.1295	25.488	-32.	-33.	-21.	10.	17.	0.921	1.471	-38.	5.9	14.8
912	6	16	2054333.25	3.1067	22.622	4.1827	26.126	-31.	-32.	-19.	11.	18.	0.891	1.401	-39.	5.6	14.6
912	6	18	2054335.25	3.1606	23.399	4.2434	26.829	-31.	-32.	-18.	13.	20.	0.862	1.329	-40.	5.4	14.4
912	6	20	2054337.25	3.2230	24.263	4.3135	27.607	-30.	-31.	-17.	14.	21.	0.833	1.256	-41.	5.1	14.2
912	6	22	2054339.25	3.2964	25.233	4.3959	28.473	-29.	-30.	-15.	15.	22.	0.804	1.182	-42.	4.8	14.0
912	6	24	2054341.25	3.3841	26.329	4.4942	29.443	-28.	-29.	-14.	16.	24.	0.776	1.107	-42.	4.5	13.8
912	6	26	2054343.25	3.4908	27.575	4.6133	30.534	-27.	-27.	-13.	17.	25.	0.750	1.031	-42.	4.1	13.5
912	6	28	2054345.25	3.6228	29.002	4.7603	31.766	-26.	-26.	-12.	18.	26.	0.724	0.955	-42.	3.8	13.3
912	6	30	2054347.25	3.7893	30.641	4.9447	33.155	-24.	-24.	-11.	19.	26.	0.700	0.879	-42.	3.5	13.0
912	7	2	2054349.25	4.0033	32.522	5.1805	34.707	-22.	-22.	-10.	19.	26.	0.677	0.805	-40.	3.1	12.8
912	7	4	2054351.25	4.2839	34.659	5.4868	36.404	-20.	-20.	-9.	18.	26.	0.656	0.732	-38.	2.8	12.5
912	7	6	2054353.25	4.6576	37.018	5.8897	38.166	-17.	-18.	-9.	17.	24.	0.637	0.664	-35.	2.4	12.2
912	7	8	2054355.25	5.1599	39.452	6.4205	39.787	-13.	-15.	-9.	15.	22.	0.620	0.602	-31.	2.1	12.0
912	7	10	2054357.25	5.8285	41.595	7.1065	40.856	-9.	-12.	-10.	11.	18.	0.606	0.549	-25.	1.8	11.7
912	7	12	2054359.25	6.6784	42.773	7.9447	40.732	-4.	-8.	-11.	6.	12.	0.595	0.510	-17.	1.5	11.5
912	7	14	2054361.25	7.6568	42.168	8.8695	38.784	1.	-4.	-13.	-1.	5.	0.587	0.489	-7.	1.3	11.4
912	7	16	2054363.25	8.6317	39.405	9.7634	34.906	6.	0.	-15.	-9.	-4.	0.582	0.488	3.	1.3	11.4
912	7	18	2054365.25	9.4725	35.005	10.5273	29.762	10.	2.	-18.	-16.	-12.	0.580	0.508	13.	1.7	11.4
912	7	20	2054367.25	10.1290	29.979	11.1284	24.311	13.	4.	-20.	-23.	-19.	0.582	0.545	21.	1.8	11.6
912	7	22	2054369.25	10.6175	25.144	11.5826	19.258	14.	5.	-22.	-29.	-26.	0.587	0.597	27.	2.0	11.8
912	7	24	2054371.25	10.9762	20.891	11.9216	14.901	15.	5.	-24.	-34.	-30.	0.596	0.660	32.	2.3	12.1
912	7	26	2054373.25	11.2408	17.304	12.1753	11.269	15.	5.	-26.	-37.	-34.	0.607	0.729	35.	2.6	12.3
912	7	28	2054375.25	11.4384	14.327	12.3671	8.276	15.	4.	-28.	-40.	-37.	0.621	0.803	37.	2.9	12.6
912	7	30	2054377.25	11.5880	11.860	12.5138	5.807	14.	2.	-30.	-43.	-40.	0.638	0.879	38.	3.2	12.8
912	8	1	2054379.25	11.7031	9.805	12.6276	3.757	13.	1.	-32.	-45.	-41.	0.657	0.956	38.	3.4	13.1
912	8	3	2054381.25	11.7929	8.077	12.7171	2.037	12.	0.	-33.	-47.	-43.	0.679	1.033	38.	3.7	13.3
912	8	5	2054383.25	11.8640	6.609	12.7884	0.578	11.	-2.	-35.	-48.	-43.	0.702	1.109	38.	4.0	13.6
912	8	7	2054385.25	11.9213	5.348	12.8462	-0.674	9.	-3.	-37.	-49.	-44.	0.726	1.185	37.	4.2	13.8
912	8	9	2054387.25	11.9681	4.253	12.8936	-1.762	8.	-5.	-38.	-50.	-44.	0.752	1.259	37.	4.5	14.0
912	8	11	2054389.25	12.0069	3.291	12.9332	-2.716	7.	-7.	-40.	-50.	-44.	0.779	1.331	35.	4.7	14.2
912	8	13	2054391.25	12.0396	2.438	12.9667	-3.562	6.	-8.	-41.	-51.	-44.	0.806	1.402	34.	5.0	14.4
912	8	15	2054393.25	12.0677	1.675	12.9956	-4.320	5.	-10.	-43.	-51.	-43.	0.835	1.471	33.	5.2	14.5
912	8	17	2054395.25	12.0922	0.985	13.0208	-5.005	3.	-12.	-44.	-51.	-42.	0.864	1.538	32.	5.4	14.7
912	8	19	2054397.25	12.1138	0.356	13.0431	-5.628	2.	-13.	-46.	-51.	-42.	0.894	1.603	30.	5.6	14.9
912	8	21	2054399.25	12.1332	-0.221	13.0633	-6.201	1.	-15.	-47.	-51.	-41.	0.924	1.666	29.	5.8	15.0
912	8	23	2054401.25	12.1509	-0.755	13.0817	-6.730	0.	-16.	-48.	-51.	-40.	0.954	1.726	27.	6.0	15.2
912	8	25	2054403.25	12.1672	-1.252	13.0987	-7.222	-1.	-18.	-50.	-51.	-39.	0.985	1.785	26.	6.1	15.3
912	8	27	2054405.25	12.1825	-1.717	13.1146	-7.683	-2.	-19.	-51.	-51.	-37.	1.015	1.842	24.	6.3	15.5
912	8	29	2054407.25	12.1968	-2.155	13.1296	-8.117	-3.	-21.	-52.	-50.	-36.	1.046	1.897	23.	6.5	15.6
912	8	31	2054409.25	12.2105	-2.569	13.1439	-8.528	-4.	-23.	-53.	-50.	-35.	1.077	1.950	21.	6.6	15.7
912	9	2	2054411.25	12.2236	-2.963	13.1577	-8.918	-5.	-24.	-54.	-49.	-33.	1.109	2.001	20.	6.8	15.8
912	9	4	2054413.25	12.2363	-3.339	13.1710	-9.290	-7.	-26.	-55.	-48.	-32.	1.140	2.050	18.	6.9	15.9
912	9	6	2054415.25	12.2486	-3.699	13.1839	-9.646	-8.	-27.	-56.	-48.	-30.	1.171	2.097	16.	7.1	16.1
912	9	8	2054417.25	12.2605	-4.045	13.1964	-9.989	-9.	-29.	-57.	-47.	-29.	1.202	2.143	15.	7.2	16.2

YR	MH	DY	JD	RA(DATE)	DEC	RA(J2000.0)	DEC	TWE	9PM	MN	3AM	TWB	R	DEL	ELONG	TMAG	NMAG
837	1	4	2026776.25	22.9436	-5.488	23.9370	0.915	37.	4.	-33.	-59.	-45.	1.240	1.526	54.	7.4	15.5
837	1	6	2026778.25	22.8878	-5.546	23.8815	0.842	35.	1.	-35.	-60.	-43.	1.209	1.548	51.	7.3	15.5
837	1	8	2026780.25	22.8346	-5.596	23.8286	0.778	33.	-1.	-37.	-61.	-41.	1.178	1.570	49.	7.2	15.4
837	1	10	2026782.25	22.7836	-5.637	23.7779	0.721	31.	-4.	-40.	-61.	-39.	1.147	1.590	46.	7.1	15.4
837	1	12	2026784.25	22.7345	-5.672	23.7292	0.670	29.	-6.	-42.	-61.	-37.	1.116	1.609	43.	7.0	15.4
837	1	14	2026786.25	22.6871	-5.702	23.6820	0.624	26.	-8.	-44.	-60.	-35.	1.084	1.627	40.	6.9	15.3
837	1	16	2026788.25	22.6411	-5.727	23.6363	0.582	24.	-11.	-46.	-60.	-33.	1.053	1.643	38.	6.8	15.3
837	1	18	2026790.25	22.5962	-5.748	23.5917	0.543	22.	-13.	-48.	-59.	-32.	1.023	1.657	35.	6.7	15.2
837	1	20	2026792.25	22.5521	-5.768	23.5479	0.505	19.	-15.	-49.	-58.	-30.	0.992	1.670	32.	6.5	15.2
837	1	22	2026794.25	22.5088	-5.787	23.5048	0.468	17.	-17.	-51.	-57.	-28.	0.961	1.681	30.	6.4	15.1
837	1	24	2026796.25	22.4658	-5.805	23.4621	0.431	15.	-20.	-53.	-56.	-26.	0.931	1.690	27.	6.3	15.1
837	1	26	2026798.25	22.4230	-5.824	23.4196	0.392	12.	-22.	-54.	-54.	-24.	0.901	1.697	25.	6.1	15.0
837	1	28	2026800.25	22.3802	-5.845	23.3770	0.350	10.	-24.	-56.	-53.	-22.	0.871	1.702	22.	6.0	15.0
837	1	30	2026802.25	22.3371	-5.869	23.3343	0.305	7.	-26.	-57.	-51.	-21.	0.842	1.704	19.	5.8	14.9
837	2	1	2026804.25	22.2937	-5.897	23.2911	0.255	5.	-28.	-58.	-50.	-19.	0.813	1.704	17.	5.6	14.8
837	2	3	2026806.25	22.2496	-5.930	23.2474	0.198	2.	-30.	-59.	-48.	-17.	0.786	1.702	14.	5.5	14.7
837	2	5	2026808.25	22.2048	-5.968	23.2030	0.135	0.	-32.	-60.	-46.	-15.	0.759	1.696	11.	5.3	14.6
837	2	7	2026810.25	22.1591	-6.014	23.1577	0.063	-3.	-35.	-60.	-44.	-14.	0.733	1.688	9.	5.1	14.6
837	2	9	2026812.25	22.1125	-6.068	23.1115	-0.018	-6.	-37.	-61.	-42.	-12.	0.708	1.677	6.	4.9	14.5
837	2	11	2026814.25	22.0647	-6.130	23.0642	-0.109	-8.	-39.	-61.	-40.	-10.	0.685	1.662	3.	4.7	14.4
837	2	13	2026816.25	22.0160	-6.202	23.0159	-0.212	-11.	-41.	-61.	-39.	-9.	0.664	1.644	1.	4.6	14.3
837	2	15	2026818.25	21.9661	-6.284	22.9667	-0.326	-14.	-43.	-61.	-37.	-7.	0.644	1.623	-2.	4.4	14.2
837	2	17	2026820.25	21.9154	-6.377	22.9166	-0.453	-16.	-45.	-61.	-35.	-5.	0.627	1.597	-5.	4.2	14.1
837	2	19	2026822.25	21.8639	-6.481	22.8657	-0.592	-19.	-47.	-60.	-33.	-4.	0.612	1.568	-8.	4.1	14.0
837	2	21	2026824.25	21.8118	-6.595	22.8145	-0.744	-22.	-48.	-60.	-31.	-2.	0.600	1.535	-10.	3.9	13.9
837	2	23	2026826.25	21.7596	-6.721	22.7630	-0.908	-24.	-50.	-59.	-29.	-1.	0.591	1.498	-13.	3.8	13.8
837	2	25	2026828.25	21.7075	-6.857	22.7118	-1.083	-27.	-52.	-58.	-26.	1.	0.585	1.457	-16.	3.7	13.8
837	2	27	2026830.25	21.6560	-7.002	22.6613	-1.268	-30.	-54.	-57.	-24.	3.	0.582	1.412	-19.	3.6	13.7
837	3	1	2026832.25	21.6056	-7.156	22.6118	-1.461	-33.	-55.	-55.	-22.	4.	0.583	1.364	-21.	3.8	13.6
837	3	3	2026834.25	21.5565	-7.317	22.5638	-1.662	-35.	-57.	-54.	-20.	6.	0.587	1.312	-24.	3.8	13.5
837	3	5	2026836.25	21.5092	-7.485	22.5176	-1.869	-38.	-58.	-53.	-18.	7.	0.595	1.256	-27.	3.7	13.5
837	3	7	2026838.25	21.4640	-7.659	22.4734	-2.081	-40.	-59.	-51.	-17.	8.	0.605	1.198	-30.	3.7	13.4
837	3	9	2026840.25	21.4210	-7.838	22.4315	-2.297	-43.	-61.	-50.	-15.	10.	0.619	1.137	-32.	3.6	13.3
837	3	11	2026842.25	21.3803	-8.024	22.3920	-2.517	-45.	-62.	-48.	-13.	11.	0.635	1.074	-35.	3.6	13.3
837	3	13	2026844.25	21.3420	-8.215	22.3549	-2.743	-47.	-62.	-47.	-11.	12.	0.653	1.009	-37.	3.5	13.2
837	3	15	2026846.25	21.3059	-8.416	22.3200	-2.975	-50.	-63.	-45.	-9.	13.	0.674	0.942	-40.	3.5	13.1
837	3	17	2026848.25	21.2718	-8.627	22.2872	-3.218	-52.	-63.	-43.	-7.	15.	0.696	0.874	-42.	3.4	13.0
837	3	19	2026850.25	21.2393	-8.854	22.2560	-3.475	-54.	-64.	-42.	-6.	16.	0.720	0.804	-45.	3.4	12.9
837	3	21	2026852.25	21.2079	-9.104	22.2260	-3.753	-56.	-64.	-40.	-4.	17.	0.745	0.733	-47.	3.3	12.8
837	3	23	2026854.25	21.1769	-9.385	22.1966	-4.064	-58.	-64.	-39.	-2.	18.	0.771	0.661	-50.	3.2	12.6
837	3	25	2026856.25	21.1452	-9.714	22.1668	-4.422	-59.	-64.	-37.	-1.	19.	0.799	0.589	-52.	3.0	12.5
837	3	27	2026858.25	21.1113	-10.112	22.1350	-4.853	-61.	-64.	-36.	1.	20.	0.827	0.516	-55.	2.9	12.2
837	3	29	2026860.25	21.0725	-10.620	22.0991	-5.398	-63.	-64.	-34.	3.	21.	0.856	0.442	-58.	2.6	12.0
837	3	31	2026862.25	21.0244	-11.309	22.0549	-6.133	-65.	-63.	-32.	4.	21.	0.885	0.368	-60.	2.4	11.7
837	4	2	2026864.25	20.9577	-12.319	21.9940	-7.209	-67.	-63.	-31.	6.	22.	0.915	0.294	-64.	2.0	11.2
837	4	4	2026866.25	20.8510	-13.981	21.8974	-8.979	-69.	-63.	-29.	7.	23.	0.945	0.220	-67.	1.5	10.7
837	4	6	2026868.25	20.6375	-17.270	21.7057	-12.492	-72.	-62.	-26.	9.	23.	0.976	0.146	-73.	0.7	9.9
837	4	8	2026870.25	19.9629	-26.594	21.1094	-22.604	-74.	-58.	-21.	10.	21.	1.006	0.075	-86.	-0.7	8.5
837	4	10	2026872.25	13.4747	-43.936	14.7037	-49.468	-8.	1.	11.	1.	-9.	1.037	0.034	-166.	-2.3	6.9
837	4	12	2026874.25	10.2130	-9.001	11.1727	-15.097	44.	46.	25.	-10.	-26.	1.068	0.090	132.	-0.1	9.0
837	4	14	2026876.25	9.7749	-1.488	10.7510	-7.302	53.	51.	23.	-13.	-28.	1.099	0.162	121.	1.3	10.4
837	4	16	2026878.25	9.6144	1.351	10.5997	-4.342	56.	52.	22.	-15.	-29.	1.130	0.236	116.	2.2	11.2
837	4	18	2026880.25	9.5343	2.816	10.5250	-2.813	58.	52.	20.	-16.	-30.	1.162	0.310	112.	2.9	11.9
837	4	20	2026882.25	9.4887	3.700	10.4828	-1.893	58.	51.	19.	-18.	-31.	1.193	0.385	109.	3.5	12.4

YR	MH	DY	JD	RA(DATE)	DEC	RA(J2000.0)	DEC	TWE	9PM	MN	3AM	TWB	R	DEL	ELONG	TMAG	NMAG
760	3	27	1998734.25	1.0082	7.439	2.0985	13.777	-8.	-26.	-47.	-33.	-16.	1.231	2.225	6.	8.2	16.3
760	3	29	1998736.25	1.0071	7.660	2.0981	13.998	-10.	-27.	-47.	-32.	-15.	1.200	2.200	4.	8.1	16.2
760	3	31	1998738.25	1.0060	7.887	2.0978	14.226	-12.	-29.	-47.	-31.	-14.	1.168	2.173	2.	7.9	16.1
760	4	2	1998740.25	1.0049	8.120	2.0974	14.459	-13.	-30.	-47.	-29.	-13.	1.137	2.144	1.	7.7	16.0
760	4	4	1998742.25	1.0038	8.360	2.0971	14.700	-15.	-31.	-47.	-28.	-12.	1.106	2.112	-1.	7.6	15.9
760	4	6	1998744.25	1.0027	8.608	2.0967	14.948	-17.	-32.	-46.	-27.	-11.	1.075	2.079	-3.	7.4	15.8
760	4	8	1998746.25	1.0014	8.864	2.0963	15.205	-18.	-32.	-46.	-25.	-10.	1.044	2.043	-5.	7.2	15.7
760	4	10	1998748.25	1.0001	9.130	2.0959	15.471	-20.	-33.	-45.	-24.	-9.	1.013	2.006	-7.	7.0	15.6
760	4	12	1998750.25	0.9988	9.406	2.0954	15.748	-21.	-34.	-45.	-22.	-7.	0.982	1.966	-9.	6.9	15.5
760	4	14	1998752.25	0.9974	9.694	2.0950	16.036	-23.	-35.	-44.	-21.	-6.	0.952	1.923	-11.	6.7	15.4
760	4	16	1998754.25	0.9960	9.995	2.0946	16.338	-24.	-36.	-43.	-19.	-5.	0.922	1.879	-12.	6.4	15.3
760	4	18	1998756.25	0.9948	10.312	2.0944	16.656	-26.	-36.	-43.	-18.	-4.	0.892	1.832	-14.	6.2	15.2
760	4	20	1998758.25	0.9937	10.647	2.0944	16.991	-27.	-37.	-42.	-16.	-3.	0.862	1.782	-16.	6.0	15.0
760	4	22	1998760.25	0.9931	11.002	2.0950	17.346	-28.	-38.	-41.	-14.	-1.	0.833	1.730	-18.	5.8	14.9
760	4	24	1998762.25	0.9931	11.382	2.0962	17.726	-30.	-38.	-40.	-13.	0.	0.805	1.675	-20.	5.5	14.7
760	4	26	1998764.25	0.9940	11.791	2.0986	18.133	-31.	-39.	-39.	-11.	1.	0.777	1.618	-21.	5.3	14.6
760	4	28	1998766.25	0.9963	12.234	2.1025	18.574	-32.	-39.	-37.	-9.	3.	0.751	1.558	-23.	5.0	14.4
760	4	30	1998768.25	1.0005	12.718	2.1085	19.054	-32.	-39.	-36.	-8.	4.	0.725	1.495	-25.	4.8	14.3
760	5	2	1998770.25	1.0075	13.251	2.1175	19.582	-33.	-39.	-35.	-6.	6.	0.701	1.430	-26.	4.5	14.1
760	5	4	1998772.25	1.0181	13.846	2.1306	20.168	-34.	-39.	-34.	-4.	7.	0.678	1.362	-28.	4.3	13.9
760	5	6	1998774.25	1.0339	14.514	2.1494	20.824	-34.	-39.	-32.	-3.	8.	0.657	1.291	-29.	4.0	13.7
760	5	8	1998776.25	1.0567	15.274	2.1757	21.566	-34.	-38.	-31.	-1.	10.	0.638	1.218	-31.	3.7	13.6
760	5	10	1998778.25	1.0888	16.149	2.2124	22.415	-34.	-38.	-29.	1.	11.	0.622	1.142	-32.	3.5	13.4
760	5	12	1998780.25	1.1337	17.166	2.2629	23.395	-34.	-37.	-28.	2.	12.	0.608	1.064	-33.	3.2	13.2
760	5	14	1998782.25	1.1957	18.362	2.3324	24.540	-33.	-36.	-26.	4.	14.	0.596	0.985	-33.	2.9	12.9
760	5	16	1998784.25	1.2812	19.785	2.4278	25.888	-32.	-35.	-25.	5.	15.	0.588	0.905	-34.	2.7	12.7
760	5	18	1998786.25	1.3988	21.493	2.5587	27.488	-31.	-33.	-23.	6.	15.	0.583	0.825	-33.	2.5	12.5
760	5	20	1998788.25	1.5609	23.556	2.7393	29.393	-29.	-31.	-22.	7.	16.	0.582	0.746	-32.	2.5	12.3
760	5	22	1998790.25	1.7858	26.053	2.9902	31.651	-26.	-28.	-20.	8.	16.	0.584	0.669	-30.	2.3	12.1
760	5	24	1998792.25	2.1003	29.048	3.3419	34.274	-22.	-25.	-19.	8.	15.	0.589	0.597	-27.	2.1	11.8
760	5	26	1998794.25	2.5435	32.528	3.8373	37.163	-18.	-21.	-17.	6.	14.	0.597	0.531	-22.	1.8	11.6
760	5	28	1998796.25	3.1674	36.266	4.5288	39.958	-12.	-15.	-16.	4.	11.	0.609	0.476	-15.	1.7	11.4
760	5	30	1998798.25	4.0191	39.599	5.4500	41.850	-5.	-9.	-15.	0.	6.	0.623	0.436	-6.	1.6	11.3
760	6	1	1998800.25	5.0839	41.381	6.5476	41.716	3.	-2.	-14.	-5.	0.	0.640	0.414	5.	1.5	11.2
760	6	3	1998802.25	6.2199	40.654	7.6486	38.982	11.	6.	-12.	-11.	-7.	0.659	0.415	17.	1.6	11.3
760	6	5	1998804.25	7.2296	37.657	8.5796	34.355	18.	12.	-12.	-16.	-14.	0.680	0.436	27.	1.9	11.5
760	6	7	1998806.25	8.0152	33.567	9.2870	29.152	23.	16.	-11.	-21.	-20.	0.703	0.475	36.	2.1	11.7
760	6	9	1998808.25	8.5917	29.421	9.8039	24.296	26.	19.	-11.	-26.	-25.	0.727	0.528	42.	2.5	12.0
760	6	11	1998810.25	9.0114	25.716	10.1821	20.138	27.	20.	-12.	-29.	-29.	0.753	0.589	47.	2.8	12.3
760	6	13	1998812.25	9.3217	22.574	10.4639	16.698	28.	20.	-13.	-32.	-32.	0.779	0.656	50.	3.2	12.6
760	6	15	1998814.25	9.5567	19.955	10.6790	13.877	28.	20.	-13.	-34.	-35.	0.807	0.727	52.	3.5	12.9
760	6	17	1998816.25	9.7390	17.775	10.8472	11.555	27.	20.	-15.	-36.	-37.	0.835	0.800	53.	3.9	13.2
760	6	19	1998818.25	9.8840	15.950	10.9817	9.625	26.	19.	-16.	-38.	-39.	0.864	0.875	54.	4.2	13.5
760	6	21	1998820.25	10.0018	14.406	11.0917	8.001	25.	18.	-17.	-39.	-41.	0.894	0.950	54.	4.5	13.7
760	6	23	1998822.25	10.0995	13.085	11.1834	6.620	24.	16.	-18.	-41.	-42.	0.924	1.025	54.	4.7	14.0
760	6	25	1998824.25	10.1820	11.944	11.2612	5.429	23.	15.	-20.	-42.	-43.	0.954	1.099	53.	5.0	14.2
760	6	27	1998826.25	10.2529	10.946	11.3282	4.391	21.	14.	-21.	-43.	-44.	0.985	1.173	53.	5.2	14.4
760	6	29	1998828.25	10.3147	10.064	11.3870	3.477	20.	12.	-23.	-44.	-45.	1.016	1.247	52.	5.5	14.6
760	7	1	1998830.25	10.3695	9.278	11.4391	2.663	19.	11.	-24.	-45.	-46.	1.047	1.319	51.	5.7	14.8
760	7	3	1998832.25	10.4185	8.571	11.4859	1.931	17.	9.	-26.	-46.	-46.	1.078	1.391	50.	5.9	15.0
760	7	5	1998834.25	10.4629	7.929	11.5286	1.269	16.	8.	-27.	-47.	-47.	1.109	1.461	49.	6.1	15.1
760	7	7	1998836.25	10.5036	7.341	11.5677	0.663	15.	6.	-28.	-48.	-47.	1.140	1.531	48.	6.3	15.3
760	7	9	1998838.25	10.5413	6.800	11.6040	0.106	13.	5.	-30.	-48.	-47.	1.171	1.599	47.	6.5	15.5
760	7	11	1998840.25	10.5765	6.299	11.6380	-0.410	12.	3.	-31.	-49.	-47.	1.202	1.666	46.	6.7	15.6

YR	MM	DY	JD	RA(DATE)	DEC	RA(J2000.0)	DEC	TWE	9PM	MN	3AM	TWB	R	DEL	ELONG	TMAG	NMAG
684	8	9	1971110.25	4.5932	23.513	5.9294	24.924	-30.	-26.	1.	36.	49.	1.232	1.160	-69.	6.8	14.9
684	8	11	1971112.25	4.6528	24.140	5.9954	25.432	-30.	-25.	2.	37.	50.	1.201	1.086	-70.	6.5	14.7
684	8	13	1971114.25	4.7200	24.849	6.0700	26.008	-29.	-24.	3.	38.	52.	1.170	1.011	-71.	6.3	14.5
684	8	15	1971116.25	4.7972	25.660	6.1555	26.665	-28.	-23.	4.	39.	53.	1.139	0.936	-72.	6.0	14.2
684	8	17	1971118.25	4.8875	26.600	6.2555	27.423	-27.	-22.	5.	40.	54.	1.108	0.861	-72.	5.6	14.0
684	8	19	1971120.25	4.9955	27.700	6.3750	28.306	-26.	-21.	6.	40.	55.	1.077	0.785	-73.	5.3	13.7
684	8	21	1971122.25	5.1282	29.007	6.5212	29.346	-25.	-19.	6.	41.	56.	1.045	0.710	-73.	4.9	13.5
684	8	23	1971124.25	5.2960	30.581	6.7053	30.582	-24.	-18.	7.	41.	56.	1.014	0.635	-72.	4.6	13.1
684	8	25	1971126.25	5.5158	32.499	6.9444	32.060	-22.	-17.	7.	40.	56.	0.984	0.562	-71.	4.1	12.8
684	8	27	1971128.25	5.8157	34.852	7.2666	33.819	-20.	-16.	7.	39.	55.	0.953	0.490	-69.	3.7	12.4
684	8	29	1971130.25	6.2444	37.711	7.7183	35.850	-17.	-14.	6.	36.	53.	0.923	0.421	-66.	3.2	12.0
684	8	31	1971132.25	6.8872	40.989	8.3740	37.955	-14.	-13.	3.	32.	48.	0.893	0.359	-60.	2.7	11.6
684	9	2	1971134.25	7.8754	44.006	9.3340	39.388	-9.	-11.	-1.	24.	39.	0.863	0.306	-51.	2.2	11.2
684	9	4	1971136.25	9.3011	44.690	10.6410	38.377	-2.	-9.	-7.	13.	27.	0.834	0.269	-37.	1.7	10.9
684	9	6	1971138.25	10.9231	40.284	12.0905	33.028	6.	-6.	-15.	-2.	11.	0.805	0.256	-19.	1.5	10.7
684	9	8	1971140.25	12.2523	31.544	13.3199	24.381	13.	-3.	-22.	-17.	-6.	0.777	0.271	1.	1.4	10.7
684	9	10	1971142.25	13.1427	22.329	14.1921	15.695	17.	-2.	-28.	-30.	-19.	0.751	0.311	15.	1.5	10.9
684	9	12	1971144.25	13.7137	14.831	14.7777	8.739	19.	-2.	-32.	-39.	-28.	0.725	0.366	25.	1.7	11.2
684	9	14	1971146.25	14.0882	9.230	15.1738	3.576	19.	-2.	-34.	-45.	-35.	0.700	0.432	31.	1.9	11.5
684	9	16	1971148.25	14.3417	5.090	15.4480	-0.229	19.	-3.	-36.	-49.	-39.	0.678	0.504	34.	2.1	11.8
684	9	18	1971150.25	14.5177	1.981	15.6416	-3.089	19.	-4.	-38.	-53.	-41.	0.656	0.580	36.	2.3	12.0
684	9	20	1971152.25	14.6411	-0.408	15.7797	-5.295	18.	-5.	-40.	-55.	-43.	0.637	0.658	37.	2.4	12.2
684	9	22	1971154.25	14.7273	-2.289	15.8781	-7.043	17.	-7.	-42.	-57.	-44.	0.620	0.737	36.	2.5	12.4
684	9	24	1971156.25	14.7861	-3.802	15.9470	-8.462	15.	-8.	-43.	-58.	-44.	0.606	0.816	36.	2.6	12.6
684	9	26	1971158.25	14.8240	-5.042	15.9934	-9.640	14.	-10.	-45.	-59.	-43.	0.595	0.894	35.	2.7	12.7
684	9	28	1971160.25	14.8456	-6.077	16.0223	-10.637	13.	-12.	-47.	-60.	-42.	0.586	0.972	33.	2.8	12.9
684	9	30	1971162.25	14.8546	-6.953	16.0372	-11.495	12.	-14.	-49.	-60.	-41.	0.581	1.048	32.	3.0	13.0
684	10	2	1971164.25	14.8534	-7.706	16.0413	-12.246	10.	-16.	-51.	-60.	-40.	0.580	1.122	30.	3.1	13.2
684	10	4	1971166.25	14.8444	-8.361	16.0367	-12.911	9.	-18.	-52.	-60.	-38.	0.581	1.193	28.	3.5	13.3
684	10	6	1971168.25	14.8292	-8.938	16.0253	-13.507	7.	-20.	-54.	-59.	-37.	0.586	1.261	26.	3.7	13.4
684	10	8	1971170.25	14.8094	-9.451	16.0089	-14.048	6.	-22.	-56.	-59.	-35.	0.595	1.327	24.	3.8	13.6
684	10	10	1971172.25	14.7862	-9.914	15.9887	-14.543	4.	-24.	-57.	-58.	-33.	0.606	1.388	22.	4.0	13.7
684	10	12	1971174.25	14.7608	-10.334	15.9659	-14.999	3.	-26.	-59.	-57.	-31.	0.620	1.447	19.	4.1	13.9
684	10	14	1971176.25	14.7339	-10.721	15.9413	-15.423	1.	-28.	-61.	-56.	-29.	0.637	1.502	17.	4.3	14.0
684	10	16	1971178.25	14.7062	-11.079	15.9157	-15.821	-1.	-30.	-62.	-54.	-26.	0.656	1.553	15.	4.5	14.1
684	10	18	1971180.25	14.6783	-11.414	15.8896	-16.195	-2.	-32.	-63.	-53.	-24.	0.677	1.601	13.	4.7	14.3
684	10	20	1971182.25	14.6504	-11.730	15.8635	-16.550	-4.	-34.	-65.	-52.	-22.	0.700	1.645	10.	4.8	14.4
684	10	22	1971184.25	14.6229	-12.030	15.8376	-16.888	-5.	-36.	-66.	-50.	-20.	0.724	1.686	8.	5.0	14.5
684	10	24	1971186.25	14.5960	-12.316	15.8121	-17.211	-7.	-38.	-67.	-48.	-18.	0.750	1.724	6.	5.2	14.7
684	10	26	1971188.25	14.5698	-12.590	15.7873	-17.522	-9.	-40.	-67.	-47.	-15.	0.777	1.758	3.	5.3	14.8
684	10	28	1971190.25	14.5442	-12.855	15.7631	-17.822	-10.	-42.	-68.	-45.	-13.	0.805	1.790	1.	5.5	14.9
684	10	30	1971192.25	14.5194	-13.112	15.7395	-18.113	-12.	-44.	-68.	-43.	-11.	0.833	1.818	-1.	5.6	15.0
684	11	1	1971194.25	14.4953	-13.361	15.7166	-18.395	-14.	-46.	-68.	-42.	-9.	0.862	1.844	-3.	5.8	15.1
684	11	3	1971196.25	14.4718	-13.604	15.6942	-18.670	-15.	-48.	-68.	-40.	-7.	0.892	1.867	-6.	5.9	15.2
684	11	5	1971198.25	14.4489	-13.842	15.6724	-18.938	-17.	-50.	-68.	-38.	-5.	0.922	1.887	-8.	6.0	15.3
684	11	7	1971200.25	14.4265	-14.075	15.6511	-19.201	-19.	-52.	-67.	-36.	-2.	0.952	1.905	-10.	6.2	15.4
684	11	9	1971202.25	14.4044	-14.304	15.6301	-19.459	-20.	-54.	-66.	-35.	0.	0.983	1.921	-13.	6.3	15.5
684	11	11	1971204.25	14.3827	-14.529	15.6093	-19.713	-22.	-56.	-66.	-33.	2.	1.014	1.934	-15.	6.4	15.6
684	11	13	1971206.25	14.3611	-14.750	15.5887	-19.963	-24.	-58.	-64.	-31.	4.	1.045	1.945	-17.	6.5	15.6
684	11	15	1971208.25	14.3396	-14.968	15.5681	-20.209	-26.	-60.	-63.	-29.	6.	1.076	1.954	-19.	6.6	15.7
684	11	17	1971210.25	14.3180	-15.184	15.5474	-20.453	-28.	-61.	-62.	-27.	8.	1.107	1.961	-22.	6.7	15.8
684	11	19	1971212.25	14.2963	-15.396	15.5265	-20.693	-29.	-63.	-61.	-25.	10.	1.138	1.966	-24.	6.8	15.8
684	11	21	1971214.25	14.2743	-15.606	15.5052	-20.931	-31.	-65.	-59.	-23.	11.	1.170	1.969	-26.	6.9	15.9
684	11	23	1971216.25	14.2518	-15.812	15.4835	-21.167	-33.	-66.	-57.	-22.	13.	1.201	1.970	-28.	7.0	16.0

YR	MH	DY	JD	RA(DATE)	DEC	RA(J2000.0)	DEC	TWE	9PM	MN	3AM	TWB	R	DEL	ELONG	TMAG	NMAG
607	1	19	1942783.25	23.1474	-4.739	24.3345	2.989	29.	-5.	-40.	-60.	-38.	1.243	1.743	44.	7.7	15.8
607	1	21	1942785.25	23.1087	-4.711	24.2959	3.012	27.	-7.	-42.	-59.	-36.	1.212	1.757	42.	7.6	15.7
607	1	23	1942787.25	23.0714	-4.677	24.2586	3.039	25.	-9.	-44.	-59.	-34.	1.181	1.769	39.	7.5	15.7
607	1	25	1942789.25	23.0351	-4.639	24.2223	3.070	23.	-11.	-46.	-58.	-33.	1.150	1.780	37.	7.4	15.7
607	1	27	1942791.25	22.9998	-4.598	24.1870	3.104	21.	-13.	-47.	-57.	-31.	1.119	1.789	34.	7.3	15.6
607	1	29	1942793.25	22.9652	-4.554	24.1524	3.141	18.	-15.	-49.	-56.	-29.	1.088	1.797	32.	7.1	15.6
607	1	31	1942795.25	22.9311	-4.508	24.1184	3.179	16.	-17.	-50.	-55.	-28.	1.057	1.803	29.	7.0	15.5
607	2	2	1942797.25	22.8975	-4.460	24.0848	3.218	14.	-19.	-52.	-54.	-26.	1.026	1.806	27.	6.9	15.4
607	2	4	1942799.25	22.8641	-4.411	24.0513	3.258	12.	-21.	-53.	-53.	-24.	0.995	1.808	24.	6.7	15.4
607	2	6	1942801.25	22.8307	-4.361	24.0179	3.297	9.	-23.	-54.	-51.	-23.	0.964	1.808	22.	6.6	15.3
607	2	8	1942803.25	22.7972	-4.312	23.9844	3.336	7.	-25.	-55.	-50.	-21.	0.934	1.806	19.	6.4	15.2
607	2	10	1942805.25	22.7635	-4.264	23.9507	3.373	5.	-27.	-56.	-48.	-20.	0.903	1.802	17.	6.3	15.2
607	2	12	1942807.25	22.7293	-4.217	23.9165	3.408	2.	-29.	-57.	-47.	-18.	0.874	1.795	14.	6.1	15.1
607	2	14	1942809.25	22.6946	-4.172	23.8817	3.440	0.	-31.	-58.	-45.	-16.	0.844	1.786	12.	5.9	15.0
607	2	16	1942811.25	22.6592	-4.130	23.8463	3.469	-3.	-33.	-58.	-44.	-15.	0.816	1.774	10.	5.7	14.9
607	2	18	1942813.25	22.6230	-4.090	23.8100	3.493	-5.	-34.	-59.	-42.	-13.	0.788	1.759	7.	5.5	14.8
607	2	20	1942815.25	22.5859	-4.055	23.7729	3.514	-8.	-36.	-59.	-40.	-12.	0.761	1.741	5.	5.4	14.7
607	2	22	1942817.25	22.5478	-4.023	23.7348	3.529	-10.	-38.	-59.	-38.	-10.	0.735	1.721	2.	5.2	14.6
607	2	24	1942819.25	22.5088	-3.995	23.6958	3.538	-13.	-40.	-59.	-36.	-9.	0.710	1.697	0.	5.0	14.5
607	2	26	1942821.25	22.4687	-3.972	23.6557	3.542	-15.	-42.	-59.	-35.	-7.	0.686	1.670	-3.	4.8	14.4
607	2	28	1942823.25	22.4278	-3.953	23.6147	3.540	-18.	-43.	-58.	-33.	-6.	0.665	1.639	-6.	4.6	14.3
607	3	2	1942825.25	22.3860	-3.938	23.5729	3.533	-20.	-45.	-58.	-31.	-4.	0.645	1.605	-8.	4.4	14.2
607	3	4	1942827.25	22.3436	-3.927	23.5306	3.521	-22.	-47.	-57.	-29.	-3.	0.627	1.567	-11.	4.2	14.1
607	3	6	1942829.25	22.3009	-3.919	23.4879	3.505	-25.	-48.	-56.	-27.	-1.	0.612	1.525	-13.	4.0	14.0
607	3	8	1942831.25	22.2583	-3.912	23.4453	3.487	-27.	-50.	-55.	-25.	0.	0.600	1.479	-16.	3.9	13.8
607	3	10	1942833.25	22.2162	-3.905	23.4033	3.468	-30.	-51.	-54.	-23.	2.	0.590	1.430	-18.	3.7	13.7
607	3	12	1942835.25	22.1752	-3.895	23.3623	3.452	-32.	-52.	-53.	-21.	3.	0.584	1.377	-21.	3.6	13.6
607	3	14	1942837.25	22.1360	-3.880	23.3231	3.442	-34.	-53.	-52.	-19.	5.	0.581	1.320	-23.	3.5	13.5
607	3	16	1942839.25	22.0993	-3.854	23.2864	3.443	-37.	-55.	-50.	-17.	6.	0.582	1.260	-26.	3.6	13.4
607	3	18	1942841.25	22.0657	-3.816	23.2527	3.458	-39.	-55.	-49.	-15.	7.	0.585	1.196	-28.	3.5	13.3
607	3	20	1942843.25	22.0360	-3.758	23.2228	3.495	-41.	-56.	-47.	-13.	9.	0.592	1.130	-31.	3.5	13.2
607	3	22	1942845.25	22.0110	-3.677	23.1976	3.558	-43.	-57.	-46.	-12.	10.	0.603	1.062	-33.	3.4	13.1
607	3	24	1942847.25	21.9915	-3.563	23.1777	3.657	-45.	-57.	-45.	-10.	11.	0.616	0.991	-35.	3.3	13.0
607	3	26	1942849.25	21.9784	-3.410	23.1642	3.800	-46.	-58.	-43.	-8.	13.	0.632	0.918	-37.	3.2	12.9
607	3	28	1942851.25	21.9728	-3.206	23.1579	4.000	-48.	-58.	-42.	-6.	14.	0.650	0.844	-39.	3.1	12.8
607	3	30	1942853.25	21.9760	-2.936	23.1602	4.272	-49.	-58.	-40.	-5.	15.	0.670	0.769	-41.	3.0	12.7
607	4	1	1942855.25	21.9901	-2.579	23.1731	4.639	-50.	-58.	-39.	-3.	16.	0.693	0.692	-43.	2.9	12.5
607	4	3	1942857.25	22.0177	-2.105	23.1993	5.132	-50.	-57.	-38.	-2.	17.	0.716	0.615	-44.	2.8	12.3
607	4	5	1942859.25	22.0635	-1.465	23.2431	5.804	-51.	-56.	-36.	-1.	17.	0.742	0.538	-45.	2.6	12.1
607	4	7	1942861.25	22.1349	-0.580	23.3121	6.737	-50.	-56.	-35.	0.	18.	0.768	0.461	-46.	2.4	11.8
607	4	9	1942863.25	22.2455	0.694	23.4199	8.081	-50.	-54.	-34.	1.	18.	0.795	0.383	-46.	2.1	11.5
607	4	11	1942865.25	22.4224	2.636	23.5939	10.121	-48.	-52.	-33.	2.	18.	0.824	0.307	-44.	1.7	11.1
607	4	13	1942867.25	22.7275	5.859	23.8981	13.480	-44.	-49.	-33.	1.	18.	0.852	0.232	-41.	1.2	10.6
607	4	15	1942869.25	23.3319	11.894	24.5153	19.638	-36.	-42.	-32.	-1.	15.	0.882	0.162	-32.	0.6	9.9
607	4	17	1942871.25	0.8251	24.101	2.1133	31.284	-15.	-24.	-29.	-8.	5.	0.912	0.106	-8.	-0.2	9.0
607	4	19	1942873.25	4.3238	34.719	5.8706	36.540	26.	13.	-13.	-20.	-16.	0.942	0.093	38.	-0.4	8.8
607	4	21	1942875.25	6.9282	27.341	8.3414	24.124	52.	37.	3.	-22.	-27.	0.972	0.136	69.	0.5	9.7
607	4	23	1942877.25	7.9081	20.932	9.2300	16.103	59.	45.	9.	-22.	-30.	1.003	0.202	82.	1.5	10.6
607	4	25	1942879.25	8.3558	17.330	9.6375	11.856	60.	47.	11.	-22.	-31.	1.034	0.275	87.	2.2	11.4
607	4	27	1942881.25	8.6068	15.146	9.8674	9.338	59.	47.	11.	-22.	-32.	1.065	0.350	89.	2.9	12.0
607	4	29	1942883.25	8.7675	13.697	10.0155	7.686	58.	47.	10.	-23.	-32.	1.096	0.426	90.	3.4	12.4
607	5	1	1942885.25	8.8801	12.665	10.1197	6.519	57.	46.	10.	-24.	-33.	1.127	0.502	90.	3.8	12.9
607	5	3	1942887.25	8.9646	11.890	10.1981	5.644	56.	45.	9.	-25.	-34.	1.158	0.578	89.	4.2	13.2
607	5	5	1942889.25	9.0312	11.281	10.2602	4.960	55.	44.	8.	-26.	-35.	1.190	0.654	88.	4.6	13.6

YR	MH	DY	JD	RA(DATE)	DEC	RA(J2000.0)	DEC	TWE	9PM	MN	3AM	TWB	R	DEL	ELONG	TMAG	NMAG
530	8	4	1914856.25	4.3502	22.397	5.8309	24.331	-32.	-28.	-2.	33.	45.	1.229	1.228	-66.	6.9	15.0
530	8	6	1914858.25	4.4080	22.989	5.8954	24.796	-31.	-27.	-1.	34.	46.	1.198	1.154	-67.	6.7	14.8
530	8	8	1914860.25	4.4727	23.653	5.9676	25.316	-30.	-26.	0.	35.	47.	1.167	1.080	-68.	6.4	14.6
530	8	10	1914862.25	4.5462	24.405	6.0497	25.905	-29.	-25.	1.	36.	49.	1.135	1.005	-69.	6.1	14.4
530	8	12	1914864.25	4.6312	25.265	6.1445	26.575	-29.	-24.	2.	37.	50.	1.104	0.930	-69.	5.8	14.2
530	8	14	1914866.25	4.7313	26.261	6.2562	27.346	-28.	-23.	3.	38.	51.	1.073	0.855	-70.	5.5	13.9
530	8	16	1914868.25	4.8521	27.427	6.3904	28.241	-27.	-22.	4.	38.	52.	1.042	0.779	-70.	5.1	13.6
530	8	18	1914870.25	5.0014	28.809	6.5556	29.287	-25.	-21.	4.	39.	53.	1.010	0.704	-70.	4.8	13.4
530	8	20	1914872.25	5.1916	30.466	6.7646	30.517	-24.	-19.	5.	38.	53.	0.979	0.630	-69.	4.4	13.1
530	8	22	1914874.25	5.4422	32.469	7.0370	31.959	-22.	-18.	5.	38.	53.	0.949	0.557	-68.	3.9	12.7
530	8	24	1914876.25	5.7853	34.887	7.4040	33.620	-20.	-17.	4.	36.	51.	0.918	0.487	-65.	3.5	12.4
530	8	26	1914878.25	6.2746	37.728	7.9147	35.415	-17.	-16.	3.	33.	48.	0.888	0.420	-61.	3.0	12.0
530	8	28	1914880.25	6.9973	40.752	8.6400	37.001	-13.	-14.	0.	28.	42.	0.858	0.361	-55.	2.5	11.6
530	8	30	1914882.25	8.0610	43.006	9.6511	37.443	-8.	-12.	-4.	19.	33.	0.829	0.314	-44.	2.0	11.2
530	9	1	1914884.25	9.4699	42.402	10.9210	35.124	-2.	-9.	-11.	7.	20.	0.800	0.285	-30.	1.7	10.9
530	9	3	1914886.25	10.9287	37.252	12.2201	29.133	6.	-6.	-18.	-7.	5.	0.772	0.280	-12.	1.5	10.8
530	9	5	1914888.25	12.0809	29.133	13.2870	21.093	11.	-4.	-24.	-20.	-9.	0.745	0.302	4.	1.5	10.9
530	9	7	1914890.25	12.8669	21.071	14.0551	13.489	15.	-3.	-29.	-31.	-21.	0.720	0.345	17.	1.6	11.1
530	9	9	1914892.25	13.3872	14.508	14.5862	7.414	17.	-2.	-32.	-39.	-29.	0.695	0.403	25.	1.7	11.3
530	9	11	1914894.25	13.7374	9.511	14.9550	2.829	18.	-3.	-34.	-45.	-35.	0.672	0.471	30.	1.9	11.6
530	9	13	1914896.25	13.9789	5.742	15.2151	-0.617	17.	-3.	-36.	-49.	-39.	0.651	0.544	33.	2.1	11.8
530	9	15	1914898.25	14.1482	2.863	15.4009	-3.250	17.	-4.	-38.	-52.	-41.	0.632	0.621	35.	2.2	12.1
530	9	17	1914900.25	14.2676	0.622	15.5345	-5.310	16.	-6.	-40.	-54.	-42.	0.615	0.699	35.	2.4	12.3
530	9	19	1914902.25	14.3511	-1.160	15.6299	-6.958	15.	-7.	-42.	-55.	-43.	0.601	0.779	35.	2.5	12.5
530	9	21	1914904.25	14.4077	-2.602	15.6966	-8.307	14.	-9.	-43.	-57.	-43.	0.590	0.858	35.	2.6	12.6
530	9	23	1914906.25	14.4440	-3.791	15.7413	-9.433	13.	-11.	-45.	-57.	-42.	0.582	0.937	34.	2.7	12.8
530	9	25	1914908.25	14.4645	-4.785	15.7689	-10.390	11.	-12.	-47.	-58.	-42.	0.577	1.015	32.	2.8	12.9
530	9	27	1914910.25	14.4727	-5.629	15.7831	-11.216	10.	-14.	-49.	-58.	-41.	0.576	1.090	31.	3.3	13.1
530	9	29	1914912.25	14.4712	-6.354	15.7869	-11.940	9.	-16.	-50.	-58.	-39.	0.578	1.163	29.	3.4	13.2
530	10	1	1914914.25	14.4624	-6.986	15.7825	-12.582	7.	-18.	-52.	-58.	-38.	0.583	1.234	27.	3.6	13.4
530	10	3	1914916.25	14.4480	-7.543	15.7719	-13.158	6.	-20.	-54.	-57.	-36.	0.592	1.302	25.	3.8	13.5
530	10	5	1914918.25	14.4295	-8.039	15.7567	-13.680	4.	-22.	-55.	-57.	-34.	0.604	1.366	23.	3.9	13.7
530	10	7	1914920.25	14.4082	-8.486	15.7383	-14.158	3.	-24.	-57.	-56.	-32.	0.619	1.427	21.	4.1	13.8
530	10	9	1914922.25	14.3849	-8.894	15.7176	-14.599	1.	-26.	-59.	-55.	-30.	0.636	1.484	18.	4.3	14.0
530	10	11	1914924.25	14.3606	-9.269	15.6956	-15.010	0.	-28.	-60.	-54.	-28.	0.655	1.538	16.	4.5	14.1
530	10	13	1914926.25	14.3357	-9.617	15.6728	-15.394	-2.	-30.	-61.	-52.	-26.	0.677	1.588	14.	4.6	14.3
530	10	15	1914928.25	14.3107	-9.943	15.6496	-15.756	-3.	-32.	-63.	-51.	-24.	0.700	1.635	12.	4.8	14.4
530	10	17	1914930.25	14.2859	-10.250	15.6266	-16.100	-5.	-34.	-64.	-50.	-21.	0.725	1.679	9.	5.0	14.5
530	10	19	1914932.25	14.2616	-10.543	15.6038	-16.427	-6.	-36.	-65.	-48.	-19.	0.751	1.719	7.	5.2	14.7
530	10	21	1914934.25	14.2378	-10.822	15.5815	-16.740	-8.	-38.	-65.	-47.	-17.	0.778	1.756	5.	5.3	14.8
530	10	23	1914936.25	14.2146	-11.090	15.5598	-17.042	-10.	-40.	-66.	-45.	-15.	0.806	1.790	3.	5.5	14.9
530	10	25	1914938.25	14.1922	-11.350	15.5386	-17.333	-11.	-42.	-66.	-44.	-13.	0.835	1.821	0.	5.6	15.0
530	10	27	1914940.25	14.1703	-11.601	15.5181	-17.615	-13.	-44.	-67.	-42.	-11.	0.865	1.850	-2.	5.8	15.1
530	10	29	1914942.25	14.1491	-11.845	15.4981	-17.889	-14.	-46.	-67.	-40.	-8.	0.895	1.875	-4.	5.9	15.2
530	10	31	1914944.25	14.1285	-12.083	15.4785	-18.156	-16.	-48.	-66.	-39.	-6.	0.925	1.898	-6.	6.1	15.3
530	11	2	1914946.25	14.1083	-12.316	15.4595	-18.417	-17.	-50.	-66.	-37.	-4.	0.955	1.919	-9.	6.2	15.4
530	11	4	1914948.25	14.0885	-12.544	15.4408	-18.672	-19.	-52.	-66.	-35.	-2.	0.986	1.937	-11.	6.3	15.5
530	11	6	1914950.25	14.0690	-12.768	15.4223	-18.923	-21.	-53.	-65.	-34.	0.	1.017	1.953	-13.	6.5	15.6
530	11	8	1914952.25	14.0498	-12.988	15.4041	-19.169	-22.	-55.	-64.	-32.	2.	1.048	1.966	-15.	6.6	15.7
530	11	10	1914954.25	14.0306	-13.204	15.3859	-19.411	-24.	-57.	-63.	-30.	4.	1.080	1.978	-17.	6.7	15.7
530	11	12	1914956.25	14.0115	-13.417	15.3676	-19.650	-26.	-59.	-62.	-28.	6.	1.111	1.987	-20.	6.8	15.8
530	11	14	1914958.25	13.9922	-13.627	15.3492	-19.886	-27.	-60.	-61.	-26.	8.	1.142	1.994	-22.	6.9	15.9
530	11	16	1914960.25	13.9727	-13.834	15.3306	-20.119	-29.	-62.	-59.	-25.	10.	1.174	2.000	-24.	7.0	16.0
530	11	18	1914962.25	13.9529	-14.037	15.3115	-20.349	-31.	-63.	-58.	-23.	12.	1.205	2.004	-26.	7.1	16.0

YR	MH	DY	JD	RA(DATE)	DEC	RA(J2000.0)	DEC	TWE	9PM	MN	3AM	TWB	R	DEL	ELONG	TMAG	NMAG
451	5	4	1885909.25	1.8394	11.675	3.2541	18.447	-26.	-35.	-41.	-17.	-6.	1.241	2.197	-14.	8.2	16.3
451	5	6	1885911.25	1.8536	11.994	3.2708	18.744	-27.	-35.	-41.	-16.	-5.	1.209	2.152	-16.	8.1	16.2
451	5	8	1885913.25	1.8683	12.326	3.2882	19.054	-28.	-36.	-40.	-14.	-4.	1.178	2.104	-18.	7.9	16.1
451	5	10	1885915.25	1.8834	12.672	3.3062	19.376	-29.	-36.	-39.	-13.	-2.	1.147	2.055	-19.	7.7	16.0
451	5	12	1885917.25	1.8992	13.034	3.3249	19.714	-30.	-37.	-38.	-11.	-1.	1.115	2.005	-21.	7.5	15.8
451	5	14	1885919.25	1.9156	13.414	3.3445	20.068	-31.	-37.	-37.	-10.	0.	1.084	1.952	-22.	7.3	15.7
451	5	16	1885921.25	1.9329	13.815	3.3651	20.442	-32.	-37.	-36.	-8.	1.	1.053	1.897	-24.	7.1	15.6
451	5	18	1885923.25	1.9512	14.239	3.3870	20.837	-33.	-38.	-35.	-7.	3.	1.021	1.841	-25.	6.9	15.5
451	5	20	1885925.25	1.9707	14.690	3.4105	21.257	-33.	-38.	-34.	-5.	4.	0.990	1.782	-27.	6.7	15.3
451	5	22	1885927.25	1.9918	15.172	3.4357	21.705	-34.	-38.	-33.	-4.	5.	0.959	1.722	-28.	6.5	15.2
451	5	24	1885929.25	2.0147	15.690	3.4633	22.186	-34.	-38.	-31.	-2.	7.	0.929	1.660	-30.	6.2	15.0
451	5	26	1885931.25	2.0401	16.250	3.4938	22.705	-34.	-37.	-30.	0.	8.	0.898	1.596	-31.	6.0	14.9
451	5	28	1885933.25	2.0684	16.859	3.5278	23.268	-34.	-37.	-29.	1.	10.	0.868	1.530	-32.	5.7	14.7
451	5	30	1885935.25	2.1006	17.528	3.5663	23.882	-34.	-37.	-27.	3.	11.	0.839	1.462	-34.	5.4	14.5
451	6	1	1885937.25	2.1376	18.265	3.6106	24.558	-34.	-36.	-26.	4.	12.	0.810	1.392	-35.	5.2	14.4
451	6	3	1885939.25	2.1809	19.086	3.6623	25.305	-34.	-36.	-25.	6.	14.	0.781	1.320	-36.	4.9	14.2
451	6	5	1885941.25	2.2324	20.008	3.7235	26.139	-33.	-35.	-23.	7.	15.	0.754	1.247	-37.	4.6	14.0
451	6	7	1885943.25	2.2945	21.051	3.7972	27.074	-32.	-34.	-22.	9.	17.	0.728	1.172	-37.	4.3	13.8
451	6	9	1885945.25	2.3708	22.244	3.8873	28.132	-32.	-33.	-20.	10.	18.	0.703	1.096	-38.	4.0	13.5
451	6	11	1885947.25	2.4661	23.619	3.9994	29.334	-30.	-31.	-19.	11.	19.	0.679	1.019	-38.	3.6	13.3
451	6	13	1885949.25	2.5871	25.216	4.1414	30.706	-29.	-30.	-17.	13.	20.	0.657	0.942	-38.	3.3	13.1
451	6	15	1885951.25	2.7435	27.082	4.3240	32.273	-27.	-28.	-16.	13.	20.	0.637	0.865	-37.	3.0	12.8
451	6	17	1885953.25	2.9491	29.264	4.5631	34.047	-25.	-26.	-15.	14.	21.	0.619	0.789	-36.	2.6	12.5
451	6	19	1885955.25	3.2243	31.798	4.8805	36.012	-22.	-23.	-14.	14.	20.	0.604	0.716	-34.	2.3	12.3
451	6	21	1885957.25	3.5979	34.668	5.3060	38.075	-18.	-20.	-13.	13.	19.	0.592	0.648	-30.	2.0	12.0
451	6	23	1885959.25	4.1079	37.730	5.8741	39.989	-14.	-16.	-12.	11.	17.	0.582	0.588	-25.	1.7	11.8
451	6	25	1885961.25	4.7947	40.585	6.6108	41.260	-9.	-12.	-12.	8.	13.	0.576	0.539	-18.	1.5	11.6
451	6	27	1885963.25	5.6720	42.483	7.4998	41.166	-3.	-7.	-12.	3.	8.	0.574	0.506	-10.	1.3	11.4
451	6	29	1885965.25	6.6760	42.548	8.4510	39.115	3.	-1.	-12.	-3.	1.	0.575	0.492	0.	1.6	11.4
451	7	1	1885967.25	7.6619	40.446	9.3352	35.200	9.	3.	-13.	-10.	-6.	0.579	0.499	10.	1.6	11.4
451	7	3	1885969.25	8.4980	36.763	10.0656	30.239	13.	7.	-15.	-16.	-13.	0.587	0.525	19.	1.8	11.5
451	7	5	1885971.25	9.1427	32.483	10.6281	25.158	16.	9.	-16.	-22.	-19.	0.598	0.568	26.	2.0	11.8
451	7	7	1885973.25	9.6202	28.338	11.0495	20.534	18.	10.	-17.	-26.	-25.	0.611	0.624	32.	2.3	12.0
451	7	9	1885975.25	9.9716	24.660	11.3645	16.571	19.	11.	-19.	-30.	-29.	0.628	0.688	36.	2.6	12.3
451	7	11	1885977.25	10.2329	21.525	11.6023	13.262	19.	10.	-20.	-33.	-32.	0.647	0.758	39.	2.9	12.6
451	7	13	1885979.25	10.4305	18.891	11.7844	10.518	18.	10.	-22.	-36.	-35.	0.668	0.832	40.	3.2	12.8
451	7	15	1885981.25	10.5828	16.680	11.9264	8.238	17.	9.	-24.	-38.	-37.	0.691	0.907	41.	3.5	13.1
451	7	17	1885983.25	10.7024	14.816	12.0389	6.326	16.	7.	-25.	-40.	-39.	0.715	0.983	42.	3.8	13.3
451	7	19	1885985.25	10.7981	13.230	12.1297	4.708	15.	6.	-27.	-42.	-40.	0.741	1.059	42.	4.1	13.6
451	7	21	1885987.25	10.8760	11.867	12.2041	3.323	14.	5.	-28.	-43.	-41.	0.768	1.135	41.	4.3	13.8
451	7	23	1885989.25	10.9406	10.684	12.2662	2.124	13.	3.	-30.	-44.	-42.	0.795	1.209	41.	4.6	14.0
451	7	25	1885991.25	10.9950	9.647	12.3187	1.076	11.	2.	-31.	-45.	-42.	0.824	1.283	40.	4.8	14.2
451	7	27	1885993.25	11.0415	8.728	12.3639	0.149	10.	0.	-33.	-46.	-43.	0.853	1.355	39.	5.1	14.4
451	7	29	1885995.25	11.0820	7.908	12.4033	-0.679	9.	-2.	-34.	-46.	-43.	0.883	1.426	38.	5.3	14.6
451	7	31	1885997.25	11.1177	7.168	12.4382	-1.424	8.	-3.	-36.	-47.	-43.	0.913	1.495	37.	5.5	14.8
451	8	2	1885999.25	11.1496	6.495	12.4696	-2.100	6.	-5.	-37.	-47.	-43.	0.944	1.562	35.	5.7	14.9
451	8	4	1886001.25	11.1785	5.879	12.4980	-2.719	5.	-6.	-39.	-48.	-42.	0.975	1.628	34.	5.9	15.1
451	8	6	1886003.25	11.2049	5.311	12.5241	-3.290	4.	-8.	-40.	-48.	-42.	1.006	1.692	33.	6.1	15.3
451	8	8	1886005.25	11.2294	4.783	12.5484	-3.819	3.	-10.	-41.	-48.	-41.	1.037	1.754	31.	6.3	15.4
451	8	10	1886007.25	11.2523	4.291	12.5712	-4.313	1.	-11.	-43.	-48.	-40.	1.068	1.815	30.	6.5	15.5
451	8	12	1886009.25	11.2739	3.828	12.5927	-4.776	0.	-13.	-44.	-48.	-40.	1.100	1.873	29.	6.6	15.7
451	8	14	1886011.25	11.2944	3.392	12.6131	-5.213	-1.	-14.	-45.	-47.	-39.	1.131	1.930	27.	6.8	15.8
451	8	16	1886013.25	11.3140	2.978	12.6327	-5.627	-2.	-16.	-46.	-47.	-38.	1.162	1.986	26.	6.9	15.9
451	8	18	1886015.25	11.3328	2.584	12.6516	-6.021	-3.	-17.	-47.	-47.	-37.	1.194	2.039	24.	7.1	16.0

YR	MH	DY	JD	RA(DATE)	DEC	RA(J2000.0)	DEC	TWE	9PM	MN	3AM	TWB	R	DEL	ELONG	TMAG	NMAG
373	12	22	1857652.25	22.3226	-10.289	23.7233	-1.548	38.	8.	-28.	-61.	-54.	1.242	1.382	61.	7.2	15.3
373	12	24	1857654.25	22.2509	-10.342	23.6530	-1.646	37.	5.	-31.	-62.	-52.	1.211	1.409	58.	7.1	15.3
373	12	26	1857656.25	22.1831	-10.383	23.5864	-1.731	35.	3.	-34.	-63.	-49.	1.180	1.435	55.	7.1	15.2
373	12	28	1857658.25	22.1187	-10.414	23.5232	-1.807	33.	0.	-36.	-64.	-47.	1.149	1.461	52.	7.0	15.2
373	12	30	1857660.25	22.0573	-10.436	23.4630	-1.873	31.	-2.	-39.	-65.	-45.	1.117	1.485	49.	6.9	15.2
374	1	1	1857662.25	21.9986	-10.450	23.4053	-1.933	29.	-5.	-41.	-65.	-43.	1.086	1.508	46.	6.8	15.2
374	1	3	1857664.25	21.9421	-10.459	23.3498	-1.986	27.	-7.	-44.	-65.	-40.	1.055	1.530	43.	6.7	15.1
374	1	5	1857666.25	21.8875	-10.463	23.2962	-2.036	25.	-10.	-46.	-65.	-38.	1.024	1.551	40.	6.5	15.1
374	1	7	1857668.25	21.8345	-10.464	23.2442	-2.082	23.	-12.	-48.	-64.	-36.	0.993	1.570	38.	6.4	15.1
374	1	9	1857670.25	21.7828	-10.463	23.1934	-2.127	21.	-15.	-50.	-64.	-34.	0.962	1.588	35.	6.3	15.0
374	1	11	1857672.25	21.7320	-10.460	23.1435	-2.171	19.	-17.	-52.	-63.	-32.	0.931	1.603	32.	6.2	15.0
374	1	13	1857674.25	21.6819	-10.458	23.0943	-2.216	16.	-19.	-54.	-61.	-29.	0.901	1.617	29.	6.0	14.9
374	1	15	1857676.25	21.6322	-10.457	23.0454	-2.263	14.	-22.	-56.	-60.	-27.	0.871	1.629	27.	5.9	14.9
374	1	17	1857678.25	21.5826	-10.458	22.9967	-2.313	11.	-24.	-58.	-58.	-25.	0.842	1.639	24.	5.7	14.8
374	1	19	1857680.25	21.5329	-10.462	22.9479	-2.369	9.	-26.	-59.	-57.	-23.	0.813	1.646	21.	5.6	14.7
374	1	21	1857682.25	21.4828	-10.471	22.8988	-2.430	7.	-29.	-61.	-55.	-21.	0.785	1.651	18.	5.4	14.7
374	1	23	1857684.25	21.4322	-10.484	22.8491	-2.498	4.	-31.	-62.	-53.	-19.	0.758	1.653	16.	5.2	14.6
374	1	25	1857686.25	21.3807	-10.504	22.7988	-2.575	1.	-33.	-63.	-51.	-17.	0.731	1.653	13.	5.1	14.5
374	1	27	1857688.25	21.3284	-10.531	22.7476	-2.661	-1.	-36.	-64.	-49.	-15.	0.706	1.649	10.	4.9	14.4
374	1	29	1857690.25	21.2750	-10.566	22.6954	-2.759	-4.	-38.	-65.	-47.	-13.	0.683	1.642	7.	4.7	14.3
374	1	31	1857692.25	21.2205	-10.611	22.6421	-2.868	-6.	-40.	-65.	-45.	-11.	0.661	1.632	5.	4.5	14.3
374	2	2	1857694.25	21.1649	-10.665	22.5879	-2.990	-9.	-42.	-66.	-43.	-9.	0.641	1.619	2.	4.4	14.2
374	2	4	1857696.25	21.1082	-10.730	22.5326	-3.125	-12.	-45.	-66.	-40.	-7.	0.623	1.602	-1.	4.2	14.1
374	2	6	1857698.25	21.0504	-10.806	22.4764	-3.275	-15.	-47.	-65.	-38.	-6.	0.608	1.580	-4.	4.1	14.0
374	2	8	1857700.25	20.9919	-10.893	22.4196	-3.438	-17.	-49.	-65.	-36.	-4.	0.596	1.555	-7.	3.9	13.9
374	2	10	1857702.25	20.9328	-10.992	22.3623	-3.616	-20.	-51.	-64.	-34.	-2.	0.586	1.526	-10.	3.8	13.9
374	2	12	1857704.25	20.8735	-11.103	22.3050	-3.807	-23.	-53.	-63.	-32.	0.	0.580	1.493	-12.	3.7	13.8
374	2	14	1857706.25	20.8144	-11.224	22.2478	-4.010	-26.	-55.	-62.	-29.	2.	0.577	1.456	-15.	3.6	13.7
374	2	16	1857708.25	20.7558	-11.357	22.1913	-4.225	-29.	-57.	-60.	-27.	3.	0.578	1.415	-18.	3.9	13.7
374	2	18	1857710.25	20.6980	-11.499	22.1357	-4.451	-31.	-59.	-59.	-25.	5.	0.582	1.370	-21.	3.8	13.6
374	2	20	1857712.25	20.6413	-11.652	22.0813	-4.686	-34.	-61.	-57.	-23.	6.	0.589	1.322	-24.	3.8	13.6
374	2	22	1857714.25	20.5859	-11.814	22.0283	-4.931	-37.	-62.	-56.	-21.	8.	0.600	1.270	-27.	3.8	13.5
374	2	24	1857716.25	20.5320	-11.985	21.9768	-5.183	-40.	-64.	-54.	-19.	10.	0.613	1.216	-29.	3.7	13.5
374	2	26	1857718.25	20.4794	-12.166	21.9267	-5.445	-42.	-65.	-52.	-17.	11.	0.630	1.159	-32.	3.7	13.4
374	2	28	1857720.25	20.4280	-12.358	21.8779	-5.717	-45.	-66.	-50.	-14.	12.	0.648	1.100	-35.	3.7	13.4
374	3	2	1857722.25	20.3774	-12.563	21.8300	-6.001	-47.	-67.	-49.	-12.	14.	0.669	1.038	-38.	3.7	13.3
374	3	4	1857724.25	20.3271	-12.783	21.7826	-6.301	-50.	-67.	-47.	-11.	15.	0.691	0.975	-40.	3.7	13.2
374	3	6	1857726.25	20.2764	-13.022	21.7349	-6.622	-53.	-68.	-45.	-9.	16.	0.715	0.911	-43.	3.6	13.2
374	3	8	1857728.25	20.2242	-13.286	21.6861	-6.970	-55.	-68.	-43.	-7.	17.	0.741	0.845	-46.	3.6	13.1
374	3	10	1857730.25	20.1694	-13.582	21.6350	-7.356	-58.	-68.	-41.	-5.	19.	0.768	0.778	-49.	3.5	13.0
374	3	12	1857732.25	20.1099	-13.920	21.5797	-7.793	-60.	-68.	-39.	-3.	20.	0.795	0.710	-52.	3.4	12.9
374	3	14	1857734.25	20.0432	-14.316	21.5180	-8.302	-62.	-68.	-37.	-1.	21.	0.824	0.641	-55.	3.3	12.7
374	3	16	1857736.25	19.9654	-14.791	21.4463	-8.910	-65.	-67.	-35.	1.	22.	0.853	0.572	-58.	3.2	12.5
374	3	18	1857738.25	19.8705	-15.380	21.3591	-9.664	-67.	-66.	-33.	3.	23.	0.882	0.502	-61.	3.0	12.3
374	3	20	1857740.25	19.7488	-16.137	21.2475	-10.637	-70.	-65.	-30.	6.	25.	0.912	0.433	-65.	2.8	12.1
374	3	22	1857742.25	19.5826	-17.151	21.0956	-11.954	-72.	-63.	-27.	8.	26.	0.943	0.363	-70.	2.5	11.8
374	3	24	1857744.25	19.3380	-18.581	20.8723	-13.847	-73.	-60.	-23.	11.	27.	0.973	0.294	-75.	2.2	11.4
374	3	26	1857746.25	18.9398	-20.716	20.5089	-16.772	-73.	-55.	-18.	15.	28.	1.004	0.227	-83.	1.7	10.9
374	3	28	1857748.25	18.1952	-24.011	19.8252	-21.648	-66.	-46.	-10.	20.	29.	1.035	0.164	-96.	1.1	10.2
374	3	30	1857750.25	16.5732	-27.957	18.2838	-29.312	-46.	-27.	6.	26.	26.	1.066	0.113	-119.	0.4	9.5
374	4	1	1857752.25	13.6257	-23.962	15.1965	-31.264	-8.	9.	30.	24.	11.	1.098	0.097	-161.	0.2	9.2
374	4	3	1857754.25	11.3994	-11.474	12.7882	-20.504	26.	39.	39.	12.	-7.	1.129	0.129	162.	0.9	9.9
374	4	5	1857756.25	10.3892	-3.710	11.7531	-12.477	43.	51.	37.	3.	-16.	1.160	0.187	143.	1.8	10.8
374	4	7	1857758.25	9.8899	0.352	11.2597	-8.060	51.	55.	33.	-2.	-20.	1.191	0.252	133.	2.5	11.5

YR	MH	DY	JD	RA(DATE)	DEC	RA(J2000.0)	DEC	TWE	9PM	MN	3AM	TWB	R	DEL	ELONG	TMAG	NMAG
295	2	24	1828861.25	23.8731	-0.920	1.3316	8.432	8.	-21.	-51.	-49.	-25.	1.243	2.110	22.	8.1	16.2
295	2	26	1828863.25	23.8596	-0.754	1.3182	8.604	6.	-22.	-52.	-48.	-23.	1.212	2.102	20.	8.0	16.1
295	2	28	1828865.25	23.8462	-0.584	1.3049	8.779	4.	-24.	-52.	-46.	-22.	1.180	2.091	18.	7.9	16.1
295	3	2	1828867.25	23.8328	-0.411	1.2917	8.957	2.	-25.	-53.	-45.	-21.	1.149	2.079	16.	7.7	16.0
295	3	4	1828869.25	23.8195	-0.234	1.2785	9.138	0.	-27.	-53.	-44.	-20.	1.118	2.064	14.	7.6	15.9
295	3	6	1828871.25	23.8062	-0.053	1.2653	9.324	-2.	-28.	-54.	-42.	-18.	1.086	2.048	12.	7.4	15.8
295	3	8	1828873.25	23.7926	0.131	1.2519	9.513	-4.	-29.	-54.	-41.	-17.	1.055	2.029	9.	7.3	15.8
295	3	10	1828875.25	23.7789	0.320	1.2382	9.706	-6.	-31.	-54.	-39.	-16.	1.024	2.008	7.	7.1	15.7
295	3	12	1828877.25	23.7649	0.513	1.2243	9.903	-8.	-32.	-54.	-38.	-15.	0.993	1.985	5.	6.9	15.6
295	3	14	1828879.25	23.7505	0.710	1.2099	10.105	-10.	-33.	-54.	-36.	-14.	0.962	1.960	3.	6.7	15.5
295	3	16	1828881.25	23.7357	0.913	1.1952	10.312	-12.	-35.	-54.	-35.	-12.	0.931	1.932	1.	6.6	15.4
295	3	18	1828883.25	23.7205	1.121	1.1800	10.525	-14.	-36.	-54.	-33.	-11.	0.901	1.902	-1.	6.4	15.3
295	3	20	1828885.25	23.7048	1.336	1.1643	10.744	-16.	-37.	-53.	-32.	-10.	0.871	1.870	-3.	6.2	15.2
295	3	22	1828887.25	23.6886	1.559	1.1481	10.971	-18.	-38.	-53.	-30.	-9.	0.842	1.834	-5.	6.0	15.0
295	3	24	1828889.25	23.6719	1.790	1.1314	11.206	-20.	-40.	-52.	-28.	-7.	0.813	1.796	-7.	5.7	14.9
295	3	26	1828891.25	23.6548	2.031	1.1142	11.452	-22.	-41.	-52.	-27.	-6.	0.785	1.755	-9.	5.5	14.8
295	3	28	1828893.25	23.6374	2.284	1.0967	11.709	-24.	-42.	-51.	-25.	-5.	0.757	1.711	-11.	5.3	14.7
295	3	30	1828895.25	23.6197	2.552	1.0789	11.981	-26.	-43.	-50.	-23.	-3.	0.731	1.664	-13.	5.1	14.5
295	4	1	1828897.25	23.6021	2.837	1.0612	12.270	-28.	-44.	-49.	-21.	-2.	0.706	1.614	-16.	4.8	14.4
295	4	3	1828899.25	23.5848	3.144	1.0439	12.580	-29.	-44.	-48.	-20.	-1.	0.682	1.560	-18.	4.6	14.2
295	4	5	1828901.25	23.5684	3.477	1.0273	12.917	-31.	-45.	-47.	-18.	1.	0.660	1.504	-20.	4.4	14.1
295	4	7	1828903.25	23.5533	3.843	1.0122	13.285	-33.	-46.	-46.	-16.	2.	0.640	1.444	-22.	4.1	13.9
295	4	9	1828905.25	23.5404	4.249	0.9993	13.693	-34.	-46.	-45.	-14.	3.	0.622	1.380	-24.	3.9	13.8
295	4	11	1828907.25	23.5308	4.705	0.9898	14.151	-35.	-47.	-43.	-12.	5.	0.607	1.314	-25.	3.7	13.6
295	4	13	1828909.25	23.5258	5.225	0.9850	14.672	-37.	-47.	-42.	-11.	6.	0.595	1.244	-27.	3.4	13.4
295	4	15	1828911.25	23.5271	5.825	0.9868	15.272	-37.	-47.	-40.	-9.	8.	0.585	1.172	-29.	3.2	13.3
295	4	17	1828913.25	23.5369	6.526	0.9975	15.971	-38.	-47.	-39.	-7.	9.	0.579	1.097	-30.	3.0	13.1
295	4	19	1828915.25	23.5579	7.354	1.0200	16.796	-39.	-46.	-37.	-5.	10.	0.576	1.019	-32.	2.9	12.9
295	4	21	1828917.25	23.5938	8.347	1.0581	17.781	-39.	-46.	-36.	-4.	11.	0.577	0.940	-33.	3.0	12.8
295	4	23	1828919.25	23.6493	9.551	1.1171	18.972	-38.	-45.	-34.	-2.	12.	0.581	0.860	-33.	2.8	12.6
295	4	25	1828921.25	23.7307	11.028	1.2042	20.426	-38.	-43.	-33.	-1.	13.	0.588	0.780	-34.	2.6	12.4
295	4	27	1828923.25	23.8471	12.865	1.3296	22.222	-36.	-41.	-31.	0.	14.	0.599	0.700	-33.	2.5	12.2
295	4	29	1828925.25	0.0120	15.174	1.5088	24.457	-34.	-39.	-30.	1.	14.	0.612	0.621	-32.	2.3	12.0
295	5	1	1828927.25	0.2458	18.106	1.7663	27.250	-31.	-36.	-28.	2.	14.	0.628	0.546	-29.	2.1	11.8
295	5	3	1828929.25	0.5810	21.831	2.1416	30.709	-27.	-32.	-26.	2.	13.	0.647	0.475	-25.	1.9	11.5
295	5	5	1828931.25	1.0690	26.473	2.6981	34.821	-20.	-26.	-24.	1.	11.	0.668	0.413	-19.	1.7	11.3
295	5	7	1828933.25	1.7855	31.865	3.5264	39.149	-12.	-18.	-21.	-2.	8.	0.690	0.363	-9.	1.5	11.1
295	5	9	1828935.25	2.8078	37.053	4.6964	42.330	-1.	-8.	-18.	-5.	2.	0.714	0.330	3.	1.4	11.0
295	5	11	1828937.25	4.1052	40.104	6.0962	42.328	11.	3.	-14.	-10.	-5.	0.740	0.320	18.	1.5	11.0
295	5	13	1828939.25	5.4262	39.657	7.3905	38.648	22.	13.	-10.	-14.	-12.	0.767	0.334	32.	1.7	11.1
295	5	15	1828941.25	6.4978	36.625	8.3606	33.158	30.	21.	-6.	-18.	-18.	0.794	0.370	43.	2.0	11.4
295	5	17	1828943.25	7.2640	32.796	9.0284	27.744	36.	26.	-4.	-21.	-22.	0.823	0.421	51.	2.4	11.8
295	5	19	1828945.25	7.7964	29.204	9.4879	23.158	39.	29.	-3.	-24.	-26.	0.852	0.481	56.	2.8	12.2
295	5	21	1828947.25	8.1733	26.157	9.8137	19.468	40.	31.	-3.	-26.	-28.	0.882	0.548	60.	3.2	12.5
295	5	23	1828949.25	8.4490	23.651	10.0534	16.527	41.	31.	-3.	-28.	-30.	0.912	0.619	62.	3.6	12.9
295	5	25	1828951.25	8.6575	21.598	10.2359	14.164	41.	31.	-4.	-29.	-32.	0.942	0.691	64.	3.9	13.2
295	5	27	1828953.25	8.8203	19.902	10.3793	12.240	40.	31.	-4.	-30.	-34.	0.973	0.766	64.	4.3	13.5
295	5	29	1828955.25	8.9508	18.485	10.4950	10.648	39.	30.	-5.	-32.	-35.	1.004	0.840	65.	4.6	13.7
295	5	31	1828957.25	9.0582	17.285	10.5907	9.310	38.	29.	-6.	-33.	-36.	1.035	0.915	65.	4.9	14.0
295	6	2	1828959.25	9.1484	16.256	10.6715	8.169	37.	28.	-8.	-34.	-37.	1.066	0.990	64.	5.1	14.2
295	6	4	1828961.25	9.2257	15.363	10.7410	7.182	35.	27.	-9.	-35.	-38.	1.097	1.065	64.	5.4	14.4
295	6	6	1828963.25	9.2930	14.578	10.8019	6.319	34.	26.	-10.	-36.	-39.	1.129	1.139	63.	5.6	14.6
295	6	8	1828965.25	9.3526	13.881	10.8560	5.554	32.	24.	-11.	-38.	-40.	1.160	1.212	62.	5.9	14.8
295	6	10	1828967.25	9.4060	13.255	10.9047	4.869	31.	23.	-13.	-39.	-41.	1.191	1.285	61.	6.1	15.0

YR	MH	DY	JD	RA(DATE)	DEC	RA(J2000.0)	DEC	TWE	9PM	MN	3AM	TWB	R	DEL	ELONG	TMAG	NMAG
218	3	24	1800765.25	0.5308	3.376	2.0796	12.701	-9.	-29.	-51.	-36.	-17.	1.232	2.229	6.	8.2	16.3
218	3	26	1800767.25	0.5297	3.612	2.0793	12.937	-10.	-30.	-51.	-35.	-16.	1.200	2.203	4.	8.1	16.2
218	3	28	1800769.25	0.5286	3.854	2.0791	13.180	-12.	-32.	-51.	-34.	-15.	1.169	2.175	2.	7.9	16.1
218	3	30	1800771.25	0.5275	4.103	2.0790	13.430	-14.	-33.	-51.	-32.	-14.	1.138	2.146	0.	7.8	16.0
218	4	1	1800773.25	0.5263	4.360	2.0788	13.686	-16.	-34.	-51.	-31.	-12.	1.107	2.114	-2.	7.6	15.9
218	4	3	1800775.25	0.5251	4.624	2.0786	13.951	-17.	-35.	-50.	-29.	-11.	1.076	2.080	-4.	7.4	15.8
218	4	5	1800777.25	0.5238	4.897	2.0784	14.225	-19.	-36.	-50.	-28.	-10.	1.045	2.044	-6.	7.2	15.7
218	4	7	1800779.25	0.5224	5.181	2.0781	14.510	-21.	-37.	-49.	-26.	-9.	1.014	2.006	-7.	7.0	15.6
218	4	9	1800781.25	0.5210	5.476	2.0779	14.805	-22.	-37.	-49.	-25.	-8.	0.983	1.965	-9.	6.9	15.5
218	4	11	1800783.25	0.5196	5.783	2.0776	15.113	-24.	-38.	-48.	-23.	-7.	0.953	1.923	-11.	6.7	15.4
218	4	13	1800785.25	0.5182	6.105	2.0774	15.436	-26.	-39.	-47.	-22.	-6.	0.922	1.878	-13.	6.4	15.3
218	4	15	1800787.25	0.5168	6.444	2.0774	15.776	-27.	-40.	-46.	-20.	-4.	0.892	1.830	-15.	6.2	15.2
218	4	17	1800789.25	0.5157	6.803	2.0777	16.135	-28.	-40.	-45.	-19.	-3.	0.863	1.780	-17.	6.0	15.0
218	4	19	1800791.25	0.5150	7.185	2.0785	16.516	-30.	-41.	-44.	-17.	-2.	0.834	1.728	-18.	5.8	14.9
218	4	21	1800793.25	0.5149	7.593	2.0801	16.924	-31.	-41.	-43.	-15.	-1.	0.805	1.673	-20.	5.5	14.7
218	4	23	1800795.25	0.5157	8.033	2.0827	17.362	-32.	-42.	-42.	-14.	1.	0.778	1.615	-22.	5.3	14.6
218	4	25	1800797.25	0.5179	8.510	2.0869	17.837	-33.	-42.	-41.	-12.	2.	0.751	1.555	-24.	5.0	14.4
218	4	27	1800799.25	0.5219	9.033	2.0933	18.356	-34.	-42.	-40.	-10.	3.	0.725	1.492	-25.	4.8	14.3
218	4	29	1800801.25	0.5287	9.611	2.1027	18.927	-35.	-42.	-38.	-8.	5.	0.701	1.426	-27.	4.5	14.1
218	5	1	1800803.25	0.5391	10.256	2.1163	19.561	-36.	-42.	-37.	-7.	6.	0.678	1.358	-28.	4.3	13.9
218	5	3	1800805.25	0.5545	10.983	2.1356	20.272	-36.	-42.	-36.	-5.	7.	0.657	1.287	-30.	4.0	13.7
218	5	5	1800807.25	0.5768	11.811	2.1625	21.078	-36.	-42.	-34.	-3.	9.	0.638	1.213	-31.	3.7	13.5
218	5	7	1800809.25	0.6083	12.765	2.2000	22.001	-36.	-41.	-32.	-2.	10.	0.622	1.138	-32.	3.5	13.3
218	5	9	1800811.25	0.6523	13.877	2.2515	23.068	-36.	-40.	-31.	0.	11.	0.608	1.060	-33.	3.2	13.1
218	5	11	1800813.25	0.7132	15.189	2.3223	24.315	-35.	-39.	-29.	2.	13.	0.596	0.981	-33.	2.9	12.9
218	5	13	1800815.25	0.7970	16.752	2.4194	25.786	-34.	-38.	-28.	3.	14.	0.588	0.902	-34.	2.7	12.7
218	5	15	1800817.25	0.9123	18.633	2.5529	27.532	-33.	-36.	-26.	4.	15.	0.583	0.822	-33.	2.4	12.5
218	5	17	1800819.25	1.0709	20.914	2.7373	29.611	-31.	-34.	-24.	5.	15.	0.581	0.743	-32.	2.5	12.3
218	5	19	1800821.25	1.2907	23.688	2.9939	32.075	-28.	-31.	-22.	6.	15.	0.583	0.667	-30.	2.3	12.1
218	5	21	1800823.25	1.5975	27.037	3.3543	34.936	-24.	-27.	-21.	6.	15.	0.588	0.596	-27.	2.0	11.8
218	5	23	1800825.25	2.0290	30.971	3.8632	38.082	-19.	-22.	-19.	5.	13.	0.597	0.532	-22.	1.8	11.6
218	5	25	1800827.25	2.6355	35.288	4.5741	41.114	-12.	-16.	-17.	3.	11.	0.608	0.479	-14.	1.7	11.4
218	5	27	1800829.25	3.4652	39.342	5.5181	43.170	-5.	-9.	-15.	0.	6.	0.622	0.441	-5.	1.6	11.3
218	5	29	1800831.25	4.5106	41.983	6.6314	43.104	4.	-1.	-13.	-4.	1.	0.639	0.423	6.	1.6	11.3
218	5	31	1800833.25	5.6420	42.177	7.7311	40.405	12.	6.	-11.	-9.	-6.	0.658	0.426	17.	1.7	11.3
218	6	2	1800835.25	6.6629	40.016	8.6482	35.851	19.	13.	-10.	-14.	-12.	0.679	0.449	28.	1.9	11.5
218	6	4	1800837.25	7.4656	36.573	9.3391	30.743	25.	17.	-9.	-18.	-17.	0.702	0.490	36.	2.2	11.8
218	6	6	1800839.25	8.0574	32.875	9.8420	25.966	28.	20.	-8.	-22.	-22.	0.726	0.543	42.	2.5	12.1
218	6	8	1800841.25	8.4890	29.463	10.2095	21.853	30.	22.	-9.	-25.	-26.	0.752	0.604	46.	2.9	12.4
218	6	10	1800843.25	8.8080	26.505	10.4834	18.429	30.	23.	-9.	-28.	-28.	0.778	0.672	49.	3.2	12.7
218	6	12	1800845.25	9.0493	24.001	10.6926	15.604	30.	23.	-10.	-30.	-31.	0.806	0.743	51.	3.6	13.0
218	6	14	1800847.25	9.2364	21.892	10.8563	13.264	30.	22.	-11.	-32.	-33.	0.835	0.816	53.	3.9	13.3
218	6	16	1800849.25	9.3850	20.109	10.9874	11.310	29.	22.	-12.	-34.	-35.	0.864	0.890	53.	4.2	13.5
218	6	18	1800851.25	9.5056	18.589	11.0946	9.659	28.	21.	-14.	-35.	-36.	0.893	0.965	53.	4.5	13.8
218	6	20	1800853.25	9.6055	17.281	11.1840	8.249	27.	19.	-15.	-37.	-38.	0.923	1.039	53.	4.8	14.0
218	6	22	1800855.25	9.6898	16.144	11.2599	7.030	26.	18.	-16.	-38.	-39.	0.953	1.114	53.	5.0	14.2
218	6	24	1800857.25	9.7622	15.146	11.3254	5.964	24.	17.	-18.	-39.	-40.	0.984	1.188	52.	5.3	14.4
218	6	26	1800859.25	9.8253	14.261	11.3828	5.023	23.	15.	-19.	-40.	-41.	1.015	1.261	52.	5.5	14.6
218	6	28	1800861.25	9.8811	13.470	11.4337	4.184	22.	14.	-20.	-41.	-42.	1.046	1.333	51.	5.7	14.8
218	6	30	1800863.25	9.9310	12.757	11.4796	3.429	20.	12.	-22.	-42.	-42.	1.077	1.405	50.	5.9	15.0
218	7	2	1800865.25	9.9763	12.108	11.5213	2.743	19.	11.	-23.	-43.	-43.	1.108	1.475	49.	6.1	15.2
218	7	4	1800867.25	10.0177	11.514	11.5597	2.116	17.	9.	-25.	-43.	-43.	1.139	1.544	48.	6.3	15.3
218	7	6	1800869.25	10.0561	10.966	11.5953	1.539	16.	8.	-26.	-44.	-43.	1.170	1.612	46.	6.5	15.5
218	7	8	1800871.25	10.0918	10.458	11.6286	1.004	14.	6.	-27.	-45.	-44.	1.201	1.679	45.	6.7	15.6

YR	MH	DY	JD	RA(DATE)	DEC	RA(J2000.0)	DEC	TWE	9PM	MN	3AM	TWB	R	DEL	ELONG	TMAG	NMAG
141	1	27	1772585.25	22.9926	-6.718	24.5768	3.581	22.	-12.	-47.	-60.	-34.	1.233	1.885	36.	7.9	15.9
141	1	29	1772587.25	22.9632	-6.613	24.5475	3.681	20.	-14.	-49.	-59.	-32.	1.202	1.892	34.	7.7	15.9
141	1	31	1772589.25	22.9347	-6.505	24.5190	3.784	18.	-16.	-50.	-58.	-31.	1.171	1.897	31.	7.6	15.8
141	2	2	1772591.25	22.9067	-6.394	24.4910	3.890	16.	-18.	-52.	-57.	-29.	1.140	1.900	29.	7.5	15.8
141	2	4	1772593.25	22.8791	-6.280	24.4635	3.997	13.	-20.	-53.	-56.	-27.	1.109	1.901	27.	7.4	15.7
141	2	6	1772595.25	22.8519	-6.164	24.4362	4.107	11.	-22.	-54.	-55.	-26.	1.078	1.900	24.	7.2	15.7
141	2	8	1772597.25	22.8248	-6.046	24.4091	4.217	9.	-23.	-55.	-53.	-24.	1.047	1.898	22.	7.1	15.6
141	2	10	1772599.25	22.7978	-5.927	24.3820	4.329	7.	-25.	-56.	-52.	-23.	1.016	1.893	20.	6.9	15.5
141	2	12	1772601.25	22.7707	-5.806	24.3548	4.442	5.	-27.	-57.	-50.	-21.	0.985	1.887	17.	6.8	15.4
141	2	14	1772603.25	22.7433	-5.684	24.3273	4.555	2.	-29.	-58.	-49.	-20.	0.955	1.878	15.	6.6	15.4
141	2	16	1772605.25	22.7156	-5.561	24.2994	4.668	0.	-31.	-59.	-47.	-18.	0.924	1.867	13.	6.4	15.3
141	2	18	1772607.25	22.6874	-5.438	24.2711	4.782	-2.	-32.	-59.	-45.	-17.	0.895	1.853	10.	6.3	15.2
141	2	20	1772609.25	22.6587	-5.313	24.2421	4.895	-4.	-34.	-60.	-44.	-15.	0.865	1.837	8.	6.1	15.1
141	2	22	1772611.25	22.6292	-5.188	24.2125	5.008	-7.	-36.	-60.	-42.	-14.	0.836	1.819	6.	5.9	15.0
141	2	24	1772613.25	22.5990	-5.063	24.1820	5.121	-9.	-37.	-60.	-40.	-12.	0.808	1.797	3.	5.7	14.9
141	2	26	1772615.25	22.5679	-4.936	24.1507	5.234	-11.	-39.	-60.	-38.	-11.	0.780	1.773	1.	5.5	14.8
141	2	28	1772617.25	22.5360	-4.808	24.1185	5.347	-14.	-41.	-60.	-37.	-9.	0.753	1.746	-1.	5.3	14.7
141	3	2	1772619.25	22.5032	-4.679	24.0854	5.460	-16.	-42.	-59.	-35.	-8.	0.728	1.715	-4.	5.1	14.6
141	3	4	1772621.25	22.4696	-4.548	24.0515	5.574	-18.	-44.	-59.	-33.	-6.	0.704	1.682	-6.	4.9	14.5
141	3	6	1772623.25	22.4351	-4.413	24.0167	5.691	-21.	-45.	-58.	-31.	-5.	0.681	1.645	-8.	4.7	14.3
141	3	8	1772625.25	22.4001	-4.275	23.9813	5.810	-23.	-47.	-57.	-29.	-3.	0.660	1.604	-11.	4.5	14.2
141	3	10	1772627.25	22.3648	-4.130	23.9454	5.934	-25.	-48.	-56.	-27.	-2.	0.641	1.560	-13.	4.3	14.1
141	3	12	1772629.25	22.3294	-3.976	23.9095	6.066	-27.	-49.	-55.	-25.	0.	0.624	1.512	-16.	4.1	14.0
141	3	14	1772631.25	22.2944	-3.812	23.8740	6.208	-30.	-51.	-54.	-23.	1.	0.610	1.461	-18.	3.9	13.8
141	3	16	1772633.25	22.2604	-3.632	23.8394	6.366	-32.	-52.	-53.	-21.	3.	0.598	1.406	-20.	3.7	13.7
141	3	18	1772635.25	22.2281	-3.432	23.8064	6.543	-34.	-53.	-52.	-19.	4.	0.590	1.347	-23.	3.6	13.6
141	3	20	1772637.25	22.1983	-3.207	23.7758	6.748	-36.	-54.	-50.	-17.	6.	0.585	1.285	-25.	3.4	13.5
141	3	22	1772639.25	22.1720	-2.949	23.7485	6.987	-38.	-54.	-49.	-15.	7.	0.583	1.220	-27.	3.3	13.4
141	3	24	1772641.25	22.1502	-2.648	23.7256	7.271	-40.	-55.	-47.	-14.	8.	0.585	1.152	-29.	3.5	13.2
141	3	26	1772643.25	22.1341	-2.293	23.7082	7.613	-41.	-55.	-46.	-12.	10.	0.590	1.081	-31.	3.3	13.1
141	3	28	1772645.25	22.1251	-1.870	23.6977	8.029	-43.	-55.	-44.	-10.	11.	0.598	1.008	-33.	3.2	13.0
141	3	30	1772647.25	22.1248	-1.361	23.6956	8.538	-44.	-55.	-43.	-8.	12.	0.609	0.933	-35.	3.1	12.9
141	4	1	1772649.25	22.1352	-0.739	23.7040	9.166	-45.	-55.	-41.	-6.	14.	0.623	0.857	-37.	3.0	12.7
141	4	3	1772651.25	22.1590	0.029	23.7255	9.951	-45.	-55.	-39.	-5.	15.	0.639	0.779	-38.	2.9	12.6
141	4	5	1772653.25	22.1997	0.991	23.7636	10.942	-45.	-54.	-38.	-3.	16.	0.658	0.701	-39.	2.8	12.4
141	4	7	1772655.25	22.2626	2.220	23.8239	12.213	-45.	-53.	-36.	-2.	17.	0.679	0.622	-40.	2.6	12.2
141	4	9	1772657.25	22.3559	3.825	23.9148	13.876	-44.	-51.	-35.	-1.	17.	0.702	0.544	-40.	2.4	12.0
141	4	11	1772659.25	22.4935	5.982	24.0509	16.109	-43.	-49.	-34.	0.	18.	0.726	0.467	-39.	2.2	11.8
141	4	13	1772661.25	22.6993	8.983	24.2586	19.201	-40.	-46.	-32.	1.	18.	0.751	0.392	-37.	2.0	11.4
141	4	15	1772663.25	23.0198	13.328	24.5909	23.629	-35.	-41.	-30.	1.	18.	0.778	0.320	-32.	1.6	11.1
141	4	17	1772665.25	23.5517	19.823	1.1646	30.094	-26.	-34.	-28.	0.	16.	0.805	0.255	-24.	1.2	10.7
141	4	19	1772667.25	0.5079	29.243	2.2556	38.898	-13.	-21.	-23.	-2.	11.	0.834	0.202	-9.	0.9	10.2
141	4	21	1772669.25	2.2448	39.414	4.3109	46.187	8.	-2.	-15.	-7.	1.	0.863	0.176	15.	0.7	10.0
141	4	23	1772671.25	4.5407	42.132	6.7559	43.093	31.	18.	-5.	-13.	-10.	0.892	0.185	41.	0.9	10.2
141	4	25	1772673.25	6.2195	37.232	8.2701	33.922	46.	32.	2.	-16.	-18.	0.922	0.226	59.	1.4	10.7
141	4	27	1772675.25	7.1442	31.578	9.0518	26.184	53.	40.	6.	-18.	-22.	0.952	0.284	69.	2.0	11.3
141	4	29	1772677.25	7.6695	27.254	9.4924	20.795	56.	43.	8.	-20.	-25.	0.983	0.351	75.	2.6	11.8
141	5	1	1772679.25	7.9970	24.125	9.7688	17.051	57.	44.	8.	-21.	-27.	1.013	0.423	78.	3.1	12.3
141	5	3	1772681.25	8.2187	21.821	9.9572	14.355	57.	44.	8.	-22.	-29.	1.044	0.497	79.	3.6	12.7
141	5	5	1772683.25	8.3786	20.073	10.0943	12.337	56.	44.	7.	-23.	-30.	1.075	0.572	80.	4.0	13.0
141	5	7	1772685.25	8.4999	18.706	10.1990	10.772	55.	43.	7.	-24.	-31.	1.106	0.647	80.	4.3	13.4
141	5	9	1772687.25	8.5959	17.608	10.2823	9.521	53.	42.	6.	-25.	-32.	1.137	0.723	80.	4.7	13.7
141	5	11	1772689.25	8.6744	16.704	[illegible]	[illegible]	52.	41.	4.	-27.	-33.	1.168	0.798	79.	5.0	13.9
141	5	13	1772691.25	8.7405	15.944	10.4088	7.635	50.	40.	3.	-28.	-34.	1.199	0.874	78.	5.3	14.2

YR	MH	DY	JD	RA(DATE)	DEC	RA(J2000.0)	DEC	TWE	9PM	MN	3AM	TWB	R	DEL	ELONG	TMAG	NMAG
65	12	2	1745135.25	21.6054	-15.074	23.3032	-5.211	38.	15.	-20.	-56.	-66.	1.235	1.116	72.	6.7	14.8
65	12	4	1745137.25	21.4948	-15.134	23.1965	-5.395	37.	12.	-23.	-59.	-64.	1.204	1.150	68.	6.7	14.8
65	12	6	1745139.25	21.3921	-15.172	23.0976	-5.554	36.	10.	-26.	-61.	-62.	1.173	1.185	65.	6.6	14.8
65	12	8	1745141.25	21.2967	-15.192	23.0055	-5.693	35.	7.	-29.	-63.	-59.	1.142	1.219	61.	6.5	14.8
65	12	10	1745143.25	21.2076	-15.196	22.9194	-5.815	33.	4.	-32.	-65.	-57.	1.111	1.253	58.	6.5	14.8
65	12	12	1745145.25	21.1240	-15.189	22.8386	-5.921	32.	1.	-35.	-67.	-54.	1.080	1.285	55.	6.4	14.8
65	12	14	1745147.25	21.0452	-15.173	22.7624	-6.016	30.	-1.	-38.	-68.	-52.	1.049	1.318	52.	6.3	14.8
65	12	16	1745149.25	20.9706	-15.149	22.6902	-6.101	29.	-4.	-40.	-69.	-49.	1.018	1.349	49.	6.2	14.8
65	12	18	1745151.25	20.8996	-15.120	22.6215	-6.179	27.	-6.	-43.	-70.	-46.	0.987	1.378	46.	6.1	14.8
65	12	20	1745153.25	20.8316	-15.087	22.5555	-6.252	25.	-9.	-45.	-70.	-44.	0.957	1.407	43.	6.0	14.7
65	12	22	1745155.25	20.7661	-15.053	22.4920	-6.321	23.	-11.	-48.	-70.	-41.	0.927	1.434	40.	5.9	14.7
65	12	24	1745157.25	20.7026	-15.017	22.4304	-6.389	21.	-14.	-50.	-69.	-38.	0.897	1.460	37.	5.8	14.7
65	12	26	1745159.25	20.6406	-14.982	22.3703	-6.457	19.	-17.	-53.	-68.	-36.	0.867	1.484	34.	5.6	14.6
65	12	28	1745161.25	20.5798	-14.949	22.3113	-6.526	17.	-19.	-55.	-67.	-33.	0.839	1.506	31.	5.5	14.6
65	12	30	1745163.25	20.5197	-14.918	22.2530	-6.600	14.	-22.	-57.	-65.	-31.	0.810	1.526	28.	5.4	14.6
66	1	1	1745165.25	20.4600	-14.891	22.1951	-6.678	12.	-24.	-59.	-63.	-28.	0.783	1.544	25.	5.2	14.5
66	1	3	1745167.25	20.4004	-14.868	22.1374	-6.762	10.	-27.	-61.	-62.	-26.	0.756	1.559	22.	5.1	14.5
66	1	5	1745169.25	20.3405	-14.851	22.0794	-6.855	7.	-29.	-63.	-60.	-24.	0.731	1.572	20.	4.9	14.4
66	1	7	1745171.25	20.2802	-14.841	22.0211	-6.956	5.	-32.	-65.	-57.	-21.	0.706	1.582	17.	4.8	14.3
66	1	9	1745173.25	20.2192	-14.839	21.9622	-7.069	2.	-34.	-67.	-55.	-19.	0.684	1.590	14.	4.6	14.3
66	1	11	1745175.25	20.1573	-14.845	21.9025	-7.194	0.	-37.	-68.	-53.	-16.	0.663	1.594	11.	4.5	14.2
66	1	13	1745177.25	20.0945	-14.860	21.8419	-7.331	-3.	-39.	-69.	-51.	-14.	0.643	1.594	8.	4.4	14.2
66	1	15	1745179.25	20.0307	-14.885	21.7806	-7.483	-5.	-42.	-70.	-48.	-12.	0.627	1.592	5.	4.2	14.1
66	1	17	1745181.25	19.9659	-14.921	21.7183	-7.649	-8.	-44.	-70.	-46.	-10.	0.612	1.585	2.	4.1	14.0
66	1	19	1745183.25	19.9003	-14.968	21.6554	-7.830	-11.	-47.	-70.	-43.	-7.	0.601	1.575	-1.	4.0	14.0
66	1	21	1745185.25	19.8339	-15.028	21.5919	-8.026	-14.	-49.	-69.	-41.	-5.	0.592	1.560	-4.	3.9	13.9
66	1	23	1745187.25	19.7671	-15.099	21.5281	-8.238	-16.	-52.	-69.	-38.	-3.	0.587	1.542	-7.	3.8	13.9
66	1	25	1745189.25	19.7000	-15.182	21.4642	-8.463	-19.	-54.	-68.	-36.	-1.	0.585	1.519	-10.	3.8	13.8
66	1	27	1745191.25	19.6330	-15.276	21.4006	-8.702	-22.	-56.	-66.	-34.	1.	0.586	1.493	-13.	4.0	13.8
66	1	29	1745193.25	19.5662	-15.383	21.3372	-8.954	-25.	-59.	-65.	-31.	3.	0.591	1.462	-16.	4.0	13.8
66	1	31	1745195.25	19.4999	-15.501	21.2745	-9.218	-28.	-61.	-63.	-29.	5.	0.599	1.428	-19.	4.0	13.8
66	2	2	1745197.25	19.4342	-15.631	21.2124	-9.494	-31.	-63.	-61.	-26.	7.	0.610	1.391	-22.	4.0	13.7
66	2	4	1745199.25	19.3690	-15.772	21.1510	-9.782	-34.	-65.	-59.	-24.	9.	0.623	1.350	-25.	4.0	13.7
66	2	6	1745201.25	19.3041	-15.924	21.0902	-10.082	-37.	-66.	-57.	-22.	10.	0.640	1.306	-28.	4.0	13.7
66	2	8	1745203.25	19.2395	-16.088	21.0297	-10.394	-39.	-68.	-55.	-19.	12.	0.658	1.260	-31.	4.0	13.7
66	2	10	1745205.25	19.1746	-16.265	20.9691	-10.721	-42.	-69.	-53.	-17.	14.	0.679	1.211	-34.	4.1	13.7
66	2	12	1745207.25	19.1090	-16.455	20.9080	-11.064	-45.	-71.	-51.	-15.	15.	0.701	1.161	-37.	4.1	13.7
66	2	14	1745209.25	19.0418	-16.660	20.8456	-11.428	-48.	-71.	-49.	-12.	17.	0.725	1.108	-39.	4.1	13.6
66	2	16	1745211.25	18.9723	-16.882	20.7811	-11.815	-51.	-72.	-47.	-10.	18.	0.751	1.053	-43.	4.1	13.6
66	2	18	1745213.25	18.8992	-17.124	20.7135	-12.232	-54.	-72.	-44.	-8.	19.	0.777	0.998	-46.	4.1	13.5
66	2	20	1745215.25	18.8212	-17.388	20.6414	-12.686	-57.	-72.	-42.	-6.	21.	0.804	0.941	-49.	4.1	13.5
66	2	22	1745217.25	18.7364	-17.679	20.5632	-13.184	-60.	-71.	-40.	-3.	22.	0.833	0.883	-52.	4.1	13.4
66	2	24	1745219.25	18.6425	-18.002	20.4767	-13.738	-63.	-70.	-37.	-1.	23.	0.861	0.824	-55.	4.0	13.4
66	2	26	1745221.25	18.5366	-18.363	20.3791	-14.363	-66.	-69.	-35.	1.	25.	0.891	0.764	-59.	4.0	13.3
66	2	28	1745223.25	18.4146	-18.767	20.2665	-15.076	-69.	-67.	-32.	4.	26.	0.920	0.705	-63.	3.9	13.2
66	3	2	1745225.25	18.2709	-19.224	20.1338	-15.901	-71.	-64.	-29.	6.	27.	0.951	0.645	-67.	3.8	13.0
66	3	4	1745227.25	18.0981	-19.742	19.9737	-16.867	-74.	-62.	-25.	9.	29.	0.981	0.585	-71.	3.7	12.9
66	3	6	1745229.25	17.8852	-20.325	19.7756	-18.012	-75.	-58.	-22.	12.	30.	1.012	0.526	-76.	3.6	12.7
66	3	8	1745231.25	17.6165	-20.972	19.5241	-19.379	-75.	-54.	-17.	16.	31.	1.042	0.468	-82.	3.4	12.5
66	3	10	1745233.25	17.2692	-21.657	19.1958	-21.010	-72.	-48.	-12.	19.	32.	1.073	0.412	-88.	3.3	12.3
66	3	12	1745235.25	16.8109	-22.298	18.7561	-22.916	-66.	-42.	-6.	23.	32.	1.104	0.360	-97.	3.1	12.1
66	3	14	1745237.25	16.1992	-22.686	18.1557	-24.994	-58.	-33.	2.	28.	32.	1.135	0.314	-107.	2.8	11.9
66	3	16	1745239.25	15.3938	-22.384	17.3398	-26.853	-46.	-22.	12.	32.	30.	1.166	0.276	-120.	2.7	11.6
66	3	18	1745241.25	14.3964	-20.739	16.2905	-27.633	-31.	-7.	23.	34.	25.	1.197	0.252	-136.	2.6	11.5

YR	MH	DY	JD	RA(DATE)	DEC	RA(J2000.0)	DEC	TWE	9PM	MN	3AM	TWB	R	DEL	ELONG	TMAG	NMAG
-11	8	17	1717269.25	4.0222	20.198	6.0201	23.042	-31.	-24.	7.	43.	56.	1.233	0.923	-79.	6.3	14.4
-11	8	19	1717271.25	4.0758	20.899	6.0840	23.576	-30.	-22.	8.	44.	58.	1.202	0.847	-80.	6.0	14.1
-11	8	21	1717273.25	4.1382	21.725	6.1584	24.208	-29.	-21.	9.	45.	59.	1.171	0.772	-81.	5.7	13.9
-11	8	23	1717275.25	4.2126	22.719	6.2475	24.967	-28.	-20.	10.	46.	61.	1.140	0.695	-82.	5.3	13.6
-11	8	25	1717277.25	4.3044	23.940	6.3576	25.898	-27.	-19.	11.	47.	62.	1.109	0.619	-83.	4.9	13.3
-11	8	27	1717279.25	4.4221	25.480	6.4986	27.065	-26.	-18.	12.	48.	64.	1.078	0.543	-83.	4.5	12.9
-11	8	29	1717281.25	4.5805	27.481	6.6877	28.561	-24.	-16.	13.	48.	64.	1.047	0.468	-82.	4.0	12.6
-11	8	31	1717283.25	4.8074	30.174	6.9560	30.529	-22.	-15.	13.	48.	65.	1.017	0.393	-81.	3.5	12.1
-11	9	2	1717285.25	5.1598	33.924	7.3653	33.163	-19.	-13.	13.	47.	63.	0.986	0.321	-78.	2.9	11.6
-11	9	4	1717287.25	5.7709	39.230	8.0478	36.595	-15.	-11.	11.	42.	59.	0.956	0.254	-72.	2.3	11.0
-11	9	6	1717289.25	6.9775	45.991	9.2810	40.071	-9.	-8.	6.	33.	48.	0.926	0.198	-60.	1.6	10.4
-11	9	8	1717291.25	9.3215	49.099	11.3394	38.991	2.	-4.	-3.	14.	27.	0.896	0.163	-37.	1.0	9.9
-11	9	10	1717293.25	11.8541	38.974	13.4808	27.995	14.	0.	-15.	-10.	1.	0.867	0.166	-5.	0.9	9.9
-11	9	12	1717295.25	13.2326	24.589	14.8096	14.953	21.	3.	-24.	-29.	-20.	0.838	0.204	19.	1.2	10.3
-11	9	14	1717297.25	13.9101	14.432	15.5346	5.981	23.	3.	-29.	-40.	-33.	0.810	0.264	32.	1.6	10.7
-11	9	16	1717299.25	14.2831	8.005	15.9555	0.354	23.	2.	-31.	-47.	-40.	0.782	0.333	38.	1.9	11.2
-11	9	18	1717301.25	14.5093	3.800	16.2190	-3.315	22.	1.	-33.	-51.	-44.	0.756	0.407	41.	2.2	11.5
-11	9	20	1717303.25	14.6552	0.899	16.3929	-5.851	21.	0.	-35.	-54.	-46.	0.730	0.483	42.	2.4	11.8
-11	9	22	1717305.25	14.7521	-1.202	16.5114	-7.699	20.	-2.	-37.	-56.	-47.	0.706	0.561	42.	2.5	12.1
-11	9	24	1717307.25	14.8166	-2.783	16.5927	-9.106	19.	-3.	-39.	-58.	-48.	0.684	0.639	41.	2.7	12.3
-11	9	26	1717309.25	14.8581	-4.012	16.6476	-10.218	18.	-5.	-41.	-59.	-47.	0.663	0.717	40.	2.8	12.5
-11	9	28	1717311.25	14.8825	-4.990	16.6828	-11.124	17.	-7.	-42.	-60.	-47.	0.644	0.795	39.	2.9	12.6
-11	9	30	1717313.25	14.8936	-5.786	16.7027	-11.882	15.	-9.	-44.	-60.	-46.	0.628	0.872	37.	2.9	12.8
-11	10	2	1717315.25	14.8939	-6.445	16.7105	-12.531	14.	-10.	-46.	-60.	-45.	0.614	0.947	36.	3.0	12.9
-11	10	4	1717317.25	14.8855	-6.999	16.7082	-13.099	13.	-12.	-48.	-60.	-43.	0.602	1.021	34.	3.1	13.0
-11	10	6	1717319.25	14.8698	-7.472	16.6978	-13.603	11.	-14.	-49.	-60.	-41.	0.594	1.093	32.	3.2	13.2
-11	10	8	1717321.25	14.8482	-7.880	16.6806	-14.058	10.	-16.	-51.	-60.	-39.	0.589	1.162	29.	3.2	13.3
-11	10	10	1717323.25	14.8218	-8.237	16.6580	-14.475	8.	-18.	-53.	-59.	-37.	0.587	1.229	27.	3.4	13.4
-11	10	12	1717325.25	14.7916	-8.553	16.6312	-14.860	7.	-20.	-54.	-58.	-35.	0.589	1.292	25.	3.7	13.5
-11	10	14	1717327.25	14.7585	-8.837	16.6009	-15.220	5.	-23.	-56.	-57.	-33.	0.593	1.353	22.	3.9	13.6
-11	10	16	1717329.25	14.7234	-9.096	16.5682	-15.560	4.	-25.	-58.	-56.	-31.	0.601	1.409	20.	4.0	13.7
-11	10	18	1717331.25	14.6868	-9.334	16.5339	-15.882	2.	-27.	-59.	-55.	-29.	0.612	1.463	17.	4.1	13.9
-11	10	20	1717333.25	14.6496	-9.555	16.4987	-16.189	0.	-29.	-61.	-53.	-26.	0.626	1.512	15.	4.3	14.0
-11	10	22	1717335.25	14.6122	-9.764	16.4630	-16.483	-1.	-31.	-62.	-52.	-24.	0.642	1.558	12.	4.4	14.1
-11	10	24	1717337.25	14.5749	-9.963	16.4274	-16.767	-3.	-33.	-63.	-50.	-21.	0.661	1.600	10.	4.6	14.2
-11	10	26	1717339.25	14.5382	-10.154	16.3921	-17.040	-5.	-35.	-64.	-49.	-19.	0.682	1.639	8.	4.7	14.3
-11	10	28	1717341.25	14.5022	-10.339	16.3575	-17.306	-6.	-37.	-65.	-47.	-17.	0.704	1.673	5.	4.9	14.5
-11	10	30	1717343.25	14.4670	-10.518	16.3236	-17.564	-8.	-39.	-65.	-45.	-14.	0.728	1.705	3.	5.0	14.6
-11	11	1	1717345.25	14.4327	-10.694	16.2905	-17.816	-10.	-41.	-66.	-44.	-12.	0.753	1.733	0.	5.2	14.7
-11	11	3	1717347.25	14.3993	-10.867	16.2583	-18.062	-11.	-43.	-66.	-42.	-10.	0.780	1.758	-2.	5.3	14.8
-11	11	5	1717349.25	14.3668	-11.037	16.2270	-18.303	-13.	-45.	-66.	-40.	-7.	0.807	1.781	-5.	5.5	14.9
-11	11	7	1717351.25	14.3352	-11.205	16.1964	-18.540	-15.	-47.	-66.	-38.	-5.	0.835	1.800	-7.	5.6	15.0
-11	11	9	1717353.25	14.3043	-11.371	16.1665	-18.772	-17.	-49.	-65.	-36.	-3.	0.864	1.816	-10.	5.7	15.1
-11	11	11	1717355.25	14.2740	-11.535	16.1373	-19.001	-18.	-51.	-64.	-34.	0.	0.893	1.830	-12.	5.9	15.2
-11	11	13	1717357.25	14.2443	-11.698	16.1086	-19.227	-20.	-53.	-64.	-32.	2.	0.923	1.841	-14.	6.0	15.3
-11	11	15	1717359.25	14.2150	-11.859	16.0802	-19.450	-22.	-55.	-63.	-30.	4.	0.953	1.850	-17.	6.1	15.3
-11	11	17	1717361.25	14.1860	-12.019	16.0520	-19.670	-24.	-57.	-62.	-28.	6.	0.983	1.857	-19.	6.2	15.4
-11	11	19	1717363.25	14.1571	-12.176	16.0240	-19.889	-26.	-59.	-60.	-26.	8.	1.014	1.861	-22.	6.3	15.5
-11	11	21	1717365.25	14.1283	-12.333	15.9959	-20.105	-27.	-60.	-59.	-24.	10.	1.044	1.864	-24.	6.4	15.5
-11	11	23	1717367.25	14.0992	-12.487	15.9675	-20.319	-29.	-62.	-57.	-22.	13.	1.075	1.864	-26.	6.5	15.6
-11	11	25	1717369.25	14.0699	-12.640	15.9388	-20.531	-31.	-63.	-56.	-20.	15.	1.106	1.862	-29.	6.6	15.7
-11	11	27	1717371.25	14.0400	-12.790	15.9096	-20.742	-33.	-65.	-54.	-18.	17.	1.137	1.859	-31.	6.7	15.7
-11	11	29	1717373.25	14.0096	-12.938	15.8796	-20.951	-35.	-66.	-52.	-16.	18.	1.168	1.854	-34.	6.8	15.8
-11	12	1	1717375.25	13.9784	-13.083	15.8488	-21.159	-37.	-67.	-50.	-14.	20.	1.199	1.847	-36.	6.9	15.8

YR	MH	DY	JD	RA(DATE)	DEC	RA(J2000.0)	DEC	TWE	9PM	MN	3AM	TWB	R	DEL	ELONG	TMAG	NMAG
-86	6	12	1689809.25	2.4542	13.909	4.4214	21.118	-39.	-41.	-28.	4.	11.	1.243	1.867	-38.	7.9	15.9
-86	6	14	1689811.25	2.4844	14.339	4.4575	21.469	-39.	-41.	-27.	5.	13.	1.212	1.804	-40.	7.7	15.8
-86	6	16	1689813.25	2.5162	14.797	4.4956	21.843	-39.	-40.	-26.	7.	14.	1.181	1.740	-41.	7.5	15.7
-86	6	18	1689815.25	2.5501	15.285	4.5363	22.242	-39.	-40.	-25.	8.	16.	1.150	1.674	-42.	7.3	15.5
-86	6	20	1689817.25	2.5863	15.810	4.5800	22.670	-39.	-39.	-23.	10.	17.	1.119	1.607	-44.	7.0	15.4
-86	6	22	1689819.25	2.6255	16.378	4.6273	23.132	-38.	-39.	-22.	11.	19.	1.088	1.539	-45.	6.8	15.2
-86	6	24	1689821.25	2.6682	16.994	4.6790	23.632	-38.	-38.	-20.	13.	20.	1.057	1.470	-46.	6.6	15.1
-86	6	26	1689823.25	2.7152	17.669	4.7360	24.178	-37.	-37.	-19.	14.	22.	1.026	1.400	-47.	6.3	14.9
-86	6	28	1689825.25	2.7677	18.413	4.7997	24.776	-37.	-36.	-18.	16.	23.	0.995	1.328	-48.	6.1	14.7
-86	6	30	1689827.25	2.8268	19.239	4.8715	25.435	-36.	-35.	-16.	17.	24.	0.965	[illegible]	-49.	5.8	14.5
-86	7	2	1689829.25	2.8945	20.164	4.9537	26.168	-35.	-34.	-15.	18.	26.	0.934	1.182	-50.	5.5	14.3
-86	7	4	1689831.25	2.9731	21.209	5.0492	26.986	-34.	-33.	-14.	20.	27.	0.905	1.107	-50.	5.2	14.1
-86	7	6	1689833.25	3.0659	22.399	5.1616	27.905	-33.	-32.	-12.	21.	28.	0.875	1.032	-50.	4.9	13.9
-86	7	8	1689835.25	3.1773	23.767	5.2964	28.942	-31.	-30.	-11.	22.	29.	0.846	0.957	-51.	4.6	13.6
-86	7	10	1689837.25	3.3138	25.353	5.4608	30.116	-30.	-29.	-10.	23.	30.	0.818	0.882	-50.	4.2	13.4
-86	7	12	1689839.25	3.4846	27.203	5.6651	31.443	-28.	-27.	-9.	23.	31.	0.790	0.808	-49.	3.9	13.1
-86	7	14	1689841.25	3.7030	29.368	5.9241	32.926	-26.	-25.	-8.	23.	31.	0.763	0.735	-48.	3.5	12.8
-86	7	16	1689843.25	3.9890	31.892	6.2583	34.544	-23.	-23.	-7.	23.	31.	0.737	0.664	-46.	3.1	12.6
-86	7	18	1689845.25	4.3720	34.778	6.6957	36.203	-20.	-20.	-7.	21.	29.	0.713	0.599	-42.	2.7	12.2
-86	7	20	1689847.25	4.8937	37.908	7.2697	37.669	-16.	-17.	-7.	19.	26.	0.689	0.540	-37.	2.3	12.0
-86	7	22	1689849.25	5.6030	40.901	8.0073	38.476	-11.	-13.	-8.	15.	22.	0.668	0.491	-30.	2.0	11.7
-86	7	24	1689851.25	6.5278	42.951	8.8984	37.920	-6.	-9.	-10.	9.	16.	0.648	0.456	-21.	1.7	11.5
-86	7	26	1689853.25	7.6103	42.999	9.8625	35.388	0.	-5.	-12.	2.	8.	0.631	0.440	-11.	1.5	11.3
-86	7	28	1689855.25	8.6831	40.541	10.7716	30.957	5.	-1.	-14.	-7.	-1.	0.616	0.446	0.	1.4	11.3
-86	7	30	1689857.25	9.5843	36.245	11.5311	25.499	10.	2.	-17.	-14.	-10.	0.604	0.471	11.	1.4	11.4
-86	8	1	1689859.25	10.2643	31.330	12.1188	20.031	13.	4.	-19.	-21.	-17.	0.595	0.515	19.	1.5	11.5
-86	8	3	1689861.25	10.7547	26.675	12.5576	15.166	15.	5.	-21.	-27.	-23.	0.589	0.572	25.	1.7	11.7
-86	8	5	1689863.25	11.1052	22.644	12.8819	11.087	15.	5.	-24.	-32.	-28.	0.586	0.639	29.	1.9	12.0
-86	8	7	1689865.25	11.3571	19.286	13.1217	7.752	15.	4.	-26.	-35.	-32.	0.586	0.711	32.	2.4	12.2
-86	8	9	1689867.25	11.5400	16.524	13.3001	5.036	15.	3.	-27.	-38.	-34.	0.590	0.788	34.	2.7	12.4
-86	8	11	1689869.25	11.6740	14.253	13.4334	2.815	14.	2.	-29.	-40.	-36.	0.597	0.866	35.	2.9	12.7
-86	8	13	1689871.25	11.7729	12.372	13.5337	0.981	13.	1.	-31.	-42.	-38.	0.607	0.945	35.	3.2	12.9
-86	8	15	1689873.25	11.8463	10.799	13.6093	-0.551	12.	-1.	-33.	-43.	-39.	0.620	1.024	35.	3.4	13.1
-86	8	17	1689875.25	11.9011	9.470	13.6667	-1.848	11.	-2.	-34.	-45.	-39.	0.636	1.102	34.	3.6	13.3
-86	8	19	1689877.25	11.9420	8.333	13.7103	-2.958	9.	-4.	-36.	-45.	-39.	0.654	1.178	33.	3.9	13.5
-86	8	21	1689879.25	11.9727	7.349	13.7436	-3.921	8.	-6.	-38.	-46.	-39.	0.674	1.252	32.	4.1	13.7
-86	8	23	1689881.25	11.9958	6.488	13.7692	-4.765	7.	-8.	-39.	-46.	-39.	0.696	1.324	31.	4.3	13.9
-86	8	25	1689883.25	12.0132	5.727	13.7889	-5.514	5.	-9.	-41.	-47.	-38.	0.720	1.394	29.	4.6	14.1
-86	8	27	1689885.25	12.0265	5.046	13.8043	-6.184	4.	-11.	-42.	-47.	-37.	0.744	1.461	28.	4.8	14.3
-86	8	29	1689887.25	12.0366	4.432	13.8165	-6.790	3.	-13.	-44.	-47.	-37.	0.771	1.526	26.	5.0	14.5
-86	8	31	1689889.25	12.0445	3.873	13.8261	-7.343	1.	-15.	-45.	-46.	-35.	0.798	1.588	24.	5.2	14.6
-86	9	2	1689891.25	12.0506	3.360	13.8340	-7.851	0.	-16.	-46.	-46.	-34.	0.826	1.648	23.	5.4	14.8
-86	9	4	1689893.25	12.0556	2.886	13.8406	-8.321	-1.	-18.	-47.	-46.	-33.	0.854	1.705	21.	5.6	14.9
-86	9	6	1689895.25	12.0597	2.443	13.8462	-8.760	-2.	-20.	-49.	-45.	-32.	0.883	1.760	19.	5.8	15.1
-86	9	8	1689897.25	12.0632	2.029	13.8511	-9.171	-3.	-21.	-50.	-45.	-30.	0.913	1.812	18.	5.9	15.2
-86	9	10	1689899.25	12.0663	1.638	13.8556	-9.559	-5.	-23.	-51.	-44.	-29.	0.943	1.862	16.	6.1	15.3
-86	9	12	1689901.25	12.0691	1.268	13.8597	-9.926	-6.	-25.	-52.	-43.	-27.	0.973	1.910	14.	6.3	15.4
-86	9	14	1689903.25	12.0717	0.916	13.8635	-10.276	-7.	-26.	-52.	-42.	-26.	1.004	1.955	12.	6.4	15.6
-86	9	16	1689905.25	12.0743	0.579	13.8673	-10.611	-8.	-28.	-53.	-42.	-24.	1.035	1.998	10.	6.6	15.7
-86	9	18	1689907.25	12.0767	0.256	13.8709	-10.931	-9.	-29.	-54.	-41.	-22.	1.066	2.039	9.	6.7	15.8
-86	9	20	1689909.25	12.0791	-0.055	13.8744	-11.240	-10.	-31.	-55.	-40.	-20.	1.097	2.078	7.	6.8	15.9
-86	9	22	1689911.25	12.0815	-0.355	13.8779	-11.538	-11.	-32.	-55.	-39.	-19.	1.128	2.115	5.	7.0	16.0
-86	9	24	1689913.25	12.0839	-0.646	13.8813	-11.827	-13.	-34.	-56.	-38.	-17.	1.159	2.149	3.	7.1	16.1
-86	9	26	1689915.25	12.0863	-0.928	13.8847	-12.106	-14.	-35.	-56.	-37.	-15.	1.190	2.182	1.	7.2	16.2

YR	MH	DY	JD	RA(DATE)	DEC	RA(J2000.0)	DEC	TWE	9PM	MN	3AM	TWB	R	DEL	ELONG	TMAG	NMAG
-163	9	23	1661788.25	2.6140	9.063	4.6004	16.111	-14.	8.	44.	64.	52.	1.229	0.298	-137.	3.8	11.9
-163	9	25	1661790.25	2.0835	6.990	4.0387	15.346	-8.	15.	49.	60.	43.	1.198	0.236	-148.	3.2	11.4
-163	9	27	1661792.25	1.2102	3.269	3.1146	13.394	2.	25.	55.	49.	29.	1.167	0.181	-163.	2.5	10.7
-163	9	29	1661794.25	23.7743	-3.159	1.6228	8.621	16.	37.	51.	29.	6.	1.136	0.145	173.	1.9	10.2
-163	10	1	1661796.25	21.8616	-10.765	23.7254	0.619	32.	44.	33.	0.	-24.	1.105	0.141	141.	1.7	10.1
-163	10	3	1661798.25	20.2076	-15.111	22.1509	-6.246	39.	37.	12.	-24.	-48.	1.074	0.171	115.	2.0	10.4
-163	10	5	1661800.25	19.1555	-16.457	21.1566	-10.042	38.	28.	-2.	-39.	-62.	1.043	0.222	98.	2.4	10.9
-163	10	7	1661802.25	18.5194	-16.697	20.5498	-12.008	36.	21.	-11.	-48.	-69.	1.012	0.282	86.	2.8	11.4
-163	10	9	1661804.25	18.1137	-16.622	20.1587	-13.109	34.	16.	-18.	-54.	-71.	0.981	0.346	79.	3.1	11.8
-163	10	11	1661806.25	17.8368	-16.468	19.8896	-13.785	32.	12.	-23.	-58.	-71.	0.951	0.413	72.	3.3	12.1
-163	10	13	1661808.25	17.6363	-16.307	19.6934	-14.235	30.	9.	-26.	-62.	-69.	0.921	0.480	68.	3.5	12.3
-163	10	15	1661810.25	17.4836	-16.158	19.5433	-14.557	28.	6.	-30.	-64.	-67.	0.891	0.548	63.	3.6	12.5
-163	10	17	1661812.25	17.3620	-16.024	19.4234	-14.801	27.	3.	-33.	-66.	-65.	0.862	0.615	60.	3.7	12.7
-163	10	19	1661814.25	17.2615	-15.906	19.3240	-14.996	25.	1.	-36.	-68.	-62.	0.833	0.683	56.	3.8	12.9
-163	10	21	1661816.25	17.1755	-15.801	19.2387	-15.160	24.	-2.	-38.	-69.	-59.	0.805	0.749	53.	3.8	13.0
-163	10	23	1661818.25	17.0996	-15.708	19.1633	-15.305	22.	-4.	-40.	-70.	-57.	0.777	0.815	50.	3.8	13.1
-163	10	25	1661820.25	17.0306	-15.625	19.0948	-15.438	21.	-6.	-43.	-70.	-54.	0.751	0.880	47.	3.8	13.2
-163	10	27	1661822.25	16.9663	-15.550	19.0309	-15.565	19.	-9.	-45.	-71.	-51.	0.725	0.944	44.	3.8	13.3
-163	10	29	1661824.25	16.9051	-15.482	18.9701	-15.689	18.	-11.	-47.	-70.	-49.	0.701	1.006	41.	3.8	13.3
-163	10	31	1661826.25	16.8457	-15.422	18.9111	-15.815	16.	-13.	-50.	-70.	-46.	0.679	1.067	38.	3.7	13.4
-163	11	2	1661828.25	16.7872	-15.367	18.8530	-15.944	15.	-15.	-52.	-69.	-43.	0.658	1.126	35.	3.7	13.4
-163	11	4	1661830.25	16.7288	-15.319	18.7951	-16.079	13.	-18.	-54.	-68.	-41.	0.640	1.183	32.	3.7	13.5
-163	11	6	1661832.25	16.6702	-15.278	18.7370	-16.220	11.	-20.	-56.	-67.	-38.	0.623	1.237	29.	3.7	13.5
-163	11	8	1661834.25	16.6110	-15.242	18.6784	-16.370	10.	-22.	-58.	-65.	-35.	0.609	1.289	26.	3.6	13.6
-163	11	10	1661836.25	16.5510	-15.214	18.6190	-16.528	8.	-25.	-60.	-63.	-32.	0.598	1.338	23.	3.6	13.6
-163	11	12	1661838.25	16.4902	-15.192	18.5588	-16.696	6.	-27.	-62.	-62.	-29.	0.591	1.383	20.	3.6	13.7
-163	11	14	1661840.25	16.4287	-15.178	18.4981	-16.872	4.	-30.	-64.	-60.	-27.	0.586	1.426	17.	3.7	13.7
-163	11	16	1661842.25	16.3668	-15.172	18.4370	-17.058	2.	-32.	-65.	-58.	-24.	0.585	1.464	15.	4.0	13.8
-163	11	18	1661844.25	16.3047	-15.175	18.3757	-17.252	0.	-34.	-67.	-55.	-21.	0.587	1.498	12.	4.0	13.8
-163	11	20	1661846.25	16.2426	-15.185	18.3145	-17.453	-2.	-37.	-68.	-53.	-18.	0.592	1.529	9.	4.1	13.9
-163	11	22	1661848.25	16.1809	-15.204	18.2537	-17.661	-4.	-39.	-69.	-51.	-16.	0.600	1.555	6.	4.2	14.0
-163	11	24	1661850.25	16.1199	-15.231	18.1937	-17.874	-6.	-42.	-70.	-48.	-13.	0.612	1.578	3.	4.3	14.0
-163	11	26	1661852.25	16.0598	-15.267	18.1346	-18.092	-8.	-44.	-70.	-46.	-10.	0.626	1.596	0.	4.4	14.1
-163	11	28	1661854.25	16.0007	-15.310	18.0766	-18.314	-11.	-47.	-70.	-44.	-8.	0.643	1.611	-3.	4.5	14.2
-163	11	30	1661856.25	15.9427	-15.360	18.0197	-18.539	-13.	-49.	-70.	-41.	-5.	0.662	1.622	-6.	4.6	14.3
-163	12	2	1661858.25	15.8859	-15.418	17.9640	-18.767	-15.	-51.	-69.	-39.	-2.	0.683	1.629	-9.	4.7	14.3
-163	12	4	1661860.25	15.8302	-15.481	17.9094	-18.997	-17.	-54.	-68.	-37.	0.	0.706	1.633	-11.	4.8	14.4
-163	12	6	1661862.25	15.7755	-15.550	17.8559	-19.228	-20.	-56.	-67.	-34.	3.	0.730	1.634	-14.	5.0	14.5
-163	12	8	1661864.25	15.7217	-15.624	17.8032	-19.461	-22.	-58.	-65.	-32.	5.	0.755	1.632	-17.	5.1	14.6
-163	12	10	1661866.25	15.6686	-15.703	17.7513	-19.696	-24.	-60.	-64.	-29.	7.	0.782	1.628	-20.	5.2	14.6
-163	12	12	1661868.25	15.6160	-15.785	17.6998	-19.932	-27.	-62.	-62.	-27.	10.	0.810	1.620	-23.	5.3	14.7
-163	12	14	1661870.25	15.5636	-15.871	17.6485	-20.170	-29.	-64.	-60.	-24.	12.	0.838	1.610	-25.	5.4	14.8
-163	12	16	1661872.25	15.5112	-15.959	17.5972	-20.410	-32.	-66.	-58.	-22.	14.	0.867	1.598	-28.	5.5	14.8
-163	12	18	1661874.25	15.4585	-16.049	17.5455	-20.652	-34.	-68.	-56.	-20.	16.	0.896	1.584	-31.	5.6	14.9
-163	12	20	1661876.25	15.4052	-16.140	17.4931	-20.896	-36.	-69.	-54.	-17.	18.	0.926	1.568	-34.	5.7	14.9
-163	12	22	1661878.25	15.3511	-16.231	17.4398	-21.142	-39.	-70.	-51.	-15.	20.	0.956	1.550	-36.	5.7	15.0
-163	12	24	1661880.25	15.2956	-16.323	17.3852	-21.391	-41.	-71.	-49.	-12.	22.	0.987	1.530	-39.	5.8	15.0
-163	12	26	1661882.25	15.2386	-16.413	17.3288	-21.642	-44.	-71.	-47.	-10.	24.	1.018	1.508	-42.	5.9	15.0
-163	12	28	1661884.25	15.1797	-16.502	17.2704	-21.896	-47.	-71.	-44.	-8.	25.	1.048	1.486	-45.	6.0	15.1
-163	12	30	1661886.25	15.1184	-16.588	17.2094	-22.153	-49.	-71.	-42.	-5.	27.	1.079	1.462	-48.	6.0	15.1
-162	1	1	1661888.25	15.0543	-16.670	17.1455	-22.412	-52.	-70.	-39.	-3.	28.	1.110	1.436	-50.	6.1	15.1
-162	1	3	1661890.25	14.9871	-16.747	17.0782	-22.674	-54.	-69.	-37.	0.	30.	1.141	1.410	-53.	6.1	15.1
-162	1	5	1661892.25	14.9162	-16.817	17.0069	-22.937	-57.	-67.	-34.	2.	31.	1.172	1.382	-56.	6.2	15.1
-162	1	7	1661894.25	14.8412	-16.879	16.9311	-23.202	-59.	-66.	-31.	5.	33.	1.203	1.354	-59.	6.2	15.2

YR	MH	DY	JD	RA(DATE)DEC		RA(J2000.0)DEC		TWE	9PM	MN	3AM	TWB	R	DEL	ELONG	TMAG	NMAG
-239	3	31	1633853.25	0.3923	1.450	2.3360	13.071	-15.	-35.	-54.	-34.	-15.	1.237	2.246	-1.	8.3	16.3
-239	4	2	1633855.25	0.3952	1.724	2.3404	13.341	-17.	-36.	-53.	-33.	-14.	1.206	2.214	-2.	8.1	16.2
-239	4	4	1633857.25	0.3982	2.005	2.3449	13.618	-18.	-36.	-53.	-31.	-13.	1.175	2.180	-4.	7.9	16.1
-239	4	6	1633859.25	0.4013	2.296	2.3495	13.904	-20.	-37.	-52.	-30.	-11.	1.144	2.144	-6.	7.8	16.0
-239	4	8	1633861.25	0.4044	2.596	2.3543	14.200	-22.	-38.	-52.	-28.	-10.	1.113	2.107	-8.	7.6	16.0
-239	4	10	1633863.25	0.4075	2.907	2.3592	14.506	-23.	-39.	-51.	-27.	-9.	1.082	2.067	-10.	7.4	15.8
-239	4	12	1633865.25	0.4107	3.230	2.3642	14.824	-25.	-40.	-50.	-25.	-8.	1.051	2.025	-11.	7.2	15.7
-239	4	14	1633867.25	0.4140	3.566	2.3694	15.156	-26.	-41.	-50.	-24.	-7.	1.021	1.981	-13.	7.1	15.6
-239	4	16	1633869.25	0.4174	3.919	2.3748	15.503	-28.	-41.	-49.	-22.	-6.	0.990	1.935	-15.	6.9	15.5
-239	4	18	1633871.25	0.4211	4.289	2.3806	15.868	-29.	-42.	-48.	-21.	-5.	0.959	1.886	-16.	6.6	15.4
-239	4	20	1633873.25	0.4251	4.680	2.3869	16.253	-31.	-43.	-47.	-19.	-4.	0.929	1.836	-18.	6.4	15.3
-239	4	22	1633875.25	0.4296	5.094	2.3937	16.661	-32.	-43.	-46.	-18.	-2.	0.899	1.783	-20.	6.2	15.1
-239	4	24	1633877.25	0.4346	5.537	2.4015	17.096	-33.	-44.	-45.	-16.	-1.	0.870	1.728	-22.	6.0	15.0
-239	4	26	1633879.25	0.4406	6.012	2.4103	17.562	-34.	-44.	-44.	-14.	0.	0.841	1.670	-23.	5.7	14.8
-239	4	28	1633881.25	0.4479	6.524	2.4207	18.065	-35.	-44.	-42.	-13.	1.	0.813	1.610	-25.	5.5	14.7
-239	4	30	1633883.25	0.4568	7.083	2.4332	18.610	-36.	-44.	-41.	-11.	3.	0.785	1.548	-26.	5.3	14.5
-239	5	2	1633885.25	0.4680	7.695	2.4485	19.207	-37.	-44.	-40.	-9.	4.	0.758	1.483	-28.	5.0	14.4
-239	5	4	1633887.25	0.4823	8.373	2.4674	19.865	-37.	-44.	-38.	-8.	5.	0.733	1.416	-29.	4.7	14.2
-239	5	6	1633889.25	0.5008	9.131	2.4913	20.597	-38.	-44.	-37.	-6.	7.	0.708	1.346	-31.	4.5	14.0
-239	5	8	1633891.25	0.5248	9.985	2.5218	21.417	-38.	-44.	-35.	-4.	8.	0.685	1.274	-32.	4.2	13.8
-239	5	10	1633893.25	0.5562	10.959	2.5611	22.346	-38.	-43.	-34.	-2.	9.	0.664	1.200	-33.	3.9	13.6
-239	5	12	1633895.25	0.5976	12.080	2.6123	23.408	-38.	-42.	-32.	-1.	11.	0.645	1.124	-34.	3.6	13.4
-239	5	14	1633897.25	0.6524	13.387	2.6796	24.633	-37.	-41.	-31.	1.	12.	0.628	1.047	-35.	3.3	13.2
-239	5	16	1633899.25	0.7254	14.925	2.7687	26.059	-36.	-40.	-29.	2.	13.	0.614	0.969	-35.	3.0	13.0
-239	5	18	1633901.25	0.8232	16.756	2.8880	27.732	-35.	-38.	-27.	4.	14.	0.602	0.890	-35.	2.8	12.7
-239	5	20	1633903.25	0.9550	18.953	3.0491	29.701	-33.	-36.	-25.	5.	15.	0.593	0.812	-34.	2.5	12.5
-239	5	22	1633905.25	1.1344	21.605	3.2692	32.018	-30.	-33.	-23.	6.	16.	0.588	0.735	-32.	2.2	12.3
-239	5	24	1633907.25	1.3807	24.804	3.5735	34.708	-27.	-30.	-21.	7.	16.	0.585	0.662	-30.	2.0	12.0
-239	5	26	1633909.25	1.7225	28.609	3.9979	37.721	-22.	-25.	-20.	7.	15.	0.586	0.595	-26.	2.0	11.8
-239	5	28	1633911.25	2.1998	32.965	4.5897	40.820	-17.	-20.	-17.	6.	14.	0.591	0.537	-20.	1.8	11.6
-239	5	30	1633913.25	2.8610	37.530	5.3923	43.414	-10.	-14.	-15.	4.	11.	0.598	0.491	-12.	1.7	11.4
-239	6	1	1633915.25	3.7394	41.492	6.3978	44.521	-2.	-6.	-13.	1.	6.	0.609	0.462	-3.	1.6	11.3
-239	6	3	1633917.25	4.7935	43.707	7.4876	43.259	7.	1.	-11.	-4.	1.	0.623	0.453	8.	1.6	11.4
-239	6	5	1633919.25	5.8709	43.483	8.4805	39.711	14.	8.	-9.	-8.	-5.	0.639	0.465	19.	1.8	11.5
-239	6	7	1633921.25	6.8031	41.239	9.2701	34.916	20.	14.	-8.	-13.	-11.	0.657	0.496	28.	2.0	11.7
-239	6	9	1633923.25	7.5238	38.010	9.8571	29.964	25.	18.	-8.	-17.	-16.	0.677	0.542	35.	2.3	11.9
-239	6	11	1633925.25	8.0555	34.628	10.2863	25.465	27.	20.	-8.	-20.	-20.	0.700	0.599	40.	2.6	12.2
-239	6	13	1633927.25	8.4461	31.505	10.6033	21.613	29.	21.	-8.	-23.	-23.	0.724	0.663	44.	3.0	12.5
-239	6	15	1633929.25	8.7373	28.774	10.8422	18.390	29.	22.	-9.	-26.	-26.	0.749	0.732	46.	3.3	12.8
-239	6	17	1633931.25	8.9591	26.434	11.0263	15.706	29.	22.	-10.	-28.	-29.	0.775	0.803	48.	3.6	13.1
-239	6	19	1633933.25	9.1320	24.437	11.1714	13.463	29.	21.	-11.	-30.	-31.	0.802	0.877	49.	3.9	13.3
-239	6	21	1633935.25	9.2699	22.730	11.2882	11.570	28.	20.	-13.	-32.	-32.	0.830	0.952	49.	4.2	13.6
-239	6	23	1633937.25	9.3821	21.260	11.3841	9.958	27.	19.	-14.	-33.	-34.	0.859	1.027	50.	4.5	13.8
-239	6	25	1633939.25	9.4753	19.983	11.4644	8.570	25.	18.	-15.	-34.	-35.	0.888	1.101	49.	4.8	14.1
-239	6	27	1633941.25	9.5540	18.865	11.5326	7.361	24.	17.	-17.	-36.	-36.	0.918	1.175	49.	5.0	14.3
-239	6	29	1633943.25	9.6215	17.876	11.5916	6.298	23.	15.	-18.	-37.	-37.	0.948	1.249	48.	5.2	14.5
-239	7	1	1633945.25	9.6804	16.995	11.6434	5.354	21.	14.	-19.	-38.	-38.	0.979	1.321	47.	5.5	14.7
-239	7	3	1633947.25	9.7325	16.202	11.6894	4.508	20.	12.	-21.	-39.	-39.	1.009	1.392	46.	5.7	14.8
-239	7	5	1633949.25	9.7791	15.484	11.7308	3.744	19.	11.	-22.	-39.	-39.	1.040	1.463	45.	5.9	15.0
-239	7	7	1633951.25	9.8214	14.829	11.7686	3.048	17.	9.	-24.	-40.	-40.	1.071	1.532	44.	6.1	15.2
-239	7	9	1633953.25	9.8601	14.227	11.8033	2.409	16.	8.	-25.	-41.	-40.	1.102	1.600	43.	6.3	15.3
-239	7	11	1633955.25	9.8959	13.670	11.8356	1.820	14.	6.	-26.	-41.	-40.	1.133	1.666	42.	6.5	15.5
-239	7	13	1633957.25	9.9293	13.152	11.8658	1.273	13.	5.	-28.	-42.	-40.	1.164	1.731	40.	6.6	15.6
-239	7	15	1633959.25	9.9607	12.668	11.8944	0.761	11.	3.	-29.	-42.	-40.	1.195	1.795	39.	6.8	15.8

APPENDIX III

A CATALOGUE OF POSSIBLE NOVAE AND SUPERNOVAE FROM FAR EASTERN SOURCES

Format of Each Entry

The first line of each entry gives the appropriate reference number and date of observation. The first item of the second line gives the place of observation. The item after the country of origin lists the reign-period (in the case of China and Japan) or name of the king (for Korea). This is followed by the year (of the reign-period or king), the lunar month, and the cyclical day with its number in bracket. The respective record is put between quotes. After the text, the source of the record is always included. At the end of each entry, the appropriate reference numbers to other catalogues are also listed. The following abbreviations are used: XB denotes the catalogue of Xi and Bo (1965), CS - Clark and Stephenson (1977), and HO - Ho Peng Yoke (1962).

Appendix III

1. 532 BC Spring
[China] Ching-wang 13th year, spring. "A star appeared in *Wu-nu.*" (*Shih-chi*, 14) (XB2, CS1, HO6)

2. 134 BC Jul/Aug
[China] Yuan-kuang reign-period 1st year, 6th month. "A guest star was seen at *Fang* (LM4)." (*Han-shu*, 26) (XB4, CS3, HO40)

3. 110 - 105 BC
[China] During the Yuan-feng reign-period. "A star emerged (*po*) at *Ho-yun.*" (*Han-shu*, 26) (XB5, HO45)

4. 104 - 101 BC
[China] During the T'ai-ch'u reign-period. "A star emerged (*po*) at *Chao-yao.*" (*Han-shu*, 26) (HO46)

5. 77 BC Oct/Nov
[China] Yuan-feng reign-period 4th year, 9th month. "A guest star situated within *Tzu-kung* (the 'Purple Palace') between Polaris and *Tou-shu* (alpha UMa)." (*Han-shu*, 26) (XB6, CS4, HO50)

6. 48 BC May/Jun
[China] Ch'u-yuan reign-period 1st year, 4th month. "A guest star as large as a melon with a bluish-white colour was about 4 *ch'ih* to the east of the 2nd star of *Nan-tou.*" (*Han-shu*, 26) (XB7, CS5, HO57)

7. 4 BC Apr/May
[China] Chien-p'ing reign-period 3rd year, 3rd month. "A star emerged (*po*) at *Ho-k'u.*" (*Han-shu*, 11) (XB9, HO64)

8. AD 29
[China] Chien-wu reign-period 5th year. "A guest star invaded *Ti-tso.*" (*Hou-han-shu*, 83) (XB10, HO67)

9. AD 70 Dec/71 Jan
[China] Yung-p'ing reign-period 13th year, 11th month. "A guest star appeared at *Hsien-yuan* for 48 days." (*Hou-han-shu*, 20) (CS11, HO79)

10. AD 101 Dec 30
[China] Yung-yuan reign-period 13th year, 11th month, day *i-ch'ou* (2). "A small guest star appeared at the fourth star of *Hsien-yuan.* It was bluish-yellow in colour." (*Hou-han-shu*, 20) (CS13, HO88)

11. AD 107 Sep 13
[China] Yung-ch'u reign-period 1st year, autumn, 8th month, day *wu-shen.* "A guest star was at the south-west of the *Wu* star of *T'ung-ching* (LM22)." (*Hou-han-shu*, 20) (XB12, CS14, HO90)

12. AD 125 Dec/126 Jan
[China] Yen-kuang reign-period 4th year, winter, 11th month (Dec 13 - Jan 11). "A guest star was seen at *T'ien-shih.*" (*Hou-han-shu*, 20) (XB13, CS15, HO94)

13. AD 158 Mar/Apr
[Korea] Ch'adae Wang 13th year, spring, 2nd month. "A star emerged (*po*) at *Pei-tou* (the 'Plough')." (*Samguk Sagi*, 15) (XB14, HO104)

14. AD 185 Dec 7
[China] Chung-p'ing reign-period 2nd year, 10th month, day kuei-hai (60). "A guest star appeared within *Nan-men.* It was as large as half of a mat and with scintillating variegated colours. It became smaller and disappeared in the 6th month of the *next* year." (*Hou-han-shu*, 20) (XB15, CS17, HO109)

15. AD 200 Nov 6
[China] Chien-an reign-period 5th year, 10th month, day *hsin-hai* (48). "A star emerged (*po*) at *Ta-liang.*" (*Hou-han-shu*, 20) (XB16, HO115)

16. AD 207 Nov 10
[China] Chien-an reign-period 12th year, 10th month, day *hsin-mao* (28). "A star emerged (*po*) at *Ch'un-wei.*" (*Hou-han-shu*, 20) (XB17, HO119)

17. AD 213 Jan/Feb
[China] Chien-an reign-period 17th year, 12th month (Jan 10 - Feb 7). "A star emerged (*po*) at *Wu-chu-hou.*" (*Hou-han-shu*, 20) (XB18, HO120)

18. AD 222 Nov 4
[China] Huang-ch'u reign-period 3rd year, 9th month, day *chia-ch'en* (41). "A guest star was seen inside *Tso-i-men* of the *T'ai-wei* (Enclosure)." (*Chin-shu*, 13 and *Sung-shu*, 23) (CS18, HO123)

19. AD 269 Oct/Nov
[China] T'ai-shih reign-period, 5th year, 9th month (Oct 13 - Nov 10). "A star emerged (*po*) in *Tzu-kung.*" (*Chin-shu*, 13 and *Sung-shu*, 23) (XB19, HO145)

20. AD 275 Jan/Feb
[China] T'ai-shih reign-period, 10th year, 12th month (Jan 14 - Feb 12). "A star emerged (*po*) in *Chen* (LM28)." (*Chin-shu*, 13 and *Sung-shu*, 23) (XB20, HO146)

21. AD 290 Apr/May
[China] T'ai-hsi reign-period, 1st year, summer, 4th month (Apr 27 - May 25). "A guest star was seen at *Tzu-kung.*" (*Chin-shu*, 13 and *Sung-shu*, 23) (XB21, CS20, HO155)

22. AD 304 Jun/Jul
[China] Yung-hsing reign-period, 1st year, summer, 5th month (Jun 19 - Jul 18). "A guest star guarded *Pi* (LM14)." (*Chin-shu*, 13 and *Sung-shu*, 24) (XB22, CS21, HO163)

23. AD 305 Nov 21
[China] Yung-hsing reign-period, 2nd year, 10th month, day *ting-ch'ou* (14). "A star emerged (*po*) at *Pei-tou.*" (*Chin-shu*, 13 and *Sung-shu*, 24) (HO165)

24. AD 329 Aug/Sep
[China] Hsien-ho reign-period, 4th year, 7th month (Aug 11 - Sep 9). "A star emerged

(*po*) at the NW. It invaded *(Pei-)tou*. After 23 days it was extinguished." (*Chin-shu*, 13 and *Sung-shu*, 24) (XB23, CS22, HO165)

25. AD 340 Mar 25
[China] Hsien-k'ang reign-period, 6th year, 2nd month, day *keng-ch'en* (17). "A star emerged (*po*) at *T'ai-wei*." (*Chin-shu*, 13 and *Sung-shu*, 24) (HO169)

26. AD 369 Mar/Apr
[China] T'ai-ho reign-period, 4th year, spring, 2nd month (Mar 24 - Apr 22). "A guest star was seen at the West Wall of *Tzu-kung*. It lasted until the 7th month (Aug 19 to Sep 17) and then it extinguished." (*Chin-shu*, 13 and *Sung-shu*, 24) (XB24, CS23, HO174)

27. AD 386 Apr/May
[China] T'ai-yuan reign-period, 11th year, spring, 3rd month (Apr 15 to May 14). "A guest star was (seen) at *Nan-tou*. It lasted until the 6th month (Jul 13 to Aug 10) and then it disappeared." (*Chin-shu*, 13 and *Sung-shu*, 25) (XB25, CS24, HO177)

28. AD 393 Feb/Mar
[China] T'ai-yuan reign-period, 18th year, spring, 2nd month (Feb 27 to Mar 28). "A guest star was seen within *Wei* (LM6). It lasted until the 9th month (Oct 22 to Nov 19) and then it extinguished." (*Chin-shu*, 13 and *Sung-shu*, 25) (XB26, CS25, HO179)

29. AD 396
[China] Huang-shih reign-period, 1st year. "Previously, a large yellow star appeared at the division of *Mao* and *Pi* (LM18 and LM19) for more than 50 days. In winter, the 11th month, a yellow star was again seen." (*Wei-shu*, 105) (XB27, CS26, HO182)

30. AD 415 Jul 20
[China] Shen-jui reign-period, 2nd year, 6th month, day *i-szu* (42). "A star emerged (*po*) at the south of *Mao* (LM18)." (*Wei-shu*, 105) (XB28, HO187)

31. AD 419 Feb 17
[China] Yuan-hsi reign-period, 1st year, 1st month, day *wu-hsu* (35). "A star emerged (*po*) at the West Wall of *T'ai-wei* (Enclosure)." (*Chin-shu*, 10 and 13) (XB29, HO192)

32. AD 421 Jan/Feb
[China] T'ai-ch'ang reign-period, 5th year, 12th month (Jan 20 to Feb 17). "A guest star was seen at *I* (LM27)." (*Wei-shu*, 105) (XB30, CS28, HO194)

33. AD 436 Jun 21
[China] T'ai-yen reign-period, 2nd year, 5th month, day *jen-shen* (9). "A star emerged (*po*) at *Fang* (LM4)." (*Wei-shu*, 105) (XB31, HO199)

34. AD 437 Feb 26
[China] T'ai-yen reign-period, 3rd year, 1st month, day *jen-wu* (19). "A star was seen at the north-east in daytime before the hour *pu* (same as hour *shen*, 3 - 5 pm). It was in the vicinity of *(Tung-)Ching* (LM22) with a yellowish-red (i.e. orange) colour and as large as a tangerine." (*Wei-shu*, 105 and *Sung-shu*, 26) (XB32, CS29, HO200)

35. AD 541 Feb/Mar
[China] Yuan-hsing reign-period, 4th year (or Ta-t'ung reign-period, 7th year of the

Northern Dynasty), 1st month (Feb 11 - Mar 12). "A guest star appeared at *Tzu-kung*." (*Wei-shu*, 105) (XB33, CS32, HO220)

36. 561 Sep 26
[China] Pao-ting reign-period, 1st year, 9th month, day *i-szu* (42). "A guest star was seen at *I* (LM27)." (*Sui-shu*, 21 and *Chou-shu*, 5) (XB34, CS33, HO224)

37. AD 575 Apr 27
[China] T'ai-chien reign-period, 7th year, 4th month, day *ping-hsu* (23). "A star emerged (*po*) at *Ta-chueh*." (*Sui-shu*, 21 and *Ch'en-Shu*, 5) (XB35, HO231)

38. AD 588 Nov 22
[China] K'ai-huang reign-period, 8th year, 10th month, day *chia-tzu* (1). "A star emerged (*po*) at *Ch'ien-niu*." (*Sui-shu*, 21) (XB36, HO235)

39. AD 642 Aug 9
[Japan] Kogyoku-tenno reign-period, 1st year, 7th month, day *jen-hsu* (59). "A guest star entered within the Moon." (*Nihon Temmon Shiryo*, 476) (HO247)

40. AD 708 Jul 28
[China] Ching-lung reign-period, 2nd year, 7th month, 7th day. "A star emerged (*po*) between *Wei* and *Mao* (LM17 and LM18)." (*Chiu-t'ang-shu*, 36 and *Hsin-t'ang-shu*, 32) (XB39, HO262)

41. AD 709 Sep 16
[China] Ching-lung reign-period, 3rd year, 8th month, 8th day. "A star emerged (*po*) at the wall of *Tzu-wei*." (*Chiu-t'ang-shu*, 36 and *Hsin-t'ang-shu*, 32) (XB40, HO263)

42. AD 722 Aug 19
[Japan] Yoro reign-period, 6th year, 7th month, 3rd day, *jen-shen* (9). "A guest star was seen beside *Ko-tao* for a total of 5 days." (*Nihon Temmon Shiryo*, 478) (XB41, CS36, HO266)

43. AD 725 Feb 11
[Japan] Jinki reign-period, 2nd year, 1st month, 24th day, *chi-mao* (16). "A star emerged (*po*) at *Hua-kai*." (*Nihon Temmon Shiryo*, 478) (XB42, HO267)

44. AD 745 Jan 8
[Japan] Tempyo reign-period, 16th year, 12th month, 2nd day, *keng-yin* (27). "A star emerged (*po*) at *Chiang-chun*." (*Nihon Temmon Shiryo*, 479) (XB44, HO271)

45. AD 829 Nov
[China] T'ai-ho reign-period, 3rd year, 10th month. "A guest star appeared at *Shui-wei*." (*Hsin-t'ang-shu*, 32) (CS37, HO288)

46. AD 837 Apr 29
[China] K'ai-ch'eng reign-period, 2nd year, 3rd month, day *chia-shen* (21). "A guest star appeared below *T'ung-ching*. In the 4th month, day *ping-wu* (43) - May 21 - the guest star below *T'ung-ching* disappeared." (*Hsin-t'ang-shu*, 32) (XB45, CS38, HO291)

47. AD 837 May 3
[China] K'ai-ch'eng reign-period, 2nd year, 3rd month, day *wu-tzu* (25). "Another guest star appeared separately within *Tuan-men* near *P'ing-hsing*. In the 5th month, on day

kuei-yu (10) - Jun 17, the guest star within *Tuan-men* disappeared." (*Hsin-t'ang-shu*, 32) (XB46, CS39, HO291)

48. AD 837 Mar 22
[China] K'ai-ch'eng reign-period, 2nd year, 5th month, day *jen-wu* (19). "A guest star like a *po* (bushy) star was seen between *Nan-tou* and *T'ien-yo*." (*Hsin-t'ang-shu*, 32) (CS40, HO291)

49. AD 891 May 11
[Japan] Kempyo reign-period, 3rd year, 3rd month, 29th day, *chi-mao* (16). "At the hour of *hai* (9-11 p.m.), a guest star was at the east of a star of *Tung-hsien* and separated from it by about one *t'sun* (1/10 deg)." (*Nihon Temmon Shiryo*, 484) (XB49, CS42, HO313)

50. AD 902 Mar 6
[China] T'ien-fu reign-period, 2nd year, 1st month, day *chi-szu* (6). "A guest star was at *Kang* and guarded it. The next year it was still there." (*Hsin-t'ang-shu*, 32) (XB50, CS43, HO320)

51. AD 911 May/Jun
[China] Ch'ien-hua reign-period, 1st year, 5th month (May 31 - Jun 28). "A guest star invaded *Ti-tso*." (*Wu-tai-shih*, 59 and *Hsu-t'ang-shu*, 14) (XB51, CS44, HO324)

52. AD 1006
(i) From 1006 May 6 to 1007 Sep
[China] Ching-te reign-period, 3rd year, 4th month, day *wu-yin* (15). "A *Chou-po* star appeared at 1 deg west of *Ch'i-kuan* at the south of *Ti* (LM3). Its shape was like a half Moon and had horned rays. It was glittering so intensely that one could see things in detail. It continued to be at the east of *K'u-lou*. In the 8th month it followed the celestial sphere and entered the horizon. In the 11th month, it was again seen at *Ti* (LM3). There afterward, it was frequently seen in the 11th month in the morning in the SE direction and in the 8th month, it entered the horizon at the SW. (*Sung-shih*, 56) (XB53, CS45, HO356)

(ii) AD 1006 May 30
[China] Ching-te reign-period, 3rd year. "In the 5th month, day *jen-yin* (39) - May 30 - a *Chou-po* star was seen. In the 11th month, day *jen-yin* (Nov 26), the *Chou-po* star was again seen." (*Sung-shih*, 7) (XB53, CS45, HO356)

(iii) 1006 May 1
[China] Ching-te reign-period, 3rd year. "The Director of the Astronomical Bureau reported, 'Previously in the 2nd day of the 4th month, at the 1st watch of the night, a large star was seen. Its clouor was yellow and appeared east of *K'u-lou* and west of *Ch'i-kuan*. Gradually, it increased its brightness and was measured 3 *tu* from *Ti*.' " (*Sung-hui-yao*) (XB53, CS45, HO356)

(iv) 1006 May 1
[Japan] Kanko reign-period, 3d year, 4th month, 2nd day, *kuei-yu* (10). "At nightfall, there was a large guest star within *Ch'i-kuan*. It was like Mars and its light was scintillating. For consecutive nights it was seen in the S direction. Or it was said that

the *Ch'i-ch'en Chiang-chun* star had changed its body and increased its brightness." (*Meigetsuki*, 3) (XB53, CS45, HO356)

(v) 1006 Apr 28
[Japan] Kanko reign-period, 3d year, 3rd month, day *wu-tzu* (25) (read *keng-wu* (7)). "A guest star enterd *Ch'i-(kuan)*. Its colour was whitish-blue. The astronomical doctor Abe Yoshimasa reported it." (*Ichidai Yoki*) (XB53, CS45, HO356)

53. AD 1011 Feb 8
[China] Ta-chung-hsiang-fu reign-period, 4th year, 1st month, day *ting-ch'ou* (14). "A guest star was seen in front of the head of *Nan-tou*." (*Sung-shih*, 56) (XB54, CS46, HO358)

54. AD 1054
(i) 1054 Jul 3 to 1055 Jul +
[China] Chih-ho reign-period, 1st year, 5th month, day *chi-ch'ou* (26). "A guest star appeared about several *ts'un* SE of *T'ien-kuan*. After more than a year it gradually disappeared." (*Sung-shih*, 56) (XB57, CS48, HO375)

(ii) AD 1054 Jun/Jul to 1056 Apr 6
[China] Chia-yu reign-period, 1st year, 3rd month, day *hsin-wei* (8). "The director of the Astronomical Bureau reported, 'Since the 5th month (Jun 9 - Jul 7) of the 1st year of the Chih-ho reign-period, a guest star had appeared in the E direction. It guarded *T'ien-kuan* and now it has disappeared." (*Sung-shih*, 12)

(iii) 1054 Aug 27
[China] Chia-yu reign-period, 1st year, 3rd month. "The Director of the Astronomical Bureau said, 'The guest star had disappeared; an omen for a guest leaving. Early in the 5th month of the 1st year of Chih-ho reign-period, (the guest star) appeared in the E direction in the morning, and guarded *T'ien-kuan*. It was seen during day-time like Venus with horned rays in all directions. It had a reddish-white colour and lasted for a total of 23 days." (*Sung-hui-yao*)

(iv) 1054 Jun 10
[China] Chih-ho reign-period, 1st year, 5th month, day *i-ch'ou* (2). "A guest star appeared about several *ts'un* SE of *T'ien-kuan*. (*Hsu-tzu-chih T'ung-chien Ch'ang-pien*, 176)

(v) 1054 May/Jun
[Japan] Tengi reign-period, 2nd year, 4th month (May 10 - Jun 8). "After the middle decade (i.e. after the first 20 days) of the month, at the hour of *ch'ou* (1 - 3 a.m.), a guest star appeared in the degrees of *Tsui* and *Shen* Lunar Mansions (LM20 and LM21). It was seen in the E direction and emerged (*po*) at the *T'ien-kuan* star. It was as large as Jupiter." (*Meigetsuki*, 12)

(vi) 1054 May/Jun
[Japan] Tengi reign-period, 2nd year, 4th month (May 10 - Jun 8). "A guest star appeared in the degrees of *Tsui* and *Shen* (LM20 and LM21). It was seen in the E direction and emerged (*po*) at the *T'ien-kuan* star. It was as large as Jupiter." (*Ichidai Yoki*, 1)

55. AD 1065 Aug 1
[Korea] King Munjong, 19th year, 6th month, day *i-mao* (52). "A guest star was (seen) as large as a lamp." (*Koryo-sa*, 47) (XB58, HO379)

56. AD 1065 Sep 11
[China] Hsien-yung reign-period, 1st year, 8th month, day *ping-shen* (33). "A guest star invaded *T'ien-miao*." (*Liao-shih*, 22) (XB58, CS49, HO379)

57. AD 1070 Dec 25
[China] Hsi-ning reign-period, 3rd year, 11th month, day *ting-wei* (44). "A guest star appeared at *T'ien-chun*." (*Sung-shih*, 56) (CS51, HO382)

58. AD 1073 Oct 9
[Korea] King Munjong, 27th year, 8th month, day *ting-ch'ou* (14). "A guest star was seen at the south of the stars of *Tung-pi*." (*Koryo-sa*, 47) (XB59, CS52, HO383)

59. AD 1074 Aug 19
[Korea] King Munjong, 28th year, 7th month, day *keng-shen* (57). "A guest star as large as a papaya was seen at the south of *Tung-pi*." (*Koryo-sa*, 47) (CS53, HO384)

60. AD 1082 Aug 4
[Korea] King Munjong, 36th year, 7th month, day *ting-hai* (24). "A star appeared in the *Tzu-wei* (Enclosure) and trespassed upon Polaris." (*Koryo-sa*, 47)

61. AD 1113 Aug 15
[Korea] King Yejong, 8th year, 7th month, day *hsin-szu* (18). "A star emerged (*po*) at *Ying-shih*." (*Koryo-sa*, 47) (XB60, HO394)

62. AD 1123 Aug 11
[Korea] King Injong, 1st year, 7th month, day *chi-szu* (6). "A star emerged (*po*) at *Pei-tou*." (*Koryo-sa*, 47) (XB61, HO395)

63. 1138 Jun/Jul
[China] Shao-hsing reign-period, 8th year, 5th month (Jun 9 to Jul 8). "A guest star guarded *Lou* (LM16)." (*Sung-shih*, 56) (XB62, CS54, HO403)

64. 1139 Mar 23
[China] Shao-hsing reign-period, 9th year, 2nd month, day *jen-shen* (9). "A guest star guarded *Kang* (LM2)." (*Sung-shih*, 56) (XB63, CS55, HO404)

65. 1163 Aug 10
[Korea] King Uijong, 17th year, 7th month, day *wu-hsu* (35). "A guest star trespassed against the Moon." (*Koryo-sa*, 47) (CS56, HO411)

66. 1175 Aug 10
[China] Shun-hsi reign-period, 2nd year, 7th month, day *hsin-ch'ou* (38). "A star emerged in the NW direction. It was placed at the outside of the Wall of *Tzu-wei* Enclosure and above *Ch'i-kung*. It was as small as Mars with rays bushy out luxuriously in all directions. Until day *ping-wu* (43) - Aug 15 - then it was dispersed." (*Sung-shih*, 56) (XB64, CS57, HO413)

67. AD 1181
(i) AD 1181 Aug 6 to 1182 Feb 6

[China] Shun-hsi reign-period, 8th year, 6th month, day *chi-szu* (6). "A guest star appeared in the *K'uei* Lunar Mansion (LM15). It trespassed upon the stars of *Ch'uan-she*. Until day *kuei-yu* (10) in the 1st month of the next year, after a total of 185 days, then it extinguished." (*Sung-shih*, 56) (XB65, CS58, HO415)

(ii) AD 1181 Aug 11
[China] Ta-ting reign-period, 21st year, 6th month, day *chia-hsu* (11). "A guest star was seen at *Hua-kai*. After a total of 156 days it was extinguished." (*Kin-shih*, 20)

(iii) 1181 Aug 7
[Japan] Jisho reign-period, 5th year, 6th month, 25th day, *keng-wu* (7). "At the hour of *hsu* (7-9 p.m.), a guest star was seen in the N direction near *Wang-liang* guarding *Ch'uan-she*." (*Meigetsuki*, 3)

(iv) 1181 Aug 7
[Japan] Jisho reign-period, 5th year, 6th month, 25th day, *keng-wu* (7). "At the hour of *hsu* (7-9 p.m.), a guest star like Saturn was seen in the NE direction. It had a bluish-red colour and horned rays." (*Azuma Kagami*)

68. AD 1203 Jul 28 to Aug 6
[China] Chia-t'ai reign-period, 3rd year, 6th month, day *i-mao* (52). "A guest star appeared at the SE inside the *Wei* Lunar Mansion (LM6). Its colour was bluish-white and it was as large as Saturn. On day *chia-tzu* (1), it guarded *Wei* (LM6)." (*Sung-shih*, 56) (XB66, CS59, HO419)

69. AD 1220 Dec/ 1221 Jan
[Korea] King Kojong, 7th year, 12th month (1220 Dec 27 to 1221 Jan 24) "A star emerged (*po*) at *Pei-tou*." (*Koryo-sa*, 47) (XB67, HO424)

70. AD 1224 Jul 11
[China] Chia-ting reign-period, 17th year, 6th month, day *chi-ch'ou* (26). "A guest star guarded and trespassed upon the *Wei* Lunar Mansion (LM6)." (*Sung-shih*, 56) (XB68, CS60, HO427)

71. AD 1240 Aug 17
[China] Chia-hsi reign-period, 4th year, 7th month, day *keng-yin* (27). "A guest star appeared at the *Wei* Lunar Mansion (LM6)." (*Sung-shih*, 56) (XB70, CS61, HO433)

72. AD 1356 May 3
[Korea] King Kongmin Wang, 5th year, 4th month, day *kuei-ch'ou* (50). "A guest star trespassed against the Moon." (*Koryo-sa*, 47) (CS62, HO460)

73. AD 1399 Jan 5
[Korea] King T'aejo, 7th year, 11th month, day *keng-tzu* (37). "A guest star trespassed against the Moon." (*T'aejo Sillok*) (CS64)

74. AD 1399 Oct 7
[Japan] O-ei reign-period, 6th year, 9th month, 8th day, *i-hai* (12). "A guest star was seen in the S direction." (*Nihon Temmon Shiryo*, 556) (HO486)

75. AD 1408 Jul 14
[Japan] O-ei reign-period, 15th year, 6th month, 21st day, *wu-hsu* (35). "A guest star was seen." (*Nihon Temmon Shiryo*, 570) (HO492)

76. AD 1408 Oct 24
[China] Yung-lo reign period, 6th year, 10th month, day *keng-ch'en* (17). "At night, in the zenith, at the south-east of *Nien-tao* (an asterism in Cygnus and Lyra), there was a star as large as a cup (*chan*). It was yellow in colour and its light had a sheen (*jun*). It emerged (*ch'u*), but it did not move. It was a *Chou-po* ('Earl of Chou'), a virtuous star". (*Ming-shih-lu*) (CS65, HO490)

77. AD 1430 Sep 3
[China] Hsuan-te reign-period, 5th year, 8th month, day *chia-shen* (21). "At night, a guest star was seen more than a *ch'ih* NE of *Nan-ho*. Its colour was bluish-black. On day *keng-yin* (27), a guest star as large as a pellet was seen beside *Nan-ho* with a bluish-black colour. It extinguished after a total of 26 days." (*Ming-shih-lu*) (XB74, CS66, HO501)

78. AD 1437 Mar 11
[Korea] King Sejong, 19th year, 2nd month, day *i-ch'ou* (2). "A guest star was seen between the 2nd and 3rd stars of *Wei* (LM6). It was nearer to the 3rd star and separated from it by about a half of a *ch'ih*. It was there for a total of 14 days." (*Sejong Sillok*) (XB75, CS68, HO508)

79. AD 1460 Feb/Mar
[Vietnam] Kuang-shun reign-period, 1st year, spring, 2nd month (Feb 22 to Mar 22). "A star emerged (*po*) at *I* (LM27)." (*Ta-yu shih-chi*) (XB77, CS69)

80. AD 1572 Nov 8
(i) [China] Lung-ch'ing reign-period, 6th year, 10th month, day *ping-ch'en* (53). "A guest star was seen in the north-eastern direction like a pellet. It appeared beside *K'o-tao* in the degrees of the *Pi* Lunar Mansion (LM14). Gradually, it had short bright rays. On the 19th day (*jen-shen* (9)), at night, the mentioned star was reddish-yellow in colour. It was as large as a cup and its rays were shooting in all directions. Editor: it was not until the 2nd month of the 1st year of the Wan-li reign-period (1573) that the brightness of this star then gradually began to dim. On the 4th month of the 2nd year it was then disappeared. A memorandan from the Department of Rites: ... from the 10th month, a guest could be seen in the day, it was extraordinary brilliant .... " (*Ming-shih-lu*) (XB79, CS70, HO565)

(ii) [Korea] King Sonjo, 5th year, 10th month. "A guest star was seen at (*yu*) *T'se-hsing*. It was larger than Venus." (*Sonjo Sillok*)

81. AD 1584 Jul 11
[China] Wan-li reign-period, 12th year, 6th month, day *chi-yu* (46). "Tonight, a strange star appeared at *Fang* (LM4)." (*Ming-shih-lu*) (XB80, CS71, HO572)

82. AD 1592 Nov 28
[Korea] The first report is on day *ping-wu* (43) in the 10th month of the 25th year of King Sonjo (1592 Nov 28): "In the first watch of the night, a guest star was seen beside (*yu*) the stars of *T'ien-ts'ang*". Thereafter the records are repeated in a similar style

with little extra details. These are listed below:
On Dec 4 the position is a little more specific: "A guest star was seen within (nei) the stars of T'ien-ts'ang. Mar 4 in AD 1593 contains the last entry before conjunction with the Sun: "At night a guest star was seen within the stars of *T'ien-ts'ang.*" After the lapse of more than four months, the guest star was recovered on day ting-szu in the 7th month of the 26th year of King Sonjo (civil date 1593 Aug 2): "In the fifth watch of the night, the stars of *T'ien-ts'ang* were seen at the eastern direction. The guest star was still at the east of *T'ien-ts'ang*. From last year *jen-ch'en* 11th month, 22nd day (i.e. AD 1592 Nov 25) until this year 2nd month (some time between Mar 3 and Apr 1 in AD 1593) it was often seen."

On Aug 13, "the guest star was at *T'ien-ts'ang*, within (*nei*) the third star from the east and about 3 *ts'un* away. Its colour and form were less (conspicuous) than the stars of *T'ien-ts'ang.*" On Nov 19, a significant fading was noted: "From the first watch to the fifth watch, the guest star was at *T'ien-ts'ang*, within the third star from the east and about 3 *ts'un* away. Its form and body were very small."

The last entry is found on day kuei-wei in the 1st month of the 27th year of King Sonjo (1594 Feb 23) reads as follows: "From the first watch of the night to the second watch, the guest star was at *T'ien-ts'ang*, within the third star from the east and about 3 *ts'un* away." (*Sonjo Sillok*) (XB81, CS72, HO577)

83. 1592 Nov 30
[Korea] The first report is found on day *kuei-ch'ou* (50) in the 10th month of the 25th year of King Sonjo (1592 Nov 30): "A guest star was seen at the east of *Wang-liang.*" The most accurate position is given on Jan 25 and Jan 30, also repeated in the last entry on Mar 28: "A guest star was seen at *Wang-liang* between the first and second stars from the east." (*Sonjo Sillok*) (XB82, CS73, HO577)

84. AD 1592 Dec 4
[Korea] The first report is found on day *ting-szu* (54) in the 11th month of the 25th year of King Sonjo (1592 Dec 4): "A guest star was seen at the first star from the west (of *Wang-liang*)." From Dec 5 onwards until the last entry on 1593 Mar 4 the guest star was described as 'within' the first star from the west of *Wang-liang*. (*Sonjo Sillok*) (XB83, CS74, HO577)

85. AD 1592 Dec 12
[Korea] The first report is found on day *i-ch'ou* (2) in the 11th month of the 25th year of King Sonjo (1592 Dec 12): "A guest star was also seen above the stars of *K'uei.*" There are only two reports of this guest star, the next and last entry is on Jan 18 in AD 1593 with the description almost identical to that of the first entry. (*Sonjo Sillok*)

86. AD 1604
(i) [China] Wan-li reign-period, 32th year, 9th month, day *i-ch'ou* (2). "At night, in the SW direction there produced a strange star. It was as large as a pellet and its body was reddish-yellow in colour. Its name was known as *k'o-hsing.*" (*Ming-shih-lu*) (XB85, CS75)

(ii) [China] Wan-li reign-period, 32th year, 12th month, day *hsin-yu* (58). "Tonight, the guest star followed the sky and changed its position, it was now seen in the SE direction.

It was as large as a pellet with a yellow colour but its bright rays were becoming small. It situated in the *Wei* Lunar Mansion (LM6). (*Ming-shih-lu*)

(iii) [China] Wan-li reign-period, 33rd year, 8th month, day *ting-mao* (4). "At night, the guest star was not seen. From the 33rd year, 9th month, the guest star was seen at the division of *Wei* (LM6). At the hours of the 1st watch, it was (always) seen appearing in the SW direction. It followed the motion of the heaven and appeared in the W. In the 10th month, it set in the evening and could not be seen. In the 11th month, in the 5th watch, it was frequently appearing in the SE direction. This year, in the 2nd month, its brightness was gradually dimming. Now it had extinguished." (*Ming-shih-lu*)

(iv) AD 1604 Oct 13 [Korea] King Sonjo reign-period, 37th year, 9th month, day *wu-ch'en* (5). "In the first watch of the night a guest star was at the 10th degree of *Wei* Lunar Mansion and distant 110 degrees from Polaris. Its form was slightly smaller than Jupiter. Its colour was yellowish-red (orange) and it was scintillating. In the 5th watch there was a mist." (*Sonjo Sillok*)

The following night, the position was adjusted to "the 11th degree of *Wei* and distant 109 degrees from the pole" and the details "above *T'ien-chiang*" was added. Thereafter on every clear night up to Nov 26, the guest star was reported in this pattern, retaining the revised position, with only occasional changes to the brightness of the star. Between Oct 28 and Nov 5, the guest star was compared with Venus in brightness, and from Oct 28 to 31 the description "its ray emanations were very resplendent" was added which could have suggested that it was at maximum brilliance near this period. After Nov 26, the guest star was not seen for a few days due 'dense clouds'. There are no records of the star between Nov 30 and Dec 3, and by Dec 4 the star would have already set heliacally. The record on this date says: "The guest star was close to the sun. Before dusk, it sank in the west, and could not be observed." The precise date of heliacal setting is uncertain, but it must have been sometime between Nov 27 and Dec 3.

The star reappeared on Dec 27. The record mentions that, "At daybreak, the guest star was seen in the east above the stars of *T'ien-chiang*. It was within the 11th degree of *Wei* and distant 109 degrees from the pole. Its form was larger than Antares. Its colour was orange and it was scintillating". Until Apr 5, a similar record (with minor textual variations) to that of Dec 27 was given on almost every night except when the brightness of the Moon hindered the observation. From Apr 6 onwards, there are only a few reports of the guest star, possibly due to some of the repetative records had been left out by the compilers. The record on Apr 23 follows the same pattern as before, and on May 2 the record states that, "at the 4th watch the guest star was faintly visible through rifts in the clouds". Only three more records were found after this date. Two of these concerned the astrological significance of the guest star. The final mention of the guest star was on September 15, the record reads: "there were dense clouds and the guest star was not seen." It seems likely that the guest star continued to be observed for a further length of time than given here, maybe comparable with that in China and Europe (i.e. for almost a full year).

87. AD 1690 Sep 29
(i) [China] K'ang-hsi reign-period, 29th year, 8th month, day *i-yu* (22). "An unusual

star was seen at *Chi* (LM7). Its colour was yellow and lasted for a total of 2 nights." (*Ch'ing-shih-k'ao*)

(ii) [China] K'ang-hsi reign-period, 29th year, 8th month, 27th day, *i-yu* (22). "At the hour of *hsu* (7-9 p.m.), it was observed to the east of the 3rd star of the *Chi* Lunar Mansion (LM7) in the S direction, an unusual star. It was yellow in colour and without a ray tail. By instrument, it was measured 3 *tu*, 18 *fen* from *Ch'ou-kung* with a south 'latitude' (declination) of 34 *tu*, 20 *fen*. On the 28th day, it was seen to be a guest star, and still at the east of the 3rd star of the *Chi* Lunar Mansion (LM7). It was yellow in colour and without a tail. By instrument it was measured and shown that it did not move." (*Astronomical Bureau Report*) (XB90)

APPENDIX IV

A REVISED CATALOGUE OF FAR EASTERN OBSERVATION OF SUNSPOTS (165 BC TO AD 1918)

This catalogue has already been accepted for publication in *Q. Jl. R. astr. Soc.* in June 1988. The following four pages are the first four pages of the proofs of the paper, which are essentially the introduction to the catalogue. For the sake of clarity, I have included after these four pages my original printout of the catalogue.

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A Revised Catalogue of Far Eastern Observation of Sunspots (165 BC to AD 1918)

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SUMMARY

A revised catalogue of naked-eye sunspots from the Far East is presented. This is based both on the collation of a number of recent catalogues and the systematic consultation of original Oriental historical sources. A special feature of the present list is the inclusion of a considerable number of naked-eye sunspot records from the telescopic era – extending down to the early 20th century.

INTRODUCTION

In the investigation of solar variability in the past, observations of sunspots provide the most direct data source. Telescopic sightings of sunspots extend as far back as the early 17th century. These have been analysed in detail to study both the roughly 10-year solar cycle and long-term trends in solar activity such as the Maunder Minimum (e.g. Eddy 1976).

Before the rediscovery of sunspots by Galileo and others around AD 1610 – using the newly invented telescope – these phenomena were recorded almost exclusively in East Asia (China, Korea, Japan and Vietnam). Less than ten European sightings are recorded in the whole of the pre-telescopic period (Wittmann & Xu, 1987). Even the number of naked-eye sightings from the Orient amounts to little more than 150 over nearly 18 centuries, a mean frequency of only about one per decade. This is vastly less than the expected number. According to Newton (1955), a large sunspot (a single spot or a compact group) with an area 500 millionths of the area of the Sun's hemisphere (i.e 1′ arc in diameter) should be visible to the naked-eye if it is situated near the centre of the solar disk. On this basis, the actual number of preserved records from the whole of the pre-telescopic period is only about 0·1 per cent of the expected number, suggesting highly sporadic observations (Eddy 1983). Despite this drawback, at times when naked-eye sunspot records are of above average frequency, they should serve as fairly useful indicators of the approximate years of maxima of the appropriate solar cycles. It is well established that the probability of observing a large sunspot is much higher in the peak years of the sunspot cycle than at other times. In addition, the existing pre-telescopic observations are of value in the investigation of protracted intervals of weak solar activity, such as the Sporer Minimum – AD 1420–1530 (Eddy 1977).

Various compilations of Far Eastern observations of sunspots exist. Several of these have been published in a European language (specifically English) but others have appeared only in Chinese. The most recent catalogues (within the last 10 years or so) that have appeared in Western journals include those of the Yunnan Observatory Group (1977), Clark & Stephenson (1978) and Wittmann & Xu (1987). All of these compilations suffer from one or more of the following defects: data omissions, mistranslations, dating errors and the inclusion of irrelevant material. It is the aim of the present work to try to eliminate such shortcomings.

The present work is an extension of the catalogue by Clark & Stephenson (1978), which was restricted to the pre-telescopic period. This contained 139 entries between 28 BC and AD 1604. We have increased the number of pre-telescopic entries to 158. In addition, our catalogue has been enlarged to include 77 more recent records – mainly from Chinese local gazettes, together with a few from Korean and Vietnamese chronicles. In compiling the present work we have made use of the detailed catalogues of Kanda (1933), Clark & Stephenson (1978), Chen & Dai (1982), Chen (1984) and Wittmann & Xu (1987). We have also consulted the paper by Xu & Jiang (1984) which is restricted to 17th century observations of sunspots. The work of Chen & Dai (1982), an updated version of the catalogue of the Yunnan Observatory Group (1977), is at present available only in Chinese. The catalogue of Chen (1984), also in Chinese, is excerpted from the yet unpublished *A Union Table of Ancient Chinese Records of Celestial Phenomena*. In addition, we have ourselves made an extensive search of original oriental histories, annals, etc., all of which are written in Classical Chinese – the common script of China, Japan, Korea and Vietnam until relatively recent times. We have carefully translated or retranslated all of the records which we have included in the present catalogue, with particular regard to uniformity of style.

For the pre-telescopic period, we have concentrated mainly on records cited in the following sources: (i) from earliest times to the late 14th century AD officially compiled dynastic histories, especially the astronomical treatises of these works; (ii) since the late 14th century detailed day-to-day chronicles. Whenever possible, we have avoided the use of late secondary sources. We have found frequent instances of careless copying from earlier dynastic histories in these late texts, especially with regard to dates of occurrence. Such errors often give the impression of additional records which are not found in the original texts. Our investigations have uncovered many such instances of spurious duplication.

In the catalogue below, each entry begins with the appropriate reference number. When an asterisk precedes the data, this means that the record is from a local gazette, rather than a dynastic history or official chronicle. When two asterisks precede the date, this indicates that the record comes from a secondary source such as an historical encyclopædia (there are only three entries in this category). The data is expressed in terms of either the Julian or Gregorian calendar, use of the latter commencing in AD 1582. We have converted Oriental dates to the Western calendar using the tables of Chen (1962) and Chueh & Ou-yang (1956). We have also designed a computer program to expedite date conversion; this is based on the rules outlined by Chueh & Ou-yang (1956). If a date range is given, separated by '–', this implies that only the month or year is quoted in the original record (this is qualified by a comment in parentheses). Whereas if the date range is separated by 'to', it means a specific number of days of visibility (again there is a parenthetical note). A question mark is placed after the date where this is uncertain due to, in most cases, scribal errors in the original text.

The second line of each entry begins with the country of origin. This is followed by the reign period (in the case of China, Japan and Vietnam) or name of the king (for Korea). Subsequently, in order, are given the year (of the reign period or king), lunar month, day of the sexagenary (60-day) cycle and/or day of the month,/whenever these are specified. After the cyclical day we have always supplied the equivalent day number; this materially assists the conversion of dates to the Julian or Gregorian calendar. In some cases, records of the same spot from more than one source exist; these are kept together under one entry.

A translation of the relevant text is placed between quotes. This is followed by the source of the record, including chapter number. When a record in a primary source is copied in a secondary work, we omit any reference to the latter. Reference numbers to other sunspot catalogues complete each entry whenever this is appropriate. The source designations are as follow: numbers preceded by CS indicate that observations are contained in the catalogue of Clark & Stephenson (1978); K denotes Kanda (1933), CD – Chen & Dai (1982), CH – Chen (1984) and XJ – Xu & Jiang (1984). The entries in Wittmann & Xu (1987) do not have numberings; these are here simply indicated by WX. In a number of cases, we have included descriptive details not found in other catalogues; these are based on information given in the day to day chronicles of China and Korea from the late 14th century onwards.

The description of a sunspot in Classical Chinese is usually quite specific. The terms *hei-tzu* ('a black spot') or *hei-ch'i* ('a black vapour') are the standard descriptions. Other similar expressions, which are only rarely used, are *hei-tien* and *hei-pan*, both of which we have rendered as 'black dot'. Occasionally we find less obvious descriptions such as 'a star was seen within the Sun'. Provided that the record affirms that the object was 'within' (*chung*) the Sun, we can be fairly confident that a sunspot is referred to. Even if an account is less definite, we can still be confident that a sunspot is referred to if the object is clearly of small angular size. Hence the terms 'black spot' and 'black dot' are probably self-sufficient. However, the expression translated 'black vapour' is a less reliable indication of sunspot nature unless the text emphasises that the phenomenon actually appeared on the Sun itself or remained visible for several days. The general term 'vapour' is often applied to atmospheric phenomena and may thus be of large angular extent. It is thus necessary to exercise caution when interpreting references to *hei-ch'i*.

In classical Chinese, it is not always possible to distinguish between singular and plural. Hence unless a record is quite definite regarding the number of sunspots visible we have normally assumed only a single spot. Venus is visible to the unaided eye on the rare occasions when it is in transit across the solar disc (Goldstein 1969). We have checked all dates of sunspot sightings in the present catalogue against the dates of Venus transits computed by Meeus (1958) but without success. Obviously the probability of such an event actually being observed is extremely low.

Most of the sunspot sightings in our catalogue are from China. the first Korean observation dates from AD 1151 but after that date, sunspot records from Korea are fairly frequent. Only a single early Japanese report of a sunspot (in AD 851) has ever been uncovered (Kanda 1933). In addition, we have included three Vietnamese observations – the earliest in AD 1276. It is clear from the various records that sunspots were often sighted when the brightness of the Sun was much reduced – e.g. when the Sun was low in the sky (near sunrise or sunset) or when mist, haze, etc. prevailed. Even in the telescopic era, observations seem to have still continued in the traditional style; there is no evidence that any of the spots listed in the present catalogue were seen with telescopic aid.

This catalogue is produced purely as a reference work; there is no attempt to analyse the data for cyclical behaviour or long-term trends. Such an investigation will form the subject of a separate paper.

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REVISED CATALOGUE

1. ** 165 BC Jan/Feb - Mar/Apr (only season given)
[CHINA] Emperor Wen-ti, Ch'ien-yuan reign-period, 15th year, spring. "Within the Sun there was the character *wang* ('king')." (*T'se-fu Yuan-kuei*) (CD1, WX)

2. 43 BC May 5 - June 3 (only month given)
[CHINA] Yung-kuang reign-period, 1st year, 4th month. "The Sun was pale blue (blue-white) in colour and cast no shadows. Right in the middle (of the Sun) frequently there were shadows and no brightness. That summer was cold until the 9th month, the Sun then regained its brightness. The contemporary *Ching-fang I-ch'uan* ("Biographies of the Book of Changes" by Ching-Fang) commented, '... As to the strange darkness of the Sun, even with the gale blowing and the sky cloudless, yet the sunlight was dimmed. It is not difficult to give the explanation. It was said that a dark patch as large as a pellet was seen situated off centre on the Sun.'" (*Han-shu*, 27) (CD2)

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3. 32 BC Mar 8 - Apr 5 (only month given - retrospective entry)
[CHINA] Emperor Ai, Chien-p'ing reign-period, 4th year (3 BC). "[When Emperor Ai] was about to confer nobility on Shang, a cousin of the Empress grandmother Fu, Cheng-ch'ung, remonstrated, 'When Emperor Ch'eng enfeoffed his maternal uncles as Marquises, the sky became orange and there was darkness by day; within the Sun there was a black vapour.....'" (*Han-shu*, 77) (CD3, WX)
[N.B. The relevant historical event is listed in the *Annals of Emperor Ch'eng* (*Han-shu*, 10) under the 2nd month of the 1st year of the Chien-shih reign-period (32 BC Mar 8 - Apr 5)].

4. 28 BC May 10? (probable scribal error in day number)
[CHINA] Ho-p'ing reign-period, 1st year, 3rd month, *i-wei* (32), (no *i-wei* in 3rd month probably read *chi-wei* (56) - May 10). "At sunrise the Sun was yellow. There was a black vapour as large as a coin; it was situated right in the middle of it (the Sun)." (*Han-shu*, 27) (CS1, K1, CD4, WX)

5. AD 15 Mar 10 - Apr 7 (only month given)
[CHINA] T'ien-feng reign-period, 2nd year, 2nd month. "... A general amnesty was declared for the whole country. At the time, a 'star' was seen within the Sun." (*Han-shu*, 27) (CD5, WX)

6. AD 20 Mar 17
[CHINA] Ti-huang reign-period, 1st year, 2nd month, day *jen-shen* (9). "The Sun's middle was black. (Wang) Mang disliked it. He issued an edict which said: 'Recently within the Sun was seen a shadow; the Yin is encroaching on the Yang. A black vapour is an abnormality.' The people were all alarmed." (*Han-shu*, 99) (CS2, K2, CD6, WX)

7. 187 Mar/Apr? (scribal error in date)
[CHINA] Chung-p'ing reign-period, 4th year, 3rd month, day *ping-shen* (33), (no *ping-shen* in 3rd month, cannot suggest a viable alternative). "A black vapour as large as a melon was within the Sun." (*Hou-han-shu*, 18) (CS3, K3, CD7, WX)

8. 188 Feb 15 - Mar 15 (only month given)
[CHINA] Chung-p'ing reign-period, 5th year, 1st month. "The Sun was orange (reddish-yellow) in colour. Within it there was a black vapour like a flying magpie. After several months it dispersed." (*Hou-han-shu*, 18) (CS4, K4, CD8, WX)

9. ** 240 (only year given)
[CHINA] Ch'ih-wu reign-period, 3rd year. "Within the Sun, a three-legged crow was seen." (*K'ai-yuan Chan-ching, Jih-chan*, 2) (CD9, WX)

10. 299 Feb 17 - Mar 18 (only month given)
[CHINA] Yuan-k'ang reign-period, 9th year, 1st month. "Within the Sun there was the form of a flying swallow. After several days/months it dispersed." (*Chin-shu*, 12 and *Sung-shu*, 34) (CS6, K5, CD11, WX)
[N.B. *Chin-shu*, 12 records a duration of several days; *Sung-shu*, 34 states several months]

11. 301 Jan 19
[CHINA] Yung-k'ang reign-period, 1st year, 12th month, day *keng-hsu* (47). "Within the Sun there was a black vapour." (*Chin-shu*, 12) (CS7, K6, CD13, WX)

12. 301 Oct 20
[CHINA] Yung-ning reign-period, 1st year, 9th month, day *chia-shen* (21). "Within the Sun there was a black spot." (*Chin-shu*, 12 and *Sung-shu*, 34) (CS8, K7, CD14, WX)

13. 302 Dec 6 - 303 Jan 4 (only month given)
[CHINA] T'ai-an reign-period, 1st year, 11th month. "Within the Sun there was a black vapour." (*Chin-shu*, 12) (CS9, K8, CD15, WX)

14. 304 Dec 14 - 305 Jan 11 (only month given)
[CHINA] Yung-hsing reign-period, 1st year, 11th month. "Within the Sun there was a black vapour; it divided the Sun." (*Chin-shu*, 12 and *Sung-shu*, 34) (CS10, K9, CD16, WX)

15. 311 Apr 7
[CHINA] Yung-chia reign-period, 5th year, 3rd month, day *keng-shen* (57). "The sun-light was diffused like blood flowing downwards; everything that it illuminated was red. Within the Sun there was an object like a flying swallow." (*Chin-shu*, 12 and *Sung-shu*, 34) (CS11, K10, CD18, WX)

16. 321 May 7
[CHINA] T'ai-hsing reign-period, 4th year, 3rd month, day *kuei-wei* (20). "Within the Sun there was a black spot." (*Chin-shu*, 12 and *Sung-shu*, 34) (CS12, K11, CD20, WX)

17. 322 Nov 6
[CHINA] Yung-ch'ang reign-period, 1st year, 10th month, day *hsin-mao* (28). "Within the Sun there was a black spot." (*Chin-shu*, 12 and *Sung-shu*, 34) (CS13, K12, CD21, WX)

18. 342 Mar 7 to Mar 11 (visible for 5 days)
[CHINA] Hsien-k'ang reign-period, 8th year, 1st month, day *jen-shen* (9). "Within the Sun there was a black spot. On day *ping-tzu* (13) - Mar 11 - it was then extinguished." (*Chin-shu*, 12 and *Sung-shu*, 34) (CS14, K13, CD22, WX)

19. 352 (only year given - visible for 5 days)
[CHINA] Yung-ho reign-period, 8th year. "Chang Chung-hua was at Liang-chow. The Sun was scorching red like fire. Within it there was a three-legged crow; its shape was distinctly seen. After five days then it ceased." (*Chin-shu*, 12) (CS15, K14, CD23, WX)
[NB *Sung-shu*, 34 gives the same record but incorrectly places the event under the 6th year of the T'ai-ho reign-period (371-2). This was long after the death of Chang Chung-hua (353 Dec 9)].

20. 354 Nov 7
[CHINA] Yung-ho reign-period, 10th year, 10th month, day *keng-ch'en* (17). "Within the Sun there was a black spot as large as a hen's egg." (*Chin-shu*, 12) (CS16, K15, CD24, WX)

21. 355 Apr 4
[CHINA] Yung-ho reign-period, 11th year, 3rd month, day *wu-shen* (45). "Within the the Sun there were two black spots as large as peaches." (*Chin-shu*, 12) (CS17, K16, CD25, WX)

22. 359 Nov 7
[CHINA] Sheng-p'ing reign-period, 3rd year, 10th month, day *ping-wu* (43). "Within the Sun there was a black spot as large as a hen's egg." (*Chin-shu*, 12) (CS18, K17, CD26, WX)

23. 369 Nov 27? (probable scribal error in day number)
[CHINA] T'ai-ho reign-period, 4th year, 10th month, day *i-wei* (32), (no *i-wei* in 10th month, probably read *chi-wei* (56) - Nov 27). "Within the Sun there was a black spot." (*Chin-shu*, 12) (CS19, K18, CD27, WX)

24. 370 Mar 29
[CHINA] T'ai-ho reign-period, 5th year, 2nd month, day *hsin-yu* (58). "Within the Sun there was a black spot as large as a plum" (*Chin-shu*, 12) (CS20, K19, CD28, WX)

25. 373 Jan 28? (possible scribal error in month)
[CHINA] Hsien-an reign-period, 2nd year, 11th month, day *ting-ch'ou* (14), (no *ting-ch'ou* in 11th month, possibly read 12th month, *ting-ch'ou* - Jan 28) "Within the Sun there was a black spot." (*Chin-shu*, 12) (CS21, K20, CD29, WX)

26. 373 Dec 26
[CHINA] Ning-k'ang reign-period, 1st year, 11th month, day *chi-yu* (46). "Within the Sun there was a black spot as large as a plum." (*Chin-shu*, 12) (CS22, K21, CD30, WX)

27. 374 Apr 6
[CHINA] Ning-k'ang reign-period, 2nd year, 3rd month, day *keng-yin* (27). "Within the Sun there were two black spots as large as duck's eggs." (*Chin-shu*, 12) (CS23, K22, CD31, WX)

28. 375 Jan 10
[CHINA] Ning-k'ang reign-period, 2nd year, 11th month, day *chi-szu* (6). "Within the Sun there was a black spot as large as a hen's egg." (*Chin-shu*, 12) (CS24, K23, CD32, WX)

29. 388 Apr 2
[CHINA] T'ai-yuan reign-period, 13th year, 2nd month, day *keng-tzu* (37). "Within the Sun there were two black spots as large as plums." (*Chin-shu*, 12) (CS25, K24, CD33, WX)

30. 389 Jul 17
[CHINA] T'ai-yuan reign-period, 14th year, 6th month, day *hsin-mao* (28). "Within the Sun there was again a black spot as large as a plum." (*Chin-shu*, 12) (CS26, K25, CD34, WX)

31. 395 Dec 13
[CHINA] T'ai-yuan reign-period, 20th year, 11th month, day *hsin-mao* (28). "Within the Sun there was again a black spot." (*Chin-shu*, 12) (CS27, K26, CD35, WX)

32. 400 Dec 6
[CHINA] Lung-an reign-period, 4th year, 11th month, day *hsin-hai* (48). "Within the Sun there was a black spot." (*Chin-shu*, 12) (CS28, K27, CD36, WX)

33. 499 Jul 4? (probable scribal error in day number)
[N. CHINA] T'ai-ho reign-period, 23th year, 6th month, day *chi-mao* (16), (no day *chi-mao* in the 6th month, probably read *i-mao* (52) - Jul 4). "Within the Sun there was a black vapour." (*Wei-shu*, 105) (CS29, K28, CD39, WX)

34. 500 Jan 29, 30
(i) [N. CHINA] T'ai-ho reign-period, 23rd year, 12th month, day *chia-shen* (21) - 500 Jan 29. "Within the Sun there was a black spot as large as a peach." (*Wei-shu*, 105) (CS30, K29, CD40, WX)

(ii) [S. CHINA] Yung-yuan reign-period, 1st year, 12th month, day *i-yu* (22) - 500 Jan 30. "Within the Sun there were three black spots." (*Nan-ch'i-shu*, 12) (CS31, K29, CD40, WX)

35. 501 Sep 4
[N. CHINA] Ching-ming reign-period, 2nd year, 8th month, day *wu-ch'en* (5). "The Sun was red and dim; within it there was a single black spot." (*Wei-shu*, 105) (CS32, K30, CD41, WX)

36. 502 Feb 8, Feb 11 and Feb 12 (visible on 3 separate days)
[N. CHINA] Ching-ming reign-period, 3rd year, 1st month, day *i-szu* (42) - Feb 8. "Within the Sun there was a black vapour like a goose's egg; days *(wu)-shen* - Feb 11 and *(chi)-yu* - Feb 12 - it was again seen. Also there were two black vapours threading across the Sun." (*Wei-shu*, 105) (CS33, K31, CD42, WX)

37. 502 Mar 26? (possible scribal error in month)
[N. CHINA] Ching-ming reign-period, 3rd year, 2nd month, day *hsin-mao* (28), (no *hsin-mao* in 2nd month, possibly read 3rd month, *hsin-mao* - Mar 26). "Within the Sun there was a black vapour as large as a goose's egg." (*Wei-shu*, 105) (CS34, K32, CD43, WX)

38. 505 Jan 4
[N. CHINA] Cheng-shih reign-period, 1st year, 12th month, day *ping-hsu* (23). "A black vapour threaded through the Sun." (*Wei-shu*, 105) (CD44)

39. 510 Mar 17
[N. CHINA] Yung-p'ing reign-period, 3rd year, 2nd month, day *chia-tzu* (1). "Within the Sun there were two black vapours" (*Wei-shu*, 105) (CS35, K33, CD45, WX)

40. 511 Dec 16
[N. CHINA] Yung-p'ing reign-period, 4th year, 11th month, day *kuei-mao* (40). "Within the Sun there were two black vapours as large as peaches." (*Wei-shu*, 105) (CS36, K34, CD46, WX)

41. 513 Apr 17
[N. CHINA] Yen-ch'ang reign-period, 2nd year, intercalary 2nd month, day *hsin-hai* (48). "Within the Sun there was a black vapour." (*Wei-shu*, 105) (CS37, K35, CD47, WX)

42. 566 Mar 29
(i) [N. CHINA] T'ien-ho reign-period, 1st year, 2nd month, day *keng-wu* (7). "The Sun was flickering and its light was becoming faint; inside the Sun a crow was seen." (*Chou-shu*, 5 and *Pei-shih*, 10) (CS38, K36, CD48, WX)

(ii) [S. CHINA] T'ien-chia reign-period, 7th year (566), 2nd month, day *keng-wu* (7). "The Sun was dim and a crow was seen." (*Sui-shu*, 21) (CS38, K36, CD48, WX)

43. 567 Dec 10 to Dec 18 (visible for 9 days)
[N. CHINA] T'ien-ho reign-period, 2nd year, 10th month, day *hsin-mao* (28) - Dec 10. "At sunrise and sunset there was a single black vapour as large as a cup within the Sun. On day *chia-wu* (31) - Dec 13 - another (black vapour) was added. (Together) they lasted for 6 days and then were extinguished." (*Sui-shu*, 21 and *Chou-shu*, 5) (CS39, K37, CD49, WX)

44. 577 Dec 30? (possible scribal error in month)
[S. CHINA] Chien-te reign-period, 6th year, 11th month, day *chia-ch'en* (41), (no day *chia-ch'en* in 11th month, possibly read 12th month, *chia-ch'en* - Dec 30). "At the hour *pu* (i.e *shen*, 3-5 p.m.), within the Sun there was a black spot as large as a cup." (*Sui-shu*, 21) (CS40, K38, CD50)

45. 579 Apr 3 to Apr 6 (visible for 4 days)
[N. CHINA] Ta-hsiang reign-period, 1st year, 2nd month, day *kuei-wei* (20). "Just after sunrise and just before sunset, on both occasions there was a black colour within (the Sun). It was as large as a hen's egg. It lasted for 4 days, then it was extinguished." (*Chou-shu*, 7 and *Pei-shih*, 10) (CS41, K39, CD51, WX)

(N.B. NO RECORDS IN THE 7TH AND 8TH CENTURIES; POSSIBLY LARGELY DUE TO DESTRUCTION OF THE CHINESE CAPITAL DURING AN LU-SHAN'S REBELLION c. AD 760)

46. 826 May 7
[CHINA] Pao-li reign-period, 2nd year (826), 3rd month, day *chia-wu* (31). "Within the Sun there was a black vapour like a cup." (*Hsin-t'ang-shu*, 32) (CS42, K41, CD52, WX)

47. 826 May 24? (probable scribal error in month)
[CHINA] Pao-li reign-period, 2nd year, 3rd month, day *hsin-hai* (48), (no day *hsin-hai* in 3rd month, read 4th month then entries in the text which follow will be in correct sequence). "Within the Sun there was a black spot." (*Hsin-t'ang-shu*, 32) (CS43, K41, CD53, WX)

48. 832 Apr 21
[CHINA] T'ài-ho reign-period, 6th year, 3rd month, day *keng-hsu* (47). "Within the Sun there was a black spot." (*Hsin-t'ang-shu*, 32) (CS44, K43, CD55, WX)

49. 837 Dec 22
[CHINA] K'ai-ch'eng reign-period, 2nd year, 11th month, day *hsin-szu* (18). "Within the Sun there was a black spot as large as a hen's egg. The Sun was red like ochre and in the daytime it was like evening until day *kuei-wei* (20) - Dec 24." (*Hsin-t'ang-shu*, 32) (CS45, K45, CD57, WX)

50. 841 Dec 30
[CHINA] Hui-ch'ang reign-period, 1st year, 11th month, day *keng-hsu* (47). "Within the Sun there was a black spot." (*Hsin-t'ang-shu*, 32) (CS46, K46, CD58, WX)

51. 851 Dec 2
[JAPAN] Ninju reign-period, 1st year, 11th month, day *chia-hsu* (11). "The Sun was dim. Within it there was a black dot as large as a plum." (*Montohu Jitzurohu*) (CS47, K47, CD59, WX)

52. 865 Jan 31 - Feb 28 (only month given)
[CHINA] Hsien-t'ung reign-period, 6th year, 1st month. "A white rainbow penetrated the Sun. Within the Sun there was a black vapour like a hen's egg." (*Hsin-t'ang-shu*, 32) (CS48, K48, CD60, WX)

53. 874 (only year given)
[CHINA] Ch'ien-fu reign-period, 1st year. "Within the Sun there was a black spot." (*Hsin-t'ang-shu*, 32) (CS49, K49, CD61, WX)

54. 875 (only year given)
[CHINA] Ch'ien-fu reign-period, 2nd year. "Within the Sun there was an object like a flying swallow." (*Hsin-t'ang-shu*, 32) (CS50, K50, CD62, WX)

55. 904 Feb 19
[CHINA] T'ien-yu reign-period, 1st year, 2nd month, day *ping-yin* (3). "Within the Sun was seen *Pei-tou* (the 'Northern Dipper' - i.e. the Plough)." (*Hsin-t'ang-shu*, 32) (CS51, CD64, WX)

56. ** 927 Mar 9
[CHINA] T'ien-cheng reign-period, 2nd year, 2nd month, day *i-yu* (22). "Within the Sun there was a black vapour shaped like a hen's egg." (*Wen-hsien T'ung-k'ao*, 284) (CS52, K52, CD66,C56, WX)

57. 947 Nov 26
[CHINA] T'ien-fu reign-period, 12th year, winter, 10th month, day *jen-ch'en* (29). "On the Sun there was a black spot like a hen's egg." (*Wu-tai-shih*, 100) (CD67, WX)

58. 974 Mar 3
[CHINA] K'ai-pao reign-period, 7th year, 2nd month, day *ping-hsu* (23). "On the Sun there were two black spots." (*Sung-shih*, 4 and 52) (CS53, K53, CD68, WX)
[N.B. *Sung-shih*, 52 incorrectly gives the lunar month as the 1st month].

59. 1077 Mar 7 to Mar 21 (visible for 15 days)
[CHINA] Hsi-ning reign-period, 10th year, 2nd month, day *hsin-mao* (28). "Within the Sun there was a black spot like a plum, until day *i-szu* (42) - Mar 21 - when it dispersed." (*Sung-shih*, 15 and 52) (CS54, K54, CD69, WX)

60. 1077 Jun 7
[N. CHINA] Ta-k'ang reign-period, 3rd year, 5th month, day *kuei-hai* (60). "Within the Sun there was a black spot." (*Liao-shih*, 23) (CS55, K55, CD70, WX)

61. 1078 Mar 11 to Mar 29 (visible for 19 days)
[CHINA] Yuan-feng reign-period, 1st year, intercalary 1st month, day *keng-tzu* (37) - Mar 11. "Within the Sun there was a black spot like a plum, until the 2nd month, day *wu-wu* (55) - Mar 29 - a total of 19 days, when it dispersed." (*Sung-shih*, 52) (CS56, K56, CD71, WX)

62. 1079 Jan 11 to Jan 22 (visible for 12 days)
[CHINA] Yuan-feng reign-period, 1st year, 12th month, day *ping-wu* (43) - Jan 11. "Within the Sun there was a black spot as large as a plum, until day *ting-szu* (54) - Jan 22 - a total of 12 days, when it dispersed." (*Sung-shih*, 52) (CS57, K57, CD72, WX)

63. 1079 Mar 20 to Mar 29 (visible for 10 days)
[CHINA] Yuan-feng reign-period, 2nd year, 2nd month, day *chia-yin* (51) - Mar 20. "Within the Sun there was a black spot like a plum, until day *kuei-hai* (60) - Mar 29 - when it dispersed." (*Sung-shih*, 15 and 52) (CS58, K58, CD73, WX)

64. 1105 Dec 6
[CHINA] Ch'ung-ning reign-period, 4th year, 10th month, day *jen-ch'en* (29). "Within the Sun there was a black spot as large as a date." (*Sung-shih*, 20 and 52) (CS59, K59, CD74, WX)
[N.B. *Sung-shih* 52 incorrectly gives the year as the 3rd year of the Ch'ung-ning reign period].

65. 1112 May 2
[CHINA] Cheng-ho reign-period, 2nd year, 4th month, day *hsin-mao* (28). "Within the Sun there were black spots, sometimes two, sometimes three; they were as large as chestnuts." (*Sung-shih*, 52) (CS60, K60, CD75, WX)

66. 1118 Dec 17
[CHINA] Cheng-ho reign-period, 8th year, 11th month, day *hsin-hai* (48). "Within the Sun there was a black spot as large as a plum." (*Sung-shih*, 52) (CS61, K61, CD76, WX)

67. 1120 Jun 7
[CHINA] Hsuan-ho reign-period, 2nd year, 5th month, day *chi-yu* (46). "Within the Sun there was a black spot as large as a date." (*Sung-shih*, 52) (CS62, K62, CD77, WX)

68. 1122 Jan 10
[CHINA] Hsuan-ho reign-period, 3rd year, 12th month, day *hsin-mao* (28). "Within

the Sun there was a black spot as large as a plum." (*Sung-shih*, 22 and 52) (CS63, K63, CD78, WX)

69. 1129 Mar 22 to Apr 14 (visible for 24 days)
(i) [S. CHINA] Chien-yen reign-period, 3rd year, 3rd month, day *chi-mao* (16), 1st day - Mar 22. "Within the Sun there was a black spot. On day *jen-yin* (39) - Apr 14 - the black spot within the Sun died away." (*Sung-shih*, 25) (CS64, K64, CD79, WX)
[N.B. There is a very similar account in *Sung-shih*, 52].

(ii) [N. CHINA] T'ien-hui, 7th year, 3rd month, day *chi-mao* (16), 1st day - Mar 22. "Within the Sun there was a black spot." (*Kin-shih*, 20) (CS64, K64, CD79, WX)

70. 1131 Mar 12 to Mar 14/15 (visible for 3 or 4 days)
(i) [S. CHINA] Shao-hsing reign-period, 1st year, 2nd month, day *chi-mao* (16). "Within the Sun there was a black spot as large as a plum for 3 days; then it became hidden." (*Sung-shih*, 52) (CS65, K65, CD80, WX)

(ii) [S. CHINA] Shao-hsing reign-period, 1st year, 2nd month, day *chi-mao* (16). "Within the Sun there was a black spot for 4 days; then it died away." (*Sung-shih*, 26) (CS65, K65, CD80)

71. 1136 Nov 23 to Nov 27 (visible for 5 days)
(i) [S. CHINA] Shao-hsing reign-period, 6th year, 10th month, day *jen-hsu* (59) - Nov 23. "Within the Sun there was a black spot as large as a plum 11th month, day *ping-yin* (3) - Nov 27 - when it dispersed." (*Sung-shih*, 52) (CS66, K66, CD81, WX)

(ii) [N. CHINA] T'ien-hui reign-period, 14th year, 11th month, day *ping-yin* (3) - Nov 27. "Within the Sun there were black spots. They moved together along an oblique angle." (*Kin-shih*, 20) (CS67, K66, CD81, WX)

72. 1137 Mar 1 to Mar 10 (visible for 10 days)
[S. CHINA] Shao-hsing reign-period, 7th year, 2nd month, day *keng-tzu* (37). "Within the Sun there was a black spot as large as a plum for 10 days; then it dispersed." (*Sung-shih*, 52) (CS68, K67, CD82, WX)

73. 1137 May 8 to May 22 or later (visible for 15 days or more)
[S. CHINA] Shao-hsing reign-period, 7th year, 4th month, day *wu-shen* (45) - May 8. "Within the Sun there was a black spot, until the 5th month (May 22 - Jun 19) when it dispersed." (*Sung-shih*, 52) (CS69, K68, CD83, WX)
[N.B. There is an abbreviated record in *Sung-shih* 28].

74. 1138 Mar 16 (or Mar 17)
(i) [S. CHINA] Shao-hsing reign-period, 8th year, 2nd month, day *keng-shen* (57) - Mar 16. "Within the Sun there was a black spot." (*Sung-shih*, 29)

(ii) [S. CHINA] Shao-hsing reign-period, 8th year, 2nd month, day *hsin-yu* (58) - Mar 17. "Within the Sun there was a black spot." (*Sung-shih*, 52) (CS70, K69, CD84, WX)

75. 1138 Nov 26
[S. CHINA] Shao-hsing reign-period, 8th year, 10th month, day *i-hai* (12). "Within the Sun there was a black spot." (*Sung-shih*, 29 and 52) (CS71, K70, CD85, WX)

76. 1139 Mar 3 - 31 (only month given)
[S. CHINA] Shao-hsing reign-period, 9th year, 2nd month. "In this month (Mar 3 - Mar 31), within the Sun there was a black spot. After more than a month then it died away." (*Sung-shih*, 29) (CS72, K71, CD86, WX)

77. 1139 Nov 20
[S. CHINA] Shao-hsing reign-period, 9th year, 10th month, day *chia-hsu* (11). "Within the Sun there was a black spot." (*Sung-shih*, 29) (CS73, K72, CD87, WX)

78. 1145 Jun/Jul? (scribal error in date - visible for 2 days)
[S. CHINA] Shao-hsing reign-period, 15th year, 6th month, day *ping-wu* (43), (no day *ping-wu* in 6th month, cannot suggest a viable alternative). "Within the Sun there was a black vapour rocking to and fro. On (the following) day *ting-wei* (44) within the Sun there was a black spot; the Sun was dim." (*Sung-shih*, 52) (CS74, K73, CD88, WX)

79. 1151 Mar 21, Mar 31 and Apr 1 (visible on 3 separate days)
[KOREA] King Uijong, 5th year, 3rd month, day *kuei-yu* (10) - Mar 21. "On the Sun there was a black spot as large as a hen's egg. On day *kuei-wei* (20) - Mar 31 - and day *chia-shen* (21) - Apr 1 - it was the same." (*Koryo-sa*, 47) (CS75, K74, CD89, CD90, WX)

80. 1160 Feb 28 to Mar 1 (visible for 3 days)
[KOREA] King Uijong, 14th year, 1st month, day *chi-hai* (36). "Within the Sun there was a strange vapour for three days." (*Koryo-sa*, 47) (CS76, K75, CD91)

81. 1160 Sep 26
[N. CHINA] Cheng-lung reign-period, 5th year, 8th month, day *keng-wu* (7). "Within the Sun there was a black spot shaped like a man." (*Kin-shih*, 20) (CS77, K76, CD92, WX)

82. 1160 Sep 29
[KOREA] King Uijong, 14th year, 8th month, day *kuei-yu* (10). "Within the Sun there was a black spot." (*Koryo-sa*, 47) (CS78, K76, CD93, WX)

83. 1171 Oct 20
[KOREA] King Myongjong, 1st year, 9th month, day *hsin-mao* (28). "On the Sun there was a black spot as large as a peach." (*Koryo-sa*, 47) (CS79, K77, CD94, WX)

84. 1171 Nov 16
[KOREA] King Myongjong, 1st year, 10th month, day *wu-wu* (55). "On the Sun there was a black spot as large as a peach." (*Koryo-sa*, 47) (CS80, K78, CD95, WX)

85. 1183 Dec 4 to Dec 5 (visible for 2 days)
[KOREA] King Myongjong, 13th year, 11th month, day *chi-mao* (16). "On the Sun there was a black spot for 2 days." (*Koryo-sa*, 47) (CS81, K79, CD96, WX)

86. 1185 Feb 10, 11
(i) [S. CHINA] Shun-hsi reign-period, 12th year, 1st month, day *kuei-szu* (30) - Feb 10. "Within the Sun there was produced a black spot as large as a date." (*Sung-shih*, 52) (CS82, K80, CD97, WX)

(ii) [KOREA] King Myongjong, 15th year, 1st month, day *chia-wu* (31) - Feb 11. "On the Sun there was a black spot as large as a pear." (*Koryo-sa*, 47) (CS83, K80, CD97, WX)

87. 1185 Feb 15 to Feb 27 (visible for 13 days)
[S. CHINA] Shun-hsi reign-period, 12th year, 1st month. "From day wu-hsu (35) - Feb 15 - until day *keng-hsu* (47) - Feb 27 - within the Sun for the whole time there was a black spot." (*Sung-shih*, 52) (CS84, K80, CD98, WX)
[N.B. There is an abbreviated record in *Sung-shih* 35].

88. 1185 Mar 27
[KOREA] King Myongjong, 15th year, 2nd month, day *wu-yin* (15). "On the Sun there was a black spot as large as a pear." (*Koryo-sa*, 47) (CS85, K81, CD99, WX)

89. 1185 Apr 18 to Apr 19 (visible for 2 days)
[KOREA] King Myongjong, 15th year, 3rd month, day *keng-tzu* (37) - Apr 18. "On the Sun there was a black spot. On day *hsin-ch'ou* (38) - Apr 19 - it was the same." (*Koryo-sa*, 47) (CS86, K82, CD100, WX)

90. 1185 Nov 14
[KOREA] King Myongjong, 15th year, 10th month, day *keng-wu* (7). "On the Sun there was a black spot." (*Koryo-sa*, 47) (CS87, K83, CD101, WX)

91. 1186 May 23 to May 27 (visible for 5 days)
(i) [S. CHINA] Shun-hsi reign-period, 13th year, 5th month, day *keng-ch'en* (17) - May 23. "Within the Sun there was produced a black spot as large as a date, until day *chia-shen* (21) - May 27 - when it disappeared" (*Sung-shih*, 52) (CS88, K84, CD102, WX)

(ii) [S. CHINA] Shun-hsi reign-period, 13th year, 5th month, day *kuei-wei* (20) - May 26. "Within the Sun there was a black spot." (*Sung-shih*, 35) (CS88, K84, CD102, WX)

92. 1193 Dec 3 to Dec 12 (visible for 10 days)
[S. CHINA] Shao-hsi reign-period, 4th year, 11th month, day *hsin-wei* (8) - Dec 3. "Within the Sun there was a black spot, until day *keng-ch'en* (17) - Dec 12 - when it dispersed." (*Sung-shih*, 52) (CS90, K85, CD103, WX)
[N.B. There is a similar record in *Sung-shih* 36].

93. 1200 Sep 19
[KOREA] King Sinjong, 3rd year, 8th month, day *kuei-szu* (30). "On the Sun there was a black spot as large as a plum." (*Koryo-sa*, 47) (CS91, K86, CD104, WX)

94. 1200 Sep 21 to Sep 26 (visible for 6 days)
[S. CHINA] Ch'ing-yuan reign-period, 6th year, 8th month, day *i-wei* (32) - Sep 21. "Within the Sun there was a black spot as large as a date, until day *keng-tzu* (37) - Sep 26 - when it dispersed." (*Sung-shih*, 52) (CS92, K86, CD104, WX)
[N.B. There is an abbreviated record in *Sung-shih* 37].

95. 1201 Jan 9 to Jan 29 (visible for 21 days)
(i) [S. CHINA] Ch'ing-yuan reign-period, 6th year, 12th month, day *i-yu* (22) - Jan 9. (Following the last entry) "Another (black spot as large as a date) was produced until

day *i-szu* (42) - Jan 29 - when it dispersed." (*Sung-shih*, 52) (CS93, K87, CD105, WX) [N.B. There is a similar record in *Sung-shih* 37].

96. 1201 Apr 6.
[KOREA] King Sinjong, 4th year, 3rd month, day *jen-tzu* (49). "Within the Sun there was a black spot as large as a plum." (*Koryo-sa*, 47) (CS94, K88, CD106, WX)

97. 1202 Aug 23.
[KOREA] King Sinjong, 5th year, 8th month, day *ping-tzu* (13). "Within the Sun there was a black spot as large as a pear." (*Koryo-sa*, 47) (CS95, K89, CD107, WX)

98. 1202 Dec 19 to Dec 31 (visible for 13 days)
[S. CHINA] Chia-t'ai reign-period, 2nd year, 12th month, day *chia-hsu* (11) - Dec 19. "Within the Sun there was produced a black spot as large as a date; on day *ping-hsu* (23) - Dec 31 - it then dispersed." (*Sung-shih*, 52) (CS96, K90, CD108, WX)
[N.B. There is an abbreviated record in *Sung-shih* 38].

99. 1204 Feb 3 to Feb 5 (visible for 3 days)
[KOREA] King Sinjong, 7th year (1204), 1st month, day *i-ch'ou* (2), 1st day. "Within the Sun there was a black spot as large as a plum for a total of three days." (*Koryo-sa*, 47) (CS97, K91, CD109, WX)

100. 1204 Feb 21
[S. CHINA] Chia-t'ai reign-period, 4th year, 1st month, day *kuei-wei* (20). "Within the Sun there was a black spot as large as a date." (*Sung-shih*, 52) (CS98, K92, CD110, WX)
[N.B. There is an abbreviated record in *Sung-shih* 38].

101. 1205 May 4
[S. CHINA] K'ai-hsi reign-period, 1st year, 4th month, day *hsin-ch'ou* (38). "Within the Sun there was a black spot as large as a date." (*Sung-shih*, 52) (CS99, K93, CD111, WX)
[There is an abbreviated record in *Sung-shih* 38].

102. 1238 Dec 5
[S. CHINA] Chia-hsi reign-period, 2nd year, 10th month, day *chi-szu* (6). "Within the Sun there was a black spot." (*Sung-shih*, 52) (CS100, K94, CD112, WX)
[N.B. There is a similar record in *Sung-shih* 42].

103. 1258 Sep 15 to Sep 16 (visible for 2 days)
[KOREA] King Kojong, 45th year, 8th month, day *kuei-szu* (30). "Within the Sun there was a black spot as large as a hen's egg. On the following day (Sep 16), it was shaped like a man." (*Koryo-sa*, 47) (CS101, K95, CD113, WX)

104. 1276 Feb 17
[S. CHINA] Te-yu reign-period, 2nd year, 2nd month, day *ting-yu* (34), 1st day. "Within the Sun there were black spots like goose's eggs, agitating one another." (*Sung-shih*, 52) (CS102, K96, CD114, WX)
[N.B. There is a similar record in *Sung-shih* 47].

105. 1276 Mar 17 - Apr 15 (only month given)
[VIETNAM] Bao-phu reign-period, 4th year, 3th month. "Within the Sun there was a

black spot as large as a hen's egg. It appeared to scintillate for a long time". (*Dai-Viet Su'ky, Ban-ki Toan-thu'*, 5)

106. 1278 Aug 31
[KOREA] King Ch'ungnyol Wang, 4th year, 8th month, day *kuei-hai* (60). "Within the Sun there was a black spot as large as a hen's egg." (*Koryo-sa*, 47) (CS103, K97, CD115, WX)

107. 1356 Apr 4 to Apr 5 (visible for 2 days)
[KOREA] King Kongmin Wang, 5th year, 3rd month, day *chia-shen* (21) - Apr 4. "The Sun was dim; within it there was a black spot. On day *i-yu* (22) - Apr 5 - it was the same. On day *ping-hsu* (23) - Apr 6 - the Sun was faint and dim. It could be viewed directly without dazzling the eyes." (*Koryo-sa*, 47) (CS104, K98, CD116, WX)

108. 1361 Mar 16
[KOREA] King Kongmin Wang, 10th year, 2nd month, day *hsin-mao* (28). "On the Sun there was a black spot." (*Koryo-sa*, 47) (CS105, K99, CD117, WX)

109. 1362 Oct 5
[KOREA] King Kongmin Wang, 11th year, 9th month, day *chi-wei* (56). "On the Sun there was a black spot." (*Koryo-sa*, 47) (CS106, K100, CD118, WX)

110. 1365 (first half of year)
[CHINA] Official History: Entry under Hung-wu reign-period 8th year, 4th month, day *ting-szu* - 1375 May 28. "The Earl of Sincerity Liu Chi died (an obituary follows) ... (Liu) Chi was made the Grand Astronomer. One day, (Liu) Chi saw that within the Sun there was a black spot and memorialized His Imperial Majesty, 'In the SE, an able general will be lost.' Later, general Hu Shen attacked Fukien and indeed was defeated and killed." (*T'ai-tsu Shih-lu*, 99)

[CHINA] Local History: "Year I-szu (1365), Chen Yu-ting intruded on the border at Fukien, (Hu) Shen was ordered to repel the offenders ... he was killed, aged 52. At the time, the Grand Astronomer Liu Chi saw that within the Sun there was a black spot." (*Che-kiang T'ung-chih*, 34) (CH36, WX)
[N.B. Hu Shen was killed 1365 July 14]

111. * 1368 (visible throughout year)
[CHINA] Hung-wu reign-period, 1st year. "From the 1st month - 1368 Jan/Feb - until the 12th month - 1369 Jan/Feb - within the Sun there was a black spot (*or* there were black spots)." (*Hu-nan T'ung-chih*, 243) (CH38, WX)

112. * 1368 Jul/Aug - Oct/Nov (only season given)
[CHINA] Hung-wu reign-period, 1st year. This autumn the sky roared and trembled. Within the Sun there were spots, from one to three; they were seen every day." (*Ch'ing-t'ien Hsien-chih*, 13) (CH37)

113. * 1369 Dec 30 - 1370 Jan 27 (only month given)
[CHINA] Hung-wu reign-period, 2nd year, winter, 12th month. "Within the Sun frequently there was a black spot." (*Erh-shen Yeh-lu*, 1) (CH39, WX)

114. 1370 Jan 1
[CHINA] Hung-wu reign-period, 2nd year, 12th month, day *chia-tzu* (1). "Within the Sun there was a black spot." (*T'ai-tsu Shih-lu*, 47) (CS107, K101, CD119, WX)

115. 1370 Jan 28 to Feb 3 (visible for 7 days)
[CHINA] Hung-wu reign-period, 3rd year, 1st month, day *ting-yu* (34) - Feb 3. "The Astronomical Bureau reported that from the 1st day (of the month) - Jan 28 - until today - Feb 3 - within the Sun there was a black spot." (*T'ai-tsu Shih-lu*, 48)

116. 1370 (frequently visible throughout year)
[CHINA] Hung-wu reign-period, 3rd year, 12th month, day *jen-wu* (19) - 1371 Jan 14. "In regard to the frequent black spots within the Sun from the 1st month (1370 Jan/Feb) until this month, His Imperial Majesty appealed to Court officials to report errors (of the throne)." (*T'ai-tsu Shih-lu*, 59) (CS112, K105, CD125, WX)

117. * 1370 Apr 25
[CHINA] Hung-wu reign-period, 3rd year, 3rd month, 1st day, *wu-wu* (55). "At this time, within the Sun repeatedly there was a black spot." (*Kuo-chueh*, 4) (CH41)

118. 1370 Oct 2
[CHINA] Hung-wu reign-period, 3rd year, 9th month, day *wu-hsu* (35) "Within the Sun there was a black spot." (*T'ai-tsu Shih-lu*, 56) (CS108, K102, CD121, WX)

119. 1370 Oct 21
[CHINA] Hung-wu reign-period, 3rd year, 10th month, day *ting-szu* (54). "Within the Sun there was a black spot." (*T'ai-tsu Shih-lu*, 57) (CS109, K103, CD122, WX)

120. 1370 Dec 7
[CHINA] Hung-wu reign-period, 3rd year (1370), 11th month, day *chia-ch'en* (41). "In regard to the approaching (annual) sacrifice to Heaven and because of the frequent black spots within the Sun, His Imperial Majesty hence issued an edict..." (*T'ai-tsu Shih-lu*, 58) (CS110, K104, CD123, WX)

121. * 1370 Dec 19
[CHINA] Hung-wu reign-period, 3rd year, 12th month, day *ping-ch'en* (53), 1st day. "Within the Sun repeatedly there was a black spot." (*Kuo-chueh*, 4) (CH42)

122. 1371 Jan 2
[KOREA] King Kongmin-wang, 19th year, 12th month, day *keng-wu* (7). "On the Sun there was a black spot." (*Koryo-sa*, 47 and 42) (CS111, K105, CD124, WX)

123. 1371 Mar 31
[CHINA] Hung-wu reign-period, 4th year, 3rd month, day *wu-hsu* (35). "Within the Sun there was a black spot." (*T'ai-tsu Shih-lu, 62*) (CS113, K106, CD126, WX)

124. 1371 Jun 13 to Jul 12. (visible for 30 days)
[CHINA] Hung-wu reign-period, 4th year, 5th month, day *hsin-szu* (18) - Jul 12. "From day *jen-tzu* - Jun 13 - until today - Jul 12 - within the Sun there was a black spot." (*T'ai-tsu Shih-lu, 65*) (CS114, K107, CD127, WX)

125. 1371 Oct/Nov? (scribal error in date)
[KOREA] King Kongmin-wang, 20th year, 9th month, day *kuei-szu* (30), (no *kuei-szu*

in 9th month, cannot suggest a viable alternative). "Within the Sun there was a black spot." (*Koryo-sa*, 47) (CS116, K109, CD128, WX)

126. 1371 Nov 6
[CHINA] Hung-wu reign-period, 4th year, 9th month, day *wu-yin* (15). "Within the Sun there was a black spot." (*T'ai-tsu Shih-lu*, 68) (CS115, K108, CD129, WX)

127. 1372 Feb 6
[CHINA] Hung-wu reign-period, 5th year, 1st month, day *keng-hsu* (47). "Within the Sun there was a black spot." (*T'ai-tsu Shih-lu*, 71) (CS117, K110, CD130, WX)

128. 1372 Apr 3
[CHINA] Hung-wu reign-period, 5th year, 2nd month, day *ting-wei* (44). "Within the Sun there was a black spot." (*T'ai-tsu Shih-lu*, 72) (CS118, K111, CD131, WX)

129. 1372 May 8
[KOREA] King Kongmin-wang, 21st year, 4th month, day *jen-wu* (19). "On the Sun there was a black spot." (*Koryo-sa*, 47) (CS119, K112, CD132, WX)

130. 1372 Jun 19
[CHINA] Hung-wu reign-period, 5th year, 5th month, day *chia-tzu* (1). "Within the Sun there was a black spot." (*T'ai-tsu Shih-lu*, 73) (CS120, K113, CD133, WX)

131. 1372 Aug 25
[CHINA] Hung-wu reign-period, 5th year, 7th month, day *hsin-wei* (8). "Within the Sun there was a black spot." (*T'ai-tsu Shih-lu*, 75) (CS121, K114, CD134, WX)

132. 1373 Apr 26, 27 (visible for 2 days)
[KOREA] King Kongmin Wang, 22nd year, 4th month, day *i-hai* (12). "On the Sun there was a black spot for two days." (*Koryo-sa*, 47) (CS122, K115, CD135, WX)

133. 1373 Oct 23
[KOREA] King Kongmin Wang, 22nd year, 10th month, day *i-hai* (12). "On the Sun there was a black spot." (*Koryo-sa*, 47) (CS123, K116, CD136, WX)

134. 1373 Nov 15
[CHINA] Hung-wu reign-period, 6th year, 11th month, day *wu-hsu* (35), 1st day. "Within the Sun there was a black spot." (*T'ai-tsu Shih-lu*, 86) (CS124, K117, CD137, WX)

135. 1374 Mar 27 to Mar 31 (visible for 5 days)
[CHINA] Hung-wu reign-period, 7th year, 2nd month, day *chia-yin* (51) - Mar 31. "From day keng-hsu (47) - Mar 27 - until today - Mar 31 - within the Sun there was a black spot." (*T'ai-tsu Shih-lu*, 87) (CS125, K118, CD138, WX)

136. 1375 Mar 20 to Mar 22 (visible for 3 days)
(i) [KOREA] King Sinu, 1st year, 2nd month, day *wu-shen* (45) - Mar 20 - "On the Sun there was a black spot. Day *chi-yu* (46) - Mar 21 - it was the same." (*Koryo-sa*, 47) (CS126, K119, CD139, WX)

(ii) [CHINA] Hung-wu reign-period, 8th year, 2nd month, day *keng-hsu* (47) - Mar 22. "Within the Sun there was a black spot." (*T'ai-tsu Shih-lu*, 97) (CS127, K119, CD139, WX)

137. 1375 Oct 21
[CHINA] Hung-wu reign-period, 8th year, 9th month, day *kuei-wei* (20). "Within the Sun there was a black spot." (*T'ai-tsu Shih-lu*, 101) (CS128, K120, CD140, WX)

138. 1376 Jan 19
[CHINA] Hung-wu reign-period, 8th year, 12th month, day *kuei-ch'ou* (50). "Within the Sun there was a black spot." (*T'ai-tsu Shih-lu*, 102) (CS129, K121, CD141, WX)

139. 1381 Mar 22 to Mar 25 (visible for 4 days)
(i) [CHINA] Hung-wu reign-period, 14th year, 2nd month, day *i-yu* (22) - Mar 25. "From day *jen-wu* (19) - Mar 22 - until today - Mar 25 - within the Sun there was a black spot." (*T'ai-tsu Shih-lu*, 135) (CS130, K122, CD142, WX)

(ii) [KOREA] King Sinu, 7th year, 2nd month, day *kuei-wei* (20) - Mar 23. "On the Sun there was a black spot." (*Koryo-sa*, 47 and 134) (CS131, K122, CD142, WX)

140. 1382 Mar 9 to Mar 11 (visible for 3 days)
[KOREA] King Sinu, 8th year, 2nd month, day *chia-hsu* (11). "On the Sun there was a black spot as large as a hen's egg for a total of three days." (*Koryo-sa*, 47 and 134) (CS132, K123, CD143, WX)

141. 1382 Mar 21
[CHINA] Hung-wu reign-period, 15th year, intercalary 2nd month, day *ping-hsu* (23). "Within the Sun there was a black spot." (*T'ai-tsu Shih-lu*, 143) (CS133, K124, CD144, WX)

142. 1383 Jan 10
[CHINA] Hung-wu reign-period, 15th year, 12th month, day *hsin-szu* (18). "Within the Sun there was a black spot." (*T'ai-tsu Shih-lu*, 150) (CS134, K125, CD145, WX)

143. 1387 Apr 15
[KOREA] King Sinu, 13th year, 3rd month, day *ting-ch'ou* (14). "On the Sun there was a black spot." (*Koryo-sa*, 47) (CS135, K126, CD146, WX)

144. 1402 Nov 15
[KOREA] King T'aejong, 2nd year, 10th month, day *keng-wu* (7). "Within the Sun there was a black dot." (*T'aejong Sillok*, 4) (CS136, K127, CD147, WX)

145. 1520 Mar 9
[KOREA] King Chungjong, 15th year, 2nd month, day *chi-mao* (16). "Within the Sun there were black vapours agitating one another." (*Chungjong Sillok*, 38) (CS137, K128, CD148, WX)

146. 1556 Apr 17
[KOREA] King Myongjong, 11th year, 3rd month, day *ting-mao* (4). "Within the Sun there was a black spot as large as a hen's egg. The sky was covered with a dense vapour" (*Myongjong Sillok*, 20) (CD149, WX)

147. * 1562 (only year given)
[CHINA] Chia-ching reign-period, 41st year. "On the Sun there was a black spot." (*Nan-yang Hsien-chih*, 2) (CH47, WX)

148. * 1566 Jan 21 - Feb 19 (only month given - visible for 5 days)
[CHINA] Chia-ching reign-period, 45th year, spring, 1st month. "Within the Sun there was a black spot as large as an egg, rocking to and fro for 5 days, then it was extinguished." (*Kwangchow Fu-chih*, 78) (CH48, WX)

149. * 1567 Feb/Mar - Apr/May (only season given)
[CHINA] Lung-ch'ing reign-period, 1st year, spring. "Within the Sun there were black spots agitating one another." (*Lu-ch'i Hsien-chih*, 1) (CH49, WX)

150. * 1569 Jan 17 (visible for several days)
[CHINA] Lung-ch'ing reign-period, 3rd year, 1st month, 1st day. "Within the Sun there was (something) for several days. After about ten days then it disappeared. In the summer (Apr/May - Jul/Aug), a black light agitated the Sun." (*Ho-chian Fu-chih*, 4) (CH50)

151. * 1573 - 1619 (only reign period given)
[CHINA] In the years of Wan-li reign-period. "Within the Sun there were black spots agitating one another." (*An-hai chih*, 8) (CH51)

152. * 1590 May 4 - Jun 1 (only month given)
[CHINA] Wan-li reign-period, 18th year, summer, 4th month. "Within the Sun there was a black vapour; the sunlight was dim for a long time." (*Chin-chow Hsin-chih*, 6) (CH52, WX)

153. 1593 Jan 3
[VIETNAM] King Shih-tsuan, 15th year, 12th month, 1st day. "At the hour of *mao* (5-7 a.m.), within the Sun there were two black spots shaped like crows, for three days." (*Dai-Viet Su'ky, Ban-ki Thu'c-bien'*, 5) (CD150, WX)

154. 1603 Apr 4 - May 10 (only month given)
[VIETNAM] Chia-yu reign-period, 46th year, spring, 3rd month. "Within the Sun there were three black spots." (*Dai-nam Thu'c-luc chien-bien*, 1) (CD152, WX)

155. 1603 Apr 16
[KOREA] King Sonjo, 36th year, 3rd month, day *jen-hsu* (59). "At the hour of *mao* (5-7 a.m.), the Sun was red and without brightness; it had three dots of black cloud shaped like large coins. From the north of the Sun they seemed to be separating and joining across the Sun towards the south." (*Sonjo Sillok*, 160) (CS138, K129, WX)

156. 1604 Oct 24, 25 (visible for 2 days)
[KOREA] King Sonjo, 37th year, intercalary 9th month, day *chi-mao* (16) - Oct 24. "At sunrise, within the Sun there was a black spot as large as a hen's egg. On day *keng-ch'en* (17) - Oct 25 - at sunrise, within the Sun there was a black spot as large as a hen's egg." (*Sonjo Sillok*, 179) (CS139, K130, CD153, WX)

157. 1608 May 10
[KOREA] King Kwanghae-gun, year of accession (1608), 3rd month, day *kuei-ch'ou* (50). "From daybreak to the hour of *yu* (5-7 p.m.), in every direction it was dull and hazy as if dust was falling. At the hour of *mao* (5-7 a.m.), within the Sun there was a dot of dark vapour as large as a pear." (*Kwanghae-gun Sillok*, 1) (CD154, WX)

158. * 1613 Mar 30
[CHINA] Wan-li reign-period 41st year, 2nd month, 10th day. "Within the Sun there was a black light and it was wavering." (*Fukien T'ung-chih*, 65) (CH53, XJ3, WX)

159. 1616 Oct 10
[CHINA] Wan-li reign-period, 44th year, 8th month, day *wu-ch'en* (5). "Within the Sun there was a black light." (*Shen-tsung Shih-lu*, 548) (K131, CD155, XJ4, WX)

160. * 1617 Jan 11
[CHINA] Wan-li reign-period, 44th year, 12th month, 5th day. "Between the hours of *ch'en* and *szu* (7-11 a.m.), on one side of the Sun there were several black spots rocking to and fro." (*Ching-chiang Hsien-chih*, 11) (CH54, XJ6, WX)

161. * 1617 (only year given)
[CHINA] Wan-li reign-period, 45th year. "Within the Sun there was a black spot rocking to and fro." (*Hu-kwang T'ung-chih and Chung-hsiang Hsien-chih*, 10) (CH55, K132, XJ7, WX)

162. * 1618 (only year given)
[CHINA] Wan-li reign-period, 46th year. "Within the Sun there was a black spot." (*Lai-pin Hsien-chih*, 2nd part) (CH56)

163. ** 1618 Apr 25 - May 23 (only month given)
[CHINA] Wan-li reign-period, 46th year, 4th month. "Within the Sun there was a black spot." (*Ming-hui-yao*, 68) (XJ8, WX)

164. * 1618 May 24 - Jun 21 (only month given)
(i) [CHINA] Wan-li reign-period, 46th year, intercalary 4th month. "Within the Sun there was a black spot like a ladle." (*Fukien T'ung-chih*, 146) (CH57, XJ9, WX)

(ii) [CHINA] Wan-li reign-period, 46th year, intercalary 4th month. "Within the Sun there was again a black spot; its light was wavering." (*Chang-shu-hsien Szu-chih*) (XJ9, WX)

165. 1618 Jun 20 to 22 (visible for 3 days)
[CHINA] Wan-li reign-period, 46th year, intercalary 4th month, day *ping-hsu* (23) - Jun 20. "From this day until day *wu-tzu* (25) - Jun 22 - for three days. On one side of the Sun there was a black vapour, coming in and out of the Sun and rocking to and fro for a long time. It was reported by the Astronomical Bureau at Nanking; it was not reported by the Astronomical Bureau at Peking." (*Shen-tsung Shih-lu*, 569) (K133, CD156, WX)

166. * 1618 Jun 22
[CHINA] Wan-li reign-period, year wu-wu (46th year), 5th month, 1st day. "Within the Sun there was a black vapour." (*Sung-kiang Fu-chih*, 47) (CH58, XJ11, WX)

167. 1620 Oct 15 - Oct 24
[CHINA] T'ai-ch'ang reign-period, 1st year, 10th month, day *kuei-yu* (10) (Nov 23). "... Moreover, when Your Majesty ascended the throne in the last 'decade' (of the previous month) - Oct 15 to Oct 24 - there was a black vapour on the Sun; it was fighting the Sun." (*Hsi-tsung Shih-lu*, 9)

168. 1621 May 23
[CHINA] T'ien-ch'i reign-period, 1st year, 4th month, day *chia-hsu* (11). "Within the

Sun there was a black vapour rocking to and fro." (*Hsi-tsung Shih-lu*, 9) (CD157, XJ12, WX)

169. * 1622 Jun 9 - Jul 7 (only month given)
[CHINA] T'ien-ch'i reign-period, 2nd year, 5th month. "Within the Sun, (the shapes of) the Moon and a star were seen. (*Ming-hui-yao*, 68)

170. 1624 Mar 17 to Mar 20 (visible for 4 days)
[CHINA] T'ien-ch'i reign-period, 4th year, 1st month, day *kuei-wei* (20). "The Sun was red and dim. There were two or three black spots lying laterally on the Sun. They gradually increased to about a hundred (*sic*), and lasted for four days." (*Ming-shih*, 27) (K134, CD158, XJ13, WX)

171. 1624 May/Jun? (scribal error in date)
[CHINA] T'ien-ch'i reign-period, 4th year, 4th month, day *kuei-yu* (10), (no day *kuei-yu* in 4th month, cannot suggest a viable alternative). "Within the Sun there was a black vapour rocking to and fro." (*Ming-shih*, 27) (K136, CD159, XJ15, WX)

172. * 1625 May/Jun - Jul/Aug (only season given)
[CHINA] T'ien-ch'i reign-period, 5th year, summer. "Within the Sun there appeared a star and the Sun was without brilliance. On its side there was a black spot. It remained like this for more than ten days." (*Cheng-kiang Fu-chih* and *Li-yang Hsien-chih*, 3) (CH59, XJ16, WX)

173. * 1626 Jun 29
[CHINA] T'ien-ch'i reign-period, 6th year, 6th month, 6th day. "Within the Sun a ladle was seen." (*Hsiang-yuan Hsien-chih*, 8 and *Lu-an Fu-chih*) (CH60, XJ17, WX)

174. * 1631 Feb 25
[CHINA] Ch'ung-cheng reign-period, 4th year, 1st month, 25th day. "Within the Sun there was a black spot." (*Hsin-cheng Hsien-chih* and *Hsin-hsiu Ch'ang-shan Hsien-chih*, 7) (CH61, XJ18, WX)

175. * 1635 Feb 17 - Mar 18 (only month given)
[CHINA] Ch'ung-cheng reign-period, 8th year, 1st month. "On the Sun there was a black light rocking to and fro." (*Hunan T'ung-chih*) (XJ19, WX)

176. * 1637 (only year given)
[CHINA] Ch'ung-cheng reign-period, year *ting-chou*. "Within the Sun there were several black spots." (*Chu-yung Hsien-chih*) (XJ20, WX)

177. * 1638 Sep 8 - Oct 6 (only month given)
[CHINA] Ch'ung-cheng reign-period, 11th Year, 8th month. "A black spot was rocking to and fro on one side of the Sun." (*Tai-tsang Chow-chih*) (XJ22, WX)

178. 1638 Dec 9
[CHINA] Ch'ung-cheng reign-period, 11th Year, 11th month, day *kuei-hai* (60). "Within the Sun there was a black spot, and black and pale blue vapours." (*Ming-shih*, 27) (K137, CD160, XJ23, WX)

179. * 1639 Oct 26
[CHINA] Ch'ung-cheng reign-period, 12th Year, winter, 10th month, 1st day. "Within the Sun a ladle was seen." (*Chu-chi Hsien-chih*) (XJ26, WX)

180. * 1643 Jun 16 - Jul 15 (only month given)
[CHINA] Ch'ung-cheng reign-period, 16th year, summer, 5th month. "Within the Sun a star was seen." (*Tai-hu Hsien-chih*, 40) (CH64, XJ27, WX)

181. 1643 July 2
[KOREA] King Injo, 21st year, 5th month, day *chi-yu* (46). "Within the Sun there was a black vapour shaped like a flying bird." (*Injo Sillok*, 44) (CD161, WX)

182. * 1647 (only year given)
[CHINA] Shun-chih reign-period, 4th year. "Within the Sun there was a form like a cutlass." (*Ch'en-ch'i Hsien-chih*) (CH65, XJ28, WX)

183. 1648 Jan 16
[KOREA] King Injo, 25th year, 12th month, day *wu-tzu* (25). "Within the Sun there was a black spot." (*Injo Sillok*, 48) (CD162, WX)

184. * 1648 Apr/May - Jul/Aug (only season given)
[CHINA] Shun-chih reign-period, summer. "On the Sun a star was seen." (*Chang-shan Hsien-chih*) (WX)

185. * 1650 Oct 25
[CHINA] Shun-chih reign-period, year *keng-yin* (1650), 10th month, 1st day. "The Sun was eclipsed. At noon, within the Sun a ladle was seen." (*Chu-yung Hsien-chih*) (XJ29, WX)
[N.B. The solar eclipse of Oct 25 was total in China]

186. * 1655 Apr 30
[CHINA] Shun-chih reign-period, 12th Year, 3rd month, 24th day. "At the hour *shen* (3-5 p.m.), within the Sun there was a black spot. After a long while then it dispersed." (*San-kang Shih-lueh*, 3) (CH66, XJ30, WX)

187. * 1656 Jan/Feb - Mar/Apr (only season given)
[CHINA] Shun-chih reign-period, 13th year, spring. "Within the Sun there was seen a black spot." (*Hu-kuang T'ung-chih*, 3) (CH67, XJ31, WX)

188. * 1665 Feb 15 - Mar 16 (only month given)
[CHINA] K'ang-hsi reign-period, 4th year, 1st month. "Within the Sun there was a black light wavering." (*Chao-chow Fu-chih*) (WX)

189. * 1665 Feb/Mar - Apr/May (only season given)
[CHINA] K'ang-hsi reign-period, 4th year, spring. "Within the Sun there was a black spot rocking like a shuttle." (*Lu-an Chow-chih*) (WX)

190. * 1665 Feb 20
[CHINA] K'ang-hsi reign-period, 4th year, 1st month, 6th day. "Within the Sun there were two black spots; they were rocking to and fro for a long time." (*Shuang-lin Cheng-chih*, 19) (CH68, XJ32, WX)

191. * 1665 Aug 27
[CHINA] K'ang-hsi reign-period, 4th year, 7th month, day *hsin-ch'ou* (38). "On the Sun a star was seen." (*Yi-tu Hsien-chih*) (WX)

192. * 1684 Mar 16 to Mar 18 (visible for 3 days)
[CHINA] K'ang-hsi reign-period, 23rd year, 2nd month, 1st to 3rd day. "Within the Sun

the *tou-hsing* (either *Pei-tou* or *Nan-tou*, both are ladle shaped asterisms) was seen." (*Yu-hsien-chih* and *Ch'ang-sa Fu-chih*, 37) (CH69, XJ33, WX)

193. * 1709 (only year given)
[CHINA] K'ang-hsi reign-period, 48th year. "Within the Sun there was a black spot rocking to and fro." (*Kao-mi-chih*, 9) (CH70)

194. 1720 Jun 1
[KOREA] King Sukjong, 46th year, 4th month, day *jen-hsu* (59). "At sunrise, the colour (of the Sun) was red and it was dim. Within the Sun there was a black vapour." (*Sukjong Sillok*, 65)

195. 1726 Oct 20, 21 (visible for 2 days)
[KOREA] King Yongjo, 2nd year, 9th month, day *chia-yin* (51) - Oct 20. "At the hour of *yu* (5.00 to 7.00 pm), on the Sun there was a black vapour. On day *i-mao* (22) - Oct 21 - from daybreak until the hour of *mao* (5.00 to 7.00 a.m.) there was dense fog. At the hour of *chen* (7.00 to 9.00 am), within the Sun there was a black vapour." (*Yongjo Sillok*, 10)

196. * 1732 May 11
[CHINA] Yung-cheng reign-period, 10th year, 4th month, 17th day. "The colour of the Sun was red as blood; within it there were two black spots rocking between *wei* and *shen* (ie. south-western part). Within the Sun, there was (also) a band of black halo; the redness increased still further. It was like this for several days." (*Tseng-hsiu Teng-chow Fu-chih*, 23) (CH71)

197. 1743 Oct 19 to 21 (visible for 3 days)
[KOREA] King Yongjo, 19th year, 9th month, day *jen-wu* (19) - Oct 19. "Within the Sun there was a black vapour. On day *kuei-wei* (20) - Oct 20 - within the Sun there was a black vapour. On day *chia-shen* (21) - Oct 21 - within the Sun there was a black vapour." (*Yongjo Sillok*, 58)

198. * 1757 Jun 16 - Jul 15 (only month given)
[CHINA] Ch'ien-lung reign-period, 22nd year, 5th month. "On the Sun there was a black spot rocking to and fro." (*Kao-mi Hsien-chih*, 10) (CH72)

199. * 1792 (only year given)
[CHINA] Ch'ien-lung reign-period, 57th year. "Within the Sun there was a flying swallow." (*Chen-yuan Hsien-chih*, 7) (CH73)

200. * 1799 Feb 5
[CHINA] Chia-ch'ing reign-period, 4th year, spring, 1st month, 1st day. "Within the beautiful Sun there were three men." (*Wu-ch'ang Hsien-chih*, 10) (CH74)

201. * 1819 Aug 21 - Sep 18 (only month given)
[CHINA] Chia-ch'ing reign-period, 24th year, 7th month. "By (viewing) the Sun reflected in water, there was seen within it the character *ching* ('well'). It was like this for several months." (*Hsin-hui Hsien-chih*, 14) (CH75)

202. * 1848 May 3 to May 15 (visible for 13 days)
[CHINA] Tao-kuang reign-period, 28th year, 4th month, from 1st day to 13th day. "Within the Sun there was a black spot." (*Fu-shan Hsien-chih*, 8) (CH76)

203. * 1851 Feb - Apr (only season given)
[CHINA] Hsien-feng reign-period, 1st year, spring. "Within the Sun there was a black spot." (*Ting-nan Hsien-chih*, 6) (CH77)

204. * 1851 Dec 25
[CHINA] Hsien-feng reign-period, 1st year, winter, 11th month, 4th day. "On the face of the Sun there was a black dot." (*Kan-su ch'uan-sheng Hsin-T'ung-chih*, 2) (CH78)

205. * 1852 Jan 19
[CHINA] Hsien-feng reign-period, 1st year, winter, 11th month, 29th day. "Within the Sun there was a black dot." (*Kan-su ch'uan-sheng Hsin-T'ung-chih*, 2) (CH79)

206. * 1852 Mar 22
[CHINA] Hsien-feng reign-period, 2nd year, 2nd month, 2nd day. "The Director of the Astronomical Bureau reported that on one side of the Sun there were three black spots." (*I-hsien Hsien-chih*, 15) (CH80)

207. * 1852 Apr 2
[CHINA] Hsien-feng reign-period, 2nd year, 2nd month, 13th day. "Within the Sun there was a black spot." (*T'ung-ch'eng Hsien-chih*, 10) (CH81)

208. * 1852 Dec 29
[CHINA] Hsien-feng reign-period, 2nd year, 11th month, 19th day. "Within the Sun there was a flying crow." (*T'ung-ch'eng Hsien-chih*, 10) (CH82)

209. * 1853 Feb 8 - Mar 9 (only month given)
[CHINA] Hsien-feng reign-period, 3rd year, 1st month. "Within the Sun two shadows were seen, one red and one black, they were fighting one another." (*Hu-pei T'ung-chih*, 76) (CH83)

210. * 1853 May 17
[CHINA] Hsien-feng reign-period, 3rd year, summer, 4th month, 10th day. "On one side of the Sun there was a black spot." (*An-hua Hsien-chih*, 34) (CH84)

211. * 1853 Jun 7 - Jul 5 (only month given)
[CHINA] Hsien-feng reign-period, 3rd year, 5th month. "Within the Sun there was a black spot rocking to and fro. It dispersed after more than one *k'o* (about 15 minutes)." (*Hsu-hsiu Tien-chow Fu-chih*, 93) (CH85)

212. * 1853 Aug 5 - Sep 2 (only month given)
[CHINA] Hsien-feng reign-period, 3rd year, 7th month. "Within the Sun there was a black form like a wool ball, with pointed rays shooting out on all sides." (*T'un-Liu Hsien-chih*, 1) (CH86)

213. * 1855 Jan 20
[CHINA] Hsien-feng reign-period, 4th year, 12th month, 3rd day. "Within the Sun there was seen a black spot." (*T'ung-ch'eng Hsien-chih*, 10) (CH87)

214. * 1856 Feb 8
[CHINA] Hsien-feng reign-period, 6th year, 1st month, 3rd day. "The wind was strong; within the Sun there was a black spot." (*Puchow Chih*, 2) (CH88)

215. * 1856 Aug 30 - Sep 28 (only month given)
[CHINA] Hsien-feng reign-period, 6th year, 8th month. "Within the Sun there was seen a black spot." (*Lo-ch'i Cheng-chih*, 8) (CH89)

216. * 1860 Dec 4
[CHINA] Hsien-feng reign-period, 10th year, 10th month, 22nd day. "Within the Sun there were two black spots. One of them was extremely dark and situated near the centre; it was still and did not move. The other was slightly paler and situated below, but seemed to be unstable. After 5 or 6 days, then they were not seen." (*Hsu-Hanchow Chih*, 20) (CH90)

217. * 1861 Mar 30 to Apr 10 (visible for 12 days)
[CHINA] Hsien-feng reign-period, 11th year, 2nd month, 20th day. "At the hour of *ch'en* (7-9 a.m.), within the Sun there were two black spots, until the 1st day of the 3rd month - Apr 10 - when they were extinguished." (*Mien-chu Hsien-chih*, 18) (CH91)

218. * 1861 Nov 24
[CHINA] Hsien-feng reign-period, 11th year, 10th month, 22nd day. "Within the Sun there was a black spot." (*Te-yang Hsien-chih*, 42) (CH92)

219. * 1863 Mar 19
[CHINA] T'ung-chih reign-period, 2nd year, spring, 2nd month, day *ting-ch'ou* (14). "Within the Sun there was a black spot." (*Hui-min Hsien-chih*, 17) (CH93)

220. * 1865 Mar 27 - Apr 24 (only month given)
[CHINA] T'ung-chih reign-period, 4th year, 3rd month. "Within the Sun there were three human shadows." (*Hu-nan T'ung-chih*, 244) (CH94)

221. * 1865 Jul 18
[CHINA] T'ung-chih reign-period, 4th year, intercalary 5th month, day *chi-ch'ou* (26). "Within the Sun there was a shadow, beside it there was a star. It lasted for five or six days before vanishing." (*Wu-yang Chih-yu*, 5) (CH95)

222. * 1873 Feb 23, 24 (visible for 2 days)
[CHINA] T'ung-chih reign-period, 12th year, 1st month, 26th and 27th day. "Within the Sun there was a black spot." (*T'ai-shun Fen-chiang Lu-chih*, 10) (CH96)

223. * 1874 Feb/Mar - Apr/May (only season given)
[CHINA] T'ung-chih reign-period, 13th year, spring. "Within the Sun there was a black light rocking to and fro." (*Hai-yang Hsien-chih*, 25) (CH97)

224. * 1874 Dec 9
[CHINA] T'ung-chih reign-period, 13th year, 11th month, 1st day. "Within the Sun there was a black spot." (*Shih-men Hsien-chih*, 11) (CH98)

225. * 1883 Dec 26
[CHINA] Kuang-hsu reign-period, 9th year, 11th month, 27th day. "At sunset, black spots moved to and fro for a long while." (*Lo-an Hsien-chih*, 13) (CH99)

226. * 1885 Jul 5
[CHINA] Kuang-hsu reign-period, 11th year, summer, 5th month, day *hsin-yu* (58). "Within the Sun, a black vapour moved to and fro for a long while." (*Hui-min Hsien-chih*, 17) (CH100)

227. * 1900 Feb 15
[CHINA] Kuang-hsu reign-period, 26th year, 1st month, 16th day. "Within the Sun there was a black spot." (*Hsiang-ch'eng Hsien-chih*, 37) (CH101)

228. * 1904 Feb 16
[CHINA] Kuang-hsu reign-period, 30th year, 1st month, 1st day. "Within the Sun there was a black spot." (*Chuang-ho Hsien-chih*, 1) (CH102)

229. * 1905 (only year given)
[CHINA] Kuang-hsu reign-period, 31st year. "Within the Sun there was a black spot." (*Lin-an Hsien-chih*, 1) (CH104)

230. * 1905 Feb 4
[CHINA] Kuang-hsu reign-period, 31st year, 1st month, 1st day. "At sunrise, within (the Sun) there was a black spot as large as a clenched fist; it lasted for five minutes and then was extinguished." (*Hsu-hsiu Ta-chu Hsien-chih*, 15) (CH103)

231. * 1905 Oct 31
[CHINA] Kuang-hsu reign-period, 31st year, 10th month, 4th day. "On the Sun there was a black spot." (*Feng-yin-hsien Hsu-chih*, 28) (CH105)

232. * 1911 Jan 30
[CHINA] Hsuan-t'ung reign-period, 3rd year, 1st month, 1st day. "Within the Sun there was produced a black spot." (*Ch'ing-feng Hsien-chih*, 2) (CH106)

233. * 1916 Jul/Aug - Sep/Oct (only season given)
[CHINA] 5th year of the Republic, autumn. "Within the Sun there was a black spot." (*Ch'ueh-shan Hsien-chih*, 20) (CH107)

234. * 1917 Feb 11
[CHINA] 6th year of the Republic, 1st month, 20th day. "Within the Sun there was a black spot like a hen's egg." (*Fang-ch'eng Hsien-chih*, 5) (CH108)

235. * 1918 Feb 11
[CHINA] 7th year of the Republic, 1st month, 1st day. "A black spot was seen within the Sun. It disappeared after several days." (*Fu-ning-hsien Hsin-chih*, 1 and *Szu-yang Hsien-chih*, 3) (CH109)

APPENDIX V

A CATALOGUE OF EAST ASIAN OBSERVATION OF AURORAE

For the format of each entry see Appendix III above (p.207). Here DC denotes the catalogue of Dai Nian-zu and Chen Mei-dong (1980), and KE denotes the catalogue of Keimatsu (1970-76).

Appendix V

1. 193 BC
[China] Emperor Hui-ti 2nd year. "The sky opened in the NE, it was more than 10 *chang* (about 100 deg) in width and more than 20 *chang* (about 200 deg) in length." (*Han-shu*, 26) (DC10)

2. 154 BC Aug/Sep
[China] Emperor Ching-ti, Ch'ien-yuan reign-period, 3rd year, 7th month. "In the N sky there was a red object like a mat. It was more than 10 *chang* in length. Some said that it was a red vapour; others said that the sky had been split apart." (*Han-shu*, 26) (DC12)

3. 139 BC Jun 11
[China] Emperor Wu-ti, Chien-yuan reign-period, 2nd year, 4th month summer, day *wu-shen* (45). "It was as if the Sun appeared at night." (*Han-shu*, 6) (DC13, KE7)

4. 113 BC Dec 24
[China] Yuan-ting reign-period, 5th year, 11th month, day *hsin-szu* (18), 1st day of the month, the day of winter solstice. "... this night, there was a beautiful light." (*Han-shu*, 25) (DC15)

5. 112 BC Jan 3
[China] Yuan-ting reign-period, 5th year, 11th month, day *hsin-mao* (28). "At night, there seemed to be ten auspicious lights; two of these were bright." (*Han-shu*, 6) (DC16)

6. 32 BC May 13
[China] Chien-shih reign-period, 6th year, 4th month, day *hsin-ch'ou* (38). "At night, in the NW it was as if there were flames." (*Han-shu*, 27) (DC31)

7. 30 BC Aug/Sep
[China] Chien-shih reign-period, 3rd year, 7th month. "At night, there was a blue and yellow-white vapour. It was more than 10 *chang* in length and shining on the ground with a brilliant light. It was said that the sky had been split apart or broken." (*Ku-chin T'u-shu Chi-ch'eng*, 68) (DC32)

8. 15 BC Mar 27
[China] Yung-shih reign-period, 2nd year, 2nd month, day *kuei-wei* (20). "At night, a red coloration as large as 3 to 4 arm-stretches was in the E direction. It was 2 to 3 *chang* in length and shaking like a tree. In the S direction, a fire of 4 to 5 arm-stretches moved downwards for more than 10 *chang*. They all extinguished before reaching the ground." (*Han-shu*, 26 and *Hsi-Han Hui-yao*, 28) (DC33, KE16)

9. AD 12 Summer
[China] Shih-chien-ku reign-period, 4th year, summer. "A red vapour appeared in the SE and extended across the sky." (*Han-shu*, 99 and *T'ai-p'ing Yu-lan*, 877) (DC35, KE20)

10. AD 22
[China] Ti-huang reign-period, 3rd year. "In the early days of Emperor Kuang-wu-ti

... a light in the form of a bright red fire was seen. It disappeared after a short time." (*Lun-heng*, 2) (DC36)

11. AD 104 May 30
[China] Yung-yuan reign-period, 16th year, 4th month, day *ting-wei* (44). "A white vapour like unspun silk emerged at *Tzu-kung* (in the circumpolar region of sky)." (*Hou-Han-shu*, 21) (DC39, KE30)

12. AD 127 Oct 28
[China] Yung-chien reign-period, 2nd year, 9th month, day *wu-yin* (15). "A white vapour, 3 *ch'ih* in width and over 10 *chang* in length, extended from the south of *Pei-lao Shih-men* to *(Nan-)tou*." (*Hou-Han-shu*, 28) (KE31)

13. AD166 Apr 21
[China] Yen-hsi reign-period, 9th year, 3rd month, day *kuei-szu* (30). "At night, in the capital, there was a flame in a rolling motion. The people were alarmed." (*Hou-Han-shu*, 24) (DC40)

14. AD 182 Apr 18
[Korea] King Kogukch'on Wang 4th year, 3rd month spring, day *chia-yin* (51). "At night, a red vapour penetrated *T'ai-wei*. It was like a snake." (*Samguk Sagi*, 16) (DC41, KE35)

15. AD 195 Nov 24
[China] Hsing-p'ing reign-period, 2nd year, 10th month winter, day *jen-yin* (39). "This night, a red vapour penetrated *Tzu-kung*." (*Hou-Han-shu*, 9) (DC42)

16. AD 215
[China] Chien-an reign-period, 25th year. "... In the SW, there were frequently yellow vapours standing vertically several *chang*." (*San-kuo-chih*, 32) (DC43)

17. AD 216
[China] Chien-an reign-period, 21st year. "During this year, on several occasions there were vapours like flags. They extended from W to E and moved along the zenith." (*San-kuo-chih*, 2) (KE39)

18. AD 222 Jul
[China] chang-wu reign-period, 2nd year, 6th month summer. "A yellow vapour was seen... It was several tens of *chang* in width." (*San-kuo-chih*, 32) (DC44)

19. AD 254 Dec
[China] Cheng-yuan reign-period, 1st year, 11th month. "A white vapour appeared beside *Nan-tou*. It was several *chang* in width and its length extended across the sky." (*Chin-shu*, 13 and *Sung-shu*, 23) (KE43)

20. AD 280 Feb
[China] T'ai-k'ang reign-period, 1st year, 1st month. "A multi-coloured vapour penetrated *Nan-tou*." (*An-ching Fu-chih* and *Tang-tu Hsien-chih*) (DC46)

21. AD 286
[China] T'ai-k'ang reign-period, 7th year. "... A violet vapour was seen between *Nan-tou* and *Niu*." (*Nan-ch'ang Fu-chih*) (DC47)

22. AD 292 Mar
[China] Yuan-k'ang reign-period, 2nd year, 2nd month. "In the north-western sky there was a large fissure." (*Chin-shu*, 12 and *Sung-shu*, 24) (DC48)

23. AD 303 Jan 1
[China] Yung-ning reign-period, 2nd year, 11th month, day *jen-yin* (39). "At night, a red vapour extended across the sky with an obscure sound." (*Chin-shu*, 4 and *Wen-hsien T'ung-k'ao*, 298) (DC51, KE49)

24. 305 Jan 20
[China] Yung-hsing reign-period, 1st year, 12th month, day *jen-yin* (39). "At night, there was a red vapour stretching across the sky with an obscure crashing sound." (*Chin-shu*, 13 and *Sung-shu*, 24) (DC52)

25. 305 Nov 21
[China] Yung-hsing reign-period, 2nd year, 10th month, day *ting-ch'ou* (14). "A red vapour was seen in the N direction. It extended across the sky from E to W." (*Chin-shu*, 13 and *Sung-shu*, 24) (DC53, KE20)

26. 307 Jan 22-26
[China] Kuang-hsi reign-period, 1st year, 12th month, day *chia-shen* (21). "A white vapour, similar to a rainbow, extended downwards from the north of the zenith onto the ground. It was seen altogether for 5 nights; then it was extinguished." (*Chin-shu*, 13 and *Sung-shu*, 24) (KE52)

27. 309 Dec 28
[China] Yung-chia reign-period, 3rd year, 11th month, day *i-hai* (12). "White vapours like ribbons appeared in the S and N with two in each direction. They rose from Earth towards the sky and penetrated *Shen* and *Fa*." (*Chin-shu*, 5, 13 and *Sung-shu*, 24) (KE54)

28. 313 Dec 1
[China] Chien-hsing reign-period, 1st year, 10th month, day *chi-szu* (6). "At night, a red vapour shone brilliantly in the NW." (*Chin-shu*, 13) (DC55, KE55)

29. 318 Dec 21
[China] Ta-hsing reign-period, 1st year, 11th month, day *i-mao* (52). "The Sun appeared at night at a height of 3 *chang*. Within it there was a reddish-blue *erh* ('ear-ring')." (*Chin-shu*, 12) (DC56, KE57)

30. AD 329
[China] Hsien-ho reign-period, 4th year. "This year, the sky split apart at the NW." (*Chin-shu*, 9) (DC57)

31. AD 411 Feb/Mar
[China] I-hsi reign-period, 7th year. "The Grand Astronomer, Jen-i said to Yao-hsing, 'A white vapour appeared in the N direction and extended 500 *li* across the sky from E to W. There bound to be defeat and bloodshed'" (*Chin-shu*, 118) (KE70)

32. AD 426 Jan 27
[China] Yuan-chia reign-period, 3rd year, 1st month, day *chia-yin* (51). "At night, there

was a dark vapour in the south-eastern sky. It was 1 *chang* in width and more than 10 *chang* in length." (*Sung-shu*, 26 and *Wei-shu*, 112) (KE71)

33. AD 430 Dec 1
[China] Yuan-chia reign-period, 7th year, 11th month, day *kuei-wei* (20). "At the SW there was a vapour with a red top and bottom, and a dark middle. It was 3 *ch'ih* in width and more than 30 *chang* in length with a form similar to a flag." (*Sung-shu*, 26) (DC59, KE72)

34. 441 Aug
[China] T'ai-p'ing-chen-chun reign-period, 2nd year, 7th month. "A yellow light was shining brilliantly in the sky." (*Wei-shu*, 112) (DC60)

35. 441 Aug 14
[China] Yuan-chia reign-period, 18th year, 7th month, day *jen-ch'en* (29) "At night, there was a yellow light shining brilliantly in the sky." (*Sung-shu*, 34) (DC61, KE78)

36. 441 Dec
[China] Yuan-chia reign-period, 26th year, 11th month. "A white vapour penetrated *Pei-tou*." (*Sung-shu*, 26) (KE82)

37. 459 Feb or Mar
[China] Ta-ming reign-period, 3rd year, 1st month. "At night, there was a thin misty cloud all over the sky. In all directions, there appeared red vapours 3 or 4 *chang* in length, now disappearing and now reappearing. Soon afterwards, they were all vanished. The "Book of Divination" named them *Sui-hsing* or *Tao-hsing*." (*Sung-shu*, 26) (DC62, KE85)

38. AD 460 Mar
[China] Ta-ming reign-period, 4th year, 2nd month. "A red vapour, more than 1 *ch'ih* in length, was at the north of Venus and *Ti-tso*." (*Sung-shu*, 26) (DC63, KE86)

39. AD 460 Dec or Jan
[China] Ta-ming reign-period, 4th year, 12th month. "All over the sky there were clouds. They appeared together in eight places with lengths of 4 *ch'ih*. Now appearing and now disappearing, soon they were all dispersed." (*Sung-shu*, 26) (DC64, KE88)

40. 463 Feb
[China] Ta-ming reign-period, 7th year, 1st month, "At night, there were thin clouds all over the sky. In all directions there appeared a total of 8 vapours, pale white in colour. They were 2 or 3 *chang* in length, now appearing, now disappearing. They were named *Tao-hsing* ('sword star')." (*Sung-shu*, 26) (DC65, KE94)

41. 466 Jan 18
[China] T'ai-shih reign-period, 1st year. 12th month, day *i-hai* (12). "A white vapour entered *Tzu-kung*." (*Sung-shu*, 26) (KE97)

42. 466
[China] T'ai-shih reign-period, 2nd year, 1st month, day *ping-ch'en* (53). "A dark vapour penetrated the *hsiu* ('lunar mansion')." (*Sung-shu*, 26) (KE98)

43. 466 Jul 21
[China] T'ai-shih reign-period, th year, 6th month, day *chi-mao* (16). "After sunset

there were yellow-white and red-white vapours. They extended across the sky from E to W. They shone brilliantly and were lustrous (*jun-chai*); they lasted for a long time." (*Sung-shu*, 29) (DC66)

44. 467 Feb 6
[China] T'ai-shih reign-period, 3rd year, 1st month, 17th day. "A white vapour was seen in the SW. It extended from E to W across half of the sky. It was named *chang-keng*." (*Nan-ch'i-shu*, 12) (KE101)

45. 470 Nov 6
[China] T'ai-shih reign-period, 6th year, 9th month, 27th day. "A white vapour was again seen in the SE. It was 2 *chang* in length with a form long and large. It was more fierce than a comet." (*Nan-ch'i-shu*, 12) (KE102)

46. 478 Mar
[Korea] King Chabi Maripkan 21st year, 2nd month spring. "At night, there was a red light like a piece of unspun silk. From Earth it reached the sky." (*Samguk Sagi*, 3) (DC67, KE105)

47. 478 Dec 13
[China] T'ai-ho reign-period, 2nd year, 11th month, day *ting-wei* (44). "At night, three white vapours emerged from Earth. A moment later, they turned yellow-red and shone brilliantly onto the ground." (*Wei-shu*, 112) (DC68, KE106)

48. 486 Jan 29
[China] Yung-ming reign-period, 4th year, 1st month, day *hsin-wei* (8). "A yellow-white vapour, about one and a half *chang* in length entered *T'ai-wei*." (*Nan-ch'i-shu*, 13) (DC69, KE111)

49. 489 Nov 9
[China] Yung-ming reign-period, 7th year, 10th month, day *hsin-wei* (8). "A stalk-shaped cloud (*keng-yun*) with a green-black colour, was pointing with one head to the ENE and the other to the W. It was 3 *ch'ih* in width and penetrating *Tzu-kung*. It disappeared slowly after a long time." (*Nan-ch'i-shu*, 13) (KE112)

50. 490 Aug 1
[China] Yung-ming reign-period, 8th year, 6th month, day *ping-shen* (33). "A yellow light extended across the sky and shone the ground like gold." (*Nan-shih*, 4) (DC70)

51. 492 Oct 10
[China] T'ai-ho reign-period, 16th year, 9th month, day *ting-szu* (54). "At dusk a red vapour was seen at the NW. It was 20 *chang* in length and 8 or 9 *ch'ih* in width. After the duration of a dinner, only then it was extinguished." (*Wei-shu*, 112) (DC71, KE114)

52. 511 Oct 10
[China] T'ien-chien reign-period, 10th year, 9th month, day *ping-shen* (33). "In the north-western sky there was a loud roaring sound and a red vapour descending to the ground." (*Liang-shu*, 2 and *Sui-shu*, 21) (KE120)

53. 512 Apr 7
[China] Yen-ch'ang reign-period, 1st year, 3rd month, day *ping-shen* (33). "A red vapour

was seen in the sky. It extended from the E to the WNW." (*Wei-shu*, 112) (DC72, KE121)

54. 520 Nov 26
[China] Cheng-kuang reign-period, 1st year, 11th month, day *hsin-wei* (8). "At the NW there was a red vapour extending across the horizon. It was like a fire vapour. It was not seen at the capital but reported from Liang-chow (in Kansu Province)." (*Wei-shu*, 112) (DC73, KE123)

55. 522 Oct 20
[China] Cheng-kuang reign-period, 3rd year, 9th month, day *chia-ch'en* (41). "At night, in the NW there was a red vapour like flames. From E to W it measured more than 1 *p'i* (= 4 *chang*)." (*Wei-shu*, 112) (DC74, KE124)

56. 536 Apr 4?
[China] T'ien-p'ing reign-period, 3rd year, 1st month (read 2nd month), day *chi-hai* (36). "At the hour of *hsu* (19-21 hr), in the E direction there was a red vapour. It was more than 3 *chang* in length. It lasted for 3 meal times." (*Wei-shu*, 112) (DC77, KE131)

57. 549 Feb 4
[China] T'ai-ch'ing reign-period, 2nd year, 12th month, day *wu-shen* (45). "The NW sky split apart at the middle. There was a light like a fire." (*Liang-shu*, 3 and *Nan-shih*, 7) (DC78, KE132)

58. 564 Jul 14
[China] T'ien-chia reign-period, 5th year, 6th month, day *ting-wei* (44). "At night, there were two bands of white vapour. They appeared to the SE of *Pei-tou* and linked the Earth." (*Ch'en-shu*, 3) (KE133)

59. 567 May 31
[China] T'ien-t'ung reign-period, 3rd year, 5th month, day *wu-yin* (15). "Early in the night, in the NW there was a red vapour extending across the sky. At midnight then it extinguished." (*Sui-shu*, 21) (DC79, KE134)

60. 567 Nov 25?
[China] T'ien-t'ung reign-period, 3rd year, 10th month, day *ping-wu* (43) (error in date, possible read *ping-tzu*). "In the NW sky there was frequently a red vapour." (*Sui-shu*, 21) (DC80, KE135)

61. 571 Mar 22
[China] T'ien-ho reign-period, 6th year, 2nd month, day *chi-ch'ou* (26). "At night, there was a green cloud more than 3 *chang* in width. It extended across the sky from *hsu* (WNW) to *ch'en* (ESE)." (*Sui-shu*, 21 and *Chou-shu*, 5) (KE137)

62. 573 Apr 6
[China] T'ai-chien reign-period, 5th year, 2nd month, day *i-mao* (52). "At night, there was a white vapour like a rainbow. From the north it penetrated *Pei-tou* and *Tzu-kung*." (*Ch'en-shu*, 5) (KE139)

63. 580 Jul 17
[China] Ta-hsiang reign-period, 2nd year, 6th month, day *chia-hsu* (11). "A red vapour

rose in the W direction. Gradually it moved E and spread all over the sky." (*Chou-shu*, 8) (DC82, KE146)

64. 581
[China] Ta-ting reign-period, 1st year. "A red vapour rose in the W direction. It moved E and spread all over the sky." (*T'ai-ping Yu-lan*, 877) (DC83)

65. 584 Jan 11
[China] Chih-te reign-period, 1st year, 12th month, day *wu-wu* (55). "At night, the sky opened from NW to SE. Within it there was a blue-yellow colour. There was a sound like thunder." (*Ch'en-shu*, 6) (KE147)

66. 599
[China] K'ai-huang reign-period, 19th year. "At night, a red rainbow was seen. Its light shone several hundred *li*." (*Sui-shu*, 51) (DC84)

67. 601
[China] Jen-shou reign-period, 1st year. "A report from Cheng, 'When I ascended the city tower last night. I saw a red vapour in the N with a length of more than a hundred *li*. They were all like two feet hanging down." (*Sui-shu*, 51) (DC85)

68. 602
[China] Jen-shou reign-period, 2nd year. "A red light extended across the sky. The people in the palace were quite alarmed. At the same time the cattle and horses all cried out." (*Hai-shan-chi*) (DC86)

69. 620 Dec 30
[Japan] Empress Suiko 28th year, 12th month, day *keng-yin* (27), 1st day of the month. "In the sky there was a red vapour. It was more than 1 *chang* in length and shaped like a pheasant's tail." (*Nihon-shoki*, 22) (DC88, KE152)

70. 644 Jul 29
[China] Cheng-kuan reign-period, 18th year, 6th month, day *jen-hsu* (59). "A blue-black vapour, 6 *ch'ih* in width, extended across the sky from ESE to WNW." (*Hsin-t'ang-shu*, 34) (DC90)

71. 707 Oct 18-20
[China] Ching-lung reign-period, 1st year, 9th month, 18th day. "A red vapour stretched across the sky with its light illuminating the ground. It lasted for 3 days and then it ceased." (*Chiu-t'ang-shu*, 36) (DC93-95, KE162)

72. 708 Jul 24-26
[China] Ching-lung reign-period, 2nd year, 7th month, day *kuei-szu* (30). "A red vapour was on the horizon with its light illuminating the Earth. After 3 days it was then ceased." (*Hsin-t'ang-shu*, 34 and *Chiu-t'ang-shu*, 7) (DC96-98, KE164)

73. 757 Feb 20
[China] Chih-te reign-period, 2nd year, 1st month, day *ping-tzu* (13). "At Nan-yang, at night, there were four white rainbows. They stretched upwards for more than 100 *chang*." (*Hsin-t'ang-shu*, 36) (KE170)

74. 760 Jul
[China] Ch'ien-yuan reign-period, 3rd year, 6th month. "At dusk, there were three blue vapours in the NW." (*Hsin-t'ang-shu*, 36) (DC99)

75. 762 May 1
[China] Pao-ying reign-period, 2nd year, 4th month, day *jen-tzu* (49). "At night, a red light like flames was seen in the NW. Its blazing flames stretched across the sky and penetrated *Tzu-wei*. It gradually floated towards the E and spread to the N. It shone brilliantly for several tens of *li*. After a long time then it was dispersed." (*Chiu-t'ang-shu*, 36) (DC100, KE174)

76. 762 May 20
[China] Pao-ying reign-period, 2nd year, 4th month, day *hsin-wei* (8). "At night, at Chiang-ling (in Hu-pei Province) a red light was seen. It penetrated *Pei-tou*." (*Chiu-t'ang-shu*, 36) (DC101, KE175)

77. 762 Sep 16
[China] Pao-ying reign-period, 2nd year, 8th month, day *keng-wu* (7). "At night, there was a red light stretching across the sky and penetrating *Tzu-wei*. It gradually moved towards NE and permeated half of the sky." (*Hsin-t'ang-shu*, 34 and *Chiu-t'ang-shu*, 11) (DC103, KE176)

78. 767 Oct 8
[China] Ta-li reign-period, 2nd year, 9th month, day *wu-wu* (55). "At night, a white mist rose from the NW of *Wei*. It spread all over the sky." (*Chiu-t'ang-shu*, 36) (KE182)

79. 770 Jun 20
[China] Ta-li reign-period, 5th year, 5th month, day *chia-shen* (21). "In the NW, a white vapour extended across the sky." (*Chiu-t'ang-shu*, 11) (KE183)

80. 770 Jul 20
[China] Ta-li reign-period, 5th year, 6th month, day *chia-yin* (51). "A white vapour appeared in the NW direction. It extended across the sky." (*Chiu-t'ang-shu*, 36) (KE184)

81. 796 Oct 20
[China] Cheng-yuan reign-period, 12th year, 9th month, day *kuei-mao* (40). "At night, there was a red vapour like fire. It was seen in the N direction with its upper part reaching *Pei-tou*." (*Hsin-t'ang-shu*, 34) (DC106, KE189)

82. 826 Jan 22
(i) [China] Pao-li reign-period, 1st year, 12th month, day *i-yu* (22) (should read day *chi-yu*, see following entry) "At night, a mist rose in the NW direction. A moment later, it spread all over the sky. Above the mist there was a red vapour. Its colour fluctuated between dark and light red. After a long while it was then dispersed." (*Chiu-t'ang-shu*, 36) (DC108, KE199)

(ii) [China] Pao-li reign-period, 1st year, 12th month, day *chi-yu* (46). "At night, in the NW there was a mist. After the mist had gone, there was a red vapour either in dark or light colours. After a long while then it was dispersed." (*Hsin-t'ang-shu*, 34) (DC108, KE199)

83. 827 May 18
[China] Ta-ho reign-period, 1st year, 4th month, day *keng-hsu* (47). "In the N direction there was a red vapour. Within it there are several white vapours." (*Hsin-t'ang-shu*, 34) (DC109, KE200)

84. 827 Jul 22
[China] Ta-ho reign-period, 1st year, 6th month, day *i-mao* (52). "At night, in the NW there was a red vapour." (*Hsin-t'ang-shu*, 34) (DC110, KE201)

85. 827 Sep 8
[China] Ta-ho reign-period, 1st year, 8th month, day *kuei-mao* (40). "In the capital, it was seen a red vapour filled the whole sky." (*Hsin-t'ang-shu*, 34) (DC111, KE202)

86. 828 May 17
[China] Ta-ho reign-period, 2nd year, intercalary 3rd month, day *i-mao* (52). "In the N direction, there was a red vapour like blood." (*Hsin-t'ang-shu*, 34) (DC112, KE203)

87. 839 Aug 10
[Japan] Showa reign-period, 6th year, 6th month, day *ting-ch'ou* (14). "Tonight there was a red vapour of 40 *chang* square. It began in the SW direction and reached above the Shishinden (palace). It was more than 20 *chang* above the ground with a light like a torch. A moment later it was vanished." (*Shyoku-nihon-koki*, 8) (DC113, KE206)

88. 858 Jul 16
[Japan] Tennan reign-period, 2nd year, 6th month, day *jen-ch'en* (29). "Tonight, ... it was seen to the N of Kitano, above the Inari-Jinjya shrine, two cocks fighting each other in the sky. Their colour appeared to be red. While they were fighting their feathers scattered and fell. Although they were far away, they appeared as if they were in front of one's eyes. After a long while then they were ceased." (*Montoku-jitsuroku*, 10) (KE209)

89. 859 Nov 13
[Japan] Jogan reign-period, 1st year, 10th month, 15th day, *ting-yu* (34). "In the SE sky there was a strange cloud. Within it there was a red colour like a lightning flash." (*Nihon Temmon Shiryo*, 8) (DC114)

90. 870 Jul 12
[Japan] Jogan reign-period, 12th year, 6th month, 10th day, *hsin-mao* (28). "Tonight, a white rainbow was seen in the NW. Its head and tail touched the ground." (*Sandai-jitsuroku*, 18) (KE212)

91. 875 Jun 22
[Japan] Jogan reign-period, 17th year, 5th month, 16th day, *ting-yu* (34). "At night, a cloudy vapour extended across the sky like a flag. Its head hang on the western mountains and its tail on the eastern mountains." (*Sandai-jitsuroku*, 27) (KE215)

92. 882 Jul 24
[China] Chung-ho reign-period, 2nd year, 7th month, day *ping-wu* (43). "At night, in the NW direction, there was a red vapour like a piece of red silk. It extended across the sky." (*Chiu-t'ang-shu*, 19 and *Hsin-t'ang-shu*, 34) (DC116, KE217)

93. 886 Nov/Dec
[China] Kuang-ch'i reign-period, 2nd year, 10th month, day *jen-ch'en* (29) (error in

date). "At night, a white rainbow was seen in the W direction." (*Chiu-t'ang-shu*, 19 and *Hsin-t'ang-shu*, 36) (KE220)

94. 899 Spring
[China] Kuang-hua reign-period, 2nd year. "In the spring, a white vapour extended across the sky like a piece of silk. It spread from the SW to NE and back again." (*Chiu-t'ang-shu*, 20) (KE224)

95. 904 May
[China] T'ien-yu reign-period, 1st year, 4th month. "A star shaped like a man, with a red head and a dark body, was below *Pei-tou* within *Tzu-wei* (Enclosure)." (*Hsin-t'ang-shu*, 32) (DC118, KE229)

96. 905 Apr 13
[China] T'ien-yu reign-period, 2nd year, 3rd month, day *i-ch'ou* (2). "During the night, ... (a meteor shower).... Later, there was a green-white vapour like a bamboo thicket soaring to the sky; and the colour within it was obscure." (*Hsin-t'ang-shu*, 32) (KE231)

97. 908 Oct 14
[China] K'ai-p'ing reign-period, 2nd year, 9th month, day *i-yu* (22). "In the morning, in the W direction, there was a vapour like a crowd of people lying stretched out on the ground. A while later it was then dispersed." (*Chiu Wu-tai-shih*, 139) (DC119)

98. 921
[Japan] T'ien-yu reign-period,, 18th year. "This year, there was a red ominous vapour like blood in the NW sky." (*Chiu Wu-tai-shih, Pen-chi*)

99. 924 Nov 16
[Japan] Encho reign-period, 2nd year, 10th month. 17th day. "At the hour of *hsu* (7–9 p.m.), a white rainbow stretched across the W sky." (*Fuso-ryakki*) (KE237)

100. 928 Jan 10
[China] T'ien-ch'eng reign-period, 2nd year, 12th month, day *jen-chen* (29). "In the SW there was a red vapour like a blazing fire. Its flames extended about 2000 *li*." (*Chiu Wu-tai-shih*, 139) (DC120, KE239)

101. 937 Feb 14
(i) [China] T'ien-fu reign-period, 2nd year, 1st month, day *i-mao* (52). "Tonight, there was a red-white vapour in alternated layers like a cultivated bamboo grove, extending from NW to NE. It rose from the horizon and passed the zenith. It was flickering and wavering. It spread all over the 28 lunar mansions and dispersed at dawn." (*Hsin Wu-tai-shih*, 76) (DC121-122,KE245)

(ii) [China] T'ien-fu reign-period, 2nd year, 1st month, 2nd day. "Early in the night, in the N direction there was a red vapour. To the W it reached a place near the NW and to the E it reached a place near NE. It was 3 *chang* in width from N to S and had a form like flames. From within the red vapour the stars of *Tzu-wei-kung* and *Pei-tou* were visible. At the 3rd watch, within it there were several bands of white vapour. They moved together towards the W. Until midnight when they were dispersed." (*Wu-tai Hui-yao*, 11) (DC121-122,KE245)

102. 939 Jul
(i) [Japan] Tengyo reign-period, 2nd year, 6th month. "A red vapour extended across the sky." (*Zoku-honcho-tsugan*) (DC123, KE246)

(ii) [Japan] Tengyo reign-period, 2nd year. "There was a red vapour." (*Azumakagami*) (DC123, KE246)

103. 951 Dec 7
[China] Kuang-shun reign-period, 1st year, 11th month, day *chia-tzu* (1). "At night, in the SE, a white rainbow stretched across the sky." (*Chiu Wu-tai-shih*, 112 and *Chou-shu*, 3) (KE247)

104. 965 Aug 10
[China] Ch'ien-te reign-period, 3rd year, 7th month, day *chi-mao* (16). "At night, in the W direction rose a green-white vapour of 50 *chang* in length. It linked *T'ien-chuan* and *Wu-che*, and extended to the *Ching* Lunar Mansion." (*Sung-shih*, 60, 66) (DC125, KE249)

105. 967 Oct 14
[Japan] Koho reign-period, 9th month, 9th day. "At the hour of *yu* (5–7 p.m.), a dark cloud like a piece of cloth was stretching from S to N; it was seen in the W direction. At the hour of *hsu* (7–9 p.m.), a green rainbow halo was seen." (*Nihon-kiryaku* and *Yasutomiki*) (KE250)

106. 968 Nov 2
[China] Ch'ien-te reign-period, 6th year, 10th month, day *chi-wei* (56). "At dawn, three bands of green-white vapour rose in the NW. They were 20 *chang* in length. They moved E and dispersed." (*Sung-shih*, 60, 66) (DC126, KE251)

107. 979 May 9 or 19
(i) [China] T'ai-p'ing-hsing-kuo reign-period, 4th year, 4th month, day *chi-wei* (56) - May 9. "At night, in the NW there was a white vapour oppressing *Pei-tou*." (*Sung-shih*, 66) (KE253)

(ii) [China] T'ai-p'ing-hsing-kuo reign-period, 4th year, 4th month, day *chi-szu* (6) - May 19. "At night, in the NW there was a white vapour oppressing *Pei-tou*." (*Sung-shih*, 60) (KE253)

108. 986 Feb 22
[China] Yung-hsi reign-period, 3rd year, 1st month, day *keng-chen* (17). "At night, at the 1st *k'e* of the clepsydra (about 7.15 p.m.), in the N there was a red vapour like a city. It lasted until dawn without dispersing." (*Sung-shih*, 5, 60) (DC127, KE254)
N.B. *Sung-shih* 60 gives the date as *chi-wei* (56).

109. 986 Mar 9
[China] Yung-hsi reign-period, 3rd year, 1st month, day *chi-wei* (56), (should be day *i-wei* (32)). "At night, there was a red vapour like a city." (*Sung-shih*, 60) (DC128)

110. 988 Dec 16
[China] Tuan-kung reign-period, 1st year, 11th month, day *wu-wu* (55), (read *wu-tzu* (25)). "At night, in the NW direction, there was a red vapour like sunrays. It was 2 *chang* in height." (*Sung-shih*, 60, 64) (DC129, KE257)

111. 993 Jan
[Korea] King Songjong 11th year, 12th month. "At night, the gate of Heaven was opened." (*Koryo-sa*, 47) (DC130)

112. 996 Feb 26
[China] Chih-tao reign-period, 2nd year, 2nd month, day *ping-tzu* (13). "At night, in the W direction, there were eight bands of green-white vapour of various lengths like the broom tails of comets. Their ends passed through the milky way and entangled like intertwined snakes. (*Sung-shih*, 60, 66) (DC131, KE258)

113. 1003 Jul 14
[China] Hsien-p'ing reign-period, 6th year, 6th month, day *hsin-wei* (8). "A red vapour appeared at *Lou* and penetrated *T'ien-yu*. (*Sung-shih*, 64) (DC132, KE264)

114. 1004 Apr/May
[China] Ching-te reign-period, 1st year, 3rd month. "A white vapour penetrated *Hsien-yuan* and more than ten green-white vapours like a piece of cloth extended across the sky." (*Sung-shih*, 60) (DC133, KE269)

115. 1004 Aug 17
(i) [China] Ching-te reign-period, 1st year, 7th month, day *hsin-hai* (48). "A yellow vapour appeared at the *Pi* Lunar Mansion; it was more than 5 *chang* in length." (*Sung-shih*, 60) (DC134, KE271)

(ii) [China] Ching-te reign-period, 1st year, 7th month, day *hsin-hai* (48). "... it was more than 5 *ch'ih* in length." (*Sung-shih*, 67) (DC134, KE271)

116. 1006 Apr 14
[China] Ching-te reign-period, 3rd year, 3rd month, day *ping-ch'en* (53). "In the N direction, a red vapour extended across the sky." (*Sung-shih*, 60, 64) (DC136, KE274)

117. 1007 Dec 18
[China] Ching-te reign-period, 4th year, 11th month, day *chi-szu* (6). "At the zenith, there was a red vapour like a broom; it was 7 *ch'ih* in length and situated S of *Yu-kuei*." (*Sung-shih*, 60) (DC137, KE278)

118. 1009 Sep 27
[China] Ta-chung hsiang-fu reign-period, 2nd year, 9th month, day *wu-wu* (55). "A yellow vapour like a column rose in the SE. It was about 5 *chang* in length." (*Sung-shih*, 60, 67) (DC139)

119. 1010 Jan 25
[China] Ta-chung hsiang-fu reign-period, 3rd year, 12th month, day *kuei-hai* (60). "A blue-red vapour penetrated *T'ai-wei*." (*Sung-shih*, 60, 64) (DC140, KE282)

120. 1012 Jun 12
[Korea] King Hyonjong 3rd year, 5th month, day *ting-hai* (24). "A red vapour like fire was seen in the S direction." (*Koryo-sa*, 53) (DC141)

121. 1014 Apr 6
[Korea] King Hyonjong 5th year, 3rd month, day *keng-yin* (27). "At night, in all directions there were red ominous vapours." (*Koryo-sa*, 54) (DC143)

122. 1014 Jun/Jul
[China] Ta-chung hsiang-fu reign-period, 7th year, 5th month. "A vapour appeared in *Tzu-wei* like a palace gate. Its light illuminated the ground." (*Sung-shih*, 60) (DC144, KE284)

123. 1017 Jan 27
[Korea] King Hyonjong 7th year, 12th month, day *ting-yu* (34). "In all directions, there were red ominous vapours." (*Koryo-sa*, 53) (DC146)

124. 1017 Mar 4
[Korea] King Hyonjong 8th year, 2nd month, day *kuei-yu* (10). "A red ominous vapour like a fire filled the sky." (*Koryo-sa*, 53) (DC147)

125. 1017 Dec 15
[Korea] King Hyonjong 8th year, 11th month, day *chi-wei* (56). "At night, a white vapour like a piece of sackcloth stretched across the sky. Very soon, it changed into a red vapour." (*Koryo-sa*, 54) (DC148)

126. 1019 Mar 6
[Korea] King Hyonjong 10th year, 1st month, day *i-yu* (22). "A red vapour stretched across the sky." (*Koryo-sa*, 53) (DC149)

127. 1024 Dec
[Korea] King Hyonjong 15th year, 11th month. "The gate of Heaven opened." (*Koryo-sa*, 47) (DC152)

128. 1028 Sep 25
[Korea] King Hyonjong 19th year, 9th month, day *ping-shen* (33). "At night, a red vapour stretched across the sky." (*Koryo-sa*, 53) (DC153)

129. 1032 Nov 7
[China] Ming-tao reign-period, 1st year, 10th month, day *keng-tzu* (37). "At night, five yellow-white vapours penetrated the wall of *Tzu-wei*." (*Sung-shih*, 60, 67) (DC154, KE287)

130. 1033 Jan 28
[China] Ming-tao reign-period, 1st year, 12th month, day *jen-hsu* (59). "In the NW, there was a green-white vapour extending across the sky." (*Sung-shih*, 60, 66) (DC155, KE288)

131. 1052 Jul 18
[Korea] King Munjong 6th year, 6th month, day *kuei-szu* (30). "A white vapour stretched across the sky in the form of a turtle. And a blue-violet vapour penetrated somewhere inside it. After a long while then it was dispersed." (*Koryo-sa*, 54) (DC157)

132. 1067 Dec 10
[China] Chih-p'ing reign-period, 4th year, 11th month, day *ping-tzu* (13). "At night, a dark green vapour rose in the S direction. It was 3 *chang* in length and 2 *ch'ih* in width. To the east it reached *Ku-lou*, to the N it reached *Nan-ho*, and at the same time penetrated across *I*." (*Sung-shih*, 60) (DC175)

133. 1069 Dec
[China] Hsi-ning reign-period, 2nd year, 11th month. "In every evening, a red vapour

like fire was seen in the NW direction. It lasted until *jen-ting* (9–11 p.m.), when it was extinguished." (*Sung-shih*, 60, 64) (DC176, KE301)

134. 1071 Mar 8
[Japan] Enkyu reign-period, 3rd year, 2nd month, 4th day, *keng-shen* (57). "At night, there was an unusual occurence in the sky. A strange 'star' appeared with a body similar to a cloud but it was luminous." (*Nihon Temmon Shiryo*, 7) (DC177)

135. 1071 Apr 19
[Japan] Enkyu reign-period, 3rd year, 3rd month, 17th day, *jen-yin* (39). "At the hour of *hsu* (7–9 p.m.), a great light extended from E to W like a nearly full moon." (*Nihon Temmon Shiryo*, 7) (DC178)

136. 1073 Jan 12
[Korea] King Munjong 26th year, 12th month, day *ping-tzu* (13). "A white vapour from the NW reached the SE and linked the SW, Then it turned into a red vapour." (*Koryo-sa*, 54) (DC179)

137. 1073 Oct 13
[Korea] King Munjong 27th year, 9th month, day *keng-hsu* (47). "At night, at the south of the stars of *Tien-yuan* the sky had a fissure. It was about 5 or 6 *ts'un* in width. Within it there was a red colour." (*Koryo-sa*, 47) (DC180)

138. 1073 Dec 28
[Korea] King Munjong 27th year, 11th month, day *ping-yin* (3). "At night, to the west of *Wen-chuan* the sky split apart. It was 15 *ch'ih* in length and 3 *ch'ih* in width. Its colour was bluish-red." (*Koryo-sa*, 47) (DC181)

139. 1077 Oct 2
[China] Hsi-ning reign-period, 10th year, 9th month, day *keng-shen* (57). "At night, a dark green vapour rose in N direction. From the handle of *Pei-tou* it penetrated the wall of *Tzu-wei* and reached *T'ien-p'ou.*" (*Wen-hsien-t'ung-k'ao*, 294) (DC182)

140. 1088 Aug 12
[China] Yuan-yu reign-period, 3rd year, 7th month, day *ting-mao* (4). "At night, the NE direction was as bright as daytime and very soon appeared a red vapour. Within it there was a white vapour. It covered the whole sky." (*Sung-shih*, 64) (DC183, KE303)

141. 1088 Aug 13
[China] Yuan-yu reign-period, 3rd year, 7th month, day *wu-ch'en* (5). "At night, close to the NE horizon, the sky was bright such that it illuminated the Earth like a rising moon. Near the NW, a white vapour covered the sky." (*Sung-shih*, 60) (DC184)

142. 1088 Sep 4
[Korea] King Sonjong 5th year, 7th month, day *chi-szu* (6). "There was a red vapour like fire." (*Koryo-sa*, 53) (DC185)

143. 1088 Sep 23
[China] Yuan-yu reign-period, 3rd year, 9th month, day *chi-yu* (46). "At night, a red vapour rose in the N. Gradually, it produced several bands of white vapour." (*Sung-shih*, 60) (DC186, KE304)

144. 1090 Feb 25
[Korea] King Sonjong 7th year, 1st month, day *i-ch'ou* (2). "A violet vapour scattered like flames of a fire. It lasted until dawn then it extinguished." (*Koryo-sa*, 53) (DC187)

145. 1090
[China] Yuan-yu reign-period, 5th year. "At midnight, a red fog stretched across the sky." (*Jen-shou Hsien-chih* and *Ching-yen Hsien-chih*) (DC188)

146. 1095 Feb 9
[China] Shao-sheng reign-period, 2nd year, 1st month, day *chi-hai* (36). "At night, within the clouds in the NW, there was a flame of fire. It was over 2 *chang* in length and several *ch'ih* in width. It was frequently seen by people." (*Sung-shih*, 67) (DC189)

147. 1098 Mar 23
[Japan] Jotoku reign-period, 2nd year, 2nd month, 18th day, *ting-yu* (34). "At about the hour of *yu* (5–7 p.m.), in the N there was a light in the sky. Its length stretched from E to W. It was very strange." (*Nihon Temmon Shiryo*, 8) (DC190, KE306)

148. 1099 Oct 15
[China] Yuan-fu reign-period, 2nd year, 9th month, day *wu-ch'en* (5). "At night, a red vapour rose in the N, the *Tzu-wei* and the south-east of *Pei-tou*. Also 10 bands of white vapour appeared, each of about 5 *ch'ih* in length." (*Sung-shih*, 60) (DC191, KE308)

149. 1101 Jan 31
(i) [China] Chien-chung Ching-kuo reign-period, 1st year, 1st month, 1st day. "In the evening, a red vapour rose in the NE. It extended across and filled the western sky. Some time later, two white vapours appeared within it. When the red vapour was about to disperse, two black vapours appeared on its side." (*Sung-shih*, 64) (DC192, KE310)

(ii) [N China] Shou-ch'ang reign-period, 7th year, 1st month spring, day *jen-hsu* (59) (1st day of the month). "Tonight, a white vapour like silk descended from the sky. Dark clouds rose in the NW, they flew very fast with a sound. In the N, there were blue-red and dark-white vapours entangling among themselves and falling down." (*Liao-shih*, 26) (DC192, KE310)

(iii) [Korea] King Sukjong 6th year, 1st month, day *jen-hsu* (59) (1st day of the month). "At night, a red vapour pointed from N towards W like a silk cloth covering the sky. At times, a white vapour also appeared. It lasted a long time then it dispersed." (*Koryo-sa*, 53) (DC192, KE310)

150. 1103 Jun 16
[China] Ch'ung-ning reign-period, 2nd year, 5th month, day *wu-tzu* (25). "At night, a green-white vapour rose in the SE with a length of 3 *chang*. It penetrated (the lunar mansions) *Mei*, *Ch'i* and *Tou*." (*Sung-shih*, 60, 66) (DC193)

151. 1104 Feb 7
[Korea] King Sukjong 9th year, 1st month, day *chia-shen* (21). "At night, a red vapour was seen in the SE. It was over 10 *chang* in length." (*Koryo-sa*, 53) (DC194)

152. 1105 Jan 19
[Korea] King Sukjong 10th year, 1st month, day *hsin-wei* (8). "At night, a red-white vapour was seen in the SE, it lasted until dawn." (*Koryo-sa*, 53) (DC195)

153. 1105 Feb 15
[Japan] Choji reign-period, 2nd year, 1st month, 29th day. "Tonight, at about the hour of *hai* (9–11 p.m.), there was a brilliant light in the sky. Everyone had seen it and was greatly alarmed." (*Nihon Temmon Shiryo*, 7) (DC196)

154. 1105 Feb 17
[Korea] King Sukjong 10th year, 2nd month, day *keng-tzu* (37) (1st day of the month). "At night, there was a light appearing somewhere between the NW and SE like the moon had just risen." (*Koryo-sa*, 53) (DC197)

155. 1105 Feb 24
[Korea] King Sukjong 10th year, 2nd month, day *ting-wei* (44). "A yellow-red vapour appeared at *Tung-hsien* and penetrated the south of *Ti-tso*. It was about 3 *chang* in length." (*Koryo-sa*, 55) (DC198)

156. 1109 May 13
[Korea] King Yejong 4th year, 4th month, day *ping-hsu* (23). "Above a monastery .... a red vapour was soaring into the sky. Some time later, it turned yellow-black. It moved towards the E and extinguished." (*Koryo-sa*, 53) (DC200)

157. 1111 Dec 17
[China] Cheng-ho reign-period 1st year, 11th month, day *chia-hsu* (11). "At night, a green-white vapour rose from the wall of *Tzu-wei* and penetrated *Ssu-fu*." (*Sung-shih*, 60) (DC201, KE315)

158. 1112 Nov 30
[Japan] Ten-ei reign-period 3rd year, 11th month, 10th day. "Recently, a brilliant light was seen every night." (*Nihon Temmon Shiryo*, 7) (DC202)

159. 1114 Apr 2
[Korea] King Yejong 9th year, 2nd month, day *hsin-wei* (8). "At night, a red vapour like flames radiated in the directions of NW, NE and S. Until dawn when it was extinguished." (*Koryo-sa*, 53) (DC203)

160. 1115 Mar 21
[Korea] King Yejong 10th year, 2nd month, day *chia-tzu* (1). "There was a red vapour like fire in the NE." (*Koryo-sa*, 53) (DC204)

161. 1116 Oct 10
[Korea] King Yejong 11th year, 9th month, day *kuei-szu* (30). "At night, a red vapour was seen at the NW." (*Koryo-sa*, 53) (DC205)

162. 1116 Oct 17
[Korea] King Yejong 11th year, 9th month, day *keng-tzu* (37). "At night, in the WSW direction there was a red vapour." (*Koryo-sa*, 53) (DC206)

163. 1117 Jun 29
[China] Cheng-ho reign-period 7th year, 5th month, day *i-mao* (52). "At night, a red cloud and a white vapour rose in the NE direction." (*Sung-shih*, 60) (DC207, KE319)

164. 1117 Dec 16
[Korea] King Yejong 12th year, 11th month, day *i-szu* (42). "At night, in the N direction, there was a red vapour produced in *Tzu-wei*. It pointed towards NW and NE like a

piece of cloth dispersing in the sky. Also, a red vapour rose in the NE." (*Koryo-sa*, 53) (DC208)

165. 1118 Feb
[N China] T'ien-ch'ing reign-period 8th year, 1st month, spring. "This evening, there was a red vapour like flames rose from the E. It was wavering to and fro. After the lapse of a short time it was then dispersed." (*Ch'i-tan Kuo-chih*, 10) (DC209)

166. 1119 Spring
[China] T'ien-ch'ing reign-period 9th year, spring. "There was a red colour (vapour) 3 to 4 arm-hold in circumference and 2 to 3 *chang* in length. It was wavering like a tree. In the W direction, there were five lumps of fire. They travelled down for over 10 *chang* and extinguished without touching the ground." (*Ch'i-tan Kuo-chih*, 11) (DC211)

167. 1119 May 11
[China] Hsuan-ho reign-period 1st year, 4th month, day *ping-tzu* (13). "At night, in the NW, there were several tens of bands of red vapour stretching across the sky. It invaded *Tzu-kung* and *Pei-tou*. When one looked up, all stars appeared to have been separated by a layer of deep-red coloured gauze. There was a breaking and tearing sound. Among the red vapours there were also two black and white vapours. From the NW suddenly they entered the NE and extended to the SE. Until dawn when they ceased." (*Sung-shih*, 64) (DC212, KE321)

168. 1119 Jun
[China] Hsuan-ho reign-period 1st year, 5th month. "This month, in the NW, there were a red vapour stretching across the sky." (*Sung-shih*, 22) (DC213)

169. 1119
[Japan] Gen-ei reign-period 2nd year. "There was a red vapour." (*Nihon Temmon Shiryo*, 8) (DC214)

170. 1119 Jul 15
[China] Hsuan-ho reign-period 1st year, 6th month, day *hsin-szu* (18). "At night, a red vapour rose in the N, half of the sky was like on fire." (*Sung-shih*, 60) (DC215, KE322)

171. 1119 Aug 21
[China] Hsuan-ho reign-period 1st year, 7th month, day *wu-wu* (55). "At night, a red cloud rose in the NE and was linking more than 30 bands of white vapour." (*Sung-shih*, 60) (DC216, KE324)

172. 1120 Jan 31
[Japan] Gen-ei reign-period 2nd year, 12th month, 29th day. "Tonight, there was a large bright light in the sky." (*Nihon Temmon Shiryo*, 7) (DC217)

173. 1120 Mar 28
[China] Hsuan-ho reign-period 2nd year, 2nd month, day *wu-hsu* (35). "At night, a red cloud rose in the NE. Gradually it moved towards the NW and entered *Tzu-wei-yuan*." (*Wen-hsien T'ung-k'ao*, 294) (DC218, KE326)

174. 1121 Feb 23
[Korea] King Yejong 16th year, 2nd month, day *keng-wu* (7). "At night, a red vapour

(extended) from NW to SE with a length of about 3 *ch'ih*. A white vapour (extended) from *Fang-hsing* to *Ch'ui* with a length of about 7 *ch'ih*. (*Koryo-sa*, 53) (DC219)

175. 1121 Apr 14
[Korea] King Yejong 16th year, 3rd month, day *keng-shen* (57). "A red vapour rose in between the lunar mansions *Chang* and *I*." (*Koryo-sa*, 53) (DC220)

176. 1122 May 15
[Korea] King Yejong 17th year, 4th month, day *ping-shen* (33). "In the S direction, there was a strange vapour with bright variegated colours. It lasted for a long time then it dispersed." (*Koryo-sa*, 53) (DC221)

177. 1122 May 21
[Korea] King Yejong 17th year, 4th month, day *jen-shen* (9) (possibly read *jen-yin*). "During the evening, there was a dark vapour emitting from the NW. Also sometime a blue vapour was appearing among the clouds, and sometime a red vapour was pressing against its sides. They joined together and moved towards SE. They lasted until the early watches and extinguished." (*Koryo-sa*, 53) (DC222)

178. 1123 Mar 21
[Korea] King Injong 1st year, 2nd month, day *ping-wu* (43). "At night, in the W direction there was a white vapour. Within it there was a red vapour." (*Koryo-sa*, 54) (DC223)

179. 1125 May 15
[China] Hsuan-ho reign-period 7th year, 4th month, day *jen-tzu* (49) (possibly read day *jen-wu* (19)). "At night, there were red clouds entering the *Tzu-wei-yuan*." (*Sung-shih*, 60) (DC224, KE328)

180. 1126 Feb 4
[China] Ch'ing-k'ang reign-period 1st year, 1st month, day *ting-ch'ou* (14). "At night, a red-white vapour rose in the W direction." (*Sung-shih*, 60) (DC225, KE329)

181. 1126 Dec 21
[China] Ch'ing-k'ang reign-period 1st year, intercalary 11th month, day *ting-yu* (34). "A red vapour stretched across the sky." (*Sung-shih*, 60) (DC226, KE332)

182. 1127 Feb 13
[China] Chien-yen reign-period 1st year, 1st month, day *hsin-mao* (28). "At night, in the NW there was a flame amongst the snow." (*Sung-shih*, 64) (DC227)

183. 1127 Feb 21
[China] Ch'ing-k'ang reign-period 2nd year, 1st month, day *chi-hai* (36). "At night, in the NW, there was a flame amongst the dark clouds. It was more than 2 *chang* in length and several *ch'ih* in width. It was seen through the night." (*Sung-shih*, 60, 67) (DC228, KE334)

184. 1127 Apr 5
[China] Ching-k'ang reign-period 2nd year, 2nd month, day *jen-wu* (19). "At night, a white vapour like a rainbow stretched from S to N. A moment later, it moved to the SW and reached the NE. It vanished at dawn." (*Sung-shih*, 60) (KE335)

185. 1127 Sep 20
[China] Chien-yen reign-period 1st year, 8th month, day *keng-wu* (7). "In the NE direction there was a red vapour." (*Sung-shih*, 64) (DC229, KE337)

186. 1127 Autumn
[China] Chien-yen reign-period 1st year, autumn. "There was a violet vapour between the lunar mansions *Tou* and *Niu*." (*Chia-hsing Hsien-chih*, 1) (DC230)

187. 1127 Sep 22
[China] Chien-yen reign-period 1st year, 8th month, day *jen-shen* (9). "In the NE, there was a red vapour." (*Sung-shih*, 60) (DC231)

188. 1127 Oct 17 to 20
[Korea] King Injong 5th year, 9th month, day *ting-yu* (34). "At night, a red vapour appeared in the SE. Until day *keng-tzu* (37) – Oct 20, when it was extinguished." (*Koryo-sa*, 53) (DC232-235)

189. 1128 Feb 28
[Korea] King Injong 6th year, 1st month, day *hsin-hai* (48). "At night, in the N direction, there was a red-white vapour entering *Tzu-wei-kung*." (*Koryo-sa*, 53) (DC236)

190. 1128 Oct 20
[Korea] King Injong 6th year, 9th month, day *ping-wu* (43). "A red vapour from the NW passed *Tzu-wei* and entered the NE. Also, dark vapours were running into it from the S and N." (*Chungbo Munhon Pigo*, 8) (DC237)

191. 1128 Dec 13
[Korea] King Injong 6th year, 11th month, day *keng-tzu* (37). "From the NW to SW, a red vapour soared and filled the sky." (*Koryo-sa*, 53) (DC238)

192. 1129 Jan 10
[Korea] King Injong 6th year, 12th month, day *wu-chen* (5). "At night, a red vapour rose from the NE direction. It passed through *Tou-shao* (handle of the Dipper) and entered *Tzu-wei-kung*." ((*Koryo-sa*, 47, 53) (DC239)

193. 1129 Oct 25
[Korea] King Injong 7th year, 9th month, day *ping-chen* (53). "Red vapours emitted from the NW and NE directions in turn and soared towards *Tzu-wei-kung*." (*Koryo-sa*, 47, 53) (DC240)

194. 1129 Dec 27
[Korea] King Injong 7th year, 11th month, day *chi-wei* (56). "A red vapour from between the NE and NW directions entered the *Tzu-wei-kung*." (*Koryo-sa*, 53) (DC241)

195. 1130 Mar 31
[Korea] King Injong 8th year, 2nd month, day *kuei-szu* (30). "At night, a red vapour like a piece of cloth was extended from E to N." (*Koryo-sa*, 53) (DC242)

196. 1130 June
(i) [China] Chien-yen reign-period 4th year, 5th month. "At night, at Lake Tung-ting, a red light like fire was seen to extend across the NE sky. Suddenly, it turned towards the SE." (*Sung-shih*, 64) (DC243)

(ii) [China] "A red light was seen at Lake Tung-ting at night. It extended across the NE sky like a fire illuminating the lake. From top to bottom it was the same colour. Suddenly, it turned SE." (*Wen-hsien T'ung-k'ao*, 298) (DC243)

197. 1130 June 18

(i) [China] Chien-yen reign-period 4th year, 5th month, day *jen-tzu* (49). "A red cloud stretched across the sky. Within it there were more than 10 bands of white vapour penetrating it like unspun silk. It rose from *Tzu-wei* and invaded *Pei-tou* and *Wen-ch'ang*. It dispersed from the SE." (*Sung-shih*, 60) (DC244, KE338)

(ii) [China] "At night, in the NW direction, there was a red vapour spreading all over the sky. Also there were more than 10 bands of white vapour like unspun silk penetrating it. It invaded *Pei-tou*, *Wen-ch'ang* and *Tzu-wei* and dispersed from the SE." (*Sung-shih*, 64) (DC244, KE338)

198. 1130 June 19

[Korea] King Injong 8th year, 5th month, day *kuei-ch'ou* (50). "A dark vapour was seen in the NE direction with a circumference of about 20 *ch'ih*. It entangled into knots which did not loosen until suddenly it emitted dazzling lights like birds flapping their wings. It was then dispersed." (*Koryo-sa*, 53) (DC245)

199. 1130 Sep 29

[Korea] King Injong 8th year, 8th month, day *i-wei* (32). "At the 1st watch, a red vapour like shadows of fire was emitted from the N direction. It then entered the head of *Pei-tou*. It was flickering constantly. Until the 3rd watch when it was extinguished." (*Koryo-sa*, 53) (DC246)

200. 1134 Dec 16

[China] Shao-hsing reign-period 4th year, 11th month, day *chia-hsu* (11). "A red cloud was seen at night. A white vapour was also seen." (*Sung-shih*, 64) (DC247)

201. 1137 Jan 31

[China] Shao-hsing reign-period 7th year, 1st month, day *hsin-wei* (8). "At night, in the NE there was a red vapour like fire appearing from the *Tzu-wei-kung*." (*Sung-shih*, 60) (DC248)

202. 1137 Feb 14

[China] Shao-hsing reign-period 7th year, 1st month, day *i-yu* (22). "At night, in the N direction there was a red vapour lasting until dawn." (*Sung-shih*, 64) (DC249)

203. 1137 Feb 20

[China] Shao-hsing reign-period 7th year, 1st month, day *hsin-mao* (28). "At night, between (the lunar mansions) *Tou* and *Niu* there was a red vapour like fire." (*Sung-shih*, 64) (DC250)

204. 1137 Mar 4

[China] Shao-hsing reign-period 7th year, 2nd month, day *kuei-mao* (40). "It was again like this – following the entry of 1137 Jan 31". (*Sung-shih*, 60) (DC251)

205. 1137 Dec 29

[China] Shao-hsing reign-period 7th year, 11th month, day *kuei-mao* (40). "In the S direction there was a red vapour and in the NE red clouds were everywhere. They lasted from sunset to the 1st watch of the night." (*Sung-shih*, 64) (DC252)

206. 1138 Jun 10
[Japan] Hoen reign-period 4th year, 5th month, 2nd day. "At the hour of *hsu* (7–9 p.m.), a bright light appeared in the sky." (*Nihon Temmon Shiryo*, 7) (DC253)

207. 1138 Aug 28.
[Korea] King Injong 16th year, 7th month, day *i-szu* (42). "At night, in the NW direction there was a red vapour like fire." (*Koryo-sa*, 53) (DC254)

208. 1138 Sep 3
[Korea] King Injong 16th year, 7th month, day *hsin-hai* (48). "At night, it was again like this - following the entry of 1138 Aug 28." (*Koryo-sa*, 53) (DC255)

209. 1138 Oct 6
(i) [Korea] King Injong 16th year, 9th month, day *chia-shen* (21). "At night, there was a vapour emitted from the NE direction." (*Koryo-sa*, 53) (DC256)

(ii) [China] Shao-hsing reign-period 8th year, 9th month, day *chia-shen* (21), the 1st day of the month. "At night, there was a red vapour like fire. It appeared within the wall of *Tzu-wei*." (*Sung-shih*, 60) (DC256)

(iii) [China] A red vapour appeared at the wall of *Tzu-wei*." (*Sung-shih*, 64) (DC256)

(iv) [China] "At the true N there was a red vapour like the shadow of fire." (*Wen-hsien T'ung-k'ao*, 294) (DC256)

210. 1141 Aug 23
[Korea] King Injong 19th year, 7th month, day *ping-ch'en* (53). "At night, a red vapour emitted from *Pei-tou*." (*Koryo-sa*, 53) (DC257)

211. 1141 Nov 22
[Korea] King Injong 19th year, 10th month, day *ting-hai* (24). "At night, a red vapour soared into the sky. It reached *Kou-chen* and *Tzu-wei*. Also there were more than 10 bands of white vapour interlocking each other, rising and pausing at the same time. Further, there was a dark vapour about 4 *chang* in length, soaring to and penetrating *Pei-tou* from E to W." (*Koryo-sa*, 53) (DC258)

212. 1141 Dec 23
[Korea] King Injong 19th year, 11th month, day *wu-wu* (55). "At night, a red vapour was emitted from the N. Also there appeared two bands of white vapour. They penetrated the celestial north pole and *Kou-chen*. They reappeared again after they extinguished." (*Koryo-sa*, 53) (DC259)

213. 1148 Aug 17
[China] Shao-hsing reign-period 18th year, 8th month, day *ting-hai* (24). "In the NW direction, there was a red vapour like fire." (*Sung-shih*, 60, 64) (DC260)

214. 1148 Nov 12
[China] Shao-hsing reign-period 18th year, 9th month, day *chia-yin* (51). "At night, there was a red vapour like fire." (*Sung-shih*, 64) (DC261)

215. 1150 Aug 12

[Japan] Kyuan reign-period 6th year, 7th month, 18th day, *jen-ch'en* (29). "Tonight, in the N direction there was a red vapour. In a moment it reached the NE direction." (*Nihon Temmon Shiryo*, 8) (DC262)

216. 1150 Oct 8

[Japan] Kyuan reign-period 6th year, 9th month, 16th day, *chi-ch'ou* (26). "Today at the hour *yin* (3–5 a.m.) in the N sky and in the W direction ther was a red vapour like a forest fire." (*Nihon Temmon Shiryo*, 8) (DC263)

217. 1152 Jul 10

[Japan] Nimpei reign-period 2nd year, 6th month, 7th day, *keng-wu* (7). "At the hour *hsu* (7–9 p.m.), in the N direction there was a yellow vapour." (*Nihon Temmon Shiryo*, 8) (DC264)

218. 1157 Apr 30

[China] Shao-hsing reign-period 27th year, 3rd month, day *i-yu* (22). "A red vapour appeared at the wall of *Tzu-wei*." (*Sung-shih*, 60, 64) (DC265)
N.B. Recorded as 2nd month in *T'ien-wen-chih*.

219. 1157 Nov 13

[China] Shao-hsing reign-period 27th year, 10th month, day *jen-yin* (39). "There was a red vapour like fire." (*Sung-shih*, 64) (DC266)

220. 1160 Apr 1

(i) [China] Shao-hsing reign-period 30th year, 1st month, day *jen-shen* (9) (error in date, possibly read 2nd month) "In the NE direction there was a belt of red vapour. In five places it was like the shadows of fire." (*Sung-shih*, 60) (DC267)

(ii) [China] Shao-hsing reign-period 30th year, 2nd month, day *jen-shen* (9). "There was a red vapour like fire." (*Sung-shih*, 64) (DC267)

(iii) [China] Shao-hsing reign-period 30th year, 2nd month, day *jen-shen* (9). "Along the NW, N and NE directions, in about five places, there were red vapours like the shadows of fire." (*Wen-hsien T'ung-k'ao*, 294) (DC267)

221. 1165 Sep 12

[China] Ch'ien-tao reign-period 1st year, 8th month, day *jen-wu* (19). "There was a red vapour at the zenith. It lasted from sunset until the first watch of the night." (*Sung-shih*, 64) (DC268)

222. 1165 Nov 18

[China] Ch'ien-tao reign-period 1st year, 10th month, day *chi-ch'ou* (26). "At night, a green-white vapour was seen in the S direction. It entered the lunar mansion *I*." (*Sung-shih*, 66) (DC269)

223. 1170 Dec 6

[Japan] Kao reign-period 2nd year, 10th month, 27th day. "In the W direction there was a red vapour." (*Nihon Temmon Shiryo*, 8) (DC270)

224. 1171 Feb 28

[Japan] Shoan reign-period 1st year, 1st month, 22nd day. "In the S direction there was a red vapour. It was shaped like a wheel." (*Nihon Temmon Shiryo*, 7) (DC271)

225. 1175 Sep 18
[Japan] Angen reign-period 1st year, 9th month, 2nd day, *keng-ch'en* (17). "Tonight, in the sky there was a fire-vapour." (*Nihon Temmon Shiryo*, 8) (DC273)

226. 1175 Nov 13
[Korea] King Myongjong 5th year, intercalary 9th month, day *ping-tzu* (13). "A red vapour like fire was seen in the SE direction. It turned dark and then extinguished." (*Koryo-sa*, 53) (DC274)

227. 1176 Mar 13
[Korea] King Myongjong 6th year, 2nd month, day *ting-ch'ou* (14). "At night, a red vapour of bad omen was seen at the NW direction. It was like a blazing smoke. In the S direction it was also like this." (*Koryo-sa*, 53) (DC275)

228. 1176 Mar 19
[Korea] King Myongjong 6th year, 2nd month, day *kuei-wei* (20). "At night, a red vapour was again seen in the W direction. Its form was like a shield with a length of about 15 *ch'ih*." (*Koryo-sa*, 53) (DC276)

229. 1176 Dec 5
[Japan] Angen reign-period 2nd year, 11th month, 3rd day, *chia-ch'en* (41). "Lately, there was a red vapour in the sky. Among these, the red vapour of this morning was the most extraordinary. The sky was like sunrise with a colourful light shining on the ground." (*Nihon Temmon Shiryo*, 8) (DC277)

230. 1177 Feb 19
[Korea] King Myongjong 7th year, 1st month, day *keng-shen* (57). "A red vapour like fire was seen in the E direction. It was also seen in the SW and NW directions." (*Koryo-sa*, 53) (DC278)

231. 1177 May 31
[Japan] Jisho reign-period 1st year, 5th month, 2nd day, *hsin-ch'ou* (38). "At the hour *hsu* (9–11 p.m.), suddenly, the NE sky shone brilliantly; the people were afraid." (*Nihon Temmon Shiryo*, 8) (DC279)

232. 1178 Apr 7
[Korea] King Myongjong 8th year, 3rd month, day *jen-tzu* (49). "In all directions, there were red vapours like fire." (*Koryo-sa*, 53) (DC280)

233. 1178 Nov 12
[Korea] King Myongjong 8th year, 10th month, day *hsin-mao* (28). "At midnight, it was very cloudy and dark. In the NW direction, an obscure brightness illuminated the ground. There were shadows of men. They lasted through the night." (*Koryo-sa*, 53) (DC281)

234. 1178 Nov 15
[Korea] King Myongjong 8th year, 10th month, day *chia-wu* (31). "In the N direction, there was a vapour like the Sun." (*Koryo-sa*, 53) (DC282)

235. 1178 Dec 11
[Korea] King Myongjong 8th year, 11th month, day *keng-shen* (57), 1st day of the

month. "In the S direction, the sky was bright, there was a vapour like fire." (*Koryo-sa*, 53) (DC283)

236. 1178 Dec 14
[Korea] King Myongjong 8th year, 11th month, day *kuei-hai* (60). "At night, it was again seen at the SW." - following the entry of 1178 Dec 11 (*Koryo-sa*, 53) (DC284)

237. 1179 Mar 12.
[Korea] King Myongjong 9th year, 2nd month, day *hsin-mao* (28). "A red vapour like fire was seen in the S direction." (*Koryo-sa*, 53) (DC285)

238. 1180 Mar 28
[Korea] King Myongjong 10th year, 3rd month, day *kuei-ch'ou* (50). "In the NW direction, there was a red vapour like fire." (*Koryo-sa*, 53) (DC286)

239. 1180 Aug 23
[Korea] King Myongjong 10th year, 8th month, day *hsin-yu* (58). "In the N direction, there was a red vapour like fire." (*Koryo-sa*, 53) (DC287)

240. 1181 Sep 4
[Korea] King Myongjong 11th year, 7th month, day *wu-hsu* (35). "There was a red vapour soaring into the sky." (*Koryo-sa*, 53) (DC288)

241. 1185 Mar 26
[Korea] King Myongjong 15th year, 2nd month, day *ting-ch'ou* (14). "At night, on the E and W horizons, there were red colours like the shadows of fire." (*Koryo-sa*, 53) (DC289)

242. 1188 Sep 29
[China] Shun-hsi reign-period 15th year, 9th month, day *keng-tzu* (37). "At night, in the S direction there was a red vapour; it covered the palace." (*Sung-shih*, 35, 67) (DC290)

243. 1188 Oct 29-31
[Korea] King Myongjong 18th year, 10th month, day *keng-wu* (7). "In the SW direction, there was a red vapour like fire for three days." (*Koryo-sa*, 53) (DC291-293)

244. 1192 Dec 29
[Korea] King Myongjong 22nd year, 11th month, day *jen-ch'en* (29). "A red vapour like fire was seen in the W direction". (*Koryo-sa*, 53) (DC294)

245. 1193 Jan 22
[N. China] Ming-ch'ang reign-period 3rd year, 12th month, *ping-ch'en* (53). "In the N direction, there was a small amount of red vapour." (*Kin-shih*, 20) (DC295)

246. 1193 Apr
[N. China] Ming-ch'ang reign-period 4th year, 3rd month. "In the N direction, there was a red vapour. At dawn then it was dispersed." (*Kin-shih*, 23) (DC296)

247. 1193 Dec 5
[China] Shao-hsi reign-period 4th year, 11th month, day *kuei-yu* (10). "At night, there was a red cloud and a white vapour." (*Sung-shih*, 36) (DC297)

248. 1193 Dec 6

(i) [China] Shao-hsi reign-period 4th year, 11th month, day *chia-hsu* (11). "At night, a red cloud and a white vapour were seen." (*Sung-shih*, 60) (DC298)

(ii) [China] "A red cloud was seen at night; it was separated by a white vapour." (*Sung-shih*, 64) (DC298)

249. 1194 Oct 23

[China] Shao-hsi reign-period 5th year, 10th month, day *i-wei* (32). "There was a yellow-red vapour in the sky." (*Sung-shih*, 67) (DC299)

250. 1195 Apr 8

[Korea] King Myongjong 15th year, 2nd month, day *jen-wu* (19). "At night, a red vapour like fire was seen in the E and W directions." (*Koryo-sa*, 53) (DC300)

251. 1196 Aug 28

[Korea] King Myongjong 26th year, 8th month, day *wu-ch'en* (45). "At night, a vapour stretched across the sky; it was red like blood." (*Koryo-sa*, 53) (DC301)

252. 1196 Nov 9

[Korea] King Myongjong 26th year, 10th month, day *kuei-hai* (60). "A red vapour like fire was seen in the S direction." (*Koryo-sa*, 53) (DC302)

253. 1200 Jan 4

[Korea] King Sinjong 2nd year, 12th month, day *chia-hsu* (11). "A red vapour like fire (extended) from the NE to NW." (*Koryo-sa*, 53) (DC303)

254. 1200 Nov

[China] Ch'ing-yuan reign-period 6th year, 10th month. "At night, a red vapour emitted across the sky." (*Sung-shih*, 64) (DC304)

255. 1202 Dec 19

[Japan] Kennin reign-period 2nd year, 11th month, 4th day. "At the hour *hsu* (7–9 p.m.), there was a red vapour." (*Nihon Temmon Shiryo*, 8) (DC305)

256. 1203 Nov 14

[N. China] T'ai-ho reign-period, 3rd year, 10th month, day *chia-ch'en* (41). "The colour of the sky was red; was it the night returning to dawn?" (*Kin-shih*, 20)

257. 1204 Feb 21-22

(i) [Japan] Genkyu reign-period 1st year, 1st month, 19th day. "After dusk, in the N and NE directions there were red vapours. Their roots were like the Moon rising in the E. They were bright and white in colour. Their branches were flickering like the light from a funeral pyre at a distance. In four or five places they were white in colour and three or four of the stems were red. They were not clouds; if they were clouds stars would not be seen. In the brighter part, it was like the white and red lights were interchanging. They were very strange indeed and terrifying." (*Nihon Temmon Shiryo*, 8) (DC306-307)

(ii) [Japan] 19th day. "At the hour *hsu* (7–9 p.m.), a red vapour and a white cloud were interchanging. They were seen from the NW to NNE. On the 20th day (i.e. the next day), it was the same." (*Nihon Temmon Shiryo*, 8) (DC306-307)

258. 1204 Feb 23

[Japan] Genkyu reign-period 1st year, 1st month, 21st day. "After dark, in the N to NE direction, there was again a red vapour. It was like funeral pyres burning in distant mountains. It was most terrifying." (*Nihon Temmon Shiryo*, 8) (DC308)

259. 1204 Mar 29

(i) [China] Chia-t'ai reign-period 4th year, 2nd month, day *keng-shen* (57). "At night, a red vapour extended across the sky." (*Sung-shih*, 38) (DC309)

(ii) [China] Chia-t'ai reign-period 4th year, 2nd month, day *keng-ch'en* (17) (should read *keng-shen* as in preceding entry) "At night, a red vapour mixed with a white vapour was stretching across the N sky." (*Sung-shih*, 64) (DC309)

260. 1204 Apr

[N. China] T'ai-ho reign-period 4th year, 3rd month. "At the zenith towards the N, there was a dark red colour like that of blood." (*Ta-kin Kuo-chih*, 20) (DC310)

261. 1205 Oct 18

[N. China] T'ai-ho reign-period 5th year, 9th month, day *wu-tzu* (25). "At the hour *hsu* (7–9 p.m.), in the NW direction, there was a dark cloud partitioned by red vapours like fire. Also, the SW, S and SE directions were reddened with white vapours, now visble now hidden, penetrating through them. It started to rain and followed by wind. Until the early hours of the 2nd watch, those red vapours among the dark clouds rose again in the NW, and also in the W, E and NE. They kept floating to and fro. Within them, several bands of white vapour appeared at times. Thereafter, a red vapour again filled the sky at the zenith. At about the 4th watch, they were all dispersed." (*Kin-shih*, 20) (DC311)

262. 1206 Oct 10

[N. China] T'ai-ho reign-period 6th year, 9th month, day *i-yu* (22). "At night, near dawn, in the N direction, there were several bands of red-white vapour oppressing *Wang-liang* from below. Gradually, they moved to the E of *Pei-tou* and then they dispersed." (*Kin-shih*, 20) (DC312)

263. 1207 Jan 25

[N. China] T'ai-ho reign-period 6th year, 12th month, day *jen-shen* (9). "At night, at Hsing-Chow, the sky was red like blood; it illuminated the ground like daytime." (*Ta-kin Kuo-chih*, 21) (DC313)

264. 1209 May 14

[N. China] Ta-an reign-period, 1st year, 4th month, day *jen-shen* (9). "In the N direction, there was a dark vapour like a wide road extending across the sky from N to E. It lasted until the 5th watch and then it dispersed." (*Kin-shih*, 20)

265. 1213 Dec 2

[China] Chia-ting reign-period 6th year, 10th month, day *i-mao* (52). "There was a red vapour like sunrise." (*Wen-hsien T'ung-k'ao*, 294) (DC314)

266. 1222 Dec 7

[N. China] Yuan-kuang reign-period 1st year, 11th month, day *ting-wei* (44). "In the NE, there was a red cloud like fire." (*Kin-shih*, 20) (DC317)

267. 1224 Oct 15
[Korea] King Kojong 11th year, 9th month, day *i-ch'ou* (2). "A red cloud (extended) from the SW to N. It was like the shadows of fire." (*Koryo-sa*, 53) (DC318)

268. 1226 Apr 13
[N China] Cheng-ta reign-period 3rd year, 3rd month, *keng-wu* (7). "Before daybreak, there was a slightly yellow vapour. From the NE, it stretched to the SW. Its form was like a rainbow. Within it there were more than 10 white objects flying to and fro. Also, a light similar to two stars was suddenly seen. After the lapse of a short time it was then extinguished." (*Kin-shih*, 20) (DC320)

269. 1226 Autumn
[Korea] King Kojong 13th year, autumn. "In the W, there was a yellow-red vapour; it was extraordinary luminous." (*Chungbo Munhon Pigo*, 8) (DC321)

270. 1227 Jul 20
[Korea] King Kojong 14th year, 6th month, day *kuei-ch'ou* (50). "A red rainbow soared into the sky. Its head and tail touched the Earth." (*Koryo-sa*, 53) (DC322)

271. 1227 Sep 1
[Japan] Antei reign-period 1st year, 7th month, 19th day, *ping-shen* (33). "After a fairly severe thunderstorm, at the hour *hai* (9–11 p.m.), the sky was somewhat clearer. From the western mountains, a red vapour was standing up almost reaching the sky. It was red-white in colour. Its west end was hidden in the dark clouds and east end was shining the bright Moon, now appearing and now disappearing. After a short while, it was dispersed. Near dawn, it was heavy rain again." (*Nihon Temmon Shiryo*, 8) (DC323)

272. 1229 Sep 9
[Korea] King Kojong 16th year, 8th month, day *chi-mao* (16). "From the NE to SE there was a red vapour like fire." (*Koryo-sa*, 53) (DC324)

273. 1239 May 27
[Japan] En-o reign-period 1st year, 4th month, 23rd day, *jen-hsu* (59). "The sky was clear. At the hour *hsu* (7–9 p.m.), there was a baleful vapour with its rays pointing towards the SE. It was 8 *ch'ih* in length and 1 *ch'ih* in width. It was white-red in colour. Although without a star body, its brightness illuminated the sky like a forest fire. Everyone in the palace had seen it and was curious about it. It continued for about two hours and then it dispersed." (*Nihon Temmon Shiryo*, 6) (DC325)

274. 1240 Mar 17
[Japan] Ninji reign-period 1st year, 2nd month, 22nd day, *ting-szu* (54). "Tonight, the weather was fine. At about the hour *hai* (9–11 p.m.), the western sky was again luminous. Its cause was not known." (*Nihon Temmon Shiryo*, 7) (DC326)

275. 1241 Mar 17
[Japan] Ninji reign-period 2nd year, 2nd month, 4th day, *jen-hsu* (59). "At the hour *hsu* (7–9 p.m.), three bands of white-red vapour appeared. Gradually, they dispersed. The red vapour on its eastern side reappeared with a length of 7 *ch'ih*. The original vapour was becoming smaller. On its western side, a band of red vapour appeared with a length of 4 *ch'ih*. The onlookers were bewildered." (*Nihon Temmon Shiryo*, 8) (DC327)

276. 1247 Aug 10
(i) [Japan] Hoji reign-period 1st year, 7th month, 8th day, *chi-wei* (56) "The night was bright and there was a red vapour in the N direction." (*Nihon Temmon Shiryo*, 8) (DC328)

(ii) [Japan] "At the hour *hai* (9–11 p.m.), a red vapour was seen in the N direction like a forest fire. Within it there were several patches of white vapour, intertwining one another and obscuring *Pei-tou*. They dispersed after a while." (*Nihon Temmon Shiryo*, 8) (DC328)

277. 1252 Jan 2
[Korea] King Kojong 38th year, 11th month, day *i-szu* (42). "In the NE direction, there was a red vapour like blood." (*Koryo-sa*, 53) (DC329)

278. 1253 Aug 29
[Korea] King Kojong 40th year, 8th month, day *keng-hsu* (47). "In the W, there was a yellow-red vapour. It was extremely bright." (*Koryo-sa*, 53) (DC330)

279. 1257 Mar 14
[Korea] King Kojong 44th year, 2nd month, day *kuei-wei* (20). "At night, a red vapour stretched across the sky. It was as bright as in daytime." (*Koryo-sa*, 53) (DC331)

280. 1257 Jun 26
[Korea] King Kojong 44th year, 5th month, day *ting-mao* (4). "In the SE direction, there was a red vapour; it soared into the sky." (*Koryo-sa*, 53) (DC332)

281. 1257 Aug 2
[Korea] King Kojong 44th year, 6th month, day *chia-hsu* (11). "Yellow-red clouds were all over the sky. It was as bright as in daytime." (*Koryo-sa*, 55) (DC333)

282. 1259 Jan 14
[Korea] King Kojong 45th year, 12th month, day *chia-wu* (31). "In the E, there was a yellow-red vapour soaring into the sky." (*Koryo-sa*, 53) (DC334)

283. 1259 Jan 26
[Korea] King Kojong 46th year, 1st month, day *ping-wu* (43). "A red vapour soared into the sky like flames." (*Koryo-sa*, 53) (DC335)

284. 1260 Oct 30
[Korea] King Wonjong 1st year, 9th month, day *chi-ch'ou* (26). "In the N direction, a red vapour like fire stretched across the sky." (*Koryo-sa*, 53) (DC336)

285. 1260 Dec 4
[Korea] King Wonjong 1st year, 11th month, day *chi-wei* (56). "At the 2nd watch, in both the NW and SE directions red vapours stretched across the sky. At the 3rd watch, it soared into the sky in the NW direction." (*Koryo-sa*, 53) (DC337)

286. 1260 Dec 26
[Korea] King Wonjong 1st year, 11th month, day *ping-hsu* (23). "In the NE direction, a red vapour like fire soared vertically into the sky." (*Koryo-sa*, 53) (DC338)

287. 1262 Feb 9
[China] Chung-t'ung reign-period 2nd year, 1st month spring, day *hsin-wei* (8). "At

night, in the NE a red vapour illuminated on people. It was as large as a mat." (*Yuan-shih*, 4) (DC339)

288. 1263 Feb 26-27
(i) [Japan] Kocho reign-period 3rd year, 1st month, 17th day, *wu-hsu* (35). "At the hour *hsu* (7–9 p.m.), the NW and SE directions were like having flames. When the light in one corner was bright, the light in another was dim and vice versa. The onlookers were bewildered." (*Nihon Temmon Shiryo*, 8) (DC340-DC341)

(ii) [Japan] 18th day, *chi-hai* (36). "It was dull. In the NW and SE, the brightnese was similar to those of last night." (*Nihon Temmon Shiryo*, 8) (DC340-DC341)

289. 1277 Sep 11
[China] Ching-yen reign-period 2nd year, 8th month, day *chi-szu* (6). "At night, the sky was red in colour." (*Hsu Wen-hsien T'ung-k'ao*, 212) (DC343)

290. 1278 Mar 26
[Korea] King Ch'ungnyol Wang 4th year, 3rd month, day *i-yu* (22). "A red vapour was seen in the S direction. The night was as bright as in daytime." (*Koryo-sa*, 53) (DC344)

291. 1279 Oct 25
[Korea] King Ch'ungnyol Wang 5th year, 9th month, day *kuei-hai* (60). "A violet vapour was seen in the W directon. It was more than 10 *ch'ih* in length. Its light was similar to that of lightening." (*Koryo-sa*, 53) (DC345)

292. 1288 Nov 13
[Korea] King Ch'ungnyol Wang 14th year, 10th month, *keng-wu* (7). "A red vapour was seen in the E direction. Sometime it was like a piece of silk cloth, sometime it was like a blazing fire." (*Koryo-sa*, 53) (DC346)

293. 1296 Feb 29
[Korea] King Ch'ungnyol Wang 22th year, 1st month, day *chia-wu* (31). "A red-white vapour soared into the sky." (*Koryo-sa*, 53) (DC347)

294. 1316 Mar 24
[Korea] King Ch'ungsuk Wang 3rd year, 3rd month, *kuei-mao* (40), the last day of the month. "Red vapours were seen in the SE. Three of these were like torches." (*Koryo-sa*, 53) (DC348)

295. 1320 Feb 1
[Korea] King Ch'ungsuk Wang 6th year, 12th month, *jen-shen* (9). "At night, there was a red vapour." (*Koryo-sa*, 53) (DC349)

296. 1323 Aug 19
[Korea] King Ch'ungsuk Wang 10th year, 7th month, day *ting-wei* (44). "A violet vapour like a rainbow was seen in the NW. Suddenly, it turned yellow and spread all over the sky." (*Koryo-sa*, 53) (DC350)

297. 1347 Aug 12
[Korea] King Ch'ungmok Wang 3rd year, 7th month autumn, day *ping-wu* (43). "At night, a rainbow rose in the E and fell on Nan-shan mountains. Suddenly, it rose again but divided into two. They moved separately to the N and S." (*Koryo-sa*, 53) (DC351)

298. 1347 Aug 29
[China] Chih-yuan reign-period 7th year, 7th month, 23rd day, *jen-ch'en* (29). "At the early watch, suddenly, an auspicious light illuminated the sky with variegated colours. It extended over 100 *li*. People were struggling with one another to catch a glimse. It continued until midnight when it dispersed." (*Hai-ning Hsien-chih*) (DC352)

299. 1349 Jul 18
[Japan] Shohei reign-period 4th year, intercalary 6th month, 3rd day. "At the hour *hsu* (7–9 p.m.), the SE and NW directions were brilliantly lit like in a battle." (*Nihon Temmon Shiryo*, 8) (DC353)

300. 1354 Dec 18
[China] Chih-cheng reign-period 14th year, 12th month, day *hsin-mao* (28). "In Chiang-Chow, there was a red vapour. It rose in the N direction and covered almost half of the sky. After the lapse of a short time it was then dispersed." (*Yuan-shih*, 51) (DC354)

301. 1354
[China] Chih-cheng reign-period 14th year. "In Wei-hui-lu Province, there was a sky brightness seen in the W direction." (*Yuan-shih*, 51) (DC355)

302. 1358 Feb 28
[Korea] King Kongmin Wang 7th year, 1st month, day *chi-wei* (56). "At night, a violet vapour soared (into the sky) from the NW." (*Koryo-sa*, 53) (DC356)

303. 1358 Apr 11
[Korea] King Kongmin Wang 7th year, 3rd month, day *hsin-ch'ou* (38). "At night, a red vapour was seen in the NE direction." (*Koryo-sa*, 53) (DC357)

304. 1359
[China] Chih-cheng reign-period 19th year. "At midnight, a red vapour stretched across the horizon from NW to NE." (*T'ien-tsin Fu-chih* and *Yen-shan Hsien-chih*) (DC358)

305. 1359 Feb 20
[Korea] King Kongmin Wang 8th year, 1st month, day *ping-ch'en* (53). "At night, a violet vapour soared (into the sky) from the NW." (*Koryo-sa*, 53) (DC359)

306. 1359 Oct 21
[China] Chih-cheng reign-period th year, 9th month, last day of the month. "I reached Chia-ho at dawn, at the time when the morning star was still on the tree top. Suddenly, the sky at the SW split open several tens of hundreds of *chang*. It had flames similar to a fierce fire which thoroughly illuminated the wilderness. At once, the village dogs all started to bark and the roosting birds cried and flew. When I looked carefully at the place where the sky had been split I saw wriggling motion. Within it, it was again very bright like gold was being melted by a foundary worker. The opening closed after a little while. The boatman said to me, 'This is the sky opening its eye.' " (*Chia-hsing Hsien-chih* and *Lo-chiao Szu-yu*) (DC360)

307. 1361 Aug 21
[China] Chih-cheng reign-period 21st year, 7th month, day *chi-szu* (6). "At the NW of Hsin-chou in Chi-ning-lu, there was a red vapour covering the sky like blood. It continued for a long while then it dispersed." (*Yuan-shih*, 51) (DC361)

308. 1361 Sep 3
[China] Chih-cheng reign-period 21st year, 8th month, day *jen-wu* (19). "At midnight in Ti-Chow, a red vapour stretched across the sky. It rose in the NW and reached the NE." (*Yuan-shih*, 51; *Hui-min Hsien-chih*, 17; *Wu-ting Fu-chih*, 14) (DC362)

309. 1361 Sep 4
[China] Chih-cheng reign-period 21st year, 8th month, day *kuei-wei* (20). "At the NW of Chang-te, at night, a red vapour stretched across the sky. It lasted until dawn then it ceased." (*Yuan-shih*, 51) (DC363)

310. 1361 Sep 6
[China] Chih-cheng reign-period 21st year, 8th month, day *i-yu* (22). "At the N of Ta-tung-lu, at night, a red vapour covered the sky. It stood vertically and passed through the heaven. It extended from E to W. After the lapse of a short time it was then dispersed. There were three such vapours." (*Yuan-shih*, 51) (DC364)

311. 1361 Nov 13
[China] Chih-cheng reign-period 21st year, 10th month, day *kuei-szu* (30). "Just before daylight, in the N direction of Chian-chow there was a red vapour like fire." (*Yuan-shih*, 51) (DC365)

312. 1362 Dec 19
[Korea] King 11th year, 12th month, day *chia-hsu* (11). "At night, there was a violet vapour seen in the NW direction." (*Koryo-sa*, 53) (DC366)

313. 1363 Apr 6
[China] Chih-cheng reign-period 23rd year, 3rd month, day *jen-hsu* (59). "At night, in Ta-tung-lu, there was a red vapour stretching across the sky. Its middle part invaded *Pei-tou*." (*Yuan-shih*, 51) (DC367)

314. 1363 Jul 30
(i) [China] Chih-cheng reign-period 23rd year, 6th month, day *ting-szu* (54). "At dusk in Chian-chow, a red light like fire was seen in the N direction. Within it, it was interspersed with dark vapours. Also, there were two white rainbows soaring straight into *Pei-tou*. After a long time then they were dispersed." (*Yuan-shih*, 51) (DC368)

(ii) [Japan] Shohei reign-period 18th year, 6th month, 19th day, *ting-szu* (54). "During the night, in the NE and N directions there was a light similar to a distant funeral pyre. The cause was not known; some said that this was a sign for a drought." (*Nihon Temmon Shiryo*, 8) (DC368)

(iii) [Japan] "Tonight, there was a red vapour in the N and NE. Was this a sign for a severe drought?" (*Nihon Temmon Shiryo*, 8) (DC368)

315. 1363 Aug 2
[China] Chih-cheng reign-period 23rd year, 6th month, day *keng-shen* (57). "At dusk, to the N of Chin-ning-lu, the sky was red. Within it there were three white vapours like rainbows. One penetrated *Pei-tou*, one penetrated *Pei-chi* and one penetrated *T'ien-huang*. Until midnight when they were extinguished." (*Yuan-shih*, 51) (DC369)

316. 1363 Sep 27
[China] Chih-cheng reign-period 23rd year, 8th month, day *ping-ch'en* (53). "At night,

to the NE of Hsin-chow, there was a red vapour stretching across the sky. Within it there was a white vapour like a snake. It gradually moved towards W. After a long time then it was dispersed." (*Yuan-shih*, 51) (DC370)

317. 1363 Nov 6
[China] Chih-cheng reign-period 23rd year, 10th month, day *ping-shen* (33), 1st day of the month. "In Ta-ming-lu towards the directions of Ching and Chi (counties), there was a red vapour shining brilliantly for a thousand *li*." (*Yuan-shih*, 51) (DC371)

318. 1364 Feb 26
[Korea] King Kongmin Wang 13th year, 1st month, day *wu-tzu* (25). "At night, in the SW there was a red vapour like a dragon." (*Koryo-sa*, 53) (DC372)

319. 1364 Oct 8
(i) [China] Chih-cheng reign-period 24th year, 9th month, day *kuei-yu* (10). "At the NW of Ping-chin county in Chi-ning-lu, at night, half of the sky was red like a partitioned-wall. A little while later, it dispersed from the E." (*Yuan-shih*, 51) (DC373)

(ii) [China] "At night, in the NW sky there was a red light, it reached E and then it dispersed." (*Hsu Wen-hsien T'ung-k'ao*, 212 and *T'ai-yuan Hsien-chih*, 15) (DC373)

320. 1365 Mar 14
[Korea] King Kongmin Wang 14th year, 2nd month, day *keng-hsu* (47). "At night, a red vapour was seen in the W direction." (*Koryo-sa*, 53) (DC374)

321. 1365 Mar 17
[Korea] King Kongmin Wang 14th year, 2nd month, day *kuei-ch'ou* (50). "At night, a red vapour was seen in the E direction." (*Koryo-sa*, 53) (DC375)

322. 1365 Mar 19
[Korea] King Kongmin Wang 14th year, 2nd month, day *i-mao* (52). "At night, a red vapour was seen in the S and N directions." (*Koryo-sa*, 53) (DC376)

323. 1365 Aug 15
[Korea] King Kongmin Wang 14th year, 7th month, day *chia-shen* (21). "At night, in the E direction there was a red cloud." (*Koryo-sa*, 53) (DC377)

324. 1367 Feb 7
[Korea] King Kongmin Wang 16th year, 1st month, day *i-yu* (22). "There was a red vapour like fire. Most of it was in the W direction." (*Koryo-sa*, 53) (DC378)

325. 1367 Feb 28
(i) [Korea] King Kongmin Wang 16th year, 1st month, day *ping-wu* (43). "At night, in the W direction it was as bright as daylight." (*Koryo-sa*, 54) (DC379)

(ii) [Korea] "At night, a red vapour was seen in the E direction." (*Koryo-sa*, 53) (DC379)

326. 1367 Mar 1
[Korea] King Kongmin Wang 16th year, 2nd month, day *ting-wei* (44). "At night, a red vapour was seen in the E and W." (*Koryo-sa*, 53) (DC380)

327. 1367 Mar 2
[Korea] King Kongmin Wang 16th year, 2nd month, day *wu-shen* (45). "At night, a red vapour was seen in the E." (*Koryo-sa*, 53) (DC381)

328. 1367 Mar 4
[Korea] King Kongmin Wang 16th year, 2nd month, day *keng-hsu* (47). "At night, red vapours soared into the sky from E, W and S directions." (*Koryo-sa*, 53) (DC382)

329. 1367 Mar 6
[Korea] King Kongmin Wang 16th year, 2nd month, day *jen-tzu* (49). "At night, a red vapour soared into the sky." (*Koryo-sa*, 53) (DC383)

330. 1367 Jun 13
[Korea] King Kongmin Wang 16th year, 5th month, day *hsin-mao* (28). "At night, a red vapour was seen in the NW." (*Koryo-sa*, 53) (DC384)

331. 1367 Jun 14
[Korea] King Kongmin Wang 16th year, 5th month, day *jen-ch'en* (29). "At night, a red vapour was seen in the NE." (*Koryo-sa*, 53) (DC385)

332. 1368 Feb 21
[Korea] King Kongmin Wang 17th year, 2nd month, day *chia-ch'en* (41). "At night, there was a red vapour like fire." (*Koryo-sa*, 53) (DC386)

333. 1368 Mar 10 and Mar 12
[Korea] King Kongmin Wang 17th year, 2nd month, day *jen-hsu* (59). "At night, there was a red vapour. On day *chia-tzu* (1), it was the same." (*Koryo-sa*, 53) (DC387-388)

334. 1368 Mar 19 to 23
[Korea] King Kongmin Wang 17th year, 3rd month, day *hsin-wei* (8), 1st day of the month. "At night, there was a red vapour like fire. It lasted until day *i-hai* (12)" (*Koryo-sa*, 53) (DC389-393)

335. 1368 Jul 19
(i) [China] Chih-cheng reign-period 28th year, 7th month, day *kuei-yu* (10). "In the capital, a red vapour filled the sky like a light shining upon people. It lasted from the hour *yin* to *ch'en* ($\sim$ 3 to 9 a.m.); both vapour and flame were then ceased." (*Yuan-shih*, 51) (DC394)

(ii) [China] Chih-cheng reign-period 28th year, 7th month, autumn, day *kuei-yu* (10). "In the capital, a red vapour filled the sky like a fire shining upon people." (*Hsu Tzu-chih-T'ung-chien*) (DC394)

336. 1369 Dec 15
[Korea] King Kongmin Wang 18th year, 11th month, day *ting-wei* (44). "A red vapour like fire was seen in the SW." (*Koryo-sa*, 53) (DC395)

337. 1370 Feb 11
(i) [Korea] King Kongmin Wang 19th year, 1st month, day *chia-ch'en* (41). "A violet vapour filled the NW sky. The shadows it cast were all on the S." (*Koryo-sa*, 53) (DC396)

(ii) [Korea] King Kongmin Wang 19th year, 1st month. "This evening, to the NW of the capital, a violet vapour filled the sky. The shadows it cast were all on the S." (*T'aejo Sillok*) (DC396)

338. 1370 Sep
[Korea] King Kongmin Wang 19th year, 8th month. "Tonight, there was a red vapour shooting towards the camp like a blazing fire." (*T'aejo Sillok*) (DC397)

339. 1370 Oct 27
[Japan] Kentoku reign-period 1st year, 10th month, 8th day. "From the hour of *hsu* (7–9 p.m.) onwards, a red vapour was seen in the northern sky. It lasted until midnight. Its form was like a burning object. Everyone was puzzled. This was also seen last year." (*Nihon Temmon Shiryo*, 8) (DC398)

340. 1370 Nov 24
[Japan] Kentoku reign-period 1st year, 11th month, 6th day, *hsin-mao* (28). "At night, in the hours of *tzu* (11 p.m.–1 a.m.), *ch'ou* (1–3 a.m.) and *yin* (3–5 a.m.), in the northern sky there appeared a red vapour. Following, its colour gradually became deep red. The people was frightened. There were also different sizes of white and dark coloured ribbons. Towards the S and N there appeared a brightness above the red vapour. It was an extraordinary scene." (*Nihon Temmon Shiryo*, 8) (DC399)

341. 1370 Nov 25
[Japan] Kentoku reign-period 1st year, 11th month, 7th day, *jen-ch'en* (29). "A red vapour was seen in the N direction. There was also a light of dark and white colours." (*Nihon Temmon Shiryo*, 8) (DC400)

342. 1371 Oct
[Japan] Kentoku reign-period 2nd year, 9th month. "A red vapour was seen in the N direction." (*Nihon Temmon Shiryo*, 8) (DC401)

343. 1380 Apr 2
[Korea] King Sin'u 6th year, 2nd month, day *wu-tzu* (25). "A red vapour was seen in the W direction as bright as torches." (*Koryo-sa*, 53) (DC402)

344. 1381 Feb 27
[Korea] King Sin'u 7th year, 2nd month, day *chi-wei* (56). "In the SW and N directions, a red vapour like blood floated in the air." (*Koryo-sa*, 53) (DC403)

345. 1397 Dec 22
[Korea] King T'aejo 6th year, 12th month, day *hsin-szu* (18). "At night, in the E and W directions there were red vapours." (*T'aejo Sillok*) (DC405)

346. 1400 Jul 23
[Korea] King Chongjong 2nd year, 7th month, day *i-ch'ou* (2). "At dawn, in the N direction there was a red vapour." (*Chongjong Sillok*) (DC406)

347. 1401 Feb 5
[Korea] King T'aejong 1st year, 1st month, day *jen-wu* (19). "At night, there were red vapours in all directions." (*T'aejong Sillok*) (DC407)

348. 1401 Feb 7
[Korea] King T'aejong 1st year, 1st month, day *chia-shen* (21). "At night, there was a red vapour in the SE." (*T'aejong Sillok*) (DC408)

349. 1402 Jan 7
[Korea] King T'aejong 1st year, 12th month, day *wu-wu* (55). "At dusk, in the E there was a red vapour stretching across the sky." (*T'aejong Sillok*) (DC409)

350. 1403 Feb 16
[Korea] King T'aejong 3rd year, 1st month, day *kuei-mao* (40). "At night, in the NE and SE directions there were red vapours and in the W direction there was a white vapour." (*T'aejong Sillok*) (DC410)

351. 1403 Mar 8
[Korea] King T'aejong 3rd year, 2nd month, day *kuei-hai* (60). "At night, in the E direction there was a red vapour." (*T'aejong Sillok*) (DC411)

352. 1405 Jan 10
[Korea] King T'aejong 4th year, 12th month, day *ting-ch'ou* (14). "At night, in the S direction there was a red vapour." (*T'aejong Sillok*) (DC412)

353. 1405 Jan 21
[Korea] King T'aejong 4th year, 12th month, day *wu-tzu* (25). "At night, in the ENE and E directions there were red vapours." (*T'aejong Sillok*) (DC413)

354. 1405 Jan 22 to 23
[Korea] King T'aejong 4th year, 12th month, day *chi-ch'ou* (26). "At night, in the SE and NW directions there were red vapours. On day *keng-yin* (27) it was the same." (*T'aejong Sillok*) (DC414-415)

355. 1405 Jan 26
[Korea] King T'aejong 4th year, 12th month, day *kuei-szu* (30). "At night, in the NE direction there was a red vapour." (*T'aejong Sillok*) (DC416)

356. 1405 Mar 11
[Korea] King T'aejong 5th year, 2nd month, day *ting-ch'ou* (14). "At night, in the NE direction there was a red vapour." (*T'aejong Sillok*) (DC417)

357. 1406 Jan 11
[Korea] King T'aejong 5th year, 12th month, day *kuei-wei* (20). "At night, in the NE and E directions there were red vapours." (*T'aejong Sillok*) (DC418)

358. 1406 Jan 16
[Korea] King T'aejong 5th year, 12th month, day *wu-tzu* (25). "At night, in the NE direction there was a red vapour." (*T'aejong Sillok*) (DC419)

359. 1409 Aug 15
[Korea] King T'aejong 9th year, 7th month, day *i-hai* (12). "In the E there were red, black and white vapours shooting into the sky." (*T'aejong Sillok*) (DC420)

360. 1411 Mar 3
[Korea] King T'aejong 11th year, 2nd month, day *keng-tzu* (37). "At night, in the NW direction there was a white vapour and also in the NW and SE directions there were pale red vapours." (*T'aejong Sillok*) (DC421)

361. 1417 Dec 15 and Dec 31
[Korea] "A report from China: 'Yung-lo reign-period 15th year, 11th month, 8th day. Chen Kuei and others reported that an auspicious light, numerous auspicious clouds and vapours were seen. They shone brightly through the Milky Way. ... On the 18th day, Chen Kuei and others again reported that propitious clouds exhibiting variegated colours, mixed with enshrouding mists, neither smoke nor cloud, also coloured spirals were floating beautifully in the air. They were transforming, rolling and unrolling, and completely filled the palace. Amidst these propitious clouds appeared an auspicious light, as round as the moon, just above the throne; the light was brightly coloured. It was like flowers from Heaven dazzling with the lustre of gems and shining brilliantly and clearly with a glorious blaze of fire. The stars were clear and the moon was bright, and they floated like candle flames. They continued to float in all directions, twice they covered the palace garden and stayed in the palace for a long time. Everyone including the imperial guards and artisans had seen them.' " (*T'aejong Sillok*) (DC422-423)

362. 1426 Jul 25
[China] Hsuan-te reign-period 1st year, 6th month, day *kuei-wei* (20). "At night, there was a green-white vapour stretching across the sky from E to W." (*Ming-shih*, 30) (DC426)

363. 1429 Jul 14
[China] Hsuan-te reign-period 4th year, 6th month, day *wu-tzu* (25). "At night, multi-coloured clouds were seen." (*Ming-shih*, 27) (DC427)

364. 1433 May 13
[Japan] Eikyo reign-period 5th year, 4th month, 24th day. "Tonight at the hour of *hai* (9-11 p.m.), in the western sky there was a bright object like a vibrating burning pine-splints. Was it a red vapour? It was not clear." (*Nihon Temmon Shiryo*, 8) (DC429)

365. 1433 Oct 10
[China] Hsuan-te reign-period 8th year, intercalary 8th month, day *ting-ch'ou* (14). "There was a yellowish-red colour seen in the SE direction. It was like a star but not a star, like a cloud but not a cloud; it must be a Kuei-hsieh." (*Ming-shih*, 27) (DC430)

366. 1440 Sep 12
(i) [Japan] Eikyo reign-period 12th year, 8th month, 16th day. "The whole sky was red like blood, it dispersed after a short while." (*Nihon Temmon Shiryo*, 8) (DC431)

(ii) [Japan] "There was a red vapour extending across the sky." (*Nihon Temmon Shiryo*, 8) (DC431)

367. 1450 Nov 4
[China] Ching-t'ai reign-period 1st year, 10th month, day *hsin-wei* (8). "There was a dark vapour like smoke and fire extending across the sky from N to S." (*Hsu Wen-hsien T'ung-k'ao*, 216) (DC432)

368. 1455 Aug 14
(i) [Japan] Kosho reign-period 1st year, 7th month, 2nd day, *i-hai* (12). "... There was a red vapour pointing towards the N. Its shape was like a piece of thin silk, or similar to a red flag. Also it was very much like a rainbow." (*Nihon Temmon Shiryo*, 8) (DC433)

(ii) [Japan] 7th month, 2nd day, *i-hai* (12). "... There was a red vapour shaped like a flag. It pointed and moved towards N." (*Nihon Temmon Shiryo*, 8) (DC433)

369. 1467 Aug 19 to 21
[Korea] King Sejo 13th year, 7th month, day *kuei-wei* (20). "In the evening, there was a large star appearing in the E direction with its rays hanging down. Also there was a red light similar in shape, almost totally eclipsed the large star. At the 3rd watch then it was extinguished. It was like this for three nights." (*Sejo Sillok*) (DC434-436)

370. 1486 Oct 5
[Japan] Bummei reign-period 18th year, 9th month, 9th day, *hsin-hai* (48). "Today it was heard that late last night at the Eastern River Plain that almost everyone had seen several tens of light over the fields. They were not something created by man, were they elfin fire?" (*Nihon Temmon Shiryo*, 8) (DC437)

371. 1488
[China] Hung-chih reign-period, year wu-shen. "At Shensi Province, the gate of Heaven was opened, a million calvary troops were seen entering from below." (*Nung-t'ien-yu-hua*, 4) (DC438)

372. 1490 Jan 26
[China] Hung-chih reign-period 3rd year, 1st month, 6th day. "At midnight, in the N, a red light rose vertically from Earth. It was like rows of trees. From the star of *Mao* it moved across half of the sky from E to W. Its colour was like a rose sunset. Through it the constellations were red. Both chicken and dogs cried out." (*Nung-t'ien-yu-hua*) (DC439)

373. 1490 Apr 14
[Japan] Entoku reign-period 2nd year, 3rd month, 25th day. "On the same night, pillars of fire stood vertically." (*Nihon Temmon Shiryo*, 7) (DC440)

374. 1491 Jan 18
[Japan] Entoku reign-period 2nd year, 12th month, 6th day. "At night, above this palace there were two pillars of fire, all of the servants had seen them ... they were very extraordinary indeed." (*Nihon Temmon Shiryo*, 7) (DC441)

375. 1491
[China] Hung-chih reign-period 4th year. "... it was seen a man chasing a red goat in the air from N to S and moving quite fast ..." (*Pao-ting Fu-chih*) (DC442)

376. 1500 Jan
[Japan] Meio reign-period 8th year, 12th month winter. "Two bands of red vapour were seen in the SW; they were more than 3 *chang* in length." (*Nihon Temmon Shiryo*, 8) (DC443)

377. 1500 Feb 17
[Japan] Meio reign-period 9th year, 1st month, 18th day. "At night, an auspicious light was seen." (*Nihon Temmon Shiryo*, 8) (DC444)

378. 1506 Jan 24
[China] Cheng-te reign-period 1st year, 1st month, 1st day. Reign period Cheng-te 1st year, 1st month, 1st day. "At the true N the sky split apart with a red light of two

chang in width and several tens of *chang* in length. A moment later, the light was extinguished; it was like rolling a mat from below and upwards." (*Chien-ning Fu-chih*) (DC445)

379. 1506 Apr 21
[China] Cheng-te reign-period 1st year, 3rd month, day *wu-shen* (45). "At night, a red light was seen in the air over T'ai-yuan like a bent bow. It was 6 or 7 *ch'ih* in length. Subsequently, it turned yellow and then white. Gradually, it increased its length to more than 20 *chang* with its rays stretching across the sky." (*Ming-shih*, 30) (DC446)

380. 1507 Jan 24
[Korea] King Chungjong 2nd year, 1st month, day *ping-wu* (23). "At night, there was a red vapour." (*Chungjong Sillok*) (DC447)

381. 1507 Oct 4
[China] Cheng-te reign-period 2nd year, 8th month, day *chi-hai* (36). "A red light was seen in Ning-hsia; its length was 5 *chang*." (DC448) (*Ming-shih*, 30)

382. 1508 Apr 5
[Korea] King Chungjong 3rd year, 3rd month, day *kuei-mao* (40). "At night, from the 1st to fourth watch, the horizon was faintly lit in all directions, there was a fire-like vapour now seen and now extinguished." (*Chungjong Sillok*) (DC449)

383. 1512 Jan 17
[Korea] King Chungjong 6th year, 12th month, day *i-szu* (42). "At night, in the SW direction there was a red vapour. Above it there was a strip of white vapour. The red vapour was shaped like a torch and the white vapour was shaped like a cross approximately 1 *chang* in length." (*Chungjong Sillok*) (DC450)

384. 1512 Mar 21
[Korea] King Chungjong 7th year, 3rd month, day *chi-yu* (42). "Today in the early evening, in the N direction there was a red vapour like fire." (*Chungjong Sillok*) (DC451)

385. 1515 Mar 15
[Korea] King Chungjong 10th year, 3rd month, day *wu-wu* (55). "At night, at the 1st watch, in the N direction there was a fire-like vapour. At the 4th watch, it was also in the E direction." (*Chungjong Sillok*) (DC452)

386. 1515 Mar 18
[Korea] King Chungjong 10th year, 3rd month, day *hsin-yu* (58). "At night, in the NW and NE directions there were vapours like fire." (*Chungjong Sillok*) (DC453)

387. 1515 Mar 20
[Korea] King Chungjong 10th year, 3rd month, day *kuei-hai* (60). "At night, in the SW and N directions there were vapours like fire." (*Chungjong Sillok*) (DC454)

388. 1515 Mar 21
[Korea] King Chungjong 10th year, 3rd month, day *chia-tzu* (1). "At night, in the NE and SE directions there were vapours like fire." (*Chungjong Sillok*) (DC455)

389. 1515 Apr 7
[Korea] King Chungjong 10th year, 3rd month, day *hsin-szu* (18). "At night, in the NE and SE directions there were red vapours." (*Chungjong Sillok*) (DC456)

390. 1515 Apr 8
[Korea] King Chungjong 10th year, 3rd month, day *jen-wu* (19). "At night, in the E direction there was a fire-like vapour." (*Chungjong Sillok*) (DC457)

391. 1515 Apr 13
[Korea] King Chungjong 10th year, 3rd month, day *ting-hai* (24). "At night, in the S direction there was a fire-like vapour." (*Chungjong Sillok*) (DC458)

392. 1515 Apr 19
[Korea] King Chungjong 10th year, 4th month, day *kuei-szu* (30). "Tonight, in the E direction there was a fire-like vapour." (*Chungjong Sillok*) (DC459)

393. 1516 Aug 2
[China] Cheng-te reign-period 11th year, 7th month, 5th day. "SE of Ba-ling the sky split apart with a length of more than 3 *chang*. Its red light dazzled people." (*Hu-nan T'ung-chih*, 244 and *Tun-ting-hu Chih*) (DC460)

394. 1517 Feb 27
[Korea] King Chungjong 12th year, 2nd month, day *kuei-ch'ou* (50). "At night, in the SE direction there was a fire-like vapour." (*Chungjong Sillok*) (DC461)

395. 1517 Mar 19
[Korea] King Chungjong 12th year, 2nd month, day *kuei-yu* (10). "At night, in the NW direction there was a fire-like vapour." (*Chungjong Sillok*) (DC462)

396. 1517 Mar 20
[Korea] King Chungjong 12th year, 2nd month, day *chia-hsu* (11). "At night, in the S direction there was a fire-like vapour." (*Chungjong Sillok*) (DC463)

397. 1518 Jan 17
[China] Cheng-te reign-period 12th year, intercalary 12th month, day *ting-ch'ou* (14). "At night, there was a red vapour in Hsu-chou. It turned white and shaped like a carpenter's square. Inside and outside there were two black vapours which inter-changed for a long time." (*Ming-shih*, 28) (DC464)

398. 1518 May 18
[Korea] King Chungjong 13th year, 4th month, day *kuei-yu* (10). "At night, at the 5th watch, in the SW direction there was a fire-like vapour. (*Chungjong Sillok*) (DC465)

399. 1519 Jul 2
[Korea] King Chungjong 14th year, 6th month, day *wu-ch'en* (5). "To the west of the Hsing-Chow district, shortly after sunset and the moon was quite bright, in the W direction there was a misty cloud. Also there was a light like lightning but not lightning, like a fire but not a fire, or was it like shooting arrows filling the sky, or shooting stars passing over, or red snakes prancing, or sparks dispensing, or curving like a bended bow ... . From the W it gradually moved towards NE. Until the 2nd watch then it was extinguished." (*Chungbo Munhon Pigo*, 8) (DC466)

400. 1520 Apr 10
[Korea] King Chungjong 15th year, 3rd month, day *hsin-hai* (48). "At night, in the S horizon there was a fire-like vapour. On day *jen-tzu* (49), last night at the 4th watch the Day Official came to report that in the S direction there was a red vapour and it

was very strange. We (your ministers) got up and observed it and indeed there was a red vapour floating in the sky like a burning torch. It kept flickering and moving south and east, and back and forth. It was not commonly seen and we were startled. In the morning, the Day Official was again questioned. He said it started in the 1st watch and was still going in the 5th watch." (*Chungjong Sillok*) (DC467)

401. 1520 Apr 12
[Korea] King Chungjong 15th year, 3rd month, day *kuei-ch'ou* (50). "At night, in the NE direction there was a fire-like vapour." (*Chungjong Sillok*) (DC468)

402. 1522 Mar 25
[Korea] King Chungjong 17th year, 2nd month, day *i-szu* (42). "At night, in the SW and S directions there were vapours like fire. On day *ping-wu*, the Astronomer-Royal reported: 'Last night there was a vapour seen in the SW like a fire-vapour. It lasted until dawn then it disappeared.' When it was checked against the *Wen-hsien-tung-kuo*, it was known as the vapour of a fierce general. The royal decree said: 'This is not a common disaster. Although it should not be regarded as a certain incident, but everybody ought to be fearful." (*Chungjong Sillok*) (DC469)

403. 1522 Mar 31
[Korea] King Chungjong 17th year, 3rd month, day *hsin-hai* (48). "At night, in the NE direction there was a fire-like vapour." (*Chungjong Sillok*) (DC470)

404. 1522 Apr 23
[Korea] King Chungjong 17th year, 3rd month, day *chia-szu* (11). "At night, in the NE and SE directions there were vapours like fire." (*Chungjong Sillok*) (DC471)

405. 1522 Sep 16
[Korea] King Chungjong 17th year, 8th month, day *keng-tzu* (37). "At night, in the SE direction there was a fire-like vapour." (*Chungjong Sillok*) (DC472)

406. 1522 Nov 20
[Korea] King Chungjong 17th year, 11th month, day *i-szu* (42). "At night, in all directions there were vapours like fire." (*Chungjong Sillok*) (DC473)

407. 1523 Apr 14
[Korea] King Chungjong 18th year, 3rd month, day *keng-wu* (7). "At night, in the SW and SE directions there were vapours like fire." (*Chungjong Sillok*) (DC474)

408. 1523 Nov 9
[Korea] King Chungjong 18th year, 10th month, day *chi-hai* (36). "At night, in all directions there were vapours like fire." (*Chungjong Sillok*) (DC475)

409. 1523 Nov 18
[Korea] King Chungjong 18th year, 10th month, day *wu-shen* (45). "At night, in the E and SW directions there were vapours like fire." (*Chungjong Sillok*) (DC476)

410. 1524 Feb 1
[Korea] King Chungjong 18th year, 12th month, day *kuei-hai* (60). "At night, in the SE, S and N directions there were vapours like fire." (*Chungjong Sillok*) (DC477)

411. 1524 Mar 10
[Korea] King Chungjong 19th year, 2nd month, day *hsin-ch'ou* (38). "At night, from the S to the SE directions there were vapours like fire." (*Chungjong Sillok*) (DC478)

412. 1524 Mar 26
[Korea] King Chungjong 19th year, 2nd month, day *ting-szu* (54). "At night, in the NE and SE directions there were vapours like fire." (*Chungjong Sillok*) (DC479)

413. 1524 Sep 23
[Korea] King Chungjong 19th year, 8th month, day *wu-wu* (55). "At night, in the W direction there was a fire-like vapour." (*Chungjong Sillok*) (DC480)

414. 1524 Nov 19
[Korea] King Chungjong 19th year, 10th month, day *i-mao* (52). "At night, in the S direction there was a fire-like vapour." (*Chungjong Sillok*) (DC481)

415. 1525 Jan 15
[Korea] King Chungjong 19th year, 12th month, day *jen-tzu* (49). "After sunset, a red vapour covered the sky from the W to SE." (*Chungjong Sillok*) (DC482)

416. 1525 Feb 13
[Korea] King Chungjong 20th year, 1st month, day *hsin-szu* (18). "At night, in the SE direction there was a fire-like vapour." (*Chungjong Sillok*) (DC483)

417. 1525 Mar 18
[Korea] King Chungjong 20th year, 2nd month, day *chia-yin* (51). "At night, in the NW, SE and SW directions there were vapours like fire." (*Chungjong Sillok*) (DC484)

418. 1525 Mar 28
[Korea] King Chungjong 20th year, 3rd month, day *chia-tzu* (1). "At night, in the SE to ESE directions there were vapours like fire." (*Chungjong Sillok*) (DC485)

419. 1525 Apr 6
[Korea] King Chungjong 20th year, 3rd month, day *kuei-yu* (10). "At night, in the S direction there was a fire-like vapour." (*Chungjong Sillok*) (DC486)

420. 1525 Apr 10
[Korea] King Chungjong 20th year, 3rd month, day *ting-ch'ou* (14). "At night, in the SE and SW directions there were vapours like fire." (*Chungjong Sillok*) (DC487)

421. 1525 Apr 15
[Korea] King Chungjong 20th year, 3rd month, day *jen-tzu* (49). "At night, in the S direction there was a fire-like vapour." (*Chungjong Sillok*) (DC488)

422. 1525 Apr 22
[Korea] King Chungjong 20th year, 3rd month, day *chi-ch'ou* (26). "At night, in the S direction there was a fire-like vapour." (*Chungjong Sillok*) (DC489)

423. 1525 Nov 13
[Korea] King Chungjong 20th year, 10th month, day *chia-yin* (51). "At night, in the SW direction there was a fire-like vapour." (*Chungjong Sillok*) (DC490)

424. 1526 Mar 21
[Korea] King Chungjong 21st year, 2nd month, day *jen-hsu* (59). "At night, in the S direction there was a fire-like vapour." (*Chungjong Sillok*) (DC492)

425. 1526 Apr 8
[Korea] King Chungjong 21st year, 2nd month, day *keng-ch'en* (17). "At night, in the W direction there was a fire-like vapour." (*Chungjong Sillok*) (DC493)

426. 1526 Apr 30
[Korea] King Chungjong 21st year, 3rd month, day *jen-yin* (39). "At the 3rd watch, in the SE direction there was a fire-like vapour." (*Chungjong Sillok*) (DC494)

427. 1526 May 6
[Korea] King Chungjong 21st year, 3rd month, day *wu-ch'en* (5). "At night, in the SW direction there was a fire-like vapour." (*Chungjong Sillok*) (DC495)

428. 1526 Jun 20
[Korea] King Chungjong 21st year, 5th month, day *kuei-szu* (30). "At night, in the S direction there was a fire-like vapour." (*Chungjong Sillok*) (DC496)

429. 1526 Jun 30
[Korea] King Chungjong 21st year, 5th month, day *kuei-mao* (40). "At night, in the NW direction there was a fire-like vapour." (*Chungjong Sillok*) (DC497)

430. 1526 Jul 18
[Korea] King Chungjong 21st year, 6th month, day *hsin-yu* (58). "At night, there was a fire-like vapour." (*Chungjong Sillok*) (DC498)

431. 1526 Aug 5
[Korea] King Chungjong 21st year, 6th month, day *i-mao* (52) (read day *chi-mao* (16)). "At night, in the S direction there was a fire-like vapour." (*Chungjong Sillok*) (DC499)

432. 1526 Aug 7
[Korea] King Chungjong 21st year, 6th month, day *hsin-szu* (18). "At night, in the S direction there was a fire-like vapour." (*Chungjong Sillok*) (DC500)

433. 1526 Sep 24
[Korea] King Chungjong 21st year, 8th month, day *chi-szu* (6). "At night, in the E direction there was a fire-like vapour." (*Chungjong Sillok*) (DC501)

434. 1526 Dec 7
[Korea] King Chungjong 21st year, 11th month, day *kuei-wei* (20). "At the fifth watch, in the SE direction there was a fire-like vapour." (*Chungjong Sillok*) (DC502)

435. 1526 Dec 13
[Korea] King Chungjong 21st year, 11th month, day *chi-ch'ou* (26). "At the fifth watch, in the S direction there was a fire-like vapour." (*Chungjong Sillok*) (DC503)

436. 1527 Mar 1
[Korea] King Chungjong 22nd year, 1st month, day *ting-wei* (44). "At the fifth watch, in the S direction there was a fire-like vapour." (*Chungjong Sillok*) (DC504)

437. 1528 Mar 17
[Korea] King Chungjong 23rd year, 2nd month, day *chi-szu* (6). "At night, from the NW, NE to SE directions there were vapours like fire." (*Chungjong Sillok*) (DC505)

438. 1528 Mar 19
[Korea] King Chungjong 23rd year, 2nd month, day *hsin-wei* (8). "At night, in the S direction there was a fire-like vapour." (*Chungjong Sillok*) (DC506)

439. 1528 Mar 31
[Korea] King Chungjong 23rd year, 3rd month, day *kuei-wei* (20). "At night, in the S direction there was a fire-like vapour." (*Chungjong Sillok*) (DC507)

440. 1528 Apr 14
[Korea] King Chungjong 23rd year, 3rd month, day *ting-yu* (34). "At night, in the S direction there was a fire-like vapour." (*Chungjong Sillok*) (DC508)

441. 1528 Apr 22
[China] Chia-ching reign-period 7th year, 4th month, 4th day. "At the 5th watch, a strange vapour like flames was seen in Ho-chien. Its shape was like a dragon. It suspended from the air onto Earth in the SW direction. It lasted for several *k'e* and then it extinguished." (*Ho-chian Hsien-chih* and *T'ien-tsin Fu-chih*) (DC509)

442. 1528 Jun 16
[Korea] King Chungjong 23rd year, 5th month, day *keng-tzu* (37). "At night, in the SW direction there was a fire-like vapour." (*Chungjong Sillok*) (DC510)

443. 1529 Mar 8
[Korea] King Chungjong 24th year, 1st month, day *i-ch'ou* (2). "At night, in the N direction there was a fire-like vapour." (*Chungjong Sillok*) (DC511)

444. 1530 Feb 21
[Korea] King Chungjong 25th year, 1st month, day *i-mao* (52). "At the 3rd watch, in the NW direction there was a fire-like vapour." (*Chungjong Sillok*) (DC512)

445. 1530 Feb 22
[Korea] King Chungjong 25th year, 1st month, day *ping-ch'en* (53). "At the fourth watch, in the NW direction there was a fire-like vapour." (*Chungjong Sillok*) (DC513)

446. 1531 Feb 24
[Korea] King Chungjong 26th year, 2nd month, day *kuei* (60). "At night, in the SW, S and SE directions there were vapours like fire." (*Chungjong Sillok*) (DC514)

447. 1531 Apr 13
[Korea] King Chungjong 26th year, 3rd month, day *hsin-hai* (48). "At night, in the S direction there was a fire-like vapour." (*Chungjong Sillok*) (DC515)

448. 1531 May 23
[Korea] King Chungjong 26th year, 5th month, day *hsin-mao* (28). "At night, in the E direction there was a fire-like vapour." (*Chungjong Sillok*) (DC516)

449. 1531 Jun 10
[Korea] King Chungjong 26th year, 5th month, day *chi-yu* (46). "At night, at the 3rd watch, in the SW direction there was a fire-like vapour. It lasted until the 4th watch." (*Chungjong Sillok*) (DC517)

450. 1531 Jul 19
[Korea] King Chungjong 26th year, intercalary 6th month, day *wu-tzu* (25). "At night, in the SE direction there was a fire-like vapour." (*Chungjong Sillok*) (DC518)

451. 1531 Aug 6
[Korea] King Chungjong 26th year, intercalary 6th month, day *ping-wu* (43). "Tonight, in the SE direction there was a fire-like vapour." (*Chungjong Sillok*) (DC519)

452. 1532 Mar 12
[Korea] King Chungjong 27th year, 2nd month, day *i-yu* (22). "At night, in the S, NW and NE directions there were vapours like fire." (*Chungjong Sillok*) (DC520)

453. 1532 Mar 13
[Korea] King Chungjong 27th year, 2nd month, day *ping-hsu* (23). "At night, in the SE, S and NW directions there were vapours like fire." (*Chungjong Sillok*) (DC521)

454. 1532 Apr 3
[Korea] King Chungjong 27th year, 2nd month, day *ting-wei* (44). "At night, in the SE direction there was a fire-like vapour." (*Chungjong Sillok*) (DC522)

455. 1532 Sep 26
[Korea] King Chungjong 27th year, 8th month, day *kuei-mao* (40). "At night, in the SW direction there was a fire-like vapour." (*Chungjong Sillok*) (DC523)

456. 1533 Jan 28
[Korea] King Chungjong 28th year, 1st month, day *ting-wei* (44). "At night, in the NE, SE and SW directions there were vapours like fire." (*Chungjong Sillok*) (DC524)

457. 1533 Feb 2
[Korea] King Chungjong 28th year, 1st month, day *jen-tzu* (49). "At night, in the S direction there was a fire-like vapour. In the SW and NE directions there were white vapours covering the sky." (*Chungjong Sillok*) (DC525)

458. 1533 Feb 19
[Korea] King Chungjong 28th year, 1st month, day *chi-szu* (6). "At night, in the E direction there was a fire-like vapour." (*Chungjong Sillok*) (DC526)

459. 1533 Feb 21
[Korea] King Chungjong 28th year, 1st month, day *hsin-wei* (8). "At night, in the E and W directions there were vapours like fire." (*Chungjong Sillok*) (DC527)

460. 1533 Mar 27
[Korea] King Chungjong 28th year, 3rd month, day *i-szu* (42). "At night, in the SE direction there was a fire-like vapour." (*Chungjong Sillok*) (DC528)

461. 1533 Apr 29
[Korea] King Chungjong 28th year, 4th month, day *wu-yin* (15). "At night, in the N direction there was a fire-like vapour." (*Chungjong Sillok*) (DC529)

462. 1533 Apr 30
[Korea] King Chungjong 28th year, 4th month, day *chi-mao* (16). "At night, in the N and SE directions there were vapours like fire." (*Chungjong Sillok*) (DC530)

463. 1533 May 1
[Korea] King Chungjong 28th year, 4th month, day *keng-ch'en* (17). "At night, in the E, N, SE and NE directions there were vapours like fire." (*Chungjong Sillok*) (DC531)

464. 1533 May 2
[Korea] King Chungjong 28th year, 4th month, day *hsin-szu* (18). "At night, in the NE, SE and SW directions there were vapours like fire." (*Chungjong Sillok*) (DC532)

465. 1533 May 23
[Korea] King Chungjong 28th year, 4th month, day *jen-yin* (39). "Tonight, in the SW direction there was a fire-like vapour." (*Chungjong Sillok*) (DC533)

466. 1533 Jul 25
[Korea] King Chungjong 28th year, 7th month, day *i-szu* (42). "At night, in the NW, SW and SE directions there were vapours like fire." (*Chungjong Sillok*) (DC534)

467. 1533 Oct 24
[Korea] King Chungjong 28th year, 10th month, day *ping-tzu* (13). "At the 3rd watch, a blue yellow-white vapour appeared at the star *Wen-chang.* Its tail was pointing the star *Wang-liang.* It was like a piece of cloth and shaped like a dragon. It extinguished after a long while." (*Chungjong Sillok*) (DC535)

468. 1534 Jan 13
[Korea] King Chungjong 28th year, 12th month, day *ting-yu* (34). "At night, in the NE direction there was a red vapour." (*Chungjong Sillok*) (DC536)

469. 1534 Jan 23
[Korea] King Chungjong 29th year, 1st month, day *ting-wei* (44). "At night, in the SE and NE directions there were vapours like fire." (*Chungjong Sillok*) (DC537)

470. 1534 Feb
[China] Chia-ching reign-period 13th year, 1st month, spring. "At night, thousands of flames lit up the sky like candles. They extinguished after several *k'e*." (*Kiang-hsi T'ung-chih*) (DC538)

471. 1534 Apr 14
[Korea] King Chungjong 29th year, 3rd month, day *wu-ch'en* (5). "At night, in the SW direction there was a fire-like vapour." (*Chungjong Sillok*) (DC539)

472. 1534 Apr 16 and 17
[Korea] King Chungjong 29th year, 3rd month, day *keng-wu* (7) and *hsin-wei* (8). "At night, in the E direction there was a fire-like vapour." (*Chungjong Sillok*) (DC540-541)

473. 1534 Apr 23
[Korea] King Chungjong 29th year, 3rd month, day *ting-ch'ou* (14). "At night, in the SW direction there was a fire-like vapour." (*Chungjong Sillok*) (DC542)

474. 1534 May 1
[Korea] King Chungjong 29th year, 3rd month, day *i-yu* (22). "At night, in the N direction there was a fire-like vapour." (*Chungjong Sillok*) (DC543)

475. 1534 May 20
[Korea] King Chungjong 29th year, 4th month, day *chia-ch'en* (41). "At night, from the

4th to 5th watch, in the S and SE directions there were vapours like fire." (*Chungjong Sillok*) (DC544)

476. 1534 Jun 12
[Korea] King Chungjong 29th year, 5th month, day *ting-mao* (4). "At night, in the SW direction there was a fire-like vapour." (*Chungjong Sillok*) (DC545)

477. 1534 Sep 6
[Korea] King Chungjong 29th year, 7th month, day *kuei-szu* (30). "At night, in the SW direction there was a fire-like vapour." (*Chungjong Sillok*) (DC546)

478. 1535 Jan 4
[Korea] King Chungjong 29th year, 12th month, 1st day, *kuei-szu* (30). "At night, in the SE and NE directions there were vapours like fire." (*Chungjong Sillok*) (DC547)

479. 1535 Jan 7
[Korea] King Chungjong 29th year, 12th month, day *ping-shen* (33). "At night, in the S direction there was a fire-like vapour." (*Chungjong Sillok*) (DC548)

480. 1535 Jan 8
[Korea] King Chungjong 29th year, 12th month, day *ting-yu* (34). "At night, in the SW direction there was a fire-like vapour." (*Chungjong Sillok*) (DC549)

481. 1535 Mar 3
[Korea] King Chungjong 30th year, 1st month, day *hsin-mao* (28). "At night, the W horizon was coloured red." (*Chungjong Sillok*) (DC550)

482. 1535 Mar 6
[Korea] King Chungjong 30th year, 2nd month, day *chia-wu* (31). "At night, in the SE to SW directions there were vapours like fire." (*Chungjong Sillok*) (DC551)

483. 1535 Mar 31
[Korea] King Chungjong 30th year, 2nd month, day *chi-wei* (56). "At night, in all directions there were vapours like fire." (*Chungjong Sillok*) (DC552)

484. 1535 Apr 2
[Korea] King Chungjong 30th year, 3rd month, 1st day, *hsin-yu* (58). "At night, in the NE, SW and W directions there were vapours like fire." (*Chungjong Sillok*) (DC553)

485. 1535 Apr 29
[Korea] King Chungjong 30th year, 3rd month, day *wu-tzu* (25). "At night, in the SE direction there was a fire-like vapour." (*Chungjong Sillok*) (DC554)

486. 1535 Apr 30
[Korea] King Chungjong 30th year, 3rd month, day *chi-ch'ou* (26). "At night, in the SE direction there was a fire-like vapour." (*Chungjong Sillok*) (DC555)

487. 1535 May 6
[Korea] King Chungjong 30th year, 4th month, day *i-wei* (32). "At night, in the NW and SE directions there were vapours like fire." (*Chungjong Sillok*) (DC556)

488. 1535 May 30
[Korea] King Chungjong 30th year, 4th month, day *chi-wei* (56). "At night, in the SW direction there was a fire-like vapour." (*Chungjong Sillok*) (DC557)

489. 1535 Jun 25
[Korea] King Chungjong 30th year, 5th month, day *i-yu* (22). "At night, in the E and SW, SE and S directions there were vapours like fire." (*Chungjong Sillok*) (DC558)

490. 1535 Jun 30 and Jul 1
[Korea] King Chungjong 30th year, 6th month, day *keng-yin* (27). "At night, in the E, S and W directions there were vapours like fire." (*Chungjong Sillok*) (DC559-560)

491. 1535 Jul 28
[Korea] King Chungjong 30th year, 6th month, day *wu-wu* (55). "At night, in the NE direction there was a fire-like vapour." (*Chungjong Sillok*) (DC561)

492. 1535 Nov 14
[Korea] King Chungjong 30th year, 10th month, day *ting-wei* (44). "At night, in the S direction there was a fire-like vapour." (*Chungjong Sillok*) (DC562)

493. 1535 Dec 22
[Korea] King Chungjong 30th year, 11th month, day *i-yu* (22). "At night, in the E and SW directions there were vapours like fire." (*Chungjong Sillok*) (DC563)

494. 1535 Dec 31
[Korea] King Chungjong 30th year, 12th month, day *chia-wu* (31). "At night, in the NE and SW directions there were vapours like fire." (*Chungjong Sillok*) (DC564)

495. 1536 Feb 17
[Korea] King Chungjong 31st year, 1st month, day *jen-wu* (19). "At night, in the S, E and NE directions there were vapours like fire." (*Chungjong Sillok*) (DC565)

496. 1536 Feb 23
[Korea] King Chungjong 31st year, 2nd month, day *wu-tzu* (25). "At night, in the E, NE, SE, S, SW and NW directions there were vapours like fire." (*Chungjong Sillok*) (DC566)

497. 1536 Mar 12
[Korea] King Chungjong 31st year, 2nd month, day *ping-wu* (43). "At night, in the E, N and W directions there were vapours like fire." (*Chungjong Sillok*) (DC567)

498. 1536 Mar 13
[Korea] King Chungjong 31st year, 2nd month, day *ting-wei* (44). "At night, in the SE direction there was a fire-like vapour." (*Chungjong Sillok*) (DC568)

499. 1536 Mar 17
[Korea] King Chungjong 31st year, 2nd month, day *hsin-hai* (48). "At night, in the N, S, NE and SE directions there were vapours like fire." (*Chungjong Sillok*) (DC569)

500. 1536 May 17
[Korea] King Chungjong 31st year, 4th month, day *jen-tzu* (49). "At night, in the NW direction there was a fire-like vapour." (*Chungjong Sillok*) (DC570)

501. 1537 Mar 7
[Korea] King Chungjong 32nd year, 1st month, day *ping-wu* (43). "At night, in the NE direction there was a fire-like vapour." (*Chungjong Sillok*) (DC571)

502. 1537 Jun 12
[Korea] King Chungjong 32nd year, 5th month, day *kuei-wei* (20). "In the SW direction there was a fire-like vapour." (*Chungjong Sillok*) (DC572)

503. 1537 Jun 13
[Korea] King Chungjong 32nd year, 5th month, day *chia-shen* (21). "At night, in the SW direction there was a fire-like vapour." (*Chungjong Sillok*) (DC573)

504. 1537 Dec 5
[Korea] King Chungjong 32nd year, 11th month, day *chi-mao* (16). "At night, in the SE and SW directions there were vapours like fire." (*Chungjong Sillok*) (DC574)

505. 1538 Jan 20
[Korea] King Chungjong 32nd year, 12th month, day *i-ch'ou* (2). "At night, in the S, SE and E directions there were vapours like fire." (*Chungjong Sillok*) (DC575)

506. 1538 Mar 4
[Korea] King Chungjong 33rd year, 2nd month, day *wu-shen* (45). "At night, in the E, W and S directions there were vapours like fire." (*Chungjong Sillok*) (DC576)

507. 1538 Mar 5
[Korea] King Chungjong 33rd year, 2nd month, day *chi-yu* (46). "At night, in the S direction there was a fire-like vapour." (*Chungjong Sillok*) (DC577)

508. 1538 Jun 1
[Korea] King Chungjong 33rd year, 5th month, day *ting-ch'ou* (14). "At night, in the W direction there was a fire-like vapour." (*Chungjong Sillok*) (DC578)

509. 1538 Jun 2
[Korea] King Chungjong 33rd year, 5th month, day *wu-yin* (15). "At night, in the W direction there was a fire-like vapour." (*Chungjong Sillok*) (DC579)

510. 1538 Jun 24
[Korea] King Chungjong 33rd year, 5th month, day *keng-tzu* (37). "At night, in the SE direction there was a fire-like vapour." (*Chungjong Sillok*) (DC580)

511. 1538 Oct 20
[Korea] King Chungjong 33rd year, 9th month, day *wu-hsu* (35). "At night, in the NW and E directions there were vapours like fire." (*Chungjong Sillok*) (DC581)

512. 1538 Oct 21
[Korea] King Chungjong 33rd year, 9th month, day *chi-hai* (36). "At night, in the S direction there was a fire-like vapour." (*Chungjong Sillok*) (DC582)

513. 1538 Dec 3 and 4
[Korea] King Chungjong 33rd year, 11th month, day *jen-wu* (19). "At night, in the NE and SE directions there were vapours like fire." (*Chungjong Sillok*) (DC583-584)

514. 1539 Jan 9
[Korea] King Chungjong 33rd year, 12th month, day *chi-wei* (56). "At night, in the S, NE ad NW directions there were red lights like fire-vapours." (*Chungjong Sillok*) (DC585)

515. 1539 Jan 10
[Korea] King Chungjong 33rd year, 12th month, day *keng-shen* (57). "At night, in the W direction there was a red light like a fire-vapour. And a white vapour covered the sky from the E to SW. At day break, it turned into a dark vapour and extinguished from the SW direction." (*Chungjong Sillok*) (DC586)

516. 1539 Jan 18
[Korea] King Chungjong 33rd year, 12th month, day *wu-ch'en* (5). "At night, in the N direction there was a red light like fire." (*Chungjong Sillok*) (DC587)

517. 1539 Feb 5
[Korea] King Chungjong 34th year, 1st month, day *ping-hsu* (23). "At night, in the S and SW directions there were vapours like fire." (*Chungjong Sillok*) (DC588)

518. 1539 Mar 21
[Korea] King Chungjong 34th year, 3rd month, day *keng-wu* (7). "At night, in the NW, S and SE directions there were vapours like fire." (*Chungjong Sillok*) (DC589)

519. 1539 Apr 8
[Korea] King Chungjong 34th year, 3rd month, day *wu-tzu* (25). "At night, in the N and SE directions there were vapours like fire." (*Chungjong Sillok*) (DC590)

520. 1539 Apr 9
[Korea] King Chungjong 34th year, 3rd month, day *chi-ch'ou* (26). "At night, in the N and S directions there were vapours like fire." (*Chungjong Sillok*) (DC591)

521. 1539 May 14
[Korea] King Chungjong 34th year, 4th month, day *chia-tzu* (1). "In the SE direction there was a fire-like vapour." (*Chungjong Sillok*) (DC592)

522. 1539 May 29
[Korea] King Chungjong 34th year, 5th month, day *chi-mao* (16). "At night, in the E direction there was a fire-like vapour." (*Chungjong Sillok*) (DC593)

523. 1542 Feb 17
[Korea] King Chungjong 37th year, 2nd month, day *chia-yin* (51). "At night, in the NE direction there was a vapour like flames illuminating the Earth." (*Chungjong Sillok*) (DC594)

524. 1542 Mar 12
[Korea] King Chungjong 37th year, 2nd month, day *ting-ch'ou* (14). "At night, there was a fire-like vapour." (*Chungjong Sillok*) (DC595)

525. 1542 Apr 21
[Korea] King Chungjong 37th year, 4th month, day *ting-szu* (54). "At night, in the SE direction there was a fire-like vapour." (*Chungjong Sillok*) (DC596)

526. 1542 Jun 8
[Korea] King Chungjong 37th year, 5th month, day *i-szu* (42). "At night, in the E and S directions there were vapours like fire." (*Chungjong Sillok*) (DC597)

527. 1542 Jun 13
[Korea] King Chungjong 37th year, intercalary 5th month, 1st day, *keng-hsu* (47). "At

night, in the SE and SW directions there were vapours like fire." (*Chungjong Sillok*) (DC598)

528. 1542 Jun 21
[Korea] King Chungjong 37th year, intercalary 5th month, day *wu-wu* (55). "At night, there was a fire-like vapour." (*Chungjong Sillok*) (DC599)

529. 1542 Oct 26.
[Korea] King Chungjong 37th year, 9th month, day *i-ch'ou* (2). "At night, in the W direction there was a vapour like a torch fire." (*Chungjong Sillok*) (DC600)

530. 1543 Feb 5
[Korea] King Chungjong 38th year, 1st month, day *ting-wei* (44). "At night, in the SE, NE and S directions there were vapours like fire." (*Chungjong Sillok*) (DC601)

531. 1543 Feb 22
[Korea] King Chungjong 38th year, 1st month, day *chia-tzu* (1). "At night, in the SW direction there was a fire-like vapour." (*Chungjong Sillok*) (DC602)

532. 1543 Feb 27
[Korea] King 38th year, 1st month, day *chi-szu* (6). "At night, in the SW direction there was a fire-like vapour." (*Chungjong Sillok*) (DC603)

533. 1543 Mar 29
[Korea] King Chungjong 38th year, 2nd month, day *chi-hai* (36). "At night, in the NW direction there was a fire-like vapour." (*Chungjong Sillok*) (DC604)

534. 1543 Mar 30
[Korea] King Chungjong 38th year, 2nd month, day *keng-tzu* (37). "At night, in the NW direction there was a fire-like vapour." (*Chungjong Sillok*) (DC605)

535. 1543 May 10
[Korea] King Chungjong 38th year, 4th month, day *hsin-szu* (18). "At night, in the SW direction there was a fire-like vapour." (*Chungjong Sillok*) (DC606)

536. 1543 May 23
[Korea] King Chungjong 38th year, 4th month, day *chia-wu* (31). "At night, in the W direction there was a fire-like vapour." (*Chungjong Sillok*) (DC607)

537. 1543 Aug 6
[Korea] King Chungjong 38th year, 7th month, day *chi-yu* (46). "At night, in the E, W and S directions there were vapours like fire." (*Chungjong Sillok*) (DC608)

538. 1544 Mar 29
[Korea] King Chungjong 39th year, 3rd month, day *i-szu* (42). "At night, in the NE direction there was a fire-like vapour." (*Chungjong Sillok*) (DC609)

539. 1544 Apr 29
[China] Chia-ching reign-period 23th year, 4th month, day *ping-tzu* (13). "At midnight, there was an unusual happenning; the sky was like that it had been split apart." (*Chi-nan Fu-chih*) (DC610)

540. 1544 Jun 25
[Korea] King Chungjong 39th year, 6th month, day *kuei-yu* (10). "At night, in the SW direction there was a fire-like vapour." (*Chungjong Sillok*) (DC611)

541. 1544 Jul 18
[Korea] King Chungjong 39th year, 6th month, day *ping-shen* (33). "At night, there was a vapour with a green-white colour. It rose in the zenith and (stretched) across like a piece of silk. Gradually, it moved towards the S. After a long while then it was extinguished." (*Chungjong Sillok*) (DC612)

542. 1544 Nov 16
[Korea] King Chungjong 39th year, 11th month, day *ting-yu* (34). "At night, in the S direction there was a fire-like vapour." (*Chungjong Sillok*) (DC613)

543. 1545 Apr 1
[Korea] King Injong 1st year, 2nd month, day *kuei-ch'ou* (50). "At night, in the SW and NE directions there were vapours like fire." (*Injong Sillok*) (DC614)

544. 1545 Jun 7
[Korea] King Injong 1st year, 4th month, day *keng-shen* (57). "At the 1st watch, in the SE direction there was a fire-like vapour." (*Injong Sillok*) (DC615)

545. 1546 Mar 9
[Korea] King Myongjong 1st year, 2nd month, day *i-wei* (32). "At night, in the NE and SW directions there were vapours like fire." (*Myongjong Sillok*) (DC616)

546. 1546 May 9
[Korea] King Myongjong 1st year, 4th month, day *ping-shen* (33). "At night, in the SE, S and SW directions there were vapours like fire." (*Myongjong Sillok*) (DC617)

547. 1546 Jul 14
[Korea] King Myongjong 1st year, 6th month, day *jen-yin* (39). "At night, in the early evening, in the NW direction there was a vapour like a rainbow. It was tortorous with a length of a piece of cloth. It was blue inside and yellow outside." (*Myongjong Sillok*) (DC618)

548. 1547 Jul 10
[Korea] King Myongjong 2nd year, 6th month, day *kuei-mao* (40). "At night, the S, N and NW directions were like a fire-vapour." (*Myongjong Sillok*) (DC619)

549. 1548 Jan 1
[Korea] King Myongjong 2nd year, 11th month, day *wu-hsu* (35). "At night, the NW, SW and SE directions were like a fire-vapour." (*Myongjong Sillok*) (DC620)

550. 1548 May 10
[Korea] King Myongjong 3rd year, 4th month, day *wu-shen* (45). "At night, the SW direction was like a fire-vapour." (*Myongjong Sillok*) (DC621)

551. 1548 Jul 3
[Korea] King Myongjong 3rd year, 5th month, day *jen-yin* (39). "At night, the S direction was like a fire-vapour." (*Myongjong Sillok*) (DC622)

552. 1550 Jul 12
[Korea] King Myongjong 5th year, 6th month, day *hsin-yu* (58). "At night, in the NW, SW and W directions there were vapours like fire." (*Myongjong Sillok*) (DC623)

553. 1551 Mar 15
[Korea] King Myongjong 6th year, 2nd month, day *ting-mao* (4). "At the 5th watch, in the SE direction there was a fire-like vapour." (*Myongjong Sillok*) (DC624)

554. 1551 Apr 1
[Korea] King Myongjong 6th year, 2nd month, day *chia-shen* (21). "At night, in the E direction there was a fire-like vapour." (*Myongjong Sillok*) (DC625)

555. 1551 Apr 11
[Korea] King Myongjong 6th year, 3rd month, day *chia-wu* (31). "At night, in the NE direction there was a fire-vapour." (*Myongjong Sillok*) (DC626)

556. 1551 May 27
[Korea] King Myongjong 6th year, 4th month, day *keng-ch'en* (17). "At night, the S and N directions were like a fire-vapour." (*Myongjong Sillok*) (DC627)

557. 1551 Jul 1
[Korea] King Myongjong 6th year, 5th month, day *i-mao* (52). "In the NW, NE and SE sky, a yellow-red colour shone brilliantly; soon it was extinguished." (*Myongjong Sillok*) (DC628)

558. 1551 Nov 27
[Korea] King Myongjong 6th year, 10th month, day *chia-shen* (21). "At night, the NE direction was like a fire-vapour." (*Myongjong Sillok*) (DC629)

559. 1552 Feb 16
[Korea] King Myongjong 7th year, 1st month, day *i-szu* (42). "At night, in the SW and SE directions were like a fire-vapour." (*Myongjong Sillok*) (DC630)

560. 1552 Mar 30
[Korea] King Myongjong 7th year, 3rd month, day *wu-tzu* (25). "At night, the N direction was like a fire-vapour." (*Myongjong Sillok*) (DC631)

561. 1552 Apr 19
[Korea] King Myongjong 7th year, 3rd month, day *wu-shen* (45). "At night, the SE and S directions were like a fire-vapour." (*Myongjong Sillok*) (DC632)

562. 1552 May 1
[Korea] King Myongjong 7th year, 4th month, day *keng-shen* (57). "At night, the SE, E and W directions were like a fire-vapour." (*Myongjong Sillok*) (DC633)

563. 1552 May 28
[Korea] King Myongjong 7th year, 5th month, day *ting-hai* (24). "At night, the SE and SW directions was like a fire-vapour." (*Myongjong Sillok*) (DC634)

564. 1552 Oct 29
[Korea] King Myongjong 7th year, 10th month, day *hsin-yu* (58). "At night, just before daybreak, a red vapour filled the sky with its light shining on Earth." (*Myongjong Sillok*) (DC635)

565. 1552 Nov 19
[Korea] King Myongjong 7th year, 11th month, day *jen-wu* (19). "After sunset, a vapour with a yellow top and violet bottom filled the W and SW horizon. Its light illuminated the ground. Not until the 1st watch then it was extinguished." (*Myongjong Sillok*) (DC636)

566. 1553 Jan 15
[Korea] King Myongjong 8th year, 1st month, day *chi-mao* (16). "At night, a vapour of fire was blazing upwards into the sky and shining brightly with a red light. After a long while then it was extinguished." (*Myongjong Sillok*) (DC637)

567. 1553 Feb 7
[Korea] King Myongjong 8th year, 1st month, day *jen-yin* (39). "At night, the E, S and W directions were like a fire-vapour." (*Myongjong Sillok*) (DC638)

568. 1553 Feb 8
[Korea] King Myongjong 8th year, 1st month, day *kuei-mao* (40). "At night, the SE and S directions were like a fire-vapour." (*Myongjong Sillok*) (DC639)

569. 1553 Mar 16
[Korea] King Myongjong 8th year, 3rd month, day *chi-mao* (16). "At night, the SE and NE directions were like a fire-vapour." (*Myongjong Sillok*) (DC640)

570. 1553 Mar 18
[Korea] King Myongjong 8th year, 3rd month, day *hsin-szu* (18). "At night, the E and S directions were like a fire-vapour. Also in the SW direction there was a vapour of fire." (*Myongjong Sillok*) (DC641)

571. 1553 Jul 13
[Korea] King Myongjong 8th year, 6th month, day *wu-yin* (15). "At night, the SW direction was like a fire-vapour." (*Myongjong Sillok*) (DC642)

572. 1554 Mar 4
[Korea] King Myongjong 9th year, 2nd month, day *jen-shen* (9). "At night, the NE, E, SE, S, SW and NW directions were like a fire-vapour." (*Myongjong Sillok*) (DC643)

573. 1554 Mar 9
[Korea] King Myongjong 9th year, 2nd month, day *ting-ch'ou* (14). "At night, the E and W direction were like a fire-vapour." (*Myongjong Sillok*) (DC644)

574. 1554 Apr 21
[Korea] King Myongjong 9th year, 3rd month, day *keng-shen* (57). "At night, all directions were like a fire-vapour." (*Myongjong Sillok*) (DC645)

575. 1554 May 5
[Korea] King Myongjong 9th year, 4th month, day *chia-hsu* (11). "At night, the S direction was like a fire-vapour." (*Myongjong Sillok*) (DC646)

576. 1554 Jun 10
[Korea] King Myongjong 9th year, 5th month, day *keng-hsu* (47). "At night, from the 4th to 5th watch, in the SW, SE and S directions were like a fire-vapour." (*Myongjong Sillok*) (DC647)

577. 1554 Jun 29
[Korea] King Myongjong 9th year, 5th month, day *chi-szu* (6). "At night, the SW, NE, S, E and W directions were like a fire-vapour." (*Myongjong Sillok*) (DC648)

578. 1554 Jul 7
[Korea] King Myongjong 9th year, 6th month, day *ting-ch'ou* (14). "At night, the NW direction was like a fire-vapour." (*Myongjong Sillok*) (DC649)

579. 1554 Jul 8
[Korea] King Myongjong 9th year, 6th month, day *wu-yin* (15). "At night, the SW direction was like a fire-vapour." (*Myongjong Sillok*) (DC650)

580. 1554 Aug 7
[Korea] King Myongjong 9th year, 7th month, day *wu-shen* (45). "At night, the SE direction was like a fire-vapour." (*Myongjong Sillok*) (DC651)

581. 1554 Oct 9
[Korea] King Myongjong 9th year, 9th month, day *hsin-hai* (60). "At night, it was like a fire-vapour." (*Myongjong Sillok*) (DC652)

582. 1554 Dec 16
[Korea] King Myongjong 9th year, 11th month, day *chi-wei* (56). "At night, the NE and S directions were like a fire-vapour." (*Myongjong Sillok*) (DC653)

583. 1555 Jan 18
[Korea] King Myongjong 9th year, 12th month, day *jen-ch'en* (29). "At night, the SW direction was like a fire-vapour." (*Myongjong Sillok*) (DC654)

584. 1555 Feb 12
[Korea] King Myongjong 10th year, 1st month, day *ting-szu* (54). "At night, the E and S directions were like a fire-vapour." (*Myongjong Sillok*) (DC655)

585. 1555 Feb 22
[Korea] King Myongjong 10th year, 2nd month, day *ting-mao* (4). "At night, the SE, S and NE directions were like a fire-vapour." (*Myongjong Sillok*) (DC656)

586. 1555 Feb 27
[Korea] King Myongjong 10th year, 2nd month, day *jen-shen* (9). "At night, the SW and NE directions were like a fire-vapour." (*Myongjong Sillok*) (DC657)

587. 1555 Mar 14
[Korea] King Myongjong 10th year, 2nd month, day *ting-hai* (24). "At night, the SE, NE and E directions were like a fire-vapour." (*Myongjong Sillok*) (DC658)

588. 1555 Mar 16
[Korea] King Myongjong 10th year, 2nd month, day *chi-ch'ou* (26). "At night, all directions were like a fire-vapour." (*Myongjong Sillok*) (DC659)

589. 1555 Mar 17
[Korea] King Myongjong 10th year, 2nd month, day *keng-yin* (27). "At night, the SW and NE directions were like a fire-vapour." (*Myongjong Sillok*) (DC660)

590. 1555 Mar 22
[Korea] King Myongjong 10th year, 2nd month, day *i-wei* (32). "At night, the NE and E directions were like a fire-vapour." (*Myongjong Sillok*) (DC661)

591. 1555 Mar 28
[Korea] King Myongjong 10th year, 3rd month, day *hsin-ch'ou* (38). "At night, the E and SE directions were like a fire-vapour." (*Myongjong Sillok*) (DC662)

592. 1555 Apr 19
[Korea] King Myongjong 10th year, 3rd month, day *kuei-hai* (60). "At night, the NE, S and NW directions were like a fire-vapour." (*Myongjong Sillok*) (DC663)

593. 1555 Jun 8
[Korea] King Myongjong 10th year, 5th month, day *kuei-ch'ou* (50). "At night, the NE, E, S and SW directions were like a fire-vapour." (*Myongjong Sillok*) (DC664)

594. 1555 Jun 13
[Korea] King Myongjong 10th year, 5th month, day *wu-wu* (55). "At night, the SE and E directions were like a fire-vapour." (*Myongjong Sillok*) (DC665)

595. 1555 Jul 13
[Korea] King Myongjong 10th year, 6th month, day *wu-tzu* (25). "At night, the SW direction was like a fire-vapour." (*Myongjong Sillok*) (DC666)

596. 1555 Dec 9
[Korea] King Myongjong 10th year, 11th month, day *ting-szu* (54). "At night, the SE direction was like a fire-vapour." (*Myongjong Sillok*) (DC667)

597. 1555 Dec 12
[Korea] King Myongjong 10th year, 11th month, day *keng-shen* (57). "At night, the S direction was like a fire-vapour." (*Myongjong Sillok*) (DC668)

598. 1556 Jan 7
[Korea] King Myongjong 10th year, intercalary 11th month, day *ping-hsu* (23). "At night, the S direction was like a fire-vapour." (*Myongjong Sillok*) (DC669)

599. 1556 Jan 15
[Korea] King Myongjong 10th year, 12th month, day *chia-wu* (31). "At night, the NW direction was like a fire-vapour." (*Myongjong Sillok*) (DC670)

600. 1556 Mar 2
[Korea] King Myongjong 11th year, 1st month, day *hsin-szu* (18). "At night, the NE direction was like a fire-vapour." (*Myongjong Sillok*) (DC671)

601. 1556 Mar 5
[Korea] King Myongjong 11th year, 1st month, day *chia-shen* (21). "At night, the SW, SE and N directions were like a fire-vapour." (Myongjong Sillok) (DC672)

602. 1556 Mar 8
[Korea] King Myongjong 11th year, 1st month, day *ting-hai* (24). "At night, the SW and S directions were like a fire-vapour." (*Myongjong Sillok*) (DC673)

603. 1556 Mar 10
[Korea] King Myongjong 11th year, 1st month, day *chi-ch'ou* (26). "At night, the N direction was like a fire-vapour." (*Myongjong Sillok*) (DC674)

604. 1556 Mar 11
[Korea] King Myongjong 11th year, 2nd month, day *keng-yin* (27). "At night, the SE, S and SW directions were like a fire-vapour." (*Myongjong Sillok*) (DC675)

605. 1556 Apr 5
[Korea] King Myongjong 11th year, 2nd month, day *i-mao* (52). "At night, the S, SE and E directions were like a fire-vapour." (*Myongjong Sillok*) (DC676)

606. 1556 Apr 7
[Korea] King Myongjong 11th year, 2nd month, day *ting-szu* (54). "At night, the E and SE directions were like a fire-vapour." (*Myongjong Sillok*) (DC677)

607. 1556 Apr 8
[Korea] King Myongjong 11th year, 2nd month, day *wu-wu* (55). "At night, the E direction was like a fire-vapour." (*Myongjong Sillok*) (DC678)

608. 1556 Apr 13
[Korea] King Myongjong 11th year, 3rd month, day *kuei-hai* (60). "At night, the SE and NW directions were like a fire-vapour." (*Myongjong Sillok*) (DC679)

609. 1556 May 3
[Korea] King Myongjong 11th year, 3rd month, day *kuei-wei* (20). "At night, the SW and NE directions were like a fire-vapour." (*Myongjong Sillok*) (DC680)

610. 1556 Jun 4
[Korea] King Myongjong 11th year, 4th month, day *i-mao* (52). "After sunset, a red vapour stretched across the sky from the NW to NE. When it started to move it extinguished." (*Myongjong Sillok*) (DC681)

611. 1556 Jun 6
[Korea] King Myongjong 11th year, 4th month, day *ting-szu* (54). "At night, the E and S directions were like a fire-vapour." (*Myongjong Sillok*) (DC682)

612. 1556 Jun 10
[Korea] King Myongjong 11th year, 5th month, day *hsin-yu* (58). "At night, all directions were like a fire-vapour." (*Myongjong Sillok*) (DC683)

613. 1556 Jun 14
[Korea] King Myongjong 11th year, 5th month, day *i-ch'ou* (2). "At night, the S direction was like a fire-vapour." (*Myongjong Sillok*) (DC684)

614. 1556 Jun 19
[Korea] King Myongjong 11th year, 5th month, day *keng-wu* (7). "At night, the SE and S directions were like a fire-vapour." (*Myongjong Sillok*) (DC685)

615. 1556 Jul 8
[Korea] King Myongjong 11th year, 6th month, day *chi-ch'ou* (26). "At night, the E, S and SW directions were like a fire-vapour." (*Myongjong Sillok*) (DC686)

616. 1556 Aug 11
[Korea] King Myongjong 11th year, 7th month, day *kuei-hai* (60). "At night, the E, S and W directions were like a fire-vapour." (*Myongjong Sillok*) (DC687)

617. 1556 Oct 30
[Korea] King Myongjong 11th year, 9th month, day *kuei-wei* (20). "At night, the SW direction was like a fire-vapour." (*Myongjong Sillok*) (DC688)

618. 1556 Nov 11
[Korea] King Myongjong 11th year, 10th month, day *i-wei* (32). "At night, the SE, S and SW directions were like a fire-vapour." (*Myongjong Sillok*) (DC689)

619. 1557 Feb 20
[Korea] King Myongjong 12th year, 1st month, day *ping-tzu* (13). "At night, the NE, E, SE and S directions were like a fire-vapour." (*Myongjong Sillok*) (DC690)

620. 1557 Mar 16
[China] Chia-ching reign-period 36th year, 2nd month, 16th day. "At Sh'in-Chow, the sky split apart several *chang*. Its light candle lit the Earth. After a long while then it was closed." (*Shan-hsi T'ung-chih*) (DC691)

621. 1557 Mar 25
[Korea] King Myongjong 12th year, 2nd month, day *chi-yu* (46). "At night, the E, SE, NW and W directions were like a fire-vapour." (*Myongjong Sillok*) (DC692)

622. 1557 Apr 28
[Korea] King Myongjong 12th year, 3rd month, day *kuei-wei* (20). "At night, the W, SW, S, SE and E directions were like a fire-vapour." (*Myongjong Sillok*) (DC693)

623. 1557 Jun 4
[Korea] King Myongjong 12th year, 5th month, day *keng-shen* (57). "At night, the SW and SE directions were like a fire-vapour." (*Myongjong Sillok*) (DC694)

624. 1557 Dec 12
[Korea] King Myongjong 12th year, 11th month, day *hsin-wei* (8). "At night, a vapour of fire rose from the E horizon with its flames pointing into the sky. It was about 1 *chang* in length and extinguished after a while." (*Myongjong Sillok*) (DC695)

625. 1558 Mar 6
[Korea] King Myongjong 13th year, 2nd month, day *i-wei* (32). "At night, the SE, E and N directions were like a fire-vapour." (*Myongjong Sillok*) (DC696)

626. 1558 Mar 16
[Korea] King Myongjong 13th year, 2nd month, day *i-szu* (42). "At night, the E and SE directions were like a fire-vapour." (*Myongjong Sillok*) (DC697)

627. 1558 Mar 17
[Korea] King Myongjong 13th year, 2nd month, day *ping-wu* (43). "At night, the SE, SW and E directions were like a fire-vapour." (*Myongjong Sillok*) (DC698)

628. 1558 Apr 16
[Korea] King Myongjong 13th year, 3rd month, day *ping-tzu* (13). "At night, the NW and SE directions were like a fire-vapour." (*Myongjong Sillok*) (DC699)

629. 1558 Apr 21
[Korea] King Myongjong 13th year, 4th month, day *hsin-szu* (18). "At night, the N, NE, SE, S and SW directions were like a fire-vapour." (*Myongjong Sillok*) (DC700)

630. 1558 May 4
[Korea] King Myongjong 13th year, 4th month, day *chia-wu* (31). "At night, the NW, SE and S directions were like a fire-vapour." (*Myongjong Sillok*) (DC701)

631. 1559 Feb 2
[Korea] King Myongjong 13th year, 12th month, day *wu-ch'en* (5). "At night, the W, E and S directions were like a fire-vapour." (*Myongjong Sillok*) (DC702)

632. 1559 Feb 9
[Korea] King Myongjong 14th year, 1st month, day *i-hai* (12). "At night, the E direction was like a fire-vapour." (*Myongjong Sillok*) (DC703)

633. 1559 Mar 7
[Korea] King Myongjong 14th year, 1st month, day *hsin-ch'ou* (38). "At night, in the NW, SW and E directions were like a fire-vapour." (*Myongjong Sillok*) (DC704)

634. 1559 Apr 4
[Korea] King Myongjong 14th year, 2nd month, day *chi-szu* (6). "At night, in the NE, SE and S directions were like a fire-vapour." (*Myongjong Sillok*) (DC705)

635. 1559 May 9
[Korea] King Myongjong 14th year, 4th month, day *chia-ch'en* (41). "At night, the NW and SE directions were like a fire-vapour." (*Myongjong Sillok*) (DC706)

636. 1559 Dec 19
[Korea] King Myongjong 14th year, 11th month, day *wu-tzu* (25). "At night, the SE and NW directions were like a fire-vapour." (*Myongjong Sillok*) (DC707)

637. 1559 Dec 24
[Korea] King Myongjong 14th year, 11th month, day *kuei-szu* (30). "At night, the S direction was like a fire-vapour." (*Myongjong Sillok*) (DC708)

638. 1560 Jan 2
[Korea] King Myongjong 14th year, 12th month, day *jen-yin* (39). "At night, the NE and SE directions were like a fire-vapour." (*Myongjong Sillok*) (DC709)

639. 1560 Mar 23
[Korea] King Myongjong 15th year, 2nd month, day *kuei-hai* (60). "At night, the SE and SW directions were like a fire-vapour." (*Myongjong Sillok*) (DC710)

640. 1560 Apr 17
[Korea] King Myongjong 15th year, 3rd month, day *wu-tzu* (25). "At night, the SE direction was like a fire-vapour." (*Myongjong Sillok*) (DC711)

641. 1560 Jun 24
[Korea] King Myongjong 15th year, 6th month, day *ping-shen* (33). "At night, the E and SE directions were like a fire-vapour." (*Myongjong Sillok*) (DC712)

642. 1560 Jun 26
[Korea] King Myongjong 15th year, 6th month, day *wu-hsu* (35). "At night, the NW and W directions were like a fire-vapour." (*Myongjong Sillok*) (DC713)

643. 1560 Jun 29
[Korea] King Myongjong 15th year, 6th month, day *hsin-ch'ou* (38). "At night, the E, S and W directions were like a fire-vapour." (*Myongjong Sillok*) (DC714)

644. 1561 Nov 8
[Korea] King Myongjong 16th year, 10th month, day *wu-wu* (55). "At night, the SW direction was like a fire-vapour." (*Myongjong Sillok*) (DC715)

645. 1562 May 7
[Korea] King Myongjong 17th year, 4th month, day *wu-wu* (55). "At night, the SW direction was like a fire-vapour." (*Myongjong Sillok*) (DC716)

646. 1562 Jun 7
[Korea] King Myongjong 17th year, 5th month, day *chi-ch'ou* (26). "At night, the S direction was like a fire-vapour." (*Myongjong Sillok*) (DC717)

647. 1563 Mar 16
[Korea] King Myongjong 18th year, 2nd month, day *hsin-wei* (8). "At night, the SE direction was like a fire-vapour." (*Myongjong Sillok*) (DC718)

648. 1563 Apr 18
[Korea] King Myongjong 18th year, 3rd month, day *chia-ch'en* (41). "At night, the SE direction was like a fire-vapour." (*Myongjong Sillok*) (DC719)

649. 1563 Apr 22
[Korea] King Myongjong 18th year, 4th month, day *wu-shen* (45). "At night, the SE and SW directions were like a fire-vapour." (*Myongjong Sillok*) (DC720)

650. 1563 Apr 26
[Korea] King Myongjong 18th year, 4th month, day *jen-tzu* (49). "At night, the E, SE and S directions were like a fire-vapour." (*Myongjong Sillok*) (DC721)

651. 1563 Jun 17
[Korea] King Myongjong 18th year, 5th month, day *chia-ch'en* (41). "At night, the SE and S directions were like a fire-vapour." (*Myongjong Sillok*) (DC722)

652. 1563 Jun 26
[Korea] King Myongjong 18th year, 6th month, day *kuei-ch'ou* (50). "At night, a band of yellow-white vapour rose from the SE and reached the N. It was like a piece of silk covering the sky. After a short while then it was extinguished." (*Myongjong Sillok*) (DC723)

653. 1563 Jul 24
[Korea] King Myongjong 18th year, 7th month, day *hsin-szu* (18). "Early in the evening, from the E to the NW there was a vapour with a blue-black colour. After a short while then it was extinguished." (*Myongjong Sillok*) (DC724)

654. 1564 Feb 8
[Korea] King Myongjong 19th year, 1st month, day *keng-tzu* (37). "At night, the SE direction was like a fire-vapour." (*Myongjong Sillok*) (DC725)

655. 1564 Feb 12
[Korea] King Myongjong 19th year, 2nd month, day *chia-ch'en* (41). "At night, the SW and NE directions were like a fire-vapour." (*Myongjong Sillok*) (DC726)

656. 1564 Mar 11
[Korea] King Myongjong 19th year, 2nd month, day *jen-shen* (9). "At night, the SE and N directions were like a fire-vapour." (*Myongjong Sillok*) (DC727)

657. 1564 Apr 15
[Korea] King Myongjong 19th year, 3rd month, day *ting-wei* (44). "At night, the SE direction was like a fire-vapour." (*Myongjong Sillok*) (DC728)

658. 1566 Feb 23
[Korea] King Myongjong 21st year, 2nd month, day *ping-yin* (3). "At night, the SW, SE and E directions were like a fire-vapour." (*Myongjong Sillok*) (DC729)

659. 1566 Mar 26
[Korea] King Myongjong 21st year, 3rd month, day *ting-yu* (34). "At night, in the S direction there was a red vapour. Amid the blazing flames there was a vapour like a flared-up torch; it was standing erect with a length of about 2 *ch'ih* and it kept on flickering. After a long while then it was ceased." (*Chungbo Munhon Pigo*, 8) (DC730)

660. 1566 Aug 10
[Korea] King Myongjong 21st year, 7th month, day *chia-shen* (21). "At night, the SE direction was like a fire-vapour." (*Myongjong Sillok*) (DC731)

661. 1566 Nov 3
[Korea] King Myongjong 21st year, 10th month, day *i-mao* (52) (read *chi-mao* (16)). "At night, the SE and S directions were like a fire-vapour." (*Myongjong Sillok*) (DC732)

662. 1567 May 7
[Korea] King Myongjong 22nd year, 3rd month, day *chia-shen* (21). "At night, the SE, S, SW and NW directions were like a fire-vapour." (*Myongjong Sillok*) (DC733)

663. 1567 May 11
[Korea] King Myongjong 22nd year, 4th month, day *wu-tzu* (25). "At night, the SE and SW directions were like a fire-vapour." (*Myongjong Sillok*) (DC734)

664. 1568 Aug 25
[China] Lung-ch'ing reign-period 2nd year, 8th month, day *chia-ch'en* (41). The sky split apart at the NW of Chian-chow. It lasted from 1 to 5 a.m. then it was closed." (*Ming-shih*, 27) (DC735)

665. 1573
[China] Wan-li reign-period 1st year. "At Chian-chow, the sky split apart." (*Shan-hsi T'ung-chih*) (DC736)

666. 1582 Mar 8
(i) [Japan] Tensho reign-period 10th year, 2nd month, 14th day. "Tonight, there was a red cloudy vapour in the sky." (*Nihon Temmon Shiryo*, 8) (DC738)

(ii) [Japan] Tensho reign-period 10th year, 2nd month, 14th day, *kuei-mao* (40). "At night, there was a red vapour filling the N sky." (*Nihon Temmon Shiryo*, 8) (DC738)

667. 1583 Feb 14

(i) [Japan] Tensho reign-period 11th year, 1st month, 22nd day, *ping-tzu* (13). "A light was seen in the NE direction." (*Nihon Temmon Shiryo*, 7) (DC739)

(ii) [Japan] "On the Jui Mountain, fire columns were burning and lasted quite a while. The time was at night." (*Nihon Temmon Shiryo*, 7) (DC739)

668. 1587 Mar 4

[Japan] Tensho reign-period 15th year, 1st month, 25th day. "At night, there was a red vapour filling the N sky." (*Nihon Temmon Shiryo*, 8) (DC740)

669. 1588 Apr 5

[Japan] Tensho reign-period 16th year, 3rd month, 10th day. "In the hours of midnight, it could be seen from the woods of the temple that in the near N direction, to the N of the Ch'un-jih Mountain and near the barren temple, there rose columns of fire which were taller than even the Yu Mountain." (*Nihon Temmon Shiryo*, 7) (DC741)

670. 1588 Jul 24

[Korea] King Sonjo 21st year, intercalary 6th month, day *i-szu* (42). "A report from a town in the north: On the 2nd day of this month at the 2nd watch, there was a lump of fire shaped like a man sitting on a round mat or said that he was carrying bows and arrows. It floated and flew in the air towards N. Shortly afterwards, there was a thundering noise like the cracking of ice. The wind brought the heat of the vapour onto people's face. This strange happenning is an extraordinary matter." (*Sonjo Sillok*) (DC742)

671. 1591 Aug

[Korea] King Sonjo 24th year, 7th month. "A red vapour rose in the E direction. It divided into three branches, one branch extended towards the N across the whole sky; one branch extended towards the W across half of the sky; one branch extended towards the S again across half of the sky. Their lights candle lit the Earth." (*Sonjo Sillok*) (DC743)

672. 1593 Nov 27

[Korea] King Sonjo 26th year, 11th month, day *i-mao* (52). "At the 1st watch, in the E direction there was a fire-vapour." (*Sonjo Sillok*) (DC744)

673. 1594 Jan 5

[Korea] King Sonjo 26th year, intercalary 11th month, day *chia-wu* (31). "At the 1st watch, in the W direction there was a red vapour." (*Sonjo Sillok*) (DC745)

674. 1594 Jan 13

[Korea] King Sonjo 26th year, intercalary 11th month, day *jen-yin* (39). "At the 1st watch, in the W direction there was a red vapour." (*Sonjo Sillok*) (DC746)

675. 1594 Feb 11

[Korea] King Sonjo 26th year, 12th month, day *hsin-wei* (8). "At night, in all directions there were red ominous vapour." (*Sonjo Sillok*) (DC747)

676. 1594 Mar 20

[Korea] King Sonjo 27th year, 1st month, day *wu-shen* (45). "At night, at the 1st watch, in the E and NW directions there were fire-vapours." (*Sonjo Sillok*) (DC748)

677. 1595 Mar 20
[Korea] King Sonjo 28th year, 2nd month, day *kuei-ch'ou* (50). "At night, at the 1st and 2nd watch, the SE and SW directions were like a fire-vapour." (*Sonjo Sillok*) (DC749)

678. 1595 Apr 30
[Korea] King Sonjo 28th year, 3rd month, day *chia-wu* (31). "At night, at the 1st watch, in the NE direction, amongst the clouds it was like a fire-vapour. (*Sonjo Sillok*) (DC750)

679. 1596 Oct 31
[Korea] King Sonjo 29th year, 9th month, day *chia-ch'en* (41). "Just before daybreak, a blue-red vapour rose in the NW horizon and pointed towards the sky. Its width was just visible and body length was about 5 to 6 *chang*. It lasted a long while then it was extinguished." (*Sonjo Sillok*) (DC752)

680. 1596 Dec 26
[Korea] King Sonjo 29th year, 11th month, day *keng-tzu* (37). "At night, at the 1st watch, in the SE direction there was a fire-like vapour. When it started to move then it extinguished." (*Sonjo Sillok*) (DC753)

681. 1597 Feb 5
[Korea] King Sonjo 29th year, 12th month, day *kuei-wei* (20). "A report: 'On the 19th day of this month, at the 2nd watch of the night, in all directions there were vapours of fire. Their tails were like comets and resembled a piece of silk. They were shining with a white light and all were pointing into the sky. What had been seen were frighfully strange.'" (*Sonjo Sillok*) (DC754)

682. 1597 Feb 17
[Korea] King Sonjo 30th year, 1st month, day *kuei-szu* (30). "At night, from the 1st to 2nd watch, in the SE direction there was a red vapour with a width of more than 2 *ch'ih* and a length of more than 10 *chang*. It rose from the horizon and pointed into the sky. Its light was shining onto the ground. In the S and SW directions, they were also like this." (*Sonjo Sillok*) (DC755)

683. 1597 Feb 18
[Korea] King Sonjo 30th year, 1st month, day *chia-wu* (31). "At night, at the 1st and 2nd watch there was a red vapour." (*Sonjo Sillok*) (DC756)

684. 1597 Feb 20
[Korea] King Sonjo 30th year, 1st month, day *ping-shen* (33). "At night, at the 1st watch, in the E and S directions there were red vapours." (*Sonjo Sillok*) (DC757)

685. 1597 Feb 22
[Korea] King Sonjo 30th year, 1st month, day *wu-hsu* (35). "At night, at the 1st and 2nd watch, in the S and SW directions there were red vapours." (*Sonjo Sillok*) (DC758)

686. 1599 Mar 23
[Korea] King Sonjo 32nd year, 2nd month, day *ting-ch'ou* (14). "At night, there were violet vapours like arrows and spears, four in the SE direction and one in the W direction. They were advancing to and fro with one and another. When they started to move then they extinguished." (*Sonjo Sillok*) (DC759)

687. 1599 Mar 27
[Korea] King Sonjo 32nd year, 3rd month, day *hsin-szu* (18). "At night, at the 2nd

watch, in three directions E, W and S, there were flame-like red vapour." (*Sonjo Sillok*) (DC760)

688. 1601 Jan 28
[Korea] King Sonjo 33rd year, 12th month, day *chia-tzu* (1). "... a red vapour first rose in the SE direction and then in the NW direction. It started to move and covered the sky. It shone brilliantly in all directions such that shadows of people could be seen. It lasted a long while then it dispersed." (*Sonjo Sillok*) (DC761)

689. 1601 Mar 31
[Korea] King Sonjo 34th year, 2nd month, day *ping-shen* (33). "At night, at the 1st watch, in the SW direction there was a fire-like vapour. Its length was about 7 or 8 *ch'ih* and width was more than 1 *ch'ih*. It lasted a long while then it extinguished." (*Sonjo Sillok*) (DC762)

690. 1601 Apr 4
[Korea] King Sonjo 34th year, 3rd month, day *keng-tzu* (37). "At the 1st watch, the NE and SW directions were like a fire-vapour. At the 5th watch, the NE, SW and SE directions were like a fire-vapour." (*Sonjo Sillok*) (DC763)

691. 1602 Dec 27
[Korea] King Sonjo 35th year, 11th month, day *jen-shen* (9). "At night, from the 1st to 3rd watch, in the NE direction there was a fire-like vapour." (*Sonjo Sillok*) (DC764)

692. 1603 Feb 1
[Korea] King Sonjo 35th year, 12th month, day *wu-shen* (45). "At night, at the 1st watch, in the SE direction, amongst the dense clouds there was a fire-like vapour. Its length was more than 1 *chang* and width was about several *ch'ih*." (*Sonjo Sillok*) (DC765)

693. 1603 Feb 5
[Korea] King Sonjo 35th year, 12th month, day *jen-tzu* (49). "At night, at the 1st watch, in the NE direction there was a red vapour. It lasted for a long while then it extinguished." (*Sonjo Sillok*) (DC766)

694. 1603 Jul 3
[Korea] King Sonjo 35th year, 12th month, day *keng-ch'en* (17). "At night, at the 1st and 2nd watch, in the S direction there was as if a fire-vapour." (*Sonjo Sillok*) (DC767)

695. 1604 Feb 27
[Korea] King Sonjo 37th year, 1st month, day *chi-mao* (16). "At night, at the 1st watch, the E and SE directions were like a fire-vapour. (*Sonjo Sillok*) (DC768)

696. 1604 Dec 15
[Korea] King Sonjo 37th year, 10th month, day *hsin-wei* (8). "At night, at the 1st watch, the E direction there was a fire-like vapour." (*Sonjo Sillok*) (DC769)

697. 1605 Jan 17
[Korea] King Sonjo 37th year, 11th month, day *chia-ch'en* (41). "In the early evening, in every direcion amongst the dark clouds there was a red vapour blazing like flames. It first rose in the SE direction. Amidst the blaze there was another band of vapour like the burning fire of a torch. It was standing upright with a length of about 2 to 3 *chang*.

Then red vapours also rose in the S, SW, W , NW, N and E directions in that order. Their shapes and sizes were more or less the same and were constantly flickering. Until the 4th watch, the clouds were dense and the snow was falling, they were not seen." (*Sonjo Sillok*) (DC771)

698. 1605 Feb 10
[Korea] King Sonjo 37th year, 12th month, day *wu-ch'en* (5). "At night, at the 1st watch, in the NE, E and S directions there were vapours like fire. They were constantly flickering." (*Sonjo Sillok*) (DC772)

699. 1605 Mar 8
[Korea] King Sonjo 38th year, 1st month, day *chia-wu* (31). "At night, at the 1st and 2nd watch, in all directions there were red vapours like the colour of fire." (*Sonjo Sillok*) (DC773)

700. 1605 Mar 11
[Korea] King Sonjo 38th year, 1st month, day *ting-yu* (34). "At night, at the 1st watch, in the S direction there was a red vapour blazing like flames. Within it there was a band of vapour like a torch fire standing in an upright position. It was about 2 *ch'ih* in length and constantly wavering. After a long while then it was ceased. At the 2nd watch, there was a band of white vapour shaped like a standing broom. It penetrated the 3rd star of Kou-chen. Its length was about 1 *ch'ih*. Until the end of the 2nd watch then it was extinguished." (*Sonjo Sillok*) (DC774)

701. 1605 Mar 21
[Korea] King Sonjo 38th year, 2nd month, day *ting-wei* (44). "At night, at the 1st watch, in the NW, E and S directions there were red vapours like flames." (*Sonjo Sillok*) (DC775)

702. 1606 Jan 30
[Korea] King Sonjo 38th year, 12th month, day *chi-szu* (6). "A report: 'On the 22nd day of this month, at the 1st watch, there was a band of red vapour in the sky above the S horizon. Its light was like a flame. It had a shape like a piece of silk cloth. Sometime it stretched across the whole sky, sometime half of the sky. And moments later, another band rose to follow, its shape was like before. At the 3rd watch then they were extinguished. Those places which had been lit by the flames were bright as the colour of a faint moon. These strange happenings were extraordinary events.'" (*Sonjo Sillok*) (DC776)

703. 1606 Apr 7
[Korea] King Sonjo 39th year, 3rd month, day *chi-szu* (6). "At night, the 1st to 2nd watch, there was a red vapour." (*Sonjo Sillok*) (DC777)

704. 1611 Mar 10
[Korea] King Kwanghae-gun 3rd year, 1st month, day *ting-mao* (4). "At night, at the 1st watch, in three directions E, W and N there were red vapours. Five of which were shaped like torches. After a long while then they were extinguished." (*Kwanghae-gun Sillok*) (DC779)

705. 1613 Apr 16
[Korea] King Kwanghae-gun 5th year, 2nd month, day *i-mao* (52). "At night, at the 1st

watch, there were red vapours as large as one to two arms' stretches and 3 to 4 *chang* in length. They shaped like torches. Three of these lined up below *Pei-tou*, two in the S direction and one each in the E and SE directions. After a long while then they were extinguished." (*Kwanghae-gun Sillok*) (DC780)

706. 1618 May 17
(i) [China] T'ien-ming reign-period 3rd year, 4th month, day *jen-tzu* (49). "There were two bands of blue-black vapour stretching across the sky from W to E. (*Ch'ing-shih-kao*, 39) (DC782)

(ii) [China] (T'ien-ming reign-period 3rd year, 4th month, day *jen-tzu* (49)). "This evening, there were two bands of blue-black vapour stretching across the sky from W to E. (*Ch'ing-shih-lu*, 5) (DC782)

707. 1618 Jul 19
[China] T'ien-ming reign-period 3rd year, 5th month, day *i-mao* (52). "There were three vapours of red, green and white hanging down from the sky. They wavered left and right; the top was circular like a door." (*Ch'ing-shih-kao*, 31) (DC783)

708. 1618 Nov 17
[Korea] King Kwanghae-gun 10th year, 10th month, day *ping-ch'en* (53). "At night, at the 1st watch, in NW and NE directions there were vapours like flames." (*Kwanghae-gun Sillok*) (DC784)

709. 1618 Dec 14
[Korea] King Kwanghae-gun 10th year, 10th month, day *kuei-wei* (20). "At night, in the E direction there was a flame-like vapour." (*Kwanghae-gun Sillok*) (DC785)

710. 1619 Jan 4
[Korea] King Kwanghae-gun 10th year, 11th month, day *chia-ch'en* (41). "At night, a band of green-white vapour rose from the NW and pointed straight towards the E. Its length extended across the whole sky and width was about 2 to 3 *ch'ih*." (*Kwanghae-gun Sillok*) (DC786)

711. 1619 Jan 5
[Korea] King Kwanghae-gun 10th year, 11th month, day *i-szu* (42). "At night, in the S direction there was a flame-like vapour. Also there was a red vapour standing upright with a length of 3 to 4 *ch'ih* and width of more than 1 ch'ih. After a long while then they were extinguished." (*Kwanghae-gun Sillok*) (DC787)

712. 1619 Jan 7
[Korea] King Kwanghae-gun 10th year, 11th month, day *ting-wei* (44). "At night, in the E direction there was a flame-like vapour." (*Kwanghae-gun Sillok*) (DC788)

713. 1620 Oct 19
[China] Wan-li reign-period 48th year, 9th month, 24th day. "A red vapour stretched across the sky." (*Chang-shan Hsien-chih*) (DC789)

714. 1623 Mar 28
[Korea] King Kwanghae-gun 15th year, 2nd month, day *wu-tzu* (25). "At night, green-red vapours rose from the SW towards the sky as they fought among themselves. At the 4th watch, the SE was the same." (*Kwanghae-gun Sillok*) (DC790)

715. 1624 Feb 21 and Feb 25
[Korea] King Injo 2nd year, 1st month, day *jen-hsu* (59). "The 3rd day of this month, at the 1st watch, in the W direction there was a red vapour with an extraordinary shape. The common people who saw it were frighten. The officials on duty were reluctant to go up the observatory to observe, hence the director of the observatory requested their punishment. At night, at the 1st watch, in the E, SE and W directions there were vapours like flames. At the 4th watch, in the S direction there was a flame-like vapour." (*Injo Sillok*) (DC791-792)

716. 1624 Feb 26
[Korea] King Injo 2nd year, 1st month, day *kuei-hai* (60). "At night, at the 3rd watch, in the SE direction there was a flame-like vapour. At the 4th and 5th watch, in the NE, SE and SW directions there were vapours like flames." (*Injo Sillok*) (DC793)

717. 1624 Mar 21
[Korea] King Injo 2nd year, 2nd month, day *ting-hai* (24). "At the 1st watch, in SE direction there was a fire-like vapour." (*Injo Sillok*) (DC794)

718. 1624 Apr
[China] T'ien-ch'i reign-period 4th year, 3rd month. "Every village near Hang-chow and Chia-hsing reported that flames were seen in the sky at midnight like galloping calvary horses, and obscure clinking noises of spears or lances were heard." (*Chia-hsing Hsien-chih* and *Chia-hsing Fu-chih*) (DC795)

719. 1624 Apr 18
[Korea] King Injo 2nd year, 3rd month, day *i-mao* (52), 1st day of the month. "Just before daybreak, in the SE there was a flame-like vapour. At night, in the S, NE, SE and SW directions there were vapours like flames." (*Injo Sillok*) (DC796)

720. 1624 Apr 19
[Korea] King Injo 2nd year, 3rd month, day *ping-ch'en* (53). "In the early evening, in the E direction there was a flame-like vapour." (*Injo Sillok*) (DC797)

721. 1624 Apr 21
[Korea] King Injo 2nd year, 3rd month, day *wu-wu* (55). "Just before daybreak, in the E direction there was a flame-like vapour. At night, in the E direction, a red vapour shone brilliantly on the horizon. In the N and SW directions there were vapours like flames." (*Injo Sillok*) (DC798)

722. 1624 Jun 9
[Korea] King Injo 2nd year, 4th month, day *ting-wei* (44). "At night, a blue-red vapour from the W direction pointed towards the NE direction. In the S direction there was a vapour like the moon-light." (*Injo Sillok*) (DC799)

723. 1624 Jul 12
[Korea] King Injo 2nd year, 5th month, day *chi-mao* (16). "At night, in the SW direction there was a red vapour like fire." (*Injo Sillok*) (DC800)

724. 1624 Jul 13
[Korea] King Injo 2nd year, 5th month, day *keng-ch'en* (17). "At night, in all directions there was a fire-like vapour." (*Injo Sillok*) (DC801)

725. 1624 Dec 31
[Korea] King Injo 2nd year, 11th month, day *jen-shen* (9). "At night, in the SW direction there was a flame-like vapour." (*Injo Sillok*) (DC802)

726. 1625 Feb 6
[Korea] King Injo 2nd year, 12th month, day *chi-yu* (46). "At night, in the SW direction there was a flame-like vapour." (*Injo Sillok*) (DC803)

727. 1625 Feb 9
[Korea] King Injo 3rd year, 1st month, day *jen-tzu* (49). "At night, in the NW direction there was a flame-like vapour." (*Injo Sillok*) (DC804)

728. 1625 Mar 2
[Korea] King Injo 3rd year, 1st month, day *kuei-yu* (10). "At night, there was a flame-like vapour." (*Injo Sillok*) (DC805)

729. 1625 Mar 6
[Korea] King Injo 3rd year, 1st month, day *ting-ch'ou* (14). "At night, in the E and W directions there were flame-like vapours." (*Injo Sillok*) (DC806)

730. 1625 Mar 11
[Korea] King Injo 3rd year, 2nd month, day *jen-wu* (19). "At night, in the NE and SW directions there were flame-like vapours." (*Injo Sillok*) (DC807)

731. 1625 Mar 31
[Korea] King Injo 3rd year, 2nd month, day *jen-yin* (39). "At night, in the SE and NE directions there were flame-like vapours." (*Injo Sillok*) (DC808)

732. 1625 Apr 2
[Korea] King Injo 3rd year, 2nd month, day *chia-ch'en* (41). "In all directions there were flame-like vapours." (*Injo Sillok*) (DC809)

733. 1625 Apr 7
[Korea] King Injo 3rd year, 3rd month, day *chi-yu* (46), 1st day of the month. "At night, in the N and SE directions there were flame-like vapours." (*Injo Sillok*) (DC810)

734. 1625 Apr 8
[Korea] King Injo 3rd year, 3rd month, day *keng-hsu* (47). "At night, in the E and SE directions there were flame-like vapours." (*Injo Sillok*) (DC811)

735. 1625 Apr 11
[Korea] King Injo 3rd year, 3rd month, day *kuei-ch'ou* (50). "At night, in the NE, SE and SW directions there were flame-like vapours." (*Injo Sillok*) (DC812)

736. 1625 Aug 4
[Korea] King Injo 3rd year, 7th month, day *wu-shen* (45). "At night, in the NE direction there was a vapour like fire." (*Injo Sillok*) (DC813)

737. 1625 Aug 13
[Korea] King Injo 3rd year, 7th month, day *ting-szu* (54). "At night, a band of green-white vapour rose from the NE horizon. It pointed vertically into the sky with a length of more than 10 *chang*." (*Injo Sillok*) (DC814)

738. 1625 Aug 28
[Korea] King Injo 3rd year, 7th month, day *jen-shen* (9). "At night, in the NW and SW directions there were flame-like vapours." (*Injo Sillok*) (DC815)

739. 1625 Sep 16
[Korea] King Injo 3rd year, 8th month, day *hsin-mao* (28). "In the early evening, in the NE and NW directions there were flame-like vapours." (*Injo Sillok*) (DC816)

740. 1625 Sep 20
[Korea] King Injo 3rd year, 8th month, day *i-wei* (32). "At night, in the NE and SW directions there were flame-like vapours." (*Injo Sillok*) (DC817)

741. 1625 Nov 2
[Korea] King Injo 3rd year, 10th month, day *wu-yin* (15). "At night, in the SW direction there was a flame-like vapour." (*Injo Sillok*) (DC818)

742. 1625 Nov 24
[Korea] King Injo 3rd year, 10th month, day *keng-tzu* (37). "At night, in the S direction there was a flame-like vapour." (*Injo Sillok*) (DC819)

743. 1625 Nov 30
[Korea] King Injo 3rd year, 11th month, day *ping-wu* (43), 1st day of the month. "At night, in the SW direction there was a flame-like vapour." (*Injo Sillok*) (DC820)

744. 1625 Dec 15
[Korea] King Injo 3rd year, 11th month, day *hsin-yu* (58). "At night, in the SW and NE directions there were flame-like vapours." (*Injo Sillok*) (DC821)

745. 1625 Dec 28
[Korea] King Injo 3rd year, 11th month, day *chia-hsu* (11). "At night, there was a flame-like vapour." (*Injo Sillok*) (DC822)

746. 1626 Jan 3
[Korea] King Injo 3rd year, 12th month, day *keng-ch'en* (17). "At night, in the E direction there was a flame-like vapour." (*Injo Sillok*) (DC823)

747. 1626 Jan 25
[Korea] King Injo 3rd year, 12th month, day *jen-yin* (39). "At night, in the W direction there was a flame-like vapour." (*Injo Sillok*) (DC824)

748. 1626 Jan 26 to 27
[Korea] King Injo 3rd year, 12th month, day *kuei-mao* (40). "At night, in the SW direction there was a flame-like vapour." (*Injo Sillok*) (DC825-826)

749. 1626 Mar 6
[Korea] King Injo 4th year, 2nd month, day *jen-wu* (19). "At the 5th watch, in the E and SE directions there were flame-like vapours." (*Injo Sillok*) (DC827)

750. 1626 Mar 18
[Korea] King Injo 4th year, 2nd month, day *chia-wu* (31). "At night, at the 1st and 2nd watch, in the S direction there was a flame-like vapour." (*Injo Sillok*) (DC828)

751. 1626 Mar 19
[Korea] King Injo 4th year, 2nd month, day *i-wei* (32). "At night, in the S direction there was a flame-like vapour." (*Injo Sillok*) (DC829)

752. 1626 Mar 20 to 21
[Korea] King Injo 4th year, 2nd month, day *ping-shen* (33) and *ting-yu* (34). "At night, in E and SE directions there were flame-like vapours." (*Injo Sillok*) (DC830-831)

753. 1626 Mar 22
[Korea] King Injo 4th year, 2nd month, day *wu-hsu* (35). "At night, in the NW, SE and S directions there were flame-like vapours." (*Injo Sillok*) (DC832)

754. 1626 Mar 23
[Korea] King Injo 4th year, 2nd month, day *chi-hai* (36). "At night, in the SE direction there was a flame-like vapour." (*Injo Sillok*) (DC833)

755. 1626 Mar 25
[Korea] King Injo 4th year, 2nd month, day *hsin-ch'ou* (38). "At night, in the E direction there was a flame-like vapour." (*Injo Sillok*) (DC834)

756. 1626 Mar 29
[Korea] King Injo 4th year, 3rd month, day *i-szu* (42). "At night, in the S direction there was a vapour like flames shining down on Earth." (*Injo Sillok*) (DC835)

757. 1626 Mar 31
[Korea] King Injo 4th year, 3rd month, day *ting-wei* (44). "At night, in the S direction there was a flame-like vapour." (*Injo Sillok*) (DC836)

758. 1626 Apr 2
[Korea] King Injo 4th year, 3rd month, day *chi-yu* (46). "At night, in the NE and E directions there were flame-like vapours." (*Injo Sillok*) (DC837)

759. 1626 Apr 3
[Korea] King Injo 4th year, 3rd month, day *keng-hsu* (47). "At night, in the S direction there was a flame-like vapour." (*Injo Sillok*) (DC838)

760. 1626 Apr 18
[Korea] King Injo 4th year, 3rd month, day *i-ch'ou* (2). "At night, in the NE, SE and S directions there were flame-like vapours." (*Injo Sillok*) (DC839)

761. 1626 Apr 20
[Korea] King Injo 4th year, 3rd month, day *ting-mao* (4). "At night, in the E and NE directions there were flame-like vapours." (*Injo Sillok*) (DC840)

762. 1626 Apr 22
[Korea] King Injo 4th year, 3rd month, day *chi-szu* (6). "At night, in the NE, E, SE and S directions there were flame-like vapours." (*Injo Sillok*) (DC841)

763. 1626 Apr 28
[Korea] King Injo 4th year, 4th month, day *i-hai* (12). "At night, at the 1st watch, in the S direction there was a flame-like vapour." (*Injo Sillok*) (DC842)

764. 1626 Jun 7
[Korea] King Injo 4th year, 5th month, day *i-mao* (52). "At night, at the 1st watch, a

band of green-white vapour rose in the SW direction and pointed upwards into the sky. Its length was 3 to 4 *chang* and width was about 1 *ch'ih*. After a long while then it was extinguished." (*Injo Sillok*) (DC843)

765. 1626 Jun 16
[Korea] King Injo 4th year, 5th month, day *chia-tzu* (1). "At night, in the SW and E directions there were flame-like vapours." (*Injo Sillok*) (DC844)

766. 1626 Jun 24
[Korea] King Injo 4th year, 6th month, day *jen-shen* (9), 1st day of the month. "At night, in the W, E and NE directions there were flame-like vapours." (*Injo Sillok*) (DC845)

767. 1626 Dec 7
[Korea] King Injo 4th year, 11th month, day *wu-wu* (55). "At night, at the 1st watch, in the W direction there was a flame-like vapour." (*Injo Sillok*) (DC846)

768. 1626 Dec 11
[Korea] King Injo 4th year, 11th month, day *jen-hsu* (59). "At night, on the E horizon there was a flame-like vapour." (*Injo Sillok*) (DC847)

769. 1626 Dec 16
[Korea] King Injo 4th year, 10th month, day *ting-mao* (4). "At night, in the NW direction there was a flame-like vapour." (*Injo Sillok*) (DC848)

770. 1626 Dec 18
[Korea] King Injo 4th year, 10th month, day *chi-szu* (6). "At night, in the E direction there was a flame-like vapour." (*Injo Sillok*) (DC849)

771. 1626 Dec 19
[Korea] King Injo 4th year, 11th month, day *keng-wu* (7), 1st day of the month. "At night, at the 1st watch, in the S direction there was a flame-like vapour. From the 2nd to 4th watch, in the E and SW directions there were flame-like vapours." (*Injo Sillok*) (DC850)

772. 1626 Dec 26
[Korea] King Injo 4th year, 11th month, day *ting-ch'ou* (44). "At night, at the 3rd watch, in the SW direction there was a flame-like vapour." (*Injo Sillok*) (DC851)

773. 1627 Jan 16
[Korea] King Injo 4th year, 11th month, day *wu-hsu* (35). "At night, in the S and SE directions there were flame-like vapours." (*Injo Sillok*) (DC852)

774. 1627 Jan 24
[Korea] King Injo 4th year, 12th month, day *ping-wu* (43). "At night, at the 1st and 2nd watch, a band of green-white vapour rose in the NE direction and pointed straight towards the NW. Its length was 3 to 4 *chang*." (*Injo Sillok*) (DC853)

775. 1627 Feb 4
[Korea] King Injo 4th year, 12th month, day *ting-szu* (54). "At night, in the SW, E and SE directions there were flame-like vapours." (*Injo Sillok*) (DC854)

776. 1627 Feb 9
[Korea] King Injo 4th year, 12th month, day *jen-hsu* (59). "At night, in the S and NE directions there were flame-like vapours." (*Injo Sillok*) (DC855)

777. 1628 Apr 4
[Korea] King Injo 6th year, 3rd month, day *jen-hsu* (59). "At night, at the 2nd watch, in all directions there were flame-like vapours." (*Injo Sillok*) (DC856)

778. 1629 Sep 4
[Korea] King Injo 1st year, 3rd month, day *hsin-szu* (18). "Just before daybreak, a blue-red vapour of fire, nor an illusion or a halo, was standing on the SW direction and pointing into the sky. Its width was several tens of *ch'ih*." (*Injo Sillok*) (DC858)

779. 1631 Sep 21
[China] T'ien-ts'ung reign-period 5th year, 8th month, day *ting-mao* (4). "... a thick fog, such that people could not be seen. Suddenly, there was a blue-green vapour from the sky rushed into the enemy camp. And very sudden, its middle part opened like a door. Our soldiers hence won." (*Ch'ing-shih-kao*, 39) (DC859)

780. 1633 Feb 9
[Korea] King Injo 11th year, 1st month, day *chia-wu* (31). "A red vapour pillared the sky." (*Injo Sillok*) (DC860)

781. 1634 Feb
[China] Ch'ung-cheng reign-period 7th year, 1st month. "A multi-coloured vapour like rings of different sizes was everywhere in the sky. After a long time then it was extinguished." (*Yen-shan Hsien-chih* and *T'ien-tsin Fu-chih*) (DC861)

782. 1634 Mar 16
[Korea] King Injo 12th year, 2nd month, day *chia-hsu* (11). "Just after moonrise, there was a red vapour shaped like a torch-fire." (*Injo Sillok*) (DC862)

783. 1635 Dec 15
[Korea] King Injo 13th year, 10th month, day *wu-shen* (45). "In the E direction there was a flame-like vapour." (*Injo Sillok*) (DC864)

784. 1638 Dec 23
[China] Ch'ung-cheng reign-period 11th year, 11th month, 19th day. "In the NE there were several tens of bands of red vapour like swords and lances arranged in a line." (*Tung-cheng Hsu-hsiu Hsien-chih*) (DC865)

785. 1639 Apr 8
[Korea] King Injo 17th year, 3rd month, day *kuei-hai* (60). "In the SE direction, a red vapour lit the sky like candles." (*Injo Sillok*) (DC866)

786. 1639 Apr
[China] Ch'ung-cheng reign-period 12th year, 3rd month. "In Chen-chow, at night, there was a five-coloured rainbow descended on the ground for several *k'o* (about an hour)." (*Chi-chou Chih*) (DC867)

787. 1640 Dec 24
[China] Ch'ung-cheng reign-period 13th year, 11th month, 12th day. "A short time after the 1st watch, a red vapour filled the sky." (*Ching-Chiang Hsien-chih*) (DC868)

788. 1643 Sep 26
[China] Ch'ung-cheng reign-period 16th year, 8th month, 14th day. "At night, at the county of Li-cheng, the stars and moon were clear and bright, and there was not a single cloud or thunder. A dragon ascended with a wriggling motion and glittered with a golden light. All windows and doors reflected the yellow light." (*Lu-an Fu-chih*) (DC870)

789. 1644 Feb 8
[China] Ch'ung-cheng reign-period 17th year, 1st month, 1st day. "In the hours of *yin* (3–5 a.m.), a red vapour stretched across the sky." (*Chen-ting Hsien-chih*) (DC871)

790. 1646 Mar 1
[China] Shun-chih reign-period 3rd year, 1st month, day *jen-hsu* (59). "At night, in the N direction amongst the clouds there was a red light similar to a shadow of fire." (*Ch'ing-shih-kao*, 39) (DC872)

791. 1648 Jan
[China] Shun-chih 5th year, 12th month, 30th day. "At the 1st watch, there were hanging white clothes similar to coarse sackclothes. Four pieces of the clothes spread out vertically into approximately several tens of bands. The cold light reflected down made one's heart and eyes palpitated." (*Ch'ing-shih-kao*)

792. 1648 Summer
[China] Shun-chih reign-period 5th year, summer. "In the county of Chia-Ting, a red vapour was seen stretching across the E." (*Ch'ing-shih-kao*, 41) (DC874)

793. 1648 Nov 16
[Korea] King Injo 26th year, 10th month, day *kuei-szu* (30). "At night, in the E direction there was a red vapour like a dragon or snake." (*Injo Sillok*) (DC875)

794. 1650 Feb 27
[China] Shun-chih reign-period 7th year, 1st month, 27th day. "At night, to the west of the River Wang there was a blue vapour stretching across the sky." (*Ch'ing-shih-kao*, 42) (DC876)

795. 1651 Feb 19
[China] Shun-chih 7th year, 12th month, 30th day. "In the Hsiao district, several tens of white vapour like coarse sackclothes were seen. The reflected cold light dazzled people." (*Ch'ing-shih-kao*)

796. 1655 Jul 20
[China] Shun-chih reign-period 12th year, 6th month, day *keng-wu* (7). "In the N direction there was a blue-black cloudy vapour changing shapes like a dragon." (*Ch'ing-shih-kao*, 39) (DC878)

797. 1659 Jan 16
[China] Shun-chih reign-period 15th year, 12th month, 24th day. "At night, in Lungyang county there were 3 bands of red light. They shone vertically into the city like a torch. It began to disappear at dawn." (*Hu-nan T'ung-chih*, 2) (DC879)

798. 1660 Jan 13
[Korea] King Hyonjong 1st year, 12th month, day *wu-tzu* (25). "At night, at the 1st watch, there was a flame-like vapour." (*Hyonjong Sillok*) (DC880)

799. 1660 Jan 15
[Korea] King Hyonjong 1st year, 12th month, day *keng-yin* (27). "At night, there was a flame-like vapour." (*Hyonjong Sillok*) (DC881)

800. 1660 Jan 24
[Korea] King Hyonjong 1st year, 12th month, day *chi-hai* (36). "At night, in the SE and SW directions there were flame-like vapours." (*Hyonjong Sillok*) (DC882)

801. 1660 Jan 31
[Korea] King Hyonjong 1st year, 12th month, day *ping-wu* (43). "In the SE direction there was a flame-like vapour." (*Hyonjong Sillok*) (DC883)

802. 1666 Mar 14
[China] K'ang-hsi reign-period 5th year, 2nd month, day *keng-shen* (57). "In the hours of *hai* (9–11 p.m.), at the zenith there were 4 or 5 bands of green-white vapour. (*Ch'ing-shih-kao*, 39) (DC884)

803. 1667 Feb 12
[China] K'ang-hsi reign-period 6th year, 1st month, 20th day. "In the evening hours, in the NE there were flames blazing like a burning fire. It gradually spread out to filled the NW. When one looked out from a high point of the city wall, one could see a red vapour stretching across the sky. After a long time then it was extinguished." (*San-kang-shih-lueh* and *Shanghai Hsien-chih*) (DC885)

804. 1673 Feb 25
[China] K'ang-hsi reign-period 12th year, 1st month, day *keng-ch'en* (17). "In the NW and NE, a green-white vapour extended across the sky like a piece of cloth." (*Ch'ing-shih-kao*, 39) (DC886)

805. 1673 Early Summer
[China] K'ang-hsi reign-period 12th year, early summer. "In the NW direction a broad sword was seen. It was more than a *chang* in length and coloured red. After a long while then it disappeared." (*Hu-nan T'ung-chih*, 244) (DC887)

806. 1675 Jan 31
[Korea] King Sukjong 1st year, 1st month, day *i-ch'ou* (2). "At night, there was a green-red vapour like a rainbow." (*Chungbo Munhon Pigo*, 8) (DC888)

807. 1678 Jul 30 to Aug 1
[China] K'ang-hsi reign-period 17th year, 6th month, day *hsin-szu* (18). "On day *hsin-szu* (18), there was a band of blue vapour with a width of more than 5 *ch'ih*. On day *jen-wu* (19), there were a band of green-white vapour and 3 bands of blue vapour with widths of more than a *ch'ih*. On day *kuei-wei* (20), there was a band of blue vapour with a width of more than 6 *ch'ih*. They were all from the NW to NE." (*Ch'ing-shih-kao*, 39) (DC889-891)

808. 1679 Nov 20
[Korea] King Sukjong 5th year, 10th month, day *chi-mao* (16). "At night, in the E direction there was a flame-like vapour." (*Sukjong Sillok*) (DC892)

809. 1679 Dec 2
[Korea] King Sukjong 5th year, 10th month, day *hsin-mao* (28). "At night, in the E direction there was a flame-like vapour." (*Sukjong Sillok*) (DC893)

810. 1681 Jul 24
[China] K'ang-hsi reign-period 20th year, 6th month, day *hsin-mao* (28). "In the NE there were 6 bands of blue vapour." (*Ch'ing-shih-kao*, 39) (DC894)

811. 1681 Dec 19
[Korea] King Sukjong 7th year, 11th month, day *chi-wei* (56). "At night, in the W direction there was a flame-like vapour." (*Sukjong Sillok*) (DC895)

812. 1682 Mar 12
[Korea] King Sukjong 8th year, 2nd month, day *jen-wu* (19). "At night, in the SE direction there was a flame-like vapour." (*Sukjong Sillok*) (DC896)

813. 1682 Mar 25
[Korea] King Sukjong 8th year, 2nd month, day *i-wei* (32). "At night, in the S direction there was a flame-like vapour." (*Sukjong Sillok*) (DC897)

814. 1682 Apr 1
[Korea] King Sukjong 8th year, 2nd month, day *jen-yin* (39). "At night, there was a flame-like vapour." (*Sukjong Sillok*) (DC898)

815. 1682 Apr 3
[Korea] King Sukjong 8th year, 2nd month, day *chia-ch'en* (41). "At night, in the S, N and NW there were flame-like vapours." (*Sukjong Sillok*) (DC899)

816. 1687 Jun 24
[China] K'ang-hsi reign-period 26th year, 5th month, last day of the month. "At the NW of Chiungchou county, a blue vapour extended across the sky." (*Ch'iung-chou Fu-chih*) (DC900)

817. 1693 Apr 30
[Korea] King Sukjong 19th year, 3rd month, day *chi-szu* (6). "At night, there was a flame-like vapour." (*Sukjong Sillok*) (DC901)

818. 1703 Nov 5
[Korea] King Sukjong 29th year, 9th month, day *chi-szu* (6). "At night, in the SE and SW directions there were flame-like vapours." (*Sukjong Sillok*) (DC902)

819. 1703 Nov 16
[Korea] King Sukjong 29th year, 10th month, day *keng-ch'en* (17). "In the N direction there was a flame-like vapour." (*Sukjong Sillok*) (DC903)

820. 1712 Sep 4
[Korea] King Sukjong 38th year, 8th month, day *i-mao* (52). "In the early evening, in the W direction there was a red vapour like flames. It lasted for a long while then it was extinguished." (*Sukjong Sillok*) (DC904)

821. 1713 Nov 19
[Korea] King Sukjong 39th year, 10th month, day *ping-tzu* (13). "In the W direction there was a flame-like vapour." (*Sukjong Sillok*) (DC905)

822. 1713 Mar 17
[Korea] King Sukjong 43rd year, 2nd month, day *keng-yin* (27). "At night, in the NE and SW directions there were flame-like vapours." (*Sukjong Sillok*) (DC906)

823. 1717 Apr 30
[Korea] King Sukjong 43rd year, 3rd month, day *chia-hsu* (11). "In the SW direction there was a flame-like vapour." (*Sukjong Sillok*) (DC907)

824. 1720 Dec 22
[Korea] King Kyongjong 1st year, 11th month, day *ping-hsu* (23). "At night, from the 1st to 3rd watch, in the SE direction there was a flame-like vapour." (*Kyongjong Sillok*) (DC908)

825. 1721 Mar 29
[Korea] King Kyongjong 1st year, 3rd month, day *kuei-hai* (60). "At night, from the 1st to 5th watch, in the NW, SW and SE directions there were flame-like vapours." (*Kyongjong Sillok*) (DC909)

826. 1721 Apr 17
[Korea] King Kyongjong 1st year, 3rd month, day *jen-wu* (19). "At night, from the 1st to 4th watch, in the NE, SE and SW directions there were flame-like vapours." (*Kyongjong Sillok*) (DC910)

827. 1721 Apr 18
[Korea] King Kyongjong 1st year, 3rd month, day *kuei-wei* (20). "At night, from the 1st to 5th watch, in the NE, SE and SW directions there were flame-like vapours." (*Kyongjong Sillok*) (DC911)

828. 1721 Apr 20
[Korea] King Kyongjong 1st year, 3rd month, day *i-yu* (22). "At night, from the 1st to 2nd watch, in the SE direction there was a flame-like vapour." (*Kyongjong Sillok*) (DC912)

829. 1721 Jul 21
[Korea] King Kyongjong 1st year, 6th month, day *ting-szu* (54). "At night, from the 2nd to 5th watch, in the SE, S and SW directions there were flame-like vapours." (*Kyongjong Sillok*) (DC913)

830. 1721 Jul 22
[Korea] King Kyongjong 1st year, 6th month, day *wu-wu* (55). "At night, from the 1st to 5th watch, in the S and SE directions there were flame-like vapours." (*Kyongjong Sillok*) (DC914)

831. 1722 Jul 17
[Korea] King Kyongjong 2nd year, 6th month, day *wu-wu* (55). "At night, from the 3rd to 4th watch, in the NW and SW directions there were flame-like vapours." (*Kyongjong Sillok*) (DC915)

832. 1722 Nov 9
[Korea] King Kyongjong 2nd year, 10th month, day *kuei-ch'ou* (50), 1st day of the month. "At night, in the S and SW directions there were flame-like vapours." (*Kyongjong Sillok*) (DC916)

833. 1723 Jul 8
[Korea] King Kyongjong 3rd year, 6th month, day *chia-yin* (51). "At night, from the

1st to 5th watch, in the SW, SE and NE directions there were flame-like vapours." (*Kyongjong Sillok*) (DC917)

834. 1726 May 22
[Korea] King Yongjo 2nd year, 4th month, day *kuei-wei* (20). "At night, at the 2nd watch, in the NW direction there was a flame-like vapour." (*Yongjo Sillok*) (DC918)

835. 1726 Jul 1
[Korea] King Yongjo 2nd year, 6th month, day *kuei-hai* (60). "At night, at the 3rd watch, in the E, S and W directions there were flame-like vapours." (*Yongjo Sillok*) (DC919)

836. 1726 Jul 6
[Korea] King Yongjo 2nd year, 6th month, day *wu-ch'en* (5). "At night, at the 4th and 5th watch, in the SW direction there was a flame-like vapour." (*Yongjo Sillok*) (DC920)

837. 1727 Apr 12
[Korea] King Yongjo 3rd year, 3rd month, day *wu-shen* (45). "There was a flame-like vapour." (*Yongjo Sillok*) (DC921)

838. 1727 Apr 19
[Korea] King Yongjo 3rd year, 3rd month, day *i-mao* (52). "At night, there was a flame-like vapour." (*Yongjo Sillok*) (DC922)

839. 1728 Apr 16
[Korea] King Yongjo 4th year, 3rd month, day *wu-wu* (55). "At night, at the 3rd and 4th watch, in the E direction there was a flame-like vapour." (*Yongjo Sillok*) (DC923)

840. 1730 Feb 15
(i) [China] Yung-cheng reign-period 7th year, 12th month, 28th day. "At night, there was a violet coloured auspicious light stretching across the NE of the Ba-erh-fu-erh army camp. It lasted for eight hours with a brilliant display of splendid light." (*Ch'ing-shih-lu*) (DC924)

(ii) [China] Yung-cheng reign-period 7th year, 12th month, 28th day. "During the night, a red light was seen all over the wilderness of Fuk-shan." (*Ch'ing-shih-kao*, 41) (DC924)

841. 1730 Mar 18
[Korea] King Yongjo 6th year, 1st month, day *chi-hai* (36). "At night, in the SW and S directions there were flame-like vapours." (*Yongjo Sillok*) (DC925)

842. 1730 May 21
[Korea] King Yongjo 6th year, 4th month, day *kuei-mao* (40). "At night, in the SW direction there was a flame-like vapour." (*Yongjo Sillok*) (DC926)

843. 1731 Jul 13
[Korea] King Yongjo 7th year, 6th month, day *hsin-ch'ou* (38). "At night, there was a flame-like vapour in the SW direction." (*Yongjo Sillok*) (DC927)

844. 1738 Dec 16
[China] Ch'ien-lung reign-period 2nd year, 10th month, 25th day. "At night, at the hour of *tzu* (11 p.m.–1 a.m.), according to the report from soldiers on patrol of the

city wall, a red light was observed to the N. Following a carefull watch, the light was seen first rose in the NE and gradually moved to the W. It extended across the whole of the N; the colour of the sky was like fire, with a height equalling that of the Nan mountain. Within it there was a black vapour and also there were four erect bands of white vapour. After the 3rd watch, the four bands of white vapour changed into several tens of bands and the black vapour gradually receded. After the 4th watch most of them vanished without a trace; only the red light lasted until after the 5th watch when its colour gradually faded away. At sunrise everything had dispersed and could not be seen." (*Ch'ing-shih-lu*) (DC928)

845. 1747 Apr 10
[Korea] King Yongjo 23rd year, 3rd month, day *hsin-mao* (28). "At night, in all directions there were flame-like vapours." (*Chungbo Munhon Pigo*, 8) (DC929)

846. 1770 Sep 17
[China] Ch'ien-lung reign-period, 35th year, 7th month, 28th day. "A red light rose in the N direction; at midnight, it gradually receded. To the NW of the Ch'ang-shan Mountain a red vapour was seen filling the sky. Within it there was a white vapour like separated silken threads. After the fourth watch, then they dispersed." (*Ch'ing-shih-kao*)

847. 1770 Sep 18
[China] Ch'ien-lung reign-period, 35th year, 7th month, 29th day. "At night, there was a vapour like a fire extending across and covering the NW. It stretched several tens of *chang* and contained a red light. It rose in ranks like a forest of swords and spears pointing upwards." (*Ch'ing-shih-kao*)

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