COSMOGRAPHICAL DISCUSSIONS IN CHINA FROM EARLY TIMES UP TO THE T'ANG DYNASTY

by

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Volume I

A B S T R A C T

Cosmography is the study of the shape, size, disposition and other properties of the large-scale components of the physical universe. The following survey assembles and discusses available Chinese material on this subject from early times up to the rise of the T'ang dynasty in A.D. 618, after which Chinese interest in the topic seems to have diminished.

Part I discusses evidence from texts dating before 250 B.C. A cosmography involving a number of mythical elements is thus reconstituted; heaven is a solid vault over a flat square earth. Geographical speculations about the existence of several continents are discussed. Part II describes the _Kai t'ien_ theory according to the _Chou pei_, a book possibly compiled in the first century B.C.; an umbrella-like heaven rotates over a similarly shaped earth. The dimensions of this universe are linked to astronomical observations made with a gnomon. Parts III, IV and V follow the general discussion of cosmography from 250 B.C. to the close of the survey. The _Kai t'ien_ theory was repeatedly criticised on empirical grounds, and by about 100 A.D. had been replaced by the _Hun t'ien_ theory, which involved a spherical heaven rotating about an inclined axis and enclosing a flat earth. Within the context of this scheme there was much discussion of points of detail, including

the cause of the luminosity of the heavenly bodies and the mechanism of eclipses. Considerable efforts were made to establish the dimensions of the Hun t'ien universe, but were vitiated by lack of an adequate geometry. A number of other original but less important theories were proposed. It appears that the ancient Chinese never conceived of the earth as spherical; implications of this are discussed in the Introduction.

A C K N O W L E D G M E N T S

My first debt of gratitude is naturally to my supervisor, Professor D. C. Lau, whose unfailing helpfulness and encouragement made this survey possible. Other members of the Department of the Far East at SOAS, principally Professor A. C. Graham, were kind enough to discuss various points with me. All errors and omissions are of course my responsibility alone. Jenny Goodliffe bravely converted a somewhat chaotic manuscript to orderly typescript.

I would like to thank the University of London Computer Centre for their aid in the investigation described in Appendix (vi).

C O N T E N T S

II : CHOU PEI SUAN CHING

III : COSMOGRAPHY IN THE HAN DYNASTY

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V : THE END OF ORIGINALITY

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INTRODUCTION

(a) The subject of cosmography

This study is an attempt to give a comprehensive account of pre-T'ang Chinese cosmography. In considering a large amount of often fragmentary textual evidence I have tried to find answers to the following questions, amongst others :

(i) Which text belongs to which author, and when did the author write ?

(ii) What can we say with any degree of probability about each author's cosmographical views, and what can plausibly be conjectured ?

(iii) How are the texts connected by agreement and disagreement on common points, and what awareness do the authors show of one another's work ? What main traditions emerge from this ?

(iv) To what arguments if any do the authors appeal in support of their views and in opposition to their opponents ? What can we deduce from this about the development in China of astronomy, mathematics, and natural science generally ?

(v) Can we trace any influences which may have determined the views of individual authors, and can anything be said about the overall development of cosmographical thought in China in relation to the general problem of the history of Chinese scientific thought ?

Before any detailed discussion of sources and methods I would like to try to justify my choice of subject boundaries for this survey. It will be noticed here and elsewhere that I use the term "cosmography" rather than "cosmology"; I feel this marks an important distinction. Cosmology covers the whole subject of the nature of the universe we inhabit in all its aspects and involves a wide range of essentially philosophical problems, such as those of causality and ontology. Cosmography I understand in a much more limited sense as including the discussion of the composition, size, shape, disposition and motion of the large-scale components of the physical universe. For someone interested, as I am, in the development of mathematics and science in China this restriction is a natural one, apart from any considerations of the space and effort required for a wider investigation. Nor can it be said to limit discussion to an over-narrow compass : the topic of cosmography is inextricably linked with many questions that would nowadays be dealt with under the heads of astronomy, meteorology, geography, and physics generally.

No matter how clearly defined the subject to be studied, it is a risky procedure to skim through ancient texts picking out fragments relevant to some more or less arbitrarily selected topic. However carefully these are then pieced into an academic jigsaw entitled "The Ancient Chinese View of" socialism or schizophrenia or whatever else, we have no guarantee that the overall result represents anything that ever found a place in a Chinese mind at any epoch. Fortunately there is less risk of this sort with the subject of cosmography, a subject that has been clearly distinguished in China since at least the first century B.C., and on which a long series of often brilliant men wrote. Their work forms a well-defined corpus, bound together by a common concern with certain main problems and often cross-linked by explicit references to one another's writings. It is quite distinct, for example, from poetical effusions on the starry heavens. These men are concerned with objective knowledge about physical reality; they frequently make statements about the cosmos which could in principle be checked and pronounced true or false, and the worst attack they can make on an opponent is not that his idea is new-fangled or impious but that it predicts phenomena which are not those actually observed. I do not claim that even the most iconoclastic writer always resisted the temptation to appeal to authority (see Wang Ch'ung 王充 on eclipses, III (6)(f)) nor that judgements of ritual propriety are never mingled with physical reasoning (Liu Chih, IV (6)(b)), but for the principal writers of this survey the cosmos is basically an assemblage of moving things with properties, rather than a community of beings with wills and intentions or a mere phantasmagoria of illusion.

Much of the material to be discussed in this survey, deserves, in my opinion, to be regarded as at least proto-science if by science we mean a Popperian process of conjecture and testing. I would contend that cosmography is by the nature of its subject-matter more likely to manage this than, for example, medicine, which is at present the most widely studied aspect of Chinese natural philosophy. The cosmos presents us with the diurnal regularities of sunrise and sunset, the nocturnal rotation of the stars with its obvious deviation from a vertical axis, the monthly phases of the moon, the annual cycle of the sun's declination and the succession of the seasons with its overwhelming significance to the whole of human life. Especially amongst a nation that paid great attention to celestial portents, the challenge to attempt a unified explanation must always have been present to those with the leisure and taste for speculative thought. The same challenge was of course presented by the workings of the human body, all too often with tragic urgency. My point is, however, that plausible explanations of the cosmos could be offered in terms of the shape and motion of more or less solid bodies, or of wind-like currents of <u>ch'i</u>

together with extensions of common-sense ideas of optics. Ingenuity and intellectual courage were certainly called for, but the task could be attempted fairly successfully without the need for concepts removed from all common experience. The observational implications of a theory could be deduced and tested against reality, and opponents had at least some basis of common ground. Thus the Kai t'ien 蓋天 theory stated clearly that heaven and the heavenly bodies had certain precisely defined dispositions and motions. Simple physical arguments and elementary geometry enabled its opponents to deduce certain consequences from these postulates, which, they pointed out, conflicted with common observation (see for instance III (4)(b)). The field was thus cleared for the adoption of the Hun t'ien 渾天 theory (see III (7)), and within the new theory the critical debate continued further.

Although the previous account is over-simplified, it does illustrate the difference between ancient Chinese cosmography and medicine already mentioned. Apart from very elementary notions of structure and function, there was no chance of a successful speculative attack on problems of physiology and pathology without the conceptual equipment provided by the last two centuries of work in biology, chemistry, and physics. I do not deny the considerable (although often exaggerated) amount of empirically effective expertise gathered by practitioners of traditional medicine, but we must surely distinguish between science and lore. Without some idea of the sort of entities that medical theories must involve, such theories as did arise were *a priori* dogmatic structures, infinitely flexible, without predictive power and hence invulnerable to criticism. In the words of a recent study :

> " ... Chinese medicine showed with other premodern medical systems the lack of steady methodological pressure for changes [in concepts and therapeutics]. Its dynamic view of the body and its disorders, far from being empirical, was built upon metaphysical concepts (yin-yang, *wu-hsing* 五行 or Five Phases, and others) that experience could not discredit."
>
> Cooper & Sivin (1), 204

It is certainly true that cosmography was by no means free from the stultifying effect of metaphysical pigeonhole systems (e.g. IV (3)(b), IV (8)(a)). The point is, however, that while theoretical medicine could not at that time have any hope of doing more than build a conceptual pagoda, cosmographers had the equipment to construct theories whose consequences could be deduced and tested - in a word, *scientific* theories.

I hope this brief sketch will serve to indicate why I think that cosmography is a particularly rewarding aspect of scientific thought in ancient China. The justification of my choice of epoch for this study belongs naturally after the next section.

(b) Sources

My object in this survey has been to locate all material falling within the prescribed boundaries of subject and date. I do not claim that my judgements of what to include or omit have been infallible, but it would be pusillanimous of me not to state my conviction that nothing of importance has been omitted simply because it escaped my notice. This conviction is not based on any belief in my own literary acumen, but on the fact that I have been able to draw on the work of a considerable number of previous writers in the field, as well as conducting my own searches. Without their efforts my task would have been much more difficult and my progress correspondingly much more halting. Perhaps I can combine a description of the stages by which the gathering of material proceeded with a proper acknowledgement of my debt to these scholars.

Inevitably I began by reading the survey of Joseph Needham (SCC III, 210-228 and elsewhere throughout SCC), and I was then guided through a preliminary check of his sources by my supervisor Professor D. C. Lau. Needham's account convinced me of the importance of the subject, and my brief view of the material available made it obvious thqt it deserved a study of monograph length. Continuing the effort to find my bearings I worked through Maspero (2), (3) and Forke (1), after which I felt in a position to begin a search of the literature, with the aim of compiling an analytical catalogue arranged by authors, and collating variant versions of texts. This search proceeded along several fronts simultaneously. Indispensable, although not to be relied upon as they stood, were the great fragment collections by Yen K'o-chün (1) and Ma Kuo-han (1), in which I checked on all authors whom I knew to have written anything on cosmography. I also searched Yen's index for likely titles, by which means I came across a certain amount of useful additional material. The biographies of Juan Yuan (1) served a similar purpose. I traced all sources given and began to analyse and recollate the fragments thus found. While so doing, I made a systematic search through the secondary sources involved (as the primary sources of the fragments were by definition lost). These fell into a number of groups.

Firstly there were the standard dynastic histories, now mostly available in the punctuated and collated editions published in Peking over the last few years. Within the period of this survey I have had occasion to use most of them for general reference and biographical detail, but by far the most important items were the essays on cosmography which are to be found at the beginning of the astronomical monographs in the <u>Sung shu</u> 宋書 (monographs c. A.D. 500), the <u>Chin shu</u> 晉書 (A.D. 648) and the <u>Sui shu</u> 隋書 (monographs A.D. 656).

These three accounts, which are to some extent synoptic, set themselves to fulfil the same basic task as the present survey, which is perhaps no more than an attempt to do their joh more thoroughly and critically than was possible under their historical circumstances. Partly for this reason, and partly because of my choice of time-limit I have not usually considered the editorial views expressed in these essays as being within my terms of reference. The exception is the Sung shu (see V (4)), which falls within my chosen epoch and serves as a comprehensive summary of what one man knew about cosmography towards the end of it. Its status as a standard history spared it "the martyrdom ofjakes and fire" suffered by some other works of contemporary date, now in fragments.

I also searched what seemed to be the relevant sections of the lei shu 類書 (topically arranged encyclopaedias) following

I wen lei chü (IWLC)	藝文類聚	(A.D. 624)
Pei t'ang shu ch'ao (PTSC)	北堂書鈔	(c. A.D. 630)
Ch'u hsüeh chi (CSC)	初學記	(c. A.D. 700)
Po k'ung liu t'ieh (PKLT)	白孔六帖	(A.D. 800)
T'ai p'ing yü lan (TPYL)	太平御覽	(A.D. 983)
Shih lei fu (SLF)	事類賦	(A.D. 1000)
Yü hai (YH)	玉海	(A.D. 1267)
Ku chin t'u shu chi ch'eng (TSCC)	古今圖書集成	(A.D. 1725)

As well as helping in the reconstitution of fragmentary material these works often pointed to passages of interest in extant books. I have used neither of the last two works as basic sources for texts within my epoch. So far as I have been able to check, the Yü hai never has an independent version of pre-T'ang cosmographic material; its contents on the present topic stem (often in abbreviated form) from earlier sources such as TPYL. In view of its date this is scarcely surprising. TSCC was used partly because the vast range of its material made it a useful long-stop in the attempt not to miss anything relevant, and partly because I hoped to gain an overview of the period subsequent to this survey. It also produced some undated (and despite my efforts frustratingly undatable) material of Taoist and Buddhist origin which has at least a peripheral connection with section V (5) on Liang Wu Ti's importation of Indian cosmography.

In a class of its own is the K'ai yuan chan ching 開元占經 (A.D. 729) of Ch'ü-t'an Hsi-ta 瞿曇悉達. According to the preface of the current edition a single copy was found in the 16th century, hidden within the body of a statue in a Buddhist temple. Without this book our knowledge of ancient Chinese astronomy would be greatly impoverished in all its aspects. It is a compendium of material on astrology, divination generally, and calendrical mathematics, comparable to a greatly enlarged version of the dynastic history monographs mentioned above, and like them it begins with an essay on cosmography. The compiler of KYCC gives us material at much greater length than the histories, however, and at times even tells us regretfully that he has had to omit transcribing some of his sources, presumably for lack of time. To compensate for this he does give us some material mentioned nowhere else, but this should perhaps increase our regret for what we have missed.

Another important group of sources were the commentaries (mainly Han) and subcommentaries (mainly T'ang) on the classics and on other works. For the classics I have naturally used the *Shih san ching chu su* 十三經注疏 (SSCCS) collection in the 1815 collated edition. Although some sections of this vast corpus obviously deserved particular attention, such as the material on the astronomical references at the beginning of the *Shang shu* 尚書, I have been very grateful to previous reconstitutors of fragments for guidance towards fruitful material. These texts are of course well-known as containing many quotations from the so-called Apocryphal Books (see Appendix (i) and III (10)), portions of which also occur in *lei shu*. For these somewhat arcane works I originally used Sun Chüeh (1) but lat*Shusei* 緯書集成ern Japanese collection *Ishō Shusei* 緯書集成, which is infinitely more satisfactory(Yasui, (1)). Other important commentaries were the three on the *Shih chi* 史記

(one Liu Sung, two T'ang), the T'ang commentary on the Han shu 漢書, and the Liang commentary on the monographs now included in the Hou Han shu 後漢書 but originally part of the Hsü Han shu 續漢書 written under the Chin.

In addition to the fragments in the preceding texts I have of course also referred to a large number of books still extant. I review the Chou pei suan ching 周髀算經 almost in its entirety (see II) and certain parts of Wang Ch'ung's Lun hêng 論衡 are treated at length (III (6)). Paradoxically enough both these books are proponents of the rejected Kai t'ien 蓋天 theory; we have nothing at such length on the side of the Hun t'ien 渾天.

In Section I a study is made of material from the Ch'u tz'u 楚辭 collection, in particular the T'ien wen 天問 which contains a good deal of information on mythical ideas of the cosmos. Similar notions recur in Huai nan tzu 淮南子, which is also a source for an early attempt at mathematical cosmography (III (2)). In IV (10) sections of Lieh tzu 列子 are treated in detail, and throughout the survey a number of shorter references are made to other philosophical works. I have of course made frequent use of both ancient commentaries and modern studies as acknowledged in the relevant sections.

(c) The choice of epoch

If ancient Chinese cosmography is as interesting and significant a subject as I have argued, why does this survey not continue the story up to the introduction of the Ptolemaic world view by the Jesuits under the Ming, or even beyond ? I do not deny that there remains a great deal of uninvestigated material, and in the long term I certainly look forward to completing the task. Perhaps, however, the reader will not consider the present length of this survey as an irrelevant consideration in arguing against a longer treatment. In addition I feel that there are good methodological and historical grounds for drawing the line as I have chosen to do.

Firstly, the nature of the sources as outlined above clearly suggests the recovery of pre-T'ang material as an autonomous task. The three great monographs in the Sung Chin and Sui histories would be stimulus enough, but to these we must add the sequence of lei shu culminating in the T'ai p'ing yü lan, the huge volume of T'ang sub-commentaries on the classics, and once more in a class by itself the K'ai yuan chan ching. The scholarship of the three T'ang centuries picks up the literary débris of the preceding dynasties like flotsam and jetsam on the crest of a wave and carries it through to the present day. The job of sorting and evaluating this rich but confused deposit is quite different from that of working through the much better preserved sequence of material from later times.

Secondly, I would like to suggest that the T'ang marks something of a discontinuity in cosmographical writing. The efforts of those with an interest in the subject during that dynasty seem to have been almost totally devoted to the assembling of material from earlier centuries. In the histories editorial comment is sparse, as in the selections given in the subcommentaries. The K'ai yuan chan ching has a few brief comments as links between passages, and the lei shu carry the process to the extreme point, exhibiting the fragments unaccompanied. (Even the introductory essays in the Ch'u hsüeh chi are in great part mosaics of quotations.) Perhaps most significant, however, is the fact that the lei shu compiled at the end of the T'ang (TPYL and SLF) contain little or nothing of cosmographic interest from the preceding three centuries. Similarly KYCC contains virtually no T'ang cosmographic material. Surely this is *prima facie* evidence that little of interest was being produced ? The 7th century Hun t'ien fu 渾天賦 by Yang Chiung 楊炯 (TSCC, chien hsiang tien, 6) is quite unoriginal and appears to base itself directly on the Chin shu and Sui shu monographs. I find it highly suggestive that from the T'ang onwards the references to cosmography at the beginning of the astronomical monographs of dynastic histories are cut to a few perfunctory lines until the account of Western notions in the Ming shih 明史. There is, however, an exception which makes this evident abandonment of cosmography quite explicit.

In A.D. 725 the monk I-hsing 一行 and the Astronomer Royal, Nan-kung Yüeh 南宮說 conducted an extensive meridian survey involving measurements of solsticial shadow-length and polar altitude over a line that may have been 2,500 km long (see Beer et al. (1); SCC IV, 44 ff; Chiu T'ang shu 舊唐書 35, 6a ff SPTK; Hsin T'ang shu 新唐書 31, 813 ff. CHSC). They were basically attempting to fulfil the programme suggested a century earlier by Liu Ch'uo 劉焯 (V (6)(b)). For reasons which I believe (unpublished work, 1976) to have been largely a fortuitous combination of various errors these workers (correctly) concluded that noon solstice shadow-length did not vary linearly with north-south displacement, while angular polar altitude did. This was a striking rejection of the practice of the preceding millennium (see II (2)(a) and Appendix (iii)), and was a stimulus which might have brought the idea of a spherical earth into Chinese thought; but this is not what actually happened.

Whether through a sense of shock at the collapse of the traditional methods or a simple lack of the geometry required to make sense of their conclusions, it is evident that the writers of the survey report in the T'ang histories had conceived what almost amounted to a positive distaste for cosmography. A brief sketch of the end of the document may be of interest. Firstly, it is pointed out that if traditional methods (see, e.g. IV (2)(c)) are applied to the survey's data then the resultant diameter of the heavens is only 50,000 _li_ (approximately 17,000 miles), a figure rejected as improbably small. Older estimates had been some four times larger. Two "thought experiments" are described both of which point to the hopelessness of attempting a survey of the universe from an inadequate base-line. It is then noted that during the winter solstice ceremonies of A.D. 725 dawn was observed from the top of Mt. T'ai 泰 well before it was seen from below the mountain. This opportunity to hypothesise a spherical earth is lost: the effect is dismissed as inexplicable, and as a proof of how little can be expected from observations with a gnomon much smaller than a mountain. Finally the writers stress their belief that "the ancients" concentrated on improving calendrical practice, not on deciding between rival cosmographies; for them, such questions are unresolvable. The survey's results are then commended for their utility in eclipse prediction, calculating variation in daylength, and in providing a reconciliation of shadow-measurements throughout the empire. The situation is thus as described in Sivin (1),3:

> " ... the computations at the basis of the Chinese calendar were as independent of any physical model of the world as those of Babylonian astronomy, on the basis of still very incomplete evidence, seems to have been ...

> ... Between the origin of Chinese astronomy and its full flowering as a mathematical science in the Sui and T'ang, the sense of cosmos almost completely dropped out."

I do not therefore feel that the T'ang is an inappropriate point to break off this survey. The story of Chinese cosmography certainly does not end there : Neo-Confucianism in the Sung brought a renewed attention to the old problems particularly on the part of Chu Hsi 朱熹 (A.D. 1130-1200) himself (TSCC, ch'ien hsiang tien, 5, 46 ff), while the Cheng meng 正蒙 (A.D. 1076) of Chang Tsai 張載 has material of considerable interest in its first chapter. Some criticism of this book is made by Wang K'o-ta 王可大 under the Ming in connection with ideas of terrestrial motion (TSCC, ch'ien hsiang tien, 5, 55). All this and much elsewhere certainly deserves study, but I think I have shown that the task can be separated from the present survey without a completely artificial break.

(d) Aims and methods

I have tried to fit the general structure and detailed treatment of this survey both to the tasks set at the beginning of the introduction and to the nature of the material. Most of this material is of course fragmentary, and textual problems are thus inevitable. All versions have been compared carefully, usually by means of character-by-character collations. In many instances the discrepancies are quite insignificant, and I have restricted myself to listing sources in my references. More difficult cases are discussed in the main survey when this does not involve losing the thread of discussion (e.g. III (10)(b), but from time to time I have chosen to relegate the untangling of textual threads to a Textual Note. Various non-textual questions requiring an expanded treatment that might have unbalanaced the section to which they were relevant have likewise been dealt with in Appendices. I hope therefore that I have been able to dispense with footnotes at the price of only occasional turgidities.

My aim has been to let authors speak for themselves. This sounds very hackneyed, and must in any case be subjected to a number of qualifications. In the first case there is the obvious difficulty of translating from a language which is not by any means always completely understood. It might also be felt that the technical nature of the subject would prove a further handicap. Actually there are certain advantages in this feature of the task, not least the fact that once the fairly narrow range of specialist vocabulary is known there is a great deal of transfer of understanding from one text to the next. In addition, since a writer on cosmography is usually discussing the size, shape, motion and appearance of physical objects there are at least prima facie certain limitations on what he is likely to be saying in a disputed passage, and thus fruitful conjectures may suggest themselves. I am not suggesting that it is in any way legitimate to (adapting Dr. Johnson) "get the Chinese from the sense, not the sense from the Chinese", simply that when confronted by an opaque section of text conjectures may at first be necessary. These must then be tested as rigorously as possible, against parallels elsewhere as well as the sense of the rest of the text. Where my rendering of a text remains conjectural I have tried to say so as clearly as possible, but many translations of which I am now fairly certain began their careers as enlightened guesses. In three instances I have decided to render an alien concept by transliteration : Yin 陰 , Yang 陽 and ch'i 氣 . Sinologists will, I hope, agree that no single words or phrases could adequately represent these terms, and it seemed to me that non-sinologue readers of this survey were more likely to be hindered than helped by a continually changing set of makeshift renderings designed to fit particular circumstances. The best short prescription for gaining a general orientation to these concepts is, of course, to refer to the indexes of SCC, especially volume II.

Apart from the directly linguistic aspect there are other problems of translation involved. The reader cannot be said to have understood a text if he has no idea of the context within which it was written and of the purpose behind it. I have attempted throughout, therefore, to annotate, analyse, and cross-reference the material so as to bring out the coherence of the tradition within which authors wrote. From time to time I have made use of the dubious freedom to speculate granted by lack of hard evidence as to how a theory arose (e.g. III (3)(c)) or how a textual problem might be resolved (e.g. III (9)(b)). All I can claim in these cases is that my speculation springs from an intensive study of the literature, and has no less chance of hitting the mark than most others. If the reader finds my suggestions unacceptable I hope they will at least provide a starting-point for something better.

Given these qualifications I repeat that this survey is an attempt to provide a medium through which the ancient cosmographers can be understood as far as is possible over the gap of language, culture, and time. I have not tried to set their work in the context of any theory of the development of scientific thought in China or the world generally. This is because I believe that we shall have to look much more closely at a larger number of detailed instances of scientific history than have so far been examined, before we are in any position to form or test theories of this kind. And in any case I do not think we have the right to assume that we can necessarily form a scientific theory of the development of science, in the sense, that is, of a theory with predictive power. Ought not such a theory to enable us to predict future scientific developments before they occur, surely a reductio ad absurdum, and ought it not to be able to predict its own creation? Such ambitions are not yet, perhaps, within our reach. The most we can hope for at present seems to be to establish what may be called a taxonomy of the history of science. By this I mean that through a long acquaintance with the minutiae of scientific history we may come to recognise what counts as significant in that sphere. Thus in the same way that economists extract from the apparent chaos of events the concepts of inflation, boom, balance of payments and money supply we may eventually hope to discover useful characterisations of generalised entities in the history of science. Kuhn's conjecture (Kuhn (1)) that science, roughly speaking, develops by revolutions is valuable as an attempt of this sort whether or not it deserves the status of a descriptive theory of the development of science.

It does at least suggest to us that it would be of interest to see if we can find examples of "revolutions" in particular fields of study. If the description "revolution" turns out to be widely applicable, then will be the time to test theories of the causal relation between these revolutions and other events. General theories cannot be created before the field to which they are intended to apply has been supplied with a vocabulary of generalised concepts between which the aspiring theory can postulate relationships. This survey attempts neither task, but simply tries to add to our stock of evidence which may turn out to be relevant or useful.

I ought at this point to declare a personal bias. This will appear (or may already have appeared) in my use of the word "scientific". Although I do not claim complete consistency my usage is closely tied to the demarcation criterion between science and non-science proposed and discussed in Popper (1), (2), (3); briefly, I reserve the word for theories which are, at least in principle, capable of disproof so long as certain methodological decisions are made. But, even given that this criterion does actually distinguish one sort of theory from the rest, why should we apply the word "scientific" to the chosen group and deny it to the rest ? There are of course no compelling logical reasons for this. In explaining what must remain a personal decision one can only argue firstly that little confusion will result from the refinement of usage, as the criterion seems to coincide quite well with the usual application of the word. Secondly it is common enough practice to replace a fuzzy-edged usage by a more sharply defined one : there is the example of the refinement of "temperature" from a subjective idea of hotness to an operationally defined concept. I do not think it will be denied that useful results often follow. Thirdly, to be honest, there is a question of prestige. Such theories as those of Newtonian dynamics and its Einsteinian successor, or of modern biochemistry are rightly commended for their intellectual rigour and practical achievements. Attempts are therefore frequently made by practitioners of the arcana of neo-astrology, pop vitalism and pseudo-sociological slogan-systems to borrow some of this prestige for their own creations. This is done by the adoption of a jargon bearing some resemblance to the science that is being flattered by imitation, possibly with the introduction of some rather opaque mathematics. If, as I do, one views such attempts with distaste, it is natural to try to sum up briefly the way in which the would-be borrowers of laurels differ from the laurel-owners and to state clearly one's reasons for making the distinction and denying them the title they seek. As I have already mentioned in (a) above my reason for choosing to examine cosmography in China was because of its relatively high "scientific" content under the demarcation criterion mentioned.

The considerations just set out have, of course, conditioned the way I have treated my material within the subject boundaries specified. I have tended to see the succession of writers on cosmography as engaged in a debate, and I believe the texts bear me out on this point. Authors criticise the ideas of others, and produce and expound their own theories, which are in turn attacked by their successors. The discussions of the Kai t'ien are a somewhat one-sided example of this (see II (3)(h)); a better example might be eclipse theory (III (5)(a); III (6)(f); III (7)(d); IV (6)(c); IV (9)(b)) or the horizon illusion (III (5)(b), (c); III (7)(f); IV (2)(e); IV (9)(c); V (3)(c)). The fact of mortality means, alas, that this is a debate where one cannot reply to opponents in person. Since the literature is largely in fragments there are instances where our only knowledge of an author is a bald statement without rationale, and we cannot of course assume that he ever supplied any. I have tried to fill such gaps by offering a plausible conjecture where any has occurred to me, and I have as already mentioned usually attempted to explain how an author might have been led by his circumstances towards a particular view. On many occasions, however, we must be content to acknowledge the inexplicable power of creative originality.

In this section it seems appropriate to explain my attitude to other modern studies of the subject of this survey. I have already mentioned my debt to the works of Needham, Maspero and Forke as means of orientation and as preliminary guides to the source material. In addition mention must be made of Ho (1), Ch'en (1), Cheng and Hsi (1), Cheng Wen-kuang (1) and Cheng Yen-tsu(1), all of which discuss cosmography generally, as well as a number of specialist studies such as those of Chatley (1) and Eberhard (1). It will be noticed, however, that I never rely on the authority of any of these authors for conclusions within the field of this survey, neither do I make many explicit attempts to correct what appear to me to be errors in their work. There are two main reasons for this approach. Firstly, there is the obvious consideration of space : this survey would be at least half as long again if it was partly an effort at refutation of all mistaken views ever advanced on its topic. Nevertheless I have included comments on a few of what seem to me the most important points of dissension (e.g. II (3)(f) and Appendix (2)); Secondly, and I hope without arrogance, this survey is not designed to compete with previous accounts but to supersede them in both breadth and detail of coverage. Given the expenditure of so much more time, space and resources than before on this subject a very moderate degree of competence suffices to uncover old mistakes or untangle confusions. It would be both pointless and ungrateful to indulge in continual nit-picking at the expense of those who made preliminary surveys of a field which I have had the privilege of examining in detail. I cannot, however, leave this subject without warning the reader that the work of Cheng and Hsi, Cheng Wen-kuang and Cheng Yen-tsu must be treated with great caution. Their combination of strident Marxism with a jingoistic determination to prove that Chinese cosmographers thought of everything first makes at times for a degree of tendentiousness verging on mendacity. On some points I am at present (1976) preparing detailed critiques for future publication

(e) The main features of ancient Chinese cosmography

Considerable guidance to the content and structure of this survey can, I hope, be gained from the list of headings preceding this introduction. As a further aid to the reader, a short connected account of the principal features of the story is provided here in an effort to prevent him smothering in the details of the survey itself.

Part I attempts a partial recovery of pre-Han cosmography. Mythological material is discussed during an examination of the poem T'ien wen 天問 "Heavenly questions" which may date from the fourth century B.C. This text seems with others to point to a cosmos (I (2) (c)) in which the inhabited world is flat and square, possibly with a central mountain. Surrounding this square continent are the four seas, beyond which is a ring of mountains on which the solid heaven is supported like a round dome. It looks as if this dome is fixed, which naturally raises problems in connection with the motion of the heavenly bodies. In the case of the sun it seems plain that a new one rises from the east of the world each day to perform its trip overhead (I (2)(b)(15-16), finally sinking back to earth in the west. Part I concludes with an account of the work of Tsou Yen 騶衍 (c. 350-270 B.C.) who held that the world actually contained nine continents like the one on which China was situated, separated from one another by great expanses of sea (I (3)).

Part II is completely devoted to an examination of the anonymous book entitled Chou pei 周髀 which may have been compiled during the first century B.C. or the beginning of the first century A.D. (Appendix (iv)). It contains a detailed account of the Kai t'ien 蓋天 theory (lit. "heaven [like a] cover"). According to the Chou pei both heaven and earth are basically flat discs, although they are convex to the extent that their centres are higher than their circumference by about 12 per cent of their diameter. Heaven is a constant distance above earth, not in contact with it, and rotates once daily about a vertical axis running through the centres of heaven and earth, carrying the heavenly bodies with it. The point where this axis intersects the earth has many of the characteristics of the north (or south) pole on a spherical earth in terms of climate and a six-month day and night (II (3)(c)). Day and night at a particular point on the earth are made to depend on the alleged fact that the sun becomes invisible when carried more than a certain distance away by the rotation of heaven. Noon occurs when the sun lies above the radius from the "pole" intersecting the observer. At that moment it is midnight on the other side of the pole. In summer the sun moves nearer to the axis of heaven than in winter, and is thus higher in the sky and closer to the observer (II (3)(d)). The various dimensions of this universe are derived from a fairly consistent application of the mathematics of similar triangles and the theorem of Pythagoras, in combination with a "shadow-principle" by which north-south distances are related to the length of a gnomon shadow (II (2)). Although false, this latter principle was not seriously challenged for 800 years. There is evidence that the cosmography of the Chou pei may have been known in pre-Ch'in times (II (3)(g)). During and after the Eastern Han the Kai t'ien theory was severely criticised on many points of substance (II (3)(h)) and ceased to be held so far as the literary evidence shows. Wang Ch'ung 王充 (III (6)) defended it during the 1st century A.D.

During the first century B.C. (III (3)) we find the first evidence of the rise of the Hun t'ien 渾天 theory (lit. "complete [or entire] heaven", presumably as opposed to the partial coverage of earth under the Kai t'ien). This was to become the orthodox cosmography for most of the period of this survey. The first systematic account of it was given by Chang Heng 張衡 around A.D. 120 (III (7)). Essentially it states that heaven is a hollow sphere surrounding a flat earth which extends wholly or partly across its horizontal diametral plane. Despite claims to the contrary, I have found no evidence for a spherical earth in ancient Chinese thought (Appendix (乙)). The celestial sphere rotates daily about an axis inclined at some 35° above the northern horizon, carrying the heavenly bodies with it. Day and night result from the sun rising and sinking over the edge of the earth, and the seasons result from its annual approach towards and recession from the north celestial pole. The design of this theory, and in particular the angle of inclination of the axis make it plain that the Chinese observer was thought of as being at the centre of this sphere, a fact at times explicitly stated (IV (2)(c)).

A third theory usually mentioned in company with the two preceding from the second century A.D. onwards (III (8)(a)) is named Hsüan yeh 宣夜 (the significance of this name is obscure). There is a fragment alleged to be of Han date in which it is claimed that according to this theory heaven is not a solid vault at all, but simply a great depth of space without limit in which the heavenly bodies move independently. After a comprehensive examination of this and related material (III (9)) I conclude that although ideas of this sort are found in China from quite early times onwards it is doubtful whether the fragment in question is genuinely Han. It seems to me that the original content of the Hsüan yeh (whatever it was) had been forgotten by the Eastern Han and that at some later date the name was attached to the theory now associated with it. The original feature of this theory is not, as sometimes stated, the infinity of space, but is simply the non-existence of a heavenly vault. No Chinese cosmographer known to me gives any signs of not believing that space (as opposed to the region within the heavenly vault) is infinite, and some state this explicitly. This is contrary to the Aristotelian view common in the West, according to which space as well as matter ends at the sphere of the fixed stars (Dreyer (1), 109).

A number of somewhat eccentric theories testify to the fertility of the cosmographical tradition. In the third century it was suggested that the seasons might be explained by an annual rising and sinking of the heavenly vault (IV (5)). The Yü 虞 family produced two writers on cosmography (IV (7)) one of whom in the third century put forward a theory according to which heaven was supported pneumatically, while his successor a century later postulated a fixed heavenly vault of infinite size. None of these theories really entered the mainstream of discussion. The same can be said of the sixth century attempt to introduce Buddhist cosmography by Emperor Wu 武 of the Liang (V (5)). In this latter, however, there are several signs of the influence of purely Chinese ideas, especially in the rôles of the Yin and Yang and their tidal fluctuation. There was a succession of theories in which the varying strengths of these principles served to explain the annual cycles of solar altitude, daylength, and temperature. An early example is found in Huai nan tzu 淮南子 (III (2)(c)), and Wang Ch'ung criticises the idea that the sun's disappearance at dusk occurs because it is obscured by a cloud of Yin (III (6)(g)). In the third century A.D. Yang Ch'üan 楊泉 took up the theme again, in a cosmography that seems quite independent of the Hun t'ien or Kai t'ien (IV (3)).

A further unorthodox but fascinating strand begins with fragments of one of the so-called Apocryphal Books (see Appendix (1)), possibly dating from the first century B.C. In these fragments and in later work based on them (see III (10)) it is stated that the earth goes through an annual cycle of displacement, which may include motion vertically and in a horizontal plane. In contrast to Western reactions to such upsetting suggestions it is claimed that men will not be more aware of their motions than are passengers in a closed boat. In the early material no attempt is made to discuss the astronomical consequences of terrestrial motion, but the fourth century writer Chiang Chi 姜岌 (IV (9)) makes a determined effort to fit the theory into the Hun t'ien cosmos. For some reason none of these texts are discussed by the dynastic history monographs, despite the fact that the T'ang classical subcommentaries treat them in detail.

Throughout the period of this survey the Chinese showed much interest in establishing the dimensions of the physical universe. The basis, if any, of the most ancient estimates is unknown (I (2)(b)(38-39); III (2)(b)). An early application of geometry to this problem is sketched in III(2)(d) and described in detail in Cullen (1). The most systematic and self-consistent attempt to measure the universe was certainly that made by the Chou pei (II, passim;

Appendices (3), (5), (6)). With the rejection of the Kai t'ien cosmography, however, later writers were at something of a loss. Chang Heng claimed that the dimensions he gave to the Hun t'ien were mathematically derived (III (7)(c)), but left no hint of his method if indeed he had one. Lu Chi 陸績 (fl. A.D. 245) simply borrowed a dimension from the Chou pei without comment (III (2)(a)). Lu's contemporary Wang Fan 王蕃 discussed but rejected this figure and attempted a new calculation more suited to the Hun t'ien cosmography (III (2)(c)). Unfortunately he lacked adequate knowledge of the geometry of circles and continued to use the false shadow-principle of the Chou pei (Appendix (3). A more sophisticated attempt, but still using the false principle, was made by Tsu Keng-chih 祖暅之 around A.D. 510 (V (3)(b)). During the period of this survey two suggestions were made which might have led out of this impasse, one by Liu Hui 劉徽 c. A.D. 263 (III (2)(d), and the other by Liu Ch'ao 劉焯 c. A.D. 600 (V (6)(b)). Both of these men proposed experiments on a large scale, resembling the programme eventually carried out by I-hsing 一行 and Nan-kung Yüeh 南宮説 in the eighth century, as described earlier in this introduction. Paradoxically, it will be remembered, the results of these experiments may have been disturbing enough to cause a revulsion from cosmography for some time.

Mostly within the context of the Hun t'ien, there were detailed discussions of various aspects of the heavenly bodies. It should be acknowledged at once that there were no attempts at anything that could be called celestial mechanics, except perhaps a passing reference by Chang Heng (III (7) (e)). Nor did the authors in the survey attempt to derive the detailed movements of the heavenly bodies by compounding physical series of simpler motions as did the Greeks with their "cycles on epicycles, orb on orb". The cycles underlying Chinese calendrical mathematics were expressed arithmetically rather than geometrically (see Sivin (1)); it will probably remain a moot point whether the Chinese poverty in deductive geometry caused the choice of calendrical technique or *vice versa*. In their preference for arithmetical methods in astronomy the Chinese resembled the Babylonians of the Seleucid period (4th - 1st centuries B.C.), although the Hellenistic Greeks were by no means averse to such procedures (Neugebauer, (1), 97 ff, 157 ff.).

Some of the most obvious phenomena requiring explanation were of course those involving changes in the appearance of the sun and moon, including eclipses of either body, and the lunar phases. Naturally all of these were matters closely connected with calendrical mathematics. It has been claimed that the *Chou pei* says that the moon shines by the sun's reflected light, but I find this interpretation doubtful (II (3)(e)). Ching Fang 京房 (fl. 40 B.C.) stated that both the moon and stars are Yin in nature, and reflect the radiance of the sun, which is the essence of Yang (III (5)(a)). Solar eclipses are caused by the Yin "encroaching upon" the Yang. Whether this should be taken as implying physical obstruction by the moon is hard to tell. A century later Wang Ch'ung discussed the problem and rejected any idea of the moon as the cause of the effect : he preferred a theory of the spontaneous fluctuation of the sun's Yang essence. Nevertheless Wang's attempted refutation confirms the currency of the correct theory. He also discusses a number of important related topics; see III (6) passim and particularly (d), (f), (h). A generation later Chang Heng first enunciated the lunar eclipse theory normally associated with the Hun t'ien, which is that the moon is obscured when crossing the earth's shadow diametrically opposite the sun on the celestial sphere (III (7)(d)). The difficulty with this basically correct idea was that on the Chinese view the earth extended so far across the celestial sphere that an extremely large shadow would be expected. This problem was discussed in detail by Liu Chih 劉智 (IV (6)(b)(c)) and Chiang Chi (IV (9)(b)) in the third and fourth centuries A.D., together with other questions such as which of the heavenly bodies are self-luminous.

The foregoing sketch must remain incomplete if it is not to sacrifice all attempts at brevity; much interesting material remains unmentioned. I hope however that I have gone some way towards justifying my previous contention that cosmography is a particularly fruitful area for the study of Chinese science and proto-science, as well as giving the reader some idea of the general nature of the contents of this survey.

(f) Some conclusions and conjectures

So far I have tried to define the task undertaken in this survey, explain why it seemed worthwhile, and describe the means by which its completion was attempted. The preceding section was written in the hope that a skeleton account might spare the reader initial confusion when he eventually begins to follow the tangled threads of cosmographical debate. In addition the reader is perhaps entitled to be told what he will get out of this survey that cannot be attained by reading the short studies already published by Needham and others. This very pertinent question does not admit of a single concise answer, and I would maintain that this is inevitable by the nature of the case. My main claim, as indicated already in this introduction, is that I have treated the subject in greater detail and more comprehensively than before. This could of course be a demerit if it simply meant that the reader is to be confronted with an undigested mass of material subjected to no greater critical process than a roughly chronological arrangement. A collection of a few well-chosen pressed specimens clearly labelled is a more useful entry to botanical knowledge than a garden rubbish-heap, however large. With all modesty I would suggest a different comparison : whereas previous accounts of this field have been sketch-maps or aerial photographs, the present work has attempted to be an Ordnance Survey.

This means, of course, that a great part of its difference from its predecessors does not consist of flat contradiction of their conclusions, apart perhaps from the not unimportant point of the lack of any theory of a spherical earth (Appendix (2)), or the misinterpretation of the _Kai t'ien_ theory by Chatley (II (3)(f)). In many cases only such a lengthy treatment as given here could honestly show how complex are the questions at issue, and how open to doubt any conclusions must be. The origin of the _Hun t'ien_ theory is such a case (III (3)), likewise the "moving earth" fragments (III (10)). The reader who is interested in the development of Chinese mathematics can only be satisfied, similarly, by a step-by-step analysis of the mathematical working of the ancient writers such as that given in the section on the _Chou pei_ (II, _passim_). Another advantage of a full-length treatment is that one is not forced to sort authors into more or less artificial "schools" or "tendencies" so that an account of one of them characterises the whole group. Thus a number of writers are here for the first time given the substantial treatment they deserve, and due attention is paid to their individuality. After reading this survey I hope the reader may agree, for instance, that although Chang Hêng (III (7)), Wang Fan (IV (2)), Liu Chih (IV (6)), Ko Hung (IV (8)), Chiang Chi (IV (9)) and Tsu Keng-chih (V (3)) could all be described as supporters of the _Hun t'ien_ it would be very misleading to blur the important differences between their standpoints. In instances such as these I have tried to put the reader in a position where he can get as close as possible to the original sources without too much interference from any opinions I have conceived myself.

This survey would have been a somewhat unrewarding task, however, if it had led nowhere but to the correction of details and the multiplication of instances. Although I continue to believe that general theories of scientific development are premature I would like to end this introduction with a few conjectures about some of the large-scale characteristics of ancient Chinese cosmography. In particular I would like to consider the relationship between the contents of the _Kai t'ien_ and _Hun t'ien_ theories (see (e) above) and the problem of the later development of cosmography, or more accurately, its failure to develop. In my view the crux of the matter is the persistence in both theories of the belief that the earth was flat. (Note here that the slight curvature of the surfaces of heaven and earth in some versions of the _Kai t'ien_ is without significance : See II (3)(c).)

In Dreyer's discussion of Pre-Socratic astronomy an attempt is made to suggest what may have led Parmenides of Elea (early fifth century B.C.) to introduce the idea of a spherical earth into Greek cosmography (Dreyer (1), 19). This is, by the way, one of a number of instances where comparison of Chinese and early Western material is of interest, although a full treatment demands time and space not now available. According to Dreyer :

> "We cannot doubt that the true figure of the earth was first made clear through the reports of travellers about certain stars becoming circumpolar when the observer proceeded to the north of the Euxine, while a very bright star (Canopus), invisible in Greece, was just visible above the horizon at Rhodes, and rose higher the further the navigator went south. Travellers had probably also announced the different length of the day in different latitudes, a fact which has even been supposed to be known to the writer of the Odyssey. Parmenides may, however, also have supposed that the earth ought to be of the same figure as its surroundings, as he arranged the universe in concentric layers round the earth."
>
> op. cit., 20

To these considerations one might add Aristotle's observation (c. 340 B.C.) that the shadow of the earth seen during a lunar eclipse is always circular (De caelo, II, 14), and that of Posidonius (c. 100 B.C.) that the Persians see the sun rise four hours earlier than the Iberians (Dreyer (1), 172), leaving aside all arguments not based on direct experience. A reading of Part II below will show that the Kai t'ien with its flat earth was at least qualitatively correct in its predictions on nearly all of these points. With its postulate that objects beyond a certain range gave the illusion of setting (II (3)(d)) it was well able to explain why a journey northwards would cause a change in the stars visible as well, of course, as an elevation of the celestial pole. Similarly the question of varying daylength with latitude presented no difficulty;

the six-monthly alternation of light and dark at the north pole was clearly described (loc. cit.). Posidonius' point is dealt with both by the Chou pei itself and by Wang Ch'ung (III (6)(b)). Admittedly lunar eclipses are incapable of a purely optical explanation under the Kai t'ien, but as mentioned in (e) above their detailed explanation was a point of great difficulty for the Hun t'ien in its turn.

Thus Chinese astronomers of the late Western Han need not have felt compelled to abandon the Kai t'ien by the evidence that is alleged to have led the Greeks to conceive of a spherical earth, so long, that is, as the arguments remained qualitative rather than quantitative. When the attack on the Kai t'ien came, however, it was on different grounds altogether; none of the objections were based on the variation of phenomena with geographical location. Collections of these criticisms will be found in III (4) and IV (8)(b). In part they are essentially directed against the aspect of the Kai t'ien theory according to which the apparent risings and settings of heavenly bodies are explained in terms of a limiting range beyond which human vision fails and light from the sun, etc., does not penetrate. (For expositions of this theory see II (3)(d) and III (6)(b)). Other objections point out that the paths followed by the sun moon and stars by day and night are not in accord with the idea that they are circling horizontally above the earth. Perhaps the earliest and most striking difficulty raised was the question of the equinoxes (III (4)(a)) : the Kai t'ien is subject to the dilemma that if day and night are to be equal at some date and location, the sun cannot on that day rise exactly due east and set exactly due west of the observer, whereas an exact east-west path cannot give equal day and night (see Fig. III (ii)). (In reality, of course, both sets of conditions occur together in both spring and autumn throughout the world.)

It seems fair to sum up the objections to the Kai t'ien in the judgement "it doesn't look like that from here", "here" being of course the Yellow River basin on which Chinese culture centred and where many of the writers in this survey probably lived and worked, particularly if they held employment as official astronomers. The Hun t'ien was, in at least the legal sense of the word, calculated to survive the criticisms to which the Kai t'ien had been subjected. It could do this, however, for one set of observers only, and those observers had to be at the centre of the heavenly sphere. Chinese authors seem to have shown no reluctance to assume that their position of observation was uniquely privileged. Although there is evidence for early beliefs that the centre of the earth was at Mt. Kun-lun (I (2)(b)(40)) it became usual to assert that the centre of the Middle Kingdom was likewise the centre of the world (III (10)(c)(vii); IV (2)(c); V (3)(e)). The Hun t'ien universe is comparable to a vast planetarium designed to display the sky as seen from the Loyang region; the effect works quite well so long as a member of the audience is near the centre of the dome but becomes unrealistic if he moves towards the walls. Could a further reason for abandoning the Kai t'ien have been that it placed the Chinese observer in a position of no particular distinction, 103,000 li from the centre of a world 476,000 li in diameter (Fig. II (i)) ? In fairness I should say that the literature gives no hint of this.

The Hun t'ien met the Chinese objections to the Kai t'ien well enough, but consideration of Fig. III (4) makes it plain that it is less capable than the Kai t'ien of withstanding the Greek objections to a flat earth. (I repeat that one conclusion at least for which I feel some fair certainty is that the Chinese cosmographical literature shows no signs of a spherical earth; see Appendix (2).) On the Hun t'ien theory all observers see the same stars simultaneously, and observers far off-centre will see strikingly asymmetrical effects. The Kai t'ien, as mentioned, deals with the effect of north-south motion to some considerable extent, and definitely treats all observers of the same "latitude" (distance from centre of earth) as equivalent. Neither theory gives the true linear variation of polar altitude with meridian displacement (see (c) above), but when the observer actually arrives beneath the celestial pole the Kai t'ien gives an uncannily accurate prediction of conditions (II (3)(d)), while from Fig. III (7)(i) it can be seen that the Hun t'ien is wildly unrealistic. In connection with this, it may be noted that unlike the Kai t'ien the Hun t'ien fails to predict any variation in daylength with north-south displacement, or any variation in the time of noon with east-west motion : Posidonius' observation would have been fatal to it. Under the Hun t'ien when the sun rises or sets it does so for all observers simultaneously, and it is only due south at mid-day for observers on a central meridian. Similarly, on the two days in the year when day and night are (for all Hun t'ien observers) of equal length only those on the east-west diameter of the sphere will see the sun's equinoctial rising due east and setting due west. Chinese astronomers were fully aware of these implications of the theory; Tsu Keng-chih actually proposed to use them in a procedure by which an observer could check his centrality (V (3)(e)).

I ought perhaps to make it clear that my object in the preceding paragraphs is certainly not to enter into polemics on behalf of one long-dead theory against another. The point I hope to make is that insofar as the Kai t'ien/Hun t'ien shift was the result of rational arguments, those arguments could not have included the points that Dreyer suggests were decisive in persuading the Greeks to replace a flat earth with a sphere. This is, of course, scarcely surprising, as both the Chinese theories involved a flat earth. One is faced with two main possibilities :

(i) Chinese cosmographers never knew of the "Greek evidence" and hence stuck to the notion of a flat earth in default of evidence to the contrary.

(ii) They were aware of the facts mentioned but were unable or unwilling to frame a theory that could account for them.

One can question the likelihood of (i) without falling into purely emotional sinophilia. For a start there is the odd way that the Kai t'ien gives such a good approximation to the geographical facts, and the Han Chinese do not seem to have been strangers either to long overland expeditions or sea-voyages to distant countries (SCC III 510 ff; SCC IV, 3, 440 ff.). I would conjecture that the Kai t'ien may have been a conscious attempt to form a cosmographical scheme that would take the totality of astronomical and geographical knowledge into account. It is not at all conjectural that this scheme could not stand up to quantitative criticism, and its replacement, the Hun t'ien, throws all generality aside in its successful attempt to save the phenomena for a central observer.

I am conjecturing once more when I point out that the central observers par excellence were the official astronomers at the capital, and ask the reader to consider the fact that it is from these circles that the criticisms of the Kai t'ien and support of the Hun t'ien seem mainly to come. Wang Ch'ung, the great Han iconoclast, supported the Kai t'ien; in his condemnation of the theories of the Chou pei c. A.D. 180 Ts'ai Yung (III (8)(a)) says it is "in error when checked with the celestial phenomena, and so the [astronomical] officials do not use it". Could it be that the state astronomers who worked steadily to improve their instrumentation and technique throughout the Western and Eastern Han insisted eventually on a cosmography that would harmonise with their observations (see III (3) passim) and were prepared to discount travellers' tales to get it ? As already mentioned the new cosmography possessed the advantage of sinocentricity, and its mechanism of physical risings and settings of heavenly bodies over the edge of the earth could be said to have the support of the ancient classical texts (see IV (2)(a)) for an example of such argument). Unlike the astronomers of the Greek world scattered round the Mediterranean basin, Chinese astronomers were a tightly-knit and centralised group of bureaucrats, and a theory that suited them was unlikely to succumb to amateur criticism.

There is one point, however, (as I find myself repeating) on which all Chinese cosmographers agree, whether professional astronomers or not. Earth may be stationary or oscillate up, down, or sideways; it may be supported hydraulically or pneumatically; heaven may be flat or spherical, in rotation or at rest; it too may oscillate, or it may be completely insubstantial. Despite a flood of original and often highly eccentric thinking, the home of man is always the comfortingly flat earth. Indeed, we never find so much as a dismissal of the spherical earth as a ludicrous fantasy. Could it be that the Kai t'ien's false start made the evidence for sphericity disreputable once the Hun t'ien officially declared such phenomena non-existent ? It may well be of course that the idea of the sphere is so great a leap for the intellect that it does not suggest itself as the result of physical reasoning. All our explanations of the making of this discovery by the Pythagoreans in the fifth century B.C. Greece are no more than post hoc rationalisations, and the origin of the idea may have been purely mystical for all we know. Once launched, of course, it was well fitted to win through to victory in the Darwinian struggle of rival theories, despite obstacles of ignorance and obscurantism for centuries to come. But in China the seed was never apparently sown, and even the strong stimulus of the eighth century survey results previously mentioned failed to produce a reaction in a fruitful direction. The attempt to guess why this was raises topics too large for proper treatment within the boundaries of the present work. Meanwhile the interesting task remains of seeing what a succession of brilliant and original minds made of a problem to which the most vital clue of all was never found: what is the nature of the world in which we live?

I : SOME ARCHAIC NOTIONS

(1) The importance of a background

The declared object of this survey is to give an account of early Chinese cosmographical argument. Why then does it begin with a somewhat miscellaneous mixture of legend and unsupported assertion, much of which was dismissed, except for poetical purposes, as early as Wang Ch'ung in the first century A.D. (see III (6)) ? I reply that one of the main reasons for discussing such material is precisely that we can judge the nature and power of later thinking by the way it interprets these traditions and how many of them it feels compelled to reject. If we neglect the study of the context in which ideas arose, we cannot form a proper idea of their originality or significance, and may find ourselves puzzled over points where an ancient reader would have shared an unstated assumption.

This section is not a complete study of the available evidence. All that will be done is to present a selection of cosmographically interesting material of mostly pre-Ch'in date. This will necessarily involve a certain amount of tearing out of context, a regrettable process as I have already noted. One has to begin somewhere, however, and it cannot be denied that a complete discussion of, for instance, the universe of the Ch'u tz'u needs the methods of the mythographer rather than those of the historian of science. I would also argue that this is not an instance where we need be over-scrupulous about establishing the precise religious or philosophical significance of ideas in their original cultural setting. This is because we are only dealing with the influence of early thinking in the somewhat fossilised form it had taken on by the time our survey properly begins. The transformation involved was often a very radical one indeed. Maspero (1) deals amongst other such matters with the case of Hsi Ho, regarded in early legend as the mother and charioteer of the sun. After suffering a Confucian sea-change, this rich and strange being appears in the Shu ching as two ancient official astronomers and their sons !

By way of providing a background to the main part of this survey, therefore, I will give an account firstly of a body of belief with its roots firmly in myth. This will be followed by an attempt to recover what we can of the cosmography of Tsou Yen, whose importance is not so much the arguments (we know of none) by which he supported his theories, but rather the novelty with which his ideas struck his contemporaries. The beginning of novelty is, after all, the end of myth.

(2) The world of the T'ien wen 天問

(a) Origin and nature of the work

The T'ien wen forms part of the Ch'u tzu 楚辭 collection, which was compiled by Liu Hsiang 劉向 c. 50 B.C. and added to and given a commentary by Wang I 王逸 c. A.D. 130. In the introduction to his translation Hawkes (1), 45, says on the question of authorship and date :

> "The traditional attribution to Ch'ü Yüan [屈原 c. 300 B.C.] could be correct; though I am inclined to think it was written earlier - perhaps as much as a century earlier - than Li sao another poem of the anthology, formerly attributed to Ch'ü Yüan , and that Ch'ü Yüan knew it and was to some extent influenced by it. At all events, the view, occasionally entertained by modern scholars, that it was written some time in the Han dynasty, is almost certainly wrong. Archaeological evidence has revealed that the author of T'ien wen knew more about the early history of Shang than any Han author would appear to have done, and the stylistic archaism is unlikely to be pastiche."

The work takes the form of a number of questions, as its title T'ien wen (= 'Heavenly questions') would lead us to expect. It is irrelevant for the present purpose whether they are the remains of a ritual catechism, or perhaps a mere collection of riddles as Hawkes suggests. Whatever the purpose of the questions they certainly provide a fairly complete set of references to those legends and beliefs of pre-Ch'in times which relate to what we would now call cosmography, as well of course as many other subjects besides. The poem begins in a systematic way, dealing first with cosmogony, then with heaven, the sun, moon and stars, the great flood, and the wonders of the earth. I have therefore adopted the plan of quoting from Hawkes' translation, and adding comments on each section. The numbering refers to Hawkes' division of the original into 'lines', each consisting of two tetrasyllables: for text, see Chu Tzu, SPTK. My two main sources for the comments are Chiang Liang-Fu (1) and Wen I-To (1). This material is readily available and in the main not subject to controversy; such parts of it as are at all doubtful are in no way crucial for any of my later conclusions. For once at least in this survey, therefore, I have allowed the interests of brevity priority over those of fullness of discussion and detailed citation of references.

(b) Extracts and comments

(7-8) "Who planned and measured out the round shape and ninefold [gates of Heaven] ? Whose work was this, and who first made it ?"

The 'round shape' is an obvious enough reference to heaven, but in what way is it 'ninefold' ? Wen I-To argues convincingly for the version given by Hawkes, pointing out a number of early references to 'ninefold' gates in the context of royal residences, and distinguishing this mention of the number nine from that in lines (11-12) below.

(9-10) "How are the Ladle's Handle and the Cord tied together ? How was Heaven's Pole raised ? How do the Eight Pillars of Heaven keep it up ? Why is there a gap in the south-east ?"

The 'Ladle's Handle' and the 'Cord' are references to the stars of part of Ursa Major, sometimes indeed referred to as the 'Northern Dipper' in English. Hawkes is adopting the same rendering as Wen I-To, who also examines the very different interpretation of Wang I. Wang glosses 斡 kuan as 'a pivot' and considers that the 'Cord' wei 維 is some kind of physical suspension, presumably attached to this pivot so as to hold up heaven. Wen rejects this, but I cannot help being reminded of a passage in Kuan tzu 管子:

> "Heaven is suspended (wei 維) by something, and earth is carried (tsai 載) by something. If nothing suspended heaven, then it would fall. If nothing held up earth then it would collapse."
>
> Kuan tzu, 13, 10b, SPTK

Wen suggests that in this instance 'Pole' chi 極 may be used in its original sense of 'ridgepole of a house' as if the vault of heaven was a roof. Although there are early mentions of pillars below the earth, Wen is almost certainly justified in taking the eight pillars referred to here as the ones which hold up heaven. They appear to have been thought of as eight mountains arranged round the edge of the earth. The 'gap in the south-east' is the gap between the pillars and heaven caused by tilting after the north-west pillar had been broken by the legendary demon Kung Kung 共工 : the details of this story are given below (line 35).

(11-12) "Where do the nine divisions of Heaven each stretch to and where do they join ? The ins and outs of their edges are very many. Who knows their number ?"

The 'nine divisions' are thought to be what are often called the 'nine fields (yeh 野): one is at the centre, round the pole, and the other eight are segments of the rest of heaven. It may be of interest to note that according to Huai Nan Tzu (3, 2a, SPTK) the number of 'ins and outs' required is a somewhat hyperbolic 9,999.

(13-14) "How does Heaven coordinate its motions ?
Where are the twelve Heavenly Houses divided ?
How are the sun and moon connected with them
and the stars spaced out over them ?"

Hawkes' version of the first question must be regarded as hypothetical. Wang I glosses 沓 t'a as 合 ho 'join', and considers the question means "where do heaven and earth join ?". The reference to earth seems ill-placed in a context where preceding and subsequent questions refer to heaven alone or the heavenly bodies, and, one is moved to ask, how can heaven join on to earth if heaven rests on pillars as already mentioned ? Chiang makes the interesting suggestion that the 'joining' referred to may be the monthly conjunctions of sun and moon. As there are twelve of these annually a link is established with the second question. Wen argues that in any case t'a should not be taken as 'join together', but carries instead an implication of 'stacking up', or more abstractly of something being based on something else or relying on it. His version would be something like : "For what reason is it that Heaven is divided into twelve ?"

Lines 13, 14 recall part of the I Ching :

> "The sun and moon are connected (chu 麗) to heaven; the hundred cereals, grass, and trees are connected to earth."
>
> (Chou I, 3, 36b SPTK)

(15-16) " The sun sets out from the Valley of Morning and goes to rest in the Vale of Darkness. From the dawn until the time of darkness, how many miles is his journey ?"

A long and fascinating discussion of these beliefs is given in Maspero (1). The important point for future reference is that the sun rises up from and sets into the earth itself: the cause of day and night is obvious. The K'ai T'ien theory claimed that sunrise and sunset were mere optical illusions, while the eventually triumphant Hun T'ien insisted on physical setting and rising. In the Hun T'ien the sun follows the rotating celestial sphere below the earth and reappears in the east. The legend of the Fusang (see line 45 below) suggests that the archaic view may in contrast have held that a new sun is formed in the east each day. It has been suggested (Needham, SCC III, 218) that another poem in the Ch'u Tz'u "speaks of the sun travelling back to the east during the hours of darkness". This notion comes from a line in the poem Tung chün 東君 'The Prince of the East' (a solar deity) :

> "I seize my reins and soar up high, and in the darkness I go to the east"
>
> (Ch'u tz'u, 2, 23b, SPTK)

To claim, however, that this "may be early evidence of Hun t'ien ideas" seems rather unjustified in the general context of the rest of the Ch'u tz'u.

Two questions which occur later in the poem are appropriately dealt with immediately :

(45) "Why are the Jo flowers bright before Hsi-Ho is stirring ?"

(56) "When Yi shot down the suns, why did the ravens shed their feathers ?"

Again, a detailed examination of evidence relating to these lines is given in Maspero (1). The Jo tree is one of a pair of trees connected with the sun: it is associated with the setting sun. The rising sun comes from the Fu sang 扶桑 tree in the east, which is referred to in the Li sao. This tree bears ten suns in its branches, and each morning one of them mounts up into the sky: presumably a fresh one then grows on it. A recently excavated textile dating from the second century B.C. carries a depiction of this tree, and likewise of the raven in the sun. (New archaeological finds in China, 42, Peking, 1974)

Hsi-Ho is the charioteer who conducts the sun across the sky to the 'Vale of Darkness'. In some legends Hsi-Ho is also the mother of the suns. A further legend tells that one one occasion all ten suns rose at once, and the earth was saved from combustion when Yi, the archer, shot down nine of them. The ravens thought to be present in each sun might be an early reference to sunspots. These legends attracted the particular attention of Wang Ch'ung, who disposed of them with incisive rationalism (see III (6))

(35) "When K'ang Hui was enraged, why did the earth fall in the south-east ?"

K'ang Hui is another name for the legendary being Kung Kung 共工. The full story of this event is given in Huai nan tzu 淮南子:

> "In ancient times Kung Kung fought with Chüan Hsü 顓頊 for the imperial power. In his rage he smote mount Pu Chou 不周 : the pillars of heaven snapped and the bonds of earth broke. Thus heaven inclined to the north-west so that the sun moon and stars moved thither, and earth did not fill the south-east, so that the waters and detritus flowed in that direction."
>
> (Huai nan tzu 3, 1b, SPTK)

Elsewhere in Huai nan tzu (4, 4a SPTK) mount Pu Chou is given as the north-western of the eight circumferential mountains: these are the pillars of heaven mentioned in connection with line (10). It might seem odd that it is the north-western pillar which is damaged rather than simply the northern one. Perhaps it was felt that the north-western rupture would not only explain why the celestial pole was tilted northwards but would also suggest some cause for the westwards setting of the celestial bodies. In his discussion of the story, Wang Ch'ung mentions a further legend of the repair of the broken vault of heaven by the goddess Nü Kua (see III(6)(j))

(38-34) "What are the distances from east to west and from south to north ? From north to south the earth is longer and narrower. How much is the difference between its length and breadth ?"

Although it would be hard to argue that Hawkes is incorrect in making the text imply that the north-south dimension is longer than east-west, (this was also the view of Wang I), most examples of early alleged measurements contradict this. According to the Lü shih ch'un ch'iu for instance :

"Within the four seas i.e. the inhabited earth it is 28,000 li east-west and 26,000 li north-south"

(13, 3a SPTK)

These figures are also found in Huai nan tzu, Kuan tzu, and the Shan hai ching. Perhaps the important point is not so much which measurement is greater, but the fact that there is any difference at all. I have not so far succeeded in finding any plausible motivation for these figures. Lo Yang is some 400 miles, about 1,200 li, from the sea: doubling this figure for the width of an earth with Lo Yang at its centre gives 2,400 li, which is less than ten per cent of the values given here. Perhaps there is a connection with Tsou Yen's notion of the ninefold continents ? (see below, I(3))

(40-41) "Where is K'un Lun with its hanging gardens ?
How many miles high are its ninefold walls ?"

崑崙 Mount K'un Lun is repeatedly mentioned in the Ch'u tz'u and elsewhere in ancient literature. There seems to have been a belief that it was the central mountain of the earth, and its frequent portrayal in the form of bronze censers of the Western Han onwards underlines its importance. A fragment of an apocryphal work which makes the position and function of the mountain explicit runs :

"Mount K'un Lun is the central pillar of heaven"

(Lung yü ho t'u, quoted in I wen lei chü, 7, 130)

This work probably dates from the Western Han, as do most other such books (see Appendix (1)). Another statement is found in the Shui ching 水經 which is attributed to the Western Han but was more likely compiled during the Three Kingdoms :

> "The waste of K'un Lun is in the north-west. It is 50,000 li away from Mt. Sung Kao 嵩高 [near Lo Yang], and is the centre of the earth. It is 1,000 li high and the waters of the Yellow River flow from its north-east corner."

SPTK, 1, 1a ; quoted IWLC 7, 130

When we come to consider the work of Tsou Yen, we shall see a further instance of this view of China as being situated in the south-eastern parts of the earth. More surprisingly, perhaps, Chang Heng, author of our first extant treatise on the Hun t'ien seems to have believed this (see III (7) (c)). As might have been expected, Wang Ch'ung rejects all such stories.

(c) Summary of conclusions

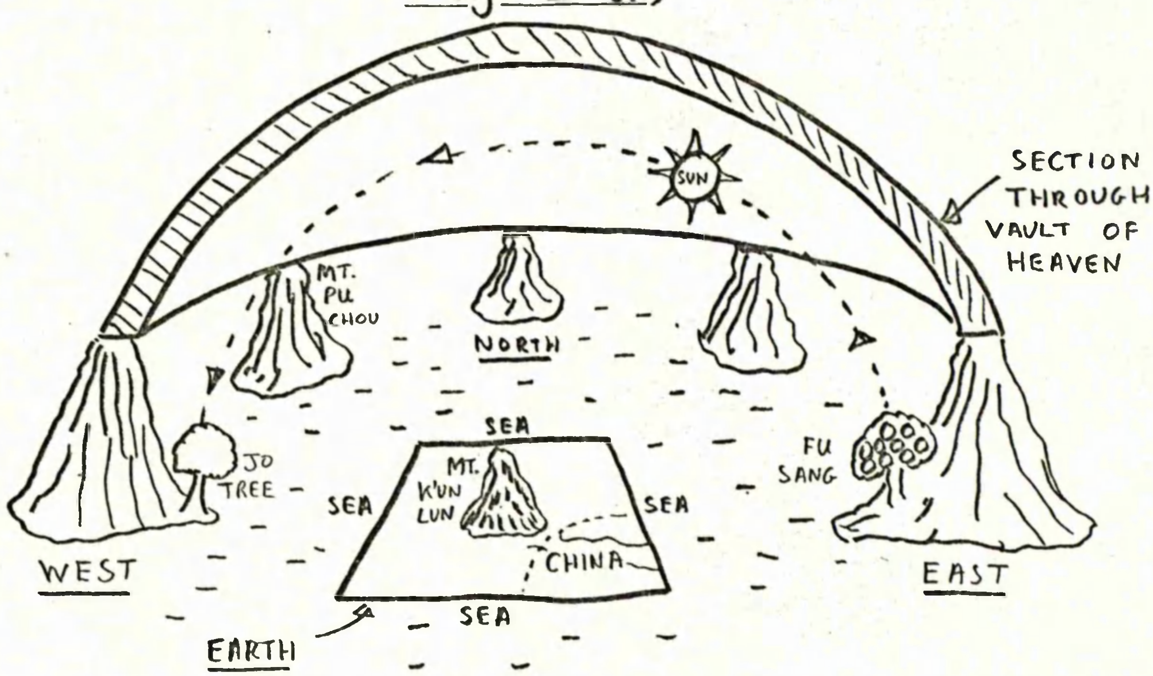
Although we cannot reasonably expect a completely consistent picture to emerge from a background of legend, it is interesting to attempt to put together some total picture of the conception of the universe which underlies the T'ien wen. Before the damage caused by Kung Kung both earth and heaven were untilted. Heaven rested on the eight mountain pillars, but it is uncertain however, exactly how the position of these is to be related to the earth itself. I suggest, on the basis of the admittedly much later account of Huai nan tzu 4, 4a, mentioned above, that the (almost) square dry land surrounded by 'the four seas' is considerably smaller than the diameter of the ring of mountains supporting the round heaven. (I think it not unreasonable to assume that the mountains are in a circle to match with heaven.) The 'Valley of Morning', in which is the Fu/sang tree, must surely have been thought of as beyond the seas to the east of China, and the 'Vale of Darkness' with the Jo tree was presumably symmetrically placed. At the centre of the earth is Mount K'un Lun. (See Fig. I(1))

The preceding account has had to draw on sources other than the T'ien wen as well as relying on assumptions of dubious status about what is 'reasonable'. It might be thought that this makes it a rather pointless exercise. I would nevertheless argue that if a Chinese of the early

Western Han had an overall picture of the universe formed on the basis of current literature, then it would not be radically different from the one I have given. It is not a satisfactory picture capable of 'saving the appearances' for all celestial phenomena. This need not suggest that we have misinterpreted the evidence, for if it had been a totally satisfactory picture, there would have been no incentive to develop a better theory of the universe, nor any motive for making the mental leap necessary to accept the unprecedented novelty of both the Hun t'ien and the Kai t'ien.

The cosmography of the T'ien wen

Fig I (1)



Sectional view of the Universe in undamaged state

(3) Tsou Yen : the beginning of theory

(a) Life and work of Tsou Yen

A detailed account of what is known of Tsou Yen 騶衍 (c. 350-270 B.C.) is given in Needham SCC vol II, 232 ff, drawing on the Shih chi, 74, and the few extant fragments of Tsou's writings. He was closely associated with the development of the 'Five Elements' theory, and may have been a 'founder member' of the famous Chi-Hsia academy at the capital of the state of Ch'i. It appears that he and his disciples were held in very high regard by the feudal lords of that time and received generous support, possibly because it was felt that the application of the Five Elements theory to statecraft was politically useful.

Tsou was certainly a man of wide-reaching views. The Shih chi says :

> "He made a profound examination of the ebb and flow of the Yin and Yang and wrote the Kuai yü chih pien, the Tung shih and the Ta sheng in more than 100,000 words. His discourses were wide-ranging and unconventional; he always began by examining something small, but continued by extrapolating to larger things, and eventually reached the infinite. First he dealt with the time from the present back to the Yellow Emperor, in common with other scholars, but by taking together the rise and fall of the ages, and basing himself on signs and rules he extrapolated to the most distant times, and reached the age before the birth of heaven and earth, that incomprehensible and originless obscurity. First he set in order the famous mountains and

> great rivers of the Middle Kingdom, its connecting valleys and wild beasts, the wealth of its water and soil and its precious products. On this basis he extrapolated to the regions beyond the seas where man cannot observe."

Shih Chi 74, 1344, CHSC

Although one ought to resist the temptation to make stimulating but possibly misleading comparisons, I would at this point like to note that a good part of our knowledge of the most distant galaxies is ultimately based on observation of small samples of gases in a laboratory, "extrapolated to the limit". Unlike Tsou, however, we can claim to have made some effort to discover what properties of things near at hand are invariant enough to warrant such extension. Perhaps comparison ought to be restricted to the following passage from the Lieh tzu : despite the risk of interpolations at any time before the Chin dynasty text stabilisation, it may be pre-Ch'in material.

> "T'ang asked : 'Is there anything beyond the four seas?'"
> "K'o said : It is the same as the Middle Land'"
> "T'ang asked : 'How do you know that is true?'"
> "K'o said : 'I went east to Ying, and the people are the same as here. I asked about the east of Ying, and they said it is still the same as Ying. I went west to Pin, and the people are the same as here. I asked about the west of Pin, and they said it is still the same as Pin. Thus I know that the four seas, the four wastes, and the four poles are no different from here."

Lieh tzu chi shih, ch. 5, 92.

This is the same practice of daring but over-confident extrapolation from the known to the unknown that was apparently the method of Tsou Yen.

(b) Tsou Yen's cosmographical thought : two accounts

Although we have no record of discussions on the heavens by Tsou Yen, a substantial fragment on the earth is available from reasonably attested sources. It occurs in the Shih chi very soon after the end of the passage already quoted.

> "What the literati call the Middle Kingdom fills but one eighty-first part of what is under heaven. The name of the Middle Kingdom is 'The wondrous region chou 州 of the red nome'. Within the wondrous region of the red nome itself there are nine 'regions', and these are the 'regions' established by Yü - but these do not count as actual regions. Outside the Middle Kingdom there are in all nine regions like the wondrous region of the red nome and these are what I call the 'nine regions'. Round these there is a 'lesser sea', impassable to people and animals, so as they are within a single boundary, they amount to a region. There are nine like this, and then there is a vast ocean round the outside. This boundary is known as the 'eight poles', where heaven and earth meet."

(I follow Shih chi, 74, for all but the last sentence, which is drawn from Yen t'ieh lun, 53.)

Later but still in all possibility authentic accounts of Tsou Yen's theories are contained in Wang Ch'ung's critique of them, written c. A.D. 80.

> "The works of Tsou Yen state : 'There are nine regions in the Empire, and these are the nine regions referred to in the Yü kung [= Tribute of Yü, part of the Shu ching]. Now these nine regions of the Yü kung I call one region, and reckoning beyond those of the Yü kung there are nine. The nine regions of the Yü kung which are the nine regions of the empire today, are in the south-east corner, and its name is

"The red nome of the wondrous region". There are eight more such regions, and each region is encircled by four seas, which are called "lesser seas". Outside these nine regions there is a vast ocean in addition'."

Lun heng 11,3a, SPTK

Whereas the Shih chi account suggested that the world contained eighty-one equivalents of the 'Middle Kingdom', it is evident that Wang Ch'ung's version gives only nine. Redundantly, however, he preserves the two ranks of sundering seas. Obviously the 'Middle Kingdom' is not completely surrounded by water, and so only a single one is required, there being only one landmass, which is made up of the nine China-sized 'regions'. It is not surprising in view of the omission of the second factor of nine involved that Wang Ch'ung came to the conclusion that Tsou Yen's estimate for the size of the world was smaller than it could have been. Despite this, his other criticisms are telling enough, as we shall see (III (6) (e) below).

In Fig. I (2)(a) I attempt to represent the statements of the Shih chi diagrammatically. I have assumed that each of the nine great continents is centred on a mountain like K'un Lun, and that their arrangement is related to the theme of squareness which the ancient Chinese so often stress in relation to the earth. For, I confess, no very strong reason, I have assumed that the great continent in the south-east corner of which is China is placed centrally. Fig. I (2)(b) carries 'reconstructor's licence' to its maximum; it is true at least that the text says that heaven and earth join, and that we have no evidence that Tsou Yen differed from the ancient tendency to think of heaven as a solid vault of some kind.

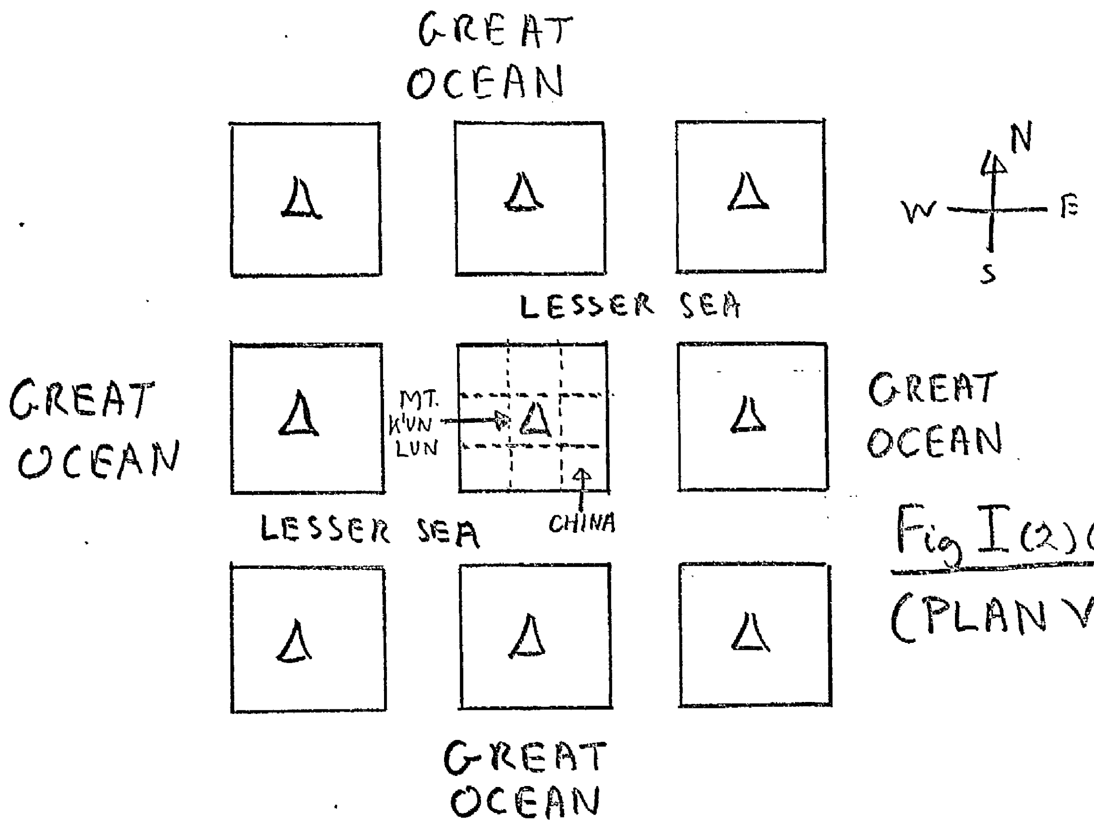


Fig I (2)(a)
(PLAN VIEW)

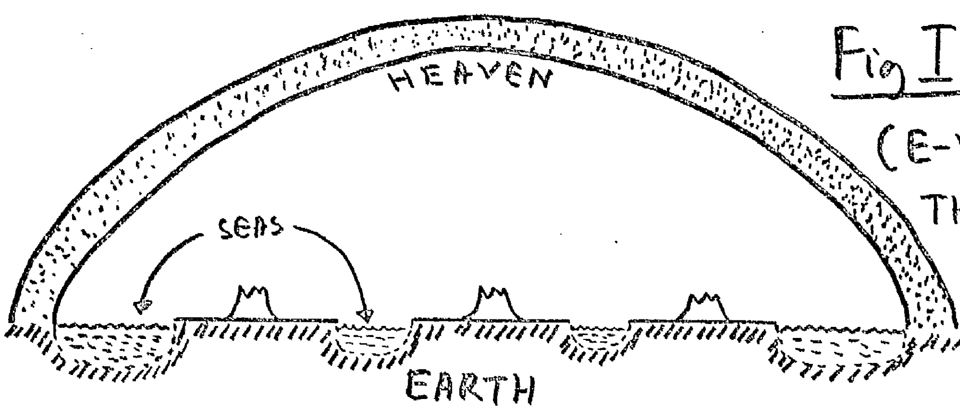


Fig I (2)(b)
(E-W SECTION THROUGH CENTRE)

Conjectural reconstruction of Tsou Yen's world

(c) The significance of Tsou Yen's theory

How did Tsou Yen arrive at the somewhat bizarre geography set out above ? If we remember that he is said to have arrived at his results by extrapolation from the known to the unknown, it seems possible that the process might have been as follows :

(i) Tsou realised that there was land far beyond the borders of the Empire.

(ii) Extrapolating, he assumed that just as there were nine regions within the Empire, so there were in all nine regions of equal size with the Empire, which formed one of them.

(iii) Aware that there was sea to the east and south of China, he thought that the nine 'Chinas' constituted a land-mass surrounded by sea with China in the south-east corner.

(iv) He was now faced with another unit, the land-mass, surrounded by sea, and extrapolated once more to give nine of them. Further multiplications would not give a qualitatively different unit, so he left the process at that point.

This is, of course, a tentative and untestable scheme, but insofar as it makes Tsou's theory less mysterious in its origins we are released from any necessity of supposing it due to, say, Indian influence. (But see V(5)(a) for some interesting comparisons).

The point remains nonetheless that Tsou created a great novelty in his notions about the earth: it is a pity that we have no record of any of his astronomical speculations. The creators of the striking novelties of the _Hun t'ien_ and _Kai t'ien_ remain unknown.

II : CHOU PEI SUAN CHING 周髀算經

(1) The importance of the work

It is very unlikely that any firm conclusion could ever be reached in a discussion of the authorship of this work and its compilation. Such evidence as there is relating to these problems is set out in Appendix (4), together with a summary account of the book's contents. The most positive statement that can be made about the book in that summary is that it must have reached a stable form by the time that it received its first commentary *circa* A.D. 222.

The aim of this survey is not however primarily bibliographic. For the history of cosmographical argument the important point is that there is a considerable body of evidence suggesting that the material of the *Chou Pei* was current during the Western Han. Indeed I shall later suggest that there is very clear proof that the cosmography of this work was known in detail in pre-Ch'in times. The actual compilation of the book, I feel, may have been a response to the aggressive and successful arguments of supporters of the *Hun t'ien* against the *Kai t'ien* cosmography which the *Chou Pei* sets out to expound. We are lucky that the results of this compilation have been preserved in a relatively uncorrupted state, for without this book nearly all of our knowledge of the *Kai t'ien* would have to be drawn from the statements of its opponents. Likewise their descriptions of their own theories gain greatly in interest by being set in contrast to a clear description of the system they sought to replace. The only other source of arguments in favour of the _Kai t'ien_ is the work of Wang Ch'ung in the second half of the first century A.D. (see below, III (6)). Although the principles of his cosmography appear identical to the _Chou Pei_ he neither mentions the work nor refers to the _Kai t'ien_ by name. It is notable also that he gives an account of the dimensions of the universe which differs considerably from the details given in the _Chou Pei_.

(2) Techniques of observation and calculation

(a) The gnomon and the shadow principle

The gnomon or simple vertical pole is the instrument used throughout the work, except for the single instance of the use of a sighting-tube described below. Indeed, the text itself claims that its title Chou Pei means 'the upright of Chou' (Ch'ien Pao-tsung, (1), 34), although the term 表 piao rather than 髀 pei is used through most of the text. The shadow cast by the gnomon at noon is observed, and by the application of a simple rule the distance from the gnomon to the point on the earth directly below the sun is derived. This method is extended to observations of a star: as its light is of course too weak to cause the gnomon to cast a shadow, a string led down along the line of sight from the top of the gnomon enables an artificial shadow to be constructed (p. 54) (All references to Ch'ien's edition)

What was the principle by which observation of a shadow yielded the distances of heavenly bodies ? We find a short but clear statement in the following terms :

> "Method : the Chou gnomon is eight feet long. The increase or decrease of the horizontal [= shadow] is one inch for a thousand li". (p. 34)

In other words, for every thousand li between the gnomon and the point below the heavenly body observed there is one inch of shadow. An example follows immediately :

> "Now set up a gnomon eight feet high and sight on the celestial pole: the horizontal is ten feet three inches. From this it is evident that northwards 103,000 li from Chou one arrives at the point below the celestial pole." (p. 34)

(The terms 'foot' and 'inch' here are renderings of the roughly equivalent 尺 ch'ih and 寸 ts'un. There were ten ts'un to a ch'ih, and the absolute value of these units is of course irrelevant as long as gnomon and shadow are measured in the same units.)

Similar procedures are used to give the result that the noon subsolar point is 16,000 li due south at the summer solstice and 135,000 li due south at the winter solstice. At these positions a gnomon is said to cast no shadow at noon on the respective dates. (p. 26)

As shown in Appendix (3), these applications of the 'inch for a thousand li' principle are completely invalid, except in a universe where the heavenly bodies lie on a flat heaven 80,000 li above a flat earth. It is not unexpected, therefore, when after describing observations made at a time when the gnomon casts a six foot shadow, the text continues :

> "From the gnomon to the point below the sun is 60,000 li, and there the gnomon has no shadow. From there upwards to the sun is 80,000 li". (p. 26)

Much later, we read :

"Heaven is 80,000 li from earth." (p. 54)

As will appear later, however, it is made clear that heaven and earth are not thought of as parallel planes, but rather as both bulging upwards 60,000 li in their centres, for a diameter of 476,000 li. The T'ang commentator Li Shun-feng is well aware that this makes a simple application of the shadow principle impossible (p. 28 f.). In his defence of the Kai t'ien Wang Ch'ung makes it clear that, for him, heaven and earth are actually flat and parallel (see III (6) (b)).

Appendix (5) contains an examination of the shadow data in terms of date and place of observation. It is there shown that it is difficult to maintain that they form a consistent set: this does not detract from their importance in that they nevertheless formed the basis of the Chou Pei's quantitative cosmography.

(b) The theorem of Pythagoras

Almost at the beginning of the text, in a section recording a dialogue between the Duke of Chou (c. 1020 B.C. according to the conventional chronology) and the minister Shang Kao, the latter refers to the 3 - 4 - 5 right-angled triangle. In part his statement reads :

> "Cut a rectangle so that the base is three broad and the altitude four long: the diagonal is five" (p. 14)

This passage has attracted a mass of exegesis and illustration from later commentators. It is of course unlikely in the extreme that the dialogue recorded here ever took place. Nevertheless the ascription of the knowledge contained in it to such ancient worthies suggests that when the text was composed this fact was not thought of as a recent discovery. Taking account also of the archaic expression of the passage as a whole compared to the rest of the book I feel inclined to claim that this section represents one of the earliest strata of tradition drawn on by the book's compilers.

In the main body of the text the general theorem is applied with confidence together with a technique for extracting square roots (not explained in the text, although correct results are produced). There is one instance (see (c) below) where an effort is made to keep to triangles of the 3 - 4 - 5 ratio, but elsewhere a triangle is solved given an hypotenuse of 238,000 _li_ and an altitude of 103,000 _li_. The base is found with good accuracy, to be 214,577½ _li_ (see pp. 39, 40) . Despite the facility with which the theorem is applied, the text does not contain anything that could be called an explicitly general proof of the result.

(c) <u>The sighting-tube</u>.

This instrument appears only once in the book, but is used as the last link in a chain of argument by which the size of the sun is established. The text which follows is largely self-explanatory :

> "Wait until the shadow [of the eight-foot gnomon] is six feet long. Then take a bamboo with a one-inch bore, and of length eight feet. Catch the rays [of the sun] and observe that the bore exactly contains the sun, and the sun corresponds to the bore. Thus in this case one can see that the ratio is that 80 inches [for the length] gives a diameter of one inch. So taking the horizontal as the original figure, and the gnomon as the altitude, from the gnomon to the point below the sun is 60,000 <u>li</u>: there the gnomon has no shadow. From that point it is 80,000 <u>li</u> up to the sun."
>
> "If one seeks the distance slantwise to the sun, take the [distance to the point] below the sun as the base and the height of the sun as the altitude. Square base and altitude, add, and take the square root. One obtains the result that going slantwise to the sun from the gnomon is 100,000 <u>li</u>."
>
> "Making use of the ratio, 80 <u>li</u> gives a diameter of one <u>li</u>, and 100,000 <u>li</u> gives a diameter of 1,250 <u>li</u>. Thus it is said : the diameter of the sun is 1,250 <u>li</u>." (pp. 27, 28)

The observation of interest here is, of course, the use of a tube to sight on the sun; the data from this amount to a statement of the apparent angular diameter of the sun. This angular diameter, S, is given by :

$$S = 2 \tan^{-1}\left(\frac{0.5}{80}\right)$$

$$S = 0^\circ 43'$$

The actual apparent angular diameter of the sun is about $0^\circ 10'$ less than this : in terms of the sighting-tube this means that the sun would only fill 0.75 inches of the diameter of the tube, which would need to be some 107 inches long before the diameter was filled, rather than only 80 inches. Even given that observations were taken when the sun was partly obscured by fog or cloud, or at dawn or sunset, the process would be difficult to perform accurately, due to the obvious problem of glare. I suspect that an eight foot sighting-tube was used by analogy with an eight foot gnomon, and the diameter of one inch (perhaps suggested by the shadow principle) was found to fit the sun-sight well enough so that no further change was felt to be required.

The actual result of 1,250 li is of course completely conditioned by the choice of the moment when the sun happens to be 100,000 li away according to the methods of the Chou Pei. As the apparent angular diameter is constant throughout the year, a choice of observation at the summer solstice when the sun is much closer would give a considerably smaller diameter in li. The conditions chosen are obviously the result of a wish to deal with a 3 - 4 - 5 triangle consisting of the 60,000 li south to the sun, the 80,000 li altitude of the sun, and the 100,000 li distance slantwise to the sun from the gnomon.

It has been alleged that certain references in the latter half of the book are descriptions of a sighting-tube made of jade: see Michel (1) quoted by Needham SCC III 333 ff. I have shown at length elsewhere (Cullen (2)) that this allegation is simply the latest in a line of mistaken assumptions over the last two millennia. The actual meaning of the term in question 璿璣 hsüan chi is discussed below, in section (3).

Further, why is the gnomon used only for observations of objects near the meridian ? The difficulty here of course is that as the sun tends towards setting, the length of the shadow tends towards infinity, suggesting an infinite distance to the subsolar point. I do not think, however, that it was as the result of any suspicion about the general applicability of the methods of section (2) that they were used to provide only four data. In my opinion these four data are the only ones necessary and sufficient to define the dimensions of a universe whose form was already present in the minds of the writer(s) of the Chou Pei. (I am not here considering the figure of 60,000 li for the upwards bulge of the centres of heaven and earth, which the text does not set out to justify.)

(b) The pole and the dimensions of the solar paths

What then were the assumptions made by the author(s) of the Chou Pei material on the general form of heaven and earth ? Most important from the point of view of its consequences for quantitative cosmography is the notion that the north celestial pole is the centre of heaven and is directly above the centre of earth, which is, as we have seen, 103,000 li to the north of the observer. The daily path of the sun is a circle centred on the celestial pole, and the diameter of this circle is a minimum at the summer solstice and a maximum at the winter solstice. An example of the procedure followed is :

> "16,000 li to the south at the summer solstice and 135,000 li to the south at the winter solstice there is no shadow at noon. Viewing matters on this basis, going southwards [from the pole] to the noon sun at the summer solstice is 119,000 li. [Calculated from 103,000 li north to the pole from the observer as previously stated, and 16,000 li south to the summer solstice noon sun.] It is the same distance northwards to [the position where it is] midnight. The diameter is 238,000 li, which is the diameter of the sun's path at the summer solstice. Its circumference is 714,000 li. From the noon sun at the summer solstice to the noon sun at the winter solstice is 119,000 li, and north to below the pole is the same distance. So from the pole southwards to the noon sun at the winter solstice is 238,000 li. From the pole north to the position where it is midnight is the same. The diameter is 476,000 li, which is the diameter of the sun's path at the winter solstice. Its circumference is 1,428,000 li." (p. 35)

Immediately following this is a calculation of the size of the solar circle for the equinoxes, based on the previously mentioned erroneous assumption that the equinoctial noon shadow is midway between the solsticial values. Given the methods of section (2) (a) the implication is that the equinoctial noon position of the sun is midway between the solsticial positions. Thus the diameter of the solar circle is 357,000 li and its circumference becomes 1,071,000 li. (Here, as throughout the entire work, the somewhat primitive approximation $\pi = 3$ is used.) The first half of the book goes over some of the same ground towards its end (p. 46 ff.) when it proceeds to calculate the size of seven representative solar circles, the first and last being the solsticial circles, the fourth being the supposedly median equinoctial circle, while the other four circles are also linearly interpolated. In this section and subsequently these solar circles are given the name heng 衡

(c) The shape of heaven and earth

It has already been pointed out, in section II (2) (a), that the mathematical methods of the *Chou Pei* can only work exactly if heaven and earth are flat and parallel plans 80,000 *li* apart. This is the universe in which a principle of 'a thousand *li* for an inch of shadow' holds good for an eight-foot gnomon. It would of course be incorrect to claim that the use of such a principle in the *Chou Pei* must imply the existence of a parallel-plane theory at some stage of the work's evolution. The principle may well have originated as no more than a piece of traditional lore unconnected with any cosmographical speculations, and we have no grounds for assuming that whenever it is used it is used in the full knowledge of its implications. Indeed, for most of the centuries during which the 'shadow principle' is found in cosmographical writings it is definitely not used in a valid context.

In any case there are plain statements in the text from which it is clear that heaven and earth were not conceived of as completely flat. The opening section of the text, which contains the cryptic and possibly archaic dialogue of Chou Kung and Shang Kao, describes heaven and earth thus :

> "The square pertains to earth and the circle pertains to heaven; heaven is round and earth is square. The numbers of the square form the pattern: the circle is produced by means of the square. A rain-hat images heaven. Heaven is green and black; earth is yellow and red. The way the numbers of heaven make up a rain-hat, is that green and black make up the outside, and cinnabar and yellow make up the inside, so as to image the positions of heaven and earth."
> (pp. 22, 23)

Near the beginning of the second part of the book we find two more statements :

> "The earth below the pole is 60,000 li higher than where men live: the pouring waters run off downwards on all sides. The centre of heaven is also 60,000 li higher than its edges all round." (p. 53)

> "The image of heaven is a covering rain-hat. The pattern of earth is an overturned pan. Even thought the winter solstice sun is on the outer hêng, it is still 20,000 li above the land below the pole." (p. 54)

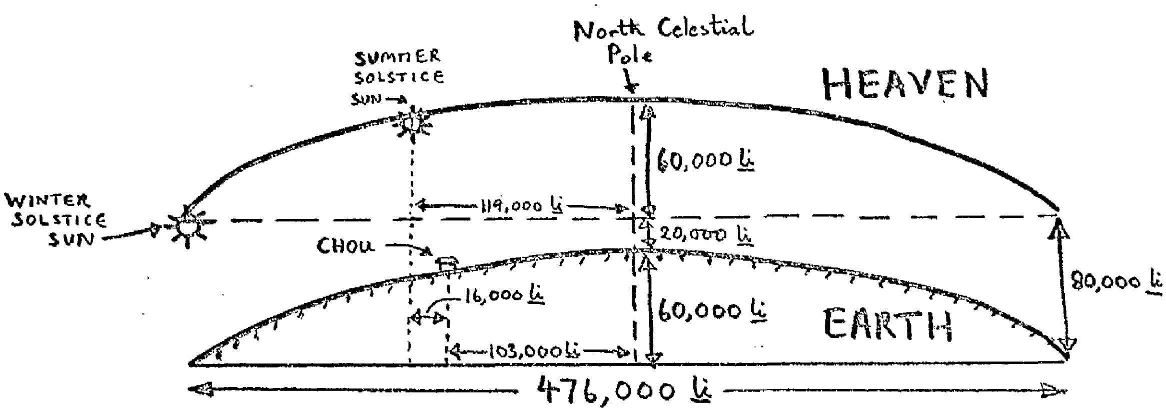
The flavour of the first passage differs markedly from the others. Heaven is rain-hat shaped in all three, but what are we to make of the mention of a square earth, which is somewhat at odds with the later statement that earth is like an overturned pan ? Chao Shuang's commentary of the early third century A.D. likewise compares the three passages and expresses puzzlement :

> " ... These [i.e. the circle and square] are not the real bodies of heaven and earth. Heaven cannot be viewed to its limit, and earth cannot be completely observed. Surely one cannot be certain of their roundness and squareness ? ... "
> (p. 22)

At present there is no evidence firm enough to come to a certain conclusion on the matter, but I feel it is not unreasonable to suggest that the first passage does not come from the same source as the other two. It is certainly true that the attempt of Chatley to take all three together leads to odd results: see section (3) (e) below. The clear statement that the earth is like an overturned pan is obviously intended to suggest that it is the same shape as the rain-hat form of heaven, so that the two remain the constant 80,000 li apart specified throughout the text. The question of the exact significance of the 'rain-hat' and 'pan' shapes is considered in more detail in connection with Chatley's suggestion, but perhaps it is permissible at this point to give Fig. II (1) as an illustration of the size and shape of heaven and earth as specified in the parts of the text so far examined. The diagram is a vertical section through along the meridian of the place of observation of the text, there specified as Chou 周 : see Appendix (5) for an account of what can be deduced about the location and date of the observer. Nowhere in the text is there any mention of any means of fixing heaven and earth in position.

In Fig. II (1) the sun is shown as coincident with heaven. The question arises of what relation was conceived between heaven and the obvious motions of sun, moon, and stars. Negative assertions cannot easily be supported, but I would maintain that the absence from the

Fig II (1)



The *Kai t'ien* universe as described in the *Chou pei*: vertical section showing solsticial sun for noon at Chou.

work of any explicit reference to this problem entitles us to assume that the obvious explanation holds. This is of course that the heavenly bodies are on the underside of heaven, and move with it in a daily revolution about a vertical axis through the pole. We have already seen statements showing that heaven, like the sun and stars, was 80,000 li above earth. (No gnomon observations of the moon are described, but there is no reason not to suppose it at the same altitude.) It would have required a certain degree of perversity to have observed the nocturnal revolution of the stars round the point specified as the centre of heaven and then to have come to any conclusion but that the stars were fixed to a rotating heaven. Clear proof that the stars were thought of as fixed relative to a rotating heaven is given when it is stated (p. 67)

that the moon lags 13 7/19 tu behind heaven: this is the amount by which it moves in a day as seen against the background of the stars. The sun is in its turn given a daily motion of 1 tu: thus in a year of $365\frac{1}{4}$ days it completes one revolution of $365\frac{1}{4}$ tu against the stellar background. No mechanism is suggested to explain these motions over heaven, nor to explain the sun's annual shift towards and away from the pole.

I have not succeeded in finding any reason for the adoption of the figure of 60,000 li for the bulge of heaven and earth. It is obviously not the consequence of any of the mathematical methods of section II (2), which in any case suggest a flat heaven and earth, nor is it taken account of in any calculations relating to solar heights and distances. It is almost as if all calculations were performed to establish the dimensions of a flat heaven and earth, and as an afterthought both were given a central bulge. I would however tentatively suggest another explanation in the following terms :

(i) The original and non-quantitative presuppositions were that the earth was flat while heaven was rain-hat shaped and rotated overhead.

(ii) It was noticed that the application of the gnomon shadow principle gave the result that the heavenly bodies were always 80,000 <u>li</u> above earth.

(iii) The evident contradiction between (i) and (ii) was noticed, i.e. that a rain-hat shaped heaven was closer to a flat earth at its edges than in the centre.

(iv) To resolve this it was assumed that earth too bulged upwards centrally, so that the vertical separation of heaven and earth was constant. This was preferable to denying that heaven was curved, as it obviously appears to be.

(d) Problems of solar illumination : day, night, polar conditions, the hsüan chi

Inspection of Fig. II (1) shows that at the winter solstice there is a clear line of sight from the observer to the sun for most of the twenty-four hours taken for a complete revolution of heaven, and that at the summer solstice the sun is in sight for the entire period of revolution. This is, of course, not the state of affairs seen by any actual observer, and it cannot be said that the introduction of the bulge of the earth is a significant contribution to eliminating this anomaly. How then does the Chou Pei explain the phenomenon of the alternation of day and night ? It is helpful to approach this problem by way of a discussion of conditions directly below the celestial pole: this is the point that corresponds to what we would call the 'North Pole' of the earth. The Chou Pei says :

> "From the division of day and night at the spring equinox to the division of day and night at the autumn equinox there is perpetual sunlight below the pole. From the division of day and night at the autumn equinox to the division of day and night at the spring equinox, there is never any sunlight below the pole. At the time of the division of day and night on the spring and autumn equinoxes, the extent of sunlight reaches just to the pole." (p. 36)

Now inspection of Fig. II (1) is sufficient to convince one that the sun should be perpetually visible at the pole for the entire year. How is this to be reconciled with the statement just translated ? It is somewhat surprising to read such an accurate description of the conditions which in fact do obtain at the earth's North Pole. Indeed, in the second half of the book we find another statement of polar conditions coupled with a mention of the tropical climate :

> "Around the north pole there is unmelting ice in summer"... "Around the middle hêng 中衡 [= solar path at the equinoxes] there are plants that do not die in winter ... the five grains ripen twice in one year." (p. 56, 57)

The attempt made by the Chou Pei to reconcile these anomalies with its cosmography is as follows :

> "The sun shines 167,000 li on all four sides. The extent of human vision must be the same as the extent of sunlight. Sighting from Chou one sees 64,000 li north beyond the pole, and 32,000 li south beyond the sun at the winter solstice." (p. 36, 37)

This seems to solve three difficulties at once: if the sun's illumination extends only over a limited radius both the problems of day and night and of polar conditions may be dealt with. The extension of this limiting distance to the range of human vision helps to dispel the difficulties caused by the obvious implication of Fig. II (1) that nearly all the stars that are ever visible should be visible simultaneously on a given night. Unfortunately matters are not brought to such a satisfactory conclusion, for the figure of 167,000 li has not been chosen on any physical basis. We might on the basis of

p 36 have expected the extent of sunlight to be chosen so that it is equal to the distance of the sun from the pole at the equinoxes. This was not done, however, for then the result would have been 178,500 li. Thus at the equinoxes the sunlight falls 11,500 li short of the pole. (As is done in all such contexts in the Chou Pei no account is taken either of the bulges of heaven and earth or of their vertical separation: everything is treated on a plan view.)

Neither can the introduction of the 167,000 li limit provide an adequate solution to the problem of day and night. Consider the example of the equinoxes, when day and night are equal and the sun rises due east and sets due west (see Fig. II (2)).

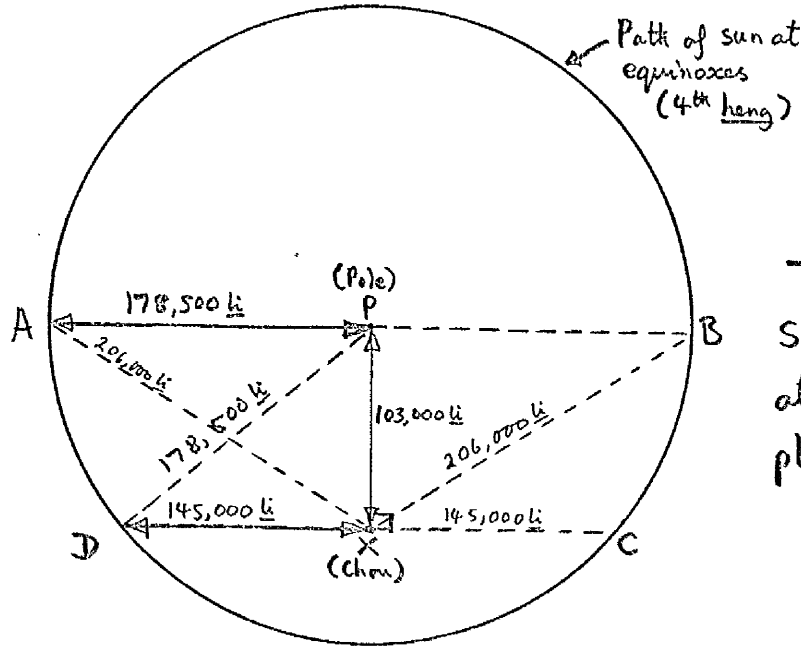


Fig II (2)

Solar visibility at equinoxes: plan view.

It is obvious that if we wish the sun both to become visible and to disappear when due east-west of Chou, then it must be at the limit of sight when at D and C. Pythagoras' theorem gives D X and C X as a little over 145,000 li, which would be the solar range required. By inspection, moreover, it is obvious that the night will be much longer than the day. If we try to achieve an equal length for day and night we require a solar range equal to A X, some 206,000 li. It must be emphasised that these results can all be obtained using the mathematical methods applied elsewhere in the Chou Pei. Evidently therefore the figure of 167,000 li has not been chosen with a view to solving the problem of day and night, and it is not hard to see that no single figure can adequately predict both day length and position of rising and setting throughout the year.

As for the third problem mentioned above, that of the proportion of stars visible at night, Fig. II (3)

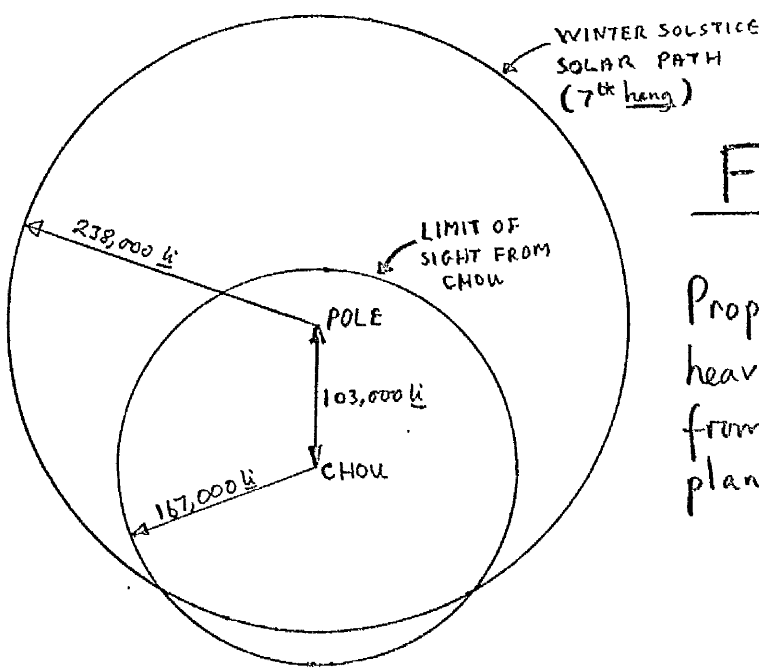


Fig II (3)

Proportion of heaven visible from Chou: plan view.

makes it plain that with a sight-range of 167,000 *li* much less than half even of those stars included within the sun's winter solstice track will be visible at any given time, a piece of information which could readily be contradicted by anyone familiar with the night sky.

We have thus seen that the introduction of a sight-range of 167,000 *li* does not appear to be a solution to any of the problems it might be expected to solve. Why then was this particular figure chosen ? I suggest that it is the result of a numerological assumption. Consider the following statement :

> "The diameter of the outward extent of solar illumination is 810,000 li." (p. 53)

Here (and also on p. 51) we have a statement of the diameter of the circle defined by the furthest outward extent of solar illumination. Now as we have seen, the diameter of the widest circle travelled by the sun is 476,000 *li*. We can therefore deduce that this implies a radius of extent of illumination by the sun of :

$\frac{1}{2}(810{,}000 - 476{,}000)$ *li* = 167,000 *li*

Here at last we have consistency: I would argue that the 810,000 *li* figure is prior to the 167,000 *li* figure on the grounds that 81 is the square of the *Yang* 陽 number, 9, (see *I Ching, passim*), and we are dealing here with the extent of illumination by the sun, which is *Yang* in the extreme. Note that the apocryphal work *Ch'un Ch'iu Yuan Ming Pao* (*ap*. TPYL 1, 10a; probably W. Han) gives the circumference of heaven as 810,000 li, deriving this from $9^2 = 81$. This relationship has been stated earlier in the Chou Pei :

> "The rectangle originates from nine nines being eightynine." (p. 14)

I am aware that these will not be felt to be compelling reasons for adopting 810,000 li as the diameter of maximum sunlight from the pole. Nevertheless my point is that some explanation of the origin of the 810,000 li figure is possible in its own right, whereas we have seen that there is no independent reason for adopting the 167,000 li figure. Since examining this point I have noticed the agreement of Nakayama (1).

There is one further possible reason for adopting 167,000 li as the figure for the radius from the sun over which its illumination extends. It will be remembered that, given the interpolated figure for the radius of the sun's equinoctial path ultimately derived from gnomon observations, it was found that 167,000 li for the sight-range meant that at the equinoxes the sun's light fell 11,500 li short of the pole. There is a long section of text (pp. 54-56) allegedly describing the observation, by means of the gnomon, of a certain heavenly body, which not only culminates exactly at midnight on the summer solstice but is also found to be 11,500 li from the pole. This is the radius of the circle of the so-called hsüan chi 璿璣 . Cullen (2) contains a detailed analysis of the history of this term, in particular refuting the claims of Michel (1) (quoted by Needham, SCC Vol. III, 333 ff.) that the hsüan chi is a reference to the use of a jade sighting-tube and circumpolar constellation template. It is there further shown that the only date at which a bright star (and a bright star is specified in the text) fulfils the conditions shown before the time the Chou Pei must have been completed is in 1100 B.C. At this date β Ursae minoris culminated at the correct time, although it approached not closer than 6.5° to the pole, rather than the 5° required to give the observations of the Chou Pei. Around 0 B.C. it was over 8° from the pole and would have culminated about four hours from the stated time. In addition to the lack of likely candidates for the celestial body allegedly observed, it is in any case hard to see why it should be assumed to lie exactly on the circumpolar limit of equinoctial sunlight. It appears, therefore, most implausible that the figure of 11,500 li results from actual observations, and we must conclude that the account of those observations is a fiction based on the consequences of the adoption of 810,000 li for the diameter of that portion of the universe which is ever illuminated. It was a consequence of that assumption that the sun's rays and the range of human vision were allowed a maximum range of effectiveness of 167,000 li.

Having dealt at some length with these points of detail it seems appropriate to close with a further example of the somewhat surprising accuracy of statements made by the Chou Pei about terrestrial conditions generally. The following text sums up assumptions which are made throughout the book :

> "Thus when the sun rotates to the north of the pole, it is noon in the northern regions, and midnight in the southern regions. When the sun is to the east of the pole it is noon in the eastern regions, and midnight in the western regions. When the sun is to the south of the pole, it is noon in the southern regions and midnight in the northern regions. When the sun is to the west of the pole, it is noon in the western regions, and midnight in the eastern regions." (p. 53)

Note here that the definition of the cardinal directions is a little odd. We might expect 'north' to mean 'towards the pole' on the Chou Pei's circular earth as it does on our spherical earth. This text, however, divides the earth into four sectors, and it is unclear whether these sectors are defined absolutely or require the existence of an observer at some named spot for their definition.

There are a good number of criticisms that can be made of the Chou Pei's cosmography, and later on in this survey its opponents' arguments will be set out. For the modern reader, however, there is surely a certain fascination in a theory that could come so oddly close to the truth.

(e) The nature of the heavenly bodies

Throughout the Chou Pei the emphasis is arithmetical and geometrical rather than physical. We do not find, for instance, any statement about the composition of heaven, the sun and moon, or the stars; nor is there any suggestion about the causes of their motion. The following passage, however, does seem to refer to a relation between the illumination of the sun and the moon :

> "Thus the sun manifests itself in the moon, whereupon the moonlight shines forth. Thus the bright moon is completed, whereupon the constellations move in order." (p. 54

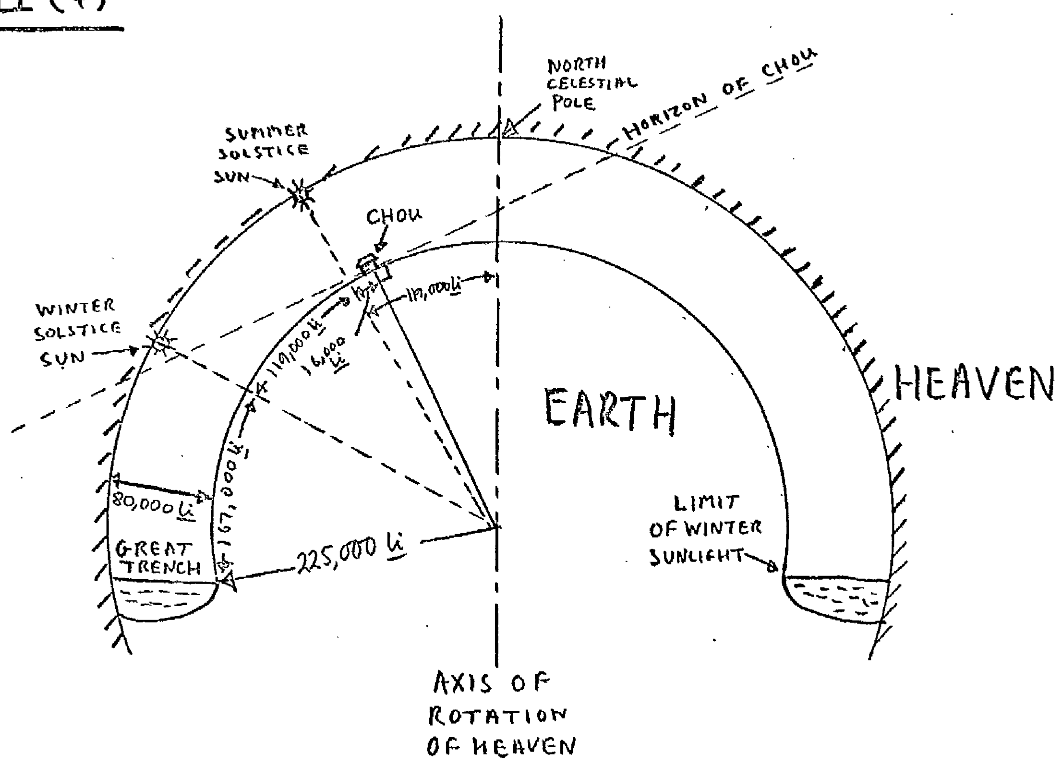
The precise way in which 日兆月 should be rendered is somewhat problematical, however, and it might be over-confident to claim, as does Needham (SCC Vol. III 227) that this is a statement that the moon shines with a purely reflected light. What in any case is the relation between the moon and the constellations in the second sentence ? It would have been difficult in the extreme for anyone committed to the full mathematical theory of the Chou Pei to claim that the moon was illuminated by the sun in a straightforward manner, for at full moon the sun and moon are diametrically opposite one another. Thus even at the summer solstice, if both moon and sun were placed on the innermost hêng they would still be 238,000 li apart, well beyond the distance of 167,000 li postulated for the range of the sun's rays. Moreover, the moon's relatively low altitude in summer would surely have suggested that it was on an outer _hêng_, and thus even further from the sun at full. In winter the positions would of course be reversed.

It would thus be difficult on the assumptions of the _Chou Pei_ to maintain consistently that the moon shone by reflected light, and by the same token the stars could not but be self-luminous. It is possible here as always that the impact of the _Chou Pei_ cosmography on these questions was never realised by its exponents: an instance of this is the early third century commentary of Chao Shuang on this passage, in which he plainly maintains that the moon's light comes from the sun (p. 54)

(f) <u>Chatley's interpretation of the Chou Pei's cosmography</u>

Chatley (1) gives a version of the cosmography of the <u>Chou Pei</u> which differs greatly from the account already given. As this is the interpretation adopted by Needham (SCC Vol. III, p. 212) and has therefore become well-known and widely quoted, it is necessary for me to justify my departure from it in some detail. The essentials of Chatley's model are shown in Fig. II (4).

Fig II (4)



Chatley's version of the <u>Kai t'ien</u>: vertical section showing noon at Chou.

One of the first remarks one might make about Chatley's model is that heaven and earth scarcely conform to the descriptions of their shapes as respectively a covering rain-hat li 笠 , and an overturned pan, p'an 槃

Both of these objects are rather flat in section. Perhaps Chatley is misled here by his wholesale adoption of the translation of Biot (1). Chatley renders p 54 . as :

> "The image of Heaven is a parasol which envelopes; that of the Earth is an overturned basin."

Biot's version is :

> "L'image du ciel est un parasol qui enveloppe; celle du terre est un bassin renversé."
> Biot (1), p. 593.

This is of course somewhat inaccurate.

Not only does Chatley's model not correspond to the general indications given in the text; not the least of the problems it raises is the fact that the horizon of the observer at Chou is inclined at about 30° to that of the polar position. There is admittedly some inclination of the observer's horizon in the model of Fig. II (1), but Chatley's suggestion raises the whole question of what exactly is meant by 'down' in a much more drastic manner. If this was the commonly accepted interpretation of the Chou Pei, why are the obvious criticisms never made by opponents of the Kai T'ien theory ?

Biot is not, however, Chatley's source for his most important datum, the figure of 225,000 li for the radius of the more than hemispherical earth. This is found by making two somewhat unwarranted assumptions. The first of these is that heaven and earth are concentric spherical domes. The second of these is that the sun, rising or setting, is thought of as lying on a tangential plane to the terrestrial surface through the observer. This misses the whole point of the introduction of the 167,000 li figure for the range of the sun's rays, the principle of which is later expounded in detail by Wang Ch'ung (see III (6)(b)) and criticised by Ko Hung (see IV (8)(b)). In Chatley's interpretation the sun actually vanishes from sight round the curve of the earth, whereas it is agreed by critics and supporters alike that in the Kai T'ien setting and rising are no more than optical illusions due to the sun passing the critical range of 167,000 li. Only in Shen Yüeh's late and garbled account of the Chou pei do we find any suggestion that the earth's relatively small bulge plays a significant rôle in the occultation of heavenly bodies (V (4)(b)).

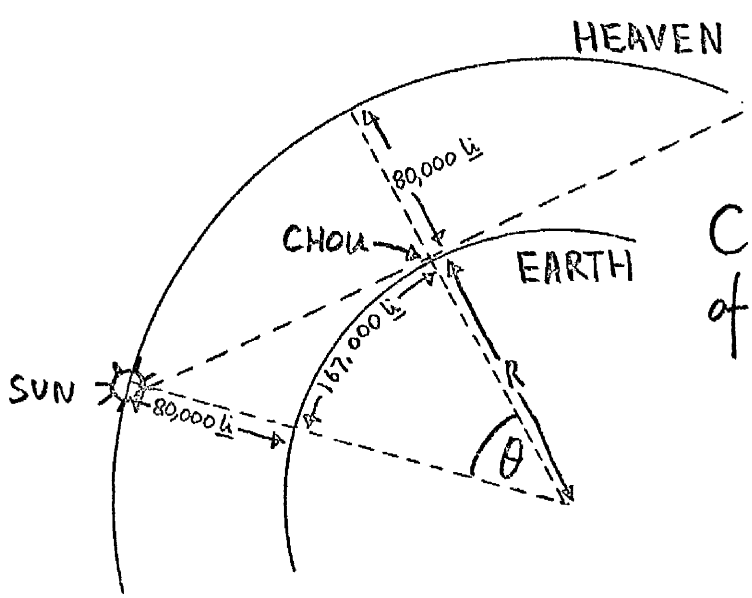


Fig II (5)

Chatley's calculation of Earth's radius.

Chatley, by contrast, pictures the situation of Fig. II (5), and writes :

$$R\ (\sec\theta\ -1) = 80{,}000\ \underline{li}$$

$$R\ \mathrm{arc}\,\theta = 167{,}000\ \underline{li}$$

$$\text{Hence } R = 225{,}000\ \underline{li}.$$

As this calculation is based on false assumptions the result is quite meaningless. Chatley does not deal with the problem of interpreting his result in the light of the fact that the writers of the Chou Pei would have found the mathematics involved here far beyond their capacity.

Let us now turn to the so-called 'rim-ocean' which Chatley depicts surrounding the base of his hemi-spherical earth. He renders the first half of T II (10) as :

> "The region below the limits is the part of the earth where man dwells, raised to an extent of 60,000 li ... [Chatley's dots] A wet ditch, a four sided precipice is what there is in the low part."

This is again taken directly from Biot (1) :

> "Le dessous du pôle est la partée elevée étendre de 60,000 li --- [Biot's dash], sur une fosse humide, un précipice des quatresh] Une fosse humide, un précipice des quatres côtés, voila ce que est dans la partie basse"
>
> Biot (1) p. 619.

In neither case can I see any justification for the rendering adopted for 滂沲四隤而下

According to Karlgren 㐌 (K 4 f) is a variant for 它 which allows us to take 滂沲 as equivalent to the well-known expression 滂沱 "water pouring down" : this usage is found in the Shih Ching 詩經, SSCCS, ch. 15, pt. 3, p. 9a. Biot's rendering of 滂 as 'humide' is very doubtful, and his translation of 沲 as 'fosse' is inexplicable unless he has mistaken 沲 for 池, which is a quite different character. As for the last four characters, Biot's version overloads them to a quite impermissible extent besides distorting the grammar beyond recognition.

For the reasons given above, I do not think that Chatley's version is a valid interpretation of the cosmography of the Chou Pei.

(g) <u>The Kai T'ien theory in pre Ch'in times</u>

It has previously been noticed (Ch'ien Pao-Tsung (1), (16)) that a short section of the <u>Lü Shih ch'un ch'iu</u> contains what appears to be a description of a cosmography similar to that described in the <u>Chou Pei</u>. As this work was composed by various scholars under the patronage of Lü Pu-Wei in 239 B.C., any cosmographical evidence it gives us dates from even before the rise of the Ch'in dynasty. The passage usually quoted is :

> "The pole star moves together with heaven but the pivot of heaven does not move. At the winter solstice the sun moves along the most distant track. It moves round the four poles, and its decree causes dark and light. At the summer solstice the sun moves along the closest track and reaches the highest point. Beneath the pivot there is neither day nor night."
> <u>Lü Shih ch'un ch'iu</u>, 13, 3b, SPTK

Qualitatively this is a clear statement of several aspects of the <u>Kai T'ien</u> theory. A point that does not so far appear to have been noticed is that there is likewise a quantitative agreement with the mathematical methods described in the <u>Chou Pei</u>. The passage immediately preceding that just quoted reads :

> "Within the four seas, it is 28,000 <u>li</u> east-west, and 26,000 <u>li</u> north-south ... Within the four poles, it is 597,000 <u>li</u> east-west and 597,000 <u>li</u> north-south."
> <u>Lü Shih ch'un ch'iu</u>, 13, 3a, SPTK.

I cannot comment further on the 28,000 <u>li</u> and 26,000 <u>li</u> figures than by saying that they represent an estimate of the size of the late Chou culture-area which is ten times too large. (See also III(2)(b), III(10)(f)). This may not, of course, be what is meant by 'within the four seas'. If these measurements are actually meant to relate to the coastline itself, they are hard to relate to geographic reality as they are approximately twenty times the distance from Lo Yang to the sea along the line of the Yellow River.

It is in the figure of 597,000 li for the diameter of the 'four poles' that we find matter of cosmographical interest. The statement in the first passage that at the winter solstice the sun 'moves round the four poles' gives us the conclusion that the diameter of the sun's path at the winter solstice is 597,000 li. In the Chou Pei this result is 476,000 li which is in no more than a very approximate correspondence. We must remember, however, that the Chou Pei result contains an arbitrary factor in the specification of the height of the gnomon as eight feet. If the height was changed and the 'inch for a thousand li' shadow principle continued to be used, then all the distances deduced would be changed in proportion to the height of the gnomon.

Consider for example the situation at the summer solstice, when the eight-foot gnomon casts a shadow of length 1.6 feet. By the rule of 'one inch for a thousand li', it is deduced that the subsolar point is 16,000 li away. Application of similar triangles gives the result of 80,000 li for the altitude of the sun (as it will whatever the shadow-length). Let us repeat the experiment using a ten-foot gnomon. This will, by simple proportion, cast a shadow 2.0 feet long. If we apply the usual shadow-rule to the gnomon (and as it is an arbitrary rule of thumb there is no reason not to), we see that the distance to the subsolar point is 20,000 li while the sun's altitude becomes 100,000 li. All distances have been increased by a factor of 10 : 8.

Let us suppose, then, that the solar and polar observations of the Chou Pei were repeated with a ten-foot gnomon throughout. Instead of 476,000 li for the diameter of the path of the sun at the winter solstice we would obtain :

$$476{,}000 \text{ li} \times \frac{10}{8} = 595{,}000 \text{ li}$$

This agreement with the Lü shih ch'un ch'iu result of 597,000 li is strikingly close. It ought to be said at this point such an agreement could have been reached whatever the texts gave as values, provided only that the second gnomon was specified at the correct ratio to the first. All that has been shown so far is that if a ten-foot gnomon was used in a similar manner to the eight-foot one in the Chou Pei, then the result would be very close to that of the present text.

There is, however, firm evidence that the ten-foot gnomon was used in early Western Han times, and it is not unreasonable to suppose that the practice may antedate our earliest and only reference to it. The Huai nan tzu book was compiled around 120 B.C., and a cosmological fragment at the end of this third chapter has been examined in Cullen (1). In part it reads :

> "To find the height of heaven, set up two gnomons ten feet high and 1,000 li apart due north-south. Measure their shadows [at noon] on the same day. The north gnomon [shadow] is two feet and the south gnomon [shadow] is one foot nine inches. Thus a thousand li due south shorten the shadow by one inch and twenty thousand li due south there is no shadow at all. This is directly below the sun. A two-foot shadow corresponds to a height of ten feet so for each unit southwards one rises five units. Therefore, if one takes the number of li from this position south to the subsolar point and multiplies by five, making 100,000 li, this is the height of heaven."
>
> Huai nan tzu, 3, 17b, SPTK.

The text suggests that the northern gnomon is the more important: it is thus to be regarded as giving the actual observation, while the 'southern gnomon' is as fictitious as all 'inch for a thousand li' constructions. As we have seen, however, a two-foot shadow for a ten-foot gnomon corresponds to a 1.6 foot shadow for an eight-foot gnomon, thus suggesting very strongly that we have here a link with the Chou Pei tradition. It does not seem at all improbable, therefore, that a ten-foot gnomon could have been used in the context of the mathematical and cosmographical methods found in the Chou Pei at a date early enough for the results of this to appear in the Lü shih ch'un ch'iu.

As I mentioned at the beginning of section II (1) this survey is mainly concerned with the tradition from which the _Chou Pei_ was drawn rather than with the date or manner in which the book itself was compiled. It is thus a very satisfactory conclusion to be able to claim with confidence that a well-developed form of the _Chou Pei_'s cosmography, mathematics included, can be found in a work compiled in 239 B.C. It does not, further, seem to stretch probability too much to claim that the tradition may have been known at a considerably earlier part of the Warring States period. There may be some significance in this fragment of a poem by 宋玉 Sung Yü, written around 300 B.C. :

方地為車圓天為蓋

> "The square earth is a chariot , the round heaven is its umbrella"
> PTSC 149, 3b; CSHK, _Shang ku san tai_, 10, 2a.

This certainly reminds one of the notion of heaven as a rain-hat over earth, and it is notable that the term for 'umbrella' here, 蓋 _kai_, is of course the word found in the name _Kai T'ien_ often used for the cosmography of the _Chou Pei_. At this point, however, we are crossing the borderline between flimsy evidence and no evidence at all.

(h) A retrospect on the Kai t'ien

The Chou pei is a book that contains no signs of controversy. As the rest of this survey will show, however, the theory it expounds was to be a target for the polemics of generations of cosmographers to come. Indeed, the first substantial material on cosmography assignable to individuals is the account of Yang Hsiung's rejection of the Kai t'ien around 0 B.C. (III (4)). A century later Wang Ch'ung used his talents as a controversialist in favour of the Kai t'ien (III (6)); oddly he never mentions the Chou pei itself and there seems some doubt as to whether he knew of it. He adopted a variant of the theory with a planar heaven and earth (III (6)(b)), and his attacks on a number of other versions suggests that the Kai t'ien was not by his time moribund and devoid of creative power (III (6)(g)(i)). Wang's manifesto remained unanswered until Ko Hung's refutation c. A.D. 330 (IV (8)(b)).

This delay should not lead us to conclude that the Kai t'ien survived the Han dynasty as a widely accepted theory. Apart from the somewhat odd case of Emperor Wu of Liang in the early 6th century A.D. (V (5)(b)), there are no more identifiable partisans of the Kai t'ien thereafter. In the preface to his 3rd century A.D. commentary on the Chou pei itself, Chao Shuang expresses fears that the book might have been lost altogether. Ts'ai Yung's memorial of c. A.D. 190 on the subject of cosmography dismisses "The methods of the Chou pei" in a single curt sentence (III (8)(a)). The basic content of the theory was not, however, forgotten, as shown by references such as those of Chiang Chi (fl. A.D. 385, see IV (9)(a)) and Tsu Keng-chih (fl. A.D. 510, see V (3)(a)). When Tsu's contemporary Shen Yüeh attempts a description of the Chou pei's cosmography in detail, he makes a somewhat mangled job of it (V (4)(b)), suggesting thereby that his acquaintance with the book itself was not at first hand. At the end of the epoch of this survey the Chin shu (11, 278, CHSC) and the Sui shu (19, 505, CHSC) give identical sections of material on the Kai t'ien, but all except a little editorial matter can be traced directly either to the Chou pei itself or to Wang Ch'ung. There was simply no-one else for them to quote, apart from opponponents of the theory.

It cannot be said that the Kai t'ien has always been kindly treated by modern writers. There is of course no question of their adopting it as true, but the same could be said of all other ancient Chinese cosmographies. Needham, under the influence of Chatley's mistaken interpretation, says of it :

> "As [Chatley] says, there is just enough physical truth in the scheme to render it acceptable to very archaic geometers having little more than the Pythagoras theorem at their disposal."
>
> SCC III, 212

According to Cheng and Hsi (1), 60, the Kai t'ien embodied the social morality of "slave society", the system to which Maoists accuse Confucians of wishing to return. Chu Hsi and other Neo-Confucians are convicted of the "two-faced trickery" of covertly attempting to smuggle Kai t'ien features into the Hun t'ien (op. cit. 84). Leaving aside any political implications, however, I would maintain that the discussion given in Introduction (f) shows that the victory of the Hun t'ien was not a completely unmixed blessing. The new theory represented the phenomena accurately for a single observer at the centre of the celestial sphere, but was quite unable to represent the variation in astronomical conditions with geographical location. In addition the geometry involved in the concept of a spherical heaven was beyond ancient Chinese mathematical capability. All that could be done was to apply inconsistently the (false) assumptions that the Kai t'ien had applied fairly consistently (see IV (2)(c)). Even granted the mathematical tools, critical development of the Hun t'ien would have required the gathering of observations over a wide geographical area. When such observations became available under the T'ang, cosmography failed to meet the challenge (Introduction, (c), (f)).

III. COSMOGRAPHY IN THE HAN DYNASTY

(1) Introduction

In this section I begin to deal with material more characteristic of the rest of this survey than in Sections I and II. For the first time we meet with individual controversialists, of whom Wang Ch'ung is the most obvious example (III (6)). Rival theories contend, and in Yang Hsiung we seem to have an example of a man converted from his former opinions by the arguments of a friend, Huan T'an (III (4)(5)). In cosmography the Han dynasty was the age of originality, and provided most of the basic elements which we will find in the works of the summarists and critics of later times.

The most significant event in the field of cosmographical theory was, of course, the replacement of the Kai t'ien theory by the Hun t'ien. Although there were dissenters, the usual Chinese picture of the universe was thenceforward to be that of a celestial sphere rotating about an inclined axis, with a flat earth occupying its horizontal diametric plane. As will appear, however, this earth was not always thought of as stationary (III (10)), and there is a possibility that some Han thinkers may have felt able to abolish the solidity of the celestial sphere altogether (III (9)).

The problem of the nature of the heavenly bodies and the cause of the appearances they present was raised several times. All this goes to make the Han period the most varied and interesting of the ages we have to consider.

(2) The Huai nan tzu 淮南子

(a) An early Western Han compendium.

The Huai nan tzu was compiled c. 120 B.C. by a group of scholars under the patronage of Liu An 劉安 prince of Huai nan. Their object seems to have been to give a systematic account of nature and man : the evidential value for this survey of such a document dating from the early Han need not be stressed. We will, of course, be disappointed if we expect to find one of the book's twenty-one chapters devoted to a crisp summary of the astronomy, cosmography, and mathematics of the time, in a form similar to the monographs in the dynastic histories compiled under the T'ang. Admittedly the chapter entitled T'ien Wen 天文 does discuss the rising and setting of planets, and lists the twenty-eight hsiu with their extent in degrees; likewise the Ti Hsing 墬形 chapter gives the dimensions of the world. All this is of great interest, but it is set in a context of cosmology rather than cosmography, and the exposition of a coherent system definitely takes precedence over any attempt to justify the statements made about the size and shape of the universe. There is in the book no suggestion that there may be a number of competing views on such questions, and for us it is a little disconcerting to read the legend of Kung Kung (see I (2) (b)) immediately after a short cosmogony quite free from myth. (Huai nan tzu, 3, 1a, SPTK)

It would be foolish to expect a book over 2,000 years old to conform to our notions of how its material should be classified. It would, however, be equally foolish to take Huai nan tzu as a complete and definitive account of some problematical entity called "Early Han Thought", extract the sections of interest to this survey and make sweeping claims about what was or was not believed about the universe at that time. Apart from the obvious point that this book is the product of one group of scholars only, there is within the field of this survey at least one example of straightforward omission of material that might reasonably be expected to have been included, and that we know was accessible to the compilers. This omitted material is the description of the Kai t'ien system (with mathematical details), found in Lü shih ch'un ch'iu, 13, 3a SPTK (see II (3)(g)). Huai nan tzu 4, 3a SPTK does, however, quote an immediately subsequent passage. There is, therefore, the possibility that the Huai nan tzu compilers either disagreed with or did not understand the notes in question.

There are two pages at the very end of the T'ien Wen chapter (3, 17a and 17b) where an attempt at quantitative cosmography is made, of a character quite different to the rest of Huai nan tzu material. This passage has been given a detailed study in Cullen (1), but a summary of the conclusions is for completeness' sake given in (d) below.

(b) Heaven and Earth.

Throughout the book there are scattered a large number of passing references which point to a view of the universe not markedly different from the pre-Han material of Part I. Heaven and earth are round and square respectively, corresponding to the shape of the human head and feet (7, 2a SPTK). Heaven covers everything, like a chariot umbrella, while earth carries everything, like the chariot body itself (1, 4b). (Compare the words of Sung Yü in 300 B.C. - see II (3)(g)) There is a contradiction between two sentences, in the first of which (8, 4a) we are told that the extent of heaven and earth can be measured, and in the second of which (15, 3a) we are told that (although still round and square) they are infinite. Earth remains fixed while heaven moves (1, 3a), but no more precise description of the motion is given. There is no hint either of the Kai t'ien notion of the central pivot of heaven directly above the centre of the earth, nor of the Hun t'ien theory that heaven moves below earth as well as above it. The legend of Kung Kung's damage to the pillars supporting heaven is recounted (3, 1a), and later the story of Nü Kua's repair with melted stones and the feet of a giant tortoise (6, 6b) - we can at least find here a confirmation of the solidity of the heavenly vault. In the Ti hsing chapter two statements are clearly inconsistent with the Kai t'ien universe : one is the mention of the far northern regions where the sun is never seen and the only illumination comes from the "lamp-dragon" (4, 9a). The other notes that in the north there is unmelting ice, while in the south there is undying vegetation (4, 5a). This second statement has two exact five-character parallels in the Chou pei suan ching (2, 56), where however they are considerably separated and set in significantly different contexts : the unmelting ice is below the pole, and the undying plants are below the middle (equinoctial) hêng. Could this be evidence that the Chou pei drew on Huai nan tzu at this point, while modifying it in accordance with Kai t'ien cosmography ?

Can any underlying scheme be perceived in the various quantitative data that the book contains ? Leaving out of consideration the anomalous section dealt with in (d), it is very hard to see any justification for most of them. Heaven is said to be 510,000 li above earth (3, 2a). From the north pole to the south pole and from

極

the east pole to the west pole is 233,500 li, 75 pu (1 li = 300 pu). In this case, "pole" chi 極 obviously refers to the utmost extremes of the flat earth. The area "within the four seas" is 28,000 li east-west and 26,000 li north-south. The diameter of the dry land is 3,000 li, while the "path of water" shui tao 水道 is 8,000 li (4, 2a). I can make nothing of the figure for the height of heaven, but I would very tentatively suggest a rationale for the dimensions of the earth. Suppose we begin with the 3,000 li figure for the diameter of the dry land. This may well be based on an assumption that the Lo-yang region is the centre of "the dry land" - 1,500 li is not a bad approximation for the distance from there to the sea. Now it is noticeable that the average diameter of the region "within the four seas" is 27,000 li, exactly nine times the diameter of "the dry land". Could this nine-fold multiplication be connected with the "nine-fold continents" theory of Tsou Yen ? (see I (3)(b)). Multiplying 27,000 li by 9 we obtain 243,000 li, which is at least suggestive of the 233,000.25 li figure given in Huai nan tzu. All this is of course mere conjecture. A further inexplicable point is that Huai nan tzu is clearly drawing on Lü shih ch'un ch'iu (13, 3a), but has a different figure from the 597,000 li there given for the diameter of the "poles". We have seen that there is a considerable chance that the Lü shih ch'un ch'iu figure has an astronomical origin (II(3)(g))

Possibly the Huai nan tzu's use of different data shows a rejection of the Kai t'ien theory on which the 597,000 li figure was based. If so, it must be said that the atmosphere of the book does not suggest that the rejection was the result of a critical process such as took place at the time of Yang Hsiung and Huan T'an (III (4)(a)). It seems more likely that the ideas the compilers met in the Lü shih ch'un ch'iu and possibly elsewhere were simply regarded as novelties to be rejected because they did not fit the traditional scheme of things.

(c) The sun.

The archaism of Huai nan tzu's cosmography is shown clearly in a detailed passage describing the sun's daily path (3, 6a and 6b). The sun rises from Yang Ku 暘谷 "the bright valley" in the east, and eventually sets in Meng ku 蒙谷 "the dark valley" in the west. Between these two points it passes over fourteen other named places on the earth; we are told that the total distance travelled by the sun is 517,309 li. All this seems designed to answer one of the questions asked in the fourth century B.C. T'ien wen (I (2)(b)(15-16)). The dimension given is, I am afraid, yet another case where no plausible derivation has occurred to me - note of course its close approximation to the 510,000 li already given for the height of heaven. The tradition met here is a very early one, and perhaps the best-known reference to it is found in the first chapter of the Shu ching, where a Confucianised version of the story refers to the dispatch of officials to attend at the bright and dark valleys (SSCCS, Shang Shu, 2, 9a). Clearly such notions as these cannot be related to the K ai t'ien, according to which sunrise and sunset were optical illusions and did not involve the sun being at ground level at all.

Despite the lack of any sign of gnomon mathematics of the sort found in the Chou pei, we do find a note of the solsticial shadows of an eight-foot gnomon as being 1.5 ft. for the summer and 13.0 ft. for the winter (3, 5b). This is placed in the context of some statements on the relative strengths of the ch'i of Yin and Yang, which are said to cause the shadow-lengths to vary. Later (3, 9b), it is said to be the alternating strengths of Yin and Yang that cause the seasonal variations in daylength : similar theories recur in subsequent centuries (see for instance Yang Ch'üan IV (3)(b)). The only passage (4, 3a) making a connection between shadow-measurements and cosmography (apart from the anomalous passage, see (d)) is, significantly perhaps, borrowed from Lü shih ch'un ch'iu (13, 3b). There it is stated that at "the centre of heaven and earth" there are no shadows at noon, and, curiously, shouting produces no echo.

(d) Quantitative cosmography : the square of gnomons.

At the end of the T'ien wen chapter (3, 17a and 17b) there occurs a short section of considerable interest, in style and content noticeably different from the rest of the book. It has been subjected to a detailed study in Cullen (1); only the main conclusions will be summarised here. The text itself may have originated a little later than the rest of Huai nan tzu, perhaps at some time early in the first century B.C. The author describes observations on the rising and setting sun made with a square of gnomons of side 1 li. From possibly hypothetical results of these observations, he arrives at a theory according to which the four points determined by the rising and setting sun at the winter and summer solstices lie at the vertices of a square 18,000 li across. Precise directions are given for ascertaining where any particular observer is with respect to the centre of this square, based on the fact that only a properly oriented square of gnomons at the centre of the sun-square can give direct sightings on the solar positions. A final passage seems closely related to the Chou pei, but uses a ten-foot gnomon instead of an eight-foot one (see II (3)(g)). In the entire section one cannot trace any connection with either the Kai t'ien or Hun t'ien cosmographies. Like the rest of Huai nan tzu, it believes that the sun rises and sets over the edge of a flat earth, but does not attempt to consider the question of what the sun does during the hours of darkness; perhaps it was believed that a new one was created daily, as in the _fu sang_ legend.

(3) Lo-Hsia Hung 落下閎 and the beginning of the Hun t'ien

(a) The T'ai Ch'u 太初 calendar reform

In 116 B.C. the Astronomer Royal and great historian Ssu-ma Ch'ien 司馬遷, with various others, memorialised the emperor on the necessity of a calendar reform (Han Shu 21A, 974, CHSC). In the course of their deliberations, these experts :

> "Fixed east and west, erected shadow instruments [sundials?], and set water clocks working."
>
> (ibid, 975)

Other calendrical mathematicians were recruited :

> " ... in all twenty-odd persons, amongst whom were the magician T'ang Tu 唐都 and Lo-hsia Hung from Pa. Tu distinguished the divisions of heaven, while Hung carried out calculations to revise the calendar."
>
> (ibid, 975)

The latter passage is a parallel to one written by Ssu-ma Ch'ien himself (Shih chi, 25, 1260 CHSC). The T'ai Ch'u calendar was finally promulgated in 104 B.C.

These references are important for two reasons :

i. Lo-hsia Hung's floruit is well established

ii. As Lo-hsia Hung was working in association with Ssu-ma Ch'ien, it seems not unreasonable to assume that Ssu-ma Ch'ien's knowledge of astronomy and calendrical methods as set out in Shih chi 26 and 27 can be taken as giving the possible level of competence of Lo-hsia Hung and indicating the techniques he may have had available.

Both these points will prove to be important in the subsequent discussion.

(b) A link with the Hun t'ien ?

In his book Fa yen 法言, Yang Hsiung 揚雄 (52 B.C. - 19 A.D.) answers a questioner in the following manner :

> "Someone asked about the Hun t'ien. He replied : Lo-hsia Hung created it, Hsien-yü Wang-jen 鮮于妄人 planned it, and Keng 耿 the palace assistant represented it. How exact it is ! No-one can contradict it."
>
> Fa Yen, 10, 1b SPPY; see III (4)

Hsien-yü Wang-jen is elsewhere mentioned as taking part in calendrical work in 78 B.C. (Han shu, 21A, 978 CHSC), while the official Keng, whose full name was Keng Shou-ch'ang 耿壽昌, submitted a memorial on solar and lunar motions in 54 B.C. (Hou Han shu, chih 2, 3029 CHSC). It is therefore possible that Yang Hsiung might have had actual contact with the latter, for, if Keng was thirty in 54 B.C. he would have been fifty-five when Yang was twenty-five in 29 B.C.

The problem about this passage is that Hun t'ien can refer to either of the following :

i. The Hun t'ien theory, i.e. that the heavens are a sphere surrounding the earth.

ii. An actual physical instrument, possibly an armillary sphere, but at this stage more probably a simple graduated ring with sights.

The practical and logical connections between (i) and (ii) will be examined in more detail in (c) below, but for the present let us discuss the evidence of the text itself. Contrary to the view of Maspero (3), Needham (SCC III, 216 and 354) feels that an instrument must be involved. His grounds for this are that the verb ying 營 translated above as 'create', more probably refers to an act of physical construction rather than to the elaboration of a theory.

In this context however I would contend that there is justification for adopting the abstract interpretation. Firstly, the extract given concludes with the statement that nobody can wei 違 (oppose, contradict, depart from) the Hun t'ien : this would surely be a more appropriate statement to make about a theory than about a physical device. There is an obviously intentional parallel here with Mencius 2, 2a. Secondly, as we shall see in III (4), Yang Hsiung follows this approval of the Hun t'ien with a condemnation of the Kai t'ien, and no-one has ever claimed that this was a reference to an instrument rather than to the Kai t'ien theory. A third objection to a physical interpretation is that the subjects of the three verbs whose object is the Hun t'ien, i.e. ying, tu 度 and hsiang 象 , are three men whose periods of activity span over sixty years. If Lo-hsia Hung made an instrument circa 110 B.C. then what function remained for the other two to perform ?

For these reasons, therefore, I have chosen to render the text so as to suggest that Lo-hsia Hung conceived the theory, Hsien-yü Wang-jen put it on an exact basis, and Keng Shou-ch'ang made a representation of some kind, which may well have been an actual instrument. As will appear in (c) immediately following, it looks very much as if Keng is in fact the first person to receive a firm mention in connection with the use of an armillary instrument.

I will shortly proceed to examine two other sources which have been claimed as evidence connecting Lo-hsia Hung with a Hun t'ien instrument : I believe neither to be reliable. Before doing this it may be helpful to examine the possible origin of armillary instruments ((c) following) and then to turn to the links between theories and instruments ((d) following).

(c) The early development of Hun t'ien armillary instruments.

A very full account of the early development of Chinese astronomical instruments of all kinds is given in Maspero (3), and a summary of information on the history of the armillary sphere is given in SCC III 342 ff. For my present purpose it is only necessary to discuss the use and significance of the basic element of all armillary instruments, the simple graduated ring with sights.

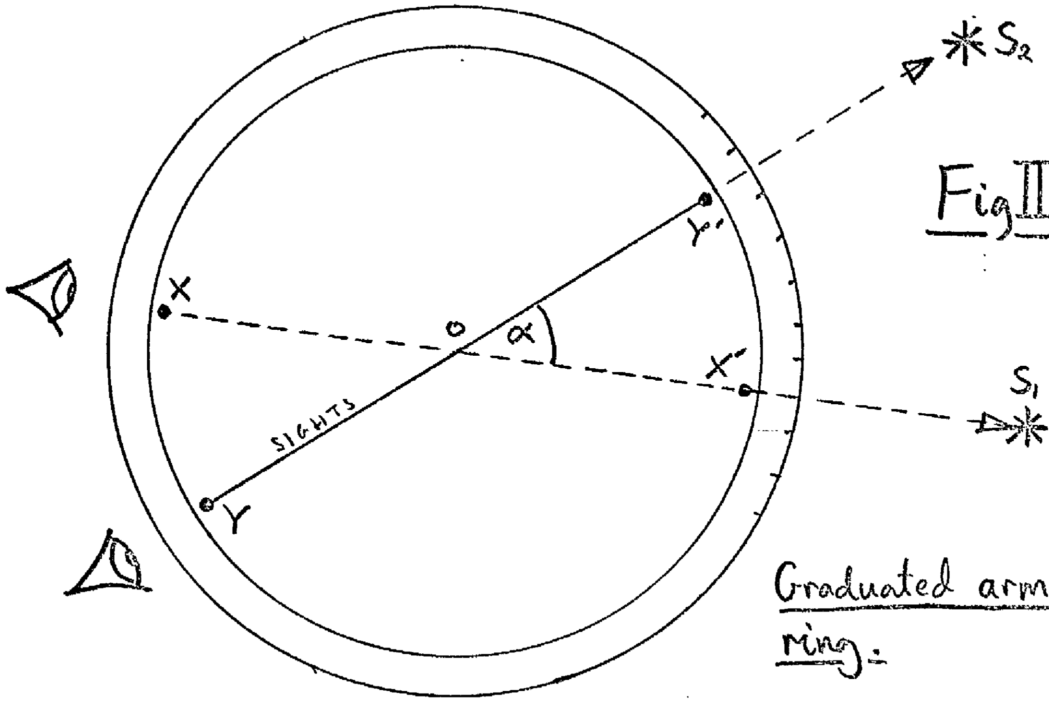


Fig III (1)

Graduated armillary ring:

Fig. III (1) illustrates the use of such a ring, which is presumed to have its circumference marked out into the $365\frac{1}{4}$ <u>tu</u> 度 (rather than 360 degrees) into which the Chinese divided a complete circle. It is provided with sights pivoted at the centre, O, of the ring (supports not shown). The ring is fixed in an appropriate plane so that any two objects of interest, in this case the stars S_1 and S_2, can be sighted on successively by rotating the sights.

By noting the difference between the graduations indicated on the two sightings, the angle α can be found.

There are, of course, a number of planes of interest in which the ring might be fixed. If a vertical plane was chosen, then measurements of the altitude and polar distance of celestial bodies can be made as they culminate, while a horizontally fixed ring provides data on the azimuth at which celestial bodies rise and set. Particularly importqnt in the Chinese context would be the use of the ring fixed in the plane of the celestial equator, along which were laid out the twenty-eight lunar mansions hsiu 宿 ; these constellations were almost certainly well-defined by the fourth century B.C. (SCC III 240 ff.). Naturally, the most convenient arrangement for observations of solar, lunar, and planetary motions would have the ring in the plane of the ecliptic.

Although the second century A.D. saw the construction of instruments containing combinations of these rings in nested form, whose necessarily spherical outline must have been very suggestive of the Hun t'ien notion of the celestial sphere, I would maintain that the earliest use of even simple rings must have been theoretically significant. Before this point can be properly made, it is necessary to say something about the sort of astronomical measurements made during the early development of quqntitative astronomy in China, and to link this with the instruments used.

It has already been mentioned that the system of the twenty-eight hsiu was established at an early date :

the earliest listing of all of them in sequence, giving the extent of each one in <u>tu</u> 度 , is in <u>Huai nantzu</u>, 3, 13b, SPTK (<u>circa</u> 120 B.C.). Naturally, the total is 365¼ <u>tu</u>. The obvious question to ask is : "by what means were these measurements derived ?" It is tempting to reply that the only means of dividing up the celestial equator in this manner must have been the use of an armillary ring aligned in the equatorial plane. To this I make two objections.

Firstly, the determinative stars of the <u>hsiu</u> are frequently found at considerable distances from the equator, and in no historical epoch has this been otherwise, despite the shift in the position of the celestial equator with precession. Nevertheless, the extensions given for each <u>hsiu</u> in <u>Huai nan tzu</u> are very definitely referred to the equator itself (SCC III, Table 24). Such measurements could not have been accurately performed using a single equatorial ring : a considerably more developed form of armillary would have been needed.

Secondly, our knowledge of the history of the development of the <u>hsiu</u> system suggests a means by which <u>hsiu</u> extensions could have been fairly accurately established using only very simple resources. As Needham has made clear (SCC III, 229 ff.), ancient Chinese calendrical astronomy directed its attention firmly towards the observation of the culmination of stars at some fixed time of night, rather than following the Mediterranean pattern of noting heliacal risings and settings. Let us see how this practice would have led to the calibration of the hsiu system in tu.

Suppose, firstly, that a north-south line has been defined. Methods by which this was actually done are given in Cullen (1). Let two fairly tall gnomons be so aligned and by sighting from these it will be possible to determine what stars lie on the observer's meridian at any given time. Further let us suppose that, perhaps using a water clock (see III (3)(a)), it is possible to ensure that observations occur at a fixed time of night, let us say midnight. If, then, at midnight on a certain date, a star S_1 crosses the meridian and aligns with the gnomon it will be found that on the following midnight it will no longer do so : it will already have transited almost four minutes earlier. It would, of course, require more than a single day to elapse before this discrepancy became easily detectable, but regular observation would readily establish that S_1 had been replaced by another star, S_2, as the midnight transit star, only to be followed by S_3, and so on.

If midnight observations were continued for a year it would become evident towards the end of that period that S_1 was once more approaching position for a midnight transit, and the cycle would thus be complete. Observation over a number of years would reveal that, inconveniently enough, the sun does not return to its original position amongst the stars in exactly 365 days. The actual length of the 'sidereal year' is 365.2564 mean solar days, a figure for which the Chinese anciently used an approximation of $365\frac{1}{4}$ days. (This may have been done as early as the second millenium B.C. (SCC III 293))

Given these facts, the obvious conclusion would have been that from one midnight to the next, the appearance of the sky shifts by $1/365\frac{1}{4}$ of a complete cycle, and it was to this daily shift that the Chinese gave the name of a tu 度. Stars that culminate on successive midnights differ in position by one tu; in general the number of days between midnight culminations gives the separation of stars in tu. Fractions of a tu will of course be represented by the fraction by which a star misses midnight culmination on its closest approach. Thus, by observation of transits at known times, it would be perfectly possible for the extensions of the hsiu to be defined in tu without the need for any device capable of measuring angles directly.

If a process similar to the one just outlined had in fact occurred, we would expect that at first the tu would only be found as a measure of the differences between the right ascensions of heavenly bodies. Its purely calendrical origin would mean that it was not thought of as a general measure of angle, suitable, for instance, for the measurement of the polar distances of stars. If we examine chapter 27 of the Shih chi, this is exactly the situation we find. The direct and retrograde motion of Jupiter, for instance, is described in terms of tu (ibid, p. 1313 CHSC), while such data as the size of comets are given in terms of the ten-foot measure chang 丈 (p. 1316). Other examples are the case of the moon being described as three feet ch'ih 尺 out of its normal path, or the altitude of celestial bodies being given as 'six chang above the earth' (p. 1331, p. 1333). (These linear measurements presumably refer to a situation in which a measuring-pole (real or imaginary ?) is held at some standard distance from the observer.) As has already been noted (III (3)(a)), it would not be unreasonable to take this as representing the level of technique available to Lo-hsia Hung.

Sooner or later, however, some enterprising astronomer might have thought of making a diagram showing the complete circle of the hsiu, divided into tu. This would have had an obvious use in keeping track of the positions of the sun, moon, and planets, which might perhaps have been represented by counters placed on a diagram drawn on silk or wood. The next step would be to pick up the diagram, and arrange it in correspondence with the hsiu as they appear in the night sky. Once this had occurred the way was open for the diagram to be held in non-equatorial planes, and for all celestial distances to be expressed in tu as the embryo instrument was modified for ease of handling and sighting. Thus, I would suggest, the simple armillary ring described at the beginning of this section might have evolved.

In support of this somewhat shaky conjecture I would point to a record of the activities of the third member of the trio headed by Lo-hsia Hung :

> "In the second year of the Kan Lu period [52 B.C.], the official Keng Shou-ch'ang memorialised that he had measured the motions of the sun and moon with a 'diagram instrument' (tu i 圖儀)."
>
> (Hou Han shu, chih 2, 3029 CHSC)

As the text goes on to point out, Keng's measurements were equatorial rather than ecliptic. The recognition of this distinction is for the present purpose less important than the exploitation of the armillary ring for measuring polar distances. The most significant of these would be, of course, the polar distances of the sun at the two solstices, from which the obliquity of the ecliptic could be deduced. The earliest evidence for this having been done is a memorial of Chia K'uei 賈逵 , dated to 92 or 93 A.D. :

> "Your servant respectfully points out that it was previously stated that at the winter solstice the sun is 115 tu from the pole, that at the summer solstice the sun is 67 tu from the pole, and that at the spring and autumn equinoxes the sun is 91 tu from the pole."
>
> (Hou Han shu, chih 2, 3029 CHSC)

Unfortunately it is not made clear whether Chia K'uei is reporting results recently obtained or citing well-known data of some antiquity. As, however, the rest of his memorial is full of quotations and citations of data gathered by others, one might have expected him to name his source in this instance also, if the figures given were not original. Perhaps the most that one can suggest is that, some time between Lo-hsia Hung's work _circa_ 116 B.C. and Chia K'uei's memorial of 92/93 A.D., the general application of armillary rings to angular measurements in all celestial planes began. It appears probable that the necessary equipment may have been developed by the time of Keng Shou-ch'ang in 52 B.C.

(Two apparently early instances of the measurement of north polar distances in _tu_ are discussed in Appendix (vi). Both of these, which occur in the _Chou pei_ and the _Hsing ching_, I believe to be of relatively late date.)

(d) _The connection between the Hun t'ien theory and the development of armillary instruments_.

The preceding account of the early development of armillary instruments was necessarily rather lengthy. I will now proceed to attempt to link it with a question which concerns this survey more directly, the question of the early development of the _Hun t'ien_ theory. Is there a connection between the theory and the armillary instruments which suggestively were also called _Hun t'ien_ ? I would argue that it is difficult to imagine either existing for very long without the other.

Suppose, for the sake of argument, that somebody with the astronomical knowledge displayed by Ssu-ma Ch'ien conceived the notion of the heavens as a sphere surrounding him. For him the hsiu would obviously be a belt half way between the poles of the sphere. Even if a physical model of the whole sphere was not made, there would surely be some motivation to construct a ring-model of the equatorial great circle of the hsiu. This would of course be graduated in tu. Once a model of one great circle had been made, the way would be open for the realisation that all great circles could be thus modelled and graduated. Thus the armillary ring would become an instrument of general application.

If on the other hand a ring-model of the hsiu was constructed before the Hun t'ien theory was thought of, let us consider the implication of any attempt to pick it up and hold it in correspondence with the night sky. Would it not immediately be seen that the half of the ring representing the hsiu invisible at that time was in such a position as to suggest that they were in some way underground ? The central idea of the Hun t'ien theory was, after all, that heaven is beneath the earth as well as above it.

We would therefore it seems to me be a little unrealistic if we drew an over-rigid distinction between the early development of the Hun t'ien theory and the Hun t'ien instrument.

(e) Did Huan T'an 桓 譚 connect Lo-hsia Hung with the Hun t'ien instrument ?

Huan T'an (40 B.C. - 30 A.D.) was a friend and contemporary of Yang Hsiung. A fragment of his (now lost) book Hsin lun 新論 is preserved in a number of differing versions. The TPYL text runs as follows :

> "Huan Tzu's Hsin lun says : Yang Tzu-yün [= Yang Hsiung] was fond of astronomy, and asked questions about it of an old palace artisan who had made a Hun t'ien."
>
> TPYL, 2, 11a

The old artisan then expresses regret at the impending loss of his skill through death, and it is probably this latter part of the story which held the point for the sake of which it was told. Corruption is suggested by the fact that his statement is introduced by an abrupt yüeh 曰 without a subject. TPYL quite frequently mangles its quotations with injudicious abbreviations.

If we turn to the version found in PTSC, an important difference appears. Firstly, the text is introduced by an editorial heading :

> "Lo-hsia Hung [and the] Hun t'ien"
>
> PTSC 130, 12a.

Secondly, Lo-hsia Hung's ming is placed immediately after "old artisan" lao kung; this would, whichever way the text was rendered, make Lo-hsia Hung appear in the rôle of an old artisan who conversed with Yang Hsiung. The notion of Lo-hsia Hung, an honoured calendrical expert as an artisan, kung, is quite unacceptable. It is further grossly improbable that he should ever have spoken to Yang Hsiung. If Lo-hsia Hung was thirty when he did his work in 116 B.C. he would have been 94 in 52 B.C., the year when Yang Hsiung was born. No text written by a contemporary and friend of Yang Hsiung could possibly have asserted anything of the kind. However, from the editorial heading it is clear that this is how at least one version of Hsin lun read when PTSC was completed in 630 A.D.

Another source of material on Lo-hsia Hung is in the fragments of a work called I pu ch'i chiu chuan 益部耆舊傳. According to the San Kuo chih, 4, 1027 CHSC, this was written by Ch'en Shu 陳術 c. 240 A.D. The Sui shu notes the work in its bibliography under the section on miscellaneous historical works (33 974 CHSC) and gives the author as Ch'en Ch'ang-shou 陳長壽. (see Textual Note (1) for all versions). The longest version is that of the seventh century Shih chi so yin :

> "[Lo-hsia] Hung's tzu was Ch'ang Kung. He was a brilliant astronomer, and went into retirement at Lo-hsia. He held the office of consultant scholar under Wu Ti, and rotated [a?] Hun t'ien at the centre of the earth. He reformed the Chuan Hsü calendar [and thus] made the T'ai Ch'u calendar. The rank of counsellor was conferred on him but he did not accept it."
>
> (Shih chi so yin, 26, 1261 CHSC)

This passage repeats the claim that Lo-hsia Hung used an armillary instrument, and it is possible that it may represent an independent tradition. There are, however, textual reasons for supposing otherwise (see Textual Note (1)), and it is quite possible that at this point the I pu ch'i chiu chuan was simply drawing on the Shih chi and Fa yen.

(f) Summary

It may be helpful to draw together the conclusions scattered through the preceding sections :

i. Lo-hsia Hung was a calendrical expert active c. 116 B.C. If the comparison with Ssu-ma Ch'ien is worth making, it is unlikely that he had the use of even a simple armillary ring. This does not of course mean that he could not have originated the Hun t'ien theory.

ii. Armillary rings were in use c. 52 B.C., although possibly in the equatorial plane alone.

iii. Yang Hsiung, writing c. 0 B.C. seems to attribute the invention of the Hun t'ien theory to Lo-hsia Hung. Other sources attributing the instrument to him are doubtful.

It seems, therefore, that the most that can be said with certainty is that, at the time that Yang Hsiung wrote, the Hun t'ien theory and possibly the instrument also, were not thought of as recent discoveries. The attribution to Lo-hsia Hung may or may not be reliable. I would go so far as to say that, for the purposes of this survey, the question is quite unimportant. It is notable that no later writer, however devoted to the antiquity of the _Hun t'ien_, can find any signs of it before the time of Yang Hsiung. Perhaps, therefore, we can conclude the present discussion by agreeing that the _Hun t'ien_ theory and the instruments associated with it are essentially developments of the latter half of the Western Han.

(4) Yang Hsiung 揚雄 (52 B.C. - 19 A.D.) and Huan T'an 桓譚 (40 B.C. - 30 A.D.).

(a) Yang Hsiung's conversion to the Hun t'ien

In a preceding section (III (3)(b)), a passage was discussed in which Yang Hsiung commended the Hun t'ien and described its origins. The complete passage reads :

> "Someone asked about the Hun t'ien. He replied : 'Lo-hsia Hung created it, Hsien-yü Wang-jen planned it, and Keng the palace assistant represented it. How exact it is ! No-one can contradict it.' They asked about the Kai t'ien. He said : 'The Kai ! The Kai ! It leads to difficulties and is inaccurate'."
>
> (Fa yen 10, 1b, SPPY

His T'ai hsüan ching 太玄經 likewise contains a note evidently favouring the Hun t'ien :

> "Heaven arches upwards and encircles below. Earth spreads sideways and faces upwards."
>
> (T'ai hsüan ching, 10, 11a SPPY

It seems, however, that Yang Hsiung may have originally been a partisan of the Kai t'ien, despite his later strictures on it. A fragment of Huan T'an's now lost Hsin lun 新論 reads :

> "Yang Tzu-yün [= Yang Hsiung], a man of deep insight, took the theories of the majority of scholars as his basis for holding Heaven to be a cover, constantly rotating leftwards while the sun moon and constellations are taken with it from east to west. Thus he drew a diagram of its physical form and the degrees of its motion, checking it against the four seasons, the calendar, dusk and dawn, day and night. He intended to set up a model for the men of his age, and thus to hand on an example to later generations.

I made the following objections: at the equinoxes day and night should be equal. At dawn the sun rises in *mao* 卯, exactly due east, and at dusk the sun sets in *yu* 酉, exactly due west. So these are the *mao* and *yu* of men, not the *mao* and *yu* of heaven. The *mao* and *yu* of heaven are defined from the north celestial pole. The north celestial pole is the pivot of heaven. This pivot is the 'nave' of heaven, in a similar way to the boss of a chariot-umbrella. Even though the chariot-umbrella rotates the boss does not move. Heaven likewise rotates, but its north pole remains fixed. From this we know it is the centre of heaven. By observation it is to the north of us, not directly overhead, but at the equinoxes the sun rises and sets to the south of the pole. If [heaven] rotated like a chariot-umbrella, then [the sun's] path to the north of us should be long, while its path to the south of us should be short. How then could day and night be of equal length ? Tzu-yün had no explanation."

(continued below)

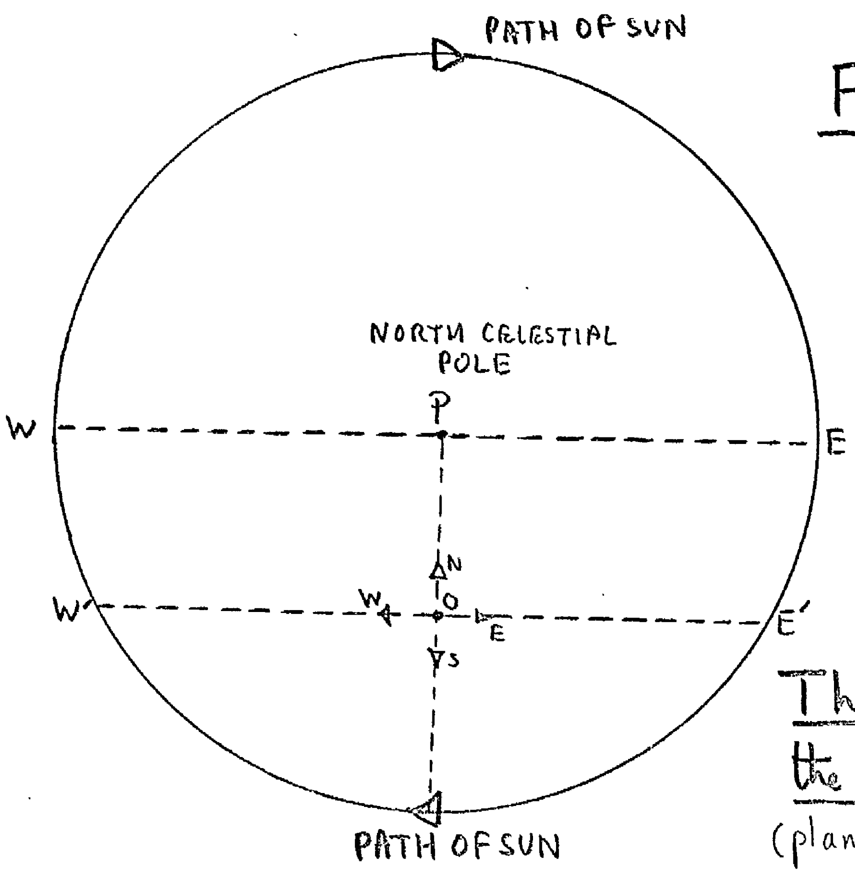


Fig III (2)

The problem of the equinoxes (plan view)

Huan T'an is clearly describing the situation of Fig. III (2). For an observer at O the equinoctial sun must rise at E′ and W′ rather than at E and W. The sun takes a shorter time to travel from E′ to W′ than from W′ to E′, and hence day should be much shorter than night. In fact they are of course equal at the equinoxes. This objection to the Kai t'ien theory is perhaps the most obvious.

Huan T'an continues :

> "On a later occasion Tzu-yün and I had court business, and were sitting beneath the gallery of the White Tiger hall. Because of the cold we had turned our backs to the warmth of the sun. After a while the sun's rays went away and we were no longer warmed by them. I took this opportunity to point it out to Tzu-yün, saying : 'Suppose heaven does rotate like a chariot umbrella. Then as the sun rotates westwards its radiance ought simply to continue shining under this verandah while shifting eastwards. As this is not the case, it corresponds on the contrary to the Hun t'ien theory.
>
> Tzu-yün abandoned his contention, and so it appears that the Confucians are incorrect in holding that heaven rotates to the left."

TPYL 2, 6b.

See also SLF 1,1a ; Chin shu 11,282 ; CHC, 1,1a ; Wen hsüan, p. 56, comm.

This is not the place for architectural controversy, and there is in any case little doubt about the essentials of the case. The two friends were some way inside the south-facing open entrance of an audience hall. Assuming (as seems necessary) that it was winter, the sun would have risen in the south-east, and shone under the eaves of the entrance onto the western interior gallery. As the sun moved westwards it also rose higher in the sky, until eventually the eaves blocked its light from the interior. It is this increasing altitude that Huan T'an uses as an objection to the Kai t'ien - why does the sun not simply circle the horizon at constant height ? We have already seen the attempt to deal with this problem in the Chou pei (II (3)(d)), and we shall shortly discuss the arguments of Wang Ch'ung (III (6)). It cannot be said that sunrise and sunset are adequately explained by the Kai t'ien, and this crucial failure on a matter of everyday observation must have contributed to its downfall.

(b) Yang Hsiung's eight objections to the Kai t'ien.

The Sui shu (656 A.D.) details eight objections to the Kai t'ien, attributed to Yang Hsiung. The existence of these eight is mentioned in the Sung shu (500 A.D.), and one of them is given by Chiang Chi 姜岌 (c. 385 A.D.). (See IV (9) (a) .) Under these circumstances we cannot claim with any confidence that the attribution is correct. It must be admitted that the combined effect of the eight is so devastating that it is hard to see why someone like Ko Hung 葛洪 (c. 320 A.D.) (see IV (8)) would have felt it worthwhile to attack the Kai t'ien independently if Yang Hsiung's work was known already. Nevertheless he did so in some detail, without mentioning Yang Hsiung although he referred to the objections raised by Huan T'an. I feel that the implication is that this is a late collection of material, plausibly enough attributed to Yang Hsiung as the first man known to have criticised the _Kai t'ien_.

Perhaps, therefore, the text translated below is a fourth century compilation quite unrelated to Yang Hsiung himself. Despite this I have chosen not to relocate it, although it probably ought not to be treated as representing the level of argument found during the Western Han. For convenience, comments are placed directly after the arguments on which they enlarge.

> "At the end of the [Western] Han, Yang Tzu-yün raised eight objections to the _Kai t'ien_ in order to propagate the _Hun t'ien_
>
> i. The sun moves eastwards along the ecliptic. [The constellation] Ch'ien Niu is 110 _tu_ northwards from the north pole and [the constellation] Tung Ching is 70 _tu_ southwards from the north pole: a total of 180 _tu_. The circumference is thrice the diameter, so the circumference of the 28 _hsiu_ round heaven should be 540 _tu_. Why then is it 360 _tu_ ?"

At first sight this seems a puzzling argument, and the clear implication that the _hsiu_ are laid out along the ecliptic is somewhat unorthodox (see SCC III,229) All that is really being done here in fact is to point out the absurdities involved in a plane pole-centred system that cannot give equal status to all great circles of the celestial sphere.

"ii. Exactly at the spring and autumn equinoxes the sun rises due east and sets due west. The day is 50 ke 刻 long. If heaven rotates like a chariot-cover, night should be double [the length of] day. Why is night also 50 ke long ?"

This argument was, as we have seen, advanced by Huan T'an.

"iii. When the sun sets the stars become visible, and when the sun rises they become invisible. Now below the Dipper the sun is visible for six months and invisible for six months. Similarly the Dipper must also be visible for six months and invisible for six months. Why then is it visible every night ?"

This refers to those features of the Chou pei cosmography dealt with in II (3)(d).

"iv. If we consider the Milky Way on a diagram like a chariot-cover, it starts from [the constellation] T'ou and passes between Lang and Hu in a curve like a wheel. Now why when we look at the Milky Way does it appear straight as a plumbline ?"

The point here is that on the Hun t'ien theory we are (almost exactly) at the centre of the celestial sphere, and so great circles are coplanar with sets of straight lines through an observer, which is certainly not the case with the Kai t'ien.

"v. The circumference of heaven [is divided into] the 28 hsiu. If we view heaven as a chariot-cover, there should be fewer visible stars than invisible ones. Now the visible and invisible are equal [in number]. Their rising and setting are independent of winter or summer. The stars of 14 hsiu are always visible, and are not more or less whether the day is long or short. Why is this ?"

"vi. Heaven is highest and earth is lowest. The sun turns attached to heaven and thus can be said to be highest. Even if the human eye can be deceived, water and shadows cannot be deceived. Now sight on the sun from a high mountain-top with a water[-level]. The sun rises from below the water[-level], and shadows can be seen cast upwards. Why is this ?"

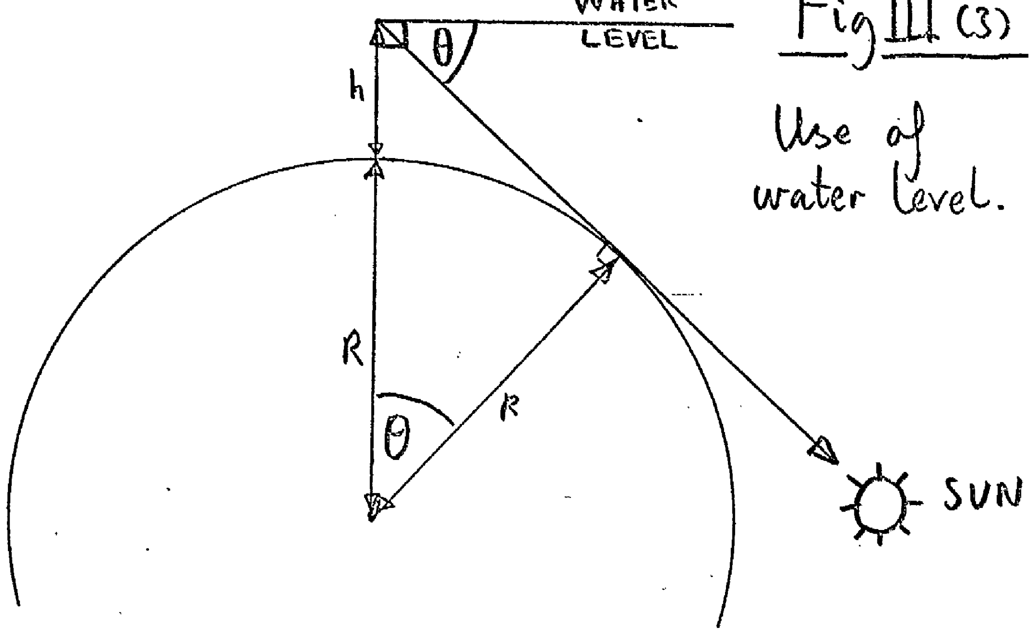


Fig III (3)

Use of water level.

The point here is of course that according to the <u>Kai t'ien</u> the sun is always above the level of all points on earth. In the <u>Hun t'ien</u>, however, the rising and setting sun is on the same horizontal level as the mean surface of the (flat) earth. Hence at sunrise it is not surprising to find the sun lower than an observer on a mountaintop. In fact the phenomenon described has a real basis in the actual spherical shape of the earth: see Fig. III (3).

h is the height of an observer above sea level, and θ is the angle by which the rising sun is seen below a water level.

Evidently, $\cos\theta = \frac{R}{(h + R)}$

$$\therefore \quad \theta = \cos^{-1}\left(\frac{1}{1 + \left(\frac{h}{R}\right)}\right)$$

Suppose that $\theta = 1^{\circ}$. Then, as R = 3,900 miles, h must be approximately 0.6 miles, which is over 3,000 ft. Mount T'ai and Mount Sung are both less than 5,000 ft. high, which would lead to a value of approximately 1.3°. It is thus evident that the effect described would not be very readily observable in central China. Perhaps, therefore, the argument of (vi) is derived from a priori considerations rather than empirical observations.

> "vii. Things appear large when near and small when distant. Now why do both the sun and the Northern Dipper appear small when near us and large when far from us ?"

This argument depends on the well-known 'horizon illusion'. The sun appears larger when on the horizon than at noon, while the Dipper seems larger when low on the horizon below the celestial pole than when above it. Of course, under the Kai t'ien cosmography the sun is nearest at noon and the Dipper is nearest when above the pole, contrary to the apparent visible evidence.

"viii. Consider the gaps between the ribs of an umbrella or the spokes of a cartwheel. Near the hub they are narrow, and further out they are wide. Now the North Pole is the hub of heaven, and the 28 hsiu are the ribs or spokes. Measuring out heaven according to the degrees of the stars, the stars corresponding to the southern parts of the earth should be several times further apart. Why are they equally spaced ?"

There really seems little enough to be said on behalf of the Kai t'ien after all this. Indeed, the fact that Wang Ch'ung argues firmly for the Kai t'ien suggests that the dialectic armoury deployed here had not yet been assembled (see III (6)).

(5) Some problems about the heavenly bodies

(a) Ching Fang on the moon, stars, and eclipses

I have already mentioned a passage in the Chou pei which, wrongly I think, has been taken as stating that the moon shines by the sun's reflected light (II (3)(e)). As well as mentioning this text, Needham (SCC III, 227) quotes a fragment found in TPYL 4, 8b, where it is attributed to Fan Li 范蠡 of the fifth century B.C. : it consists of the five characters 月水精内影 Needham translates this as "The moon is of the essence of water, reflecting like a concave mirror", but I do not think that the last two characters can bear the weight he places on them. Nevertheless there may be some suggestion of reflection here, as there certainly is in the phrase 含影 used by Chang Hêng (III (7)(d)).

The earliest reliable source on the subject of lunar reflectivity seems to be the work of Ching Fang 京房 (fl. 40 B.C.) : the relevant fragment is found in PTSC 150,4a ; Yüeh ling chu su 14,5a ; IWLC 1,5b ; TPYL 4,10a The version used here is that of TPYL 4, 10a, which quotes Ching Fang through the medium of the Ch'i Lueh 七略 by Liu Hsiang 劉向 (fl. 25 B.C.) :

> "The moon and stars are extremely Yin. They have shape but lack radiance. When the sun illuminates them they thereupon acquire radiance. This is like the mirror facing the sun, when a reflection is seen ... "

Note that Ching in enunciating the usual ancient Chinese view that the stars as well as the moon shine only when lit up by the sun; see, for instance, Chang Heng, loc. cit. Ching's explanation of a solar eclipse stresses the implications of such events in the Yin/Yang scheme rather than suggesting that the moon physically blocks the sun's rays :

> "The sun is the essence of Yang, the symbol of the ruler of men. If it shines in solitary splendour and the Yin encroaches on it then the omen of a solar eclipse occurs."

Ku Liang chu su, 1, 12a, SSCCS

The fragment given here is found in the Chin dynasty commentary. The discussion of such matters was next taken up in detail by Wang Ch'ung whose work is discussed in III (6)(f), where a relevant fragment of Liu Hsiang's work is also mentioned.

(b) Confucius and the two boys

When they are near the horizon both the sun and the moon seem, even to a casual observer, to be considerably larger than when they are well up in the sky. Although most people are aware of this in a passive way few of them trouble themselves about why this odd effect should occur, and of those who do one suspects that the majority go no further than the rather unhelpful statement that it is "an optical illusion". This presumably means no more than to deny that the two bodies in question actually swell up or approach us more closely at the time when we experience the purely local phenomena of their rising and setting. The problem of why, nevertheless, they should appear to do so has been investigated by Dember and Uibe (1) and (2) : it seems likely that the effect is caused by the eyes' propensity to perceive the sky as a flattened cap rather than a true hemisphere.

Naturally this problem was faced by a number of those Chinese thinkers who attempted a systematic account of the cosmos. The earliest reference to it is a very well-known and obviously fictional story belonging to the genre in which Confucius is portrayed as being subjected to discomfiture by hermits and other eccentrics. The text is now found in Chapter 5 of Lieh tzu 列子

and a number of early sources quote it with an attribution to that book (Textual Notes (2)) I do not intend to enter upon the complex question of the date or dates of compilation of Lieh tzu (see IV (10)), but it is of considerable interest that the story was apparently included by Huan T'an in his book Hsin Lun 新論 written c. A.D. 20, if we may rely on the quotation in the Buddhist encyclopaedia Fa yuan chu lin 法園珠林 of A.D. 668. This is unlikely to be an example of mistaken attribution, for immediately before the shorter Hsin lun version the full story is given with an attribution to Lieh tzu, although there are some slight differences from the modern text. Huan T'an is made to claim an independent source :

> "Huan T'an's Hsin lun says : 'in my youth I heard a common story that Confucius ... [etc.]'."

Fa yuan chu lin 7, 16a, SPTK

This is followed by the criticism of Kuan Ping : see (C) below. One cannot of course claim on this basis that Lieh tzu did not exist as a book in Huan T'an's time, but only that part of its material circulated independently. The story as we have it today runs :

> "Confucius travelled eastwards and saw two small boys quarrelling. He asked the reason, and one boy replied : 'I think the rising sun is nearer to us, and the noon sun further away.' The other boy said that the rising sun was further and the noon sun was nearer. The first boy said : 'When the sun rises it's as big as a chariot umbrella. By noon it's like a pot-lid. Isn't this a case of a distant thing looking small

> and a nearby thing looking big ?' The other boy said 'When the sun rises it's cool, but by noon it's boiling hot. Isn't this a case of being warm when nearby and cool when distant ?'
>
> Confucius could not settle this. The two small boys laughed and said 'Who says you know such a lot ?'."
>
> *Lieh tzu*, 5, SPPY

The introduction of the question of the variation of the sun's warmth turns the original problem into a dilemma. Huan T'an's story does not include this feature, although his account of Kuan Ping's work gives an account of an attempt to settle this difficulty also.

(C) Kuan Ping's attempt at an explanation

Some time in the first two decades of the first century A.D., Kuan Ping 關並 made an attempt to deal with the problem just described. Kuan is a partisan of the first small boy in the story, and his reply to his opponent's objection is not without ingenuity. The material now quoted is found in *Fa yuan chu lin* (loc. cit.) and *Sui shu* 19, 512, CHSC. In both cases it is attributed to Huan T'an's *Hsin lun* :

> "In the Han dynasty Kuan Tzu-yang [= Kuang Ping] from P'ing Ling was the Commander of Ch'ang Shui. He held that the sun was further away when overhead and nearer when on the horizon. What was his reason for this ? When the constellations rise out of the east at dusk the gaps between [their stars] are very wide [let us say] they are over ten feet apart. By midnight when they are directly overhead they appear much closer together, [only] one or two feet apart. If one takes measurements, it is even more obvious. Thus

we know that heaven is more distant overhead than on the horizon.

The sun is heavenly Yang while fire is earthly Yang. Earthly Yang rises upwards, while heavenly Yang comes downwards. Now if a fire is placed on the ground the heat above the fire and beside it are very different whatever the distance. At noon the sun is overhead, and we are covered [by its radiation]. We bear the brunt of the heavenly Yang, and so it is warmer than when the sun first rises. At that time it has just come out of the great Yin, and so it is cooler than when it is setting.

Huan Chün-shan [= Huan T'an] comments : Can what Tzu-yang [= Kuan Ping] says be true ?"

Kuang Ping's theory is certainly neither consistent with the <u>Kai t'ien</u> nor the <u>Hun t'ien</u>, and it is quite possible that he was thinking about the problem in isolation and without any conception of an overall cosmography. The reference to the "Great Yin" is reminiscent of the theory criticised by Wang Ch'ung (III (6)(g)) and repeated two centuries later by Yang Ch'üan (IV (3)(b)). Other references to the subject of this section are made by Chang Heng (III (7)(f)), Shu Hsi (IV (2)(e)), Chiang Chi (IV (9)(c)), and Tsu Keng-chih (V (3)(c)).

(6) Wang Ch'ung 王充 - first and last polemicist for the Kai T'ien.

(a) Introduction

Wang Ch'ung (c. A.D. 30 - A.D. 95) differs from most other writers in this survey in the great amount of his writing that has been preserved intact. Paradoxically, this leads to certain problems : if for instance the length of this section was such as to enable a detailed treatment of the cosmographically interesting parts of his book Lun heng 論衡, it would grow out of all proportion to Wang's importance as a cosmographer. A further difficulty with Wang is his polemical style, which makes it hard to disentangle statements of his own opinions from refutations of his opponents. In the interests of clarity of exposition I have attempted to do this where possible, without, I hope oversimplifying the discussion. Wang usually gives a fair account of theories he rejects : this is fortunate, for otherwise several of them would have remained unknown to us.

(b) Wang Ch'ung and the Kai T'ien

Wang's views on cosmography are basically the same as those found in the Chou pei, with certain modificationsof detail.

i. "Heaven is exactly level and no different from earth, and the sun rises, and sets, being turned round along with heaven"

Lun hêng, 11, 8b SPTK

ii. "To men heaven and earth seem to unite at a distance of no more than ten li. That is the effect of the distance, for they do not come together in fact. When we behold the sun setting, it does not set, it is also the distance. At the time when the sun sets in the west, the people living there will perhaps say that it is culminating, and looking from the point where the sun is setting eastward to our world, heaven and earth may [appear to be] joined together.

ibid.

iii. "Let a man take a big torch, and walk at night on a level road where there are no gaps. He will not have walked to a distance of one li from us before the light of the fire has gone out. It does not go out, it is the distance. In the same manner the sun revolving westwards and disappearing does not set [i.e. does not enter the earth]."

ibid, 11. 9a.

Passages (ii) and (iii) might well serve as a commentary to parts of the Chou pei; see for instance II (3)(d) above. There seems, however, to be a discrepancy in (i), where it is clearly suggested that heaven and earth are level, while the Chou pei states that they both bulge upwards somewhat at their centres (II (3)(c)). Elsewhere (11, 9b) Wang states clearly that heaven is not really lower at the edges, despite appearances : for him, this is another illusion caused by distance. This variation suggests that Wang Ch'ung was not simply expanding on ideas taken from the Chou pei. Indeed, it is quite remarkable that he never mentions the book at all. As we shall shortly see in (e) below, he fails to apply the "inch-for-a-thousand-*li*" shadow principle in a context where we would certainly expect it. The straightforward explanation of these omissions is simply that Wang Ch'ung was probably limited by his well-known provincialism, and had neither had a chance of reading the *Chou pei* nor had received mathematical training. Questions relating to the date at which the *Chou pei* was compiled are discussed in Appendix (4), and in the light of that discussion we may note here that the book may well not yet have been compiled by the time that Wang wrote. The existence of still another variant of the *Kai t'ien* - the "tilted axis" theory ((i) below) - suggests that during the first century A.D. it was still theoretically fertile. We should remember after all that our first solid literary evidence for attacks on the *Kai t'ien* is no earlier than the discussions of Yang Hsiung and Huan T'an a century previously (III (4)(a)). It would thus be wise to avoid assuming that the thinking of the *Kai t'ien* school was limited by what was eventually codified as the *Chou pei*. There seem to have been several strands of thought, operating with a large degree of independence.

(c) Wang's view of the physical nature of heaven.

According to Wang, heaven itself is certainly something solid :

> "The Literati say that heaven is ch'i ... [but] according to apocryphal works heaven is upwards of sixty-thousand li above the empire. Mathematicians reckon the entire circumference of heaven at 365 degrees. Thus the world all round is divided into degrees and its height measures a certain number of li. If heaven were really ch'i, ch'i is like clouds and mist, how could there be so many li or so many degrees ? Besides, we have the 'twenty-eight constellations' [hsiu 宿] which serve as resting-places to sun and moon, just as on earth the couriers lodge in postal stations. The postal stations on earth correspond to the star mansions on heaven. Hence the statement found in books that heaven has a body is not baseless. Looking at the question like this, it becomes evident that heaven cannot be something diffuse and vague."

Lun hêng 11, 5b (cf. 25, 10a)

Wang appears at this point to be using the (by his standards) rather reprehensible method of appealing to authority : the experts have assigned definite dimensions to heaven, therefore it must be a rigid body. Alternatively he could be motivated by the fact that the heavenly phenomena do not occur at random, but behave in a regular manner, for him more consistent with a solid heaven than an inchoate mass of ch'i. This point will come out more clearly when we come to consider Wang's ideas of the relation between the heavenly bodies and heaven itself in the next section.

(d) Sun, moon, and stars.

In a striking analogy Wang gives his theory of why it is that the sun and moon exhibit retrograde motion against the background of the stars, despite taking part in a diurnal revolution :

> "[The sun and moon] are attached to heaven, and follow its movements during the four seasons. Their movement may be compared to that of ants crawling on a [rolling] mill-stone. The movements of the sun and moon are slow, whereas heaven moves very fast. Heaven carries the sun and moon along with it, therefore, although they really move eastward, they are turned back westward."

Lun hêng 11, 11b.

(But see IV (8) (b) for the criticism by Ko Hung also Chinshu 11,279; Suishu 19,506, where this and other matter is quoted with no attribution but to "the Choupei school")

In one day the sun moves eastwards against the sky about 1 tu, while the moon moves eastwards 13 tu. Wang takes one tu as equivalent to 2,000 li; thus he calculates the daily motions of the sun and moon relative to heaven as 2,000 li and 26,000 li. These he compares respectively with the speed at which the legendary beast ch'i-lin runs, and the flight of a wild duck. Heaven itself moves 365 tu in a day, giving 730,000 li :

> "This movement is very fast and there is no way to test it. It can be compared to the rotation of a potter's wheel, or the speed of an arrow shot from a cross-bow."

Lun hêng 11, 12a.

Wang points out that the great distance of heaven means that its speed is not apparent to terrestrial observers. As for the figure of 2,000 li, it is not easy to see how this was deduced. For a start, there is something very odd in such an uncompromising supporter of the Kai t'ien giving a single length for the tu. In the instances above, the tu are of course measured along parallels of declination concentric with the north celestial pole, and on the scheme of the Chou pei, for example, the circle followed by the sun at the winter solstice has double the diameter of the summer solstice circle (II (3)(b) above). Since all circles are divided into $365\frac{1}{4}$ tu (although Wang omits the fraction), it is evident that a tu for the winter sun is twice as long as a tu in summer. We may note, in passing, a significant difference between the tu and the western degree : the latter is of course a measure of the angle between two lines, whereas the former is (in all the texts we consider) a fractional division of the circumference of a circle.

I would tentatively suggest that Wang takes his 2,000 li/tu ratio from his belief that the sun is 1,000 li across (Lun hêng 11, 16a), and an (unstated) assumption, fairly accurate, that the sun's angular diameter was $\frac{1}{2}$ tu. The Chou pei, it will be remembered, gave the sun a diameter of 1,250 li (II (2)(c) above); it may be that Wang is quoting a garbling of this or possibly the tradition may be independent. Again without any attempt at proof, the stars are said to be 100 li across (Lun hêng 11, 18a). These dimensions for sun and stars are also given in the third century A.D. by Hsü Cheng. A tantalising fragment by Lu Sheng, again in the third century, claims grounds for reducing all figures by a factor of ten (IV (4) (a), (b))

The subject of the physical nature of the sun, moon, and stars will recur below, so here I will be content with noting briefly that Wang considers the first two as composed of the essences of fire and water respectively, while he seems to imply that the stars are of stony substance. From this he draws a somewhat odd conclusion, as we shall see.

(e) The extent of the world : Wang Ch'ung and Tsou Yen.

In (b), (c) and (d) I was able to some extent to discuss Wang's views in isolation. From now on it will be necessary to take more account of the fact that Wang's usual method of expressing a view is by way of an attack on the views held by someone else, which he has previously set out. In the present instance, the theories of Tsou Yen are subjected to scrutiny (see I (3) above). It will be remembered that Wang's account of Tsou's work credits him with saying only that the world contained eight other continents the size of China, whereas the Shih chi version says that there are in all nine such "continent-clusters", each one containing nine "Chinas".

Wang is in the first instance suspicious of Tsou's credentials. He notes that the Shu Ching's short geographical account, the so-called "Tribute of Yü" (禹貢 Yü kung) makes no mention of any ninefold continents, nor does Huai nan tzu give any support.

> "Tsou Yen did not travel as far as Yü and Yi on earth, and his experience was not greater than that of either Wu Pei or Tso Wu [who contributed to the Huai nan tzu book]. His talents were not those of a sage, and he did not learn things by a special revelation from heaven. How then could he make such statements ? Examined by the light of Yü's "Mountain Book" and of Huai nan tzu's chapter on the shape of the earth, his words are utterly wrong."
>
> Lun hêng 11, 3b.

We must not be too hasty in charging Wang with bibliolatry here, for he immediately points out that the Shih chi casts considerable doubt on the accuracy of the Yü Kung, concluding:

> "It is difficult to know the facts; it is difficult to fathom truth."
>
> Lun hêng, 11, 4a.

On practical considerations, Wang is prepared to agree with Tsou that the known world is small compared to the total extent of the world (11, 4a, ff.). He notes firstly that, by symmetry, there must be more land beyond the north pole. Also, the rising sun seems the same size whether seen from the Gobi or the Eastern Sea. Wang is forgetting the fact that he has already adopted the Kai t'ien theory of solar motion, which destroys the significance of this latter argument based on a definite sunrise point. Since under the Kai t'ien sunrise occurs whenever the sun moves within a certain critical distance of any given observer, the rising sun must always appear the same size. There is a similar inconsistency in Wang's argument against Tsou's statements that China is in the south-east, when he points out that the celestial pole would not then appear due north but due north-west : hence, he concludes, China must be due south of the pole. This simply shows that Wang had not analysed the implications of defining "north" in a cosmography with a central pole. Nevertheless Wang argues that because the pole appears due north throughout the known world, the known world must be small (compared to the distance to the pole).

Finally (Lun hêng, 11, 5a), Wang sets out to investigate the quantitative implications of Tsou's "ninefold China" theory. This is done quite simply by estimating the overall size of the earth and comparing it with an estimate of the size of China. The first estimate is arrived at on the basis that the distance from the pole to the sun (apparently at the summer solstice) represents half the diameter of the earth. Wang makes a simple guess that the pole is 30,000 li north of Lo Yang, and adds to this an amount of 20,000 li for the distance from Lo Yang south to the subsolar point. This second figure is derived by referring to the experience of travellers in Jih Nan 日南 (a Han prefecture corresponding to Annam), said to be 10,000 *li* south of Lo Yang, approximately thrice the actual distance. Oddly, since the tropic of Cancer runs north of Annam, Wang feels this is not far south enough to give the subsolar point, so he doubles to give 20,000 *li* south of Lo Yang. Thus from the pole to the subsolar point is 50,000 *li*. Note that Wang has not shown any awareness of the possibility of using the shadow-principle (II (2)(a)) to obtain the data he wants. By this principle, the *Chou pei* obtains 103,000 *li* for Wang's 30,000 *li* (Lo Yang-pole) and 16,000 *li* for Wang's 20,000 *li* (Lo Yang-sun). The impression is reinforced that Wang had negligible contact with the tradition that led to the *Chou pei*'s compilation.

Doubling 50,000 *li* gives the diameter of the earth since, Wang states, there must by symmetry be as much to the north of the pole as to the south of it. The same, of course, applies to east and west, since we are dealing with a *Kai t'ien* universe. The earth is thus 100,000 *li* by 100,000 *li*. Wang multiplies these together, and obtains a result of "1,000,000 *li*" (*Lun hêng*, 11, 5b) attracting Forke's caustic comment that he is a "better theorist than arithmetician" (Forke,(2),256). This may be unfair; the figuring as Wang wrote it was, of course :

(十萬里)×(十萬里)=(百萬里) [using modern symbolism]

signifying: (10(10,000 *li*)) x (10(10,000 *li*)) = (100(10,000 *li*))

Wang seems to have treated 10,000 *li* as his unit, using a linear measure on the left-hand side of the equation, and, of course, referring to a square of 10,000 li as a unit of area in the result. If this was his procedure, however, he was not consistent in it, as will appear.

Having estimated the size of the earth on an independent basis, Wang turns to the implications of Tsou Yen's "nine-fold China" theory. He takes the diameter of the empire in Chou times as 5,000 li, which is certainly not much more than a 30 per cent overestimate. Squaring 5,000 li to find its area, he gives the result as 25,000 li. This may be the same procedure as before, but we would have to assume that his area unit is now a 1,000 li square rather than a 10,000 li square. Multiplying by nine gives 225,000 li. He points out that this figure, derived from Tsou Yen's assumptions, is considerably smaller than the 1,000,000 li derived independently for the total extent of the earth, ending with the statement that despite first appearances Tsou was guilty of an underestimate rather than an overestimate of the earth's extent. Of course, this conclusion is even more forcible if we employ a consistent arithmetical usage, in which :

independently : area = $(100{,}000 \text{ li})^2$ = 10,000,000,000 square li

Tsou Yen : area = $9 \times (5{,}000 \text{ li})^2$ = 225,000,000 square li

The accusation that Wang Ch'ung was inclined to be rather unimaginative in his scepticism is a little blunted by this instance of his being prepared to improve on the furthest flights of Tsou Yen.

(f) On eclipses : rejection of a correct theory.

When either solar or lunar eclipses are mentioned in the astronomical literature of the period with which this survey is concerned, the writer's interest is in most cases purely astrological. A relatively late example is :

> "In the third year [of the Chen Kuan period], in the eighth month, on a chi-ssu day, a new moon, the sun was eclipsed, being in the fifth degree of the lunar mansion I. Prognostication : drought."
>
> (Hsin T'ang Shu, 32, 827, CHSC)

We are not concerned here with the schemata by which eclipses were interpreted as omens, nor with the unceasing attempts made by calendrical mathematicians to find some combination of cycles by which they might be predicted. The texts to be discussed in this section, and others later on, approach the problem from the point of view of the physical phenomena involved. In doing so they reveal a good deal about the cosmographical and physical notions which formed the backgrounds of their authors' thinking. It would of course be quite misleading to give the impression that an author who discusses the physical aspects of eclipses is implicitly rejecting any ominous significance they might have. In such discussions we shall in fact see instances where a theory of solar or lunar eclipses is criticised on what can only be called political grounds (e.g. Liu Chih, IV (b) (b), (c))

Wang Ch'ung was not a man much tolerant of myths : see (j) below. It is surprising therefore that he made no attack on such theories as the following :

> "When ch'i-lin [mythical beasts] fight, the sun and moon are eclipsed."
>
> Huai nan tzu, 3, 2a SPTK

In fact the whole burden of his argument is that solar (and by implication also lunar) eclipses are not caused by any external agency at all. Firstly of course he must dispose of the suggestive fact that the sun is only eclipsed when the sun and moon are in conjunction at the end of a lunar month.

> "The literati maintain that the eclipse of the sun is caused by the moon. They have observed that the eclipses of the sun always fall on the last and first day of a [lunar] month. At that time the moon is in conjunction with the sun, and therefore can eclipse it [they think]. Many eclipses of the sun have occurred during the 'Spring and Autumn' period. The Classic [i.e. the 'Spring and Autumn annals'] records that 'on the first day of such-and-such a moon the sun was eclipsed', but it does not follow that the moon has anything to do with these eclipses. If [the chronicles] had known that [the sun] was eclipsed by the moon, why have they been silent on this point and did not mention the moon ?"
>
> Lun hêng, 11, 14a.

Wang's logical analysis is impeccable ; coincidence is not positive proof. It is still however highly suggestive, and his appeal to the silence of the classics is the sort of argument he would not have tolerated from an opponent. But what were the theories advanced by those who found the circumstantial evidence of the moon's proximity convincing evidence that it caused the sun's eclipse ? Firstly, Wang mentions a theory of the Yin-Yang variety :

> "[Some] say that the changes occurring during a solar eclipse are because the Yang is weak and the Yin strong."

Lun hêng 11, 14a.

This is a fairly common theory, and one obviously connected with prognostication : normally the sun and moon pass through conjunction without incident, but if the balance of the universe is in some way disturbed, the Yin of the moon overcomes the Yang of the sun. Typically such events would be thought of as connected with treason or rebellion in the empire, which took part in a relation of mutual correspondence with the macrocosm. A century before Wang, Ching Fang had written :

> "The sun is the essence of Yang, and the image of the ruler of men. It shines alone in the fullness of its pride, and when the Yin encroaches on it, the omen of a solar eclipse occurs."

Ku liang chu su, 1, 12a, SSCCS
(see III (5)(a))

Wang's answer is incisive. If, by hypothesis, the sun becomes invisible because it is weak and overcome by the Yin of the moon, then surely the moon, which is invisible at conjunction, must be itself very weak. How then could it possibly overcome the Yang of the sun ? Both sun and moon, he claims, are subject to periodic variations not caused by an outside force, but simply by the natural behaviour of their _ch'i_. Needham notes this as an instance of "the inhibitory effect of a world-view otherwise good in itself - organic naturalism" (SCC,III,414).

It is of course necessary for Wang to reject what seems (to us) the most obvious explanation of a solar eclipse :

> "Some say that when the sun is eclipsed the moon covers it. The sun being above, the moon below, it is covered by the shape of the moon" [reading 月 for 日]
>
> _Lun hêng_, 11, 14b.

Wang's arguments against this are hard to follow, and the text seems to be corrupt. Forke believes that he is referring to a partial eclipse, while Needham (SCC, III, 413) takes the argument as turning on the observation of annular eclipses. In neither case does there seem to be much force in the objections raised, which amount to no more than pointing out that the sun is not always completely obscured during an eclipse. Wang's views on the physical nature of the sun and moon might have led him to claim that the moon (the essence of water) would be transparent to the sun's rays or it is within the bounds of possibility that he might have framed a reply in the same terms as he used against the Yin-Yang theory first mentioned. He does not do so, however, and his argument is only of interest for us in that it becomes clear that the correct theory of solar eclipses was current in his day. It had already been mentioned by Liu Hsiang c. 20 B.C.

> "An eclipse of the sun occurs because the moon moves so as to cover it. [The proper positions] of prince and minister are interchanged, contrary to the Tao, and therefore an eclipse occurs."
>
> (KYCC, 9, 3a)

Note, of course, that a purely physical explanation of the event itself does not prevent Liu attributing a divinatory significance to the fact that conditions were such that it occurred. Because of (impending or present) disorder on earth, the sun and moon have taken up positions such that the moon obscures the sun, representing the domination of the prince by the minister who should be subordinate to him. It remains to some extent an open question whether the celestial events were thought of as causing the terrestrial events or *vice versa*, or whether the two were simply thought of as occurring simultaneously.

(g) On Yin-Yang theories of day, night, and the seasons.

It will be remembered that the archaic explanation of the alternation of day and night involved the sun (probably a new one each day) rising from a point on the earth in the east, travelling overhead, and finally sinking to rest in a position in the west (see I (2)(b)). Under the *Kai t'ien*, as we have seen, rising and setting were optical illusions consequent on the sun moving out of range of the observer as it turned round on the umbrella-like heaven overhead (see II (3)(d)). This was the view of Wang Ch'ung himself set out in (b) above. The Hun t'ien represented what might almost be called a development of the archaic notion, for in its account the setting sun, carried on the rotating heavenly sphere, continued down below the earth and rose on the other side once more. Thanks to Wang's criticisms, however, we have an account of a theory different from all these :

> "The literati say that the sun, when it becomes visible in the morning, comes forth from Yin, and that when it disappears in the evening it re-enters Yin. The Yin ch'i is dark and obscure, therefore [the sun] vanishes and is not seen."
>
> Lun hêng 11, 6a
> (cf. Chin shu 11, 279 ; Sui shu 19, 506)

The extension of this theory to explain the seasonal variation of daylength is straightforward :

> "The literati say that the shadows of the days in winter and their length in summer are also brought about by the Yin and Yang. In summer the Yang ch'i abounds, and the Yin ch'i falls short. The Yang ch'i shines with the same splendour as the sun. Consequently when the sun comes out there is nothing to obscure it. In winter the Yin ch'i is dusky and overshadows the sunlight. Therefore although the sun comes out it remains dark and invisible. Thus in winter the days are short. The Yin is plentiful and the Yang is lacking, just the reverse of what happens in summer."
>
> Lun hêng, 11, 6b.

In the third century Yang Ch'üan was to advocate very similar ideas (IV (3)(b)). Wang has three objections to raise. The first of these, although very much in his style, does not quite hit the mark. Why, he asks, if the sun is rendered invisible by the Yin ch'i at night, can fires remain alight during the hours of darkness ? Should they too not be extinguished by the Yin ? The answer to this is, of course, that the obscuring ch'i is only present in those regions into which the sun has moved. Wang tacitly admits this in his next objection, which is that in winter the sun sets to the south of us. The implication that there can be Yin ch'i in the south he rejects, quite clearly because this simply could not fit the conventional scheme of correlation under which north was associated with cold, dark, and Yin, while south was associated with warmth, light, and Yang. His final objection is the only one that is really of much force : why is it that after the sun has set we are able to see stars considerably to the north of its setting position ? Should not they, too, be obscured by the mass of Yin ch'i that has hidden the sun ?

Unfortunately Wang does not make clear what theory his opponents held as to the path followed by the sun in its daily motion into and out of the Yin mass. It seems unlikely, however, that they could have believed in the Hun t'ien, which would have had no need of their theory. Perhaps we have here a variant of the Kai t'ien, created by those who were unable to accept the usual "out of range" theory and felt the need for some actual physical blockage to explain why the sun was not visible at night.

(h) Further notes on the sun, moon, and stars.

Wang makes a number of points which, while not meriting a lengthy treatment, ought not to be left out of consideration.

(i) The problem of the sun's relative distances at dawn and at noon is mentioned, and in a somewhat ponderous argument it is demonstrated that the Kai t'ien requires that it be more distant at dawn. It is suggested that the sun is apparently smaller at noon and larger at dawn (and dusk) because, like a fire, the sun appears smaller against a bright background. (Compare III (5) (b), (c))

(Lun hêng, 11, 10a)

(ii) Contrary to the "literati" Wang denies that the sun and moon are round. They are, respectively, the essence of fire and water, which are not round on earth. Why should they be round in heaven alone ? Their apparent roundness is an effect of their great distance; the same applies to the stars and planets. This was another of Wang's views attacked by Ko Hung : see IV (8) (b)

(Lun hêng, 11, 15a)

(iii) The story of the ten suns in the branches of the Fu-sang tree, one of which rises each day, is an impossibility (see I (2)(b)(15)). No tree could be large enough or fire-proof enough to contain ten suns. Further, the position of sunrise varies considerably throughout the year, showing that the sun does not originate from a single position.

(Lun hêng, 11, 11a and 15b)

(iv) The legends of the three-legged raven in the sun and the hare or toad in the moon are dismissed. The sun is fire, and the moon is water. No animal could survive in either of them.

(Lun hêng, 11, 13b)

(i) Three theories about heaven

Wang Ch'ung now notes a theory which, although still based on Yin-Yang notions seems to have some affinities with the Hun t'ien :

> "Some people hold that in summer, when the Yang ch'i abounds (it is in the south), in consequence heaven rises up high. In winter the Yang ch'i decays, and heaven sinks down low. When [heaven] is high, the course of the sun is long, and the days are long. When [heaven] is low, the course of the sun is short, and the days are short."

(Lun hêng, 11, 7a)

(The same mechanism was to be suggested by Yao Hsin in the third century : see IV (5)(b). The phrase "it is in the south" seems intrusive.)

Since, however, this theory of the pneumatic rise and fall of heaven relies implicitly on the sun being attached to heaven and rising and falling with it, Wang disposes of it very rapidly by asking why the moon behaves in precisely the opposite manner to the sun. It is, of course, attached to heaven if the sun is. How is it then that in winter, when heaven is said to be low, the moon rises much higher than it does in summer ?

Wang, it will be remembered, makes it plain that he believes in a version of the Kai t'ien in which heaven is flat and horizontal. There was evidently a variant of the orthodox theory current in his time :

> "Some say : heaven is high in the south and low in the north. When the sun rises into the higher region it becomes visible, and when it sets into the lower one it disappears. Heaven is placed like a reclining umbrella. Therefore the celestial pole is to the north of us : this is the proof of it. The pole is the centre of heaven [omit 下] Now, as it is to the north of us, [heaven] is clearly like a reclining umbrella."

(Lun hêng, 11, 7b)

It is interesting to speculate how such a theory might have arisen. Assuming that Wang's account is a fair one, it seems that we have here an attempt to modify the Kai t'ien under the influence of the Hun t'ien with its tilted axis. If this is so it must be admitted that it combines the worst of both theories. If an umbrella-like heaven is tilted over northwards, surely there ought to be a gap visible in the south ? Wang however simply points out that if the northern edge of heaven touched the earth it would be prevented from revolving. By adopting this line, incidentally, he emphasises his belief in both a flat earth and a solid heaven.

Wang presents another theory, evidently considered by him to be different from the one just mentioned. It may well be, therefore, a reference to the Hun t'ien :

> "Some people maintain that the northern edge of heaven sinks down into the earth, and that the sun following heaven enters into the earth. The earth is massive and obscures it so that it is invisible."
>
> (Lun hêng, 11, 8a)

Wang answers with a dilemma. Either heaven must actually go underground, according to this theory, or the earth is simply much lower in the north, so that heaven does not really enter it. In the first case, heaven would have to pass through the subterranean waters, which he finds unlikely. In the second case, such a depression in the earth would mean that the rivers would flow northwards towards it without ever filling it. (In fact, of course, the rivers known to Wang flowed, in general, eastwards.) He ends his dismissal with the uncompromising statement already noted :

> "Heaven is level and no different from earth, and the sun rises and sets, being turned round with heaven."

(See also Ko Hung's rebuttal of Wang : IV (8)(b))

(j) Comments on an archaic account of heaven.

The legend according to which Kung Kung broke one of the "pillars of heaven" has already been mentioned (I(2)(b)(35)). It was presumably an attempt to explain why the celestial pole is not directly overhead : this was done by suggesting that the vault of heaven leaned over in the direction of its damaged support. Wang quotes the legend, and goes to great lengths to explain exactly why it is extremely unlikely that a man could have caused such damage (Lun hêng, 11, 1a, et seq.)

Further, he points out, heaven is far too massive to be supported on pillars in any case, even if the pillars were mountains. Note, of course, that in common with other supporters of the Kai t'ien, Wang fails to make any suggestion as to how the sky is supported. We have seen ((i) above) that he denies any possibility of contact between heaven and earth.

After Kung Kung's damage, the goddess Nü Kua is said to have repaired heaven with melted stones. In what is seemingly a separate strand of legend she is also said to have supported heaven by cutting off the legs of a sea-turtle and using them as props : Wang's comments on this can be imagined. In discussing the possibility of all these events, however, it is interesting that he raises the possibility that heaven and earth might, in the remote past, have been much closer together than today. Since then, he speculates, they may have opened out :

> "All things that contain *ch'i* grow. Heaven and earth naturally contain *ch'i*. A great many years have elapsed since their origin. Hence it is impossible to calculate the distance between heaven and earth now, whether it be wide or narrow, far or near."
>
> (*Lun hêng*, 11, 2b)

Those who enjoy spotting "anticipations" of modern theories in ancient authors are of course quite free to take this as a forerunner of the expanding universe. It would perhaps be more legitimate to suggest a connection with the legend of Pan Ku (IV (4) (a))

(k) Who were "the literati" ? A note on the Po hu t'ung i.

Apart from the case of Tsou Yen, the objects of Wang's criticism are anonymous, and in many cases the nearest we can get to an identification is in his use of the term ju 儒, here translated as "the literati", presumably Confucian scholars. It is interesting therefore to have an abstract of the report of a conference of such scholars which was held in A.D. 79, when Wang was 49, at the instance of the Emperor Chang of Han, particularly as part of their deliberations dealt with cosmographical matters. This abstract was compiled by Pan Ku 班固 author of the Han shu, and is entitled Po hu t'ung i 白虎通義, "Comprehensive discussions at the White Tiger [Hall]", a reference to the building where the conference was held.

The first of the two sections of present interest is headed T'ien ti 天地, "Heaven and earth", beginning at 8, 13a SPTK, followed immediately by a longer section Jih yüeh 日月 "Sun and moon", 8, 14a SPTK. The book is cast in the form of a catechism; the first question "What is heaven ?" elicits a response including a cosmogony of the kind familiar from Huai nan tzu, 3, 1a, SPTK. The eventual physical form and nature of the emergent heaven are not clarified in any detail. The second question and answer are however of interest :

> "Now the Yin echoes the Yang, and the female follows the male. Wh y then does the way of heaven turn leftwards [左旋] while the way of earth encircles rightwards [右周] ?
>
> This is because heaven and earth move without separating, and travel without moving apart. This 'turning leftwards' and 'encircling rightwards' is in accordance with the principle by which prince and minister, and Yin and Yang, act as opposites."
>
> 8, 13b, SPTK

The possibility of a reference to a rotating earth is too large a subject for this section, and the reader is referred to III (10) for a discussion of such matters. Note, however, the form of the explanation given, which is in terms quite foreign to the sort of approach found in Wang Ch'ung. I do not wish to adopt uncritically the two catch-all philosophical labels "materialist" and "idealist" so enthusiastically applied by Maoist authors, but in this instance they express the dichotomy very well. A similar method is applied to other problems. Thus we are told that while we might expect heaven to remain at rest while its "minister" earth did all the moving, heaven's role as the source of action dictates its motion while the earth cannot perform its function unless left in peace : an instance of practicality being allowed to prevail over propriety.

As to the heavenly bodies, which are seen to move against the background of the stars in a direction opposite to the diurnal rotation, this is explained :

> "They are Yin with respect to heaven, and so move rightwards [N.B. the Yang heaven moves leftward, see above]. This rightwards motion is like the minister facing his prince."
>
> 8, 14a, SPTK

A "political" explanation is next given why the moon (= minister) moves faster than the sun (= prince). Similarly an explanation of the moon's phases seems to amount to no more than saying the moon pays periodical homage to the sun (8, 14b). In passing, and without justification, it is stated that the sun and moon are 1,000 <u>li</u> in diameter, which may be the earliest recorded instance of this figure : cf. II (2)(c). The non-physical nature of this book's thinking appears clearly in the following two sections :

> "Why is there always day and night ?
>
> This is the proper ordering of Yin and Yang. The sun illuminates the day and the moon illuminates the night.
>
> Why do the days vary in length ?
>
> The Yin and Yang take charge of affairs in turn. Therefore in summer the days are long, and in winter the nights are long."
>
> 8, 15a, SPTK

Wang Ch'ung's explanation of the alternation of day and night is, of course, in accord with the <u>Kai t'ien</u> "optical illusion" theory (III (6)(b)). Both of the statements given above seem to me to be explicitly stated and criticised by Wang at one point (III (6)(g)), and it may be that in this instance we are in a position to contrast Wang's version of the case with that stated by "the literati" themselves. Paradoxically, Wang must be said to have expounded his opponents' theories more clearly than they did. If any conclusion follows from this, it is perhaps that we should beware of assuming that every theory set up by Wang as a dialectical Aunt Sally was always held in a developed form by a fully articulate group of thinkers.

COSMOGRAPHICAL DISCUSSIONS IN CHINA
FROM EARLY TIMES UP TO THE T'ANG DYNASTY

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(7) Chang Hêng 張衡 (A.D. 87-140) and the first full account of the Hun t'ien.

(a) General features of Chang Hêng's cosmographical writing

In his two works Ling hsien 靈憲 and Hun t'ien i 渾天儀, Chang gives a complete description of the Hun t'ien universe, beginning with an account of how it came into being, describing the physical nature of the heavens and the heavenly bodies and even dealing with the question of what is beyond the celestial sphere. In the latter work the phenomena in the heavens are closely linked with their portrayal on the armillary sphere, and questions of spherical geometry are discussed in some detail. We are lucky to have fairly good texts of both books (see Textual Notes (3))

Chang does not enter into polemic against the Kai t'ien or any other theory. In the Ling hsien his object seems to have been to record in summary form everything that at his time counted as fact about the heavens, and to a modern reader accustomed to more rigid boundaries between fields of study it is odd to find sober statements of the size of the celestial sphere and reasonable conjectures about the "horizon illusion" followed by uncritical accounts of ancient legends, such as that of the crow in the sun (already demolished by Wang Ch'ung, see III (6)(j)). We cannot easily tell whether or not Chang felt that his accounts of mythical or astrological material were to be taken with the same seriousness as what, for the sake of brevity, we may call the more scientific parts of his treatise. I feel, however, that it would be unwise to suggest that he in any way rejected the usual astrological beliefs of his time; after all, he was twice in office as T'ai shih ling 太史令 or Astronomer Royal, part of whose duties was the foretelling of auspicious days and similar prognostication. Further, in his memorial against the increasingly popular use of the ch'an wei books of divination (Hou Han shu, 59, 1911, CHSC), his argument is not that divination is futile, but that the older methods (astrology, numerology, milfoil stalks etc.) gave better results and should not be neglected. To a certain extent, therefore, it may be said that the Ling hsien is the prototype for the T'ien wen 天文 chapters of several dynastic histories, which tend to open with a physical cosmography, after which they proceed to more astrological matters. In Chang Heng's work the separation is not yet as definite as it was to become subsequently.

(b) The origin of the universe

This survey is not in general concerned with questions of cosmogony, a field in which Chinese discussions tended to be of metaphysical significance only (despite the striking way in which some theories seem to anticipate Kant's "nebular hypothesis" (SCC, II, 371)). In the case of the <u>Ling hsien</u>, however, it is worthwhile to follow the account of the beginning of heaven and earth in summary form, leading as it does into a discussion of their eventual nature and function. According to the <u>Ling hsien</u> (<u>Hou Han shu</u> comm. <u>chih</u> 10, 3215), the universe came to be in a process of three periods, each of immeasurable duration :

i. A period of void and non-existence.

ii. The emergence of the undifferentiated <u>t'ai su</u> 太素 "great plainness" from the void.

iii. The differentiation of this primal substance into two natures, one clear and hard, the other clouded and soft - the Yang and Yin.

At this final phase, says Chang Hêng :

> "Thus the original <u>ch'i</u> divided, hard and soft being separated for the first time, clear and clouded taking different positions. Heaven was formed without, and earth was fixed within. Heaven took its body from the Yang, so it was round and in motion. Earth took its body from the Yin, so it was flat and quiescent."
>
> <u>Hou Han shu</u>, 3215, CHSC

As we shall see in other parts of the <u>Ling hsien</u>, the basic conception here is by no means original - compare in particular <u>Huai nan tzu</u> 3, 1a, and also TPYL, 1, <u>passim</u>. A significant point is, perhaps, the absence of any reference to divinities. This absence is a feature of nearly all the cosmographical writings to be discussed in this survey; an exception is the story of P'an Ku ((IV)(4)(a))

Chang's account seems to be unique only in that it is made quite clear that heaven and earth are differentiated radially (outside ... inside) rather than vertically (up ... down). This is of course a necessary consequence of the _Hun t'ien_ cosmography; an example of the more usual scheme is found in _Lieh tzu_, 1, where heaven is formed by the upward motion of the clear and light substance, while the clouded and heavy substance sinks down to form earth. From the fragments in TPYL, 1, 5a, it seems that the Chin dynasty writer Huang-fu Mi 皇甫謐 followed Chang's cosmogony closely in compiling his _Ti wang shih chi_ 帝王世紀. —

(c) _Earth, heaven, and beyond_.

Chang has described the evolution of a universe in which heaven is outside, round, and in motion, while earth is inside, flat, and quiescent. In an attempt to add detail to the picture, let us consider two passages, one from the _Ling hsien_ and the other from the _Hun t'ien_ :

(i) "The diameter of the line of the eight poles is 232,300 _li_. From north to south it is 1,000 _li_ shorter, and from east to west it is 1,000 _li_ broader. From earth to heaven is half of [the diameter of] the eight poles, and so the depth of the earth is the same. Thus, measuring everything out, we have a sphere. To check these figures, one uses similar right-angled triangles [add 差 with KYCC, 1, 2a]. The sunlight casts shadows on the earth, so that one gets a difference of one inch for each 1,000 _li_ of displacement.

Beyond this is the unknown. This unknown is called yü chou 宇宙. Yü extends infinitely; chou has no limits".

Hou Han shu, chih 10, 3215
(see Textual Notes (3))

The Eastern Han commentator on Huai Nan tzu, 1, 3a, makes it plain that yü effectively means "space" and chou means "time", including both past and future.

(ii) "The Hun t'ien is like a hen's egg. The body of heaven is round as a crossbow pellet [in KYCC only]. The earth is like the yellow inside the egg, situated on its own inside heaven. Heaven is the larger and earth the smaller. There is water inside and outside heaven [in KYCC only]. Heaven encloses earth like the white of an egg enclosing the yolk. Heaven and earth each are supported by ch'i and float on water. The circumference of heaven is 365¼ tu. Dividing it down the middle, 182 5/8 tu covers the earth above and 182 5/8 tu girds earth below [TPYL, SLF read: the sun, moon and stars gird earth below]. Therefore half of the 28 hsiu are visible, and half invisible. [In KYCC only, a section follows on the N and S celestial poles, and circles of perpetual visibility and invisibility, omitted here.] It rotates continuously, and its form is unbroken [渾渾 hun hun], therefore it is called Hun t'ien [in KYCC only]. Heaven rotates like the wheel-boss of a chariot."

KYCC, 1, 5a
(see Textual Notes (3))

From (i) it is clear that the celestial sphere is 232,300 li in diameter. Despite the statement that this figure can be deduced from the shadow principle by means of the mathematical techiques we have already met in the Chou pei I have been unable to discover any process by which such a result might have been obtained, nor do later writers have any suggestion to make. It is certainly not a very large figure - in the Chou pei the smallest diurnal circle described by the sun was 238,000 li across (see II (3) (b)). I suspect that here as elsewhere Chang is simply drawing on traditional accounts, such as that found in Huai nan tzu (4, 2a, SPTK), which gives 233,500 li, 75 pu for both north-south and east-west dimensions. Several similar ancient estimates are collected in KYCC, 4, 2a, where the small difference in the two dimensions is also exemplified; this idea goes back as far as Ch'ü Yüan in the fourth century B.C. (see I (2)(b)(38)).

Given Chang's earlier explicit statement that earth is flat (in contrast to the round heaven), and adding to this the statements that the distance from earth to heaven is equal to the depth of earth (both being half the diameter of heaven) and that half of heaven is above earth, while half is below, it seems impossible to escape the conclusion that the surface of the earth is co-planar with the horizontal diametral plane of heaven. Suggestions that Chang conceived of a spherical earth (SCC, III, 218) create far more difficulties than they solve (see Appendix (2)). The analogy of the hen's egg need no more be taken to imply that the earth is shaped like the yolk than it need be taken to imply that the heavens are ovoid rather than spherical. The point is surely just that earth is completely enclosed by heaven, rather than simply covered, as in the Kai t'ien.

Although the upper surface of the earth is certainly plane, it is not easy to see how Chang thought of its lower boundary. If it was not for the suggestion that it "floats on water" and is "supported by _ch'i_", one might simply take it as hemispherical. It certainly seems that Cheng Hsüan, writing forty years or so later (III (10) (c)) thought of the earth as a fairly flat disc, and this may have been Chang's opinion. The reference to "the depth of earth" is a difficulty here, but it may be that in this context "earth" refers to the combination of solid and liquid filling the lower half of the celestial sphere.

At this stage, it may be helpful to sketch a reconstruction of the universe described; the data for the inclination of the celestial axis are found in the _Hun t'ien i_. There the north celestial pole is said to be 36 _tu_ above the earth, while the south pole is 36 _tu_ below it. It is hard to see how such statements could be reconciled with an earth that was not flat. Had Chang believed in a spherical earth, we would surely have had some hint of a variation of polar altitude for differently placed observers, and we might have had a somewhat less categorical statement of the invisibility of the south polar regions than those found in both the _Ling hsien_ and the _Hun t'ien i_.

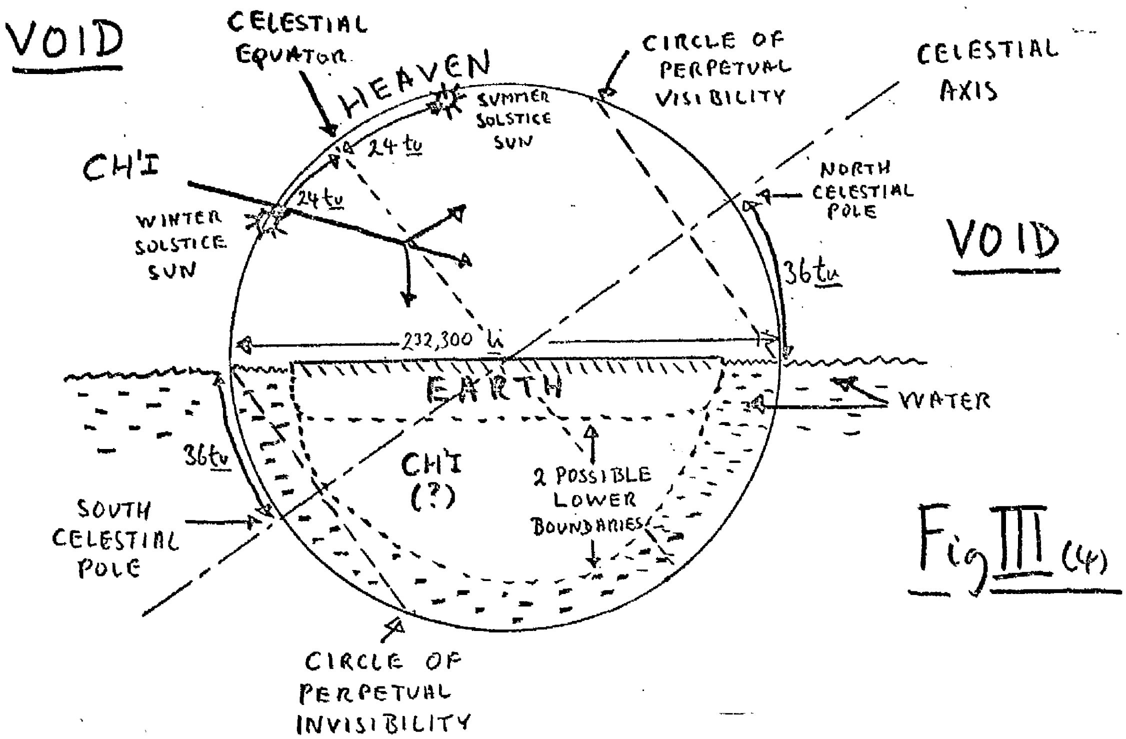


Fig III (4)

The *Hun t'ien* universe according to Chang Heng

There is not much direct evidence of where on the surface of the earth Chang placed the Chinese observer. However, the testimony of all later writers on the Hun t'ien who mention the subject is that the centre of the Middle Kingdom is at the centre of the celestial sphere. This seems to go back to the tradition of the Chou li (10, 10a, SSCS), and it is perhaps significant that the words of the Chou li are echoed by an isolated fragment attributed to the Ling hsien and preserved in TPYL, 157, 4a:

> "To the south-east of Mt. K'un-Lun is the region of the red nome where rain and wind are seasonable, and cold and heat are normal. Other than that place, to the south there is an excess of heat, to the north there is an excess of cold, to the

> east there is an excess of cloud, so the sage kings did not dwell in those places."

(The opening words here are clearly derived from the work of Tsou Yen (I (3)(b)) : this may be another instance of Chang's eclectic gathering from all the available sources.

We have only the briefest description of what is beyond the celestial sphere, and we shall not find more detail in other writers mentioned in this survey. This is scarcely surprising, as yü chou is usually described as an infinite changeless dark void, of which there is little enough to be said. Some, like Wang Fan(KYCC,1,17a) felt that the subject was one which it was quite pointless to discuss - he put it in the same category as Tsou Yen's theory of the nine great continents surrounded by the vast encircling ocean, ying hai.

(d) Sun, moon, and stars

The Ling hsien is explicit on the size of the sun and moon :

> "The diameters are 1/736 of the circumference of heaven, or 1/242 [following Hou Han shu; KYCC has 1/243] of the breadth of earth"

It might be thought that Chang was introducing an approximation that $\pi = 736 \div 242 = 3.04$, but this is scarcely likely in the light of the fact that there is some evidence that he used $\pi = \sqrt{10}$ in another context (SCC, III, 100). It is more probable that he is making the usual approximation $\pi = 3$ in this case, which requires only the very plausible emendation of 726 for 736, as $3 \times 242 = 726$.

Taking $\pi = 3$, and using the value of 232,300 li given for the diameter of heaven, we obtain a diameter for the sun and moon of 959.9 li with the emendation proposed. This is of the same order of magnitude as most other early Chinese estimates, but as with the case of the diameter of heaven, I cannot think of any justification for the exact figure given, nor does Chang hint at any. It is always possible that the basis is numerological (cf. II (3)(d)), particularly as this passage is followed by one claiming affinity between the sun (yang) and odd numbers, and the moon (yin) and even numbers. The same passage notes without criticism the story of the three-legged crow in the sun and the hare in the moon, followed by the legend of how Hêng O, wife of the great archer I, stole the drug of immortality and flew to the moon where she was transformed into a toad.

Chang clearly believes that the sun is the source of illumination for both moon and stars, as is evident from the Ling hsien :

> "The sun can be likened to fire, and the moon can be likened to water. Fire shines outwards, while water contains reflections. Therefore the moonshine comes from the illumination by the sun, and the dark part of the moon occurs where the sun is screened [from it]. When [the moon] is opposite the sun, its brightness is full; when it comes near the sun its brightness is completely cut off. The multitude of stars

> are illuminated because [the sun's] brightness is passed on by the water."

This somewhat cryptic last sentence does not say whether the water inside or outside heaven is involved, but the suggestion is clearly being made that without the water the stars would not shine. I suggest very tentatively that Chang Heng meant us to think of the sun's light being guided round the earth by the subterranean water during the hours of darkness (see below).

A later passage not only makes it plain that the heavenly bodies are spherical, but explains the origin of meteors in a way suggestive of practical experience :

> "The three luminaries [i.e. sun, moon and stars] are of similar shape, resembling jade beads. While their spirit is preserved and their essence persists, they are fixed in place and radiate brightness. But when decline sets in their spirit is exhausted and their essence is destroyed, and a falling star occurs. Then if one digs where the star has fallen, there is a stone."

It may be of interest to note that the passage preceding this one suggests that there are no less than 11,520 "faint stars " which compares interestingly with the 10,000 or so actually visible to the unaided sight.

Chang now gives a theory of lunar eclipses :

> "Diametrically opposite the sun is a place where its rays do not meet, because of the obscuration by the earth [read 地 with KYCC, rather than 他 with HHS]. This is called the dark space [an hsü 闇虛]. When it is on a star, the star fades, when the moon crosses it, it is eclipsed."

This explanation is not precisely equivalent to the modern notion of the moon crossing the earth's shadow. If Chang thought that the sun's rays were propagated only in straight lines, he would have oncluded that, when the sun was beneath the earth, none of its illumination could reach the hemisphere above the earth at all, as is evident from fig. III (4) . The earth is so large that it would form a total barrier. Thus neither the moon nor the stars would ever be illuminated at night. Similar considerations led Liu Chih to reject the an hsü theory in the third century, but it was defended by Chiang Chi a century later on the grounds that the sun's rays shone along the surface of the celestial sphere rather than in straight lines (see IV (a)(b)) There is a hint of this view in Chang's statement that the sun's rays do not "meet" [ho 合] opposite the sun, which is Chiang Chi's explanation of how the an hsü arises.

(e) The planets : an attempt at celestial mechanics

In ancient China mechanics developed very little. A consequence of this is that we rarely find the writers mentioned in this survey offering us physical explanations of why the heavenly bodies move in the manner observed. It could perhaps be said that they avoided the infinite regress of causes by dispensing very largely with causes : the sun and moon move tzu jan 自然 "of themselves", or at most are carried along by the natural currents of ch'i. In such a system no primum mobile could possibly be required.

Despite this general tendency, in one part of the Ling hsien Chang seems to be attempting a physical theory of the direct and retrograde motions (shun 順 ni 逆) of the planets :

> "The luminaries are attached to heaven, and there are seven of them that move : these are the sun, moon and five planets. They circle round, moving to the right [i.e. relative to heaven, which moves leftwards for an observer facing the pole]. The way of heaven is to honour direct motion [i.e. the normal east-wards motion of the planets]. [Planets] near to heaven move slowly, [planets] far from heaven move quickly [i.e. relative to heaven]. If motion is retarded [a planet] comes to a stationary point : after this stationary point it moves retrogradely. This retrograde motion is because it has been slowed down, being close to heaven."

This account is of course incomplete, and no reason is given for why the planet should move nearer to heaven in the first place, and then, presumably, move further away again, reverting to direct motion. Nevertheless, this theory is a significant step towards the development of a physical system for planetary motion : it was not, however, followed up by later writers.

(f) The horizon effect : an optical illusion

Chang's adoption of a detailed Hun T'ien scheme makes it impossible for him to explain the horizon effect in the same way as Kuan Ping, by claiming that the sun at its zenith was further away than when on the horizon (III (5)(c)). He therefore is faced with the problem of explaining why the apparent enlargement of the sun (and moon) on rising and setting occurs, and attempts a solution in terms that are by no means implausible. In what follows I use the fragment in Sui shu 19, 513, CHSC, as the versions found in KYCC, 1, 4a and Hou Han shu (comm.) chih 10, 3216 CHSC seem to be somewhat garbled.

> "When the sun sinks down to earth, its brightness is veiled. We are thus looking at brightness [i.e. the sun] from darkness, so the brightness has nothing to attenuate it : therefore it appears to be large. When it gets towards noon, heaven and earth are both bright, and the brightness turns back and interferes with itself : therefore it [i.e. the sun] appears to be small. [Similarly] a fire at night gives out light, but in daylight it does not shine. The moon at night differs little from [the behaviour of] the sun."

The suggestion is, of course, that in dark surroundings a source of light shows up much better than where there is general illumination. Despite the fact that this is not the actual cause of the illusion, Chang's theory is not an unreasonable construct in face of the lack of a scientific optics.

(8) Ts'ai Yung 蔡邕 (circa A.D. 130 - 191)

(a) The first summary of the cosmographical controversy

A memorial addressed to the Emperor Ling of the Han (reigned A.D. 168-189) by Ts'ai Yung has survived in a large number of versions (see Textual Notes, (4)). It is interesting enough to deserve substantial quotation : the translation given below follows the T'ang commentary on the Hou Han shu, chih 10, 3217 C H S C.

> "There are three schools of cosmography. The first is called Chou pei 周髀 the second Hsüan yeh 宣夜 , and the third Hun t'ien 渾天. The study of the Hsüan yeh is lacking in an authoritative tradition. The mathematical methods of the Chou pei are all extant, but they are greatly in error when checked with the celestial phenomena, and so the [astronomical] officials do not use them. Only the Hun t'ien comes close to attaining the truth. The bronze instrument at present used by officials on the observatory platform is designed on this theory ... The officials have the instrument, but lack the original books. Likewise former records are lacking in any discussions of it. I searched for early texts, but for years found nothing ... What should now be done is to institute a general enquiry from those amongst the ministers down to recluses who know the theory of the Hun t'ien, so they will record its meaning, thus making up an astronomical treatise ... "

Unlike Wang Ch'ung, Ts'ai Yung spent most of his life in high official circles at the capital (although he wrote this memorial from banishment). Given also his explicit statement that he spent years in the search for evidence, his conclusions should weigh very heavily with us; a number of points present themselves. Firstly, note that this is, so far as I can tell, the first reference to the Chou pei either as the name of the theory which we have elsewhere seen referred to as the Kai t'ien, or possibly as the name of the book itself. (See Appendix (iv)) Likewise this is the first reference to the Hsüan yeh : I would also maintain that it is the only indubitably early one (see III (9) below for a detailed discussion of the Hsüan yeh).

Perhaps most interesting for us is Ts'ai's description of his search for old records of the Hun t'ien. It will be remembered how very sketchy is the evidence for the early history of both instrument and theory extant today (see III (3)). There is a certain cold comfort in the knowledge that long rummaging through the official files of the second century A.D. would not have placed us in any better position, if Ts'ai is not being overmodest in his confession of failure. In addition it reveals as baseless the claims made by some later writers that the Hun t'ien was a theory of immemorial antiquity, which suffered temporary eclipse under the Ch'in (see for instance IV (2)(a) for Lu Chi's work c. A.D. 240). If Ts'ai could find no early evidence, is it likely that they were able to, especially after the destruction wrought by the chaos at the end of the Han ?

(b) Some notes on the Hun t'ien

In (a) Ts'ai Yung's ideas are contained in a memorial to the throne : in this section I draw on another type of source with which we shall meet fairly frequently, the commentary on a classical work. We have fragments of Ts'ai's Yüeh ling chang chü 月令章句 , a commentary on an ancient ritual calendar, in which he includes a short Hun t'ien cosmographical essay. In the following account the text of K Y C C 1, 9b is followed (see Textual Notes (4))

Heaven is pure hard Yang; it is spherical, enclosing the earth and in continuous motion. Ts'ai mentions the usual figures of 36 tu for the inclination of the axis of the sphere above the horizontal, 182 5/8 tu for the arcs of heaven above and below the earth, and 72 tu for the circumpolar circles of perpetual visibility and invisibility. There is nothing at all novel in this, but there are two points of interest worth mentioning. Firstly, Ts'ai gives a strong hint that his original text may have been accompanied by a diagram in the form of a planisphere; of the circle of perpetual visibility, he says :

> "This is the small red circle in the centre of the diagram"

Similarly, for the circle of perpetual invisibility :

> "This is the large red circle on the outside of the diagram"

The equator is referred to as :

> "The red circle half-way on the diagram, intersecting the constellations Lou 婁 and Chüeh 角 "

This diagram, t'u 圖 , seems to have had something in common with the one in the Chou pei suan ching, 1, 45 (see also II (3)(b)).

Secondly, Ts'ai makes an interesting reference to the pole star of his day. He clearly states that it was possible to align the eight-foot long sighting-tube then used by astronomers so that it lay along the celestial axis and the pole star could be seen fixed in position when sighted on through the tube. Hence this star was proved to mark the immobile centre of heaven. It seems possible, however, that Ts'ai had never really tried the experiment, for he also states that his eight-foot long sighting-tube had a bore of only one inch. Even supposing the axis of such a tube was accurately directed at the celestial pole, it is obvious that the only stars that would be visible permanently would be those with a north polar distance less than

$$\tan^{-1}\left(\frac{1}{80}\right) = 0.72^{\circ} \text{ (allowing oblique sighting)}$$

In Ts'ai Yung's day, the celestial pole was approximately at R.A. 12h 50m, Dec. 80° (epoch 1950), and even the nearest 6th magnitude star was just over 1° away. In any case the usual Han pole star seems to have been 1694 Camelopardalis, which is 4° away (see

SCC, III, 261). It was not until the Sung that Shen Kua 沈括 actually tried the experiment of observing the pole star for a long enough period to plot its small diurnal circle : see Meng ch'i pi t'an 夢溪筆談 7, 11, and SCC III, 267. As Shen Kua notes, however, the slight distance of the pole star from the pole had already been observed by Tsu Keng-chih 祖暅之 in the fifth century A.D.

(9) The problem of the Hsüan Yeh 宣夜 : is heaven a vault or vapour ?

(a) The account attributed to Ch'i Mêng 郗萌

It will be recalled that in his brief notice of cosmographical theories ((8)(a) above) Ts'ai Yung mentioned one called *Hsüan yeh* without giving any account of its content. Indeed, he seems almost to imply that he knows no more of it than its name. There exists, however, a short treatise purporting to be of Han date in which the name *Hsüan yeh* is used for a theory of considerable interest and originality. The translation below is taken from the *Chin shu*, 23, 279, CHSC, although the first few words follow *Sui Shu*, 19, 507, CHSC:

> "There is no-one able to teach the writings of the *Hsüan yeh*, but Ch'i Mêng, a Gentleman of the Archives under the Han, recorded the tradition of the masters of old as follows :
>
> Heaven is completely insubstantial. When one looks up at it it extends upwards to infinite distances : one's vision is overstretched. Therefore [heaven] seems to be blue. This is similar to the way that yellow mountains appear dark blue when seen from a long way off, or a thousand-fathom ravine seems black when one peers down. The dark blue is not a real colour, nor is the blackness anything solid. The sun, moon and stars drift along in the void; their movements all depend on the *ch'i*. Therefore the seven luminaries depart or remain, move directly or retrograde, disappear and reappear without fixed rules and their advances and retardations are not the same. It is because they are not attached to anything that all [their motions] are different. Thus the pole star remains fixed and the Northern Dipper does

> not set in the west with all the other stars. Jupiter and Saturn both move eastwards. The sun moves one tu [in a day] while the moon moves thirteen tu. The fact that they do as they like in the matter of speed shows that they are not tied on to anything : if they were fixed on to the body of heaven they could not do so."

There are several striking features in this passage; the principal one is, of course, the abolition of the solid heavenly vault common to the Hun t'ien, the Kai t'ien and indeed to the archaic notions as we have seen. Next comes the suggestion that the heavenly bodies move independently, perhaps carried along by ch'i. Both these will be examined in detail shortly, but before this we ought surely to look more closely at the origin of the text we are reading. Was Ch'i Mêng able to find material on the Hsüan yeh where Ts'ai Yung failed ? Or did he exist at all ? These are after all questions of some significance.

(b) The origin of the "Ch'i Mêng" material

There are three separate strands of enquiry to be pursued :

i. The identity of Ch'i Mêng

ii. The history of the term Hsüan yeh

iii. The origin and context of the cosmography described in the above fragment

This section will deal with (i) and (ii). The first of these can be discussed rapidly, for the evidence is very sparse. The earliest mention of Ch'i Mêng's name appears, perhaps significantly (see below) in Ko Hung's Pao p'u tzu 抱朴子 written c. A.D. 320. Ko notes that classically accepted books make virtually no mention of astronomical matters, and continues :

> "Accounts of all these things have only been given by Wu Hsien 巫咸, Kan Kung 甘公, Shih Shen 石申, Hai Chung 海中, Ch'i Mêng 郄萌 and Ch'i Yao 七曜."

Pao p'u tzu, 8, 9a, SPTK

This is a somewhat miscellaneous collection of names. The first three are of course well-known as astrologers of the third - fourth centuries B.C. (SCC III, 197). Hai chung are the initial words in titles of a number of astrological works found in the Han shu bibliography, and one suspects that Ko Hung has simply conjectured them to be a man's name. Perhaps the same applies to the words ch'i yao, which would normally be translated as "the seven luminaries", again a phrase with astrological connections. On this basis one would make Ch'i Mêng an astrologer too, rather than a cosmographer, and this is certainly borne out by the fact that 75 per cent of Ko Hung's lengthy list of astronomical topics not mentioned in the classics consists of various celestial omens (8, 8b-9a, SPTK). As we shall see, Ch'i Mêng appears elsewhere as an interpreter of omens.

Ch'i Mêng is not mentioned in the Hou Han shu text, and the next early references to him seem to be in Liu Chao's commentary on that work, written about A.D. 550. Throughout chih 10, 11 and 12 Liu quotes from a work of astrological prognostication, introducing his quotes by 郗萌曰 or 郗萌占曰 (I assume that 郗 chih is a variant for 郄 ch'i.) A typical example of the material given is chih 10, 322, CHSC :

> "When a falling star comes from the constellation Tung ching, the country towards which it moves will suffer floods."

The Sui shu bibliography notes a work by 郗萌 in 15 chüan, 春秋災異 Ch'un ch'iu tsai i (now of course lost), which may be the one quoted by Liu Chao (Sui shu, 22, 940, CHSC). We are also told :

> "At the end of the Han, a Gentleman called 郗萌 compiled miscellaneous prognostications from apocryphal works in 50 p'ien, and called it the Ch'un ch'iu tsai i."
>
> Sui shu, 32, 941, CHSC

This is all the evidence we have about Ch'i Mêng independent of the passage quoted in (a) above. It is really not very strong evidence about someone who lived "at the end of the Han", i.e. circa A.D. 200, for Liu's commentary was written 350 years later, and the Sui shu a century after that.

The references to Ch'i Mêng are certainly sketchy. In the case of Hsüan yeh, the name of the theory he allegedly recorded, there is much more in the way of references, but oddly enough none of them (apart from (a) above) show any signs of his work. None mention his name, and none repeat the theory he is said to have recorded. Before we examine these references, let us return to the original passage for a moment. There are four sources for it: Chin shu 11,279; Sui shu 19,507; TPYL 2,2a and PTSC 149,1b. Of these two (Chin shu, A.D. 648, Sui shu, A.D. 656) give no indication of where they found Ch'i Mêng's work recorded. Both the T'ai p'ing yü lan of A.D. 983 and the Pei t'ang shu ch'ao of about A.D. 620, however, introduce their quotes with "Pao P'u Tzu 抱朴子 says ... ". Pao P'u Tzu was the hao of Ko Hung 葛洪, who was active around A.D. 320, and a considerable amount of fragmentary material not found in his extant books it attributed to him in encyclopaedias and similar works. If the present attribution is correct, the survival of Ch'i Mêng's writing becomes more plausible : he is purported to have written only a century before Ko Hung, whose work has on the whole been well preserved. We have not yet, however, examined the other Hsüan yeh references, and, when we do, the evidence seems to cast doubt on this straightforward account. Brief notices of the other material now follow in chronological order, paraphrased for brevity : more detail will be found when the authors mentioned are dealt with later in this survey.

(i) Ts'ai Yung, (c. A.D. 180)

"No-one is able to teach the Hsüan yeh". No account of the theory is given. (Hou Han shu, chih 10, 3217, CHSC)

(ii) (allegedly) Ch'i Mêng, (c. A.D. 200)

see above : gives a full account of the Hsüan yeh.

(iii) Wang Fan 王蕃 (A.D. 227 - 266)

"The Chou pei and Hsüan yeh arose during the degenerate times of the Warring States, when the Hun t'ien was forgotten. No-one can teach the Hsüan yeh, although the Chou pei is extant." (KYCC, 1, 12b)

(iv) Ko Hung (c. A.D. 320)

See above : allegedly records Ch'i Mêng's work

(v) Yü Hsi 虞喜 (c. A.D. 300 - 370)

"The methods of the Hsüan yeh are lost ... and now quite unknown." (TPYL, 2, 9a and SSCCS, Shang Shu 3, 6b)

(vi) Ho Tao-yang 賀道養 (c. A.D. 424)

"The Hsüan yeh is a method of the Hsia or Yin dynasties"

No account given. (TPYC, 2, 9a)

(vii) Tsu Keng-chih 祖暅之 (c. A.D. 500)

"I have never heard anything about the Hsüan yeh"

(TPYL, 2, 6b)

(viii) K'ung Ying-ta 孔穎達 (c. A.D. 620)

"An old theory says it was a theory of the Yin dynasty, but nothing at all is known about it."
(SSCCS, Li chi, 14, 2a)

These are surely rather suspicious circumstances. If Ch'i Mêng's work is to be taken as genuine, then we must believe for a start that this very shadowy figure succeeded in unearthing the details of the Hsüan yeh when Ts'ai Yung's researches had failed a few years previously. Then we must believe that for the next four centuries five scholars of considerable erudition knew no more than the name of the theory, and that a sixth, Ko Hung, knew of Ch'i Mêng's work but contrived that it should not see the light of day for the remaining three centuries. A further anomaly is that when Shen Yueh (V(4)) wrote the lengthy monograph on cosmography in the Sung shu, c. A.D. 500, he said no more about the Hsüan yeh than did Ts'ai Yung, despite giving details of several other cosmographic eccentricities. Nevertheless, in the first half of the seventh century A.D. the material in (a) above was in circulation, with an attribution to Ch'i Mêng, perhaps via Ko Hung. I submit that the presence of a forger around the end of the sixth century is the simplest explanation of all the data. Perhaps some opportunistic but original cosmographer found Hsüan yeh a convenient name in search of a theory, and likewise chose Ch'i Mêng because of his connection with astronomy combined with a convenient absence of verifiable facts about him. The use of Ko Hung as a link in the chain of transmission was a useful enough afterthought. He then wrote everything out with suitable faintness, on an impressively aged scrap of silk and presented it as a literary discovery to someone who, he felt, was in a position to be appropriately grateful. This is all no more than conjecture, but I think it is less unlikely as an explanation of the evidence than taking the texts at their face value.

We are now in a position where it is evident that the original content of the theory called Hsüan yeh is as unknown to us as it was to Ts'ai Yung and his successors. There is no point in trying to guess what it might have been, for the name alone is of no importance to us. But what was the history of the theory for which our (putative) forger borrowed the vacant name ? It appears that he may have been drawing on a tradition of considerable antiquity, which will now be examined.

(c) The nature of theories of infinite space and the insubstantiality of heaven

The passage attributed to Ch'i Mêng in (a) above may not have been written by any such person, and it must remain an open question whether the Hsüan yeh theory mentioned by Ts'ai Yung and several others was in any way related to the ideas that the passage contains. Similar notions are however found in a number of other well-authenticated sources, although these sources do not use the name <u>Hsüan yeh</u> for their theories. Before we turn to these, however, the discussion may be clarified by pointing out various distinctions to be made between types of theories considered. This may be conveniently done by listing a number of propositions which might be implicitly or explicitly affirmed or denied in a cosmographical theory :

- A That space extends infinitely
- B That heaven is a solid vault
- C That the heavenly bodies are attached to heaven
- D That heaven is at an infinite distance from earth
- E That there is a plurality of worlds
- F That heaven is in motion

At first sight one might expect $2^6 = 64$ possible types of theory from this scheme, but as the propositions are not independent the number is considerably less. Thus it is obvious that $C \rightarrow B$; $D \rightarrow A$. Further, if by "world" is implied at least the combination of a "heaven and earth" $E \rightarrow \overline{D}$, and if we leave the earth unrotated, $C \rightarrow F$.

Even given this reduction, by no means all possible theories were held. No Chinese cosmographer known to me ever denies A, for instance, and although some Buddhist literature asserts E (see SCC III, 221), such notions do not enter the general debate during the period covered by this survey. Within these limitations, we can have : (+ implying affirmation)

	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)
A	+	+	+	+	+	+	+
B	+	+	+	+	+	+	0
C	+	+	0	0	0	0	0
D	+	0	+	0	+	0	(?)
E	0	0	0	0	0	0	0
F	+	+	0	0	+	+	(?)

I do not know of any instance of (i), which corresponds to a simple <u>Hun t'ien</u> of infinite size - this would of course be indistinguishable from a finite system to an observer centrally located. The <u>Hun t'ien</u> universe described by Chang Heng is represented by (ii). Yü Hsi in the fourth century A.D. describes an <u>An t'ien</u> theory similar to (iii) (see below, (IV)(7)(b)). No-one seems to have maintained (iv) or (v), but there are some signs of (vi) in the work of Chiang Chi around A.D. 380 (see below (IV)(9)(d)). The theory attributed to Ch'i Mêng is of course (vii) : space is infinite, heaven is not a solid vault and the heavenly bodies move freely. The only unique feature of this theory is its claim that the solidity of heaven is illusory, which should not, by the way, be confused with the notion of the infinity of space (see SCC, III, 220). With this analysis in mind, it is interesting to make a short review of early material of similar content.

(d) Theories related to the Ch'i Mêng fragment

Even if "Ch'i Mêng" may not have written during the Han, there is no doubt that theories similar to those of the fragment discussed were held both before and after his alleged *floruit*. Our best evidence for early ideas comes from Wang Ch'ung, who devotes considerable energy to rejecting the theory of "the literati" that heaven is no more than *ch'i* extending upwards from the surface of the earth (see III (6)(C) above). He claims by contrast that heaven is a solid material vault, and the *Kai t'ien* theory he advances is obviously of type (ii) in the preceding section. Wang would scarcely have bothered to refute the theory unless someone had actually held it to be true. Perhaps the earliest suggestions are to be found in a well known passage of *Chuang Tzu* (c. 290 B.C.) :

> "Is the blue of heaven its real colour ? Or is is because it is infinitely far away ?"
> (1, 1a SPTK)

Admittedly, it is not stated definitely that heaven is insubstantial, merely that it is infinitely distant. *Lieh Tzu* might be advanced as an instance of a clearer statement that heaven is simply an accumulation of *ch'i*, but considerable uncertainties of dating make it safer to postpone treatment of this material until

Chin dynasty thinkers are discussed (see below, (V)(10)(b)). Needham has suggested (SCC, III, 221) that the Huang ti nei ching 黃帝內經 (19, 9b, SPTK; see III(10)(f)) contains apposite material from Western Han times, but although it does make the claim that earth is held up in the great void by ch'i, I cannot find a clear statement that the heavenly vault is insubstantial. In fact, it appears that the first definite and dateable statement by a named author must be that of Yang Ch'uan c. A.D. 265 (see below, IV, (3)(b)). According to him, heaven is simply ch'i emanating from the earth, like the smoke above cinders: perhaps in view of the discussions of (b) above it is significant that he does not mention the names Hsüan yeh or Ch'i Mêng at all.

We have, therefore, reached a somewhat paradoxical conclusion. Ch'i Mêng probably did not write the fragment attributed to him, nor can the Hsüan yeh be said with any certainty to have been as described there. Nevertheless, the so-called "Hsüan yeh" theory of the insubstantiality of heaven is of fairly respectable antiquity.

(10) The moving earth and related theories

(a) Introduction

From the Han onwards it was in general the Hun t'ien that was accepted as the orthodox cosmography, and throughout the succeeding centuries it remained substantially as we have seen it described by Chang Heng. The Hun t'ien was reasonably adequate for the task it was asked to fulfil, which was to "save the phenomena" for a group of observers who imagined themselves at the centre of a flat earth. If the heavenly sphere was made to centre on these observers, and if its axis was given an inclination to the horizontal equal to their latitude, then all their astronomical observations could be explained by postulating appropriate movements of the heavenly bodies on the sphere's interior surface. Naturally, no motion of the earth was required, either in rotation or translation; the same had also been true under the Kai t'ien. The complementary opposition of Heaven (Yang, hard, bright, round, moving) and Earth (Yin, soft, dark, square, stationary) was thus preserved.

It is intriguing under these circumstances to find that from the Western Han onwards there were examples of clear and quite detailed suggestions that the earth moved about within the heavenly sphere. These theories also tended to involve the periodic translation of the sphere itself, and possibly the motion of the heavenly bodies independently of heaven. Our evidence is too fragmentary to form definite conclusions about the intentions of those who originated these schemes. There are certainly some indications that there was an astronomical motivation for the movements attributed to the earth etc. but often we seem to be dealing with analogical or correlational thinking rather than physical reasoning. In examining the Chinese theories of the motion of earth it would be a mistake to think in terms of the Copernican/Ptolemaic controversy : there is nothing so significant here as the shift from geocentricity to heliocentricity, or the introduction of the earth's diurnal rotation. All that we find is a relatively small-scale annual cycle of the earth rising and sinking, possibly combined with oscillations in the horizontal plane. In the present section, we will consider the origins of these theories in the Western Han apocrypha, and their development during the Eastern Han. This is not the last we shall hear of them, however : similar notions are discussed by Yao Hsin (c. 240 A.D.), Ko Hung (c. 320 A.D.) and Chiang Chi (c. 385 A.D.), and likewise by other writers whose work lies outside the time-limits of this survey. Oddly enough, we find no attempts by more orthodox cosmographers to attack the concept of a moving earth by deploying the wide range of "common-sense" arguments that occur in Western discussions of the subject. This may be because dynamic concepts were not well-developed in ancient China, or perhaps because the relatively gentle annual movements involved were not so disquieting as the idea of an earth spinning once daily was to Aristotelians in the West.

(b) The K'ao Ling Yao fragments

The Shang shu k'ao ling yao 尚書考靈曜 is perhaps the most interesting of the so-called ch'an-wei 纖緯 apocrypha in astronomical terms. A short general discussion of these works and their date is given in Appendix (i) : it will suffice here to note that they are generally thought to be products of the Western Han. As we shall see later, this particular book, of which only fragments remain to us, bears a commentary by Cheng Hsüan (126 - 200 A.D.); this immediately suggests that it is probably a first century A.D. work or earlier. However, its title is also mentioned in a memorial of 92 - 93 A.D. quoted in Hou Han shu, chih 2, 3027, CHSC. From the memorial it is evident that the Shang shu k'ao ling yao was regarded at that time as a work of considerable authority, and it does not seem unreasonable to suggest that it may easily have originated before the rise of the Eastern Han in 25 A.D.

It is the K'ao ling yao that has the first description of the earth's supposed motions; the fragment of most interest is found in Po wu chih 博物志 1, 2a (c. 290 A.D.); Wen Hsüan 文選 comm, 4, 1b

(c. 660 A.D.); KYCC 4, 1b (c. 779 A.D.); TPYL 36, 2a (c. 983 A.D.); a conflated version is given here:

i. "The earth has four motions [yu 游 this word has some sense of "drifting, floating"]. At the winter solstice it is 30,000 li up and north-west. At the summer solstice the earth is 30,000 li down and south-east. At the spring and autumn equinoxes it is central. The earth moves continuously without stopping, but men do not realise this. This is similar to a man sitting in a large boat with closed windows : the boat moves but the man does not notice it."

The translation of the second and third sentences is somewhat conjectural : we cannot tell whether the 30,000 li refers to the total displacement from the equinoctial position or to one of the components of this motion. And what exactly are the "four motions" ? This last question is somewhat clarified by a further fragment occurring in a T'ang sub-commentary on the Chou li. Here as elsewhere I assume that the slight variation of title is not significant. San kuang 三光 "three luminaries" may mean the sun moon and stars.

ii. "Note that the San kuang k'ao ling yao says : 'It moves four ways and rises and falls within a range of 30,000 li'."

Chou li chu su, 10, 15a

Evidently the "four-way motion" ssu yu 四游 is distinct from vertical motion : I suggest that it refers to motion in the horizontal plane, i.e. in the "four directions" ssu fang 四方 , north south east and west. The same sub-commentary has a passage apparently related to later suggestions that heaven itself moves as well as earth. In any case, it is made clear that the sun is not simply attached to the heavenly sphere together with the stars.

iii. "Note that Cheng Chün's I i ['Dissensions', a work now lost] says : 'The book San Kuang k'ao ling yao says the sun's path goes more than 10,000 li beyond the hsiu'."

Chou li chu su, 26, 28a

Perhaps it is also the sun that is referred to in the following fragment; (a similar section in Cheng Hsüan's commentary mentions the sun explicitly, see below)

iv. "The K'ao ling yao says 'In the first month there are 80,000 li above it and 104,000 li below it'."

Li chi chu su 14, 4a

These fragments are both confused and confusing. Can we perhaps clarify matters by finding some explicit description of the K'ao ling yao's overall cosmography ? In his commentary Cheng Hsüan is fairly evidently using the Hun t'ien, and the Ming fragment collection Ku wei shu, 1, 2a attributes to the K'ao ling yao a statement that "Heaven is like a crossbow pellet". This is rather doubtful, however, as the only source for this text seems to be Yueh ling chu su, 14, 2b, where it is clearly part of the T'ang sub-commentary. The only fragment that seems relevant is :

v. "Note that the K'ao ling yao says '1 tu is 2932 348/1461 li. The circumference of heaven is 1,071,000 li. This is the number of li in the periphery of heaven'."

Li chi chu su 14, 2b

These two dimensions are of course related by the fact that there are $365\frac{1}{4}$ tu in a complete circle.

$$365\tfrac{1}{4} \times 2932\ 348/1461 \text{ li} = 1{,}071{,}000 \text{ li}$$

This figure is identical to that given in the Chou pei as the circumference of the sun's equinoctial path : see II (3)(a). According to Wang Fan, writing in the third century, 1,071,000 li was the dimension adopted by a considerable number of Han cosmographical works : see IV (2)(c). It seems worthwhile to point out that the sum of the two figures in fragment (iv) is 184,000 li, which is at least closely comparable with the radius of 178,500 implied by (v).

Commentaries and sub-commentaries on the K'ao ling yao will be considered later, but in the meantime some conclusions can be drawn from the bare text. The most obvious points are negative :

a. No mechanism is described to explain how it is that the earth rises, sinks, and moves laterally.

b. No text available to us attempts to explain possible consequences of these motions.

c. There is no apparent rationale for the key figure of 30,000 li.

It is still possible, however, to make a few plausible conjectures about the reasons for the various motions ascribed to the earth. Obviously the suggestion that earth is in the north in winter and south in summer could easily be motivated by a desire to explain the seasonal variations in climate. As for the question of the earth rising and sinking, could this not be related to the observation of the varying altitude of the noon sun throughout the year ?

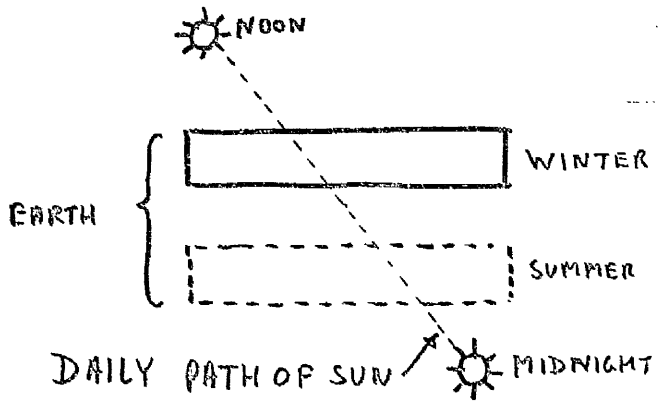


Fig III (5)

Effect of terrestrial motion.

Clearly, if the sun follows a fixed daily path as in Fig. III (5), then the rising and sinking of the earth (considered here as a disc) will cause an apparent variation of solar altitude. The earth is described in the K'ao ling yao as being high in winter and low in summer, which fits the circumstances qualitatively at least. Cheng Hsüan offers an attempt at an explanation of why the figure of 30,000 li is introduced (see below). It is much harder to find any justification for the statements, unclear as they are, relating to eastwards and westwards motion in fragment (i). I would point to the ancient notion that earth is high in the north-west and low in the south-east as having some possible connection with this : see for instance I (2)(b)(35). All this is very tentative, although this is perhaps preferable to the highly detailed but purely conjectural accounts found in T'ang works (see below, (d))

(c) Cheng Hsüan's commentary on the K'ao ling yao

Cheng Hsüan 鄭玄 (A.D. 126-200) was a prolific scholar, who wrote commentaries on a number of classical works as well as on the ch'an-wei apocrypha. His commentary on the K'ao ling yao has of course reached us in a fragmentary state, but there remains enough of it to show that his exposition does not seem to meet all the difficulties of the text, and even appears to differ from it in some respects. If even Cheng, who presumably had a complete text of the K'ao ling yao to work on, felt driven by the opacity of its expression to make his own conjectures in an effort to produce a coherent explanation, a modern student need not feel overly discouraged by a failure to do any better. Our best evidence of Cheng's views comes from the following fragment, probably a comment on the text from which (i) and (ii) were drawn (the numbering of fragments is continuous with (b)) :

(vi) "Cheng's commentary on the K'ao ling yao says : Earth is 30,000 li thick. At the spring equinox earth is exactly central. Next it sinks gradually until the summer solstice, when the earth has sunk 15,000 li and its upper face is level with the centre of heaven. After the summer solstice the earth rises gradually until the autumn equinox, when it is exactly at the centre of heaven. Next it rises gradually until the winter solstice, when it has risen 15,000 li, and its lower face is level with the centre of heaven. After the winter solstice the earth sinks gradually. This is [what is meant by] 'The earth rises and falls within a range of 30,000 li'."

Li chi chu su 14, 2b, SSCCS

We may note in the first place that Cheng has obviously adopted the spherical heaven of the Hun t'ien cosmography. If this were not so, the references to earth being at "the centre of heaven" would be meaningless. Earth itself has a thickness that is considerably less than the diameter of heaven on any ancient Chinese estimate. Fragment (v) above gives the circumference of heaven as 1,071,000 li and there is reason to think that Cheng was at least in general agreement with this; see (x) below. On the usual ancient approximation of $\pi = 3$ a diameter of 357,000 li results, nearly twelve times the alleged thickness of earth. If Cheng followed Chang Heng (III)(7)(c)) in believing that earth extended horizontally most of the way across the diameter of heaven, a rather thin plate results. We cannot tell whether Cheng thought of this as round or square, and it is notable that he does not suggest what supports earth or what causes the variation in its position.

In the K'ao ling yao fragments themselves there was no indication of a rationale for the figure of 30,000 li mentioned there as the distance by which the earth is periodically displaced from its central position. Here Cheng has used 15,000 li as the maximum displacement from the mean position, so that 30,000 li becomes the distance between the extremes. His explanation of this is found in another fragment which is a comment on the text of the Chou li :

(vii) Text : "On the day of the solstice the shadow is 1.5 ft. This is called the centre of the earth ... "

Comment : "'The shadow is 1.5 feet', so southwards to below the sun is 15,000 li. The earth and stars 'move four ways and rise and fall within a range of 30,000 li'. Therefore halving this gives the earth's centre."

Chou li chu su 10, 11b, SSCCS

Cheng is stretching the Chou li considerably from its original meaning. The text actually implies that at the middle of the (naturally flat) earth the noon shadow is one foot five inches, and the first sentence of the comment makes a deduction from this using the usual shadow-principle of "one inch for a thousand li" (see II (2)(a)). In this section the Chou li is concerned with the siting of the imperial capital, the notion of the centrality of which can be traced back as far as the closing section of the Yü kung, where the royal domain is described as surrounded by concentric regions of settlement, whose cultural level decreases with their distance from the capital (Shang shu chu su, 6, 28b ff, SSCCS). For a brief survey of Chinese attempts to use astronomical methods to locate this central point accurately see V (3)(e). Needless to say, the persistence of this idea, which is quite incompatible with any theory of the sphericity of the earth, is another confirmation that the flat earth remained unquestioned; see also Cullen (1). Cheng goes on, however, to interpret ti chung 地中 not as 'the centre of the earth' but as 'the earth's being central', which is obviously illegitimate. It may well be, of course, that the K'ao ling yao's figure of 30,000 li originated by a similar process.

I have not so far mentioned an interesting aspect of (vii) : "the earth and stars 'move four ways and rise and fall'". In the K'ao ling yao fragments motion was ascribed to the earth alone, and a consequence of this would of course be that more stars should be visible in summer than in winter (see Fig. III (6)).

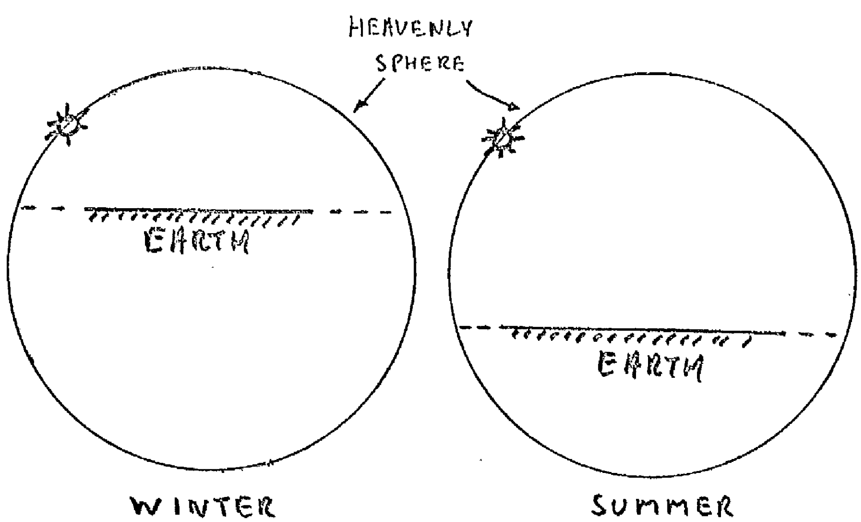


Fig III (6)

Star visibility and terrestrial motion

This is of course not the case, and the difficulty could be avoided if, as seems to be hinted here, the stars always shared the motion of the earth, so that the relative position of earth and the sphere of stars remained unchanged. Cheng says nothing more explicit on the subject, however, although in the T'ang dynasty K'ung Ying-ta prefaced one of Cheng's comments on the K'ao ling yao with the words :

(viii) "The stars likewise follow the earth in rising and falling"

Li chi chu su, 14, 3a, SSCCS

We cannot, of course, assume that he found this idea in Cheng Hsüan's writing. Cheng does, however, mention the movement of heaven :

(ix) "Cheng's commentary on the K'ao ling yao says 'Heaven moves sideways between the four piao 表 south in winter, north in summer, west in spring, and east in autumn. In each case it moves up to the four piao and stops. Likewise earth moves vertically in the centre of heaven, downwards after the winter solstice and upwards after the summer solstice. At the two solstices its height and depth go as far as the thickness of the earth'."

Li chi chu su, 14, 2b, SSCCS

We note again the usual correlation of seasons with directions; the question of the nature of the piao will be left to one side for the moment. It is interesting that while in (vii) Cheng mentions the earth as moving "four ways" (i.e. laterally) as well as vertically, in both (vi) and (ix) he gives it a vertical motion only. Possibly he felt it unnecessary to have both heaven and earth moving laterally.

So far we have not seen any evidence of Cheng's thinking about the sun. If the object of the various movements of earth and the heavens is to explain the seasonal variation in solar altitude and daylength, then we would naturally expect that the sun should follow a fixed daily path, relative to which the earth's movements take place. We have two fragments of interest :

(x) "In summer the sun's path is high and level with the four piao. It is 12 tu down to [the constellation] Tung ching, which makes 30,000 li."

Li chi chu su, 14, 3a, SSCCS

(xi) "At the summer solstice the sun is level with the piao. At the winter solstice it is 80,000 li from the sun down to earth, and 113,500 li up to heaven."

Li chi chu su, 14, 3b, SSCCS

This is a rather odd situation. Clearly in summer the sun is above the stars, and in winter the sun is well below heaven. Obviously we are not in the simple situation found in the classic form of the Hun t'ien, in which all the heavenly bodies lie on the inner surface of the heavenly sphere. The unfortunate fact that the two fragments refer to different seasons deprives us of the chance of determining the order in which heaven, the sun, and the stars lie, or of finding the distances between them. Although it is not stated explicitly, it does not seem unreasonable at any rate to assume that the sun and stars are always inside the heavenly sphere. We have already seen in (iii) above a K'ao ling yao fragment suggesting that the sun's path goes "more than 10,000 li beyond the hsiu", and the T'ang subcommentaries certainly state that the sun is sometimes nearer earth than the stars and sometimes further away (see below III (10)(d))

It is possible to see some sense behind the figures given in (x) and (xi). In the first of these, if 12 tu make 30,000 li, then 1 tu must be 2,500 li. Using the usual ancient approximation of $\pi = 3$, the radius of the circle whose tu are of this size is 152,187.5 li. (For a note on the tu as a circumferential fraction rather than an angular separation see Appendix (vi)) Which circle might this refer to ? Certainly this value for the size of a tu is not incompatible with the K'ao ling yao figure of 2,932 138/1461 li in (v) above. Unfortunately there is simply not enough evidence for us to take the matter any further.

In the light of this discussion, a reasoned speculation about Cheng Hsüan's views might make the following points :

(a) He saw the utility of the rising and falling of earth as an explanation of the seasonal variation in the sun's apparent daily path and adopted it.

(b) He realised the problem of seasonal variation in the proportion of stars visible, and thus made the stars follow the motion of the earth upwards and downwards.

(c) Noticing the K'ao ling yao references to lateral motion he simply attributed this to the sphere of heaven itself : as the sun and stars were not for him attached to heaven, no visible effect would be produced.

(d) The four _piao_ 表 are evidently some kind of limiting point or physical obstacle to the motion of heaven (see (ix)). As the sun's path is within heaven and said to be level with the _piao_ it seems likely that the _piao_ are within heaven also. I suspect that Cheng has used "the four _piao_" as an archaic form of "the four poles, _chi_ 極 ", a reference to the limits of the earth. An example of the expression occurs in the first few lines of the _Shang shu_, in a reference to the legendary emperor Yao :

"He brilliantly covered the four _piao_. He reached to [heaven] above and [earth] below"
Shang shu chu su, 2, 6b, SSCCS

It is extremely helpful to have a comment on this passage by Cheng himself :

"This means that Yao's brilliance extended beyond the four seas, and reached to heaven and earth."
Mao shih chu su, 19, 2, 26a, SSCCS

In Cheng's view, therefore, the _piao_ may be the edges of the earth, which he evidently thinks of as some kind of flat plate. This would obviously provide a limit to the motion of heaven.

(d) A note on the T'ang subcommentators

From the references in the preceding three sections it will have become evident that much of our information about the present subject comes to us by way of the copious subcommentaries on the classics compiled during the T'ang. Strictly speaking these writings, except insofar as they contain ancient material, fall outside the limits of this survey, but the picture that has emerged in sections (a), (b) and (c) is so confused and incomplete that it would be foolish to ignore the work of authors who may have had much more material available to them than we have today. We have opinions recorded by K'ung Ying-t a 孔穎達 (fl. A.D. 630) and Chia Kung-yen 賈公彥 (fl. A.D. 650) : both of them seem to be literary constructions rather than drawn from a living tradition. Chia attempts to stick closely to the K'ao ling yao as in fragment (i) above :

> " ... At the spring equinox the earth and stars are back in their old position. By the summer solstice the earth and stars have moved 15,000 li to the south-east, and the same distance downwards. By the autumn equinox they are central once more. By the winter solstice the earth and stars have moved 15,000 li to the north-west, and the same distance upwards. By the spring equinox they have returned to centrality. Their motion back and forth does not go beyond [a total range of] 30,000 li ... "

Chou li chu su, 10, 12a, SSCCS

This is simply a clarification of (i), in which Cheng's figure of 15,000 li has replaced the original

30,000 li. Chia does not go into the astronomical implications of his interpretation. K'ung confects a much more elaborate scheme, summarised in the table following :

SOLAR SEASON	POSITION OF EARTH AND STARS	
	VERTICAL	HORIZONTAL
beginning of spring	central	central
spring equinox	central	west
end of spring	central	central
beginning of summer	central	central
summer solstice	low	north
end of summer	central	central
beginning of autumn	central	central
autumn equinox	central	east
end of autumn	central	central
beginning of winter	central	central
winter solstice	high	south
end of winter	central	central

see Li chi chu su, 14, 2b

K'ung has apparently transferred to earth the horizontal motions ascribed to heaven by Cheng in (ix). This of course involves contradicting the K'ao ling yao's statement that earth is northerly in winter and southerly in summer, and it is evident that K'ung is not particularly concerned with astronomical consequences. It seems that neither Chia nor K'ung have very much to contribute to our understanding of the original texts, however imaginative their attempts at reconstruction. Perhaps there is a certain interest in the fact that they were prepared, without noticeable qualms, to accept the possibility of the rather bizarre theories we have seen expounded here and in the preceding sections.

(e) The possibility of a rotating earth in Chinese cosmography

In (a) - (d) above it was fairly clear, despite other obscurities, that the texts in question referred to motion of the earth in translation rather than rotation. Discussion in this area would however be incomplete without a mention of another group of texts, considerably more fragmentary, which seem to point to some belief in the rotation of the earth. Before turning to the texts themselves let us examine the logical relation between such a belief and the general context of Chinese cosmographical thought. In what follows I do not intend to suggest that the various implications and contradictions detailed were consciously realised by those holding the theories to which they are relevant. Indeed, I would maintain that they probably were not so realised, which obviously conditions the value we can attach to such theories as examples of scientific thought. We are certainly not entitled to take some fragmentary statement at face value and then proceed to "reconstruct" an entire theory on the basis of what is logically consistent with it, for, as this survey shows, logical or physical consistency is no more an invariable characteristic of ancient Chinese cosmography than it is of other proto-sciences in other cultures.

Let us consider first the possibility of a rotating earth within the context of the classical Hun t'ien universe as described, for instance by Chang Heng (III (7)). The physical constraints of the situation of Fig. III (4) dictate that, relative to heaven, the only possible mode of rotation of the earth is about a vertical axis through its centre. Naturally the earth's flat upper surface cannot be thought of as tilting; for the ancient Chinese "downwards" was an absolute direction. If such a rotation occurs, an odd effect would be expected : the north celestial pole would not maintain a fixed directional relation to the features of the earth's surface, but would appear to complete successive cycles in azimuth. This would of course apply whether earth was thought of as rotating once a day or once a year or in any other period of time : the fragments do not commit themselves on the question of speed. Similar difficulties obviously apply to the sun : supposing, for instance, that earth rotated once a day from west to east, then, although the direction of the noon sun would remain constant, at the equinoxes the sun would set at the same point on the earth's horizon as it rose ! Clearly no-one who believed in the Hun t'ien could have any reason for introducing a terrestrial rotation, and, even if they nevertheless made the postulate, the discrepancy between theory and observation would have been far more obvious than in the cases of translational motion previously discussed. Of course it is possible drastically to modify the Hun t'ien universe so that the rotation of the earth is a possibility. To do this it is necessary to take the earth as spherical and at the centre of a much larger coaxal heavenly sphere. Given this situation, which is in essence the cosmography of Aristotle (384 - 322 B.C.), the observer on earth cannot kinematically distinguish between any modes of rotation of heaven or earth or both giving the same resultant relative rotation. There has indeed been controversy as to whether or not Aristotle ever entertained a theory of terrestrial rotation (Dreyer, 72 ff.). Given, however, the complete lack of any references to the earth's sphericity in the Chinese literature falling within the period of this survey, and given the number of explicit references to a flat earth of diameter comparable to heaven, there seems to be no basis for suggesting that an Aristotelian cosmography can be inferred from fragments of the sort soon to be described. (See Appendix (ii))

Under the Kai t'ien system as described in the Chou pei (II (3) (c)), where heaven and earth are two parallel horizontal discs with central bulges there is much less incompatibility with the notion of terrestrial rotation. When however the subject was discussed by ancient writers it is clear that for them earth was stationary while heaven rotated about a vertical axis passing through the centre of earth and heaven (III (6) (d)). The sun moon and planets move on the heavenly "umbrella" relative to the stars which are fixed to it, but are nevertheless carried along in the diurnal rotation. A terrestrial observer could not kinematically distinguish a situation where heaven remained fixed and earth rotated once daily. At this point, however, one can surely with some force raise an objection that applies to the _Kai t'ien_ universe much more than to a classical _Hun t'ien_ system : as the observer of the _Kai t'ien_ was some 100,000 _li_ from the central axis (II (2) (a)) a diurnal rotation gives him a speed of 25,000 _li_ per hour, or 8,000 miles per hour. Wang Ch'ung, a firm adherent to the _Kai t'ien_, found such a speed inconceivably rapid (III (6) (d)); even given the primitive development of dynamic concepts, is it likely that a Chinese thinker could have accepted that he was really in such rapid rotation ? The linear motions discussed in (a) - (d) above were three orders of magnitude smaller, and there is no theoretical benefit within the _Kai t'ien_ scheme from setting the earth in any motion whatsoever.

It seems therefore that, although one should approach all new evidence without arbitrary preconceptions, suggestions that ancient Chinese texts refer to a rotating earth should be entertained with some reserve. If they are to be taken at face value it is very hard to consider them the product of minds familiar with the central traditions of Chinese cosmography. It may be worthwhile therefore to try alternative interpretations of the texts, if any seem plausible.

(f) Texts suggestive of terrestrial rotation

Several fragmentary sources are relevant to the present topic. Possibly the earliest is attributed in TPYL to the book Shih tzu 尸子, which may date from the fourth century B.C. :

> "Within the eight poles, the region where there are rulers is 28,000 li east-west and 26,000 li north-south. Thus it is said that heaven unrolls [舒 shu] leftwards, beginning from [the constellation] Ch'ien Niu, and earth moves away [闢 p'i] rightwards, beginning from [the constellations] Pi and Mao."
>
> TPYL, 37, 3a

If, by the way, the Shih tzu is authentic then the dimensions given antedate a similar reference in the Lü shih ch'un ch'iu (II (3) (g)). Although it is evident from this text that heaven and earth are thought of as doing something in opposite directions, the verbs of motion do not refer unambiguously to rotation despite the fact that heaven is normally said to rotate leftwards. (The two groups of stars referred to are antipodal on the celestial sphere.) A fragment of the Ch'un ch'iu yüan ming pao 春秋元命苞 is rather more explicit : like other works of its class it probably dates from the first century B.C.

> "The reason the earth rotates [轉 chuan] rightwards is that its ch'i is turbid and little of it is pure. It contains Yin and thus starts off slowly. Therefore in its rotation it moves in the opposite sense to heaven, assisting it in following its principle."
>
> TPYL, 36, 3a

Another fragment of the same work runs :

> "Heaven turns [旋 hsüan] leftwards and earth moves [動 tung] rightwards."
>
> Ch'u hsüeh chi 5, 1b

One can do little else with this material but call attention to it in the light of the remarks of the preceding section. There is no way of recovering the overall scheme within which the processes hinted at were thought to occur, or of deciding whether the references to rotation refer to the physical heaven and earth or to some more abstract entities. Only in one text known to me are we able to attempt an interpretation in context. This is the Huang ti nei ching su wen 黃帝內經素問 ; whatever the ultimate origin of its material it was apparently current in some form during the Western Han, as the inclusion in the Han shu bibliography of the Huang ti nei ching suggests. (Yü Chia-hsi 余嘉錫 , (1), 623, points out that the slight difference of name is not significant.) The Nei ching is of course a text to treat with great care : in his preface the T'ang commentator Wang Ping 王冰 warns us that he found it in some confusion and carried out extensive restoration and rearrangement. Indeed, there is considerable reason to suspect that pien 66 - 74 were not originally present but were inserted by Wang himself (Porkert (1), 56). Unfortunately, these chapters contain the material relevant to our present purpose, and so we have to deal with a possible millennium of uncertainty in its dating. A further difficulty is that the Nei ching is the classic source for the long-tradition of Chinese medicine, a tradition whose terminology and theoretical structures are by no means yet fully understood by modern scholars (see Porkert (1), passim, and the review of Needham and Lu, Annals of Science, Vol. 32, No. 5, September 1975). In the translation which follows I make no attempt to bring out the possible technical meanings of common words, but I warn the reader that it seems that several innocent-looking phrases should be enclosed in inverted commas to indicate a special usage.

> "[Ch'i Po said] ... 'The high and low encounter each other, and cold and heat come into contact with each other. When the ch'i correspond there is harmony, and when they do not correspond sickness occurs.'
>
> The emperor asked : 'Why does non-correspondence of the ch'i cause sickness ?'
>
> Ch'i Po replied : 'When the low moves near to the high, the position is incorrect.'

The emperor asked : 'What about motion and quiescence ?'

Ch'i Po replied : 'What is above moves to the right; what is below moves to the left. They circle round heaven to the left and the right, leaving an excess .[and hence a mis-match] but eventually being restored to correspondence.'

The emperor said : 'I heard Kuei Yü-ch'ü say that whatever answers to earth is quiescent. Now you, sir, say that what is below moves to the left. I do not know what that refers to, and would like to ask how it comes about.'

Ch'i Po replied : 'Heaven and earth move and repose, and the five elements depart and return: even though Kuei Yü-ch'ü paid attention to what is above, he could not make matters completely clear. Now the transforming functions operate insofar as heaven suspends its images and earth completes its forms. The seven luminaries thread through the void, and the five elements are attached to earth. The earth is what carries the forms of what is produced and completed. The void is what sets in order the pure <u>ch'i</u> of heaven. The motions of forms and purity are like roots and branches. If one gazes up at the images, they can be known about although distant.'

The emperor said : 'Is the earth the lowest thing or not ?'

Ch'i Po replied : 'The earth is below men, but is just something in the middle of the great void.'

The emperor said : 'But what does it rest on ?'

Ch'i Po replied : 'The great <u>ch'i</u> holds it up.' "

<u>Nei ching</u>, 19, 8b, SPTK

Note, of course, the oddity that if the "above" and "below" of Ch'i Po's third statement are to be taken as referring to physical heaven and earth, then heaven is being said to rotate rightwards, contrary to the otherwise universal Chinese convention (Wang's commentary reverts to the usual senses). Compare also Huai nan tzu 10, 7b, where above and below are linked with left and right respectively. These points of detail aside, however, can we say that we have here a description of a rotating earth ? I do not think a firm position can be taken on this question, and perhaps paradoxically I think this is because in this case the full context of Ch'i Po's statement is available. Admittedly the extract given here ends with a fairly undoubted piece of physical cosmography; the unequivocal description of earth as buoyed up by ch'i in the midst of the void has no really close parallels in the period of this survey. The opening words, however, set the discussion firmly in the field of what Porkert has called "phase energetics", and this is certainly intended to be the overall theme of the pien in which it occurs. Is an explanation of Ch'i Po's "rightwards and leftwards circling" possible in the terms of this theoretical scheme ? The answer seems to be yes, but we cannot assume that "the literal and grammatical sense" is to be ignored. Wang Ping's commentary on Ch'i Po's third statement begins :

> "'Above' means heaven, 'below' means earth. 'Circling round heaven' means that heaven circles the positions of the five elements [行 hsing] of earth. Heaven suspends the six ch'i, and earth displays the five elements."

(The five elements are, of course, wood, fire, earth, metal, and water. The six ch'i are "princely fire" chün huo 君火 , "ministerial fire" hsiang huo 相火

and the <u>ch'is</u> of earth, metal, water, and wood; see <u>Nei ching</u> 19, 18b, and Porkert (1), 64).

> "Heaven accords with earth in turning to the left, and earth supports heaven in rotating eastwards. After [one] rotation [returning to] wood [i.e. through all five elements] there will always be one heavenly <u>ch'i</u> left over. [Thus in one revolution] this remaining <u>ch'i</u>, which fell on 'princely fire' originally, will have moved back one place to fall on 'ministerial fire'. Therefore every five years [the <u>ch'i</u>] have moved back one place, retreating to the right. Thus the text says : 'They circle round heaven to the left and the right, leaving an excess but eventually being restored to correspondence' ... "
>
> <u>Nei ching</u> (comm.) 19, 9a, SPTK

According to Wang, therefore, the text is describing a cyclical permutation of two sets, one of five and one of six members. The cycle of the five elements is evidently completed in five years, and thus any physical rotation is clearly not diurnal or even annual; this would suggest that we should not look for any direct connection with astronomical phenomena. Wang's explanation certainly does fit in with other parts of the text, e.g. 19, 18b, ff., and as has been mentioned it may be that this is because he wrote this section of the work himself. Even if the text is ancient, however, I am inclined to think that Wang interprets it fairly accurately. On this view we would not be wise to take the references to rotation of the earth as straightforward propositions in physical cosmography, leaving aside all the objections to such suggestions mentioned in (e) above.

In conclusion, the idea of a rotating earth is implausible in the context of Chinese cosmographical theory, and there seems little evidence that any intellectually committed attempt was made to introduce the notion. When such evidence as exists is fragmentary it is too cryptic to be relied on, and when it is seen in context, as in the Nei ching, it really does not seem to be much more than a metaphor.

IV : COSMOGRAPHY IN WEI-CHIN TIMES

(1) Introduction

By the end of the Han the main ideas of Chinese Cosmography had been set forth. The Hun t'ien was established in a position of strength which was never to suffer serious challenge, but the Kai t'ien remained at least an interesting subject for criticism. It was at the beginning of the third century that Chao Shuang (see Appendix iv) brought out his edition of the Chou pei, thus ensuring the preservation of the text. The somewhat heterodox ideas of the movement of the earth and the insubstantiality of the heavenly vault were to recur with vigour at times. A number of problems had been broached, including the following :

(i) What were the origins of the various cosmographical theories ?

(ii) How were the dimensions of the Hun t'ien universe to be found ?

(iii) What was happening during solar and lunar eclipses ?

(iv) What was the explanation of the "horizon illusion"?

(v) How could the idea of the motion of the earth be reconciled with observation ?

In the period to be reviewed we shall see a number of attempts to deal with all these questions. Ancient opinions on (i) are naturally of the greatest interest in the context of this survey; material is found by Lu Chi (2)(a), Wang Fan (2)(b), Yang Ch'üan (3)(a), Liu Chih (6)(a), and Yü Hsi (7)(c). The second problem is of course strictly insoluble, as the underlying cosmography is false, but efforts to use gnomon shadows for this purpose continued. The difficulty was that the "inch for a thousand li" rule, (which had formed an integral part of the Kai t'ien), could not consistently be used with the Hun t'ien spherical heaven. It was nevertheless the only method known, and both Wang Fan (2)(c) and Chiang Chi (9)(d) discuss it. The attempt of Liu Hui (2)(d) to dispense with it seems to have been ignored; in ancient China geometry was just not able to deal adequately with problems involving circles.

More directly physical discussion was occasioned by (iii) and (iv); the "horizon illusion" was dealt with by Shu Hsi (2)(e) and Chiang Chi (9)(c), both of them treating it as an optical effect rather than due to distance variations. Under the classic form of the Hun t'ien it could not of course be admitted that the heavenly bodies might vary in distance from the (central) Chinese observer. Eclipse theory was a tougher problem, as we can see from the work of Liu Chih (6)(b), (c), and Chiang Chi (9)(b). Lunar eclipses created the real difficulty, for if the (flat) earth occupied nearly all of the horizontal diameter of the heavenly sphere, why was its obstruction of the sun's rays so localised ? The ingenuity of the explanations proposed is admirable, but it becomes glaringly obvious that neither of these very capable astronomers ever had the least idea that their problems might be solved by postulating a relatively small and spherical earth. Here as elsewhere no hint of this concept is to be found where it might most have been expected. (See Appendix (ii)) Chiang Chi's important work on the motion of earth and heaven (9)(d) certainly proves he was not the sort to reject such ideas through intellectual timidity, had he ever heard of them.

Indeed, if a theory of the sphericity of the earth was ever to have been put forward in ancient China it might have been expected during the period of this section. So far as the heavens were concerned there was no lack of bizarre suggestions such as that of Yao Hsin (5). The thinkers of the Wei-Chin pushed the Chinese tradition of cosmography as far as it could go, and often, it must be admitted, rather further than that.

(2) The Hun T'ien in the third century

(a) Lu Chi's claim for the antiquity of the Hun T'ien

Earlier in this survey an attempt was made to fix a date for the origin of the Hun T'ien theory (III (3)). The somewhat tentative conclusion of the discussion was that the theory and the instruments associated with it were most probably products of the latter half of the Western Han. The earliest name connected with the Hun T'ien by the literary evidence is that of Lo-hsia Hung, active c. 116 B.C., who may in any case owe the attribution to a desire on the part of Yang Hsiung (writing c. 0 B.C.) to find a single inventor for a theory whose actual origins were obscure. We have already seen that Chang Heng implied that the sages of antiquity thought of the universe as spherical (III (7)(c)), and in the work of Lu Chi 陸績 (c. A.D. 220-252) we find for the first time explicit claims that the Hun T'ien theory was in fact a product of the age of the legendary emperors in the third millenium B.C. As we shall see shortly Lu Chi's contemporary Wang Fan likewise held this view, which was in conformity with other Chinese instances of attributing such innovations as the art of writing, and the building of houses to some "culture-hero" of remote antiquity. Our only fragment of Lu Chi's writing on astronomy is in KYCC, 1, 10a-12b, partly duplicated by KYCC 2, 6a-7b. This is presumably taken from the Hun t'ien t'u 渾天圖 mentioned in his biography in San kuo chih 57, 1328, CHSC.

At the end of his quotation the editor of KYCC makes it plain that he has left uncopied a large portion of Lu's work dealing with the geometry of the celestial sphere "as in Ts'ai Yung and Chang Heng". Nevertheless, sufficient evidence remains that Lu held the orthodox Hun t'ien view with the earth enclosed by the celestial sphere, the axis of which is tilted so that the north celestial pole is 36 tu above the horizon. The circumference of the celestial sphere is stated (without proof) to be 1,071,000 li, which is of course a figure to be traced back to the circumference of the equinoctial hêng given in the Chou Pei (II (3)(b)). The evident use of the approximation $\pi = 3$ gives a diameter of 357,000 li. Lu does not enter into a detailed analysis of these figures : for that we must refer to Wang Fan.

His claim for the antiquity of the Hun t'ien is based on two grounds. The first of these relies in essence on the exegesis by Eastern Han commentators of the term hsüan chi yü hêng found in the Shu Ching (1, 6b, SPTK). Lu claims that this is a reference to a Hun t'ien instrument i.e. an armillary sphere allegedly in use by the emperor Shun, a legendary figure conventionally dated c. 2250 B.C. Even at first sight this is somewhat implausible, and a full examination as in Cullen (2) shows it to be quite baseless. The second proof of the existence of Hun t'ien notions in early times has rather more force, and is drawn from consideration of the contents of the Book of Changes, I Ching 易經. Lu believed, of course, in the conventionally accepted attribution of the basic text to the Duke of Chou (c. 1100 B.C.) and of the commentary to Confucius himself. Even if this is rejected, there is little doubt that much of the material is at least contemporary with Confucius, so that any cosmographical content would pre-date most other sources dealt with in this survey : Lu's discussion is thus of considerable interest, and it cannot be denied that he succeeds in drawing attention to a point of cosmographical significance in the texts attached to the hexagrams Chin 晉 and Ming I 明夷, in both of which there are references such as :

> "First it [the sun] rises into heaven illuminating the kingdoms on all sides; afterwards it sinks into the earth and no longer functions thus."
>
> Chou I, 4, 16a, SSCCS

Lu adds to these the Shu Ching reference to the charge of Yao to Hsi and Ho, instructing them to reside at the positions where the sun rises and sets (see I (2)(b)(15-16)). From this evidence he correctly points out that in ancient times it was evidently believed that the succession of day and night was due to the rising and setting of the sun above and below the earth rather than to the process of optical illusion described by

Kai t'ien theorists (see II (3)(d)). Thus, Lu claims, it is evident that the Hun t'ien is of considerable antiquity. Rival theories such as the Kai t'ien are the product of the degenerate times after the death of Confucius. The flaw here is of course the assumption that any cosmographical picture in which the sun rises and sets over the edge of the earth is ipso facto a Hun t'ien theory. In Section I and in III (2) we saw clear evidence for the persistence well into the Western Han of archaic theories with such solar behaviour, but quite lacking in the rotating spherical heavenly vault that is the essential feature of the Hun t'ien. Indeed, according to these accounts it is a new and quite different sun that rises from the east each morning. Although therefore Lu certainly succeeds in showing the early presence of cosmographical beliefs which are incompatible with the Kai t'ien he does not show that the Hun t'ien should be placed earlier than has been concluded in this survey.

It is worth making two points in relation to this and subsequent attempts to claim a very early date for the origin of the Hun t'ien theory. Firstly, despite the fact that they were writing at a period when much evidence now lost was still available, none of the proponents is able to add anything substantial to the picture of the origin of the Hun t'ien given in III (3). Some, like Wang Fan, maintain the antiquity of the theory while claiming that for a time all knowledge of it was lost, and that a rediscovery was necessary during the Han. It seems, therefore, that at the very minimum we can feel fairly sure that no pre-Ch'in evidence of the Hun t'ien has been known for the last two millennia. This is, of course, strongly in favour of a Western Han origin, given the other circumstances. Secondly, the high esteem and wide acceptance of the Hun t'ien is confirmed by these attempts to claim it as part of the cultural legacy of the sages.

(b) Wang Fan's account of the Hun t'ien

Chang Heng gave an adequate and well-articulated description of the Hun t'ien universe, but for really detailed treatment and critical discussion it is necessary to turn to the work of Wang Fan 王蕃 (A.D. 227-266). We have a fairly well-preserved text of a treatise by him dealing in about equal measure with the geometry of the celestial sphere and with an evaluation of attempts to establish its dimensions (see KYCC 1, 12b and Textual Notes (5)). Wang, who quotes Lu Chi at times, likewise makes the claim that the Hun t'ien was known in high antiquity but lost during the degeneracy of the Eastern Chou in which period he places the origin of the Kai t'ien and Hsüan yeh. All that survived the Ch'in was the Hun t'ien instrument on the observatory terrace, which was in any case an official secret : this presumably explains why we have no record of such an instrument from the early Western Han. A further fragment of Wang Fan's writing on this point is found in *Sung shu*, 23, 677, CHSC, where he repeats the claim that *hsüan chi yü hêng* in the *Shu Ching* is a reference to an armillary instrument. It is there accompanied, however, by a sharp criticism from Hsü Yüan 徐爰 (A.D. 393-475), who dismisses the notion that the correct theory could have been current for 2,000 years and then lost. Further, he states, the praise given to Chang Heng for his armillary sphere makes it plain that he was an innovator rather than a copyist of some existing model : with all this one can only agree.

The first half of the rest of Wang's treatise need not concern us in detail : it consists of a geometrical account of such matters as the tilt of the celestial axis, the obliquity of the ecliptic, and the position of the sun at various times of the year. Wang states that he takes his data from the *Ch'ien Hsiang* 乾象 calendar of Liu Hung 劉洪 promulgated in A.D. 222. For the purpose of this survey it is sufficient to note that Wang explains the diurnal and annual path of the sun and the variation of day and night entirely by reference to the different solar positions on the celestial sphere, at the centre of which is the observer, placed on a flat and immobile earth. This is of course the classic form of the Hun t'ien cosmography. In passing one may note one point which is illuminating as to the status of the Chinese "degree" tu 度 : since the Ch'ien Hsiang calendar gives the year 365 145/589 days rather than the old number 365¼, Wang likewise takes the circumference of heaven as 365 149/589 tu rather than 365¼ tu. This evident concept of the tu as one day's-worth of motion for the sun seems related to the discussion given in III (3)(c).

(c) Wang Fan and the dimensions of the universe

More interesting, because less certain and less fully systematised, is Wang's discussion of the size of the universe and the means by which it might be determined. He begins by noting the figure of 1,071,000 li for the circumference of heaven : this is the one used by Lu Chi in (a) above, deriving ultimately from the Chou pei. Wang (who has echoed Ts'ai Yung's rejection of the Chou pei as inaccurate) does not make the attribution, but instead gives as his source the Lo shu kuei yao tu 洛書軌曜度 and Ch'un ch'iu k'ao i yu 春秋考異郵 , two of the ch'an-wei apocryphal books, now lost. This figure is, he states, erroneous, but as it is in common use he will investigate its implications. "The ancient calendars" use 365¼ tu for the circumference of a circle, implying that the length of 1 tu on the celestial sphere is, he states :

> 2932 li, 71 pu 步, 2 ch'ih 尺, 7 ts'un 寸, 4 fen 分 and a fraction

The accuracy is of course quite pointless. Wang next recalculates the length of the tu on the basis of Liu Hung's value of 365 145/589 tu for the circumference of heaven, thereby increasing the figure by just over 9 pu. Another correction is applied when Wang points out Lu Chi's faulty assumption that the diameter of a circle is a third of its circumference : thus on the basis of a 1,071,000 li circumference Lu gave a diameter of 357,000 li. Wang proposes a new proportion equivalent to taking π = 142/45, approximately 3.16, which is within 0.6% of the actual value. (For a discussion of Chinese approximations to π, see SCC, III, 99 ff.) Thus instead of a diameter of 357,000 li he obtains over 329,401 li, which he halves to give "the height of heaven above earth".

So far, however, Wang has simply been investigating the consequences of a piece of data he has already declared to be incorrect. He now attempts an original calculation of the size of heaven, and it cannot be denied that he makes his process of deduction admirably clear. His starting point is the text of the Chou li already mentioned above (10, 10a, SSCCS; See III (10)(C)) with its Eastern Han commentaries. From thence he takes the following points :

(1) Yang-ch'eng 陽城 (near Lo-Yang) is the centre of the earth.

(2) At that point the noon summer solstice shadow of an eight-foot gnomon is 1.5 feet.

(3) For each 1,000 <u>li</u> southwards this shadow shortens by one inch. (See II (2)(a) for a discussion of this assumption.)

All this Wang apparently accepts on the basis of classical authority. Obviously from (2) and (3) it follows that at the solstice it is 15,000 <u>li</u> southwards from Yang-ch'ung to the subsolar point where there is no shadow. By simple proportion, since the gnomon that casts a 1.5' shadow is 8' high, the sun must be 80,000 <u>li</u> above the earth. Thus we have the situation of Fig. IV (i) :

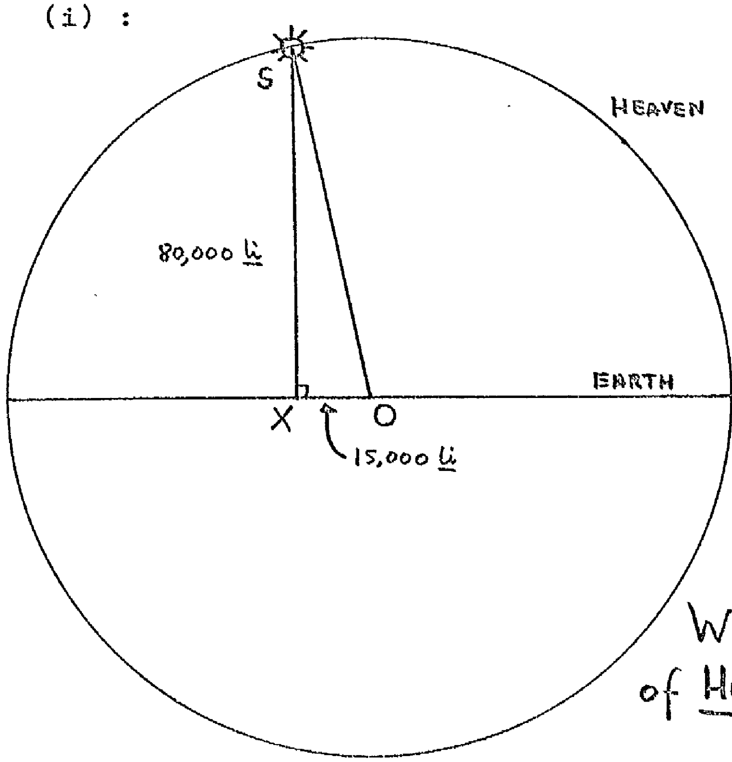


Fig IV (i)

S - sun
O - Yang-ch'eng
X - subsolar point

Wang's calculation of <u>Hun t'ien</u> radius.

In the figure Yang-ch'eng, the centre of the earth, is shown as being likewise at the centre of the heavenly sphere. This is in accordance with Wang's explicit statement. OS is therefore the radius of the heavenly sphere, and Wang calculates it by Pythagoras' theorem :

$$OS^2 = OX^2 + XS^2$$

Hence Wang obtains :

OS = 81394 li, 30 pu, 5 ch'ih, 3 ts'un, 6 fen

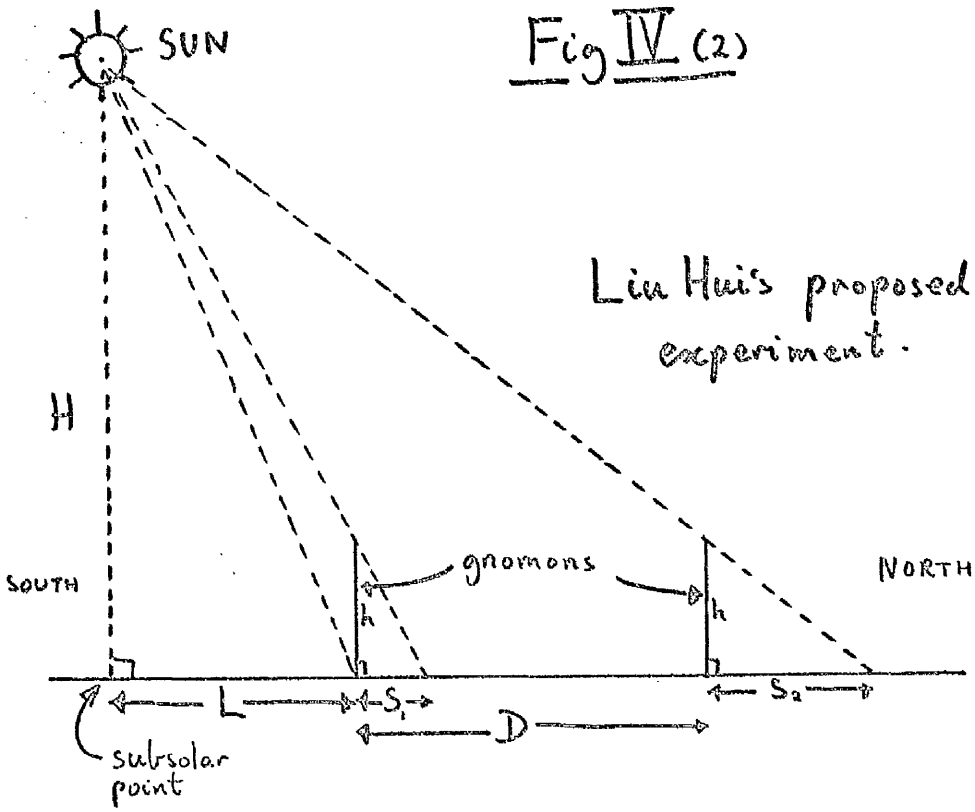
This result is correct as a square root to the nearest fen. The new calculation implies a value for the circumference of heaven of over 513,687 li, and Wang carefully notes the discrepancy between this and the old value which was twice as large, pointing out the grossness of the error that can result from not following the correct method of the ancients. Unfortunately, of course, he is in error to no less an extent than his opponents who simply took the 1,071,000 li circumference of the equinoctial hêng in the Chou pei as the circumference of their celestial sphere. The "inch-for-a-thousand-li" shadow principle is applicable only in a universe where heaven and earth are flat and parallel 80,000 li apart (see Appendix (iii)), and in a Hun t'ien universe even with the usual flat earth it cannot give consistent results. If, for instance, Wang had performed his calculation using the winter solstice shadow of approximately thirteen feet, the radius of heaven would have turned out to be some 150,000 li rather than the value he obtained. We cannot of course tell whether or not Wang felt that the application of the shadow principle was limited to the case of summer solstice shadows.

(d) The problem of measuring the Hun t'ien : Liu Hui

In Wang Fan's work we can see clearly the difficult situation in which the adoption of the Hun t'ien placed the cosmographer. On the one hand it provided a powerful and versatile method of systematising the observations of astronomers, and any astronomer familiar with the use of an armillary sphere - called, after all, a "Hun t'ien instrument" - would be continually confronted with a model of the Hun t'ien universe. On the other hand, unlike the universe of the Chou pei, the Hun t'ien was relatively intractable when it came to the problem of establishing linear dimensions. There is plenty of evidence that Chinese astronomers during the period of this survey felt that the attempt to do this was worthwhile, for it was made repeatedly. One driving force here may have been the apparent lack of the pure concept of angle in early Chinese mathematics : the tu is not so much a measure of the rotational separation of two radius vectors but is rather a measure of the linear separation of two points on the circumference of a circle. Thus a tu varies in size depending on the circumference of a circle, as appears clearly in Wang Fan's discussion, and astronomers seem to have felt some interest in knowing the absolute size of the tu which appeared in their calendrical predictions. Of course a lack of adequate geometry combined with the basic impossibility of establishing the dimensions of a sphere that was in any case non-existent led to eventual disillusion. We can see this clearly in the monk I-hsing's 一行 report on the great meridian survey of A.D. 725 (see Hsin T'ang shu, 31, 813 ff, CHSC, also main Introduction (c))

Prompted, perhaps, by the fact that his survey seemed to suggest a heavenly sphere only 50,000 li across I-hsing rejects at some length any possibility of success in finding celestial linear dimensions.

Interestingly a contemporary of Wang Fan was Liu Hui 劉徽 (fl. A.D. 263), who wrote a commentary on the Chiu chang suan shu 九章算術 . In his preface (p. 92 in Ch'ien Pao-tsung's edition), Liu gives a theoretically correct (on a flat-earth basis) if impractical prescription for observations of the sun, based on the land-survey methods of the Chiu chang itself : he presents this as a tour de force demonstrating their universal applicability. Two gnomons are to be set up in a north-south line at Lo-yang (presumably because of its status as the centre of the earth). They are to be of equal height, and their noon shadows are to be measured simultaneously (see Fig. IV (2)).



Correctly, on the assumption of a flat earth, but without proof, Liu states that :

Altitude of sun, $H = \dfrac{hD}{(S_2 - S_1)} + h$

Distance of southern gnomon from subsolar point,

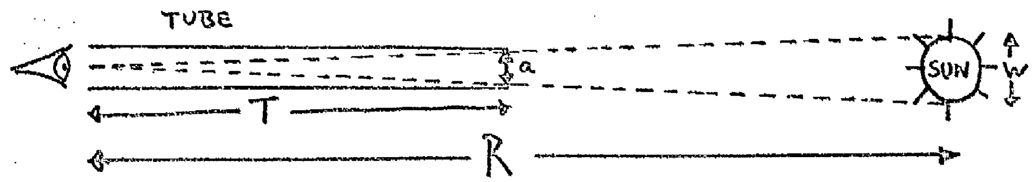
$$L = \frac{s_1 D}{(S_2 - S_1)}$$

Distance of sun from southern gnomon, $R = \sqrt{H^2 + L^2}$

(These results are, of course, given rhetorically rather than algebraically in the original text. Nevertheless they are stated in a perfectly general way.)

Finally, Liu introduces a sighting-tube, as discussed in II (2)(c) above.

Fig IV (3) The sighting-tube & solar size.



Using the dimensions of the tube and the distance of the sun already found, Liu obtains :

Diameter of sun, $W = \frac{Ra}{T}$

In conclusion, Liu exclaims :

> "If even the round arch of heaven can be called capable of being measured, how much more can it be said of the height of T'ai Shan and the breadth of the rivers and seas !"

Of course the snag was that however correct Liu's geometry was, there was no hope of meaningful results being obtained from the sort of baseline available to him. And the longer the baseline adopted, the more glaring would become the discrepancies caused by the fact that the earth is really spherical. Oddly enough, Wang Fan's only later critic on the subject of dimensions, Tsu Keng-chih (c. 490 A.D.) does not notice Liu Hui's work at all (V (2)). The situation remained that either a method was proposed which could not actually be put into practice, or that a false assumption was over-confidently applied.

(e) Shu Hsi on the horizon illusion

Faced with the apparent increase in size of the sun when on the horizon Kuan Ping argued that it must be closer than when at its zenith (III (5)(c)). As a supporter of the Hun t'ien Chang Hêng naturally could not accept this and explained the phenomenon as an optical illusion, suggesting that at noon the sun loses contrast against the bright background of the sky, thus appearing smaller (III (7)(f)).

Shu Hsi 束皙 (fl. c. A.D. 270) went into the question of the mechanism of the illusion in some detail according to the account of his work in the Sui shu, the only source. Unfortunately it is very hard to understand his explanation of the effect :

> "The regions to the side are equal [in distance from us ?] to the regions above. If one looks sideways then the body of heaven is kept at a slant [存側], and so at the time when the sun rises one sees the sun as large. The sun does not shrink or swell, but what it keeps against stretches and is compressed [所存者有伸厭]. When it is compressed its form is small, when it is stretched its body is large, and this is the principle involved."
>
> Sui shu, 19, 513

The preceding version is provisional throughout. The expression 存側 is barely comprehensible; can it perhaps refer to the fact that (in the Hun t'ien system) the surface of the heavenly sphere is vertical near the horizon ? If this is what is meant, why should the apparent size of the sun be affected ? And in the last sentence is the entity referred to the sun or heaven itself ? A century later Chiang Chi wrote on the same problem (IV (9)(c)) and made a comment on Shu Hsi's idea :

> " ... Shu Hsi's statement that the sun is large when the body of heaven is kept in the eye [存於目]is quite close to the truth ... "
>
> Sui shu, 19, 513

Presumably Chiang Chi felt he understood what Shu Hsi had said, but I cannot say that he brings me any closer to that happy position. On the basis of Chiang's commendation, it would obviously be unwise to dismiss Shu's writing as incomprehensible, and one feels much less inclined to do so after reading the rest of the material attributed to him. The Sui shu material continues :

> "When the sun is white on rising, although [apparently] large it is not very much so. When it is red on rising it is very large. This is only because of the confusion of the human eye, not because of varying distance. Further, if a vessel is set down in a large hall, then an ox-boiler looks [as small] as a kettle. If a hall is 80 ft. high then an eight-foot man seems short. It is not that the form of the man changes, but that something has overwhelmed it. Objects can confuse the mind, and shapes can deceive the sight, but this is certainly no reason for doubting fixed principles. Thus when one gazes up at the moon through moving clouds [it appears that] the moon moves continually but the clouds do not shift, and when crossing water in a boat the water [apparently] goes along and the boat does not move."
>
> loc. cit.

Shu Hsi's work is perceptive enough to make one want to see more of it; it is indeed unfortunate that we cannot quite understand some of the little we have left. The comment on the relation between solar colour and apparent size is mentioned again by Chiang Chi (IV (9)(c)).

(3) Yang Ch'üan's Yin-Yang cosmography

(a) Some notes on controversies

We have a considerable number of fragments of a work Wu li lun 物理論 by Yang Ch'üan 楊泉 (fl. c. A.D. 260). Although these are not quite enough to form a complete picture of his cosmographical views, we have enough evidence to reconstruct several interesting features. Before turning to Yang's own theories, however, it is worth noting his comments on the two main cosmological schools. According to Yang :

> "The Confucians set up the Hun t'ien in pursuit of the shape of heaven. In this they followed the idea of a cart wheel ... On rising, the sun [TPYL has 'sun and moon'] passes overhead and in the evening goes below [the earth]. Thus there is rising in the east and setting in the west."

> "The Chou pei set up the Kai t'ien, which says that the heavenly ch'i moves along the edge. In this it follows the idea of a mill-stone ... Heaven turns leftwards. The sun and moon do not move but follow heaven on its edge."

> "If one follows the Hun t'ien theory, the Dipper Pole is not central while if one uses the Kai t'ien the risings and settings of sun and moon are unpredictable."
>
> TPYL, 2, 7b

There is nothing particularly striking here, apart from two slight oddities. One is the reference to the edge-wise motion of "the ch'i of heaven" : does this mean that the ch'i drives heaven round, or vice versa ? The other is the use of Chou pei in a way that gives the impression it is thought to be a man's name (since of course the definite article is supplied in the English). A century later Yu Hsi made this suggestion explicitly, as he did likewise for Hsuan yeh. Another interesting fragment on the Hun / Kai dispute is :

> "Yang Hsiung disapproved of the Hun t'ien and formulated the Kai t'ien. He took this as a round cover, which moved leftwards while the sun moon and constellations were carried with it from east to west. Huan T'an raised objections to this which Yang Hsiung could not understand. This is another example of the difficulty of understanding the Kai t'ien."
>
> TPYL 1, 2a.

This is obviously a version of the disputes that took place about 0 B.C. (see III (4)).

(b) The Yin and Yang in cosmography

It seems that for Yang Ch'üan heaven may not have been a solid vault :

> "The Dipper Pole is the centre of heaven. In speaking of heaven one must make an analogy with man. Below the navel (chi 臍) is the Yin of of man. North of the pole (chi 極) is the Yin of heaven. That which holds up heaven and earth is water. That which makes up heaven and earth is ch'i. The ch'i of water and earth go upwards and form heaven. Heaven is the ruler. Now, the earth has shape while heaven is without body : this is analogous to the case of a fire, with the smoke above the ashes."
>
> TPYL 2, 7b.

The association with the so-called "hsüan yeh" ideas is evident (III (9)).

The physical purpose of this division of heaven into Yin and Yang regions is made clear elsewhere :

> "The North Pole is the centre of heaven and is the northern limit [lit. 'pole'] of the Yang ch'i. South of the pole is the great Yang, north of the pole is the great Yin. When the sun moon and five planets travel through the great Yin they have no radiance, but they are able to shine when they travel through the great Yang. Thus it [i.e. the pole] is the limiting extreme of dusk and dawn, cold and heat."

So yin comm. on Shih chi, 27, 1289, CHSC

This is a repetition of the theory attacked two hundred years earlier by Wang Ch'ung (III (6)(g)). As in that theory, not only the diurnal appearance and disappearance of the heavenly bodies, but also the annual succession of the seasons is explained :

> "The sun is the essence of the great Yang. In summer the Yang is at its height and Yin is in decline. Therefore the days are long and the nights are short. In winter the Yin is at its height and the Yang is in decline. Therefore the days are short and the nights are long. It is the ch'i that calls this forth. The path through the Yang is long [in summer] so it rises and sets north of an east-west line. The path through the Yin [? emend to 'Yang'] is short in winter, so it rises and sets south of an east-west line. In spring and autumn Yin and Yang are equal, and the sun travels centrally, so that day and night are equal."

TPYL, 4, 2b.

This theory is apparently being advanced as an independent alternative to both the Hun t'ien and Kai t'ien, in both of which (see (a) above) Yang Ch'üan suggests the presence of flaws. Wang Ch'ung's objections need not be repeated here, and it is quite obvious that such speculative cosmography is thinking of a different variety from that found in the work of Wang Fan, who was committed to a quantitative and detailed scheme of prediction, closely related to the practice of calendrical science. We have no way of deciding the interesting question of whether Yang's work is an original creation, or drawn from a living tradition, or whether it is a literary survival inspired by his reading of Wang Ch'ung. Such notions recur in the Buddhistic cosmography of Emperor Wu of the Liang (V (5)).

The tidal ebb and flow of Yin and Yang may lie behind a somewhat cryptic fragment :

> "The moon is the essence of water. Tides have their maximum and minimum : the moon has its waning and waxing."
>
> PTSC, 150, 2a

It would, of course, be most unwise to try to decide between the various explanations of this passage with no supporting context. Does the lunar variation affect the tides, or vice versa ? Or are the two phenomena simply both examples of a cosmic Yin / Yang oscillation ? We cannot tell. The discussion recurs in connection with the work of Ko Hung (IV (8)(C)).

(4) Hsü Cheng and a legendary cosmogony

(a) The story of Pan Ku

So far as this survey has touched on questions of cosmogony the material considered has been of a metaphysical rather than mythical nature. (See, for instance, Huai nan tzu, 3, 1a SPTK.) Even in the Ch'u tz'u we find no more direct reference to creation than the unanswered question in the T'ien wen :

> "Who planned and measured out the round shape and ninefold [gates of heaven] ? Whose work was this and who first made it ?"
>
> (see I (2)(b))

It is interesting, therefore, to find an example of creation-myth at this relatively late period. A fragment of the San wu li chi 三五曆記 written by Hsü Cheng 徐整 in the first half of the third century A.D. runs :

> "Heaven and earth were in a confused mass like a hen's egg, and Pan Ku 盤古 was born in the midst of this. After 18,000 years heaven and earth were created. The Yang, being clear, made up heaven, and the Yin, being turbid, made up earth. Pan Ku was between them. In one day he underwent nine transformations, and became more spiritual than heaven, more sagely than earth. Each day heaven rose ten feet and earth thickened ten feet. Pan Ku grew ten feet daily. Thus it continued for 18,000 years, until heaven's height reached the maximum, earth's thickness was at the maximum, and Pan Ku's growth was at the maximum. After this came the three sovereigns [i.e. Fu Hsi, Shen Nung, and Huang Ti]. Numbers begin with 1, are established with 3, completed with 5, filled out with 7, and finished off with 9. Therefore heaven is 90,000 li from earth."
>
> TPYL, 2, 4b, also IWLC, 1, 2a.

When a myth is so precisely informative as to dimensions and durations it is tempting to check its consistency. Unfortunately 18,000 years at 10 feet a day comes to some 36,500 li rather than 90,000 li, so there is apparently no relation between the last sentence and the main text. It may of course be the case that to arrive at the total we are intended to add the three figures of about 30,000 li each for heaven, Pan Ku, and earth. As for the mythical Pan Ku himself, there seems to be no earlier reference, and the legend appears to be a relatively late literary creation. In the opening chapter of the Shu i chi 述異記, a book attributed to Jen Fang 任昉 of the Liang dynasty, the story is developed at length, and the different parts of Pan Ku's body are described as becoming the mountains, seas, and heavenly bodies, etc.

(b) General remarks

A conflation of a number of shorter fragments by Hsü Cheng gives the following reconstituted account :

> "The essence of hot springs rises and gathers to form the sun. Its diameter is 1,000 li and its circumference is 3,000 li. It is 7,000 li below heaven. The essence of the multitude of clouds gathers and forms the moon. The moon's diameter is 1,000 li and its circumference is 3,000 li. It is 7,000 li below heaven. The stars are the brightness of the original ch'i and the essence of water. The large stars are 100 li in diameter, the middle stars are 50 li and the small stars 30 li. The seven stars of the Northern Dipper

are 9,000 li apart. All are below the sun and moon. The Northern Dipper is just above Mt. Kun-lun."

TPYL : 4, 1a and 10b; 5,1a; 7,1b; 38, 5b.
PTSC : 150, 1b, 2a, 2b, 5b.

There is some consistency in these figures, as both the sun and moon have an angular diameter of $\frac{1}{2}^{\circ}$, while the stars of the Northern Dipper are about 5° apart. Perhaps there is a connection with Wang Ch'ung who likewise made the sun 1,000 li across and the stars 100 li (III(6)(d)). It is however odd to find the stars below the sun and moon; the position given for the Northern Dipper may be connected with the rôle of Kun-lun as the central mountain of the earth (see I (2)(b)(40-41)). In that case there is a strong suggestion of the Kai t'ien notion of the central pole. There seems no justification for the figure of 7,000 li. Similarly cryptic is the very brief fragment by Lu Sheng 魯勝 (fl. c. A.D. 290) :

"After the winter solstice I set up a gnomon and observed the shadow. I measured the sun moon and constellations. I submit that the diameter of the moon is 100 li, not 1,000 li, and that the stars are 10 li not 100 li."

Chin shu, 94, 2433, CHSC

Lu submitted this for examination by the officials with the statement that he was willing to suffer punishment if proved incorrect. We do not hear of this having happened : presumably his arguments, now lost to us, were felt to be convincing. Neither this text nor that of Hsü Cheng can be knitted into the main sequence of cosmographical controversy. Nevertheless they are both of them valuable in establishing the existence of a considerable variety of unorthodox theories in the field, whether or not they were ever accepted apart from their authors' immediate circles.

At least in the case of Hsü Cheng we must bear in mind the possibility of influence from non-Chinese sources. Gombrich (1), 115, describes an Indian myth found in the Puruṣasūkta or Hymn of the Cosmic Man, Puruṣa, (Ṛg Veda, X, 90). This document dates from the second millennium B.C., and describes how the gods sacrifice a giant to create the physical universe :

> "Puruṣa is this all, that has been and that will be. And he is the lord of immortality, which he grows beyond through food. Such is his greatness, and more than that is Puruṣa. A fourth of him is all beings, three-fourths of him are what is immortal in heaven. From his navel was produced the air; from his head the sky was evolved; from his feet the earth, from his ear the quarters : thus they fashioned the worlds."

There seems a considerable resemblance to Jen Fang's treatment of Pan Ku mentioned above. It is certainly not inherently unlikely that the whole story could be based on material transmitted from India; a much more striking example is found in the work of Liang Wu Ti (V (5)).

(5) Yao Hsin and his Hsin t'ien theory

(a) Objections to orthodoxy

Yao Hsin 姚信 (fl. c. A.D. 250) wrote a cosmographical essay which survives in several sources (see Textual Notes (6) . His own rather odd theory will be discussed in the next section ; at present his two objections to current thinking will be set out.

Yao's first query suggests that he was not well acquainted with the mathematical aspect of astronomy :

> "I once read the Han shu, which states that at the winter solstice the sun is in the constellation Ch'ien Niu which is far from the [north celestial] pole, and that at the summer solstice the sun is in Tung Ching which is near the pole. The intention is to explain the variation in daylength. I note that the great pole is placed at the centre of the 28 hsiu : although some may be nearer than others the distance could not differ by a factor of two."
>
> Sung shu, 23, 680, CHSC

It is certainly the case that at the winter solstice the sun is about twice as far away from the pole as at the summer solstice : the actual figures are 115 tu and 67 tu. The error here is, of course, twofold. In the first place neither in Yao Hsin's time nor at present could it be said that the north celestial pole was anything like as equidistant from the determinative stars of the 28 hsiu constellations as Yao suggests. Both then and now for instance the stars of the two hsiu K'uei 奎 and Wei 尾 have been approximately 60 tu and 130 tu respectively from the north celestial pole. In the second place, when a Chinese astronomer said that the sun was "in" a particular hsiu, he meant no more than that the sun was somewhere in the segment of hour-angle defined by that hsiu. At the present day, for instance, when the sun has a Right Ascension of 10 hours it has a north Declination of about 12 degrees. Nevertheless it is "in" the hsiu Chang 張 , the determinative stars of which are some 15 degrees south of the equator, but with an identical hour angle. Yao's knowledge of astronomy was evidently somewhat amateurish compar..ed with that of someone like Wang Fan .

His second objection is more striking, but is still not properly thought through :

> "If heaven encloses earth like the white of an egg enclosing the yolk, on what could the earth be supported and be secured ? If it has four braces or stone pillars, they would interfere with the rotation of heaven. If there are no braces and it floats with the support of water, this is not in the nature of something that stands. If heaven passes under the earth through water then the sun moon and stars will not accord with their [fiery] nature. Thus we have the explanation of the two earths. The lower earth is the root of the upper earth, and heaven moves between the two earths. The earth's shape is set up below, and the image of heaven turns above."
>
> TPYL, 2, 7b.
> SLF, 1, 1a, 2b, 3a.

Yao's criticisms of any idea of earth floating on water or being supported by pillars are just enough, but neither he nor any other writer attempts to meet the question of what is to support the supports. How exactly is his "lower earth" to be prevented from falling in turn ? The Greek solution to this was ultimately found in the doctrine of "natural place" which was a considerable advance on the intuitive notions of up and down as absolute directions (Dreyer, 116). The Chinese never made this step, wedded as they were to an unquestioned concept of the flat earth. The concern for some physical support for the universe goes back to the world of the Ch'u Tz'u and may be traced in the assertion of Kuan tzu that something must be bracing heaven and holding up earth : see I (2)(h)(9-10) for both references. In the twelfth century the great Neo-Confucian Chu Hsi felt that to hold earth up in the middle of heaven required the continual whirling motion of the ch'i around it (Chu tzu ch'üan shu, 49, 19a, b).

(b) A theory of the oscillation of heaven

We have already seen that during the Han there were thinkers who were prepared to allow a seasonal displacement of the earth, and perhaps also heaven, in an attempt to explain annual variations in climate, daylength, and solar altitude (III (10)(a)). In what follows, Yao makes a similar attempt, beginning with a rather odd piece of microcosmography :

> "Man is the most spiritual creature, so his shape is most like heaven. Now a man's chin is inclined over his chest, and the back of his head does not

cover his spine. Taking the analogy from the body, we can tell that the heavens incline down into the earth in the south and are inclined upward in the north.

At the winter solstice the pole sinks down, and heaven turns nearer to the south. Thus the sun is further from men and the pole is nearer. The ch'i of north heaven comes, so it is freezing cold. At the summer solstice the pole rises and heaven turns nearer to the north. Thus the pole is further from men and the sun is nearer. The ch'i of south heaven comes, so it is boiling hot.

At the time when the pole is high the sun goes only a shallow distance below the earth, so the night is short. Heaven is high above earth, so the day is long. When the pole is low the sun travels deep into the earth, so the night is long. Heaven is not far from earth, so the day is short. Thus in winter heaven moves in accordance with the Hun t'ien, and in summer in accordance with the Kai t'ien."

(see Textual Notes (6), and Sui shu, 19, 508; Sung shu, 23, 680)

Note that Yao Hsin evidently believes in the attachment of the sun to heaven, as he makes the rising and sinking of heaven move the position of the sun. All this is, of course, exactly the position criticised by Wang Ch'ung 150 years before. Why, he asked, does the moon, also attached to heaven, appear lower in the sky in summer rather than higher ? (III (6)(i)). There is the further objection, common to all theories involving a relative translation of heaven and earth : why are not less stars visible in winter than in summer ?

In all sources of the above material Yao's theory is given the name Hsin t'ien 昕天 , which would mean something like "bright heaven". It is this term that Yü Hsi uses in his passing reference written c. A.D. 340

(IV (7)(b)). He Tao-yang (fl. c. A.D. 450) says however that Yao Hsin originated a theory called *Hsien t'ien* (V (1)(a)), and Shen Yueh the compiler of the *Sung shu* (c. A.D. 500) says that *Hsin* must be an error for *Hsien* as in *hsien ang* 軒昂 "upstanding" (*Sung shu*, 23, 680, CHSC). In the first half of the seventh century A.D. K'ung Ying-t a 孔穎達 says that in this case 昕 *Hsin* should be read as 軒 *Hsien*, meaning that heaven is inclined up high in the north and down low in the south, "like the rail (*hsien*) of a chariot" (*Li chi*, 14, 7a, subcomm. SSCCS). The proposed loans are phonetically possible whether or not they are semantically likely : for the T'ang pronunciation Karlgren gives (GSR) 443h 昕 χi̯ən and 139g' 軒 χi̯ɒn . Nevertheless these attempts at clarification do not seem particularly helpful, and all that we can say is that the meaning of the original term has always been obscure.

(6) Liu Chih : a universe in harmony

(a) Cosmographical theories

Liu Chih 劉智 (c. A.D. 220-290) is one of a number of authors whose work has been transmitted to us through a single source, the K'ai yuan chan ching. Apart from the long text in KYCC 1, 23b-27a there are only a few scraps in Sui shu, 19, 520, CHSC, in TPYL 2, 8b, and CSC 1, 1a. There are no references to Liu's theories in other authors' discussions. Nevertheless his writing is an elegant and perceptive treatment of certain problems in cosmography from the third century viewpoint, and goes a considerable way towards filling a similar rôle for celestial physics to that played for cosmological mathematics by Wang Fan's work.

Liu Chih followed the tradition that we have already met in the work of Lu Chi, claiming a very much earlier origin for cosmographical theories than the admittedly somewhat sparse evidence now available might lead us to conclude. Liu represents an interlocutor as noting in a query addressed to himself that :

> "Hsüan Hsü Shih 顓頊氏 made the Hun i and Huang Ti 黃帝 made the Kai t'ien."
>
> KYCC, 1, 25a

The conventional dates for these legendary emperors' accessions are 2513 B.C. and 2697 B.C. respectively, although some sources reverse the sequence.

It is interesting to note that priority is apparently given to the Kai t'ien : Liu's ideas on the origin of the Hun and Kai do in fact require this. He conceives of both theories as having been embodied in instruments from the very first, which is presumably why he uses the term Hun i 渾儀 [spherical instrument] rather than Hun t'ien 渾天 [spherical heaven]. Hun i is of course a well-known name for the armillary sphere. Liu does not carry his logic to the point of creating a neologism Kai i 蓋儀 . Nevertheless, he believes that a "Kai instrument" once existed :

> "Now both these are devices of ancient manufacture, but those who have handed on the theories have lost the proper method of using them. Formerly, when the sage kings ordered the calendar and clarified the seasons they made a round cover [kai] in order to illustrate the hsiu in sequence, and the pole was at its centre. They rotated it in order to view the celestial constellations, but it was not good enough for fixing dawn and dusk or ascertaining the division between day and night. Therefore they made the Hun i. They made an image of the body of heaven, likewise with the pole at the centre ... "

KYCC, 1, 25 a-b.

Disregarding the conventional but impossible chronology there is a good deal to be said for Liu's suggestion as to the origin of the main cosmographies. The diagram of the seven hêng in the Chou pei is certainly a skeleton planisphere, even if we have no ancient examples of actual physical devices of this kind (II (3)(b)). Further, I think we may reasonably conclude that there must have been an inseparable link between the conception of the celestial sphere and the development of armillary instruments (III (3)(c)). The great advantage of the Hun t'ien was of course that an armillary sphere was in effect a model of the macrocosm and that by the process of astronomical observation it could be seen to be capable of apparently exact correspondence with the large-scale universe.

Liu's general statements about the Hun t'ien are not particularly remarkable. He does say that the round heaven encloses a squqre earth (KYCC, 1, 23b), and earth is said to be supported by ch'i (KYCC, 1, 24a). The objection he raises against the Kai t'ien is the well-known one that under that system it is impossible for the sun to rise due east and set due west on a day when day and night are of equal length, which is in fact what actually occurs at the equinoxes. This point was also made by Huan T'an c.10 B.C. (III (4)(a)).

(b) Yin - Yang interaction and the cause of eclipses

It may be recalled (III (7)(c)) that Chang Heng advanced an explanation of lunar eclipses according to which the earth's shadow fell on the celestial sphere diametrically opposite the sun. This place was called by him the an hsü 闇虛 or "dark space", and when it passed through this position the moon suffered eclipse. Consistently enough, for Chang believed that the stars too drew their illumination from the sun, he considered that the passage of this shadow across a star likewise blotted it from view. Apart from this last feature, Chang's explanation seems to the modern reader both accurate and obvious.

As we shall shortly see, Liu Chih shows that he is acquainted with this theory, but nevertheless bases his ideas of eclipses on quite different principles. For him the relation of sun and moon are determined by their status as complementary opposites : the sun is the great Yang emitting radiance, the symbol of the ruler, while the moon is the great Yin, accepting the Yang's radiance, the symbol of the servant (KYCC, 1, 24a). For Liu it is therefore quite appropriate that the nearer the moon is to the sun the less it should be illuminated

> "Thus we can see that the moon is the symbol of a servant."
>
> KYCC, 1, 24b

As for a lunar eclipse, which always occurs at a full moon, this is because the greater strength of the Yang has suppressed the weaker Yin, preventing it from following its nature (ibid). Naturally a solar eclipse is an ominous matter for Liu, as representing an instance where the moon and sun have crossed in their travels, and the Yin has, contrary to nature, overcome the ruling Yang :

> "For the moon to conceal the body of the sun is for the lowly to behave coercively towards the honourable. Therefore in times of great peace conjunction [of sun and moon] occurs without an eclipse, for the honourable and lowly follow their appropriate way." KYCC, 1, 25a.

In this last passage we can see a reflection of the practical difficulty of solar eclipse prediction. At least a lunar eclipse is visible to all observers who can see the moon; in the case of a solar eclipse, however, the phenomenon will only be seen by those lying in the relatively narrow track of the moon's shadow over the earth's surface. An added difficulty for the Chinese astronomers was of course that they lacked the knowledge that the earth was spherical. Nevertheless a considerable degree of skill was developed in empirical prediction of the times when the observation of a solar eclipse was highly likely, reaching its peak with the work of the Yüan astronomers before decline set in under the Ming (see SCC III 420).

Chou Huang 周晃 , a contemporary of Liu Chih, wrote a memorial which was evidently meant as an apologia for instances where a predicted solar eclipse had failed to occur :

> "At the moment of conjunction it may happen that the moon covers the sun. When this occurs it obscures the body of the sun and the sun's radiance wanes. This is called a solar eclipse. Or possibly the sun covers the moon, and then the sun travels over the moon. This is called 'the Yin not encroaching on the Yang'. Even though [the sun and moon] meet, no change occurs. There is no way of predicting when the sun and moon will obscure one another in such a way that an eclipse must occur."

<u>Tung tien</u>, 78

(c) Liu's criticism of the "dark space" theory of lunar eclipses

Wang Ch'ung rejected the correct theory of solar eclipses, and it cannot be said that his objections were very convincing ones (III (6)(f)). I do not think it is quite clear from the passages quoted above whether or not Liu Chih is rejecting the theory of solar eclipses in its usual form involving physical obstruction. He seems rather to be saying that such events are bad omens rather than that they could never occur (cf. SCC III, 414). Liu is, however, quite uncompromising on the question of the "dark space" theory of lunar eclipses :

> "Someone asked : 'Discussions of lunar eclipses in ancient calendars ... sometimes say that it is the "dark space" ... Now why is it that you, sir, do not agree with this ?'
>
> Liu Chih replied : 'As to the "dark space", it is held that diametrically opposite the sun is the shadow of the earth, where the sun's rays do not reach, and this is called the "dark space". Now when light is emitted, and the radiating body is smaller than the object obscuring it, the shadow is larger than the original object. Now, if the sun, with a diameter of 1,000 li, is obscured by the body of the earth then the "dark space" shadow will be more than half [of heaven (?)]. So why should it only be at the precise point of opposition that the stars disappear and the moon wanes ? By this argument it is evident that the better theory is that the Yin [i.e. the moon] does not take in the illumination [of the sun]. [Because, that is, it has been weakened by the Yang as in (b) above]."
>
> KYCC, 1, 26a.

Liu's argument is quite devastating. The "dark space" theory is completely untenable in the universe pictured by any ancient Chinese cosmographer of whose work we have evidence. For all of them who give an opinion, the sun is a relatively small body compared to the earth which extends almost completely across the heavenly sphere. Thus Liu's objection holds, and it does not seem quite fair to call him "a mind prevented from accepting the simplest explanation of the facts by a preconceived theory of an organic universe of inevitably interacting parts" (SCC III, 415).

Liu is quite alive to the consequences of his argument, for he makes his imaginary interlocutor continue :

> "If, as you have argued, there must be a large shadow, how is it that the moon shines when in opposition to the sun ?"
>
> ibid

Indeed, why are there any luminous bodies in the night sky at all ? Liu responds by rejecting anything approaching geometrical optics as an explanation of why the moon shines. For him it is a question of a much more subtle transmission of influence, akin almost to radio transmission :

> "Liu Chih replies : 'The Yin is bright because it takes in the Yang. It does not need the brightness of the Yang to illuminate it. The Yin and Yang respond to one another, that which is transparent taking in brightness, and that which is cold taking in warmth. [This is] penetration without an opening : the mutual response takes place whatever the distance. Thus clouds appear where stone is found(?): this is the penetration of the <u>ch'i</u> of water. [The sun and moon] face each other and reach each other irrespective of any distance or barrier."
>
> ibid

Liu goes on to argue that if the sun really illuminated the moon directly, a strong sun (Yang) would imply a bright moon (Yin), which would contradict the usual principle according to which Yin and Yang predominate alternately.

Liu's universe is certainly harmonious and organic, but the trouble is that the Yin - Yang theories he uses are far too accommodating. All solar and lunar phenomena can easily be "explained" in terms of the ebb and flow of the Yin and Yang, or of their conflict or misbehaviour. The "dark space" theory proved its Popperian credentials by being so vulnerable to testing that it met its end, ironically enough, by failing to fit into a falsely conceived cosmos. As only catastrophic changes in the common world-view could have prevented this, involving an increase in the scale of the universe by at least twenty-fold so that the sun could be larger than earth, Liu cannot be blamed much for rejecting the theory.

(7) Two Theories from the Yü family

(a) Heaven supported pneumatically

The Yü family produced two men who apparently took an interest in cosmography. The better known was Yü Hsi 虞喜 (fl. A.D. 340), said to have discovered the precession of the equinoxes (SCC III, 356); his theories are discussed in (b) below. Here I shall deal with the work of Yü Sung 虞聳, his senior by two generations, and possibly active c. A.D. 265. (See Textual Notes (7) for the difficulties of authorship and genealogy here.)

Following the Yü Sung fragment in Chin shu, 11, 280, CHSC, we have :

> " ... [Yü] Sung further set up the Ch'iung t'ien 穹天 theory, which says : 'The form of heaven arches (ch'iung) upwards like an eggshell and its edge meets the boundary of the four seas on all sides. It floats on top of the primal ch'i. This is analogous to pressing an inverted bowl down on water, when it does not sink, the reason being that it is full of ch'i. The sun circles the north pole, setting in the west and returning from the east : it does not go in or out of the earth. Heaven has its pole in the same way that a chariot umbrella has a boss. From the north of heaven down to earth is 30 tu, and likewise the pole's tilt places it 30 tu north of the east-west line [mao-yu 卯酉] of earth. Man dwells over 100 ,000 li to the south of the east-west line, and therefore below the Dipper pole is not the centre of earth, which should correspond to the position of the east-west line of heaven and earth. The sun follows the ecliptic round the pole. The pole is 115 tu away from the ecliptic northwards and 67 tu

away from the ecliptic southwards. The long and short distances are where [the sun] lodges at the two solstices."

Yü Sung's idea that heaven is supported by the ch'i underneath it is not new, although it is vividly expressed : see Chang Heng's reference, III (7) (c). There seems to be a strong hint, reinforced by the box analogy, that heaven is approximately hemispherical rather than the usual complete sphere of the Hun t'ien. The whole fragment is, unfortunately, too incomplete and elliptical in expression for us to form a definite picture of Yü Sung's cosmography. Are we to gather that he believed in the Kai t'ien theory of the illusory nature of sunrise and sunset from his denial that the sun goes "in or out of the earth" ?

The statement that man is over 100,000 li south of "the east-west" line may come from the Chou pei's figure for the distance from the observer to the sub-polar point : this was of course 103,000 li (II (2) (a)). Yü Sung seems to be suggesting that the celestial pole ought to be over the centre of earth but was not in fact so placed. Could he have believed that some disaster such as that of Kung Kung had caused the tilt ? (I (2) (b) (35)). A century later Ko Hung (IV (8)) pointed out that under Yü Sung's scheme the northern stars, being more distant, should appear closer together than the southern stars (TPYL, 595, 3a : see Textual Notes (7) on the attribution to Hung 洪). The Kai t'ien was of course subject to similar criticisms (III (4) (b) (viii)).

(b) Yü Hsi's theory of the fixity of heaven

Before we examine Yü Hsi's opinions on other cosmographical theories, let us see what his own An t'ien 安天 theory consisted of :

> " ... I consider that heaven is infinitely high, and earth unfathomably deep. Heaven is firmly placed above, and has a form constantly at rest (an), while earth is solidly below and has a body reposing in quiet. The one is covered by the other, which fits it. If one is square both are square; if one is round both are round. It makes no sense for them to be different as to squareness or roundness. The luminaries are disposed in order, each one moving round on its own, like the ebb and flow of the Yangtze and the sea, or the activity and retirement of persons in office."

Sui shu, 19, 507, CHSC

(see also Textual Notes, (7))

Apart from the denial that heaven and earth differ in shape, Yü Hsi's fixed vault represents a return to archaic ideas (I (2) (c)). Naturally, as heaven cannot, as in the Hun t'ien, carry the celestial bodies round with it, they must move of their own accord. It may be this feature that caused the Sui shu and Chin shu to suggest that Yü based his thinking on Hsüan yeh ideas (III (9) (a)). Both of these likewise mention the criticism by Ko Hung, who was a contemporary of Yü Hsi :

"If the constellations are not attached to heaven, then heaven has no function, and one might as well say it did not exist. What is the point in saying that it exists but does not move ?"

Sui shu, 19, 508

Note that it is clear from the work of Ko Hung (see IV (8), *passim*) that he believed in the *Hun t'ien*. We must therefore take this criticism as a protest against the denial of heaven's rightful function rather than as urging Yü Hsi to go all the way and abandon a solid heaven altogether. The reference to the shapes of heaven and earth by Yü Hsi may be a reminiscence of the well-known passage from the beginning of Chapter 83 of the *Ta tai li chi* :

"If heaven was really round and earth really square this would mean that the four corners [of the earth] would not be covered."

(c) Yü Hsi on cosmographical theories

A sizeable fragment in TPYL, 2, 9a, partly paralleled in *Shang shu chu su*, 3, 6b, SSCCS, gives a discussion by Yü Hsi of the three main cosmographies. Both the *Hun t'ien* and *Kai t'ien* are correctly but briefly characterised, with a note of the *Chou pei*'s theory of sunrise and sunset as optical illusions. A novel criticism of the *Hun t'ien* is as follows :

"I submit that if heaven enclosed earth like the yolk in the middle of an egg, then earth is an object in heaven. Why did the Sages give it a separate name and make it the correlate of heaven ?"

TPYL, 2, 9b

Yü also criticises "an ancient tradition", obviously connected with the archaic notions of I (2) (b) (15), according to which the sun and moon pass through a "flying valley" Fei ku 飛谷 somewhere in the earth. He points out that this would involve the celestial bodies passing through water (see also IV (8) (a)). Oddly he connects this with the Kai t'ien. As for the Hsuan yeh, he states that nothing is known of what form it took. He notes that a Mr. Chen 陳氏 thought that the names of the cosmographical theories might simply be the hsing and ming of their inventors. However, he also explains Chou pei 周髀 as referring to the circling, chou, of heaven above the low pei 卑 earth. Likewise Hsüan yeh means "light and dark", because "its methods united the calculations of dark and light" (Shang shu chu su, 3, 6b, SSCCS). This is, of course, all speculation on Yü's part.

(8) Ko Hung

(a) On the Hun t'ien and the hexagrams

Ko Hung 葛洪 (fl. A.D. 320-340) is equally well known by his hao Pao P'u Tzu 抱朴子 . A book by this name and indisputably written by 抱朴子 extant, but little of the material used in this survey is drawn from it. He was best known as an alchemist (SCC V : 2, 62) although I hope what follows will show that he was also well-informed on matters of cosmography. A good text of an essay by him is preserved in Chin shu, 11, 281, CHSC, paralleled closely by Sui shu, 19, 509, CHSC, and partly by TPYL, 869, 4b (small fragment in CSC, 1, 3b) The essay begins with a condensation of the beginning of Chang Heng's Hun t'ien i (III (7)(c)) and praises the exactitude of the Hun t'ien theory. Lu Chi is named as one who carried on Chang's work, and it is interesting that Ko Hung leads into a discussion connected with Lu's "proof" that the Hun t'ien was described in the text of the I ching (IV, (2)(a)).

The problem confronted is as follows : clearly if heaven surrounds the earth, and earth is supported on water as described by Chang Heng, then heaven must pass under this water. Yü Hsi, a contemporary of Ko Hung, was one of those who objected to this (IV (7)(c)), and the problem had been raised by Wang Ch'ung three centuries earlier (III (6)(i)). Ko does not attempt to deny the existence of the waters beneath the earth, but answers the difficulty by pointing out that there is no real problem in this situation. Indeed, he gives his answer in terms of the "correlative thinking" that others relied on to suggest the impropriety of the submersion of the heavenly sphere. Thus, he argues, both heaven and dragons are Yang. Dragons are aquatic creatures. (It must be remembered that this is not the fiery dragon wyrm of Germanic myth, but the beneficient rain-bringing lung 龍 .) Therefore heaven, being likewise Yang, should find no obstacle to being under-water. This is the usual correlative pattern, according to which groups selected on fairly arbitrary criteria are said to be closely linked in their essential properties and behaviour (SCC II, 279). Ko Hung gives a further proof using a similar thought scheme, in this case the theory of the wu hsing 五行 "five elements" i.e. water, fire, wood, metal, and earth. Heaven corresponds to the element metal, and metal and water are linked by the relation of "mutual production" hsiang sheng 相生 (SCC II, 255). Hence there is no incompatibility about heaven passing through water

Even more non-physical for a modern reader is Ko Hung's second argument, in which he turns to the I ching. It will be remembered (IV (2)(a)) that Lu Chi had already used the text of this work to argue that the

Hun t'ien was known in very ancient times. Ko Hung, however, takes it as axiomatic that the I ching is a repository of truth, and proceeds to prove that heaven can pass beneath the earth by pointing out that this can be deduced from the hexagrams themselves. Here he relies on the fact that the component trigrams of a hexagram have their own significance. Thus :

☰	Ch'ien 乾	heaven
☷	K'un 坤	earth
☵	K'an 坎	water
☲	Li 离	fire

Given this scheme he points to the two following hexagrams as evidence that the sun can be either above earth or below it :

䷢	Chin 晉	(fire above earth)
䷣	Ming I 明夷	(fire below earth)

Similarly, heaven can pass beneath water :

䷄	Hsü 需	(heaven below water)

A logical objection which springs to mind is that since the I ching contains all possible hexagrams (a total of 64), it can be used to prove that any given set of circumstances can occur, given the wide range of symbolism attached to the component trigrams and even to individual lines. Perhaps, however, Ko Hung, as a Taoist committed to a universe of continual transformation (SCC, II, 439), would not have seen this as an objection of any force, but rather as a point in support of his views.

(b) The attack on Wang Ch'ung

The reader will recall Wang's voluminous polemic in favour of the Kai t'ien (III (6)). One of his first points against other theories was of course that they involved the passage of heaven through the subterrene waters. Ko Hung does not mention Wang's name in the argument reviewed in (a), but the references to him in subsequent sections suggest strongly that the whole essay is intended to act as an antidote to his arguments for the Kai t'ien. For convenience of reference I shall deal with Ko Hung's points in a numbered sequence in the same order in which they occur in the original. (The arguments are paraphrased for the sake of brevity.)

(i) Huan T'an is quoted for the two arguments referred to in III (4)(a), q.v.

(ii) From rising to setting, all heavenly bodies rise upwards from the eastern horizon, culminate, and move down over the western horizon. Hence heaven cannot be moving "like a mill-stone" as Wang Ch'ung argued (III (6)(d)), for then we would expect the stars etc. to perform a circuit east-south-west-north-east ..., and they do not do so.

There are extant three fragments, parallel in essentials, in which Ko Hung describes the mill-stone analogy as a theory of the "Chou pei school", in words very similar to those used by Wang Ch'ung : see TPYL 967, 5b; 762, 8a, and PKLT, 84, 13b. (cf. Chin shu 11,279; Sui shu 19, 506)

(iii) The sun is 1,000 li across, much bigger than stars. Even if, as under the Kai t'ien, the sun has moved too far away for its rays to be visible, one should still be able to see its body. Further, if the stars are visible when to the north of the pole, why not the sun, which is much brighter ?

It is interesting from the point of view of optics to note that Ko Hung distinguishes between seeing the light from a body and seeing the body itself. On the second part of the argument, a Kai t'ien supporter might well have argued that the sun, viewed as an aggregate of small sources of light, could have no greater illuminating range than each source alone. One can easily imagine Wang Ch'ung replying thus, but by the time of Ko Hung the supporters, if any, of the Kai t'ien are no longer represented in the remaining literature.

(iv) If, following Wang Ch'ung's analogy of the torch (III (6)(b), it is assumed that the setting of the sun and moon is an illusion, and that what is really happening is that they move too far away to remain visible, then they should gradually shrink away at "setting". But, on the contrary, they appear larger.

(v) When the sun has half set, it is "like a mirror broken horizontally". But if it is really moving round northwards as under the

Kai t'ien, the northern edge should be first to pass out of range, and so the dividing line should be vertical.

(vi) Even when the relatively weakly shining moon is obscured by clouds, the night is still not completely dark. So even if the sun did pass to the north of the pole, surely, as it is very bright, the night should never be very dark at all.

(vii) Heaven intends the sun and moon to shine on the earth in turn. This could hardly be the case if, as under the Kai t'ien, the sun is always above the earth.

(viii) Wang argued that the sun and moon were, respectively, the essences of fire and water, and that since fire and water were not round on earth, no more could the sun and moon be so in heaven. Their apparent roundness was an illusion due to distance (III (6)(h)). In apparent opposition to this, Ko Hung states that water and fire are "the surplus ch'i of Yin and Yang", while the sun and moon are the essences of Yin and Yang. Thus fire can be obtained from the sun with a speculum, and water can be obtained from the moon with a dew-tank (SCC, IV : 1, 89-90), but the process is not reversible. Clearly therefore, fire and water do not produce the sun and moon. Ko disposes of Wang's supposed relation between the producing agent and the product by pointing out that the fire from a speculum is not round, nor is the water from a dew-tank square.

(ix) As to Wang's theory that the apparent roundness of sun and moon is an illusion due to their distance, Ko Hung points to the phases of the moon. If Wang was right, the moon ought not to change shape, but should remain round while periodically shrinking and swelling. Similar considerations apply to solar eclipses.

Needham (SCC, III, 413, (g)) suggests that Ko Hung, like Aristotle, is arguing here for the moon's sphericity from the appearance of its phases. I do not think that this is the point he is making. Ko's argument would not be affected if the moon was simply a disc whose shape changed periodically, and it is hinted in (iv) that the sun is in fact a disc. The sphericity of sun and moon does not seem to be explicitly stated before Chiang Chi c. A.D. 385 (IV (9)(b)).

Note that Ko Hung does not refer to the eight objections to the Kai t'ien supposedly propounded by Yang Hsiung (III (4)(b)). As already mentioned, this may suggest that that material is of later date than it purports to be.

(c) The tides and the motion of heaven

In the period of this survey it is not easy to find evidence of detailed discussion of the relation between tidal phenomena and the moon (see SCC III, 483 ff). Ko Hung makes the connection in one fragment :

> "The essence of the moon produces water. Therefore when the moon is full the tides are large."
>
> TPYL, 4, 8b.

The trouble is, of course, that although spring tides do indeed occur at full moon, they also occur at new moon, when the moon vanishes entirely. Nevertheless it is interesting that Ko Hung does seem to believe that the moon actually causes the tidal variation. Yang Ch'üan, as can be seen from a fragment of his Wu li lun seems to have been more typically Chinese in that he simply points out a correlation :

> "The moon being the essence of water, on the one hand there are large and small tides, and on the other hand there are waxings and wanings of the moon."
>
> PTSC, 150, 2a

Note, by the way, the difference over which of the moon/water pair has priority : see above, (b)(viii).

Elsewhere Ko Hung deals with the tides in much more mechanical terms. In one instance the Milky Way, known as the T'ien ho 天河 "celestial river" is taken as actual water. Beneath the earth :

> " ... it meets with the lower waters and joins with the waters of the sea. The three waters mix together, and the rotation of heaven stirs them. Therefore they seethe turbulently and form the tides."
>
> TPYL, 68, 5b.

After rejecting an attempt to derive 潮 ch'ao "tide" from 朝 "morning", he states :

> " ... The waters come from the edge of heaven. In the course of a month heaven goes eastwards twice and westwards twice. Therefore the tides are twice large and twice small. Again, in summer the sun is in a southern hsiu. The Yin is depleted and the Yang is full. Thus heaven rises 15,000 li and so the tides are large. In winter the sun is in a northern hsiu. The Yin is full and the Yang is depleted. Thus heaven sinks 15,000 li and the tides are small. Again in spring the sun is in an eastern hsiu, and heaven is rising [lit: "is high"] 15,000 li, so the spring tides gradually increase. In autumn the sun is in a western hsiu, and heaven is falling [lit: "is low"] 15,000 li, so the autumn tides gradually lessen"
>
> TPYL, 68, 5b
> also
> TPYL, 23, 6a, in part

Ko describes the monthly phenomena correctly enough in the second sentence, but his notions of high tides in summer and low tides in winter apply only to the day tides. The figure of 15,000 li is obviously connected with the K'ao ling yao tradition (see III (10)), but the fact that the Yin and Yang are stressed and that it is heaven that moves rather than earth suggests a stronger link with Yao Hsin's theories (see IV, (5)). All this is certainly something of an unexpected addition to Ko Hung's otherwise straightforward Hun t'ien views. Note that Ko's tidal theory seems to demand a solid heaven. The question of his possible involvement with an insubstantial heaven is dealt with in III (9).

Volume 3 of 3

COSMOGRAPHICAL DISCUSSIONS IN CHINA

FROM EARLY TIMES UP TO THE T'ANG DYNASTY

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Volume 3

(9) Chiang Chi

(a) The Hun t'ien and Kai t'ien

Chiang Chi 姜岌 (fl. A.D. 385) is one of several cosmographers who would have remained almost unknown to us if not for the slender chain of good fortune that preserved selections from their work in the *K'ai yuan chan ching*. In succeeding sections I shall discuss his views on the motion of the earth and on questions of what may be called "celestial optics", such as the horizon illusion; these are of considerable interest and originality. Before this, however, a brief account of his notions about more central issues may help to set the rest of his thinking in context.

A substantial essay by him, entitled *Lun t'ien* 論天 is found in KYCC 2, 1a - 5a. It opens with the statement that two cosmographical theories, the *Hun t'ien* and *Kai t'ien*, have come down to his day. Perhaps significantly, the *Hsüan yeh* is not mentioned (see III (9)). The *Kai t'ien* is accurately described, with its slightly convex earth and its distance-illusion theory of sunrise and sunset. Yang Hsiung is mentioned as an opponent of the *Kai t'ien*, and it is interesting that the one objection given as propounded by him is the comparatively subtle "water-level" experiment. This claims that the use of a water-level on a mountain top shows that the rising sun is below the observer, thus falsifying the Kai t'ien claim that the heavenly bodies are always far above the earth. It is the sixth of the "eight objections" discussed in III (4) (b), where it was concluded that there was some doubt as to whether they should in fact be attributed to Yang Hsiung.

Chiang's short description of the Hun t'ien is paralleled almost exactly in KYCC 1, 20b. Earth is inside the sphere of heaven, and the axis of this sphere is tilted, so that the north celestial pole is 36 tu above the earth, and the south celestial pole is 36 tu below it. The consequence of this is that round the north pole there is a 72 tu diameter circle of perpetual visibility, while in the south there is a 72 tu diameter circle of perpetual invisibility. The equator and the ecliptic are not mentioned, and we are simply told that the orbits of the seven luminaries follow a constant rule. It becomes clear later than Chiang does not believe that the heavenly bodies are moving on the inner surface of the heavenly sphere. Further, although he does not seem to wish to dismiss altogether a seasonal displacement of the sun's orbit, he lays far greater stress on the effect of the displacement of heaven and earth, the sun's path being regarded as fixed in space. Naturally, therefore, the ecliptic as a circle on the heavenly sphere has less significance for him than for more orthodox followers of the Hun t'ien who believed the earth to be at rest.

(b) The sun and moon; eclipses

Another work by Chiang Chi is his Hun t'ien lun ta nan 渾天論荅難 , preserved in KYCC 1, 20a - 22b. It is in the form of a dialogue between Chiang and an objector. In the first place the problem is raised that whereas it is perfectly proper for the sun (Yang) to emit light, how is it that the moon (Yin) can do this also ? Chiang responds that the moon shines by the sun's reflected light : this is the position first stated by Ching Fang in the first century B.C. (III (5)(a)) and rejected by Liu Chih (IV (6) (c)). Chiang goes on to make an important statement, in which the phases of the moon are correctly explained for the first time :

> "Also, the moon does not wane and wax. Waning and waxing are due to men's [point of view]. The bodies of sun and moon are like round pellets, each of diameter 1,000 li. Where the moon faces the sun it is always bright. At the new moon the sun illuminates its west side, but men are to the east of it, and do not see the brightness ... at opposition men are between sun and moon, and so they see [the moon] as round. Suppose that at the time of new moon a man was transported to between the sun and moon and looked eastwards; the moon would shine as round as at opposition."
>
> KYCC 1, 21a

This appears to be the earliest explicit statement that sun and moon are spherical, although we have of course seen previous examples of their being referred to as "round" yuan 圓 , which could mean either a sphere or a disc. Naturally, no convincing explanation of the moon's phases was possible until this point had been cleared up. The dimension given is, of course, the usual figure.

Remembering Liu Chih's discussion of lunar illumination, the next objection is predictable :

> "The brightness of moon and stars is, [according to you] produced when the sun illuminates them. But at midnight at the time of full moon the sun is below the earth and the moon is above the earth. The earth interposes between them. How can the sun's rays manage to illuminate the moon ? And how can there [only] be a 'dark space' always diametrically opposite the sun ?"
>
> KYCC, 1, 21b

Chiang's interest in lunar eclipses was not purely theoretical. In A.D. 384 he compiled a calendar, the San chi chia tzu yuan li 三紀甲子元曆 (Chin shu, 18, 566, CHSC), and pioneered the technique of locating the precise position of the sun on the assumption that it is diametrically opposite the moon during a lunar eclipse (ibid, 570). The point about the 'dark space' an hsü 闇虛 was thus of great importance to him. Unlike Liu Chih, Chiang Chi was committed to the actual irradiation of the moon by the sun, and he could only maintain this position if he could suggest a means by which the sun's rays might reach the moon despite the presence of the flat earth extending over most of the horizontal diameter of heaven. His answer is :

> "In illuminating the heavens, the sun leaves no place, whether in darkness or light, that it does not reach. It blazes forth between the four poles,

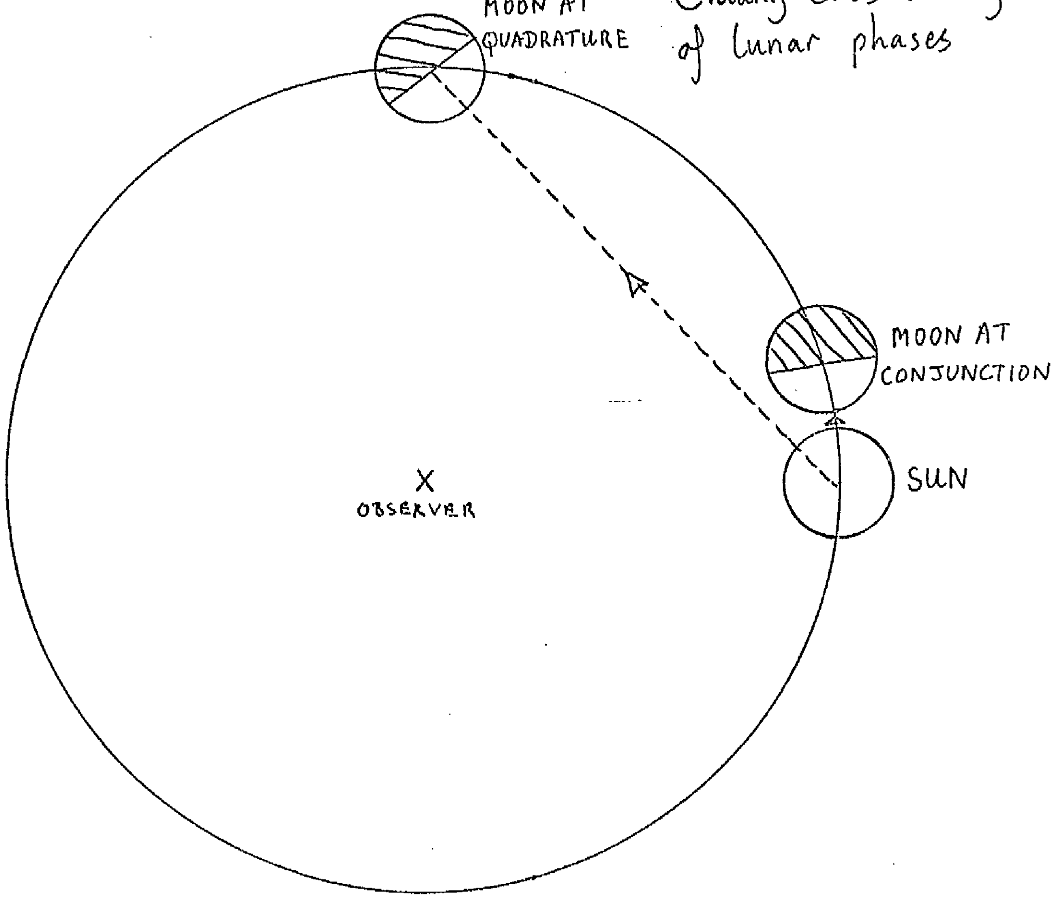
> and shines throughout the universe. [Its rays] shine along [the surface of] heaven and illuminate the stars and the moon, like flames licking up inside a chimney, with the result that its illumination passes through every place. Only diametrically opposite [the sun] it does not shine, and this is called the 'dark space'."
>
> KYCC, 1, 21b.

Thus the sun's rays are propagated along the inner surface of the celestial sphere, and illuminate the moon and stars despite the fact that there is no direct line of sight. Chiang's analogy of flames licking along the inside surface of a chimney is striking enough; the modern reader might tend to think in terms of the phenomenon of total internal reflection. It is by no means clear, however, why the sun's rays should just fail to reach the diametrically opposite point to the sun, creating the "dark space". Perhaps, if pressed, Chiang would have retreated to a position of claiming that since there evidently is such an unilluminated position it must, by symmetry, be exactly opposite the sun, and can thus be used as required for calendrical purposes.

Returning now to the question of lunar illumination in the light of Chiang's theory of curvilinear propagation it is evident that his explanation of the moon's phases has certain flaws. Assuming for the sake of argument that the earth was no obstacle and that the sun's rays travelled in straight lines, the phases could not be accurately predicted so long as sun and moon were thought of as equidistant from the earth. Under such circumstances a half-moon should occur at conjunction, and at quadrature it would appear three-quarters full.

Fig IV (4)

Chiang Chi's theory of lunar phases



The problem is partly solved, for the period immediately around conjunction at least, if the moon is placed somewhat closer to the centre of the heavenly sphere than the sun. As we shall shortly see, Chiang suggests this. Nevertheless an accurate theory of lunar phases on the basis of rectilinear propagation of the sun's light is only possible if it is assumed that the sun is very much further from the earth than is the moon. As in the case of lunar eclipse theory a straightforward explanation is only possible if the basic scheme of the Hun t'ien universe is modified out of all recognition, and no cosmographer ever seems to have risen to the challenge. It appears, however, that Chiang Chi may not have ignored the difficulty altogether. In a somewhat obscure passage (KYCC, 1, 21b-22a) he seems to be approaching the problem from the standpoint of his hypothesis that the sun's rays travel round the inner surface of the celestial sphere. I am unable to reach a fully satisfactory version of his views, but it is possible that he held that the earth's intervention between sun and moon at opposition acts as a variety of "flame spreader" so that the moon is evenly illuminated, an effect which cannot occur at conjunction. There is a reminiscence of Liu Chih's ideas of Yin-Yang resonance in his statement that, even though they are over 300,000 li apart at opposition, the sun illuminates the moon in the same way that a flame leaps from one lamp-wick to another. Incidentally, this dimension is taken from the same Kai t'ien source as Chiang's later figures (see (d) below).

As we have seen, Chiang devotes some effort to "saving the phenomena" of lunar eclipses and lunar phases. He next attempts to justify the occurrence of a completely imaginary phenomenon, a general stellar eclipse. This is said to occur when a solar eclipse happens at night, and the basis for this allegation is presumably the notion that the stars as well as the moon shine only by reflected light (see III (7) (d)). Chiang's imaginary objector argues :

> "When the sun is eclipsed at night the multitude of stars vanishes. Now the body of the moon is not larger than the earth. When the sun is below the earth, and the moon is above the earth, even though the body of the earth is large, it still cannot block off the sun so that it does not shine on the moon. The moon's body is smaller than earth, so how can it block off the sun, so that it does not illuminate the stars ?"
>
> KYCC, 1, 22a

To this Chiang replies :

> " ... The sun is above, the moon comes next, and the stars are placed below this. The earth is inside the <u>hsiu</u>, so it cannot block off the sun. The sun's rays follow along the stars and moon and illuminate them. The moon is outside the <u>hsiu</u>. Therefore when the moon blocks the sun it cannot illuminate the stars."
>
> KYCC, 1, 22b, emended as in CSHK., Chin, 153, 15a

Whether or not Chiang's solutions to this and other problems are felt to be fully convincing, he certainly faced up to their existence more perceptively than other cosmographers in the Chinese tradition.

(c) <u>On the horizon illusion</u>

A fragment on this subject is attributed to an otherwise unknown An Chi 安岌 in the <u>Sui shu</u>, 19, 513, CHSC. The CHSC editors note suggestions that An 安 should be considered as a mistake for Chiang 姜 , which is not in itself improbable, nor is the content of the material such as to disqualify it for attribution to Chiang Chi. The question of authorship is in any case not very important, and it seems sufficient to note that the Sui shu evidently considers that this is a Chin text, a view confirmed by an introductory reference to Shu Hsi, fl. A.D. 270.

After rejecting any idea of actual variation of angular size on the celestial sphere for bodies at the horizon and zenith, the text embarks on an exposition which attempts to link apparent solar size to colour variation :

> "The sun is the essence of pure Yang; when its bright light blazes outwards it dazzles the human eye, so that it appears to be small. When it first rises, if there are wandering vapours coming out of the earth which obscure the sun's brightness, the human eye is not dazzled, and the sun appears red and large. If there are no wandering vapours it is white and not so large. If the vapours of the earth do not reach heaven, then in the course of a day the sun is red at dawn and dusk, and white at noon. When the earth's vapours rise up and obscure all space so that they are merged into heaven, then even at noon the sun is red. The sun is of the same category as fire. The body of a fire is red but its flames are yellow, so the sun's redness is quite appropriate. Thus the redness of the sun is like a fire being without flames. Its brightness is diminished and it has lost its normal state, and hence the difference."

Sui shu, 19, 513, CHSC

(d) Motion of earth and heaven

Chiang Chi's originality and critical spirit have, I hope, been exemplified in the material already discussed. Finally I will turn to his account of the motion of earth and heaven. In this it seems fair to say that he exposed the difficulties and inadequacies of the theoretical scheme within which he worked, without being able to achieve any significant advance. The main obstacle was, as elsewhere in cosmographical discussions, the inadequacy of Chinese geometry at this period. As has already been mentioned Chiang had done original work in the mainly arithmetical field of calendrical science, but this had not equipped him with any better tool for solving right triangles than the ancient "inch for a thousand li" rule. He evidently realised that it gave doubtful results in the context in which he applied it, but does not seem to have known that the rule only worked for a universe in which heaven and earth were plane and parallel. Wang Fan had already missed this point (IV (2) (c)) and Tsu Keng-chih (V (3) (b)) continued to use Wang's figure for the radius of heaven, despite the fact that he introduced a more general use of the mathematics of similar triangles. Even the great meridian survey of A.D. 725, although it rejected any linear distance shadow length relation (Hsin T'ang shu, 31, 816, CHSC), seems to have done so on purely empirical grounds (but cf. SCC IV (1) 44 ff. & main Introduction, (c)).

In his account of the periodic motions of earth and heaven Chiang does not refer to the K'ao ling yao at all, and he mentions Cheng Hsüan twice only. Nevertheless it is evident that these are his sources : at time he repeats Cheng's material word for word. Like Cheng he does not advance any mechanism to explain why heaven and earth should move in the manner described, but unlike Cheng he examines the astronomical consequences of these motions in some detail. Chiang's discussion opens (KYCC, 2, 2a) with a statement that, according to the Chou pei :

1 tu = 2932 li + a fraction

summer solstice shadow [of 8' gnomon] = 1.4' [actual Chou pei figure is 1.6']

winter solstice shadow [of 8' gnomon] = 13.5'

Circumference of heaven = 1,071,000 li

diameter of heaven = 357,000 li [read 億 for 千]

Of course these figures for the celestial dimensions apply only to the equinoctial hêng of the Kai t'ien theory (II (3) (b)), but in common with others, such as Lu Chi (IV (2) (a)), Chiang has applied them to the celestial sphere. This was the problem confronting all Hun t'ien theorists : their assumption that the observer was at the centre of the celestial sphere meant that he had no means of discovering its size. Therefore if they wanted to put figures to their model these had to be taken from the gnomon mathematics of an incompatible cosmography, the Kai t'ien. Chiang now describes a scheme of celestial and terrestrial motions :

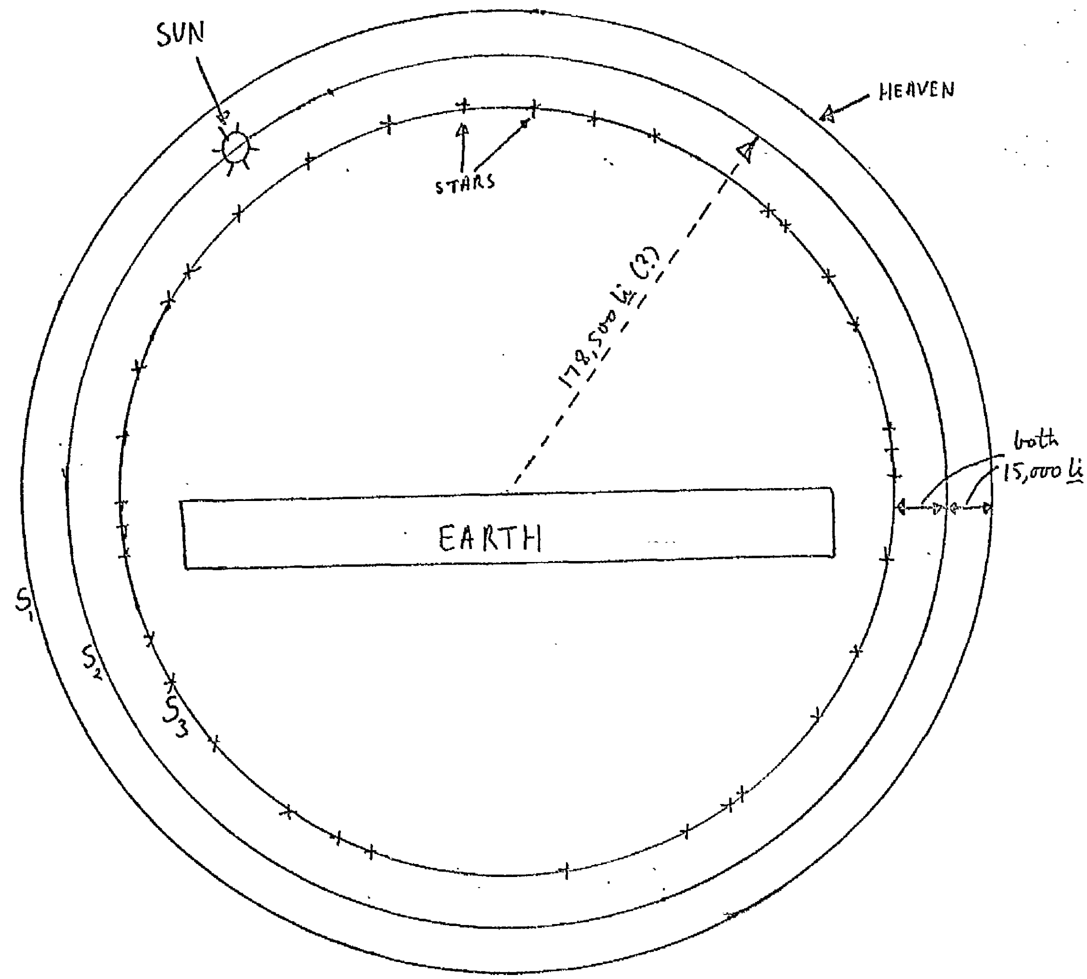
> "Within the four piao 表 there are 15,000 li, and outside them there are 15,000 li. Therefore heaven [KYCC adds "[and the] sun", which is inconsistent with the rest of the text] moves in four directions within a range of 30,000 li, south in winter, north in summer, west in spring, and east in autumn. In each case it moves up to the four piao and stops. Earth likewise rises and falls in the midst of heaven, and the amount of its lateral motion is equal to that of heaven. The sun likewise passes 15,000 li outside the constellations, and the diameter of its orbit is exactly in correspondence with the four piao."
>
> KYCC, 2, 2a.

There is nothing here that is not contained in the known fragments of Cheng Hsüan's work (III (10) (c)). Although there seems to be a greater degree of coherence it is still difficult to form a consistent mental picture of the situation Chiang envisaged. A first conjecture might be as in Fig. IV (5):

(P.T.O.)

Fig. IV (5)

The *Hun t'ien* according to Chiang Chi.



S_2 is the sphere on which the sun and the four *piao* lie; S_3 is the sphere of stars, and S_1 is heaven itself. It can at least be said in favour of this model that it corresponds to the arrangement of heaven, sun and stars described by Chiang Chi elsewhere (see (b) above and KYCC 1, 22b). Unfortunately Chiang is inconsistent in his use of terms. In the section just quoted heaven and the four *piao* are obviously distinct, but a little later (KYCC, 2, 2b) Chiang states that at the equinoxes, when the earth's surface is centrally placed, the distance between heaven and earth, to be obtained by halving the diameter of the *piao*, is 190,000 *li*. But we have already been told that heaven has a diameter of 357,000 *li*, which gives a radius of 178,500 *li*, an inconsistency of 11,500 *li*. If we allow ourselves to ignore the reference to the *piao* in connection with the 190,000 *li* figure, we might feel that this larger sphere was the actual sphere of heaven itself, while the 357,000 *li* "heaven" was simply the orbit of the sun, said earlier to coincide with the *piao*. Further, if 190,000 *li* is an approximation to the figure of 193,500 *li* that can be drawn from Cheng Hsüan's data (III (10) (c) (xi)), the separation of the spheres becomes 15,000 *li* as described. This somewhat confusing state of affairs, and much of Chiang's subsequent discussion, gives the impression that Chiang himself never progressed beyond puzzling over Cheng Hsüan's work, and did not evolve a consistent scheme. Had he thought geometrically rather than arithmetically, the drive to visualise a physical model might have been greater; as it was, Chiang seems to have been content with a more piecemeal approach.

The originality of Chiang's contribution lies in his examination of the numerical quantities involved in the theory of the displacement of heaven and earth. He begins by noting that a source he designates as the

I shuo 易說 (perhaps the lost work by Ching Fang ?) has the following data (KYCC, 2, 3a) :

winter solstice shadow	13.0'	spring equinox shadow	7.24'
summer solstice shadow	1.48'	autumn equinox shadow	7.24'
total :	14.48'		14.48'

Of course the equinoctial shadows are simply fictitious data obtained, as in the Chou pei, by averaging the solstical shadows. From this, he says, it is concluded that "east to west and north to south the diameter ching 經 and [orthogonal] diameter wei 緯 are equal". Such an argument might be based on the assumption that as the two solstices and two equinoxes define a pair of perpendicular diameters of the celestial sphere, then the distance between (say) the two solstices can be found from the sum of the two solsticial shadows, since each of these represents the distance from one end of the diameter to an observer.

Solsticial solar distances.

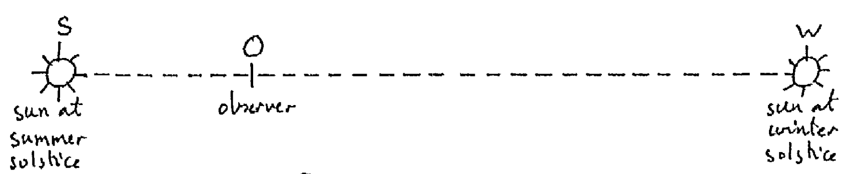


Fig IV (6)

Thus O S corresponds to the summer solstice shadow and O W corresponds to the winter solstice shadow. The flaw is, of course, that even if the ancient linear shadow distance relation holds, it gives the distances across te the flat earth to the subsolar point, not the direct slant distances to the sun. Although Chiang does proceed to criticise the argument of the <u>I shuo</u>, he does not attack it on this ground, but simply faults the data used. He does this by means of figures taken from the <u>Ching ch'u</u> 景初 calendar of A.D. 237 (see <u>Chin shu</u>, 18, 550, CHSC for original source).

season :	summer solstice	winter solstice	spring equinox	autumn equinox
shadow :	1.5'	13.0'	5.25'	5.5'
north polar distance of sun :	67 1/8 <u>tu</u>	115 <u>tu</u>	89 5/16 <u>tu</u>	90 5/8 <u>tu</u>

KYCC, 2, 3b

The equinoctial data here correspond fairly closely to reality. Of course the two north polar distances should both be 90° = 91 5/16 tu, and the shadows should be equal.

Chiang points out that the equinoctial shadows add up to 3.75' less than the solsticial shadows. Hence, he argues, the east-west diameter is 37,500 <u>li</u> less than the north-south diameter. There is of course also a defect of 2 3/16 <u>tu</u> in the equinoctial north polar distances, which Chiang approximates as 3 <u>tu</u>. His complaint that "the number of <u>li</u> from the degrees and from the shadows are different" presumably stems from using his declared value of 2,932 <u>li/tu</u> to obtain 8,796 <u>li</u>. He later approximates this as 9,000 li. All this is simply the application of rules of thumb in arithmetical calculation, and is quite without any geometrical foundation. The factor of four between the two results of 9,000 li and 37,500 li leads him to wonder whether Cheng Hsüan's statement of the "inch for a thousand li" rule should not be revised to give four inches for a thousand li.

At this point Chiang returns to the question of the motion of heaven and earth. He makes it quite explicit that for him the significance of these effects is that they cause the observed variation in solar altitude :

> "Heaven moves up to the four boundaries mien 面 and stops, but the path of the sun is level with the four piao, and neither rises nor sinks ... After the spring equinox heaven and earth sink down and go south [KYCC adds an inconsistent 'west'], until the summer solstice, when the motion of heaven reaches the southern piao and stops. Therefore the sun appears high and northerly ... "
>
> KYCC, 2, 4b.

Clearly, for Chiang as apparently with Cheng Hsüan, the sun's orbit remains fixed while heaven, earth, and the stars move in relation to it. He even concludes his account by a "thought experiment" using a model Hun t'ien to show that the rising and sinkingof the earth can affect the apparent position of the sun relative to the pole. Naturally he does not miss an opportunity for calculation. The angular distance between the two solstices is 24 tu of north polar distance, which, using the usual 2,932 li/tu figure gives, as he notes, "more than 60,000 li". So the motion of heaven and earth is not bounded by 30,000 li as usually held. Sadly, this exercise of critical thought was quite wasted in manipulation of meaningless relations. Throughout this part of Chiang's work there are hints that he realised that it was all leading to no more than the multiplication of confusion. The scheme he worked within was, alas, just adequate to prevent him discarding it and leaving the way open for the basic geometrical thinking that was really needed.

(10) Cosmographical points from Lieh Tzu

(a) The book and its contents

The work which at present bears the name Lieh tzu 列子 was traditionally attributed to Lieh Yü-k'ou 列禦寇, a Taoist of the fifth century B.C. There has however long been doubt as to the weight to be placed on this tradition, and the now most widely held view is that the book is a Chin dynasty compilation, much of its material being of late origin. It is for this reason that it is dealt with in the present section of this survey. In his edition Lieh tzu chi shih 列子集釋 (Hong Kong 1958), Yang Po-chün 楊伯峻 has collected a large number of essays on the origin of the book, and an account of the modern view is found in A. C. Graham (2). Graham (1) translates the work, and it is from his version that the following extracts are taken.

Material from Lieh tzu has already been referred to in earlier parts of this survey : in I (3)(a) a dialogue on the infinity of space was quoted, and in III (5)(a) the story of Confucius and the two small boys was discussed. As was then pointed out, the circumstances of the appearance of this second passage in other early sources without an attribution to Lieh tzu is at least consistent with the hypothesis of the late origin of the book as we have it today.

(b) Ch'i as the celestial substance

I have already mentioned the history of the notion of the insubstantiality of heaven in connection with the problem of the Hsüan yeh theory. There (III (9)(d)) it was pointed out that in the first century A.D. Wang Ch'ung attacked the idea that heaven was no more than a mass of ch'i above the earth. Possibly this theory can be traced back as far as Chuang Tzu, and it may be that the following passage is simply another instance where the Lieh tzu repeats, modifies, or expands on ideas found in the earlier book.

> "There was a man of Ch'i country who was so worried that heaven and earth might fall down and his body would have nowhere to lodge, that he forgot to eat and sleep. There was another man who was worried that he should be so worried about it, and therefore went to enlighten him.
>
> 'Heaven is nothing but the accumulated air [ch'i]; there is no place where there is not air. You walk and stand all day inside heaven, stretching and bending, breathing in and breathing out; why should you worry about it falling down ?'
>
> 'If heaven really is accumulated air, shouldn't the sun and moon and stars fall down ?'
>
> 'The sun and moon and stars are air which shines inside the accumulated air. Even if they did fall down, they couldn't hit or harm anyone.'
>
> 'What about the earth giving way ?'

> 'The earth is nothing but accumulated soil, filling the void in all four directions; there is no place where there is not soil. You walk and stand all day on the earth, stamping about with abrupt spurts and halts; why should you worry about it giving way ?'
>
> The man was satisfied and greatly cheered; and so was the man who enlightened him."
>
> Lieh tzu chi shih, 1, 18;
> Graham (2), 27

The text continues with the comment of another interlocutor that as "heaven and earth are one tiny thing within the void" we can by no means rely on their permanence. Finally Lieh Tzu himself urges, in Taoist fashion, that indifference to the ultimate fate of the universe is far the best attitude to adopt.

The writer of this passage almost certainly felt that the topic he was dealing with was of great interest in its own right, but equally certainly his main aim was to make a philosophical point. Nevertheless, although its ideas were by no means new in Chin times, we have here a very clear and unambiguous statement of the cosmographical theory which, rightly or wrongly, became known as Hsüan yeh. Especially interesting is the statement that the heavenly bodies are themselves no more than ch'i. I mention the resemblance to modern ideas of the constitution of the stars only to point out that it is quite without significance. The fact, by the way, that earth is said to extend infinitely on all sides is yet another indication that earth was considered as basically flat.

If only because it can be reliably dated in a way that the main text cannot, it is worth giving the commentary of the Chin scholar Chang Chan 張湛 [fl. + 350] on this section :

> "The blueness of heaven is not a solid substance; isn't what we call 'heaven' just unfathomable distance ? From earth upwards it is all heaven ... "
>
> ibid

Chang's opening statement and question are of course no more than a slightly modified version of the famous passage at the beginning of Chuang tzu. As Needham notes (SCC III, 222) the last sentence was quoted by Ma Yung-ch'ing 馬永卿 in the twelfth century. This commentary shows that whatever the date of the Lieh tzu text itself the essential idea of the alleged Hsüan yeh theory was certainly current during the fourth century A.D.

Before leaving the topic of Lieh tzu, it seems worth noting the following short section :

> "Turning without end,
> Heaven and earth shift secretly.
> Who is aware of it ?"
>
> Lieh tzu chi shih 1, 18. Graham (1), 27.

It is not impossible, of course, that such a passage might contain a hint of the motion of the earth in translation or rotation. If it does it must be read subject to all the qualifications expressed in III (10), but the rest of the section from which it comes suggests strongly that what we have here is no more than a description of the universe as in a state of continual flux, a familiar enough idea in all Taoist writing.

V : THE END OF ORIGINALITY

(1) Introduction

In part (c) of the main Introduction to this survey I set out my reasons for choosing to end the period considered at the rise of the T'ang (A.D. 618). This section deals with material from the two centuries preceding that date, and the nature of its contents, in my view, gives confirmation that the vein of Chinese cosmography was at least temporarily running out. Tsu Keng-chih exhausts the possibilities of the geometry of the age without achieving a satisfactory solution to the problem of finding the size of the universe. Liu Ch'uo's proposal, when eventually adopted in the 8th century led to the virtual rejection of cosmography rather than its improvement. It is not surprising that we find two writers prepared to "effect a compromise" in the effort to escape the impasse ((6)(a)). In the Sung shu monograph we see the beginning of the effort to save the evidence of past discussions rather than to continue them. Perhaps it is significant that the only wholly unfamiliar note is struck by the work of Liang Wu Ti in his attempt to introduce a cosmography whose origin was religious rather than scientific.

(2) Two fragments on the history of theories

(a) Hö Tao-yang

A small section of material ascribed to Ho Tao-yang 賀道養 (fl. c. A.D. 430) is preserved in TPYL, 2, 10a. Eight characters of it are also found in PTSC 149, 4a. In full, it reads :

> "Ho Tao-yang's Hun t'ien chi 渾天記 says : 'There are three [schools] of those who discussed the body of heaven in the past. No-one knows the origin of the Hun i; presumably it is this spherical body that the Shu says is "in order to rectify the seven governments". The second is called Hsüan yeh, a method of the Hsia or Yin. The third is called Chou pei, which must have been made by [a man called] Chou Pei; it is not a method of the Chou house.
>
> Further, in recent times, there have been four other methods. The first is called Fang t'ien 方天, which arose from Wang Ch'ung. The second is called Hsien t'ien 軒天, which sprang from Yao Hsin. The third is called Ch'iung t'ien 穹天, which came from Yü Hsi (sic). These are all unfounded and empty theories, with nothing worthwhile in them. Only the Hun t'ien has certainty, being supported by testing."
>
> TPYL, 2, 10a

Ho's view of the antiquity of the Hun t'ien is another appearance of the view first expressed by Lu Chi in the third century A.D. (IV (2) (a)), and the hypothesis about the origin of the name Chou pei may stem from the note by Yü Hsi (IV (7) (c)). The suggestion that the Hsüan yeh came from the Hsia or Yin dynasties seems previously unattested, and Ho may be the source for the seventh century statement to this effect by K'ung Ying-t a (III (9) (b)).

Apart from the question of the name of Yao Hsin's theory (see IV (5) (b)), Ho's account of recent theories raises two problems. Firstly, it seems odd that Wang Ch'ung's views should be characterised as the "Fang t'ien" (lit: "square heaven") theory; Wang certainly did not believe in a rectangular heaven. I can only suggest that fang 方 is being used in the wider sense of "set squarely in place", i.e. not tilted. By such a usage Ho might be referring to Wang's denial of theories involving the inclination of the celestial axis (III (6) (i)). Secondly, why are we promised four theories and given only three ? I suspect that this may be linked with the misattribution of Yü Sung's theory to Yü Hsi (see IV (7)) by an instance of "copyist's jump" through which the bracketed section was omitted from a putative original :

> "The third is called Ch'iung t'ien, which came from Yü [Sung. The fourth is called An t'ien, which came from Yü] Hsi."

The jump from one Yü to the next is not implausible.

(b) Ho Ch'eng-t'ien

Ho Ch'eng-t'ien 何承天 (c. A.D. 370-447) sought to show that ancient writers described the existence of a body of water around and below the the earth.

It will be remembered that subterranean waters were linked with the Hun t'ien by early opponents such as Wang Ch'ung (III (6) (i)) and supporters such as Chang Heng (III (7) (b)). Material by Ho is preserved in Sui shu, 19, 511, closely paralleled in KYCC, 1, 27b, and in a shorter form in Sung shu, 23, 677.

> "Researching into previous theories, I came to examine the Hun i, and in seeking its meaning it dawned on me that the shape of heaven is perfectly round, with water occupying half of it. The earth's centre is higher than its periphery, and water forms a circle round its lower part. When men discuss the four directions, the east is called the Bright Valley 暘谷 yang ku, which is where the sun comes out. The west is called the Misty Pool meng ssu 濛汜 which is where the sun goes in. Further, Chuang Tzu says 'In the northern ocean there is a fish, which changes into a bird, and then departs for the southern ocean'. This, too is another record transmitted from antiquity. All this goes to provide evidence for there being water in all four directions. This water in all four directions is referred to as the Four Seas ssu hai 四海.
>
> The five elements produce each other [in turn]. Water is produced by Metal. Hence the hundred streams all well up from the mountains, and rush down from the heights to pour into the sea. The sun is the essence of Yang, and its radiance is blazing hot. During the course of a night it enters the water, and boils away and consumes all it passes through. However the hundred streams pour in, and are sufficient to make up [this loss]. Therefore 'it neither reduces during a drought, nor increases during a flood'."
>
> Sui shu, 19, 511

On the question of the sun's rising and setting, compare the archaic material of the Ch'u tz'u (I (2) (b) (15-16)). It will be remembered that Lu Chi used similar references in the Shu ching to argue that the Hun t'ien was known in very early times (IV (2) (a)). The references to the northern and southern oceans are of course abbreviated from the famous opening lines of Chuang Tzu 莊子 . Ho's theory about the sun's submarine passage is interesting : it is fairly clear that he is not claiming that the water boiled away by the sun ever returns to the sea. Apparently it is to be thought of as completely annihilated, while the water from the mountains is, conversely, newly created. There is, however, evidence that the meteorological water cycle of evaporation and precipitation was understood in China by Ho's time (SCC III, 467). Ho may in this instance be adapting from a further Chuang Tzu passage, found in the Autumn Floods (Ch'iu shui 秋水) chapter :

> "Of all the waters in the world, the biggest is the sea. The myriad streams go into it - I don't know a time when they stop - but it gets no bigger. The tail-gate wei lü 尾閭 drains it - I don't know when it ceases - but it doesn't empty."

Chuang tzu, 17, 16 SPTK

For Chuang Tzu, the wei lü seems to have been a sort of cosmic bath-plug. During the Chin, Ssu-ma Piao 司馬彪 explained this passage as follows :

> "The wei lü is where water leaves the water of the sea. Another name is the Water Burner wu chiao 沃焦 ... In the midst of the eastern sea ... to the east of the Fu sang (see I (2)(b)) there is a rock 40,000 li all round, and 40,000 li thick. When the waters of the sea pour into it, none fails to be burnt up. Therefore it is [also] called the Water Burner."

Wen hsüan, 53, 1140, comm, Commercial Press edn.

Perhaps Ho Ch'eng-t'ien simply replaced the wu chiao rock by the sun during its nocturnal immersion ? If he did, then his theory stems from a Buddhist source, for the wu chiao is actually :

> "The rock, or mountain, Pātāla, on the bottom of the ocean, just above the hot purgatory, which absorbs the water and thus keeps the sea from increasing and overflowing."

Dictionary of Chinese Buddhist Terms, Soothill and Hodous, 241

See also the entry for 沃焦 in the Tz'u hai 辭海 dictionary for Buddhist texts on the subject.

(3) Tsu Keng-chih

(a) On previous theories

Tsu Keng-chih 祖暅之 (fl. A.D. 510) was the son of the famous mathematician and calendrical expert Tsu Ch'ung-chih 祖沖之 (A.D. 429-501). His work is the final example of critical cosmography to be considered in this survey, and it exemplifies well the strengths and weaknesses of the tradition within which he wrote. The main points of interest in his work are in the field of detailed analysis of matters relating to the orthodox Hun t'ien, but before turning to them it is appropriate to deal with a fragment mentioning other theories. The few lines following are all that remain to us of his T'ien wen lu 天文錄 originally consisting of thirty chapters, according to the Sui shu bibliography (Sui shu, 29, 1019, CHSC) :

> "There are three [schools] amongst the men of old who discussed the shape of heaven and earth. The first is called Hun t'ien; the second is called Kai t'ien; the third is called Hsüan yeh. I have never heard any explanation of the Hsüan yeh.
>
> Later there was Yü P'ing 虞昺 (sic) who made the Ch'iung t'ien lun, Yao Hsin who made Hsin t'ien lun, and Yü Hsi who made the An t'ien lun. Each differs from the other as to the shape [of heaven].
>
> Further, there are three kinds of body [of heaven] in the Kai t'ien. One says heaven is like a chariot cover moving between the eight extremes. One says heaven is like a rain-hat,

> high in the middle and lower all round. Another says heaven is like a tilted chariot cover, high in the south and low in the north."

TPYL, 2, 6b (only source)

Tsu is of course yet another instance of a well-informed scholar denying any knowledge of the Hsüan yeh theory : on the significance of this for the status of the material attributed to Ch'i Meng see III (9) (b). The question of whether the Ch'iung t'ien was originated by Yü P'ing or Yü Sung 虞 聳 is discussed in Textual Note (7)

As for the three versions of the Kai t'ien, the second is the familiar image used in the Chou pei itself (II (3) (c)). The third is in almost precisely the words used by Wang Ch'ung (III (6) (i)) to describe one of the theories he attacked. I would suggest that the first version is, similarly, a reference to Wang Ch'ung's notion of heaven as essentially a flat disc rotating horizontally (III (6) (b)) in contrast to the slightly domed heaven of the Chou pei. It is a great pity that Tsu Keng-chih's criticisms of these theories, if any, have not been preserved to us.

(b) A survey of some uranometrical problems

I have already dealt with Wang Fan's attempt to put the question of the dimensions of the universe on a more rational basis (IV (2) (c)). Tsu Keng-chih also wrote on this problem, and in KYCC 1, 29a-33a (paralleled for 2/3 by Sui shu, 19, 514) we have a detailed account of his conclusions. After an opening commendation of the Hun t'ien, he goes on :

> "In the K'ao ling yao previous scholars obtained the result that heaven and earth were 178,500 li apart. A check on this with the gnomon shadow shows that it errs on the side of excess. In any case they did not give any derivation but baselessly gave the result alone. This is exaggeration, not the teaching of the Sages. Students mostly have adopted this theory without correcting it - surely not because they did not know how to seek out the true principles ? Or, perhaps, they could not find the figures. Wang Fan's examination and check of previous theories was tantamount to reducing [this result] by half. Even though this was not guesswork, but worked out according to principle, it did not really get at the whole truth. It was however quite accurate."
>
> KYCC, 1, 29a

It will be recalled that in his criticism Wang quoted two apocryphal works as giving a figure of 1,071,000 li for the circumference of heaven : this, of course, implies a radius of 178,500 li on the usual assumption of $\pi = 3$. Apparently these dimensions were indeed adopted by the K'ao ling yao also (see III (10) (b) (v)). As I have already pointed out several times, the ultimate source for such data was the Kai t'ien tradition of the Chou pei (II (3) (b)). Tsu Keng-chih's mathematical ability was more than sufficient to have enabled him to see this point if he had been familiar with the Chou pei. The fact that he makes no mention of it is something of a suggestion that the book was not studied in his time; if Tsu Keng-chih did not read it, it was unlikely that many others would have done so.

Tsu now proceeds to a series of calculations designed to carry on from where Wang Fan left off. Let us follow the first of these in full :

> "Accordingly I took Wang Fan's figure for the height of heaven, and thence sought the altitude of the sun and its distance southwards from the centre of the earth for the winter solstice and the spring equinox.
>
> Method :
>
> suppose gnomon height is 8'
>
> and winter solstice shadow length is 13'
>
> Square each, add, and take the square root. Make this the divisor.
>
> Multiply the height of heaven by the gnomon height to make the dividend
>
> Dividing, the result is :
>
> Winter solstice solar altitude = 42,658 li + a fraction."

ibid.

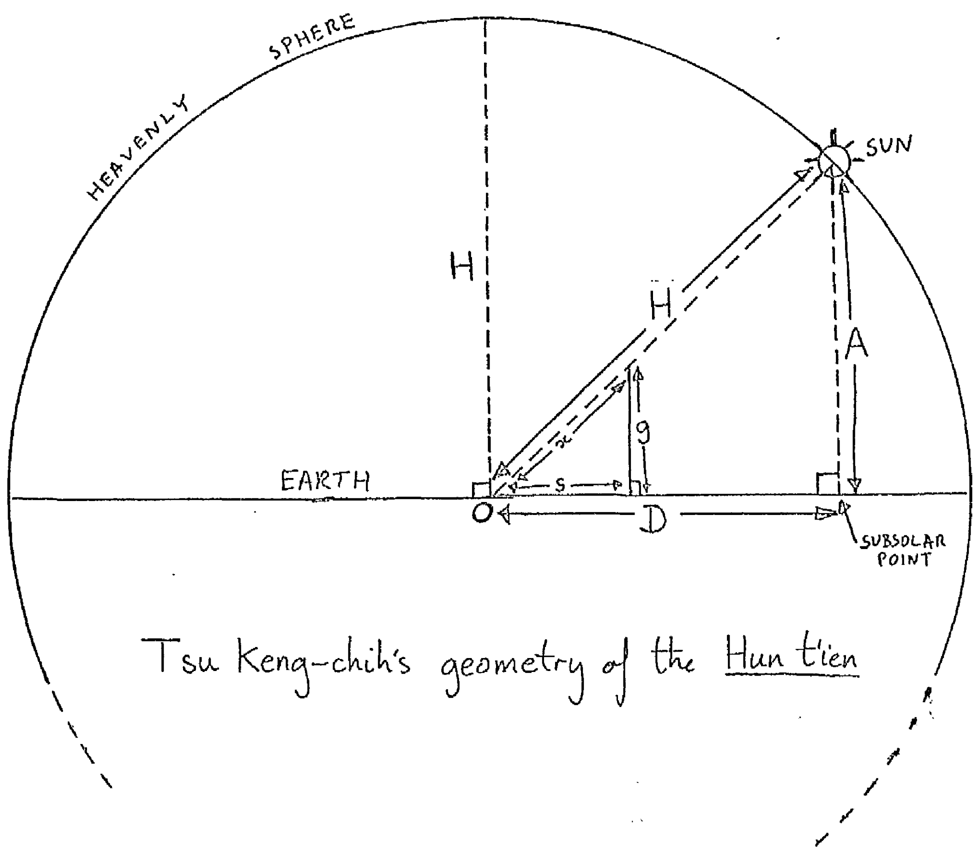
Wang Fan's result for "the height of heaven" was :

81,394 <u>li</u>, 30 <u>pu</u>, 5 <u>ch'ih</u>, 3 <u>ts'un</u>, 6 <u>fen</u>

KYCC, 1, 16a; see also IV (2) (c)

As Wang himself makes clear, this is the radius of heaven as well as simply the height of heaven above the usual central observer. In Fig. V (3) (i), this radius is H; g is the gnomon height, and s is the length of its shadow; x is the distance from the tip of the shadow to the top of the gnomon; A is the altitude of the sun above the flat earth, and D is the distance from the centre of the heavenly sphere, O, to the subsolar point.

Fig. V (1)



Tsu Keng-chih's geometry of the *Hun t'ien*

Note of course that Tsu is following the classical form of the *Hun t'ien* in which the heavenly bodies lie on the celestial sphere and the earth remains fixed. It can easily be seen that Tsu's algorithm is the rhetorical equivalent of the algebraic formulation :

$$A = \frac{Hg}{\sqrt{g^2 + s^2}}$$

This follows immediately from the two facts :

$$\frac{A}{H} = \frac{g}{x} \quad \text{(by similar triangles)}$$

$$x = \sqrt{g^2 + s^2} \quad \text{(Pythagoras)}$$

Tsu's numerical result for A is correct for the initial data given. Next, by using the relation

$$D = \frac{Hs}{\sqrt{g^2 + s^2}}$$

Tsu obtains the result that at the winter solstice the distance from the central observer to the noon subsolar point is 69,320 li plus a fraction. He obtains the corresponding figures for the equinoxes by substituting a shadow-length of 5.39' for the 13' used for the winter solstice. This equinoctial shadow-length is apparently drawn from the Yuan chia 元嘉 calendar prepared by Ho Ch'eng-t'ien in A.D. 443 (Sung shu, 13, 280, CHSC). (In common with several other calendars, the Yuan chia gives summer and winter solsticial shadows of 1.5' and 13.0' respectively.) Thus for the equinoxes Tsu obtains 67,502 li for solar altitude and 45,479 li for the distance of the subsolar point.

Tsu points out that the observations and calculations applied to the sun can also be used for obtaining data on the height of the Pole Star and the distance to the sub-polar point (KYCC, 1, 30a). Although he does not prescribe the use of a string as a sighting-aid his method is highly reminiscent of the Chou pei (II (2) (a); (3) (d)); Tsu gives no actual data, and contents himself with a description of the method of calculation. Note once more that the prescribed use of Wang Fan's celestial radius in this context implies that for Tsu the stars as well as the sun lie on the heavenly sphere. Similarly (KYCC, 1, 31b) we are given a description of the use of a sighting-tube of known length and diameter such that when the observer applies his eye to one end he sees the sun (or moon) just included in the other aperture. The fact that the distance from the observer to the sun is known (Wang Fan's radius) enables the diameter of either celestial body to be found by simple proportion (cf II (2) (c) and IV (2) (d)). Once more the method is described without illustrative data.

All this is certainly very methodical, and perhaps Tsu is justified in criticising earlier writers for failing to reach his standard of mathematical technique. No-one could claim that his methods were at all new-fangled : both Pythagoras' theorem and the method of similar right-angled triangles are found in the Chou pei and the Chiu chang suan shu. Of Chang Heng (see III (7) (d)) he complains that his figure of 232,300 li for the diameter of the universe is without any rational basis whatsoever (KYCC, 1, 31b), which is true enough. When, however, he criticises Chang's statement that the diameters of the sun and moon correspond to 1/736 of heaven's circumference and 1/242 of earth's width, an arithmetical slip (232 for 242) makes him complain that this implies what is, in effect, an over-sized value of π. Note, of course, that Tsu implicitly accepts that the surface of earth extends over a diametral plane of heaven.

Unfortunately Tsu's methodical approach does not suffice to place the question of the dimensions of the Hun t'ien universe on a sound footing. The whole basis of his calculations is Wang Fan's figure for the radius of the heavenly sphere, the derivation of which was examined in IV (2) (c). There we saw that Wang, assuming himself at the centre of the celestial sphere, noted the 1.5' shadow of an eight-foot gnomon at the summer solstice noon. Thus he deduced that it was 15,000 li to the subsolar point. A combined application of simple proportion and Pythagoras' theorem gave the result that the sun was just over 81,394 li away from the observer. Unfortunately the step from 1.5' to 15,000 li was made with the aid of the "inch-for-a-thousand-li" shadow-principle, which is completely invalid in the Hun t'ien universe (see Appendix iii). Oddly, Tsu gives no sign of being aware of this as a flaw, despite the fact that his calculations for the equinoxes and winter solstice give results which contradict the shadow-principle in those instances : thus at the equinoxes a shadow of 5.39' would, by the shadow principle, imply 53,900 li to the subsolar point rather than the 45,479 li obtained by Tsu.

I have already noted in the case of Liu Hui (IV (2) (d)) the paradox that in the case of the Hun t'ien universe the consistent application of the best mathematical tools available meant doing without initial data to which they could be applied. As I mentioned then, the eight-century attempt of I-hsing to obtain some empirical basis ended by confronting astronomers with a linear variation of angular polar altitude with meridional displacement rather than a modified shadow-principle. Had the astronomers been able to make the leap to the concept of a spherical earth, comparatively distant from the sun, this relation would have appeared sensible. As it was, the only result was a tendency towards scepticism about all attempts at cosmography.

(c) The sun : the horizon illusion and the seasons

Tsu Keng-chih is, as we have seen, committed to a cosmography of the classic Hun t'ien type, in which the heavenly bodies lie on a sphere centred on the observer. Thus the sun is always the same distance from the observer, and as one would expect Tsu offers an explanation of the apparent enlargement of the rising and setting sun in terms of optical illusion :

"The reason that the sun is observed as larger sideways and smaller overhead is that bending back and looking is difficult, but looking along the level is easy. [The effect] comes from the ease and difficulty of vision, not from relative distances. Now if a pearl is hung up 800' high, or placed 800' in front of one, when one proceeds to examine them there is a difference of size. Former scholars have taken no account of this. They have used a great amount of brushes and ink, seeking circuitous routes and employing polemics. Were they not wide of the mark ?"

KYCC, 1, 30b

Tsu's theory is of course an addition to a succession of attempts at explanation beginning at least as far back as the early Eastern Han (see III (5)). As far as it goes, it has the advantage that no special celestial effects are invoked : he simply points out that similar illusions are visible on a local and terrestrial scale. Of course he makes no real impact on the problem of why the direction of vision should have the effect noted. More original is Tsu's attack on another problem implied by his belief that the sun is always the same distance away :

"The sun's distance from the centre of the earth is the same in winter, summer, spring and autumn, and at dawn and dusk or day and night. The reason that, despite this, there is cold weather and hot weather is that the ch'i of earth rises upwards and the ch'i of heaven sinks down. Therefore far from the subsolar point it is cold, and near the subsolar point it is hot. It is not that [the sun itself] is further or nearer. This is analogous to the fire being blazing hot even at some distance when it is above, but weak when it is on the side even when one is nearby."

KYCC, 1, 30b

Heat is thus to be thought of as pouring down from the sun like water from a shower-bath. One has to be at the subsolar point or near it to gain the full effect, despite the fact that the sun itself is a constant 81,394 li away. In winter the shower, according to Tsu, plays on a point 69,320 li away from the observer, whereas in summer the subsolar point is only 15,000 li away. This ingenious theory may not be completely original : around 20 A.D. Kuan P'ing suggested a similar explanation of why the sun was hottest at noon (III (5) (b)). So far as I know, however, Tsu's next attempt at meteorological physics has no earlier parallel; the names used are of course references to the 24 equal solar seasons, ch'i, into which the Chinese year was divided.

> "Now Great Cold ta han 大寒 is two ch'i after the Winter Solstice : this is because the cold has accumulated and not yet dissipated. Great Heat ta shu 大暑 is two ch'i after the Summer Solstice : this is because the heat has accumulated and is not yet subsided. Cold and heat are in balance two ch'i after the equinoxes : this is because cold and heat have accumulated and are not yet even. This is analogous to the case of a fire first being taken into a room when it is not at first very warm. Although one adds no firewood it gets hotter with time, and when the fire has been taken away there is still some heat left."
>
> KYCC, 1, 31a

Tsu has faced the problem that the hottest time of the year is later than the time when the sun is at its highest , etc., and answered it in terms that are almost equivalent to those that a modern physicist would use.

The concept of heat capacity is at least partially realised, andit is interesting to find this example of "phase lag" described by an author accustomed to write within the tradition of wavelike cyclical change.

(d) On the moon and stars

Like Chiang Chi (IV (9) (b)), Tsu Keng-chih explained the moon's phases in purely optical terms. Although he uses the ambiguous word "round" yüan 圓 which could also mean "discoid", his account seems to demand a spherical moon. Chiang, of course, made this point explicit. Tsu's explanation runs :

> "The moon is the essence of Yin, and it is round in shape. It receives the rays of the sun and thus makes itself visible. The part which does not face the sun's rays is called po 魄 Therefore, on the day of lunar opposition, the sun and moon being opposite each other, man is between them. One can see the whole of the [lunar] body, so its shape is round. At the two quadratures the sun shines on it obliquely, and man looks at it sideways. Therefore, half [appears] dark and half illuminated. At the time of conjunction the sun [read 日 for 月] illuminates its outside, but man is on the inside, so one does not see the [moon's] shape."
>
> KYCC, 1, 32a

Tsu Keng-chih may well have taken his explanation directly from Chiang Chi, for the preservation of a fragment of his criticising Chiang proves that he knew Chiang's work. Tsu attacks the idea that the stars are closer to us than the sun, a theory advanced by Chiang in an attempt to justify the possibility of a general stellar eclipse (IV (9) (b)) :

"This saying of Chiang Chi is false. The stars, like the moon, receive the sun's rays and only then become visible. If the stars were within [the orbit of] the sun, then they ought to wax and wane [like the moon]. Now as this is not so, one can tell that the stars are beyond [the orbit of] the sun so that they are constantly bright."

KYCC, 1, 23a

The passage continues with a statement in contradiction which is in my view either an editorial insertion or the work of Liang Wu Ti : see V (5) (C). Evidently Tsu Keng-chih would have had no difficulty in understanding the phases of Venus if only he had had the benefit of a telescope through which to see them, nor would he have lacked the wit to explain why the major planets show no phases. Of course, his understanding would have been cramped within the confines of his geocentric world-view.

(e) Finding the centre of the earth

The idea that an observer at the cultural centre of the Chinese world was literally at the centre of heaven and earth has been met frequently in the course of this survey : see for instance III (10) (c) (vii). Perhaps the oldest expression of this view is found in the Shu ching :

"May the king come and take over the work of God on High, and himself manage [the government] in the centre of the land [t'u chung 土中]."

Shang Shu, 15, 8b, SSCCS (tr. Karlgren)

Cullen (1) deals in detail with a 1st century B.C. attempt to locate the centre of the flat earth by means of large-scale geometry. Tsu Keng-chih likewise describes a method for achieving this, in a text preserved only in Sui shu, 19, 522, CHSC. The Sui shu editors precede Tsu's work with a short account of the well-known references to the use of gnomon-shadows for this purpose in the Chou li. Tsu's description of his proposed method is as detailed and explicit as we might expect from his other work.

In essence, Tsu relies on the existence of what he views as four cardinal points :

(i) North : defined by the north celestial pole.

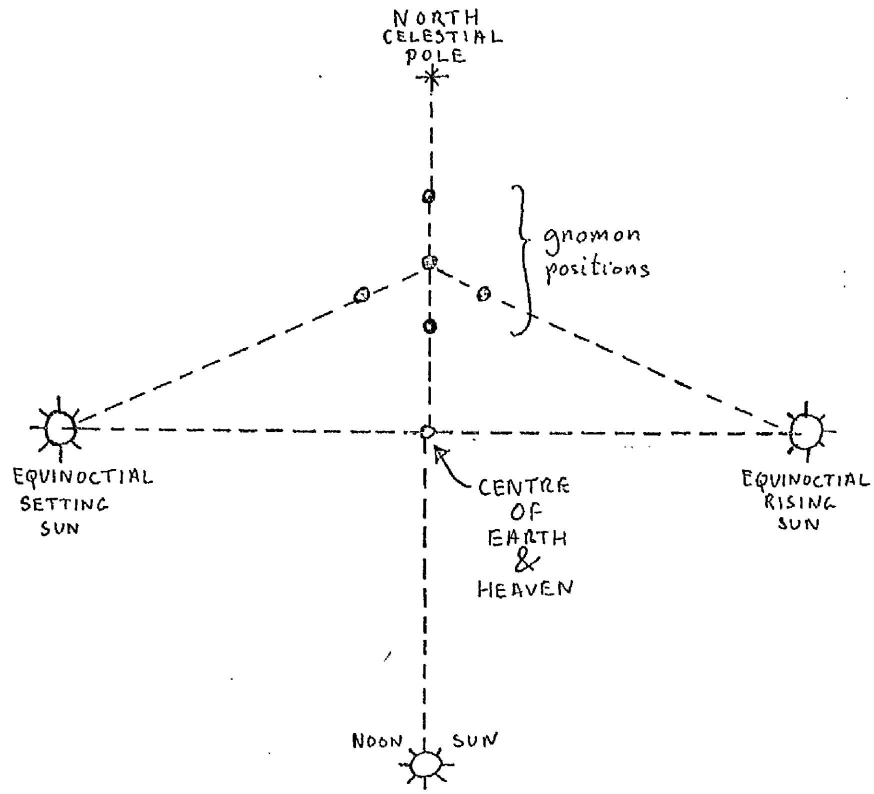
(ii) South : defined by the position of the sun at a moment midway between rising and setting, as found by clepsydra.

(iii) East : the rising equinoctial sun

(iv) West : the setting equinoctial sun

Tsu prescribes the setting up of five upright gnomons on level ground, so that from the central gnomon the other four each align on one of the cardinal points as above defined. The centre of the earth, for Tsu, is given by the point where the northern, central, and southern gnomons are in alignment, as are the eastern, central, and western gnomons. If one is off centre a failure of alignment will occur in either or both sets. For instance, in Fig. V (2) the observer is on the main north-south line of the earth, but is to the north of the east-west centreline :

Fig. V (2) Tsu Keng-chih's check for observer centrality (not to scale): plan view.



Tsu Keng-chih could easily have put his method to a practical test. If he did so, the chances are that he found the result most satisfactory, for in the real world any observer wherever placed will find an exact alignment of the two sets of gnomons. As Tsu in all probability would have carried out his experiment at or near the Chinese capital, the consequent confirmation of its centrality would have been politically convenient as well as geometrically interesting.

(4) The Sung shu monograph

(a) The origin of Shen Yüeh's work

The astronomical monographs T'ien wen chih 天文志 of several dynastic histories have been important sources of material during the compilation of this survey, as the reader will have become aware. However the intention of their authors was in the main to record and to interpret astrological portents, and in the earlier histories this was their exclusive purpose. Shen Yüeh 沈約 (A.D. 441-513) was the first author of an extant dynastic history to introduce the practice of prefacing the T'ien wen monograph with a cosmographical treaties : this he did in his Sung shu 宋書, a history of the Liu Sung dynasty (A.D. 420-478). A succinct account of the composition of this work is given in the editorial preface to the CHSC edition. Apparently Ho Ch'eng-t'ien had already written a T'ien wen chih in A.D. 439, which would have formed part of the material available to Hsü Yüan when he compiled his (now lost) history of the Sung in A.D. 462. Shen Yüeh began his work on the Sung in A.D. 487, although the monographs do not seem to have been completed until some time after A.D. 500. We cannot tell whether or not Ho Ch'eng-t'ien or Hsü Yüan may have been the first to discuss cosmography under the heading T'ien wen. Both of them were, as we have seen, interested in the subject (see IV (2) (b) and V (2) (b)), and Shen's monograph quotes material from both writers.

The Sung shu monograph is of course mainly relevant to this survey insofar as it contains quotations from the work of earlier writers, and it might be felt that such a secondary source cannot appropriately be dealt with on equal terms with more original authors. Shen Yüeh's work is admittedly a different literary form from (say) Tsu Keng-chih's cosmographical writings, which represent the critical thought of an individual. Shen is more interested in recording what others have said, although he permits himself a certain amount of comment. The point of describing his monograph at the end of this survey is thus twofold. Firstly, it gives us an interesting check on the sort of material that was available on the subject of cosmography around A.D. 500. Secondly, it serves to mark the end of an era of originality, and to begin the age of the summarists and commentators who preserved the material on which this survey is based.

(b) The contents of the monograph

The Sung shu's T'ien wen chih fills Chapters 23 - 25 of the work, and the part containing matter of cosmographical interest fills the first eighth of this. Of this eighth part, Shen Yüeh's own words make up only about a quarter of the material. Shen begins in terms that the reader will by now find familiar :

> "There are three schools of those who discuss the heavens. The first is called Hsüan yeh; the second is called Kai t'ien; the third is called Hun t'ien. However the classics give us no explanation from former times of what the real shape of heaven is, and [Ssu-]ma [Ch'ien's] [T'ien kuan] shu [in the Shih chi] and Pan [Ku's] [T'ien wen] chih [in the Han shu] lack any material."

Sung shu, 23, 673, (CHSC)

Shen then gives the text of Ts'ai Yung's memorial, in which he urged research into the Hun t'ien (see III (8) (a)), adding in conclusion :

> "At that time the eunuchs were in power, and Ts'ai's suggestion was not proceeded with."

ibid

Although the mention of the eunuchs certainly reflects Eastern Han conditions, one suspects that it is based on the often not unjustified dislike of eunuchs amongst Shen Yüeh's social class, rather than on factual information about why Ts'ai's proposal was not followed.

Elsewhere Shen refers to Ts'ai Yung's work in terms which strengthen the impression that it was from this memorial that he derived the idea of introducing the topic of cosmography into his history. In the general preface to his monographs we read :

> "Important as the T'ien wen monograph [in the Han shu] was, it did not say anything about the form of the heavens, and thus it came about that 'the three theories about heaven became confused so that no-one could sort them out' [Quoting Hsü Yüan, cf. Sung shu, 23, 678, CHSC]. Therefore Ts'ai Yung sent his memorial from

> Shuo Fang, saying that what had been handed down [on the subject of cosmography] ought to be included."
>
> Sung shu, 11, 203, CHSC

After a passing commendation of Lu Chi (IV (2) (a)) for his understanding of the Hun t'ien, Shen gives a long section of material by Wang Fan (IV (2) (b) and (c)). This appears to be a shorter version of the text found in KYCC 1, 12b, ff, and is presumably included as an authoritative account of the Hun t'ien, fulfilling the need originally expressed by Ts'ai Yung. Following this Shen arranges material relevant to the question of the antiquity of the Hun t'ien and the armillary instruments associated with it. He first gives quotations from Ho Ch'eng-t'ien and Hsü Yüan, which may represent part of the writing they had intended for a Sung history (see (a) above). Ho's work deals with the question of the circumterrene waters in ancient writers (V (2) (b)), while Hsü takes issue with Wang Fan's assertion that armillary instruments are mentioned in the Shu ching (IV (2) (b)). Hsü points to the inherent unlikeliness of the Hun t'ien theory having been widely known in ancient times but later forgotten. At their time, he notes, the work of Yang Hsiung (III (3) (b)) and Chang Heng (III (7)) was clearly regarded as innovatory. Wang Fan relies on Cheng Hsüan's commentary in maintaining that the Shu ching reference was to an instrument rather than to the stars as had otherwise been held (see Cullen (2)). Hsü dismisses

Cheng's right to pronounce on the matter, and comes down in favour of a stellar interpretation as more probable.

Shen Yüeh, however, cannot accept this view (*Sung shu*, 23, 678, CHSC). What, he asks, is so improbable about the manufacture of astronomical instruments in ancient times ? The literature of the *Hun t'ien* theory was evidently lost, which explains the currency of such inadequate theories as the *Hsüan yeh* and *Kai t'ien*. For information on the possible survival of *Hun t'ien* instruments he turns to Yang Hsiung's *Fa yen* text, discussed in III (3) (b) above, which he interprets as referring entirely to instruments rather than a theory. Thus, Shen claims, all Chang Heng did was to reconstruct ancient instruments, the existence of which had been noted by Yang Hsiung a century earlier. In any case, he points out, Wang Fan actually gives the dimensions of the instruments preceding Chang Heng's reconstruction, making it clear that Chang was not the inventor of armillary instruments as Hsü Yüan had claimed he was.

It may be remembered that this survey's conclusion on this question was calculated to withstand at least some of the objections of both Shen and Hsü (III (3) (f)). It certainly does seem to have been Chang Heng who originated the fully-fledged *Hun t'ien i* armillary sphere with its nests of rings, but it also appears very probable that simpler instruments were known in the first century B.C., and that Yang Hsiung referred to these. Of course, in the light of modern knowledge of ancient China as well as in view of the absence of any literary evidence, it can no longer be maintained that the Hun t'ien could have had the remote origin claimed for it by Wang Fan and Shen Yüeh.

After some notes on the history of armillary instruments up to the Sung, Shen turns to the topic of the Kai t'ien :

> "As for the methods of the Kai t'ien, it is said that they come from when Tan, Duke of Chou, made enquiries of Yin Shang; this idea is a mere fabrication. Its text is called Chou pei, pei meaning 'a gnomon', and chou referring to the measurement of heaven. The theory states :
>
> 'Heaven is like a covering lid, and earth is like an inverted basin. Earth is high in the middle and falls away all round. The sun and moon rotate with heaven, and give rise to day and night as they are hidden [in turn] by the height of the earth. Heaven and earth are everywhere 80,000 li apart, and the centres of heaven and earth are 60,000 li higher than their outer hêng. The high point on top of the earth is 20,000 li higher than heaven's outermost hêng.'
>
> Someone asked Yang Hsiung about the Kai t'ien. Yang Hsiung cried :
>
> 'Oh, the Kai, the Kai !'
>
> And thereupon he raised objections to eight things about it. Further, Cheng Hsüan objected to two things. All this proved incomprehensible to students of the Kai t'ien."
>
> Sung shu, 23, 679, CHSC

Some oddities in Shen's account suggest that he may not have had a good first-hand acquaintance with the text of the Chou pei. His statement that the Kai t'ien explains day and night by the occultation of the sun and moon behind the bulge of the earth is of course quite erroneous (see II 93) (d)). Could Shen be under the influence of Buddhist ideas about the central mountain as set forth by Liang Wu Ti (V (5) (b)) ? Further, the statement that the top of the earth is 20,000 <u>li</u> higher than the outermost <u>hêng</u> of heaven contradicts the previous sentence. In the <u>Chou pei</u>, of course, the correct deduction is made that the top of the earth is 20,000 <u>li</u> <u>lower</u> than the edge of heaven (II (3) (c)). Shen is the first to mention the existence of the "eight objections" attributed to Yang Hsiung (III (4) (b)), and is unique in his statement about Cheng Hsüan.

A short discussion then follows on whether the moon should be said to be moving faster or slower than the sun. The matter is of course in reality a question of definition : is one to consider the motion of the two bodies relative to the horizon, or relative to the background of the stars ? Shen reverts to more directly cosmographical material in giving an account of Yü Hsi's <u>An t'ien</u> theory (IV (7) (b)) and the <u>Ch'iung t'ien</u> of his ancestor Yü Sung (IV (7) (a)). Both are fairly brief; they are followed by a longer section of Yao Hsin's work (IV (5)). As for criticism, Shen limits himself to saying :

"All these three theories are nothing but the chatter of those who enjoy perversity; they are deeply in error."

Sung shu, 23, 680, CHSC

This concludes the monograph's material on cosmography.

(c) Comments

We cannot deduce a great deal from what material was not included in his work by Shen Yüeh. It may simply have been a desire for conciseness that led him to omit any mention of, for instance, Wang Ch'ung or Ko Hung. In the context of the problem about the content and origin of the Hsüan yeh theory (III (a)), however, I would maintain that Shen's silence must be given some weight. This is, after all, one of the three ancient theories he mentions in his opening lines; given the fact that he describes the other two, as well as a number of more recent eccentricities, can we doubt that he would have given some sketch of it if he felt anything was known of the theory ? Further, both the Sui shu and Chin shu introduce Yü Hsi's work in terms almost identical to those used by Shen, except that they both add the rider that Yü Hsi "took the Hsüan yeh theory as a basis". Bearing in mind that Shen had at his disposal the work of Ho Ch'eng-t'ien and of Hsü Yüan, as well as the resources of the imperial archives, is not the impression strengthened that the alleged Han material relating to the Hsüan yeh appeared at a relatively late date ?

Whatever its shortcomings compared to the fuller and more organised work of the monographs appearing during the T'ang and later, I think it has become plain that Shen Yüeh's text represents a qualitative change in cosmographic writing. He is, by comparison with his predecessors, "a transmitter, not a maker", and this was to be the pattern for most of those who subsequently took an interest in cosmography in China. It is for this reason that he deserves to find a place in this survey, which is, after all, simply an attempt to fulfil Shen Yüeh's task more comprehensively and critically than his limitations of resources and background allowed him to do.

(5) Liang Wu Ti and the influence of Indian cosmography

(a) Indian cosmographic systems

Apart from Needham's conjecture that the Kai t'ien may be of Babylonian origin (SCC III, 212), I know of little in the way of suggestions that foreign influence had a very marked effect on the development of the cosmographic theories discussed so far in this survey. Indeed, under the historical circumstances I cannot think that such suggestions have much chance of either positive corroboration or disproof and in any case the questions involved do not really fall within my terms of reference. I would argue further that these terms of reference are not simply an arbitrary demarcation. It is not damaging to the autonomy of Chinese cosmography as a field of study if a Chinese author borrows his theory from a foreign source, so long as he advocates and defends it on its own merits and does not simply proclaim it on the basis of an alien authority. As I shall, however, shortly discuss the one instance during the period of this survey when such a process of importation occurred, backed with imperial prestige, it is necessary to discuss the origins of the system of ideas which entered China by these means. The following notes on Indian cosmography are almost entirely drawn from Gombrich (1).

Classical Hindu, Buddhist and Jain cosmographies all agree in describing a cosmic mountain as forming an axis mundi running through the inhabited world from the hells below to the upper heavenly levels. This mountain is called Meru in Sanskrit, and Sumeru or Sineru in Pali; in Chinese transliterations used in Buddhist scriptures those names became Mi Lou 彌樓 and Hsü Mi Lou 須彌樓 respectively (see DCBT, 457, 394) with a number of variants. Mt. Meru is mentioned in late Vedic literature dating from around the beginning of the first millennium B.C., and as would be expected there are strong hints that it may be an apotheosis of the Himalayas. It seems to play a role very reminiscent of the one allotted to Mt. Kun Lun 崑崙 in early Chinese thought (I (2)(b)(40)), and it is consistent with a fair knowledge of geography that the Indians placed themselves to the south of their mountain while the Chinese claimed a south-easterly position for their world relative to K'un Lun (loc. cit.). In Chinese thought however there was also an ancient tradition that the cosmic centre was in the middle of China itself (III (10)(c)), and eventually Mt. Sung Kao 嵩高 near Lo Yang was thought to be the central peak by orthodox cosmographers (see Cullen (1), 109).

In the Ṛg Veda (second half of first millennium B.C.) sky and earth, personified as Dyaus and Pṛthivī, appear as a complementary pair. In Gombrich's words (p. 113) :

> "Dyaus and Pṛthivī are compared to the two wheels at the ends of an axle, in which case the earth must be conceived of as flat, but also to two bowls, and to two leather bags, in which case the earth is presumably concave. Kirfel interprets the two-bowl image as implying that the lower bowl is the underworld, with the earth as the diameter where the two bowls join, but evidence for his view seems weak."

I explicitly abjure any intention of suggesting a connection of any kind, but there seems no reason not to point out a prima facie resemblance between the "two-wheel" idea and the planar version of the Kai t'ien as advocated by Wang Ch'ung at a considerably later date (II (3)(c); III (6)(b)). As an alternative to Kirfel's hypothesis I offer for the criticism of Indologists the suggestion that the two bowls may perhaps both be inverted as described at the beginning of the second chapter of the Chou pei.

The classic form of Hindu cosmology is found in material in the Pūraṇas, texts variously compiled during the first millennium B.C. From early times we meet examples of the universe referred to as an egg, the "egg of Brahman"; the earth is a flat disc at the centre of this egg. With the same qualification as previously, the parallel with the "hen's egg" simile of the Hun T'ien theorists is noteworthy (see III (7)(c)). Mt. Meru marks the centre of the disc, and surrounding Meru is the huge central continent of

Jambudvīpa. India, here called Bhāratavarṣa, occupies the southern quarter. The Uttarakurus occupy the north and the remaining two quadrants are East and West Videha. Round this central continent runs the salt ocean, and beyond this are six other continents, all ringshaped and concentric with Meru. The continents

> "are divided from one another by ring-shaped oceans of sugar-cane juice, wine, clarified butter, milk, whey (or whey and milk), and fresh water respectively. These circles are enclosed in a ring of mountains, called Lokāloka, beyond which is a realm of darkness that extends to the uttermost bounds of the universe ... The heavenly bodies were supposed to have their orbits in planes parallel to that of the earth ... and to move round Meru at their centre. Their light is intercepted by Meru, and thus night and day arise. The variation in the height of the sun above the horizon is explained by the supposition that the sun's orbit round Meru varies, being narrowest at the summer solstice and widest at the winter solstice. The sun is imagined to move in summer more slowly by day than by night, and in winter move more slowly by night than by day, the motions being equal only at the equinoxes."
>
> L. D. Barnett (1), pp. 196-7,
> quoted in Gombrich (1), 126.

The overall diameter of this universe is given as 500 million yojanas; a yojana can it seems be either nine miles or half that length. Mt. Meru is 84,000 yojanas high and 84,000 yojanas deep.

The Buddhist cosmography found in Buddhaghosa's Visuddhimaga (c. A.D. 400) differs from the Hindu picture in a number of features. In the first place an infinity of worlds was held as a commonplace. Our world, like all the others, has an axial mountain surrounded by seven concentric rings of mountains. Next comes the ocean in which four great continents are situated at the cardinal points : ours is the southern of these. Beyond the ocean is the world's mountain-wall. Note of course that neither here nor for Hindu cosmography has any reference been made to the important physical and metaphysical distinctions between the various heavens and underworlds outside the world of living men. I hope nevertheless that enough has been said to give a background, however sketchy, to the discussion which follows.

(b) Liang Wu Ti and cosmography

The emperor Wu 武 of the Liang 梁 dynasty (reigned A.D. 502-549) is well-known as a patron of literature and a devout Buddhist. The dynastic histories contain a few phrases which bring him within the field of this survey :

> "[After Yang Hsiung's attack on it] Huan T'an, Cheng Hsüan, Ts'ai Yung and Lu Chi each stated that the Chou pei was much in error when checked against the appearance of the heavens. Subsequently emperor Wu of Liang lectured in the Ch'ang Ch'un hall and gave judgement about the body of heaven in complete accordance with the text of the Chou pei. Presumably he produced some new idea in order to displace the Hun t'ien theory from its position."
>
> Sui shu, 19, 507, CHSC

If this was all we knew, then Wu Ti would simply have to be put down as a possibly conservative unknown quantity. Once again, however, the K'ai yuan chan ching has preserved for us material of which no trace exists elsewhere : we have several pages of an essay on cosmography by him, certainly enough to constitute the substance of a lecture. He begins with a sweeping dismissal of his predecessors :

> "From antiquity onwards many have discussed the heavens, but none have understood their form."

KYCC, 1, 23a

Man is a mere insect and the universe is infinite : how can be know anything about its true nature ? After a number of generalities Wu Ti, paradoxically enough, begins to give a detailed description of the cosmography of our world. It soon becomes evident that there is really no paradox involved, for the information given comes from religious revelation rather than from human reason :

> "Beyond the four great seas in the Diamond Mountain (金剛山), also called the Iron Boundary Mountain (鉄圍山). To the north of Diamond Mountain there is also the Black Mountain (黑山). The sun and moon rotate round this mountain, completing a circuit round it in a day and a night. When they are visible in the south they cannot be seen in the north."

KYCC, 1, 34b

It becomes clear immediately that this is a strand never before met in Chinese cosmography. Further there is an obvious similarity with the Indian theories previously described. Evidently Wu Ti is basing himself on borrowings from Buddhist scriptures, although he nowhere refers to any by name. Despite what the Sui shu says, any resemblance to the Chou pei cosmography is limited to the postulate of a horizontal solar orbit round a point above the earth's centre, as will appear. It is however not easy to achieve a correspondence between Wu Ti's terms and those of Indian thought. If the "four great seas" are the oceans surrounding the central mountain, then the Diamond mountain or Iron Boundary mountain is presumably the peripheral mountain of the disc-like world, Lokāloka for Hindus as we have seen, and Cakravāla for Buddhists (DCBT, 281; 485). Black mountain looks very much like Meru. In later references, unfortunately, Wu Ti does not seem to locate these mountains in the usual way; there is already something odd in the fact that Black mountain is said to be north of Diamond mountain, which is conventionally thought of as a ring centering on it.

Wu Ti's explanation of the sun's motion is very similar to the account given by Barnett above:

> "In winter the Yang sinks down low, and in summer it rises up high. When it is high the days are long, and when it is low the days are short : heat and cold, darkness and light are all caused by this. When the Yang rises in summer the sun is high and its path beyond [the obscuration of] the

> mountain is long; when the Yang sinks in winter the sun is low and its path beyond [the obscuration of] the mountain is short. When the path beyond the mountain is long the days are long. When the path beyond the mountain is short the days are short. At the two equinoxes it is just midway between high and low, so half [the time] it is invisible and half visible. Therefore day and night are equal and do not differ in duration."
>
> KYCC 1, 34b

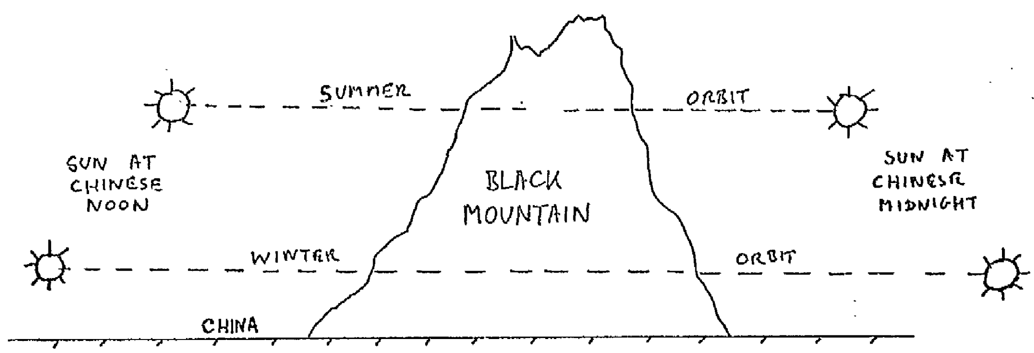
The role of the obscuring mountain is unique in Chinese cosmography. The rising and falling of the Yang with the seasons is of course quite familiar, being referred to by Wang Ch'ung (III (6)(g)) and Yang Ch'üan (IV (3)(b)) to give only two examples. This is possibly an instance where Wu Ti sinified his Indian source material. He continues :

> "The sun shines in the south; therefore the <u>ch'i</u> of the south is warm. The sun is hidden in the north; therefore the <u>ch'i</u> of the north is cold. The reason that it is always warm in the south is that in the winter months the sun is near the south and low down; therefore [the south] is still warm even though it is winter. In summer the sun is near the north but high up; therefore even though it is summer [the north] is still not hot, which is the reason why the north is always cold."
>
> KYCC 1, 35a

It seems that Wu Ti has in mind some picture such as Fig. V (3) ; China's midnight would be the Hyperboreans' noon, as in the <u>Chou pei</u>.

Fig. V (3)

Liang Wu Ti's cosmography.



This is relatively straightforward, and before things become more complicated it seems appropriate to clear up the point of whether the sun moves independently of heaven or not. We have seen that Wu Ti seems to mention the rising and falling of the sun as a direct consequence of the rising and falling of the Yang. Unlike the case of Yao Hsin (IV (5)(b)) it does not seem to be carried up and down on an oscillating heaven. Fortunately Wu Ti is explicit on this point :

> "The bodies of the three ch'en 辰 [= sun, moon, stars] are controlled by the Yin and Yang, sometimes rising, sometimes falling, moving in accordance with the seasons. When we come to the ch'i of heaven, it is clear and subtle, encircling everything; it moves by itself without ceasing. The sun, moon and constellations move slowly or quickly, each according to a different rule. They are not attached to heaven."
>
> KYCC, 1, 35b

To a certain extent, therefore, Wu Ti's view, and his justification for it, is similar to that found in the Ch'i Mêng material (III (9)(a)). It is more difficult to picture the physical relations involved in the following passage, in which the objective is evidently to explain why the sun rises and sets at different points on the horizon throughout the year :

> "The peak of Black Mountain is directly to the south of the North [Celestial] Pole. Therefore in summer even though the sun is high it has to reach [the direction] <u>yin</u> 寅 (60° E of N) before it appears, and disappears in [the direction] <u>hsü</u> 戌 (60° W of N). At the spring and autumn equinoxes it is midway between high and low. In the morning it has got outside Diamond Mountain; even though it is level with the mountain it is far beyond the mountain, and is thus obscured by Diamond [Mountain] so that the sun cannot come out. [The sun] has to get to [the direction] <u>mao</u> 卯 (E) before it can be seen. [On setting] in the west the situation is the same. In winter the sun orbits lower, and the time for which it is hidden is accordingly longer. In the morning it reaches [the direction] <u>ch'en</u> 辰 (60° E of S) and only then comes out above Diamond [Mountain]. In the evening it reaches [the direction] <u>shen</u> 申 (60° W of S) and goes down below Diamond [Mountain]. Diamond [Mountain] is level [in height] on all sides. Black Mountain is to the north, and in the north it is very high, with peaks joined from east to west; near the front [i.e. the south] it becomes lower. That is why the sun is hidden [when it is] in the north and visible [when it is] in the south. Now the human eye reaches its limit when it gazes far away, so even though the two mountains vary in height, no part of them can be seen."
>
> KYCC, 1, 35a

Bearing in mind the probable identification of Diamond Mountain as the ring of mountains at the world's edge, it is not impossible to comprehend the general picture described by Wu Ti. During the night the sun is outside this wall, and dawn occurs when the sun reappears over the peripheral mountains. Naturally the higher the sun is the sooner we shall glimpse it over the mountains. The sun's orbit is obviously not concentric with the mountain ring, and this seems consistent with previous statements that Black Mountain, marking the orbital centre, is "in the north". This situation is certainly not precisely equivalent to the Indian schemes, and I think it would be mistaken to attempt a detailed geometrical reconstruction of the sort of cosmography involved. Such an attempt at a consistent reconstruction would presuppose a consistent theory on Wu Ti's part for us to reconstruct, and I cannot say that I feel forced to make this supposition. I conjecture, rather, that Wu Ti took the idea of the central mountain from Buddhist holy writ and used it to explain day and night in general terms by placing the heavenly bodies in orbit round it. To this extent he was certainly within the tradition as described above. The attempt to explain seasonal solar phenomena using Diamond Mountain was a separate matter and I am not in a position to say whether or not this idea has its roots in Indian tradition. It would however surprise me to find that the last sentence did not originate from the text of the Chou pei (II (3)(d)), which it must be admitted was superior to Wu Ti in economy of means.

While he attempts to explain solar phenomena by two obscuring mountains, and then proceeds to invoke optical illusion to explain why the mountains cannot be seen, the Chou pei operates with an optical illusion alone.

Wu Ti's text is followed (KYCC, 1, 36a) by material attributed to various officials of his Shang lin 上林 office, who not surprisingly express their wholehearted endorsement of the imperial cosmography. They make a gallant attempt to graft degree measurements of the conventional spherical system onto the arrangement of the cosmic mountains; the picture that results seems to place the two mountains at the ends of what would be the horizontal north-south diameter of the celestial sphere, if there was one. This does not seem to fit the idea of Diamond Mountain as a ring wall, but we must surely not expect consistent astronomical sense from a document of such origins.

I have not found any evidence of later Chinese interest in Wu Ti's cosmographical writing. Buddhist cosmography was certainly promulgated, but through the medium of the huge bulk of translated Buddhist scriptures which accumulated through succeeding centuries. Cosmographically interesting examples of these may conveniently be found in TSCC, Ch'ien hsiang tien, 9, 140 ff. Evenhandedly enough the TSCC editions also include (p. 148) a polemic against the Mt. Meru cosmography; unfortunately I have been unable to determine the date or authorship of this criticism.

An odd historical footnote to all this is found in the nineteenth century Japanese controversies between advocates of Buddhist cosmography and those holding the modern views (Nakayama (1)) With typical Japanese thoroughness the proponents of Mt. Meru constructed mechanical models of their world picture, complete with circular tracks for the sun and moon centering on Meru. These models are described and illustrated by Needham, SCC IV : 2, 529. To my knowledge this is more than any Chinese advocate of the Kai t'ien theory ever did.

(c) Against Chiang Chi's theory of lunar illumination

The intolerant reader may feel inclined to dismiss Wu Ti as a religious enthusiast who made use of his position to demand assent to his chosen world-picture. Although one is tempted to think of a parallel with Cosmas Indicopleustes' flat -earth Christian Topography of circa A.D. 540 (Dreyer (1), 214), it would be a little unfair to do so. Wu Ti's work bears no resemblance to Cosmas' polemical philistinism, mistaken though it is in comparison with the Hun t'ien, and another fragment shows a considerable acuteness of reasoning. This is on the subject of whether or not the sun is the source of illumination for all other heavenly bodies; in KYCC this is placed between Chiang Chi's assertion of this principle (IV (9)(b)) and Tsu Keng-chih's comment (V (2)(c)).

> "Liang Wu Ti's Ch'ang I 嘗儀 [otherwise unknown] says : The moon's body is not bright all over [i.e. the explanation of its phases is that ohly half of the lunar sphere emits light, and presumably we see it at varying angles throughout the lunation] and the stars likewise shine by their own light. They do not receive their light from the sun. Suppose it was true that the sun caused the moon to shine, and [as we see] its brightness is at a maximum far from the sun and at a minimum near to the sun. But the five planets in their orbits likewise approach and recede from the sun. How is it then that the planets do not wax and wane ? Of course we know that they do not. The essence of the great Yin shines of itself, but, unlike the great Yang it is not uniformly radiant [and so the moon is not bright all over]. The stars, moon and sun are all round in shape, not round like a mirror, but just like a pellet [i.e. spherical]."

KYCC, 1, 23a

Wu Ti's criticism is very telling; it is indeed hard to avoid the conclusion that the planets should show phases if they were illuminated by the sun. Kepler himself used this argument for the self-luminosity of both stars and planets until he learned of the varying telescopic appearance of the planets from Galileo's Sidereus Nuncius of 1610 (Dreyer (1), 411). It is of course only the inferior planets, Mercury and Venus, that show phases and it is interesting to note that Tsu Keng-chih in his paragraph on this subject is to a certain extent aware of the necessity of this distinction. He realises that stars closer to earth than the sun is should show phases if not self-luminous, and thence argues that all stars and planets must, in the absence of phases, be further away than the sun. Naturally neither Wu Ti nor Tsu Keng-chih could see the discs of the planets and their denial of phases must be based on their failure to detect a noticeable variation in the planets' luminosities.

(A recent Japanese study of Wu Ti's cosmography is Umehara (1). It was not referred to during the composition of this section, but appears to use no Chinese material unknown to me.)

(6) Ends and Beginnings

(a) Syncretism

This survey has been mainly concerned with examples of the tradition of critical debate on cosmography, and if one thing is certain about the history of cosmographical theories in China it is that it is a story of controversy and material disagreement. It is perhaps fitting that the period considered should end at the time when the idea was being put forward that all the discussion was perhaps rather pointless. Under the Liang we find the example of Ts'ui Ling-en 崔靈恩 (fl. c. A.D. 514), of whom it is said :

> "He set up a new theory, according to which the Hun t'ien and Kai t'ien were identical."
>
> Liang shu, 48, 677, CHSC

Unfortunately we know no more of his ideas than this brief reference. A plausible conjecture might be that Ts'ui simply pointed out that the mapping of the heavens on either a sphere or a plane disc could provide equivalent information. Fuller material of a similar kind is found in the extant preface to the lost work Ssu shu chou pei tsung 四術周髀宗 by Hsin-tu Fang 信都芳 of the Northern Ch'i (A.D. 550-579). After mentioning Yang Hsiung's condemnation of the Kai t'ien (III (4)(a)) around 0 B.C. he continues:

"At that time Yin Hsien 尹咸 the Astronomer Royal thoroughly investigated the [gnomon] shadow and the Kai [t'ien]. He changed the ancient Chou method, whereupon Yang Hsiung noticed it and made out difficulties. From Chou Kung's measurement of the shadow at Wang Ch'eng long ago up to the Han dynasty this was the one attack made on the Kai t'ien. The Hun t'ien viewed heaven as a cover and its text was the Ling hsien. The Kai t'ien looked up to view heaven, and its text was the Chou pei. Even though covering and looking up are diffecent, in the end [they turn out] the same."

Pei shih, 89, 13a (SPTK)

Hsin-tu Fang is apparently contending that what Yang Hsiung attacked was a mistaken revision of what had originally been a correct theory. As for the mention of Yin Hsien the only relevant material I know of is in the preface of the bibliographical monograph of the Han shu (30, 1701, CHSC) which says that he compiled a collection which formed the basis of Liu Yin's Shu shu lueh 數術略 This was done "in the time of Emperor Cheng (32 B.C. - 6 B.C.)." I know of no authority for saying that Yin was a Kai t'ien theorist. The mention of shadows is perhaps authorised by the inclusion of a "Book on solar shadows" Jih k'uei shu 日晷書 in the Shu shu lueh. Hsin-tu Fang's view is of course somewhat implausible and there is a rather odd atmosphere in his contention that basically opposed theories are really identical. Perhaps this readiness to tolerate contradictions is a symptom of the strain induced by the attempt to make a flat-earth view of the universe fit reality.

(b) A new proposal to solve an old problem.

There is no evidence that cosmographical theorising suffered a discontinuity in the period between the Liang and T'ang. A fragment by Chu Shih 朱史 (fl. c. A.D. 563) is reminiscent of Chiang Chi in that it certainly involves a seasonal change in the distance between heqven and earth.

> "The sun is 1,670 li across. The circumference of heaven if 600,231 li. Seeking the size of the diameter one gets 194,164 li [implying a value of $\pi \doteq 3.09$]. Halving it [read 半 for 求] one obtains 97,800 li. This is the distance of heaven from earth on the days of the equinoxes. On the day of the summer solstice heaven is 81,394 li above earth. On the day of the winter solstice heaven is 106,020 li above earth."

KYCC 1, 37a

Unlike the case of Chiang Chi, however, (IV (9) (d)) one cannot guess at the rationale behind these figures. If we may go by precedent it is unlikely that they have any basis other than the gnomon shadows and "inch-for-a-thousand-li" rule that had guided cosmographers for the preceding millenium. In the third century Liu Hui had criticised this scheme by implication when he described a method for establishing the dimensions of the universe without the arbitrary shadow-rule assumption (IV (2)(d)), but his was a purely theoretical construct. Liu Ch'uo 劉焯 however, writing in A.D. 604 (Sui shu 19, 520, CHSC) made a practical proposal which if implemented would have partly anticipated the work of I-Hsing and Nan-kung Yüeh over a century later (see SCC III, 292; SCC IV, 42 ff; Beer et al. (1)). Liu gives a not very remarkable survey of cosmographic theories and their differences, but then turns to a criticism of the ancient shadow-rule :

> "The 'inch difference for a thousand li' is quite lacking in basis; it is clearly just dreamed up and in fact is unreliable. Now [far to the south] in Chiao and Ai provinces there is no shadow to the north of a gnomon, showing that one does not need to go 10,000 li southwards to reach the point below the sun. [The old rule predicted at least 15,000 li.] This shows that 'an inch for a thousand li' is not the real rate of change. Now in my explanation of the sphere I take distance as my main quantity, but these distances remain as yet unmeasured. If I could find the rate of change [of the shadow, these distances] would become clear. Now these are the years of [your majesty] the Great Sage, times of peace, the reform of abuses, and of setting the seasons newly to rights. I request that I be given the services of a hydraulic technician and mathematicians, with whom I shall select a level area of land to the north and south of the [Yellow] River, so that it can be measured for several hundred li, first having fixed north and south. We shall check times with clepsydras, and level the ground with plumblines, and by following the seasons of solstices and equinoxes we shall measure the shadow on the same day [at different places]. When we have found the quantity of difference [in the shadows], the number of li [corresponding to this] can be known. Then nothing in heaven and earth will be able to conceal its form, and no heavenly body will escape calculation. [Your Majesty will thus] surpass previous illustrious sages, emulating them in removing doubts. I beg you not to dismiss these words because of the speaker."
>
> Sui shu 19, 521, CHSC and KYCC, 1, 39 a

Liu Ch'uo's research proposal was not viewed with favour: after detailing it both Sui shu and KYCC have the terse record of its dismissal : pu yung 不用

"Not adopted". In comparing Liu's work with the survey of A.D. 724 we should of course remember that Liu did not expect to find anything more significant than a more correct version of the shadow-rule, whereas the later survey ended by disproving the rule altogether in any form. Liu was however capable of a high level of critical thought, as his short discussion of solar eclipses shows (KYCC, 1, 39b). In it he clearly realises that different observers will see the same solar eclipse differently, although it is not quite obvious whether this idea was originally arrived at empirically. The classical Hun t'ien cosmography certainly implied that the moon might only obscure the sun for a limited number of observers on the (flat) earth. Liu does seem to have been the first to realise this, and perhaps he might have been equally perceptive in his conduct of a meridian survey. We should remember however that the effect of the survey's results, when it came, was to convince those engaged in it of the foolishness of all attempts at cosmography rather than to lead them towards a more accurate view which would have involved abandoning the flat earth (see Hsin T'ang shu, 31, 816, CHSC).

APPENDIX (i)

Some notes on the apocryphal books

Certain books referred to in this survey may conveniently be classed together into a group usually called "apocryphal books" in English or *wei shu* 緯書 (sometimes *ch'an wei* 讖緯)in Chinese. They may be grouped in the first instance by their titles, which mostly make some reference to one of the accepted *ching* classics, adding some more or less cryptic qualification; two examples are the *Shang shu k'ao ling yao* 尚書考靈曜 (see III (10)(b)) and the *Ch'un ch'iu yuan ming pao* 春秋元命苞 (see III (10)(f)). Note that *ching* can also refer to the lengthwise warp thread in weaving, while *wei* means the crosswise weft. This is probably connected with the traditional suggestion that the *wei shu* preserve an esoteric teaching passed on orally by the disciples of Confucius by way of supplement to the orthodox contents of the *ching*. A further characteristic of the group is the nature of their contents : these are typically a blend of numerology, astrology, omen interpretation, and what has been called "phenomenalism" of the sort that may originally have stemmed from Tsou Yen (SCC II, 378). These books were well-known by the second century A.D., and the high repute they enjoyed is shown by the fact that Cheng Hsüan wrote commentaries to several of them. In later centuries they were held in less regard, and their banning and widespread destruction under Emperor Yang of the Sui (A.D. 605-617) ensured that all wei shu except a few connected with the Book of Change now exist only in fragments collected from scattered quotations in ancient works. The first modern attempt to reconstitute the wei was the Ku wei shu 古微書 of Sün Chüeh 孫瑴 during the Ming. Ch'ing scholars such as Ma Kuo-han 馬國翰 continued the work (see his Yü han shan fang chi i shu 玉函山房輯佚書), and perhaps the most complete effort is the recent Japanese Isho Shūsei 緯書集成, Yasui (1). In this survey the wei shu have been particularly important in connection with early theories of the motion of the earth (III (10)). As was seen in IV (2)(c) they also played a rôle in supplying Wang Fan with a starting point in his calculations of the size of the heavenly sphere. Lest it should seem that the wei shu drew their cosmography solely from the Hun t'ien it is worth mentioning here that TPYL 1, 10b and PTSC 149, 4b preserve fragments of the Hsiao ching yüan shen ch'i 孝經援神契 in which the dimensions of the seven hêng are given as in the Chou pei (II (3)(b)). The most convenient survey of the origins and dating of these books is the account (in English) in Tseng Chu-sen (1), 100 ff. The detailed researches of Ch'en P'an 陳槃 have been appearing in the Bulletin of the Institute of History and Philology

(Academia Sinica) since 1945, and a resumé of part of his work is found in Kaltenmark (1). There is fairly general agreement that the <u>wei shu</u> are products of the first century B.C., but it may be of interest to mention evidence to this effect having particular relevance to this survey.

An obvious source of information about the dating of any book is the existence of early quotations from it : the first quotation, if authentic, gives us a <u>terminus ad quem</u> for the composition of the work. We must beware, of course, of forgetting that the book may have been written considerably earlier than our first evidence for its existence. In the case of the apocrypha, mentions appear rather abruptly and in some profusion in the first century A.D. Admittedly Tung Chung-shu 董仲舒 produced something not dissimilar from the <u>wei shu</u> in title and contents when he wrote his <u>Ch'un ch'iu fan lu</u> 春秋繁露 c. B.C. 135, as did Ching Fang in his <u>I chüan</u> 易傳 . I have however reviewed the monographs of the <u>Han shu</u> in an effort to discover possible <u>wei shu</u> references in the Western Han edicts etc. preserved therein without finding anything more plausible than the title <u>Ch'un ch'iu wai chüan</u> 春秋外傳 (<u>Han shu</u>, 21, 1012, CHSC). If the <u>wei shu</u> existed before A.D. 10 they were obviously not accorded the same importance as in later times.

Wang Mang 王莽 (reigned A.D. 9-23) was renowned for the attention he paid to omens, prognostications, and what may be with varying degrees of generosity called proto-sciences or pseudo-sciences. One of the ways in which this appears in his biography in the Han shu is by an interest in what look very much like wei shu. Immediately before his accession Wang Ch'i 王奇 et al. published a book of omens, Fu ming 符命 in 42 chapters (Han shu 99, 4112); in those times such action was unambiguously political. Similarly, in A.D. 21 Li Yen 李焉 procured the writing of a ch'an shu 讖書 in some 100,000 characters (Han shu 99, 4166) : this last seems highly relevant to the present discussion. Perhaps the best evidence for growing recognition of the wei shu is that when in A.D. 3/4 Wang Mang gathered experts on various subjects ranging from the classics to military strategy we are specifically told that he also called on those who were acquainted with the t'u ch'an 圖讖 (Han shu 99, 4069). Both Wang Ch'ung and Chang Hêng use these terms as if they were closely connected with, if not a synonym for wei 緯

A flood of wei shu references begins with the restoration of the Han. The emperor Kuang Wu 光武 (reigned A.D. 25-58) was notorious for his reliance on the apocrypha. In a discussion of the arrangements for a sacrifice on Mt. T'ai in A.D. 56 eight different apocrypha are mentioned, with titles including the Ho t'u hui ch'ang fu 河圖會昌符 and the Hsiao ching kou ming chueh 孝經鉤命決

(Hou han shu, chih 7, 3165, CHSC). More to the present point is the fact that the Shang shu k'ao ling yao 尚書考靈曜 (see III (10)) is thrice quoted in a memorial of Chia K'uei written in A.D. 92/93 (Hou han shu, chih 7, 3027, CHSC). On this basis one would certainly look for an origin of the wei shu by at least the early years of the first century A.D. The Po hu t'ung (A.D. 80) quotes them frequently as authorities (see III (6)(k)), and not unexpectedly Wang Ch'ung, writing almost simultaneously, sets out to deflate their pretensions (Lun heng, 26).

This note may be well concluded by quoting an early opinion on the origin of the apocrypha; it is worthy of some attention, as it is that of Chang Hêng, whose date in the second century and whose high court position combined to place him at a better vantage point than we can hope for today. In a memorial directed against the use of the apocrypha in state affairs, he notes :

> "Liu Hsiang and his son set the archives in order and critically reviewed the nine schools of philosophers, but they gave no material on the ch'an [books]. These are first heard of after the emperors Chêng [32 B.C. - 7 B.C.] and Ai [6 B.C. - A.D. 1] ... When we come to Wang Mang's usurpation, this was a time of great disaster for the Han; why did the eighty chapters give no warning ? Thus one can tell that the t'u and ch'an were completed by the end of [the reigns of the emperors] Ai and P'ing [A.D. 1-5]."
>
> Hou Han shu 59, 1912, CHSC

This may serve to strengthen the conclusion that the origin of most of the apocrypha lies near the time of Wang Mang's usurpation. It is not therefore surprising that they show signs of Hun t'ien influence as that theory was by then well on the way towards supplanting its rival

APPENDIX (ii)

Claims for a Chinese discovery of the earth's sphericity

In examining the material from which this survey has been compiled I have kept in mind, amongst other things, the possibility that it might contain some hint at least of a theory of the earth's sphericity. I do not pretend that I have been able to do the impossible and approach the evidence with a mind empty of preliminary conjectures, nor do I deny that my initial conjecture was that the ancient Chinese conceived of the earth as basically flat. Having completed the survey I am unable to find any instance where this conjecture has been refuted by the literary evidence and in some instances fairly explicit statements supporting its application have been found. There is in contrast considerable and often insuperable difficulty in interpreting the texts on the basis that their authors believed in a spherical earth, and at no point do we find any sentence stating the earth's sphericity. On this basis I feel rationally justified in continuing to hold to my preliminary conjecture, i.e. that Chinese cosmographers never on their own initiative made the step of rejecting the common-sense notion of the flatness of the earth.

The preceding statement is intended to describe the logical form of my position on this question, and in it I have deliberately refrained from discussing particular instances. In the absence of any previous dispute by scholars it might perhaps have been satisfactory enough simply to ask the reader to bear these remarks in mind while reading the survey. Matters are, unfortunately, not so simple. Several eminent scholars, Western and Chinese have stated in print their conviction that the earth was held to be spherical by ancient Chinese cosmographers, particularly by supporters of the Hun t'ien. Needham (see below) is of course the most influential of these, and Chinese examples are to be found in Cheng and Hsi (1), 67ff. and Cheng (1). It might be felt, therefore, that since this survey expresses a contrary view a detailed refutation of the writings of these authors should have been provided. I agree that it would certainly be unfortunate if such (in my view) erroneous conclusions went unchallenged, and I am at present (1976) preparing a detailed rebuttal for possible publication. Nevertheless I will only deal briefly with the question at this point, not from a wish to avoid difficulties, but simply because the evidence falling within the field of this survey is so very weak. When a serious misconception has been put into print the only safe course in a printed reply is to give a self-contained and detailed retort of sufficient completeness to ensure that the matter is settled to the satisfaction of anyone who has read both sides of the question. In the present context it should be sufficient to point out the factual basis on which the opposition's case rests and to exhibit its inadequacy.

This is most conveniently done by taking the example of Needham. The sphericity of the earth in ancient Chinese thought is affirmed in SCC II, 192, 193; III 217-219, 438(a), 498, 499; IV (1) 52; IV (2) 483 (f); IV (3) 585; V (2) 102. The evidence to which Needham refers is principally the use by Chang Heng (III (7)(c) of the simile of an egg in describing heaven and earth, in particular the comparison of the earth with an egg's yolk. This, in his view,

> "shows clearly how the conception of a spherical earth with antipodes would arise naturally out of [the visualisation of the celestial sphere]."
>
> SCC III 217-219

Reference to my detailed examination of Chang Heng's writing (III (7)(c)) shows that this conception certainly did not arise in Chang Heng's mind. He states explicitly that earth is "flat and quiescent", and makes the depth of earth equal to the radius of the celestial sphere. For him the earth's surface is clearly a horizontal diametral plane of heaven. The analogy of the yolk is evidently a reference to the earth being completely enclosed by heaven rather than just covered as in the <u>Kai t'ien</u>.

李

In III, 498, Needham, in my view, misreads the text of the thirteenth century writer Li Yeh 李冶 thus making him state that the earth is spherical when all he actually says is that the edge of the [flat and square] earth is rounded off so that it does not obstruct the rotation of heaven (see Cullen (1) 109). It might seem that Needham has stronger evidence when he claims that

> "The great cosmologists of the Han repeatedly said that the earth floated in the heavens like the yolk in a hen's egg, or that the earth was 'as round as a crossbow bullet' suspended in space."
>
> SCC IV (3), 584

I have already dealt with the hen's egg analogy; I know of no example of a Chinese cosmologist making the latter statement before the time of the Jesuits, although Chang Heng and others certainly compare <u>the heavenly sphere</u> (not the earth) to a crossbow pellet. This is surely a slip of the pen such as must from time to time occur in a work as vast as Needham's. Leaving aside Needham's highly conjectural (SCC V (2), 102) interpretation of the words 閶緯 as a reference to the pole of a spherical earth in a rhapsodic poem of 110 B.C., the only remaining evidence for his claims is found in SCC II 192-193. Here he deals with a number of paradoxes due to the pre-Ch'in <u>ming chia</u> 名家 school of logicians, and in particular with some attributed to Hui Shih 惠施 (fourth century B.C.) in chapter 33 of

Chuang tzu. Relevant to our purpose are :

(a) The South has at the same time a limit and no limit.

(b) I know the centre of the world, it is north of the State of Yen and south of the State of Yüeh [Yen is of course north of Yüeh].

Needham notes Hu Shih's suggestion that the basis of these two paradoxes might have been a belief in the earth's sphericity, but very fairly points out Feng Yu-lan's objection to this. The reader of this survey has seen that there is no mention of the Hun t'ien (the theory Needham associates with the spherical earth) until three centuries after the probable date of the Hui Shih text, and it seems far safer to leave the paradox unresolved rather than base any suppositions on such a doubtful interpretation. Even supposing that (which I deny) Hui Shih conceived of a spherical earth, and all the accompanying hypotheses required to make sense of such a notion, the rest of the evidence forces us to the conclusion that his suggestion was completely ignored by later generations.

I hope I have said enough to make it clear why I do not think the suggestion that the ancient Chinese knew of the earth's sphericity worthy of very much discussion in the present context, however important it may be in general to ensure that incorrect theories are properly refuted.

APPENDIX (iii)

The shadow principle

It is extremely common to find reliance in early Chinese cosmographical works on a principle, sometimes not however stated explicitly, which suggests a simple proportion between the length of a shadow cast by a gnomon and the distance from the gnomon to the point below the heavenly body concerned, which is usually the sun. Most commonly the relation claimed is that a 1,000 li displacement north or south of an eight foot gnomon changes its shadow by one inch: this is the case in the Chou pei suan ching. In the Huai nan tzu the 'inch for 1,000 li' principle is applied to a ten foot gnomon. Is any such principle ever valid ? The answer is negative on two counts. Firstly, on a spherical earth a linear relationship between shadow length and north-south displacement of gnomon is impossible. Secondly, in the latitudes where all the observations discussed in this survey were made, the relationships given do not hold even as an approximation.

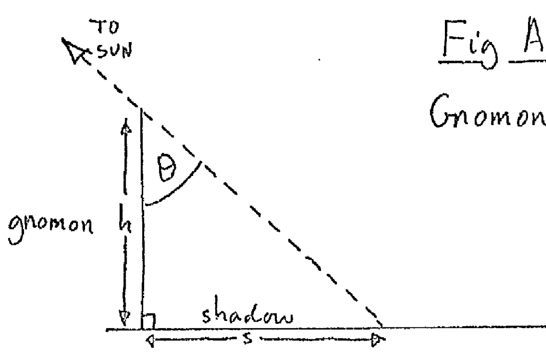


Fig A(1)
Gnomon shadow.

Let us consider first the general form of the relationship. The spherical form of the earth and its circumference of 24,800 miles means that in Fig. A (1) which shows a gnomon used for an observation of the noon sun, a movement of the gnomon 69 miles north or south will cause an increase or decrease of one degree in the angle This is true wherever the gnomon is erected, and follows from the fact that the sun's rays, coming as they do from 93,000,000 miles away, strike the earth's surface sensibly parallel to one another, as in Fig. A (2)

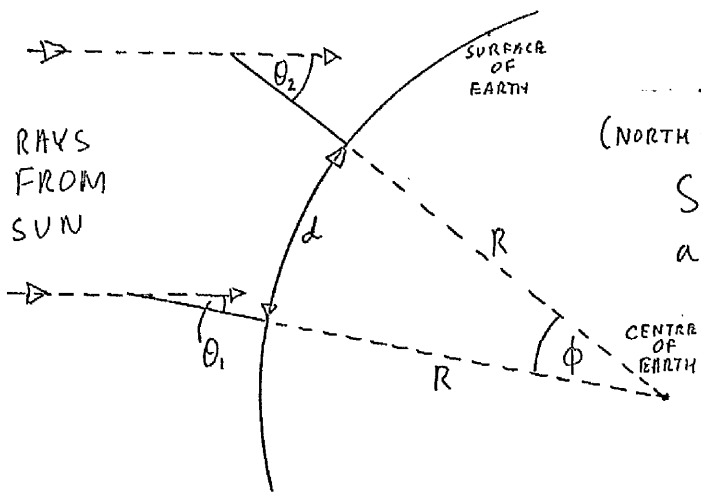


Fig A (2)
(NORTH - SOUTH SECTION)
Solar altitude on a spherical earth.

Obviously the difference between the angles at the two gnomons is given by :

$$\theta_2 - \theta_1 = \phi \quad , \quad \text{and} \quad d \propto \phi$$

If ϕ is one degree, then as there are 360 degrees in a complete revolution :

$$d = \frac{24,800}{360} \text{ miles}$$

$$\therefore \quad d = 69 \text{ miles}$$

Thus we have arrived at a simple linear relation between the angle θ at the gnomon and movement north or south. However, the length of the shadow cast by the gnomon is given by :

$$s = h \tan\theta$$

This means that the relation between s and θ is not one of simple proportion: in fact when θ is 90 degrees s becomes infinite, as can be seen directly from Fig. A (1) Although, therefore, there is a linear relation between north-south motion and the angle at the gnomon, there can be no such simple relation between north-south motion and shadow length.

Let us now consider the relationship in a particular case : the <u>Chou Pei</u> gives the shadow of an eight foot gnomon at the summer solstice as 1.60 feet, which implies that the angle is given by :

$$\theta = \tan^{-1}\left(\frac{1.6}{8}\right) = \tan^{-1} 0.2$$
$$\therefore \theta = 11.3^{\circ}$$

Now suppose the gnomon was moved 69 miles ($\doteqdot$200 <u>li</u>) northwards. As we have seen, θ would increase to 12.3°, and the new shadow-length would be given by

$$s = (8\text{ feet}) \tan 12.3^{\circ}$$
$$\therefore s = 1.74\text{ feet}$$

Thus a motion of only 200 <u>li</u> has caused a change in shadow-length of more than one inch. For larger values of θ, such as would be found nearer the winter solstice, a much larger change in shadow-length would result. We have already seen that a linear relation cannot generally hold; we have now seen that the figure of 'one inch for a thousand li' is not even a local approximation for China.

Nevertheless the figure remained unexamined and accepted for a considerable time. Needham, SCC III, 292 ff gives an account of attempts to find an accurate value, leading up to the survey of 一行 I Hsing in A.D. 721 to 725. No such effort, in the absence of a theory of the sphericity of the earth, could in any case ever have been more than an approximation valid in the region of observation. There is in fact a configuration of the universe in which such linear relations can hold, and this is one in which the heavenly bodies move on a flat heaven which is a constant distance from a flat earth, as in Fig. A (3)

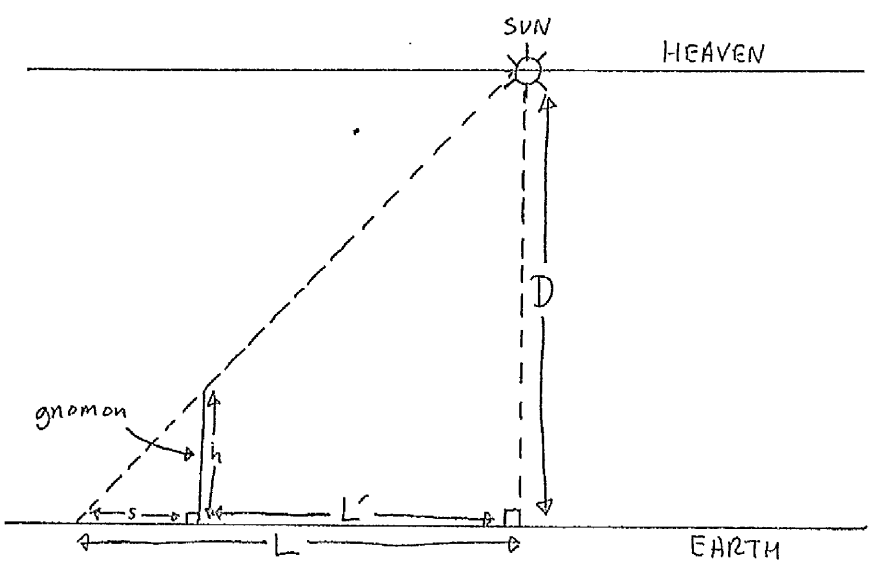


Fig A (3) Gnomon shadow variation

By similar triangles :

$$\frac{s}{h} = \frac{L}{D}$$

$$\therefore \quad s = \frac{hL}{D}$$

As h and D are constant, evidently :

$$s \propto L$$

And, as s is very small compared to L, so that $L \doteqdot L'$, we may say :

$$s \propto L'$$

Or, in other words, the shadow length is proportional to the distance from the gnomon to the subsolar point.

The distance between the flat heaven and earth can be found if the length of the gnomon and the relationship between shadow and distance to subsolar point are given. Thus, for an eight-foot gnomon and an 'inch for a thousand li', we have :

$$\frac{1 \text{ inch}}{80 \text{ inches}} = \frac{1{,}000 \text{ li}}{D}$$

$$\therefore \quad D = 80{,}000 \text{ li}.$$

If the same principle is applied to a ten-foot gnomon, D, the height of heaven, becomes 100,000 li.

APPENDIX (iv)

Some bibliographical notes on the Chou pei suan ching
周髀算經

A full and up-to-date study of this work in a Western language is long overdue: the version of Biot (1) was a pioneering endeavour and naturally suffered from those faults inseparable from the first advances into a difficult field. In default of such a study, the following note may be of interest. It may be compared with the account of Needham, SCC, III, 19 ff.

The early history of the book is most obscure. Its title was, it may be noted in passing, originally Chou pei alone. The present title was not adopted until the T'ang dynasty. The first firm evidence we have for the existence of the book is the fact that it bears a commentary by one Chao Shuang 趙爽 whose references to the Ch'ien Hsiang 乾象 calendar promulgated in A.D. 222 suggest he wrote after that date. According to his preface, the Chou pei was the text of the Kai t'ien school as the Ling Hsien of Chang Heng (A.D. 78-140) was the text of the Hun t'ien.

We have seen a good deal of evidence, particularly in II (3)(g), that the methods and cosmography of the Chou pei probably go back to the time of the Warring States. I would stress here as elsewhere, however, that this does not prove that the book itself was extant in whole or in part at that time. Ch'ien Pao-Tsung (2), points out two pieces of evidence that would date the actual work, as they relate to information that would probably not have been included in the book after it had become obsolete. Firstly he notes that the Chou pei uses the old Ssu fen li 四分曆 'quarter remainder calendar', replaced by the Tai ch'u 太初 'great inception' calendar in 104 B.C. Secondly the names of the 24 solar terms used in the Chou pei, as well as stellar data for the sun's position at the solstices and equinoxes, are in agreement with those in Huai nan tzu (c. 120 B.C.). Thus we can say that the last third of the book at least (where these subjects are mentioned) probably dates from before 100 B.C. The more directly cosmographical points were not necessarily then present.

The bibliography of the Han shu, compiled by Pan Ku 班固 (A.D. 32-92) and ultimately based on the Pieh lu 別錄 composed by 劉向 Liu Hsiang between B.C. 26 and B.C. 6, makes no mention of the Chou pei. The same could of course be said of other works definitely then extant, so we need not conclude that the Chou pei was not known at the time. Despite the fact that Wang Ch'ung (c. A.D. 30-95) is an eloquent defender of K'ai t'ien notions he neither mentions the Chou pei nor betrays any knowledge of its mathematical contents. The figures he suggests for the size of the universe are quite incompatible with the Chou pei's results (see III (6)(e)). This may of course be no more than a consequence of Wang's well-known provincialism. Around A.D. 180 Ts'ai Yung mentions the Chou pei, but it seems likely that he refers to the theory rather than the actual book, as he mentions the Hun t'ien and Hsüan yeh in similar terms (see III (8)(a)). In his advocacy of the Hun t'ien, Lu Chi (c. A.D. 240) mentions the Kai t'ien as a theory, but does not refer to the Chou pei (see IV (2)(a)). Wang Fan (IV (2)(b)) mentions both, so perhaps it is not unreasonable to suggest here that he is using Chou pei as the name of a book; it may have been that Chao Shuang's efforts were beginning to rescue the work from obscurity. Further commentaries on the work by Chen Luan 甄鸞 (c. A.D. 570) and Li Shun-Feng 李淳風 (c. A.D. 640) have been preserved.

This lack of evidence for the existence of a book called Chou pei before the third century A.D. is provoking but of little consequence for the purposes of this survey: we have already seen plenty of evidence that its contents had been current during the whole period of interest to us. As nothing depends on the result there seems little point in balancing probabilities about the book's origin, but the temptation is hard to resist. On the basis of what is little more than enlightened guesswork, therefore, I would say that the book might have been compiled during the first century A.D. around a nucleus of more ancient material such as the calendrical section and the dialogues of Chou Kung and Chen Tzu. Such a date allows a reasonable two centuries for it to become hoary enough for a commentary to be appropriate, while still giving some excuse for it not being noticed by Pan Ku or Wang Ch'ung. A slight addition to this rather insubstantial basis is the consideration that the first century A.D. seems to have been the time when the arguments between supporters of the _Hun t'ien_ and _K ai t'ien_ theories were being stated clearly for the first time as far as our records show. There would thus have been some motive for bringing into a convenient summary the somewhat heterogeneous collection of documents, generally connected with the _Kai t'ien_, which make up the _Chou pei_ as we have it today.

APPENDIX (v)

Some implications of gnomon observations in the Chou pei

This appendix sets out to see what conclusions can be deduced from three data for the shadow of an eight-foot gnomon represented in the Chou pei as derived from observation

(i) Summer solstice noon sun : 1.6 ft.

(ii) Winter solstice noon sun : 13.5 ft.

(iii) North celestial pole (constructed shadow): 10.3 ft.

Consider the diagram of the celestial sphere and the horizon of an observer given in Fig. A (4)

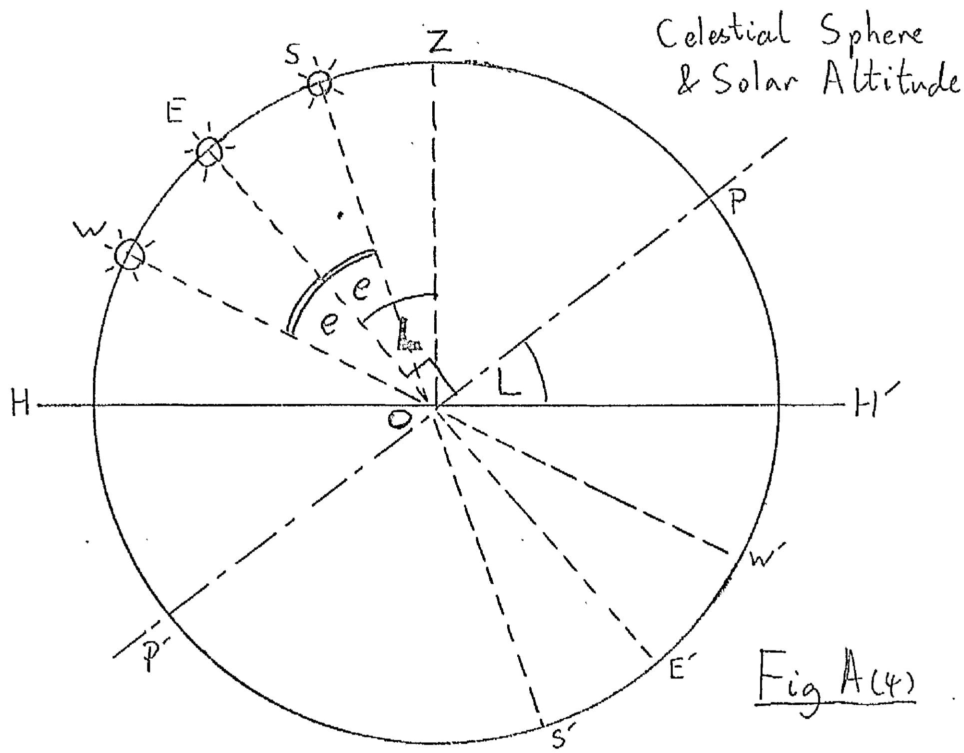


Fig A(4)

O is the observer, HH′ his horizon, and Z his zenith. P is the north celestial pole, and L is the observer's latitude. E is the equinoctial sun, so EOE′ is a projection of the plane of the celestial equator. The obliquity of the ecliptic is e, and S, W represent the noon sun at the summer and winter solstices.

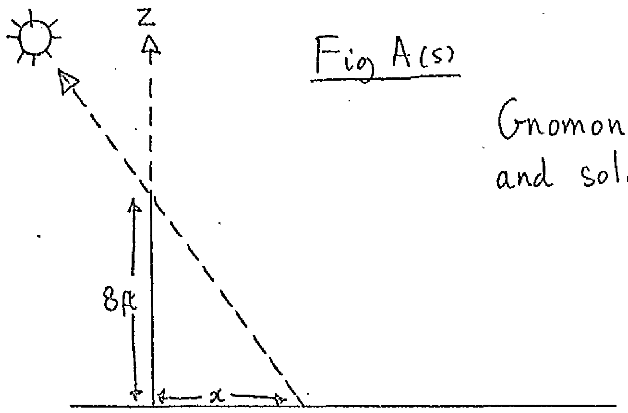


Fig A(5)

Gnomon shadow and solar altitude

Fig. A (5) makes the connection between the angles of Fig. A (4) and x, the length of the 8 foot gnomon's shadow. Obviously :

$$\tan \theta = \frac{x}{(8 \text{ ft})}$$

where θ is the angle between the zenith and the celestial body concerned. If, therefore, the length of the summer solstice shadow is H and the winter solstice value is T, we have :

$$\tan (L-e) = \frac{H}{8 \text{ ft.}}$$

and

$$\tan (L+e) = \frac{T}{8 \text{ ft.}}$$

If we assume that the summer and winter shadows given in the Chou pei represent a pair taken at the same latitude, and at the same date so that e too is constant, we may write :

$$\tan(L-e) = \frac{1.6\text{ ft.}}{8.0\text{ ft.}} = 0.20$$

$$\tan(L+e) = \frac{13.5}{8.0} = 1.68$$

Hence

$$L - e = 11^{\circ}19'$$

$$L + e = 59^{\circ}14'$$

Therefore : $\underline{\underline{L = 35^{\circ}16'}}$ and $\underline{\underline{e = 23^{\circ}57'}}$ (both to the nearest minute)

This value for the latitude is tolerable enough: the place of observation is a few tens of miles to the north of the Yellow River near Lo Yang, or, obviously, anywhere on an east-west line through such a point, but as can be seen from Needham SCC III 289 the value for the obliquity of the ecliptic suggests the most implausible epoch of about 2,200 B.C.

Let us see, therefore, what the effect would be if we kept the same latitude but revised the date of observation to 300 B.C. This is 60 years before the Lü shih ch'un ch'iu gives clear evidence of knowledge of the Chou pei tradition. In 300 B.C. the obliquity of the ecliptic was $23^{\circ}44'$; thus, keeping $L = 35^{\circ}16'$ we have:

$$L - e = 11^{\circ}32'$$

$$L + e = 59^{\circ}0'$$

recalculating the shadow-length on this basis, we have :

$$H = 8 \text{ ft.} \times \tan 11^\circ 32'$$

$$T = 8 \text{ ft.} \times \tan 59^\circ 0'$$

$$\therefore \quad H = \underline{\underline{1.63 \text{ ft.}}} \qquad T = \underline{\underline{13.3}} \text{ ft.}$$

Evidently, therefore, the change in the summer solstice shadow is imperceptible: taking account of the effect of low solar altitude in increasing the 'fuzzinesss' of the shadow-end we may likewise tolerate the change of two decimal inches in the winter solstice shadow. The shadow-data are, therefore, insensitive to considerable changes in date of observation for constant latitude.

Changes in place of observation have a more significant effect: suppose we add 2° to the latitude of the observer, which puts him level with An Yang. We thus have:

$$L - e = 13^\circ 19'$$

$$L + e = 61^\circ 14'$$

$$\therefore \quad H = 8 \text{ ft.} \times \tan 13^\circ 19' = 1.89 \text{ ft.}$$

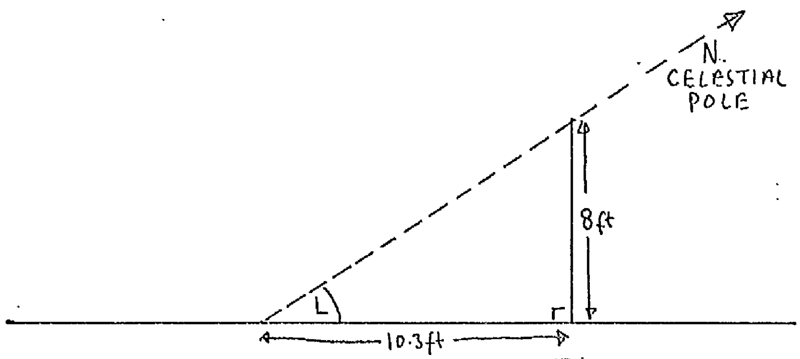
$$T = 8 \text{ ft.} \times \tan 61^\circ 14' = 14.6 \text{ ft.}$$

The discrepancy here is considerable. To sum up so far, we can say that if the summer and winter shadows represent a consistent set, then they originate from observations within some 50 miles of the latitude of Lo Yang, and date from any time up to and including the Western Han.

Let us now consider the 10.3 ft. constructed 'shadow' for the gnomon observation of the celestial pole. If this is an observation of the pole itself rather than of the pole star, and the text suggests this strongly, then we may proceed to calculate the latitude of the observer directly, independently of epoch.

Fig A(6)

Altitude of Pole



This implies a place of observation over 150 miles to the north of the one specified by the shadow data. If the polar altitude had also been observed from latitude $35^{\circ}16'$, one would have expected a polar 'shadow of length:

$$\frac{8 \text{ ft.}}{\tan 35^{\circ}16'} = 11.3 \text{ ft.}$$

Need we accept that 10.3 ft. is a genuine observation of polar altitude that has been imported from further north ? I think there is some evidence that the polar altitude has been adjusted from a value actually observed to a value leading to more satisfying conclusions than the observed facts warranted. For if we follow the procedures of the Chou pei and calculate the radius of the sun's circle round the pole at the two solstices, but using 11.3 ft. instead of 10.3 ft., we obtain :

summer solstice radius = (11.3 ft. + 1.6 ft.) x $\frac{10{,}000\ \underline{li}}{1\ ft.}$

= 129,000 li

winter solstice radius = (11.3 ft. x 13.5 ft.) x $\frac{10{,}000\ \underline{li}}{1\ ft.}$

= 248,000 li

It will be remembered that with the 10.3 ft. value we obtained :

summer solstice radius = (10.3 ft. + 1.6 ft.) x $\frac{10{,}000\ \underline{li}}{1\ ft.}$

= 119,000 li

winter solstice radius = (10.3 ft. + 13.5 ft.) x $\frac{10{,}000\ \underline{li}}{1\ ft.}$

= 238,000 li

Here the winter solstice radius is exactly double the summer solstice radius, a pleasingly simple relationship between two such important quantities. Now the procedure for constructing the polar 'shadow' is considerably more complex and indirect than the straightforward measurement of solstice shadows. It would not, therefore, have required very much wishful thinking on the part of an observer to convince himself that the result was close enough to 10.3 ft. for him to continue his belief in the grand simplicity of the seasonal variation in the radius of the solar path. If this is really what happened, we are faced with the interesting conclusion that the two solstice shadows are the only genuine empirical elements in the cosmography of the Chou pei.

APPENDIX (vi)

The significance of measurements of north polar distances in the Chou pei and Hsing ching 星經

In my discussion of the origin of Hun t'ien instruments it is argued that measurements of the angular distances between heavenly bodies and the north celestial pole were probably first made during the first century B.C. (III (3)(e)). I base this conclusion on consideration of the datable literary evidence involving such measurements. For the sake of completeness I shall give here my reasons for rejecting possible claims that considerably earlier north polar distance measurements are to be found in the texts of the Chou pei and Hsing ching, and that the invention of the armillary ring ought therefore to be set at an earlier date than I have calculated.

As we have seen, the Chou pei contains a considerable number of purported measurements of important celestial dimensions in the Kai t'ien system, such as the size of the sun's daily path at different seasons of the year. These measurements are given in li, and stem in each case from the mathematical scheme of similar triangles based on alleged gnomon shadow measurements (III (3)(b)). Apart from the instance to be considered, the Chou pei treats of the tu only as 1/365.25 of the circumference of the circles (hêng 衡) which mark the daily path of of the sun at different times of the year. As these circles vary in circumference from 714,000 li at the summer solstice to 1,428,000 li at the winter solstice the size of the tu varies by a factor of 2, being given by the text to an exact fraction of the double-pace pu. It is obvious that this state of affairs is consistent with the use of the tu with reference to the daily amount of the sun's displacement, against the stellar background, which I have elsewhere argued was the origin of the concept of the tu (III (3)(c)). The use of armillary rings is certainly not implied, and is, if anything, counter-indicated by the fact that the use of the tu as a measurement is only meaningful along some given hêng where its value is constant.

Later in the Chou pei, however, occur three instances of north polar distance measurements expressed in an odd mixture of tu and other units :

> "Ch'ien Niu is distant from the north pole by 115 tu 1,695 li 21 819/1461 pu"
>
> Chou pei 2, 60 in Ch'ien's edition

> "Lou and Chüeh are distant from the north pole by 91 tu 610 li 264 1296/1461 pu"
>
> ibid, 2, 62

> "Tung Ching is distant from the north pole by 66 tu 1,481 li 155 1245/1461 pu"
>
> ibid, 2, 63

Now the constellations names here are, in that order, the four hsiu in which the sun lay at the winter solstice, the two equinoxes, and the summer solstice.

Other than these data the earliest similar statement comes from Chia Kuei's memorial of A.D. 92/93 in which he gives 115 _tu_, 91 _tu_ and 67 _tu_ for the north polar distance of the sun at the given seasons (III (3)(c)). Chia's measurements, which are correct to the nearest _tu_, may possibly date from the work of Keng Shou-ch'ang c. 52 B.C. Could it be that in the _Chou pei_ we have another early example of north polar distance measurements with an armillary ring ? There is certainly a good _prima facie_ case for this, but it cannot stand up to a closer look at the text, which goes into some detail in explaining how its results are obtained. The method it describes bears no relation to armillary rings of any kind, but consists solely of mathematical manipulation of the celestial distance data allegedly obtained from gnomon measurements as already mentioned.

If armillary rings are thus to be discounted, are we to take it that the writers of this part of the _Chou pei_ were able to obtain the sun's angular altitude (and hence its north polar distance) from gnomon-shadow observations ? The answer is emphatically negative. In the first place such a suggestion would involve a knowledge of trigonometrical techniques of which there is no hint in China until the eighth century A.D. (SCC III 148). Secondly, it will be remembered that the gnomon data in the _Chou pei_ were at least partly falsified in order to give conveniently simple results for the seasonally varying radius of the sun's daily path (Appendix (v)). In fact the text's procedure is not a little strange; the derivations are as follows :

> <u>Ch'ien Niu</u> : "Set up the distance from the outer <u>hêng</u> to the north pole pivot :
>
> 238,000 <u>li</u>
> subtract 11,500 <u>li</u> for the <u>hsüan chi</u>
> leaving 226,500 <u>li</u> which is made the dividend.
>
> Take as divisor the size of a <u>tu</u> on the innermost <u>hêng</u> :
>
> 1,954 <u>li</u> 247 933/1461 <u>pu</u>."

loc. cit.

The result of this is indeed that the distance is 115 <u>tu</u> with the given remainder. Before considering why this bizarre method gives correct results, let us note the calculations for the other two results.

> <u>Lou</u> and <u>Chüeh</u> "Set up the distance from the middle <u>hêng</u> to the north pole pivot :
>
> 178,500 <u>li</u> which is the dividend
>
> Take as divisor the size of a tu on the innermost <u>hêng</u>."

loc. cit.

> <u>Tung Ching</u> : "Set up the distance from the innermost hêng to the north pole pivot :
>
> 119,000 <u>li</u>
> add 11,500 <u>li</u> for the <u>hsüan chi</u>
> giving 130,500 <u>li</u> which is made the dividend.
>
> Take as divisor the size of a tu on the innermost <u>hêng</u>."

loc. cit.

Notice in the first place the extremely suspicious introduction of the fictitious "<u>hsüan-chi</u> radius", the product of a piece of numerology (II (3)(d)). Here it is treated as the polar distance (in <u>li</u>) of a "pole star" with the same Right Ascension as the winter solstice; its addition and subtraction for the solsticial data means that this pseudo-star, rather than the actual pole, is the point from which distances are being measured. We shall shortly see why this is necessary. Let us turn first, however, to the size of a <u>tu</u> on the innermost <u>hêng</u>. As the radius of this <u>hêng</u> is 119,000 <u>li</u> and the <u>Chou pei</u> always approximates π as 3, this is :

$$1 \ \underline{tu} = \frac{2 \times 3 \times 119{,}000 \ li}{365\frac{1}{4}}$$

This is the <u>tu</u> used by the <u>Chou pei</u> in its measurements of north polar distance. It has virtually nothing to do with angular measurements but is simply the length of a fraction of circumference of an apparently arbitrarily chosen circle. Let us see what would have happened if this <u>tu</u> was applied to the <u>hêng</u> radii without the <u>hsüan-chi</u> "correction". We would have obtained :

season	hêng radius	radius in standard tu	=	n.p.d. of sun
winter solstice	238,000 <u>li</u>	$\frac{365\frac{1}{4}\ tu}{3}$	=	$121\frac{3}{4}$ <u>tu</u>
equinoxes	178,500 <u>li</u>	$\frac{365\frac{1}{4}\ tu}{4}$	=	91 5/16 <u>tu</u>
summer solstice	119,000 <u>li</u>	$\frac{365\frac{1}{4}\ tu}{6}$	=	60 7/8 <u>tu</u>

The equinoctial result is completely satisfactory, as 91 5/16 <u>tu</u> = 90°. This follows straightforwardly from the fact that the equinoctial hêng was taken as halfway between the solsticial hêng. The solsticial radii are, of course, only in a ratio of 2 : 1 because of the falsification of a polar sighting as mentioned in Appendix (v). Turning to the solsticial results, the departure from the observed values of 115 tu and 67 tu is marked. The application of the hsüan-chi "correction" as in the text produces the more acceptable results there given, but at the price of paradoxically obtaining correct values of north polar distance which are not actually measured from the celestial pole as they should be.

In the light of this analysis, I conjecture with some confidence that we have in this text the record of an ad hoc attempt to "derive" by the methods of the Chou pei results drawn from quite a different set of techniques. The writer knew in advance the results he wanted to obtain, and thus chose the innermost hêng to define his north polar distance, tu length, probably on the basis of the correct prediction of equinoctial north polar distance. The hsüan chi "correction" for the solstices seems to me inexplicable except in the context of a conscious attempt to arrive at a known result. It remains to consider the circumstances under which such mathematical cookery might have seemed necessary. In the first place, since the north polar distance results used here can only have been obtained by armillary rings, the text can only logically have been written after the invention of those instruments. This point is of course trivial. More substantially, however, I would argue that the author's rather desperate attempts to show that gnomons can do all that armillaries can suggests that the text comes from a time when the use of armillary instruments was becoming well-established. Immediately preceding the text considered the Chou pei has an equally dubious attempt to show that hsiu extensions can readily be found by a method involving gnomon sightings. (This can of course be done by noting the time interval between southings; the point is that the method given in this text is quite useless.) I have argued elsewhere (III (3) (d)) that the rise of armillary instruments is inextricably bound up with the Hun t'ien theory. Our text may therefore be a product of the sharp controversies of that theory with the Kai t'ien, and this is not inconsistent with my suggestion (Appendix (iv)) that the Chou pei was compiled under the pressure of the polemics first evidenced in the writings of Huan T'an and Yang Hsiung around 1 B.C. In no way does it force us to move back the date of invention of armillary beyond the first century B.C.

I turn now to the data found in the present text of the Hsing ching 星經. Needham relies on the work of Ueta and others in dating the north polar distance measurements for various stars contained in this astrological work (SCC III 268), reaching the conclusion that armillary rings may have been used for north polar distance measurements by astrologers such as Shih Shen 石申 and Kan Te 甘德 in the fourth century B.C. Ueta's method was a graphical one, and in an attempt to settle the question more definitely I have now run a detailed check on the Hsing ching data using the University of London computing service. This involved in the first place an attempt to identify the actual stars referred to in the book as we have it today. The computer was then made to recalculate their coordinates at ten-year intervals from A.D. 1500 to 3000 B.C., allowing for precession and variation in the obliquity of the ecliptic. During this process it identified the epoch at which the Hsing ching data best fitted the actual position of the star concerned, firstly for the given north polar distance and secondly for the given position in the specified hsiu. I hope eventually to publish a fuller account of this project, but for the present purpose it is sufficient to note provisional conclusions briefly. The Hsing ching contains numerical data for 46 stars. The north polar distance and hsiu positions give fits implying epochs fairly evenly distributed between 2,500 B.C. and 1000 A.D. For both north polar distance and hsiu calculations more than a quarter of the stars failed to find a fit with the range of epochs for which calculations were made. Of those stars which fell within the range of calculation only five had dates for north polar distance and hsiu position agreeing within 300 years. Results of this kind are quite inadequate as a basis on which to construct theories about the date at which measurements with armillary rings may first have been made. The wide spread of the epochs calculated may of course be explicable in a number of ways : the book may be recording genuine but inaccurate observations, or possibly completely fictitious ones, or again there may be textual corruption. Again we must remember that we cannot be definite in interpreting Chinese star-names. Whatever the reqson, it seems clear that there is little hope of dating the text by its numerical contents.

There are also literary grounds for doubting whether the Hsing ching contains early material. Hsü Chia-tzu (1), 710 notes evidence for concluding that the present text was not current in Han times. In particular 75 per cent of the provinces mentioned in it were not created until the Sui or T'ang. Evidénce drawn from a book of this nature is not sufficient to revise conclusions on the subject of the first use of armillary rings.

TEXTUAL NOTE (1)

The I pu ch'i chiu chuan 益部耆舊傳
(III (3)(e)

Needham is surely in error in attributing this book to Lo-hsia Hung himself (SCC III, 199), and there seems no reason to follow him in assuming that there were "several other books" with this title. *I pu* is equivalent to *I chou* 益州 , a Han name for Szechwan where Lo-hsia Hung's native place Pa 巴 was located : compare the Sung dynasty work *I pu fang wu lueh chi* 益部方物略記 on the local products etc. of the province, by Sung Ch'i 宋祁 . The title thus is "Old chronicles of the elders of Szechwan", and does not refer to the "[astronomical] bureau" as Needham has it.

The passage of interest is found in four versions, of which the first is the fullest.

(a) *Shih chi*, 26, 1261, (CHSC), *So yin* commentary (T'ang).

(b) PTSC 130, 11b (A.D. 630)

(c) *Shih lei fu*, 1, 1b (c. A.D. 1000)

(d) *Sui shu* 19, 516 (CHSC), (A.D. 656), but attributed to Yü Hsi (see IV (7)(c)) - perhaps he was quoting Ch'en Shu ? Ch'en might also be the "Mr. Ch'en" elsewhere mentioned by Yü (IV (7)(c)). All versions have the clause 於地中轉渾天

despite their varying length. The reference is evidently to an instrument, or otherwise, the specified location is irrelevant, but why are we told that he "rotated" it ? One might rather have expected to be told that he made it ts'ao 造 or set it up li 立 . I suggest that the odd phrasing might be explained if Ch'en Shu was influenced by the Shih chi's words 運算轉曆 translated above as "carried out calculations to revise the calendar". Perhaps Ch'en was, like Lu Chi and Wang Fan (IV (2)(a),(b)) anxious to maintain the antiquity of the Hun t'ien, and thought he saw suggestions of the instrument in Ssu-ma Ch'ien's text. This is certainly more plausible than assuming he had access to material unmentioned by the Shih chi and unknown to his contemporaries Lu and Wang.

TEXTUAL NOTE (2)

The story of Confucius and the two boys (III (5)(b)

This story occurs in a considerable number of versions :

(1) Lieh tzu, 5, 105, (in Lieh tzu chi shih)

(2) Fa yüan chu lin 7, 15b, SPTK, attr. Lieh tzu

(3) Fa yüan chu lin 7, 16a, SPTK, attr. Hsin lun

(4) Chin lou tzu, 4, 159.

(5) PTSC, 149, 7b, attr. Lieh tzu

(6) Sui shu, 19, 512, attr. Lieh tzu

(7) Ch'u hsüeh chi, 1, 3a, attr. Lieh tzu

(8) TPYL 3, 5b, attr. Lieh tzu

(9) TPYL 385, 1b, attr. Lieh tzu

(10) Po wu chih, 8.

(11) Shih lei fu, 1, 5b, attr. Lieh tzu

Collation of these sources shows no significant textual conflicts. Naturally (3) is the most interesting, involving as it does an early Eastern Han source which is connected with the discussions of Huan T'an and Yang Hsiung. The fact that FYCL actually produces versions from the Lieh tzu and Hsin lun side by side is firm confirmation of both attributions. I do not think we can come to any conclusion as to whether the Lieh tzu drew on the Hsin lun (presumably during a Chin compilation ?) or whether the Hsin lun drew on a (proto ?) Lieh tzu during the Han.

Perhaps the latter is less likely, as the _Hsin lun_ introduces its version as "a common story"; it may be that both works drew on a third source now lost.

TEXTUAL NOTE (3)

The works of Chang Heng (III (7))

For a general view the reconstitutions contained in CSHK, H/Han, 55 are quite sufficient as versions of the Ling hsien 靈憲 and Hun t'ien i 渾天儀. The following notes are intended to provide a more detailed account of our sources for these texts.

The two main sources for the Ling hsien are :

(i) Hou Han shu, chih 10, 3215, (comm.) CHSC

(ii) KYCC 1, 1a.

The first of these is both earlier and more complete. The commentary here is not, of course, the T'ang commentary of Li Hsien, written to accompany the main part of the history as compiled by Fan Yeh about A.D. 450, but is by Liu Chao (sixth century) who wrote his work to accompany the monographs in the third century history by Ssu-ma Piao, the Hsü Han shu 續漢書. It was from this earlier book that the monographs now in the Hou Han shu were borrowed. Liu was probably quoting the Ling hsien at first hand, for the inclusion in the Sui shu bibliography of "The Ling hsien in one chapter, by Chang Heng" (Sui shu, 34, 1018, CHSC) shows that it was extant around A.D. 600.

KYCC, compiled in A.D. 729, contains almost identical material to the Hou Han shu. As the Ling hsien seems still to have been extant during the T'ang (Hsin T'ang shu 59, 1544, CHSC; Chiu T'ang shu 49, 12b, SPTK) this too may be a first-hand quotation. Thus we have two possibly independent sources giving the same material for a work consisting of a single chapter; on this basis it does not seem improbable that we possess Chang Heng's work in its entirety

Shorter fragments of the Ling hsien are to be found in :

KYCC : 5, 2a; 5, 6a.

PTSC : 149, 7a; 150, 30a; 150, 4a; 150, 5b; 150, 6a; 157, 3a.

TPYL : 1, 5b; 2, 5b; 4, 9a; 7, 1b; 157, 4a; 869, 8a.

CHC : 8, 26a.

IWLC : 1, 5b; 95, 6a.

Sui shu : 19, 504; 19, 513.

Chou pei suan ching : 2, 54 (comm.)

The last of these (a reference to the illumination of the moon by the sun) is interesting because of its early date in the third century A.D. In nearly all cases the above fragments simply provide parallels to the main sources.

Although the Hun t'ien i opens with the famous analogy of the egg, most of it is on the subject of the geometry of the celestial sphere rather than physical cosmography. The two fullest sources for the cosmographical material are :

(i) KYCC 1, 5a

(ii) TPYL, 2, 8b (see also 2, 11b)

Much material is also found in *Hou Han shu*, *chih* 3, 3076, CHSC (comm.), but the cosmography is lacking. The earliest quotations seem to be by Ko Hung, c. A.D. 320 (*Sui shu* 19, 509; *Chin shu*, 11, 281). Miscellaneous *lei shu* fragments are IWLC 1, 1a; PTSC 149, 3b; PTSC 150, 1a; SLF 1, 1a and 2b; CHC, 1, 1a.

Oddly enough KYCC introduces its material as 渾儀註 (1, 5a) and later changes to the title 渾儀圖注 (1, 7b). This break is well into material quoted as a unit (titled 渾儀) in the *Hou Han shu* comm. There is a possibility that the work is referred to in Chang Hêng's biography written in the fifth century A.D. (*Hou Han shu*, 59, 1898 CHSC) which says that Chang

作渾天儀著靈憲

but despite the mention of the *Ling hsien* the *Hun t'ien i* here is probably the actual instrument itself. The *Sui shu* bibliography notes a book *Hun t'ien i* in two chapters, without attribution (34, 1018, CHSC) while a work of that title in one chapter is attributed to Chang Hêng in the *Chiu T'ang shu* (49, 12b, SPTK). In both this case and that of the *Ling hsien* we should note the existence of collections of Chang's writings, 11 chapters in the *Sui shu* (35, 1057) and 10 in the *Hsin T'ang shu* (60, 1578, CHSC).

TEXTUAL NOTE (4)

Ts'ai Yung's memorial and Yueh ling commentary (III (8))

Much of Ts'ai's memorial has been preserved in a number of versions; the first two mentioned below are the fullest. Insofar as they overlap there are no significant textual conflicts.

(a) Hou Han shu, chih 10, 3217 CHSC, comm.

(b) Hou Han shu, 59, 1898, CHSC, comm.

(c) Sung shu, 23, 673, CHSC

(d) Chin shu, 11, 278, CHSC

(e) Sui shu, 19, 507, CHSC

(f) CHC, 1, 1a and 1b

(g) SSCCS, Shang shu, 3, 13a

(h) Shang shu cheng i, 3, 6b, SPTK

(i) KYCC 1, 9a

It is interesting to note that (b) claims to draw on a work called Han ming ch'en tsou 漢名臣奏 "Memorials of famous Han ministers", no doubt one of the many sources available in the sixth century but now lost.

The Yüeh ling commentary is less frequently quoted but nonetheless well attested. The main fragment is given in KYCC 1, 9b, paralleled at beginning and end by two fragments in PTSC 149, 2a. KYCC repeats its fragment at 2, 5a where, however, it carries an introduction and comment by Chiang Chi, giving us firm evidence for its existence only two centuries later than Ts'ai Yung himself. The Han hsüeh t'ang ts'ung shu reconstitution claims in addition a not very striking account of the geometry of the celestial sphere as being by Ts'ai, but inspection of the original source (Shang shu cheng i 11, 26b, SPTK) makes it plain that the text is by a T'ang editor.

TEXTUAL NOTE (5)

The work of Wang Fan : IV (2)(b).

The extant sources for Wang's cosmographical writing are related in a somewhat complex way. Perhaps the most rapid method of explaining the distribution of the material is by outlining a hypothesis which I have adopted after a detailed collation of the early texts. On the basis of this collation I conjecture that around A.D. 500 an extended essay by Wang was in existence; evidently it was well enough thought of for Tsu Keng-chih to take it as the starting-point for his calculations (V (3)(b)). The Sung shu was compiled at that time and includes material by Wang (23, 674, CHSC) which we find almost word for word in the Chin shu monograph (11, 285, CHSC) written in A.D. 648. Neither book gives the essay a title but the original text is presumably the Hun t'ien hsiang chu 渾天象注 (in one chapter) attributed to Wang in the Sui shu bibliography, 34, 1018 CHSC. All the Sung shu and Chin shu material is however to be found embedded in a considerably longer version given in the K'ai yuan chan ching of A.D. 729 (1, 12b-20a). My collation suggests very strongly that KYCC preserves an authentic text which the earlier versions abbreviate. The T'ai p'ing yü lan of A.D. 983 mentions the Hun t'ien shuo 渾天說 by Wang Fan in its initial book list

(TPYL, *yin shu mu*, 22a), and its two quotations (2, 8a and 11a) contain no material differing from KYCC, apart from an introductory column of 16 characters lacking elsewhere. We cannot of course tell whether TPYL drew directly on KYCC or shared a common source then still extant. A fragment of Wang's writing is also found in the subcommentary of K'ung Ying-ta (fl. c. A.D. 630) on the *Shang shu* (SSCCS, 3, 6b); it is interesting that one instance where this text differs from KYCC for fifteen characters is reproduced exactly in TPYL. K'ung's subcommentary adds a short passage stating that Mt. Sung Kao 嵩高 near Lo-yang is at the centre of heaven, and giving sketchy data about the sun's seasonal north polar distance variation. I doubt that this is really by Wang Fan, on the grounds of its imprecision and his belief stated elsewhere that Yang-ch'eng is the central position. The only other text of significance is *Sui shu* (19, 516, CHSC) compiled c. A.D. 656 (monographs), which is apparently a brief mosaic of material paralleled only in KYCC, of fragments unique to PTSC 130, 11b, and a mention of the *hsüan chi yü hêng* found only in *Sung shu* 23, 677. (Note that this last is not found in the *Sung shu* version of Wang's cosmographical essay but is quoted second-hand via Hsü Yüan.) It is, I think evident that one will not go far wrong by treating KYCC as the basic text for Wang's work. (Eberhard (1) has a useful translation of part of Wang Fan's work.)

TEXTUAL NOTE (6)

Yao Hsin (IV (5))

The full source list is :

(a) Sung shu, 23, 680, CHSC

(b) PTSC, 149, 2a and 4a

(c) Sui shu, 19, 508, CHSC

(d) Chin shu, 11, 280, CHSC

(e) TPYL, 2, 7b.

(f) SLF, 1 : 1a, 2b and 3a

All attribute their material to Yao Hsin's Hsin t'ien lun. The reference to the distance of the hsiu from the pole is in (a) alone, while the discussion of the earth's support is only in (e) and (f). The analogy of heaven and man is in (c), (d) and (e), and the rising and falling of heaven is described in all texts. (c) and (d) do not include the final reference to the Hun t'ien and Kai t'ien.

TEXTUAL NOTE (7)

The Yü family and their writings (IV (7))

A genealogical note will be helpful in the subsequent discussion. The founder of the family fortunes seems to have been Yü Fan 虞翻, one of the aides of Sün Ch'üan 孫權, first ruler of the kingdom of Wu (reigned A.D. 222-252). According to his biography (San kuo chih 53, 1317, CHSC), he died aged 70 : the general circumsstances of his life indicate that he may have been born c. A.D. 170, dying c. A.D. 240. Fan had eleven sons, of whom San kuo chih finds three worthy of note :

(1) Yü Fan 汜, tzu Shih-hung 世洪, made an Inner Palace Attendant in A.D. 258.
(2) Yü Sung 聳, tzu Shih-lung 世龍, at one time governor of Ho Chien 河間
(3) Yü Ping 昺, tzu Tzu-wen 子文, once governor of Chi Yin 濟陰

op. cit., 1327

Yü Hsi 喜 was evidently two generations away from these brothers : three histories state that Yü Sung was his tsu tsu 族祖 (Chin shu 11, 280; Sui shu 19, 508; Sung shu, 23, 680), and Yü Hsi himself refers to "my tsu tsu from Ho Chien" (TPYL, 2, 9b). Hsi's biography (Chin shu 91, 2348) shows that he clung to private life despite solicitations under the reigns of three emperors who reigned from A.D. 290 to 343. He was active under emperor Mu (A.D. 345-362) and submitted a memorial in A.D. 345. According to the Chin, Sui, and Sung histories (loc. cit.) he wrote on cosmography during the period A.D. 335 to 343. These dates are quite consistent with his being in the second generation from Yü Sung.

The Ch'iung t'ien lun sources are :

(a) Chin shu 11, 280

(b) Sui shu 19, 508

(c) Sung shu 23, 680

(d) TPYL 2, 6b

(e) CHC 1,1a

(f) SLF 1,1a

(g) PTSC 149, 4a

(h) TPYL 595, 3a (in a text by Ko Hung)

(a)-(c) attribute to Sung 聳 , (d)-(f) to Ping 昺 , (g) to Shih-hung 世洪 (= Fan 汜) and (h) to simply 洪 . Chin shu and Sui shu have the fullest text, and the three histories have common textual differences from the version found in the lei shu. Other

Other ancient attributions are :

(i) Yü Hsi "my tsu tsu from Ho Chien" (TPYL, 2, 9b).

(ii) Ho Tao-yang (see V (2)(a)) : to Yü Hsi (1) (TPYL, 2, 10a), although Yü Hai, 2, 44b "corrects" to Yü Ping.

(iii) Tsu Keng-chih (see V (3)(a) : to Yü Ping (TPYL,2,6b).

(iv) K'ung Ying-t'a 孔穎達 (c. A.D. 640) says he does not know which member of the Yü family wrote it (Li chi, SSCCS, 14, 2a).

(vi) TPYL book list, 13b, gives Yü Ping.

The authorship is not, of course, a critical question, but if a decision was necessary I would feel that the testimony of Yü Hsi himself added to that of the three histories clinches the matter in favour of Yü Sung. Perhaps joint authorship might be a partial explanation of the confusion here ?

There are no doubts about whether or not Yü Hsi wrote the An t'ien lun. His biography states explicitly :

> "Hsi devoted himself to the classics and their commentaries, and was equally well-read in the ch'an-wei [see Appendix (i)]. He wrote his An t'ien lun to raise objections to the Hun and Kai ... "

Chin shu, 91, 2349

Fragments are now found in :

(a) TPYL, 2, 9b

(b) Chin shu, 11, 280

(c) Sui shu, 19, 508

(d) Sung shu, 23, 680

(e) Shang shu cheng i, I, 3, 6b

(f) PTSC, 149, 1b

(g) TPYL, 54, 6b

(h) TPYL, 4, 10a

(i) CHC, 1, 1b.

The first of these is the fullest; the three histories, as already mentioned, date the writing of the An t'ien lun to the years A.D. 335-343.

ABBREVIATIONS

BW	Watson (1)
CHSC	*Chung hua shu chü* 中華書局 publishing co.
CM	*Ssu ku ch'uan shu chien ming mu lu* 四庫全書簡明目錄 (1964, CHSC edn.)
CSC	*Ch'u hsüeh chi*
DCBT	Soothill & Hodous (1)
EW	Wlkinson (1)
F	Feng Yü-lan (1)
IWLC	*I wen lei chü*
KYCC	*K'ai yüan chan ching*
MCPT	*Meng ch'i pi t'an*
PC	Hsü chia-tzu (1)
PKLT	*Po k'ung liu t'ieh*
PTSC	*Pei t'ang shu ch'ao*
SCC	Needham, *Science & Civilization in China*
TB	Teng & Biggerstaff (1)
TH	*Tz'u hai* 辭海, CHSC, 1937
TPYL	*T'ai p'ing yü lan*
TSCC	*Ku chin t'u shu chi ch'eng*

B I B L I O G R A P H Y

(1) Ancient Chinese works, by title

(Abbreviated references thus : CM : are to bibliographical sources)

CHENG MENG 正蒙

Sung, c. A.D. 1076. Chang Tsai 張載
Neo-Confucian work for students

(1) SPTK
(2) CHSC, Peking, 1975 : CM

CH'I LUEH 七略

W. Han, c. 5 B.C. Liu Hsin 劉歆

Booklist in seven categories, based on the catalogue of Liu Hsiang (c. 10 B.C.); in turn it formed the basis of Pan Ku's bibliography in the Han shu, q.v.

Not extant TB

CHIN LOU TZU 金樓子

Liang, c. A.D. 550. Liang Yüan Ti 梁元帝

Reflections of Emperor Yüan of the Liang (reigned A.D. 552-4).

(1) Taiwan, 1969, ed. Hsü Te-ping 許德平

CHIN SHU 晉書

Tang, A.D. 648. Fang Hsüan-ling 房玄齡 et al.

History of the Chin dynasty, A.D. 265-419.

(1) CHSC, Peking, 1974
(2) SPTK

EW, CM, SCL, PC

CHIU CHANG SUAN SHU 九章算術

E. Han, 1st cent. A.D. Writer unknown

Mathematical compendium, probably containing some material as early as the Ch'in.

(1) SPTK
(2) In Ch'ien Pao-tsung (2) SCC, CM

CHOU LI 周禮

Present form reached during early W. Han ?

Compilers unknown.

An idealised description of the bureaucratic structure of Chou dynasty administration

(1) SSCCS
(2) SPTK BW, SCC, TH

CHOU PEI SUAN CHING 周髀算經

Compiled 1st cent. B.C./A.D. Writers unknown

Mathematical and astronomical compendium, embodying Kai t'ien ideas (see II)

(i) SPTK
(2) Ch'ien Pao-ts'ung (2) SCC, CM

CHU TZU CHUAN SHU 朱子全書

A.D. 1713. Chu Hsi 朱熹

Complete works of the Neo-Confucian philosopher Chu Hsi (A.D. 1093-1151)

(1) Palace ed. 1713/14 F, CM, SCC

CH'U HSUEH CHI 初學記

T'ang, c. A.D. 700. Hsü Chien 徐堅 et al.

Encyclopaedia

(1) Yün shih chai ts'ung shu 蘊石齋叢書
(2) CHSC, Peking, 1962; Taipei 1966

CH'U TZU 楚辭

Warring States, c. 300 B.C. Ch'ü Yuan 屈原 et al.

Anthology of poems compiled by Wang I 王逸
c. A.D. 150

(i) SPTK
(2) Chiang Liang-fu (1) BW, CM, SCC

CHUANG TZU 莊子

Warring States, c. 290 B.C. Chuang Chou 莊周

Large parts certainly not by Chuang Chou, although possibly by his disciples.

(1) SPTK
(2) Tr. Watson (2) BW, SCC, F

CH'UN CH'IU 春秋

After 480 B.C. in present form ? compilers unknown.

Chronicle compiled in state of Lu, giving an annalistic account of events from 722 to 481 B.C.

(1) SSCCS
(2) SPTK BW, SCC

CH'UN CH'IU FAN LU 春秋繁露

W. Han, c. 140 B.C. Tung Chung-shu 董仲舒

Phenomenalist work, influential in development of Han Confucianism

(1) SPTK CM, SCC, BW

FA YEN 法言

A.D. 5. Yang Hsiung 楊雄

Philosophical work in imitation of the Lun yü

(1) SPTK SCC, CM, F

FA YUAN CHU LIN 法苑珠林

T'ang, A.D. 668 Tao Shih 道世

Buddhist encyclopaedia

(1) SPTK TH, SCC, CM

HAN SHU 漢書

E. Han, c. A.D. 90. Pan Ku 班固 et. al.

History of (Western) Han dynasty, 209 B.C. - A.D. 25

(1) CHSC, Peking, 1962
(2) SPTK EW

HOU HAN SHU 後漢書

Liu Sung, A.D. 450. Fan Yeh 范曄

History of E. Han dynasty, A.D. 25-220. Monographs taken from Hsü Han shu q.v.

(1) CHSC, Peking, 1963
(2) SPTK EW

HSIN LUN 新論

E. Han, A.D. 20   Huan T'an 桓譚

Philosophical work

(1) SPTK   CM, SCC, F

HSIN T'ANG SHU 新唐書

Sung, c. A.D. 1060   Ou-yang Hsiu 歐陽修 et. al

New Standard History of the T'ang;
A.D. 618-906.

(1) CHSC
(2) SPTK   EW

HSING CHING 星經

T'ang or earlier ?   compilers unknown

Star catalogue and astrological work, compiled from earlier material (see Appendix (vi)).

(1) TSCC   SCC, CM, PC

HSU HAN SHU 續漢書

Chin, c. A.D. 270   Ssu-ma Piao 司馬彪

Continuation of Han shu.

Not extant, but its monographs are incorporated into the Hou Han shu.

CM, TH

HUAI NAN TZU 淮南子

c. 120 B.C.   scholars gathered by Prince Liu An

A Taoist compendium of natural philosophy. [劉安

(1) SPTK   BW, SCC, CM, F

HUANG TI NEI CHING 黃帝內經

? E. Han, 1st cent. B.C. Writer unknown

Medical classic. May have been compiled under E. Han, but some material could be due to later commentators

(1) SPTK
(2) partial tr. Veith (1) CM, PC, SCC

I CHING 易經

Chou (partly pre-Confucian ?) with W. Han additions Compilers unknown

Originally a book of divination, whose commentaries make it the basis of a highly developed metaphysics

(1) SSCCS
(2) SPTK BW, SCC, F

I WEN LEI CHU 藝文類聚

T'ang, A.D. 624. Ou-yang Hsün 歐陽詢 et al.

Encyclopaedia

(1) CHSC, Hong Kong, 1973. TB, CM, SCC

K'AI YUAN CHAN CHING 開元占經

T'ang, A.D. 729 Ch'ü-t'an Hsi-ta 瞿曇悉達

Compendium of material on astrology, divination generally, calendrical mathematics, and cosmography. Rediscovered in 16th cent., see preface.

(1) Heng te t'ang tsang pan 恆德堂藏板 (microfilm) SCC

KUAN TZU 管子

up to W. Han ? attrib. Kuan Chung 管仲

A compilation of exceedingly varied material, Legalist, Confucian, Taoist, etc. from a wide range of dates.

(1) SPTK BW, CM, SCC, F

KU CHIN T'U SHU CHI CH'ENG 古今圖書集成

Ch'ing, A.D. 1725. Chiang T'ing-hsi 蔣廷錫 et al.

The largest extant Chinese encyclopaedia

(1) Taipei : Wen-hsing shu-tien, 1964.
(2) Yung-ch'eng palace edn. TB

LAO TZU 老子

4th cent. B.C. unknown.

Collection of Taoist material.

(1) SPTK
(2) tr. Lau (1) BW, SCC, F

LI CHI 禮記

W. Han, c. 50 B.C. ed. Tai Sheng 戴聖

An extremely varied collection of material relating to ritual

(1) SSCCS
(2) SPTK BW

LIANG SHU 梁書

Sui, c. 600 Yao ch'a 姚察 and Yao Ssu-lien 思廉

History of the Liang dynasty, A.D. 502-556

(1) CHSC, Peking, 1973
(2) SPTK BW

LIEH TZU 列子

4th cent. A.D. attrib. Lieh Yü-k'ou 列禦寇

Taoist compilation, including some early material

(1) SPTK
(2) Lieh tzu chi shih 列子集釋
ed. Yang Po-chün 楊伯峻 , Hong Kong, 1965.

BW, CM, SCC, F.

LU SHIH CH'UN CH'IU 呂氏春秋

Warring States, 239 B.C. scholars gathered by Lü Pu-wei 呂不韋

A compendium of knowledge

(1) SPTK CM, BW, SCC

LUN HENG 論衡

E. Han, A.D. 82/83. Wang Ch'ung 王充

Critical discussions

(1) SPTK
(2) Tr. Forke (2) BW, SCC, CM, F

MAO SHIH 毛詩

(alternative name for SHIH CHING, qv)

MENG CH'I PI T'AN 夢溪筆談

Sung, A.D. 1086. Shen Kua 沈括

Essays on a wide range of scholarly and scientific subjects

(1) SPTK
(2) CHSC, Hong Kong, 1975

SCC, CM

MENG TZU 孟子

Warring States, 3rd cent. B.C. (disciples of ?) Meng K'o 孟軻

Book of the philosopher Mencius, second only to the Lun Yü as a classic of early Confucianism

(1) SSCCS
(2) SPTK
(3) tr. Lau (2) BW, SCC, F

PAO P'U TZU 抱朴子

Chin, 4th cent. A.D. Ko Hung 葛洪

Taoist work, mainly on alchemy

(1) SPTK
(2) tr. Ware (1) SCC, CM

PEI SHIH 北史

T'ang, c. A.D. 629. Li Yen-shou 李延壽

History of the Northern Dynasties, A.D. 368-618

(1) CHSC, Peking, 1974
(2) SPTK EW

PEI T'ANG SHU CH'AO 北堂書鈔

T'ang, c. A.D. 639. Yü Shih-nan 虞世南

Encyclopaedia : collated and annotated by K'ung Kuang-t'ao 孔廣陶 in 1888.

(1) Taipai, 1962, 2 vols. Wen hai 文海 pub. co. TD, CM, SCC

PO HU T'UNG I 白虎通義

E. Han, c. A.D. 80. Pan Ku 班固

Condensed memoirs of a conference of literati held in the White Tiger Hall on the instructions of Emperor Chang 章 (A.D. 76-89).

(1) SPTK
(2) tr. Tsêng Chu-sen (1) CM

PO K'UNG LIU T'IEH 白孔六帖

T'ang, c. A.D. 800. Po Chü-i 白居易
K'ung Ch'uan 孔傳

Encyclopaedia

(1) Ming Chia-ching print, c. 1540.
(2) Taipei : Hsiu-hsing shu chü, 1969 TB

PO WU CHIH 博物志

Chin, c. A.D. 290. Chang Hua 張華

The extant miscellany of this name probably contains much extraneous material.

(1) fragments in TPYL, 8, 10b; CHC, 6, 10a.
(2) SPPY

CM, SCC

SAN KUO CHIH 三國志

Chin, c. A.D. 290. Ch'en Shou 陳壽

History of the Three Kingdoms, A.D. 221-280.

(1) CHSC, Peking, 1962
(2) SPTK EW

SHAN HAI CHING 山海經

Mainly pre-Ch'in? Compilers unknown

A work containing geographical material, often of an obviously legendary nature

(1) SPTK CM, PC, SCC, CW

SHANG SHU 尚

(alternative name for SHU CHING, q.v.)

SHANG SHU K'AO LING YAO 尚書考靈曜

E. Han, 1st century B.C. Writer unknown.

One of the ch'an wei books. See Appendix (i)

Not extant.

(1) fragments in TPYL, etc. See III (10)(h).
(2) reconstitution in Sun Chüeh (1)
(3) reconstitution in Yasui (1)

SHIH CHI 史記

W. Han, c. 90 B.C. Ssu-ma Ch'ien 司馬遷

Universal history from early times to 99 B.C.

(1) CHSC, Peking 1962.
(2) tr. Chavannes (1) partially.
(3) tr. Watson (3) partially. EW

SHIH CHING 詩經

9th-5th century B.C. unknown.

Collection of poems ranging from love-songs to dynastic hymns.

(1) SSCCS
(2) SPTK
(3) tr. Karlgren (3)
(4) tr. Waley (1) BW, SCC

SHIH LEI FU 事類賦

Sung, c. A.D. 1000 Wu Shu 吳淑

Encyclopaedia, now usually found in enlarged form.

(1) Tseng pu shi lei t'ung pien 增補事類統編 Shanghai, 1930

CM, TB, SCC

SHIH SAN CHING CHU SU 十三經注疏

——— various

Commentaries (mainly Han) and subcommentaries (mainly T'ang) on the thirteen classics, with basic texts.

(1) I wen 藝文 printing co.
Taipei, 1972 (repr. of 1815 edn.) EW

SHIH TZU 尸子

Pre Ch'in, 4th cent. B.C. ? Attrib. Shih Chiao 尸佼

Shih Chiao was the master of the Legalist Shang K'o (Lord Shang). A book bearing his name circulated until the Yüan dynasty.

Not extant. (See Han shu bibliographical monograph)

(1) fragment in TPYL, 37, 3a; see III (10)(f).
(2) various Ch'ing reconstitutions, incl. by Sün Hsing-yen SCC, TH, HC

SHU CHING 書經

8th-4th cent. B.C. Compilers unknown

Collection of documents, mostly recording speeches etc. of ancient rulers and their ministers. Much of it is purely legendary.

(1) SSCCS
(2) SPTK
(3) tr. Karlgren (2) BW, SCC

SHUI CHING 水經

San Kuo, 3rd cent. Compilers unknown.

The traditional ascription to a W. Han writer is unlikely; the 5th/6th century commentary is important.

(1) SPTK CM, SCC, EW

SUI SHU 隋書

T'ang, A.D. 636 Wei Cheng 魏徵 et al.

History of the Sui dynasty, A.D. 581-617.
Monographs not added until A.D. 656

I1) CHSC, Peking, 1973
(2) SPTK EW, CM, SCC, PC

SUNG SHU 宋書

Nan Ch'i, A.D. 488 Shen Yueh 沈約

History of Liu Sung dynasty, A.D. 420-479.
Monographs added after A.D. 500

(1) CHSC, Peking, 1974
(2) SPTK EW, CM, SCC, PC

TA TAI LI CHI 大戴禮記

ascr. W. Han c. 50 B.C. allegedly ed. Tai Te 戴德

Traditionally said to contain the material rejected when Tai Sheng compiled the Li chi from his elder brother's work. Possibly, however, it was not in fact assembled until c. A.D. 100.

(1) SPTK BW, CM, TH, SCC

T'AI HSUAN CHING 太玄經

E. Han, A.D. 10. Yang Hsiung 楊雄

Philosophical work in imitation of I ching

(1) SPTK SCC, CM, F

T'AI P'ING YÜ LAN 太平御覽

Sung, A.D. 983. Li Fang 李昉 et al.

Encyclopaedia.

(1) CHSC, Shanghai, 1960, (4 vols)
(2) SPTK (text identical to (1))

TB, CM, SCC

T'UNG TIEN 通典

T'ang, A.D. 801. Tu Yu 杜佑

Encyclopaedic history of institutions.

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A Chinese Eratosthenes of the flat earth: a study of a fragment of cosmology in *Huai Nan tzu* 淮南子

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A CHINESE ERATOSTHENES OF THE FLAT EARTH: A STUDY OF A FRAGMENT OF COSMOLOGY IN *HUAI NAN TZU* 淮南子

By C. CULLEN

This paper attempts to deal with a short passage found at the end of the third chapter of the *Huai Nan tzu* 淮南子 book, a compendium of learning assembled in about 120 B.C. under the patronage of the prince Liu An 劉安. I first became interested in it after reading the tantalizing reference in Needham (*SCC*, III, 224).[1] (It occurs to me that the preceding sentence or some variant of it is likely to occur in learned journals with a high frequency for the next 50 years at least.) My first efforts to understand the original text led me to the conclusion that it was unique in a number of ways and had points of interest that did not fully appear in the version of Maspero, 1929, 348 ff. Professors A. C. Graham and D. C. Lau both gave very generously of their time in discussions of my first draft. Professor Graham raised the question of possible Mohist influences and brought to my notice a commentary by the Ch'ing scholar Ch'ien T'ang 錢塘, *Huai Nan tzu t'ien wen hsün pu chu* 淮南子天文訓補注, *c.* 1788. I did not feel able to follow Ch'ien in all he wrote, but was relieved to find that we reached the same general conclusions about what the text was saying, although Ch'ien seems to miss much that is important. While there are still some obscurities of language in what appears to be a rather corrupt text, I offer the version given here with a fair degree of conviction that it does not substantially misrepresent the intentions of the unknown author. Any errors that I have obstinately retained despite the helpful advice given to me throughout the time I was engaged on this work are, of course, my responsibility alone.

I shall argue later that this passage is probably not part of the original *Huai Nan tzu* text. We shall certainly never know who its author was, and we can form only vague notions of when he wrote. Whoever he was, I consider this fragment strong evidence for a powerful and original mind. The text consists largely of a probably hypothetical attempt to find the dimensions of the world by large-scale geometry using the gnomon, or simple vertical pole, which was the basic instrument of ancient Chinese astronomy and surveying. This is nothing unusual in the literature of the pre-T'ang cosmological debate. The unique feature of this author, however, is that the main method he proposes is based on a geometrical principle which is simple and accurate, needing none of the false but traditional assumptions used elsewhere. Despite his early date, his work is never referred to again by other astronomers, nor do they use any similar method.

This undeserved oblivion does not detract from the originality of his work, which is, I would suggest, not much below the level of the attempt of

[1] For list of references, see p. 127.

Eratosthenes (276–196 B.C.) to find the size of the earth by observing the noon solsticial altitude of the sun at Alexandria, a known distance north of Syene (modern Aswan) where at the same instant the sun was directly overhead (see Dreyer, 174). Whereas, however, Eratosthenes' computation of the diameter of the earth as 7,850 miles was correct to within 1%, the method of the Chinese author was doomed to failure in practice, for he was attempting to find the distance of the sun from the observer, using a base-line only 1 *li* ($\simeq \frac{1}{3}$ mile) long. As the sun is some 93,000,000 miles away the accuracy demanded was far beyond his capacity and only meaningless results would have been obtained (see below, p. 119).

This contrast is a good example of the characteristics of success and failure in science. Eratosthenes had two hypotheses of considerable predictive power, despite the fact that he would have found some difficulty in justifying them: (*a*) the earth is spherical; (*b*) the sun is for practical purposes at an infinite distance so that its rays reach the earth sensibly parallel. As it will appear, the Chinese author believed neither of these things: that condemned his proposal to sterility. His difficulty sprang from a false but typically Chinese idea about the shape of the cosmos. From his writing it is possible to reconstruct the general picture of the universe he thought he lived in, and it turns out to be a rather interesting one. Before considering the text itself, it seems relevant to make some points about Chinese cosmology in general.

In Greece the Ionian philosophers of the seventh and sixth centuries B.C. taught cosmologies with a flat earth (Dreyer, 11 ff.). This apparently self-evident doctrine continued to be held by the Epicurean Lucretius as late as the first century B.C. (*De rerum natura*, I, 1050; V, 546). Four centuries earlier, however, Philolaus, a Pythagorean, stated that the earth was spherical and in motion, not round the sun, but round the 'central fire' of the universe (Dreyer, 40 ff.). Despite this, and the heliocentric suggestion of Aristarchus in the third century B.C. (Dreyer, 137) the standard Greek view became that expressed with finality by Aristotle (384–322 B.C.): the earth is immobile at the centre of the universe. (Dreyer, 108 ff.) There was, however, never any chance of such a powerful and successful hypothesis as the sphericity of the earth being abandoned so long as rational discussion continued.

In contrast, Chinese thought on the form of the earth remained almost unchanged from early times until the first contacts with modern science through the medium of Jesuit missionaries in the seventeenth century. While the heavens were variously described as being like an umbrella covering the earth (the *Kai t'ien* 蓋 天 theory), or like a sphere surrounding it (the *Hun t'ien* 渾 天 theory), or as being without substance while the heavenly bodies float freely (the *Hsüan yeh* 宣 夜 theory), the earth was at all times flat, although perhaps bulging up slightly.

A convenient summary of ancient and medieval Chinese cosmological thought is given by Needham (*SCC*, III, 210 ff.). Note, however, that Needham quotes an account of the *Kai t'ien* theory taken from Chatley (see p. 127).

In what is perhaps an attempt to make the theory correspond more closely to reality, Chatley tacitly assumes that it describes the earth as rather more than a hemisphere, radius 225,000 *li* (1 *li* $\simeq \frac{1}{3}$ mile) with the result that an observer in China has his horizon at 25° to that of an observer on top of the earth at the North Pole. However, Chatley's source, the *Chou pei suan ching*, probably a work of the first century B.C. (see Ch'ien Pao-tsung, 1932, 23 ff.), states explicitly that heaven and earth are both shaped like Chinese rain-hats, are 80,000 *li* apart and bulge upwards only 60,000 *li* for a diameter of 476,000 *li* (*Chou pei suan ching*, 2, 1a, *SPTK*). If Chatley's interpretation was correct, the *Kai t'ien* theory would never have been subject to the criticisms that led to its downfall: see for instance the eight objections of Yang Hsiung 揚雄 (53 B.C.–A.D. 18) quoted in *Sui shu*, 19, 4a, *SPTK*). Fresh difficulties suggest themselves under Chatley's theory, such as the problem of defining what is meant by 'down', but no early author mentions any such considerations.

In fact the *Kai t'ien* theory is a not unsophisticated attempt to give at least a qualitatively correct picture of astronomical phenomena under the crippling handicap of the flat earth. The sun and other heavenly bodies perform their long-term motions on the underside of the 'umbrella' of the sky, which rotates once daily about an imaginary vertical axis passing through the centre of the earth: this position corresponds to the North Pole, and the observer of the *Chou pei suan ching* is 103,000 *li* away from it (*Chou pei suan ching* 1, 38a, *SPTK*). In summer the sun rotates nearer to the pole than in winter, and the six-month day and night at the pole are clearly described (1, 42a, and 2, 9a). Since, however, the sun never actually falls lower than 20,000 *li* above the earth's highest point (2, 3a), the only way that sunrise and sunset can be explained is by saying that they are illusions consequent upon all objects becoming invisible when more than a fairly arbitrary 167,000 *li* away (1, 43a, b): compare the first century A.D. exposition of this doctrine by Wang Ch'ung 王充 (*Lun hêng* 11, 8b and 9a, *SPTK*). This and other flaws led to the widespread rejection of the *Kai t'ien* theory in favour of the *Hun t'ien* by the second century A.D. To a certain extent this was a regression, although the *Hun t'ien* predicted appearances exactly for an observer at the centre of the celestial sphere, which was also the centre of the flat earth. In contrast to the *Chou pei suan ching* (2, 2a), dawn and dusk occurred simultaneously over the entire earth, and polar conditions were not represented in any way. Further, the latitude of observers at the Chinese centres required that the axis of the sphere be given an apparently arbitrary tilt of 55° to the vertical. On the flat earth assumption progress beyond this point was impossible, and this assumption was not discarded by any Chinese cosmologist on his own initiative.

Needham (*SCC*, III, 498) while noting the prevailing Chinese belief in a flat earth suggests that there were examples of dissent from this idea. In fact the objections in ancient authors referred to by him are all objections to the earth being *square* (*fang* 方), not to its being flat (*p'ing* 平). Even Chang Hêng 張衡, who said in the first century A.D. that heaven surrounds earth like the white of an egg round the yolk only intends to convey an image of complete enclosure by this simile, for he also says that earth is 'flat and quiescent' (*p'ing i ching* 平以靜). Some of his other statements, such as that the depth of the earth is equal to the height of heaven above the earth's surface, both being the radius of the heavenly sphere, make no sense unless we take the earth as flat. (For the relevant material see the standard collection of fragments, *Ch'üan Shang Ku San Tai Ch'in Han San Kuo Liu Ch'ao wên, Hou Han*, 55, 4a f.)

Needham likewise interprets the thirteenth century A.D. writer Li Yeh 李冶 as saying that the earth is spherical like heaven, but smaller. Li does not actually say this: after noting that the corners of a square earth might stick into the sphere of heaven, he suggests that although the earth is generally square its edge should be rounded off so as to be spherical like heaven, and that it is a little smaller than heaven:

...竊謂地體大率雖方而其實周匝亦當渾如天但差小耳...

Li Yeh, 1.

The lack of instances of arguments for a spherical earth is, of course, compounded by the lack of instances of any counter-argument at all: the flat earth remained unquestioned. This situation persisted until well into the seventeenth century, as can be seen from a letter of the Jesuit missionary Ricci, written in 1595. He notes that the Chinese say: 'The earth is flat and square, and the sky is a round canopy; they did not succeed in conceiving the possibility of the antipodes' (*SCC*, III, 438).

Confirmation of this can be found in the contemporary (1609) encyclopaedia *San ts'ai t'u hui.* 三才圖會 which has an actual illustration of a flat earth extending over the horizontal diametral plane of a spherical heaven (*San ts'ai t'u hui*, 4, 6a). The centre of the terrestrial disc coincides with the centre of the celestial sphere: at this point is Mt. Sung 嵩山, which is 40 miles south-east of Lo Yang.

The text of which the translation now follows also naturally assumes a flat earth. I think it will become evident, however, that it cannot be classed under either the *Hun t'ien* or *Kai t'ien* theories, not because it represents what can in any sense be called a rival theory, but because it has primitive characteristics suggesting an origin before either of these two systems. If this is so, there is a possibility that this is the earliest known Chinese attempt at quantitative empirically based cosmology.

I have divided the originally continuous text into sections for convenience of comment and reference, without, however, making any attempt at rearrangement. I have followed the text as in *Huai Nan tzu*, 3, 17a and 17b, *SPTK*.

(*a*) 正朝夕先樹一表東方操一表郤去前表十步以參望日始出北廉日直入又樹一表于東方因西方之表以參望日方入北廉則定東方兩表之中與西方之表則東西之正也。

'To fix [the directions of] sunrise and sunset (1), first set up a gnomon (2) in the east. Grasp another gnomon and retreat ten paces from the former gnomon, sighting [3] on the sun as it first leaves the northern edge [4]. Exactly at sunset plant a further gnomon in the east, sighting in conjunction with the western gnomon on the sun as it is about to enter the northern edge. Thus [the positions] are fixed [5]. The midpoint of the two eastern gnomons, and the western gnomon define [a line running] due east-west.' [6]

(1) A parallel to this usage occurs in the section of the *Chou li* 周禮 known as the 'Artificers' record', *K'ao kung chi* 考工記: the eighteenth-century scholar Chiang Yung 江永 suggested that this may be a state document of Ch'i 齊 and hence may date from the third century B.C. Even if this is true, later editors are not likely to have preserved the text unaltered; but for our purposes its relevance is sufficiently assured so long as it dates before the first century B.C.

晝參諸日中之影夜考之極星以正朝夕 (*Chou li*, 12, 15b, *SPTK*)
'By day they observe the noon solar shadow and by night they examine the pole star, in order to fix [the directions of] sunrise and sunset'.
Again in *Mo tzu* 墨子 (fourth century B.C.):
言而毋儀譬猶運鈞之上而立朝夕者也 (*Mo tzu*, 35, 1b, *SPTK*)
'Speaking without defined principles is like someone setting out [the directions of] sunrise and sunset on top of a potter's wheel which is free to rotate'.

In the light of these I am inclined to take *chao hsi* 朝夕 as a rather formal periphrasis for 'east and west' which are referred to as usual by *tung hsi* 東西 for the rest of the passage. An alternative might be that this passage is concerned with the fixing of the direction of any given sunrise or sunset with reference to the standard east-west line which is defined by the procedure given. This theory has considerable relevance to the ideas expressed in later sections, which pay attention to the geographical significance of the directions of sunrise and sunset.

(2) In ancient Chinese usage, the gnomon was a simple vertical pole. In this case the height is unspecified and is irrelevant, but a later section suggests the use of a pole ten *ch'ih* 尺 high rather than the eight *ch'ih* usually found.

(3) Here and in later sections the usage *ts'an wang* 參望 refers to situations where two objects define a line of sight running in the direction of a third object. It is interesting therefore to note that Karlgren (GSR, 647a) notes early uses of *ts'an* as both 'a triad' and 'straight'. Pronounced *shen*, it is, of course, also used for the line of three stars that forms Orion's belt. The fifty-seventh definition of the Mohist canon has: 直參也 (see T'an Chieh-fu, 50). As the basis meaning of *chih* 直 is, of course, 'straight' the 'alignment' sense of *ts'an* 參 is confirmed.

(4) The function of the term *pei lien* 北廉 is highly problematical, and I have not succeeded in finding a helpful parallel. My first impulse was to take *lien* in its sense of 'corner, edge', and make it refer to the sun itself, thus translating: 'sighting on the northern limb of the sun as it first rises'. There is some point in specifying whether the sight is to be taken on the northern or

southern limb; if the gnomons are ten paces apart the sun's angular diameter of $\frac{1}{2}°$ would cause an uncertainty of some six inches unless a particular point on the sun is named. It seems, however, that this rendering strains the grammar, and hence we are left with a reference to the sun coming out of the northern *lien* of something else. Since the sun goes into this northern *lien* at sunset as well as apparently coming out of it at dawn, *pei lien* cannot very well refer to a part of the earth or some particular direction on the horizon. (Cf. the use of the term *wei* 維 in (*b*) below.) We are left, therefore, with the possibility that *pei lien* refers to the gnomons. Ch'ien T'ang accepts this, but then loads the text well beyond breaking point with an interpretation in terms of the shadow of one gnomon just grazing the edge of another, finishing by attributing to this text a precision of knowledge of solar motion not found, by his own admission, until the fifth century A.D. A simpler explanation seems possible in the following terms.

Assume that the observer does his sighting from close behind one gnomon, and that these gnomons have the not unreasonable diameter of one inch. Then, taking one pace as about sixty inches (a Chinese 'pace' *pu* was made up of two steps), the gnomon ten paces away will have an angular diameter θ as seen by the observer, where

$$\theta = \tan^{-1} \tfrac{1}{600} \text{ (to a very close approximation)}$$
$$\therefore \theta \simeq \tfrac{1}{12}°$$

For comparison, the sun has an angular diameter of about $\frac{1}{2}°$ for observers on the earth and the gnomon thus covers about one-sixth of it.

Further, it is reasonable to suppose that the observer will not bring his eye so close to the nearer gnomon that he cannot focus his eye on it: this distance is, of course, subject to individual variations, but is not far from five inches. The angular diameter ϕ, at the eye, of the inch-thick gnomon is then given approximately by:

$$\phi = \tan^{-1} \tfrac{1}{5}$$
$$\therefore \phi \simeq 10°$$

Thus, if the nearer gnomon was transparent and provided with some sort of graticule, the sun would cover about 0.05 inches on the scale, while the further gnomon might cover about a sixth of this already very small distance. (This transparency is, of course, only introduced for purposes of illustration.)

Considering the sighting process in more detail, it becomes evident that two gnomons can be used to obtain a number of different lines of sight. In fig. 1 (gnomon width much exaggerated) the main ones are shown. The angle θ is obviously the quantity calculated earlier as about $\frac{1}{12}°$. Note, of course, that for very distant objects like the sun parallel sightings such as B and C are equivalent. Returning to the text, and noting that the version chosen demands that we find a 'northern edge' for the sun to 'leave', let us choose the sight-line that uses the two northern edges of the gnomons. Then when the centre of the sun is just on the horizon in the east we can arrange the gnomons so that the situation of fig. 2 will occur. The line XX′ represents the aligned northern

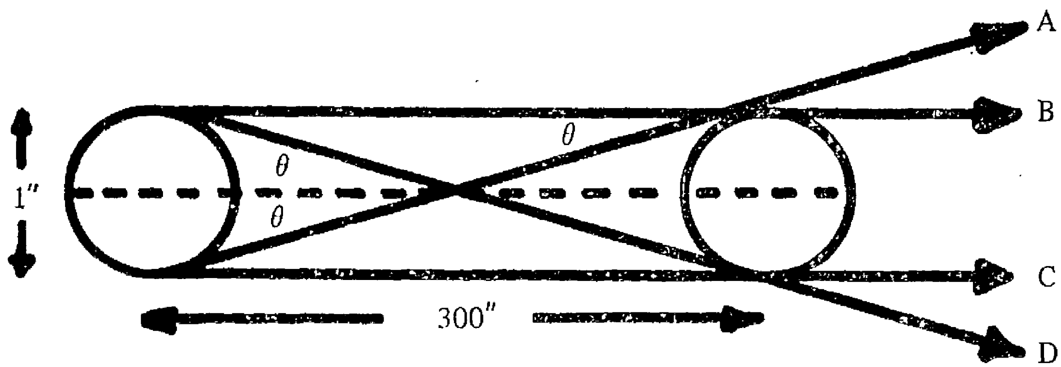

FIG. 1. (Not to scale)

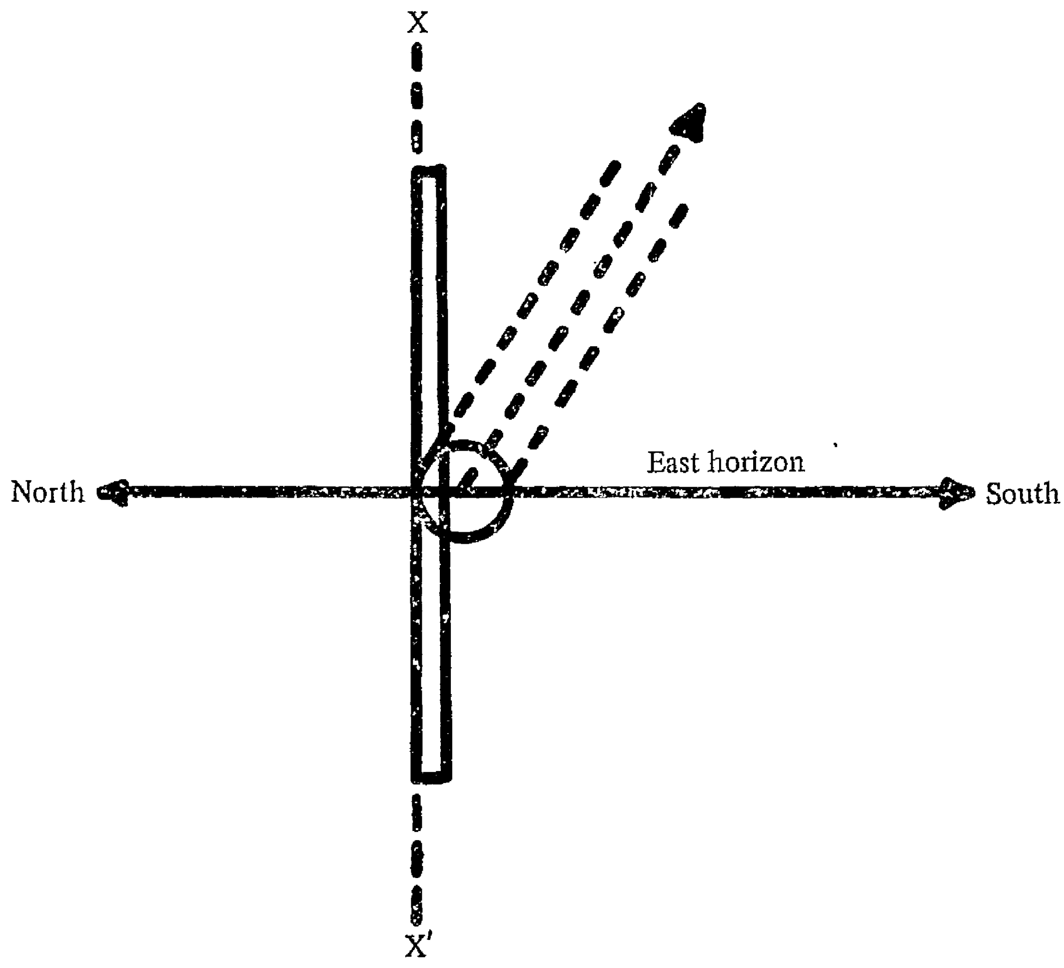

FIG. 2

edges of both gnomons, arranged so that at rising the sun is just in contact with it. As the sun rises it will take the path shown: the angle of this path to the vertical is equal to the observer's latitude, some 34° for the Han capital Ch'ang An. It can thus be said to 'leave the northern edge' as the text specifies. The situation at sunset will, of course, be a simple reflection of fig. 2 in the line XX′, the direction of the sun's motion being reversed: at that time the sun 'enters the northern edge'.

Notice that if we wish the sun to be just leaving the aligned northern edges of the gnomons at sunrise and just meeting them at sunset, our alignments must be made with the sun's northern limb. It appears, therefore, that the only effect of referring *pei lien* to the gnomons rather than to the sun is to imply that the observer keeps his eye close enough to a gnomon for its width to be significant: sights must still be taken on the sun's northern limb.

(5) Punctuation is doubtful here. Ch'ien T'ang divides after 方, while T'an Chieh-fu, 50, omits any punctuation. Ch'ien insufficiently emphasizes the fact that we need the midpoint of the two eastern gnomons. By punctuating after 定, I attempt to indicate a parallel between 則 定 for the gnomons and the later 則 ... 正 for the directions: none of these variants makes any practical difference.

(6) A plan view of the final arrangement is shown in fig. 3, in which the size of the gnomons is much exaggerated. I have made the assumption, without which the method will not work, that in planting C the observer retreats ten paces from A, repeating the procedure he used in planting A. ZZ′ is a line of sight on the rising sun, and YY′ is a line of sight on its setting. The situation shown would occur in the summer: at the solstice the angles α and β would be of the order of 60° for observers near Ch'ang An. At the equinoxes B and C coincide, and by the winter solstice they have become reversed. To a close approximation the angles α and β are equal, but if we take account of the annual motion of the sun on the celestial sphere, it becomes evident that from the winter solstice to the summer solstice the sun will set a little further north than it rose, making β less than α. From the summer solstice to winter solstice β will exceed α. However this difference is always small, and even at the equinoxes when it reaches its largest value it does not exceed $\frac{1}{4}°$ for a Ch'ang An observer.

As AB is parallel to ZZ′ and CA is parallel to YY′, it is evident therefore that if D is the midpoint of BC the line DA runs due east-west with an acceptable degree of accuracy: an error of one inch in fixing the position of a gnomon will as we have seen cause an error of only $\frac{1}{12}°$.

I must confess that I do not feel completely satisfied with the solution of the *pei lien* problem in (4) above. In particular I do not think that the terms 出 and 入 really apply very well to the supposed motion of the sun relative to the aligned northern, edges of the gnomons at rising and setting. Nor does it seem right to ignore the fact that the phrase 日 始 出 occurs elsewhere in contexts where it has no object, and means literally 'when the sun first comes out', i.e. the moment of dawn itself. (See for instance the story of Confucius and the two small boys in *Lieh tzu* 列 子, 5, 12b, *SPPY*, or the example following from the *Chou pei suan ching*.) On purely practical grounds the observer's closeness to one gnomon involves a very fussy procedure, and speaking personally it seems more natural when checking the alignment of two gnomons to step far enough back from them so that their thickness can be neglected.

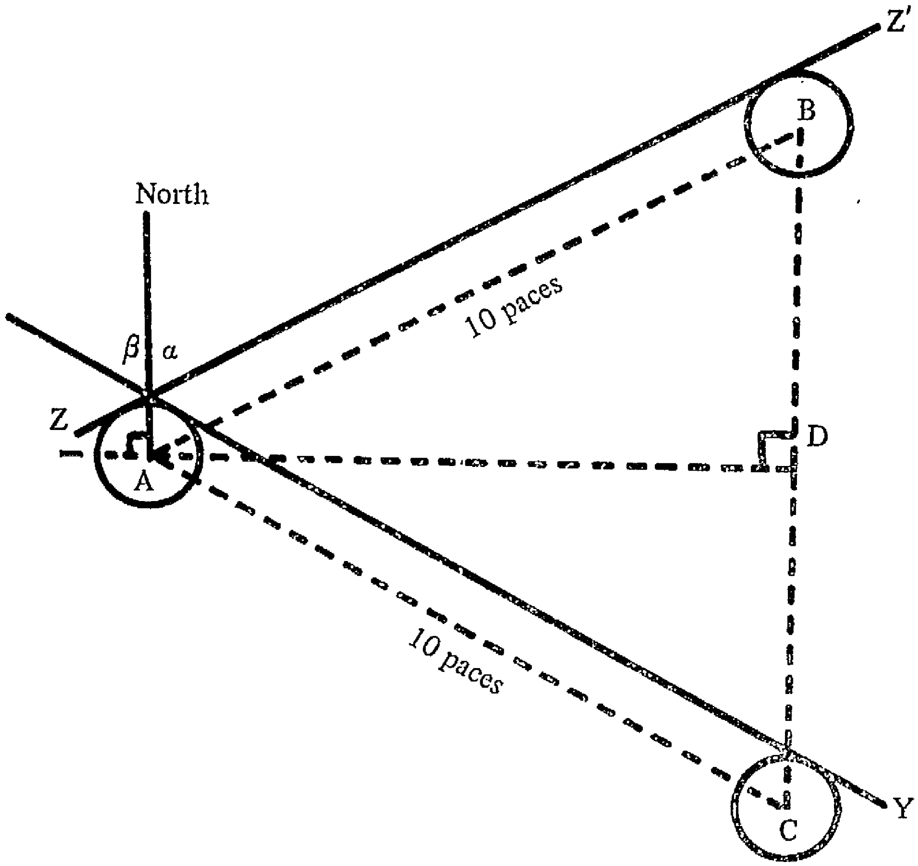

FIG. 3

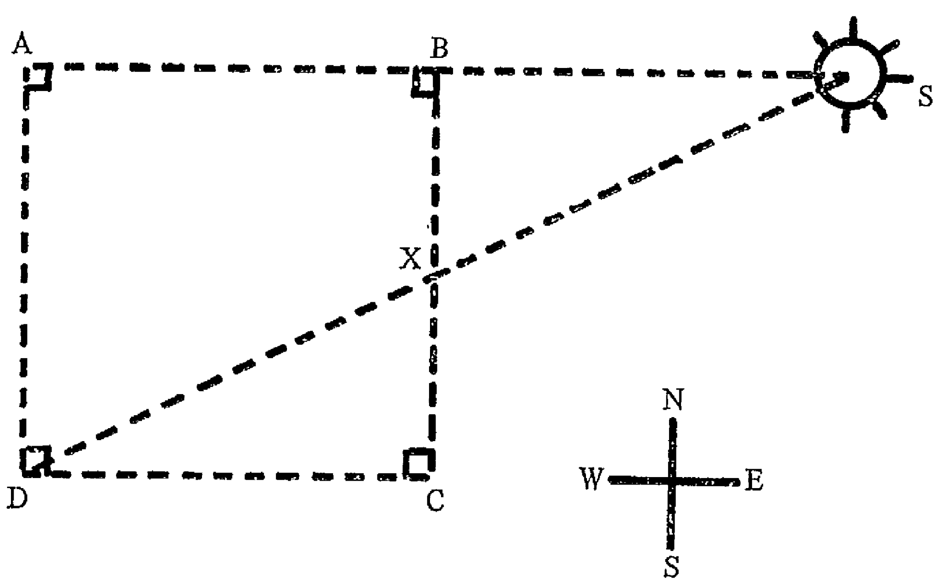

FIG. 4

This would, of course, force us back to referring *pei lien* to the sun itself. This may make a clumsy expression of 日 始 出 北 廉, but one might sometimes prefer to yield to the temptation to assume that an author's sense is better than his literary style.

In any case I do not think that any of the several ways of rendering the passage could result in a description of a practical method differing from the others by more than $\frac{1}{2}°$ in its definition of an east-west line. Experimental errors would in all likelihood be equal to or greater than this theoretical divergence.

For comparison, here is a short passage from the *Chou pei suan ching.*

日始出立表而識其晷日入復識其晷晷之兩端相直正東西也中折之指表者正南北也 (*CPSC*, 2, 8a, *SPTK*)

'At dawn set up a gnomon and observe its shadow. At sunset observe its shadow once more. The ends of the shadow align to indicate due east-west. [The line from] their midpoint to the gnomon indicates due north-south'.

This method is simpler in that it uses only one gnomon and involves no aligning by the observer. It suffers from the disadvantage that dawn and sunset shadows will naturally have extremely ill-defined ends: this can be overcome, however, by the fairly obvious expedient of marking an equal length along each shadow and thus defining arbitrary shadow-ends which will serve the purpose just as well.

(*b*) 日冬至日出東南維入西南維至春秋分日出東中入西中夏至出東北維入西北維。

'On the day of the winter solstice the sun rises on the south-east diagonal and sets on the south-west diagonal [(7)]. On the arrival of the spring and autumn equinoxes the sun rises in the middle of the east and sets in the middle of the west. At the summer solstice it rises on the north-east diagonal and sets on the north-west diagonal.'

(7) The term *wei* 維, translated here as 'diagonal', has a precise meaning in the main body of the chapter:

兩維之間九十一度(也)十六分度之五 (*Huai Nan tzu*, 3, 6a, *SPTK*)

'Between two *wei* the interval is $91\frac{5}{16}$ *tu*'.

(Comparison with other texts suggests 也 here is a printing error.) As there are $365\frac{1}{4}$ *tu* in a complete circle, $91\frac{5}{16}$ *tu* is 90°, a right angle. It will become clearer later on that 'diagonal' here refers to a square thought to be formed by the four positions occupied by the sun at the moments of rising and setting at the summer and winter solstices. (See section (*i*).) In fact it is only for an observer at a latitude of about 57° that these four positions appear to lie along the diagonals of a square centred on the observer: this is far to the north of China. It becomes plain, however, that these statements are not meant approximately, although the author is prepared to concede that some observers may not be at the centre of the square and hence will not see the simple situation described here. Despite these modifications the theoretical scheme developed cannot predict the observations of an observer near Ch'ang

An or Lo Yang. For such an observer lines running from his position towards sunrise and sunset at the summer solstice include an obtuse angle of about 120°. The same applies to the winter solstice except, of course, that rising and setting are to the south of the observer. The rest of the *Huai Nan tzu* gives us no comparison data about sunrise and sunset.

In the *Chou pei suan ching*, however, we find:

冬至晝極短日出辰而入申...夏至晝極長日出寅而入戌 (*CPSC*, 2, 42b and 43a, *SPTK*)

'On the winter solstice daylight is shortest. The sun rises in *ch'en* and sets in *shen*. . . . On the summer solstice the day is longest. The sun rises in *yin* and sets in *hsü*'.

Now *ch'en*, *shen*, *yin*, and *hsü* are respectively names for the directions 30° south of east, 30° south of west, 30° north of east, and 30° north of west. These data imply the 120° angles between solsticial setting and rising that actually occur. It is puzzling therefore to find our author putting forward what appear to be obvious inaccuracies: according to him the angle should be 90° for a central observer. Indeed later on he describes a procedure for checking this prediction.

(*c*) 至則正南。

'At culmination it is due south.' (8)

(8) I am inclined to take this as a misplaced fragment. Normally *chih* 至 would refer to a solstice, and the sun culminating at noon would be referred to as *chung* 中. *Chih* may be used here with reference to the sun having reached its maximum altitude at noon, when it is in fact due south.

(*d*) 欲知東西南北廣袤之數者立四表以爲方一里距先春分若秋分十餘日從距北表參望日始出及旦以候相應相應則此與日直也輒以南表參望之以入前表數爲法除舉廣除立表袤以知從此東西之數也。

'If you wish to know the figures for the breadth and length of east, west, north, and south set up four gnomons to make a right-angled figure one *li* square. More than ten days before the spring or autumn equinox sight along the northern gnomons of the square on the sun from its first appearance to its rise above the horizon.(9) Wait for [the day when] they coincide. When they coincide they are in line with the sun. Each time (10) take a sight on it [the sun] with the southern gnomons, and take the amount by which it is within the forward gnomons as the divisor. Divide the whole width [and/or?] divide the length [between] the standing gnomons in order to know the measurements east and west from here.' (11)

(9) This is a somewhat provisional rendering of 日始出及旦. *Tan* 旦 does suggest graphically a situation where the sun's lower limb is only just in contact with the horizon: a different interpretation could scarcely change the practical significance of the passage.

(10) Presumably on each day of the 'more than ten days before' the equinox.

The mathematical procedure following only works, however, for the day when the northern gnomons align with the sun.

(11) This last sentence is very cryptic. There is some help to be gained by adopting the suggestion of D. C. Lau (private communication) that 舉 *chü* (Karlgren: **ki̯o/ki̯wo:*) may be a phonetic loan for the earlier 距 *chü* (K: **g'i̯o/g'i̯wo:*) itself obviously a loan for 矩 *chü* (K: **ki̯wo/ki̯u:*). If we take this view, then 'the whole width' becomes 'the square's width' which makes explicit what would otherwise be an obvious inference. One advantage possessed by the translator of scientific texts, however, is that he can often feel fairly sure what the text ought to mean by a simple reference to mathematical or physical facts. Now the geometry of the arrangement described here is obviously as shown in fig. 4, which is not, of course, to scale. A, B, C, D are gnomons and S is the rising sun. CX is the amount by which it (i.e. the sun) is within the forward gnomons. A, B are the northern gnomons, C, D are the southern gnomons, and B, C are the forward gnomons.

Now the triangles SAD, DCX are similar.

$$\because \frac{SA}{AD} = \frac{DC}{CX}$$

$$\therefore SA = \frac{DC \times AD}{CX} \qquad \qquad (1)$$

A similar procedure to this one is found in the *Chiu chang suan shu* 九章算術, perhaps compiled in the first century A.D. Most of this book's techniques were, of course, probably current before its compilation.

有木去人不知遠近立四表相去各一丈令左兩表與所望參相直從後右表望之入前右表三寸問木去人幾何。

荅曰三十三丈三尺三寸少半寸。

術曰令一丈自乘爲實以三寸爲法實如法而一。 (*Suan ching shih shu*, ed. Ch'ien Pao-tsung, 257)

'There is a tree an unknown distance from a man. He sets up four gnomons ten feet apart [i.e. as a square], so that the left two gnomons align with the object sighted on. Sighting on it from the rear right gnomon it [appears] to be three inches within the forward right gnomon. How far away is the tree?

Answer: 333 feet, $3\frac{1}{3}$ inches.

[1 'foot' *ch'ih* 尺 has 10 'inches' *ts'un* 寸.]

Method: square the ten feet and make that the dividend. Take the three inches as the divisor and divide the dividend by the divisor.'

The method here set out in words is, of course, exactly that symbolized by equation (1) above. Although the *Chou pei suan ching* does not contain a similar problem, its mathematical language and methods are very similar. What conclusions can be drawn, then, about the strange sentence at the end of (*d*), which is expressed in terms quite different from the smooth formalism of the *Chiu chang suan shu*? Note further that in (*e*) we are given what amounts to an alternative mathematical process for obtaining the results required. I have not succeeded in finding any parallels to the expressions that end (*d*).

There seem three courses open: (i) emend the text until it says clearly what it 'ought' to say; (ii) assume that the meaning of a valid but previously unknown expression is now revealed; (iii) treat the text as an abortive and unique attempt to deal with concepts new to the author.

The easiest course is naturally (i): by omitting 除舉廣 (or equally 除立表袤), one obtains a prescription for $\frac{AD}{CX}$ or $\frac{DC}{CX}$. As both AD and DC are one *li* the result will be numerically identical to $\frac{DC \times AD}{CX}$, the result for SA in equation (1): it will, however, be a pure number unlike SA which is a length. The spirit of this reading is close to that of the method expressed in (*e*). Nevertheless it seems rough handling simply to slice three or four characters out of the text, and no more subtle emendation seems possible.

To follow (ii) is a path of despair, especially as it seems very unlikely that a parallel will be found to test the rendering. Even given the 'blessed assurance' that we have a very good idea what the text means on mathematical grounds, (ii) demands that we should give up the attempt to understand the author's mental processes. If one is to do this one might as well give up reading the text altogether. Besides, if this method was generally applied it would bring the danger that by ignoring the consistency of the language as a guide, and relying on physical and mathematical precognition instead one might miss the instances of interesting but incorrect thinking which are a great part of the matter of the history of science.

If we adopt (iii) and bear in mind the subsequent explanations of (*e*), I am inclined to take 除舉廣 and 除立表袤 as alternatives, translating 'Divide the whole width [or] divide the length [between] the standing gnomons'. This gives us the choice between $\frac{AD}{CX}$ and $\frac{DC}{CX}$ as before, these two being equal. If, however, the clauses are in conjunction rather than disjunction, there is the somewhat slender chance that by telling us to divide *both* width and length the author wants us to divide their product as in equation (1).

However we read this passage it is hard to avoid the conclusion that this author had only relatively primitive mathematical tools at his disposal. The neat expressions of the *Chiu chang suan shu*, particularly the phrase 實如法 for the division process are also found in the *Lü shu* chapter of the *Shih chi* (*SC*, 25, 11a, *SPTK*) which may date from before 90 B.C. Another parallel is in the *Chou pei suan ching*, 1, 70b. Leaving aside the possibility of gross corruption therefore we might conclude that the author of the *Huai Nan tzu* passage wrote either in some isolation or else before such usage became standard.

(*e*) 假使視日出入前表中一寸是寸得一里也一里積萬八千寸得從此東萬八千里視日方入入前表半寸則半寸得一里半寸而除一里積寸得三萬六千里除則從此西里數也幷之東西里數也則極徑也。

'Suppose that the rising sun is observed one inch within the forward gnomons. This implies that for an inch one gets one *li*. One *li* contains 18,000 inches, so one gets 18,000 *li* eastwards from here to the sun (12). [Suppose] one observes the sun just as it sets, and it sets half an inch within the forward gnomon: then for half an inch one gets one *li*. Dividing the number of inches in a *li* by half an inch, one gets 36,000 *li* (13). Divide, and then [you have] the number of *li* westward from here (14). Add them, [and you have] the number of *li* east and west, which is the diameter of the extreme limits.' (15)

(12) The words *chia shih* 'suppose' make it likely that this passage is based on hypothetical data. It is plain that this must be so for two reasons. (i) An observer at the rear gnomon could not possibly distinguish so small a separation as one inch from a gnomon one *li* away: this inch would subtend an angle of less than 0.003° at the eye of the observer, less than 1% of the sun's angular diameter of 0.5°. (ii) As the sun is in any case some 93,000,000 miles away ($\simeq$ 300,000,000 *li*) the actual distance of the sun within the forward gnomons (given alignment of the northern gnomons) would be given by

$$x = \frac{1\ li \times 1\ li}{300{,}000{,}000\ li} \times 18{,}000 \frac{(inches)}{(\ li\ )}$$

$$\therefore x \simeq 0.00006\ inches$$

Thus any observations made would consist overwhelmingly of experimental error.

However, the principle of simple proportion as set down in this section is, of course, correct.

(13) This half-inch is, of course, also hypothetical: it is interesting, however, to note that the author conceives the possibility of being closer to the rising sun than the setting sun, if, that is, the inch and half-inch are to be taken as measured by the same observer.

(14) If the rather awkward 除 at the beginning of this sentence could be omitted, this sentence would fit neatly on to the preceding one.

(15) As the result of this addition is not stated, the possibility is left open that the pronoun *chih* 之 is intended to refer to whatever results are obtained when the process prescribed is carried out in practice, rather than to the 18,000 *li* and 36,000 *li* already mentioned.

(*f*) 未春分而直已秋分而不直此處南也未秋分而直已春分而不直此處北也分至而直此處南北中也。

'If the alignment occurs before the spring equinox and not until after the autumn equinox, this [implies that] you are in the south. If the alignment occurs before the autumn equinox and not until after the spring equinox, this [implies that] you are in the north. If when the equinox arrives the alignment occurs, this [implies that] you are midway between north and south.' (16)

(16) 'The alignment' referred to is, of course, the dawn alignment of the sun with the northern pair of gnomons. In fact this occurs exactly at the equinoxes

for all observers wherever they are on the earth. It is evident from this section, however, that the author has a world-conception in which the sun rises over the edge of the earth or out of the earth (which is, of course, flat) at a different position each day. At the summer solstice this position is furthest north, and at the winter solstice it is furthest south: at the equinoxes (probably defined as the days midway between the solstices) the sun rises 'midway between north and south' and an observer who is also 'midway' will see his gnomons aligned with the sun at dawn. If the observer is further north he will observe alignments at two dates nearer the summer solstice: if he is to the south the dates will be nearer the winter solstice. This lends point to the prescription in (*d*) above that observations must commence 'more than ten days before the spring or autumn equinox': it is thus ensured that a non-central observer will not miss his alignment. A later section, (*j*), describes a method of finding how far north or south a particular observer is.

(*g*) 從中處欲知中南也。

'From a central position, to know [the distance] south of the centre.'

(*h*) 未秋分而不直此處南北中也。

'If the alignment does not occur until the autumn equinox, this [implies that] you are midway between north and south.' (17)

(17) Neither of these sections seems properly placed; (*g*) seems a distortion of the beginning of (*i*), while (*h*) seems to belong with (*f*).

(*i*) 從中處欲知南北極遠近從西南表參望日日夏至始出與北表參則是東與東北表等也正東萬八千里則從中北亦萬八千里也倍之南北之里數也。

'From a central position, to know the distance of the limits of north and south, sight on the sun from the south-west gnomon. At the summer solstice, if when the sun rises you [try to] align it with the gnomon to your north [i.e. the north-west gnomon] the result is that it is to the east equally with the north-east gnomon. It is 18,000 *li* due east, so from the centre northwards it is also 18,000 *li*. Double this to obtain the number of *li* from south to north.' (18)

(18) The first two sentences of this section are, of course, simply equivalent to the statement of section (*h*) 'At the summer solstice it [the sun] rises on the north-east diagonal'. Note that the end of this section now takes for granted the 18,000 *li* figure that was introduced as the result of the hypothetical one-inch measurement in (*e*). This figure is also implicit in the statements of section (*j*). Although the author may have believed that one inch was in fact a correct figure, I am more inclined to believe that he adopted it as a working hypothesis to enable him to work out the implications of his ideas in the absence of a flexible symbolism.

At this stage I feel able to suggest that fig. 5 is a likely version of the world-view of this author. The size of the central observer's gnomon-square ABCD is, of course, greatly exaggerated.

The positions V, W, and X represent the rising sun at the summer solstice,

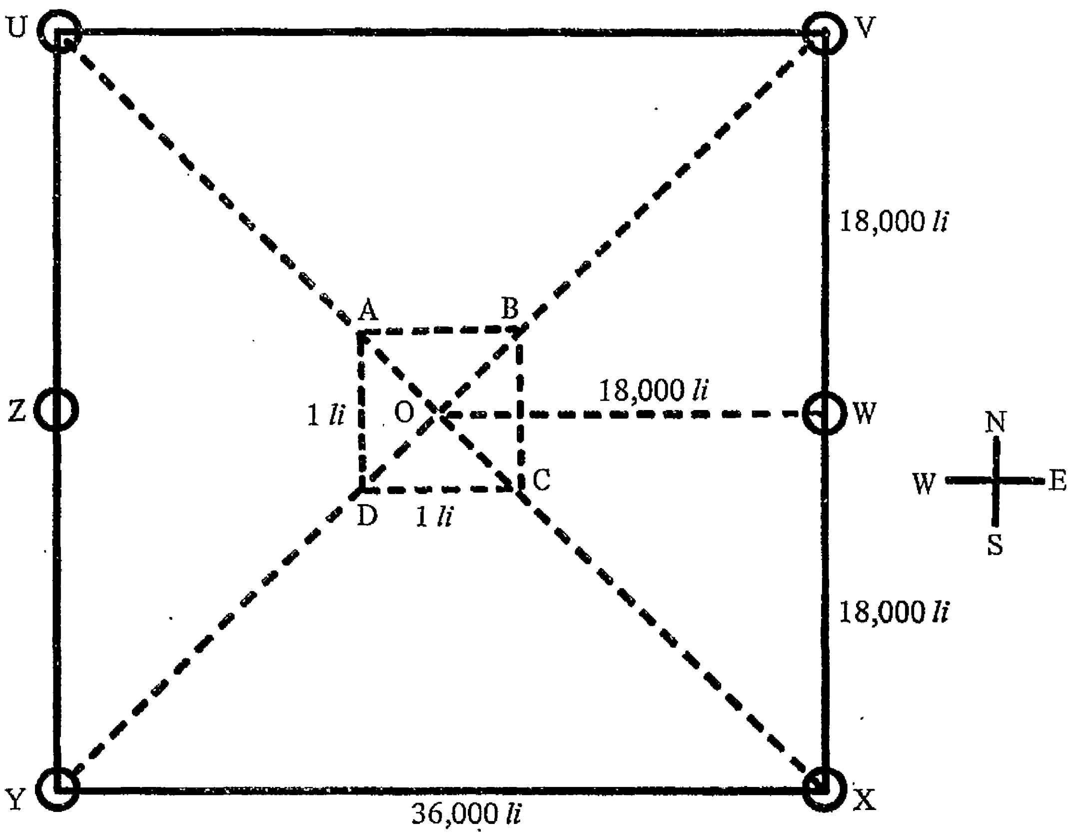

FIG. 5. (Not to scale)

equinoxes, and winter solstice respectively, and these positions are fixed explicitly by the text (W by (*e*) and V, X by (*i*)). By fixing the setting positions U, Z, Y symmetrically I am relying on the clear statements of (*b*) and the evidence of any observer's eyes. I have not felt compelled however, to adopt the half-inch figure for sunset given in (*e*). As I suggested earlier, it seems to be only an alternative illustration to the one-inch figure, and its adoption here would make VXYU into a trapezium rather than a square, with UY = 2VX.

As it stands, fig. 5 is highly suggestive of the perennial Chinese notion of the square earth. It is, of course, only a diagram of rising and setting solar positions. If, however, the author thought of the sun as rising and setting over the edge of the earth, we have a picture of the shape of that earth in fig. 5 It is probable that he also thought of himself as near the centre of the earth, in which case his obvious knowledge that the sun is always due south at noon would have forced the conclusion that in its journey from (say) W to Z the sun passed well to the south of O.

Maspero (1929, 350) misses the point of the last two sentences. He proposes to read ' westwards ' for ' northwards ' and ' east to west ' for ' south to north ', which robs section (*j*) of any rational basis and misses the connexion with (*b*). His object is to avoid contradicting the 20,000 *li* figure of (*k*) for the distance south to the subsolar point, but as this is apparently a noon distance it cannot conflict with a sunrise and sunset distance southwards of 18,000 *li*. In any case it will soon appear that the 20,000 *li* figure must refer to the summer solstice, corresponding therefore to the sun rising and setting 18,000 *li* north of the observer. Further, there is really little point in making drastic emendations in an attempt to avoid clashes between actual data and what are evidently arbitrary hypotheticals.

(*j*) 非不從中之數也以出入前表之數益損之表入一寸寸減日近一里表出一寸寸益遠一里。

'The amount [the observer] is off centre is larger or smaller depending on the amount that [the sun] is inside or outside the forward gnomons. If [the sun] is one inch inside the gnomons, that inch brings the sun one *li* closer. If [the sun] is one inch outside the gnomons, that inch increases the distance by one *li*.' (10)

(19) The geometry of this section is true for observers on a north-south line through the 'central position' of section (*i*). In fig. 6 ABCD represent the gnomon-square of a central observer, while A′B′C′D′ are to the north of centre. S represents the rising sun at the summer solstice.

As ZD′ is parallel to SD

DD′ = BB′ = ZS = the distance by which the observer is to the north of centre.

$$\text{By similar triangles, } \frac{B'X}{D'C'} = \frac{ZS}{D'T}$$

$$\therefore ZS = \frac{D'T \times B'X}{D'C'}$$

$$\text{Now } D'C' = 1\ li,\ D'T = 18{,}000\ li$$

$$\therefore ZS = 18{,}000\ B'X$$

If B′X is measured in inches, then, as there are 18,000 inches in a *li* (see section (*e*)), ZS will measure one *li* for every inch of B′X, which in this diagram of course is a distance 'inside the gnomon'.

An observer near Lo Yang would see the sun rising about 60° east of north at the summer solstice, and would thus locate X some 8,000 inches from B′, concluding that he was 8,000 *li* to the north of the centre of the earth, which point would thus lie somewhere near Vietnam. This does not sound the kind of conclusion that would commend itself to a Chinese audience in ancient times: Later Han commentators on the *Chou li* claim that the capital of the Chou dynasty was located at the centre of the earth (see *Chou li* 10, 13a ff, *Shih san ching chu su*), and this capital was of course Lo Yang itself. In any case, observation of the winter solstice sunrise would have suggested that, according to the theory given here, the observer was 8,000 *li* to the *south* of centre. Once again, we see that the procedure given here is merely hypothetical.

(*k*) 欲知天之高樹表高一丈正南北相去千里同日度其陰北表二尺南表尺九寸是南千里陰短寸南二萬里則無景是直日下也陰二尺而得高一丈者是南一而高五也則置從

此至日下里數因而五之爲十萬里則天高也若使景與表等卽高與遠也。

'To find the height of heaven, set up [two] gnomons ten feet high and 1,000 *li* apart due north-south. Measure their shadows [at noon] on the same day. The north gnomon [shadow] is two feet, and the south gnomon [shadow] is one foot nine inches. Thus a thousand *li* due south shorten the shadow by one inch and twenty thousand *li* due south there is no shadow at all. This is directly below the sun. A two-foot shadow corresponds to a height of ten feet so for each unit southwards one rises five units. Therefore, if one takes the number of *li* from this position south to the subsolar point and multiplies by five, making 100,000 *li*, this is the height of heaven. Supposing the shadow is equal to the gnomon, then the height is equal to the distance.' (20)

(20) This section is unrelated to those that precede it, although the style and vocabulary are not sensibly different . The 'inch for a thousand *li*' principle used here is found in all other early Chinese work with gnomons (e.g. *Chou pei suan ching, passim*). It is a unique feature of this text, however, that it refers to a ten-foot gnomon and not to an eight-foot gnomon which is the size used

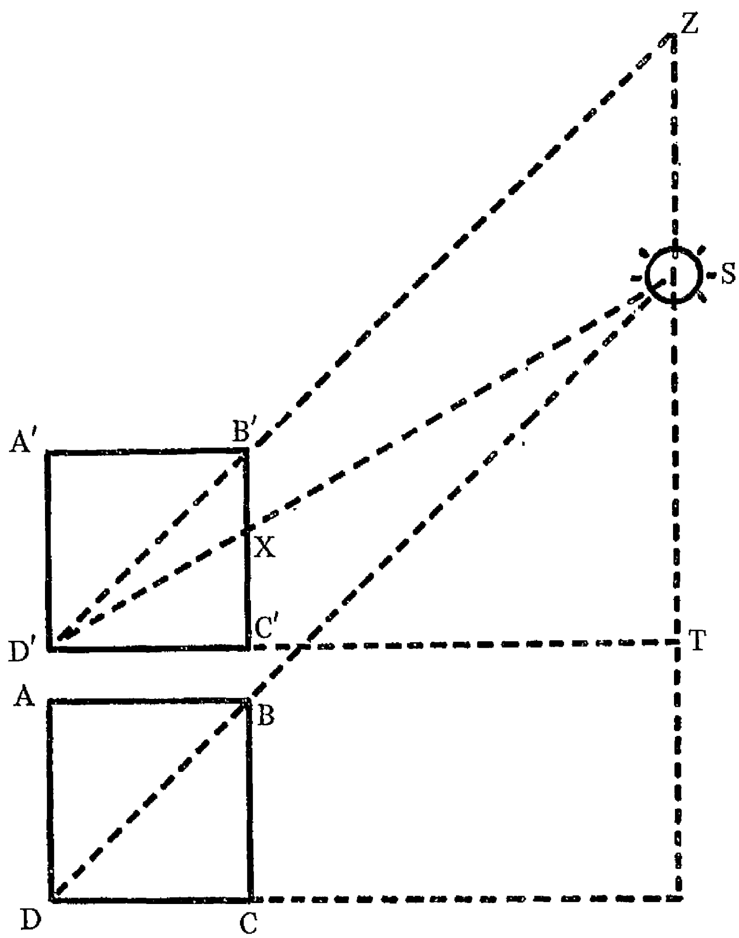

FIG. 6. (Not to scale)

everywhere else: the shadow principle is not modified in any way, despite this. Thus while here we are given 100,000 *li* for the 'height of heaven', the *Chou pei suan ching*, using the same principle for a smaller gnomon, concludes that the height is 80,000 *li* (*Chou pei suan ching* 1, 26b, *SPTK*).

Despite this, the two-foot shadow may be the one piece of observed data in the whole text, for it implies a solar altitude of $\tan^{-1} 5 = 78.7°$. (With data of this kind there seems little point in working to greater accuracy.) Using de Sitter's (1938) expression for the obliquity of the ecliptic,

$$E = 23° \, 27' 8''.29 - 47''.080t - 0''.0059t^2 + 0''.00186t^3$$

where t is measured forward in centuries from A.D. 1900

we obtain $E = 23.7°$ for 120 B.C.

If the shadow given here corresponds to noon at the summer solstice, then the latitude implied for the observer is given by

$$L = 90° + 23.7° - 78.7°$$

$$\therefore L = 35.0°$$

Several important ancient sites, including the Chou dynasty capital Lo Yang, lie within 50 miles of this line of latitude. There is the further interesting point that the *Chou pei suan ching* (1, 25a) states that the noon summer solsticial shadow of an eight-foot gnomon is 1.6 feet. This corresponds exactly to a two-foot shadow for a ten-foot gnomon, which is the case given here. We have, of course, no means of deciding whether one figure was obtained from the other, or both drawn from a common literary source, or perhaps both taken from actual observation at the same latitude.

The 1 foot 9 inches shadow (there were as already noted 10 'inches' to a Chinese 'foot') would, if it were a summer solstice noon shadow, correspond to a latitude of 34.5° in 120 B.C. Taking 3 *li* as 1 mile, this would place the second gnomon only 100 *li* south of the first rather than 1,000 *li*. This figure is obviously a fictitious construction.

Let us now take the text as a whole and see what conclusions if any can be drawn about its origin and the thought that lay behind it. This somewhat incomplete and muddled account occurs at the end of a chapter that contains nothing else of a similar nature or style, and is in no way continuous with it. There is an earlier reference to gnomons (3, 5b) but to gnomons of eight feet rather than ten feet, and with a noon summer solstice shadow of 1.5 feet rather than the 1.6 feet that would correspond to the two-foot shadow for the ten-foot gnomon given here. A further discrepancy is the use there of *hsiu* 修 'length' where one would have expected *piao* 表 'gnomon' as in most other texts of all dates. The main text states that heaven is 510,000 *li* away from earth (3, 2a) and in what is admittedly a different chapter the over-all dimensions of the universe are given as 233,500 *li* and 75 paces north-south and east-west, while the inhabited land 'within the four seas' is 26,000 *li* north-south and 28,000 *li* east-west (4, 2a). It is hard, therefore, to maintain that our text really belongs in its present position.

It is not, however, inconsistent with what we know of the early history of many Chinese books to suggest that a later editor, attempting to arrange disordered bundles of bamboo strips, came across these isolated notes on the gnomon mixed up with the genuine *Huai Nan tzu* text, and appropriately enough attached them to the end of the astronomy chapter. It may even have been a later author who added his own notes and left them filed in an obvious location in his copy of *Huai Nan tzu*. If he had copied the main text in his own hand, a subsequent copyist would have simply assimilated the notes to the chapter itself without suspecting the interpolation.

If we accept that we are not dealing with a part of the treatise prepared for Prince Liu An, but with what amounts to one man's private notes, it becomes easier to understand the odd way the text veers between fact and hypothesis, with little attention to over-all consistency. Sections (*i*) and (*j*) for instance take for granted the 18,000 *li* dimension introduced in (*e*) as obtained from an explicitly hypothetical one-inch observation, and the figure of 36,000 *li*, which in conjunction with (*b*) would imply that the four extreme solar positions form a trapezium is not mentioned again. This sort of sequence of thought is, however, familiar to anybody who has tried to work out the implications of a new idea in practice.

Despite the correspondence of the gnomon shadows already noted, there is little trace here of the developed *Kai t'ien* cosmology found in the *Chou pei suan ching*. On the contrary, sections (*d*) to (*j*) clearly imply that the sun rises and sets level with the edge of the earth. The primitive notion that the sun's extreme risings and settings mark out a square rules out any possibility that this text is based on the relatively late *Hun t'ien* theory, which at least gave an accurate picture of the phenomena for a central observer.

In fact it is easy to draw connexions with the archaic descriptions found elsewhere, in which the sun (perhaps a new one each day) rises from some point in the east, *Yang Ku* 暘 谷 'the bright valley' often associated with a magic mulberry tree, *fu sang* 扶 桑, in whose branches the suns hang like fruit. It travels over the earth and finally sinks to rest at *Mei Ku* 昧 谷 'the dark valley'. The earliest reference to this is perhaps in the first chapter of the *Shu ching* 書 經 (*c.* 400 B.C.) where the legendary Emperor Yao despatches his astronomers Hsi and Ho to keep watch at these positions (1, 1b, *SPTK*); *Huai Nan tzu* itself has a detailed account of the sun's daily journey (3, 9a). This and similar legends are discussed in Maspero, 1924. Such ideas are obviously prior to the *Kai t'ien* attempt at systematization, which as we have seen suggested that sunrise and sunset were optical illusions. Although therefore we may not be dealing with original *Huai Nan tzu* material, it would still be unwise to set a date very far into the first century B.C. for its origin.

In view of the structure of the text and its partly hypothetical nature the attempt of Maspero (1926, 350 ff.) followed by Needham (*SCC*, III, 224) to take all the sections together to form a total cosmological theory seems risky. In Needham's words this leads to 'a theory in which the sun at the meridian is five times further away from the earth than at its rising and setting, which would at least involve a very elliptical cover or shell'. (This statement should perhaps be revised to refer to distances from a central observer rather than heights above the earth's surface, for as we have seen the rising and setting sun are apparently taken as level with the earth.) Maspero contrasts this with the *Kai t'ien* situation, in which, of course, the sun is closest to us when on the meridian, and suggests that we are dealing with an alternative school of cosmology. He goes further, and proposes that we have a reference to the disputes between the rival schools in the *Lieh tzu* book (5, 12b, *SPPY*) where there is a story of Confucius confronted by two small boys quarrelling about the relative distance of the rising, setting, and noonday sun. This argument, however, turns on the apparent contradiction of the sun's larger apparent diameter at dawn with its greater heat at noon, and needs no further explanation than that it is yet another Taoist attempt to present Confucius as a ridiculous figure whose 'wisdom' cannot resolve the problem. Although as Needham notes there were actual disputes on this point, the text we have here cannot bear the weight that is placed on it, and for all we know the problem had not occurred to its author who in any case does not seem to have troubled unduly over presenting a clear picture of his views.

Although this early attempt to solve problems of location on the flat earth could not have succeeded I have not so far found any criticism of it in a later writer, nor indeed any reference to it at all. In fact several authors made independent suggestions of their own for finding the centre of the earth. An Eastern Han example of the second century A.D. is found in the comments of the two Chêngs on the *Chou li* (10, 13a f., *Shih san ching chu su*). They are followed in more detail by the T'ang editor (ibid). Around A.D. 490 we find Tsu Kêng-chih 祖暅之 writing at length on the same topic (*Sui shu*, 19, 21a, *SPTK*). It may seem odd that the failure of these proposals was not apparent, especially to Tsu Kêng-chih who was an expert astronomer as his other writing shows. It happens, however, that unlike the *Huai Nan tzu* method, all later procedures automatically lead to the conclusion that the observer is at the centre of the earth. This is exactly the result that would have been expected by an astronomer working at (probably) the capital city of what was in any case 'the Middle Kingdom'.

I have repeatedly stressed the hypothetical nature of parts of the text examined here, and it is this feature that chiefly makes it stand out from its setting in the rest of *Huai Nan tzu*. The dimensions found earlier in chapter iii and in chapter iv are simply given; there is no question of any supporting rationale being provided. Here, however, we have an instance of a hypothesis (the square of sunrises and sunsets) being put forward and its implications worked out in detail. Now as we have seen this hypothesis predicts phenomena which are not those actually observed. This does not in any way detract from the fact that it is a truly scientific hypothesis in that it is vulnerable to testing in a way that other early Chinese thought-schemes were not; the Five Elements theory predicted everything and hence predicted nothing. The unknown author of this fragment deserves great credit for intellectual daring, whatever the long-term results of his endeavour.

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