New Historical Records and Relationships among ^{14}C Production Rates, Abundance and Color of Low Latitude Auroras and Sunspot Abundance

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http://www.clim-past.net/9/1879/2013/cp-9-1879-2013-supplement.zip

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Abstract

Incursions of high-energy particles from space, specifically solar energetic particles and galactic cosmic rays, have significant effects on the Earth, including disruption of the Earth's magnetic field, generation of electric fields strong enough to damage electronic devices as well as the production of auroras at low-latitudes, within 45° of the magnetic equator. We examine the relationships among ^{14}C production, auroral abundance, auroral color and sunspot abundance using existing data supplemented by a new dataset. The new dataset, based on ancient Chinese records from A.D. 1100-1700, includes 46 new or revised records of sunspots and 279 records of low-latitude auroras. Low-latitude auroras are predominantly red (66%, 835 events) with lesser proportions of white (20%, 253 events) and black auroras (6%, 67 events). All other auroral colors (green, yellow, multicolored, blue and purple) aggregate to a total of 100 events (8%). Overall, white auroras are more frequent during times of higher ^{14}C production. We use two empirical methods of evaluating the flux of high-energy particles: modeled peaks and lows in ^{14}C production and peaks and lows in the ^{14}C calibration curve. We find that comparison to modeled ^{14}C production gives significant results. White auroras are significantly more abundant (98% probability) at times of high production of ^{14}C. Red auroras are somewhat more abundant (88% probability) at times of low production of ^{14}C. The abundances of black, multicolored, green, yellow, and blue auroras between times of low and high ^{14}C production are not significantly different. Violet/purple auroras are significantly more abundant (98% probability) at times of low ^{14}C production. The positive correlation of violet/purple auroras with times of **low** ^{14}C production rate and the lack of correlation of blue auroras with times of **high** ^{14}C production is surprising, for this portion of the visible spectrum contains strong emission lines and some lines with high energies of excitation. Observations of emissions in the blue to violet part of the spectrum may be biased towards time periods when the atmosphere is exceptionally clear, as these colors are more difficult for the human eye to perceive.

1. Introduction

Production of ^{14}C and ^{10}Be in the Earth's atmosphere is governed by the flux of high-energy particles into the atmosphere. Recent data from tree rings shows spikes in ^{14}C production of a factor of ~20 during the 8th century (Miyake et al 2012) and a factor of ~12 during the 10th century (Miyake et al 2013). Observations of low-latitude auroras described in Chinese records might teach us more about these events, because high-energy particles can also produce auroras, with low-latitude auroras, those within 45° of the magnetic equator, signaling higher fluxes. (In Europe and Asia the magnetic equator is north of the geographic equator so geographic latitudes are higher than magnetic latitudes.) In addition, we examine the distribution of colors of low-latitude auroras and attempt to evaluate how auroral colors vary as a function of their relative energy.

2. Background

High-energy particles come from both solar and extra-solar sources, with the former being referred to as “solar energetic particles” and the latter as “galactic cosmic rays” (or sometimes, just as “cosmic rays”) (Hambaryan & Neuhäuser 2013, Pavlov et al 2013, Pavlov et al 2014, Usoskin et al 2013). They consist mostly of protons and alpha particles and have a flux that falls off strongly with energy (Hörandel 2005). They strongly interact with the Earth’s magnetosphere, causing ionization and excitation of atmospheric gases and auroral emissions through incompletely understood mechanisms. Secondary neutrons produced by the collision of high-energy particles with atmospheric ^{14}N lead to the production of ^{14}C. The ^{14}C production rate varies temporally. Both variations in the strength of the source of high-energy particles (Mekhaldi et al 2015) and heliomagnetic and geomagnetic modulations of the flux reaching the Earth’s atmosphere have been demonstrated (Beer et al 1988, Muscheler et al 2007).

The 1859 Carrington event, solar in origin, provides a well-documented example of the effects of a large increase in high-energy particle flux. On September 1, 1859, the Sun emitted an unusual white light flare observed by Carrington and Hodgson (Carrington 1860, Hodgson 1860). This was caused by an ejection of plasma from the Sun, a coronal mass ejection. When the flare arrived at the Earth, it disturbed the magnetosphere, the operations of telegraphs and produced worldwide, low latitude auroras (Green & Boardsen 2006, Green et al 2006, Humble 2006). A Carrington-like event today would have widespread deleterious effects given the vulnerability of our electronic civilization (Hapgood 2011, Lang 2009, Melott & Thomas 2012).

Sunspots are dark spots on the surface of the Sun that correspond to regions of lower surface temperatures. They are produced by high concentrations of magnetic flux lines that inhibit the convective transfer of heat from the Sun's interior to its surface. Their frequency of occurrence is a proxy for solar activity (Hoyt & Schatten 1988), which in turn is a proxy for the flux of solar energetic particles.

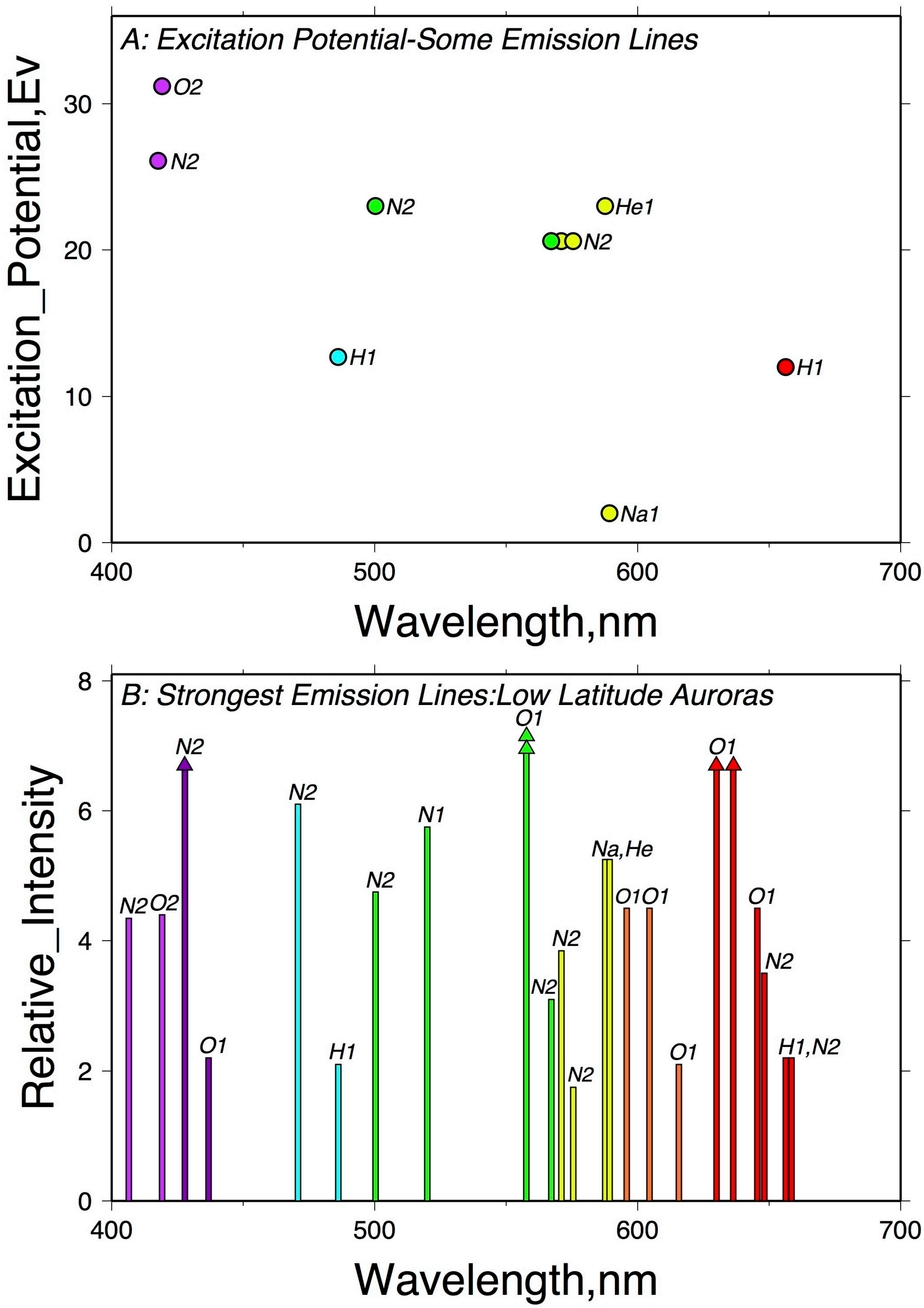
2. 1 High-energy Particle Events During the Common Era

Recent work on high-energy particle events has defined three high-flux events in the 700-1500 A.D. time interval: the first in A.D. 774-775 (Jull et al 2014, Miyake et al 2012), the second in A.D. 993-994 (Miyake et al., 2013), and the third in A.D. 1460-1462 (Usoskin & Kovaltsov 2012). All three are generally considered to have been larger than the A.D. 1859 Carrington event (Usoskin and Kovaltsov, 2012; Miyake et al., 2013). However, there are many models of their size that disagree substantially (Miroshnichenko & Nymmik 2014). What has not been appreciated until recently is that sizes of disturbances in the flux of high-energy particles can be additive (Melott & Thomas 2012); that is, two large closely spaced events would have an effect similar to that of a single event that was twice as large as the mean of two smaller events. Stephenson (2015) assesses whether ancient European and East Asian records of auroras during 774-775 A.D. and A.D. 993-994 can distinguish the number of events, but finds them inadequate for this task. In this paper, we investigate whether or not auroral colors are correlated with the flux of the specific high-energy particles. There are at most seven auroras during the three high-energy particle events, so we use the modeled production of

^{14}C in the Earth's atmosphere (Usoskin & Kromer 2005) as a proxy for the flux of ionizing, high-energy particles.

2.2 Physics of Color of Auroras and Excitation of Atmospheric Gases

Auroras are generated in the ionosphere by the excitation of specific atmospheric gas species by energetic charged particles. As the gas transitions to its normal, unexcited state, it emits energy, some in the form of visible light. Auroras have a characteristic suite of emission lines in the visible spectrum. Each emission line is associated with a transition in a specific gas species. The emission line's color reflects the energy of the transition (Figure 1B) and its intensity depends on the flux of the exciting particles and on the excitation potential of the gas species (Figure 1A). Many visible-light auroral emissions are due to trace gasses that require different excitation energies than major components of the atmosphere, so that some important auroral emissions do not originate with the gases N_2 and O_2 that compose 99% of the bulk atmosphere. Atmospheric composition varies both with elevation and time. Thus, the mix of emission lines changes, depending on the mixture of gases that are being excited, the relative intensities of excitation and the depth range of the excitation within the ionosphere. The perceived color of an aurora is determined by the response of the human visual system to the mix of emission lines. Perceived color closely reflects wavelength for monochromatic emissions, but diverges in cases where several emission lines of different wavelength but similar intensity are present (Gegenfurtner & Sharpe 1999). Color perception is most variable at the shorter wavelengths; different observers may describe the same wavelength as blue, violet or purple.


A: Excitation Potential-Some Emission Lines
Excitation_Potential,Ev
O2
N2
N2
He1
N2
H1
H1
Na1
0
10
20
30
400
500
600
700
Wavelength,nm
B: Strongest Emission Lines:Low Latitude Auroras
Relative_Intensity
N2
O2
N2
O1
N2
H1
N2
N1
O1
N2
N2
N2
Na,He
O1
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600
700
Wavelength,nm

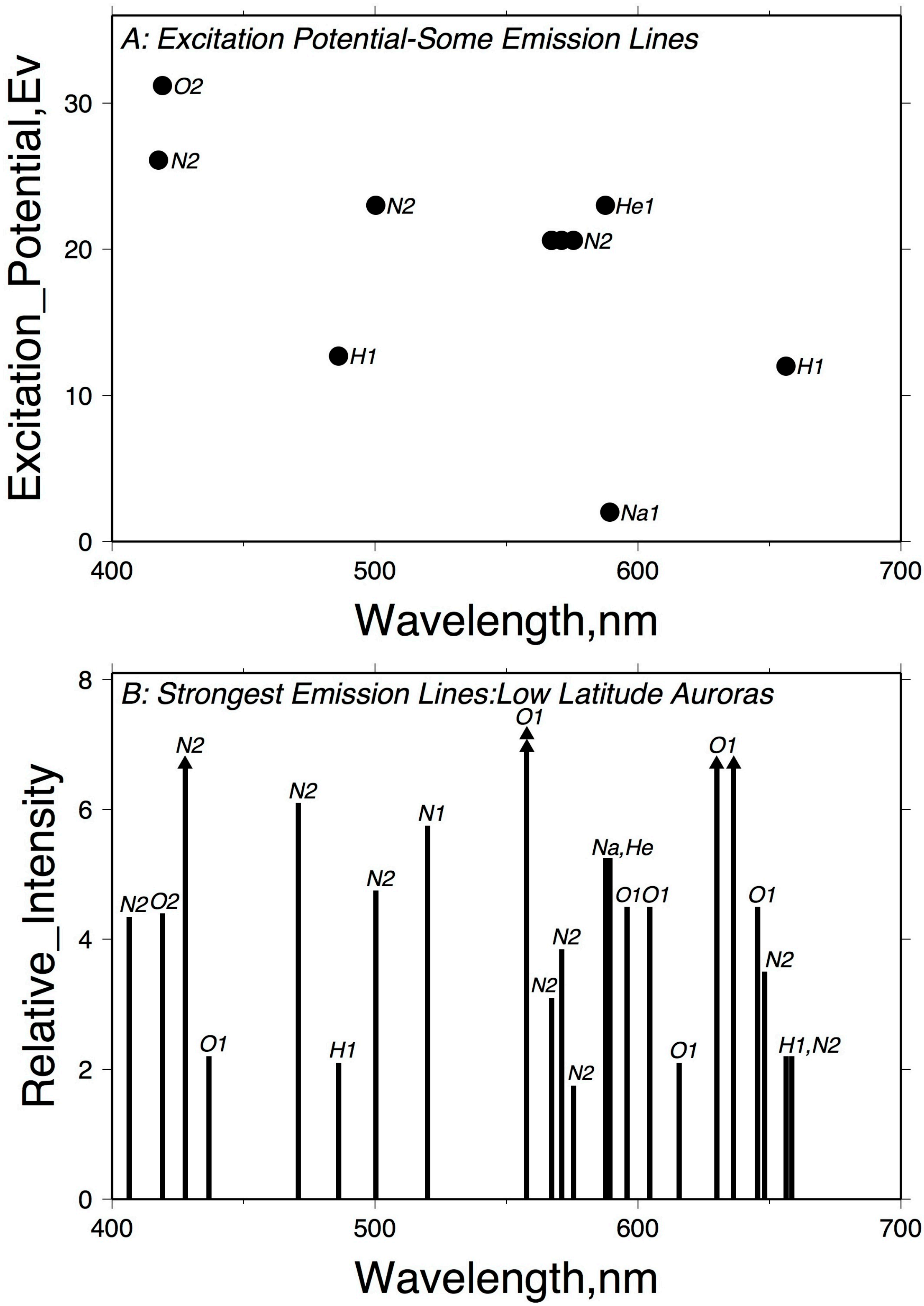

A: Excitation Potential-Some Emission Lines
Excitation_Potential,Ev
0
10
20
30
O2
N2
N2
He1
N2
H1
H1
Na1
400
500
600
700
Wavelength,nm
B: Strongest Emission Lines:Low Latitude Auroras
Relative_Intensity
0
2
4
6
8
N2
O2
N2
O1
N2
H1
N2
N1
O1
N2
N2
N2
Na,He
O1
O1
O1
O1
O1
N2
H1,N2
400
500
600
700
Wavelength,nm

Figure 1. A: Circles: Excitation energy needed to produce emission of visible light from common atmospheric gases after (Jones 1971). Around 575 nm, nitrogen has three emission lines with similar excitation energies. Some gases producing auroral colors emit energy during "forbidden transitions", and they lack calibrated excitation energies.
B: Typical intensities of emission lines from low latitude auroras within the visible spectrum of 400-700 nm, after (Yashchenko 1968). Colors from left to right: violet, purple, light blue/aqua, green, orange and red. Darker blue emission lines are not present. (B & W: Perceived color (for monochromatic light) is correlated to wavelength in nm as follows: 400-420 nm (light purple/violet), 420-450 nm (dark purple), 450-465 nm (blue), 465-500 nm (light blue/aqua), 500-570 nm (green), 570-590 nm (yellow), 590-620 nm (orange), 620-700 nm (red).) Gases are He_1, H_1, O_1, N_2, O_2, N_1 and Na. Arrow: emission line whose relative intensity (peak height) reaches above the maximum scale on the plot. Double headed arrow: the most intense emission line, the green line of O_1.

Auroral emissions are dominated by monatomic nitrogen (N_1), molecular nitrogen (N_2) and molecular oxygen (O_2) at altitudes of 90-150 km. From altitudes of 150 to ~900 km, the most important gas is monatomic oxygen (O_1). Above ~900 km, the most important gases are helium (He) and monatomic hydrogen (H_1) (Russell 2005b).

We are most interested in how colors reflect the relative strength of auroral excitation. The O_1 lines at 557.5 nm (green), 630 nm (red) and 636.4 nm (red) and the N_2 line at 427.8 nm (purple) are the most intense lines in typical low-latitude auroras (Yashchenko 1968) (Figure 1B). Spectral studies show that secondary electrons exciting oxygen are the main source of the green color of auroras (Russell 1995). Because the green O_1 line at 557.5 nm has the highest relative intensity, green auroras at high latitudes

(latitudes more than 45° from the magnetic equator) may represent the weakest levels of excitation by high-energy particles. The two most intense emission lines in the red part of the spectrum around 630 nm are produced mainly but not exclusively by ionized oxygen (O_1). Red colors also can be produced by weaker emissions from oxygen, nitrogen and hydrogen (Figure 1B). The red emissions from ionized hydrogen above ~900 km are of particular interest for low latitude auroras as the upper part of the high latitude ionosphere might be visible at low latitudes. Nitrogen has a dark purple emission peak around 420 nm that appears to be as intense as the two red emission lines associated with oxygen around 630 nm (Figure 1). Nitrogen also has a weaker light blue emission peak around 400 nm. Despite the intense dark purple emission peak from nitrogen, blue/violet/purple auroras are rare at high latitudes (> 45° from the magnetic equator) compared to green and red auroras. One possible reason is that molecular nitrogen (N_2) is the dominant gas lower in the ionosphere (90 to 150 km altitude) whereas excited oxygen (O_1) dominates at higher altitudes (150 to 900 km). Thus, higher fluxes or more energetic fluxes of particles may be necessary to excite the molecular nitrogen in the lower ionosphere.

The observation that some high latitude auroras are red at the top, green in the middle and deep red to violet on the bottom is consistent with the idea that some blue/purple/violet colors in auroras come from excitation of N_2 low in the ionosphere. Spectral measurements of blue auroras in the laboratory and in the field have confirmed this hypothesis (Holma et al 2006). They have also confirmed that higher energies are necessary to excite blue auroras than red and green auroras.

Some historical observations also imply that violet/purple or blue low-latitude auroras represent higher energies (Botley 1972). The 1872 auroral event is thought to have been comparable in intensity to or even larger than the Carrington event in 1859 (Silverman 2008). Silverman documented the colors of auroras during the 1872 event. Most were red but some low-latitude auroras were other colors. In Bombay, India, the aurora changed in color over time and become deep violet when it was most intense. At the Cape of Good Hope, South Africa, the aurora was blue.

2.3 Complications in Inferring Relative Auroral Strength

The physics of the excitations that produce colors in auroras are not straightforward. The relative intensity of different wavelengths of emission in low latitude auroras is based on empirical observations (Yashchenko 1968) (Figure 1B) rather than laboratory measurements. Natural cycles in the abundance of common ions also affect auroral colors. For example, although ionized Na is only a minor component of the lower ionosphere and is most concentrated from 85 to 95 km altitude, it emits strongly in the yellow part of the spectrum (Figure 1B). The relative intensities of emissions from ionized Na have seasonal cycles, with maximum intensities in April through May and October through November (Smith & Steiger 1968). Thus, yellow auroras tend to be most common during these months, reflecting the seasonally highly abundance of ionized Na (Kirchhoff et al 1979, Kirchhoff et al 1981, Swider 1986).

Some auroras appear blue because they are backlit by sunlight (Störmer 1939), which facilitates the perception of the blue color. Because the sensitivity of human color perception is poorest at short wavelengths, blue, purple and violet colored auroras are more difficult to see than red and green auroras of comparable light intensity (Köppen &

Talbot 2007). Sightings of blue to violet auroras might imply an especially intense event or perhaps that the atmosphere is unusually clear.

Human perception of color is affected by the overall brightness (luminosity) of the light, in addition to its spectral content. When light has higher luminosity, a value well above the threshold for visibility, the cones in human eyes saturate and the light is seen as white (Shevell 2003). Thus, the most luminous light from auroras will appear either as completely white or as white and colored. Red auroras that are not luminous enough to appear white will appear pink.

Black auroras are dark areas of aurora-like activity within a surrounding aurora (Oguti 1975, Royrvik & Davis 1977). The surrounding aurora can have many colors: white, red, blue, green and yellow (Table 1). When light levels are low, the cones in the eye cannot see color and a dim light source is perceived as black. Black auroras therefore are inferred to emit light having low luminosity. The origins of black auroras are not fully understood, although many hypotheses exist (Kimball & Hallinan 1988, Marklund et al 1997). The most recent hypothesis suggests that black auroras represent disturbance of the Earth's magnetosphere rather than penetration of the lower atmosphere by energetic particles and subsequent excitation of gases there (Archer et al 2011, Gustavsson et al 2008).

Some workers believe that white auroras represent weak fluxes of cosmic rays. This is true in some cases: photographs of faint white auroras reveal that they contain a colored component (Repsher 2013, Taylor 2013). However, as we will show, the overall pattern is more complicated.

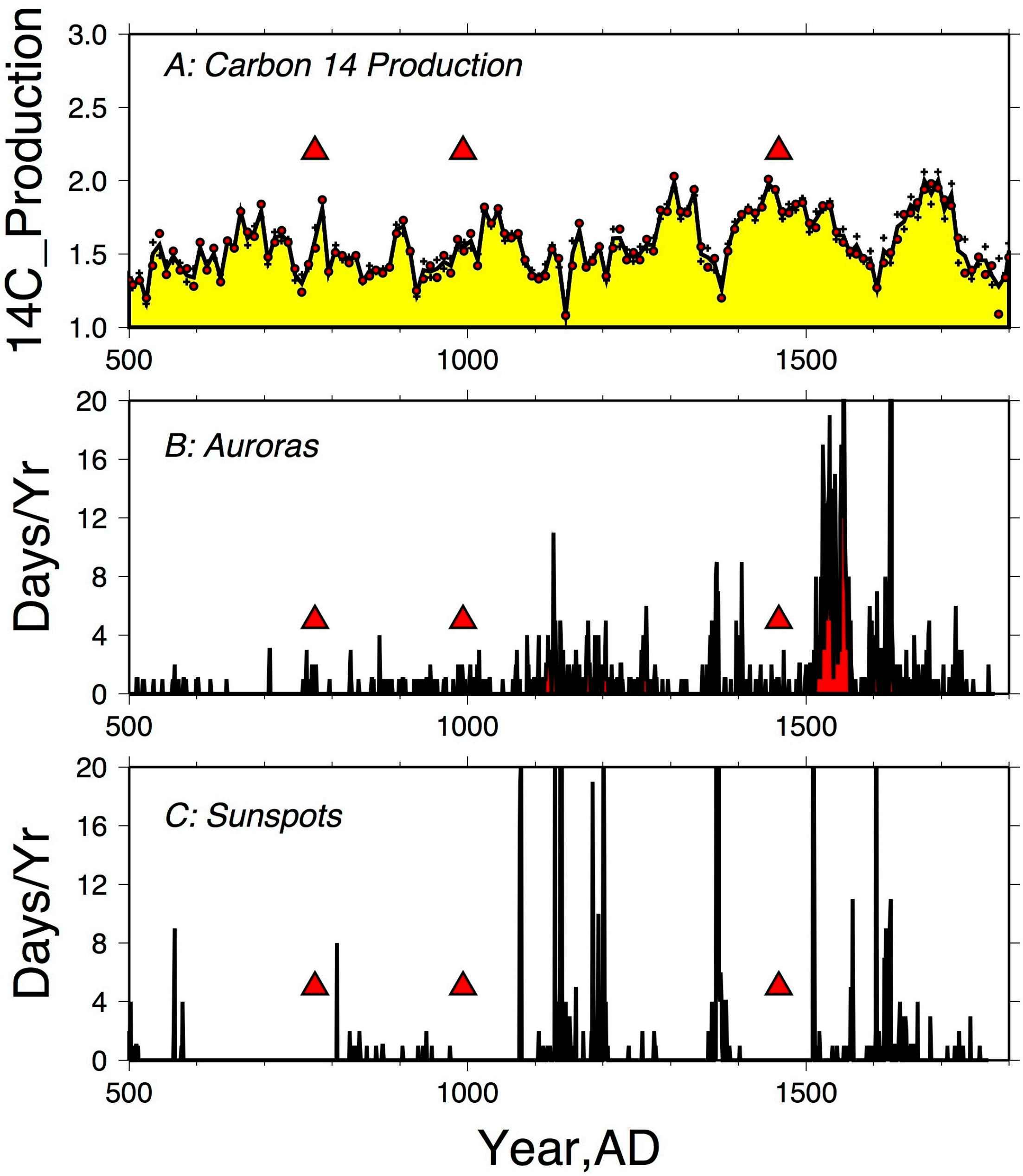
Based on the science of color vision and the physics of emission spectra (Figure 1), we postulate that the most energetic (e.g. luminous) auroras will have a white component. The least energetic auroras may be either green or red. The other colors of auroras: yellow, dark blue, violet, purple and light blue are produced by less intense emission peaks and/or they require higher excitation energies (Figure 1) and are more likely to represent auroral excitation during higher energy events (Russell 2005a). However, observation of some auroral colors may depend on the clarity of the atmosphere, on seasonal cycles or on backlighting by sunlight. Testing these latter hypotheses is beyond the scope of this paper. In this paper, we empirically test the idea that auroral color and relative abundance is a proxy for high-energy particle intensity. Our time series of auroral color and relative abundance is based on a new compilation of low-latitude auroras from ancient sources. We use ^{14}C production rate as a proxy for the flux of high-energy particles.

3. Data Analysis and Compilation: Low-latitude Auroras A.D. 500-1770

Previous compilations of data contained 165 observations of sunspots and 795 observations of auroras between A.D. 500 and 1800 (Yau & Stephenson 1988, Yau et al 1995). In our data compilation, we searched historical records for new data on aurora and sunspots. Most of the new data is from Chinese and Korean sources that were previously unavailable in English (Anonymous 1739, Dajin-Guozhi 1234, Gaozong-Benji 1162, Gaozongji 1162, Goryeosa 1418-1450, Gujin-Tushu-Jicheng 1725, Guoque 1644, Gwanghae 1623, Hyeojong 1031, Hyeongae 1674, Injo 1649, Jeongjong 949, Jinshi-Tianwen 1343, Jungjong 1544, Kanda 1933, Keimatsu 1970, Keimatsu 1971, Keimatsu 1972, Keimatsu 1973, Keimatsu 1974, Keimatsu 1975, Keimatsu 1976, Lee et al 2004, Ming-Taizushilu 1644, Ming-Xizongshilu 1627, Ming-Xuandeshilu 1435, Ming-Xuanzongshilu 1435, Ming-Yingzongshilu 1067, Minghuiyao 1644, Mingshi-Tianwen 1644, Mingtongjian 1644-1911, Myeongjong 1567, Niu 2007, Osaki 1894, Qingshi-Tianwen 1912, Sejo 1468, Sejong 1450, Seonjo 1608, Seonsu 1608, Shenzongshilu 1620, Songshi 1345, Songshi-Gaozong 1162, Songshi-Gaozongji 1162, Songshi-Huizongji 1126, Songshi-Ningzongji 1224, Songshi-Tianwen 1279, Songshi-Tianwen-Wuxing 1343, Songshi-Wuxing 1343, Songshi-Xiaozong-Benji 1189, Sukjong 1105, Taejo 1398, Taejong 1418, Tongzhou-Zhili-Zhouzhi 1871-1908, Wenxiantongkao-Xiangwei 1317, Wittmann & Xu 1987, Wuxing 1418-1450, Xinyuanshi ~1900-1920, Xu-Wenxiantongkao 1317, Xuwenxiantongkao-Xiangwei 1317, Yeonsangun 1506, Zhenjiang-Fuzhi 1674, Zhuyong-Xianzhi 1650(?)). Some data is from English language publications (Basurah 2004, Basurah 2006, Basurah 2010, Hayakawa et al 2015, Johnson 1894, Matsushita 1956, Newton 1972, Schove 1951, Schove & Ho 1959, Silverman 1998, Vaquero & Vázquez 2009, Vyssotsky 1949, Willis & Stephenson 2000, Willis et al 2007, Xu et al 2000), often supplemented by sources in languages other than English. Most of our new data comes from the time period between 1100 and 1700 A.D. We found and translated or amended the translation of 279 observations of auroras and 46 observations of sunspots (Appendixes A, B, Supplemental Tables 1, 2).

We made a continuous time series of the dataset, binning aurora and sunset sightings at one-year intervals (Figure 2). The time series shows three years with an especially intense low-latitude auroral activity (> 20 aurora sightings/yr.): A.D. 1556, 1625 and 1626 (Supplemental Table 3). Ten different years have especially intense sunspot activity (>20 sunspot sightings/yr.): A.D. 1079, 1129, 1137, 1139, 1201, 1368, 1369, 1371, 1511 and 1604 (Supplemental Table 4). The year A.D. 1368 had an extremely active Sun: according to local histories, sunspots were observed frequently during the year and every day during autumn (Yau & Stephenson 1988, Zhuang 1988). None of the above years with the highest sunspot activity overlap with years with the highest number of low-latitude auroras.

Due to the lowered intensity of the solar wind, there is a general pattern of a higher influx of galactic cosmic rays during times of low solar activity. A higher influx of cosmic rays produces more ^{14}C in the Earth's atmosphere. Perhaps because the errors in estimates of ^{14}C production are ±5 years in the period AD 500-1800, Figure 2 shows an apparently weak correlation of auroral activity to peaks in production of ^{14}C. When the estimated temporal errors of the ^{14}C production curve are used to make a time series of the auroral and sunspot records (Figure 3), we can better discern the correlations among solar activity, auroral activity and ^{14}C production in the Earth's atmosphere.



14C_Production
3.0
2.5
2.0
1.5
1.0
A: Carbon 14 Production
500
1000
1500
Days/Yr
20
16
12
8
4
0
B: Auroras
500
1000
1500
Days/Yr
20
16
12
8
4
0
C: Sunspots
500
1000
1500
Year,AD

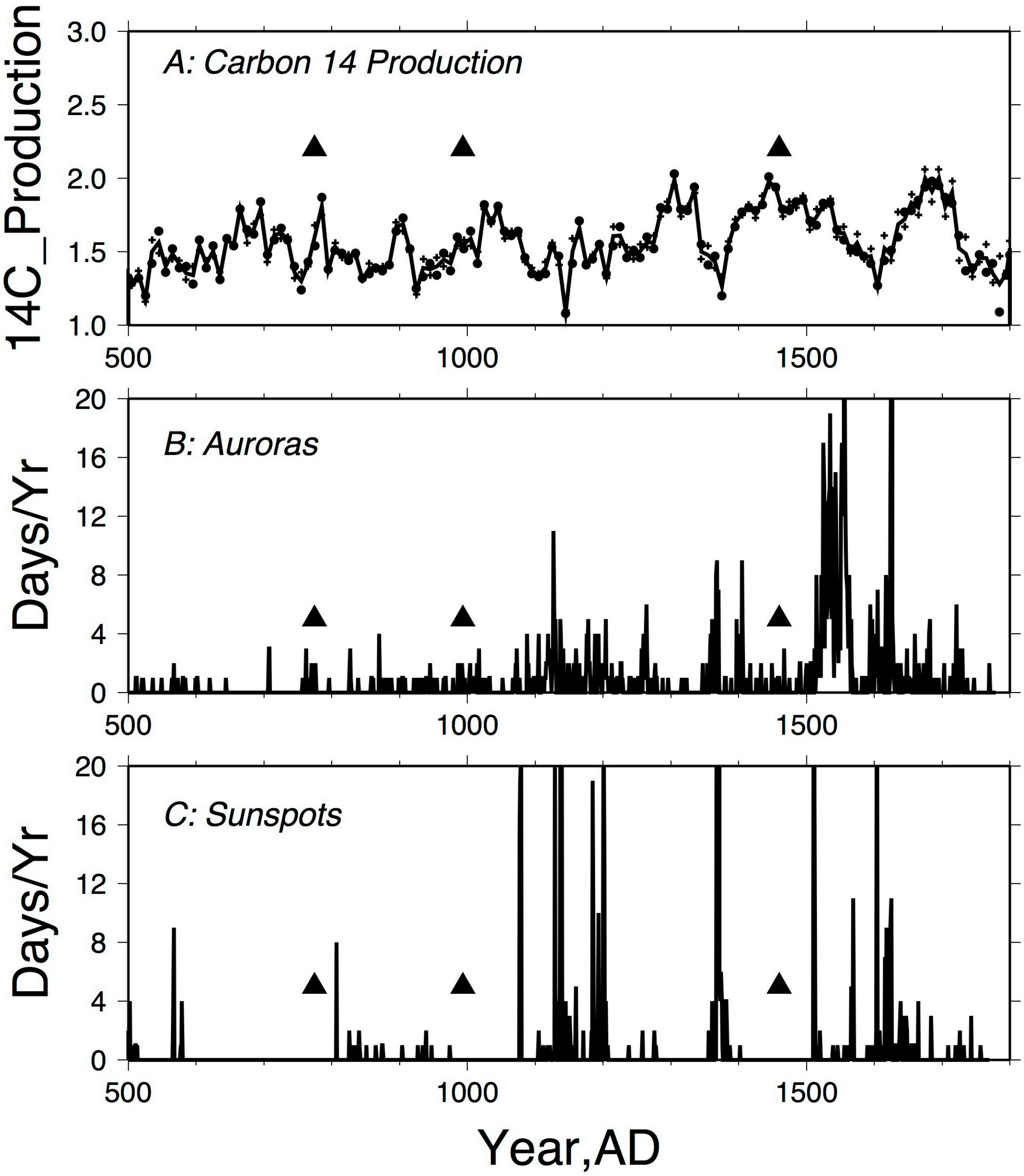


Figure 2. Triangles: high-energy particle events. A: ^{14}C production versus calendar year. Black line: average ^{14}C production (Usoskin & Kromer 2005). ^{14}C production is estimated using two different methods. Dots: results from classic iteration method. Crosses: results from Fourier filter method. B: Number of auroral observations per year

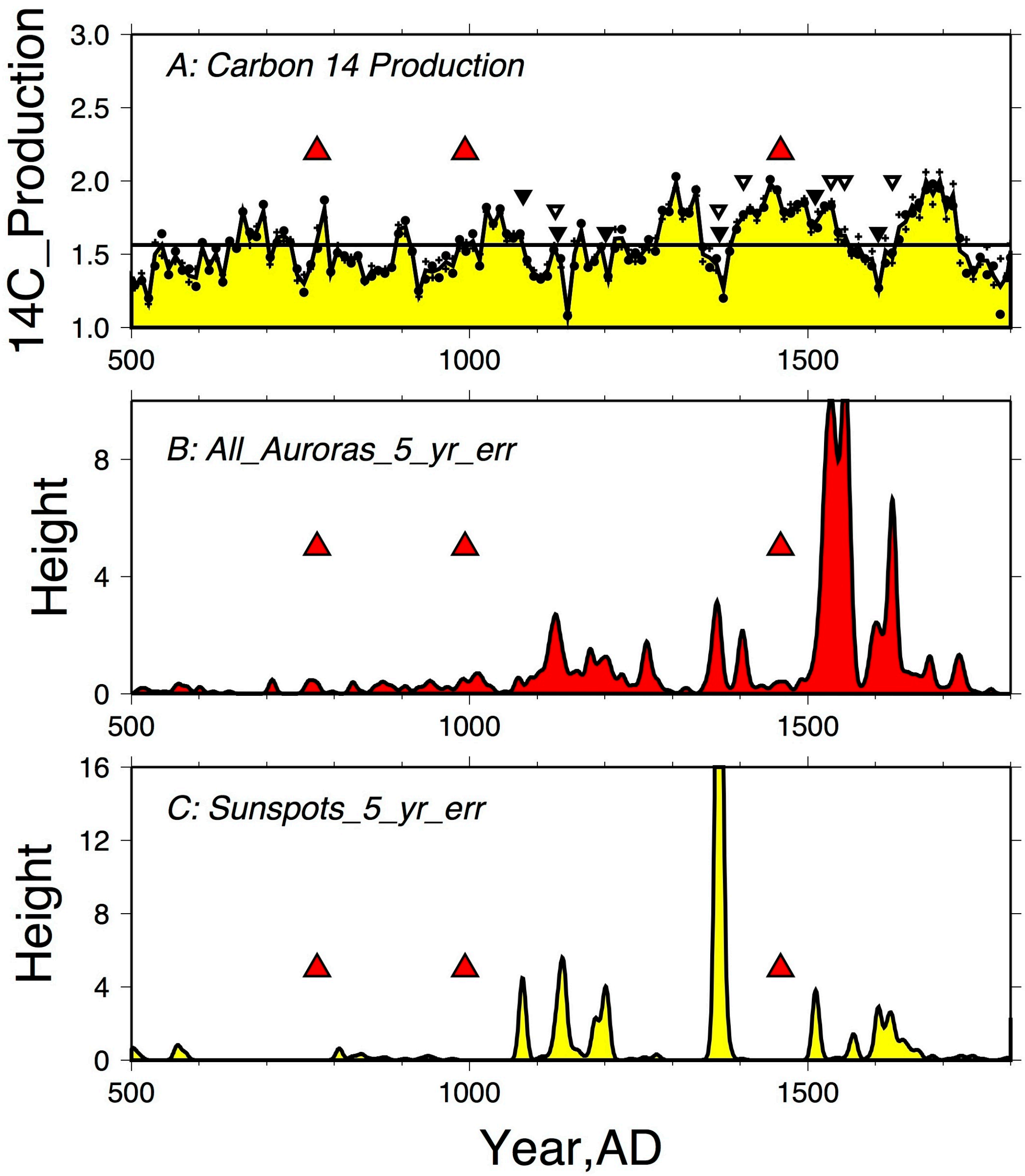
versus calendar year: black line. C: Number of sunspot observations per year versus calendar year: black line. The sunspot and auroral plots have annual resolution.

3.1 Numerical Methods

To adequately compare the auroral and sunspot data to the time series of estimated production of ^{14}C, we process the auroral and sunspot data using the errors in the time series of ±5 years (Usoskin & Kromer 2005). We use a program that adds each observation and its error to form a time series (Abbott & Isley 2002a, Abbott & Isley 2002b, Isley & Abbott 1999, Isley & Abbott 2002). The error is assumed to be Gaussian in form. This makes the time series smoother and allows better determination of relationships among the time series.

The peak height of a single measurement with an error of ±5 years is 0.08. This means that the peak height scales with the number of observations in a given year but is lower than the total number of observations just as a Gaussian curve would be. The time series we generate has one point per calendar year.

We checked maximum peak heights and there is less than 1% variation in peak height with time of year of the astronomical observation. Due to the small variability of peak heights, it is not necessary to adjust the program to generate more than one point per year in the time series.



A: Carbon 14 Production
14C_Production
3.0
2.5
2.0
1.5
1.0
500
1000
1500
B: All_Auroras_5_yr_err
Height
8
4
0
500
1000
1500
C: Sunspots_5_yr_err
Height
16
12
8
4
0
500
1000
1500
Year,AD

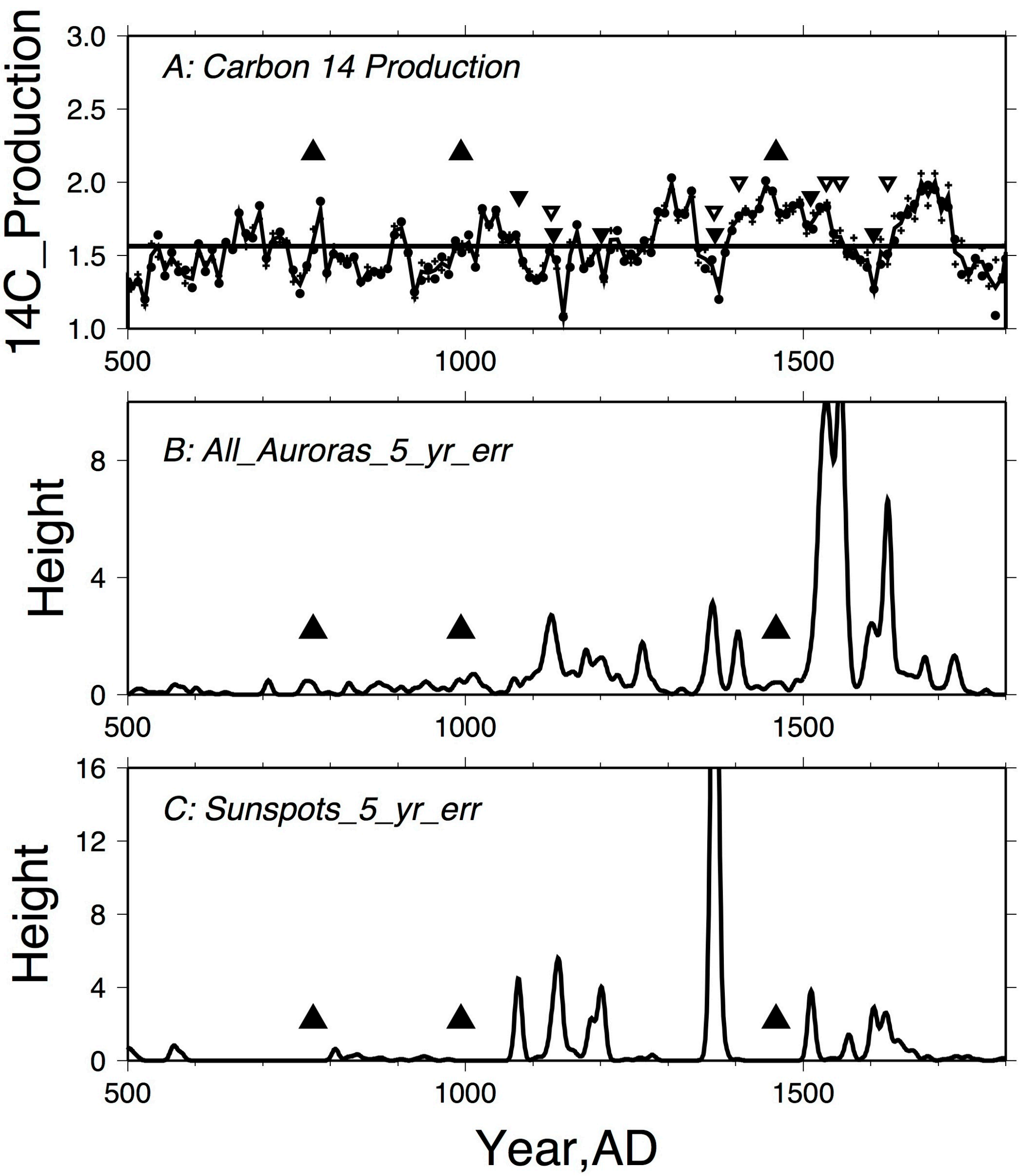


Figure 3. Comparison of time series of sunspots, auroras and ^{14}C production values. A: ^{14}C production. Black line: average ^{14}C production versus calendar year (Usoskin & Kromer 2005). ^{14}C production is modeled using two different methods. Dots: results from classic iteration method. Crosses: results from Fourier filter method. Horizontal black line: average ^{14}C production from A.D. 500 to 1770 (1.562 atoms/cm^2). B: All auroras: black line. C: Sunspots: black line. Triangles: high-energy particle events. Open upside

down triangles: the ten time periods or years with the maximum auroral abundance (>9 auroras per year): 1127, 1368, 1405, 1525-1526, 1528-1529, 1533-1536, 1538-1539, 1542-1544, 1551-1558, 1624-1626. Due to the close temporal spacing of periods of intense auroral activity in the 16th century, they plot as 6 events. Black upside down triangles: the nine time periods or years with maximum sunspot abundance (>22 days per year with sunspot observations): 1079, 1129, 1137, 1139, 1201, 1368-1369, 1371, 1511, 1604. Due to close spacing of years in the 12th and 14th century, they plot as 6 events. A.D. 1368 is the only year present in both of the above lists. Errors in all time series are ±5 years.

All three high-energy particle events (Figure 3) occur during times of no sunspot activity (Chapman et al 2015, Stephenson 2015). These observations fit the classic model where sunspots and ^{14}C production are anti-correlated (Silverman 1992). Of the six periods with the highest sunspot activity four occur at times of below average production of ^{14}C. Four of six periods with the highest yearly numbers of auroral observations occur at times of above average production of ^{14}C. During the two remaining periods with high auroral abundance, the production rate of ^{14}C is average and below. Thus, it appears that periods of high auroral activity correlate more often with periods of high to average ^{14}C production and periods of high sunspot activity correlate more often with periods of low ^{14}C production. The two time periods with high auroral activity and average or below average ^{14}C production are close in time to periods of high sunspot activity, which does not fit the classic model. These latter observations probably require a different model.

There are two favored models describing the relationship between auroras and ^{14}C production. The first suggests that the strength of the solar wind governs the flux of high-energy particles, so that low solar activity permits a greater flux of galactic cosmic rays and a greater production of ^{14}C in the Earth's atmosphere. The second suggests that increased ^{14}C production has a solar rather than a galactic origin. As we will show, both models may be appropriate, with each individually explaining a subset of the observations.

If the energies of galactic cosmic rays are distributed over a broad range that includes both the energies needed to produce auroras and the energies needed to produce ^{14}C, then increased auroral activity during high-energy particle events should correlate with higher production of ^{14}C. Unfortunately, only seven auroras are associated with the three high-energy particle events. Thus, we must use the entire auroral dataset to determine how ^{14}C production is related to auroral color.

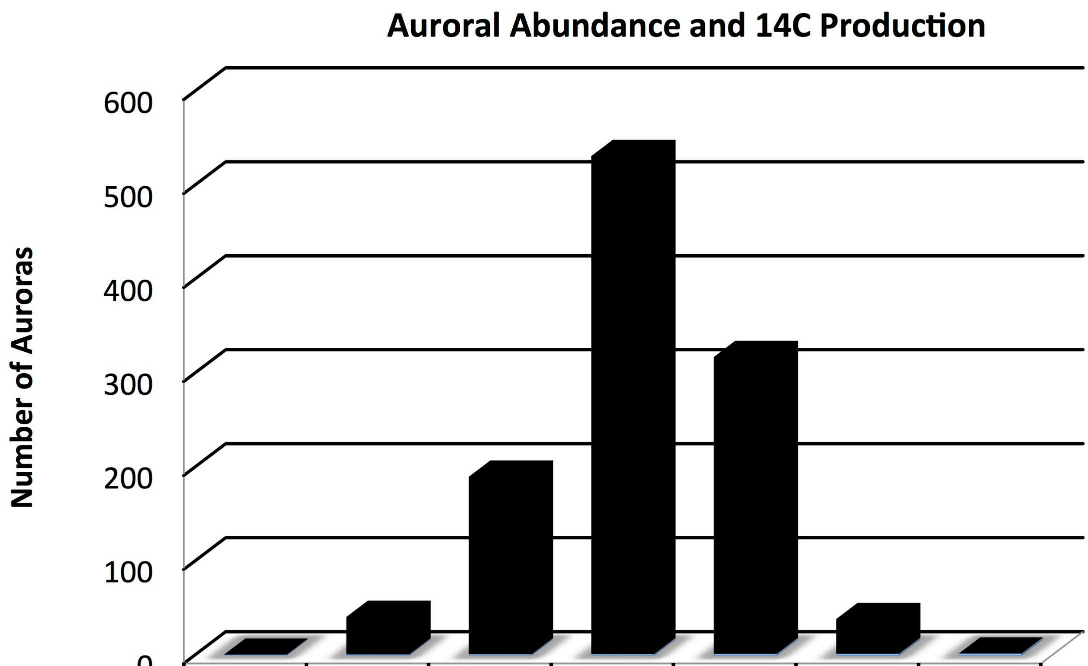
Year	Number of Auroras	Year	^{10}Be: Annual Flux-Atoms (cm^2/sec)
1525	17	1389	0.00576
1526	14	1390	0.00568
1528	10	1398	0.00524
1529	13	1399	0.0051
1533	13	1435	0.0059
1534	14	1457	0.00511
1535	19	1538*	0.00411
1536	12	1547	0.00556
1538*	12	1552*	0.00483
1539	14	1555*	0.00478
1542	11	1568	0.00547
1543	15	1571	0.00628

1551	12	1581	0.00613
1552*	17	1582	0.00548
1553	12	1584	0.00557
1554	13	1603	0.00425
1555*	17	1604	0.00403
1556	30	1615	0.00615
1557	13	1619	0.00569
1558	10	1627	0.00427
1624	13	1629	0.00617
1625	23	1633	0.00423
1626	31	1649	0.00483
		1650	0.00628
		1655	0.00486
		1661	0.00462
		1739	0.00397
		1743	0.00629
		1744	0.00419
		1752	0.00278
		1767	0.00466
		1776	0.00478

Table 1. Comparison of Years of High Auroral Frequency and Low ^{10}Be Values. Left columns: Years with ≥ 10 auroral observations. Right columns: Years of ^{10}Be lows. Stars: Years appearing in both data sets.

In the past 600 years, the well-dated NGRIP ice core records three years of unusually low Be^{10} production, with an annual flux< 0.0063 cm^2/s: A.D. 1538, 1552, 1555 (Berggren et al 2009). Between 1400 and 1700 A.D., there were >10 auroral observations per year in the same three years (Table 1). During those three years, modeled ^{14}C production is above average (Figure 3). However, the numbers of years that are not matched is much larger, even when errors of up to 2 years in the Be^{10} chronology are considered. The fact that some times of high auroral abundance correlate to times during which there is little generation of Be^{10} is consistent with the idea that not all auroras reflect equal levels of excitement of high energy particles. (Because the ^{14}C production is a 10-year average, there is not necessarily a one-to-one correspondence between decades with high ^{14}C production and single years with low Be^{10} production.) Furthermore, the generation of auroras also is related to variations in the magnetic field of the Earth. These anomalies and inconsistencies should be investigated in future work.

We look next at the basic patterns of auroral abundance, auroral color and ^{14}C production and ^{14}C peaks (see the complete data in Appendix A). First, we look to see if all auroras, regardless of their color are actually more common during times of higher generation of ^{14}C. We bin the data at intervals of the standard deviation of the mean ^{14}C production derived by averaging Q_i (^{14}C production estimated using an iterative method) and Q_f (^{14}C production estimated using the Fourier filter method) (Usoskin & Kromer 2005) for the period from 500 A.D. to 1800 A.D. The mean ^{14}C production is 1.562 atoms/cm^2-s and the standard deviation is 0.193 atoms/cm^2-s.



	1	2	3	4	5	6	7
Auroras,#	0	40	189	530	316	37	0
14C Production	0.983	1.176	1.369	1.562	1.755	1.948	2.141

Figure 4. Total number of auroras versus ^{14}C production. Data on ^{14}C production taken from (Usoskin & Kromer 2005). The bins widths are one standard deviation (0.193 atoms/cm^2-s) of the mean ^{14}C production of 1.562 atoms/cm^2-s. Each bin is centered about the value in the bottom row.

Figure 4 shows that there are approximately 50% more auroras (343) at times of above average ^{14}C production (one or more standard deviations above the mean) than at times of below average ^{14}C production (one or more standard deviations below the mean) (n=229). Periods of below average ^{14}C production occur during more years (460) than periods of above average ^{14}C production (n=390) (Figure 3). If the auroral totals are normalized by the number of years they cover, the ratio increases from 1: 1.5 to 1:1.8. We conclude that higher auroral abundance is correlated with higher ^{14}C production, although not necessarily in a simple way.

In the following section, we look at the color distribution of auroras and ask if the colors of auroras are related to the flux of the energetic cosmic rays that produce ^{14}C in the Earth's atmosphere. We use all low-latitude auroras with color information in our synthesis. If the aurora is reported as having more than one color, each color is included as a separate data point. Because some auroras were recorded on the same day at different locations, we removed duplicate descriptions of the same event while retaining the information on auroral color.

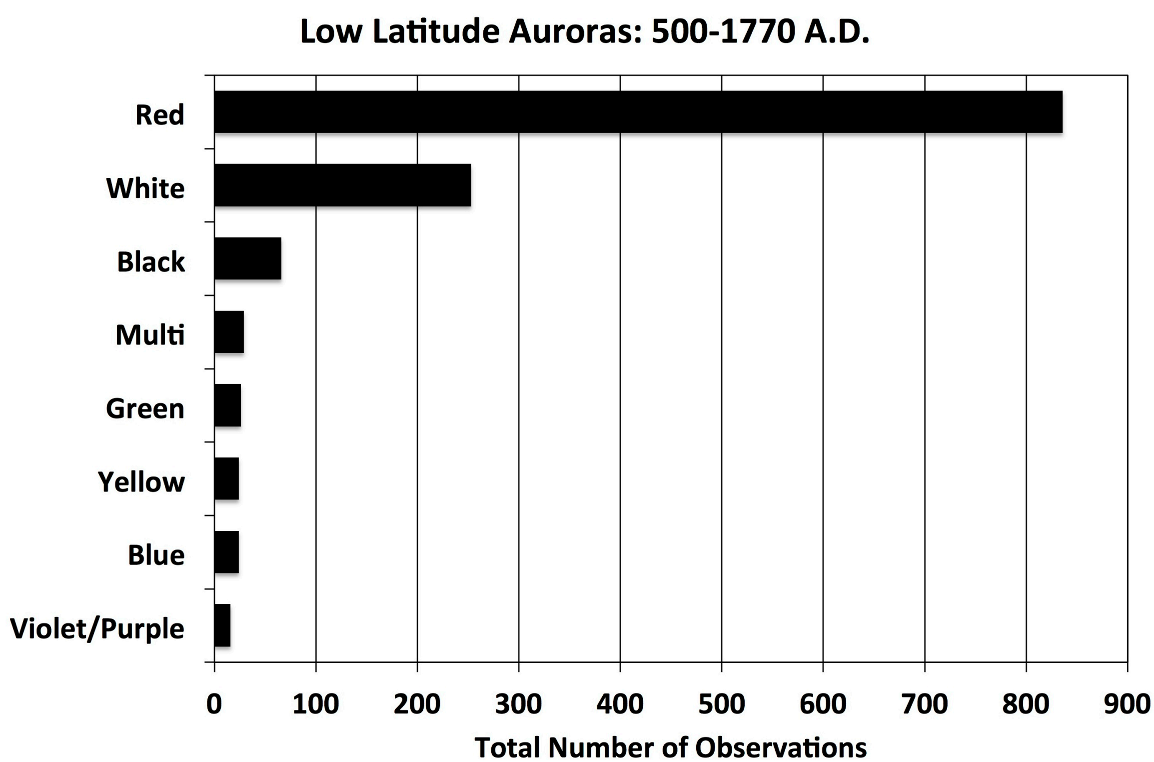


Figure 5. Histogram of color distribution of low-latitude auroras: AD 500-1770.

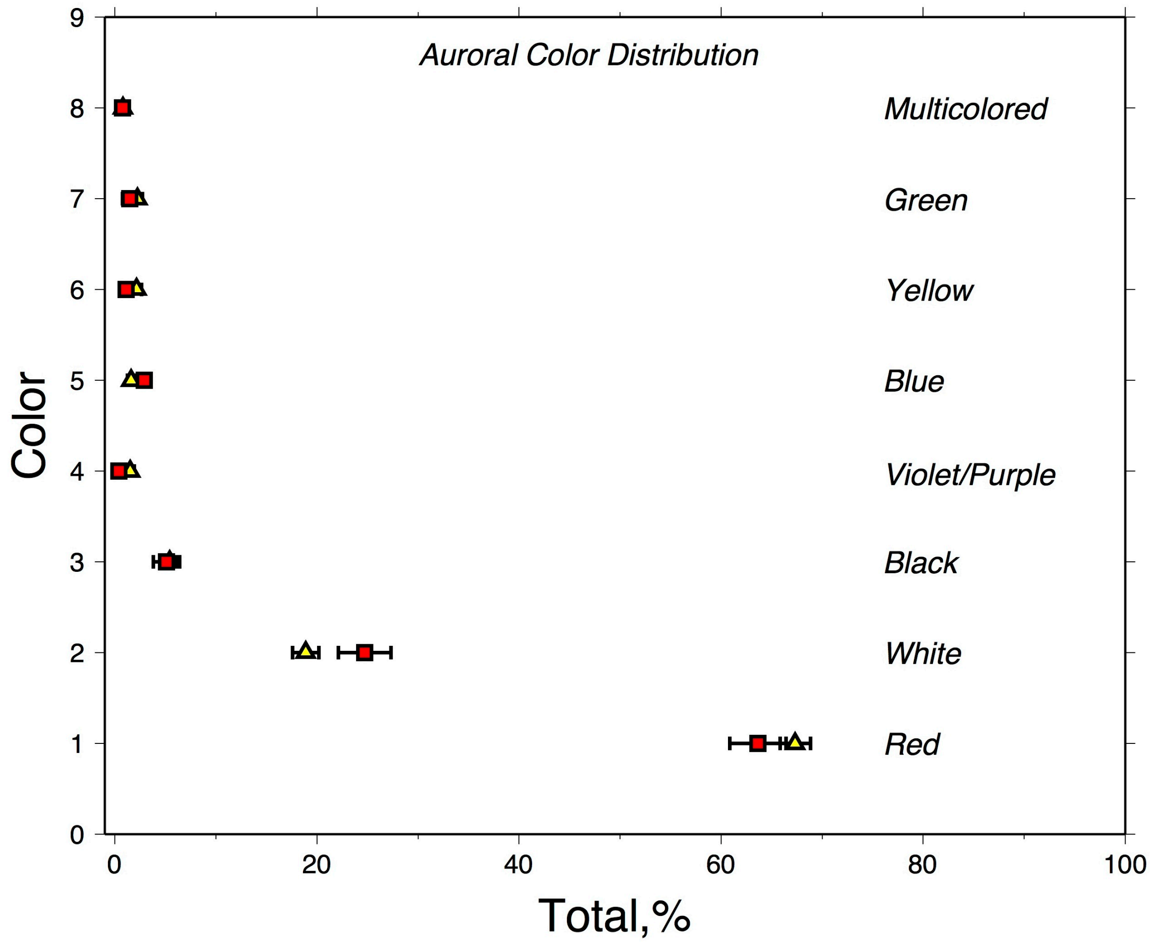
Color	Total Number	% Total
Violet/Purple	17	1.3
Blue	24	1.9
Yellow	24	1.9
Green	26	2.0

Multi	10	0.5
Black	67	5.3
White	253	19.8
Red	835	65.5
Total	1276	100

Table 2. Distribution of Colors of Low Latitude Auroras, A.D. 500-1700

The most common colors of low-latitude auroras are red, black and white (Figure 5, Table 2). Multicolored, green, yellow, blue and violet/purple auroras are the least common. If color is directly related to abundance with the strongest auroras being the least common, then multicolored, yellow, green, blue and violet/purple auroras should represent the strongest fluxes of cosmic rays. We use the record of auroras at times of low and high ^{14}C production and also at peaks in the ^{14}C calibration curve to test this hypothesis.

4. Results



Auroral Color Distribution
Multicolored
Green
Yellow
Blue
Violet/Purple
Black
White
Red
Color
Total,%
0
1
2
3
4
5
6
7
8
9
0
20
40
60
80
100

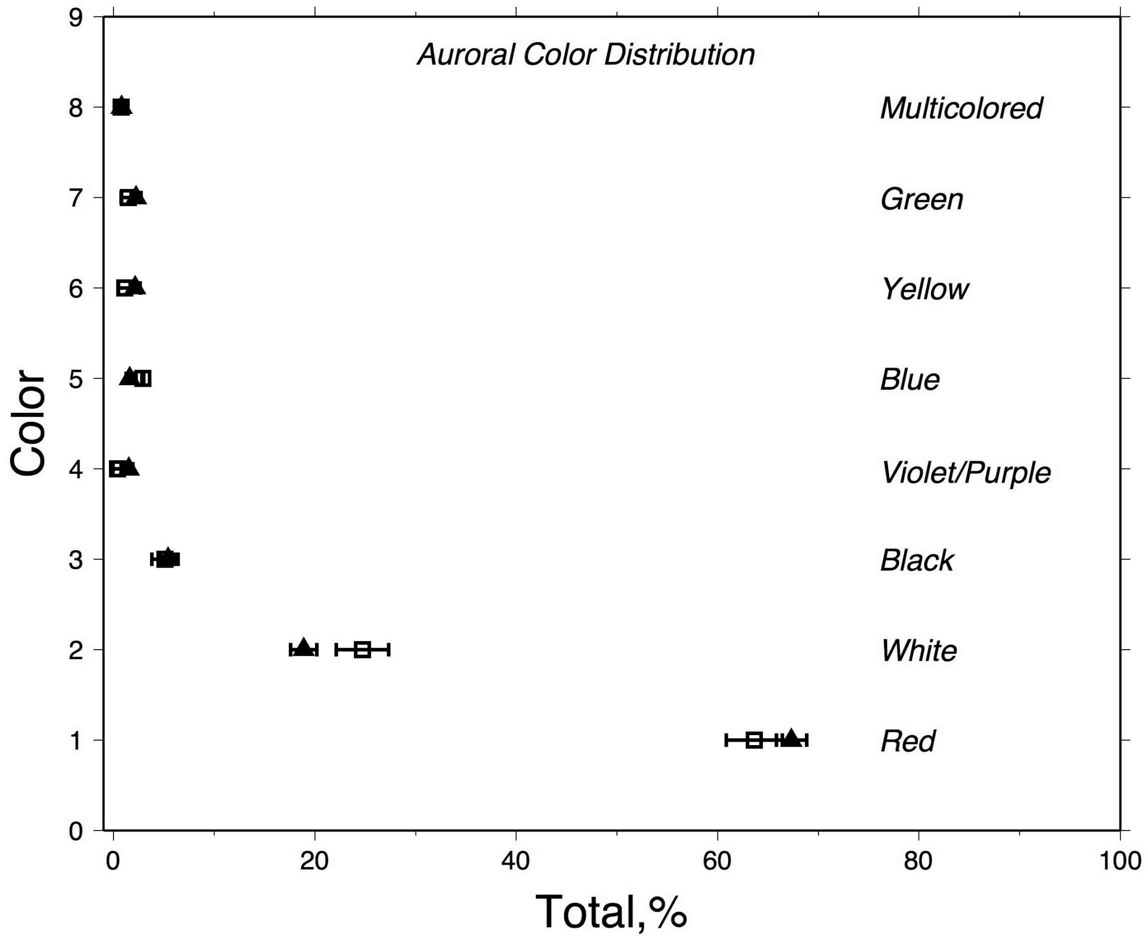


Figure 6. Percentage distribution of different colors of auroras during 10-year intervals with high ^{14}C production: squares and low ^{14}C production: triangles. Error bars represent the area between the 2nd and 98th percentiles of the probability distribution.

Auroral Color	Total Number	% of Auroras during High ^{14}C Production	Total Number	% of Auroras during Lower ^{14}C Production	Pval, %
Red	175	63.6±2.8	660	67.3±1.5	87.5
White	68	24.7±2.6	185	18.9±1.3	**98.1**
Black	14	5.1±1.3	53	5.4±0.7	59.2

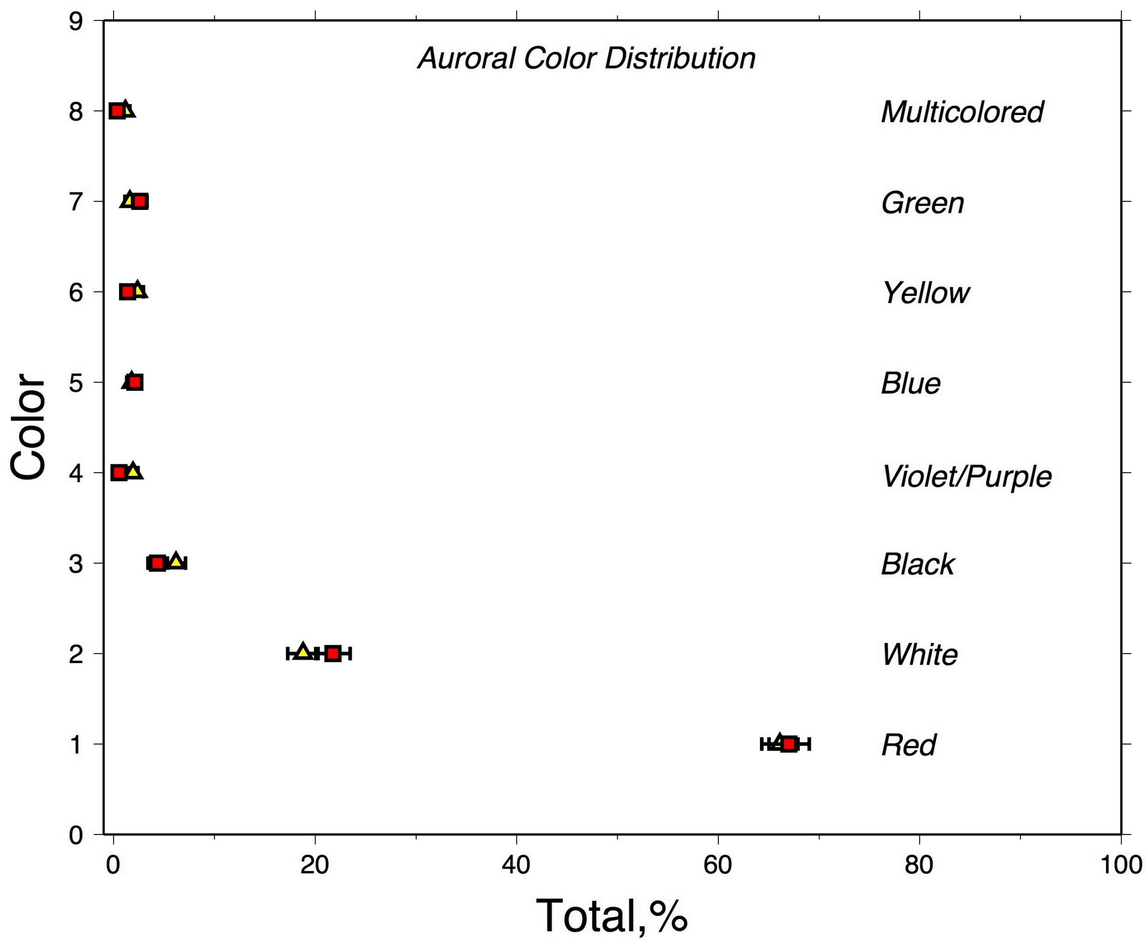
Violet/Purple	1	0.4±0.4	15	1.5±0.4	**97.9**
Blue	8	2.9±0.1	16	1.6±0.4	88.1
Yellow	3	1.1±0.6	21	2.1±0.5	90.8
Green	4	1.5±0.7	22	2.2±0.5	82.6
Multicolored	2	0.7±0.5	8	0.8±0.5	57.6
Sum	275	100	980	100	-

Table 3. Percentage of auroras with a given color during times of higher and lower ^{14}C production, with the probability value (pval) that the larger percentage is significantly larger than the smaller percentage. Pvals that approach or exceed 98% are highlighted in bold.

4.1 Auroral Abundance and Variations in ^{14}C Production

A comparison of the relative abundances of auroras at times of high ^{14}C production (production more than one standard deviation above the mean) and at times of lower ^{14}C production (all remaining data) shows mostly insignificant differences (Figure 6, Table 3). Estimates of the percentage of auroras of a given color occurring during times of either high or low C^{14} production were made from the counts of auroras in each category. Confidence limits were computed via a bootstrapping technique as discussed in Section 12.8 of (Menke & Menke 2016). The dataset is randomly resampled (with duplications) 10^4 times, with percentages computed for each resampled dataset, and ensemble statistics calculated for the resulting distribution of values. This technique also provides an assessment of the probability value (pval) that the percentage assessed for intervals of higher ^{14}C production is significantly higher or lower than the percentage for intervals of lower ^{14}C production. To 98% confidence, white auroras occur more often during times of high C^{14} production than low C^{14} production, while violet/purple auroras have a significantly lower percentage during times of high ^{14}C production. Less significant differences (pval>85%) were observed for red, blue and yellow auroras.

As a check on our results and methodology, we also compare auroral abundances at peaks in the ^{14}C calibration curve to the remaining data. We use the errors in the dates of each peak to select the dates of auroras representing ^{14}C peaks. We note that some peaks are very modest and could represent times of below average ^{14}C production over the time between 500 and 1800 A.D. We include these because more recent data shows that a few peaks in ^{14}C generation were more pronounced than had previously been realized (Jull et al 2014, Miyake et al 2013, Miyake et al 2012).



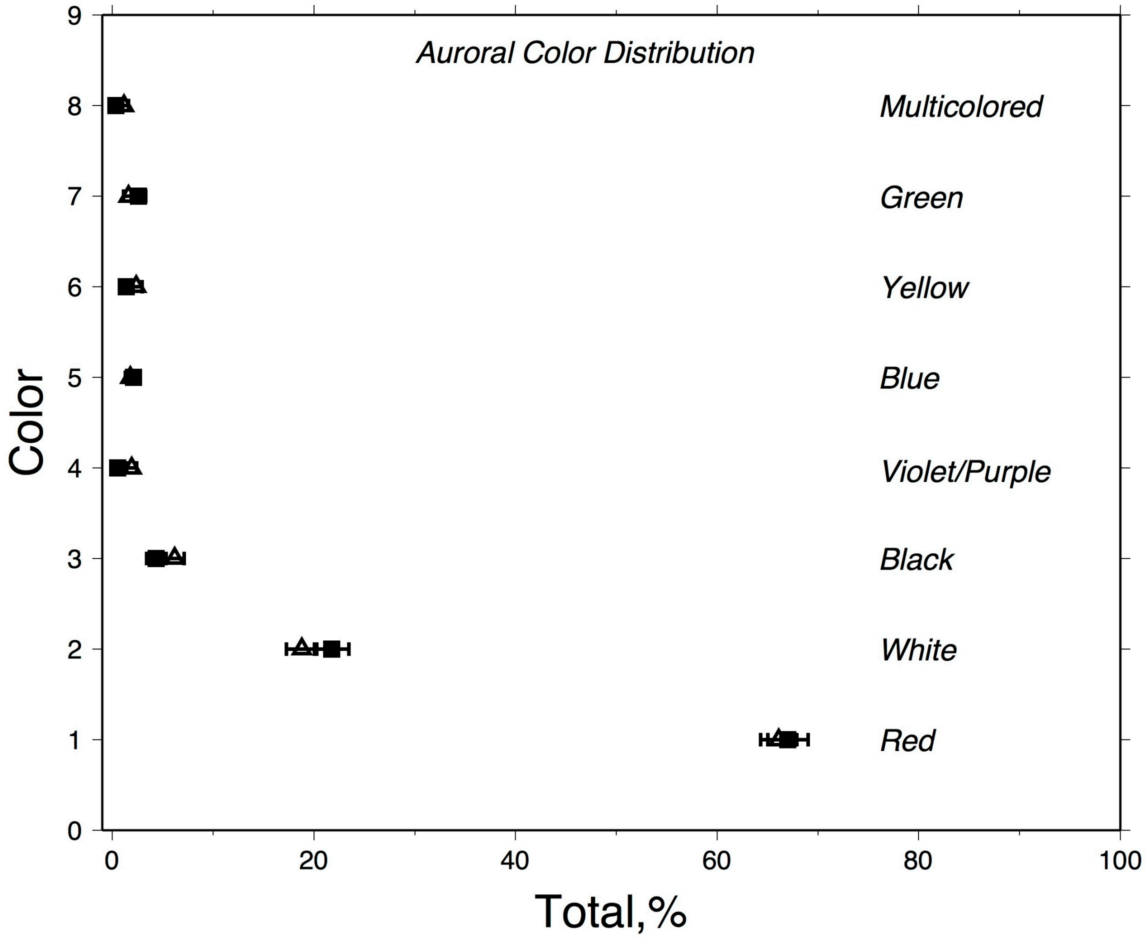


Figure 7. Percentage distribution of different colors of auroras at peaks in the ^{14}C calibration curve: squares compared to the rest of the dataset: triangles. Error bars represent the area between the 2nd and 98th percentiles of the probability distribution.

Auroral Color	Total Number	Number of Auroras at ^{14}C Peak	% of Auroras at Peak ±Error	Number of Auroras not at ^{14}C Peak	% of Auroras not at Peak ±Error	Pval, %
Red	835	388	67.0±2.0	447	66.1±1.8	63.1
White	253	126	21.8±1.7	127	18.8±1.5	90.3
Black	67	25	4.3±0.9	42	6.2±0.9	93.3

Violet/Purple	16	3	0.5±0.3	13	1.9±0.5	**99.1**
Blue	24	12	2.1±0.6	12	1.8±0.5	64.7
Yellow	24	8	1.4±0.5	16	2.4±0.6	90.3
Green	26	15	2.6±0.7	11	1.6±0.5	88.3
Multicolored/ Rainbow	10	2	0.3±0.2	8	1.2±0.4	**96.4**
Total	1255	579	100	676	100	-

Table 4. Percentage of auroras at peaks in the ^{14}C calibration curve compared to the rest of the dataset, with the probability value (pval) that the larger percentage is significantly larger than the smaller percentage. Pvals that exceed 98% are highlighted in bold.

We find that in comparing peaks in the ^{14}C calibration curve to the rest of the data, only multicolored and purple/violet aurora show significant differences with >96% confidence (Figure 7, Table 4). White auroras are more abundant at ^{14}C peaks. Black and purple auroras are more abundant in the rest of the data set. For the most abundant auroras, white auroras and red auroras, the only significant differences occur when times of low and high ^{14}C production are compared. Because some of the ^{14}C peaks are from times when the overall ^{14}C production is very low, comparing times of ^{14}C peaks to the rest of the data mixes times of lower and higher ^{14}C production. Consequently, the significance of the smaller peaks in ^{14}C production is difficult to interpret. Therefore, we discuss further only the comparisons of auroras at times of above average ^{14}C production to times of below average ^{14}C production.

4.2 Discussion

The increased abundance of white auroras at times of higher ^{14}C production fits with our initial postulate that some white auroras result from higher luminosity. Because we are dealing exclusively with low latitude auroras, white auroras produced by lower energy events are less likely to be observed at low latitudes.

The lack of statistical significance (<98% confidence level) for the occurrence of red auroras between times of low and high ^{14}C production (Figure 1) may be because there are so many types of red auroras. Low latitude auroras in the northern hemisphere that appear to come from the northern part of sky are weaker than auroras that appear directly overhead, south, east or west of the observer (Silverman 2006). We include information on Chinese constellations in our database that could allow this subdivision in the future. Because constellations shift their position in the sky over the night and over the course of the year, this is not a trivial exercise. It will involve calculating the position of the constellation at the time of the observation of the aurora. For this reason, we leave this potential application of our database to future investigators.

5. High Energy Particle Events and Auroras

Because this paper focuses on high-energy particle events, we look at the auroras associated with these events to see if there are any indications that these auroras were unusually intense. The A.D. 774/775 high-energy particle event has now been dated using ^{14}C studies of both northern and southern hemisphere tree rings. The event occurred sometime between the start of September 774 and the end of September 775 (Güttler et al 2015). Recent work on corals suggests that the A.D. 775 event consisted of three smaller events during the summer of A.D. 776 (Ding et al 2015), which contradicts the timing inferred by (Güttler et al 2015) from measurements on tree rings. Because we know that tree rings record calendar years and coral dating is less accurate (A.D. 776 ± 14) (Ding et al 2015), the coral data are interpreted as evidence that the A.D. 775 event likely consisted of three smaller events rather than a single large event. There are no recorded Chinese auroras during A.D. 774 or 775 (Stephenson 2015). The A.D. 993/994 event could plausibly have occurred between September 993 and August/September 994. There are no Chinese records of auroras during this time period but there is one European record on Dec. 26, 993. "On the night of the birthday of St. Stephen.light in the manner of the day shone from the north such that many people said that the day was beginning. However, it lasted for a whole hour, and afterwards the sky became somewhat reddened, changing to its usual color…" quoted after sources in (Stephenson 2015). This aurora could have been white initially but it is not clear. "Light in the manner of the day" might mean a reddish color as at dawn or it might mean the more white light of full daylight. Because the aurora appeared to originate from the north, it does not fit the standard criteria for a strong aurora (Silverman 2006). Furthermore, Nienburg, Saxony (now Germany), the location of the chronicler of this event is at a magnetic latitude of ~ 51°N so strictly speaking this was not a low latitude aurora. The third high-energy particle event is dated to circa 1460 A.D. with an error of ±12 years (Reimer et al 2013). The ^{10}Be record shows two peaks of equal height at 1451 and 1458 A.D. (Bard et al 1997), with lower values at 1446 A.D. and 1463 A.D. There are no ^{10}Be measurements in between the cited years. The peak values are the highest ^{10}Be values between 843 A.D. and 1982 A.D. Between 1448 and 1472 A.D.; there were six auroras in China and Korea (Appendix A). The aurora observed in Korea on May 14, 1449 was white but appeared in the northeast. This probably means it was driven by a smaller flux of high-energy particles. The aurora observed in China on November 1, 1449 was black and red and appeared in the southwest, a candidate for a larger event. The auroras observed in China on November 20, 1458 and January 19, 1460 were both red and appeared in the southwest and south respectively, therefore these are also candidates for larger events. The aurora observed in China on January 14, 1459 was red and appeared in the north. The Korean aurora on Sept. 19, 1468 appeared in the southwest and was black. These historical records could mean that higher fluxes of cosmic rays are involved in the production of some red auroras but cannot prove an association. The observations of white auroras and black auroras are difficult to interpret. Overall, until we have a better constrained date for the circa 1460 A.D. high-energy particle event, we cannot say if the historical accounts of auroras support any association of auroral activity and this high-energy particle event.

Some authors have argued that certain types of extrasolar, high-energy particle events would be too brief to produce auroras (Hambaryan & Neuhäuser 2013), but the preponderance of opinion is that the three recent high-energy particle events were solar in origin (Mekhaldi et al 2015, Melott & Thomas 2012, Usoskin et al 2013). In particular, most extra-solar sources of high-energy particles would produce a different amplitude of the ^{14}C signal in the southern and northern hemispheres and this is not observed during the A.D. 774/775 event (Güttler et al 2015). We are left with the option of continuously cloudy nights or an especially weak terrestrial magnetic field to explain the apparent absence of auroras associated with the A.D. 774/775 high-energy particle event. Although paleointensity data has poor resolution (Snowball & Muscheler 2007), some recent models and data suggest a weaker terrestrial magnetic field during A.D. 774/775 (Genevey et al 2008, Korte & Constable 2005, Usoskin 2013). The former option of continuous cloudy nights is difficult to accept as the high-energy particle event is estimated to have lasted at least a month and possibly as long as a year (Güttler et al 2015). The data of Ding et al., 2015 suggest three events: two lasted at least 2 weeks and one lasted about a week. Nevertheless, a weak correlation of a 3 to 4% increase in cloudiness has been found during solar maxima as compared to solar minima (Svensmark & Friis-Christensen 1997). If so, an extremely large, energetic solar event might produce two weeks to a month with continuous cloud cover, precluding astronomical observations. It seems unlikely, but such continuous cloudiness should be searched for in ancient records.

The results for blue and violet/purple auroras are inconsistent with their known physics: that blue and violet/purple auroras are generated by more energetic events, presumably also associated with a higher production of ^{14}C. Because we know that auroras at the blue end of the spectrum are more difficult for the human eye to see, this could mean that observations of blue and violet/purple auroras are biased towards times and locations with greater atmospheric clarity.

6. Future Work

There is a need for a more comprehensive evaluation of the record of auroras and sunspots that occurred between AD 500 and 1100. This time period was not exhaustively covered during our present search. Because ^{14}C production was lower during the 6th through 11th centuries than during the 12th through 18th centuries, it is likely that auroras were less abundant. As our study shows, there likely are untapped historical data in China and Korea, and perhaps as well in Arabic and Roman records. There is also untapped historical data on low latitude auroras in ancient Hawaiian records (W. B. Masse, oral comm.). These data sets need to be incorporated and investigated for improved comparisons of ^{14}C production, auroral color and ^{10}Be generation.

If the colors and intensity of low-latitude auroras can be related directly to the strength of the combination of galactic and solar cosmic ray flux these observations could help to refine ice core, ^{14}C production, and ^{10}Be timescales (Bard et al 1997, Hughen et al 1998, Melott et al 2016, Muscheler et al 2008, Reimer et al 2009, Reimer et al 2013). However, we need a better understanding of the controls on auroral color and strength before this can be implemented. In particular, we need to evaluate whether auroral colors that are particularly difficult to see (blue, purple and violet) were preferentially observed when or where the atmosphere was unusually clear. Because the ancient Chinese and Korean astronomers were selected for their visual acuity, it seems unlikely that the visual acuity of individual astronomers was a significant variable. Because the clarity of the atmosphere is affected both by volcanic aerosols and by the influx of cosmic dust (Abbott et al 2014a, Abbott et al 2014b), auroral observations might form a valuable complement to ancient observations of stars and planets of differing visual magnitudes. By compiling such observations, we can complement ice core records of sulfate deposition after volcanic eruptions, and better date the onset and duration of climatically effective volcanic eruptions.

7. Conclusions

We find that low-latitude white auroras are significantly more abundant during times of high ^{14}C production than during times of low ^{14}C production. We attribute this to higher intensities of spectral emission by ionospheric gases that produce more luminosity, saturating the cones in the eyes and producing white regions within the aurora. Low-latitude red auroras are somewhat more abundant during times of low ^{14}C production. Other auroral color variations also may be related to varying fluxes of high-energy particles but the data are inconclusive. They also might be related to variations in the strength of the Earth's magnetic field or to variations in atmospheric clarity. In order to fully test the relative strengths of auroral excitation by cosmic rays we need models of ^{14}C production, ^{10}Be production and nitrate production that are annually resolved and derived from studies of tree rings and ice cores respectively. We also need to compile data on sightings of planets and stars as an index of atmospheric clarity. Only then can we fully test the extent to which auroral colors vary as a function of the flux of high-energy particles.

Acknowledgements. We thank Lamont Doherty Earth Observatory of Columbia University for access to the literature. We thank Ann Isley and Henry Shaw for editing. We thank P. Shea, A. Melott and unknown reviewers for many helpful suggestions. We thank J. Menke for teaching us to use database software for merging large datasets. We thank W. Menke for bootstrapping error analysis of our results.

Appendix A - Aurora from 1100-1695 AD

Appendix A contains an extensive compilation (Table A4) of low latitude aurora identified from a large number of documents and references. This comprehensive list contains 279 new or revised low latitude aurora.

To understand Table A4, some explanatory material is necessary. Table A1 presents a list of the 28 lunar mansions: the Chinese equivalent of the western zodiac constellations. These mansions more or less follow the ecliptic through the sky.

Table A1. The 28 Lunar Mansions (Xu et al 2000)

No.	Name	Translation	Det. star
1	角 (Jiǎo)	(Dragon's) Horn	2 stars including α Vir
2	亢 (Kàng)	(Dragon's) Neck	4 stars incl. κ Vir
3	氐 (Dǐ)	Root	4 stars incl. α^1 Lib
4	房 (Fáng)	Room/chamber	4 stars incl. π Sco
5	心 (Xīn)	(Dragon's) Heart	3 stars incl. σ Sco
6	尾 (Wěi)	(Dragon's) Tail	9 stars incl. μ Sco
7	箕 (Jī)	Winnowing Basket	4 stars incl. γ Sgr
8	斗 (Nan) Dǒu	(Southern) Dipper	6 stars incl. φ Sgr
9	牛 (Qian) Niú	Ox/cow	6 stars incl. β Cap
10	女 (Wu) or (Xu) Nǚ	Girl/woman	4 stars incl. ε Aqr
11	虛 (Xū)	Emptiness	2 stars incl. β Aqr
12	危 (Wēi)	Rooftop	3 stars incl. α Aqr
13	室 (Ying) Shì	Encampment/room	2 stars incl. α Peg
14	壁 (Dong) Bì	Wall	2 stars incl. γ Peg
15	奎 (Kuí)	Legs/foot	16 stars incl. η And
16	婁 (Lóu)	Bond/hill	3 stars incl. β Ari
17	胃 (Wèi)	Stomach	3 stars incl. 35 Ari
18	昴 (Mǎo)	Pleiades/hairy head/stopping place	7 stars incl. 17 Tau
19	畢 (Bì)	Hunting net	8 stars incl. ε Tau
20	觜 (Zuī)	Turtle Beak/snout	3 stars incl. λ Ori

21	參 (Shēn)	Three Stars/investigator	10 stars incl. ζ Ori
22	(Dong) 井 (Jǐng)	Eastern Well	8 stars incl. μ Gem
23	(Yu) 鬼 (Guǐ)	Ghost/devil	5 stars incl. θ Cnc
24	柳 (Liǔ)	Willow	8 stars incl. δ Hya
25	星 (Xīng)	Seven stars	7 stars incl. α Hya
26	張 (Zhāng)	Extended/stretched Net	6 stars incl. υ^1 Hya
27	翼 (Yì)	Wings	22 stars incl. α Crt
28	軫 (Zhěn)	Carriage	4 stars incl. γ Crv

Table A2 lists the asterisms/stars mentioned in the third column of Table A4.

Table A2. Asterisms/stars (Xu et al 2000):
Beihe (ρ Gem),
Beidou (7 stars incl. α Uma)
Bi (8 stars incl. ε Tau),
Bizuogu Dierxing (θ^2 Tau),
Daling (8 stars incl. 9 Pers),
Dizuo (α UMin),
Dongbi (2 stars incl. γ Peg),
Dongjing (8 stars incl. μ Gem),
Dou (Nandou; 6 stars incl. φ Sgr),
Fang (4 stars incl. π Sco),
Gui (Yugui; 5 stars incl. θ Cnc),
Hegu (3 stars incl. α Aql),
Ji (4 stars incl. γ Sgr),
Jiao (2 stars incl. α Vir),
Jing (Dongjing; 8 stars incl. μ Gem),
Juanshe (7 stars incl. v Per),
Kui (16 stars incl. η And),
Liu (8 stars incl. δ Hya),
Lou (3 stars incl. β Ari),
Mao (Pleiades; 7 stars incl. 17 Tau),
Nandou (6 stars incl. φ Sgr)

Nandoukui (ζ Sgr)
Nanhe (ε Canis Min),
Niuxing (3 stars incl. α, β, and γ Aql
Qixing (7 stars incl. α Hya),
Shen (10 stars incl. ζ Ori),
Shangxiang (β1 & 2 Sco),
Shenliangjian (α & γ Ori),
Shenyoujian (γ Ori),
Shenzuojian (α Ori),
Sheti (6 stars on sides of Arcturus inclu. ο & η Boö),
Taiwei (10 stars incl. stars from Coma Ber-β Vir-Leo),
Taiwei Xifan (σ Leo),
Taiwei Dizuo (β UMin),
Taiwei Youzhifa (β Vir),
Tianjin (9 stars in Cygnus incl. γ Cyg),
Tianchuan (9 stars incl. η Per),
Tianshi or Tianshiyuan (22 stars incl. ζ Oph)
Wei (Stomach, 3 stars incl. 35 Ari),
Wei (Dragon's Tail, 9 stars incl. μ Sco),
Weixing (μ^1 Sco),
Wenchang (6 stars incl. θ UMa),
Wuche (5 stars in Aur and Tau, including α Aur),
Wuche Erxing (α Aur),
Wuche Liangxing (possibly ι & α Aur),
Wuche Sanxing (β Aur),
Wuche Sixing (θ Aur),
Wuche Wuxing (β Tau),
Xin (3 stars incl. σ Sco),
Xuanyuan (17 stars incl. α Leo),
Xuanyuandaxing (υ Scor),
Xuanyuan Zuojiao (ρ Leo),
Yixing (α Crt),
Yougu (ε Tau),
Yugui (5 stars incl. θ Cnc),
Zhinü (4 stars incl. α Lyr),
Zhang (6 stars incl. υ^1 Hya),

Zhen Erxing (ε Corvi),
Zigong, Ziwei,
Ziweigong, Ziweiyuan; 15 circumpolar stars incl. κ Dra),
Zui (3 stars incl. λ Ori),
Zuojiao (α Vir),
Zuozhifa (η Vir),

There are several technical terms in Table A4 as follows:

(1) *Cun* (1 *chi* = 10 *cun*);
(2) Embracement (semi-circles found by the side of and **concave** towards the sun);
(3) Hong (daytime: parhelic circle/arc, nighttime: arc);
(4) Opposition (a bluish-white and red vapor shaped like the new moon but **convex** towards the sun);
(5) Zhang (10°).

Information on the capital cities and observation locations are given in Table A3. The geomagnetic coordinates were calculated for 1900 and give an indication of the differences between geographic and geomagnetic coordinates for that Epoch.

Table A3. Capitals/Observation Locations (Xu et al 2000): Geographic (Geo.) and Magnetic (Mag.) Latitudes and Longitudes. Latter calculated for Epoch 1900 A.D. using http://wdc.kugi.kyoto-u.ac.jp/igrf/gggm/. For comparison studies, the magnetic latitude of the various locations should be calculated using an appropriate Epoch of the geomagnetic field. This information is available at 50-year intervals from A.D. 0 onwards.

Country	Location of Capital or Observation Location	Geo. Lat.	Geo. Lon.	Date Range, A.D.	Mag. Lat.	Mag. Lon.
China	Jiankang	32.03	118.78	317-589	20.56	-173.13
China	Louyang	34.75	112.47	494-534	23.19	-178.87
China	Ye	36.35	114.58	550-577	24.8	-177
China	Chang'an (now Xian)	34.27	108.90	557-581	22.71	-177.93
China	Daxing (now Xian)	34.27	108.90	581-618	22.71	-177.93
China	Chang'an (now Xian)	34.27	108.90	618-907	22.71	-177.93
China	Yanjing	39.92	116.42	907-1125	28.39	-175.45
China	Bian	34.78	114.33	960-1127	23.23	-177.2

China	Lin'an	30.25	120.17	1127-1279	18.82	-171.82
China	Zhongdu (now Beijing)	39.92	116.42	1115-1234	28.39	-175.45
China	Dadu (now Beijing)	39.92	116.42	1206-1368	28.39	-175.45
China	Nanjing	32.03	118.78	1368-1403	20.56	-173.13
China	Beijing	39.92	116.42	1403-1911	28.38	-175.45
Japan	Heian (now Kyoto)	35.01	135.77	795-1868	24.36	-158
Japan	Kamakura	35.32	139.55	~ 1185	24.97	-154.64
Japan	Edo (now Tokyo)	35.69	139.69	1590-1858	25.35	-154.56
Korea	Gaesung	37.97	126.58	918-1392	26.76	-166.43
Korea	Hanyang	37.55	126.97	1394-	26.36	-166.06
Germany	Nienburg	51.82	11.75	Aurora-Dec 26, 993	52.07	95.11
USA	Honolulu, Hawaii	21.31	-157.86		20.93	-93.47
Italy	Rome	41.90	12.50		42.42	91.6

Table A4. Auroral Observations 1100-1695. Column 1 is the date of the aurora. Column 2 displays the Aurora information in the original language (Chinese or Korean), the translation of which is in column 3. Column 4 gives the country of the observation (C = China; K = Korea; JP = Japan), the color of the observation (W = White; R = Red; B = Black; P = Purple, etc.) and information on whether this aurora was listed by Yau et al. (1995) where IY = In Yau et al. and NIY = Not in Yau et al. The final column is information on the original reference. The entire listing is grouped by centuries as identified by the years at the upper left.

1100-1199

		Only the determinative star of asterisms is given. See the list of Stars and Asterisms Mentioned for details.		
2 Nov 1121	宋徽宗宣和三年九月壬午夜，蒼白氣長三丈，貫月，主其下有亂者.	Night. A pale white vapor 3 *zhang* long (30°) passed over the moon (21st day of lunar month).	C: Aurora (NIY, W)	宋史天文十三流隕四 Songshi Tianwen 13

11 May* 1127	[宋欽宗靖康二年]三月戊子夜，白氣貫鬥。	China: White vapors passed over [Nan]Dou (φ Sgr) [*wuzi* (戊子) is a common scribal error for *wuwu* (戊午).]	C: Aurora (NIY, W)	宋史天文十三流隕四 Songshi Tianwen 13
22 Sep 1127	宋高宗建炎元年八月壬申 是夕，東北方有赤氣。 東北有赤氣。 東北方有赤氣。	China: There were red vapors in the NE. [Two similar entries.]	C: Aurora (NIY, R)	宋史高宗纪卷 24 Songshi Gaozongji 24 宋史天文志卷 60 Songshi Tianwen 60 文献通考·象纬十七卷 294 Wenxiantongkao Xiangwei 17, 294 Zhuang: 35
7 Nov 1128	[宋建炎二年 仁宗六年]十月 甲子黑氣如布匹竟天犯天津天船五車文昌三台星中	K: Black vapors like bolts of cloth stretched across the sky, trespassing against Tianjin (γ Cyg), Tianchuan (η Per), Wuche (ι Aur), Wenchang (θ UMa), and the stars of Sandai (ι λ, ν UMa).	K: Aurora (NIY, B)	高麗史 47 卷-志 1-天文 1-月五星淩犯及星變-116 Goryeosa 47
19 Jun 1130	[宋建炎四年 仁宗八年]五月癸丑赤黑氣見於艮方方圓二十尺許. 屯結不解奮發光曜如鳥拂翼乃散.	K: Red and black vapors were seen in the NE with a circumference of about 20 *chi* (20°). "[They] entangled into knots which did not loosen until suddenly [they] emitted dazzling lights like birds flapping their wings. [They] then dispersed." [Yau omitted "red" vapors.] [Day after intense aurora in China.]	K: Aurora (R & B) (IY but not complete)	高麗史 53 卷-志 7-五行 1-火-074 Goryeosa 53 Yau: 21

25 Nov 1133	[宋紹興三年] [仁宗]十一年十月戊申黑氣一條廣五尺餘發自太微五帝座中指奎南外屏天溷不行而滅.	K: A band of black vapor more than 5 *chi* wide (5°) emerged from the midst of *Taiwei* (β Vir) and *Wudizuo* (γ Cep) pointing toward *Waibing* (δ Pis) and *Tianhun* (φ3 Cet), S of Kui (η And) lunar mansion. It remained w/o moving and disappeared. [27th day of lunar month.]	K: Aurora (NIY, B)	高麗史 53 卷-志 7-五行 1-水-181 Goryeosa 53
1 Feb 1134	[宋紹興四年 仁宗]十二年正月丙辰月暈白氣從暈中發竟天	K: The moon haloed. A white vapor emerged from within the halo to stretch across the sky. [6th day of lunar month.]	K: Aurora (NIY, W)	高麗史 47 卷-志 1-天文 1-月五星淩犯及星變-122 Goryeosa 47
27 Nov 1151	紹興…二十一年…冬十月...甲申，夜有赤氣。 冬十月…甲申，夜有赤氣。	There was a red vapor during the night. There was a red vapor during the night.	C: Aurora (NIY, R)	Songshi Tianwen Wuxing 宋史·本紀第三十高宗七 Zhuang: 36
25 Apr 1156	[宋紹興二十六年]毅宗十年四月乙亥夜赤氣如火長三十尺許廣一尺.	K: Night. A red vapor like fire about 30 *chi* (30°) long and one *chi* wide. [1st red vapor like fire prior to 1174.]	K: Aurora (NIY, R)	#高麗史 53 卷-志 7-五行 1-火-075 Goryeosa 53
30 Apr 1157	[紹興]二十七年三月乙酉，赤氣出紫微垣。	C: A red vapor emerged in *Ziweiyuan* (κ Dra, 15 circumpolar stars).	C: Aurora (NIY, R)	宋史五行二 Songshi Wuxing 2 宋史天文十三 Songshi Tianwen 13 Zhuang: 36
18 Dec 1160	[宋高宗紹興]三十年…十一月…癸巳夜，有白氣出入危、昴間。	C: A white vapor emerged from and entered between *Wei* (α Aqr) and *Mao* (17 Tau).	C: Aurora (NIY, W)	宋史本紀第三十高宗八 Songshi Gaozong 8

19 Dec 1160	宋高宗紹興三十年十一月甲午夜，西南有白氣出危入昴。	C: Night. A white vapor in the SW emerged from *Wei* (α Aqr) and entered *Mao* (17 Tau).	C: Aurora (NIY, W)	宋史卷六十六·志第十九五行四 Songshi 66, Wuxing
2 Jan 1161	宋高宗紹興三十年十二月戊申，白氣出尾入軫，貫天市垣.	C: Night. A white vapor emerged from *Wei* (μ Sco) and entered *Zhen* (γ Crv), passing through the enclosure of *Tianshi* (ζ Oph). [Must have been a high-angle arc.]	C: Aurora (NIY, W)	宋史 66 五行四 Songshi 66 Wuxing 4
21 Dec 1161	宋高宗紹興三十一年十二月辛丑，白氣如帶，東西亙天，出斗歷牛.	C: A white vapor like a belt stretched E to W across the sky, emerging from [Nan]*dou* (φ Sgr) and passing through *Niu* (β Cap).	C: Aurora (NIY, W]	宋史 66 五行四 Songshi 66 Wuxing 4
15 Mar 1184	[宋淳熙十一年 明宗]十四年二月辛酉夜有白氣起自坤一向艮一向北橫天俄而滅.	K: Night. White vapors arose in the SW, stretching across the sky, with one moving toward the NE, one moving toward the N. Suddenly they disappeared.	K: Aurora (NIY, W)	高麗史 54 卷-志 8-五行 2-金-095 Goryeosa 54
26 Dec 1197	[宋慶元三年 明宗二十七年十一月]乙卯月暈內青外赤四方有赤白氣如杵長十尺許西南方有珥.	K: The moon haloed, inner blue-green, outer red. There were red and white vapors like pestles/sticks in all directions. They were about 10 *chi* (10°) long. Those in the SW had earrings.	K: Lunar halo & Aurora (NIY, R & W)	高麗史 48 卷-志 2-天文 2-月五星淩犯及星變-049 Goryeosa 48

1200-1299

		Only the determinative star of asterisms is given. See the list of Stars and Asterisms Mentioned for		

		details.		
23 Apr 1211	金衛紹王大安三年三月辛酉辰刻，北方有黑氣如堤，內有白氣三，似龍虎之狀。	NC: 07-09h. There was a black vapor in the N like an embankment. W/in it were three white vapors that had a majestic air.	NC: Aurora (Not in Yau=NIY, W)	金史天文志卷二十 Jinshi Tianwen 20 Zhuang: 38
23 Nov 1213	宣宗貞祐元年十月丙午，夜有白氣三，衝紫微而不貫。	NC: In the night there were three white vapors. They towered into *Ziwei* (κ Dra) but did not pass through it.	NC: Aurora (NIY, W)	金史天文志卷二十 Jinshi Tianwen 20
16 Jul 1221	[宣宗]興定五年六月戊寅，日將出，有氣如大道，經丑未，歷虛危，東西不見首尾，移時沒。	NC: As the sun was about to rise, there was a vapor like a wide road. Its heading was 30° to 210°. It passed through Xu (β Aqr) and Wei (α Aqr). Its beginning and end were not visible in the E or W. After a while it disappeared [25th day of lunar month.]	NC: Aurora (NIY)	金史天文志卷二十 Jinshi Tianwen 20
18 Jul 1215	宣宗貞祐三年六月戊申，夜有黑氣，廣如大路，自東南至于西北，其長竟天。	NC: In the night there was a black vapor as broad as a large road. It stretched lengthwise across the sky from SE to NW.	NC: Aurora (NIY, B)	金史天文志卷二十 Jinshi Tianwen 20
24 Feb 1256	[宋寶祐四年 高宗]四十三年正月己未黑氣從南方東西橫天貫尾星廣三尺長三百尺許.	A black vapor from the S extended E to W across the sky passing through *Weixing* (μ Sco). It was 3 chi (3°) wide and about 300 chi (300°) in length.	K: Aurora (NIY, B)	高麗史 53 卷-志 7-五行 1-水-184 Goryoesa 53

20 Mar 1259	[宋開慶元年 高宗]四十六年二月己亥黑氣從南斗魁抵河鼓.	K: A black vapor reached from *Nandoukui* (ζ Sgr) to *Hegu* (α Aql).	K: Aurora (NIY, B)	高麗史 53 卷-志 7-五行 1-水-184 Goryeosa 53
9 Feb 1261	[元世祖]中統二年正月辛未，御帳殿受朝賀，是夜東北有赤氣照人，大如席。	C: That night, in the NE there was a red vapor as big as a mat shining on people.	C: Aurora (NIY, R)	新元史卷四十四·志第十一五行中 Xinyuanshi 44 Zhuang: 38
10 Jun 1263	[景定四年]四年五月壬午巽方有黑氣如布匹入於南河及東井.	K: There was a black vapor as big as a cloth in the SE. It entered *Nanhe* (ε Canis Min) and Dongjing (μ Gem).	Aurora (NIY, B)	高麗史 53 卷-志 7-五行 1-水-185 Goryeosa 53
28 Jun 1264	[宋景定五年] [元宗]五年六月丙午白虹見于南北方.	K: A white vapor was seen S to N. [3rd day of lunar month.]	K: Aurora (NIY. W)	高麗史 54 卷-志 8-五行 2-金-099 Goryeosa 54
3 Jul 1264	[元宗五年六月]辛亥夜白虹見于西南方.	K: Night. A white *hong* (arc) appeared in the SW.	Aurora (NIY, W)	高麗史 54 卷-志 8-五行 2-金-099 Goryeosa 54
15 Feb 1269	[宋咸淳五年] [元宗]十年正月己未夜白雲自巽竟天廣三尺許。	K: Night. A white cloud about 3 *chi* (3°) wide stretched across the sky from SE.	Aurora (NIY, W)	高麗史 54 卷-志 8-五行 2 Goryeosa 54
21 Jan 1273	[宋咸淳九年] 元宗十四年正月乙卯東方有黃紫氣中有直竪衝天者如塔.	K: In the E there was a yellow and purple vapor; within it was something straight and erect like a pagoda towering in the sky.	K: Aurora (NIY, Y, P)	高麗史 55 卷-志 9-五行 3-土-141 Goryeosa 55
2 Dec 1276	[宋端宗景炎元年]忠烈王二年十月丙戌巽方赤氣橫天其上白氣如槍長三尺許.	In the SE there was a red vapor stretching across the sky; above it were white vapors like spears about 3 *chi* (3°) long.	K: Aurora (NIY, R, W)	高麗史 53 卷-志 7-五行 1-火-081 Goryeosa 53

11 May 1277	[宋景炎二年 忠烈王]三年四月丙寅白氣如虹貫北斗月犯軒轅	K: A white vapor like a *hong* (arc) passed through *Beidou* (α Uma); the moon trespassed against *Xuanyuan* (α Leo).	K: Aurora (NIY, W)	高麗史 49 卷-志 3-天文 3-月五星淩犯及星變-003 Goryeosa 49

1300-1399

		Only the determinative star of asterisms is given. See the list of Stars and Asterisms Mentioned for details.		
19 Nov 1357	[元至正十七年] [恭愍王]六年十月戊寅雷電紫氣見于北方.	K: Thunder and lightning. A purple vapor was seen in the N.	K: Aurora (NIY, P)	高麗史 53 卷-志 7-五行 1-水-125 Goryeosa 53
31 Jan 1358	[元至正十七年] 六年十二月辛卯夜有白氣風雷雨.	K: Night. There was a white vapor, wind, lightning, and rain. [Aurora in midst of storm?]	K: Aurora (NIY, W)	高麗史 54 卷-志 8-五行 2-金-102 Goryeosa 54
8 Oct 1359	[元順帝至正十九年九月] 丙午，夜，白虹貫天。	Night, a white *hong* (arc, aurora) passed through the sky.	C: Aurora (NIY, W)	元史卷四十五本纪第四十五 Yuanshi 45 Benji 45
10 Feb 1370	[大明洪武三年 恭愍王]十九年正月甲辰西北方紫氣漫空影皆南.	K: A purple vapor filled the sky in the NW. The shadows [it made] all pointed S. [14th day of lunar month. Yau dates it as 11 Feb.]	K: Aurora (IY, P)	高麗史 53 卷-志 7-五行 1-火-085 Goryeosa 53 Yau: 35-36
13 Oct 1389	[大明洪武二十二年] [辛昌元年]恭讓王元年九月己丑夜有黑氣.	Korea: Night. There was a black vapor.	Aurora (NIY, B)	高麗史 53 卷-志 7-五行 1-水-189 Goryeosa 53 Wuxing 1

20 Mar 1397	甲辰/夜, 北方有白氣。	K: Night. There was a white vapor in the N.	K: Aurora (NIY, W)	太祖 11 卷, 6 年 (1397 丁丑 / 명 홍무(洪武) 30 年) 2 月 21 日(甲辰) Taejo 11
31 Mar 1397	丙辰/暴風。 夜, 東北有赤氣。	K: Storm. Night. There was a red vapor in the NE.	K: Aurora (NIY, R)	太祖 11 卷, 6 年 (1397 丁丑 / 명 홍무(洪武) 30 年) 3 月 3 日(丙辰) Taejo 11
6 Apr 1397	3 月 9 日(壬戌)日暈。夜,南有赤白氣。	Korea: Solar halo. Night. There were red and white vapors in the S.	Korea: Solar halo, aurora (NIY, R & W)	太祖 11 卷, 6 年 (1397 丁丑 / 명 홍무(洪武) 30 年) 3 月 9 日(壬戌) Taejo 11
28 Dec 1397	丁亥/夜, 乾方有白氣。	K: Night. There was a white vapor in the NW.	K: Aurora (NIY, W)	太祖 12 卷, 6 年 (1397 丁丑 / 명 홍무(洪武) 30 年) 12 月 9 日(丁亥) Taejo 12
17 Jan 1398	丁未/夜, 東西有白氣竟天。	K: Night. There was a white vapor stretching across the sky E to W.	K: Aurora (NIY, W)	太祖 12 卷, 6 年 (1397 丁丑 / 명 홍무(洪武) 30 年) 12 月 29 日(丁未) Taejo 12

1400-1499

		Only the determinative star of asterisms is given. See the list of Stars and Asterisms Mentioned for details.		
17 Feb 1400	戊子/西北東有赤氣。	K: There was a red vapor in the NW. [23rd day of lunar month]	K: Aurora (NIY, R)	定宗 3 卷, 2 年 (1400 庚辰 / 명 건문(建文) 2 年) 1 月 23 日(戊子)

				Jeongjong 3
23 Apr 1402	甲辰/夜, 白氣起氐、房間, 過攝提北斗魁文昌, 抵北。	K: Night. A white vapor arose between Di (α Lib) and Fang (π Sco), passed *Sheti* (ο & η Boö), *Beidokui* (Ursa Major) and *Wenchang* (θ UMa), and reached the N.	K: Aurora (NIY, W)	太宗 3 卷, 2 年 (1402 壬午 / 명 건문(建文) 4 年) 3 月 21 日(甲辰) Taejong 3
24 May 1402	乙亥/坤方有白氣。	K: There was a white vapor in the SW.	K: Aurora (NIY, W)	太宗 3 卷, 2 年 (1402 壬午 / 명 건문(建文) 4 年) 4 月 23 日(乙亥) Taejong 3
17 Feb 1403	甲辰/坎方有白氣竟夜。	K: There was a white vapor in the N throughout the night.	K: Aurora (NIY, W)	太宗 5 卷, 3 年 (1403 癸未(永樂) 1 年) 1 月 26 日(甲辰) Taejong 6
14 Dec 1403	甲辰朔/夜, 北方有淡赤氣, 長丈許。	K: Night. There was a dim red vapor in the N. It was about 1 *zhang* (10°) long.	K: Aurora (NIY, R)	太宗 6 卷, 3 年 (1403 癸未 / 명 영락(永樂) 1 年) 閏 11 月 1 日(甲辰) Taejong 6
17 Feb 1405	乙卯/夜, 寅方有白氣。	K: Night. There was a white vapor in the ENE.	K: Aurora (NIY, W)	太宗 9 卷, 5 年 (1405 乙酉 / 명 영락(永樂) 3 年) 1 月 18 日(乙卯) Taejong 9
25 Feb 1405	夜, 白氣起酉戌方至巽方, 狀如匹布。	K: Night. A white vapor arose in the W and WNW directions and reached to	K: Aurora (NIY, W)	太宗 9 卷, 5 年 (1405 乙酉(永樂) 3 年) 1 月 26 日(

		the SE direction; it was shaped like a bolt of cloth.		癸亥) Taejong 9
18 Mar 1405	甲申/夜, 庚方有白氣。	K: Night. There was a white vapor in the WSW.	K: Aurora (NIY, W)	太宗 9 卷, 5 年 (1405 乙酉(永樂) 3 年) 2 月 18 日(甲申) Taejong 9
1 Jan 1406	癸酉/太白晝見。夜, 离方有白氣。	K: Venus was seen in daylight. Night. There was a white vapor in the S direction.	K: Aurora (NIY, W)	太宗 10 卷,5 年 1405 乙酉(永樂) 3 年) 12 月 11 日(癸酉) Taejong 10
14 Jan 1406	丙戌/巽方有赤氣, 金、土星相犯。	K: There was a red vapor in the SE; Venus and Saturn trespassed against one another.	K: Aurora (NIY, R)	太宗 10 卷, 5 年 (1405 乙酉 / 명 영락(永樂) 3 年) 12 月 24 日(丙戌) Taejong 10
25 Jul 1426	宣德元年六月癸未夜，有蒼白氣，東西竟天。 夜有蒼白雲一道東西竟天...五鼓有流星大如杯色青白尾跡有光後二小星隨之出右旗西行入雲中。	C: "At night, there was a green-white vapour stretching across the sky from E to W." C: Night. There was a band of green-white cloud stretching E to W across the sky….At the 5th watch, there was a star (meteor) as big as a cup, colored green-white. Two smaller stars (meteors) followed it. It emerged from *Youqi* (μ Aquilae) and traveled W into clouds. [The vapor may	K: Aurora? (In Yau as aurora, but may be meteor trail)	明史卷三十行三 Mingshi 30 Wuxing 明宣宗實錄卷之十八 Ming Xuandeshilu 18 Yau: 38

		have been a meteor trail because three features of the meteors (date, color, direction) match the vapor description.]		
14 Jul 1429	[宣德]四年六月戊子，夜五色云见。戊子夜月生五色云鲜明	C: "At night, multi-coloured clouds were seen." C: The moon developed a bright multicolored cloud. [14th day of lunar month. Indicates Yau's multicolored cloud was not aurora.]	C: Aurora? Multicolored cloud C: Moon cloud	史卷二十七天文三 Mingshi 27 Tianwen 3 Yau: 38 明宣宗章皇帝实录卷之五十五 Ming Xuanzongshilu 55
14 May 1449	夜, 白氣見于東北方。	K: Night. A white vapor was in the NE.	K: Aurora (NIY, W)	世宗 124 卷, 31 1449 己巳(正統) 14 年) 4 月 23 日(壬申) Sejong 124

1 Nov 1449	**明英宗正**统十四年十月癸亥夜，昏刻，西南赤黑气如火烟，须臾化苍白气，重迭六道，徐徐北行，至中天而散。 **昏刻，西南赤黑气如焰**，须臾化苍白气六道，北至中天而散。	C: Dusk. A red and black vapor like smoke in the SW. In a minute it changed to a pale vapor with 6 bands. It gradually moved N and dispersed on arriving at mid-sky. C: Dusk. A red and black vapor like a flame in the SW. In a minute it changed to a pale vapor with 6 bands. It moved N and dispersed on arriving at mid-sky.	C: Aurora (NIY, R & B)	**明英宗**实录卷 184 Ming Yingzongshilu 184 **国榷卷** 28 Guoque 28 Zhuang: 40
20 Nov 1458	**明英宗天**顺二年十月己巳南京日入后，西南方有赤气如火影，光明烛地，至亥时散。	C: In Nanjing after sunset there was a red vapor like a *huoying* in the SW. Its light lit up the earth. It dispersed at 9-11pm.	C: Aurora (NIY, R)	**明英宗**实录卷 296 Ming Yingzongshilu 296 Zhuang: 40
14 Jan 1459	**明英宗天**顺二年十二月甲子夜，正北火影中见赤气一道，阔余二尺，直冲天中，约余五十丈，其形上锐，状如立枪。	C: Night. A single band of red vapor more than 2 *chi* (2°) wide was seen within a *huoying* due N. Towering straight into mid-sky, it was more than 50(->5?) *zhang* long, was pointed, and shaped like an erect spear.	C: Aurora (NIY, R)	**明英宗**实录卷 298 Ming Yingzongshilu 298 续文献通考·**象**纬六》卷 215 Xu Wenxiantongkao 215 Zhuang: 40

19 Jan 1460	**明英宗天**顺三年十二月甲戌夜, 南方火影中见赤气，阔余二尺，长余十丈，其形上锐如立，直冲中天。 **夜, 南方火影中**见赤气，阔二尺余，长十余丈，其形上锐如立枪。	C: Night. A red vapor was seen within a *huoying* in the S. It was more than 2 *chi* (2°) wide and more than ten zhang (100°) long. Its shape was pointed at the top like an erect [spear] and towered straight into mid-sky.	C: Aurora (NIY, R)	**明英宗**实录卷 310 Ming Yingzongshilu 310 续文献通考·**象**纬六》卷 215 Xu Wenxiantongkao 215 Zhuang: 40 Usoskin: 10
19 Sep 1468	**○庚申/彗星見, 命都承旨權**瑊及安孝禮候之。 瑊等登簡儀臺以望。 **夜三皷, 西南忽有黑氣, 且有聲如萬馬群奔, 俄而雷電以雨。 雨止**, 瑊等復登以觀, **彗星光芒如前。**	Korea:….Night. At the 3rd watch (11-01h), there suddenly was a black vapor in the SW. It made a sound like 10,000 horses galloping. Suddenly there was lightning and rain. When the rain stopped...the comet was still sparkling as before.	K: Black aurora (NIY) & comet	**世祖** 47 **卷**, 14 **年** (1468 **戊子** / 명 성화(**成化**) 4 **年**) 9 **月** 4 **日**(**庚申**) Sejo 47
25 Dec 1475	**明**宪宗成化十二年十二月己卯夜，西北方赤气一道冲天，长五丈许，状如矛锋。	C: Night. A single band of red vapor towered into the sky. It was about 5 *zhang* (50°) long and shaped like a lance.	C: Aurora (NIY, R)	**明**宪宗实录**卷** 160 Ming Xianzongshilu 160 **国榷卷** 37 Guoque 37 Zhuang: 40-41

8 Aug 1499	傳于承政院曰: “六月三十日夜, 予在大造殿觀之, 天際有如群炬之氣, 上觸于空, 流動不定。 初若自南山上而向東, 俄復西流, 又轉而向東, 始自四更, 至于五更乃滅。 其狀又如旱時月色, 或如禪家所云放光。 其召金應箕問之。” 應箕考《文獻通考》以啓曰: “所謂赤氣也。”	K: On 8 Aug 1499, the king said to a high official: “In the night of 6 Aug, I saw it at the Dazao Palace. On the horizon there were clusters of dim candle-like vapors, reaching into the heavens and making irregular movements. At first they seemed to move E from above the southern mountains. Suddenly they switched to moving back W, and then they switched again to move E. They started at the 4th watch [of the night] and disappeared at the 5th. They were like the color of the moon during drought or like what the Zen Buddhists call ‘*fangguang*.’ Ask Kim Yingji about this matter.” Kim Yingji responded after checking the *Wenxian Tongkao*: “It is called ‘red vapors’ (auroras).”	K: Aurora (NIY)	燕山君 34 卷, 5 年 (1499 己未 / 명 홍치(弘治) 12 年) 7 月 2 日(庚申) Yeonsangun 34

1500-1599

		Only the determinative star of asterisms is given. See the list of Stars and Asterisms Mentioned for details.		

5 May 1503	[明孝宗弘治]丙午/夜, 流星出句陳, 入於乾方, 狀如拳, 色白, 尾五尺許。 又自西方至東方, 白氣經天, 廣二尺許。	K: Night. A meteor…. There also was a white vapor crossing the sky from W to E. It was about 2 chi (2°) wide.	K: Aurora (Not In Yau: NIY, W)	燕山 49 卷, 9 年 (1503 癸亥 / 명 홍치(弘治) 16 年) 4 月 10 日(丙午) Yeonsan 49
Report: 24 Jan 1507, Event: 12 Jan 1507	"臣等亦聞前月晦日夜, 乾方有赤氣如火光, 南方雲淡色黃。又聞是日, 山火偶發於高嶺、鐘山等處, 連燒數里, 疑是此火之光也。"	K: [An official said:] "We also have heard that in the last night of the previous lunar month (12 Jan 1507) there was a red vapor like a *huoguang* flame in the NW and pale yellow clouds in the S. However, we've also heard of wildfires burning for several *li* on the same day. [What people saw] may have been the light from the wildfires." [Yau gives impression the *huoguang*/wildfires were seen in the night of 24 Jan rather than 12 Jan.]	K: Aurora? (In Yau but misdated and questionable)	中宗 2 卷, 2 年 (1507 丁卯 / 명 정덕(正德) 2 年) 1 月 12 日(丙戌) Jungjong 2 Yau: 41
17 Dec 1509	自三更至五更, 北方有赤氣。	K: There was a red vapor in the N from the 3rd to the 5th watch (23-01h to 03-05h).	K: Aurora (NIY, R)	中宗 10 卷, 4 年 (1509 己巳 / 명 정덕(正德) 4 年) 11 月 6 日(甲子) Jungjong 10
17 Jan 1512	夜坤方有赤氣, 其上有白氣一條。 赤氣狀如炬, 白氣狀如十字, 一丈許。	K: Night. There was a red vapor in the SW. Above it was a strip of white vapor. The red vapor was shaped like a torch, the white vapor like the character for "ten" (a	K: Aurora (NIY, R & W)	中宗 14 卷, 6 年 (1511 辛未 / 명 정덕(正德) 6 年) 12 月 29 日(乙巳) Jungjong 10

		plus sign); it was one zhang long (10°).		
19 July 1512	是日戌初, 有黑氣起自西北, 一本分爲三條, 至天中, 三條相距漸闊, 至東南, 還爲一本, 如梭形。	Korea: On that day at 19h, black vapors arose from the NW. One part divided into 3 strips reaching to mid-sky. Keeping the same distance from one another, they gradually broadened, reaching to the SE, where they reformed into one [strip] in the shape of a shuttle.	K: Aurora (NIY)	中宗 16 卷, 7 年(1512 壬申(正德) 7 年) 6 月 7 日(己酉) Jungjong 16
22 Nov 1514	二更, 南方有白氣。	K: At the 2nd watch (21-23h) there was a white vapor in the S.	K: Aurora (NIY, W)	中宗 21 卷, 9 年(1514 甲戌 / 명 정덕(正德) 9 年) 11 月 7 日(乙丑) Jungjong 21
13 May 1518	夜五更, 坤方、巽方有氣如火。[Yau dated it 18 May] [Example of 氣如火 before 1522]	K: King Jungjong, 13th year, 4th month, day kuei-yu (10). "At night, at the 5th watch, in the SW direction, there was a vapour like fire."	K: Aurora (In Yau but misdated)	中宗 32 卷, 13 年(1518 戊寅 / 명 정덕(正德) 13 年) 4 月 5 日(癸酉) Jungjong 32 Yau: 42
8 Mar 1520	全羅道 谷城縣, 夜有赤氣渾天, 山野皆明, 村屋可數, 良久而銷。	K: In the night there were red vapors all over the sky; the hills and fields were brightly illuminated and one could count the dwellings in villages; it burned out after a long time.	K: Aurora (NIY, R)	中宗 38 卷, 15 年(1520 庚辰 / 명 정덕(正德) 15 年) 2 月 19 日(戊寅) Jungjong 38

29 Mar 1520	參贊官尹殷弼曰: "近日非常之災甚多, 全羅道 谷城之災, 日中有黑光相盪, 又星月上下, 有相戰之狀, 戌時又有火光照物, 村廬可數, 又有地震。	A counsellor official said: "Recently there have been unusually many disasters, the …, within the sun were black lights rocking against one another, also stars and the moon were moving up and down, seemingly fighting with one another. And at the 19-21h double-hour there were *huoguang* flames shining on things….	K: Reports of sunspots, auroras (NIY)	中宗 38 卷, 15 年(1520 庚辰 / 명 정덕(正德) 15 年) 3 月 11 日(己亥) Jungjong 38
8 Oct 1521	夜, 白氣自乾方至巽方, 布天。	K: Night. White vapors stretched across the sky from NW to SE.	K: Aurora (NIY, W)	中宗 42 卷, 16 年(1521 辛巳 / 명 정덕(正德) 16 年) 9 月 9 日(丁巳) Jungjong 42
27 Mar 1522	…又啓曰: "近來, 災變疊興, 前年冬有雷動電光, 今年正月下赤雪, 昨昨夜有火氣, 是亦災變, 上下所當修省之時。	K: An official reported by message: "Recently, …. Since the New Year (28 Jan 1522), red snow has fallen and two nights ago (25 Mar) there were fire-vapors at night. These are portents of disasters; it is time for all, whether high or low, to reflect on how to improve the situation."	K: Assessment of Fire-vapor Auroras (NIY)	中宗 44 卷, 17 年(1522 壬午 / 명 가정(嘉靖) 1 年) 2 月 30 日(丁未) Jungjong 44
29 Apr 1522	夜, 白氣自乾方至巽方布天。	K: Night. White vapors stretched across the sky from NW to SE.	K: Aurora (NIY, W)	中宗 44 卷, 17 年(1522 壬午 / 명 가정(嘉靖) 1 年) 4 月 4 日(庚辰) Jungjong 44

24 May 1522	夜, 流星..., 白氣布天, 暫時消散。	K: Night…. White vapors stretched across the sky; they dispersed soon.	K: Aurora (NIY, W)	中宗 44 卷, 17 年(1522 壬午 / 명 가정(嘉靖) 1 年) 4 月 29 日(乙巳) Jungjong 44
20 Nov 1522	夜, 赤氣布天。	K: Night. Red vapors stretched across the sky. [Yau translated “red vapors” as "vapours like fire”.]	K: Aurora (In Yau, but mistranslated)	中宗 46 卷, 17 年(1522 壬午 / 명 가정(嘉靖) 1 年) 11 月 3 日(乙巳) Jungjong 46 Yau: 43
8 Aug 1523	自夜四更, 至五更, 黑氣自西方至東方, 布天。	K: A black vapor stretched across the sky from the W to the E from the 4th to 5th watches (03-07h). [Note association of 布天 with 自西方至東方, from one direction to another direction: movement]	K: Black aurora (NIY)	中宗 48 卷, 18 年(1523 癸未(嘉靖) 2 年) 6 月 27 日(丙寅) Jungjong 48
21 Nov 1523	夜, 白氣布天。	Night. White vapors stretched across the sky.	K: Aurora (NIY, W)	中宗 49 卷, 18 年(1523 癸未 / 명 가정(嘉靖) 2 年) 10 月 15 日(辛亥) Jungjong 49
25 Feb 1524	夜, 白氣二道, 自東至西布天。	K: Night. Two bands of white vapor stretched across the sky from the E to the W.	K: Aurora (NIY, W)	中宗 50 卷, 19 年(1524 甲申 / 명 가정(嘉靖) 3 年) 1 月 22 日(丁亥) Jungjong 50

9 Nov 1524	夜, 巽方、乾方, 白氣布天。	K: Night. White vapors stretched across the sky in the SE and NW.	K: Aurora (NIY, W)	中宗 52 卷, 19 年(1524 甲申 / 명 가정(嘉靖) 3 年) 10 月 14 日(乙巳) Jungjong 52
6 Mar 1525	夜, 白氣布天。	K: Night. White vapors stretched across the sky.	K: Aurora (NIY, W)	中宗 53 卷, 20 年(1525 乙酉 / 명 가정(嘉靖) 4 年) 2 月 13 日(壬寅) Jungjong 53
7 Mar 1525	夜, 白氣自坤方, 至艮方布天。	K: Night. White vapors stretched across the sky from SW to NE.	K: Aurora (NIY, W)	中宗 53 卷, 20 年(1525 乙酉 / 명 가정(嘉靖) 4 年) 2 月 14 日(癸卯) Jungjong 53
29 Mar 1525	日重暈、兩珥, 有冠、有履, 日上白暈貫日。 夜, 巽方如火氣。	K: The sun had a triple halo, …. Night. There was a dim fire-vapor in the SE.	K: Aurora (NIY, FV)	中宗 53 卷, 20 年(1525 乙酉 / 명 가정(嘉靖) 4 年) 3 月 6 日(乙丑) Jungjong 53
12 Apr 1525	夜, 乾方、巽方, 白氣布天。	K: Night. White vapors stretched across the sky in the NW and SE.	K: Aurora (NIY, W)	中宗 53 卷, 20 年(1525 乙酉 / 명 가정(嘉靖) 4 年) 3 月 20 日(己卯 Jungjong 53
25 Jul 1525	夜, 白氣自乾方觸月。	K: White vapors from NW touching the moon.	K: Aurora (NIY, W)	中宗 54 卷, 20 年(1525 乙酉 / 명 가정(嘉靖) 4 年) 7 月 6 日(癸亥)

				Jungjong 54
10 Sep 1525	夜, 乾方至巽方, 白氣布天, 狀如虹。	K: Night. White vapors stretched across the sky [from] the NW to SE. They were shaped like a *hong* (arc).	K: Aurora (NIY, W)	中宗 55 卷, 20 年(1525 乙酉 / 명 가정(嘉靖) 4 年) 8 月 23 日(庚戌) Jungjong 55
30 Oct 1525	夜一更, 白氣自艮方, 至西方布天。	K: At the 1st watch of the night (19-21h) white vapors stretched across the sky from the NE to the W.	K: Aurora (NIY, W)	中宗 55 卷, 20 年(1525 乙酉 / 명 가정(嘉靖) 4 年) 10 月 15 日(庚子) Jungjong 55
8 Nov 1525	夜, 白氣自艮方, 向坤方布天。	K: Night. White vapors stretched across the sky from NE toward SW.	K: Aurora (NIY, W)	中宗 55 卷, 20 年(1525 乙酉 / 명 가정(嘉靖) 4 年) 10 月 24 日(己酉) Jungjong 55
22 Mar 1526	夜, 月暈, 有白氣橫貫。	K: Night. The moon haloed and there was a white vapor passing through it transversely.	K: Aurora (NIY, W)	中宗 56 卷, 21 年(1526 丙戌 / 명 가정(嘉靖) 5 年) 2 月 10 日(癸亥) Jungjong 56
26 Oct 1526	夜, 黑氣布天。	K: Night. A black vapor stretched across the sky.	K: Aurora (NIY, B)	中宗 57 卷, 21 年(1526 丙戌 / 명 가정(嘉靖) 5 年) 9 月 21 日(辛丑) Jungjong 57

7 Apr 1527	夜, 艮方白氣布天。	K: Night. White vapors stretched across the sky in the NE.	K: Aurora (NIY, W)	中宗 58 卷, 22 年(1527 丁亥 / 명 가정(嘉靖) 6 年) 3 月 7 日(甲申) Jungjong 58
30 Jun 1527	夜, 白氣布天。	K: Night. White vapors stretched across the sky.	K: Aurora (NIY, W)	中宗 59 卷, 22 年(1527 丁亥 / 명 가정(嘉靖) 6 年) 6 月 3 日(戊申) Jungjong 59
26 Feb 1528	夜, 艮方有白氣如烟。	K: Night. There were white vapors like smoke in the NE.	K: Aurora (NIY, W)	中宗 60 卷, 23 年(1528 戊子 / 명 가정(嘉靖) 7 年) 2 月 7 日(己酉) Jungjong 60
1 Mar 1528	夜, 自南方至乾方, 黑氣布天; 自巽方至艮方, 白氣布天。	K: Night. Black vapors stretched across the sky from S to NW; white vapors stretched across the sky from SE to NE.	K: Aurora (NIY, B, W)	中宗 60 卷, 23 年(1528 戊子(嘉靖) 7 年) 2 月 11 日(癸丑) Jungjong 60
31 Mar 1528	癸未/大雨夜, 自南方至艮方, 白氣布天, 南方有氣如火。	K: Heavy rain at night. White vapors stretched across the sky from the S to NE; there was a vapor like fire in the S.	K: Aurora (In Yau but “white vapors” not translated	中宗 60 卷, 23 年(1528 戊子 / 명 가정(嘉靖) 7 年) 3 月 12 日(癸未) Jungjong 60
4 Apr 1528	〔夜〕, 坤方、巽方, 黑氣布天。	K: (Night.) Black vapors stretched across the sky in the SW and SE.	K: Aurora (NIY, B)	中宗 60 卷, 23 年(1528 戊子 嘉靖) 7 年) 3 月 16 日(丁亥) Jungjong 60

28 Jul 1528	夜, 艮方坤方, 白氣布天。	K: Night. White vapors stretched across the sky in the NE and SW.	K: Aurora (NIY, W)	中宗 62 卷, 23 年(1528 戊子 / 명 가정(嘉靖) 7 年) 7 月 13 日(壬午) Jungjong 62
26 Jan 1529	夜, 白氣自坤方向東布天。	K: Night. White vapors stretched across the sky from the SW toward the E. [Note repetition of “white vapors from SW toward E,” 26 Jan-8 Feb, 11 entries in total.]	K: Aurora (NIY, W)	中宗 64 卷, 23 年(1528 戊子 / 명 가정(嘉靖) 7 年) 12 月 17 日(甲申) Jungjong 64
26-30 Jan 1529	十七日至二十一日, 江原道 三陟府, 白氣自天河, 直指南方, 隨天河而轉, 月出則光滅。 慶尙道 眞寶縣, 白氣從西南起, 向東北, 如一匹練。	From the 17th to 21 lunar days (26-30 Jan) in Samcheok-bu of Kangwon Province (37.341667, 127.920833), white vapors from the Milky Way pointed due S and turned, following the Milky Way. Their light faded when the moon rose. In Jinbohyeon (modern Cheongsong County), Gyeongsang Province (36.43 129.05), white vapors arose in the SW, [pointing] toward the NE; [they were] like a bolt of cloth.	K: Aurora (NIY, W)	中宗 64 卷, 23 年(1528 戊子 / 명 가정(嘉靖) 7 年) 12 月 17 日(甲申) Jungjong 64
27 Jan 1529	全羅道 泰仁縣, 白氣自西向東至銀河。	K: In Taein county, Jeolla-do (North Jeolla, 35.5, 126.8), [there were] white vapors from the W pointing toward the E and reaching	K: Aurora (NIY, W)	中宗 64 卷, 23 年(1528 戊子 / 명 가정(嘉靖) 7 年) 12 月 18 日(乙酉)

		to the Milky Way.		Jungjong 64
28 Jan 1529	夜, 白氣自坤方, 向東布天。	K: Night. White vapors stretched across the sky from SW toward the E.	K: Aurora (NIY, W)	中宗 64 卷, 23 年(1528 戊子 / 명 가정(嘉靖) 7 年) 12 月 19 日(丙戌) Jungjong 64
30 Jan 1529	夜, 白氣自坤方向東, 長二布長許。	K: Night. White vapors from the SW toward the E, about 2 *bu* (60°) long.	K: Aurora (NIY, W)	中宗 64 卷, 23 年(1528 戊子 / 명 가정(嘉靖) 7 年) 12 月 21 日(戊子) Jungjong 64
1 Feb 1529	庚寅/夜, 白氣自坤方向東, 長二布長許。	K: Night. White vapors from the SW toward the E, about 2 *bu* (60°) long.	K: Aurora (NIY, W)	中宗 64 卷, 23 年(1528 戊子 / 명 가정(嘉靖) 7 年) 12 月 23 日(庚寅) Jungjong 64
1 Feb 1529	全羅道 茂長縣, 白氣自西至銀河	K: White vapors [reaching] from the W to the Milky Way [seen] in Gochang County of Jeolla-do (modern Jeollabuk-do Province, 全羅北道, in the southwest of South Korea).	K: Aurora (NIY, W)	中宗 64 卷, 23 年(1528 戊子 / 명 가정(嘉靖) 7 年) 12 月 23 日(庚寅) Jungjong 64
2 Feb 1529	辛卯/白氣自坤方向東, 長一布長許, 其色漸微。	K: White vapor [reaching] from SW toward the E, about 1 *bu* long (30°); its color gradually faded.	K: Aurora? (NIY, W)	中宗 64 卷, 23 年(1528 戊子 / 명 가정(嘉靖) 7 年) 12 月 24 日(辛卯)

				Jungjong 64
4 Feb 1529	夜, 白氣自坤方向東, 長一布長餘, 其色漸微。	K: Night. White vapor [reaching] from SW toward the E, about 1 *bu* long (30°); its color gradually faded.	K: Aurora (NIY, W)	中宗 64 卷, 23 年(1528 戊子 / 명 가정(嘉靖) 7 年) 12 月 26 日(癸巳) Jungjong 64
7 Feb 1529	夜, 白氣自坤方向東, 一布長許。	K: Night. White vapor [reaching] from SW toward the E, about 1 *bu* (30°) long.	K: Aurora (NIY, W)	中宗 64 卷, 23 年(1528 戊子 / 명 가정(嘉靖) 7 年) 12 月 29 日(丙申) Jungjong 64
8 Feb 1529	夜, 白氣自坤方向東, 兩端消滅, 半布長許, 形色微。	K: Night. White vapor [reaching] from SW toward the E, with both ends fading. It was about half a *bu* long (15°) and both shape and color were dim.	K: Aurora (NIY, W)	中宗 64 卷, 23 年(1528 戊子 / 명 가정(嘉靖) 7 年) 12 月 30 日(丁酉) Jungjong 64
1 Jun 1529	頃者天災、物怪, 疊見、層出, 夜則白氣橫天, 晝則昏霧四塞, 朔野隕石, 暑月雨雹, ...	K: Recently, there have been frequent disasters and strange sights, one after the other; **at night, white vapors crossing the sky**; in daytime, dark fogs everywhere; falling stones (meteorites) in the northern wilds; hail in the hot months…. [Boldface refers to the white vapors seen 26 Jan-8 Feb above.]	K: Summary of recent portents (NIY, W)	中宗 65 卷, 24 年(1529 己丑 / 명 가정(嘉靖) 8 年) 4 月 25 日(庚寅) Jungjong 65

8 Jun 1529	日暈。 白氣布天。夜乾方有氣如火。	K: The sun haloed, with white vapors stretching across the sky. At night there were vapors like fire in the NW.	K: Aurora (NIY)	中宗 65 卷, 24 年(1529 己丑 / 명 가정(嘉靖) 8 年) 5 月 3 日(丁酉) Jungjong 65
7 Apr 1530	夜, 白氣布天。	K: Night. White vapors stretched across the sky.	K: Aurora (NIY, W)	中宗 67 卷, 25 年(1530 庚寅 / 명 가정(嘉靖) 9 年) 3 月 10 日(庚子) Jungjong 67
17 May 1530	夜, 白氣自西方向東方, 長二布長許。	K: White vapors from the W toward the E; length was about 2 *bu* (60°) long.	K: Aurora (NIY, W)	中宗 68 卷, 25 年(1530 庚寅 / 명 가정(嘉靖) 9 年) 4 月 21 日(庚辰) Jungjong 68
4 Sep 1530	夜, 白氣布天。	K: Night. White vapors stretched across the sky.	K: Aurora (NIY, W)	中宗 69 卷, 25 年(1530 庚寅 / 명 가정(嘉靖) 9 年) 8 月 13 日(庚午) Jungjong 69
12 Jul 1532	夜, 白氣自坤方至東方, 布天。	K: Night. White vapors stretched across the sky from the SW to the E.	K: Aurora (NIY, W)	中宗 73 卷, 27 年(1532 壬辰 / 명 가정(嘉靖) 11 年) 6 月 10 日(丁亥) Jungjong 73

13 Jul 1532	夜, 白氣自尾星上, 至牛星, 其長二布長許, 移至瓠瓜星, 二更乃滅。	K: Night. White vapors from above *Weixing* (μ¹ Sco) to *Niuxing* (Altair, α Aqu), length about 2 *bu* (roughly 30°) long (from μ¹ Sco to Altair is about 62°); they moved to *Huguaxing* (α Del, about 12°) and finally disappeared at the 2nd watch (21-23h).	K: Aurora (NIY, W)	中宗 73 卷, 27 年(1532 壬辰 / 명 가정(嘉靖) 11 年) 6 月 11 日(戊子) Jungjong 73
3 Oct 1532	夜, 彗星見於卯地, 尾長七、八尺許, 色微白, 白氣自西方至東方, 布天。	K: Night. Comet …. White vapors stretched across the sky from the W to E.	K: Aurora (NIY, W), comet	中宗 73 卷, 27 年(1532 壬辰 / 명 가정(嘉靖) 11 年) 9 月 5 日(庚戌) Jungjong 73
9 Nov 1532	丁亥/彗星見於卯地, 尾長三、四尺許, 色白。 乾方、雷, 自東方至西方, 白氣布天。	K: The comet was seen at the E…. White vapors stretched across the sky from the E to W.	K: Aurora (NIY, W), comet	中宗 73 卷, 27 年(1532 壬辰 / 명 가정(嘉靖) 11 年) 10 月 13 日(丁亥) Jungjong 73
3 Feb 1533	夜, 坤方、艮方, 白氣布天。	K: Night. White vapors stretched across the sky in the SW and NE.	K: Aurora (NIY, W)	中宗 73 卷, 28 年(1533 癸巳 / 명 가정(嘉靖) 12 年) 1 月 10 日(癸丑) Jungjong 73
24 Feb 1534	夜, 月暈, 白氣貫暈下, 青赤氣橫着, 長一布長許。	K: Night. The moon haloed. A white vapor passed through the lower part of the halo, which was crossed transversely by blue-green and red vapors about one *bu* (30°) long.	K: Aurora (NIY)	中宗 76 卷, 29 年(1534 甲午 / 명 가정(嘉靖) 13 年) 2 月 12 日(己卯) Jungjong 76

7 Apr 1534	夜, 東方、西方, 黑氣布天。	K: Night. Black vapors stretched across the sky E to W.	K: Aurora (NIY, B)	中宗 77 卷, 29 年(1534 甲午(嘉靖) 13 年) 閏 2 月 24 日(辛酉) Jungjong 77
13 Apr 1534	夜, 黑氣布天。	K: Night. Black vapors stretched across the sky.	K: Aurora (NIY, B)	中宗 77 卷, 29 年(1534 甲午(嘉靖) 13 年) 3 月 1 日(丁卯) Jungjong 77
23 Jun 1535	癸未/白氣布天, 日暈兩珥。 夜, 黑氣布天。	K: White vapors stretched across the sky; the sun haloed with two earrings. Night. Black vapors stretched across the sky.	K: Aurora (NIY, W)	中宗 79 卷, 30 年(1535 乙未(嘉靖) 14 年) 5 月 23 日(癸未) Jungjong 79
28 Jan 1536	夜, 自辰方至申方, 白氣布天。	K: Night. White vapors stretched across the sky from *chen* to *shen* (120° to 240°, azimuths, measured from the north towards the east).	K: Aurora (NIY, W)	中宗 81 卷, 31 年(1536 丙申 / 명 가정(嘉靖) 15 年) 1 月 6 日(壬戌) Jungjong 81
14 Mar 1536	夜, 白氣自卯地至酉地布天。	K: Night. White vapors stretched across the sky from 90° (E) to 270° (W).	K: Aurora (NIY, W)	中宗 81 卷, 31 年(1536 丙申 / 명 가정(嘉靖) 15 年) 2 月 23 日(戊申) Jungjong 81
6 Apr 1536	夜, 乾方、巽方, 白氣布天。	K: Night. White vapors stretched across the sky in the NW and SE. [Typically diametrically opposite.]	K: Aurora (NIY, W)	中宗 81 卷, 31 年(1536 丙申 / 명 가정(嘉靖) 15 年) 3 月 16 日(辛未) Jungjong 81

7 Apr 1536	夜, 巽方、坤方, 白氣布天。	K: Night. White vapors stretched across the sky in the SE and SW.	K: Aurora (NIY, W)	中宗 81 卷, 31 年(1536 丙申 / 명 가정(嘉靖) 15 年) 3 月 17 日(壬申) Jungjong 81
9 Apr 1536	甲戌/夜, 自西方至東方, 白氣布天。	K: Night. White vapors stretched across the sky from the W to E.	K: Aurora (NIY, W)	中宗 81 卷, 31 年(1536 丙申 / 명 가정(嘉靖) 15 年) 3 月 19 日(甲戌) Jungjong 81
13 Jul 1536	夜, 自乾方至南方, 白氣布天, 狀如展布, 良久乃滅。	K: Night. White vapors stretched across the sky from the NW to S. Shaped like an unrolled cloth, they disappeared after a long time.	K: Aurora (NIY, W)	中宗 82 卷, 31 年(1536 丙申 / 명 가정(嘉靖) 15 年) 6 月 26 日(己酉) Jungjong 82
20 Feb 1537	夜, 自西方至南方, 黑氣布天。	K: Night. A black vapor stretched across the sky from the W to S.	K: Aurora (NIY, B)	中宗 83 卷, 32 年(1537 丁酉 / 명 가정(嘉靖) 16 年) 1 月 11 日(辛卯) Jungjong 83
16 Mar 1538	庚申/夜, 白氣貫月布天。	K: Night. A white vapor passed through the moon and spread over the sky.	K: Aurora (NIY, W)	中宗 87 卷, 33 年(1538 戊戌 / 명 가정(嘉靖) 17 年) 2 月 16 日(庚申) Jungjong 87
15 Sep 1538	夜, 白氣自艮方南向, 半天餘, 其廣如席, 漸東去, 良久乃滅。	K: Night. A white vapor [reached] from NE toward the S, stretching over more than half the sky. Wide as a mat, it gradually moved E	K: Aurora (NIY, W)	中宗 88 卷, 33 年(1538 戊戌 / 명 가정(嘉靖) 17 年) 8 月 23 日(癸亥)

		and disappeared after a long time.		Jungjong 88
15 Jan 1539	乙丑/太白晝見。夜, 南方白氣布天, 數十尺許。	K: Venus was seen in daylight. Night. White vapors stretched across the sky in the S; they were roughly several tens of *chi* [long].	K: Aurora (NIY, W)	中宗 89 卷, 33 年(1538 戊戌 / 명 가정(嘉靖) 17 年) 12 月 26 日(乙丑) Jungjong 89
28 Apr 1539	夜, 彗星見於軒轅犀第二星, 旣已雲蔽不見。 月掩土星於太微東垣內, 黑氣如二匹, 橫布東北, 暫時而滅。	K: Comet …. black vapors like two bolts of silk stretched across the NE transversely; they disappeared in a short while. [1st instance of 橫布, occurred 1539-1604.]	K: Aurora (NIY, B)	中宗 90 卷, 34 年(1539 己亥 / 명 가정(嘉靖) 18 年) 4 月 11 日(戊申) Jungjong 90
17 Jun 1539	戊戌/夜, 有雲, 自西方至巽方橫布, 散如白氣, 漸移南方, 良久乃滅。	K: Night. There were clouds stretching across the sky transversely from the W. They dispersed like white vapors, gradually moving S and disappearing after a long time.	K: Aurora (NIY, W)	中宗 91 卷, 34 年(1539 己亥 / 명 가정(嘉靖) 18 年) 6 月 2 日 (戊戌) Jungjong 91
19 Oct 1539	壬寅/日暈。 夜有白氣, 起於坤方, 長竟天, 接于艮方、坤方、乾方, 電光雷動。	K: The sun haloed. Night. There was a white vapor that arose in the SW, stretched far across the sky, and ended in the NE. [There was] thunder and lightning in the SW and NW.	K: Aurora (NIY, W)	中宗 91 卷, 34 年(1539 己亥 / 명 가정(嘉靖) 18 年) 9 月 8 日 (壬寅) Jungjong 91

24 Nov 1539	夜, 月暈, 白氣自辰地貫暈。 白氣又自東方, 至西方布天, 暫時化爲雲而滅。	K: Night. the moon haloed, with a white vapor from the E passing through it. Another white vapor stretched across the sky from E to W. After a short time it changed into a cloud and disappeared. [Shows that vapor was more substantial than cloud.]	K: Aurora (NIY, W)	中宗 92 卷, 34 年(1539 己亥 / 명 가정(嘉靖) 18 年) 10 月 14 日(戊寅) Jungjong 92
2 Feb 1540	夜, 黑氣自西方天際, 至天苑星, 長七八丈許, 布天。	K: Night. Black vapors stretched across the sky from the western horizon reaching about 7 or 8 *zhang* (70-80°) to *Tianyuanxing* (γ Eri).	K: Aurora (NIY, B)	中宗 92 卷, 34 年(1539 己亥 / 명 가정(嘉靖) 18 年) 12 月 25 日(戊子) Jungjong 92
11 Jun 1540	夜, 白氣如匹練, 橫于月上, 起自乾方, 抵坤方。	K: White vapors like an unrolled bolt of silk crossed above the moon; they arose from the NW and reached to the SW.	K: Aurora (NIY, W)	中宗 93 卷, 35 年(1540 庚子 / 명 가정(嘉靖) 19 年) 5 月 7 日(戊戌) Jungjong 93
26 Nov 1540	夜, 有黑氣如布, 起自東方, 至西方, 其長竟天, 轉移于南, 化爲雲蔽天。	K: Night. There was a black vapor like a cloth; it arose in the E and reached to the W, stretching across the sky. It turned and moved S, where it became a cloud covering the sky.	K: Aurora (NIY, B)	中宗 94 卷, 35 年(1540 庚子 / 명 가정(嘉靖) 19 年) 10 月 28 日(丙戌) Jungjong 94
3 Apr 1541	夜, 自西至東, 有雲狀, 如白氣橫天。	K: Night. From E to W, there were [bodies] shaped like clouds. They looked like white vapors crossing the sky transversely.	K: Aurora (NIY, W)	中宗 94 卷, 36 年(1541 辛丑 / 명 가정(嘉靖) 20 年) 3 月 8 日(甲午) Jungjong 94

11 Mar 1542	夜, 白氣布天。	K: Night. White vapors stretched across the sky.	K: Aurora (NIY, W)	中宗 97 卷, 37 年(1542 壬寅 / 명 가정(嘉靖) 21 年) 2 月 25 日(丙子) Jungjong 94
21 Mar 1542	丙戌/日暈。 夜, 坤方、巽方, 黑氣布天	K: The sun haloed. Night. Black vapors stretched across the sky in the SW and SE.	K: Aurora (NIY, B)	中宗 97 卷, 37 年(1542 壬寅 / 명 가정(嘉靖) 21 年) 3 月 6 日(丙戌) Jungjong 97
29 Mar 1542	夜, 坤方、巽方, 白氣布天。	K: Night. White vapors stretched across the sky in the SW and SE. [Note predominance of white vapors in SW.]	K: Aurora (NIY, W)	中宗 97 卷, 37 年(1542 壬寅 / 명 가정(嘉靖) 21 年) 3 月 14 日(甲午) Jungjong 97
25 Oct 1542	夜, 白氣自巽方, 至西方布天。	K: Night. White vapors stretched across the sky from the SE to W.	K: Aurora (NIY, W)	中宗 99 卷, 37 年(1542 壬寅 / 명 가정(嘉靖) 21 年) 9 月 17 日(甲子) Jungjong 99
26 Mar 1543	丙申/日暈, 冠。 夜, 白氣自酉地, 至巽方布天。	K: The sun haloed…. Night. White vapors stretched across the sky from 270° to the SE.	K: Aurora (NIY, W)	中宗 100 卷, 38 年(1543 癸卯 / 명 가정(嘉靖) 22 年) 2 月 22 日(丙申) Jungjong 100
28 Mar 1543	夜, 白氣自巽方至乾方布天。	K: Night. White vapors stretched across the sky from the SE to the NW.	K: Aurora (NIY, W)	中宗 100 卷, 38 年(1543 癸卯 / 명 가정(嘉靖) 22 年) 2 月 24 日(戊戌)

				Jungjong 100
14 May 1543	夜, 巽方白氣布天。	K: Night. White vapors stretched across the sky in the SE.	K: Aurora (NIY, W)	中宗 100 卷, 38 年(1543 癸卯 / 명 가정(嘉靖) 22 年) 4 月 11 日(乙酉) Jungjong 100
18 Jul 1543	夜, 自乾方至西方, 白氣布天。	K: Night. White vapors stretched across the sky from the NW to W.	K: Aurora (NIY, W)	中宗 100 卷, 38 年(1543 癸卯 / 명 가정(嘉靖) 22 年) 6 月 17 日(庚寅) Jungjong 100
28 Jul 1543	夜, 自北方至南方, 白氣三道布天, 良久乃滅。	K: Night. [There were] 3 bands of white vapor stretching across the sky from the N to S. They disappeared after a long time.	K: Aurora (NIY, W)	中宗 100 卷, 38 年(1543 癸卯 / 명 가정(嘉靖) 22 年) 6 月 27 日(庚子) Jungjong 100
2 Aug 1543	乙巳/夜, 東北方黑氣二道布天, 暫時而滅。	K: Night. Two black bands of vapor stretched across the sky in the NE; they disappeared after a short time. [2nd lunar day.]	K: Aurora (NIY, B)	中宗 101 卷, 38 年(1543 癸卯 / 명 가정(嘉靖) 22 年) 7 月 2 日(乙巳) Jungjong 101
28 Oct 1543	夜, 艮方黑氣布天。	K: Night. A black vapor stretched across the sky in the NE.	K: Aurora (NIY, B)	中宗 101 卷, 38 年(1543 癸卯 / 명 가정(嘉靖) 22 年) 10 月 1 日(壬申) Jungjong 101

5 Jan 1544	夜, 坤方白氣布天。	K: Night. White vapors stretched across the sky in the SW.	K: Aurora (NIY, W)	中宗 101 卷, 38 年(1543 癸卯 / 명 가정(嘉靖) 22 年) 12 月 11 日(辛巳) Jungjong 101
15 Mar 1544	日暈, 兩珥冠, 白氣如環貫日。 夜, 南方、巽方、乾方, 有氣如火。	K: The sun haloed with two earrings and bonnets [at the side of the sun]. White vapors like rings passed through the sun. Night. There were vapors like fire in the S and SE.	K: Aurora (NIY, F)	中宗 102 卷, 39 年(1544 甲辰 / 명 가정(嘉靖) 23 年) 2 月 22 日(辛卯) Jungjong 102
1 May 1544	戊寅/夜有白氣, 自巽方至艮方, 布天。	K: Night. There were white vapors stretching across the sky from the SE to the NE.	K: Aurora (NIY, W)	中宗 102 卷, 39 年(1544 甲辰 / 명 가정(嘉靖) 23 年) 4 月 10 日(戊寅) Jungjong 102
19 Nov 1544	自四更至五更, 黑氣自西方至東方布天。 初昏, 西方有氣直立, 長四五丈許, 下大上銳。 初見時色黑, 漸變爲黃白, 屈曲狀如龍形。 移時乃滅。	K: A black vapor stretched across the sky from the W to E from the 4th to 5th watches (1-3am to 3–5am). At twilight, there was an erect vapor in the W, about 4-5 *zhang* (40-50°) long, big at its base and pointed above. It was black when first seen; it gradually turned yellow and white, with a crooked shape like that of a snake. It disappeared after a while.	K: Aurora (NIY, B)	中宗 105 卷, 39 年(1544 甲辰 / 명 가정(嘉靖) 23 年) 11 月 5 日(庚子) Jungjong 105

22 Jan 1545	夜, 黑氣如雲, 橫亘東西。	K: Night. Black vapors like clouds stretched across the sky transversely E to W.	K: Aurora (NIY, B)	仁宗 1 卷, 1 年(1545 乙巳 / 명 가정(嘉靖) 24 年) 1 月 10 日(甲辰) Injong 1
31 Aug 1545	巳時, 太白見於午地, 日暈。 夜, 巽方有雲如氣, 色黃白, 指中天, 移時而滅。 白雲六道, 幷起西方, 或長或短, 或屈曲如氣。 皆指天中, 漸移北方而滅。 白氣一雙, 自東方至西方布天。	K: At the 09-11 double-hour, Venus was seen at the S. The sun haloed. Night. There were clouds (dim auroras) like vapors colored yellow and white in the SE. Pointing to mid-sky, they disappeared after a while. [There were] 6 bands of white vapor, all arising in the W. Some were long, some short, some winding like vapors. All pointed to mid-sky, gradually moving to the N and disappearing. One pair of white vapors stretched across the sky from E to W.	K: Aurora (NIY, W, Y)	明宗 1 卷, 卽位年(1545 乙巳 / 명 가정(嘉靖) 24 年) 7 月 25 日(乙酉) Myeongjong 1

27 Oct 1545	午時, 太白見於未地。 夜自初更至二更, 北方、乾方、坤方有電光; 三更, 乾、坤兩方雷電; 四更, 地震, 自東而西, 乾方、坤方、南方、天中雷電, 艮方、巽方有如火氣; 五更, 坤方電動, 南北有電光。	K: …. Night….4th watch (1-3am), …There were dim fire-vapors in the NE and SE. [Note lightning, thunder, earthquakes.]	K: Aurora (NIY, FV)	明宗 2 卷, 卽位年(1545 乙巳 / 명 가정(嘉靖) 24 年) 9 月 22 日(壬午) Myeongjong 2
2 Dec 1545	夜一更, 有黑氣二道, 自乾方指坤方, 長各一匹許。	K: Night. There were two bands of black vapors, pointing from NW to SW, each about the length of a bolt of cloth (40°).	K: Aurora (NIY, B)	明宗 2 卷, 卽位年(1545 乙巳 / 명 가정(嘉靖) 24 年) 10 月 29 日(戊午) Myeongjong 2
4 Jan 1546	辛卯/夜, 南北坤三方, 如火氣。	K: Night. There were dim fire-vapors in the S, N, and SW.	K: Aurora (NIY, FV)	明宗 2 卷, 卽位年(1545 乙巳 / 명 가정(嘉靖) 24 年) 12 月 2 日(辛卯) Myeongjong 2
9 May 1546	夜, 巽方、南方、坤方, 如火氣。	K: Night. There were dim fire-vapors in the SE, S, and SW.	K: Aurora (IY, FV)	明宗 3 卷, 1 年(1546 丙午 / 명 가정(嘉靖) 25 年) 4 月 10 日(丙申) Myeongjong 3
3 Jun 1546	申時, 京師雨雹。 夜, 巽方、乾方如火氣。	K: …. Night. There were dim fire-vapors in the SE and NW.	K: Aurora (NIY, FV)	明宗 3 卷, 1 年(1546 丙午 / 명 가정(嘉靖) 25 年) 5 月 6 日(辛酉)

				Myeongjong 3
10 Jan 1547	夜, 白氣布天。 月暈。	K: Night. White vapor stretched across the sky. The moon haloed.	K: Aurora (NIY, W)	明宗 4 卷, 1 年 (1546 丙午 / 명가정(嘉靖) 25 年) 12 月 19 日(壬寅) Myeongjong 4
Report: 27 Apr; Event: 25 Apr 1548	傳曰: "予觀今月十八日夜二更, 月色沈黑如蝕,傍有紫氣, 深以爲怪	K: The emperor said: "At the 2nd watch of the night (9-11pm), the 18th day of the lunar month (25 Apr), I saw the moon colored deep black as if it were eclipsed; next to it was a purple vapor; I thought it was very strange and ominous."	K: Aurora (NIY, P)	明宗 7 卷, 3 年 (1548 戊申 / 명가정(嘉靖) 27 年) 3 月 20 日(乙未) Myeongjong 7
9 Dec 1548	夜, 乾方、艮方如火氣。	K: Night. Dim fire-vapors in the NW and NE.	K: Aurora (NIY, FV)	明宗 8 卷, 3 年 (1548 戊申 / 명가정(嘉靖) 27 年) 11 月 10 日(辛巳) Myeongjong 8
24 Jan 1549	夜, 艮方、坤方如火氣。	K: Night. Dim fire-vapors in the NE and SW.	K: Aurora (NIY, FV)	明宗 8 卷, 3 年 (1548 戊申 / 명가정(嘉靖) 27 年) 12 月 26 日(丁卯) Myeongjong 8
11 Feb 1549	夜, 月暈, 兩珥, 冠重暈。 白氣, 自西方至東方, 貫暈, 暫時而滅。	K: Night. The moon had two earrings and bonnets and a triple halo. A white vapor from the W to E passed	K: Aurora (NIY, W)	明宗 9 卷, 4 年 (1549 己酉 / 명가정(嘉靖) 28 年) 1 月 14 日(

		through the halo. It disappeared after a short while.		乙酉) Myeongjong 9
20 Dec 1549	夜, 東西南方天中, 如火氣。	K: Night. Dim fire-vapors in the E, W, S, and mid-sky.	K: Aurora (NIY, FV)	明宗 9 卷, 4 年 (1549 己酉 / 명 가정(嘉靖) 28 年) 12 月 2 日(丁酉) Myeongjong 9
14 May 1550	壬戌/日暈, 兩珥。 夜, 巽方南方坤方, 如火氣。	K: …. Night. Dim fire-vapors in the SE, the S, and the SW.	K: Aurora (NIY, FV)	明宗 10 卷, 5 年 (1550 庚戌 / 명 가정(嘉靖) 29 年) 4 月 28 日(壬戌) Myeongjong 10
10 Oct 1550	辛卯朔/夜二更, 黑雲如氣, 橫截南北, 如數匹布着天。 四更, 黑氣東西竟天, 廣如練, 良久乃滅。	K: At the 2nd watch of the night, black clouds like vapors spread, cutting across the sky S to N like several bolts of cloth. At the 4th watch, a black vapor, as wide as a bolt of silk, crossed the sky E to W. After a long time it disappeared.	K: Auroras (NIY, B)	明宗 10 卷, 5 年 (1550 庚戌 / 명 가정(嘉靖) 29 年) 9 月 1 日(辛卯) Myeongjong 10
27 Mar 1551	日微暈, 兩珥。 夜, 巽方如火氣, 月微暈。	K: …. Night. Dim fire-vapors in the SE; the moon had a slight halo.	K: Aurora (NIY, FV)	明宗 11 卷, 6 年 (1551 辛亥 / 명 가정(嘉靖) 30 年) 2 月 21 日(己卯) Myeongjong 11

16 Apr 1551	夜月暈。 白氣如練, 自乾方至巽方, 貫暈布天, 移而北, 化爲雲, 良久乃散。	K: Night. The moon haloed. A white vapor like silk spread across the sky from the NW to SE, passing through the halo. Moving northwards, it changed into a cloud (became dimer) and disappeared after a long time.	K: Aurora (NIY, W)	明宗 11 卷, 6 年 (1551 辛亥 / 명가정(嘉靖) 30 年) 3 月 11 日(己亥) Myeongjong 11
29 Apr 1551	日暈, 色內黃外青。 夜, 坤方如火氣。	K: The sun haloed; Its colors were inner yellow and outer blue-green. Night. Dim fire-vapors in the SW.	K: Aurora (NIY, FV)	明宗 11 卷, 6 年 (1551 辛亥 / 명가정(嘉靖) 30 年) 3 月 24 日(壬子) Myeongjong 11
15 May 1551	夜, 白氣自乾方至巽方布天, 暫時而滅。	K: Night. A white vapor spread across the sky from the NW to SE and disappeared after a short time.	K: Aurora (NIY, W)	明宗 11 卷, 6 年 (1551 辛亥 / 명가정(嘉靖) 30 年) 4 月 10 日(戊辰) Myeongjong 11
15 Jun 1551	月暈兩珥, 色白。 東方、南方, 如火氣。	K: The moon haloed with two earrings colored white. Dim fire-vapors in the E and S.	K: Aurora (NIY, FV)	明宗 11 卷, 6 年 (1551 辛亥 / 명가정(嘉靖) 30 年) 5 月 12 日(己亥)
1 Dec 1551	夜, 巽方、艮方、乾方, 如火氣。	K: Night. Dim fire-vapors in the SE, NE, and NW.	K: Aurora (NIY, FV)	明宗 12 卷, 6 年 (1551 辛亥 / 명가정(嘉靖) 30 年) 11 月 4 日(戊子)

3 Jan 1552	月暈。 夜, 白氣一道、黑氣一道, 自坤方貫暈, 至北河星, 黑氣滅後, 白氣漸長, 移北方, 良久乃滅。	K: The moon haloed. Night. One band of white vapor and one of black vapor passed through the halo from the SW reaching to *Beihexing* (α Gem). After the black vapor disappeared, the white vapor gradually lengthened and moved northward. It disappeared after a long time.	K: Aurora (NIY, W, B)	明宗 12 卷, 6 年 (1551 辛亥 / 명 가정(嘉靖) 30 年) 12 月 8 日(辛酉) Myeongjong 12
9 Feb 1552	夜一更, 月上, 白氣一道如虹, 自北方北斗魁第二星貫之, 至天圓星, 巽方漸移, 貫月竟天。 又月下, 白氣二道, 自巽方至艮方布天, 良久乃滅。 五更, 月暈兩珥, 色白。	K: At the 1st watch of the night, a white vapor like a *hong* (arc), beginning from the N, passed through *Beidoukui Dierxing* (β UMa), reaching to *Tianyuanxing* (?). It gradually moved to the SE, passing through the moon and stretching across the sky. It disappeared after a long time. At the 5th watch (03-05h) the moon haloed with two earrings colored white.	K: Aurora (NIY, W)	明宗 13 卷, 7 年 (1552 壬子 / 명 가정(嘉靖) 31 年) 1 月 15 日(戊戌) Myeongjong 13
27 Feb 1552	夜, 有氣如雲, 自西方至艮方布天, 長四尺許, 漸移東南方, 須更而滅。 北方、東方、南方、乾方、坤方、如火氣。	K: Night. There were vapors like clouds, about 4 chi (4°) stretching across the sky from W to NE. They gradually moved to the SE and disappeared after a while. Dim fire-vapors in the N, E, S, NW, and SW.	K: Aurora (NIY, FV)	明宗 13 卷, 7 年 (1552 壬子 / 명 가정(嘉靖) 31 年) 2 月 4 日(丙辰) Myeongjong 13

16 Mar 1552	夜, 艮方、南方、坤方、如火氣。	K: Night. Dim fire-vapors in the NE, S, and SW.	K: Aurora (NIY, FV)	明宗 13 卷, 7 年 (1552 壬子 / 명가정(嘉靖) 31 年) 2 月 22 日(甲戌) Myeongjong 13
5 Apr 1552	午時, 日有冠, 未時、申時, 日暈兩珥。 夜, 月暈, 有白氣自艮方斜抵暈上, 良久乃滅。 有白雲升自西, 漸轉天中, 橫亘艮、坤方而滅。	K: At the noon double-hour, the sun had bonnets…. Night. The moon haloed. There was a white vapor slanting from the NE to above the halo. It disappeared after a long time. There was a white vapor rising from the W; it gradually shifted to mid-sky, crossing it transversely from NE to SW.	K: Aurora (NIY, W)	明宗 13 卷, 7 年 (1552 壬子 / 명가정(嘉靖) 31 年) 3 月 12 日(甲午) Myeongjong 13
16 Jun 1552	夜, 有氣起自北方, 直抵巽方, 色白, 良久乃滅。 又黑雲如氣, 自乾方至坤方橫布, 移時乃散。	K: Night. Vapors arose from the N, reaching straight to the SE. They were colored white and disappeared after a long time. Again, black clouds like vapors stretched across the sky transversely from NW to SW, disappearing after a while. [“... clouds like vapors … stretched transversely across the sky…” could be tech term for “curtain aurora.”]	K: Aurora (NIY, W, B)	明宗 13 卷, 7 年 (1552 壬子 / 명가정(嘉靖) 31 年) 5 月 25 日(丙午) Myeongjong 13

25 Jun 1552	夜, 乾方黑雲一道如氣, 如一匹布長, 橫布巽方天際; 黑雲二道如氣, 如二匹布長橫布, 移時乃滅。	K: [The sun haloed.] Night. There was a band of black cloud like a vapor, like a bolt of cloth long (30°), stretching across the sky transversely at the SE horizon; then two bands of black clouds like vapors, like two bolts of cloth long, stretching across the sky transversely. They disappeared in a short time.	K: Auroras (NIY, B)	明宗 13 卷, 7 年 (1552 壬子 / 명가정(嘉靖) 31 年) 6 月 4 日(乙卯) Myeongjong 13
3 Jul 1552	日暈。 夜, 白雲如氣, 自坤方至艮方, 天際橫布, 良久乃滅。	K: The sun haloed. Night. White clouds like vapors stretched across the horizon transversely from SW to NE. They disappeared after a long time.	K: Aurora (NIY, W)	明宗 13 卷, 7 年 (1552 壬子 / 명가정(嘉靖) 31 年) 6 月 12 日(癸亥) Myeongjong 13
14 Aug 1552	夜, 黑雲如氣, 自南方至北橫布, 漸移於東, 良久乃滅。	K: Night. Black clouds like vapors, stretching across the sky transversely from S to N, gradually moving to the E, and disappearing after a long time.	K: Auroras (NIY, B)	明宗 13 卷, 7 年 (1552 壬子 / 명가정(嘉靖) 31 年) 7 月 25 日(乙巳) Myeongjong 13
24 Sep 1552	丙戌/夜, 白雲三度如氣, 自東方至南方橫布, 漸移巽方乃滅。	K: Night. Three lengths of white clouds like vapors, stretching across the sky transversely from E to S, gradually moving SE and disappearing.	K: Aurora (NIY, W)	明宗 13 卷, 7 年 (1552 壬子 / 명가정(嘉靖) 31 年) 9 月 7 日(丙戌) Myeongjong 13
6 Feb 1553	日微暈。 夜, 巽方如火氣。	K: The sun had a slight halo. Night. Dim fire-vapors in the SE.	K: Aurora (NIY, FV)	明宗 14 卷, 8 年 (1553 癸丑 / 명가정(嘉靖) 32 年) 1 月 24 日(辛丑)

				Myeongjong 14
24 Feb 1553	日微暈。 夜, 月暈, 有白氣如雲, 自艮方至貫索星, 暫時而滅。	K: The sun had a slight halo. Night. The moon haloed. There was a white vapor like a cloud [running] from the NE to *Guansuoxing* (π CrB); it disappeared after a short time.	K: Aurora (NIY, W)	明宗 14 卷, 8 年 (1553 癸丑 / 명가정(嘉靖) 32 年) 2 月 12 日(己未) Myeongjong 14
3 Mar 1553	夜, 黑氣如雲, 自東方至西方橫着, 良久乃滅。 月暈右珥冠。	K: Night. Black vapors like clouds stretching transversely from E to W. They disappeared after a long time. The moon haloed with left earrings and a *guan* (bonnet).	K: Aurora (NIY, B)	明宗 14 卷, 8 年 (1553 癸丑 / 명가정(嘉靖) 32 年) 2 月 19 日(丙寅) Myeongjong 14
10 Mar 1553	日暈。 夜, 坤方如火氣。	K: The sun had a slight halo. Night. Dim fire-vapors in the SW.	K: Aurora (NIY, FV)	明宗 14 卷, 8 年 (1553 癸丑 / 명가정(嘉靖) 32 年) 2 月 26 日(癸酉) Myeongjong 14
8 Aug 1553	甲辰/夜, 乾方、巽方, 如火氣。	K: Night. Dim fire-vapors in the NW and SE.	K: Aurora (NIY, FV)	明宗 14 卷, 8 年 (1553 癸丑 / 명가정(嘉靖) 32 年) 6 月 29 日(甲辰) Myeongjong 14
14 Aug 1553	夜, 南方天際有白氣如雲, 自坤方至巽方布天, 良久而滅。	K: Night. There was a white vapor like a cloud at the southern horizon. It spread across the sky from SW to SE and disappeared after a long time.	K: Aurora (NIY, W)	明宗 15 卷, 8 年 (1553 癸丑 / 명가정(嘉靖) 32 年) 7 月 6 日(庚戌) Myeongjong 15

5 Apr 1554	夜, 艮方、巽方, 如火氣。	K: Night. Dim fire-vapors in the SE, and SW.	K: Aurora (NIY, FV)	明宗 16 卷, 9 年(1554 甲寅 / 명 가정(嘉靖) 33 年) 3 月 4 日(甲辰) Myeongjong 16
4 Sep 1554	日微暈。 夜, 黑雲如氣, 自西方至巽方橫布, 良久乃滅。	K: The sun had a slight halo. Night. Black clouds like vapors stretching across the sky transversely from W to SE; they disappeared after a long time.	K: Aurora (NIY, B)	明宗 17 卷, 9 年(1554 甲寅 / 명 가정(嘉靖) 33 年) 8 月 8 日(丙子) Myeongjong 17
5 Mar 1555	日赤無光。 日微暈。 夜, 月暈, 白雲如氣, 自乾方至艮方, 布天, 良久乃滅。	The sun was red and dim with a slight halo. Night. The moon haloed. White clouds like vapors stretched across the sky from NW to NE. After a long time they disappeared. [13th lunar day]	Likely aurora (NIY, W)	明宗 18 卷, 10 年(1555 乙卯(嘉靖) 34 年) 2 月 13 日(戊寅) Myeongjong 18
21 Jun 1555	夜, 巽方、坤方, 如火氣。	K: Night. Dim fire-vapors in the SE and SW.	K: Aurora (NIY, FV)	明宗 18 卷, 10 年(1555 乙卯 / 명 가정(嘉靖) 34 年) 6 月 3 日(丙寅) Myeongjong 18
3 Feb 1556	癸丑/夜, 白氣自西方至艮方布天, 漸移東方而滅。	K: Night. A white vapor spread across the sky from the W to NE. It gradually moved E and disappeared.	K: Aurora (NIY, W)	明宗 19 卷, 10 年(1555 乙卯 / 명 가정(嘉靖) 34 年) 12 月 23 日(癸丑) Myeongjong 19

9 Mar 1556	彗星見於太微東垣外, 在角宿初度, 去北極六十五度, 尾指西南, 長三尺餘, 光芒射及東垣第五星, 色白。 黑氣一道, 自巽方至坤方布天, 良久而滅。	K: Comet…. There was one band of black vapor stretching across the sky from SE to SW. It disappeared after a long time. [Note the association of comet with vapor.]	K: Aurora (NIY, B)	明宗 20 卷, 11 年(1556 丙辰 / 명 가정(嘉靖) 35 年) 1 月 28 日(戊子) Myeongjong 20
24 May 1556	甲辰/夜, 月色赤, 有黑氣如雲, 橫帶月中, 暫時而滅。 月微暈。	K: Night. The moon was red. A [dim] black vapor like a cloud passed transversely [like a] belt through the midst of the moon and quickly disappeared. The moon had a slight halo.	K: Aurora (NIY, B)	明宗 20 卷, 11 年(1556 丙辰 / 명 가정(嘉靖) 35 年) 4 月 16 日(甲辰) Myeongjong 20
18 Jun 1556	夜, 月微暈。 白氣一道, 自坤方至巽方, 冒月而過。	K: Night. The moon had a slight halo. One band of white vapor [running] from SW to SE rose over the moon in passing.	K: Aurora (NIY, W)	明宗 20 卷, 11 年(1556 丙辰 / 명 가정(嘉靖) 35 年) 5 月 12 日(己巳) Myeongjong 20
19 Aug 1556	夜, 月暈。 黑氣一道自坤方至巽方布天, 暫時而滅。 白氣如雲, 自坤方至暈內, 漸移艮方而滅。	K: Night. the moon haloed. A band of black vapor stretched across the sky from SW to SE and disappeared quickly. A white vapor like a cloud ran from SW to w/in the halo. It gradually moved NE and disappeared.	K: Aurora (NIY, B, W)	明宗 21 卷, 11 年(1556 丙辰 / 명 가정(嘉靖) 35 年) 7 月 15 日(辛未) Myeongjong 21
30 Oct 1556	夜, 坤方如火氣。 黃海道載寧, 雷動。	K: Night. Dim fire-vapors in the SW. Thunder in ….	K: Aurora (NIY, W)	明宗 21 卷, 11 年(1556 丙辰 / 명 가정(嘉靖) 35 年) 9 月 28 日(癸未)

				Myeongjong 21
10 Nov 1556	夜, 流星出東方, …。 黑氣一度, 自南方至坤方橫布, 長三四丈許。	K: Night. A meteor…. Then a black vapor about 3-4 *zhang* long (30-40°) spread from the S to SW transversely.	K: Aurora (NIY, B)	明宗 21 卷, 11 年(1556 丙辰 / 명 가정(嘉靖) 35 年) 10 月 9 日(甲午) Myeongjong 21
11 Nov 1556	乙未/夜, 月暈。 白氣一道起巽方, 貫暈指乾方。 巽方、南方、坤方, 如火氣。	K: Night. The moon haloed. One band of white vapor, arising in the SE and pointing NW, passed through the halo. Dim fire-vapors [were] in the SE, S, and SW. [Yau omitted the white vapor.]	K: Aurora (partially IY, W, FV)	明宗 21 卷, 11 年(1556 丙辰 / 명 가정(嘉靖) 35 年) 10 月 10 日(乙未) Myeongjong 21
17 Nov 1556	辛丑/夜, 白氣一道自巽方, 至西方如布練, 竟天乃滅。	K: Night. One band of white vapor like a bolt of silk spread across the sky from SE to W. Having stretched across the sky, it disappeared.	K: Aurora (NIY, W)	明宗 21 卷, 11 年(1556 丙辰 / 명 가정(嘉靖) 35 年) 10 月 16 日(辛丑) Myeongjong 21
13 Dec 1556	丁卯/夜, 四方沈霧, 月暈。 白氣一道, 自坤方至艮方布天, 貫暈, 漸移巽方而滅。	K: Night…. The moon haloed. One band of white vapor spread across the sky from SW to NE, passing through the halo; gradually moving SE, it disappeared.	K: Aurora (NIY, W)	明宗 21 卷, 11 年(1556 丙辰 / 명 가정(嘉靖) 35 年) 11 月 12 日(丁卯) Myeongjong 21

27 Dec 1556	日暈兩珥。 夜, 黑氣一道, 自艮方至南方橫布, 良久乃滅。 四更, 黑氣一道, 自巽方至坤方, 長三四丈許, 移時而滅。	K: The sun haloed …. Night. A band of black vapor stretched transversely NE to S; it lasted a long time before it disappeared. At the 4th watch a band of black vapor about 3-4 *zhang* long (30-40°) [ran] from SE to SW; it disappeared after a while.	K: Aurora (NIY, B]	明宗 21 卷, 11 年(1556 丙辰 / 명 가정(嘉靖) 35 年) 11 月 26 日(辛巳) Myeongjong 21
9 Feb 1557	夜, 月暈。 白氣一道自艮方指坤方, 貫暈, 暫移巽方而滅。	K: Night. The moon haloed. One band of white vapor [ran] from NE pointing to the SW and passing through the halo; it shortly moved toward the SE and disappeared.	K: Aurora (NIY, W)	明宗 22 卷, 12 年(1557 丁巳 / 명 가정(嘉靖) 36 年) 1 月 11 日(乙丑) Myeongjong 22
23 Mar 1557	丁未/日微暈。 夜, 巽方、東方如火氣, 艮方雷動電光, 坤方如火氣。	Korea: Slight solar halo; night, dim fire vapor (aurora) in the SE & E; lightning in NE; a dim fire vapor in SW.	Korea: Solar halo, aurora (NIY, FV)	明宗 22 卷, 12 年 1557 丁巳 / 嘉靖) 36 年 2 月 23 日(丁未) Myeongjong 22
2 Jun 1557	日微暈。 初昏, 白氣一道, 自坤方至丑方橫布, (斬)〔暫〕移天中, 良久乃滅。	K: At early dusk, there was a band of white vapor stretching transversely from the SW to the 30° heading; it shortly moved into mid-sky and disappeared after a long time.	K: Aurora (NIY, W)	明宗 22 卷, 12 年(1557 丁巳 / 명 가정(嘉靖) 36 年) 5 月 6 日(戊午) Myeongjong 22
10 Jul 1557	夜, 月暈。 赤雲如氣, 自東方至南方橫布, 冒過月中, 暫移巽方, 變爲白雲而滅。	K: The moon haloed. A red cloud like a vapor stretched transversely across the sky from the E to the S. Passing mid-moon, it quickly moved to the SE, where it became	K: Aurora (NIY, R, W)	明宗 23 卷, 12 年(1557 丁巳 / 명 가정(嘉靖) 36 年) 6 月 15 日(丙申) Myeongjong 23

		a white cloud and disappeared.		
29 Oct 1557	白氣如布練, 自乾方横抵日上, 三尺許, 暫時而滅。 夜一更, 彗星行度, 與月行相近, 爲月光所射, 雲氣蔽不見。 彗星白氣一道, 如布練, 自乾方至巽方, 長可十五丈許, 漸移東方, 良久乃滅。 月暈。 黑氣一道, 起自巽方, 貫暈至月, 廣如布, 長十餘丈。	K: A white vapor …. At the 1st watch of the night, the comet …. The moon haloed. One band of black vapor arose in the SE and reached the moon, passing through its halo; it was as wide as a bolt of cloth and more than 10 *zhang* (100°) long.	K: Aurora (NIY, B]	明宗 23 卷, 12 年(1557 丁巳 / 명 가정(嘉靖) 36 年) 10 月 8 日(丁亥) Myeongjong 23
31 Oct 1557	己丑/日微暈。 夜, 西南天際有淡雲, 不見彗星。 白氣一道, 自艮方天際, 指天中, 廣如布練, 長十丈許, 移東方, 良久而滅。 月暈。 黑氣三道, 廣如布練, 自西方至東方彌天, 良久乃滅。	K: …. Night. There were pale clouds on the horizon and the comet was not seen. A band of white vapor pointing to mid-sky reached from NE to the horizon. It was as wide as a bolt of silk and about 10 zhang (100°) long. Moving eastward, it disappeared after a long time. The moon haloed. Three bands of black vapors as wide as bolts of silk filled the sky W to E. They disappeared after a long	K: Aurora (NIY)	明宗 23 卷, 12 年(1557 丁巳 / 명 가정(嘉靖) 36 年) 10 月 10 日(己丑) Myeongjong 23

		while.		
2 Dec 1557	夜, 月暈。 蒼白氣起乾方, 抵巽方, 長竟天, 良久乃滅。	K: Night. The moon haloed. A blue-green and white vapor arose in the NW, stretching far across the sky to reach the SE. It disappeared after a long time.	K: Aurora (NIY)	明宗 23 卷, 12 年(1557 丁巳 / 명 가정(嘉靖) 36 年) 11 月 12 日(辛酉) Myeongjong 23
30 Apr 1558	庚寅/夜, 白氣二道, 起自艮方, 至坤方布天, 移時乃滅。	K: Night. Two bands of white vapor spread across the sky, arising from NE and reaching to SW; after a while they disappeared.	K: Aurora (NIY, W)	明宗 24 卷, 13 年(1558 戊午 / 명 가정(嘉靖) 37 年) 4 月 13 日(庚寅) Myeongjong 24
4 Jun 1558	夜, 坤方、巽方、乾方, 如火氣。	K: Night. Dim fire-vapors in the SE, SW, and NW.	Aurora (NIY, FV)	明宗 24 卷, 13 年(1558 戊午 (嘉靖) 37 年) 5 月 18 日(乙丑) Myeongjong 24
19 Jul 1558	庚辰/夜, … 白氣一道, 自南方至北方竟天, 良久乃滅。	K: Night…. One band of white vapor stretched across the sky from the S to N. It disappeared after a long time.	K: Aurora (NIY, W)	明宗 24 卷, 13 年(1558 戊午 / 명 가정(嘉靖) 37 年) 閏 7 月 5 日(庚辰) Myeongjong 24

6 Nov 1558	日微暈。 夜, 巽方、坤方, 有火氣。	K: Night. There were fire-vapors in the SE and SW.	K: Aurora (NIY, FV)	明宗 24 卷, 13 年(1558 戊午 (嘉靖) 37 年) 9 月 27 日(庚子) Myeongjong 24
25 Feb 1559	日微暈。 夜, 東方、南方, 如火氣。	K: The sun had a slight halo. Night. Dim fire-vapors in the E and S.	Aurora (NIY, FV)	明宗 25 卷, 14 年(1559 己未(嘉靖) 38 年) 1 月 19 日(辛卯) Myeongjong 25
12 Aug 1560	日微暈。 夜, 白氣二道, 起於巽方, 一道至乾方, 一道至五車星, 如在練。漸移西方乃滅。	K: The sun haloed. Night. Two bands of white vapor arose at the SE. One band reached to the NW; one band was like silk and reached to Wuchexing (ι Aur). They gradually moved to the W and disappeared.	K: Aurora (NIY, W)	明宗 26 卷, 15 年(1560 庚申 / 명 가정(嘉靖) 39 年) 7 月 21 日(乙酉) Myeongjong 26
12 Mar 1561	丁巳/夜, 巽方、南方、坤方, 有火氣。	K: Night. There were fire-vapors in the SE, S, and SW.	K: Aurora (NIY, FV)	明宗 27 卷, 16 年(1561 辛酉 (嘉靖) 40 年) 2 月 27 日(丁巳) Myeongjong 27
14 Mar 1561	夜, 巽方如火氣。	K: Night. Dim fire-vapors in the SE.	K: Aurora (NIY, FV)	明宗 27 卷, 16 年(1561 辛酉(嘉靖) 40 年) 2 月 29 日(己未) Myeongjong 27
7 Apr 1561	夜, 東方、巽方、南方, 如火氣。 月微暈。	K: Night. Dim fire-vapors in the E, SE, and S.	K: Aurora (NIY, FV)	明宗 27 卷, 16 年(1561 辛酉 (嘉靖) 40 年) 3 月 23 日(癸未) Myeongjong 27

14 Apr 1561	日微暈。 夜, 艮方、巽方, 如火氣。	K: Night. Dim fire-vapors in the NE and SE.	K: Aurora (NIY, FV)	明宗 27 卷, 16 年(1561 辛酉 (嘉靖) 40 年) 4 月 1 日(庚寅) Myeongjong 27
10 Jun 1562	壬辰/夜, 有黑氣, 廣一尺餘, 東西竟天。 其狀穹窿不移, 至曉乃滅。	K: Night. There was a black vapor more than one *chi* (1°) wide stretching across the sky E to W. It was long and winding and didn't move. It disappeared at dawn.	K: Aurora (NIY, B]	明宗 28 卷, 17 年(1562 壬戌 / 명 가정(嘉靖) 41 年) 5 月 9 日(壬辰) Myeongjong 28
23 Feb 1563	庚戌朔/夜, 乾、巽、西南方及天中, 如火氣。	K: Night. Dim fire-vapors in the NW, SE, SW, and mid-sky.	K: Aurora (NIY, FV)	明宗 29 卷, 18 年(1563 癸亥 / 명 가정(嘉靖) 42 年) 2 月 1 日(庚戌) Myeongjong 29
24 Feb 1564	夜, 月暈, 白氣一道如匹練, 自巽方直至西方橫布, 良久乃滅。	K: Night. The moon haloed. One band of white vapor spread transversely, like a bolt of silk, across the sky from the SE to the W; after a long time it disappeared.	K: Aurora (NIY, W)	明宗 30 卷, 19 年(1564 甲子 / 명 가정(嘉靖) 43 年) 2 月 13 日(丙辰) Myeongjong 30
11 Jul 1566	夜, 巽方如火氣。	K: Night. Dim fire-vapors in the SE.	K: Aurora (NIY, FV)	明宗 33 卷, 21 年(1566 丙寅(嘉靖) 45 年) 6 月 25 日(甲申) Myeongjong 33
28 Mar 1594	夜一更, 白氣一道, 自坤方, 至巽方, 廣尺餘, 長五六尺, 良久乃滅。	K: At the 1st watch of the night (19-21h), [there was] one band of white vapor [running] from the SW to SE. It was more than 1 *chi* (1°) wide and 5-6 *chi* long; it	K: Aurora (NIY, W)	宣祖 48 卷, 27 年(1594 甲午 / 명 만력(萬曆) 22 年) 2 月 7 日(丙辰) Seonjo 48

		disappeared after a long time.		
24 Jul 1594	夜一更, 流星出敗苽星下, 入巽方天際, 狀如拳, 尾長五六尺許, 色赤。 白雲一道, 自乾方至巽方, 長可四五尺, 廣可二尺, 輪(困)〔囷〕而移, 良久乃滅。 白氣一道, 自天中至南方, 長可六七尺, 廣可一尺, 良久乃滅。	K: At the 1st watch of the night, …. [there was] one band of white cloud [running] from the NW to the SE. It was perhaps 4-5 *chi* (4-5°) long and 2 *chi* wide. Moving, it ringed *Tianqun* (Celestial Granary, α Cet) and disappeared after a long time. [There was] one band of white vapor [running] from mid-sky southwards, perhaps 6-7 *chi* long and 1 *chi* wide. It disappeared after a long time.	K: Auroras (NIY, W)	宣祖 52 卷, 27 年(1594 甲午 / 명 만력(萬曆) 22 年) 6 月 7 日 (甲寅) Seonjo 52
Report: 8 Dec 1595, Event: 2 Dec 1595	黃海道觀察使柳永詢報曰: “本月初二日初更爲始, 赤氣一道, 起於西方, 狀如炬火, 光燭半天, 俄而南方東方一時竝起, 雞鳴之後, 漸次消滅; 五更後, 東北間, 赤氣又起, 狀如烈焰, 平明後始滅” 云。	An official reported from Hwanghae-do (38°3′N 125°43′E): “At the 1st watch of the night on the 2nd day of this lunar month, one band of red vapor arose in the W; it was shaped like a flaming torch and lit up half the sky. Suddenly [red vapors] arose in the S and E for a short time; after the cocks crowed, they gradually disappeared. After the 5th watch (05h), red	K: Auroras (NIY, R)	宣祖 69 卷, 28 年(1595 乙未 / 명 만력(萬曆) 23 年) 11 月 8 日(丙子) Seonjo 69

		vapors again arose in the E and N. They were shaped like intense flames and disappeared only after daybreak." [8th lunar day]		
25 Feb 1599	有紫氣如箭如槍, 東西相向, 有若進退, 良久而滅。	K: There were purple vapors, [some] like arrows, [some] like spears, pointing opposite to one another, E and W and seemingly advancing and retreating. After a long time they disappeared.	K: Aurora (NIY, P)	宣修 33 卷, 32 年(1599 己亥 / 명 만력(萬曆) 27 年) 2 月 1 日(辛亥) Seonsu 33
23 Mar 1599	This entry does not appear on Yau's date in current Chosen Annals; may be original of 25 Feb entry above.	K: King Seonjo, 32nd year, 2nd month, day *dingchou* (14). "At night, there were violet vapours like arrows and spears, four in the SE direction and one in the W direction. They were advancing to and fro with one and another. When they started to move, then they were extinguished."	K: Aurora	宣祖 109 卷, 32 年(1599 己亥 / 명 만력(萬曆) 27 年) 2 月 27 日(丁丑) Seonjo 109 Yau: 67

1601-1699

		Only the determinative star of asterisms is given. See the list of Stars and Asterisms Mentioned for details.		
Report: 15 Dec 1601, Event: 30 Nov 1601	乙卯/慶尙監司李時發馳啓曰: "星州地, 本月初六日初昏, 辰、地巳地、未地、丑地, 天際有赤氣, 赤氣之上, 又有白氣一道, 狀如虹, 長可二三丈許, 自下以上, 或現或微, 夜半乃滅。 東南赤氣, 尤甚熾盛, 變異非常"事入啓。	K: An official reported by message from Gyeongsang: "On the 6th lunar day of this month (30 Nov) in Seongju (35.866667, 128.6) at dusk there were red vapors on the horizon at 120°, 150°, 210°, and 30°. Above the red vapors was one band of white vapor shaped like a *hong* (arc); it was about 20-30° long. [Its vapors] were sometimes easily visible, sometimes dim. They disappeared at midnight. The red vapors in the SE were blazing intensely. It was an unusual portent."	K: Aurora (NIY, B, W)	宣祖 143 卷, 34 年 (1601 辛丑 / 명 만력(萬曆) 29 年) 11 月 21 日(乙卯) Seonjo 143
13 Feb 1604	統制使李慶濬狀啓: "十二月十九日夜初更, 天上東西北, 赤氣二道, 光如火焰, 狀如匹練, 或竟天、或半天, 旋起旋滅, 二更而滅, 變異非常事。"	K: An official reported: "At the 1st watch (19-21h) of the night of the 19th day of the 12th lunar month, [there were] two bands of red vapor in the sky at the E and W. Their light was like flames, shaped like bolts of cloth, sometimes stretching fully across the sky, sometimes across half the sky, sometimes arising,	K: Aurora (NIY, R)	宣祖 170 卷, 37 年 (1604 甲辰 / 명 만력(萬曆) 32 年) 1 月 14 日(乙丑) Seonjo 170

		sometimes disappearing. They disappeared at the 2nd watch; it was an unusual portent.		
1 Jan 1605	戊子/昧爽。 赤雲如火光。 起自東方。 橫布南方。五更, …. 客星見於濁氣中, 大於心火星, 色黃赤, 動搖。 所在宿及去極度數, 不得測候。	K:Just before dawn, red clouds like *huoguang* flames. They arose in the E and spread transversely across the S. [Kepler's SN seen on same date in E just before dawn, same entry, 2307274.40841.]	K: Aurora (NIY, R)	宣祖 181 卷, 37 年 (1604 甲辰 / 명 만력(萬曆) 32 年) 11 月 12 日(戊子) Seonjo 181
17 Jan 1605	甲辰/巳時, 日暈。...。 初昏, 四方陰雲中有赤氣, 始起於巽方, 燄燄如火光, 燄燄中, 別有一條氣, 如炬熛火, 直立長長二三丈許。次起於南方、坤(光)〔方〕、西方、乾方、北方、東方, 皆以次而見。 大槪形體皆同, 互相明滅, 至四更, 密雲下雪不見。 五更, 密雲, 客星不見。	K: At 07-09h, the sun haloed …. At early dusk, there were red vapors w/in dark clouds, initially in the SE, blazing like fire. W/in the blaze there was a different strip of vapor like the flame of a torch; it stood straight and tall and was about 2-3 *zhang* long (20-30°). Next, [the red vapors] were seen to arise in order in the S, then the SW, the W, the NW, the N, and the E. By and large they were all shaped the same and	K: Auroras (NIY, R)	宣祖 181 卷, 37 年 (1604 甲辰 / 명 만력(萬曆) 32 年) 11 月 28 日(甲辰) Seonjo 181

		they brightened and disappeared in order. At the 4th watch (01-03h), they were no longer visible under heavy clouds and falling snow. At the 5th watch, [there were] heavy clouds, and the guest-star was not seen.		
2 Apr 1608	(夜一更, 巽方、乾方有氣如火光。)	Night. At the 1st watch there were vapors like *huoguang* flames in the SE and NW.	K: Auroras (NIY, FI]	光海 1 卷, 即位年 (1608 戊申(萬曆) 36 年) 2 月 18 日(乙亥) Gwanghae 1
3 Apr 1608	(夜一更, 巽方、坤方、乾方有氣如火光。)	Night. At the 1st watch there were vapors like *huoguang* flames in the SE and SW.	K: Auroras (NIY, FI]	光海 1 卷, 即位年 (1608 戊申(萬曆) 36 年) 2 月 19 日(丙子) Gwanghae 1
Report: 15 Mar, Event: 14 Mar 1610	觀象監, 今月二十日, 日暉。 夜一更至五更, 艮方巽方, 有氣如火光。 啓。	K: The official in charge of observing celestial phenomena [reported]: “On the 20th of this lunar month (14 Mar) the sun had rays. At night, there were vapors like *huoguang* flames in the NE and SE from the 1st through 5th watches.	K: Auroras (NIY, FI]	光海 25 卷, 2 年 (1610 庚戌(萬曆) 38 年) 2 月 21 日(丁卯) Gwanghae 25
25 Mar 1610	(夜一更, 巽方坤方, 有氣如火光。)	K: Night. At the 1st watch there were vapors like *huoguang* flames in the SE and SW.	K: Auroras (NIY, FI]	光海 26 卷, 2 年 (1610 庚戌(萬曆) 38 年) 3 月 1 日(丁丑) Gwanghae 26

10 Apr 1610	(日暈, 日上有戴。夜, 艮方、巽方、坤方, 有氣如火光。 月暈。)	K: The sun haloed and had a dai (crown, appears above the sun like a straight band with the centre protruding slightly upwards) above it. Night. There were vapors like *huoguang* flames in the NE, SE, and SW. The moon haloed. [Note relationship between halos and auroras; the next day (11 Apr) the sun was dim.]	K: Auroras (NIY, FI]	光海 26 卷, 2 年 (1610 庚戌 / 명 만력(萬曆) 38 年) 3 月 17 日(癸巳) Gwanghae 26
Report: 18 May, Event: 14 Feb 1611	辛亥四月初七日丙子政院啓曰: "伏見黃海監司崔東立書狀, '海州正月初二日初昏, 東西天邊有赤色, 夜三更, 未申地間, 火氣空中垂下, 其形如柱, 列立者四, 其長各數丈許, 居中者稍長, 戌亥間, 又有火氣如柱, 光明如晝日, 至晩乃滅, 變異非常'云。	K: On 18 May, the Central Government reported by message: "At dusk on 14 Feb (正月初二日) in Haeju (海州, 38°3′N 125°43′E), there was a red color just above the horizons E and W. At the 3rd watch of the night, fire-vapors hung down, shaped like pillars. There were 4 in a row, each about several *zhang* (several 10° long), with those in-between a bit longer. In the NW there were also fire-vapors like pillars, as bright as daylight. They disappeared late at night. These changes are not normal [they portend disasters]."	K: Report of auroras (NIY, FV)	光海 40 卷, 3 年 (1611 辛亥 / 명 만력(萬曆) 39 年) 4 月 7 日(丙子) Gwanghae 40

Report: 30 Nov, Event: 29 Nov 1611	辛亥十月二十六日壬辰(觀象監“今月二十五日夜, 自二更至四更, 坤方有氣如火光”啓	K: On 30 Nov, the official in charge of observing celestial phenomena reported: “In the night of the 25th day of this lunar month (29 Nov), there was a vapor like a *huoguang* flame in the SW from the 2nd through 4th watches.”	K: Aurora (NIY, FI]	光海 46 卷, 3 年 (1611 辛亥 / 명 만력(萬曆) 39 年) 10 月 26 日(壬辰 Gwanghae 46
Report: 20 Jan 1614	癸丑十二月十一日甲午慶源府報。“天有火光如炬, 又天動如霹靂。”	K: On 20 Jan 1614, Kyongwon-bu (now Gyeongwon-gun, 42°48′41″N 130°11′58″E) reported: “The sky had *huoguang* flames like torches and it reverberated [with sounds] like thunderclaps.” [No date for event but probably within one month prior to report date.]	K: Aurora (NIY, FI]	光海 73 卷, 5 年 (1613 癸丑(萬曆) 41 年) 12 月 11 日(甲午) Gwanghae 73
6 Feb 1617	夜一更, 坤方有氣如火光, 三更四更, 亦如之。	K: Night. At the 1st watch there were vapors like *huoguang* flames in the SW. It was the same at the 3rd and 4th watches.	K: Aurora (NIY, FI]	光海 111 卷, 9 年 (1617 丁巳(萬曆) 45 年) 1 月 1 日(丁卯) Gwanghae 111
4 Mar 1617	夜一更, 東方、巽方, 有氣如火光, 上有赤氣直立, 長丈餘, 廣尺許, 良久乃滅。	K: Night. At the 1st watch there were vapors like *huoguang* flames in the E and SE. Above them were vertical red vapors more than a *zhang* (10°) long and about a *chi* (1°) wide. They disappeared after a long time.	K: Aurora (NIY, FI]	光海 111 卷, 9 年 (1617 丁巳 / 명 만력(萬曆) 45 年) 1 月 27 日(癸巳) Gwanghae 111

9 Mar 1617	(夜一更, 巽方電光, 有氣如火光。 四更, 有氣於東方如火光。...)	K: Night. At the 1st watch, there was lightning in the SE along with vapors like *huoguang* flames. At the 4th watch, there were vapors like flames in the E. …	K: Aurora (NIY, FI]	光海 112 卷, 9 年 (1617 丁巳(萬曆) 45 年) 2 月 3 日(戊戌) Gwanghae 112
12 Mar 1617	夜五更, 巽方有氣如火光。	K: Night. At the 5th watch there were vapors like *huoguang* flames.	K: Aurora (NIY, FI]	光海 112 卷, 9 年 (1617 丁巳(萬曆) 45 年) 2 月 6 日(辛丑) Gwanghae 112
21 Mar 1617	(夜一更, 巽方、坤方, 有氣如火光。)	Night. At the 1st watch there were vapors like *huoguang* flames in the SE and NW.	K: Aurora (NIY, FI]	光海 112 卷, 9 年 (1617 丁巳(萬曆) 45 年) 2 月 15 日(庚戌) Gwanghae 112
24 Jul 1617	(初昏, 蒼白氣二道如虹, 起自巽方, 直指乾方, 長竟天, 廣尺餘, 漸移南方, 良久乃滅。...)	K: At early dusk, [there were] two bands of white vapor like *hong* (arcs) arising in the SE and pointing due NW. They were 1 *chi* (1°) wide and crossed the sky. After a long time they disappeared.	K: Aurora (NIY, W)	光海 116 卷, 9 年 (1617 丁巳 / 명만력(萬曆) 45 年) 6 月 22 日(乙卯) Gwanghae 116
27 Jul 1617	(初昏, 蒼赤氣二道起, 自西方直指艮方, 長各十餘丈, 廣各尺餘, 良久迺滅。)	K: Early dusk. Two bands of pale red vapors arose, pointing from the W due NE. Each was more than 10 *zhang* long (100°) and more than one *chi* wide (1°). After a long time they disappeared.	K: Aurora (NIY, R	光海 116 卷, 9 年 (1617 丁巳 / 명만력(萬曆) 45 年) 6 月 25 日(戊午) Gwanghae 116

15 Dec 1617	夜一更, … 巽方, 有氣如火光, 良久乃滅。	K: Night. At the 1st watch there were vapors like *huoguang* flames. They disappeared after a long while.	K: Aurora (NIY, FI]	光海 121 卷, 9 年 (1617 丁巳(萬曆) 45 年) 11 月 18 日 (己卯) Gwanghae 121
26 Apr 1618	(夜一更、二更, 巽方、艮方, 有氣如火光。)	K: Night. At the 1st and 2nd watches there were vapors like *huoguang* flames in the SE and NE.	K: Aurora (NIY, FI]	光海 126 卷, 10 年 (1618 戊午(萬曆) 46 年) 4 月 2 日(辛卯) Gwanghae 126
25 May 1618	(夜一更、二更, 巽方、艮方, 有氣如火光。)	K: Night. At the 1st and 2nd watches there were vapors like *huoguang* flames in the SE and NE.	K: Aurora (NIY, FI]	光海 126 卷, 10 年 (1618 戊午(萬曆) 46 年) 4 月 2 日(辛卯) Gwanghae 126
29 May 1618	(夜一更, 坤方有氣, 如火光。)	K: At the 1st watch there was a vapor like a *huoguang* flame in the SW.	K: Aurora (NIY, FI]	光海 127 卷, 10 年 (1618 戊午(萬曆) 46 年) 閏 4 月 6 日 (甲子) Gwanghae 127
16 Aug 1624	白氣, 自乾方直指坤方, 長十餘丈	K: [There was] a white vapor more than 10 *zhang* long (100°) [running] from the NW due SW.	K: Aurora (NIY, W)	仁祖 6 卷, 2 年 (1624 甲子 / 명 천계(天啓) 4 年) 7 月 3 日(乙卯) Injo 6
15 Mar 1625	夜一更, 四方有赤氣, 如火光, 雷動。	K: At the 1st watch of the night there were red vapors like *huoguang* flames in all directions as well as the sound of thunder.	K: Aurora (NIY, FI]	仁祖 8 卷, 3 年 (1625 乙丑 / 명 천계(天啓) 5 年) 2 月 7 日(丙戌) Injo 8
13 Aug 1625	夜, 蒼白氣一道, 起自艮方天際, 直指天中, 長十餘丈。	K: Night. One band of pale white vapor, more than 10 *zhang* long (100°), arose from the NE pointing due mid-sky.	K: Aurora (NIY, W)	仁祖 9 卷, 3 年 (1625 乙丑 / 명 천계(天啓) 5 年) 7 月 11 日(丁巳) Injo 9

17 Sep 1625	初昏, 蒼白氣一道, 起自東方, 良久乃滅。	K: At early dusk, a pale white vapor arose in the E; after a long time it disappeared.	K: Aurora (NIY, W)	仁祖 9 卷, 3 年 (1625 乙丑 / 명 천계(天啓) 5 年) 8 月 16 日(壬辰) Injo 9
13 Dec 1625	夜, 白雲一道如氣, 起自東方, 直指乾方, 長竟天。 坤方, 有氣如火光。	K: There was a band of white cloud like a vapor; it arose from the E pointing due NW, stretching far across the sky. In the SW was a vapor like a *huoguang* flame.	K: Aurora (NIY, Fl]	仁祖 10 卷, 3 年 (1625 乙丑(天啓) 5 年) 11 月 14 日(己未) Injo 10
11 Feb 1626	夜, 黑氣一道, 起自乾方天際, 直指巽方天中, 長二十丈許。 二更, 月暈, 白氣如虹, 長丈餘。 白氣一道起艮方, 指坤方, 長十餘丈。	K: One band of black vapor about 20 *zhang* (200°) long arose from the NW horizon, pointing due SE. At the 2nd watch the moon haloed. There was a white vapor like a *hong* (arc) more than one *zhang* long, and one band of white vapor arose in the NE pointing SW. It was more than 10 *zhang* long.	K: Aurora (NIY, B, W)	仁祖 11 卷, 4 年 (1626 丙寅 / 명 천계(天啓) 6 年) 1 月 15 日(己未) Injo 11
17 Dec 1626	夜, 乾方有氣如火光。	K: Night. There was a vapor like a *huoguang* flame in the NW.	K: Aurora (NIY, Fl]	仁祖 14 卷, 4 年 (1626 丙寅(天啓) 6 年) 10 月 29 日(戊辰) Injo 14
19 Jan 1627	夜, 艮方有氣如火光。	K: Night. There was a vapor like a *huoguang* flame in the NE.	K: Aurora (NIY, Fl]	仁祖 14 卷, 4 年 (1626 丙寅(天啓) 6 年) 12 月 3 日(辛丑) Injo 14

16 Apr 1628	火星犯東井星。 白氣如虹, 自艮方指巽方, 長竟天。	K: Mars…. A white vapor like a *hong* (arc) crossed the sky from the NE to SE. [13th day of L month.]	K: Aurora? (NIY, W)	仁祖 18 卷, 6 年 (1628 戊辰 / 명 천계(天啓) 8 年) 3 月 13 日(甲戌) [天啓=>明思宗崇禎元年 3 月 13 日] Injo 18
26 Jun 1628	太白見。 流星出天津星下, 入室星上。 黑氣一道, 起自坤方, 直指巽方。	K: Venus appeared. …. One band of black vapor arose in the SW pointing due SE.	K: Aurora (NIY, B]	仁祖 18 卷, 6 年 (1628 戊辰 / 명 천계(天啓) 8 年) 5 月 25 日(乙酉) [天啓=>明思宗崇禎元年 5 月 25 日] Injo 18
12 Oct 1653	癸未/夜, 黑氣長竟天。	K: Night. A black vapor stretched far across the sky.	K: Aurora (NIY, B]	孝宗 11 卷, 4 年 (1653 癸巳 / 청 순치(順治) 10 年) 8 月 21 日(癸未) Hyojong 11
24 Jan 1660	己亥/夜巽方坤方, 有氣如火光。	K: Night. There was a vapor like a *huoguang* flame in the SE and SW.	K: Aurora (NIY, Fl]	顯宗 1 卷, 卽位年 (1659 己亥(順治) 16 年) 12 月 13 日 (己亥) Hyeojong 1
19 Jun 1666	夜白氣如虹, 長十餘丈。 起西指北。	K: Night. [There was] a white vapor like a *hong* (arc). It arose in the W, pointing N, and was more than 10 *zhang* long (100°).	K: Aurora (NIY, W)	顯改 15 卷, 7 年 (1666 丙午 / 청 강희(康熙) 5 年) 5 月 17 日(丁酉) Hyeongae 15
29 Jun 1668	戊午/太白晝見。 夜, 白氣見坤方, 長竟天。	K: Venus was seen in daylight. Night. A white vapor was seen in the SW stretching across the sky.	K: Aurora (NIY, W)	顯改 19 卷, 9 年 (1668 戊申 / 청 강희(康熙) 7 年) 5 月 21 日(戊午) Hyeongae 19

28 Jan 1680	戊子/夜, 東方有氣如火光。	K: Night. There was a vapor like a *huoguang* flame in the E.	K: Aurora (NIY, FI]	肅宗 8 卷, 5 年 (1679 己未(康熙) 18 年) 12 月 27 日 (戊子) Sukjong 8
15 Jun 1681	夜, 巽方艮方有氣如火光。	K: Night. There were vapors like *huoguang* flames in the SE and NE.	K: Aurora (NIY, FI]	肅宗 11 卷, 7 年 (1681 辛酉(康熙) 20 年) 4 月 29 日(壬子) Sukjong 11
17 Jun 1681	夜, 巽方、坤方有氣如火光。	K: Night. There was a vapor like *huoguang* flames in the SE and SW.	K: Aurora (NIY, FI]	肅宗 11 卷, 7 年 (1681 辛酉(康熙) 20 年) 5 月 2 日(甲寅) Sukjong 11
10 Apr 1682	辛亥/夜, 有氣如火光。	Night. There was a vapor like a *huoguang* flame.	K: Aurora (NIY, FI]	肅宗 13 卷, 8 年 (1682 壬戌(康熙) 21 年) 3 月 3 日(辛亥) Sukjong 13
6 Nov 1695	己丑/夜, 東方白氣, 暫移。軫宿右轄星南, 直抵張星。	K: Night, there was a white vapor in the E; it soon moved to the S of *Zuoxiaxing* (α Crv) in *Zhen* (γ Crv) and straightaway reached *Zhangxing* (υ^1 Hya).	K: Comet?	肅宗 29 卷, 21 年 (1695 乙亥 / 청 강희(康熙) 34 年) 9 月 30 日(己丑) Sukjong 29

Appendix B. Sunspot and Solar Observations 1100-1684

Table B1 contains information on sunspot and solar observations from 1100-1684. This data set includes 46 new or revised records of sunspots.

Table B1. Sunspot and Solar Observations 1100-1684

Column 1 is the date of the observation. Column 2 displays the solar information in the original language (Chinese or Korean), the translation of which is in column 3. The country of the observation is given by C = China; K = Korea; JP = Japan. Column 4 contains additional notes where IY = in Yau and Stephenson (1988), NIY = Not in Yau and Stephenson (1988),
W = Wittmann (1997 & 2013), NC = North China, Viet = Vietnam, WX: Wittmann and Xu (1997 & 2013)

The final column is information on the original reference source. These are all in the bibliography. The entire listing is grouped by centuries as identified by the years at the upper left. In the fifth column, the number following the source name indicates the chapter/volume of the history. Thus, "Goryeosa 47" indicates the 47th chapter/volume of the source history Goryeosa.

1100-1199

Feb 7 1105	[肅宗]十年正月庚寅日正中無光而重暈有珥.	K: The center of the sun was dim; the sun had a double halo and earring(s).	Sunspot	Goryeosa 47 Lee,Tab 1
6 Dec 1105	[宋徽宗崇寧]三[四]年十月壬辰，日中有黑子如棗大。	C: Within the sun there was a black spot as large as a date.	Sunspot	Songshi: 20 & 52, Yau: 64
2 May 1112	宋徽宗政和二年四月辛卯，日中有黑子，乍二乍三，如栗大。	C: There were black spots as big as chestnuts within the sun, sometimes two, sometimes three.	Sunspot	Songshi Tianwen 5 Songshi Huizongji 21 Zhuang: 8

17 Dec 1118	宋徽宗政和八年十一月辛亥 日中有黑子如李大。 日中有黑子。	C: There was a black spot as big as a plum within the sun. C: There was a black spot within the sun.	Sunspot	Songshi Tianwen 5 Songshi Huizongji 21 Zhuang: 8
7 Jun 1120	宋徽宗宣和二年五月己酉 日中有黑子如枣大。 日中有黑子。	C: There was a black spot as big as a jujube (a kind of date) within the sun. C: There was a black spot within the sun.	Sunspot	Songshi Tianwen 5 Songshi Huizongji 22 Zhuang: 8
10 Jan 1122	宋徽宗宣和三年十二月辛卯 日中有黑子如李大。	C: There was a black spot as big as a plum within the sun.	Sunspot	Songshi Tianwen 5 Zhuang: 34
22 Mar -14 Apr 1129	建炎三年三月己卯，日中有黑子，至壬寅始消。 金太宗天会七年三月己卯朔日中有黑子。	C: A black spot was in the sun. It lasted till 14 April. NC: A black spot was in the sun. [Observations begin at Lin’an (new S capital).]	C: Sunspot NC: Sunspot	Songshi Tianwen 5 Jinshi Tianwen 20 Zhuang: 9
12~15 Mar 1131	紹興元年二月己卯，日中有黑子如李大，三日乃伏。 日中有黑子，四日乃沒。	C: There was a black spot as big as a plum within the sun. It subsided after three days. C: There was a black spot w/in the sun. It disappeared after 4 days.	C: Sunspot C: Sunspot	Songshi Tianwen 5 Songshi Gaozong Benji 2 Zhuang: 9

23-27 Nov 1136	紹興六年十月壬戌，日中有黑子如李大，至十一月丙寅始消。 紹興六年十月…壬戌，日中有黑子沒。 金熙宗天会十四年十一月丙寅日中有黑子，斜角交行。	C: W/in the sun was a black spot as big as a plum. It finally disappeared on 27 Nov. C: W/in the sun was a black spot, which disappeared. NC: On Nov 27 were black spots w/in the sun. They crossed at oblique angles.	C: Sunspot C: Sunspot NC: Sunspots	Songshi Tianwen 5 Songshi Gaozong 5 Jinshi 20 Yau: 71 Zhuang: 9
1-10 Mar 1137	紹興七年二月庚子，日中有黑子如李大，旬日始消。 日中有黑子，如粒，辛丑蔽日。	C: Shaoxing reign period, 7th yr, 2nd mon, day gengzi (37). "Within the Sun there was a black spot as large as a plum for 10 days; then it dispersed." [Note aurora & major sunspot coincide.] C: W/in the sun was a black spot like a grain. On 2 Mar it covered the sun.	C: Sunspot C: Sunspot (NIY or W)	Songshi Tianwen 5 Yau: 72 Zhuang: 9
8-22 May or later 1137 8 May	[紹興七年]四月戊申，日中有黑子，至五月乃消。 [紹興七年夏四月]戊申，日中有黑子。	C: W/in the sun was a black spot; it finally disappeared at the 5th month (22 May-19 Jun). C: W/in the sun was a black spot.	C: Sunspot C: Sunspot	Songshi Tianwen 5 Songshi Gaozong Benji 5 Zhuang: 9
16 Mar 1138	[紹興八年二月]庚申，日中有黑子。	C: W/in the sun was a black spot.	C: Sunspot	Songshi Gaozong Benji 6 Yau: 74 Zhuang: 9
17 Mar 1138	[紹興]八年二月辛酉，日中有黑子。 日中有黑子，大如枣。	C: W/in the sun was a black spot.	C: Sunspot C: Sunspot (NIY)	Songshi Tianwen 5 Wenxiantongkao Xiangwei 7, 284

		C: W/in the sun was a black spot as big as a date. (NIY)		Yau: 74 Zhuang: 9
26 Nov 1138	[紹興八年冬十月]乙亥，日中有黑子。 [紹興八年]十月乙亥，日中有黑子。	C: W/in the sun was a black spot. C: W/in the sun was a black spot.	C: Sunspot	Songshi Gaozong Benji 6 Songshi Tianwen 5
3-31 Mar 1139	[紹興九年二月]是月，日中有黑子，月餘乃沒。	C: In this lunar month (3-31 Mar) there was a black spot w/in the sun. After more than a month it disappeared.	C: Sunspot	Songshi Gaozong Benji 6 Zhuang: 10
20 Nov 1139	宋高宗紹興九年十月甲戌， 日中有黑子。	C: W/in the sun was a black spot.	C: Sunspot	Songshi Gaozong Benji 6 Zhuang: 10
24 May* 1145	宋高宗紹興十五年六月丙午，日中有黑氣往來. [六月丙午=>五月丙午朔]	C: Within the sun a black vapor came and went. [Changed Yau's date of 1145 Jun/Jul? to 1st and 2nd days of 5th lunar month]	C: Sunspot	Songshi Tianwen 5 Yau: 78 Zhuang: 10
25 May* 1145	宋高宗紹興十五年六月丁未，日中有黑子，日無光[六月丁未=>五月丁未]	C: Within the sun was a black spot; the sun was dim. [Changed Yau's date of 1145 Jun/Jul? to 1st and 2nd days of 5th lunar month]	C: Sunspot, dim sun	Songshi Tianwen 5 Yau: 78 Zhuang: 10
23-24* Jul 1145	宋高宗紹興十五年[七月]丙午 日中有黑氣往來 丁未，日中有黑子，日無光	"Within the sun there was a black vapor fading and reappearing. On the following day, there was a black spot on the sun, and the sun had no brilliance". Note: source gives month 6, day 43, but there was no	C: Sunspot C: Sunspot	WX 2013: 15

		day 43 in month 6. Possibly read month 7.” [Wittman’s dates should be changed to *24-25 May.]		
21 Mar 1151	五年三月癸酉日有黑子大如雞卵	K: The sun had a black spot as big as a hen’s egg.	K: Sunspot (IY)	Goryeosa 47
31 Mar-1 Apr 1151	癸未日中有黑子大如雞卵 翌日亦如之.	K: Within the sun was a black spot as big as a hen’s egg. K: The next day, it was the same.	K: Sunspots (IY)	Goryeosa 47 Lee: Tab 1
1 Apr 1152	(毅宗二年二月二十五日)	Black spot as large as a hen’s egg. [Source unclear.]	K: Sunspot (NIY)	Lee: Tab 1, 375
9 Jun 1158	[Unable to find source; could it be confusion with 26 Sep 1160 below?]	“Within the sun there was a black spot shaped like a man.” [W gives the Chinese date as 5 Jun, but his western date is 9 Jun]	NC: Sunspot (NIY)	WX 2013: 16
28 Feb-1 Mar 1160	[宋紹興三十年] [毅宗]十四年正月己亥日中有怪氣三日.	K: There was a strange vapor within the sun for three days.	K: Solar phenomena, sunspot	Goryeosa 47
26 Sep 1160	金海陵王正隆五年八月庚午，日中有黑子，状如人。	NC: Within the sun was a black spot shaped like a man.	NC: Sunspot	Jinshi 20 Tianwen Zhuang: 10
29 Sep 1160	[毅宗]十四年 八月癸酉日中有黑子.	K: Within the sun was a black spot.	K: Sunspot	Goryeosa 47

20 Oct 1171	(宋孝宗乾道七年) 明宗元年九月辛卯日有黑子大如桃.	Korea: The sun had a black spot as big as a peach.	K: Sunspot	Goryeosa 47
16 Nov 1171	[明宗元年]十月戊午日有黑子大如桃.	Korea: The sun had a black spot as big as a peach.	K: Sunspot	Goryeosa 47
4-5 Dec 1183	(宋淳熙十年) [明宗]十三年十一月壬戌朔日食己卯日有黑子二日.	K: The sun had a black spot for two days.	K: Sunspot	Goryeosa 47
10 Feb 1185	宋孝宗淳熙十二年正月癸巳，日中生黑子，大如棗。	C: Within the sun was produced a black spot as large as a date.	C: Sunspot	Songshi Tianwen 5 Yau: 86
11 Feb 1185	(宋淳熙十二年) 明宗十五年正月甲午日有黑子大如梨.	K: The sun had a black spot as big as a pear.	K: Sunspot	Goryeosa 47 Yau: 86
15-27 Feb 1185	宋孝宗淳熙十二年正月 戊戌至庚戌，日中皆有黑子。	C: From day wuxu to day gengxu there was a black spot within the sun for the whole time.	C: Sunspot	Songshi Tianwen 5 Yau: 87
27 Mar 1185	[明宗十五年]二月戊寅日有黑子大如梨	K: The sun had a black spot as big as a pear. [Note this spot correlates with *huoying* aurora on 26 Mar.]	K: Sunspot	Goryeosa 47 Yau: 88
18-19 Apr 1185	三月庚子日有黑子辛丑亦如之.	K: The sun had a black spot. The next day was the same.	K: Sunspot	Goryeosa 47 Yau: 89
14 Nov 1185	[明宗十五年]十月...庚午日有黑子.	K: The sun had a black spot.	K: Sunspot	Goryeosa 47 Yau: 90
23-27 May 1186	淳熙十三年五月庚辰，日中生黑子，大如棗。	C: The sun produced a black spot as big as a date, until day *jiashen* (May 27) when it disappeared.”	C: Sunspot	Songshi Tianwen 5 Wenxiantongkao Xiangwei 7, 284

				Zhuang: 10
26 May 1186	淳熙十三年五月癸未，日中有黑子。甲申，詔非...	C: Within the sun was a black spot.	C: Sunspot	Songshi Xiaozong Benji 3
3-12 Dec 1193	紹熙四年十一月辛未，日中有黑子，至庚辰始消	C: Within the sun was a black spot; it disappeared on 12 Dec.	C: Sunspot	Songshi Tianwen 5

1200-1299

19 Sep 1200	(宋慶元六年) [神宗三年]八月癸巳日有黑子大如李.	K: There was a black spot as big as a plum.	K: Sunspot	Goryeosa 47
21-26 Sep 1200	慶元六年八月乙未，日中有黑子如棗大，至庚子始消。 日内生黑子，如枣大，凡六日乃消伏。	C: W/in the sun was a black spot as big as a date; it finally disappeared on 26 Sep. C: A black spot as big as a date was in the sun; it lasted 6 days then disappeared.	C: Sunspot C: Sunspot	Songshi Tianwen 5 Wenxiantongkao Xiangwei 7, 284 Zhuang: 10
9-29 Jan 1201	[慶元六年十二月]乙酉，又生，至乙巳始消 日又生黑子，如枣大，凡二十日乃伏。	C: Another [black spot as big as a date] was produced [on 9 Jan] and finally disappeared on 29 Jan. C: Another black spot as big as a date was produced; it lasted 20 days.	C: Sunspot C: Sunspot	Songshi Tianwen 5 Wenxiantongkao Xiangwei 7, 284 Zhuang: 10-11
6 Apr 1201	[神宗]四年三月壬子日中有黑子大如李.	K: W/in the sun was a black spot as big as a plum.	K: Sunspot	Goryeosa 47
23 Aug 1202	[神宗]五年八月丙子日中有黑子大如梨.	K: W/in the sun was a black spot as big as a pear.	K: Sunspot	Goryeosa 47

19-31 Dec 1202	宋寧宗嘉泰二年十二月甲戌，日中生黑子，大如棗。丙戌，始消。	C: Within the sun was produced a black spot as big as a date. It finally disappeared on 31 Dec.	C: Sunspot	Songshi Tianwen 5
3-5 Feb 1204	[宋嘉泰四年 神宗]七年正月乙丑朔日中有黑子大如李凡三日.	K: First day of lunar month. Within the sun was a black spot as big as a plum. It lasted 3 days.	K: Sunspot	Goryeosa 47
21 Feb 1204 & 4 May 1205	[宋寧宗嘉泰]四年正月癸未，開禧元年四月辛丑，日中皆有黑子大如棗。 日中有黑子。	C: On both 21 Feb 1204 and 4 May 1205 there were black spots as big as dates within the sun. C: W/in the sun was a black spot	C: Sunspots	Songshi Tianwen 5 Songshi Ningzongji 38
25 Jan 1207	泰和六年十二 是月壬申夜興州天赤如血照地如晝自月初有兩日相摩於初晴之時至是復有此異。	C: At night, at Xingzhou (38.46 111.13), the sky was red like blood; it illuminated the ground like daytime. Since the beginning of the lunar month 31 Dec 1206), two suns had been [seen] rocking against one another when the weather cleared. Now this strange event has occurred again.	C: Aurora C: Sunspot (NIY nor W)	Dajin Guozhi 21 Zhuang: 38
5 Dec 1238	嘉熙二年十月己巳，日中有黑子	Within the sun there was a black spot.	C: Sunspot	Songshi Tianwen 5
15 & 16 Sep 1258	八月癸巳日中黑子大如雞子翼日又如人形.	K: Within the sun was a sunspot as big as a hen’s egg. The next day [the spot] was shaped like a man (Lee says: “like a doll”).	K: Sunspots [In Lee and Yau]	Goryeosa 47 Lee: Tab 1

27 Feb-28 Mar 1275	宋恭宗德佑元年二月日中有黑子，相荡久之。(不确定类)	C: Within the sun there were black spots agitating one another for a long time. [Corrected date in WX: 29=>28 Mar]	C: Sunspot (NIY)	WX 2013: 20 Zhuang: 21
17 Feb 1276	德祐二年二月丁酉朔日中有黑子。如鹅卵相荡。	C: Within the sun there were black spots; they rocked against one another like goose's eggs. [Also in Vietnam (sometime w/in 17 Feb-15 Mar)]	C: Sunspots Viet: Sunspots	Songshi Tianwen 5 Ho: 1964 WX 2013: 19
31 Aug 1278	[宋昺帝祥興元年][忠烈王]四年八月癸亥日中有黑子大如雞卵.	K: Within the sun was a sunspot as big as a hen's egg. [12th day of lunar month]	K: Sunspot	Goryeosa 47

1300-1399

4-6 Apr 1356	[恭愍王五年]三月甲申日無光中有黑子乙酉亦如之丙戌日澹無光直視不眩.	K: On 4 Apr the sun was dim and within it was a black spot. 5 Apr was the same. On 6 Apr, the sun was faint; one could look directly at it without being dazzled.	K: Sunspots, dim sun	Goryeosa 47 Yau: 107
16-19 Mar 1361	[至正二十一年] [恭愍王]十年二月辛卯日有黑子四日	K: The sun had a black spot for 4 days. ["for four days" omitted in Yau]	K: Sunspot	Goryeosa 47 Yau: 108
5 Oct 1362	[元至正二十二年] [恭愍王十一年] 九月己未日有黑子.	K: The sun had a black spot.	K: Sunspot	Goryeosa 47
1 Jan-30 Jun 1365	元乙巳(年) 太史刘基见日中有黑子。	The Grand Astronomer Liu Ji saw a sunspot w/in the sun [some time w/in the 1st half of the year]. (Zhuang regards as: "indefinite.")	C: Sunspot	Zhuang: 21

20 Jan 1368-6 Feb 1369	明太祖洪武元年自正月至十二月 日中有黑子。	C: W/in the sun were black spots [throughout the year].	C: Sunspots	Zhuang: 11
15 Jul-10 Nov 1368	洪武元年秋 [unable to check against source]	C: This autumn the sky roared and trembled. W/in the sun were black spots, from 1 to 3; they were seen every day.	C: Sunspots	Yau: 112
30 Dec 1369-27 Jan 1370	明太祖洪武己酉十二月 日中屡有黑子。	C: Black spots were frequently [seen] w/in the sun.	C: Sunspots	Yau: 113 Zhuang: 11
1 Jan 1370	明太祖洪武二年十二月甲子日中有黑子。 日中黑。	C: W/in the sun were black spots. C: W/in the sun [it was] black.	C: Sunspots C: Sunspot	Mingshi Tianwen 3 Guoque 3 Zhuang: 11
28 Jan-3 Feb 1370	明太祖洪武三年一月丁酉 上諭中書省參政陳亮侯至善曰司天台言朔日以來日中有黑子。	C: “The Astronomical Bureau reported that from the 1st day (of the month) - Jan 28 - until today - Feb 3 - within the Sun there was a black spot."	C: Sunspot	Ming Taizushilu 48
28 Jan 1370-14 Jan 1371	[洪武三年十二月]壬午 上以正月至是月日中屢有黑子詔廷臣言得失。	C: “In regard to the frequent black spots within the Sun from the 1st month (28 Jan) until this month, His Imperial Majesty appealed to Court officials to report errors (of the throne).”	C: Frequent Sunspots throughout yr	Ming Taizushilu 59
25 Apr 1370	明太祖洪武三年三月戊午 [時]日中频有黑子。	C: At this time, w/in the sun there repeatedly was a black spot.	C: Sunspots	Guoque 4 Zhuang: 11

2 Oct 1370	大明洪武三年九月戊戌日中有黑子	C: W/in the sun was a black spot. [13th day of lunar month]	C: Sunspot	Ming Taizushilu 56
21 Oct 1370	洪武三年冬十月丁巳日中有黑子。	C: W/in the sun was a black spot.	C: Sunspot	Ming Taizushilu 57
7 Dec 1370	甲辰 上以郊祀在迩而日中累有黑子因谕....	C: The Emperor issued an edict because of the approaching sacrifice to Heaven and Earth and the frequent black spots w/in the sun….	C: Frequent sunspots	Ming Taizushilu 58
19 Dec 1370?	洪武三年十二月丙辰 pg 433	C: "Within the sun repeatedly there was a black spot." [Cannot find this entry on 19 Dec (*bingchen* day) in Guoque 4.]	C: Frequent sunspots	Guoque 4 Yau: 121
2 Jan 1371	[大明洪武三年] [恭愍王]十九年十二月庚午日有黑子.	K: W/in the sun was a black spot.	K: Sunspot	Goryeosa 47
14 Jan 1371	明太祖洪武三年十二月壬子 日中屢有黑子。[壬子=>壬午]	C: W/in the sun there frequently were black spots. [Zhuang corrected *renzi* day to *renwu* day.]	C: Sunspot (NIY)	Guoque 4 Zhuang: 12
31 Mar 1371	洪武四年三月戊戌日中有黑子	C: W/in the sun was a black spot.	C: Sunspot	Ming Taizushilu 62
13 Jun-12 Jul 1371	洪武四年五月 辛巳日中有黑子自壬子至是日	C: W/in the sun was a black spot from 13 Jun to today (12 Jul)	C: Sunspots	Ming Taizushilu 65
?9 Oct-7 Nov? 1371=	[大明洪武四年] [恭愍王]二十年九月癸巳日有黑子.	K: W/in the sun was a black spot. [No *guisi* day 癸巳 in 9th month; if [九月癸巳=>八月癸巳= 22 Sep; if => 十月	K: Sunspot	Goryeosa 47 Yau: 125 WX 2013: 21 Lee: Tab 1

> 22 Sep* or 21 Nov* 1371		癸巳= 21 Nov; but 22 Sep more likely because of resemblance between 八 & 九; Wittmann says: 21 Nov.]		
6 Nov 1371	[洪武四年九月]戊寅日中有黑子	C: W/in the sun was a black spot.	C: Sunspot	Ming Taizushilu 68
6 Feb 1372	洪武五年春正月庚戌日中有黑子	C: W/in the sun was a black spot.	C: Sunspot	Ming Taizushilu 71
3 Apr 1372	洪武五年二月丁未日中有黑子	C: W/in the sun was a black spot. [29th day of lunar month.]	C: Sunspot	Ming Taizushilu 72
8 May 1372	[大明洪武五年] [恭愍王]二十一年四月壬午日有黑子.	K: W/in the sun was a black spot.	K: Sunspot	Goryeosa 47
19 Jun 1372	[洪武五年]甲子日中有黑子	C: W/in the sun was a black spot. [19th day of lunar month.]	C: Sunspot	Ming Taizushilu 73
25 Aug 1372	[洪武五年秋七月辛未]日中有黑子	C: W/in the sun was a black spot. [26th day of lunar month.]	C: Sunspot	Ming Taizushilu 75
26-27 Apr 1373	[大明洪武六年] [恭愍王二十二年] 四月乙亥日有黑子二日.	K: W/in the sun was a black spot for two days.	K: Sunspot	Goryeosa 47
23 Oct 1373	[大明洪武六年] [恭愍王二十二年] 十月乙亥日有黑子.	K: W/in the sun was a black spot.	K: Sunspot	Goryeosa 47
15 Nov 1373	洪武六年十一月戊戌朔 日中有黑子	C: W/in the sun was a black spot.	C: Sunspot	Ming Taizushilu 86
14 Mar 1374	明太祖洪武七年二月丁西 日有食之，日中屢有黑子。	C: The sun had an eclipse; there frequently were black spots within the sun.	C: Solar eclipse, sunspot	Zhuang: 13

			(NIY)	
27-31 Mar 1374	[明太祖洪武七年二月]甲寅日中有黑子自庚戌至于是日	C: W/in the sun was a black spot from 27 Mar [14th day of lunar month] to today (31 Mar).	C: Sunspot	Ming Taizushilu 87
20-21 Mar 1375	[大明洪武八年] 辛禑元年二月戊申日有黑子己酉亦如之.	K: A black spot was w/in the sun on the 20th; the 21st was the same.	K: Sunspot	Goryeosa 47
23 Mar 1375	[洪武八年二月]辛亥日中有黑子	C: W/in the sun was a black spot. [Yau misread 辛亥 (23 Mar) as 庚戌 (22 Mar)]	C: Sunspot	Ming Taizushilu 97
21 Oct 1375	[武八年九月]癸未日中有黑子	C: W/in the sun was a black spot.	C: Sunspot	Ming Taizushilu 101
19 Jan 1376	[武八年十二月]癸丑日中有黑子	C: W/in the sun was a black spot. [28th day of lunar month]	C: Sunspot	Ming Taizushilu 102
22-25 Mar 1381	乙酉日中有黑子自壬午至于是日 明太祖洪武十四年二月壬午至乙酉日中有黑子。	C: A black spot was w/in the sun from 22 Mar to today (25 Mar). [29th day of lunar month.] C: From 22 Mar to 25 Mar a black spot was w/in the sun.	C: Sunspot C: Sunspot	Ming Taizushilu 135 Mingshi Tianwen 3 Zhuang: 13
23 Mar 1381	[大明洪武十四年 辛禑]七年二月 癸未日有黑子.	K: The sun had a black spot.	K: Sunspot	Goryeosa 47
22-25 Mar 1381	明太祖洪武十四年二月乙酉自壬午至是日，日中黑。	C: [It was] black w/in the sun from 22 Mar to today (25 Mar).	C: Sunspot (NIY)	Guoque 7 Zhuang: 13
9-11 Mar	[大明洪武十五年 辛禑]八年二月甲戌日有	K: The sun had a black spot as big as a hen’s egg	K: Sunspot	Goryeosa 47

1382	黑子大如雞卵凡三日	for 3 days.		
21 Mar 1382	洪武十五年闰二月 丙戌日中有黑子.	C: W/in the sun was a black spot. [6th day of lunar month]	C: Sunspot	Ming Taizushilu 143
10 Jan 1383	明太祖洪武十五年十二月辛巳日中有黑子。 日中黑。	C: W/in the sun was a black spot. C: W/in the sun [it was] black. [7th day of lunar month]	C: Sunspot C: Sunspot	Mingshi Tianwen 3 Ming Taizushilu 150 Guoque 7 Zhuang: 13
15 Apr 1387	[大明洪武二十年 辛禑]十三年三月丁丑日有黑子.	K: The sun had a black spot.	K: Sunspot	Goryeosa 47

1400-1499

15 Nov 1402	太宗二年十月庚午/日中有黑點	K: W/in the sun was a black dot.	K: Sunspot	Taejong 4

1500-1599

27 May-24 Jun 1511	明武宗正德六年夏五月，南昌見日有紅白暈，中浮黑氣，有頃始散.	In Nanchang, the sun was seen to have a red and white halo; within it floated a black vapor. It disappeared after a while.	C: Sunspot (NIY)	Gujintushujicheng Zhengdian 242 WX 2013: 24
19 Jan 1512-5 Feb 1513	明武宗正德七年 是岁，日下复有黑景，或三或四，隐见不常。	That year, there were black shadows now and then at the lower part of the sun; sometimes 3, sometimes 4; sometimes visible and sometimes not visible.	C: Sunspots (NIY)	Zhuang: 13

26 Feb 1518	[明武宗正德十三年正月丁巳申時]	C: "At 3 to 5 hours in the afternoon the sun's light shimmered". C: Feb 1518: "Ripples of Sun's light"	C: Sunspot (NIY) C: Sunspot	WX 2013: 24 Jiang & Xu 1985
9 Mar 1520	[中宗 15 年 2 月 20 日 (己卯)] 日中, 有黑氣相盪, 有虹繞日。	K: Black vapors rocked against one another within the sun and a *hong* (parhelic circle) surrounded the sun.	K: Sunspot	Jungjong 38
29 Mar 1520	參贊官尹殷弼曰: "近日非常之災甚多, 全羅道 谷城之災, 日中有黑光相盪, 又星月上下, 有相戰之狀, 戌時又有火光照物, 村廬可數, 又有地震。	A counsellor official said: "Recently there have been unusually many disasters, the …, within the sun were black lights rocking against one another, also stars and the moon were moving up and down, seemingly fighting with one another. And at the 19:00 - 21:00 double-hour there were *huoguang* flame auroras shining on things….	K: Reports of sunspots, auroras (NIY)	Jungjong 38 Lee: Tab 1
26 Oct 1539	明世宗嘉靖十八年九月十五日 大雾，日高丈许，有黑日摩荡。	C: Fog. When the sun was about one zhang (10°) high, black suns rocked against one another.	C: Sunspot (NIY nor W]	Zhuang: 14
16 Jan 1546	明世宗嘉靖二十四年十二月癸卯 日旁黑气如盘，与日相荡，七日乃灭。	C: Next to the sun was a black vapor like a disc, rocking against the sun; it disappeared after 7 days.	C: Sunspot (NIY nor W]	Zhuang: 14

17 Apr 1556	日中有黑子, 大如雞子。 氛氣翳天, 日暈。夜, 月暈。	K: Yau: "Within the sun there was a black spot as large as a hen's egg. The sky was covered with a dense vapor." [Entry continues:] The sun haloed. Night. The moon haloed.	K: Sunspot, dense vapor, solar/lunar halos.	Myeongjong 20
1562	明世宗嘉靖四十一年日有黑子。 [Unable to find Zhuang's source.]	C: The sun had a black spot [some time during the year]. [WX 2013: 24 adds: "and it was hazy and gloomy for three days".]	C: Sunspot	Zhuang: 14 WX 2013: 24
7 Aug-4 Sep 1564	明世宗嘉靖四十三年七月 日正中有星。	A star was at the middle of the sun. (NIY) Strom writes: …a star in the Sun… probably observations of Sun-grazing comets near perihelion."	C: Sunspot?, Sungrazer?	Zhuang: 14 Strom, JAHH vol 11 2008, A&A 387 2002: L18
30 Jan-3 Feb 1566	明世宗嘉靖四十五年正月初十日 日中有黑子，大如卵，五日乃灭。	C: Within the sun was a black spot as big as a hen's egg. It disappeared after 5 days.	C: Sunspot (NIY)	WX 2013: 24 Zhuang: 14
Spring (9 Feb-8 May) 1567	明穆宗隆庆元年之春日中有黑子相荡。	C: Within the sun there were black spots rocking against one another.	C: Sunspots	WX 2013: 25 Zhuang: 14
17-27 Jan 1569	[Unable to access source.]	C: Within the sun was [something] for several days. After about ten days it disappeared.	C: Sunspots	WX 2013: 25
Summer	明穆宗隆庆三年夏 黑光与日相摩	C: Summer. W/in the sun were black lights rubbing	C: Sunspots	Zhuang: 14 WX 2013: 25

1569		against one another.		
4 May-1 Jun 1590	明神宗万历夏十八年四月 日中黑气，光不明者良久。	C: Within the sun there was a black vapor; [the sun's] light was dim for a long time.	C: Sunspot; dim sun	WX 2013: 25 Zhuang: 14
3 Jan 1593	[Unable to access source.]	C: "At the hour of mao (5-7 am) within the sun there were two black spots shaped like a three-legged crow (three birds) for three days". [WX 2013 dates it "2 Jan."]	Viet: Sunspots	Ho Peng-Yoke, "Dai-Viet Su'-Ky Toan-Thu" (1964) WX 2013: 25
15 Jun 1597	明神宗万历二十五年五月辛卯朔 日光转荡，旋为黑饼。	The light of the sun rocked and [soon] turned into a black cake. [Blackening of the solar disk?] New moon 14 Jun.	C: Sunspot (NIY)	WX 2013: 25 Zhuang: 14

1600-1699

4 Apr-10 May 1603	[Unable to access source.]	Viet: "W/in the sun were three black spots."	Viet: Sunspots	Dai-nam Thu'c-luc chien-bien, 1 ("Da-Nan-Shi-Lu 1") Yau: 153
16 Apr 1603	卯時, 日赤無光, 有黑雲三點, 狀如大(餞)〔錢〕, 自日北, 似有離合, (輕)〔經〕日而南。	K: At the hour of *mao* (05:00-07:00) the sun was red and dim; it had three cloudy black dots shaped like large coins. Starting from the N of the sun, [sometimes they] seemed to be separating and [sometimes] joining as they moved southward across the sun.	K: Sunspots, dim sun	宣祖 160 卷, 36 年(1603 癸卯 / 명 만력(萬曆) 31 年) 3 月 6 日(壬戌) Seonjo 160 WX 2013: 25

1-29 Mar 1604	明神宗万历三十二年二月黑光磨荡。	C: Black lights [in the sun] rubbed on one another.	C: Sunspot (NIY nor W)	Zhuang: 14
24[-25] Oct 1604	己卯/日出時, 日中有黑子, 大如鳥卵。 辰時太白見於巳地。 夜一更, 客星見....	K: At dawn the sun had a black spot as big as a bird's egg. At 07:00-09:00, Venus was seen at 150°. At the 1st watch of the night, the guest-star….	K: Sunspot, Venus, guest-star	宣祖 179 卷, 37 年(1604 甲辰 / 명 만력(萬曆) 32 年) 閏 9 月 2 日(己卯) Seonjo 179
25 Oct 1604	庚辰/日出時, 日中有黑子, 大如鷄卵。辰時, 太白見於巳地。 夜一更, 客星見....	K: [Continued from 24 Oct] At sunrise, the sun had a black spot as big as a hen's egg. ….	K: Sunspot	宣祖 179 卷, 37 年(1604 甲辰 / 명 만력(萬曆) 32 年) 閏 9 月 3 日(庚辰) Seonjo 179
28 May 1607		At about 4 pm on 28 may 1607 a sunspot described as resembling a fly was observed in the northeast quadrant of the solar disc, about one-third of the solar radius from the limb. Near its centre it was deep black (umbra), while its outer part was more diffuse (penumbra). The observation was made by kepler and others in a 4-cm solar image projected by a hole in the roof of an armatory at Prague.		[KEPLER (1608); KEPLER (1609)] WX 2013: 26

10 May 1608	(自昧爽至酉時, 四方昏濛若下塵。) 卯時, 日中有黑氣一點, 大如梨。	C: "From daybreak until the hour of *yu* (5-7 pm) in every direction it was dull and hazy as if dust was falling. At the hour of *mao* (5-7 am) within the sun there was a black spot as large as a pear".	C: Hazy, red, dim sun, sunspot	光海 2 卷, 卽位年(1608 戊申(萬曆) 36 年) 3 月 26 日(癸丑) Gwanghae 2
10 May 1608	日中有黑氣一點, 大如梨。	K: Within the sun was one black vaporous dot as big as a pear. [Same as above, this version NIY)	K: Sunspot (same as above) (NIY)	光海 2 卷, 卽位年(1608 戊申(萬曆) 36 年) 3 月 26 日(癸丑) Gwanghae 2
17 May 1608	戊申四月初四日庚申日中有黑子, 大如梨。 暫時乃滅。	K: W/in the sun was a black spot as big as a pear. It soon disappeared.	K: Sunspot (NIY)	光海 3 卷, 卽位年(1608 戊申萬曆) 36 年) 4 月 4 日(庚申) Gwanghae 3 Lee, Tab 1
30 Mar 1613	明神宗萬曆四十一年二月初十日, 興化日中黑光摩盪, 秋大旱	At Xinghua there were black lights rubbing on one another within the sun; a great drought in autumn.	C: Sunspot, autumn drought	Zhuang: 14
11 Sep-10 Oct 1616	[Unable to access source.]	"Sun's light moving about for 5 or 6 days in succession. Stopped only after a month".	C: Sunspot	["Zhili Tongzhou Zhouzhi"; Xu & Jiang (通州直隷州志) (1982)]
10 Oct 1616	明神宗萬曆四十四年八月戊辰 日中有黑光。	C: A black light was in the sun [Last day (30th day 晦) of lunar month]	C: Sunspot	Zhuang: 14
11 Jan 1617	明神宗万历四十四年十二月初五 辰、巳间，日旁有数黑子磨荡。	C: Several black spots rocked back and forth between the double-hours of *chen* and *si* (07:00-11:00).	C: Sunspots	Zhuang: 14

1617	明神宗万历四十五年 日中黑子摩荡。 明神宗萬曆四十五年, 日中黑子摩盪.	C: [Sometime during 1617,] black spots rubbed against one another w/in the sun. C: [Same as above]	C: Sunspots C: Sunspots	Zhuang: 14
25 Apr-23 May 1618	明神宗万历四十六年四月 日中有黑子。	C: Wan-li reign-period, 46th year, 4th month. "Within the Sun there was a black spot.” [This could be a misdated doublet of 24 May-21 Jun 1618 below.]	C: Sunspot	《明会要·祥异一》卷 68 页 1316 Minghuiyao 68 Yau: 163 Zhuang: 15
24 May-21 Jun 1618	明神宗万历四十六年闰四月 [Unable to access source.]	(ii) [CHINA] Wan-li reign-period, 46th year, intercalary 4th month. "Within the Sun there was again a black spot; its light was wavering."	C: Sunspot	Yau: 164
24 May-21 Jun 1618	明神宗万历四十六年闰四月 日中黑子相斗。 日中复黑子，光摩荡比于嘉靖三十三年。 注：未见嘉靖三十三年黑子记录。	C: W/in the sun black spots fought one another. C: Once again there were black spots w/in the sun. Their lights, rocking back and forth, rivaled those in the 33rd year of Jiajing (1554). (Note: No black spots recorded in 1554.)	C: Sunspot	Yau: 164 Zhuang: 15
22 May 1618	明神宗万历四十六年四月丁巳日中黑斗。	C: W/in the sun was a black dou (ladle-like tool for measuring rice, probably shaped like Big Dipper).	C: Sunspot	Guoque 83 Zhuang: 14

20-22 Jun 1618	**明神宗万**历四十六年闰四月丙戌至戊子 **日旁有黑气，出入日中磨**荡者久之。 **黑气出入日中摩**荡。 **注：天文志**载闰六月，当为闰四月之误又戊子系五月朔。	C: "From this day until day wu-tzu (25) - Jun 22 - for three days. On one side of the Sun there was a black vapour, coming in and out of the Sun and rocking to and fro for a long time." It was reported by the Astronomical Bureau at Nanking; it was not reported by the Astronomical Bureau at Peking."	C: Sunspot	《明史·天文三》卷 27 页 412 《明神宗实录》卷 569 页 13 Mingshi Tianwen 3 Shenzongshilu 569 Zhuang: 15
20-22 Jun 1618	**明神宗万**历四十六年闰四月丙戌 **日中有黑子，凡三日**	C: W/in the sun was a black spot; it lasted 3 days in total.	C: Sunspot	《明通鉴》卷 75 页 2933 Mingtongjian 75 Zhuang: 15
22 Jun 1618	**明神宗万**历四十六年五月朔 **董**应举上言："闰四月二十八、二十九日，人传日中黑斗，五月朔未刻，臣于宅用水盆仰照，见日旁黑气。 **日中有黑气。**	C: On 22 Jun, Dong, a civil service exam graduate, said: "On the 28th and 29th days of the intercalary 4th lunar month (20-21 Jun 1618), people said there was a black dou (rice measure, probably shaped like Big Dipper) w/in the sun. On the 22nd, at 1-3PM, I used a bowl of water at home to observe the sun and saw a black vapor next to the sun."	C: Sunspot	《国榷》卷 83 页 5119 明崇祯上海《松江府志》卷 47 页 28 Guoque 83 Yau: 166 Zhuang: 15
1618	[Unable to access source.]	C: [Sometime during the year,] "within the Sun there was a black spot.	C: Sunspot	來賓縣志 Yau: 162

15-24 Oct 1620 => 28 Aug-6 Sep 1620	[明光宗泰昌元年十月癸酉] 皇上登极未旬日有黑气斗日之异 Note: “八月一日光宗即位” = 28 Aug 1620,	C: T'ai-ch'ang reign-period, 1st year, 10th month, day kuei-yu (10) (Nov 23). "_ ..Moreover, when Your Majesty ascended the throne in the last 'decade' (of the previous month) [=> Not even ten days after Your Majesty had ascended the throne] - Oct 15 10 Oct 24 (=>28 Aug-5 Sep) - there was the omen of a black vapour on the Sun fighting the Sun.” [Corrected date in Yau and WX.]	C: Sunspot	明熹宗实录 9 Ming Xizongshilu 9 Yau: 167 WX 2013: 27
23 May 1621	明熹宗天启元年四月甲戌 日中有黑气摩荡。	C: W/in the sun were black vapors rocking back and forth.	C: Sunspots	《续文献通考·象纬三》卷 212 Xuwenxiantongkao Xiangwei 212 Zhuang: 15
3 May 1622	明熹宗天启二年三月己未 晡时，有黑气如日数颗，掩日相荡，如相斗状。	In late afternoon, there were a number of black vapors like suns, covering the sun and rocking against one another as if fighting.	C: Sunspots (NIY)	明崇祯上海《松江府志》卷 47 页 28 Zhuang: 16
9 Jun-7 Jul 1622	[明熹宗]天啟元年一月還陽有數日並出一[=> 二]年五月日中月星並見。 山東巡撫奏，五月中，日中月星並見。	C: T’ien-ch'i reign-period, 2nd year, 5th month. "Within the Sun, (the shapes of) the Moon and a star were seen next to one another.	C: Sunspots (moon & star seen w/in sun)	明會要卷六十八 Minghuiyao 68 Yau: 169 WX 2013: 27 (明)孫愼行 (http://archive.ihp.sinica.edu.tw/ttscgi/ttsquery?0:0:mctauac:TM%

				3D%AE%5D%B 7V%A6%E6)
17-20 Mar 1624	**明熹宗天启四年正月癸未 日赤无光，有黑子二三**荡于旁，渐至百许。凡四日。 **日旁有黑子相**荡，凡四日。	C: "The Sun was red and dim. There were two or three black spots lying laterally [=>agitating] at its sides. They gradually increased to about a hundred (sic), and lasted for four days." C: Black spots at the sun's sides rocked against one another for 4 days.	C: Sunspots C: Sunspots	《明史·天文三》卷 27 页 412 Mingshi 27 《国榷》卷 86 页 5257 Guoque 86 Zhuang: 15
15 Apr 1624	**明熹宗天启四年二月二十八日 天色黯淡，日旁黑子摩**荡。 见日旁有黑日荡磨。	The sky was gloomy and black spots rocked to and fro next to the sun. Black suns were seen rocking to and fro next to the sun.	C: Sunspots (NIY)	Zhuang: 15
16 Apr 1624	**熹宗天启四年二月癸丑黑日摩**荡日旁	C: Black suns rocked to and fro at the side of the sun.	C: Sunspots	钦定续通志卷一百七十 Xutongzhi 170 WX 2013: 28
6 May* 1624 or 15 Jun*	**明熹宗天启四年四月癸酉日中黑气摩**荡。注：本月无癸酉。**[三月癸酉** would be 6 May* 1624; **癸酉=>癸丑** = 15 Jun*]	C: Black vapors rocked to and fro w/in the sun. [No day guiyou in 4th month. Day guiyou in 3rd month would be 6 May 1624; day guichou in 4rd month would be 15	C: Sunspot (NIY)	《明史·天文三》卷 27 页 412 Mingshi Tianwen 3 Yau: 171 Zhuang: 15

1624		Jun*]		
6 May-2 Aug 1625	(Unable to access source.)	C: Stars were seen on a dim sun, black spots by its side. This went on for 10 days.	C: Sunspot (NIY)	Zhenjiang Fuzhi (镇江府志) WX 2013: 28
2 Sep 1625	明熹宗天启五年八月一日 白昼，星见日旁。	C: A star was seen next to the sun. [Possibly sun-grazing comet.]	C: Sunspot (NIY nor W)	Zhuang: 15
29 Jun 1626	[明熹宗天启六年六月六日] (Unable to access source)	C: A ladle (measuring rice tool, dou, shaped like Big Dipper) was seen w/in the sun. [Note: WX: “Jun 21 would correspond to day 6”; however, Day 6 is 29 Jun and 21 Jun corresponds to the 28th day of the 5th lunar month.]	C: Sunspot	WX 2013: 28
5 Aug 1630	明思宗崇祯三年六月二十七日 日中星现。	C: A star was seen within the sun.	C: Sunspot (NIY)	Zhuang: 15
25 Feb 1631	明思宗崇祯四年正月二十五日 日中有黑子。	Within the sun was a black spot.	C: Sunspot	Zhuang: 15-16
17 Feb-18 Mar 1635	明思宗崇祯八年正月日有黑光摩荡。	C: The sun had black lights rocking to and fro.	C: Sunspots	Zhuang: 16

1637	明思宗崇祯丁丑 日中有数黑子，磨色如口口	C: W/in the sun were several black spots, [?rocking to and fro, colored like …?] [Text corrupted]	C: Sunspots	Zhuang: 16
16 Mar 1638	[明思宗崇祯十一年二月乙未] (Unable to access source)	C: "The sun's light was shimmering all the day."	C: Sunspot	WX 2013: 28
8 Sep-6 Oct 1638	明思宗崇祯十一年八月又有黑光摩荡日旁。	C: Again, black spot(s) was/were rocking to and fro on the side(s) of the sun.	C: Sunspot	Zhuang: 16
9 Dec 1638	明思宗崇祯十一年十一月癸亥日中有黑子及黑青白气。 日入时，日光摩荡如两日。	C: W/in the sun was a black spot and black, blue-green, and white vapors. C: At sunset, the sun's light rocked to and fro as if there were two suns.	C: Sunspot C: Sunspot	《明史·天文三》卷 27 页 413 Mingshi Tianwen 3 Zhuang: 16
9 Dec* 1638	明思宗崇祯十一年十一月癸巳日中有黑子及黑青白气。	C: W/in the sun was a black spot and black, blue-green, and white vapors. [The text gives day as guisi (癸巳), which did not occur in the 11th month.=>癸亥, as entry above.]	C: Sunspot	Zhuang: 16
5 Feb 1639	明思宗崇祯十二年正月辛酉(三日) (Unable to access source)	C: "Sun's light shifting about all the day".	C: Sunspot	WX 2013: 29
7 Feb 1639	明思宗崇祯十二年正月五日 日旁青黑气若战。	C: Next to the sun were black vapors as if fighting.	C: Sunspot	Zhuang: 16
16 Mar 1639	明思宗崇祯十二年二月庚子 xxx	C: "White rays and black cloud(s) cross and cover one another, light of the sun	C: Sunspot	WX 2013: 29

		shifting about.”		
26 Oct 1639	明思宗崇禎十二年十月甲申朔 xxx	C: “A ladle (dou, rice measuring tool, probably shaped like the Big Dipper) was seen in the sun” [on the 1st day of the lunar month].	C: Sunspot	WX 2013: 29
13 Apr 1640	明思宗崇祯十三年二月二十三日 见日中有黑光摩荡之异。	C: Within the sun was a black light rocking to and fro; it was an ominous portent.	Sunspot (NIY)	Zhuang: 16
19 Feb-19 Mar 1643	明思宗崇祯十六年正月日黑光摩荡。	C: The sun had black lights rocking back and forth.	C: Sunspots (NIY)	Zhuang: 16
16 Jun-15 Jul 1643	明思宗崇祯十六年五月日中见星。 明思宗崇祯十六年 日中见星。	C: W/in the sun was a star. C: W/in the sun was a star.	C: Sunspot (NIY)	Zhuang: 16
5 May-2 Jun 1647	清世祖順治四年四月日中有形如刀。	C: W/in the sun was a shape like a sword.	C: Sunspot (NIY)	Zhuang: 16
28 Jul 1647	清世祖顺治四年六月二十七日 日中星现。	C: A star appeared w/in the sun.	C: Sunspot (NIY)	Zhuang: 16
16 Jan 1648	戊子/太白見, 日中有黑子。	K: There was a black spot in the sun.	K: Sunspot	仁祖 48 卷, 25 年(1647 丁亥(順治) 4 年) 12 月 22 日(戊子) Injo 48

23 Apr-18 Aug 1648	清世祖顺治五年夏 日中星现。	C: Summer (23 Apr-18 Aug). W/in the sun was a star.	C: Sunspot	Zhuang: 16
25 Oct 1650	順治七年十月辛巳朔巳时，日食七分太，次于亢。 xxx	C: “The sun was eclipsed [at 09:00-11:00) . At noon, within the Sun a ladle (dou) was seen.”	C: Solar eclipse, Sunspot	清史天文十二 Qingshi Tianwen 12 Zhuyong Xianzhi Yau: 185 WX 2013: 30
30 Apr 1655	清世祖顺治乙未年三月二十四日 申刻，日中有黑子，久之乃散。	C: At the hour *shen* (3-5PM), w/in the sun there was a black spot. After a long time, it dispersed.	C: Sunspot	Zhuang: 16
26 Jan-23 Apr 1656	清世祖顺治十三年春 日中见黑子	C: Spring (26 Jan-23 Apr). “W/in the sun there was seen a black spot.”	C: Sunspot	Zhuang: 17
12 Jun 1659	清世祖顺治十六年四月二十三日(癸丑) 日中黑光摩荡。	C: W/in the sun was/were black light(s) rocking to and fro.	C: Sunspot (NIY)	Zhuang: 17
22 May 1660	清世祖顺治 17 年四月十四日(戊戌)	C: “Black vapor on the sun.” K: Black gas	C, K: Sunspot	WX 2013: 30 Lee, Tab 1
5 Jul 1661	清世祖顺治十八年六月初十日 日下有黑子，自辰至酉。	C: Black spot(s) at the bottom of the sun, from the 07.00-09:00 double-hour to 17:00-19:00.	C: Sunspots	Zhuang: 17

20 Feb 1665	清圣祖康熙四年正月初六日 日有黑子二，摩荡久之。	C: The sun had two black spots; they rocked to and fro for a long time.	C: Sunspots	Zhuang: 17
15 Feb-16 Mar 1665	清圣祖康熙四年正月 日中黑光摩荡竟日。黑光蔽日摩荡不息，数日方复。	C: W/in the sun, black light(s) rocked to and fro all day long. C: Black light(s) covered the sun, rocking to and fro w/o stop. They finally were extinguished after several days.	C: Sunspots	Zhuang: 17
15 Feb-16 Mar 1665	清圣祖康熙四年正月 日中黑光摩盪竟日月杪乃滅	C: "Within the sun there was a black light wavering;" [it ended at the end of the month].	C: Sunspots	Yau: 188
1665 Spring	清圣祖康熙四年春 有黑子往来如梭，与日相荡。	C: A black spot was moving back and forth like a shuttle, rocking back and forth against the sun.	C: Sunspot	Zhuang: 17
27 Aug 1665	清圣祖康熙四年七月十七日 日中星见。	C: A star was seen w/in the sun.	C: Sunspot	Zhuang: 17
16-18 Mar 1684	清聖祖康熙二十三年二月丁酉朔 (Unable to access source.)	K: "W/in the sun the *douxing* (either the Big Dipper or the Southern Dipper, both are ladle-shaped asterisms) was seen."	C: Sunspot	Yau: 192

Appendix C: Description of Supplementary Tables. For ease of use, all are excel spreadsheets.

Supplemental Table 1. Excel spreadsheet of auroral observations in Appendix A and observations from the literature. Column A: Year, A.D., Column B: Date of Aurora in text format. Comments on exactness of date and if multiple consecutive days or observations are recorded. Column C: Date of Jan. 1, 1900 needed for excel calendar function. Column D: Month and Day of Aurora as if it occurred in 1900-needed for excel calendar function. Column E: Year fraction calculated by excel calendar function using information in columns 3 and 4. Note: this method of calculating year fraction is for a 365 day year. Column F: Basis. This is the basis used for the excel calendar function. Column G: Year plus year fraction. Column H: First color of aurora, Column I: Second color of aurora, Column J: Third color of aurora (sometimes a fourth color is listed). Column K: Reference for aurora if aurora not listed in Appendix A. Entries highlighted in yellow-new data.

Supplemental Table 2. Excel spreadsheet of sunspot observations in Appendix B. Column A: Year, A.D., Column B: Date of sunspot sighting in text format. Comments on exactness of date and if multiple accounts are recorded. Column C: Description of duration of sunspot sightings.
Column D: Date of Jan. 1, 1900 needed for excel calendar function. Column E: Month and Day of Aurora as if it occurred in 1900-needed for excel calendar function. Column F: Year fraction calculated by excel calendar function using information in columns 3 and 4. Note: this method of calculating year fraction is for a 365 day year. Column G: Basis. This is the basis used for the excel calendar function. Column G: Year plus year fraction. Entries highlighted in yellow-new data.

Supplemental Table 3. Excel spreadsheet of number of low-latitude auroras in each calendar year: calculated using histogram function in Stat Plus for excel.
Column 1: Year, A.D., Column 2: Total number of low-latitude auroras in that year.

Supplemental Table 4. Excel spreadsheet of number of sunspots in each calendar year: calculated using histogram function in Stat Plus for excel. Column 1: Year, A.D., Column 2: Number of days in the year when sunspots were visible.

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