Sky-gazing and Season-Granting: Astronomy in Ancient China

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National Astronomical Observatories of China
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Characteristics of Ancient Chinese Astronomy

Correspondence between Heaven and Man:
• Man is to follow the cosmological rhythm.
• Monthly ordinance.
• Calendar-making was essential.

The concept of change:
• Everything changes.
• No celestial and terrestrial distinction.
• The Book of Change says: "Heaven hangs up its symbols, from which are seen good and bad fortune, and the sage makes his interpretations accordingly."
The Chinese creation myth

We may find clues of this idea in the Chinese myths of the creation of the universe. According to a Chinese creation myth, the universe was created by Pan Gu the Giant Creator.
The Prehistoric Taosi Observatory
Early history of Chinese civilization

• Legendary sage kings: ca. 2500-2000 BC.
• Taosi Culture: ca. 2300 -1900 BC.

• The Xia dynasty: 2070 -1600 BC.
• The Shang dynasty: 1600 -1046 BC.
• The Zhou dynasty: 1046- 256 BC.
The Discovery of the Taosi Site

Taosi site: N 35º 53’ E111º 30’, Xiangfen, Shanxi Province.

1970s-1990s: the identification of the Taosi culture (4300 to 3900 BP).

A huge city wall, about 2 square kilometers, largest in prehistoric China, indicating the emergence of a pre-dynastic kingdom.

Related to Emperor Yao.

2003-4: He Nu discovered a semi-circular enclosure along the southern base of the Taosi city wall.
High culture at the Taosi site

A bronze cogwheel.

The Chinese character 文.
Foundation of the Taosi Altar
Airscape of the Taosi site
Astronomical alignments

E12  Jun. 25th
E11  May 21st & Jul. 30th
E10  Apr. 29th & Aug. 20th
E9   Apr. 11th & Sep. 6th
E8   Mar. 30th & Sep. 18th
E7   Mar. 20th & Sep. 27th
E6   Mar. 9th & Oct. 7th
E5   Mar. 1st & Oct. 15th
E4   Feb. 12th & Oct. 31st
E3   Jan. 25th & Nov. 18th
E2   Dec. 21st
The original center of observation
Historians of astronomy at the site, November, 2005
Observation of sunrise on December 22, 2005
Working model of the structure
The rising sun casts light to the center
The Research Team, 22 June, 2009
<table>
<thead>
<tr>
<th>Slot</th>
<th>Gregorian dates in 2100 BC</th>
<th>Julian dates in 2000 BC</th>
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<tr>
<td>E12</td>
<td>6-25</td>
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<td>7-11</td>
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</tbody>
</table>
The actual horizon at the Taosi site: the altitudes of the horizon seen through the 12 slots.
Determination of the date

Method:

For each year, we have 20 sunrises seen through 11 slots, on 20 dates of the solar year. Treat them as 20 observations. For each observation, compute the deviation of the center of the sun from the center of the slot. Calculate the standard deviation for the year. The year with the smallest standard deviation to be the date of the structure.
For the year -2018, the rising sun seen through slot 2-12 on the corresponding days. The rising moon seen in slot 1.
Top: the deviation of the moon from the center of slot 1 at moonrise.
Middle: Standard deviation of the sun from the centers of slots 2-8, at sunrises.
Bottom: Standard deviation of the sun from centers of slots 2-12, at sunrises.
Julian dates for the sunrises in the slots in -2075
• The function of slot E1: The 18.6 year cycle?
The discovery of the gnomon

The earth block that contained the painted stick.

The reconstructed painted stick.
The tomb where the painted stick was discovered
Simulative observation
The reconstructed gnomon
The use of the template
Comparing the dates derived from sunrise observations with those from gnomon measurements

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<td>R4</td>
<td>23-24.3</td>
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<td>R6</td>
<td>39-39.9</td>
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<td>E12(Jun. 24&lt;sup&gt;th&lt;/sup&gt;)</td>
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<td>42.5-43.4</td>
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<td>R8</td>
<td>53.3-54</td>
<td>May 23&lt;sup&gt;rd&lt;/sup&gt;/Jul. 23&lt;sup&gt;rd&lt;/sup&gt;</td>
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<td>E8(Sep. 18&lt;sup&gt;th&lt;/sup&gt;)</td>
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<td>E7(Mar. 18&lt;sup&gt;th&lt;/sup&gt;/Sep. 25&lt;sup&gt;th&lt;/sup&gt;)</td>
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<td>163.9-164.8</td>
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<td>170.5-171.5</td>
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<td>E6(Mar. 9&lt;sup&gt;th&lt;/sup&gt;)</td>
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<td>E2(Dec. 20&lt;sup&gt;th&lt;/sup&gt;)</td>
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The correspondence between the “horizontal calendar” and the “gnomon calendar”. Vertical green lines represent the graduation on the painted stick. Horizontal blue lines indicate the length of gnomon shadows on the dates determined by the sunrises in the slot 2-12.
He commanded the Xi and He (hereditary astronomers) reverently to follow august heaven, calculating and delineating the sun, moon, and other celestial bodies in order respectfully to grant the seasons to the people, ...to take the 366 days and, by using intercalary months, to fix the season and to define the year.
Emperor Yao

- A later Qing representation of the legend the Xi and He brothers receiving commission from the emperor Yao to observe stars and make calendar.
The four cardinal asterisms

The day is of medium length and the star is Bird (niao), and the mid-spring is determined.
The day is the longest and the star is Fire (huo), and the mid-summer is determined.
The night is of medium length and the star is Void (xu), and the mid-autumn is determined.
The day is the shortest and the star is Hair (mao), and the mid-autumn is determined.
Earlier datings of the four cardinal asterisms

- Gaubil 1732 dated these observations as between 2155 and 2796 B.C.
- Zhu Kezhen 1926 determined the date for Fire, Bird, and Void is around 1000 B.C., but for Hair, the date is about 2300 B.C.
- Iijima Tadao 1921 suggested 400 B.C. He held the opinion the Chinese astronomy had been greatly influenced by Greek-Babylonian astronomy at the time of Alexander the Great.
- Sun Xiaochun and Jacob Kistemaker 1997 suggested the date for these four cardinal asterism is around 2300 B.C., with an uncertainty of 250 years.
The four asterisms as the four cardinal points

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<tr>
<th>Asterisms</th>
<th>Determinative Stars</th>
<th>Right Ascension at 2400 B.C.</th>
<th>Deviation from the cardinal points</th>
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<td>η Tauri</td>
<td>23h 45m</td>
<td>-15m</td>
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<td>Bird</td>
<td>α Hydrae</td>
<td>5h42m</td>
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<td>Fire</td>
<td>α Scorpionis</td>
<td>12h 18m</td>
<td>+18m</td>
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<tr>
<td>Void</td>
<td>α Aquarii</td>
<td>17h47m</td>
<td>-13m</td>
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Summary of topic one

• By the 21th century B.C., astronomy reached a considerable level in China. Three basic techniques of observation were already used.

• The Taosi site had functions of an astronomical observatory. The observation of sunrises and probably of the moon.

• The Taosi site was probably connected to the legendary Emperor of Yao, being dated around 2000 B.C.
Astronomical Instruments:
The reconstruction of Su Song’s water-powered astronomical clock tower
Gnomon

A gnomon at Beijing Ancient Observatory

The Dengfeng gnomon tower constructed by Guo Shoujing, ca. 1280 AD.
The armillary sphere of 1442, based on Guo Shoujing’s earlier design in 1280.

The simplified armillary sphere of 1442.
Water Clock

Time-keeping is essential for astronomical observations. According to the Zhou Rituals, there were special officials in charge of water clock. That means the Chinese might have invented water-clock in the early Zhou dynasty (1045 -221 BC). The earliest water clock excavated in China is from the Han.
Water Clock

In the eleventh century, the Chinese developed highly sophisticated technology of water clock. Several vessels were used to maintain steady water flow. Siphons were also used. Water temperature was controlled. Even mercury was used to take place of water. Yan Su’s (961 -1040) water clock reached an accuracy of 18 seconds per day.
Water-powered Instruments

Using water flow from the clepsydra to power the instrument is a very ancient idea, both in China and in the west. Zhang Heng (78 -139 AD) constructed a celestial globe driven by water-flow. This marked the beginning of the Chinese history of water-powered celestial instruments.
Su Song’s Water-Powered Instruments

Su Song (1020 -1101) constructed the Water-powered Astronomical Clock Tower in 1092, which combined the armillary sphere, the celestial globe, time keeping and reporting mechanisms into one large automatic system. It has been hailed as first astronomical clock in the world.
The reconstruction of Su Song’s Water-powered Astronomical Clock Tower

Su Song’s Water-Powered Astronomical Clock Tower has been hailed by Joseph Needham as the earliest astronomical clock in the world. It represents the peak in the Chinese history of astronomical instrument making. Since 1950s, there have been several reconstructions of the instrument, including one by Natural Science Museum of Taiwan (1993), one by Seiko in Japan (1997), and recently one in Tongan County in Fujian Province (Su Song’s native place), all in 1:1 scale. All these reconstructions were based on J. H. Combridge’s “flip-scoop” model of the “escapement mechanism”, which hypothesizes that the 36 scoops attached to the Central Wheel were not fixed, but can flip as it was filled with water to trigger off the Celestial Balance that locked the wheel.
The escapement mechanism
The Central Wheel
The “flip-scoop” model of the escapement mechanism

The reconstruction of the escapement mechanism.

The “fixed-scoop” model of the escapement
The fixed-scoop model

Components that serve the function of the “escapement mechanism”.
“Rabbit Head”

The “Rabbit Head”, thought just as decoration in “flip-scoop” model, serves as a key component in our “fixed-scoop” model.
The transmission shafts
Power source: water
The armillary sphere
The celestial globe
Time-reporting jack-wheels
Summary

Our “fixed scoop” model is not only mechanically sounder, but fit the original descriptions by Su Song better than the “flip scoop” model.

It is a mechanical realization of the Chinese conception of “Heaven and Man in One”.
Calendar-making and computation of planetary motions: Why didn’t Eleventh Century Northern Song China produce a Kepler?
Calendar-making

A Chinese calendar (li 历) was not just an arrangement of days, months and years, it was a complete set of mathematical techniques for calculating an ephemerides which provides both positions and dates for characteristic phenomena for the sun, moon and planets, such as eclipses and conjunctions of planets.

The method of the calendrical astronomy was first to determine cycles for the astronomical phenomena to be represented, and then, by a process which amounts to finding lowest multiples, larger cycles were constructed to contain and subsume series of small ones. The system was made integral when a final “great year” cycle was found, which like an immense wheel driving a congeries of graduated smaller wheels arranges in subsystems. It was then necessary to find the epoch, to determine just how long ago the largest cycle had begun. Then the state of any smaller cycles could be determined by a simple counting process.
Generation cycle of Five Phases
Conquest cycle of Five Phases
Dynastic succession based on the conquest cycle of the Five Powers

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<thead>
<tr>
<th>Dynasty</th>
<th>Flourishing Power</th>
<th>Symbolic Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow Emperor 黃帝</td>
<td>Earth</td>
<td>Yellow</td>
</tr>
<tr>
<td>Xia (c. 2070-1600BC)</td>
<td>Wood</td>
<td>Green</td>
</tr>
<tr>
<td>Shang (c.1600-1046BC)</td>
<td>Metal</td>
<td>White</td>
</tr>
<tr>
<td>Zhou (1046-220BC)</td>
<td>Fire</td>
<td>Red</td>
</tr>
<tr>
<td>Qin (221-206 BC)</td>
<td>Water</td>
<td>Black</td>
</tr>
<tr>
<td>Han(206BC-AD220)</td>
<td>Earth</td>
<td>Yellow</td>
</tr>
</tbody>
</table>
Dynastic succession based on
the generation cycle of the Five Powers

<table>
<thead>
<tr>
<th>Power</th>
<th>Dynasty</th>
<th>Dynasty</th>
<th>Dynasty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood</td>
<td>Taihao 太颢</td>
<td>Di Ku</td>
<td>Zhou</td>
</tr>
<tr>
<td><em>Water</em></td>
<td><em>Gonggong</em></td>
<td><em>Di Zhi</em></td>
<td><em>Qin</em></td>
</tr>
<tr>
<td>Fire</td>
<td>Yan Di</td>
<td>Di Yao</td>
<td>Han</td>
</tr>
<tr>
<td>Earth</td>
<td>Huang Di</td>
<td>Di Shun</td>
<td>Xin (New)</td>
</tr>
<tr>
<td>Metal</td>
<td>Shaohao</td>
<td>Xia</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>Zhuanxu</td>
<td>Shang</td>
<td></td>
</tr>
</tbody>
</table>
Month = $29 \frac{499}{940}$ days

Year = $365 \frac{1}{4}$ days

19 years
= 235 months
= $6939 \frac{3}{4}$ days

The beginning of a large cycle

One month later
Month = \frac{499}{940} \text{ days}

Year = 365 \frac{1}{4} \text{ days}

19 \text{ years} = 235 \text{ months} = 6939 \frac{3}{4} \text{ days}

One year later

The end of a large cycle
## Synodic periods of Five Planets, as derived from the Taichu calendar (104 BC)

<table>
<thead>
<tr>
<th>Planets</th>
<th>Synodic periods as in the Taichu calendar, 104 BC (days)</th>
<th>Modern values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jupiter</td>
<td>398.7</td>
<td>398.88405</td>
</tr>
<tr>
<td>Mars</td>
<td>780.5</td>
<td>779.93609</td>
</tr>
<tr>
<td>Saturn</td>
<td>377.9</td>
<td>378.09190</td>
</tr>
<tr>
<td>Venus</td>
<td>584.1</td>
<td>583.92138</td>
</tr>
<tr>
<td>Mercury</td>
<td>115.9</td>
<td>115.87748</td>
</tr>
</tbody>
</table>
Entries on planetary events in official histories
Planetary motion

The prediction of planetary motion was a major part of the Chinese calendrical astronomy. By the time of second century BC, the Chinese had already observed the syzygies of the five planets. The Taichu calendar, the earliest existent Chinese calendar, determined the synodic periods of the five planets.

While the ancient Greeks used the deferent and epicycles for the computation of planetary motions, the Chinese used numerical and algebraic methods. For the description of the syzygy of a planet, the Chinese divided it into several segments, each representing a state of the planet’s movement.
Planetary motions

Zhang Zixin (fl. 560), after spending 30 years observing the sky on an island, discovered the inequality of the solar and planetary motions. Previously, the speed of apparent motion of the planet had been assumed to be constant during each stage of its syzygy, now he found that the speed varies in each stage, and also varies with the season.

Taken his discoveries into consideration the Tang astronomers could produce far more accurate predictions of planetary motions than before. In Yi Xing’s Great Expansion system, for instance, the syzygy for the planets was represented much closer to the actual motions.
Average error in synodic periods derived from calendars in ancient China. Chen Meidong (1997)
Similar patterns of error?

During the Northern Song, in the eleventh century, the accuracy of the calculation of planetary motions in China had already reached the similar level of the West in the sixteenth century.

Above: Prutenic Tables, 1551.
Below: Jiyuan li, 1107.
Why didn’t Northern Song China produce a Kepler?
In the beginning of the 17th century, Johannes Kepler (1571-1630), using observations made by Tycho Brahe (1546-1601), waged his “war on Mars”. He won his war with the discovery of the three laws of planetary motion, bringing about a revolutionary change in astronomy, harbingering celestial mechanics of Isaac Newton.
Shen Kua (1031-1095) who, realizing the serious discrepancies in the prediction of planetary movements, proposed a project to tackle the problem. Shen Kua’s project, however, ended in abortion. He could not achieve anything remarkable on the computation of planetary motion. The eleventh century Northern Song China, so to speak, did not produce a Kepler.
Crisis with the Mars

• 端拱二年四月己未（公元989年5月16日），翰林天文官张玭在禁中观测天象，当时宋太宗就发手诏说：“览《乾元历》细行，此夕荧惑当退轸宿而顺行，今止到角宿乃顺行，得非历差否？”In 989, on May 16, while the Hanlin astronomer Zhang Pi 张玭 was observing the sky in the inner court, Emperor Taizong wrote a note to him: “I was consulting the almanac based on the Supernal Epoch System. It says Mars will retrograde up to the lunar lodge Chariot (zhen 轸, in modern constellation Corvus) before it proceeds eastward in direct motion. But now it had retrograded only to the lunar lodge Horn (jiao 角, in Virgo) before it resumed direct motion again. Is something wrong with the system?” （[14], 2543页）
Response 1: Flatter and Ignore

张答诏回奏说：“今夕一鼓，占荧惑在轸末、角初，顺行也。据历法，今月甲寅（5月11日）至轸十六度，乙卯顺行，验天差二度．臣占荧惑明润轨道，兼前岁逆出太微垣，按历法差疾者八日，此皆上天佑德之应，非历法之可测也。”This early evening (i.e. May 16) at the first watch, it was observed that Mars began to moving eastward at the eastern end of the lunar lodge Chariot or the western end of the lunar lodge Horn. But according to calculation, it should have begun to move eastward on May 12, after moving in retrograde motion to the 16th degree of Chariot on the day of jiayin 甲寅(May 11). This is two degrees out of step with the heavens. I observed that Mars was bright and moved smoothly. In the previous year, Mars retrograded out of the constellation of Taiwei yuan 太微垣. Calculation predicted it 8 days too early. This is Heaven above helping a virtuous [ruler] with a good portent, not something that mathematical astronomy can predict.
Response 2: Test the calendar

- While astronomers like Zhang Pi manipulated astrological interpretations to flatter the emperor, astronomers like Zheng Zhaoyan saw in planetary events a good opportunity to improve the astronomical system. He used 25 historical records of planetary events since the Han times to check the calendar. He compared the computations using the Supernal Epoch System with those using the two astronomical systems from the Tang dynasty: Chimera Virtue System (linde li 麟德历, 665-728) and Great Expansion System (dayan li 大衍历, 728-758). These two Tang astronomical systems were outstanding in their predictions of planetary motions. The result was rather disappointing. Not only did the Supernal Epoch System not show much improvement in planetary predictions, but it was actually less accurate with respect to most of the planets than were the two Tang systems.
Response 3: Propose a new project

- Shen Kua, a polymathic statesman (1031-1095)
- His innovative program:
  - Making of new instrument;
  - Planned a series of observations of a kind not proposed in Europe until the time of Tycho Brahe, five centuries later: exact coordinates read three times a night for five years.
Shen Kuo’s program

• To predict the apparent positions of the planets – not merely their mean speeds and prominent phenomena.

• A new computational method he called “zhuai shu”. The computational tools available did not permit this to be done with a few observations of stationary points, occultations, and maximum elongations.
Shen Kua (1031-1095) proposed to improve on the planetary theory. But his project failed. Why?
Technical

- Technically, the criteria used for testing the accuracy of the planetary theory were problematic, which emphasized the number of “fitting” cases between calculation and observation, while avoiding prediction at the crucial moments of the planetary motion.
Errors in the predicted longitudes of Mars derived from the *Jiyuan li* (1106) (Tang Quan 2011)
Politically, in portent astrology, planetary events did not present omens as conspicuous as solar and lunar eclipses. An error in the prediction of a planetary event would not raise an alarm as failure in solar prediction did. So there was not much political motivation for improving the planetary theory.
Bureaucratic

- Bureaucratically, incumbents in the Astronomical Bureau were actually very unwilling to bring change to their routine work. When Shen Kua proposed to improve the planetary theory, he needed continuous observation of the planets for at least three years. He did not get support on this from his colleagues. On the contrary, he was interrupted with fierce quarrels between talented astronomers and incompetent placeholders.
Personal and political

Shen Kua’s relationship with Wang Anshi, the reformer. He supported reform.

Shen was appointed to the astronomical bureau, a critical position in imperial politics. He replaced Sima Guang, an ardent opponent to Wang’s New Policy reforms.
王安石的抱怨

- 我曾研究古今历法，五星行度，唯留逆之际最多差。自内而进者，其退必向外，自外而进者，其退必由内。其迹如循柳叶，两末锐，中间往还之道相去甚远，故两末星行成度稍迟，以其斜行故也。中间成度稍速，以其径绝故也。历家但知行道有迟速，不知道径又有斜直之异。熙宁中，予领太史令，卫朴造历，气朔已正，但五星未有候簿而验。前世修历，多只增损旧历而已，未曾实考天度。其法须测验每夜昏晓夜半月及五星所在度秒，置簿录之，满五年，其间剔去云阴及昼见日数，可能三年实行，然后以算术缀之，古所谓缀术者此也。是时司天历官，皆承世族，隶名食禄，本无知历者，恶朴之术过己，群沮之，屡起大狱，虽终不能摇朴，而候簿至今不成。奉元历五星步术，但增损旧历，正其甚谬处十得五六而已。相之历术，今古未有，为群人所沮，不能尽其艺，惜哉！(《梦溪笔谈》卷八，150条，第334-335页)
Shen Kua’s complaint

I have studied calendrical systems of old and new. For the prediction of planetary positions, errors are the biggest when the planets were at station or retrograde motion. ... During the Xining period (1068-1075), I served as director of the Imperial Observatory. Wei Pu was appointed to make the calendar. For the solar and lunar motions, it was quite accurate. But for planetary motions, there were no enough measurements for a good system. Formerly, when making a new calendar, they just adjust some constants in the calendar, without actually check it against the sky. I propose to measure the position of the planets three times a night for five years. Excluding cloudy nights we may have data for three years. Then we can approximate the real motion using the mathematical method of “zhui shu” (literally “stitching method”).

Unfortunately, most astronomers then at the Observatory inherited their positions from their fathers or grandfathers. They were just placeholders satisfied with receiving salaries doing nothing. No one really knew the calendar, but they were jealous of Wei Pu’s talent. They slandered Wei Pu collectively, even bring accusations against him at court. Though they could not do actual harm to Wei Pu in person. The proposed astronomical observation was out of the question.

In the computation of planetary motions, Wei Pei had to make do with correcting some constants in the old systems! There is no match to Wei Pu’s talent in calendar making. But his talent could not be used. What a pity!

(Jottings at the Dream Brook)
Economic

- However, favorite financial support of astronomy by the imperial government.
# Financial support of astronomy

<table>
<thead>
<tr>
<th>Year</th>
<th>Expenditure on astronomy (string)</th>
<th>Fiscal income (string)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1057</td>
<td>21365</td>
<td>36822541</td>
<td>0.058%</td>
</tr>
<tr>
<td>1066</td>
<td>36605</td>
<td>44000000</td>
<td>0.083%</td>
</tr>
<tr>
<td>1071</td>
<td>39533</td>
<td>50600000</td>
<td>0.078%</td>
</tr>
<tr>
<td>1082</td>
<td>36248.6</td>
<td>48480000</td>
<td>0.075%</td>
</tr>
<tr>
<td>1086-1092</td>
<td>43792.2</td>
<td>48480000</td>
<td>0.090%</td>
</tr>
</tbody>
</table>
Annual expenditure on astronomy

For comparison:

- 2007: fiscal income was 5100 billion RMB. Input in science and technology was 120 billions. Astronomy, about 0.3 billion, counting for just 0.005%, almost 20 times less than in the Northern Song!
Summary

On planetary motions, China in the eleventh century could have achieved more.
Political and bureaucratic reasons made it hard to make real innovations.
When scientists were forced to make innovations, no innovations are possible.
Observation of Celestial Phenomena
Observation of Astronomical Phenomena

Solar and lunar eclipses
The Book of Documents records perhaps a solar eclipse that occurred during the reign of King Zhongkang of the Xia dynasty, ca. 2043 BC.

On the first day of the third lunar month of the autumn, the sun and the moon was in disconcert with each other (i.e., a solar eclipse occurred) in the constellation House (i.e., Scorpion). The blind (magicians) were so alarmed as to beat the drums. The local officers rushed and the common folks panicked.
Eclipses

Oracle bone inscriptions from the 12th century BC mentioned solar eclipses. The Spring and Autumn Chronicle contains records of 37 solar eclipses, almost all of them actually occurred, from 722 BC to 481 BC.
Comets

In Chinese astrology, the appearance of comets signifies “doing away with the old [order of things] and bringing about the new [order of things]”. The Chinese were early observers of comets. The earliest reliable record is that of 613 BC, and that is believed to be the earliest record of the Halley comet.
Aurora Borealis (Northern Lights)
Aurora Borealis (Northern lights)
Sometimes, star suddenly appears where there seems no star at all, after sometime it disappears again. This could be a nova or supernova which is star undergoing a sudden increase in brightness during the final stages of its life. The Chinese felicitously called it “guest star” that comes and goes. In ancient Chinese literature, one can find nearly 100 records of “guest stars”. Such records provide invaluable data for the modern astrophysical study of stars and galaxies. A well-known example is the “guest star” near the Chinese tianguan 天关 star (ζ Tau) in 1054 which is now identified with the supernova outburst of which the Crab nebula is remnant.
Sometimes a “guest star” could be extremely bright, and the Chinese called it “resplendent star” (jing xing 景星). In 1006, a “resplendent star” was observed by the Chinese:

Jingde reign period, third year, fourth month, day wuyin [=1006 May 6]. A zhoubo (another name for jing xing) star was seen. It was to the south of Di and 1 du west to Qiguan. Its form was like the half Moon and it had spoke-like rays. It was so brilliant that it lit up things.

Previously, on the second day of the fourth month [=May 1], at the first watch of the night, a large star had been seen. Its color was yellow and appeared at the east of Kulou and at the west of Qiguan. Its brightness had gradually increased. Its position was measured as at 3 degrees in Di.

This supernovae was also observed in Japan and Arabic world. Based on these descriptions we can get a curve of change of brightness of this supernovae, which closely resemble a supernovae observed in 1987.
景德三年四月二日初更
May 1, 1006, 20:30 E
Observations on May 1.

May 1: a large star, yellow in color. Brightness increasing by days.
Mag: -1 (Chinese)

May 1: a large guest star as bright as Mars.
Mag: -2. (Japanese)
Kitab al-Muntazam: May 3, Bright as Venus and moon
Observations on May 3

May 3, 1006, new moon. A large star similar to Venus appeared in qibla. Mag: -4. (Kitab al-Muntazam)
May 5. Moon phase: 25%
Observation on May 5

Ali ibn Ridwan: 2.5 to 3 times large as Venus. Bright as quarter full moon. Mag: -8
三年四月戊寅 May 6, 20:30. S
Observations on May 6

China: Zhoubo star appeared one degree west to qiguan. Looked like half moon. Radiantly bright as to lit up surroundings. Located to the west of Kulou. Mag: -10.
八月入浊 August 27,1006
景德三年十一月壬寅

Nov. 26, 1006. 6:30 am E
Observations on May 16, 1016

• Zhoubo star reappeared.
• By 1009, this Zhoubo star was already hard to observe. Astronomers at the Song court argued about its location. It was decided that it was 3 degrees into lunar loge Di.
Light curve reconstructed from above observations

Light Curve of SN1006

Days from May 1, 1006

-magnitude
Light curve of Type Ia supernova
中国古代天象记录：世界上独一无二的宝库。
中国古代天象记录科学应用价值极大。
牛顿天体力学与中国天文记录
超新星与中国客星记录

Nature, Science上相关论文200篇以上。
Compendium of records of astronomical phenomena

庄威凤、王立兴主编：《中国古代天象记录总集》，1988。
黑子270；极光300；陨石300；
日食1600；月食1100；
月掩行星200；新星超新星100；
彗星1000；流星雨400；
流星4900；其它200。
总计10000多项记录。
Sunspots and solar activity

Sunspot records to verify long-term solar dynamo models. The Maunder minimum? Other periods in solar activity?

Usoskin et al. (2007): reconstruction of sunspot number over multiple millennia, from C–14.
Celestial events and earth environment


A dramatic increase of radiocarbon in coral from the South China Sea at the same time. (based on study by Sun Weidong, unpublished, submitted to Nature)
Measured radiocarbon content and comparison with IntCal98.
Causes: Supernova, comet, meteors?

a comet collided into the Earth’s atmosphere from the constellation of Shen (Orion) on 17 January AD 773 with coma stretched across the whole sky and disappeared within one day.

有长星出于参, 其长亘天. 长星, 彗属.

*New Tang History.*
A possible explanation? (picture by Sun Weidong et al.)

“A comet collided into the Earth’s atmosphere from the constellation of Orion on 17 Jan AD 773 with coma stretched across the whole sky and disappeared within one day, with ‘dust rain’ in the daytime” —Old Tang Dynasty Book

“七年丙寅，雨土，是夜，长星出于参” 旧唐书

As the comet drops down, $^{14}$C and $^{10}$Be are released until it burns out.

High $^{14}$C and $^{10}$Be contents

comet

atmosphere
Low $^{14}$C and $^{10}$Be contents

$^{14}$C $^{10}$Be $^{14}$C $^{10}$Be $^{14}$C $^{10}$Be $^{14}$C $^{10}$Be $^{14}$C $^{14}$C $^{14}$C

coral

tree
The Chinese Sky: correlating Heaven and Man
The Chinese Sky

The Chinese sky was constructed as a celestial empire mirroring the Chinese imperial society below. This was the result of the cosmological thought about the correspondence between Heaven and Man. It set the backdrop of the Chinese astrology.
Central Palace in the Chinese Sky

- 中宫天极星, 其一明者, 太一常居也。旁三星三公，或曰子属。后句四星，末大星正妃，余三星后宫之属也。环之匡卫十二星，藩臣。皆曰紫宫。
- —《史记天官书》
- The brightest star of the Celestial Pole is the permanent abode of the Great Unity. The three stars next to it are the Three Lords [the ruler’s paramount advisors], although some identify them as Princes. Curving behind it are four stars. The large star in the rear is the Empress. The other three belong to the imperial harem (concubines). The twelve stars that surround all of these, framing and defending them, are vassals. All of these make up the Purple Palace.
- — Book of Celestial Offices
The autumn sky: scene of harvest

- Constellations:
  Tiancang: Celestial Barn
  Tianjun: Celestial Grain Store
  Tianlin: Celestial Granary
  Tianyu: Ricks of grain in the field
  Tianhun: Cesspool
  Fuzhi: Reaping sickle
  Chuhao: Fodder
Picture of farmer’s life in the sky

- A picture of farmers separating chaff from grain by means of a winnowing basket.

- Chaff 糠 and Winnowing Baskets 箕 can be found among the constellations.
The notion of the central power

斗为帝车，运于中央，临制四乡。分阴阳，建四时，均五行，移节度，定诸纪，皆系于斗。—《史记天官书》

The Northern Dipper is the chariot of the emperor. It controls the four quarters by moving round the center. It separates yin and yang; establishes the four seasons; distributes the Five Phases, regulates the celestial movement, and determines the calendrical epochs. All these depend on the Northern Dipper.
Unlike the Greeks who imagined the sky a world of mythological heroes, the ancient Chinese designed the sky as a counterpart of the terrestrial society: stars were named and constellations were formed in the image of the earthly world. Stars and constellations became a basic correspondence system for Chinese portent astrology.

Many star names are mentioned in Chinese literature before the second century BC, but the earliest document that systematically described constellations in the whole sky is the Tianguan shu (Treatise on Celestial Officials) by Sima Qian (145 – 87 BC). About 90 constellations were mentioned, including the 28 lunar lodges. The sky was divided into five Palaces (gong). The Central Palace indicated the area surrounding the celestial North Pole (Beiji), which formed a “forbidden city” in the sky, with stars named such as emperor, queen, princes, concubines, eunuchs, and all kinds of court officials.

Painting on the ceiling of a Han tomb (ca. 2nd century BC), depicting the sun, moon and the 28 lunar lodges.
A star map from the Dunhuang collection (ca. 9th century), depicting the Central Palace of the Sky.
Chen Zhuo, an astronomer of the Three Kingdoms period (AD 220 - 280), collating constellations of various schools, finalized the traditional Chinese sky, which consisted of 283 constellations comprised of 1464 stars.

The Suzhou stone star chart, depicting the complete Chinese sky, featuring the 28 lunar lodges and the Milky Way, 1247 AD.
Remarks of Conclusion

For a period over 3000 years, China made tremendous progress in astronomy:

- It maintained the longest continuous records of all kinds of astronomical phenomena, still useful today for astronomical research;
- It made more than 100 astronomical calendars, each being a sophisticated system of astronomical computation;
- It constructed a large number of astronomical instruments, culminating in the construction of the Astronomical Clock Tower in the 11th century (the reconstruction of which is on exhibition during this conference).
Remarks of Conclusion

- Ancient Chinese astronomy: the most essential part of Chinese inquiry: to explore the connections between Heaven and Man.
- In doing this, the Chinese made remarkable achievements even from today’s perspective.
- The consciousness of man’s position in the universe is still meaningful in modern astronomy.
Thank you for your attention!"