Proceedings of "The 9th International Symposium on History of Astronomy"

Organizing committee

Hong-Jin Yang (KASI), Kiyotaka Tanikawa (NAOJ),
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Edited by

Hong-Jin Yang & Hyojun Lee
(Korea Astronomy and Space Science Institute)

March 29 2023 / On-line

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THE 9TH INTERNATIONAL SYMPOSIUM ON HISTORY OF ASTRONOMY

March 29(Wed.), 2023 09:50-18:00(UTC+09h)

On-line_Zoom **ID 378 637 1811 / PW astro9**

09:50-10:00	**OPENNING ADDRESS**	KIYOTAKA TANIKAWA (NAOJ)
SESSION 1.	**ASTRONOMICAL ALMANAC**	CHAIR : MITSURU SOMA (NAOJ)
10:00-10:30	Analysis of Calculation Method for Sunrise and Sunset Times in the Shixianli(時憲曆)	Go-Eun Choi Chungbuk National University
10:30-11:00	Lunar tidal acceleration from Solar eclipse of AD418	Kiyotaka Tanikawa National Astronomical Observatory of Japan
11:00-11:30	Stars as recorded in Seonggyeong 星鏡 (epoch 1861)	Junhyeok Jeon Chungbuk National University
11:30-12:00	The lunar movement model presented in the Sechoyuhui(細草類彙) of the Joseon(朝鮮)	Seung-Urn Choe Seoul National University
12:00-13:30	Group-Photo & Coffee Break(Lunch)	
SESSION 2.	**HISTORY OF ASTRONOMY**	CHAIR : K. RAMASUBRAMANIAN (IIT)
13:30-14:00	Establishment of the public holiday Matariki, based on the star cluster Pleiades and a particular moon phase	Pauline Harris Massey University
14:00-14:30	Observation of stars in medieval period in India	Shylaja B. S. Jawaharlal Nehru Planetarium
14:30-15:00	Orientation of Phimai Temple Related to the Acronychal Rising of the Pleiades on Saka Lunar New Year Day	Orapin Riyaprao National Astronomical Research Institute of Thailand
15:00-15:30	Stone star map in Haman Gaya tomb of 5C	Yong Bok Lee SohNam Institute for History of Astronomy
15:30-15:50	Coffee Break	
SESSION 3.	**HISTORICAL ASTRONOMY**	CHAIR : HONG-JIN YANG (KASI)
15:50-16:20	A Study on the Definition of Terms Related to Approach and Angular Distance between Celestial Bodies in Korean Historical Astronomical Records	Hyojun Lee Korea Astronomy and Space Science Institute UST
16:20-16:50	Cometary Records in the Vietnamese Historical Source Đại Nam Thực Lục Chính Biên(大南寔錄 正編)	Akira Okazaki Gunma University
16:50-17:20	Brahmatulya-Udāharaṇam by Viśvanātha - an insight into the procedures of 17th century for calculations of celestial events	Shubha B. S. Purnapramati - a center for integrated learning
17:20-17:50	On '白氣' : white vapor in Chinese ancient astronomical records	Nagatoshi Nogami Sumitomo Chemical Co., Ltd.
17:50-18:00	**CLOSING REMARK**	YONG BOK LEE (SIHA)

KASI 한국천문연구원 Korea Astronomy & Space Science Institute

国立天文台 NAOJ National Astronomical Observatory of Japan

召南天文學史研究所 SOHNAM INSTITUTE FOR HISTORY OF ASTRONOMY

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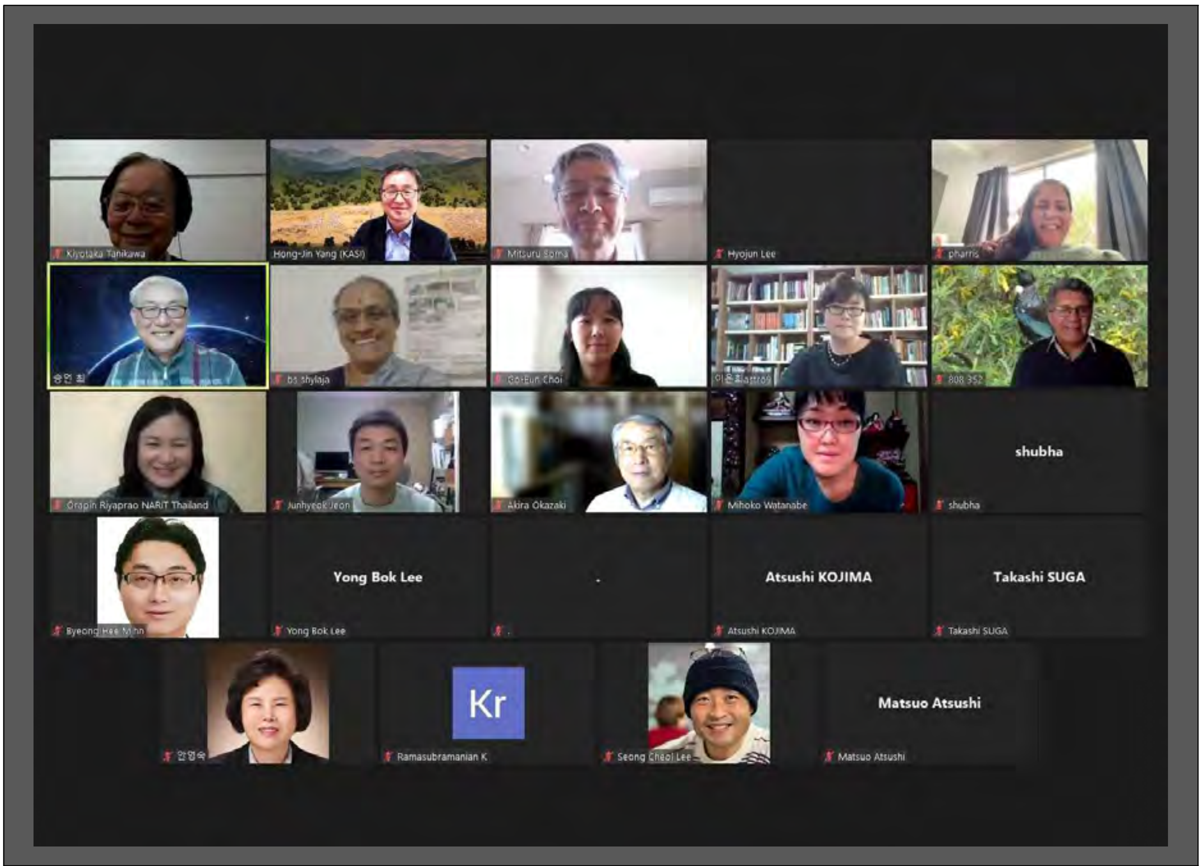

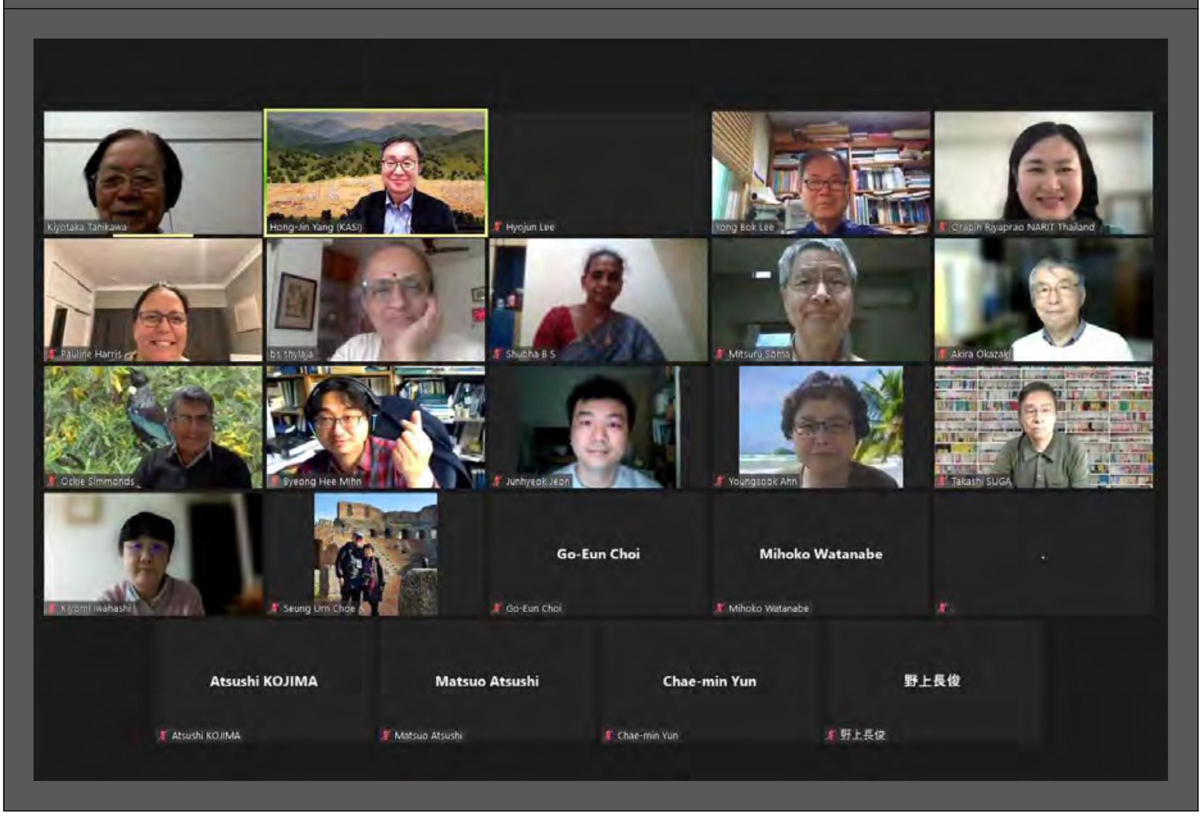

CONTENT

Opening Address

Kiyotaka Tanikawa
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Dear Friends,

Two years have passed since we had the Eighth Symposium on History of Astronomy on June 15–16, 2021 and the Symposium on Calendars Used in Asia and Oceania on March 15–16, 2021. These symposia were done through Zoom due to the pandemic of the COVID-19. Our last face-to-face meeting was done on March 11–12, 2019 as the Seventh Symposium on History of Astronomy. More than four years have passed. As a participant of the symposium I eager to meet friends and discuss intimately the history of astronomy. I may expect this in the next meeting. Ten years of our international collaboration have taught me that the center of mass of the research on the history of the Asian astronomy has shifted from Europe to Asian nations, i.e., to India, China, Korea, and Japan. This is due to the development of the respective nations including the education, the number of scholars, and the amount of budgets together with the deepening of the understanding the history of their past. The other shift of the center of mass has taken place in the study of historical astronomy. For a long time, the Great Britain, in particular the Stephenson school lead this field.

However, though their method of analysis is popular, I feel, theirs is out of fashion because their accuracy in the time domain is not enough to cope with the recent results from other fields related to the climate changes. The eastern scholars using the ancient eastern solar eclipses and occultations with data of other regions prepare a promising substitute with a new method.

In this important stage, Sôma and Tanikawa have decided to pass the baton of leading the community to Korean scholars Hong-Jin Yang and Yong-Bok Lee. This baton pass is almost inevitable. In fact, Japan is shrinking rapidly due to the un- avoidable interference of the foreign powers. This is in contrast to India, China, and Korea which are rapidly expanding in every respect. The Japanese governmental budget for science and education is decreasing. The political and economical systems are deteriorating. The Japan cannot keep the leadership.

I hope that Drs. Yang and Lee may lead the group of the Asian history of astronomy from now until the next baton pass.

Kiyotaka Tanikawa

Session 1. Astronomical Almanac

◤Chair : Mitsuru Soma /

National Astronomical Observatory of Japan◢

Analysis of Calculation Method for Sunrise and Sunset Times in the *Shixianli*

Choi, Go-Eun[1,2], Lee, Ki-Won[2], Mihn, Byeong-Hee[3]
[1]Basic Science Research Institute, Chungbuk National University
[2]Daegu Catholic University
[3]Korea Astronomy and Space Science Institute

Abstract

We conducted an analysis of the methods used to calculate sunrise and sunset times in the Shixianli, which was used in the late Joseon dynasty in Korea and the Qing dynasty in China, by referring to the Yuzhi lixiang kaocheng. The Shixianli was first introduced by Jesuit missionaries under the name Chongzhen Lishu. The Chongzhen Lishu was subsequently changed to Xiyang Xinfa Lishu, Yuzhi lixiang kaocheng and Yuzhi lixiang kaocheng houbian, as the calculation methods for celestial motion and astronomical constants were constantly revised. Shixianli was first implemented in 1654 in the Joseon dynasty, and this calendar was also changed, following the revision of the Chinese calendar. The Lixiang kaocheng was utilized in the first year of King Yeongjo (1726), and the Lixiang kaocheng houbian was employed from the 21st year of the same king (1745). We found that the observational data used to calculate the sunrise and sunset times in the Lixiang kaocheng was the daily declination of the sun. and this value was obtained using the latitude, and solar altitude on the summer solstice.

I. Motivation

Q1) How did the sunrise and sunset times are determined in the astronomical almanacs from 17C to 20C?

Q2) What were the latitude and astronomical constant values used to calculate sunrise and sunset times?

sunrise and sunset times ▶ hereafter SR&SS times

II. Calendrical Treatises of *Shixianli*

China: Ming (1368-1644) & Qing dynasty (1636-1912)

Korea: Joseon dynasty (1392-1896) & Empire of Korea (1897-1910)

2.1 *Shixianli* ?

the common name for Chinese calendars implemented in the Qing 淸 dynasty (1636-1912), was influenced by Western astronomy and mathematics and revised several times.

Similar to other Chinese calendars, this calendar was introduced into Korea during the Joseon 朝鮮 dynasty (1392-1907).

2.2. *Shixianli* of Ming & Qing dynasty

Applicable period: 1645-1912 (except for 1667-1669: previous *Datongli*)

1634: *Chongzhen lishu* 崇禎曆書 (hereafter CZL)
- the first edition of the Shixianli was compiled by Chinese scholars and Jesuits
- CZL was not adopted by the Ming court but by the Qing court.

1646: *Xiyang xinfa lishu* 西洋新法曆書 (hereafter XXL)
- After the Qing dynasty occupied Beijing, CZL was reissued by Adam Schall (1591-1666), a German Jesuit missionary.
- renamed : *Xinfa lishu* 新法曆書→ *Xinfa suanshu* 新法算書
- for inclusion in the *Siku quanshu* 四庫全書.

1724: *Yuzhi lixiang kaocheng* 御製曆象考成 (hereafter YLK)
- A practical revision of the XXL was performed during the reign of Kangxi 康熙 emperor, and the result was published

1742: *Yuzhi lixiang kaocheng houbian* 御製曆象考成後編 (hereafter YLH)
- The last major revision was published during the reign of the Qianlong 乾隆 emperor by Ignaz Kögler (1680-1746)

1723: *Lisuan quanshu* 曆算全書 (hereafter LQS)
- The calculation of SR&SS times is also concisely explained
- compiled by Chinese mathematician Mei Wending 梅文鼎 (1633-1721)

2.3. *Shixianli* of the Joseon dynasty & Empire of Korea

Applicable period: 1654-1912 (except for 1667-1669: *Datongli*)

SR time on the Summer solstice	Calendrical Treatises of *Shixianli* (Total: 10)	SR & SS		Latitude at Seoul (37°39′15″)
		times	calculation method	
different 04:46 a.m.	*Hyeonsang-sinbeob-Secho-ryuhwi* 玄象新法細草類彙 (1710)	○	×	×
same time 04:42 a.m.	*Donggook-muheon-bigo* 東國文獻備考(1770)	○	×	×
	Sinbeob-jungseonggi 新法中星紀 (1789)	○	×	○
	Chiljeong-bobeob 七政步法 (1789)	×	○	○
	Gukjo-yeoksanggo 國朝曆象考 (1796)	○	○	○
	Siheon-giyo 時憲紀要 (1860)	×	○	×
	***Chubo-cheoprye* 推步捷例 (1861)**	○	○	○
	Chubo-sokhae 推步續解 (1862)	×	○	○
	Taeyang-chulippyo 太陽出入表 (1867)	○	×	×
	Juengbo-Muheon-bigo 增補文獻備考 (1908)	○	×	○

2.4. The method of *Yuzhi lixiang kaocheng* 御製曆象考成 (YLK)

Calendrical Treatises of Joseon containing the SR&SS times calculation method were identical to the YLK.

YLK has :

1) the most detailed explanation of the methods of calculating SR&SS times with related diagrams.

2) YLH states referring to YLK for calculating these times.

▶ analyzed the calendrical methods for calculating the SR&SS times by referring to YLK.

III. Calculation method of SR&SS times in the *Shixianli*

3.1. Astronomical systems

1. key astrophysical quantities in calculating the SR&SS times for a given location : **latitude (ϕ)**, longitude (λ), **obliquity of the ecliptic (ε)**

[λ: not important when calculating using units of local apparent solar time (AST)].

2. summarizes the values of the ϕ and ε recorded in calendrical treatises.

	Calendrical Treatises (Pub. Year)	Latitude		Obliquity of the ecliptic
		Beijing	Seoul	
C	*Xiyang xinfa lishu* (XXL) 西洋新法曆書[1646]	39° 55′ /40° N	-	from Tycho 23° 31′ 30″
	Lisuan quanshu (LQS) 曆算全書[1723]	39° 55′ /40° N	36° N	23° 31′ 30″
	Yuzhi lixiang kaocheng (YLK) 御製曆象考成[1724]	39° 59′ 30″ /39° 55′ N	37° 39′ 15″ N	23° 29′ 30″
	Yuzhi lixiang kaocheng houbian (YLH) 御製曆象考成後編 [1742]	(39° 55′ /40° N)	-	from Cassini 23° 29′
	Yixiang kaocheng xubian (YKX) 儀象考成續編 [1845]	-	-	23° 27′
K	*Chubo-Cheoprye* (CCR) 推步捷例 [1861]	-	37° 39′ 15″ N	23° 27′
	Chubo-Sokhae (CSH) 推步續解 [1862]	-	37° 39′ 15″ N	23° 27′

3.2. Latitude (ϕ , 北極出地度)

$$\phi = \frac{h_p^{max} - h_p^{min}}{2}$$

(h_p^{max} , h_p^{min}: maximum & minimum altitudes of the Polaris, respectively)

In YLK

39° 59′ 30″ N (Beijing) was measured around the winter solstice.

37° 39′ 15″N (Seoul, Korea)

In YLH (No chapter to calculate latitude)

two latitude values for Beijing are mentioned.

1) The angular distance between the zenith and the North Pole in the capital is 50° 5′ (hence, **39° 55′** N)

2) altitude of the North Pole in the capital is **40°** relating to the calculations of solar eclipse times and directions of a lunar eclipse, respectively.

3.3. Obliquity of the ecliptic (ε, 黃赤距緯度)

$$\varepsilon = h^{G}_{\odot} - (90° - \phi) = 23°\ 29'\ 30'' \text{ (where } \phi \text{ is } 39°\ 59'\ 30'')$$

topocentric position: the transit altitude of the Sun on the summer solstice is **73° 29′ 10″**

↓

adding the *Taiyang dibanjingcha* 太陽地半徑差 (i.e., diurnal parallax of the Sun) of **50″**

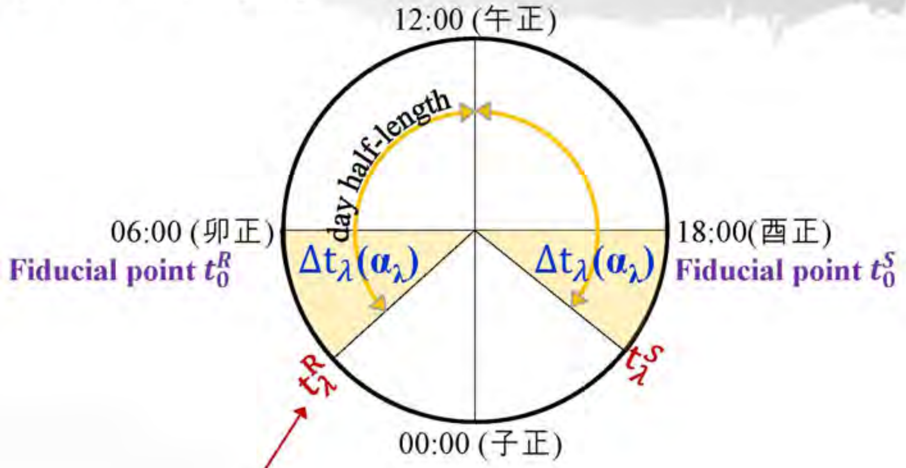
(In the YLK, the values of the solar diurnal parallax according to the topocentric altitude are tabularized in intervals of 1° ranging from 1° to 90°).

↓

$h^{G}_{\odot}$ (the geocentric transit altitude of the Sun) : **73° 30′**

3.4. calculation of the SR&SS times

Δt_λ: difference between half-length of daytime and quarter-length of a day to the *Mao-Zheng* and the *You-Zheng* single-hours, respectively

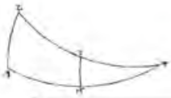


when δ_λ is North (+): SR time (t_λ^R): $t_0^R - \Delta t_\lambda$, SS time (t_λ^S): $t_0^S + \Delta t_\lambda$

when δ_λ is South (-): SR time (t_λ^R): $t_0^R + \Delta t_\lambda$, SS time (t_λ^S): $t_0^S - \Delta t_\lambda$

3.5. Flowchart for SR&SS times calculation

Declination of the Sun on the summer solstice
δ_λ ($\lambda = 90^\circ$) ▶ $\varepsilon = 23^\circ\ 29'\ 30''$



↓ **trigonometric functions, linear interpolation**

$\sin\delta_\lambda$(Solar declinations according to the λ) $=\sin\lambda \sin\varepsilon$,
[law of sines in the Right-Angled Spherical Triangles Or using **Tables of Solar Declination**]

↓

$\sin\alpha_S = \tan\varepsilon \tan\phi$ (on the summer solstice)
$\sin\alpha_\lambda$(dfference 赤道度 according to the δ_λ)$= \tan\delta_\lambda \tan\phi$ (according to the λ)
Or $\sin\alpha_\lambda = \sin\alpha_S \tan\delta_\lambda / \tan\varepsilon$
[using Right-Angled Spherical Triangles]

↓

α_λ (angle) → Δt_λ (time) [using $1h = 15^\circ$, $4m = 1^\circ$]

↓

SR time (t^R_λ): $t^R_0 \pm \Delta t_\lambda$, SS time ($t^S_\lambda$): $t^S_0 \pm \Delta t_\lambda$

t^R_0 (卯正, 06:00), t^S_0(酉正, 18:00): Fiducial point

IV. Comparison with the annual almanac

4.1. Chinese Shixian almanacs

4.2. Korean Shixian almanacs

4.1. Chinese *Shixian* almanacs

◀ **1723** on the summer solstice
: SR time (IV h 2 m 4 p)

1753 on the summer solstice ▶
: SS time (IV h 2 m 5 p)

[1670, 1719, 1723]
ϕ= 39° 55′ N or 40° N , ε = 23° 31′ 30″ **(X)**
ϕ= 40° N , ε = 23° 30′ (not 23° 31′ 30″) simplified value (O)

[1753, 1772, 1780, 1761, 1794, 1864, 1824, 1910]
ϕ= 39° 55′ N, ε = 23° 29′ 30″
same results (4 combination): ϕ= 39° 55′ N, ε = 23° 30′ (or ε = 23° 29′) ,
ϕ= 39° 59′ 30″ N, ε = 23° 29′ (or ε = 23° 27′)

4.3. Korean *Shixian* almanacs

◀ **1727** on the summer solstice
: SR time (IV h 3 m 1 p)

1728 on the summer solstice ▶
: SS time (IV h 2 m 12 p)

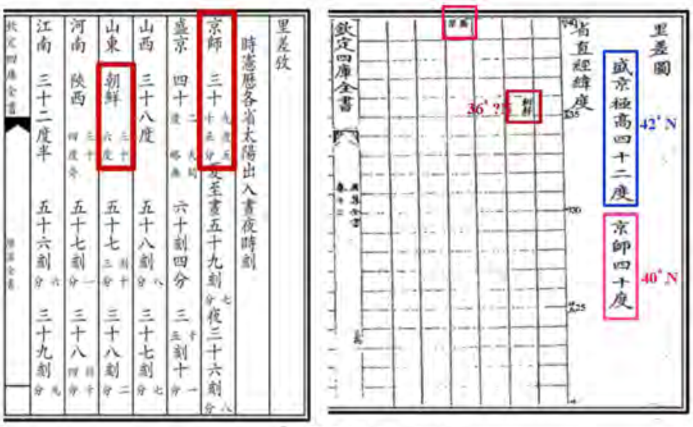
[1654-1727, *Hyeonsang-sinbeob-Secho-ryuhwi*]
ϕ= 36° N , ε = 23° 30′ (same result: ϕ= 36° N, ε = 23° 31′ 30″),
23° 30′ :might be used in accordance with the value in China

[1728-1912]
ϕ= 37° 39′ 15″ N, ε = 23° 29′ 30″ (no variation: 23° 30′ , 23° 29′ , 23° 27′)

4.3.1. Latitue of the Seoul is $\phi = 36^\circ$ N ?

According to the records of *Qingshigao* 清史稿, the latitude and the difference of longitude of the individual regions provided in the XXL were based on the distance on a geography map and thus were not accurate.
→ the altitude was measured in the years of Emperor Kangxi and the values were recorded.

In the *Lisuan quanshu* 曆算全書 (1723), the latitude of Joseon is specified as 36°. Therefore, we assume that the latitude value was not an observed value but based on a map.



Lisuan quanshu 曆算全書 (1723)

A grid chart showing relative positions of major regions in China, including Seoul, shows the latitude of **Shenyang 瀋陽** (previous capital of the Qing dynasty) as **42° N** and **Beijing as 40°** N. In contrast, when listing the latitudes for major regions, Beijing is recorded as 39° 55′ N, and **Seoul** as **36° N**.

4.4. recording rules of time

1. SR & SS times in annual almanacs are not recorded every day

Almanacs of 1654-1676 (*Shixian*): SR&SS times are recorded based on the **specific day number** from the four principal solar terms (WS, SS, VE, AE).

ex) **SS+00day → SS+17days → SS+28→ SS+37…**

1677-1908 (*Shixian*): SR&SS times on the dates corresponding to the **48 ecliptic longitudes**, as in Chinese almanacs, was applied to the Korean almanacs.

1896-1912 (*Ryeok* -Gregorian calendar) : only on the days of 24 solar terms

V. Summary & Further Work

We calculated SR&SS times for various combination of the **latitude** and the **obliquity of the ecliptic** and compared the results with those recorded in the Chinese and Korean Shixian almanacs.

First, the latitude of Beijing was measured from the observations of maximum and minimum altitudes of the Polaris in the Shixianli. Contrastingly, the obliquity of the ecliptic was measured from the relationship between the latitude of an observer, and declination and transit altitude of the Sun corrected for its diurnal parallax.

Second, Western mathematics, such as trigonometric functions, and properties of spherical right-angled triangles, known as the Napier's rule, were employed to calculate the SR&SS times.

Third, SR&SS times were recorded on the dates corresponding to the 48 ecliptic longitudes since around 1670 in China and 1677 in Korea.
However, similar to the Korean almanacs of 1654-1676, the times recorded on specific dates after the four principal solar terms at the beginning of Chinese Shixian almanacs. In addition, the recording dates were changed into the dates of the 24 solar terms in the Gregorian calendar almanacs published in Korea.

Lastly, the values of $\phi = 40°$ N & $\varepsilon = 23° 30'$ (not $23° 31' 30''$) were used in Chinese Shixian almanacs presumably before 1726 (1753, at least) for calculating the SR&SS times and $\phi = 39° 55'$ N and $\varepsilon = 23° 29' 30''$ in the almanacs since then.
In the latter Chinese almanacs, we also found no variations in the SR&SS times for $\phi = 39° 55'$ N & $\varepsilon = 23° 29'$ (not $23° 27'$),
and $\phi = 39° 59' 30''$ N & $\varepsilon = 23° 29'$ or $23° 27'$ (not $23° 29' 30''$).

the values of $\phi = 36°$ N and $\varepsilon = 23° 30'$ (in accordance with the value in China), $\phi = 37° 39' 15''$ N & $\varepsilon = 23° 29' 30''$ were used in Korea Shixian almanacs before and after 1728, respectively.
no variations in the SR&SS times in the latter Korean almanacs were found for $\phi = 36°$ N & $\varepsilon = 23° 31' 30''$, $\phi = 37° 39' 15''$ N & $\varepsilon = 23° 29'$ or $23° 27'$.

Thank you very much

ΔT and the lunar tidal acceleration for AD 418

Kiyotaka TANIKAWA[1]

[1]National Astronomical Observatory of Japan
Mitaka, Tokyo 181-8588, Japan

Received ; Accepted

Abstract

We obtain narrower and more reliable ranges of ΔT and the lunar tidal acceleration for AD 418. The latter result is particularly important because there is no method other than using the Sôma diagram to obtain this range. The first result for this range has been obtained in 2004 for the year 188BC (Tanikawa & Sôma, 2004).

Introduction

The lunar tidal acceleration means the secular deceleration of the lunar motion along its orbit due to the tidal interaction between the Earth and Moon. The longterm variations of the delay ΔT of the Earth rotation have been obtained in

Stephenson (1997): -500 to AD 1600.

Stephenson et al. (2016): 720 BC to AD 2015.

$\Delta T = \mathrm{TT} - \mathrm{UT}$

TT is the Terrestrial Time (uniform time)

UT is the Universal Time measured with reference to the rotation of the Earth.

The variations are expressed by a spline curve: a pieceiwse quadratic curve with smooth connection.

Purpose of the present report

Our evaluation on the spline curve of Stephenson (1997) and Stephenson et al. (2016)

(1) It is too much smooth.

(2) ΔT variations of periods as short as hundreds or several tens of years may have been smoothed out.

(3) The scatters of ΔT values of adjacent years amount to 10000 seconds in some cases due to the clock errors.

Our ideas

(1) We use reliable total solar eclipses.

(2) We use

(2)-1 Single deep solar eclipses observed thousands of kilometers apart;

(2)-2 Multiple deep solar eclipses of adjacent years.

(3) We plot Sôma diagram.

Purpose

We determine the ranges of ΔT and the lunar tidal acceleration using the eclipse on AD 418 July 18.

Example eclipses

We have experiences of determining the range of ΔT using multiple observations of a single solar eclipse (Fig. 1) and multiple observations of a single solar eclipse plus observations of contemporaneous solar eclipses (Fig. 2). In the former case, the data are equivalent with two independent observations of the same annular eclipse. In the latter case, the data are equivalent with five independent observations of contemporaneous deep eclipses. In both cases, parameters ΔT and the lunar tidal acceleration are common.

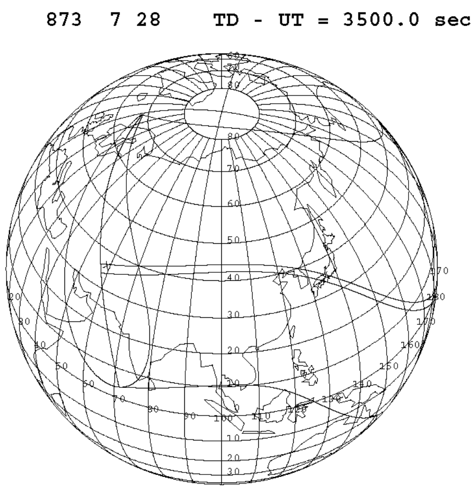


Fig. 1. Eclipses of AD 873 observed at Nishapur and Kyoto

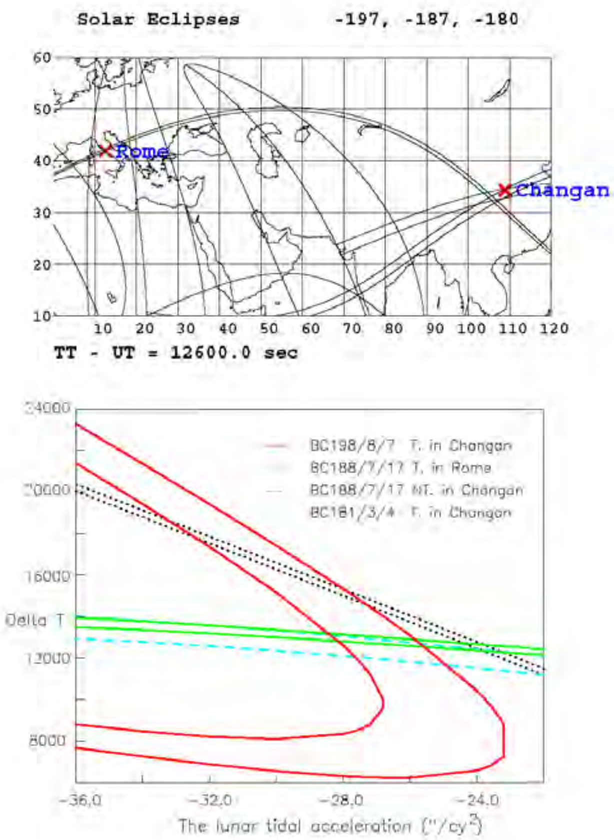


Fig. 2. Total eclipse bands for four nearly contemporary observations of eclipses on BC198 Aug 7, BC188 Jul 17, and BC181 Mar 4. The modern value of LTA is $A = -25''.97 \pm 0.05''/\mathrm{cy}^2$. The range is $[A - 2.0, A + 0.5]$

Records of the eclipse on AD 418 July 18

Byzantine

Recently, Hayakawa et al. (2022) analyzed the solar eclipses on AD 418 July 18, using the records Philostorgius' Church History. Their translation goes like this:

> When Theodosius [i.e., Emperor Theodosius II] had reached adolescence, on the nineteenth of July at about the eighth hour, the Sun was so completely eclipsed that stars appeared. And such a drought followed this event that there was everywhere an unusually high number of deaths of human beings and animals.

They interpreted the phrase "**the Sun was so completely eclipsed that stars appeared**" as implying **the total solar eclipse**. However, we reinterpret this phrase as implying the almost total solar eclipse. 'so completely eclipsed' is different from 'completely eclipsed'. 'so completely' suggests that the eclipse was almost complete.

Chaves

We have two records from *Monumenta Germaniae Historica* due to Theodorus Mommsen (1892) and G. Waitz (1881). These records are of Bishop Hydace supposed to be observed at Chaves, Portuguese in AD 418. Both say that a star appeared. *Annales Chronographi Vetusti*(Waitz 1881) says in the footnote that the star is a comet. The eclipse should have been deep, say, the magnitude was larger than 0.99.

The range of ΔT is

$$6450 \text{ sec} < \Delta T < 6900 \text{ sec}$$

and the range of the correction to the tidal acceleration is

$$A - 1.0''/\text{cy}^2 < \text{LTA} < A + 0.46''/\text{cy}^2$$

compared with the former result $A - 2''.0 < A < A + 0''.5$.

Table 1. Longitude and latitude of Observation sites

City	Longitude	Latitude
Chaves	7 ° 28'W	41 ° 44'N
Ginzo de Limia	7 ° 44'W	42 ° 04'N
Byzanz	28 ° 59'E	41 ° 1'N

If the eclipse was not almost total at Chaves, then we have

$$6450 \text{ sec} < \Delta T$$

and

$$A - 1.0''/\text{cy}^2 < A$$

i.e. compared with the former result $A - 2''.0 < A < A + 0''.5$.

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Stars as recorded in *Seonggyeong* 星鏡

(epoch 1861)

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Abstract

Seonggyeong's star data were calculated with precession correction, considering a 17-year period, with the selection of traditional East Asia asterisms and southern sky constellations from the star catalog in *Yixiang Kaocheng Xubian*. While *Seonggyeong* used improved position data, the East Asian tradition was maintained for the coordinate system and composition of the asterisms. This a dual system is characterized by the application of the latest data to reflect the new, while maintaining the old by adhering to tradition. This duality is analogous to the conditions of conflict and convergence that emerged at the end of the Joseon Korea due to changes in Western powers and values. In other words, we think that prior to the introduction of modern astronomy, *Seonggyeong* reflected the values of astronomers in Joseon Korea, who were experiencing conflicts caused by the fusion of tradition and modernity. The average position error of stars recorded in *Seonggyeong* is 5.33±0.34 arcmin. Considering that the positional error of star catalogs made in Europe at the same time is within approximately 0.5 arcmin, the positional accuracy of *Seonggyeong* is very low. In Europe, as navigation and trade exchanges became more active, and industrialization occurred, the demand for scientific knowledge increased, leading to the production of accurate star catalogs. Therefore, depending on the perspective of the time, the purpose of using the star catalog in Joseon Korea, as evidenced by the method of composition of *Seonggyeong* and the position error of recorded stars, can be understood to be completely different from that in Europe.

Introduction I

History of star catalogue in East-Asia after the 14th century

- 14th century = **明譯天文書** *Mingyi tianwen shu* (Book of astronomy translated in the *Ming* Dynasty)
- 15th century = **七政算外篇** *Chiljeongsan-Oepyeon* (Supplement to the calculations of the motion of the seven celestial determinants)
- 16th century = **七政推步** *Qizhengtuibu* (Calculation of the Seven Regulators)
- 17th century = **西洋新法曆書** *Xiyang Xinfa Lishu* (Treatises on calendrical astronomy according to the new methods from the western ocean)
- 18th century = **儀象考成** *Yixiang Kaocheng* (Compendium of imperial astronomical instruments)
- 19th century = **儀象考成續編** *Yixiang Kaocheng Xubian*

Introduction II

- 15th century : **七政算外篇** *Chiljeongsan Oepyeon*

> 黃道南北各象內外星經緯度立成 *Hwangdo-nambuk-gaksang-naeoe-seonggyungwido-ipseong*
> Catalogue of stars in ecliptic northern and southern sky.
> All of the stars' positions are arranged within ±10° on an ecliptic plane.
> Islamic/Arabic culture is assumed to have had an influence.

- 18th century : **增補文獻備考** *Jeungbo munheonbigo*, and **頤齋全書** *Yijae jeonseo*

> Only 1st magnitude and the determinative star of 28 lunar lodges were selected from the star catalogue in *Yixiang Kaocheng*

- 19th century : **星鏡** *Seonggyeong* (by Nam Byeong-gil 南秉吉, 1820-1869)

> The position of fixed stars is the result of corrections(s) to precession in the star catalogue in *Yixiang kaocheng xubian*.
> All sky data.
> Historical data that can grasp astronomical knowledge of the late Joseon Korea before the introduction of modern astronomy.

Previous research : *Seonggyeong*

- Identification of the Stars listed in "*Seong Kyung*" (Hahn and Yu, 1974)
- Identification of stars in *Song-Gyong* (Ahn, Park, and Yu, 1996)
- An Analysis of the Stars Recorded in *Seonggyeong*
  : Comparison with the Star Catalogue in *Yixiang Kaocheng Xubian* (Jeon, 2017)

Purpose of research

Based on the paper of Jeon(2017), supplemented and summarized.

- Description of the composition.
- Error analysis according to the position and magnitude of identified stars.
- Comparative review and verification with the star catalogue in *Yixiang Kaocheng Xubian*.
- Characteristics and significance of this book.

The overall contents are summarized and explained in this presentation.

Content of *Seonggyeong*

- First volume (80 pages)

> 序 (Introduction), 3垣 (Three Yuan of asterisms), 28宿 (28 lunar lodge)

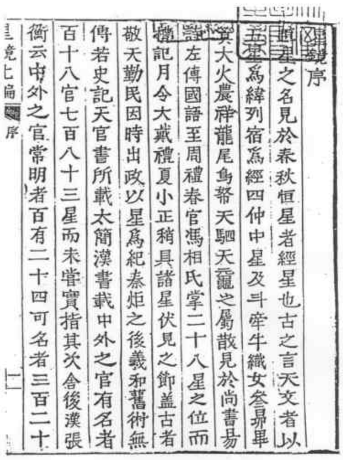
- Second volume (62 pages)

> 28宿 (28 lunar lodge), 近南極星 (the Southern constellation), 等 (Magnitude), 赤道儀圖 (Figure of equatorial instrument) , 篇後 (Book review)

All 142 pages

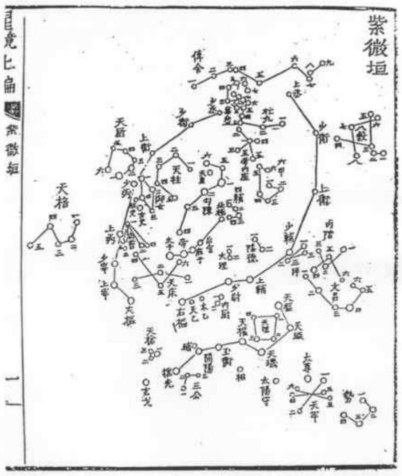
> 134 page is information(name, position, magnitude) of stars.
> not a theoretical or mathematical book

Content : 序 Introduction


序
之名見於春秋恒星者經星也古之言天文者以
爲緯列宿爲經四仲中星及斗牽牛織女參昴畢
大火農祥龍尾鳥帑天駟天黿之屬散見於尚書易
左傳國語至周禮春官馮相氏掌二十八星之位而
記月令大戴禮夏小正稍具諸星伏見之節蓋古者
敬天勤民因時出政以星爲紀秦炬之後羲和舊術無
傳若史記天官書所載太簡漢書載中外之官有名者
百十八官七百八十三星而未嘗實指其次舍後漢張
衡云中外之官常明者百有二十四可名者三百二十

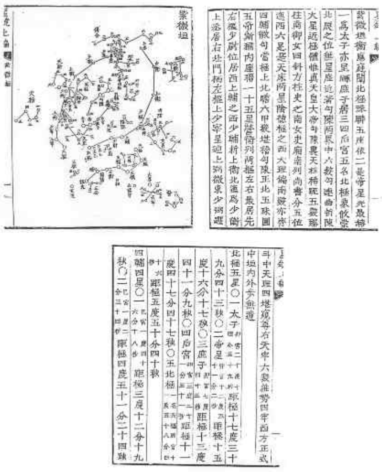
> Origins of constellations.
> How the position of the stars has been improved.
> Variation in the position of stars owing to precession.
> European astronomical knowledge introduced to Qing China by missionaries
> *Seonggyeong* with precession correction by selecting only the original constellations from the star catalogue in *Yixiang kaocheng Xubian*.

Content : 3垣 28宿 and 近南極星



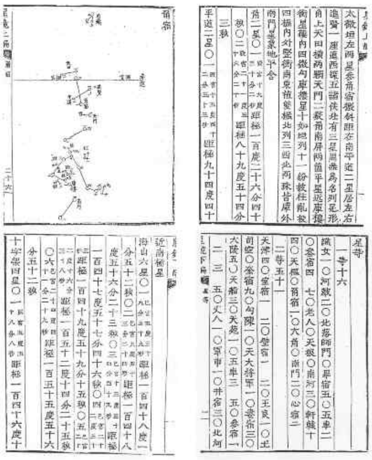
- 3垣 (紫微垣, 太微垣, 天市垣)
  Three areas enclosed by stars linked up like city walls:
  Zewei, Taiwei, Tianshi
- 28宿 : 28 lunar lodge (east, west, south, north)
- The Southern sky asterisms
- Listed by constellations, not sequentially by longitude.
- The positions of the stars are recorded as longitudes divided into 12 signs, and angular distances from the North pole according to the traditional East-Asian coordinate system.
- The magnitude is divided into separate.

Content : 3垣 28宿



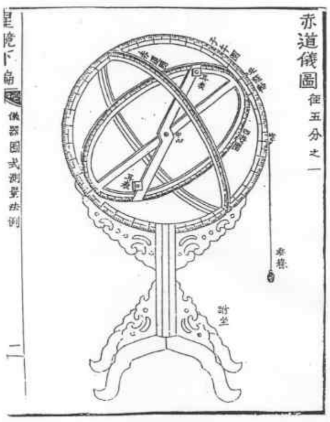
- An illustration according to the asterisms area is included.
- Similar to the form of
  步天歌 *Butiange* or 天文類抄 *Cheonmunryucho*.
- The asterisms are described in the sequence of three areas enclosed by stars linked up like city walls: *Zewei*, *Taiwei*, *Tianshi*, and the 28 lunar lodges.
- The names of asterisms and coordinates of the each stars belong to asterisms have been recorded.
- The Southern sky asterisms were recorded without illustrations(and magnitude), only their names and position.
- Magnitude of the stars are recorded separately.

Content : 3垣 28宿



- > An illustration according to the asterisms area is included.
- > Similar to the form of 步天歌 *Butiange* or 天文類抄 *Cheonmunryucho.*
- > The asterisms are described in the sequence of three areas enclosed by stars linked up like city walls: *Zewei, Taiwei, Tianshi,* and the 28 lunar lodges.
- > The names of asterisms and coordinates of the each stars belong to asterisms have been recorded.
- > The Southern sky asterisms were recorded without illustrations(and magnitude), only their names and position.
- > Magnitude of the stars are recorded separately.

Content : 赤道儀圖 Equatorial instrument



- > An illustration of the equatorial instrument and how it was used is included.
- > The position of the stars in *Seonggyeong* is not the result of observations of the equatorial instrument.
- > It should be noted that this result was calculated with precession correction.

Content : 編後 Book review


書星鏡編後
乾象垂現休咎湊應莫星度若故靑臺爲職惟測驗
最重此星鏡所以編述也第念候察之或未晤詳豈
專歸咎於術疎似無所憑式而然以若所爲欲求精
密不其僞歟於是硏究就正之方儀器則舊已弊傷
新是製成星象則以恒宿經緯考因其第次摠叙距
極而圖式歌說按類附焉俾考測時擬爲取準則自
今庶無差忒之弊其立法簡要從可知矣若乃神而
明之存乎其人然推演求合是所望於後學也于時
六一齋南侍郎提擧本監凡所勸奬釐迷之節靡不

> by Lee Jun-yang (李俊養, 1817-1886)
新法步天歌 *Sinbeob Bocheonga* (1862)
An academic colleague of Nam Byeong-gil,
the author of *Seonggyeong*

> It explains that data on the stars have been improved and updated.

> It emphasizes that it is an astronomical book of new data.

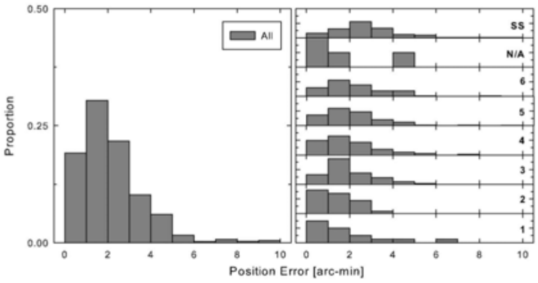
> It explains that the meaning of *Seonggyeong* is great.

Content : Summary

- This book is composed of a system that differs from the general star catalogue.
  (e.g. coordinate system, format of book etc.)
- This book is organized according to the traditional East-Asian asterisms system.
  = Similar to *Butiange*, *Cheonmunryucho*
- No theoretical statements. No astrological interpretations. No mathematical explanations.
- The star's position and magnitude were recorded.
- An illustration is attached, which is similar to the illustration format of *Butiange* or *Chenmunryucho*.
- In general, the star catalogue is tabulated with information regarding name, position, and magnitude.
  However, in *Seonggyeong*, names and positions are recorded in sentences,
  and the magnitude is classified and organized separately.
- Southern sky asterisms are recorded only by name and position.
  = No illustration. No magnitude.

"In conclusion, it is similar to the star catalogue in terms of functional aspects, but the composition system is similar to the traditional East-Asian method."

Error : Position error



Distribution according to position error

> Among 1,449 stars, 1,413 stars were identified. (~97.5%)

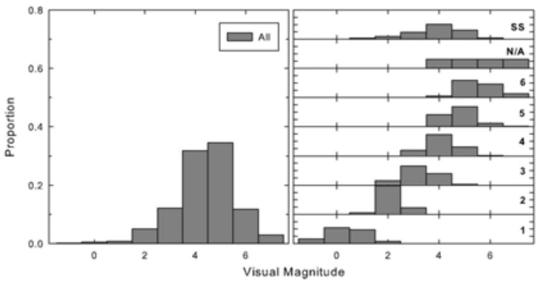
> The average position error is 5.33±0.34 arcmin

~50% < 2.0 arcmin, ~85% < 5.0 arcmin
1, 2 magnitude < 1.0 arcmin
3, 4, 5, 6 magnitude < 2.0 arcmin
southern sky asterisms < 3.0 arcmin

> As the magnitude of the star fades, the positional error increases. (Here, excluding southern sky asterisms)

> Similar to the characteristics of star catalogues published in Europe and Islamic/Arabic cultures in the 15th to 18th centuries.

Error : Magnitude error



Distribution according to magnitude

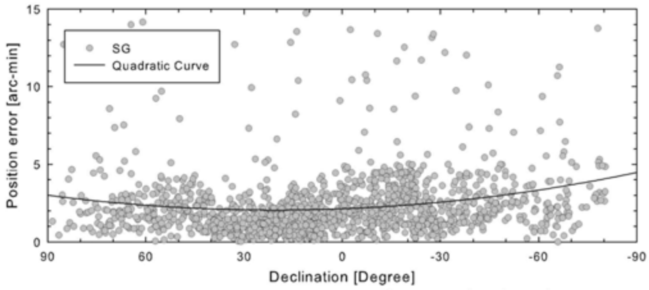
> That is, there is a correlation between recorded and modern magnitude.
> 90% = error within ±1.0 magnitude

> The distribution of stars recorded as 6th magnitude is biased towards 5th magnitude.

> Similar to the characteristics of star catalogues published in Europe and Islamic/Arabic cultures in the 15th to 18th centuries.

> Similar to the characteristics of star catalogues published in Qing China with the help of European missionaries in the 17th to 19th centuries.

Error : Position error based on the declination

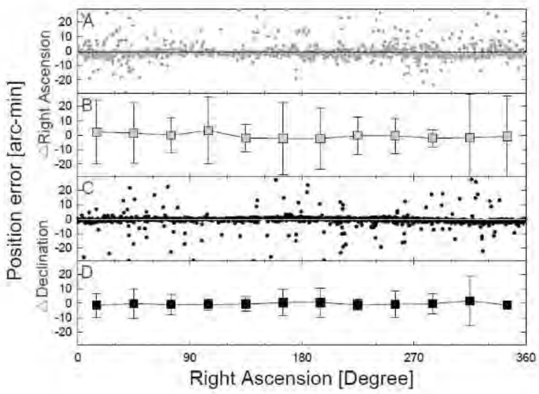


> The stars position error increases as it is closer to both poles.

> The margin of error tends to increase more when the star is positioned closer to the South pole than to the North pole.

> This is similar to the characteristics of star catalogues published in Europe and Islamic/Arabic cultures in the 15th to 18th centuries.

Error : Positional deviation in △RA and △DEC



> A, C : Deviation for each star, in which the range of deviation is within ±30.0 arcmin.

> B, D : Separated with 12 steps by 30° intervals and indicate the average value in each interval with a standard deviation. (indicated with an error bar)

> The positional deviation is greater at the equinoxes than at the solstice.

> △RA(1861-modern) is confirmed as having a larger deviation of position error than △DEC(1861-modern)

> Similar to the characteristics of star catalogues published in Europe and Islamic/Arabic cultures in the 15th to 18th centuries.

Error : Summary

- Position error.
- Magnitude error.
- Position error based on the declination.
- Positional deviation in △RA and △DEC.

1. Similar to the characteristics of star catalogues published in Europe and Islamic/Arabic cultures in the 15th to 18th centuries.
2. Similar to the characteristics of star catalogues published in Qing China with the help of European missionaries in the 17th to 19th centuries.

"In conclusion, the star catalogue in Qing China, which was influenced by European and Islamic/Arabic cultures, may have influenced *Seonggyeong*(1861)"

Comparison I

- Based on *Seonggyeong*, the average position error was calculated by selecting determinative stars of 28 lunar lodges from the previous star catalogues in Qing China.
- *Yixiang Kaocheng* (1744) and *Yixiang Kaocheng Xubian* (1844) include examinations of the star catalogues from the previous period.

Source	Standard epoch	Position error (arc-min)
Yixiang Kaocheng	1744.0	0.87
Yixiang Kaocheng Xubian	1844.0	2.19
Seonggyeong	1861.0	2.44

Comparison II

> In general, the positions of stars recorded in star catalogues tend to become more accurate over time.
> The use of telescopes increased accuracy, particularly in the 18th century.

> However, during the period of more than 100 years from *Yixiang Kaocheng* (1744) to *Yixiang Kaocehng Xubian* (1844), and from *Yixiang Kaocheng Xubian* (1844) to *Seonggyeong* (1861), the position error increased rather then decreased. In other words, the accuracy was reduced.

> Rather than interpreting that observation technology has deteriorated over time; in other words, it is more reasonable to view records in *Seonggyeong* as the result of editing with precession correction, rather than the result of observation.

> The supports the record in the preface that *Seonggyeong* is precessed and corrected from *Yixiang Kaocheng Xubian*.

Comparison III : with *Yixiang Kaocheng Xubian*

> The name, position, and magnitude of the stars are recorded in the star catalogue of *Yixiang Kaocheng Xubian* (1844).
> At the bottom of the table, precession correction values according to right ascension and declination for each star were recorded.

> I confirmed that this precession correction value reflected the 'movement value of the vernal equinox' and the 'proper motion value of each star'.
> However, it is not known how these two values were used to give the correction value.

> Further research is needed in the future.

Comparison IV : with *Yixiang Kaocheng Xubian*

| *Yixiang Kaocheng Xubian* (1844) – *Seonggyeong* (1861) |
= | 1844 year – 1861 year |
= 17 year

> As a result, it was confirmed that precession correction was used for a period of 17 years.
> It was confirmed that 1,430 stars among 1,449 stars were perfectly calculated results.

> For the remaining 19 stars, the error caused by miscalculations and miswrites were confirmed
> In particular, the error of four stars is sufficiently large to affect the identification analysis.

Summary and Discussion I

- *Seonggyeong* (1861) is the result with precession correction applied a period of 17 years from the star catalogue in *Yixiang Kaocheng Xubian* (1844).
- Seonggyeong used the improved position data, but the East-Asia tradition continued to be maintained for the coordinate system and composition of the asterisms.
- Among 1,449 stars, 1413 were identified with modern stars (HIP 2000.0).
- The average position error(angular distance) of the identified stars was 5.33±0.34 arcmin.
- Considering that the position error of star catalogues made in Europe at the same time is within approximately 0.5 arcmin, the positional accuracy of *Seonggyeong* is very low.

Summary and Discussion II

- A dual system to reflect the new by applying the latest data while maintaining the old by following the tradition. = A dual condition of conflicts and convergence amid change in Western powers and values that appeared at the end of Joseon Korea.
- Before the introduction of modern astronomy, the values of astronomer in Joseon Korea, who were experiencing conflicts caused by the fusion of tradition and modern, were reflected in *Seonggyeong* (1861).
- In Europe, at that time, navigation and trade exchanges became active, and as industrialization occurred, the demand for scientific knowledge increased, and accurate star catalogues were competitively created according to these demands.
- Depending on the perspective of the times, considering the method of composition of *Seonggyeong* (1861) and the position error of recorded stars, the purpose of using the star catalogue in Joseon Korea can be understood to be completely different from that in Europe.

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The lunar movement model presented in the Sechoyuhui 細草類彙 of the Joseon 朝鮮

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The 9th International Symposium on History of Astronomy 2023. 3. 29.

Abstract

- While comparing with《崇禎曆書》, we examine in detail how to obtain the lunar position of the moon covered in《細草類彙》,
- and even when compared with modern methods, there are some differences in the constants used, but there is no big difference in the method.
- However, as the record of《細草類彙》followed the record of <月離表> of《崇禎曆書》, it was found that it followed the misunderstanding or mis-wrighting part of <月離表> instead of the method correctly described in <月離曆指> of《崇禎曆書》.

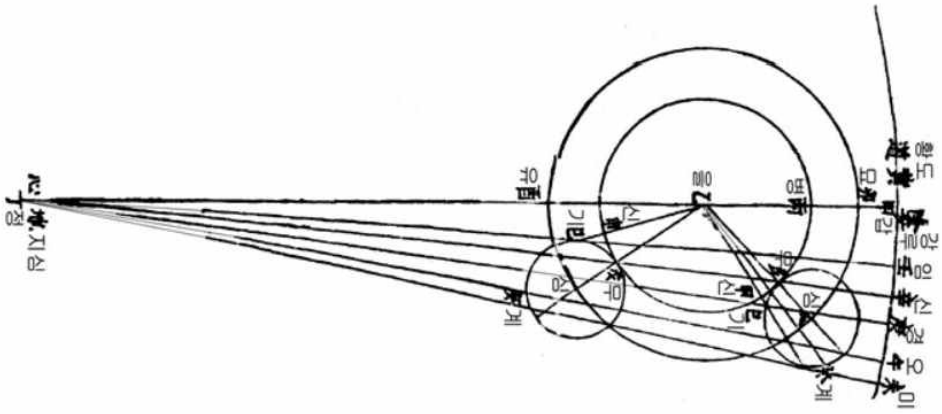
Intoduction

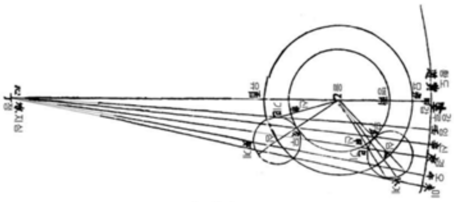
1. Joseon 朝鮮 had been interested in the Siheon calendar(or Almanac) 時憲曆 from the time of King Injo 仁祖, and had Kim Sang-beom 金尙范, an officer of the Gwansanggam 觀象監, study in China to learn the movement of the sun, moon, and five planets, started this Siheon calendar at the 4 year (1653) of King Hyojong 孝宗.
2. Afterwards, in the 31st year (1705) and 34th year (1708) of King Sukjong 肅宗, Heo Won 許遠, an official of the Ministry of Gwansanggam, was sent to China to learn all the calculation methods recorded in《Sungjeongyeokseo 崇禎曆書》or《Western New Method Almanac 西洋新法曆書》. In the 37th year of King Sukjong's reign, in the year of Gyeongin 庚寅年 (1710),《Sechoyuhui 細草類彙》was written with this almanac by Heo Won.
3. China's Siheon Almanac begins with《崇禎曆書》managed and compiled by Xú Guāngqǐ(徐光启) at the end of the Ming 明 Dynasty.

<推月離細草> in《細草類彙》Gon 坤

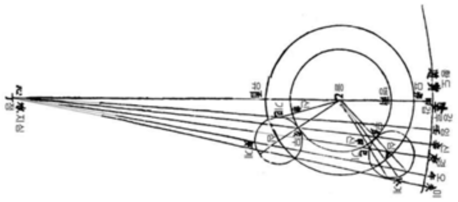
- <推月離細草>, recorded in《細草類彙》坤, records how to obtain the ecliptic longitude 黃經 and latitude 黃緯 of the Moon located on the orbit of the moon 白道.
- This method is the same as the method of obtaining the ecliptic longitude and latitude of the moon, which is recorded in <月離表> of《崇禎曆書》, not in <月離曆指> of《崇禎曆書》.
- In the case of the moon, as in the case of the sun, it is based on the winter solstice 冬至.

The two epicycles 本輪-次輪 model of the Moon explained in <月離曆指> of《崇禎曆書》

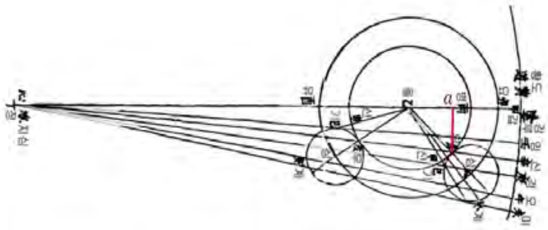




1. Center of the first epicycle 本輪心 moves eastward (counterclockwise) along the mean lunar cicle 本天(本圓) with the mean angular speed 平行 related to the sidereal month 恒星月.
2. Center of the second epicycle 次輪心 moves westward(clockwise) from the farthest point 遠點 of the first epicycle 本輪 along the first epicycle with anomalistic angular speed 自行 related to the anomalistic month 近點月.
3. Moon moves eastward(counterclockwise) from the nearest point 近點 of the second epicycle along the second epicycle 次輪 with two times of the separation angular speed of the Sun and Moon 倍離 or 倍月居日 related to the synodic month 朔望月.



1. The Moon is located at 己
2. The first equation of center is defined to the angle of 甲丁辛 or 乙丁戊. At new and full moon the first equation of center 初均數 is enough to calculate the total equation of center 總均數.
3. The second equation of center 二均數 is defined to the angle of 戊乙己, which is nessesary for calculating the third equation of center 三均數.
4. The third equation of center is defined to the angle of 辛丁庚 or 戊丁己



'정을'=1, 을심=0.1103, 심무는 0.0231

From △정읍무, 읍무=0.0872(=0.1103-0.231)

∠병을무 is the anomalistic angle from '묘': $\lambda_{[illegible]} = \theta_1$, ∠정을무=180° − θ_1

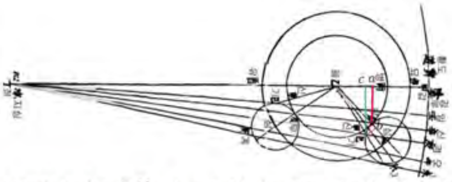
'무a'=$0.0872\sin\theta_1$, '을a'=$0.0872\cos\theta_1$, '정a'=$1+0.0872\cos\theta_1$

The first equation of center= ∠갑정신 = 갑신 = q_1: $\tan q_1 = \frac{0.0872\sin\theta_1}{1+0.0872\cos\theta_1}$

The direction of '정갑' is toward x axis. θ_1 is measured clockwise

and should be $-\theta_1$: $\tan q_1 = \frac{0.0872\sin(-\theta_1)}{1+0.0872\cos(-\theta_1)} = \frac{-0.0872\sin\theta_1}{1-0.0872\cos\theta_1}$

$0 \le \theta_1 \le 180°$ $q_1 \le 0$. At new and full moons. $\lambda_{[illegible]} = \lambda_{[illegible]} + q_1$



Because the moon is located to be '기', $\theta_2 = 2\Delta\lambda$ is measured clockwise from '무'

where $\Delta\lambda = \lambda_{실행} - \lambda_{\odot}$, the seperation of the sun and the moon.

At △을심기, from '기' to '을심' draw straight line to meet at b.

'심b'=$0.0231\cos\theta_2$, '기b'=$0.0231\sin\theta_2$, '을심'=0.1103

The second equation of center=∠심을기=q_2: $\tan q_2 = \dfrac{0.0231\sin\theta_2}{0.1103 - 0.0231\cos\theta_2}$, $0 \le \theta_2 \le 180°$ $q_2 \ge 0$

The second factor angle=∠병을신= $\theta_1 + q_2$ is measured clockwise from '묘'

$\overline{을기} = \sqrt{0.1103^2 + 0.0231^2 - 2 \times 0.1103 \times 0.0231\cos\theta_2}$

From '기' to '정병' draw straight line to meet at c. '기c'= $\overline{을기}\sin(\theta_1 + q_2)$, '을c'=$\overline{을기}\cos(\theta_1 + q_2)$

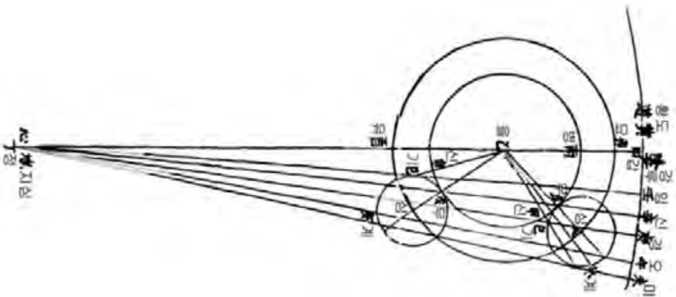
The third equation of center=∠무정기=q_3: $\tan(q_1 + q_3) = -\dfrac{\overline{을기}\sin(\theta_1 + q_2)}{1 + \overline{을기}\cos(\theta_1 + q_2)}$

After obtaining $q_1 + q_3$, subtract q_1 to get q_3.

At new and full moons, $\theta_2 = 0°$, $q_2 = 0°$, $\overline{을기} = 0.0872$ then $q_3 = 0°$

Another method

- Use vector notation



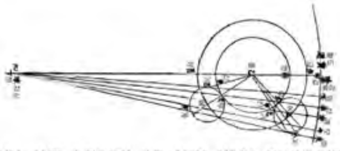
$\overrightarrow{정을} = (1,0)$, $\overrightarrow{을심} = 0.1103(\cos(-\theta_1), \sin(-\theta_1))$, $\overrightarrow{심기} = 0.0231(\cos(180° + \theta_2 - \theta_1), \sin(180° + \theta_2 - \theta_1))$

Let $\overrightarrow{정기} = (x, y)$, $x = 1 + 0.1103\cos(-\theta_1) - 0.0231\cos(\theta_2 - \theta_1)$, $y = 0.1103\sin(-\theta_1) - 0.0231\sin(\theta_2 - \theta_1)$

$$\tan(q_1 + q_3) = \frac{0.1103\sin(-\theta_1) - 0.0231\sin(\theta_2 - \theta_1)}{1 - 0.1103\cos(-\theta_1) - 0.0231\cos(\theta_2 - \theta_1)}$$

If considering the plus minus signs then $\tan(q_1 + q_3) = -\dfrac{0.1103\sin(-\theta_1) - 0.0231\sin(\theta_2 - \theta_1)}{1 + 0.1103\cos(-\theta_1) - 0.0231\cos(\theta_2 - \theta_1)}$

Simulation



In the model, the Earth is located at the center of the mean circle and the center of the first epicycle moves θ_0 counterclockwise with the mean angular speed(平行).

The real location of the Moon is (x', y'). then $x' = x\cos\theta_0 - y\sin\theta_0$, $y' = x\sin\theta_0 + y\cos\theta_0$ to be

$$x' = \cos\theta_0 + 0.1103\cos(-\theta_1 + \theta_0) - 0.0231\cos(\theta_2 - \theta_1 + \theta_0)$$
$$y' = \sin\theta_0 + 0.1103\sin(-\theta_1 + \theta_0) - 0.0231\sin(\theta_2 - \theta_1 + \theta_0)$$

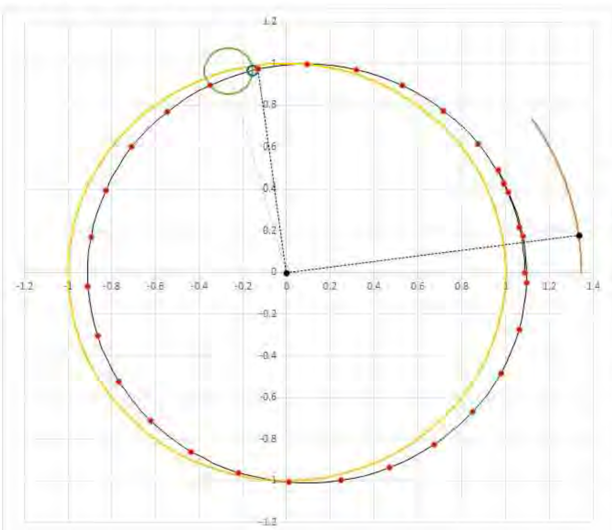
가 된다. 하루 당 평행, 자행, '태양과 달 사이의 각거리' 2배를 각각 n_0, n_1, n_2 are the mean angular speed, the anomalistic angular speed, the separation angular speed between Sun and Moon, angular speed respectively. $\theta_0 = n_0 \Delta t$, $\theta_1 = n_1 \Delta t$, $\theta_2 = n_2 \Delta t$ where $n_0 = 13°10'35''01'''$, $n_1 = 13°03'53''56'''$, $n_2 = 2 \times 12°11'26''41'''$, $n_\odot$ = 59분08초20미

The mean location of the Sun = $(x_\odot, y_\odot)$: $x_\odot = r_\odot \cos M$, $y_\odot = r_\odot \sin M$ where $M = n_\odot \Delta t$

The real location of the Sun = $(x'_\odot, y'_\odot)$ with $E = 0.03584$(differnce of two center=2 time of elogation):

$$x'_\odot = r_\odot(\cos M + E),\ y'_\odot = r_\odot \sin M$$

Simulation



- Both the moon and the sun are at apogee in their orbits at t=0. Therefore, the phase of the moon is new. The average distance to the sun was set to 1.3 conveniently. The first epicycle and the second epicycle are drawn on the moon's orbit.
- In the figure, the position of the moon is at t=8 day, and the elongation of the moon at this time is 89.92 degrees, so the phase is the first quarter. Because the moon was new at apogee, it took longer to reach the first quarter. From the first quarter to full moon, the period is shortened because it faces perigee.

<推月離細草>, recorded in《細草類彙)》坤

☐ 距冬至下實行：置平行總，加減均數，卽得.

The true longitude from the winter solstice(冬至): Add or subtract the first equation of center to the total mean longitude. $\lambda_{실행} = \lambda_{평행} \pm q_1$

☐ 引數下實行引：置平引，加減均數，卽得.

The true first factor angle(實行引) from the first factor angle(引數): Add or subtract the first equation of center to the first factor angle which is the same with the anomalistic angle.

$\lambda_{평인} = \lambda_{자행}$, $\lambda_{실행인} = \lambda_{평인} \pm q_1$

At <月離表> of《崇禎曆書》, $\lambda_{실행인} = \lambda_{평인} \pm q_1$

At <月離曆指> of《崇禎曆書》, $\lambda_{실행인} = \lambda_{자행} \pm q_2$

Continue...

☐ 距冬至下月距日次引：是置上格實行，內減去太陽恒減，卽得，不及減者，加十二宮，減之.

The second factor angle(次引) as the separation angle between the sun and the moon(月距日) from the first factor angle(引數): Add or subtract the true longitude of the sun to the true longitude of the moon.

the separation angle between the sun and the moon(月距日)=$\Delta\lambda$: $\Delta\lambda = \lambda_{실행} - \lambda_{\odot}$

☐ 距冬至下次均：是以月距日次引的宮度，三十分，進一度，查三卷四卷二三均數表，查傍右行的某宮度，以引數下實行引的宮度，三十分，進一度，查表上下的宮度，查得，橫對某宮度的度分秒，錄之，卽得，隨錄加減號于次均傍，此表右行，只有六宮，其查下六宮，只以對宮筭之.

順：空宮、一宮、二宮、三宮、四宮、五宮.

逆：六宮、七宮、八宮、九宮、十宮、十一宮.

The next equation of center(次均) from the winter solstice(冬至): Use 〈Table of the second and third equations of center(二三均數表)〉 with the true factor angle(實行引) and the second factor angle(月距日 次引) With $\Delta\lambda$ and $\lambda_{실행인}$, $q_{차균}$ in 〈Table of the second and third equations of center〉.

$q_{차균} = q_3$ at at《崇禎曆書》

Table of the second and third equation of center

- Numbers in the table can not obtained with the model described at <月離曆指> of 《崇禎曆書》
- After calculating with the model at <月離曆理> of 《曆象考成》numbers are almost matched to the table.

The lunar location

- The longitude from the winter solstice 冬至 is calculated along the lunar orbital plane 白道.
- This longitude should be calculated to the ecliptic longitude along the ecliptic with the angle between the lunar and solar orbital plane 黃白大距.
- The locations of two nodes 交点 between the lunar and solar orbital plane can be calculated. Therefore how to obtain the lunar latitude is described at <月離曆指>, <月離表> of《崇禎曆書》and <推月離細草> in《細草類彙》Gon (坤). Two methods are same each other.
- The lunar and solar eclipse 月食 or 日食 can be calculated because the first equation of center 初均數 is only needed to calculate the longitude.

Considering various anomalies in the lunar models

	A Modern Almagest (Moon) $e=0.054881$	〈月離曆理〉 of《曆象考成》 error=±0.002548(8.8′)	〈月離曆指〉 of《崇禎曆書》 error=±0.002548(8.8′)
q_1	$2e\sin M+1.43e^2\sin 2M$ $=0.109762\sin M+0.004307\sin 2M$	$0.1087\sin M+0.002756\sin 2M$	$0.1103\sin M+0.006083\sin 2M$
q_2	$0.422e\sin(2\overline{D}-M)$ $=0.02316\sin(2\overline{D}-M)$	$0.0217\sin(2\overline{D}-M)$	$0.0231\sin(2\overline{D}-M)$
q_3	$0.211e(\sin 2\overline{D}-0.066\sin\overline{D})$ $=0.01158(\sin 2\overline{D}-0.066\sin\overline{D})$	$0.01112\sin(2\overline{D})$	
q_4	$-0.051e\sin M_s$ $=-0.002799\sin M_s$		
q_5	$-0.038e\sin\overline{F}$ $=-0.002085e\sin\overline{F}$		

q_1: due to the eccentricity of the lunar orbit

q_2(evection), q_3(variation) q_4(annuak inequality): due to the perturbation of the sun

q_5(reduction to the ecliptic): due to the inclination of the lunar orbit to the ecliptic

Summary

1. <推月離細草>, recorded in《細草類彙》坤, records how to obtain the ecliptic longitude and latitude of the Moon located on the orbit of the moon(白道).
2. This method is the same as the method of obtaining the ecliptic longitude and latitude of the moon, which is recorded in <月離表> of《崇禎曆書》.
3. However in <月離曆指> of《崇禎曆書》the lunar model is described in detail.
4. As the record of《細草類彙》followed the record of <月離表> of《崇禎曆書》, it was found that it followed the wrong part of <月離表> instead of the method correctly described in <月離曆指> of《崇禎曆書》.
5. However The lunar and solar eclipse can be calculated because the first equation of center is only needed to calculate the longitude of the Moon.

Session 2. History of Astronomy

◤Chair : Krishnamurthi Ramasubramanian /

Indian Institute of Technology◢

Observation of Stars in Medieval Period in India

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Abstract

It is very well known that Indian astronomical texts list 28 stars along the zodiac to be used as references for longitudes. The stars were also used as identifiers of the position of the moon on the ecliptic and as markers of the First Point of Aries. There is yet another application which is generally not highlighted. The method uses the observation of stars for determining the ascendant, (*lagna*) as described in the 17th century manuscript *Brahmatulya Udāharaṇam* by Viśvanātha

Keywords: observational astronomy, medieval manuscripts, star lists, meridian transits of stars, *Brahmatulya Udāharaṇam*.

1. Introduction

The ancient Indian texts generally deal with the calculations pertaining to the celestial events like the eclipses, transits and conjunctions. The method of evaluation of the positions were well established and were quite accurate. Therefore, one wonders why did they need to observe the stars at all.

The purposes of observing the stars are threefold

a. To identify the position of the moon along the ecliptic
b. To identify the position of the sun along the ecliptic
c. To fix the point of intersection of the ecliptic and the equator (referred to as the First Point of Aries)

It is easy to see that all these purposes are achievable with the twelve zodiacal constellations as well. Corresponding to the 27-day orbital period of the moon there are 27 stars (+1) identified. This provides a better tool to fix the position than the zodiacal constellations which span approximately 30°.

The name of the star itself is used as the identifier for all the three purposes listed above. The position of the moon is referred to as the 'star of the day' (*nitya nakśatra*) which is very important for fixing the date of festivals. The folk tradition reckons the name of the star associated with the sun as 'rain star' – indirectly fixing the month of the year. The precession correction also is referred to with the name of the star. For example, it was *Kṛttikā* (Pleiades) 5000 years ago and it was *Aśvinī* (β Aries) around the commencement of the Common Era.

2. List of stars

The coordinates of the stars are generally introduced in the chapter devoted to conjunctions which cover planetary events extensively. Conjunctions with bright stars (for example, Saturn and Aldebaran) are often predicted and recorded as inferred from stone inscriptions. (Shylaja and Ganesha, 2021)

The coordinates of the stars are needed for yet another important application – the construction of astrolabes. These small devices are handy and very useful for routine observations. The star dial is location specific. For portability the navigators used to carry star dials for different latitudes. One such catalog of the 16th century provided coordinates of over 100 stars with magnitude estimates. (Pai and Shylaja, 2021; Shylaja and Pai, 2019)

The text *Brahmatulya Udāharaṇam* (BU) of 17th century by Viśvanātha, can be classified as *karaṇa*, a manual for the astronomical calculations (Shubha, 2020). This provides solved examples of all events. Many of these are easily verified by repeating the calculations as per *siddhāntic* texts (Shubha and Shylaja, 2020; Shylaja and Shubha 2023). A comprehensive summary of the text is provided elsewhere in this volume (Shubha, this volume)

This text provides the coordinates of stars in a unique way. They are all offset by about 90 degrees. The explanation in the text takes us to another earlier work by Ācārya Viṣṇu Daivajña, about whom not much is known. He has prescribed a method of providing the coordinates of not the stars themselves but the ascendants.

Ascendant *(lagna)* is the point on the ecliptic which is on the eastern horizon. This varies through the night and through the night. It serves the important purpose of time marker for events occurring in the night.

3. The coordinates

BU provides the coordinates of the longitudes of stars in the form of eleven verses with the numbers denoted in *bhūtasaṅkhyā* system (numerals are represented by physical entities, example eye / hand means 2; earth / moon means 1). A table with numerals facilitates cross verification. The listed coordinates correspond to the ascendant when the star in question is transiting the meridian. Thus, the first star *Aśvinī* ought to have coordinates as 8°, which becomes about 14° with precession correction for the epoch of the book. However, the number listed is 104°. This is 90+14 and therefore easily understandable.

Table 1: The longitudes (°) of stars as given in BU

Aśvinī	104	Citrā	266
Bharaṇī	114	Svātī	270
Kṛttikā	129	Jyeṣṭa	308
Rohiṇī	141	Mūlā	326
Mṛgaśirā	152	Pūrvaṣādhā	336

Ārdrā	163	Uttarāṣādhā	342
Punarvasu	183	Abhijit	353
Puṣyā	194	Śravaṇa	17(17+360)
Āśleṣā	196	Dhaniṣthā	30(30+360)
Maghā	214	Śatabiṣā	64(64+360)
Pūrvāphālguṇī	228	Pūrvābhādrā	70(70+360
Uttarāphālguṇī	246	Uttarābhādrā	90(90+360)
Hastā	260	Revatī	93(93+360)

The numbers corresponding to the other stars are not so easily achieved. There is a subtle difference which can be explained as follows

a. When the star is on the meridian its longitude, measured along the ecliptic will not be on the meridian owing to the 23.5° tilt
b. The stars may have (non-zero) finite value of latitude though small. Therefore, even when the star is on the meridian the corresponding point on the ecliptic will be slightly different depending on the declination of the star and the latitude of the observer.

Figure 1 Definition of the ascendant

The first step is to get the declination of the corresponding point on the ecliptic for the star, achieved by

$sin\delta = sin \in \sin \ \lambda$ ....(1)

Then the latitude correction is called *cara*, obtained by

$Cara = \ cos\, H = -tan\, \emptyset\ tan\delta$ ....(2)

Then we proceed to redo this taking into account the ecliptic latitude of the star. We calculated the coordinates of the ascendant point on the ecliptic for these two corrections and showed that all these have been incorporated in the list provided in BU. The details of the calculations and the final list is under preparation.

We also demonstrate that the calculation involved is rather cumbersome and so people might have adopted simpler method – namely direct observations or read out from a globe-like instrument representing the ecliptic and equator. Our search for such an instrument resulted in an instrument called *krānti yantra* in the campus of the observatories of Sawai Jaisingh at Jaipur. Unfortunately, the instrument is defunct now. Any application to show that that the star on the meridian corresponds to a specific value at the horizon is not feasible.

Figure 2 *Kānti yantra* at Jaipur Observatory (Courtesy Prof Aalok Pandya)

Direct observation appears to have been the mode since the numbers are specific to latitude. The procedure appears to have been much more simplified by composing verses as in the BU applicable for Varanasi (25.9°N). This corroborates with the idea that such location-specific tables were already in use as cited in the 19th century text. The verse cited here provides values slightly different from BU, indicating that this was specific to a different latitude (approximately 18°N)

Conclusion

The observations of stars were very important for the medieval astronomers for fixing the positions of the planets, moon and the sun. The luni-solar calendars used the names of the stars very efficiently for these purposes. The text BU provides another unique application which fixes the ascendant based on the star on the meridian. We identified the possible corrections needed for the

We thank Prof Hong -Jin Yang for giving us an opportunity to present these results in the 9th International Symposium on Historical Astronomy

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Title: Orientation of Phimai Temple Related to the Acronychal Rising of the Pleiades on Saka Lunar New Year Day

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Abstract

- Astronomical phenomena played crucial roles in several cultural products, including calendars, rituals, festivals, traditions, and archaic structures. Many ancient sites around the world, such as temples, monuments, palaces, and mysterious ruins, have been found with distinct astronomical orientations that utilized the cyclic pattern to mark the time for auspicious ceremonies or agricultural activities. Knowing the cosmic tool used for alignment, which varied by ancient ethnography, we may be able to extract the founding date of the site, particularly the one with limited written records, as is the case with the subject of this study, the Phimai temple. This temple, located in Nakhon Ratchasima Province of Thailand, was built during the Khmer Empire, which was believed to be influenced by Mahayana Buddhism and Vedic astronomy. Given the azimuth of the temple being off-east and associated cultural traces like the Loy Krathong festival and luni-solar calendar, it is probable that the astronomical alignment is related to a fixed star rather than equinoxes or solstices. To obtain the precise azimuth of the temple, we surveyed the site with a theodolite and a GPS, and then calibrated with the Stellarium software. We then employed the precession corrected Stellarium to simulate the ancient sky to find the star with the matching azimuth. Our findings suggest that the orientation of Phimai Temple is related to the acronychal rising of the Pleiades between 1010 and 1150 AD. The Pleiades rising had a connection with the traditional Lunar New Year's Day, known today in Thailand as Loy Kratong Day.


THE 9TH INTERNATIONAL SYMPOSIUM ON HISTORY OF ASTRONOMY
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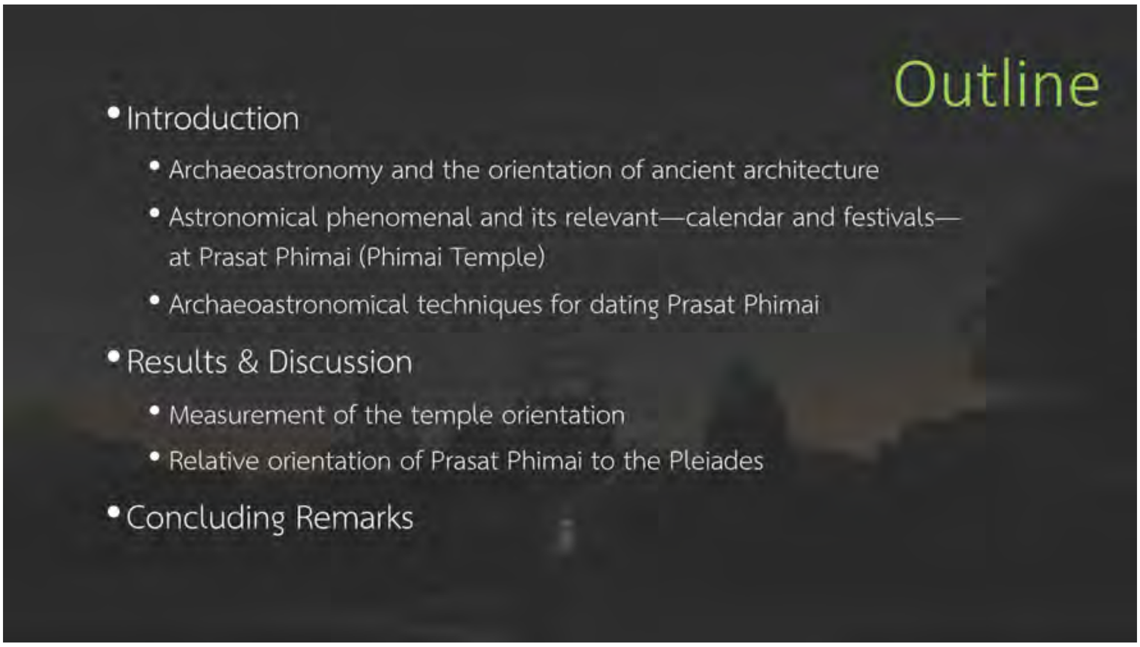
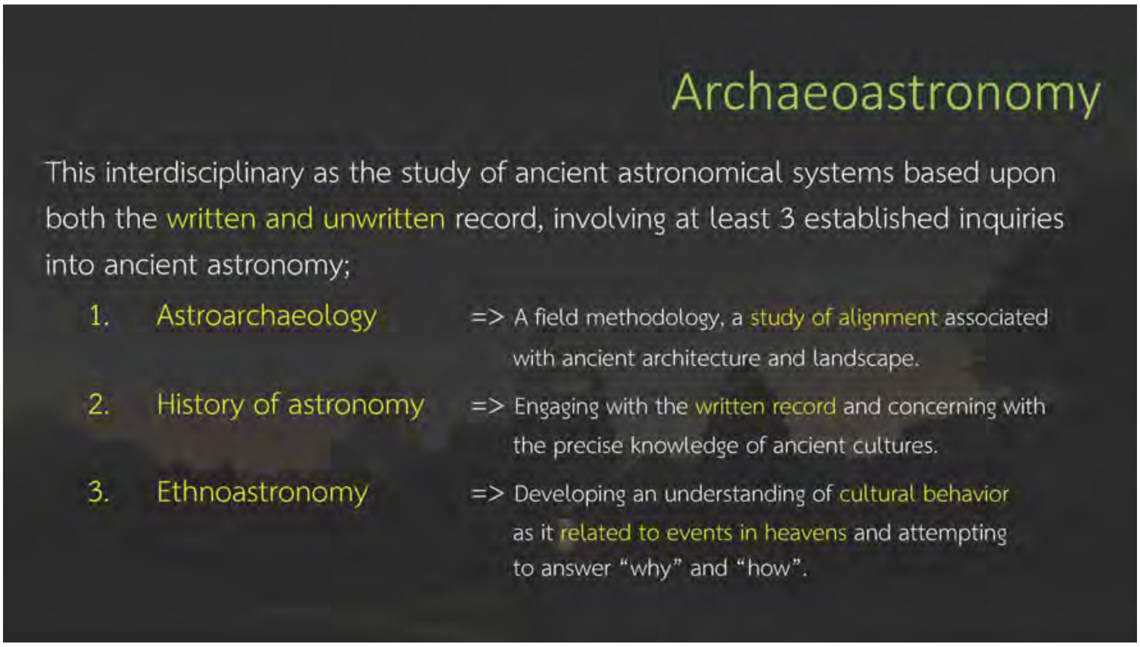
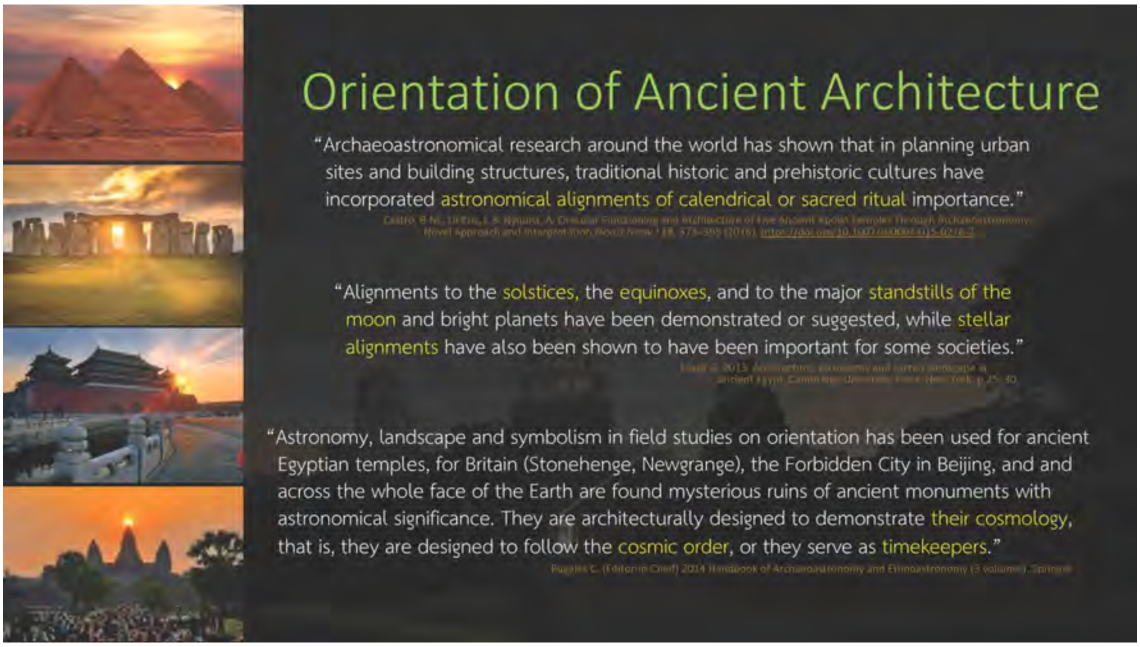
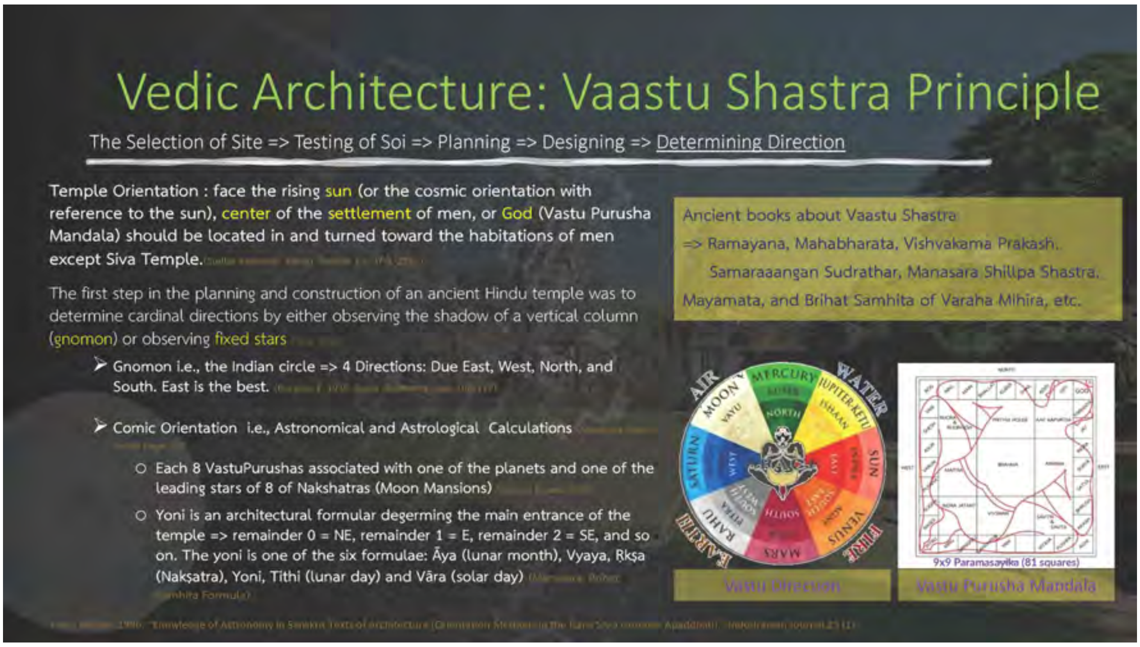
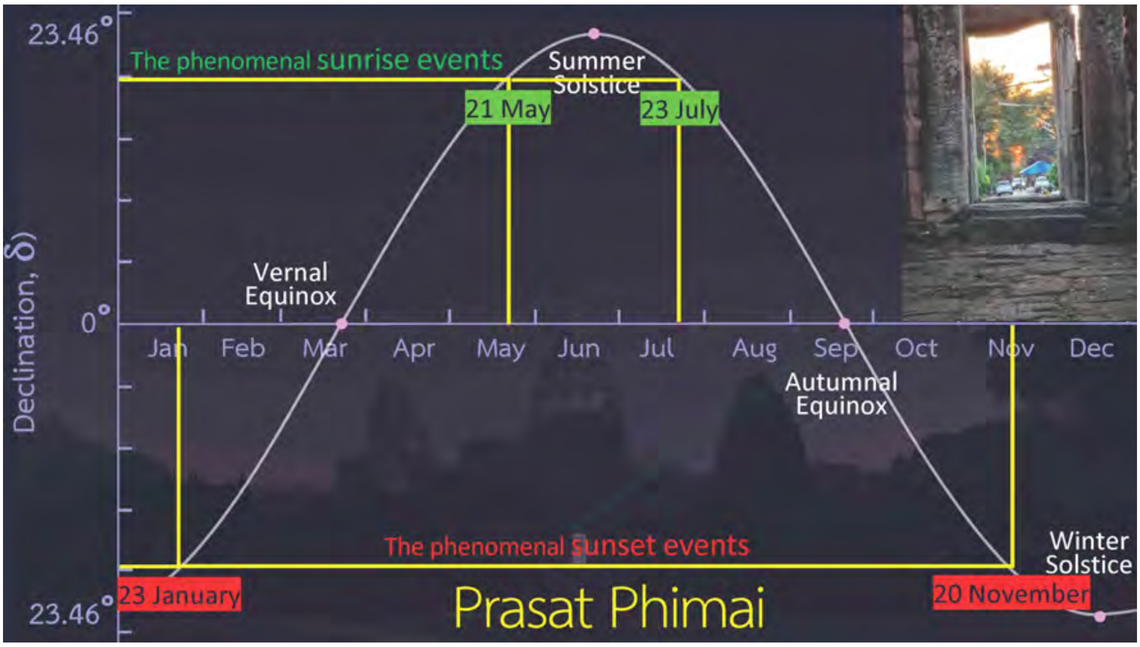

Outline
• Introduction
• Archaeoastronomy and the orientation of ancient architecture
• Astronomical phenomenal and its relevant—calendar and festivals—at Prasat Phimai (Phimai Temple)
• Archaeoastronomical techniques for dating Prasat Phimai
• Results & Discussion
• Measurement of the temple orientation
• Relative orientation of Prasat Phimai to the Pleiades
• Concluding Remarks

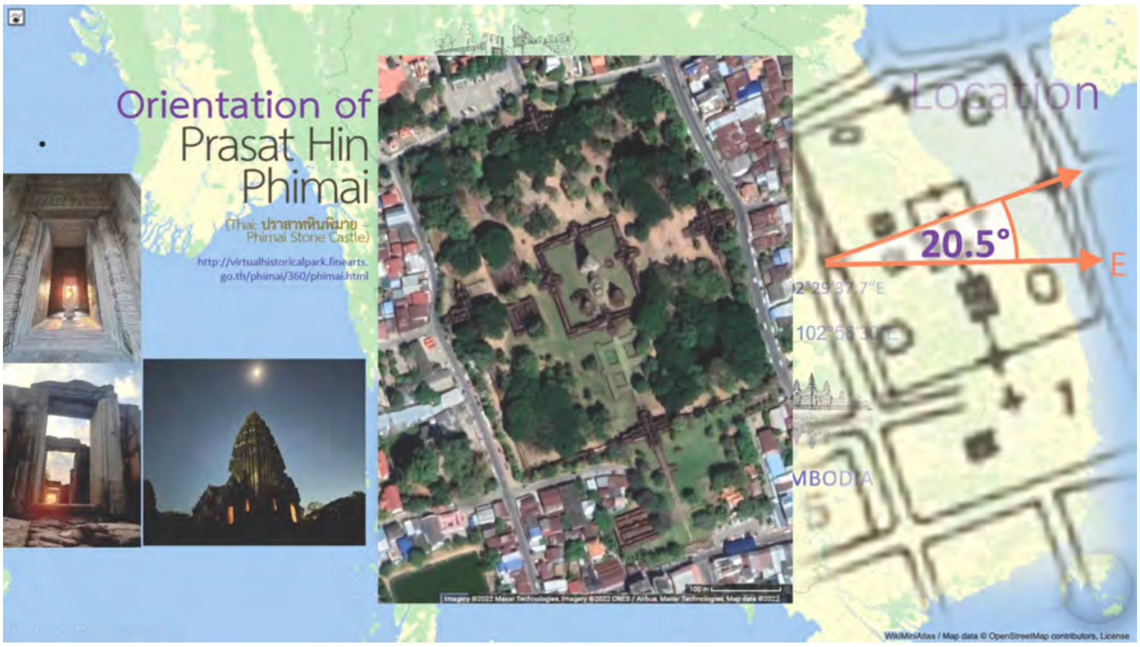

Archaeoastronomy
This interdisciplinary as the study of ancient astronomical systems based upon both the written and unwritten record, involving at least 3 established inquiries into ancient astronomy;
1. Astroarchaeology
=> A field methodology, a study of alignment associated with ancient architecture and landscape.
2. History of astronomy
=> Engaging with the written record and concerning with the precise knowledge of ancient cultures.
3. Ethnoastronomy
=> Developing an understanding of cultural behavior as it related to events in heavens and attempting to answer "why" and "how".


Orientation of Ancient Architecture
"Archaeoastronomical research around the world has shown that in planning urban sites and building structures, traditional historic and prehistoric cultures have incorporated astronomical alignments of calendrical or sacred ritual importance."
"Alignments to the solstices, the equinoxes, and to the major standstills of the moon and bright planets have been demonstrated or suggested, while stellar alignments have also been shown to have been important for some societies."
"Astronomy, landscape and symbolism in field studies on orientation has been used for ancient Egyptian temples, for Britain (Stonehenge, Newgrange), the Forbidden City in Beijing, and and across the whole face of the Earth are found mysterious ruins of ancient monuments with astronomical significance. They are architecturally designed to demonstrate their cosmology, that is, they are designed to follow the cosmic order, or they serve as timekeepers."


Vedic Architecture: Vaastu Shastra Principle
The Selection of Site => Testing of Soi => Planning => Designing => Determining Direction
Temple Orientation : face the rising sun (or the cosmic orientation with reference to the sun), center of the settlement of men, or God (Vastu Purusha Mandala) should be located in and turned toward the habitations of men except Siva Temple.
The first step in the planning and construction of an ancient Hindu temple was to determine cardinal directions by either observing the shadow of a vertical column (gnomon) or observing fixed stars
➢ Gnomon i.e., the Indian circle => 4 Directions: Due East, West, North, and South. East is the best.
➢ Comic Orientation i.e., Astronomical and Astrological Calculations
○ Each 8 VastuPurushas associated with one of the planets and one of the leading stars of 8 of Nakshatras (Moon Mansions)
○ Yoni is an architectural formular degerming the main entrance of the temple => remainder 0 = NE, remainder 1 = E, remainder 2 = SE, and so on. The yoni is one of the six formulae: Āya (lunar month), Vyaya, Rkṣa (Nakṣatra), Yoni, Tithi (lunar day) and Vāra (solar day)
Ancient books about Vaastu Shastra
=> Ramayana, Mahabharata, Vishvakama Prakash, Samaraaangan Sudrathar, Manasara Shillpa Shastra, Mayamata, and Brihat Samhita of Varaha Mihira, etc.
AIR
WATER
FIRE
EARTH
MERCURY
MOON
JUPITER-KETU
SUN
VENUS
MARS
RAHU
SATURN
NORTH
WEST
9x9 Paramasayika (81 squares)
Vastu Purusha Mandala

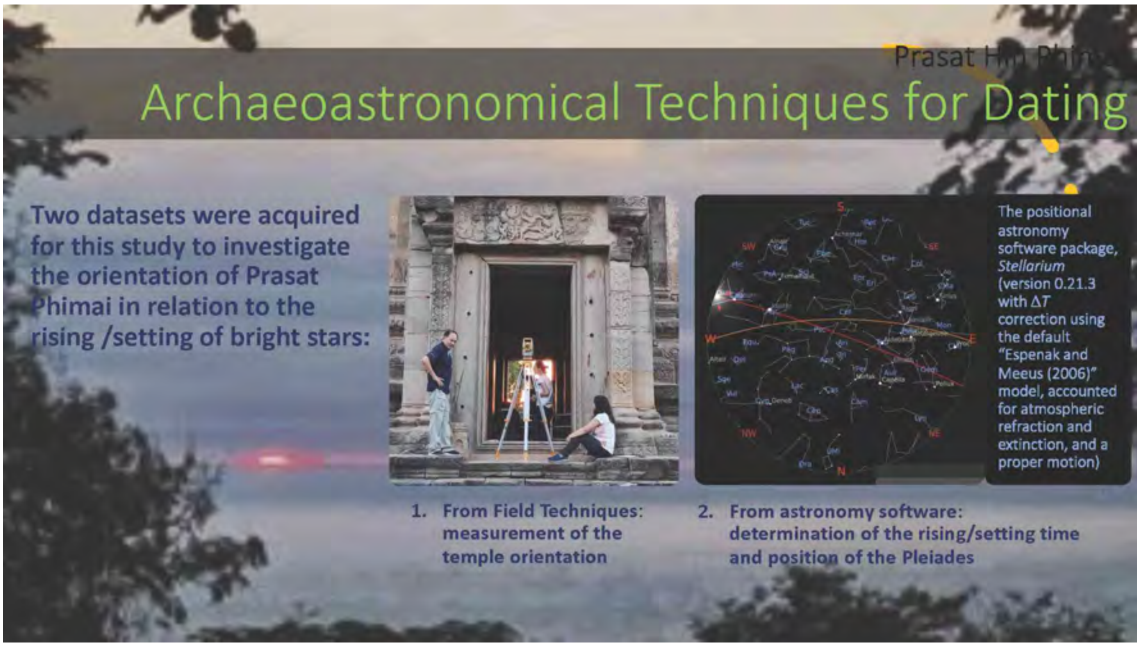

Location
Prasat
Phimai
(Thai: ปราสาทหินพิมาย – Phimai Stone Castle)
http://virtualhistoricalpark.finearts.go.th/phimai/360/phimai.html
15°13'15.8"N, 102°29'37.7"E
THAILAND
CAMBODIA
WikiMiniAtlas / Map data © OpenStreetMap contributors, License

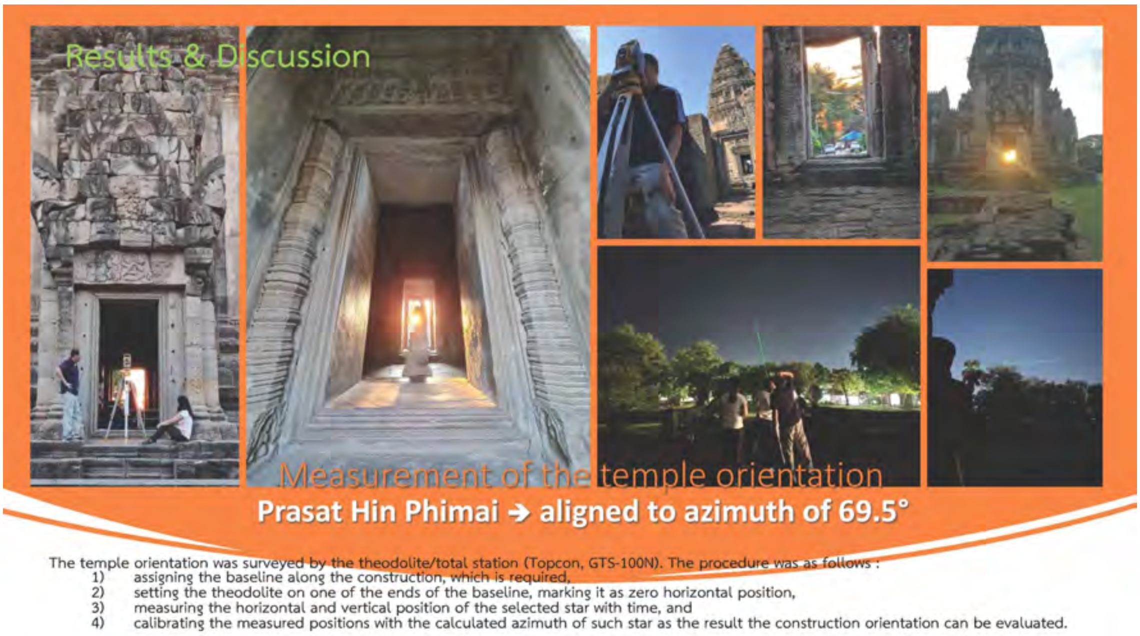

23.46°
The phenomenal sunrise events
Summer Solstice
21 May
23 July
Declination, δ)
Vernal Equinox
0°
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Autumnal Equinox
The phenomenal sunset events
Winter Solstice
23.46°
23 January
Prasat Phimai
20 November

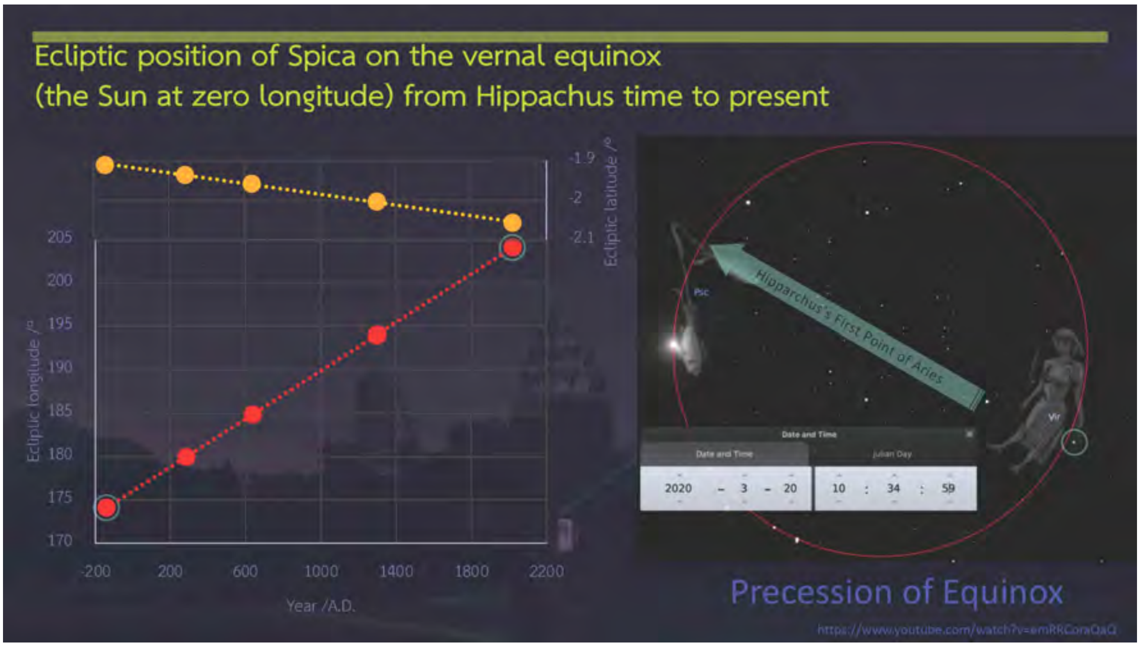

Orientation of
Prasat Hin
Phimai
(Thai: ปราสาทหินพิมาย – Phimai Stone Castle)
http://virtualhistoricalpark.finearts.go.th/phimai/360/phimai.html
Location
20.5°
E

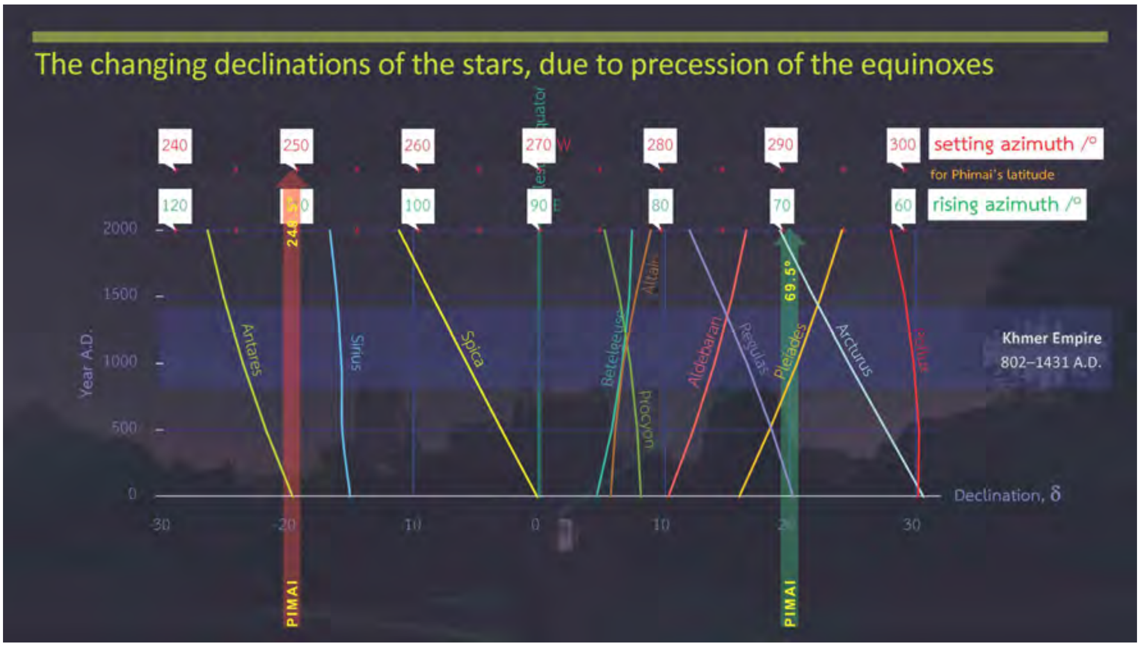

เที่ยวพิมาย
นครราชสีมา ประจำปี ๒๕๕๘
PHIMAI FESTIVAL 2015
During the Loy Krathong day each year around November
The Lunar New Year's Day => the full moon day of the Kritika lunar month => a connection to the traditional Lunar New Year's Day now known as the Loy Kratong Day in Thailand.
The Solar New Year's Day => the year that begins when the sun enters the beginning point of Mesa Rashi (Aries) (the sun moves from Pisces into Aries)=> on this day, known as the "Phayawan" (meaning "the great day"; known to Thais as "Thaloeng Sok") of the Songkran festival.
Saka Calendar and its New Year's Day

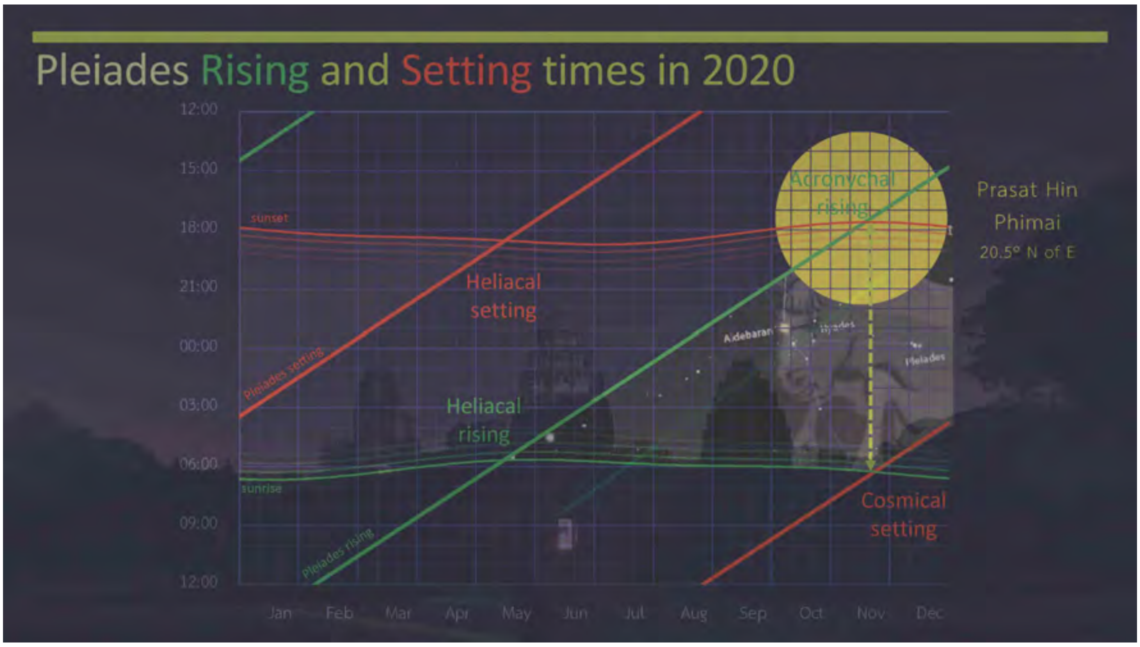

Astronomical event on the New Year's Day
"Loy Krathong Day"
on the full moon day of the
Kritika (Pleiades) lunar month
"Thaloeng Sok" of the Songkran festival
When the sun moves from Pisces into
Aries. The opposite of this point is Spica.
Hindu names of 12-Rāśi and 27-Nakshatra

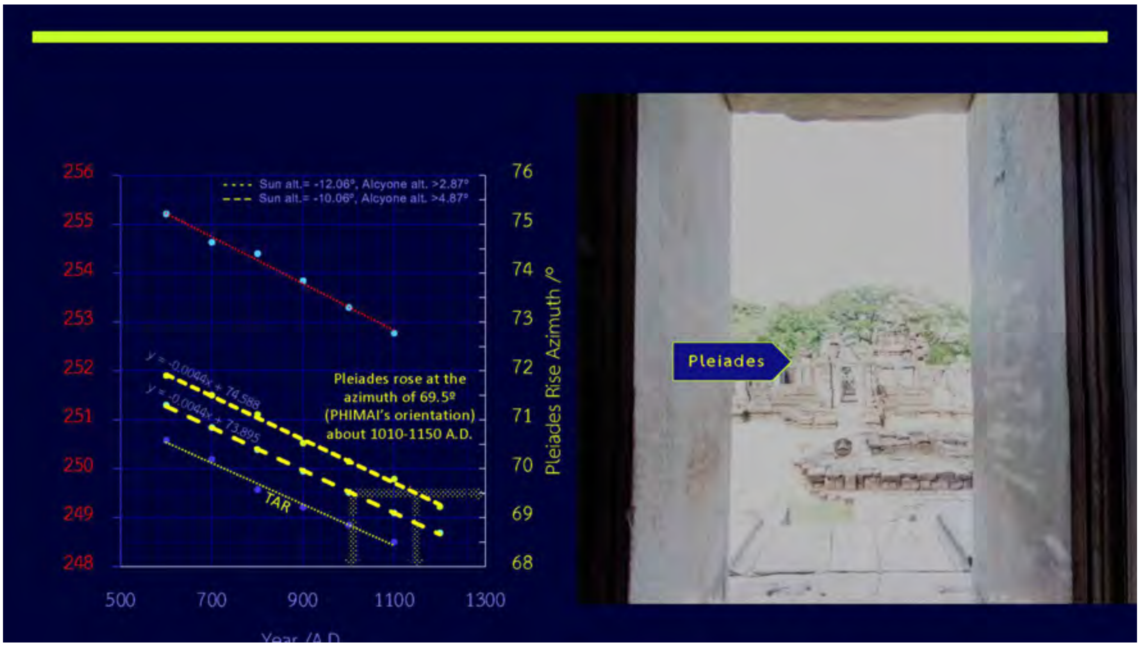

Prasat Hin Phimai
Archaeoastronomical Techniques for Dating
Two datasets were acquired for this study to investigate the orientation of Prasat Phimai in relation to the rising /setting of bright stars:
The positional astronomy software package, Stellarium (version 0.21.3 with ΔT correction using the default "Espenak and Meeus (2006)" model, accounted for atmospheric refraction and extinction, and a proper motion)
1. From Field Techniques: measurement of the temple orientation
2. From astronomy software: determination of the rising/setting time and position of the Pleiades

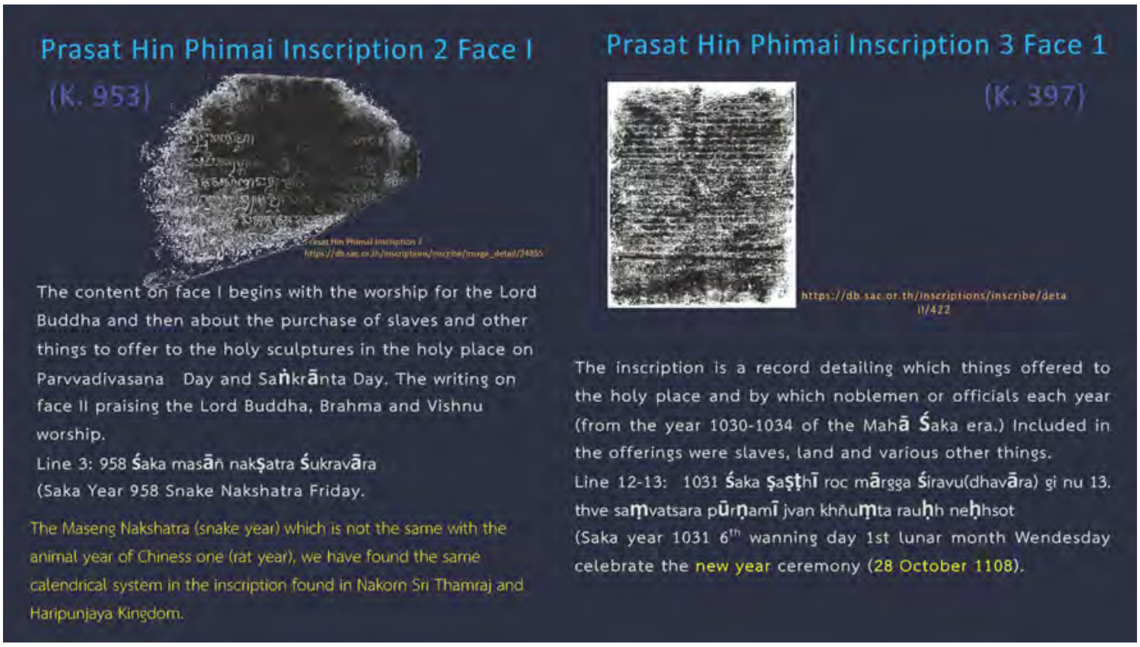

Results & Discussion
Measurement of the temple orientation
Prasat Hin Phimai → aligned to azimuth of 69.5°
The temple orientation was surveyed by the theodolite/total station (Topcon, GTS-100N). The procedure was as follows :
1) assigning the baseline along the construction, which is required,
2) setting the theodolite on one of the ends of the baseline, marking it as zero horizontal position,
3) measuring the horizontal and vertical position of the selected star with time, and
4) calibrating the measured positions with the calculated azimuth of such star as the result the construction orientation can be evaluated.

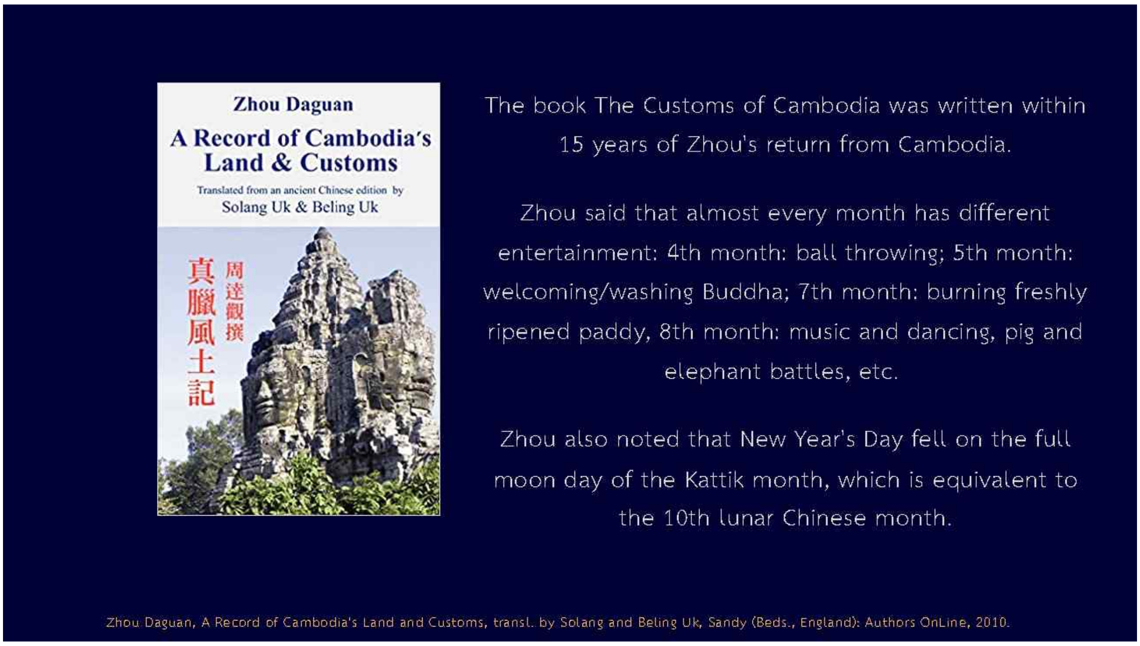

Ecliptic position of Spica on the vernal equinox
(the Sun at zero longitude) from Hippachus time to present
Ecliptic longitude /°
Ecliptic latitude /°
Year /A.D.
Hipparchus's First Point of Aries
Precession of Equinox

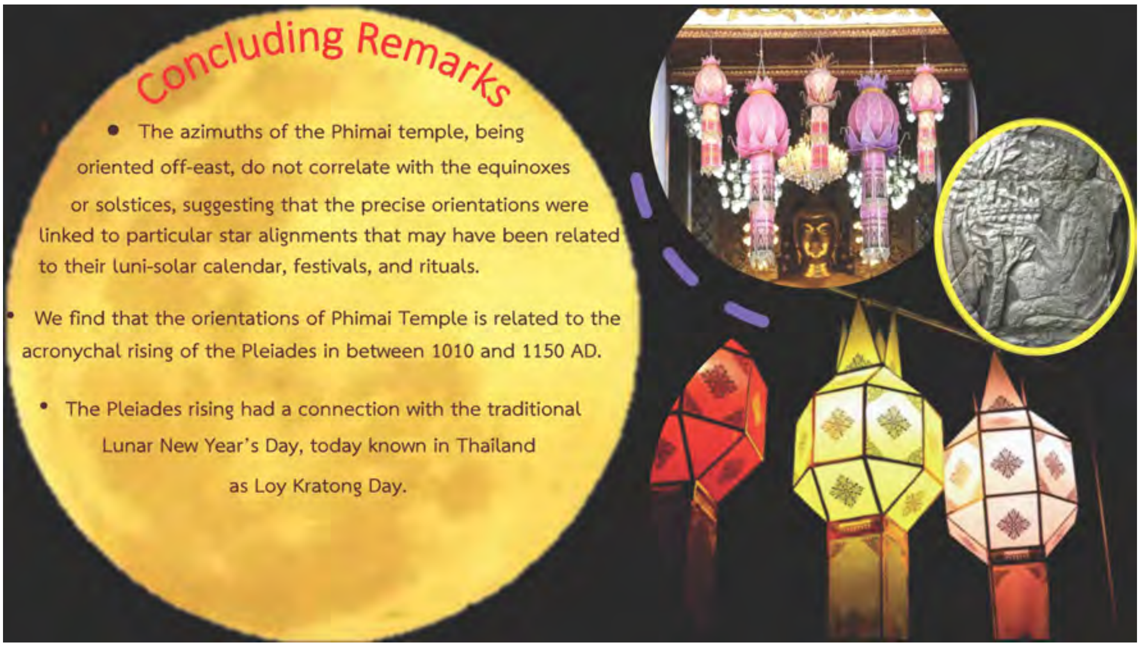

The changing declinations of the stars, due to precession of the equinoxes
setting azimuth /°
for Phimai's latitude
rising azimuth /°
Year A.D.
Khmer Empire
802–1431 A.D.
Antares
Sirius
Spica
Betelgeuse
Procyon
Altair
Aldebaran
Regulus
Pleiades
Arcturus
Declination, δ
69.5°
PIMAI
PIMAI

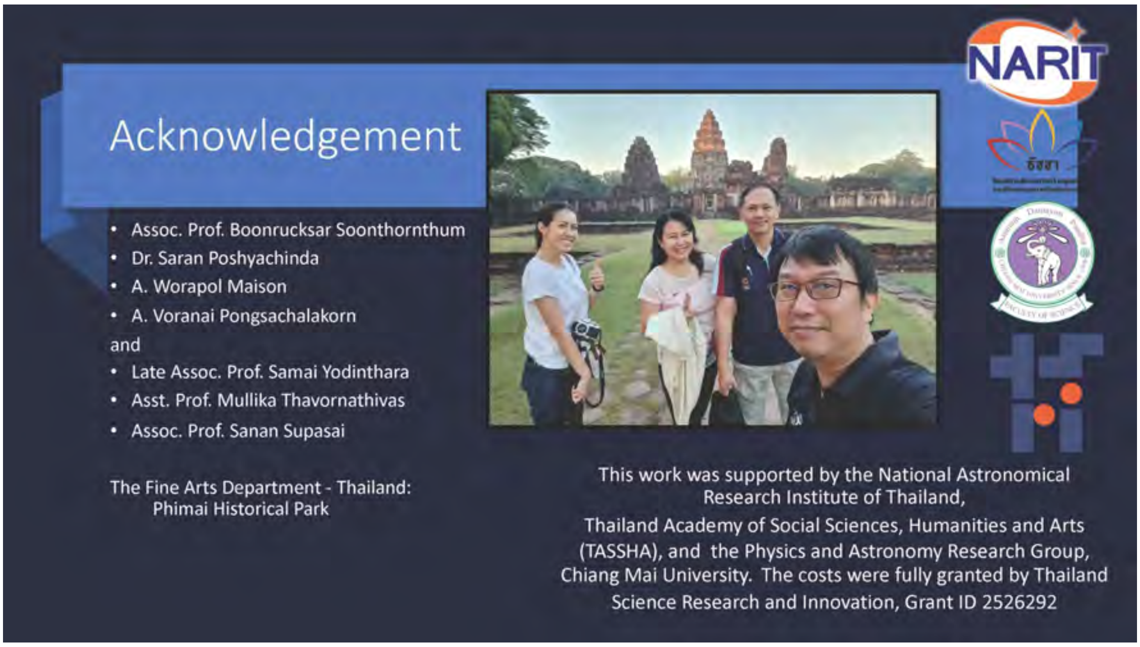

Pleiades Rising and Setting times in 2020
12:00
15:00
18:00
21:00
00:00
03:00
06:00
09:00
12:00
sunset
sunrise
Heliacal setting
Heliacal rising
Acronychal rising
Cosmical setting
Pleiades setting
Pleiades rising
Prasat Hin Phimai
20.5° N of E
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Sun alt.= -12.06°, Alcyone alt. >2.87°
Sun alt.= -10.06°, Alcyone alt. >4.87°
y = -0.0044x + 74.588
y = -0.0044x + 73.895
TAR
Pleiades rose at the azimuth of 69.5º (PHIMAI's orientation) about 1010-1150 A.D.
Pleiades Rise Azimuth /º
256
255
254
253
252
251
250
249
248
76
75
74
73
72
71
70
69
68
500
700
900
1100
1300
Pleiades


Prasat Hin Phimai Inscription 2 Face I
(K. 953)
The content on face I begins with the worship for the Lord Buddha and then about the purchase of slaves and other things to offer to the holy sculptures in the holy place on Parvvadivasana Day and Saṅkrānta Day. The writing on face II praising the Lord Buddha, Brahma and Vishnu worship.
Line 3: 958 Śaka masāṅ nakṣatra Śukravāra
(Saka Year 958 Snake Nakshatra Friday.
The Maseng Nakshatra (snake year) which is not the same with the animal year of Chiness one (rat year), we have found the same calendrical system in the inscription found in Nakorn Sri Thamraj and Haripunjaya Kingdom.
Prasat Hin Phimai Inscription 3 Face 1
(K. 397)
https://db.sac.or.th/inscriptions/inscribe/detail/422
The inscription is a record detailing which things offered to the holy place and by which noblemen or officials each year (from the year 1030-1034 of the Mahā Śaka era.) Included in the offerings were slaves, land and various other things.
Line 12-13: 1031 Śaka ṣaṣṭhī roc mārgga Śiravu(dhavāra) gi nu 13.
thve saṃvatsara pūrṇamī jvan khñuṃta rauḥh neḥhsot
(Saka year 1031 6th wanning day 1st lunar month Wendesday celebrate the new year ceremony (28 October 1108).


Zhou Daguan
A Record of Cambodia's Land & Customs
Translated from an ancient Chinese edition by
Solang Uk & Beling Uk
真臘風土記
周達觀撰
The book The Customs of Cambodia was written within 15 years of Zhou's return from Cambodia.
Zhou said that almost every month has different entertainment: 4th month: ball throwing; 5th month: welcoming/washing Buddha; 7th month: burning freshly ripened paddy, 8th month: music and dancing, pig and elephant battles, etc.
Zhou also noted that New Year's Day fell on the full moon day of the Kattik month, which is equivalent to the 10th lunar Chinese month.
Zhou Daguan, A Record of Cambodia's Land and Customs, transl. by Solang and Beling Uk, Sandy (Beds., England): Authors OnLine, 2010.


Concluding Remarks
• The azimuths of the Phimai temple, being oriented off-east, do not correlate with the equinoxes or solstices, suggesting that the precise orientations were linked to particular star alignments that may have been related to their luni-solar calendar, festivals, and rituals.
• We find that the orientations of Phimai Temple is related to the acronychal rising of the Pleiades in between 1010 and 1150 AD.
• The Pleiades rising had a connection with the traditional Lunar New Year's Day, today known in Thailand as Loy Kratong Day.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• Asst. Prof. Mullika Thavornathivas
• Assoc. Prof. Sanan Supasai
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Stone star map in Gaya tomb of 5th Century

Sohnam Institute for History of Astronomy

Yong Bok Lee

1. Introduction

(1) Megalithic

It is a large stone that has been used to construct a prehistoric structure or monument.

(2) Types of megalithic site

1) Single stone

① Menhir :
Menhir is the name used in Western Europe for a single upright stone erected in prehistoric times.

② Monolith :
Any single standing stone erected in prehistoric times

③ Capstone :
Single megaliths placed horizontally, often over burial chambers, without the use of support stones.

2) Multiple stones

① Alignments :
Multiple megaliths placed in relation to each other with intention like as rows or spirals.

② Dolmen
A Dolmen is a stone table, consisting of a wide stone supported by several other stones

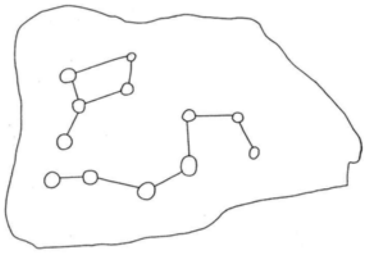
③ Cist
A Cist is a small stone like as box or ossuary for keeping the bodies and the dead. Burials are megalithic forms very similar to dolmens in underground structure.

(3) Cup marks or rock paintings

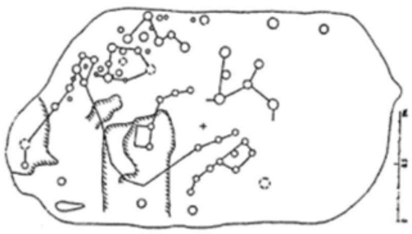
• Cup marks are artificially created simple
• Hemispherical depressions of about 2-10 cm diameter
• Up to 3 cm depth on the surface of many megaliths
• A number of separate 'cup-marked stones'.
• Cup marks often appear in groups
• Cup marks consist of more than one hundred marks on a single stone.
• Cup marks carved on manhir, dolmen, or natural rocks
• Some groups of cup marks would be star maps in bronze age

2. Cup marks in megalithic site

(1) Cup marks on dolmen

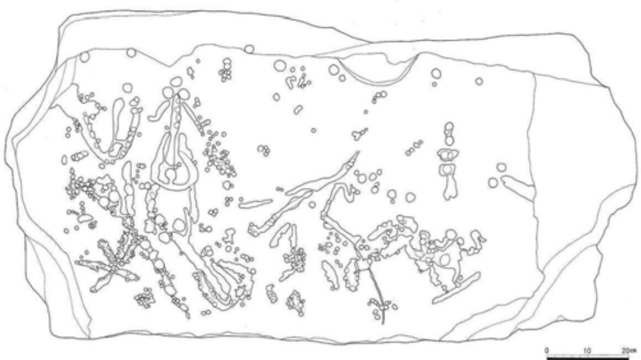


Constellation of Big Dipper on dolmen (Gonggwiri capstone)



Star maps on dolmen at Jiseok−ri

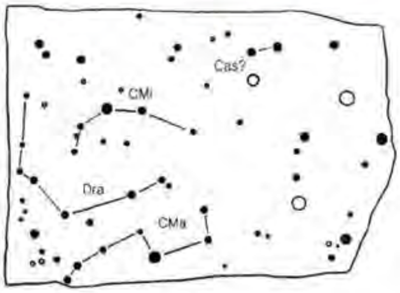
Star maps on dolmen (Andeok−ri in Gyeonggi−do)



Star maps with rock paintings on dolmen (Jisan−dong, Goryeong in Gyeongnam)

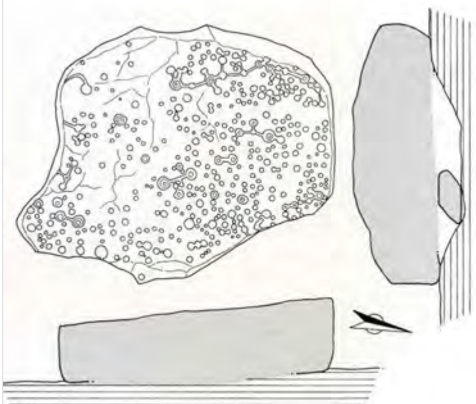
(2) Cup marks and rock paintings on Natural rocks

Star maps and circles on stone surface (Dohang–ri in Haman



Star maps around north celestial pole area on stone plate (Adeugi in Chungbuk)

3. Cup marks on dolmen in Haman Area



Many cup marks on No. 26 Dolmen in Donchon–ri

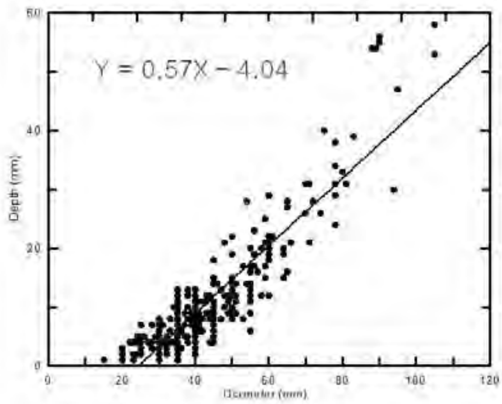


Fig. Correlation hole diameter with depth in mm
(Dolmen at Dongchon−ri)

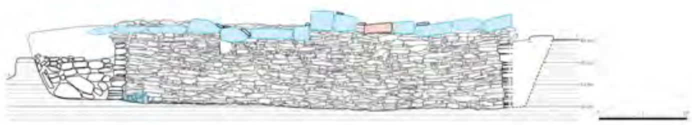
4. Description of the Gaya tomb

There are many tombs at on the hill inside in Haman area, which are built around 5th century.
On the excavation, star map stone was found among one of them. It is 13th Tomb of Mt. Malisan.

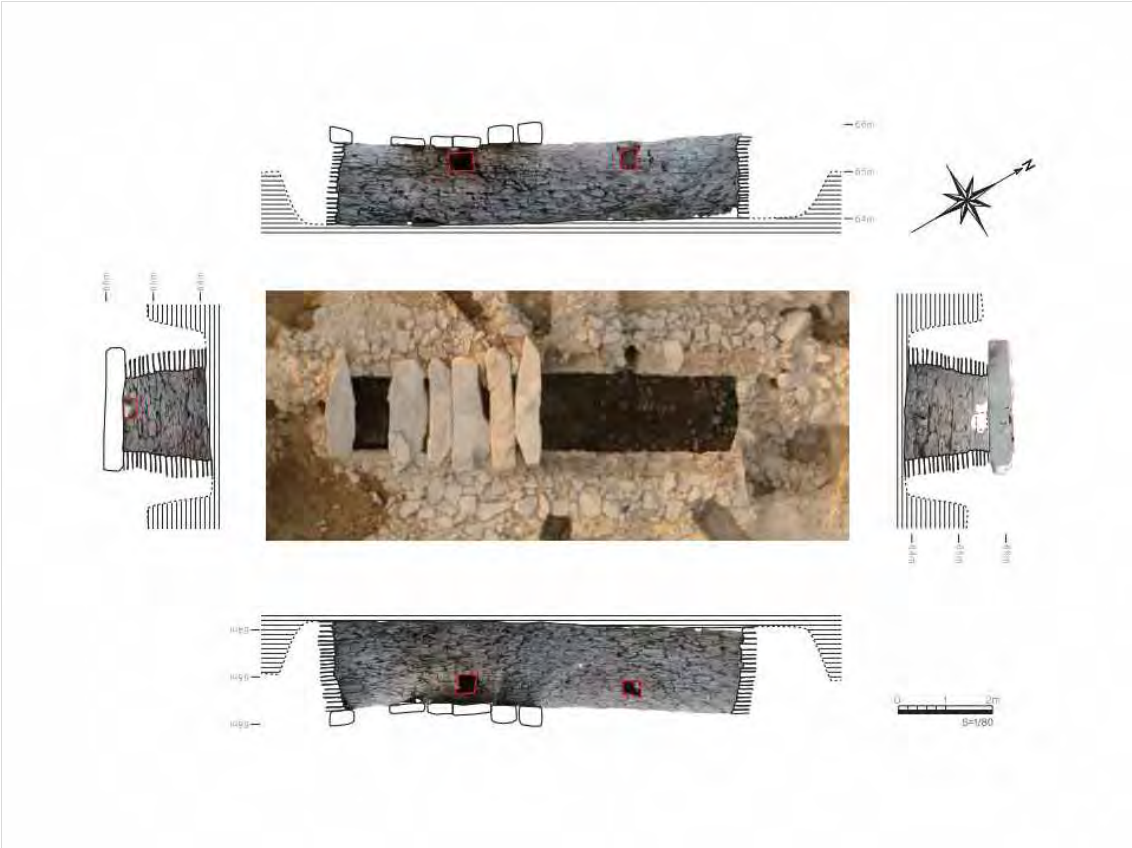
August 23, 2019

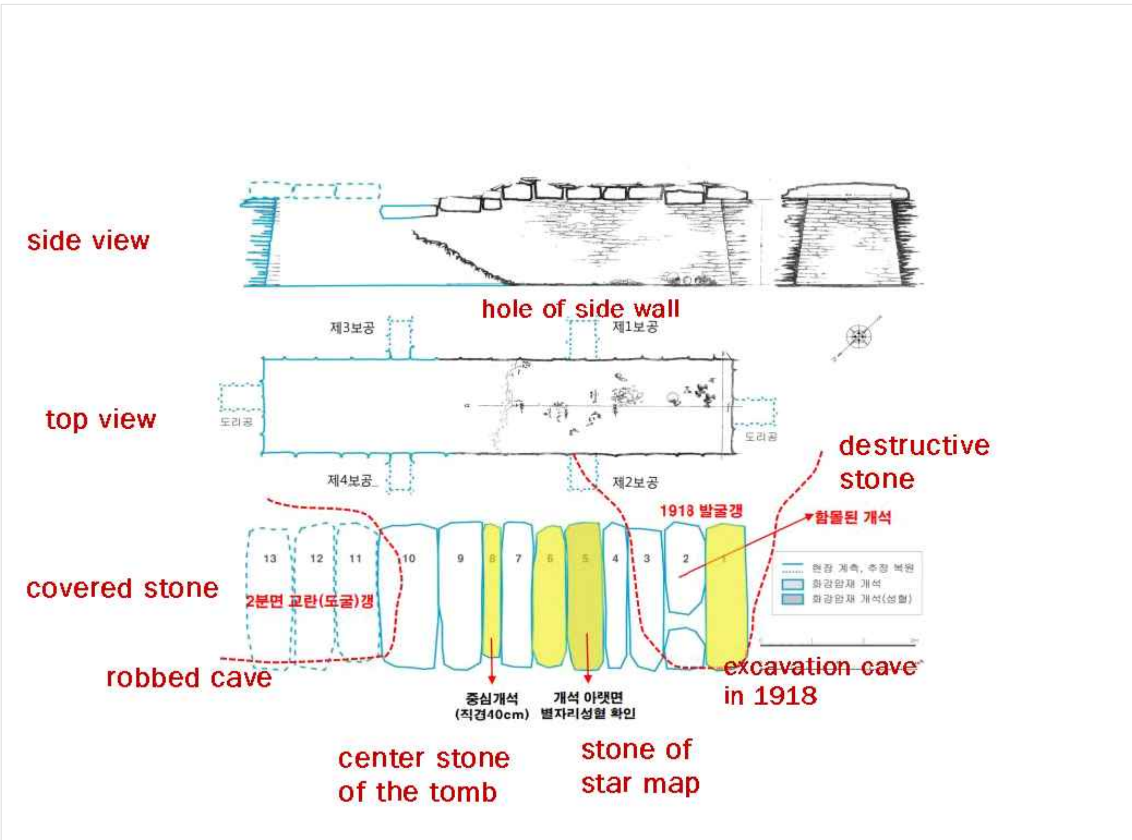
(1) Structure of the Gaya tomb

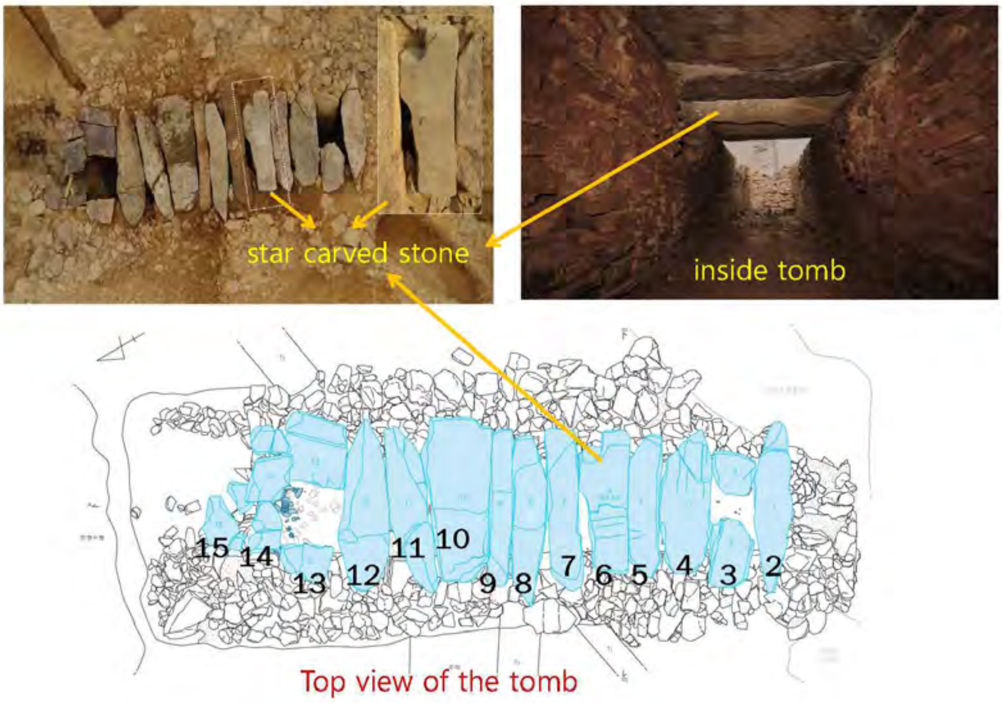
Side view



Top view




side view
hole of side wall
제3보공
제1보공
top view
도리공
도리공
제4보공
제2보공
destructive stone
1918 발굴갱
함몰된 개석
covered stone
2분면 교란(도굴)갱
robbed cave
excavation cave in 1918
중심개석 (직경40cm)
개석 아랫면 별자리성혈 확인
center stone of the tomb
stone of star map



(2) Sizes of 15 cover stones of the Gaya Tomb

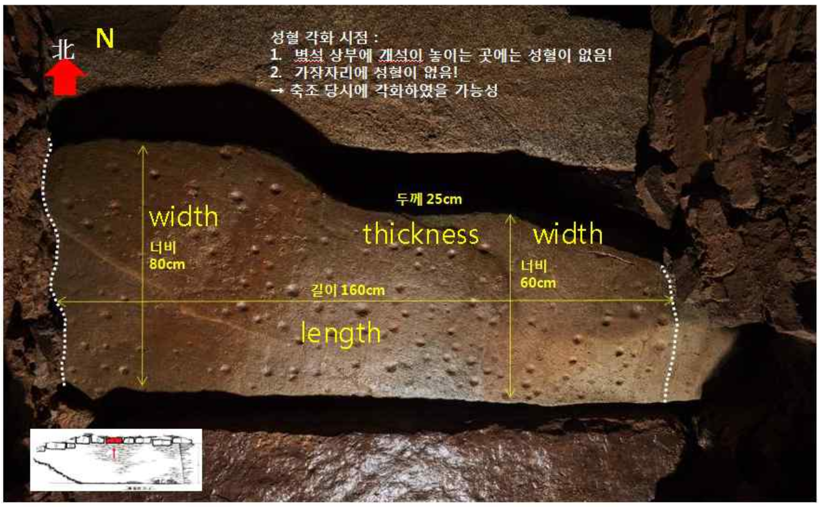
No.	Scale (㎝)			memo
	Length	Width	Depth	
1	(168)	58	(30)	destruction
2	282	62	26	
3	(218)	72	26	destruction
4	236	84	26	
5	234	52	28	
6	236	84	22	star map
7	268	54	38	
8	280	56	46	Estimated center
9	256	36	32	
10	268	114	22	
11	280	62	34	
12	282	84	30	
13	(260)	102	(20)	Destruction
14	(210)	(64)	(20)	Destruction
15	(84)	(60)	(20)	destruction

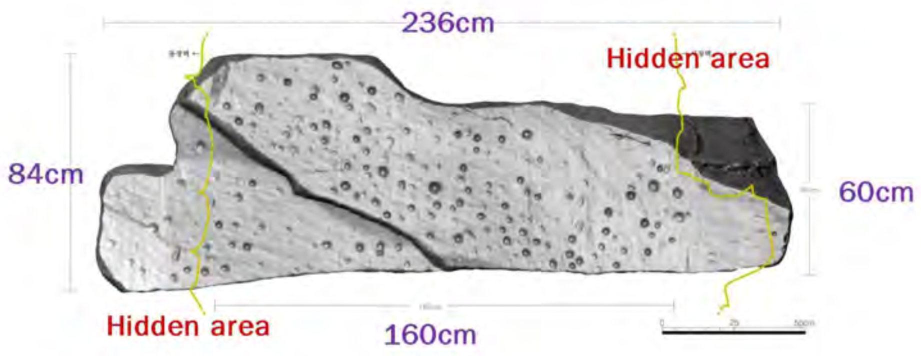
Characteristics of the tomb

- The tomb was robbed long years ago
- First excavation on 1918
- Size tomb of bottom : L 910cm, W 210cm, H 180cm
- Main direction of the tomb : N → E 38 °
- Anonymous 4 holes of side wall
- Cover stones are consist of 13-14 parts
- After excavation the cover stones were fixed 15 parts
- Size range of cover stones :
    - length : 234 – 282 cm
    - width : 234 – 282 cm
    - depth : 22 – 46 cm
- The cover stone of star map is six-th part

5. Identification of stars on the stone

(1) Size and shape of stone plate carved constellations



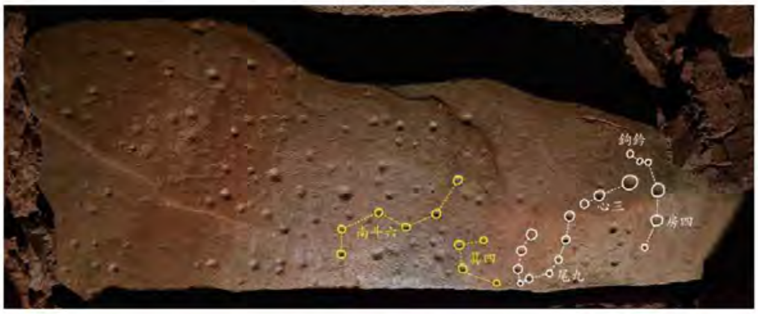


(2) Number of stars and the size of cup marks

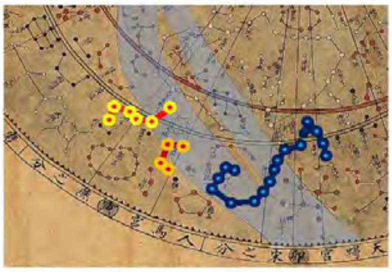
Total number of cup marks and their size with four groups (checked by eyes)

- Total number of cup marks are 125 points
- Diameter 4, depth 0.7 are 6 points
- Diameter 3, depth 0.5 are 14 points
- Diameter 3, depth 0.3 are 42 points
- Diameter 3, depth 0.1 are 63 points

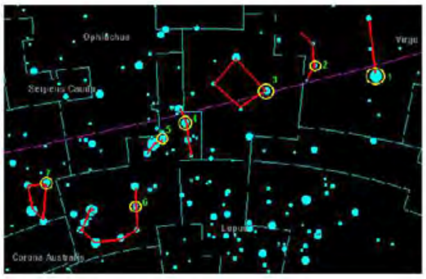
(3) Primitive identification of stone star map



Stone star map



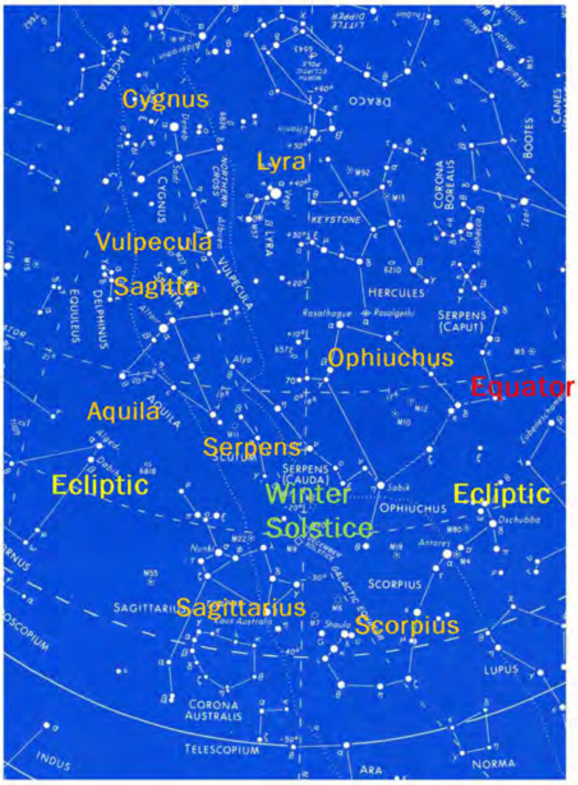
Cheonsang Yeolcha BunyaJido



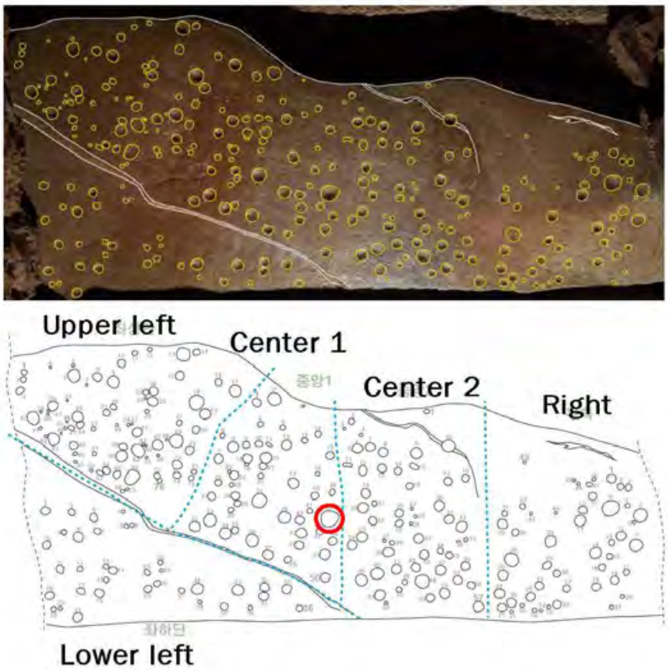
Modern star chart

Identification of the stars

- First we compared the star map with Cheonsang Yeolcha Bunyajido that is old star map during Joseon Dynasty.
- Two or three constellations were appeared on star map.
- Three constellations were clearly identified
- They are Bang(房), Sim(心), Mi(尾), Gi(箕) and Du(斗) which are belong to almost Eastern seven stars(東方七宿).



(4) Five divisions for identifying stars



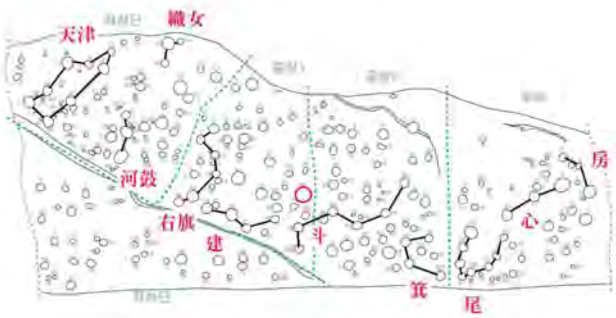
Number of stars
(Scanned data)

Upper left : 26
Lower left : 19
Center 1 : 25
Center 2 : 36
Right : 31

Total : 137

Conformed by 3D
scan method

- We divided into five regions for identifying the each constellations.
- The regions are composed of upper left, upper lower, center 1, center 2, and right part.
- Comparing star map with modern, we are aware the regions were coincident with Milky Way.
- At last, we are aware that the distribution of stars on stone is coincident with the milky way, not ecliptic.
- We identified them on stone with constellations in ancient star names.
- The result is following.

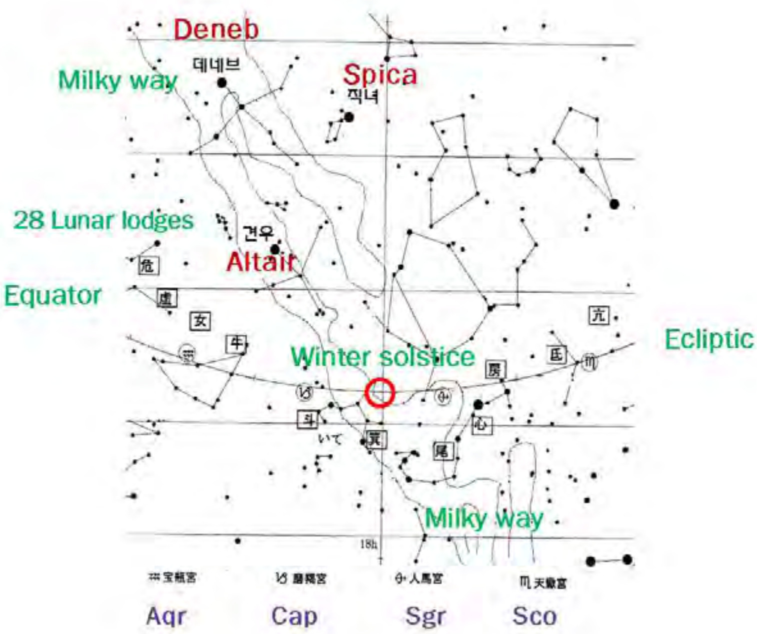


Identification of the stars on the stone plate

- Identified result is following
- Identified stars are
  Bang(房), Sim(心), Mi(尾), Gi(箕), Du(斗)
  Geon(建), Woogi(右旗), Hago(河鼓),
  Jiknyeo(織女) and cheonjin(天津)

Winter solstice and season

- Especially we found the winter solstice on stone plate.
- The winter solstice is located on the center of the plate, near the Du(斗) which is in Sagittarius.
- The position of the plate center is almost same place with winter solstice in 5th century.
- The constellations are same location on the night sky after evening civil twilight in early August.
- We can directly observe the night sky on the stone plate in August at the tomb.
- The star map would be related with ritual festival of Gaya in 5th century



6. Results

- We identified the stars on the stone plate
- The constellations on it are located on the Milky way region.
- The center of it is placed winter solstice.
- It is coincident with calculation of precession.
- We can see the night sky on it after evening civil twilight in early August.

Thank you very much for your attention

Session 3. Historical Astronomy

◤Chair : Hong-Jin Yang /

Korea Astronomy and Space Science Institute◢

A Study on the Definition of Terms Related to Approach and Angular Distance between Celestial Bodies in Korean Historical Astronomical Records

Hyo-Jun Lee[1,2,3], Hong-Jin Yang[1,3], Suk-Jin Yoon[2], and Myeong-Gu Park[4]

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Abstract

Context. Korean chronicles contain numerous records on astronomical phenomena such as eclipse, sunspot, nova, comet and close approach of celestial bodies, allowing scientific analysis through astronomical calculations. Celestial positions are generally described with angular distance (AD) from the north pole and RA distance to the reference star. However, most records of close approach of celestial bodies describe their AD with specific terms. Numerical definitions of such terms have not been constrained.

Aims. We examine five terms describing close approach of celestial bodies i.e. Entry (入, En), Invasion (犯, In), Occultation (掩, Oc), Eclipse (食, Ec) and AD unit Chi (尺). We calculate and analyze the terms using over 2,300 records in Goryeosa (高麗史, the History of Goryeo Dynasty) and Joseonwangjosillok (朝鮮王朝實錄, the Annals of the Joseon Dynasty). For the term Chi (尺), we additionally examine the sketch records of the comet observation in Joseon. We find the quantitative definitions of the terms through statistical analysis.

Methods. We survey the records and convert the luni-solar dates to Julian dates. With modern ephemeris DE431, we calculate the AD between celestial bodies from Korean historical records. We compare the results for the records of two periods, Goryeo and Joseon Dynasties. Also we calculate the angular size of Chi by measuring length of comet's tail.

Results. We find out that the ADs of the terms En, In, Oc, and Ec are respectively $1.78^{\circ}{}^{+2.36}_{-1.11}$, $0.89^{\circ}{}^{+3.54}_{-0.51}$, $0.44^{\circ}{}^{+1.15}_{-0.31}$, and $0.29^{\circ}{}^{+2.61}_{-0.16}$ for Goryeo Dynasty (918 CE - 1392 CE) and $1.36^{\circ}{}^{+1.15}_{-0.64}$, $0.51^{\circ}{}^{+1.11}_{-0.32}$, $0.25^{\circ}{}^{+0.27}_{-0.17}$, and $0.21^{\circ}{}^{+0.25}_{-0.11}$ for Joseon Dynasty (1392 CE - 1910 CE). We also estimate the unit Chi, to be 1.29° on average. We confirm that the terms are used based on the AD of closest approach of celestial bodies. Also we find that there are no correlation between the apparent magnitude of the objects and AD of each term.

Conclusions. From the statistical analysis, we find out the numerical definitions of the terms. We show that they are large in the order of En, In, Oc and Ec. The trend is consistent in the Goryeo and Joseon Dynasties, although the ADs of each term are generally smaller during the Joseon Dynasty. We assume that each term may have been defined based on the angular radius of the Moon, In being 2 times (for Joseon Dynasty) and Chi being 2.5 times the angular size of the Moon for example.

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Contents

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1. Introduction

Astronomical Records in Korean History

- Dynasties in Korean history considered observing and recording astronomical phenomena to be very important.

Dates	Period	Astronomical Heritage
BC 30C~AD 2C	石器~鐵器 (Stone age Iron Age)	岩刻畫, constellations of dolmens
BC 24C~BC 2C	檀君朝鮮 (Gojoseon)	12 astronomical records Observatory – Chamseongdan(塹星檀, 江華)
BC37 ~ AD668 BC18 ~ AD660 BC57 ~ AD935	高句麗 百濟 新羅 (Three Kingdoms Period of Korea)	Over 240 astronomical records - [illegible] 24 Goguryeo(高句麗) tombs with constellation paintings Observatory – Cheomseongdae(瞻星臺, 慶州), sundials
AD918 ~ 1392	高麗 (Goryeo Dynasty)	Over 5,000 astronomical records - [illegible] 9 Goryeo(高麗) tombs with constellation paintings Observatory – Cheomseongdang(瞻星堂, 開京)
AD1392 ~ 1910	朝鮮 (Joseon Dynasty)	More 20,000 astronomical records - [illegible] Observatory, Astronomy Book –天文類抄, 星鏡,- & Astronomical Instruments - sundials, celestial globes, water clock, astronomical clock, armillary sphere,- etc. Stone star chart - 天象列次分野之圖 (1395)

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Astronomical Records in Korean History

- Dynasties in Korean history considered observing and recording astronomical phenomena to be very important.

星變測候單子 (daily log of the comet observation in 17-18th Century)

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Astronomical Records in Korean History

- Astronomical records of Goryeo & Joseon dynasties
  - 「Goryeosa (高麗史)」, 「the Annals of the Joseon Dynasty (朝鮮王朝實錄)」
    - ~ 25,000 astronomical records
    - ~ 6,000 records related to distance & approach between celestial bodies
  - 「Cheon-byeon-deung-rok (天變謄錄)」 - Daily Log (星變測候單子)
    - Produced by Official Astronomical Observatory (Gwansanggam) of Joseon Dyansty
    - Detailed records of astronomical phenomena
    - Contain Comet observation records & drawings (including 1P/Halley observation record 1759)

- Information contained in the record (Goryeosa & Sillok)
  - Name of the King and the year of reign
  - Lunar calendar date
  - Astronomical Observations (or astronomy-related discussions and systems)
    - Solar & lunar eclipses
    - *Approach of planets, moons, and stars*
    - *Venus seen during the day*
    - *Comets, guest stars, meteors, aurora*
    - Unusual phenomena of (near) the sun and moon (sunspots, ring, etc.)
    - Atmospheric and weather phenomena

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Astronomical Records in Korean History

Many studies have been done on the astronomical records

- Yang et al. (2005) studied the characteristics of the outburst of R Aquarii from the nova records of CE 1073 and CE 1074.
- Yang, Park & Park (2005) studied meteor and shower records.
- Yang et al. (2019) analyzed the correlation between solar sunspot and climate change.
- Based on the records of solar eclipses during the Three Kingdoms period, Park & La (1998), Lee (2008) and Lee (2016) found the optimal observation site of solar eclipse.
- Lee et al. (2016) verified the accuracy of the historical records by analyzing the lunar records of *Goryeosa*.

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Observational Terms for Approach of Celestial Bodies

- One of the most steadily and heavily recorded astronomical phenomena
  → The mutual approach of two or more celestial bodies

- They were recorded using different terms depending on how close the bodies were to each other.

Entry (入, hereafter *En*) → Entering, one celestial body enters the realm of another in the celestial sphere

Invasion (犯, hereafter *In*) → One celestial body approaches the peripheral area of another

Occultation (掩, hereafter **Oc**) → Covering. One celestial body is covered by another

Eclipse (食, hereafter **Ec**) → Eating. Often used to express solar or lunar eclipse

Zhang (丈), *Chi* (尺) and *Cun* (寸) → terms used to indicate angular distance between celestial bodies

i.e. the units of angular distance

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Observational Terms for Approach of Celestial Bodies

「Seoungwanji (書雲觀志)」 - (成周悳)
Guidebook on the Role of Official Astronomical Observatory
and Observation Procedures

月五星犯食入

When light reaches an AD of within one Cun (寸), it is called invasion (犯, In), and when it is invisible, it is expressed as eclipse (食, Ec)

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Observational Terms for Approach of Celestial Bodies

Some previous studies that estimated to angular distances of the terms

- *In* (犯) = $1.0°^{+0.6}_{-0.6}$

(Ahn et al. 2010, From the records of Goryeo and Joseon that the Moon approached a specific star in the Oriental constellation of Gyonu (牽牛))

- 1 *Chi* (尺) ≈ 1

(Stephenson & Green 2002)

- 1 *Chi* (尺) ≈ 1.5 ,
- 1 *Chi* (尺) ≈ 7 – 8 for some records (unrealistically large according to Nha 1981)

(Nha 1981, from the records of the *CheonbyeonDeungrok* (天變謄錄) (hereinafter *Deungrok*) in 1664, Nha, Hong & Ahn (2012))

- There is clear discrepancy regarding the definition of *Chi* (or *Cun*)
- Previous studies used only fragmental (small number) records

→ Comprehensive study with many records (with hundreds of records) is needed

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2. Data

Data - Records of Terms Entry (入), Invasion (犯), *Occultation* (掩), *Eclipse* (食)

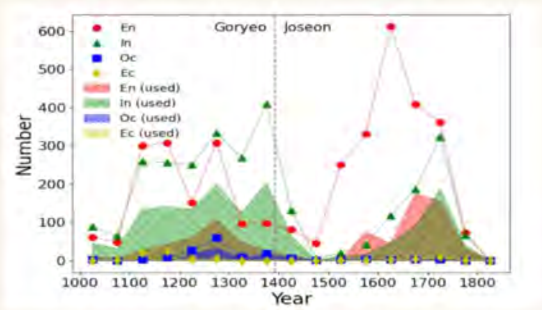
- **Conditions**

  i) One of the four terms *En, In, Oc* and *Ec* must be used.

  ii) Close approach of celestial bodies

  iii) All of the observation targets must be identifiable (e.g. Planets, Moon, identified stars)

  → Used ~2,400 records out of ~6,000 records (exclude records of meteors, comets, unidentified stars, etc.)



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Data - Records of Terms Entry (入), Invasion (犯), *Occultation* (掩), *Eclipse* (食)

Find records **related to access between celestial bodies + can be verified by calculation**

↓

Corresponding terms and target celestial bodies are labeled.
(If a constellation is included, all stars in that constellation are considered)

↓

Lunisolar calendar date → **the solar calendar date (UT)**

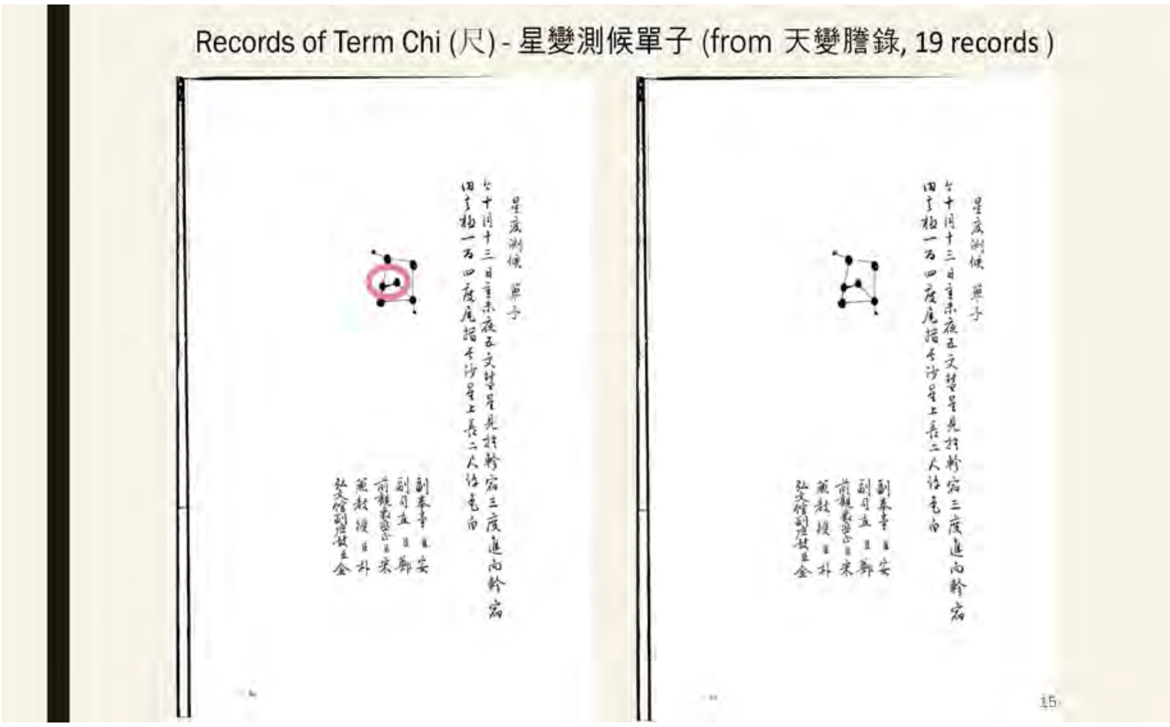
↓

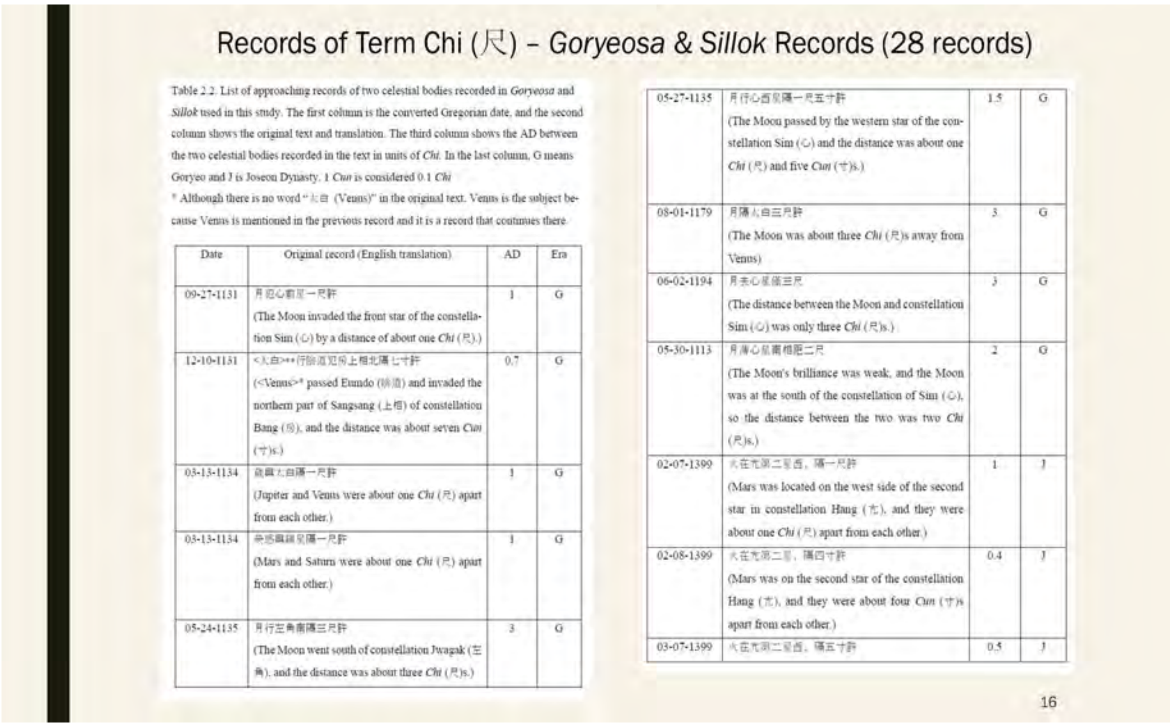
Calculation on the Data & Statistical Analysis

Input information
(target body1, target body2, ..., observer location (lon, lat), year, month, day, hour, minute, second)

Total 2433 records

14





Records of Term Chi (尺) – *Goryeosa* & *Sillok* Records (28 records)

Table 2.2. List of approaching records of two celestial bodies recorded in *Goryeosa* and *Sillok* used in this study. The first column is the converted Gregorian date, and the second column shows the original text and translation. The third column shows the AD between the two celestial bodies recorded in the text in units of *Chi*. In the last column, G means Goryeo and J is Joseon Dynasty. 1 *Cun* is considered 0.1 *Chi*

* Although there is no word "太白 (Venus)" in the original text, Venus is the subject because Venus is mentioned in the previous record and it is a record that continues there.

Date	Original record (English translation)	AD	Era
09-27-1131	月犯心前星一尺許 (The Moon invaded the front star of the constellation Sim (心) by a distance of about one *Chi* (尺).)	1	G
12-10-1131	<太白>**行餘道犯房上相北隔七寸許 (<Venus>* passed Eundo (餘道) and invaded the northern part of Sangsang (上相) of constellation Bang (房), and the distance was about seven *Cun* (寸)s.)	0.7	G
03-13-1134	歲與太白隔一尺許 (Jupiter and Venus were about one *Chi* (尺) apart from each other.)	1	G
03-13-1134	熒惑與鎭星隔一尺許 (Mars and Saturn were about one *Chi* (尺) apart from each other.)	1	G
05-24-1135	月行左角南隔三尺許 (The Moon went south of constellation Jwagak (左角), and the distance was about three *Chi* (尺)s.)	3	G
05-27-1135	月行心西星隔一尺五寸許 (The Moon passed by the western star of the constellation Sim (心) and the distance was about one *Chi* (尺) and five *Cun* (寸)s.)	1.5	G
08-01-1179	月隔太白三尺許 (The Moon was about three *Chi* (尺)s away from Venus)	3	G
06-02-1194	月去心星僅三尺 (The distance between the Moon and constellation Sim (心) was only three *Chi* (尺)s.)	3	G
05-30-1113	月薄心星南相距二尺 (The Moon's brilliance was weak, and the Moon was at the south of the constellation of Sim (心), so the distance between the two was two *Chi* (尺)s.)	2	G
02-07-1399	火在亢南二星西，隔一尺許 (Mars was located on the west side of the second star in constellation Hang (亢), and they were about one *Chi* (尺) apart from each other.)	1	J
02-08-1399	火在亢南二星，隔四寸許 (Mars was on the second star of the constellation Hang (亢), and they were about four *Cun* (寸)s apart from each other.)	0.4	J
03-07-1399	火在亢南二星西，隔五寸許	0.5	J

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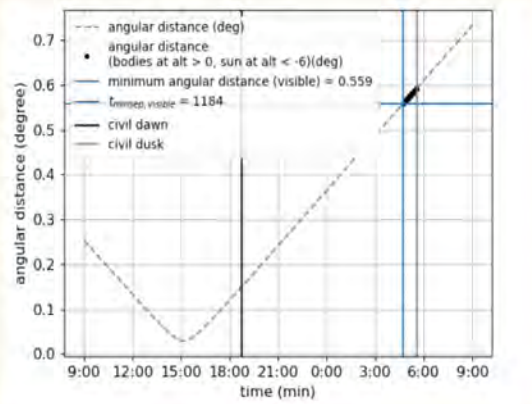
3. Methods

Astrophysical Calculation for Minimum Angular Distance from Observation Records

- Modern **ephemeris** JPL DE431
- **Calculated the position** (altitude, azimuth)
  (star identification : Park 1998)
- **Obtain** smallest observable angular distance
- **compare the values of the** minimum angular distance for each term



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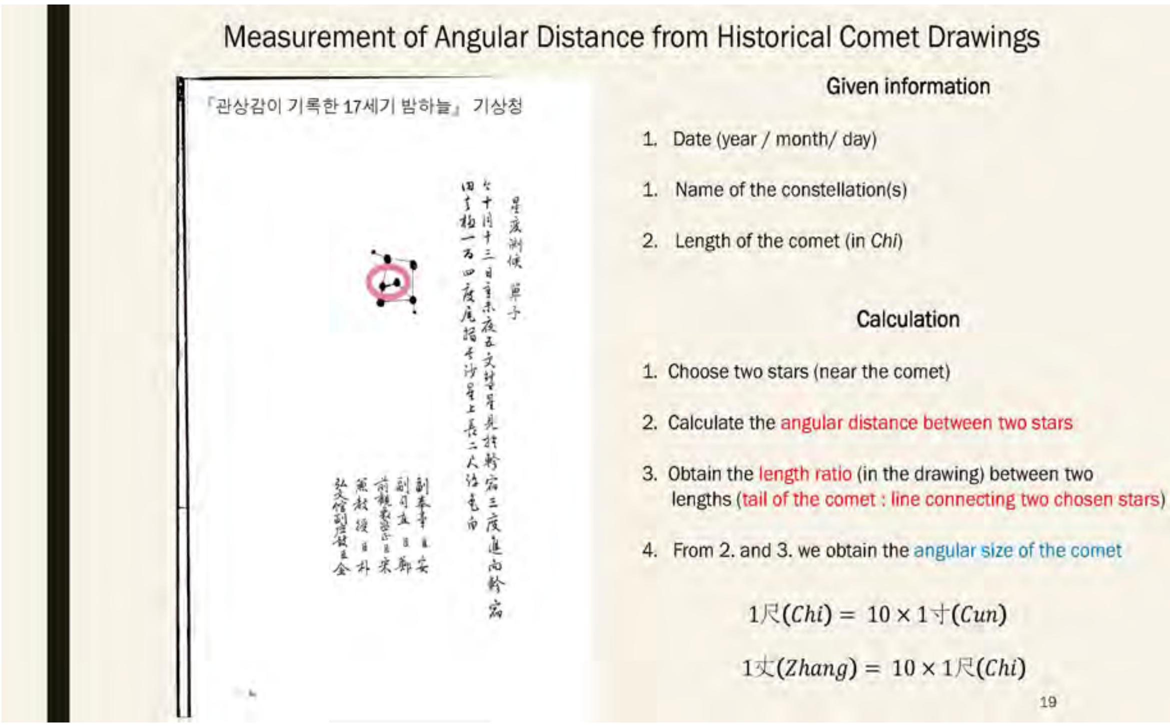
Measurement of Angular Distance from Historical Comet Drawings
「관상감이 기록한 17세기 밤하늘」 기상청
Given information
1. Date (year / month/ day)
1. Name of the constellation(s)
2. Length of the comet (in Chi)
Calculation
1. Choose two stars (near the comet)
2. Calculate the angular distance between two stars
3. Obtain the length ratio (in the drawing) between two lengths (tail of the comet : line connecting two chosen stars)
4. From 2. and 3. we obtain the angular size of the comet
1尺(Chi) = 10 × 1寸(Cun)
1丈(Zhang) = 10 × 1尺(Chi)
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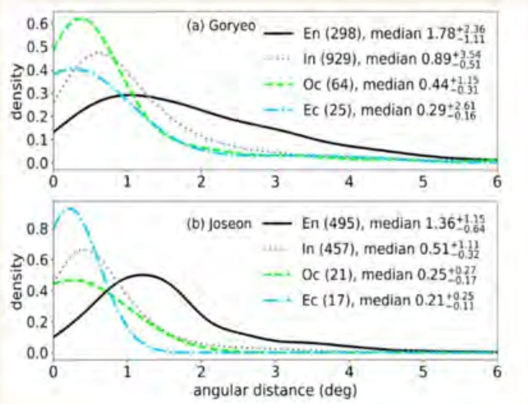
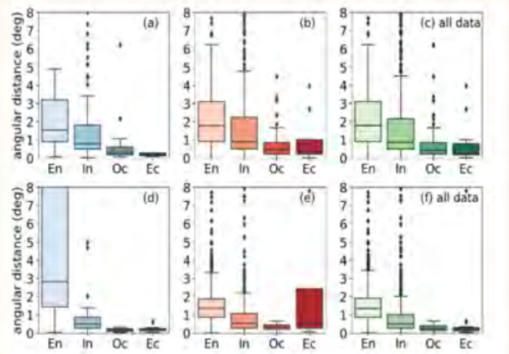
4. Results

Angular distances of terms Entry (入), Invasion (犯), *Occultation* (掩), *Eclipse* (食)





En > In > Oc > Ec
Same trend for both Dynasties

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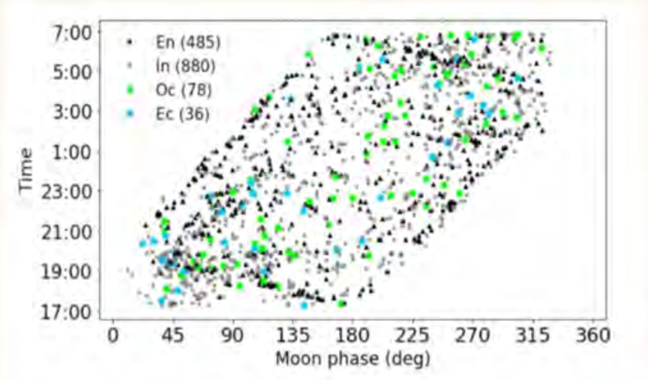
Observation Time based on the Lunar and Celestial Approach Records



Times of minimum angular distance are evenly distributed
→ Continuous Observation of astronomical phenomena
→ Records were made based on the closest approach of bodies

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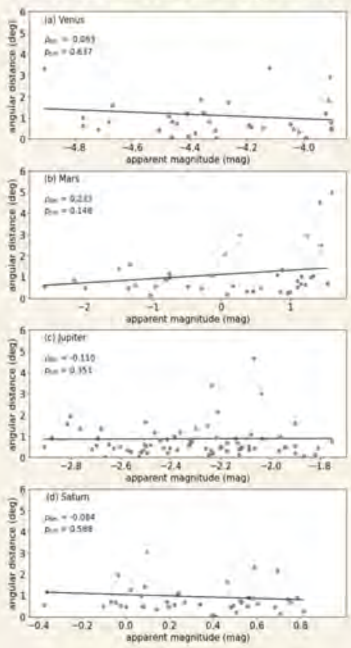
Correlation Between Brightness of Celestial Bodies and Angular Distance



No significant correlation
→ Brightness of celestial bodies did not affect observation and records

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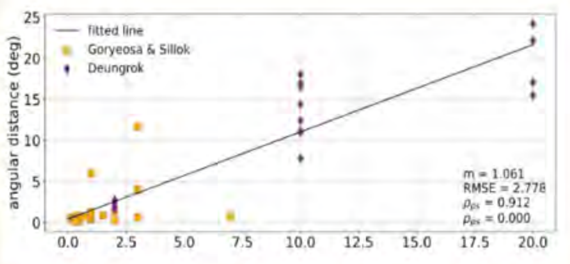
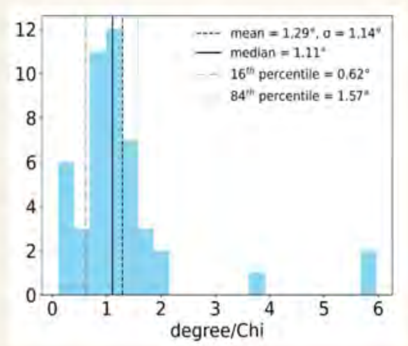
Angular Distance of Term Chi (尺) – *Deungrok, Goryeosa & Sillok (Combined)*





We find, 1 Chi = 1.29 degrees

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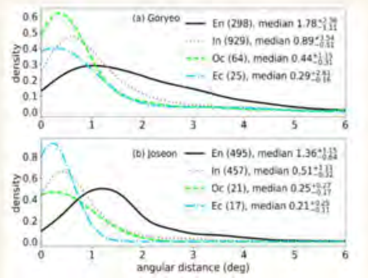
5. Summary & Discussion

Summary

- Angular distance for 4 terms from ***Goryeosa*** **and** ***Sillok***

  Entry(入, En) > Invasion(犯, In) > Occulation(掩, Oc) ≳ Eclipse(食, Ec)



- From ***Deungrok***, ***Goryeosa*** **and** ***Sillok*****,**

  the angular distance corresponding to the unit Chi (尺) : ~ 1.29 degrees

- This trend was the same in both the Goryeo Dynasty **and the** Joseon Dynasty.

  However, the values were generally smaller during the Joseon Dynasty.

- The observations were continued from early evening to dusk before sunrise.

- **Correlation between the** apparent magnitude of the planet **and the** angular distance between the celestial bodies

  → No significant correlation

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Discussions

- Astronomical records used in this study were not uniformly distributed over time
  → Follow-up study is required to know the time variation of the definition of terms with other historical documents such as *Seungjeongwonilgi* (承政院日記) and *Jeungbomunheonbigo* (增補文獻備考)
- Each term may had been defined based on the moon's angular radius. For example, ADs of four terms En, In, (Oc, Ec) and Chi are approximately 7, 3, 1-2 and 2.5 times the angular radius of the Moon.

- **Minimum angular distances for some records were ~ over 30 degrees (over 100 degrees for some records)**
  → These records may have been incorrectly recorded (dates, celestial body identification)

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Conclusion

- We found the definition of the AD terms between the celestial bodies in Korea's historical astronomical records
- Subsequent studies on other historical literature
  (such as *Seungjeongwonilgi* (承政院日記) and *Jeungbomunheonbigo* (增補文獻備考))
- Comprehensive understanding of the records can be achieved by combining the results of studies on terms related to the brightness of the celestial bodies or other astronomical attributes
- As a result, it is expected to provide a deeper understanding of various astronomical terms and records and foster the utilization of the records in the field of astronomy

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Cometary records in the Vietnamese historical source *Đại Nam Thực Lục Chính Biên* (大南寔録 正編)

Akira Okazaki
Gunma University (Retired)

The 9th International Symposium on History of Astronomy:
March 29, 2023
Online

The 9th International Symposium on History of Astronomy (Online, March 29, 2023)

Abstract

We discovered ten cometary records in the *Đại Nam Thực Lục Chính Biên* (「大南寔録」正編), which is the main volumes of the official history of the Nguyễn Dynasty of Vietnam. We determined the corresponding comets described in the records by referring to *Jet Propulsion Laboratory's Small-Body Data Base.* We compared the description of a couple of these records with the simulation results based on published orbital elements. Our analysis revealed a few discrepancies, but overall, these records are largely consistent with the results of astronomical simulations.

The 9th International Symposium on History of Astronomy (Online, March 29, 2023)

Outline

1. Introduction

Đại Nam Thực Lục Chính Biên (大南寔録 正編)

The purpose of our study

2. Collected records and Examination

The results of our survey

Analysis of a couple of these records

3. Summary

The 9th International Symposium on History of Astronomy (Online, March 29, 2023)

Đại Nam Thực Lục (hereafter, *ĐNTL*)

(大南寔録, *the Veritable Record of the Great South*)

ĐNTL, the annals of the Nguyễn dynasty (1802–), consists of two parts:

- *Tiền Biên (前編, the Early Volumes)*
- *Chính Biên (正編, the Main Volumes*, hereafter *ĐNTL-CB*).

The annals of the Nguyễn dynasty from 1778 (a few decades before the dynasty started) through to the early 20th century.

In this study, we used the facsimile edition of an original block print of the *ĐNTL* published by Keio University (1961–1981), which covers a period until 1888.

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The purpose of our study

No surveys have been reported on cometary records in the *ĐNTL-CB* to date.

In the 19th century, the Nguyễn dynasty continued traditional astronomical observations (e.g., Phạm Vũ Lộc and Lê Thành Lân, 2020), as did China, Korea, and Japan.

Comets were observed more accurately with modern instruments in the Western world in the same century, providing their reliable orbital elements.

This allows us to examine the descriptions of cometary records in the *ĐNTL-CB* in detail by comparing them with the results of astronomical computations based on these elements.

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Cometary records in the *ĐNTL-CB*

We found 10 cometary records. The followings are basic information obtained from the description of each record:

No.	Appearance date	Visibility period	Identification by our study
(1)	Sep 18–Oct 16, 1811	–	C/1811 F1 (Great comet of 1811)
(2)	Oct 1, 1825	70–80 days	C/1825 N1 (Pons)
(3)	Mar 19, 1843	10 days	C/1843 D1 (Great March comet)
(4)	Jun 19–Jul 17, 1860	–	C/1860 M1 (Great comet of 1860)
(5)	Jun 28, 1861	56 days	C/1861 J1 (Great comet of 1861)
(6)	Jun 26–Jul 25, 1881	6 + 7 days	C/1881 K1 (Great comet of 1881)
(7)	Jul 26–Aug 25, 1881	23 days	C/1881 N1 (Schaeberle)
(8)	Sep 12–Oct 11, 1882	3–4 months	C/1882 R1 (Great September comet)
(9)	Jan 9–Feb 7, 1883	3 days	C/1883 D1 (Brooks-Swift comet)
(10)	Dec 6, 1885–Jan 4, 1886	–	C/1885 X2 (Barnard):

Cometary records in the *ĐNTL-CB*

We determined the corresponding comets described in the records by referring to *Jet Propulsion Laboratory's Small-Body Data Base*, based on the dates when the comets were visible from Earth and their sky positions, if available, on those dates.

During this time period, several Chinese characters were commonly used to represent comets: In the ĐNTL-CB, we found the two cases: 彗星 (*huì* star) and 長星 (*zhǎng* star), which are a "broom star" and a "long star", respectively, in our English translation.

Record (3) describes an appearance of "white vapor (白氣)," which often represents a comet as well. In fact, the white vapor in this record is concluded to be C/1843 F1, also known as Great March comet.

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Analysis of a couple of these records

We evaluate how each comet was observed from the capital (Huế) of the Nguyễn dynasty on the date(s) described in each record by utilizing the Jet Propulsion Laboratory's *(JPL) Horizons system.*

We also use the *StellaNavigator 10* (AstroArts) for supplementary computation in some cases.

Differences in cometary position results between the above two programs are found to be completely negligible for our purpose.

Next, we will analyze the descriptions of a couple of the collected cometary records.

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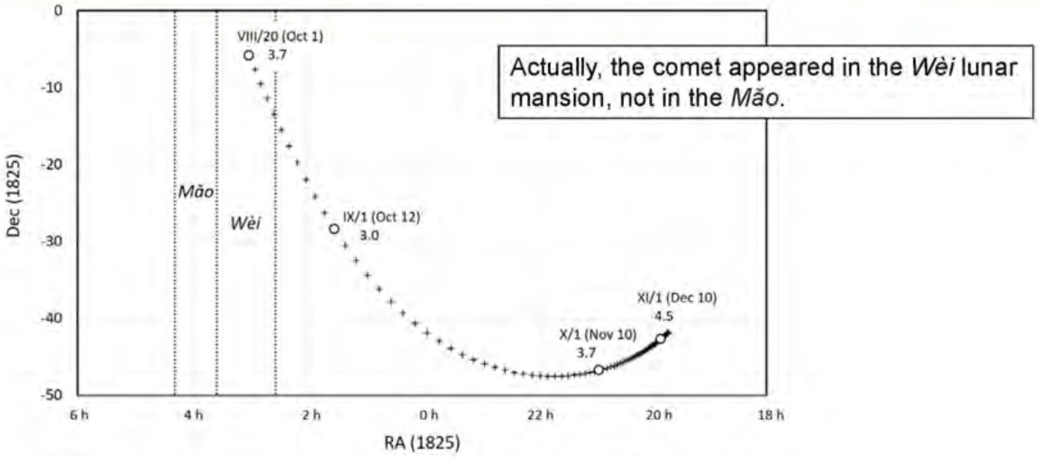
Record (2) [C/1825 N1 (Pons)]

(2) 6th year of the Minh Mệnh reign period, 8th month, day jiǎxū (20th day of the month, Oct 1, 1825), a broom star appeared in the southeast in Mǎo lunar mansion (determinative star: 17 Tau) with pointing the northwest. …, The broom star persisted for a long time without fading. …, However, the broom star gradually became fainter. During the first ten days of the 11th month (Dec 10–19, 1825), it disappeared.



The movement of C/1825 N1 in equatorial coordinates from Oct 1 through to Dec 10, 1825. The *Mǎo* and *Wèi* lunar mansions are represented by vertical dotted lines.

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… During the first ten days of the 11th month (Dec 10–19, 1825), it disappeared.

On the other hand, Chinese and Japanese records state that the comet disappeared in the 10th month (Nov 10–Dec 9, 1825),

During the times when China, Vietnam, Korea, and Japan adopted almost the same traditional astronomical observation systems, official observation reports in these countries were written in classical Chinese, using the same technical terms.

The above difference in the disappearance date may be explained by the fact Vietnam is located in advantageous position for observing the southern sky among these countries.

For simplicity, we compare the meridian altitude, h_m, of the comet (Dec ~ $-47° - -42°$) in the 10th month, for example, in Huế and Kyoto (Japan).

Huế ($\phi = 16°$): $h_m = 28° - 33°$, Kyoto ($\phi = 35°$): $h_m = 9° - 14°$

Assuming a typical value of the atmospheric extinction coefficient k = 0.2 in visual light, we find that the comet was observed fainter by 0.5–1.0 mag in Kyoto than in Huế. It should be noted that the actual observable altitude of the comet would be lower than the meridian altitude, which would result in a larger difference in magnitude.

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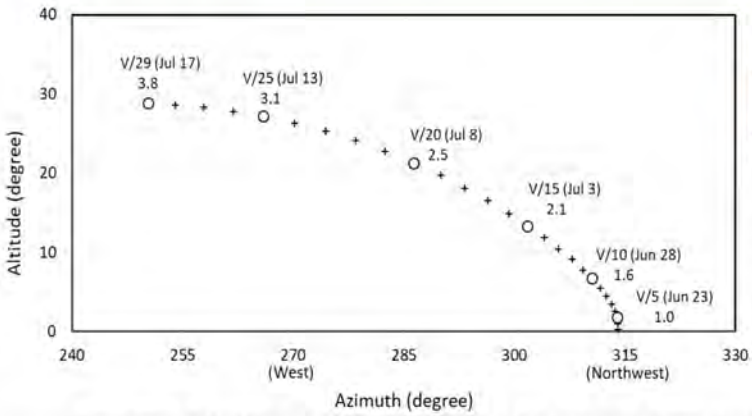
Record (4) [C/1860 M1 (Great comet of 1860)]

(4) 13th year of the Tự Đức reign period, 5th month (Jun 19–Jul 17, 1860), a broom star appeared in the northwest, with its light pointing straightly. Its length was five to six chǐ (about 5° to 6°). It rose slightly higher each night.



The positions of C/1860 M1 in the evening sky over Huế from June 19 to July 17, 1860, when the solar altitude was -12° . The notation with a Roman numeral (e.g., V/20) indicates the date (e.g., the 20th day of the 5th month) in the Vietnamese calendar. The cometary magnitude, computed using the absolute magnitude provided by Vsesvyatskij (1964), is shown below each date. It should be noted that computed magnitudes of comets have an uncertainty of 0.1–1.0 mag.

"a broom star appeared in the northwest"

⇩

"The observation would be made before the 20th day of the 5th month.

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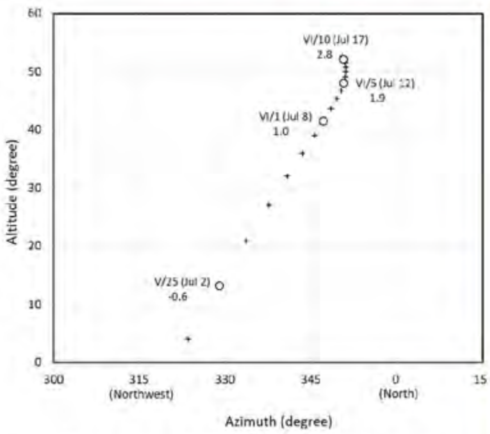
Record (5) [C/1861 J1 (Great comet of 1861)]



The positions of C/1861 J1 in the evening sky over Huế from Jul 2 through to Jul 17, 1861, when the solar altitude was -12° .

The comet was below the horizon on the 21st day of the month (Jun 28, 1861).

(5) 14th year of the Tự Đức reign period, 5th month (Jun 8–Jul 07, 1861), a white vapor appeared. The Astronomical Bureau reported that the vapor [originated] from *Zǐwēiyuán* enclosure (circumpolar area including all or a part of UMa, UMi, Cam, Dra, etc.) and passed through the regions of *Hán* and *Wèi* stars (35 and 33 Cap), and the remaining vapor reached the northern bank of the Milky Way...

A long star appeared. 21st day of the month (Jun 28, 1861), in the hour of *yǒu* (17:00–19:00), it appeared in the northwest near *Nèijiē* asterism (ο UMa, 23 UMa, and four other stars), looking like purple powder and emitting flames like clouds. It was over two *zhàng* (approximately 20°) long, pointing to *Zǐwēiyuán-xīfān* asterism (α Dra, α Cam, and five other stars). It moved forward one *du* (almost 1°) every night, and on the 28th day's night, it arrived near *Tiānshū* star (α UMa) of *Dǒu* (the Dipper). Its light near the handle of the Dipper pointed directly at *Qīgōngxīng* asterism (42 Her, δ Boo, and five other stars). On the night of the 2nd day of the 6th month (Jul 9, 1861), it arrived near *Tàiyǐ* star (around HR5162), and its flames gradually became fainter. On the night of the 17th day of the 7th month (Aug 22, 1861), it disappeared.

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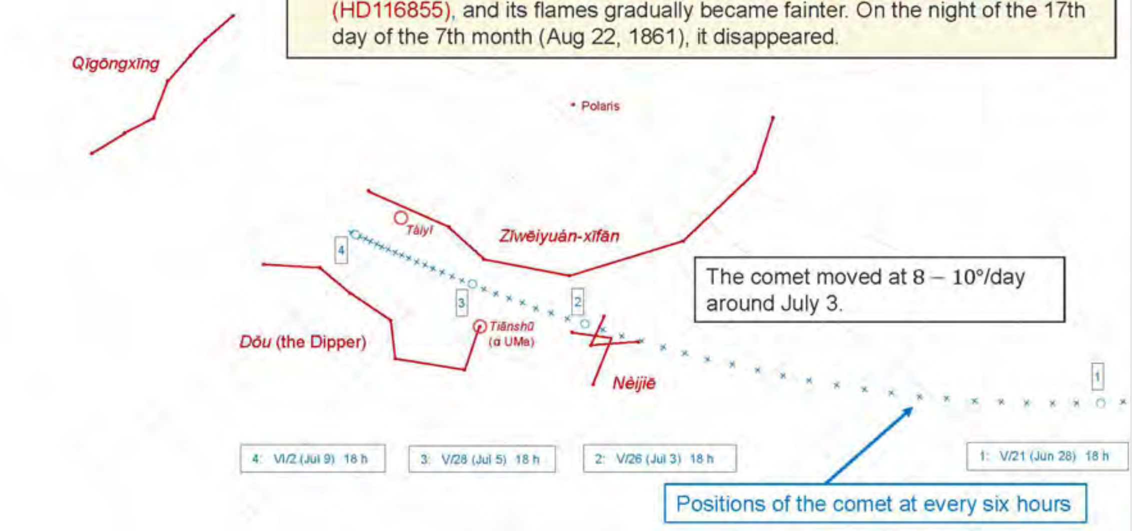

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Record (5) [C/1861 J1 (Great comet of 1861)]

A long star appeared. 21st day of the month (Jun 28, 1861), in the hour of *yǒu* (17:00–19:00), it appeared in the northwest near *Nèijiē* asterism (o UMa, 23 UMa and four other stars), looking like purple powder and emitting flames like clouds. It was over two *zhàng* (approximately 20°) long, pointing to *Zǐwēiyuán-xīfān* asterism (α Dra, α Cam and five other stars). It moved forward one *du* (almost 1°) every night, …

Note added in proof:

In addition to the 26th day of the month (July 3), the 25th day (July 2) can also be a potential appearance day if the comet was bright enough to be visible in the relatively bright sky after sunset.

"21st day of the month (Jun 28)" 「是月二十一日」
"one *du* (almost 1°)" 「一度」

⇩

"26th day of the month (Jul 3)" 「是月二十六日」
"ten *du* (almost 10°)" 「十度」

These errors might have occurred in the compiling process of the DNTL-CB.

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Summary

We discovered ten cometary records in the *ĐNTL-CB* and cross-referenced them with *JPL's Small Body Data Base*.

Using astronomical simulation software, we analyzed the descriptions of a couple of these records.

Our analysis revealed a few discrepancies, but overall, these records are largely consistent with the results of astronomical simulations.

A detailed account of this study will be published elsewhere in the near future.

Title: Brahmatulya-Udāharaṇam* by *Viśvanātha - an Insight into the Procedures of 17th Century for Calculations of Celestial Events

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Abstract:

Brahmatulya-Udāharaṇam, is a 17th century text containing examples. Based on *Karaṇakutūhala* of Bhāskarācārya II, it is a manual for application of the theory derived in *Siddhāntic* texts. Eclipses, retrograde-motion, rise and set of planets are discussed. Apart from the basic calculations for fixing the celestial positions of planets, as per the standard procedures, examples are found in this astronomical text. The emphasis is on the details of calculations. Some examples will be discussed giving importance to astronomical events that have occurred during that historical period.

1. Introduction:

The popularity of different texts can be established from the improved illustrations and commentaries written on them. Most of the texts of the medieval period are based on the works of *Bhāskarācārya* II. Specifically, the commentaries improve and update the parameters while retaining the computational proficiency of the original texts and therefore yield better results for the positions of planets. *Brahmatulya udāharaṇam* (BU) is one such text of the 17th century.

2. Author:

Viśvanātha was well versed with all the *Siddhāntic* texts as well as commentaries prior to him as evidenced by the citation of the 12th century text *Mahādevi Sāriṇi*. The present text, BU, written in *ś*aka 1557 (CE 1612), revers *Mahādeva* with great respect. Some of his works include *Gahanārtha prakāśikā* (commentary on *Sūryasiddhānta*), commentaries on *Makaranda Sāriṇi* and *Pāta Sāriṇi*. (Dikshit[1], 1981). He has written another text with solved examples called *Karaṇakutūhala- Udāharaṇam*.

3. Manuscript

The palm leaf manuscripts of the texts were collected from Bhandarkar Oriental Research Institute, Pune

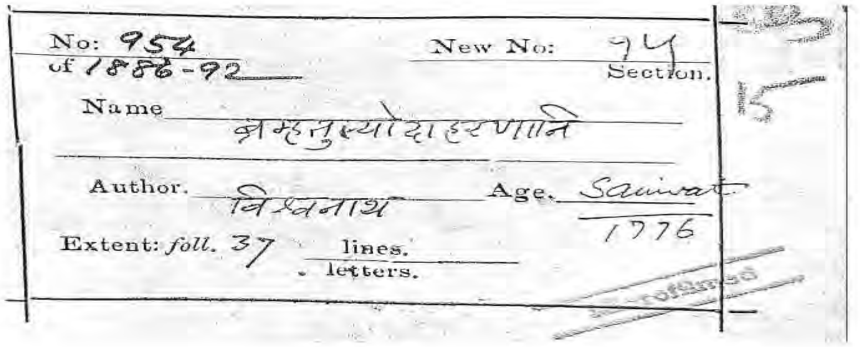

No: 954
of 1886-92
New No: 74
Section.
15
Name ब्रह्मतुल्योदाहरणानि
Author. विश्वनाथ
Age. Samvat 1776
Extent: foll. 37 lines.
letters.
Microfilmed

Fig 1: The images of the cover page of the manuscript

Chronological order is followed in the text while working on examples in each chapter. The effort in achieving the remarkable accuracy can be taken as evidence for practical observations of the astronomical events done by *Viśvanātha*. Typographical errors were carefully corrected. The numerals in Bhūtasaṅkhyā system provided a cross check. The steps involving multiple procedures were explicitly stated, assuming that the reader is aware of the procedures. We will go over the contents briefly.

3.1 *Madhyamadhikara* (Mean positions of Planets)

The procedures for calculation of the positions of planets in Indian astronomical texts start with the basic parameter *Ahargaṇa*, which represents the number of civil days elapsed from a standard epoch to the required date of the event. Using this *Ahargaṇa* value, mean positions of planets are calculated.

3.2 Spaṣṭādhikāra (True positions of Planets)

The method of computing the true positions of the planets from their mean positions is given in this chapter. It continues with the calculation of *tithi*, *karaṇa* and *yoga* at the requisite time, the smaller units of time of the day in the luni-solar calendar.

3.3 *Tripraśnaadhikāra* (Direction, Place, Time)

The word *Tripraśna* refers to the three parameters *dik*(direction), *desa*(location) and *kalā*(time), corresponding to fixing the position of the celestial body. The first exercise is to fix the location of the observer and derive the necessary constants to be applied for routine astronomical observations. We find the procedure for finding the *lagna* (ascendant), *krānti* (declination), *dinārdha* (duration of half day), *nata* (some texts use same word for hour angle but here it refers to the zenith distance) and *unnatā* (altitude) with examples, which are specific to the location and time of the day.

3.4 *Candragrahaṇa* (Lunar eclipse)

In the chapter on *candragrahaṇa,* lunar eclipse, Viśvanātha discusses an example of a total lunar eclipse that had taken place on 9th December, 1620, i e *ś*aka 1542 *margaśira śukla pūrṇimā*.

To start with, at the instant of full moon (calculated approximately) the declinations of the moon with that of the sun are compared using the *ayanāṃśa* (precession correction). In this case the difference is 11', which confirms the possibility of an eclipse (since it is less than the angular diameter of the shadow). The next step is to calculate the true longitudes of the sun and the moon with corrections for the location of the observer. Now all the calculations of the longitudes of the sun, the moon, *Rāhu* (the node), instant of full moon, declinations are redone by the process of iteration very precisely. The instantaneous speeds of the sun and the moon also are calculated. Both methods of the calculation of declination are demonstrated in this example, resulting in the latitude value of 3|37 *aṅgula*.

It should be noted that all the angles are represented in linear measure *aṅgula*, so that they can be used directly in the drawing. The standard scale is about 3' = 1 *aṅgula*.

The next step is to get the diameters of the moon, 11|41 (*chādaya bimba*) and the shadow of the earth, 27|57, (which is called *bhūbhā or chādaka bimba*) are derived. The separation between the two bodies keeps changing every instant and reaches a minimum at the instant of conjunction. With these quantities, it is possible to calculate the amount of obscuration, *khagrāsa*, at the midpoint of totality is 4|47 aṅgula.

The next step is to find the half duration of the eclipse, from the mid-point to the first point of contact, *sparśa*. The corresponding time is called the half duration of the eclipse (*stityardha*). The end point (last contact) of the eclipse, (*mokṣa*), is calculated separately taking in to account the motion of the two bodies within that interval. The timings of total eclipse are calculated as the difference between the instants of second and third contact (*vimarda*).

The direction of the points of contact *(valana)* at the beginning and ending of the eclipse, are calculated separately along the two axes (*ākṣa valana* and *ayana valana*). One correction arises because of the latitude and the other because of longitude of the observer

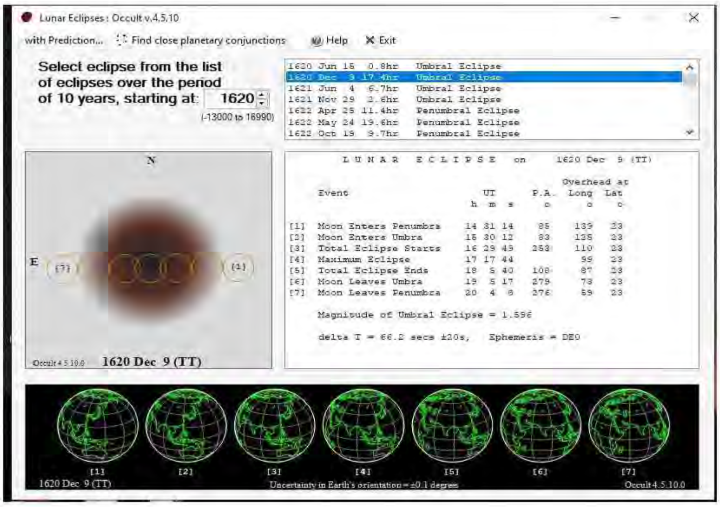


Fig 2: Lunar eclipse from Occult

Parilekhana is the procedure for geometrical representation of the diagram. It starts with drawing the cardinal directions as per the procedure termed *mukhapuchhca-sutram*, (the line joining the mouth and tail of the fish). The circles with radius of half the sum of diameters of shadow and moon is drawn. We mark the position of conjunction and the points of first contact and last contact based on the values of *valana*. The amount of obscuration at any instant also can be estimated from the drawing.

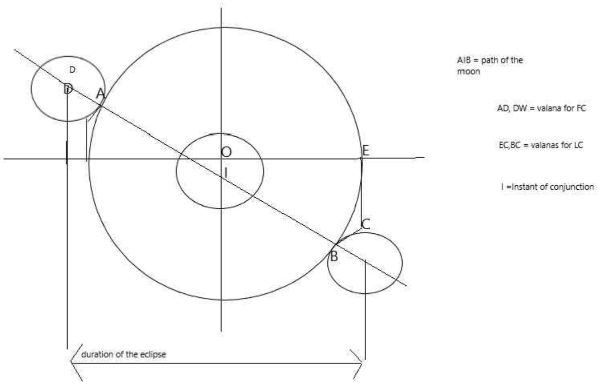


Fig 3 parilekhana for the eclipse on Dec 10 th 1620

3.5 Suryagrahaṇa (Solar eclipse)

This provides an example of solar eclipse on 15th Dec 1610. All the steps are shown very clearly in the text and the most crucial part namely the half duration of the eclipse is calculated by iteration. The declination of the moon, for example, is calculated in 6 iterations as 22|25|39, 22|26|35, 21|40|26, 21|21|26, 21|14|37 and finally 21|11|56. The instants of the first contact and second contact are also calculated by process of iteration. The parallax correction and the latitude of the moon are calculated at both the contacts and at the midpoint.

These two are very crucial in deciding the visibility criterion for a given location. The iteration process for every step is demonstrated up to 5 or 6 steps. (Shubha[2] 2020)

Saka 1532, *Margaśira Krishna paksha Amavasya* (1610 Dec 15th)	
Sparśa kala (onset)	7|24 *ghati*
Madhya kala (midpoint)	10|55 *ghati*
Mokṣa kala (end point)	14|47 *ghati*

Table 2: The details of the timings Solar eclipse

3.6 *Udayāstādhikārah* (Helical rising and setting of stars)

The phenomenon of heliacal rising and setting of stars and planets vary with the terrestrial latitude. We used the formulae as devised by *Bhāskarācārya* II for verification and noted that a derivative of sine as cosine was used for finding the rate of change of motion. The chapter also covers retrograde motion with an example in detail. The examples were recalculated and verified (BSS and BSS[3] 2021). The table below shows the comparison with results from Occult software for retrograde motion.

Dates of the stationary points as per the examples for the year 1629CE					
		tithis as per calculations	*equivalent dates*	*Dates as per Occult*	*Remarks*
Jupiter	Onset	*Jyeṣṭha śu* 6	26th May	25th May	Difference of 1 day
	End	*Bha śu* 6	23rd September	23rd September	Agreement
Mars (*Kuja*)	Onset	*Margaśira śu* 1	15th November	23rd November	Difference of 7 days
Mercury (*Budha*)	Onset	*śra śu* 11	11th August	8th August	Difference of 3 days
	End	*Bha śu* 4	23rd August	31st August	difference of 8 days

Table 3: Details of examples of retrograde motions of planets

3.7 *Śṛṅgonnati* (Elevation of Cusps)

The calculation of the elevation of horns of the moon is provided with three examples. This concept does not find coverage in European texts (although they are covered in all Indian texts). The examples provided were verified by actual calculation and the task of *parilekhana* has been completed along with the drawings. (BSS and BSS[4] 2020)

3.8 Grahayuti (conjunctions of planets)

We find one example of the conjunction of Venus and Saturn, which was verifiable by repeating calculations. It is interesting that this chapter lists the coordinates of the 28 stars in a unique way (paper "stars from the medieval period" in this volume). The chapter continues to cover *Pātadhikra* (finding the nodes).

Conclusion:

Many manuscripts have remained unknown to the astronomers and the present study is an attempt in bringing to light *Brahmatulya Udāharaṇam* of *Viśvanātha*. This is a very good manual for beginners explaining the method of iterations in great detail. Unlike other commentaries, this text offers examples for all events like the retrograde motion, conjunction and the elevation of the horns of the moon. We also note that he has devised a quick method of determining the ascendant by observing the meridian transit of stars. *Brahmatulya Udāharaṇam* of *Viśvanātha* is one of the best texts to understand siddhantic procedures with practical examples of celestial events summarized in the table below. Thus, the study leads us to explore many more such manuscripts in future. (BSS[5] and BSS 2023)

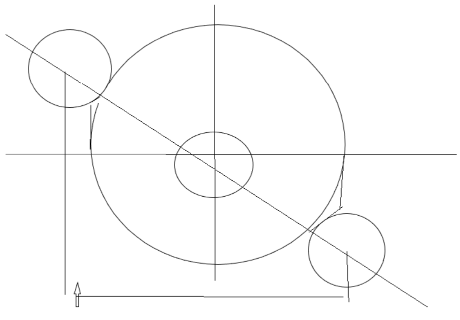
Event	**Date**	**Text**
Jupiter conjunction	20th January, 1630	*Saka* 1551 *Phalguna tryodasi*
Venus conjunction	14th July, 1629	*Saka* 1551 *Jyeṣṭa Shudha Chaturdashi*
Mercury conjunction	14th August, 1629	*Saka* 1551 *Shrāvana krishna dashmi*
Equal Declination	23rd December, 1610	*Saka* 1532 *Mārgaśira shukla shasti*
Equal Declination	23rd October, 1617	*Saka* 1539 *Kartika krishna dashmi*
Lunar eclipse	9th December, 1620	*Saka* 1542 *Mārgaśira pūrṇimā*
Solar eclipse	10th December, 1610	*Saka* 1532 *Mārgaśira amavasya*
Solar eclipse	21st June, 1629	*Saka* 1551 *Jyeṣṭa amavasya*

Table 4: List of the celestial events as described in the text

References:

1. Dikshit, S B, (1981); English Translation of *Bhartiya Jyotisa Sastra* (History of Indian Astronomy); translated by Prof R V Vaidya, vol II, the Controller of publications, New Delhi:
2. Shubha B S, (2020), *Commentaries of Karaṇakutūhala and Brahmatulya Udāharaṇam of Viswanatha*, doctoral thesis submitted to KSU.
3. Shubha B. S. and Shylaja, B. S., (2020), *Retrograde motion in Brahmatulya Udāharaṇam*, Indian Journal of History of Science, Vol 55, p: 40-48
4. Shubha B.S and Shylaja B S, *Understanding Śṛṅgonnati: Elevation of the Moon's Cusps (with examples)*, *Journal of Astronomical History and Heritage*, 23(1), 163–173 (2020)
5. Shubha B S and Shylaja B S *Mahādevī-Sāriṇī* - A Unique Table Providing True Longitudes of Planets, Indian Journal of History of Science (Submitted)

4. ***Journal of Astronomical History and Heritage*, 23(1), 163–173 (2020))**



Abstract:

Recently aurora ancient records have actively been studied. In the Eastern Asian records of the phenomena a characteristic word "白氣" : white vapor can be seen, though, it seemed to be used for not only aurora's but comet's and meteor's, too.

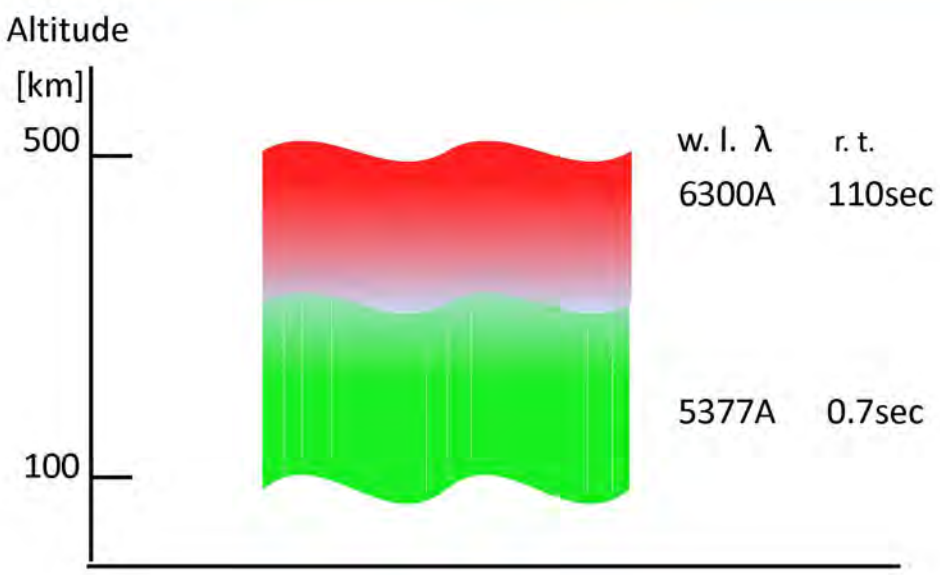
In this presentation the usage difference of "白氣" among these three phenomena are reported. The data source is *Zhongguo gudai tianxiang jilu zong ji* : "中國古代天象記録總集" in 1988. Applied data are surely identified and listed as respective phenomena, aurora, comet and meteor in this compilation book. Then the rate of "白氣" records for total records, the word used plus non-used , are calculated.

As the result following respective usage difference are proven : the "white and red vapor" as the characteristic aurora structure expression in a very strong solar activity period, "white vapor" as appearance of a coma in comet records and "white vapo" as appearance of a permanent trail or smoke of meteorite fall in meteor records.

Key words of aurora appearance

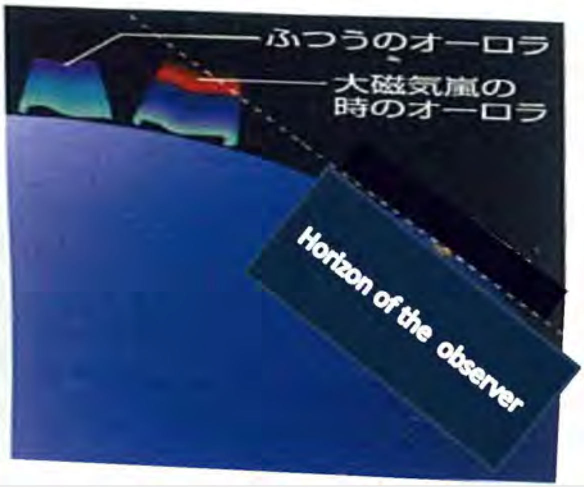
- ”天裂””天分裂“: ”the sky cracks”
- ”紅虹””赤虹”: “red rainbow”
- ”赤氣”: “red vapor”
- ”白氣”: ”white vapor”
- ”紅白氣”: ”red and white vapor ”
- ”五色虹”: ”five colors rainbow”

Structure of aurora



Aurora view at low latitudes

- Lower altitude's part of aurora hides under horizon
- In case of more active aurora, green part rises above the horizon.



Key words of comet appearance

- "孛":"bloom"
- "帚":"(bent) broom"
- "長星":"long star"
- "白氣":"white vapor"
- "色白中帯赤":"white including red"
- "白霞":"white haze"
- "赤霞":"red haze"

The same ward "white vapor" was used among aurora and comet records, … and meteor ones, too.

Data source and analysis of this study

Data: Listed records in identified classification as "Aurora", Comet", and "meteor" in *Zhongguo gudai tianxiang jilu zong ji* : 『中國古代天象記録總集』(1988)

Collection: Key word "**白氣**", "**一白氣**"*

*) Some records used such as "**紅白氣**" : red and white vapor for a two colors stripe structure.

"**白氣**" records rate for the word used ones and non used ones are in aurora, and comet records on the same day or in the same period

Aurora "白氣" records -1/2-

date	rate				
B.C.14. III. 22	1/1		red and wh.		
A.D.466.VII.21	1/1		red and wh.	yellow wh.	
478.XII.13	1/1	white			
486. I. 29	1/1			yellow wh.	
937. II. 14	3/3		red and wh.		
937. II. 15	1/1		red and wh.		
1006. IV.14	1/2	white			
1032. XI. 7	2/2			yellow wh.	
1088.VIII.12	1/1		red and wh.		
1088.VIII.13	3/3	white	red and wh.		
1088. IX.23	1/1		red and wh.		
1099. X. 15	2/2	white	red and wh.		
1101. I. 31	2/2		red and wh.		
1117. VI. 29	1/1	white			
1119. V. 11	1/1				black and wh.
1119. VIII.21	1/1		red and wh.		
1126. II. 4	1/1		red and wh.		
1130. VI. 18	5/5		red and wh.		
1193. XII. 5	1/1		red and wh.		
1193. XII. 6	2/2		red and wh.		
1204. III.29	1/3		red and wh.		
1205. X 18	3/3		red and wh.		
1206. X 10	2/3		red and wh.		
1211. IV 23	1/1				black and wh.
1216. IV 13	1/1			yellow wh.	

Aurora "白氣" records -2/2-

date	rate				
1363.VIII. 2	2/2	white			
1363. IX. 27	2/2		red and wh.		
1518. I. 17	3/3		red and wh.		
1582. III. 8	2/2	wh. cloud			
1588. X-XI	1/1		red and wh.		
1605. XI.25	1/1		red and wh.		
1605. XI.27	1/1		red and wh.		
1626. V. 22	1/1	wh. cloud			
1629. I .24	1/1				black and wh.
1635. III. 1	1/1	white			
1635. III. 24	1/1	white			
1651. II. 19	1/1	white			
1658. IX -X	1/2	white			
1659. XII.12	1/1		red and wh.		
1688. V. 16	1/1	wh. Cloud			
1737. XII.16	1/1				black and wh.
1769.VIII.27	1/1		red and wh.		
1770. IX. 15	1/2		red and wh.		
1770. IX. 17	6/8	white(1)	red and wh.(5)		
IX.11,16,18	red or	five colors			
1770.VIII-IX	3/3		red and wh.		
1770. X. 3	1/1		red and wh.		
1813. .	1/1		red and wh.		
1872. I. 10	1/1			yellow wh.	
1872. I. .	3/5			yellow wh.	

Aurora "白氣" records -Example-

◎乾隆三十五年七月二十八日(1770.IX.17)

「戌時、赤光自北方起、中有白氣十三道、望如火焰至天中、夜半漸退。」
山東<肥城縣志>巻16頁3

「夜、乾方赤氣弥天、有白氣若縷間之、亘兌至離、四更後始没。」
山東<長山縣志>巻4頁12

「亥刻、北方紅光燭天、中間白氣千條、至次日丑刻始散。」
山東<掖縣全志>巻3頁44

/ white vapor way (in red light)

/ white vapor like strings (in red light)

/ thousand of white vapor (stripes)

Comet "白氣" records -1/3-

date	rate				
A.D.101. I.12	1/1				bluish wh.
104. V.30	1/1	white			
133. II. 8/ 9	2/2	white			
254.XI-XII	1/1	white			
1034. IX.20	1/1				bl. yellow wh.
1041. IX. 1	1/1	white			
1066. IV. 2	1/1	white			
1080.VIII.10	1/1	white			
1127. I. 11	1/1	white			
1127. I. 15	1/1	white			
1362. III. 5	2/2	white			
1362. .	1/1	white			
1461.VII.30	1/1	white			
1529. I. 24	2/3	white			
1529. I. 26	2/3	white			
1529. I. .	2/3	white			
1529. II. 27	1/1	white			
1529. II. .	1/1	white			
1567. X. 27	1/1	white			
1567. XI. .	1/1	white			
1577.VIII. 9	1/1	white			
1577. IX. 8	1/1	white			
1577. X.14	1/2	wh. Cloud			
1577. winter	1/5	white			
1578. X. .	3/7	white			
1578.autumn	1/3	white			
1580. XII. .	1/3	white			
1587. VI. .	1/1	white			
1588. X. 24	1/1	white			
1614. .	1/2	white			
1615. VIII. .	2/2	white			
1616. XI. .	1/3	white			
1617. VIII. .	1/1	white			
1617. IX. .	1/2	white			
1617. X. .	1/1	white			

date	rate				
1618.VIII. .	2/3	white			
1618.IX. .	7/11	white			
1618.XI. 6	1/1	white			
1618.XI.12	2/2	white			
1618.XI.14	2/4	white			
1618.XI.15	2/5	white			
1618.XI.16/17	3/3	white			
1618.XI.20	1/2	white			
1618.XI.27	2/3	white			
1618.XI.29	1/2	white			
1618.XI. .	1/1				bluish wh.
1618.X-XI.	7/11	white			
1618.autumn	3/7	white	white cloud		
1618.XI-XII	1/11	white			
1618.winter	4/7	white			
1618. .	7/17	white			
1619.XI. .	1/1	white			
1619.autumn	1/1	white			
1619. .	2/2	white			
1620.X-XII..	2/2	white			
1620.winter.	1/2	white			
1620. .	5/12	white			
1621.spring.	1/1	white			
1621. .	1/1	white			
1625. .	1/1	white			
1640. .	1/1	white			
1650. II.26.	2/2	white			
1652.XI.22.	1/1				bluish wh.
1663.XII. 3.	1/1	white			
1664.IX-X.	1/1	white			
1664.XII-65I.	3/12	white			
1664.winter.	1/12	white			

Comet "白氣" records -2/3-

date	rate				
1668. III. 6./7	7/7	white			
1668. III. 8.	3/5	white			
1668. III. 9.	2/9	white			bluish wh.
1668. III. 11	1/1	white			
1668. III. .	1/1	white			
1668. II.-III.	6/13	white			
1668. IV. 4./5.	2/2	white			
1668. IV. 8.	2/2	white			
1668. III-IV.	4/6	white			
1668. V. 8.	1/1	white			
1668. spring.	5/6	white			
1668. IX. 2.	1/1	white			
1668. IIIV-IX	1/1	white			
1668. .	2/5	white			
1672. X. 16.	1/1	white			
1673.autumn	1/1	white			
1675.III-IV. .	1/2	white			
1678. .	1/2	white			
1679. IX. 2.	1/1	white			
1680.VII-VIII	1/2	white			
1680. X- XI.	1/4	white			
1680. XI.21.	1/3	white			
1680. XI.23.	1/3	white			
1680. XI-XII.	4/22	white			
1680. XII.21.	9/12	white			
1680. XII.22.	3/7	white			
1680.XII.23./24	5/5	white			
1680.XII.21-25	1/2	white			
1680.XII.- 87.I.	5/17	white			
1680. .	3/7	white(2)	white cloth		
1681. I. 2	1/7	white			
1681. VIII. 4	1/1	white			
1681. XI- XII.	1/2	white			
1681. XII. 13.	1/1	white			
1681.XII- 82.I.	1/1	white			
1681winter	1/1	white			
1681. .	1/7	white			

date	rate				
1681. .	1/7	white			
1682.VIII- IX.	2/5	white			
1682. .	1/4	white			
1685.VIII- IX.	1/1	white			
1689. XII. 10.	1/1	white			
1689.winter.	1/2	white			
1700. X. .	1/1	white			
1700. X - XI.	1/1	white			
1702. II. 29.	1/1	white			
1702. II - III.	1/1	white			
1769.VII -IX.	2/3		white cloth	wh. rainbow	
1808. IX - X.	1/1	white			
1811. X. 4.	2/5	white			
1821. II. 20.	1/2	white			
1825. X. 3.	1/1	white			
1840. III. 19.	2/2	white			
1840. .	1/2	white			
1841.V.21-25.	2/2	white			
1842. III.12-21.	1/2	white			
1842.spring	2/2	white			
1842. VIII- IX.	1/1	white			
1842. IX. 8.	1/1	white			
1842.autumn.	2/2	white			
1843. I. 15.	1/1	white			
1843. I - II.	2/8	white			
1843. III. 3./4	2/2	white			
1843. III. 18.	1/1	white			
1843.III. 1-30.	4/7	white			
1843. III-IV..	3/4	white			
1843. spring.	3/3	white			
1843. IV- V.	2/3	white			
1843. early sum	1/1	white			
1843. VII-VIII.	2/3	white			
1843. VIII-IX..	1/1	white			
1846.VIII- IX.	2/3	white			
1847. .	1/2	white			

Comet "白氣" records -3/3-

date	rate			
1848 VII- VIII.	1/1	white		
1850.VIII.18-27.	2/3	white		
1850. .	1/1	white		
1858. X - XI.	1/4	white		
1858. X. 10.	1/1	white		
1858. autumn.	1/4	white		
1858. XI- XII.	1/1	white		
1860. X - XI..	1/2	white		
1861. VI. 30.	1/6	white		
1861. VII. 3.	2/9	white		
1861. VI- VII.	2/26	white		
1861.VII-VIII.	2/17	white		
1862. V- VI.	1/4	white		
1871. .	1/2	white		
1872. .	1/4	white		
1882. IX - X.	1/34		white cloth	white mist
1882. autumn	1/12	white		
1883. .	1/2	white		
1885. .	1/3	white		
1910. I. 25.	1/1	white		

Comet "白氣" records -Example-

◎康熙三年十一月(1664.XII.17–1665.I.15)

「彗星出于軫度、長數丈、氣白如練、西北指、逆行、見四十餘日、至婁度而不見。」

浙江<紹興府志>巻13頁24

「彗星見于東南、尾長數丈、白氣亘天、至十餘夜始没。」

広東<始興縣志>巻10頁12

「有大星見東南方、氣白如練。」

浙江<上虞縣志>巻20頁31

/ vapor like white silk cloth

Meteor ”白氣” records -1/1-

date	rate	
1573. II– III.	1/1	white
1643. .	1/1	white
1659. III. 25	1/1	white
1659. V. 16	1/7	white
1659. V. 21	2/2	white
1661. IX. 2	3/4	white
1661. IX. 30	2/2	white
1663. VIII. 4	1/1	white
1664. IV. 25	1/1	white
1667. IIIV– IX	1/1	white
1668. VI. 18	1/1	white
1668.VIII. 16	1/3	white
1668.VIII. 26	1/1	white
1668. IX – X	2/3	white
1678.VIII –IX	1/1	white
1680. V. 26	1/1	white
1680.VII. 11	1/2	white
1722. I. 6	1/2	white
1727. I – II	2/2	white
1732.VII. 18	2/2	white
1736. X. 14	2/3	white
1736. X – XI	2/2	white
1784. II – III	1/1	white
1803. I. 4	1/1	white
1810. II. 11	1/1	white
1826 .V. 7	1/1	white

Meteor ”白氣” records -Example-

◎康熙七年七月初九日(1668.VIII.16.)
「申時、東南落火如斗、隆隆有声、見<u>白氣如龍</u>。」
河南<汝州全志>巻7頁7

/ white vapor like a dragon

◎乾隆元年9月(1736.X.5 – XI.2)
「星隕于西南方、<u>白氣如雲</u>、経天不散。」
福建<長泰縣志>巻12頁11
福建<漳州府志>巻31頁15

/ white vapor like cloud

Summery of "白氣" in Chinese astronomical records

/ Aurora

The earliest record is in B.C.14.

Most records expressed with red vapor.

These records are synchronized the solar active time.

/ Comet

The earliest record is in A.D. 101, frequently after 11th century .

Most records expressed 'white vapor'.

'White like (silk) cloth' or 'white mist' in a few records.

/ Meteor

The earliest record is in1573.

'White vapor', 'white cloud'. Some case said 'like a dragon'

The expression seems to be a permanent trail or smoke of meteorite fall.

Closing Remark

Thank you very much for many participants in this meeting.

Especially, I thank a lot to Dr. Tanikawa and Dr. Soma to contribute for this meeting for a long time.
And they recommended to be held the meeting after long rest because of Corona disease.

And I thank to Dr. Yang too. He accepted the recommendation to prepare for the meeting in glad. And then he has prepared this meeting. He is important contributor for this meeting.

And thank you very much for speakers who give good and valuable papers. They show interesting subjects on the field to all participants. Most of representations would be stimulated and influenced on the field of "History of Astronomy".

I have a hope to continue such meeting on "History of Astronomy". If possible, I would like to be held this meeting once one or two years. From next time, I hope the meeting will be opened in face to face as well as using Zoom.

Thank you again to participants to take in the meeting.
See you again in next meeting.

Yong Bok Lee
March 29, 2023

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