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# Astronomical Characteristics of *Cheonsang-yeolcha-bunyajido* from the Perspective of Manufacturing Methods

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I investigated a method for drawing the star chart in the planisphere *Cheonsang-yeolcha-bunyajido*. The outline of the star chart can be constructed by considering the astronomical information given in the planisphere alone and the drawing method described in *Xin-Tangshu*; further the chart can be completed by using additional information on the shape and linking method of asterisms out of an inherited star chart. The circles of perpetual visibility, the equator, and the circle of perpetual invisibility are concentric, and their common center locates the *Tianshu-xing*, which was defined to be a pole star in the *Han* dynasty. The radius of the circle of perpetual visibility was modified in accordance with the latitude of Seoul, whereas the other circles were drawn for the latitude of 35°, which had been the reference latitude in ancient Chinese astronomy. The ecliptic was drawn as an exact circle by parallel transference of the equator circle to fix the location of the equinoxes at the positions recorded in the epitaph of the planisphere. The positions of equinoxes originated from the Han dynasty. The 365 ticks around the boundary of the circle of perpetual invisibility were possibly drawn by segmenting the circumference with an arc length instead of a chord length with the ratio of the circumference of a circle to its diameter as accurate as 3.14 presumed. The 12 equatorial sectors were drawn on the boundary of the star-chart in accordance with the beginning and ending lodge angles given in the epitaph that originated from the Han dynasty. The determinative lines for the 28 lunar lodges were drawn to intersect their determinative stars, but seven determinative stars are deviated. According to the treatises of the Tang dynasty, these anomalies were inherited from charts of the period earlier than the Tang dynasty. Thus, the star chart in *Cheonsang-yeolcha-bunyajido* preserves the old tradition that had existed before the present Chinese tradition reformed in approximately 700 CE. In conclusion, the star chart in *Cheonsang-yeolcha-bunyajido* shows the sky of the former Han dynasty with the equator modified to the latitude of Seoul.

**Keywords**: historical astronomy, Star Chart: *Cheonsang-yeolcha-bunyajido*

## 1. INTRODUCTION

*Cheonsang-yeolcha-bunyajido* (hereafter, the C-map) is one of the representative star charts in East Asian history. The title, on translation, refers to an astronomical planisphere that shows celestial appearances in accordance with equatorial sectors and their astrological counterparts on the ground. This type of circular star chart, also called an extent chart (蓋圖, *Kaitu*), is known to have been originated as early as the former Han dynasty (Qian 1958). According to Astronomical Treatise of the History of the Sui Dynasty (隋書天文志, *Suishu Tianwenzhi*), one standard extent chart was compiled in 604 CE by *Yu Jicai* (庾季才) at the order of an emperor of the *Sui* dynasty, but currently it does not exist. An ancient example of *Kaitu* was discovered on the ceiling of the *Kitora* mural in Japan, constructed around 700 CE (Miyajima 1999). Another representative extent chart is the *Suzhou*[1] planisphere carved on stone in 1247 CE on the basis of a copy of an earlier drawing from 1193 CE (Rufus

1) The pinyin system is used in this paper for the romanization of Chinese. Korean, Chinese, and Japanese terms are denoted by italic letters.



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1945). A detailed account on the method of drawing this type of star chart is described in Treatise on Astronomy in New History of the *Tang* Dynasty (新唐書天文志, *Xin-Tangshu Tianwenzhi*).

The C-map was first investigated with a modern approach by Rufus (1913). The origin of the C-map is explained in the epitaph at the bottom of the stele. According to the epitaph, the C-map was carved in January 1396 CE based on a rubbing that had been obtained from an earlier stele. The source chart had been erected in *Pyeongyang*[2], but it sunk into a river during a war. According to the epitaph, the astronomers working in the Royal Bureau of Astronomy of the *Joseon dynasty* (書雲觀) advised the King to revise the table that listed the stars culminating at dusk and dawn for the 24 seasonal grants during a year because the coordinates had been changed owing to the precession of equinox. Hence, *Ryu Bang-taek*[3](柳方澤), an astronomer, revised the table by astronomical calculations. Sentences in the epitaph were written by *Kwon Geun* (權近), and the calligraphy was carried out by *Seol Gyeongsu* (偰慶壽).

Three versions of the C-map exist. One stele was erected in 1396 CE during the reign of King *Taejo* (太祖). That stele is now Korea's National Treasure No. 228 and is preserved in the National Palace Museum of Korea in Seoul. *Taejo*'s stele has planispheres on both sides[4]. One side has a star chart whose title is located at the top part; henceforth that side can be called the T-map. The other side shows the title at the bottom, and so that side can be referred as B-map in abbreviation. The T-map shows a smooth and almost worn-out surface. It shows vague circles, but it does have neither an ecliptic circle nor radial lines for determinative stars. It can thus be concluded that perhaps the chart was not completed and was probably abandoned by intentionally smoothing out the surface. Then they must have used the other side of the stele to complete the project. Perhaps that is just because such a large stone was quite rare and hard to obtain at that time.

Another version is a woodblock-printed copy of the C-map. This version is considered to have been printed during the reign of King *Seonjo* (宣祖, r. 1567-1608 CE), which is based on the fact recorded in a historical record during the fourth year of King *Seonjo*'s reign in *Joseon-Wangjo-Sillok*[5] that 120 rolls of planisphere were made and distributed to bureaucrats and nobles. In addition, according to the anthology of a famous Korean Neo-Confucian called *Seong Hon* (成渾, 1535-1598 CE), he was bestowed an astronomical planisphere from the King at the Royal Academic Seminar in the eighth month of 1581 CE. From this fact, we can see that the planispheres were occasionally bestowed to bureaucrats. Only two woodblock-printed copies are left now, and somehow both were present in Japan. Recenltly one copy was purchased and returned to Korea, and now it is housed at the National Palace Museum of Korea.

After 1600 CE, *Taejo*'s stele had been buried in a ruin because the palace was burned down during the Japanese invasions of *Joseon* (1592-1598 CE). Hence, a replica stele was built during the reign of King *Sukjong* (肅宗, r. 1674-1720 CE). This replica is now housed at the National Palace Museum of Korea and is designated as Korea's Treasure No. 837. Furthermore, a number of rubbings of the *Sukjong* replica exist. Most of these replicas are preserved in Korea. However, one exception is the replica preserved in the Bibliothèque nationale de France; this fine rubbing was pillaged by the French Navy during the French invasion into *Ganghwa* Island in 1866 CE where the subsidiary division of Royal Library of the *Joseon* Dynasty was located (Ahn 2010b).

There are a few issues associated with the C-map such as its origin, the epoch of observation, and the possibility of revision. These topics are reviewed by Han (2007) and Koo (2007). However, little attention has been paid to the drawing method. In this study, I investigated the characteristics of the star chart and attempted to reconstruct the procedures for drawing the star chart in the C-map. In doing so, the drawing method of the extent chart described in Astronomical Treatise of *Xin-Tangshu* was consulted. Chapter 2 describes the characteristics of the star chart in the C-map, and Chapter 3 describes the reconstructed method for drawing the star chart. Chapter 4 describes the conclusion.

## 2. CHARACTERISTICS OF THE STAR CHART

### (1) Three Concentric Circles and the Pole Star

Fig. 1 shows a schematic diagram of the C-map[6] (*Cheonsang-yeolcha-bunyajido*). The C-map, which is engraved on stone, comprises of 1,467 stars divided into 283 asterisms (Song et al. 2002). Three concentric circles can be observed while moving outward from the center of the star

**2)** The Revised Romanization of Korean released by South Korea's Ministry of Culture and Tourism in Proclamation No. 2000-8 is used in this paper.

**3)** Here, Ryu is the family name, and Bangtaek is the given name. In this paper, we adopted the name of Asian persons in history following this system; i.e. [Given name] [First name].

**4)** There have been debates on the identity of these two sides. The references can be found in Koo M-O (2007, pp.91-93).

**5)** 1571 CE, 19th day of 10th month, 3rd day of 11th month.

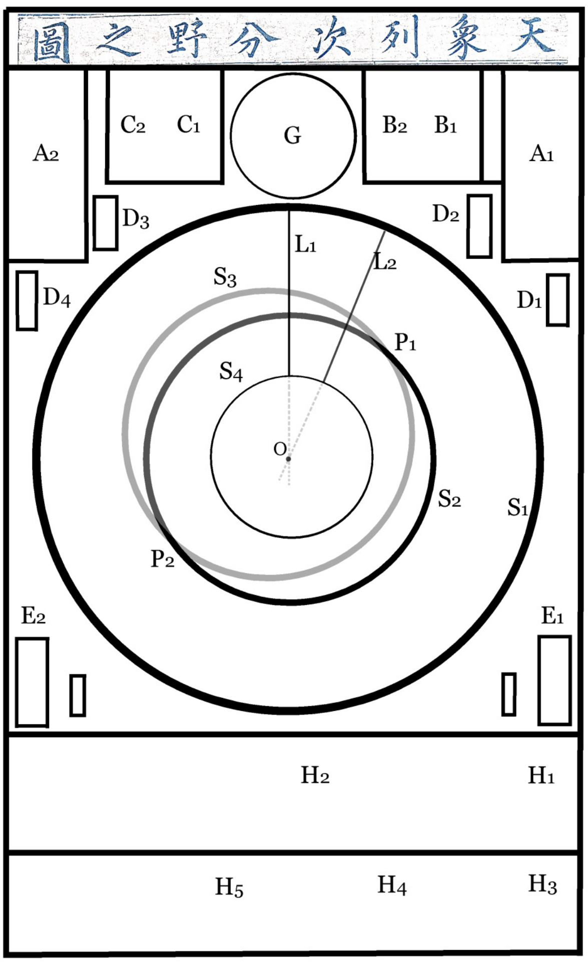


**Fig. 1.** Schematic diagram of Cheonsang-yeolcha-bunyajido. $A_1$ and $A_2$ are the right ascensions for the 12 equatorial sectors. $B_1$ and $C_1$ are the philosophical remarks for the Sun and the Moon, respectively. $B_2$ contains the remarks for the Milky Galaxy, and $C_2$ contains the explanation for the ecliptic and the celestial equator. Ds are the total angles for each of the four symbols of the Chinese asterisms. $H_1$ contains the Chinese cosmologies, and $H_2$ contains the coordinates of the determinative stars of the 28 lunar lodges. $H_3$ contains the history of the chart. $H_4$ contains the remarks advised for King Taejo written by Kwon Geun. $H_5$ contains the list of participants that constructed this chart. G is the table of culminating stars at the dawn and dusk of twenty four seasonal grants. $S_1$ is the circle of perpetual invisibility; $S_2$, the equator; $S_4$, the circle of perpetual visibility; and $S_4$, the ecliptic. $L_1$, $L_2$, ..., and $L_{28}$ are the determinative lines for the twenty eight lunar lodges. P1 denotes the vernal equinox, and $P_2$ denotes the autumnal equinox. [the diagram was cited from Ahn (2011) and Ahn (2013).]

chart; for instance, the circle of perpetual visibility ($S_4$), the celestial equator ($S_2$), and the circle of perpetual invisibility ($S_1$). The ecliptic circle ($S_3$) and the boundary lines of the Milky Way can also be observed in the C-map. The circle of perpetual invisibility ($S_1$) should be drawn with double lines in order to insert the sector names in it.

The projection method for the C-map is the azimuthal equidistant projection (Miyajima 1998), in which the distance from the center of the C-map to a star is proportional to the polar distance. Suppose that the stars in the C-map were observed by an observer located at a latitude $\phi$. We can measure the radii $r_1$, $r_2$, and $r_4$ of circles $S_1$, $S_2$, and $S_4$, respectively, and then we can calculate the latitude $\phi$ from the ratios between those radii.

$$r_1 : r_2 = \phi_1 : 90°,$$
$$r_1 : r_4 = \phi_2 : 180°\text{-}\phi_2,$$
$$r_2 : r_4 = 90° : 180°\text{-}\phi_4.$$

According to Park (1998), $r_1$=94mm, $r_2$=222.4mm, and $r_4$=361mm. Hence we obtain $\phi_1$=38.0°=38.6 *du* $\phi_2$=37.2°=37.8 *du*, and $\phi_4$=33.9°=34.4 *du*. These results are cross-checked with photographs of the three versions of the C-map in this study. It is interesting that when the circle of perpetual visibility is involved, the resultant latitudes yield approximately 38 *du*. On the other hand, when it is not involved, the resultant latitude yields 34 *du*. The meaning of these latitudes can be explained as follows.

According to Astronomical Treatise of *Xin-Tangshu*, the outermost circle of a traditional Chinese *Kaitu*-style star chart is drawn with a bamboo-stick that has 147 regular ticks on it. This number 147 represents the polar distance of the horizon in *du*. That is, 180°-$\phi$, where $\phi$ is the latitude of the observer. Hence, the latitude of the Chinese star chart described in *Xin-Tangshu* is calculated to be $\phi$=35.1°. This latitude is of special importance in the history of Chinese astronomy. Chinese astronomers adopted this latitude as a reference in commemoration of *Zhou Gong* (周公), who is believed to have carried the earliest measurement of the sun's shadow in *Yangcheng* (陽城). This place[6] has been regarded as the center of Heaven and Earth in Chinese tradition[7].

Presently there is a small town called *Denfeng* (登封) in Henan province China, where the *Dengfeng* Observatory is located. This ancient observatory forms part of the property Historic Monuments of *Dengfeng* in 'The Center of Heaven and Earth', which was inscribed on the World Heritage List. This includes the ancient architectural complex at Mount *Song* (嵩山) and the site of the *Xia* (夏) dynasty's capital. Before the *Tang* Dynasty its name was *Yangcheng*, and according to classical Chinese texts, Emperor *Yu* (禹) the Great, founder of the *Xia* Dynasty, the first Dynasty in Chinese history, made *Yangcheng* his capital in the 21st century BC. It is believed in history that there was the *Zhou Gong* Observatory (周公測景台), and *Guo Shuojing* (郭守敬,

**6)** http://www2.astronomicalheritage.net/index.php/show-entity?identity=17&idsubentity=1

**7)** *Zhouli* (周禮) *Diguansidu* II (地官司徒第二)

1231-1316) of the *Yuan* dynasty built the *Gaocheng* Astronomical Observatory (登封觀星臺) in 1276 CE. The latitude of this place[8] is currently ϕ=34° 27¢ 31.5$^{2}$= 35.45875°=35.0 *du*. Therefore, it is evident that the star chart in the C-map is scaled in accordance with the idea of the traditional Chinese astronomy, whereas the radius of the circle of perpetual invisibility ($S_1$) was adjusted to the latitude of *Seoul*. This adjustment was already pointed out by a number of researchers such as Park (1995) and Park (1998).

Since the star chart adopts the polar equatorial coordinate system, the center of the C-map should coincide with the north celestial pole (hereafter, NCP). I confirmed the concentricity of the three circles and determined the common center of the three circles using Euclidean geometry. Two methods can be used to determine the common center of the three circles. By one method, the center is obtained from the common intersection of extended determinative lines for the 28 lunar lodges. In the other method, the center is the intersection of perpendicular bisectors of arbitrary arcs for three concentric circles. Both methods give the common center as a star called *Tianshu-xing* (天樞星), which means the celestial pivot or a pole star. The star is identified as HIP 62572 (or HD 112028, GC 17443) (Pan 2009, Ahn & Song 2015). This suggests that the C-map makers intentionally placed the *Tianshu-xing* at the center and drew the three circles with a compass, because they regarded this star as a pole star.

A pole star is a visible star that is approximately aligned with the Earth's axis of rotation. The current northern pole star is the Polaris or a UMi. It is well known that the pole star has changed through history owing to the precession of equinox. In the Spring and Autumn Period and the Warring States Period in Chinese history, the Emperor Star or *Di-xing* (帝星), identified as β UMi, was a pole star. *Tianshu-xing* was designated as the pole star by the approximate period when the Western *Han* dynasty was replaced by the Eastern *Han* dynasty, approximately two millennia ago (Pan 2009).

I calculate the effects of the precession of equinoxes by using methods in Meeus (1998) to confirm that the angular distance from the NCP to the star was the smallest in 807 CE and its value was 0.54°. Thereafter, the relative distance increased with time, and the distance increased to approximately 3° around 1500 CE. *Ganui*[9] (a simplified armillary sphere) part of *Yuan-shi* (元史, History of the Yuan Dynasty) clearly specifies the fact that in 1281 CE the Polaris was far from the NCP by 2.67°. The *Ilseong-jeongsi-ui* (日星定時儀, Sun and Star Dial), created by Korean astronomers in 1437 CE in the reign of King *Sejong* the great, was designed to align the instrument with the NCP using two stars: *α* UMi and *Tianshu-xing*. The C-map makers in 1396 CE were approximately contemporary with the Korean astronomers in the King *Sejong* period. Thus, the Korean astronomers compiling the C-map must have been well aware of the fact that *Tianshu-xing* was too far from the NCP to be a pole star. Despite this, they set the center of the C-map at *Tianshu-xing*. This fact supports an idea that the C-map was not compiled on the basis of new observations.

8) http://www2.astronomicalheritage.net/index.php/show-entity?identity=17&idsubentity=1

9) This is the Korean pronunciation. The Chinese pronunciation is *Jianyi*

**(2) 365 Ticks along the Circle of Perpetual Invisibility**

In ancient East Asian countries, before the European Jesuits introduced the Babylonian 360° system, *du* (度) had been a unit for the celestial circumference. In the *du*-unit system, one complete turn equals 365.25 *du*. This unit originated from the fact that the Sun revolves once around the sky in one synodic year or 365.25 days. The star chart in the C-map shows 365 ticks along the circle of perpetual invisibility. These ticks are quite evenly spaced.

In the seventeenth century, the European Jesuits introduced the Babylonian degree system in China in *Xiyang-Xinfa-lishu* (西洋新法曆書, Calendrical Treatise in Accordance with the New Method). In this book, they described a practical method for drawing ticks in the star map as follows. "First, draw a circle, and then, obtain quadrants by intersecting two perpendicular diameters. Then, trisect each quadrant to obtain 30° segments. Next, divide each 30° segment into five equal 6° segments. Finally, divide each 6° segment into six equal parts, and therefore, we obtain 360 equal segments."

However, this method cannot be applied to the case of 365 ticks because this number has only four divisors. Thus, the circumference is divided into equal segments whose chord lengths are calculated algebraically. That is, when a circle of radius r is divided into N equal segments (N>1), the length of a single chord, L, is $L=2r\sin(\theta/2)$, where θ=2p/N or an angle corresponding to a segment between two nearby ticks on the circumference[10]. However, if there is no trigonometric table, it is impossible to obtain a proper chord length for an arbitrary number of segments.

10) This idea was presented in the 7th International Conference on Oriental Astronomy (ICOA-7) held in NAOJ during 6-10 Sep 2010. Its proceeding was published in 2011 (Ahn 2011) to "Mapping the Oriental Sky" edited by Nakamura, Orchiston, Soma, and Strom. It is noteworthy that in the meanwhile Min (2013) presented a similar idea in the 2nd seminar of Korean Traditional Science & Technology Research Association (KTSTA).

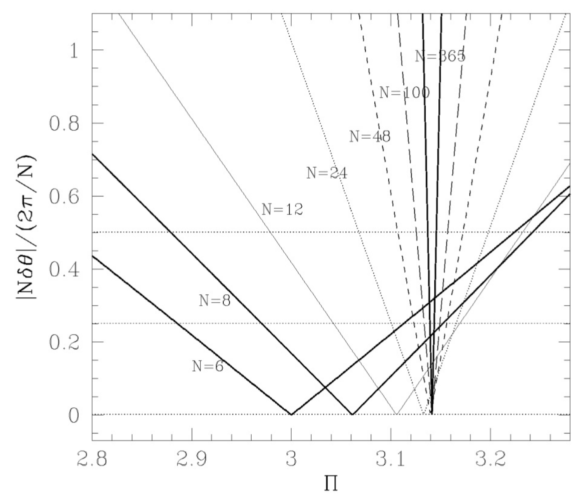


**Fig. 2.** The accumulated error when engraving N equal ticks along the circumference of a circle of radius r, assuming that the inaccurate value of the ratio of the circumference of a circle to its diameter Π is adopted and the arc length is adopted rather than the chord length. Horizontal dotted-lines represent the 50% and 25% angles corresponding to one tick. We see that P should be as precise as 3.14 when we want to divide the circumference into 365 equal segments or N=365.

Hence, when an engineer use a compass and mark ticks on the circumference, it is probable that he or she adopted an arc length $L'=2\Pi r/N$ instead of a chord length L. Here $L'$ is the length of one arc among N equal segments of the circumference. In addition to that, the p-value adopted by the engineer in the early *Joseon* dynasty was probably not the accurate value or π. Let us set the π-value he or she used to be Π. We will obtain a bit larger angle $\theta'$ given by $\theta'=2\sin^{-1}(\Pi/N)$.

The difference between the practical angle $\theta'$ and the exact value θ will be $\delta\theta=\theta'-\theta=2\sin^{-1}(\Pi/N)-2\pi/N$. Thus, the total error accumulated by the N-times of successive markings with a compass will be $\Delta\theta=\Sigma^{N}_{n=1}\delta\theta=2N\sin^{-1}(\Pi/N)-2\pi$. In order to mark ticks in a proper manner, this total error should be at least less than one quarter of one tick interval. In other words, $|\Delta\theta|<\alpha(2\Pi/N)$, where we can assume $\alpha\cong1/4$. This is a bit subject criterion, but it is good in practical uses.

Fig. 2 shows the fractional error $|\Delta\theta|$ with respect to the angle corresponding to one tick-interval or $(2\pi/N)$ as a function of Π. One can see that the π-value should be $3.1394<\Pi<3.1437$ for N=365 and $\alpha=1/4$ equivalent to 25% error for example . The π-value should be $3.1332<\Pi<3.1489$ for N=100 and $\alpha=1/4$. Therefore we conclude that the engineer, who drew the star chart in the C-map, adopted Π=3.14. This is an interesting result, because mathematicians, astronomers, and engineers of ancient times often adopted Π=3. Π=3.14 had been adopted only in unusual occasions.

In Fig. 2 we see that Π=3 is practically applicable for dividing the circumference into a small number of segments or N≤9, and Π=3.1 is sufficient for dividing the circumference into a small number of segments or 10≤N<24 within 25% error. As N→∞, the chord length approaches the arc length or $L\to L'$ and equivalently Π→π. It is also noteworthy that this result is independent of the radius of a circle. Pointing error occurring when we use a compass should be considered, but the pointing error can be small enough to be neglected for a sufficiently large circle such as that in the C-map.

Considering the history of π in the ancient Chinese mathematics (Needham 1959), the mathematical books such as *Jiu Zhang Suan Shu* (九章算術, 10th–2nd century BCE), *Zhou Bi Suan Jing* (周髀算經) (the Han dynasty), and *Zhouli Kao-Gong-Ji* (周禮 考工記) edited in the Spring and Autumn period adopted π=3. *Liu Xin* (劉歆, 53 BCE – 25 CE) used π=3.154, but it is not certain how he could obtain that value. *Zhang Heng* (張衡) adopted $\pi=\sqrt{10}=3.1622$ around 130 CE. *Wang Fan* (王蕃, 228-266 CE) defined π=142/45=3.1555 during the 3rd century. *Liu Hui* (劉徽, 225-295 CE) calculated π to 157/50 or 3.14 with a 192 sided polygon. Later, *Zu Chongzhi* (祖沖之, 429-500 CE) living in the 5th century obtained 3.1415926<π<3.1415927 with the method lost. In the 3rd century, *Chen Zhuo* (陳卓, c.330-c.420 CE) collected star charts of three schools to compile the Star Chart of the Three School (三家星圖). The π-values as accurate as 3.14 were available at that time to draw 365 ticks along the circumference. His followers were also able to use the sufficiently accurate value.

#### (3) 12 Equatorial Sectors

The outermost annulus of the C-map is segmented into twelve equal sectors, which correspond to Chinese equatorial sectors called *cha* (次) in Korean pronunciation (*ci* in Chinese pronunciation). The title of the C-map refers to these sectors, but in the rim of the star chart, the zodiac names are written instead of the names of the Chinese equatorial sectors. The zodiac was imported from India to China around the 6th century through Buddhist sutras (Pan 1989, Pan 2009). It is an important fact that the C-map was influenced by Buddhism astronomy, because Buddhism had been quite prevalent during the *Goryeo* (高麗) dynasty.

Both the beginning and the ending lodge angle for each equatorial sector are given in panels $A_1$ and $A_2$ in Fig. 1. For example, "the sector of *Xianxiao* (玄枵) is from 8 *du* of *Xunu* (須女)[11] to 15 *du* of *Wei* (危), encompasses 30 *du*

**11)** There are 28 lunar lodges in the Chinese traditional astronomy; each lodge has its determinative star that is a reference star of that lodge. Here 8 *du* of *Xunu* means 8 *du* from the determinative star of the lunar lodge *Xunu*.

in width, corresponds to the territory of the *Qi* (齊) state, belongs to *Qing Zhou* (青州), and corresponds to the direction of *Zhi* (子方, *Zhifang*)." Sentences similar to $A_1$ and $A_2$ can be seen in Treatise of Astronomy (天文志) in *Jinshu* (晉書, History of the Jin Dynasty) written in 648 CE by historians of the *Tang* dynasty, except for the widths of the sectors (Song et al. 2002). These originated from *Santong-li* (三統曆, Triple Concordance Calendar) devised by *Lui Xin* (劉歆, 46 BCE-23 CE), which was adopted in *Hanshu* (漢書, History of the *Han* Dynasty) by *Ban Gu* (班固, 32-92 CE). The determinative star of *Xunu* (須女) is η Aqr, and the determinative star of *Wei* (危) is δ Peg. Thus, the upward North should have been defined in the star chart by the midpoint between 8 *du* east of η Aqr and 15 *du* east of δ Peg. That mid-point is by chance coincided with the determinative line of *Wei* (危). In East Asian tradition, the upward direction in star charts has been regarded as the North, called the direction of *Zhi*, whereas the downward direction is the South, called the direction of *Wu* (午方, *Wufang*). Hence, the meridian is called *Zhiwu*-line in East Asian countries. Hence, the upward North is set to be the determinative line of *Wei* (危) in the C-map. And the twelve sectors in the C-map were drawn in accordance with the information written in the tables A1 and A2. Hence, they were drawn after the 365 ticks had been drawn.

This fact is rather weird in view of the ancient tradition. According to *Xin-Tangshu*, the upward North direction in an extent star chart is defined by the direction of the winter solstice. The details are presented in the next section. According to *Chiljeongsan naepyeon* (七政算內篇, Domestic Part of Calendrical Method for Seven Luminaries), the epoch of a year in the legendary times of *Yao* (堯) was the winter solstice, which was located at 6 *du* of the lunar lodge of *Xu* (虛). Traditionally, this has been the beginning point of a year in ancient Chinese calendars. However, it is noteworthy that the upward North direction in the *Suzhou* star chart is also the direction of the determinative star of *Wei* (危). Hence the *Zhiwu*-line can be often spin off from the tradition, possibly for convenience sake.

I verified that the widths of all the sectors in the star chart were in exact agreement with the values in the panels $A_1$ and $A_2$. Furthermore, the widths of the lunar lodges represented by the determinative lines in the star chart are in exact agreement with those in the epitaph $H_2$ in Fig. 1. The widths in $H_2$ and $A_{1,2}$ agree with the widths in the star chart. Thus, these facts indicate that the astronomers who compiled the C-map or built the original stele of the C-map faithfully utilized information in $H_2$ and $A_{1,2}$ when they drew the chart.

**(4) 28 Lunar Lodges**

In ancient East Asian astronomy, the visible sky is divided into 28 lunar lodges resembling the cross section of an orange. The widths of the lunar lodges are different from one another. The western edge of a segment is the beginning of a lodge, which is aligned with its determinative star. A celestial object is said to lie in a particular lodge if it crosses the meridian in a certain segment. An angle equivalent to the right ascension of a celestial body, called the lodge angle, is measured west of that body with respect to the nearest determinative line. A polar distance of a celestial body, denoted by d, can be calculated as the radial distance at the *Tianshu-xing* or the pole star in the C-map. Then, d=90°-δ, where δ is the declination of the object in the equatorial coordinate system.

In the star chart of the C-map, the determinative lines for the 28 lunar lodges emanate from *Tianshu-xing* to the circle of perpetual invisibility and pass through the determinative stars. In other words, all the radial lines in the star chart pass through the determinative stars. This fact was also pointed out by Watanabe (1987). The spacing between the neighboring determinative lines (full widths of the lodges) and the polar distances of the determinative stars are tabulated in the $H_2$ panel shown in Fig. 1. For example, the first lunar mansion is *Jiao* (角), which means Horn, and it comprises of two stars, of which *α* Vir or Spica is the determinative star. According to the table, its width is 12 du and its polar distance is 91 *du*. Thus, the determinative line of the next lunar lodge *Kang* (亢) locates eastward to the line of Jiao line by 12 ticks on the outermost circle of the star chart. *α* Vir should be plotted at a point where its radial distance from the center or *Tianshu-xing* corresponds to its polar distance. By the same procedure, all the other determinative lines and stars are plotted.

Ahn (2010a) investigated the 28 determinative stars in the C-map. He identified the determinative stars in the star chart of the C-map, and he also identified those stars in table $H_2$ in Fig. 1 with a modern star catalogue. He determined that these two types of results were not in agreement with each other for at least seven determinative stars of lunar lodges such as *Di* (氐), *Mao* (昴), *Bi* (畢), *Jing* (井), *Liu* (柳), *Zhang* (張), and *Yi* (翼). Fig. 3 shows those seven determinative stars. The identification of the determinative star of *Kui* (奎) is uncertain. In ancient Chinese star catalogues, the determinative star of *Kui* has been ζ And. However, Watanabe (1987) identified this star in a Japanese star chart called *Tenmonbunyanozu* (天文分野之圖) with modern data, and determined that it must be δ And. It is noticeable that the Japanese star chart is considered to be influenced

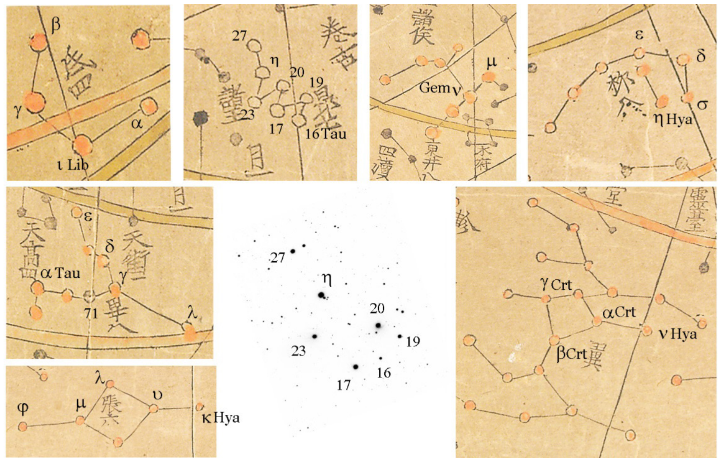


**Fig. 3.** Seven determinative stars in the C-map showing disagreement with the conventional Chinese determinative stars provided by Guo Shuojing. The determinative stars in the star chart of the C-map are different from those listed in the epitaph of the C-map. The determinative stars in the epitaph are in much better agreement with those provided by Shi Shi Xing Jing (the Star Canon of Master Shi), which originated from the fifth century BCE, but it was revised during the third century CE in the latter period of the Han dynasty. (Courtesy of National Palace Museum of Korea)

by the Korean C-map. However, the same star in the C-map is identified to be δ And. It is certain that the determinative star for *Kui* in the star chart of the C-map cannot be ζ And, which has been a determinative star by Chinese convention since the times of *Yixing* (一行, 683-727 CE).

The lunar lodge of *Mao* (昴) is quite compact, and thus the coordinates of its member stars could not be measured with a sufficient accuracy in ancient times. However, the detailed shape of *Mao* was magnified to be conspicuous enough for us to resolve its components. According to *Shi Shi Xing Jing* (石氏星經, Star Canon of Master *Shi*), the determinative star of *Mao* is the first star in the southwest. In Fig. 3, 16 Tau satisfies this description. However, 17 Tau has been the conventional determinative star of Mao in traditional Chinese astronomy.

Ahn (2010a) pointed out that there had been star charts in the Tang dynasty that had different determinative stars from the convention. The title of Volume 106 of *Kaiyuan zhanjing* (開元占經, Treatise on Astrology of the *Kaiyuan* Era) is 'Star Charts (星圖)'. *Kaiyuan zhanjing* is known to have been written in 718-726 CE. According to that volume, the determinative stars of lunar lodges such as *Jing* (井), *Liu* (柳), and *Yi* (翼) in a new chart were different from those defined in an earlier chart. The volume 35 of *Jiu-Tangshu* (舊唐書, Old History of the *Tang* Dynasty) is Treatise on Astronomy (天文志), whose contents are recompiled in the volume 31 of *Xin-Tangshu* (新唐書). These volumes describe the new coordinates of determinative stars measured by *Yixing* (一行) by comparing with the previous coordinates in an earlier star-chart. According to the records in the two books, the determinative stars of *Kui* (奎), *Liu* (柳), and *Zhang* (張) in a new chart were different from those defined in the earlier chart. The current Chinese determinative stars were reformed in the early *Tang* dynasty. The anomalistic stars in the two literatures mentioned above are subsets of the anomalistic ones in the C-map. This indicates that the original chart of the C-map was compiled on the basis of the data of times earlier than the early Tang dynasty.

### (5) Drawing the Other Stars

The other stars belonging to the 28 lunar lodges can also be plotted by referring the determinative stars plotted in the previous section. In the history of astronomical observations in China, the positions of the determinative stars were first measured during the former *Han* dynasty (Sun & Tian 1993). According to the Astronomical Treatise of *Hanshu* (漢書天文志), *Xianyu Wanren* (鮮于妄人) organized a group of astronomers to observe the positions of the determinative stars. According to a book titled *Fa Yan* (法言, Comments on the Laws of Nature) written by *Yang Xiong* (揚雄) in 90 BCE, *Luxia Hong* (落下閎, 156-87 BCE) constructed an armillary sphere; *Xianyu Wanren* used the armillary sphere to measure the positions of the determinative stars, and *Geng Shouchang* (耿壽昌, 73-49 BCE) created a celestial globe (Sun & Tian 1993, Cullen 1996). In these facts, we have two important things to note. First, a sky globe and a *Kaitu*-style star-chart is convertible to each other. Second, these measurements were handed down to *Shi Shi Xing Jing* (石氏星經, the Star Canon of Master *Shi*). Sun & Tian (1993) analyzed the coordinates in this book and confirmed that the data were obtained in 60±30 BCE. However, his error was obtained using an incorrect formula, and the corrected error is ±160 years.

These coordinate values had not been changed till the seventh century, before the new observations of *Li Chunfeng* (李春風, 602-670 CE), *Kaiyuan zhanjing*, and *Yixing* (一行) appeared. The total number of stars in the Kaiyuan zhanjing catalogue is 120 (Sun 1994). A new star catalogue was compiled in 1034 CE in the *Song* (宋) dynasty by *Yang Weide* (楊惟德). This catalogue resulted from the measurements obtained during the *Jingyou* reign (景祐, 1034-1038 CE) and lists only 341 stars (Sun & Kistemaker 1997) Subsequently, *Zhou Cong* (周琮) compiled a new catalogue in 1052 CE, which is also called the *Huangyou* (皇祐) Star Catalogue; it resulted from the measurements obtained during the *Huangyou* reign (皇祐, 1078-1085 CE). It consists of 360 stars (Sun & Kistemaker 1997). Since there are 283 Chinese asterisms, this catalogue lists approximately one reference star per asterism. In the Yuan dynasty, *Guo Shoujing* (郭守敬, 1231-1316 CE) compiled a new catalogue of 741 stars in 1280 CE (Sun & Kistemaker 1997). The Jesuits of the seventeenth century catalogued a majority of the traditional Chinese stars. Adam Schall compiled a new star catalogue in 1628 CE. It consists of 1,365 stars (Sun & Kistemaker 1997).

The star chart in the C-map was compiled in 1396 CE, and thus, even if the C-map makers had adopted the new star catalogue of *Guo Shoujing*, only half of the total Chinese stars could be plotted from astronomical observations. The other half must have been plotted from the positions and shapes depicted on the original star chart. However, the C-map makers do not appear to have adopted *Guo Shoujing*'s observations because the determinative stars in the C-map are located at the position of epoch of approximately 50±170 CE (Ahn 2015a). Furthermore, the information on the linking lines can only be provided by either star charts or sky globes. A star catalogue alone cannot provide the information on linking lines. Therefore, I conclude that the C-map makers did not revise the original

**Table 1.** Polar distances for the determinative stars of 28 lunar lodges. The stars in Star Canon (Shi Shi Xing Jing denoted by SSXJ) are identified by Sun & Kistemaker (1997), and the stars of Guo Shuojing are identified by Pan (2009). I applied the Revised Romanization of Korean system to the Korean names for the determinative stars. The Chinese names are represented by using the Pinyin system as listed by Sun (1994). D represents the measured polar distances on the C-map, and D0 represents the values written in the epitaph of the C-map. The unit of both data is du or Chinese degree.

| No. | Lodge Names | | | | Amplitude (mag) | | | Polar distances (in du) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Korean | Chinese | English | C-map | SSXJ | Guo | Δ | Δ0 | Δ-Δ0 |
| 1 | 角 | Gak | Jiao | Horn | α Vir | ″ | ″ | 98 | 91 | +7 |
| 2 | 亢 | Hang | Kang | Gullet | κ Vir | ″ | ″ | 96 | 89 | +7 |
| 3 | 氐 | Jeo | Di | Base | ι Lib | α Lib | $\alpha_2$ Lib | 94 | 97 | -3 |
| 4 | 房 | Bang | Fang | Chamber | π Sco | ″ | ″ | 105 | 108 | -3 |
| 5 | 心 | Sim | Xin | Heart | σ Sco | ″ | ″ | 106 | 108 | -2 |
| 6 | 尾 | Mi | Wei | Tail | $\mu^1$ Sco | ″ | ″ | 121 | 120 | +1 |
| 7 | 箕 | Gi | Ji | Winnower | γ Sgr | ″ | ″ | 116 | 118 | -2 |
| 8 | 斗 (南斗) | Du (Namdu) | Dou (Nandou) | Dipper | ϕ Sgr | ″ | ″ | 115 | 116 | -1 |
| 9 | 牛 (牽牛) | Wu (Gyeonwu) | Niu (Qianniu) | Ox | β Cap | ″ | ″ | 100 | 106 | -6 |
| 10 | 女 (須女) | Nyeo (Sunyeo) | Nu (Xunu) | Woman | ε Aqr | ″ | ″ | 104 | 106 | -2 |
| 11 | 虛 | Heo | Xu | Barrens | β Aqr | ″ | ″ | 102 | 104 | -2 |
| 12 | 危 | Wi | Wei | Roof | α Aqr | ″ | ″ | 98 | 99 | -1 |
| 13 | 室 (營室) | Sil (Yeongsil) | Shi (Yingshi) | House | α Peg | ″ | ″ | 84 | 85 | -1 |
| 14 | 壁 (東壁) | Byeok (Dong Byeok) | Bi (Dongbi) | Wall | γ Peg | ″ | ″ | 84 | 86 | -2 |
| 15 | 奎 | Kyu | Kui | Straddler | ε And | ζ And | ζ And | 70 | 77 | -7 |
| 16 | 婁 | Ru | Lou | Harvester | β Ari | ″ | ″ | 77 | 80 | -3 |
| 17 | 胃 | Wi | Wei | Stomach | 35 Ari | ″ | ″ | 71 | 72 | -1 |
| 18 | 昴 | Myo | Mao | Mane | 16 Tau | 17 Tau | 17 Tau | 72 | 74 | -2 |
| 19 | 畢 | Pil | Bi | Net | 71 Tau | ε Tau | ε Tau | 77 | 78 | -1 |
| 20 | 觜 | Ja | Zui | Beak | $\phi^1$ Ori | ″ | ″ | 81 | 84 | -3 |
| 21 | 參 | Sam | Shen | Trister | δ Ori | ″ | ″ | 95 | 94 | +1 |
| 22 | 井 (東井) | Jeong (Dong Jeong) | Jing (Dongjing) | Well | ν Gem | μ Gem | μ Gem | 66 | 69 | -3 |
| 23 | 鬼 | Gwi | Gui | Ghost | θ Cnc | ″ | ″ | 63 | 68 | -5 |
| 24 | 柳 | Ryu | Liu | Willow | σ Hya | δ Hya | δ Hya | 83 | 80 | +3 |
| 25 | 星 (七星) | Seong (Chil Seong) | Xing (Qixing) | Star | α Hya | ″ | ″ | 94 | 91 | +3 |
| 26 | 張 | Jang | Zhang | Spread | κ Hya | υ Hya | υ Hya | 105 | 97 | +8 |
| 27 | 翼 | Yik | Yi | Wings | ν Hya | α Crt | α Crt | 106 | 99 | +7 |
| 28 | 軫 | Jin | Zhen | Axletree | γ Crv | ″ | ″ | 100 | 98 | +2 |
| | | | | | | | | | | Mean=-0.39 du (-0.39°) σ=3.9 du (3.9°) |

star chart. I speculate that only determinative stars in the original star chart of the C-map were plotted from observed coordinates such as those in the epitaph $H_2$ of the C-map and that the other stars were plotted from the other earlier star chart.

I measured the distances of the determinative stars from the center of the star chart in the C-map and converted them into the du-unit assuming that the azimuthal equidistant projection was adopted in the C-map (Miyajima 1998). The results are shown in Table 1. The standard deviation of polar distances is as large as 4 du. These results are comparable to those obtained by Stephenson (1988). He obtained a similar result of 5° from the positional measurements of 20 of the brightest stars in the C-map when the precession of equinox is corrected to the epoch of 30 BCE. He conducted a similar analysis for 20 of the brightest stars in both the *Su Song* (蘇頌) star chart (1094 CE) and the *Suzhou* (蘇州) star chart (1193 CE). He obtained positional errors of 4° and 1°, respectively (Stephenson 1988). He ascribes the relatively small positional error in the Suzhou chart to the improvement in astrometry achieved during the *Song* dynasty.

#### (6) Ecliptic and Equinoxes

The circle $S_3$ in Fig. 1 represents the ecliptic. The radius of $S_3$ is equal to that of $S_2$. The ecliptic cannot be an exact circle in the projection method of the C-map. The locations of the equinoxes are given in the epitaph $C_2$. According to $C_2$, the autumnal equinox is at 5 1/6 du of *Jiao* (角), whereas the vernal equinox is at 14 1/3 du of *Kui* (奎). Inspecting the star chart of the C-map, we observe that the location of the autumnal equinox shows a better fit to the description in $C_2$, whereas the location of the vernal equinox is approximately 10 du away from the description. Hence, the C-map makers drew the ecliptic as a circle by adjusting its center to an appropriate position to favorably fit the autumnal equinox at the desired position; i.e., at 5 *du* of *Jiao* (角).

#### (7) Milky Way

The boundaries of the Milky Way are present in the star chart, and the Milky Way bifurcates in the vicinity of the Sagittarius region. The path of the Milky Way is described in books such as Treatise of Astronomy in *Chenshu* (晉書) that was edited by *Li Cunfeng* (602-670 CE). *Zheng Qiao* (鄭樵, 1104-1162 CE) composed a poem in 1161 CE describing the path of the Milky Way based on its description in the treatise. The title of the poem is *Tianheqimei* (天河起沒, Drain and Source of the Milky Way), and it was included in the *Butiange*[12] (步天歌, Songs of Sky-Pacers) of *Tongzhi* (通志) written by *Zheng Qiao*. The *Bocheonga*, including the *Tianheqimei* part, was published in Korea in the early period of the *Joseon* dynasty (Ahn 2009). If we compare the path of the Milky Way described in the C-map with that in *Tianheqimei*, we observe that they are in agreement with each other and that the northern and southern paths in the literature coincide with the boundaries of the eastern branch of the Milky Way in the vicinity of the Sagittarius region in the star chart. Further details will be published elsewhere (Ahn 2015b).

## 3. DRAWING METHOD IN *XIN-TANGSHU*

In this section, I describe the drawing method of an extent star chart as is outlined in the Treatise of Astronomy of *Xin-Tangshu* (新唐書天文志). The method is presented in the treatise in association with the explanation on the structure of the sky in the *Kaitian* theory (蓋天說) that was given by *Yixing*.

**Step 1.** Use the skin of bamboo[13] to build a stick one *fen* (分) in width and half fen in thickness. Its length should be identical to that of the extent star chart.

**Step 2.** Bore a hole through the midpoint of the stick, and through this midpoint, insert a pivot pin that enables the stick to revolve.

**Step 3.** Carve 147 evenly spaced ticks starting from the central pivot and moving outwards[14].

**Step 4.** Draw the circle of perpetual invisibility by revolving the entire bamboo stick of 147 ticks.

**Step 5.** Draw a circle with a radius of 147 2/3 ticks, and this circle forms an annulus of thickness 2/3 tick, on which 365 regular ticks are drawn.

**Step 6.** Draw the equator circle with a radius of 91 1/3 ticks with the stick.

12) *Bocheonga* (步天歌) is called *Butiange* in China. The book was originally written by ancient Chinese authors. However, there are also some versions revised by Korean authors and published in Korea, which is called *Bocheonga* in the Korean pronunciation of Chinese characters. See Ahn (2009) for the further information on the history of Korean

13) The skin of bamboo is used because it is flexible.

14) Here, 147 is the polar distance angle of perpetual invisibility for the latitude of *Yangcheng* or 35 Chinese degrees.

**Step 7.** Draw the circle of perpetual visibility with a radius of 35 ticks[15].

**Step 8.** Calculate the position of the Sun at the winter solstice, and determine the exact center of each equatorial sector[16].

**Step 9.** Use a stick of bamboo skin to measure on the sky globe the positions of all the bright stars belonging to the asterisms of Master *Gan* (甘德, *Gande*), Master *Shi* (石申, *Shishen*), and Master *Wuxian* (巫咸), and place points on the star chart using the same stick. The longitudinal coordinates are obtained from the lodge angles, and the vertical (or radial) coordinates are obtained from the polar distances.

**Step 10.** Divide the equator on the sky globe into 72 even segments, and measure the lodge angle of the midpoint of each segment. Next, extend the longitudinal line from the North celestial pole through the center of each segment, and determine the intersection of the line with the ecliptic. Then, with the stick of bamboo skin, measure the polar distance to the intersection. Next, draw the points on the extent star chart with the coordinate value. Connect these points to obtain the ecliptic.

**Step 11.** *Xin-Tangshu* elucidates the method of drawing the Moon's paths on the star chart, but it is omitted in this here.

Reading the above mentioned method of the seventh century written in a Chinese treatise of the eleventh century, we observe that the star chart in the C-map can be reproduced by the same method. In order to draw the circles of both the equator and the perpetual invisibility, either the C-map makers or the original-chart makers adopted 35 *du*, which is the latitude of *Yangcheng*. However, they adopted 38 *du* for the circle of perpetual visibility; moreover, 38 *du* agrees with the latitude of Seoul. These facts indicate that they modified only the circle of perpetual visibility in order to represent the actual sky viewed in the observer's location.

According to *Xin-Tangshu*, the upward North direction is the origin of the horizontal axis, and it should coincide with the right ascension of the winter solstice. A calculation shows that the winter solstice of 1396 CE was approximately at 9 *du* of *Qi* (箕). However, in the C-map, the upward North direction coincides with the determinative line of *Wei* (危), passing through its determinative star a Aqr. Another calculation also shows that the winter solstice of 2590 BCE was at α Aqr. The traditional origin of the calendar calculation in East Asian history was 6 of *Xu* (虛). The winter solstice was at this position around 2290 BCE. It is noteworthy that the legendary period of *Yao* was around 2200-2100 BCE. The upward North in the star chart of the C-map does not agree with these positions. Hence, I conclude that the C-map makers did not apply the method of defining an upward North direction as is described in Xin-Tangshu. Instead they set the *Zhi* direction (*Zhifang*) in accordance with the definition in *Hanshu* where the mid-point of *Xunu* (須女) 8 *du* and *Wei* (危) 15 *du* was defined to be the *Zhi* direction. That mid-point is by chance coincided with the determinative line of *Wei* (危); this definition is also written on the epitaph of the C-map and is explained in the previous section of this paper.

The ecliptic of the C-map was pointed out to be problematic by *Yu* (1999). The ecliptic is an exact circle that is congruent with the equator circle in the same star chart. This appears to be unusual. It is not certain whether the C-map makers of 1396 CE revised the ecliptic in the original chart. However, it is certain that only the center of the equator circle was adjusted to favorably fit the autumnal equinox in order to draw the ecliptic on the star chart.

## 4. CONCLUSIONS

In this paper, I investigated a method to draw the star chart in *Cheonsang-yeolcha-bunyajido* (C-map). The title of the C-map is translated as the star chart showing celestial appearances in accordance with the equatorial sectors and their corresponding states. I observed that the circles of the perpetual visibility, the equator, and the circle of perpetual invisibility were concentric, and their common center located the *Tianshu-xing* or HD 12287. This star was defined as the pole star in the Star Canon of Three Schools (三家星經, *San Jia Xing Jing*) written by *Chen Zhuo* (陳卓), who was a Royal astronomer during the reign of *Wudi* (武帝, *Cao Cao* 曹操, 155-220 CE) of the *Wei* (魏) dynasty. The star precessed into the closest position to the NCP in 802 CE, and around 1400 CE, when the C-map was compiled, the star became distant from the NCP by approximately 3°. This indicates that the C-map makers adopted a traditional but obsolete pole star, instead of the pole star of that time.

Further, I observed that the 365 even ticks are engraved on the stone along the circumference of perpetual invisibility. The 12 equatorial sectors are engraved in accordance with the beginning and ending lodge angles that

**15)** Here 35 ticks correspond to the latitude of *Yangcheng* (陽城).

**16)** This procedure determines the upward North direction on the star chart to be the polar axis. This direction plays a role similar to the vernal equinox in the modern equatorial coordinate system.

are given in a table of the C-map. According to Treatise of Astronomy in *Chenshu* (晉書天文志), these values date back to the *Santong-li* (三統曆, Triple Concordance Calendar) devised by *Lui Xin* (劉歆, 46 BCE - 23 CE) in 7 BCE. Despite its title, the C-map adopted the zodiac names instead of the names of the equatorial sectors. The zodiac was imported from India to China during the early period of the *Sui* dynasty through Buddhist sutras. The north direction of *Zhi* (子方, Zhifang) in the C-map is set to coincide with the determinative line for the lunar lodge *Wei* (危), which indicates that the C-map makers simply adopted the table of the beginning and ending lodge angles that originated from the *Santong-li* of the *Han* dynasty.

All the determinative lines for the 28 lunar lodges radiates from the central star *Tianshu-xing*, and more importantly, their widths are in exact agreement with the intervals of the determinative stars listed in the epitaph of the C-map. These intervals originated from the Western *Han* dynasty and were recorded in the history book of the early Eastern *Han* dynasty. These intervals were changed in 724 CE in the *Tang* dynasty after a monk astronomer *Yixing* measured the positions of the determinative stars. I conclude that the C-map makers intended to draw the determinative lines for the 28 lunar lodges in exact accordance with the coordinates measured before the *Tang* dynasty.

I located all the determinative stars in the star chart by assuming that the stars are simply present on the determinative lines. I also identified the determinative stars with those in a modern star chart. Ahn (2010a) calculated the present positions of the determinative stars listed in the epitaph of the planisphere and identified the stars with those in a modern star catalogue. I compared these two results, and observed that there are seven anomalies that are different from the current Chinese convention, which formed after the eighth century in China. In order to understand this fact, a new fact I discovered in the Chinese treatises is beneficial. According to *Xin-Tangshu* and *Kaiyuan zhanjing*, there were earlier star charts in which a few determinative stars were defined differently from those defined by *Yixing*. In other words, *Yixing*'s new observations results in a new convention in China in the eighth century. Interestingly, these different determinative stars are included in the anomalies observed in the C-map (Ahn 2010a). Thus, in conclusion, the C-map preserves a rather old tradition, which is different from the Chinese convention redefined after the eighth century.

An epitaph on the C-map mentions that the celestial equator intersects the ecliptic at two points and that the eastern intersection is located at 5 1/6 du of the *Jiao* (角) lodge, whereas the western intersection is located at 14 1/3 *du* of the *Kui* (奎) lodge. The same sentences are present in Treatise of Astronomy in *Chenshu* that was compiled around 635 CE. It is known that these sentences describe the positional data observed by *Luo Xiahong* (140-87 BCE) of the former Han dynasty (Pan 1989). We can observe a remark at the location of the vernal equinox in the C-map: "the location where the ecliptic meets the celestial equator (黃道交處)." No remarks can be observed at the location of the autumnal equinox. However, the location of the vernal equinox in the star chart is not correct, whereas the location of the autumnal equinox is more accurate. The azimuthal equidistant projection is used in the C-map (Miyajima 1998), and thus the ecliptic cannot be a circle. However, both the ecliptic and the celestial equator are drawn as congruent circles in the C-map. In addition, the equinoxes in the star chart of the C-map correspond to the positions of equinoxes written in the epitaph of the C-map. Thus, the positions of equinoxes in the star chart are not useful in estimating the epoch of the star chart. The ecliptic in the C-map is not accurate and was not drawn in a way described in *Xin-Tangshu*.

I have confirmed that the C-map makers faithfully used the table of spans between the determinative stars observed in the C-map. Consequently, it is plausible for us to assume that they also used the table of polar distances in the C-map to engrave the stars at the correct position. I measured the position of the determinative stars in the C-map, and converted them into the polar distances. I observed that the positional error of the determinative stars in the C-map was as large as 4°, which is not so inaccurate when comparing with the intrinsic errors in the polar distances themselves.

In *Xin-Tangshu*, a treatise that describes the drawing method of the extent star chart can be found. Either the star chart in the C-map or the original star chart of the C-map must have been drawn using a similar method. However, the circle of perpetual visibility was modified in accordance with a latitude of 38 d*u* instead of 35 *du*. The upward North direction was defined differently from the definition in *Xin-Tangshu*. The ecliptic circle was not adequate. It was drawn in a simplified manner. The determinative stars are depicted at their proper positions, which agree with the data of the *Han* dynasty. However, there are seven anomalistic cases that are different from the current Chinese convention, and these anomalies were also observed in the treatise of the Tang dynasty. In conclusion, the star chart in *Cheonsang-yeolcha-bunyajido* exhibits the sky of the former *Han* dynasty described in *San Jia Xing Jing* (Canon of Stars of Three Schools) by modifying the circle of perpetual visibility in accordance with the latitude of *Seoul*.

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