朝鮮世宗期における天文儀器の開発と利用

Sang-Hyeon Ahn (韓國天文研究院)

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Outline

- First briefly introduce to the history of Korea and Japan
- Focus on the period of the early Joseon dynasty, to see

  why King Sejong developed astronomy…

  how he did that

  what kinds of astronomical instruments did they make?

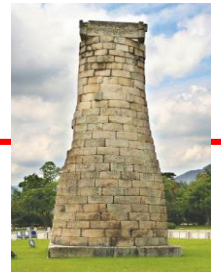
  I will talk about the systematic observations that had been made during the Joseon dynasty after the innovations…
- A brief introduction to historical astronomy…

  I will make two examples: one is the retrograde motion of Mars in 1491 and the other is the comet appeared in 1723..

  Eventually to see the paleo-geomagnetic fields.

古朝鮮 (bronze age, BC1500 ~ BC300)

Iron age many **states 國** (BC300~100)
→ 原三國時代/列國時代 Proto-Three Kingdoms
國 → 王國
Manchuria & Northern Korean peninsula
夫餘, 樂浪, 帶方, 靺鞨, 沃沮, 濊
→ 高句麗(BC37~AD668) こま/ 狛
Southern Korean peninsula
馬韓(54 states) → 百濟(BC18~AD494) くだら
弁韓(12 states) → 伽倻(AD42~562) かや
辰韓(12 states) → 新羅(BC57~AD935) しらぎ
統一新羅(AD668~935) & 渤海(698~926) ぼっかい



高麗(918~1392) こうらい

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繩文(BC10000~300) 죠몽
弥生(BC300~AD300) 야요이

古墳(300~600) 고훈

飛鳥(592~710) 아스카

奈良(691~774) 나라
平安(771~1192) 헤이안

鎌倉(1192~1334) 카마쿠라

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元嘉曆
麟德曆
大衍曆
宣明曆

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統一新羅(AD668~935) & 渤海(698~926) ぼっかい

高麗(918~1392) こうらい

武臣政權 (1170~1270)
元日戰爭 1274, 1281

朝鮮(1392~1910) ちょうせん

壬辰倭亂 1592~1598　文禄の役

Modern Korea

奈良(691~774) 나라

平安(771~1192) 헤이안

鎌倉(1192~1334) 카마쿠라
(文永の役, 弘安の役)

南北朝(1334~1392) 난보쿠초
室町(1392~1573) 무로마치

戰國時代(1493~1573) 센코쿠
桃山(1573~1600) 모모야마

江戸(1600~1867) 에도

Modern Japan(1868~)

大衍曆

宣明曆

授時曆

大統曆
七政算

時憲曆

Political Transition

高麗

Politics was based on Confucianism, and religion was Buddhism and Daoism. Basically Confucianists proclaim **the politics for the people**, but the morality was broken down during the military regime (1170~1270) and Mongolian intervention. Military regime killed many Confucian politicians, and the noble and pro-Mongolians monopolized wealth during the Mongolian intervention. There was no politics for people.

朝鮮

So some leaders who were baptized with Neo-Confucianism had revolutionized the situation and established a new dynasty.

So it was the Mission bestowed to King Sejong,
the fourth monarch of the Joseon dynasty,
to institutionalize politics and culture
based on the thought of Confucianism
in order to stabilize the new dynasty.

This mission had been described
in terms of their Language,
that they tried to establish the institution of **Rites and Music.**

What is **Rites and Music**?

The morality was well described by a sentence in a famous Chinese classic called lizi (禮記):

“大樂與天地同和. 大禮與天地同節,”

which is translated as

“Great music harmonizes with the Nature

Great rites follows the order of the Nature.”

Here the concept of harmonization is related with politics, and that was realized or demonstrated by ancestral rites 祭祀. Music is an important part in performing rituals 儀式.

Music can unite people!

Moreover, the concept of the order of Nature is realized by an exact definition of seasonal grants 節氣 that is calendar.

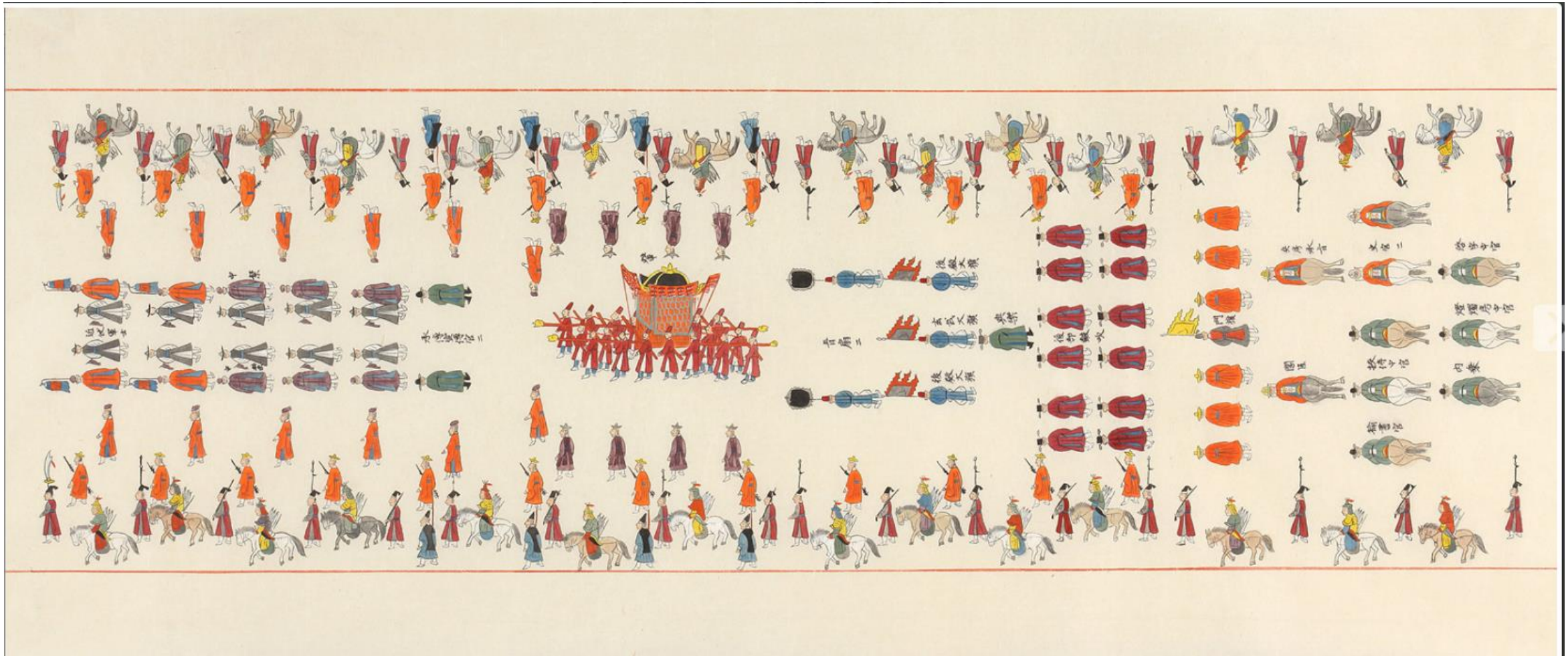
Calendar can give public order to the people!

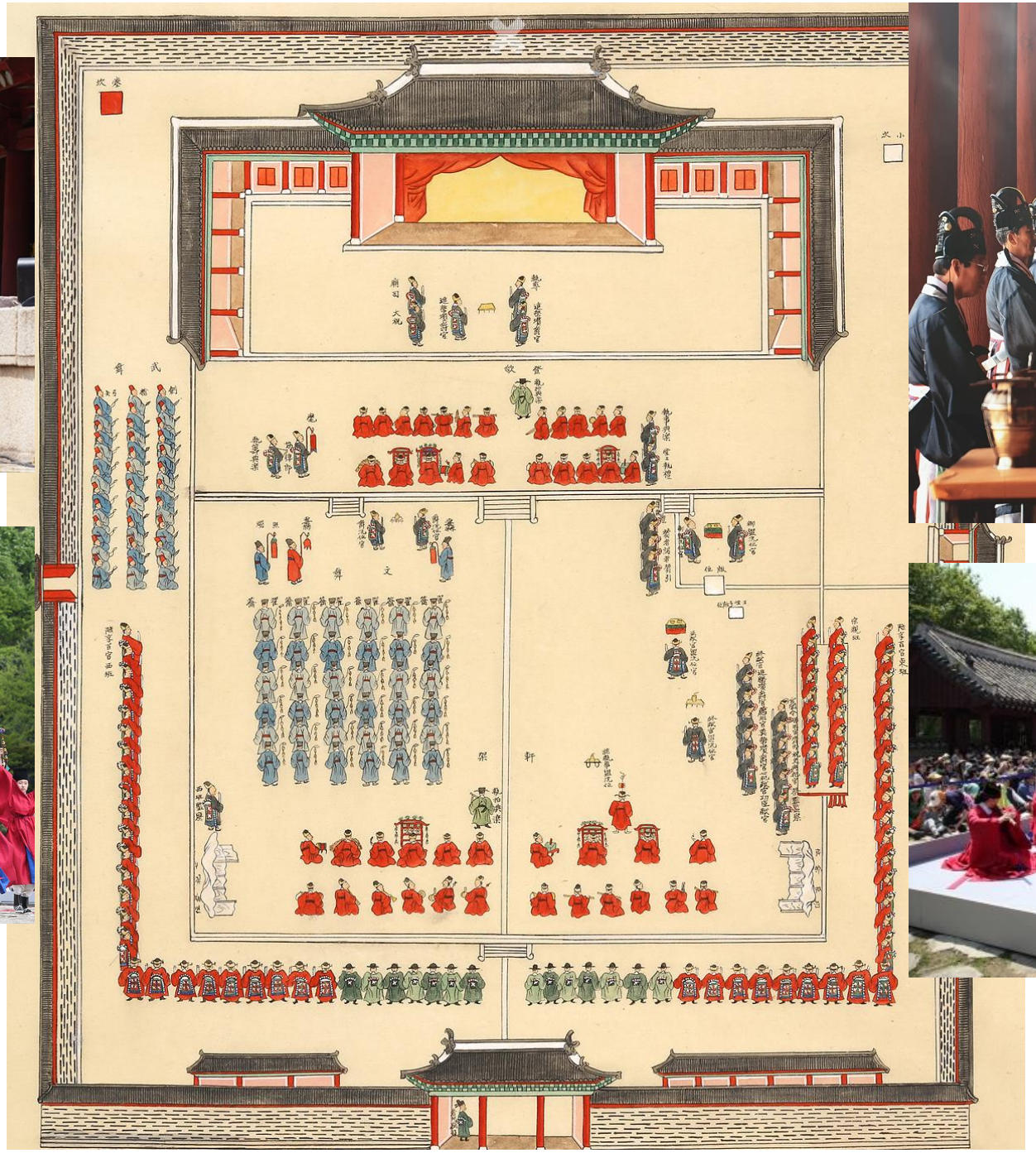
禮樂制度
example) ancestral rites 祭祀

Let us see an example of ancestral rites.
Rites for the previous kings, at the royal shrine called Jongmyo 宗廟.
This rite is still now being performed on the first Sunday of May every year as a sort of performance.

King marched to go to the shrine.

He performed an ancestral rite at the exact time sequence with music and dance played.

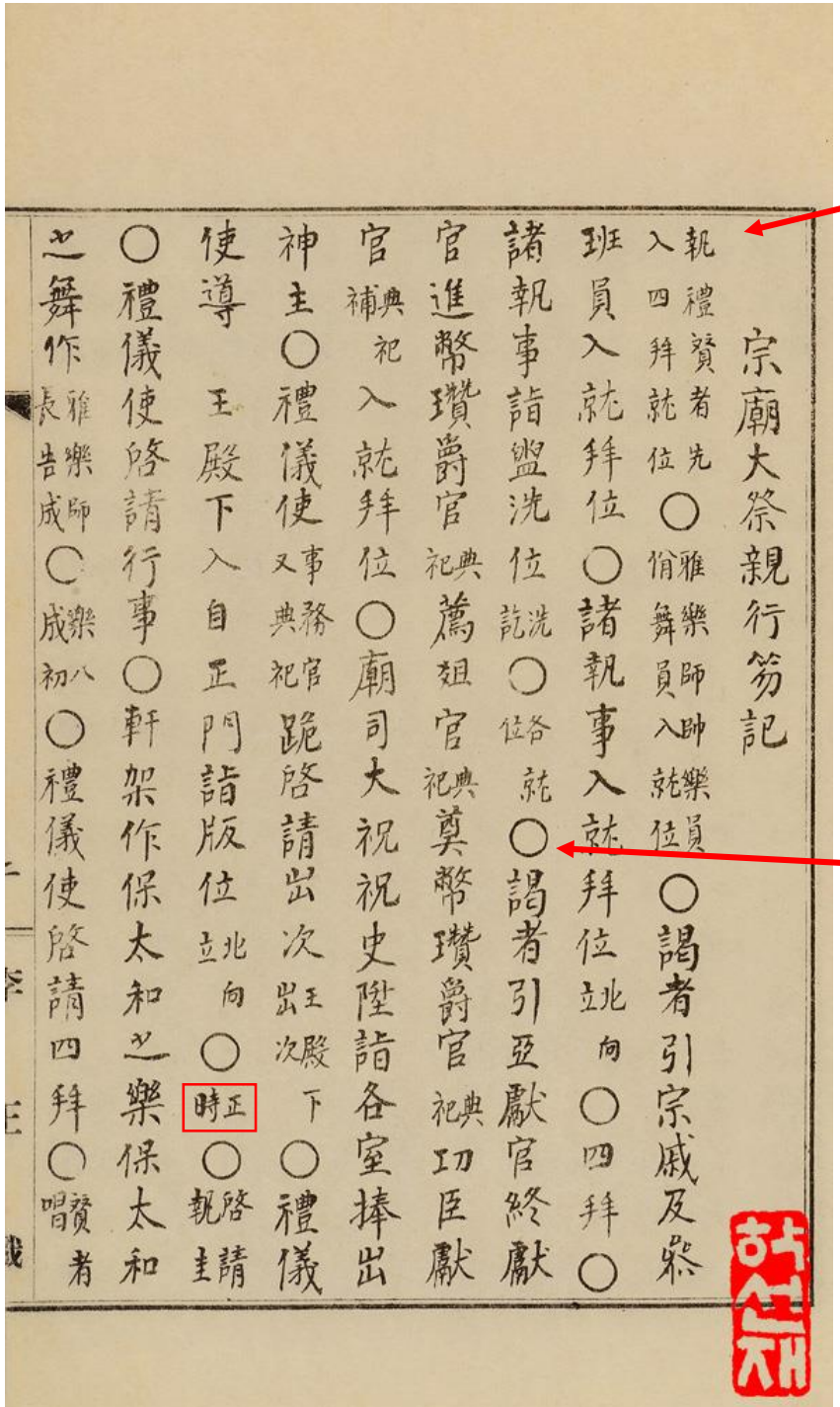




For this, King Sejong invented musical note system, and he himself composed many songs and symphonies.
The pitch was defined, and musical insturments were refined with an help of Park Yeon.

The relevance of the rites with time can be demonstrated by seeing this document showing the sequence of rite called **the order of rite 笏記.**
The sequence of rite was defined as exact times, up to an accuracy of one gak or about 15 minutes.

The time should be kept because the exact time of starting the rite was pre-determined by astrologers as being a fortunate date and time.



前3刻

前一刻

These rites had been serviced in provinces as well as in places near to the palace or in the capital.
Thus, the portable time keeping system was required.

Moreover, the date and time should be set at least based on the local capital, not on any Chinese sites.

So King Sejong developed Local astronomical calendars and time-keeping system in order to establish the ritual and music system.

As results of 20 years efforts of many scholars, as well as Sejong himself, The new calendar system was completed.
That called "**Calendar of Seven Luminaries**" **七政算**…
The calendar system has two parts:
One is the domestic Part called Naepyeon 內篇, which is based on the Shoushi calendar originated from the Chinese heritage. This was known as being the ultimate calendrical method of the Chinese origin.
The other is the foreign Part called Oepyeon 外篇, which is basically a Muslim calendar originated from Ptolemy's Almagest.. This is a lunar calendar.

In order to make calendrical method, they took steps as follows.

Step 1. Refine texts of Chinese calendrical methods
Step 2. Investigate the calculation algorithms
Step 3. Make a local calendar.

During these works, they were confronted by Two Problems

One is to solve difficult mathematical problems.

$$f(x) = ax + bx^2 + cx^3$$

1) **招差術** They must solve 3rd order equations to obtain positions of the Sun and the Moon by applying interpolation method.
2) **開方術** This method is to solve the square root value to obtain the time interval between the first contact and the eclipse maximum or between the totality and the fourth contact. The distances was given by Pythagorean theorem. $d^2 = A^2 + \Delta^2$ → $d = \sqrt{A^2 + \Delta^2}$
3) **弧矢割圓術** This method is related with the conversion of the solar ecliptic longitude into the right ascension.

To solve these problems, Sejong himself studied contemporary mathematics developed in Song and Yuan times. He also selected brilliant persons and sent them to China to study math.
As results, the problems were solved in a couple of years.

During these works, they were confronted by Two Problems
One is to solve mathematical problems.

1. 招差術
2. 開方術
3. 弧矢割圓術

The other problem was Observations.
The Chinese calendar was based upon the LOCAL observational data. Basic quantities such as the latitude of Seoul, the length of tropical year, the lengths of day and night for every 24 seasonal grant, and the positions of the major planets should be measured or at least verified. Moreover, the positions of the Sun and the Moon must be measured.

So Sejong ordered to develop observational instruments and installed in his palace.

15 instruments had been developed in Sejong era.

5 were inherited from Chinese heritage,
which is described in the history of the Yuan dynasty.
These instruments were developed by astronomers led by Guo Shoujing.
So these were reproduced.

簡儀 Ganui is an armilla

to measure the horizontal and equatorial coordinates of celestial objects.

定方案 Jeongbang'an: to set up the precise directions to install instruments.

圭表 Gyupyo is a gnomon.

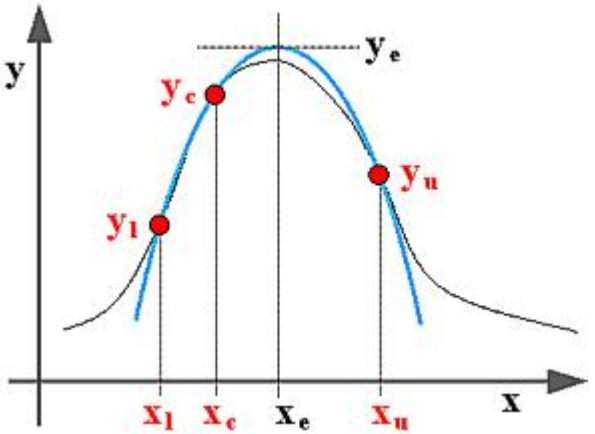
渾儀 Honui is an armillary sphere.

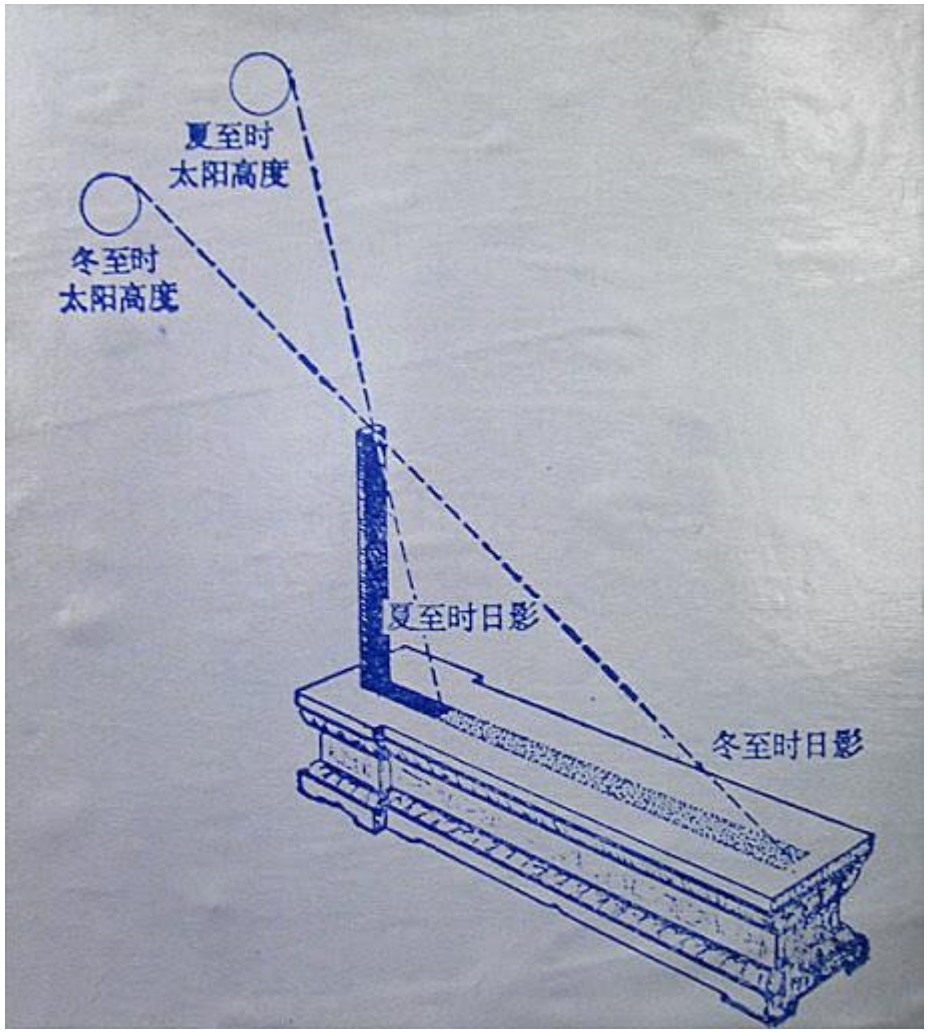
渾象 Honsang is a sky globe.

圭表

Kyupyo is a gnomon, to measure the solar altitude at its culmination, which is used to determine the tropical year=365.2422days.

Three-point interpolation





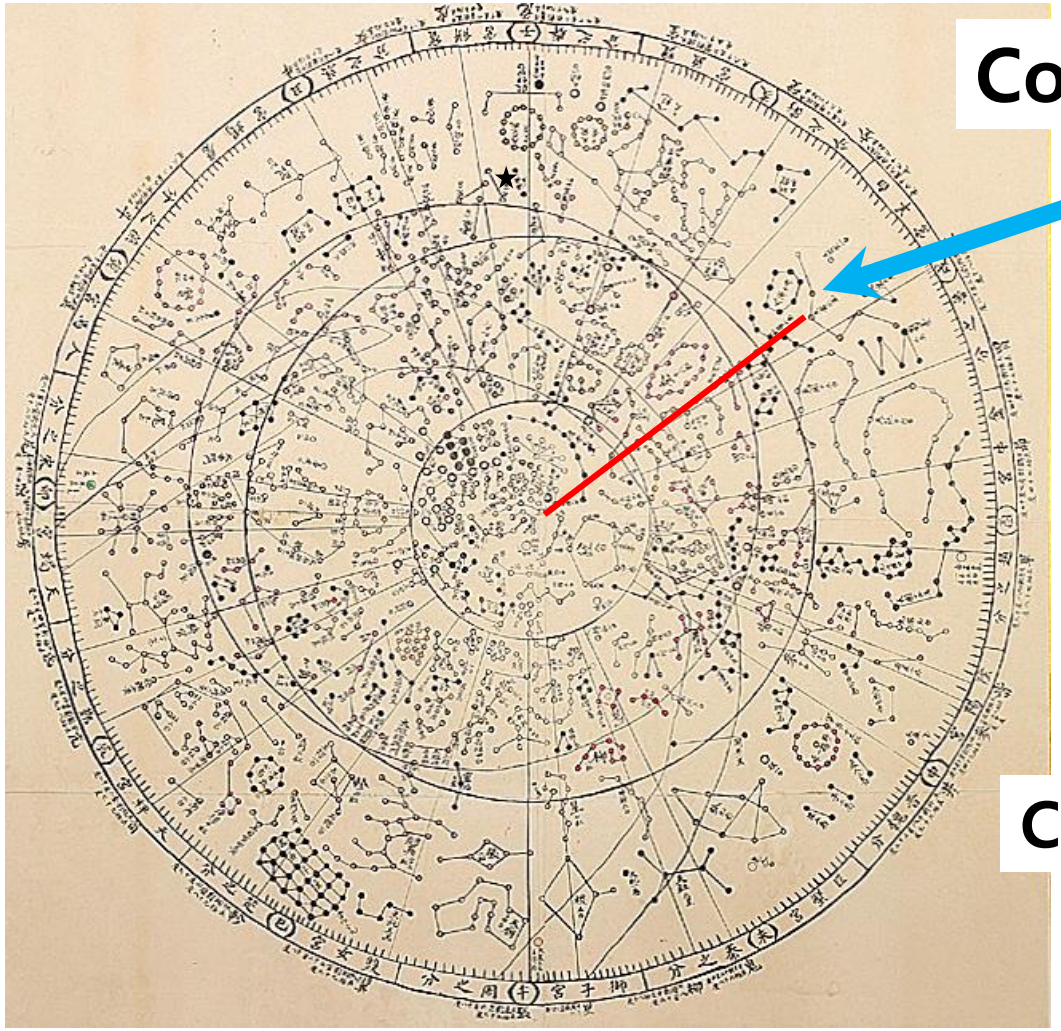
渾儀

Honui is to simulate the movement of the equator and the ecliptic, and also used for the coordinate conversion.

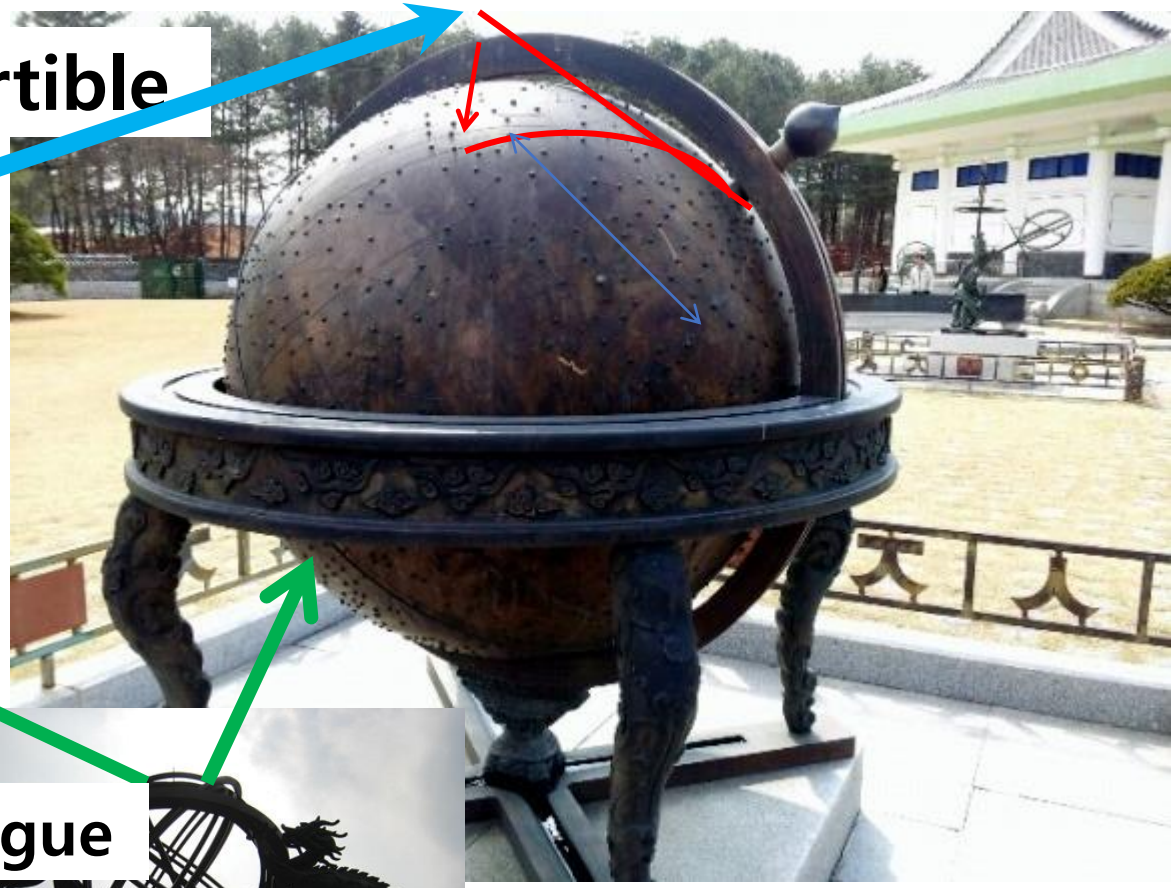
渾象

Honsang is to simulate the movement of stars,
and to perform also cordinate conversion.

Role of 渾儀 & 渾象



Convertible



Catalogue

10 Creative inventions (made several and sent to the Northern border for military use)

小簡儀 To measure the positions, designed in a simplified and minimal manner. **Main instrument** (two sets)

Clepsydra 漏

報漏閣漏 – Water Clock of Borugak Pavilion. It becomes the standard water clock of the dynasty.

欽敬閣漏 – Water Clock of Heumgyeonggak Pavilion.

行漏 – portable water clock.

Sundials 日晷

仰釜日晷 – Concave Sundial. **Two were made and installed on the street of Seoul. Public clock**.

懸珠日晷 – equatorial sundial, **portable**.

定南日晷 – to determine the north-south direction or the meridian with the Sun

天平日晷 – a portable sundial, for the use while riding on a horse.

Star-clock 星晷

日星定時儀 – Sun-Star clock (4 pieces)

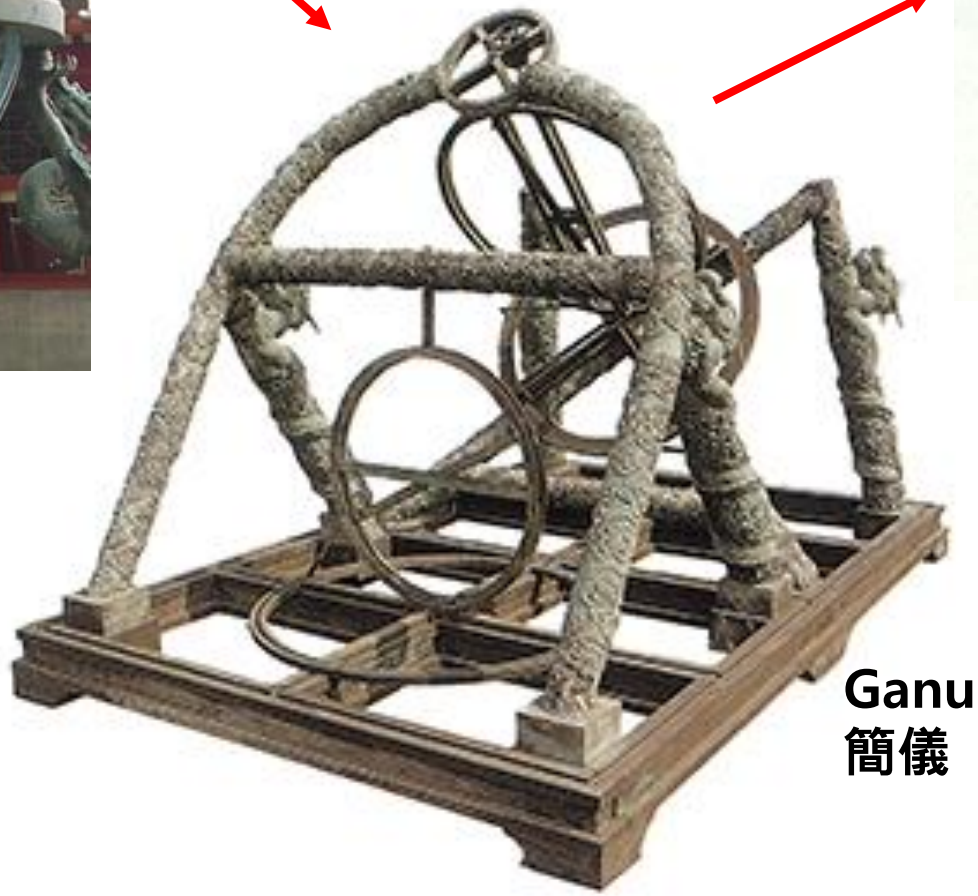
小定時儀 – smaller and portable version of sun-star clock.

大·小簡儀：positional measurements

Honui
渾儀

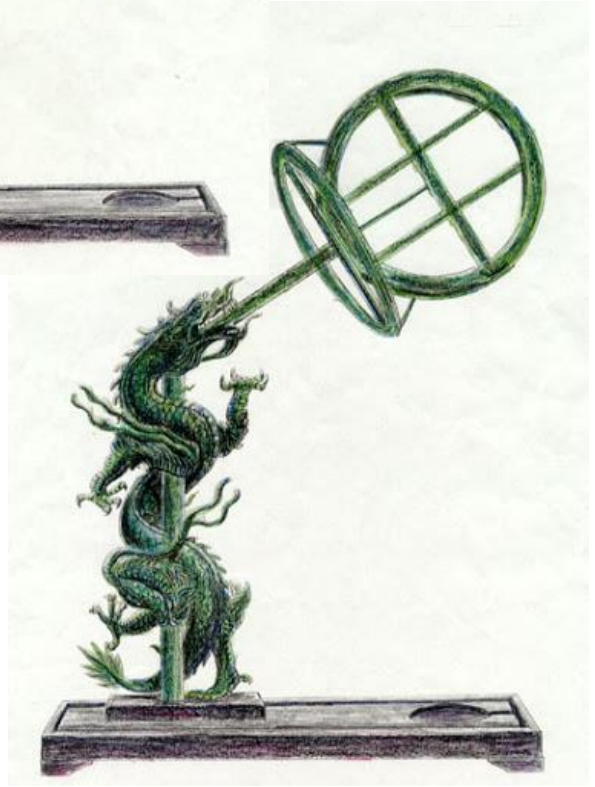
Decompose, simplify

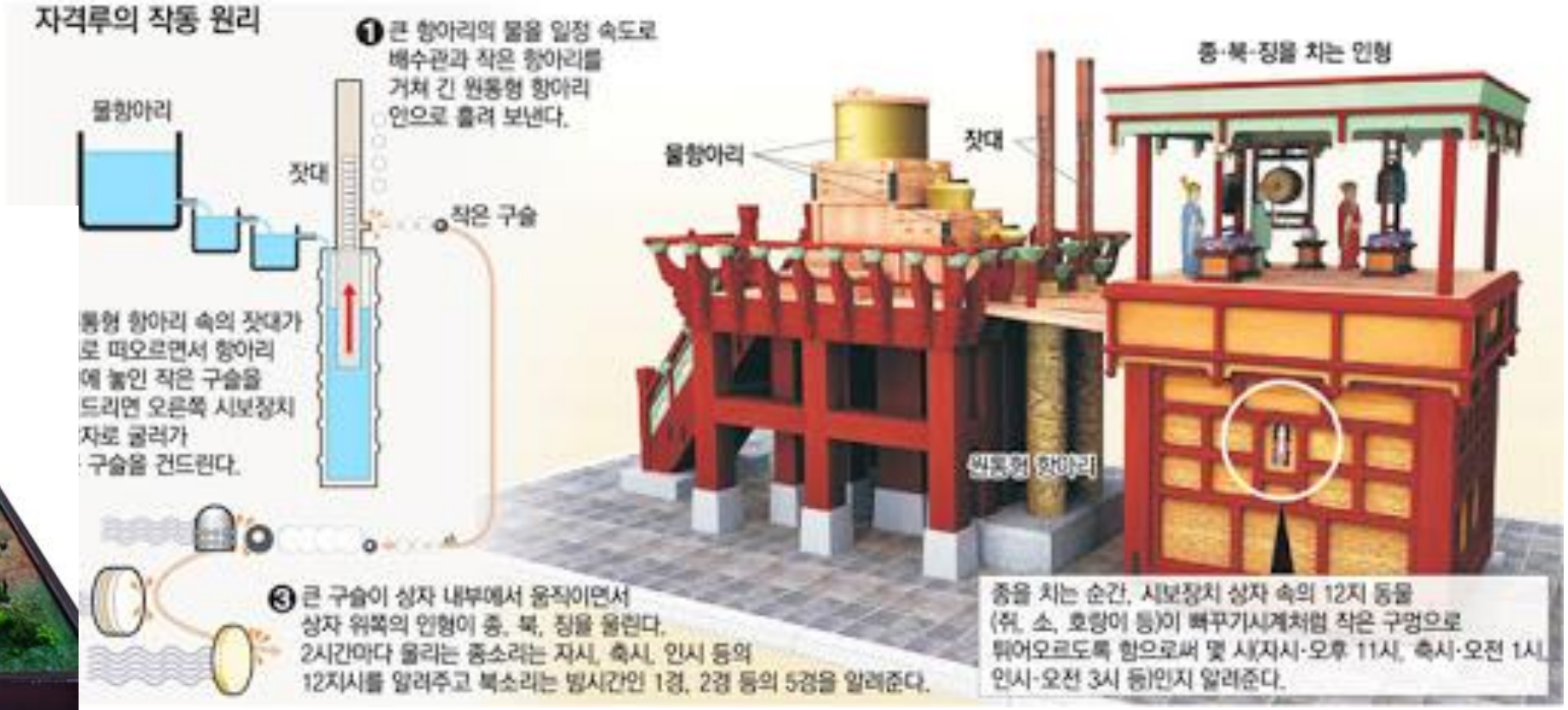
portable,
more simplify



Ganui
簡儀

SoGanui
小簡儀



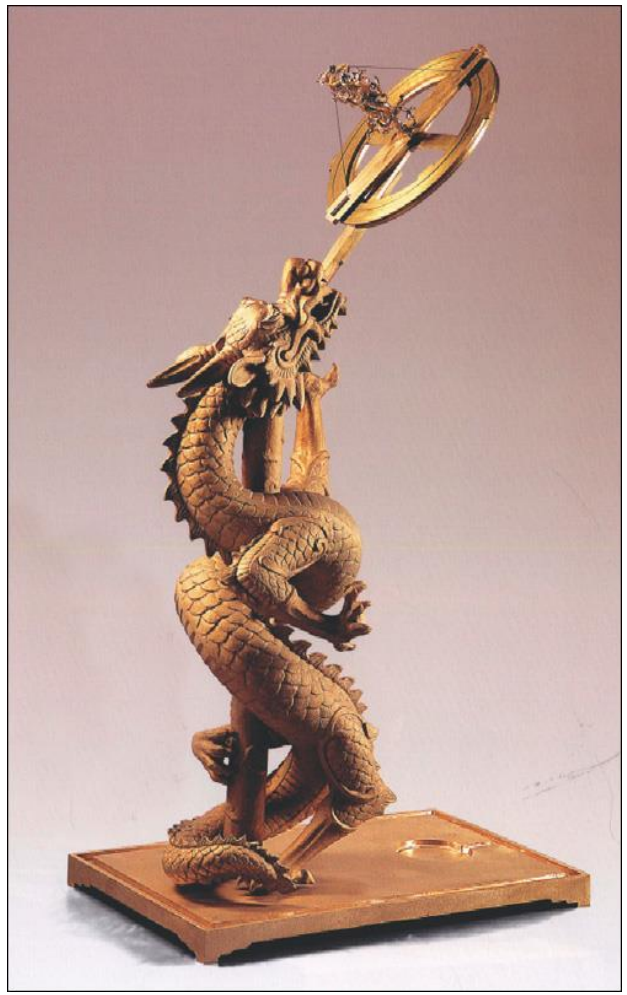

자격루의 작동 원리
❶ 큰 항아리의 물을 일정 속도로 배수관과 작은 항아리를 거쳐 긴 원통형 항아리 안으로 흘려 보낸다.
물항아리
잣대
작은 구슬
통형 항아리 속의 잣대가
로 떠오르면서 항아리
에 놓인 작은 구슬을
드리면 오른쪽 시보장치
자로 굴러가
구슬을 건드린다.
❸ 큰 구슬이 상자 내부에서 움직이면서
상자 위쪽의 인형이 종, 북, 징을 울린다.
2시간마다 울리는 종소리는 자시, 축시, 인시 등의
12지시를 알려주고 북소리는 빙시간인 1경, 2경 등의 5경을 알려준다.
종·북·징을 치는 인형
물항아리
잣대
작동형 항아리
종을 치는 순간, 시보장치 상자 속의 12지 동물
(쥐, 소, 호랑이 등)이 뻐꾸기시계처럼 작은 구멍으로
튀어오르도록 함으로써 몇 시(자시·오후 11시, 축시·오전 1시,
인시·오전 3시 등)인지 알려준다.

懸珠日晷 – equatorial sundial

仰釜日晷 – Concave Sundial

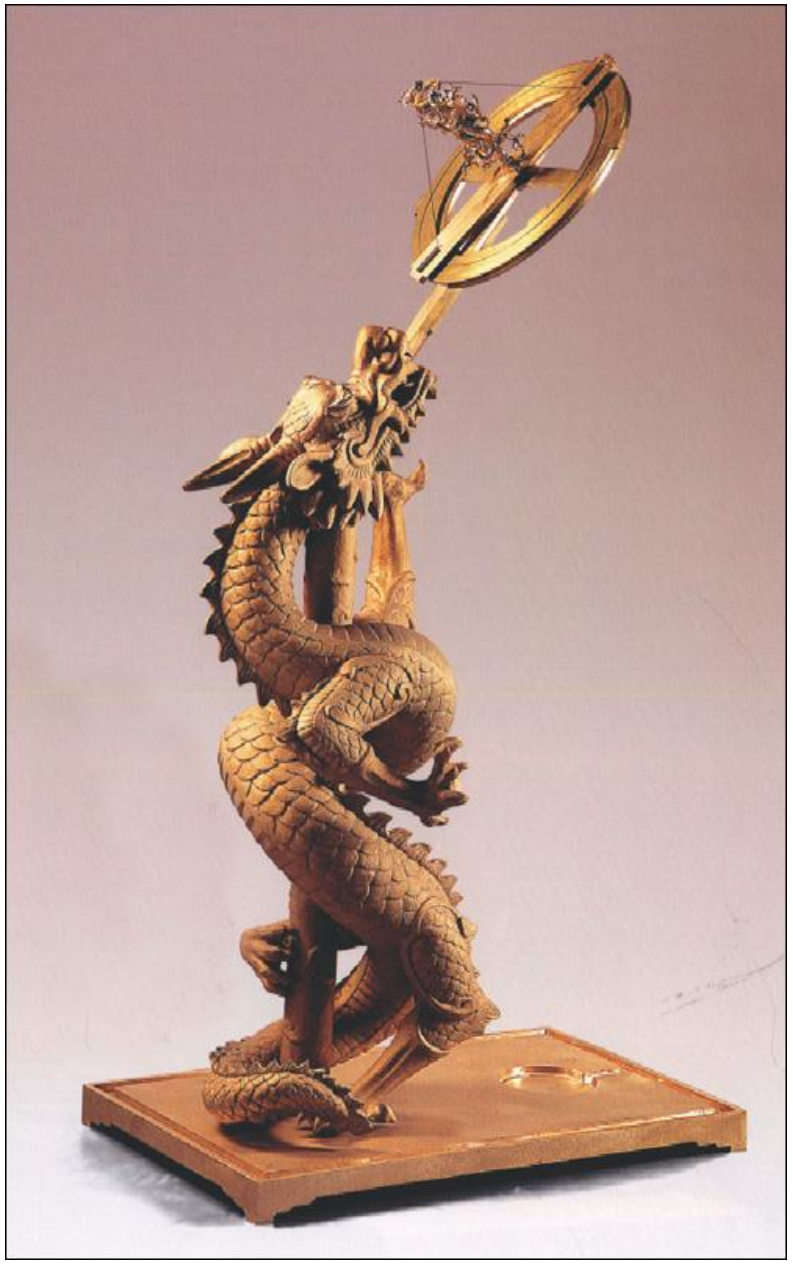
It becomes sundial during the daytime by using the diurnal motion of the Sun, and star-clock during the night time by using the diurnal motion of the Polaris

日星定時儀 Sun-and-Star Determining Time Instrument



4 sets were made: One for the King (with a Dragon decorated), another for the Royal Observatory, and two were sent to the border for the use of standing guard.

Calibration



Mission of the Royal Observatory

- Based on the astronomical system, they developed administrative institute for astronomy called Kwansang'gam. Here we call it the royal observatory.
- The observatory performed the followings.
- **Astronomy 天文**
  - making annual calendars
  - time keeping
  - astronomical and meteorological observations
  - calculation of eclipses
  - determining good time for many official schedule
  - eclipse-saving rites (求食禮)

- **Geomancy 地理** spot good places to build houses or tombs

- **Fortune-telling 命課** determine good dates and times for court affairs

Two Kinds of Calendars by Royal Astronomical Bureau

日課暦 Public Calendar

- **暦日 + 暦註**
- **暦日**

Exact time for

seasonal grants 節氣時刻

New , quarter and Full moon 合朔時刻

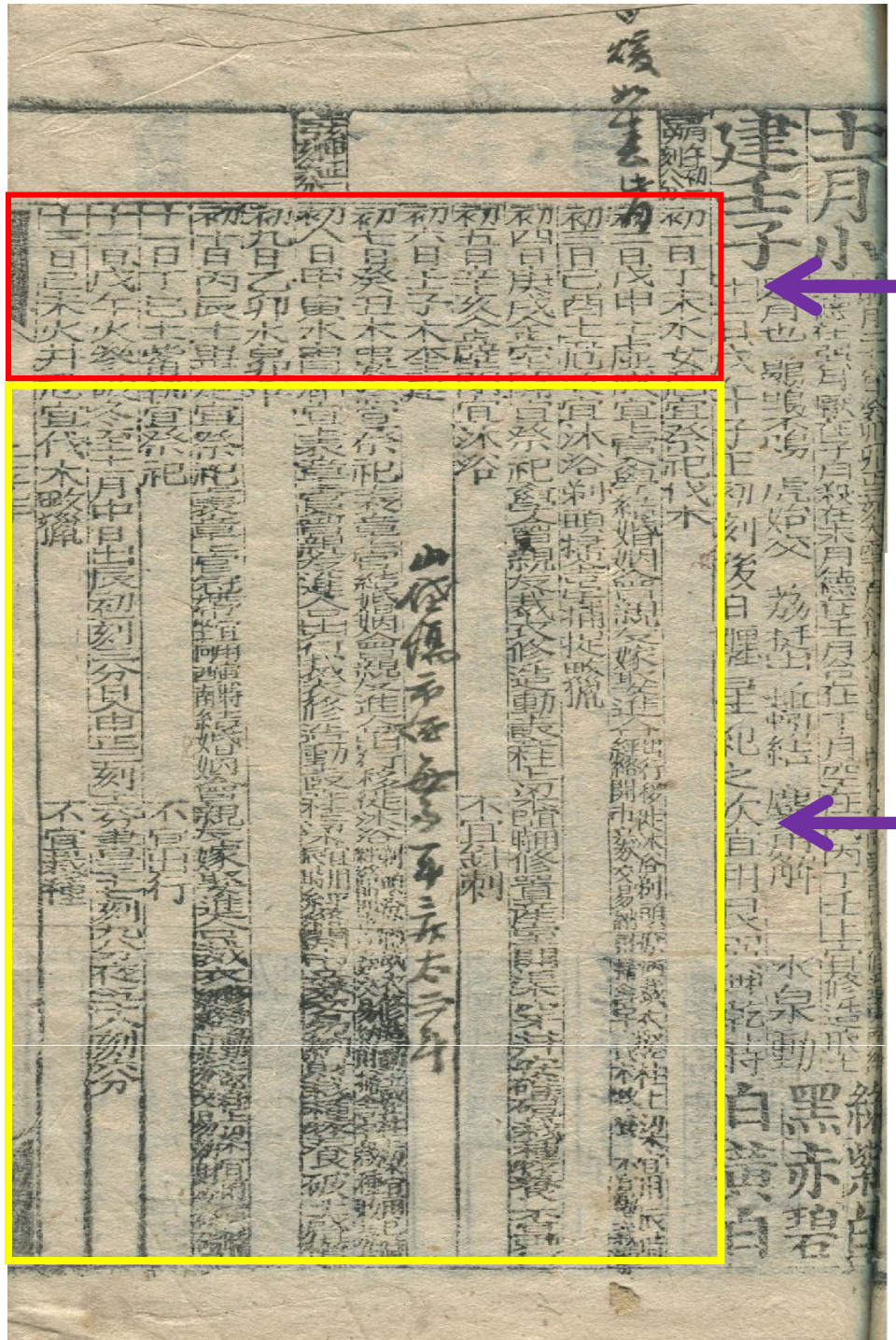
Duration of day time and night time 晝夜時刻

- **暦註**

Astrological guidance for everyday life

七政暦 Astronomical Almanac

- Positions of seven luminaries
- Ephemerides
- **Restricted use only**



日課曆

曆日 Dates for fortune-telling

曆註 action guidance

宜祭祀, 入學, 會親友, 裁衣, 修造, 嫁娶, ...

To do: Ancestral rites, enterance into a school, meeting friends, tailor's cutting, repair, marriage, ...

不宜針刺, 出行, 乘船, 渡水, 栽種, 移徙, 動土, 安葬, ...

Not to do: Applying acupuncture, going out, boarding a ship, crossing a river, sowing, moving, digging soil, burial, ...

七政曆
Seven Luminaries Ephemerides

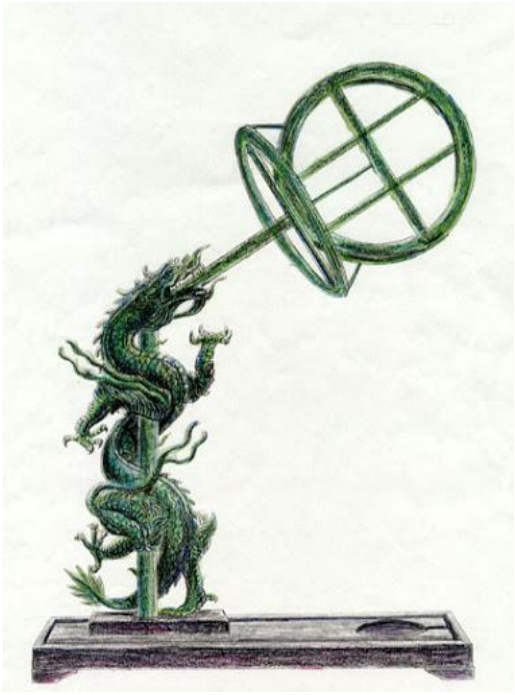
It is an astronomical almanac.
Only a couple of copies were made for the Monarch and the professional use in the Royal Observatory.

Astronomers usually Observed the sky
with theses instruments after their development.

Daily observations and reporting with documents had been routinely performed by astronomers in the Royal observatory.

They left a large amount of observational data that had been recorded in the royal chronicles.

Their main instrument had been the Small Simplified Armilla.
There had been observational stations.



今十月初十日戊辰夜五更彗星見於軫宿四度去極一百六度尾指軫星內
大餘色白 前直長田萬有 本監諸官齊測候

謄

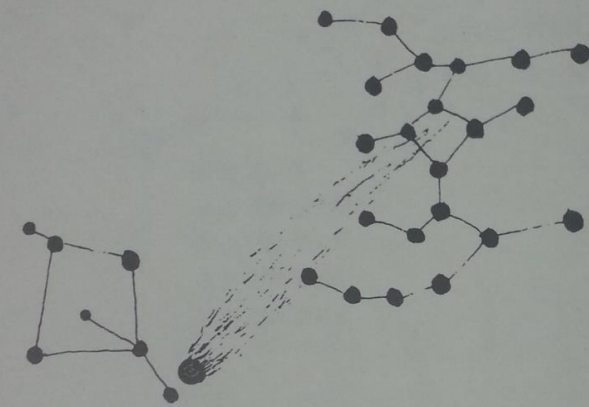
康熙甲辰年天變謄錄

三年

副奉事臣安
副司直臣鄭
前正臣宋
無教授臣朴

星變測候　單子

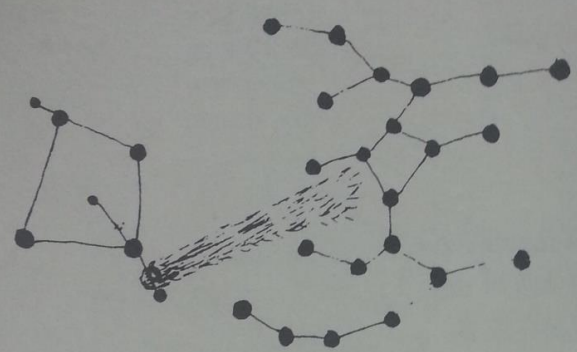
今十月二十七日乙酉夜四更彗星見於右轄星西在翼宿十五度去極一百九度半尾跡及色與昨一掃而星体漸盛大於大角星



天文学訓導臣孟
觀象監副奉事臣安
天文学教授臣黃
兼教　授臣朴
弘文館副應教臣金

星變測候　單子

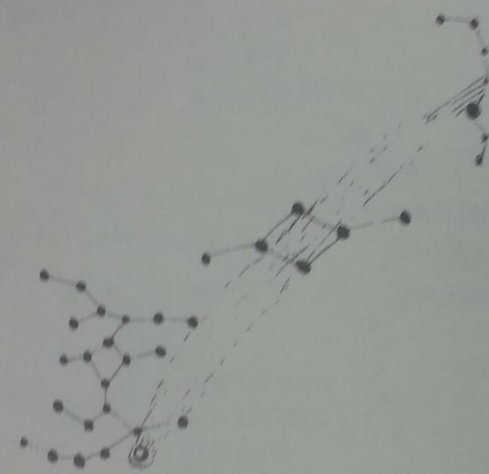
今十月二十六日甲申夜四更彗星見於軫宿西南星外犯右轄星在翼宿十七度去極一百九度半形色及尾跡與昨一掃



副司猛臣鄭
觀象監直長臣朴
天文学教授臣黃
兼教　授臣朴
弘文館修撰臣吳

星度測候　單子

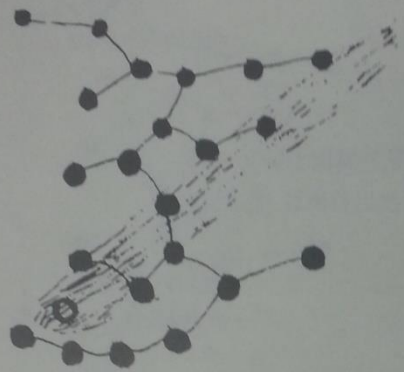
今十一月初五日壬辰夜彗星見於翼宿西南星外去張星十八度去極一百十二度行與昨无異而尾跡長度則似為稍加直



觀象監直長臣朴
副司直臣鄭
副司正臣朴
兼教授臣朴
弘文館副應教臣金

星變測候　單子

今十一月初二日己丑夜四更初彗星見於翼宿內左

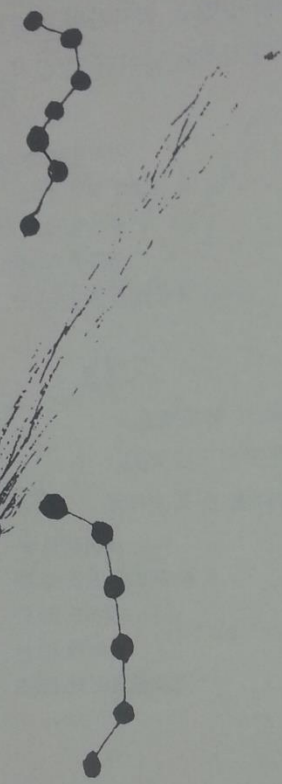


翼宿九度去極一百十度形色尾形與昨別无加減

副司勇臣鄭
天文学教授臣黃
副司正臣朴
兼教授臣朴
弘文館副校理臣洪

星變測候　單子

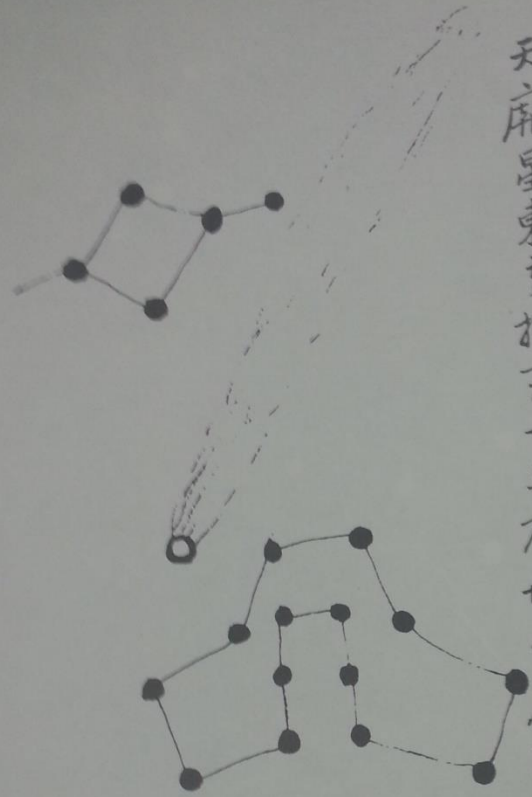
今十一月初十日丁酉夜二更四點彗星始出於巽方濁氣中而月光且盛不能測候及其三更月落之後詳細測候則在星宿初度外厨星東去極一百十七度形色尾跡共昨無異



副司猛臣鄭
副司猛臣尹
副司正臣朴
兼教授臣朴
弘文館副應教臣金

星變測候　單子

今十一月初八日乙未夜三更一點彗星始見於東方天漸有陰雲不得明見至三點雲散之後詳細測候則在張宿七度天廟星東去極一百十三度形色尾跡与昨一樣



前觀象監令正臣鄭
觀象監副奉事臣安
副司正臣朴
兼教授臣朴
弘文館副校理臣洪

星變測候單子

今十一月二十七日甲申夜一更陰雲始散彗星見於奎宿度內右梗星上而形体漸微若存若亡

觀象監直長臣朴
觀象監主簿臣
天文學教授臣黃
兼教授臣朴
司諫院司諫臣吳

星變測候單子

今上月初一日戊子夜一更彗星形体甚微

We can find scientific knowledge by analyzing these observational data.

This research field is called **historical astronomy**.

I will show some example.

One case is the observational records of the retrograde motion of **Mars during the 1491 AD**.

The other is the observational records of the **comet** that appeared in **1723** AD.

In summary,
King Sejong the great established the system of astronomical observations
In order to establish the new Kingdoms in term of Rites and Music…
One important effects of these efforts is that Korean people had come to be regulated time for their everyday lives by using the annual calendars and the public time system.
The astronomical observation system had been well performed during the following 450 years, and left a large amount of observational data.
I performed scientific analyses for a couple of cases of those observations
To estimate the secular variations of geomagnetic field,
which can be used to refined current models.
This can be an example how we can make present use of the heritage from the past.
Thank you.