On the Purposes of Traditional Chinese Astronomy

1. Introduction
2. Socio-political functions
3. Chinese lunisolar calendar
4. Astronomical calculations in Chinese calendar
5. Equatorial or ecliptic
6. Some unanswered issues

Traditional Chinese Almanacs (通勝)

Do: pray; open for business; go on a trip.

10月26日 星期六
九月廿八
宜：祭祀祈福開市出行
忌：修廚作灶
財神：東南　喜神：西北

Don't: maintain kitchen; install a cooking stove.

http://fengshui-magazine.com.hk/No.268-Oct19/Oct-10.htm

Traditional Chinese astronomy serves 3 major purposes.

1. A system of organizing days for agricultural activities. Which the celestial bodies (Sun, Earth, or Mars) are essential for agricultural activities?
2. Records and predictions of astronomical events. What observational techniques were invented and theoretical models had been developed?
3. For civil services and ritual practices. How is it related to knowledge from #1 and #2?

Mandate of Heaven

- Mandate of Heaven constituted an integral part of political ideology in the ancient Confucian culture and
- was a confirmation expressed by Heaven to support for the authority and legitimacy of the emperor.

Confucius (551 – 479 BCE), a Chinese philosopher and politician of the Spring and Autumn period.

Mandate of Heaven

- Mandate of Heaven exhibits 3 characteristics: Virtuous, Changeable, and Understandable
- Those were virtuous would deserve Mandate of Heaven (Virtuous);
- The emperor must be cautious his behaviors since Mandate of Heaven might change and could end his dynasty (Changeable);
- Heaven would send warnings through peculiar astronomical phenomena (Understandable).
- Who could and how to interpret starry messages from Heaven?
- Grant astronomers interpreted the phenomena and would suggest what the emperor should do.

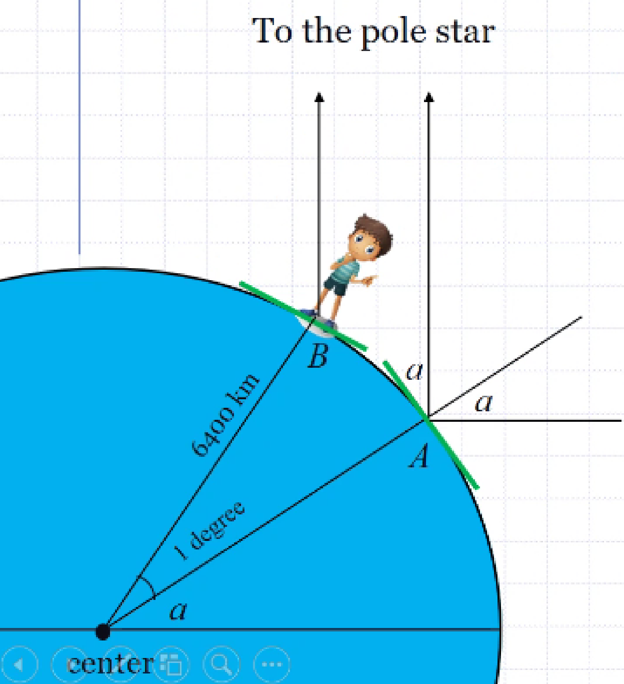
A negative exemplar

- Emperor Shang Zhou gave himself over to drinking, women and ignored all affairs of state;
- ended up setting fire to his palace and committed suicide when his army was defeated at the battle in 1046 BCE. The Shang dynasty was overthrown.
- It has been said that this was a manifestation of Mandate of Heaven.

Cultural influence on Chinese astronomy

- Monk Yi Xing led a grand survey in 724 CE;
- determined the angles of elevation of the pole star changed by 1 degree about every 131 km along the north-south line (independent of positions of the observer).
- This suggests the Earth's surface is rather round than flat.

Cultural influence on Chinese astronomy

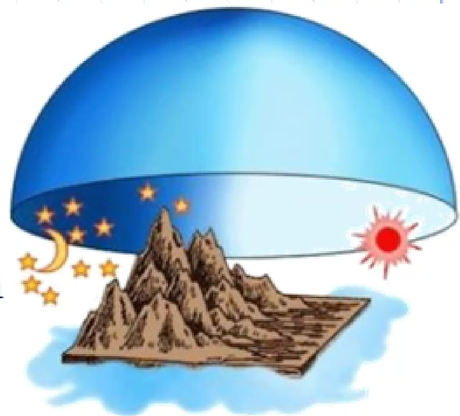


The latitude is the same as the elevation angle of the pole star. If the latitude difference between the two places along the north-south line is one degree, and the elevation angle of Polaris differs by one degree.

Given that Earth's radius of 6400 km, the distance between the two places = $\frac{\pi}{180} \times 6400 = 112$ km. The percentage error $= \frac{131-112}{112} \times 100\% \approx 17\%$ 。

Cultural influence on Chinese astronomy

- The round-Earth hypothesis is not consistent with the idea of a flat Earth (such as the Canopy heaven).
- Yet, Chinese philosophers refused to accept the round-Earth hypothesis until Western missionaries arrived in China in the 17th century. Why?



Cultural influence on Chinese astronomy

單居離問於曾子曰：「天圓而地方者，誠有之乎？」……
曾子曰：「天之所生上首，地之所生下首。上首之謂圓，下首之謂方。如誠天圓而地方，則是四角之不揜也。且來，吾語汝。參嘗聞之夫子曰：『天道曰圓，地道曰方。』方曰幽而圓曰明。明者，吐氣者也，是故外景。幽者，含氣者也是，是故內景。故火日外景，而金水內景。吐氣者施，而含氣者化。是以陽施而陰化也。

《大戴禮記》天圓篇 （第五十八篇）

Sanchü Li asked Tsêng Tzu saying, “It is said Heaven is round and Earth square, is that really so?” ...
Tsêng Tzu said, “That to which Heaven gives birth has its head on the upper side; that to which Earth gives birth has its head on the under side. The former is called round, the latter is called square. If Heaven were really round and the Earth really square the four corners of the Earth would not be properly covered. Come nearer and I will tell you what I learnt from the Master [Confucius]. He said that the Tao of Heaven was round and that of the Earth square. The square is dark and the round bright. The bright radiates chhi, therefore there is light outside it. The dark imbibes chhi, therefore there is light within it. Thus it is that Fire and the Sun have an external brightness, while Metal and Water have an internal brightness. That which irradiates is active, that which imbibes radiation is reactive. Thus the Yang is active and the Yin reactive.

English translation by Needham, p.204.

Chinese lunisolar calendar

Which of the following model would have a better prediction of planetary positions?

A. Geocentric model
B. Heliocentric model
C. Both accuracies are the same.

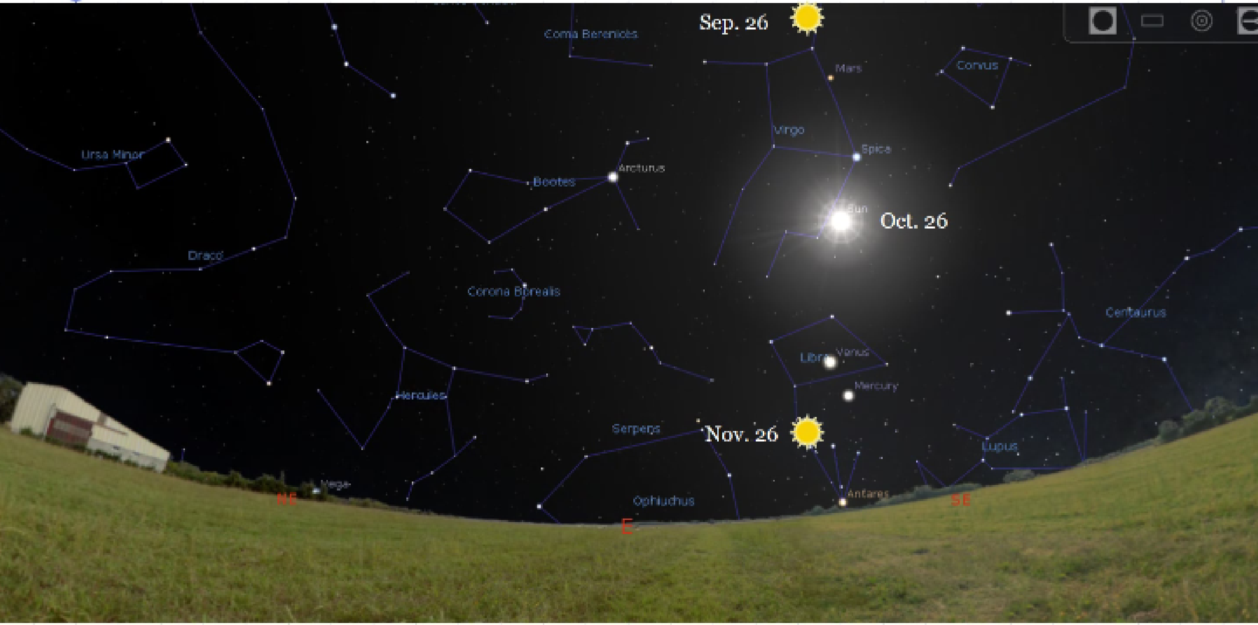
Observations: Daily motion of the Sun

https://apod.nasa.gov/apod/ap071222.html

How to define the length of a day?

- Observations: Daily motion of the Sun (together with background stars)
- Timekeeping reflects the positions of the Sun in a day. Noon is defined as the Sun at the highest position in the sky.
- The average time between 2 successive noons is defined as 1 day (24 hours).

Observations: Yearly motion of the Sun (relative to the background stars)



Stellarium.

Yearly motion of the Sun

- The Sun appears in Sagittarius in January and then enters Aquarius in March and across 12 constellations in a year.
- The Sun's trajectory is called ecliptic. Its positions determine the seasons.
- Ancient Chinese divided the ecliptic into 24 solar terms, known as *jieqi*. The farmers knew what to do (e.g., sow, harvest) in which solar term.
- A year is defined as the time for the Sun to complete its path in the sky, equivalent to 365.2422 days.

Gregorian calendar

$$R = 365.2422$$

The time for the Sun to complete its path.

Rules:

1. Every 4 year is a leap year; e.g., 1992, 1996
2. Every 100 year is a not leap year; e.g., 1800, 1900
3. Every 400 year is a leap year. e.g., 2000

Convention only

Gregorian calendar

Exercise: Suppose there are 365.321 days in a year. Formulate a set of rules for leap years.

Gregorian calendar

Exercise: Suppose there are 365.321 days in a year. Formulate a set of rules for leap years.

- $R = \frac{year}{day} = 365.321$

$$\approx 365 + \frac{1}{3} - \frac{1}{81}$$

Rules:

1. Every 3rd year is a leap year;
2. Every 81st year is a not leap year.

An anecdote

Not l

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Isaac Newton

From Wikipedia, the free encyclopedia

This article is about the scientist. For the agriculturalist, see Isaac Newton (agriculturalist).

Sir Isaac Newton PRS (25 December 1642 – 20 March 1726/27[a]) was an English mathematician, physicist, astronomer, theologian, and author (described in his own day as a "natural philosopher") who is widely recognised as one of the most influential scientists of all time and as a key figure in the scientific revolution. His book *Philosophiæ Naturalis Principia Mathematica* (*Mathematical Principles of Natural Philosophy*), first published in 1687, laid the foundations of classical mechanics. Newton also made seminal contributions to optics, and shares credit with Gottfried Wilhelm Leibniz for developing the infinitesimal calculus.

Are historians just not sure the exact year?

> Within Europe the most famous calendrical confusion occurred in the early centuries following the introduction in Catholic countries of the Gregorian calendar. Exactly because it was Catholic most Protestant states refused, at first, to introduce it, meaning that Europe was running on two different time scales making life difficult for anybody having to do outside of their own national borders, in particular for traders. This problem was particularly acute in The …

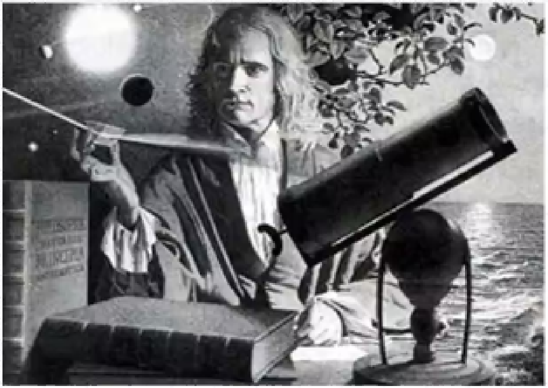
Thony, Christie (2015). "Calendrical confusion or just when did Newton die?". *The Renaissance Mathematicus*. Retrieved 20 March 2015.

Gregorian calendar (new-style) and
Julian calendar (old-style): a normal year of 365 days and a leap year of 366 days every 4 years.

In some standard references (e.g., Wikipedia)

Galileo Galilei (1564 - 1642)

Gregorian calendar



Isaac Newton (1642 – 1726/27)

25 December 1642 – 20 March 1726 (old-style) or 4 January 1643 – 31 March 1727 (new-style)

Observations: The phase cycle of the Moon

https://www.britannica.com/place/Moon/Motions-of-the-Moon

Chinese lunisolar calendar

1. A year = 365.2422 days
2. A lunar month (the period of Moon's phase cycle) = 29.5306 days
3. A year = 12.3683 lunar months (#1/#2)

How are these astronomical data incorporated into Chinese calendars?

Chinese lunisolar calendar

- 1 Year = 12.3683 lunar months
- Normal year: 12 months (6 small months and 6 big months; total 6 x 29 + 6 x 30 = 354 days)
- Leap year: 13 months (6 small months and 7 big months; total 6 x 29 + 7 x 30 = 384 days)

Question: 2021 is a normal year, and Chinese New Year was on 12 Feb. On which date will Chinese New Year 2022 be?

Chinese lunisolar calendar

- 1 Year = 12.3683 lunar months
- Normal year: 12 months (6 small months and 6 big months; total 6 x 29 + 6 x 30 = 354 days)
- Leap year: 13 months (6 small months and 7 big months; total 6 x 29 + 7 x 30 = 384 days)

Question: 2021 is a normal year, and Chinese New Year was on 12 Feb. On which date will Chinese New Year 2022 be? 1 Feb 2020

Carry on calculations, Chinese New Year can be in December or in June or any time of a year.

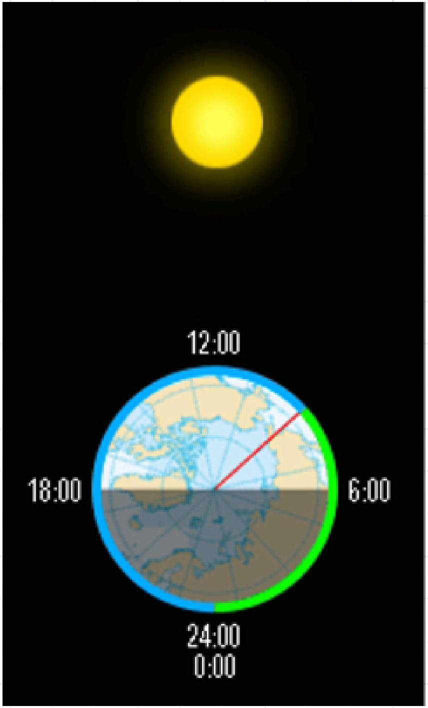
Nineteen-year cycle

- 19 years ~ 6939.6018 days (19 x 365.2422)
  ~ 234.9977 phase cycles 6939.6018 / 29.5306)
- Ancient Chinese discovered (~500 BCE) the so-called "Nineteen-year cycle of seven intercalary months"
- Leap year: 13 lunar months (6 small and 7 big)
- 19 x 12 + 7 = 235 lunar months.
- Around the same time, Meton of Athens discovered the cycle, and it is known as Metonic cycle.

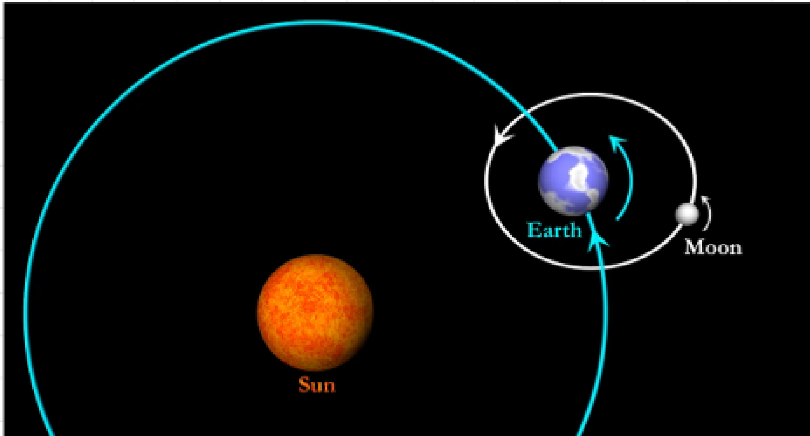
Nineteen-year cycle

The lunisolar calendar date of your 19-year-old birthday is on the same date as in your birth year. Check it out.

Gregorian-Lunar Calendar Conversion Table:
https://www.hko.gov.hk/gts/time/conversion.htm



Do we care about if the Earth's rotation when compiling a calendar? Does it matter if it is geocentric or heliocentric?



3 categories of astronomical phenomena

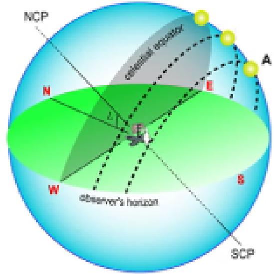
1. "Usual" phenomena such as solar motions, lunar motions, and planetary motions;
2. "peculiar" phenomena such as solar eclipses, lunar eclipses, and occultations; and
3. "extraordinary" phenomena such as comets, nova, meteors, and sunspots.

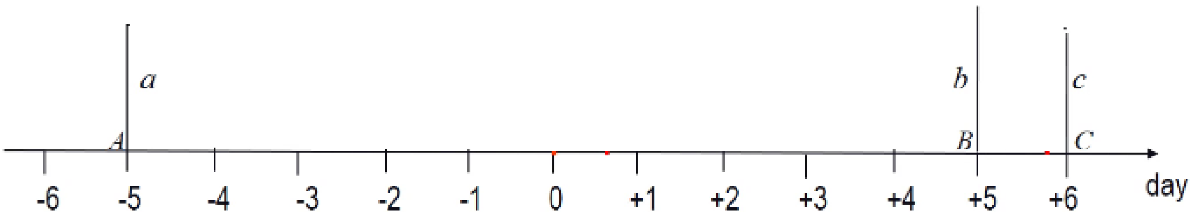
Winter solstice

Winter solstice is the beginning of a year, defined as the moment when the Sun is at the southernmost of the celestial sphere. (The exact time of winter solstice is at 3:59 p.m. on 21 December in 2021.)

21/12/2021,
3:59 p.m.
Stellarium.

Zu's scheme (5^{th} century)





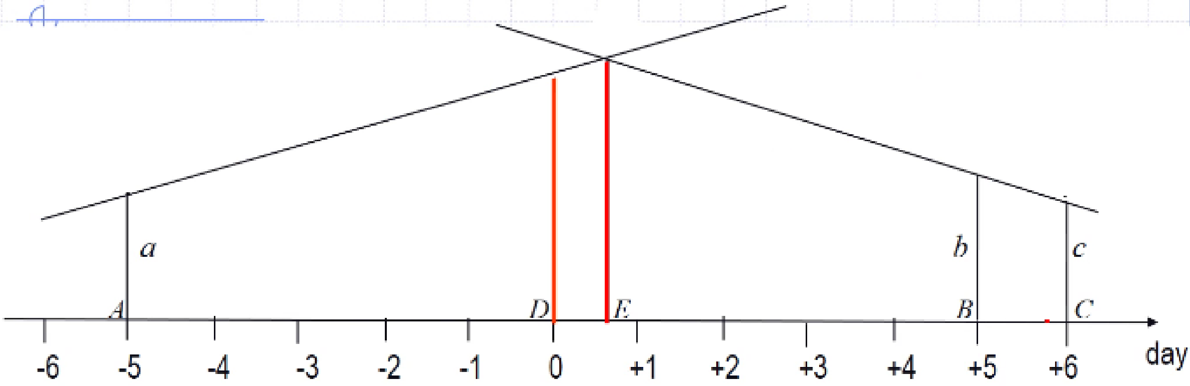
Three measurements

A: At noon on the 5^{th} day before winter solstice, the shadow length is a;

B: At noon on the 5^{th} day after winter solstice, the shadow length is b;

C: At noon on the 6^{th} day after winter solstice, the shadow length is c;

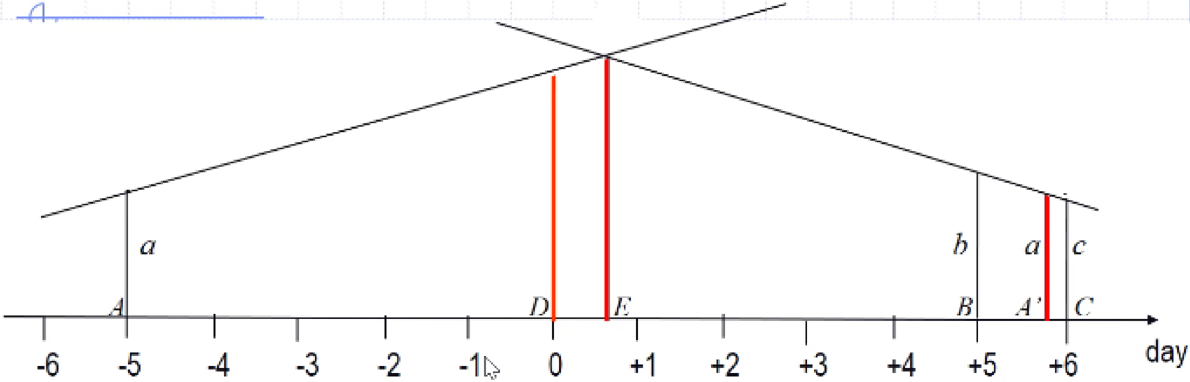
Zu's scheme (5th century)



Assume that the shadow lengths before and after winter solstice varied symmetrically and linearly with time.

D: At noon on the day of winter solstice
E: The moment when the Sun is at winter solstice

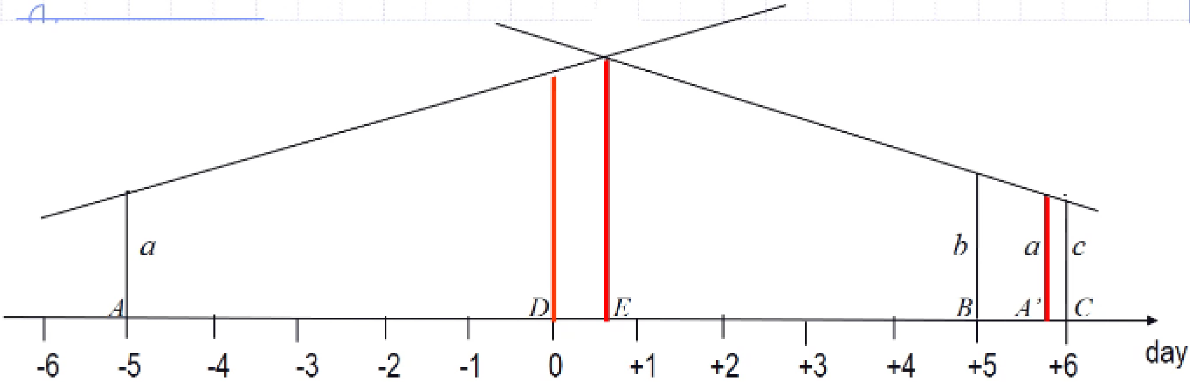
Zu's scheme (5th century)



Construct $AE = EA'$

$AD = DB$ (5 days from 0),
$EA' = EB + BA'$ and
$DB = DE + EB$.

Zu's scheme (5th century)



Construct $AE = EA'$

$AD = DB$ (5 days from 0),
$EA' = EB + BA'$ and
$DB = DE + EB$.

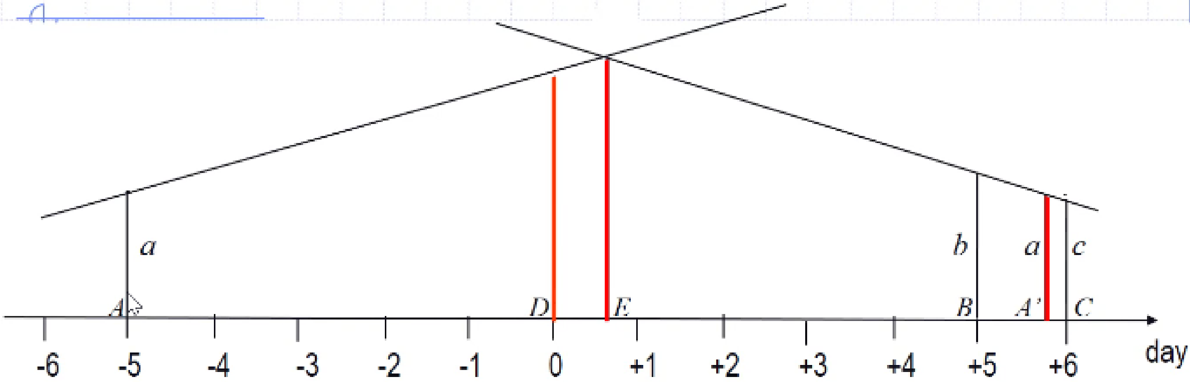
$$AE = AD + DE$$

$$EA' = DB + DE$$

$$EB + BA' = DE + EB + DE$$

$$DE = \frac{1}{2} BA'$$

Zu's scheme (5th century)



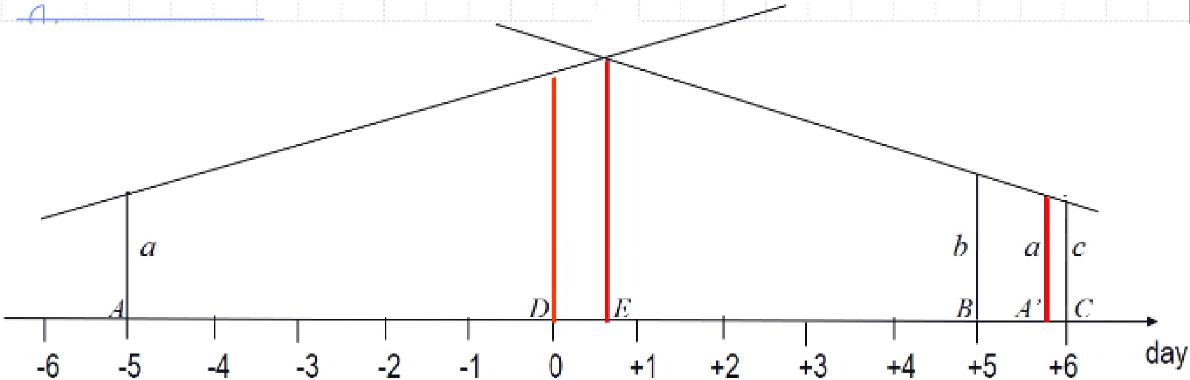
For instance, three measurements are:

At A: the shadow length is a = 0.495 m;

At B: the shadow length is b = 0.500 m;

At C: the shadow length is c = 0.490 m.

Zu's scheme (5th century)



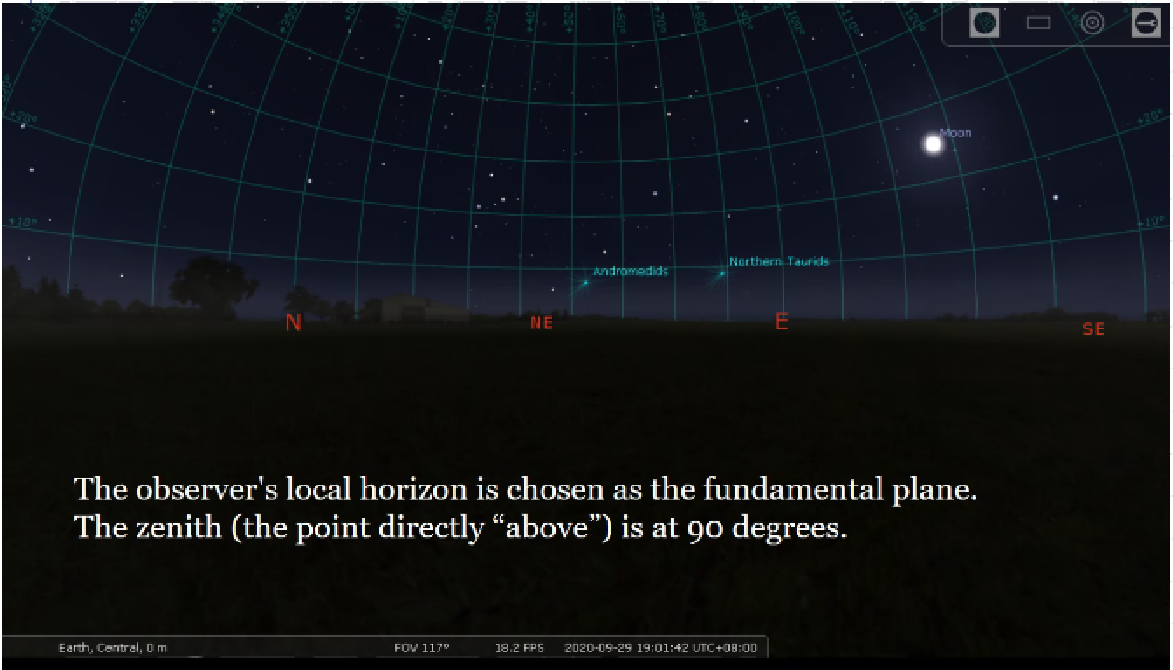
For instance, three measurements are:
At A: the shadow length is $a = 0.495$ m;
At B: the shadow length is $b = 0.500$ m;
At C: the shadow length is $c = 0.490$ m.

Then, $DE = 0.25$ days (6 hours).
The winter solstice would occur at 6 p.m. on the day of winter solstice.

To record the positions of celestial objects, a coordinate system is necessary. Assumed the Earth is surrounded by the heaven, there are at least three ancient systems of celestial coordinates:

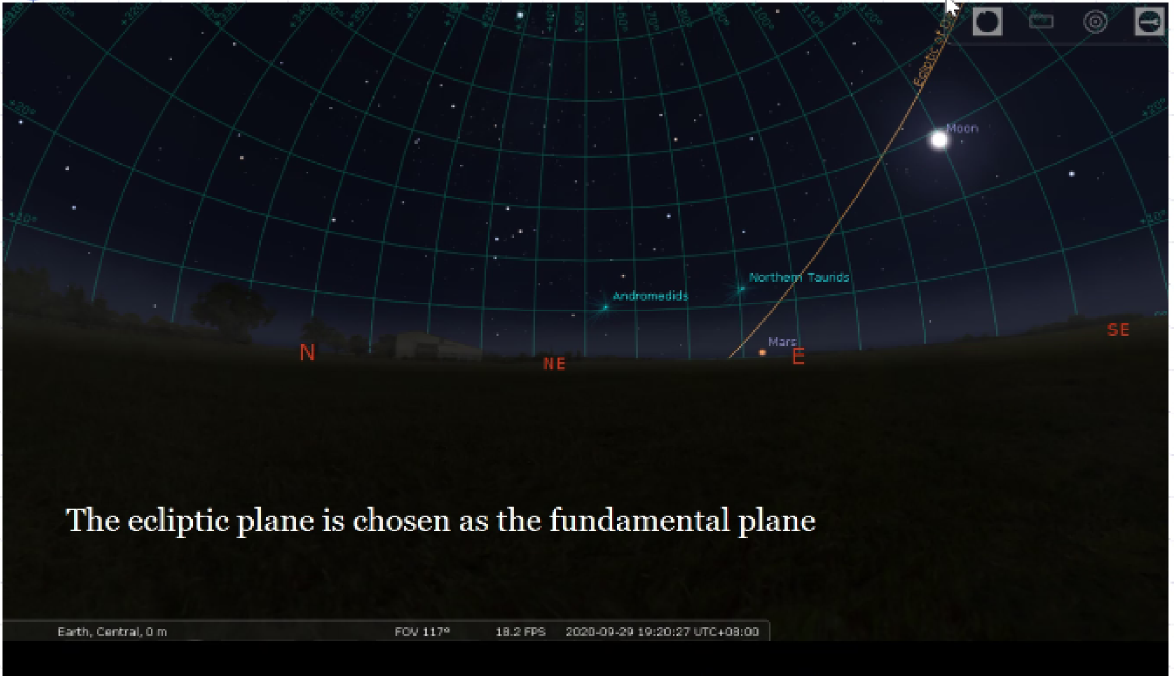
a) Arabic altazimuth system;
b) Greek ecliptic system; and
c) The equatorial Chinese system.

Arabic altazimuth system



The observer's local horizon is chosen as the fundamental plane.
The zenith (the point directly "above") is at 90 degrees.

Greek ecliptic system



Chinese equatorial system

- In ancient China, the Polar star enjoyed a special role.

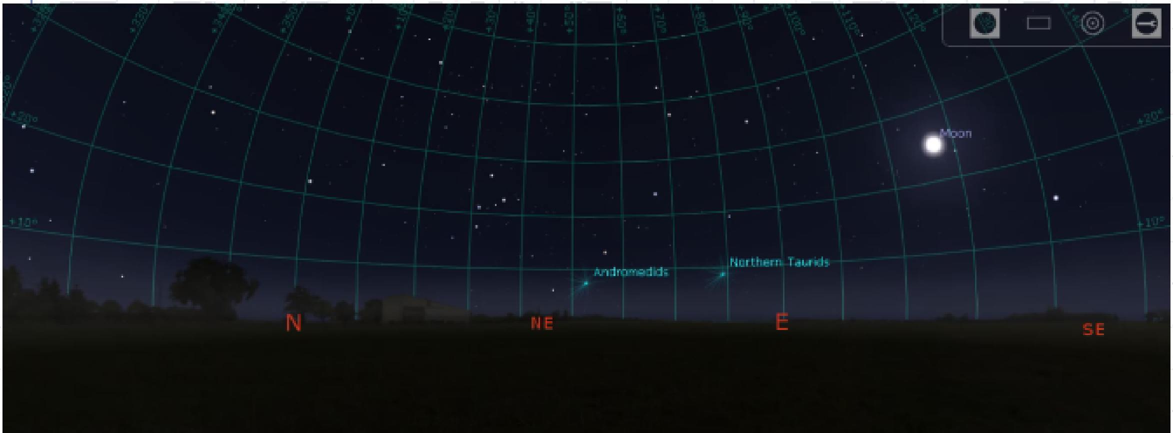
"To govern political affairs by virtue; just like the Polar star, it is in its place and arched by others." (*Analects*)

「為政以德，譬如北辰，居其所而眾星共之。」

-- 《論語 · 為政 》

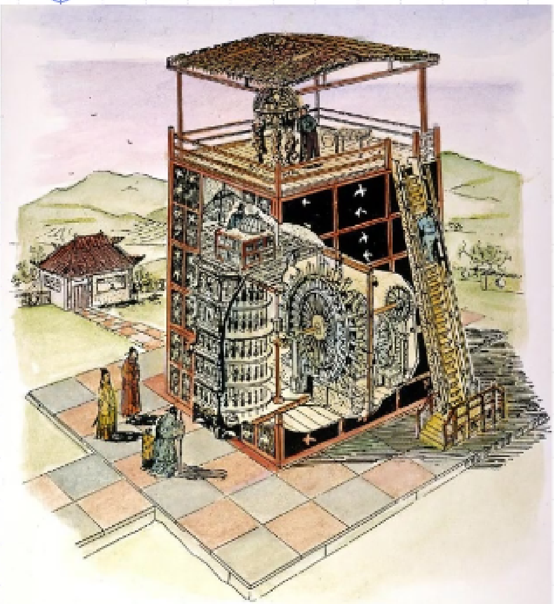
- The ancient astronomers would rather pay attention to the Polar star and circumpolar stars.

Arabic altazimuth system



- Although this choice is natural, the coordinates of the star applies only to a individual location.
- A coordinate transformation is required if an observer at different locations is searching for the same target.

Chinese equatorial system

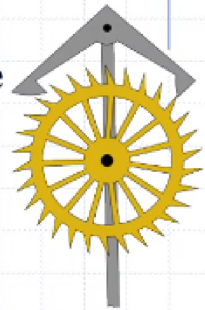


https://www.pinterest.com/pin/1683924
73539065361/

- In 1086 (the *Song* Dynasty), Su Song and his collaborators built a 12-m astronomical clock tower.
- On the top platform, there was a armillary sphere for observations; on the first floor a mechanized celestial globe was installed, operated by the hydro-mechanical clockwork.
- "Su Song Astronomical Clock Tower". https://vimeo.com/43772707.

Chinese equatorial system

- Sophisticated design of Su's Clock Tower.
- Price (2014): Chinese escapement was the source for Western escapement technology.
- Needham (1974): Choice of the equatorial coordinates in ancient China led to earlier mechanization of celestial models than the West;



- Cullen (1980): Use of the ecliptic coordinate system in the West suited the interest in planetary astronomy.