Astronomy = Astrometry ?

History of *Old* Astronomy

(古天文學：星辰定位→編製曆法，占星，導航)

辜品高

師大地科系

中研院天文所

note

Astrometry means measuring the “position” of a celestial object in a sky. Without telescopes, this is what ancient astronomers can do for their best. The periodic motion of the Sun and the Moon against the star background helped ancient people establish calendars and astrology. Therefore astrometry has had an strong impact on our daily life. Astrometry is the essence of the ancient astronomy.

In the modern astronomy, astronomers have more tools and techniques to study celestial objects. Astrometry then becomes only one of sub-disciplines of the modern astronomy. In the last few slides of this lecture, you will find much more precise astrometry achieved by modern telescopes. This “old” but “updated” technique would even help us find a earth-mass planet outside of the Solar System in the future.

Basically astrometry only gives a 2-D map of the sky. Nevertheless, Tycho adopted the idea of “parallax” to argue about the distance (i.e. the 3rd dimension) of celestial objects. We will learn more about this in one of the next lectures.

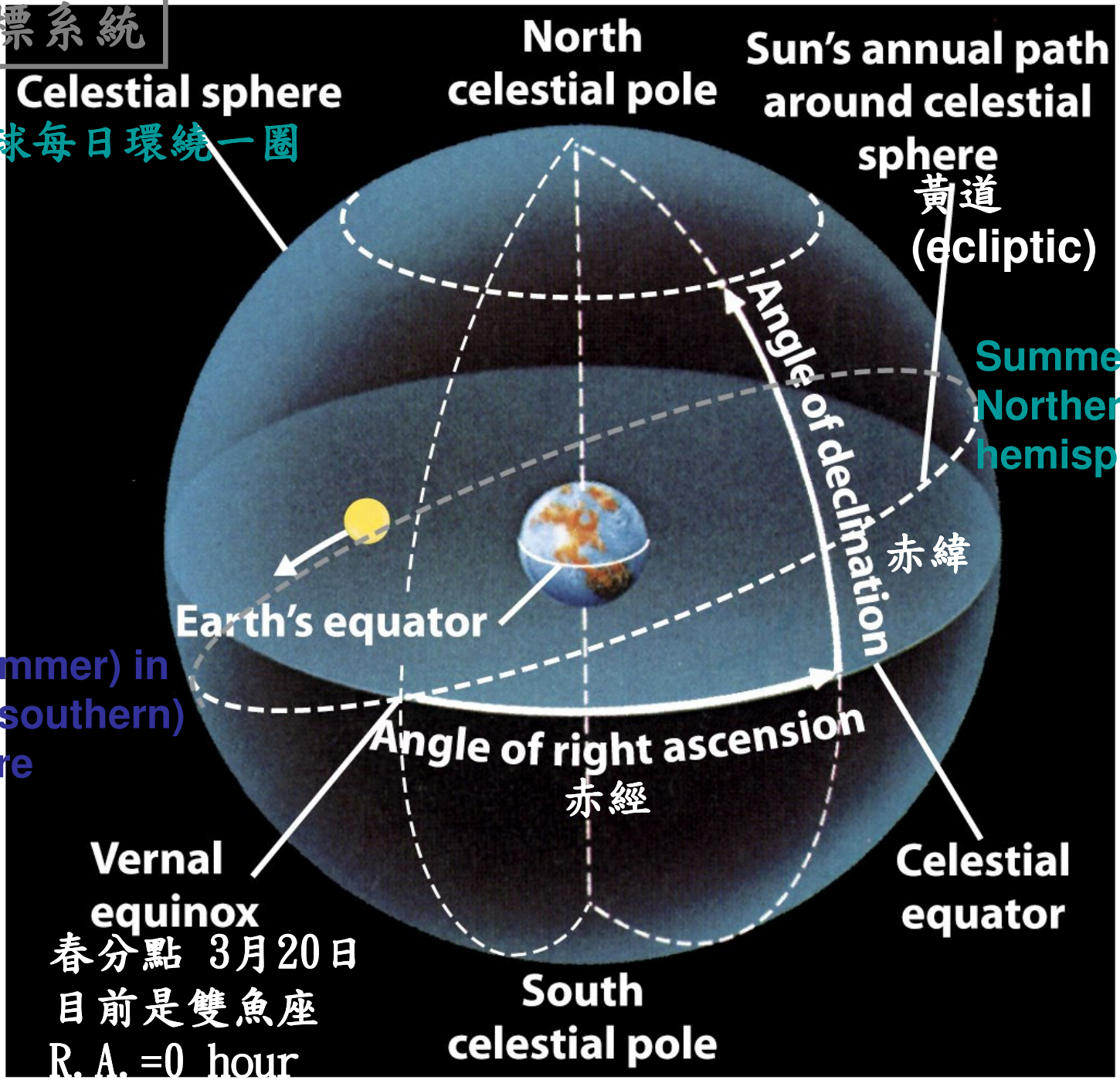
恆星(Stars) 和太陽(the Sun)

- 恆星間保持固定距離(too far!)，每日環繞北極星(Polaris for now)一周(因爲地球自轉)。西方人將其分區爲88個星座(constellation)。
- 太陽基本上每日環繞北極星(隨恆星東升西降)，但是以緩慢的速度(一年)通過13個星座(黃道12宮)而回到原星座(因爲地球公轉)。太陽的仰角隨季節而變地球(自轉軸與公轉軌道面不垂直)。

天球座標系統

恆星在天球每日環繞一圈

From the view of the earth



Summer (winter) in Northern (southern) hemisphere

winter (summer) in northern (southern) hemisphere

Figure 1-8
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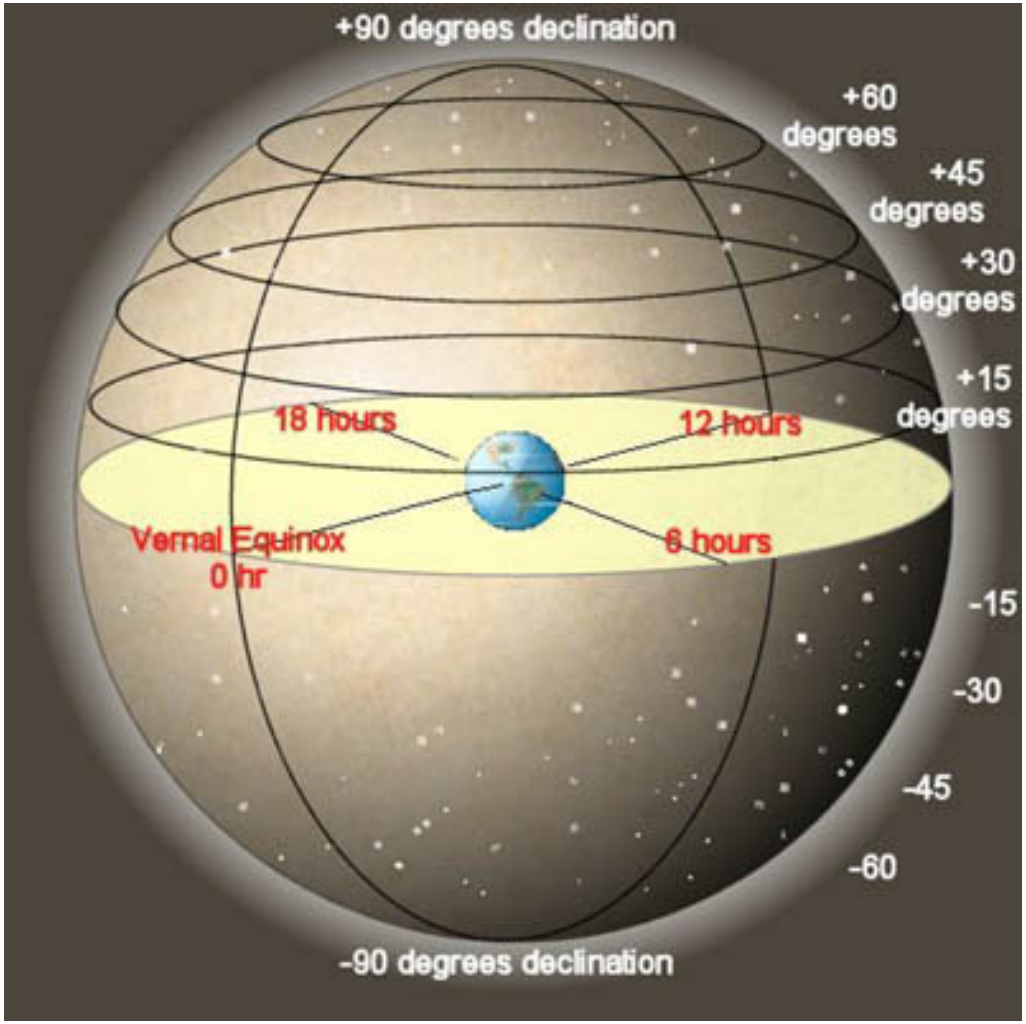
天球座標系統



http://www.astro.washington.edu/larson/Astro101/LecturesFraknoi/astro101s03.html

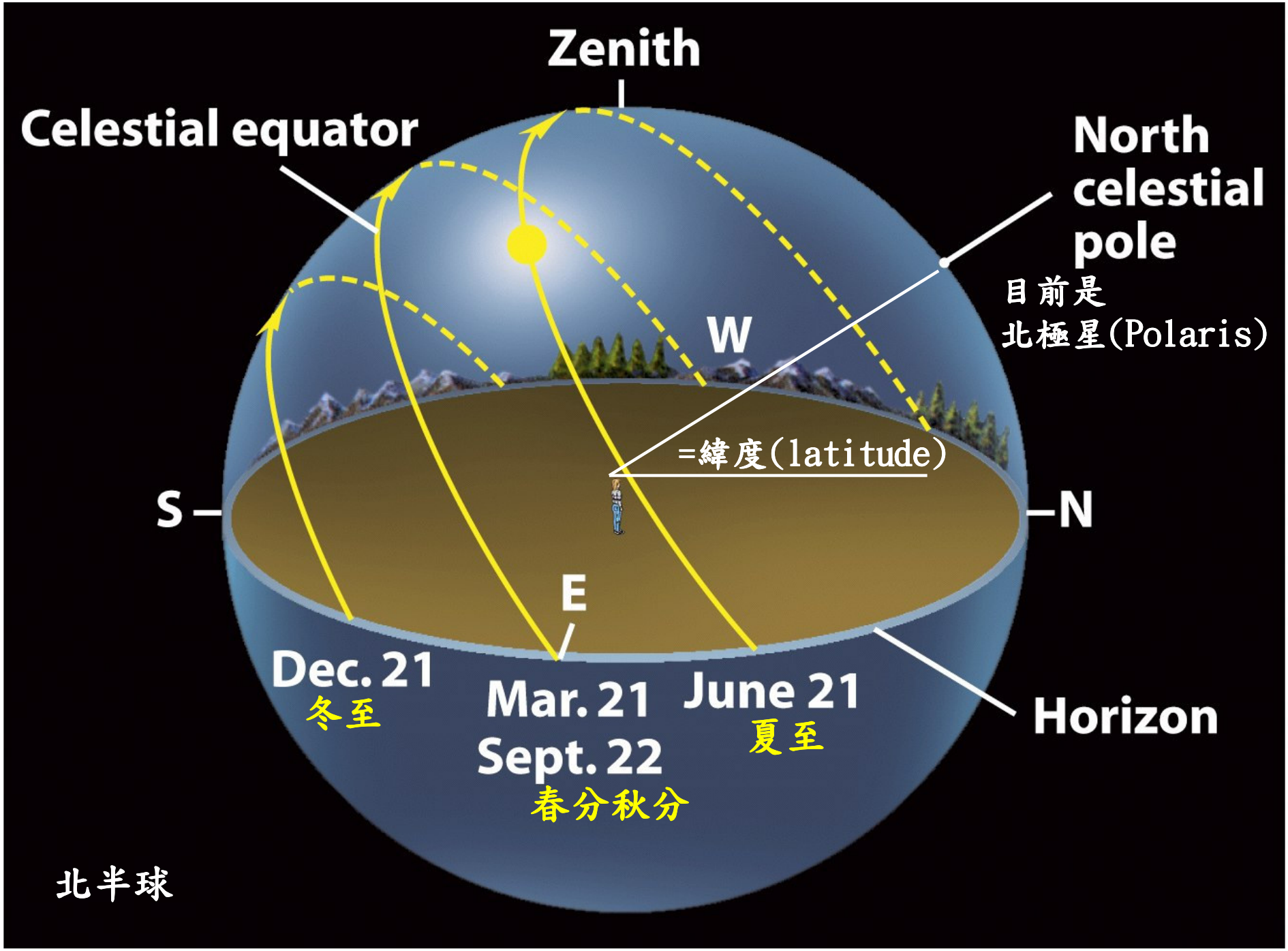


Figure 1-19
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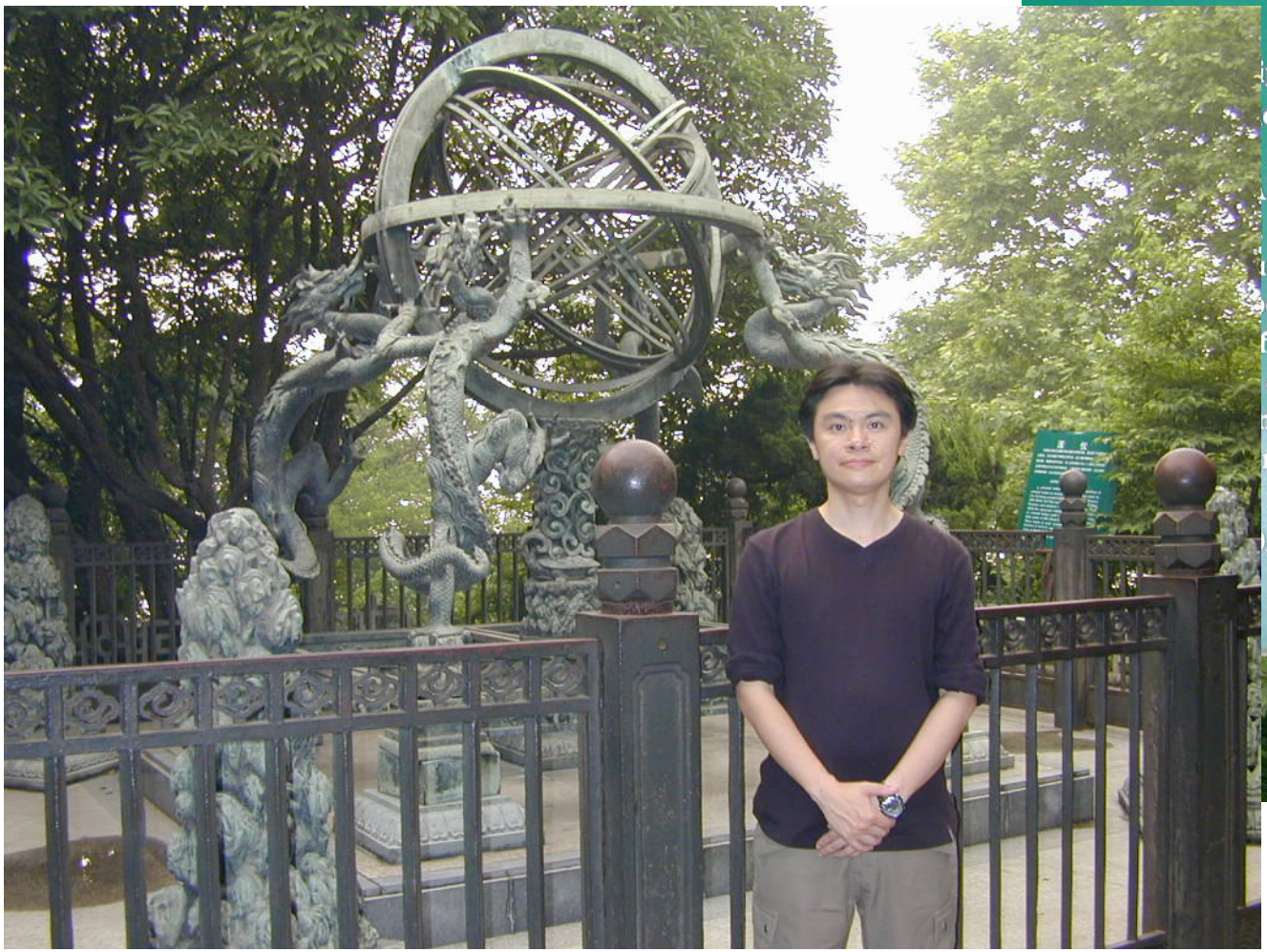
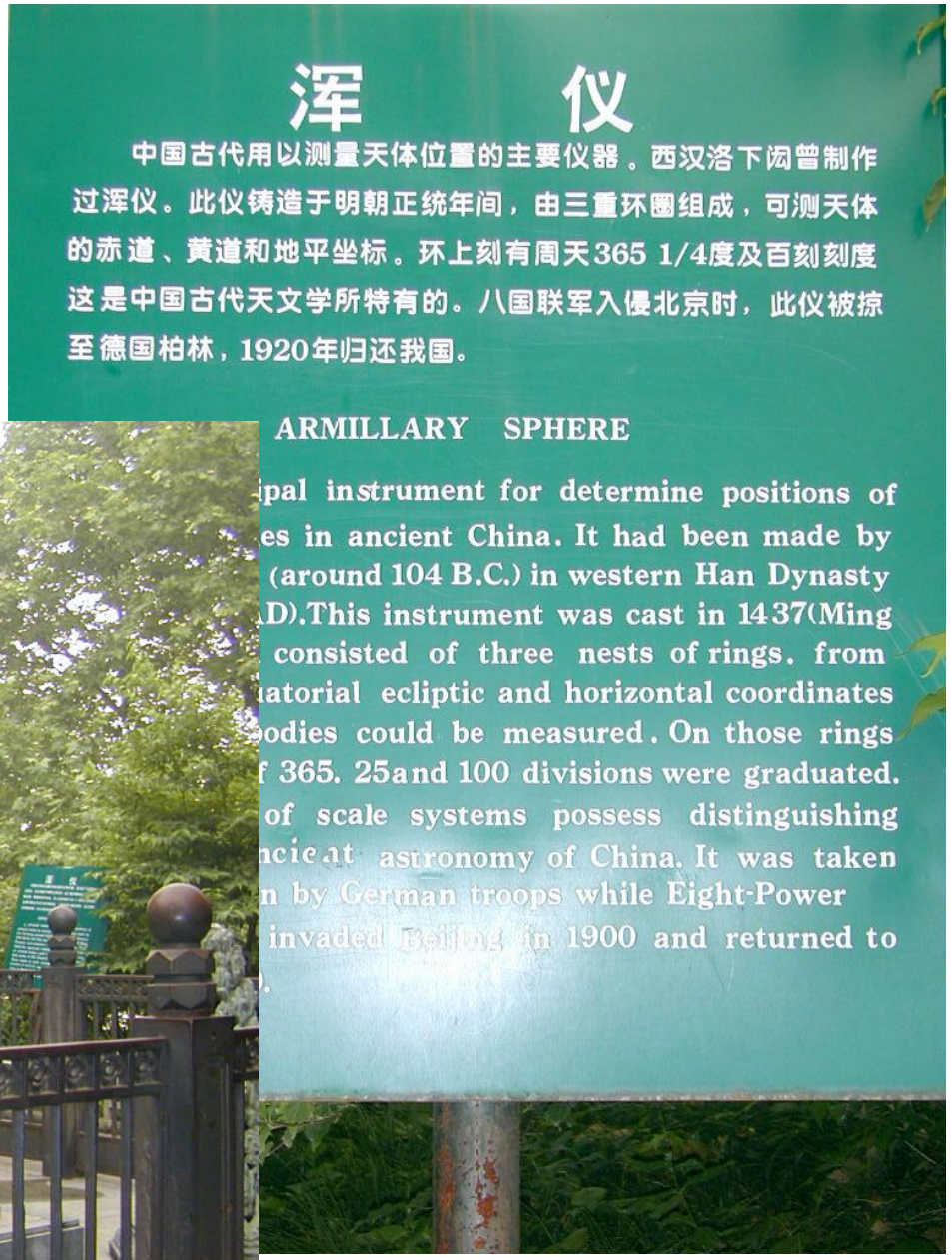
渾天儀

東漢張衡(西元78-139)
任太史令(編製曆法和為皇帝占星)





攝於紫金山天文台

為什麼座北朝南的房子比較好

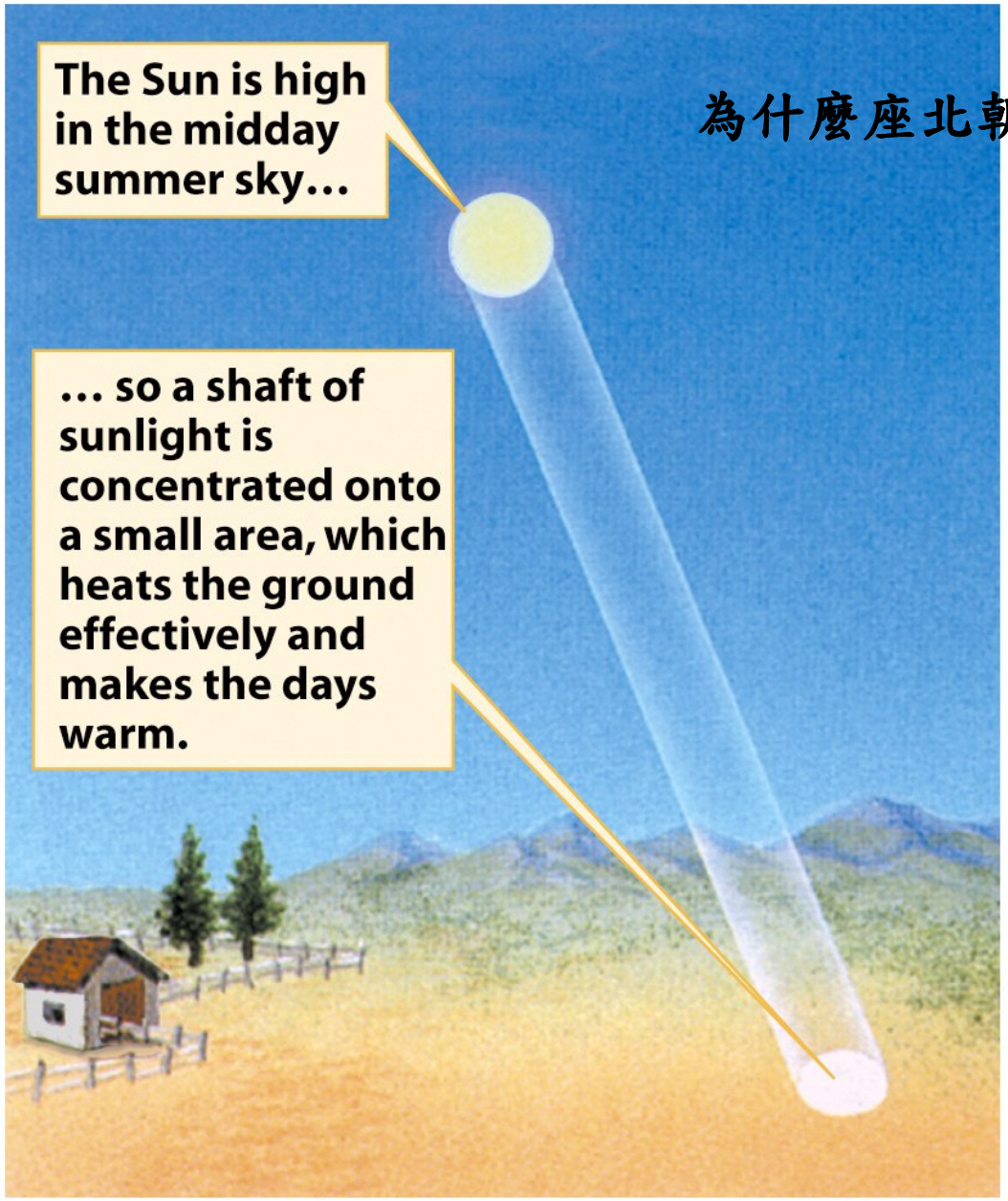


Figure 1-20a
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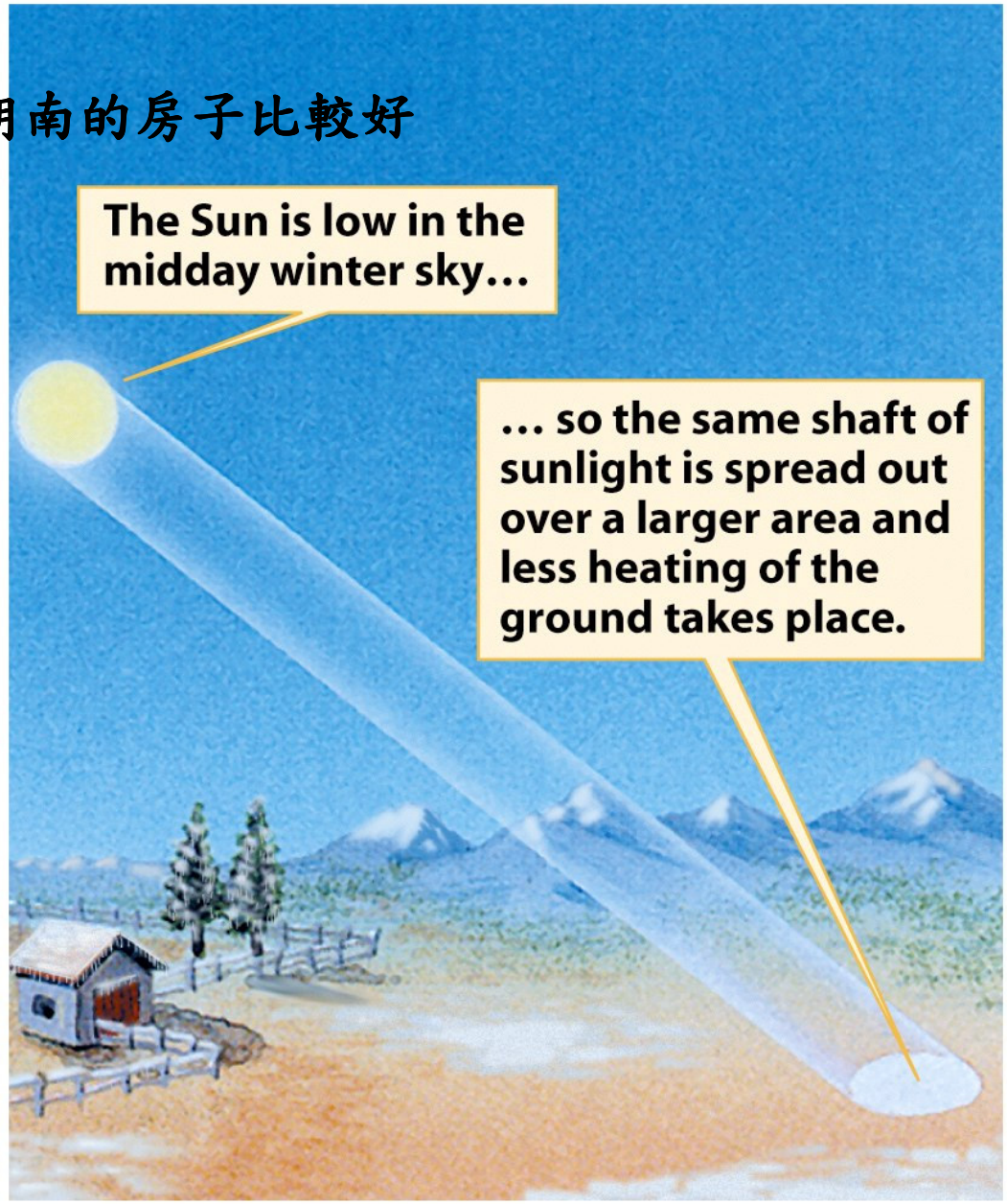

Figure 1-20b
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河南登封縣告成鎮觀星臺(郭守敬 1231-1316)

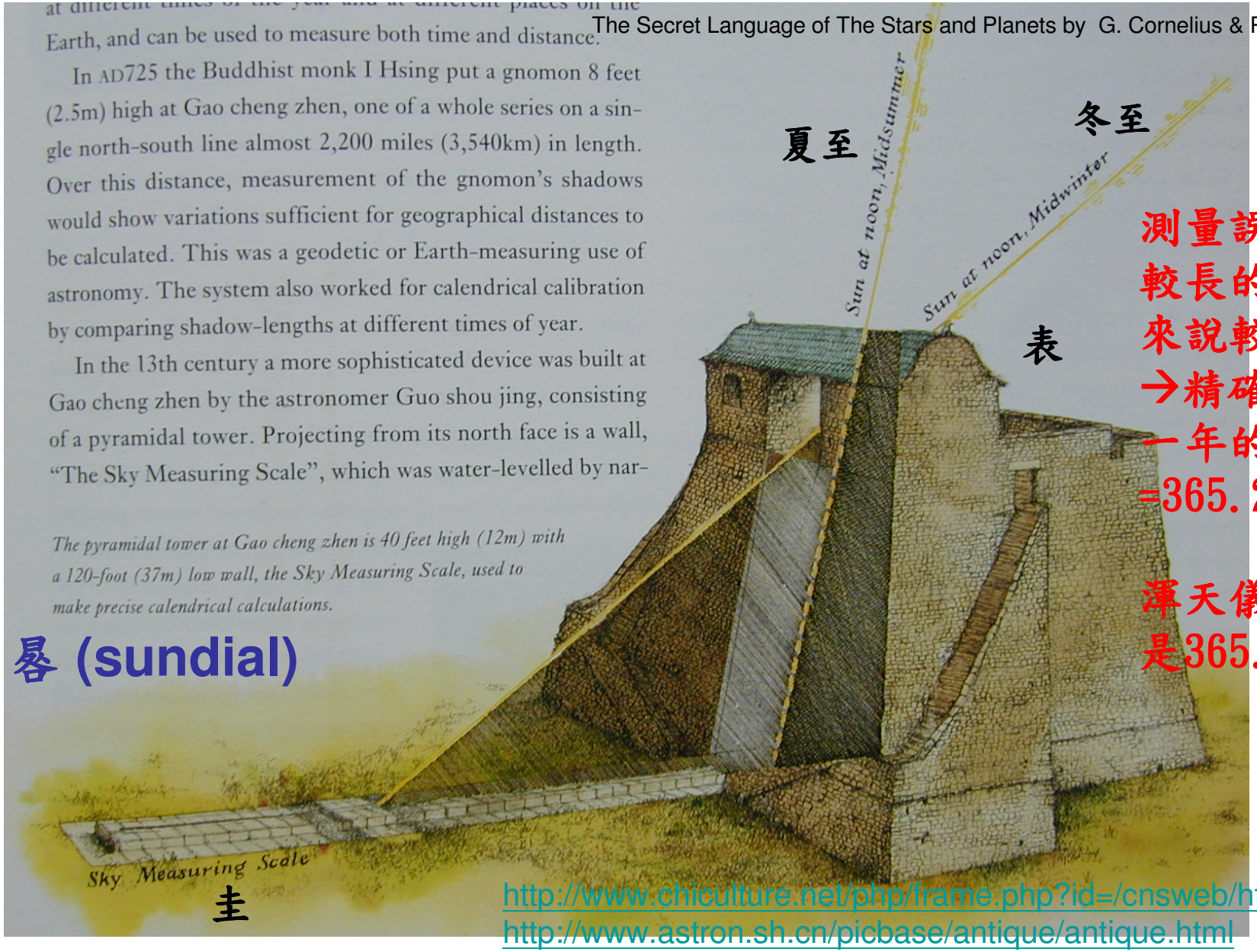
The Secret Language of The Stars and Planets by G. Cornelius & P. Devereux

Earth, and can be used to measure both time and distance.

In AD725 the Buddhist monk I Hsing put a gnomon 8 feet (2.5m) high at Gao cheng zhen, one of a whole series on a single north-south line almost 2,200 miles (3,540km) in length. Over this distance, measurement of the gnomon's shadows would show variations sufficient for geographical distances to be calculated. This was a geodetic or Earth-measuring use of astronomy. The system also worked for calendrical calibration by comparing shadow-lengths at different times of year.

In the 13th century a more sophisticated device was built at Gao cheng zhen by the astronomer Guo shou jing, consisting of a pyramidal tower. Projecting from its north face is a wall, "The Sky Measuring Scale", which was water-levelled by nar-

The pyramidal tower at Gao cheng zhen is 40 feet high (12m) with a 120-foot (37m) low wall, the Sky Measuring Scale, used to make precise calendrical calculations.



日晷 (sundial)

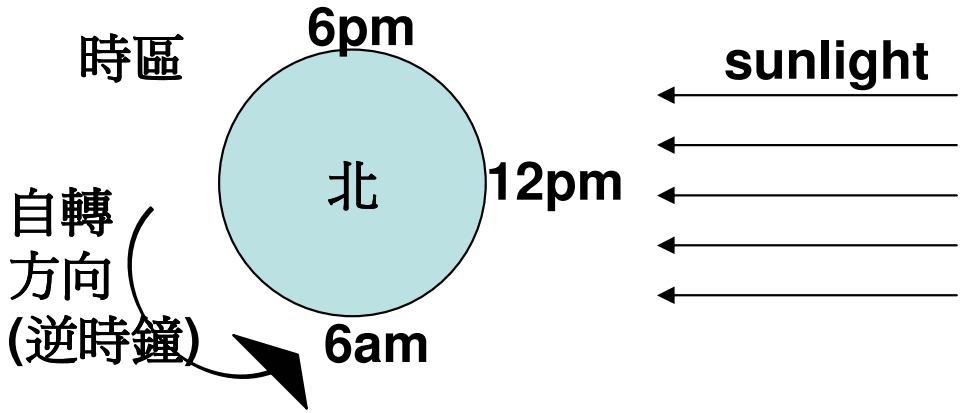
測量誤差對較長的表影來說較小
→精確測量一年的長度
=365.25天

渾天儀一圈是365.25度

http://www.chiculture.net/php/frame.php?id=/cnsweb/html/0801
http://www.astron.sh.cn/picbase/antique/antique.html

The fact is…

- 地球在自轉(造成一日)以及公轉(造成一年)，其自轉軸與公轉軌道面(黃道)並不垂直(造成四季、晝夜不等長)。**btw, do you still remember what causes “a month”?**
- **one year = 365.25 days** (四年一閏)
- 夏(冬)季時地球反而離太陽較遠(近)！這是因爲地球公轉軌道並不很橢圓。火星也是一樣，但軌道有點橢圓，四季變化較劇烈。



In summer (winter), day Is longer (shorter) than night.
But 注意南北極

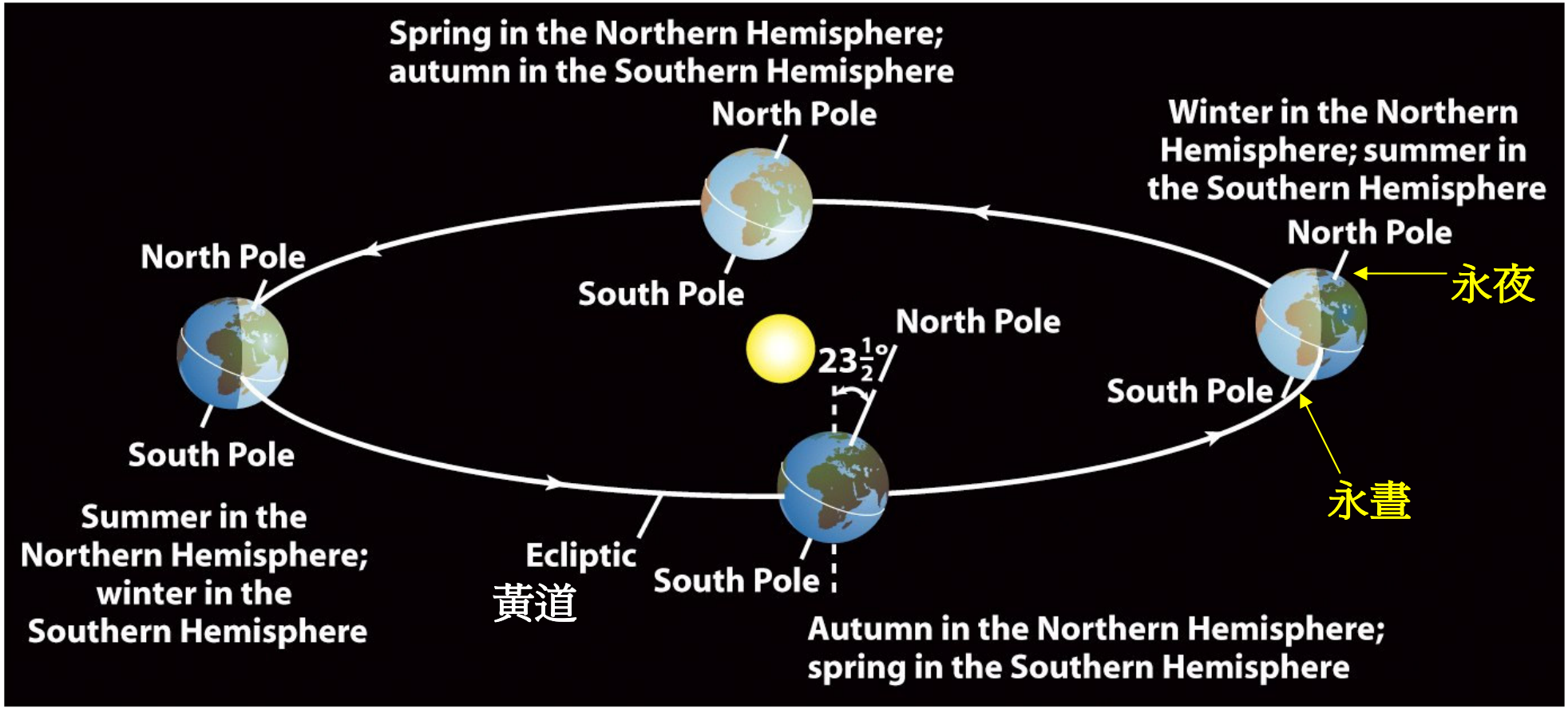


Figure 1-16
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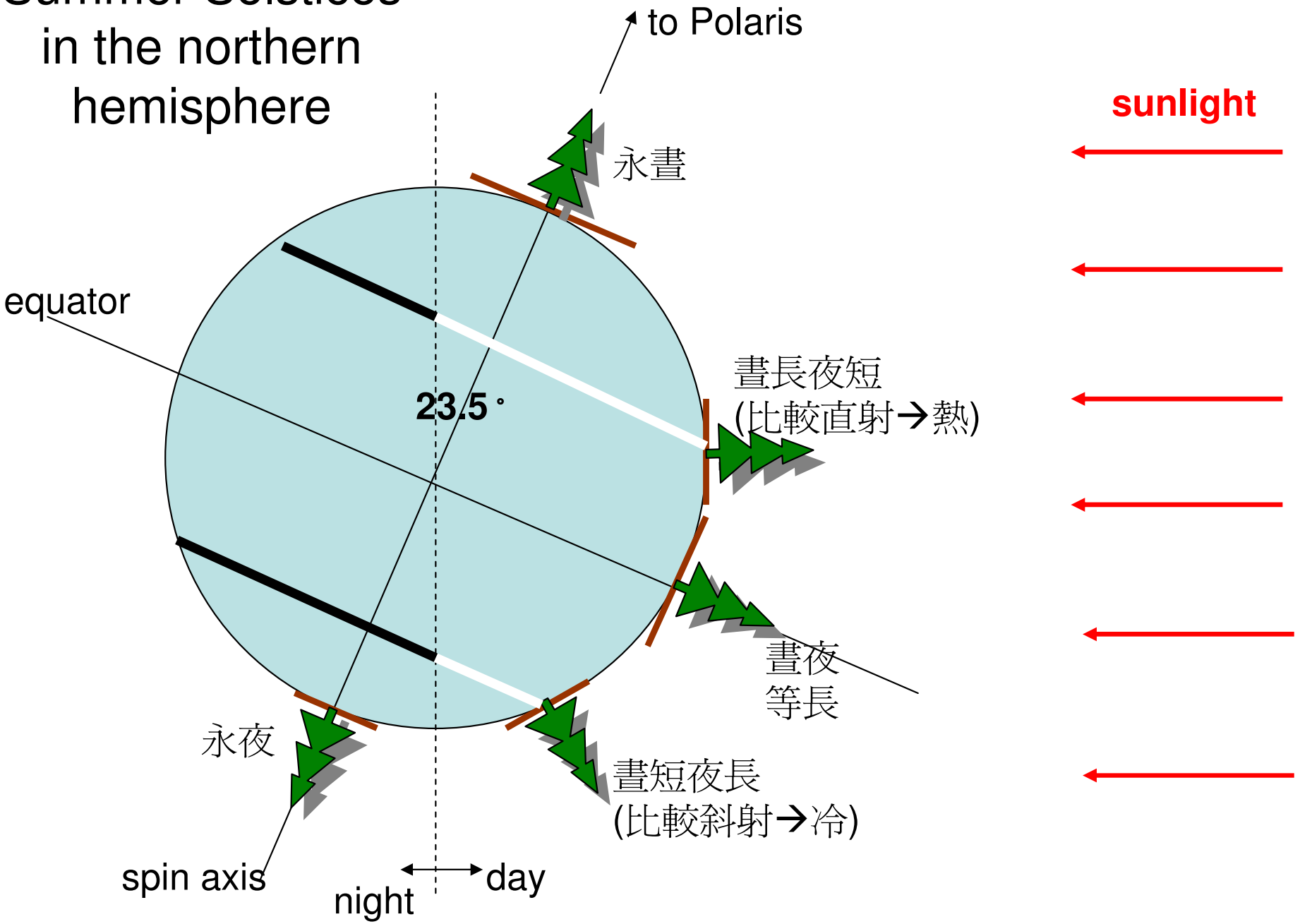
Summer Solstices in the northern hemisphere



北回歸線

嘉義縣

花蓮縣

季節和星座

summer triangle

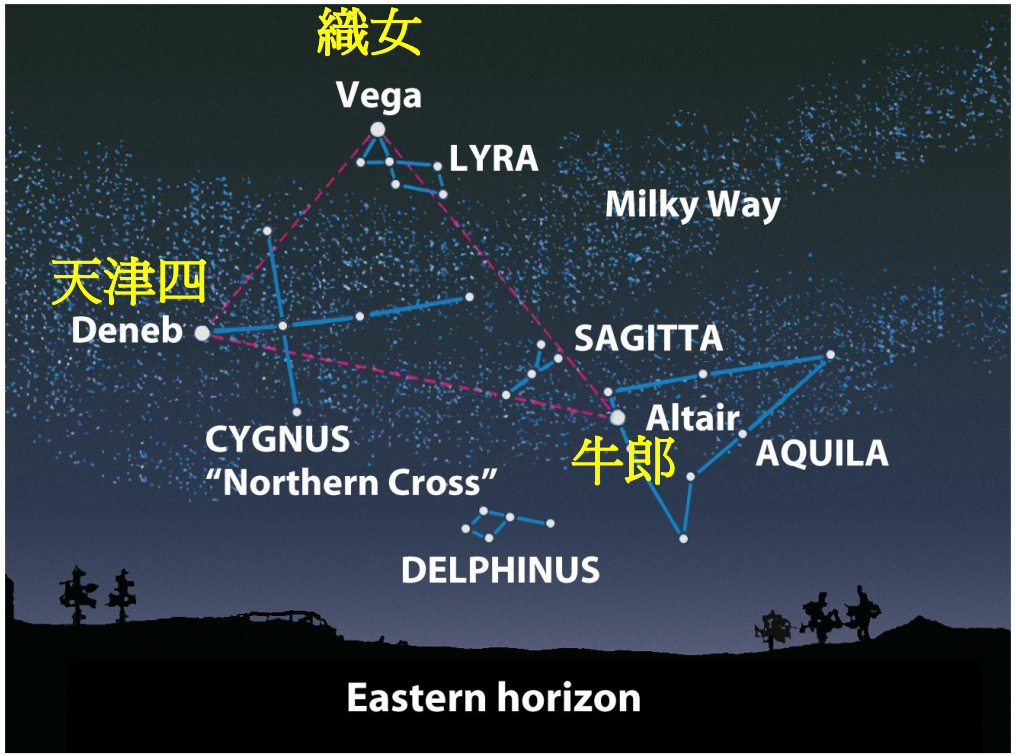


Figure 1-7
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winter triangle

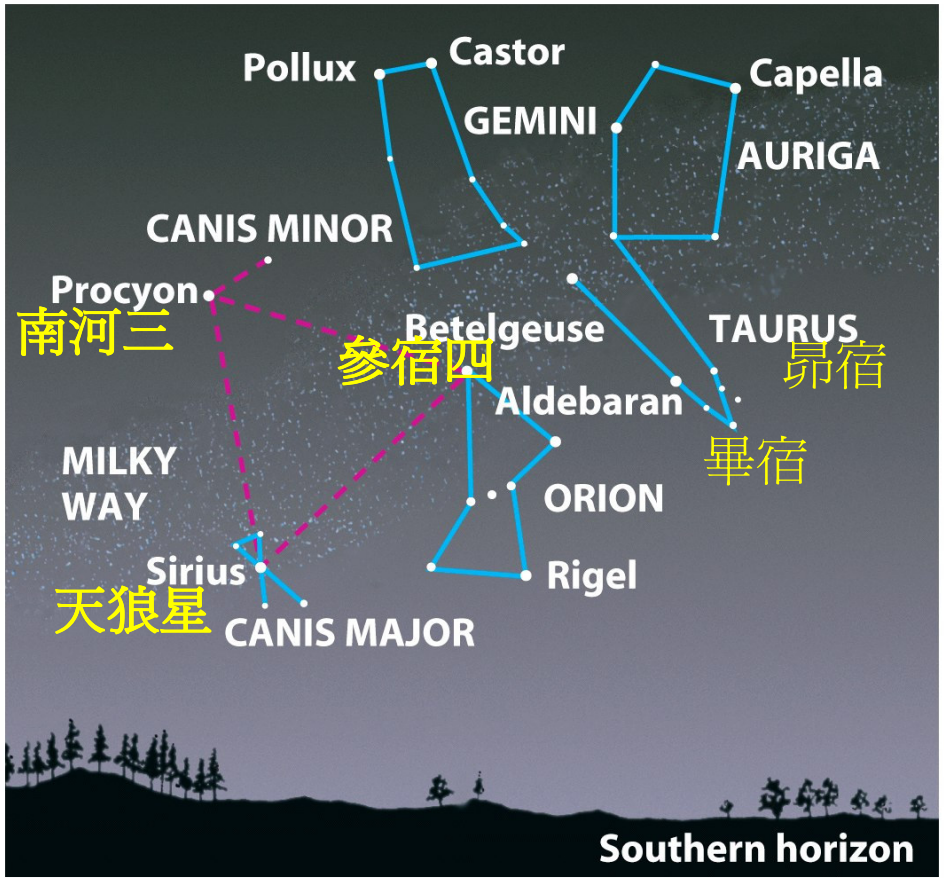

Figure 1-6
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銀河並不沿著黃道:太陽系的軌道面
與銀河系的盤面不平行

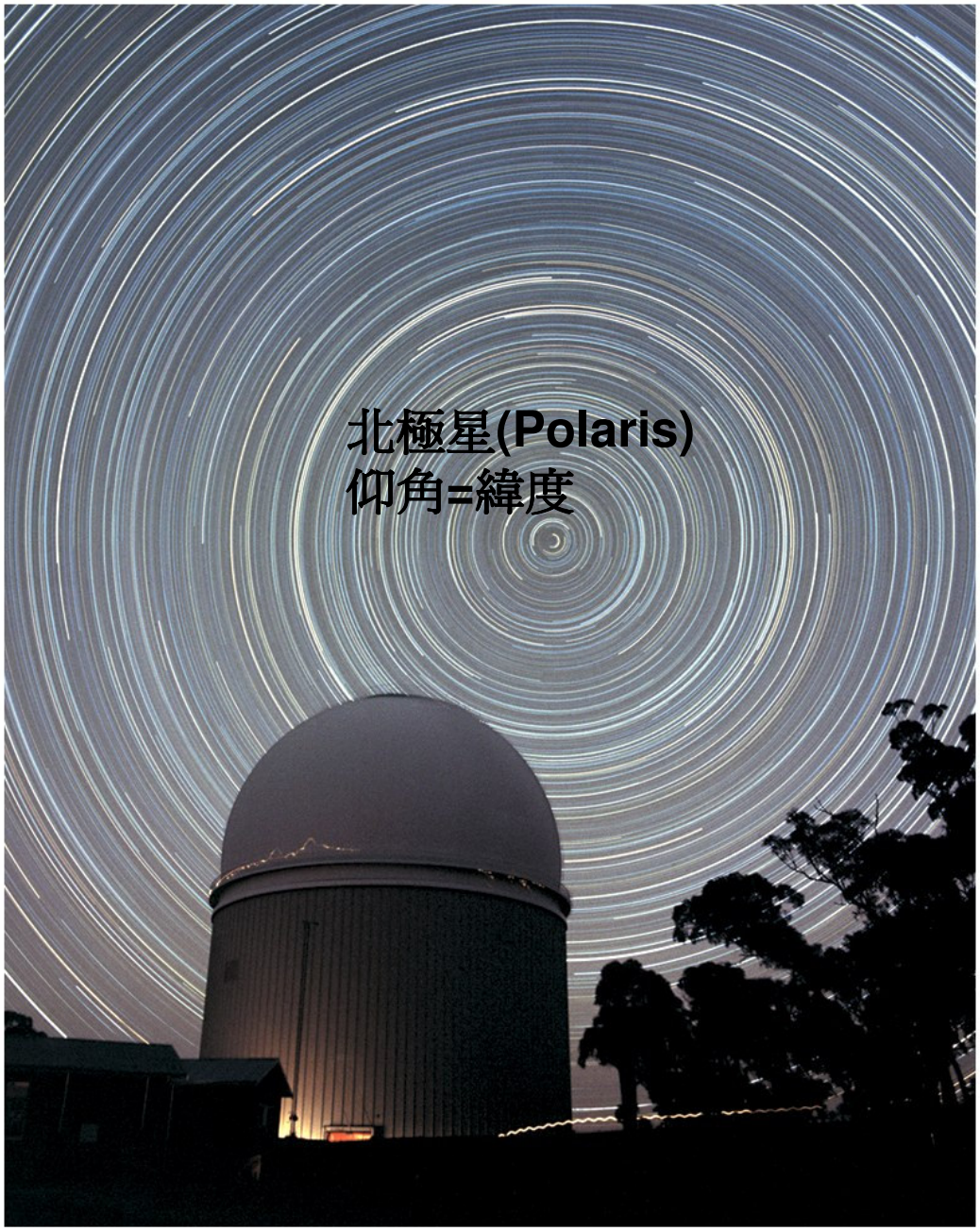

Figure 1-9
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Figure 1-11
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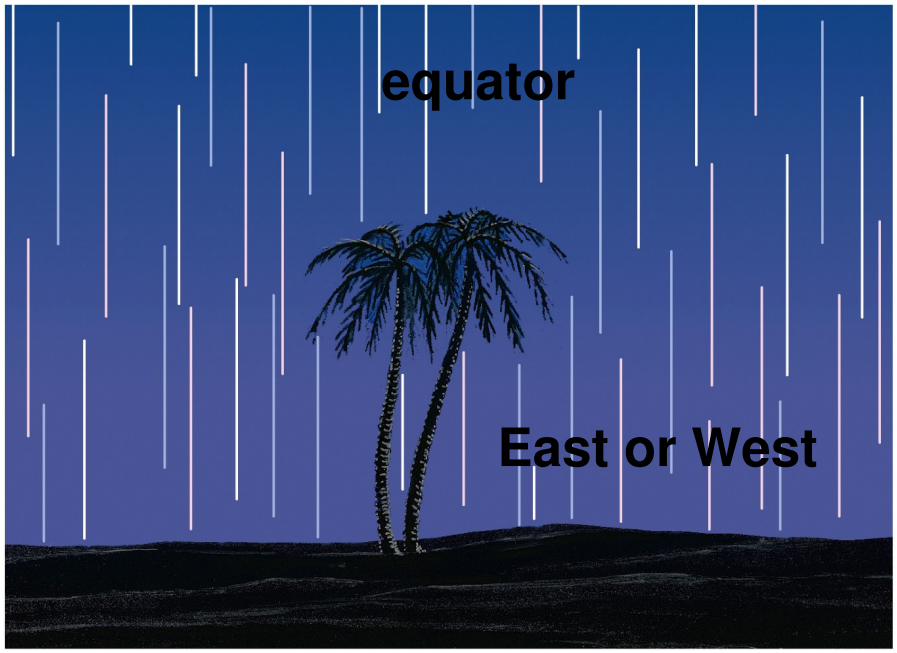

Figure 1-12
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TABLE 1-1 The 13 Constellations of the Zodiac

黃道13宮?!

Constellation	Dates of Sun's passage through
Pisces	March 13–April 20
Aries	April 20–May 13
Taurus	May 13–June 21
Gemini	June 21–July 20
Cancer	July 20–August 11
Leo	August 11–September 18
Virgo	September 18–November 1
Libra	November 1–November 22
Scorpius	November 22–December 1
Ophiuchus	December 1–December 19
Sagittarius	December 19–January 19
Capricorn	January 19–February 18
Aquarius	February 18–March 13

這裡所給的日期與占星術上的日期很不同(相差一個宮！參閱 http://en.wikipedia.org/wiki/Zodiac)

「黃道十二宮」是由古代巴比倫與希臘的天文學家所觀測出來，但「歲差運動」造成兩千多年來春分點一共向西移動了三十多度，這使得兩千多年前原本位於白羊座內的春分點，已經向西移動到雙魚座裡面了。

蛇夫座 is not included in astrology →

Table 1-1
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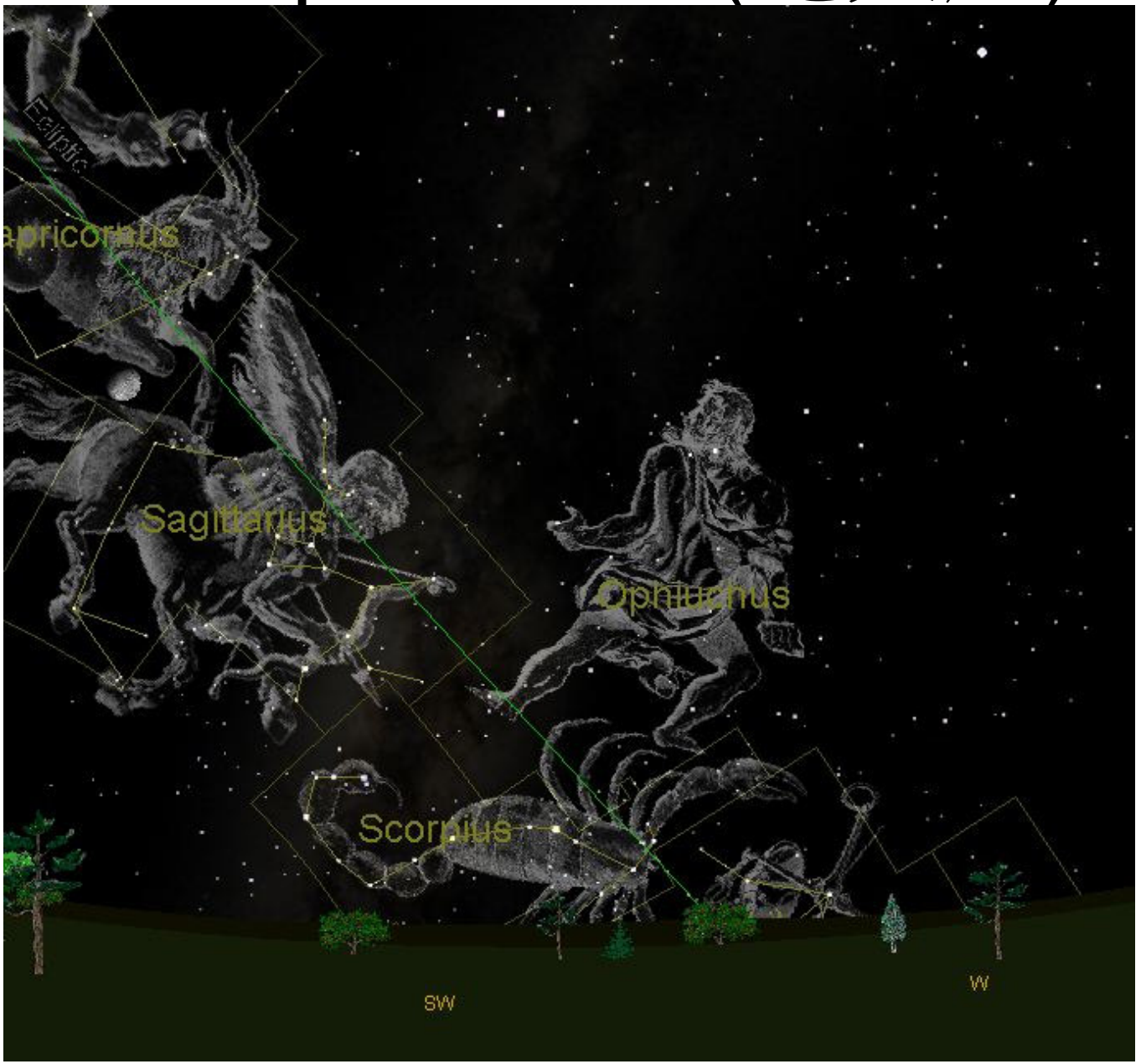
Mismatch by one sign due to Precession

Sign	***Astrology***	***Actual***
Aries(Ram)	Mar 21 - Apr 19	Apr 20 - May 13
Taurus(Bull)	Apr 20 - May 20	May 13 - Jun 21
Gemini(Twins)	May 21 - Jun 20	Jun 21 - Jul 20
Cancer(Crab)	Jun 21 - Jul 22	Jul 20 - Aug 11
Leo(Lion)	Jul 23 - Aug 22	Aug 11 - Sep 18
Virgo(Virgin)	Aug 23 - Sep 22	Sep 18 - Nov 1
Libra(balance)	Sep 23 - Oct 22	Nov 1 - Nov 22
Scorpio(Scorpion)	Oct 23 - Nov 21	Nov 22 - Dec 1
Ophiuchus	***-***	***Dec 1 - Dec 19***
Sagittarius(Archer)	Nov 22 - Dec 21	Dec 19 - Jan 19
Capricorn(Goat)	Dec 22 - Jan 19	Jan 19 - Feb 18
Aquarius(Water Bearer)	Jan 20 - Feb 18	Feb 18 - Mar 13
Pisces(Fishes)	Feb 19 - Mar 20	Mar 13 - Apr 20

Ophiuchus (蛇夫座)



The ecliptic passes only small part of Ophiuchus ☹

Note that the ecliptic does not align with the Milky Way.

Astrology & Astronomy

- Ancient times: astrology was based on astronomy
- Nowadays: conflicts between astrology & astronomy ☹
  example I: Astrologers ignore the 13th sign of horoscope and precession.

  example II: Marina Bai (born 1965), a Russian astrologer, sued NASA in July, 2005 for US$300-310 million. She claimed that the NASA probe that crashed into the Tempel 1 comet will interfere with her astrology work because the comet would no longer be the same, claiming it "ruins the natural balance of forces in the universe".

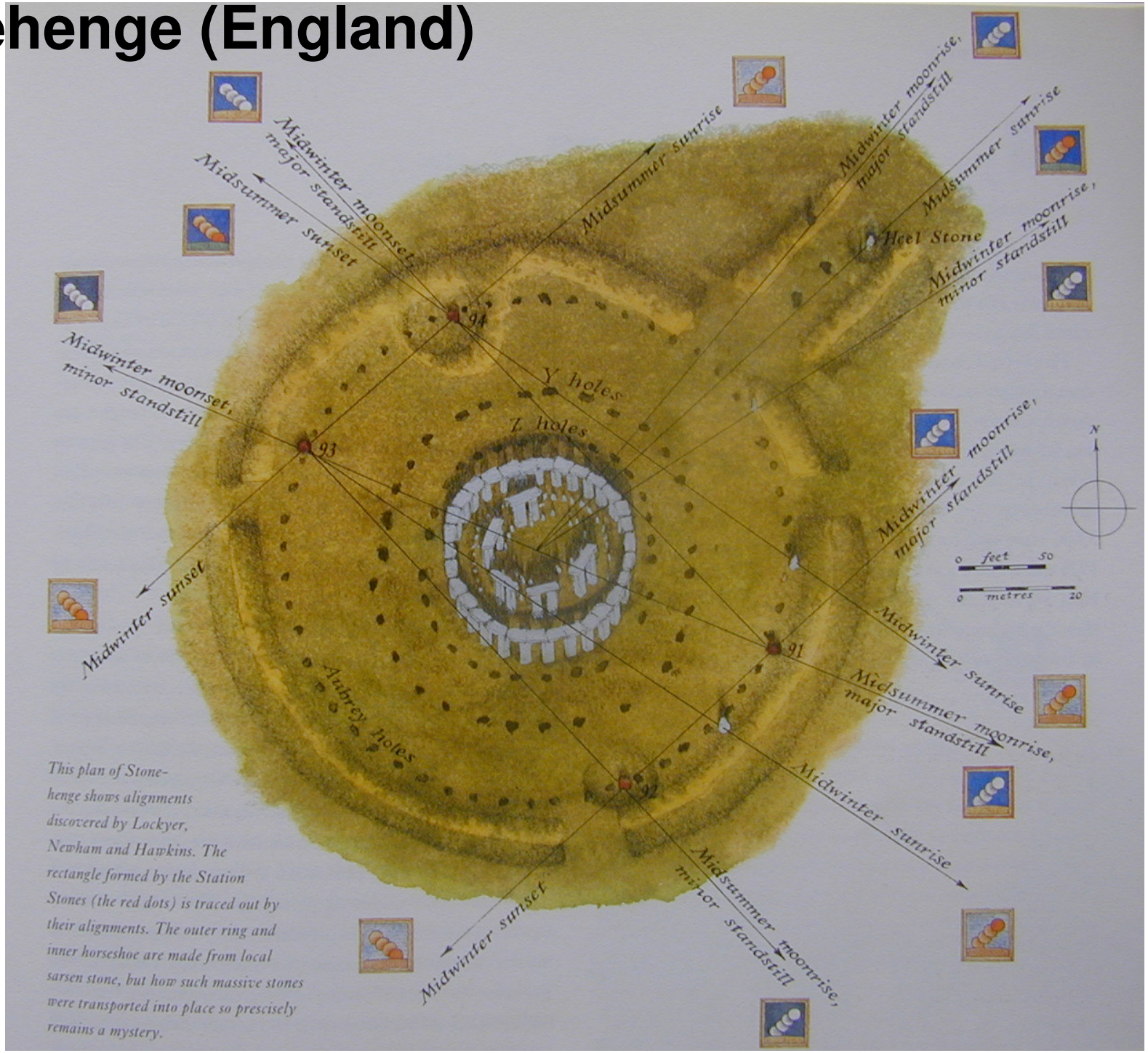
remark: alchemy → chemistry
astrology → astronomy

二十八星宿

- 角亢氐房心尾箕斗牛女虛危室壁奎婁胃昴畢觜參井鬼柳星張翼軫
- 中國的“黃道十二宮”
- 沿黃道，天球赤道，還是白道？
- 土星(鎮星)週期29.46年 → 一年坐鎮一宿？

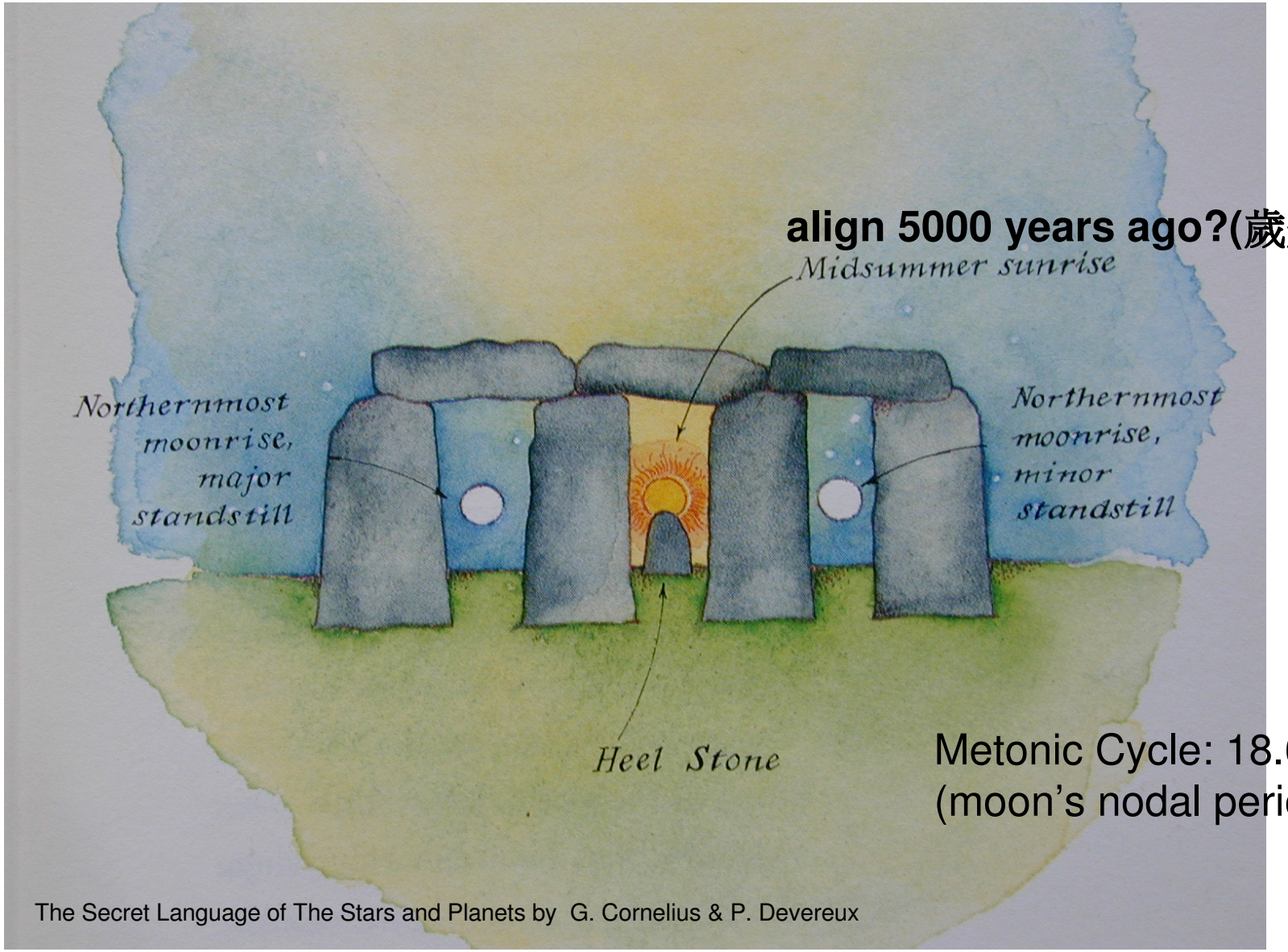
For details: 鄭文光《中國天文學源流》

Stonehenge (England)



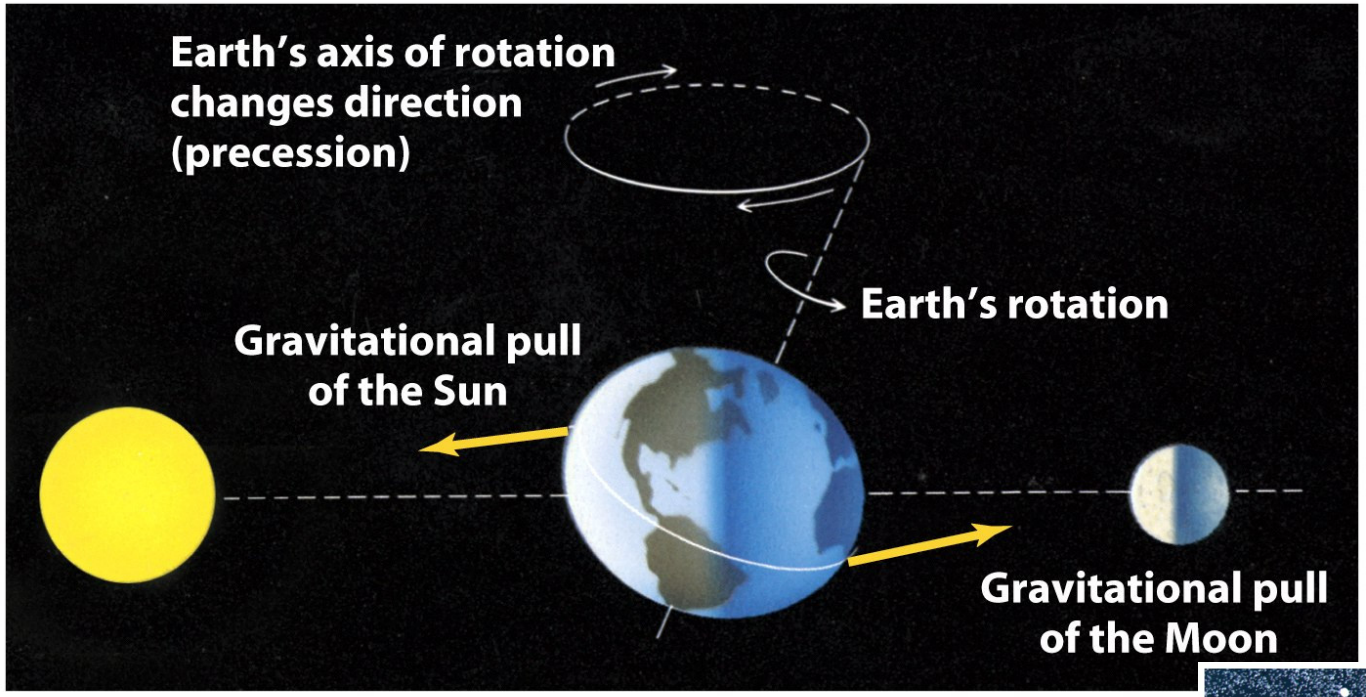
This plan of Stonehenge shows alignments discovered by Lockyer, Newham and Hawkins. The rectangle formed by the Station Stones (the red dots) is traced out by their alignments. The outer ring and inner horseshoe are made from local sarsen stone, but how such massive stones were transported into place so prescisely remains a mystery.

Stonehenge (England)



align 5000 years ago?(歲差)

Metonic Cycle: 18.6 years
(moon's nodal period)



歲差(precession)：地球自轉軸有如陀螺軸以26000年旋轉一圈

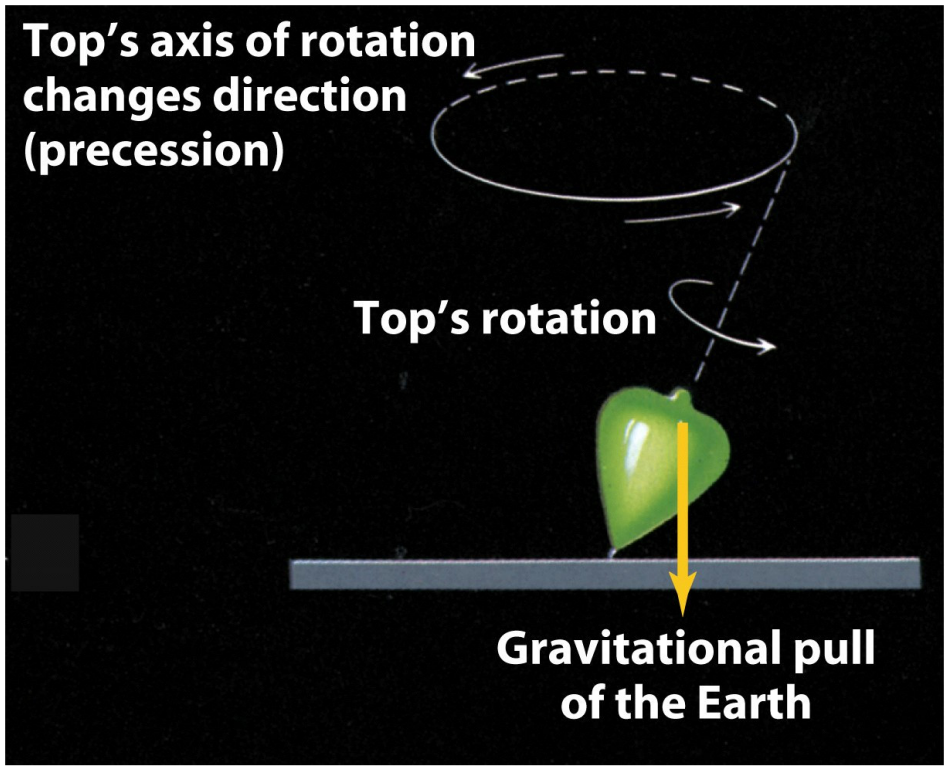


Figure 1-21b
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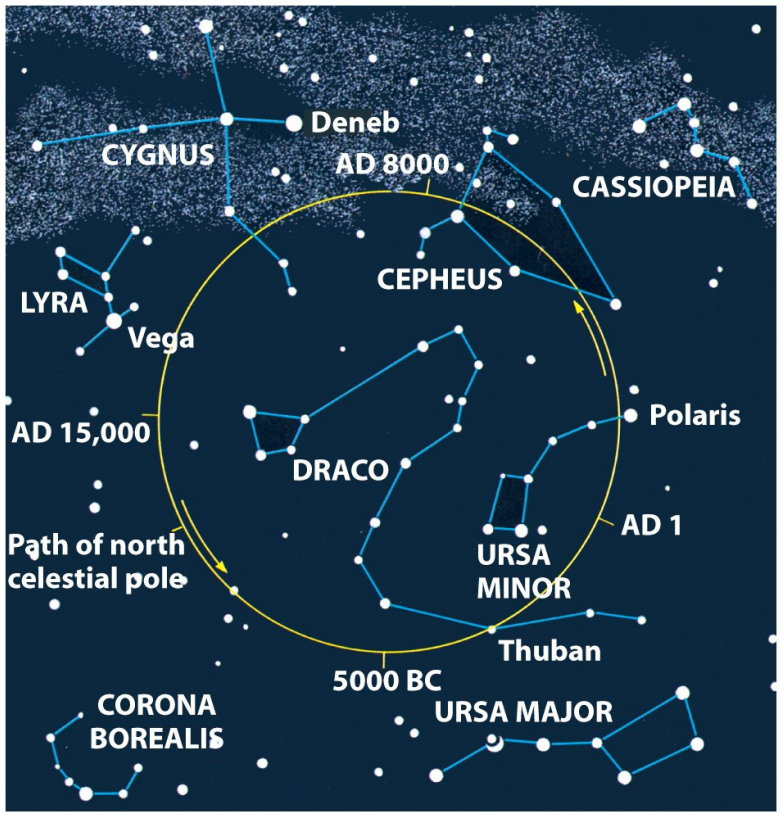
星・月亮・太陽



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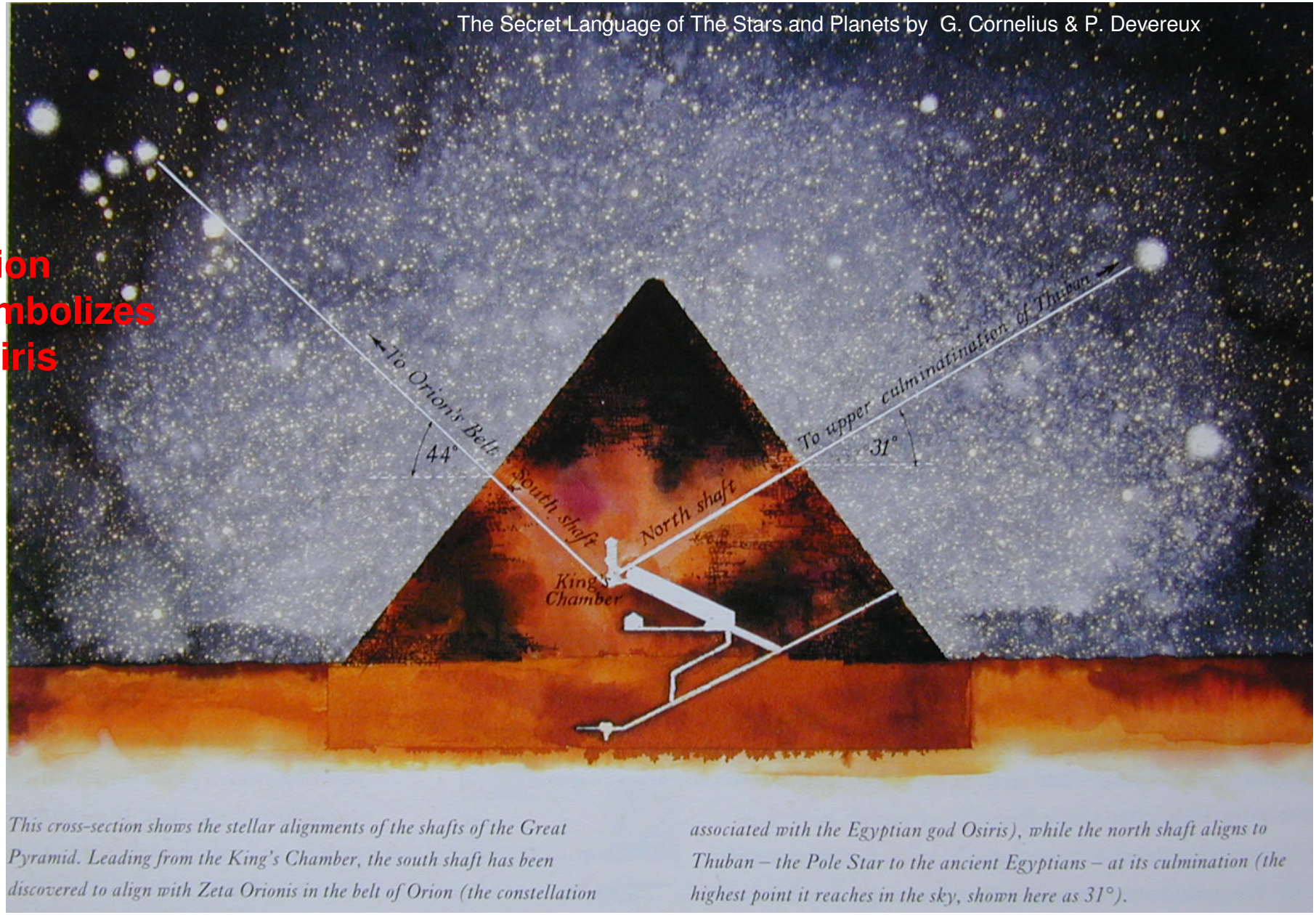
The Great Pyramid (Egypt, 2600BC)

Orion symbolizes Osiris



中國曆法爲陰陽曆

- 農曆屬於陰陽曆並用，一方面以月球繞地球運行一周為一「月」，平均月長度等於「朔望月」，這一點與陰曆原則相同，所以也叫「陰曆」；另一方面設置「閏月」以使每年的平均長度儘可能接近回歸年，同時設置二十四節氣以反映季節的變化特徵，因此農曆集陰、陽兩歷的特點於一身，也被稱為「陰陽曆」。至今幾乎全世界所有華人以及朝鮮半島和越南等國家，仍舊使用農曆推算傳統節日如春節、中秋節、端午節等節日。
- 二十四節氣每一個分別相應於太陽在黃道上每運動15°所到達的一定位置。春季：立春 雨水 驚蟄 春分 清明 穀雨夏季：立夏 小滿 芒種 夏至 小暑 大暑秋季：立秋 處暑 白露 秋分 寒露 霜降冬季：立冬 小雪 大雪 冬至 小寒 大寒

Direct & Retrograde(逆行) Motion

行星(會走的星)　　**planet (Greek) means wanderer**　　惑星(日文)

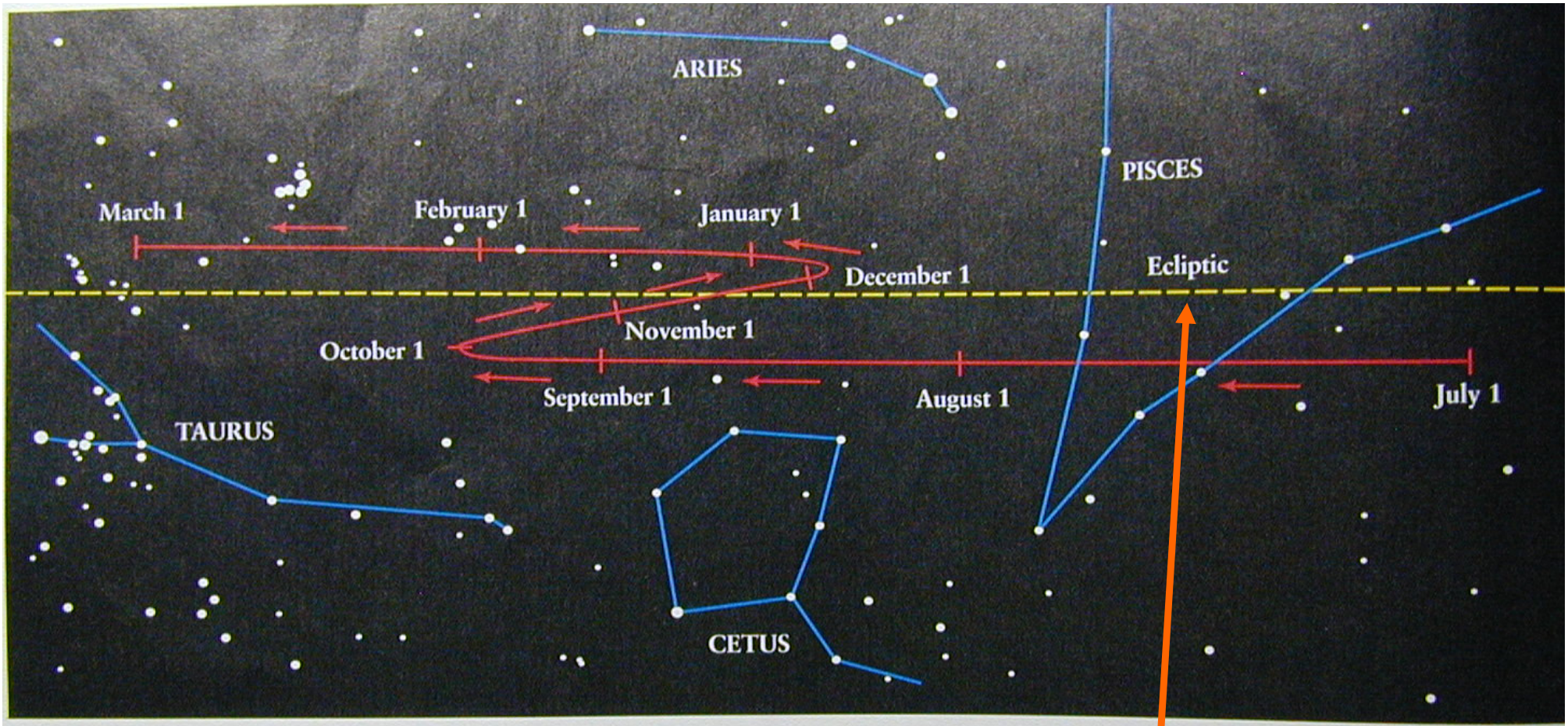


FIGURE 2-1 The Path of Mars in 2005–2006 From July 2005 through February 2006, Mars moves across the constellations of Pisces, Aries, and Taurus. From October 1 through December 12, 2005, Mars's motion will be retrograde.

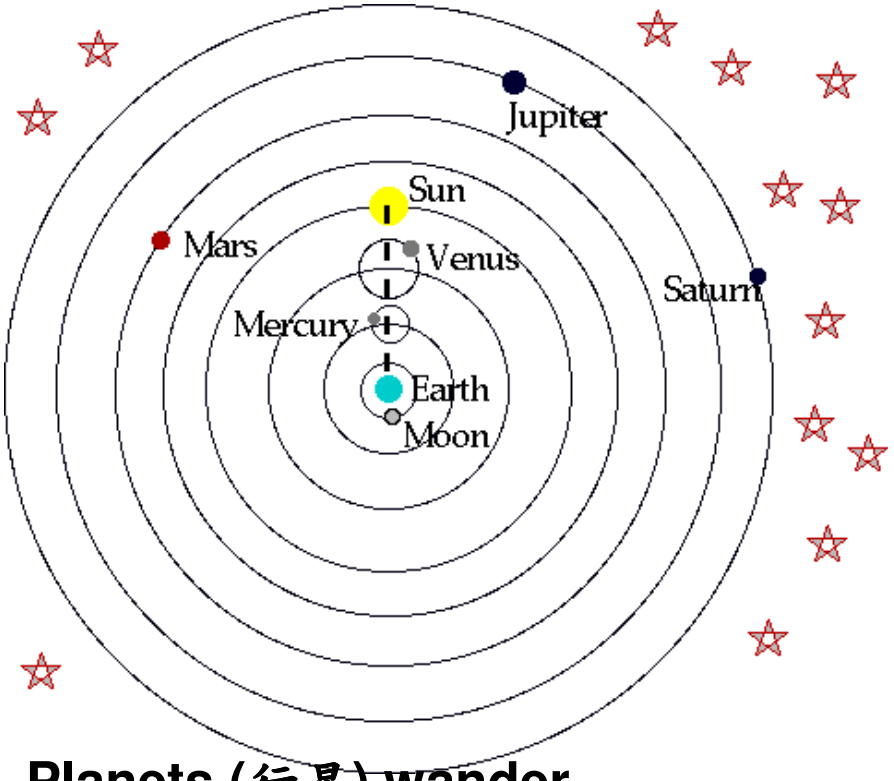
行星軌道與地球軌道幾乎在同一個平面

古宇宙觀

蓋天說：
天圓地方

渾天說：
蛋殼－天
蛋黃－地

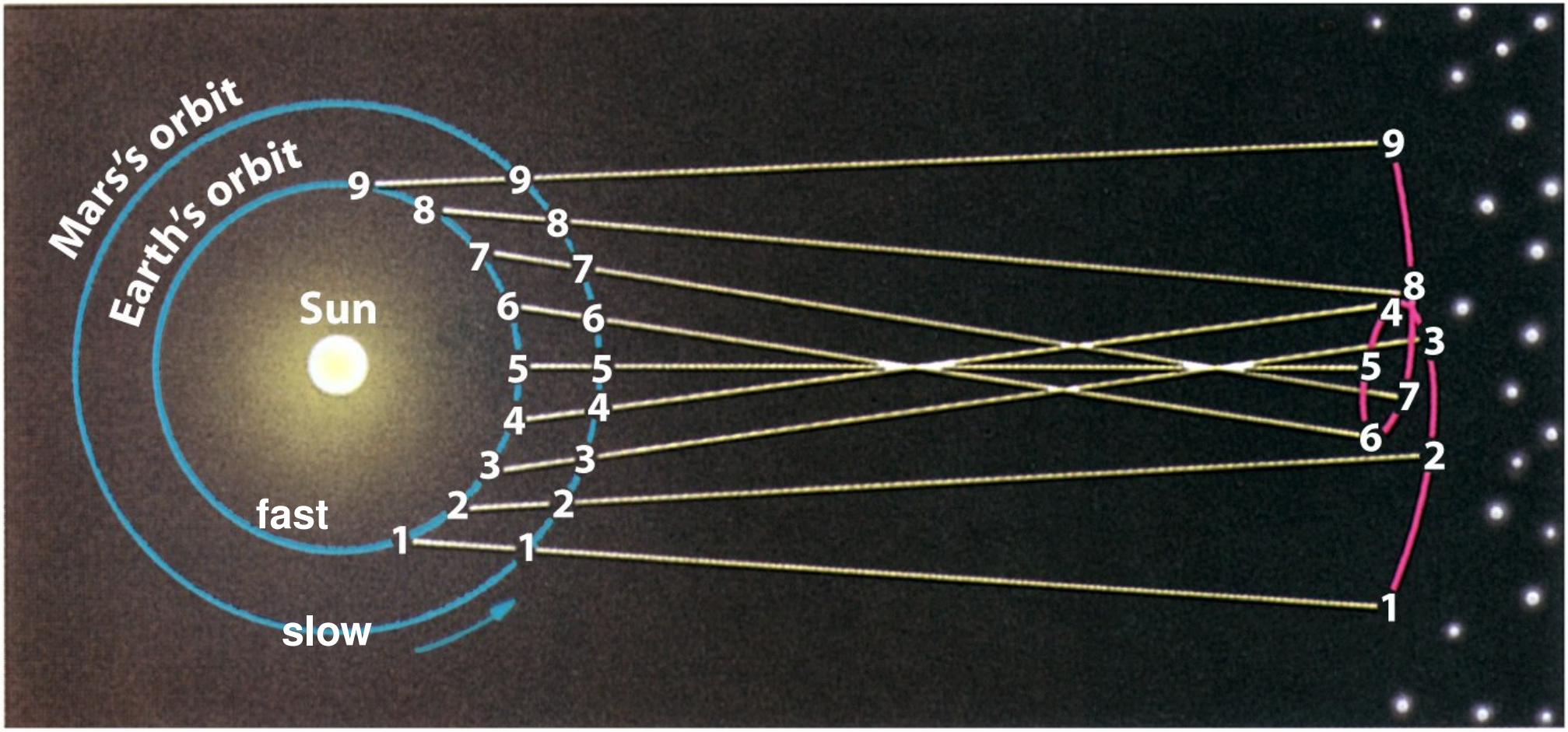
A.D. 125?
Ptolemy's geocentric model



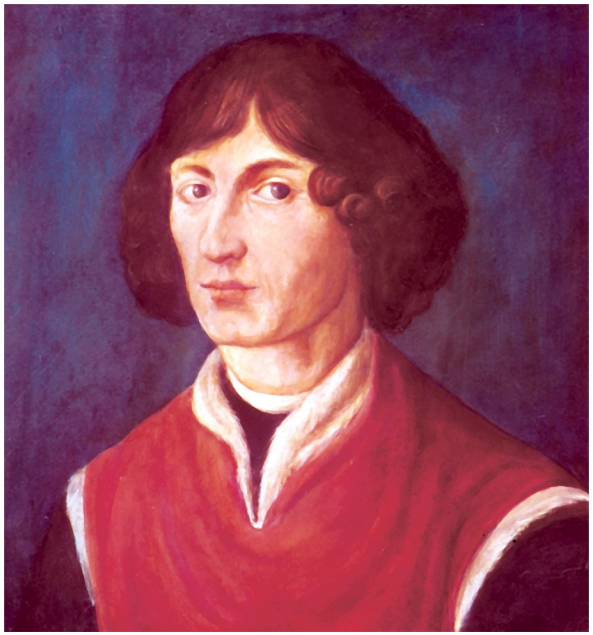
Planets (行星) wander among stars (恆星)

For more info:
http://aeea.nmns.edu.tw/AEEA/contents_list/universe_concepts.html (天文教育資訊網)

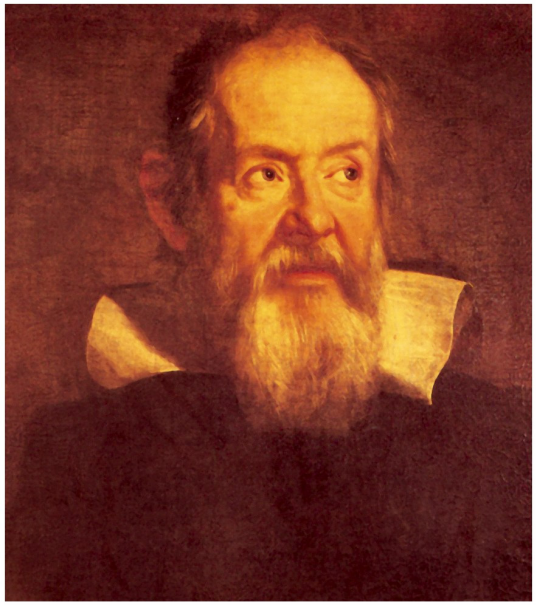
Explanation of Planetary Motion



Astronomers (A.D.1500-1700)



Copernicus (1473-1543) Heliocentric theory



Unnumbered Figure pg 43c
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Galileo (1564-1642) First use a telescope to watch the sky

Unnumbered Figure pg 43b
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Tycho (1546-1601) Half helio + Half geo & Kepler (1571-1630) 3 laws

Unnumbered Figure pg 43d
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Newton (1642-1727) Law of universal gravitation

Parallax (視差)

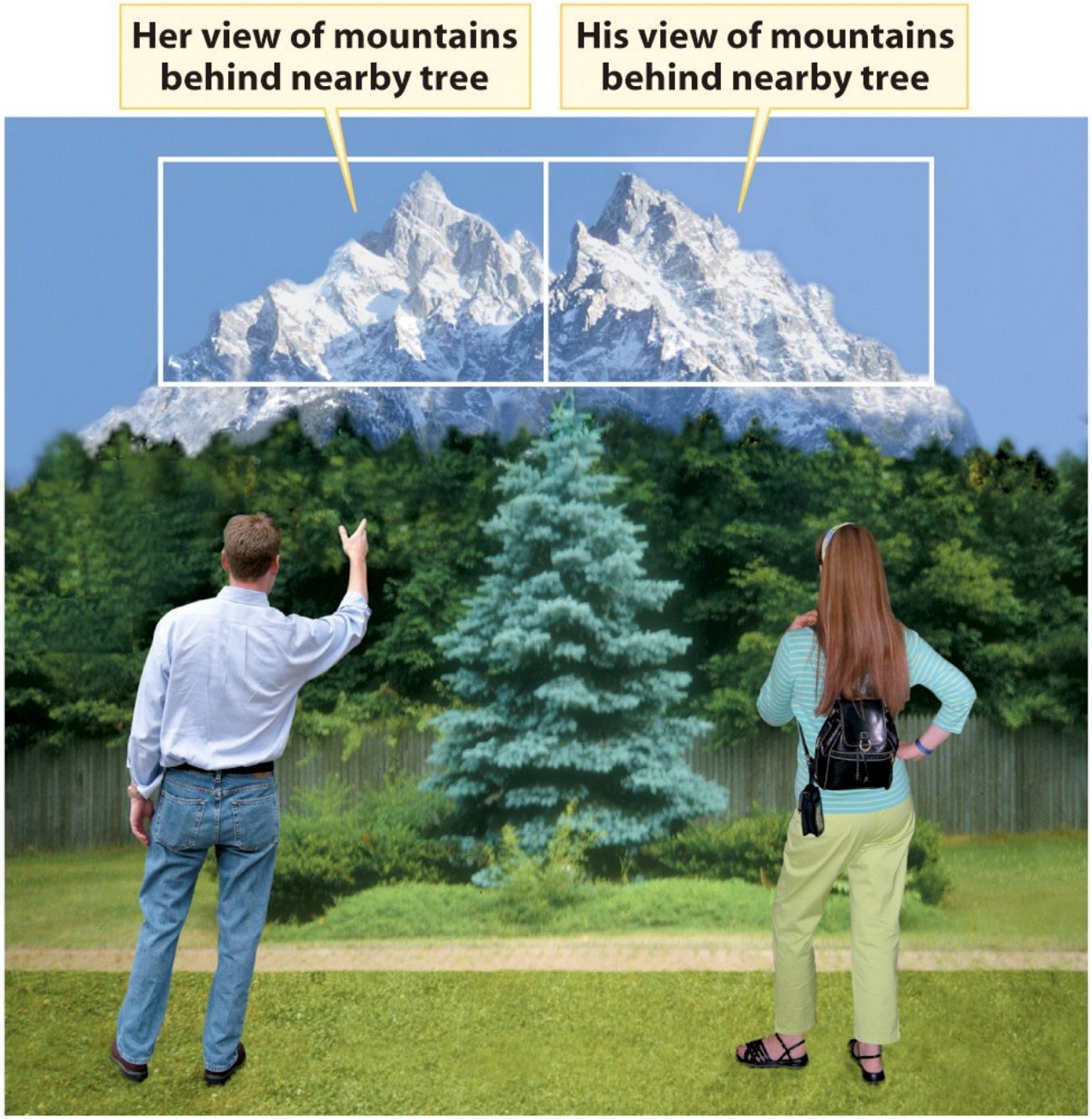

Figure 2-6
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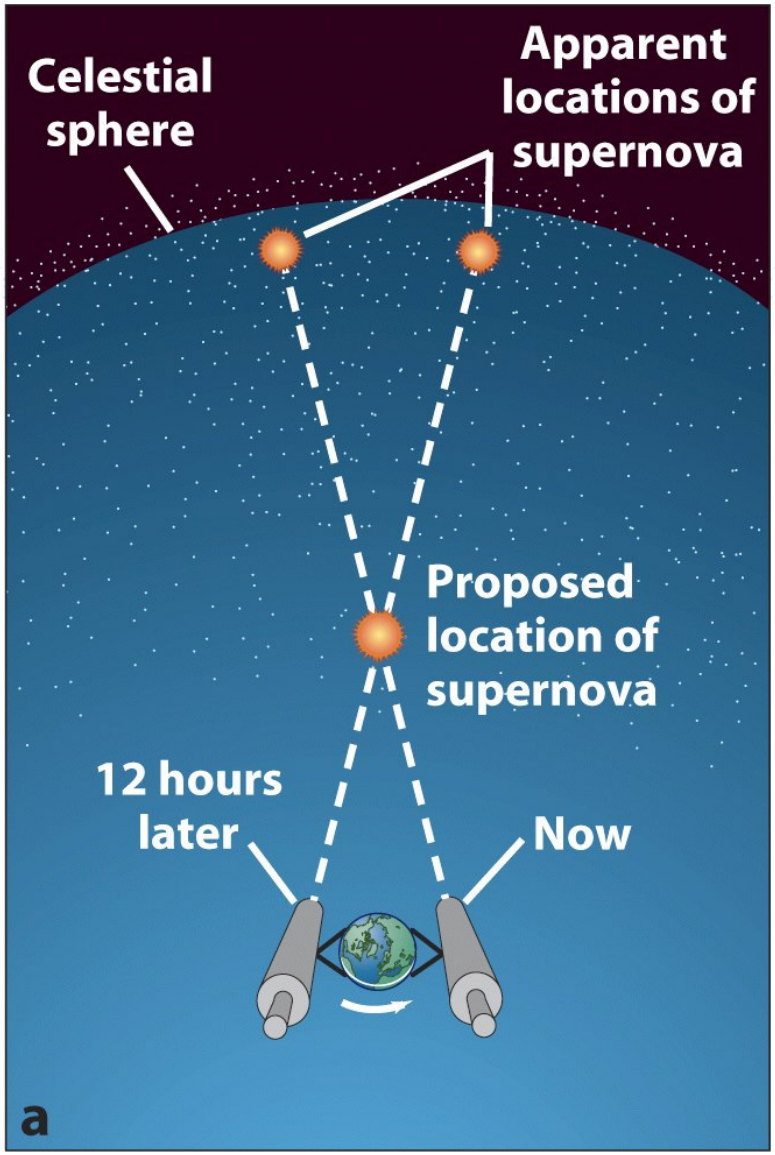
Parallax of a Nearby Object in Space



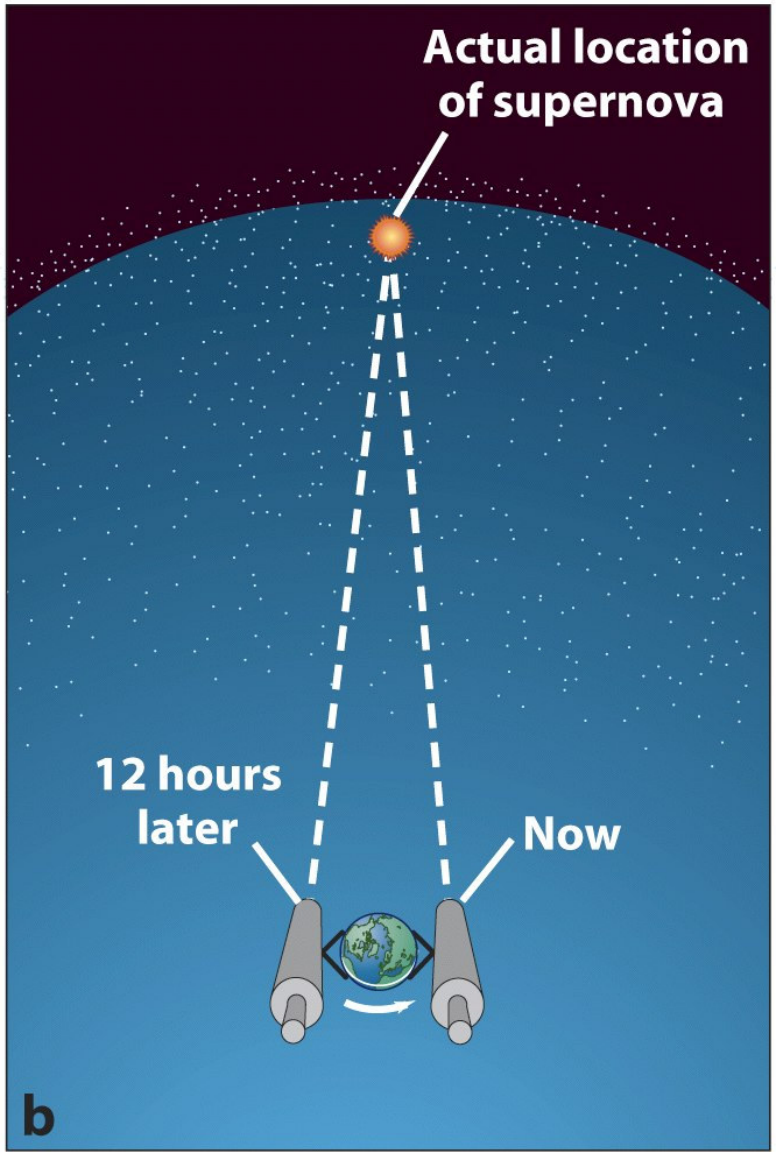


Figure 2-7
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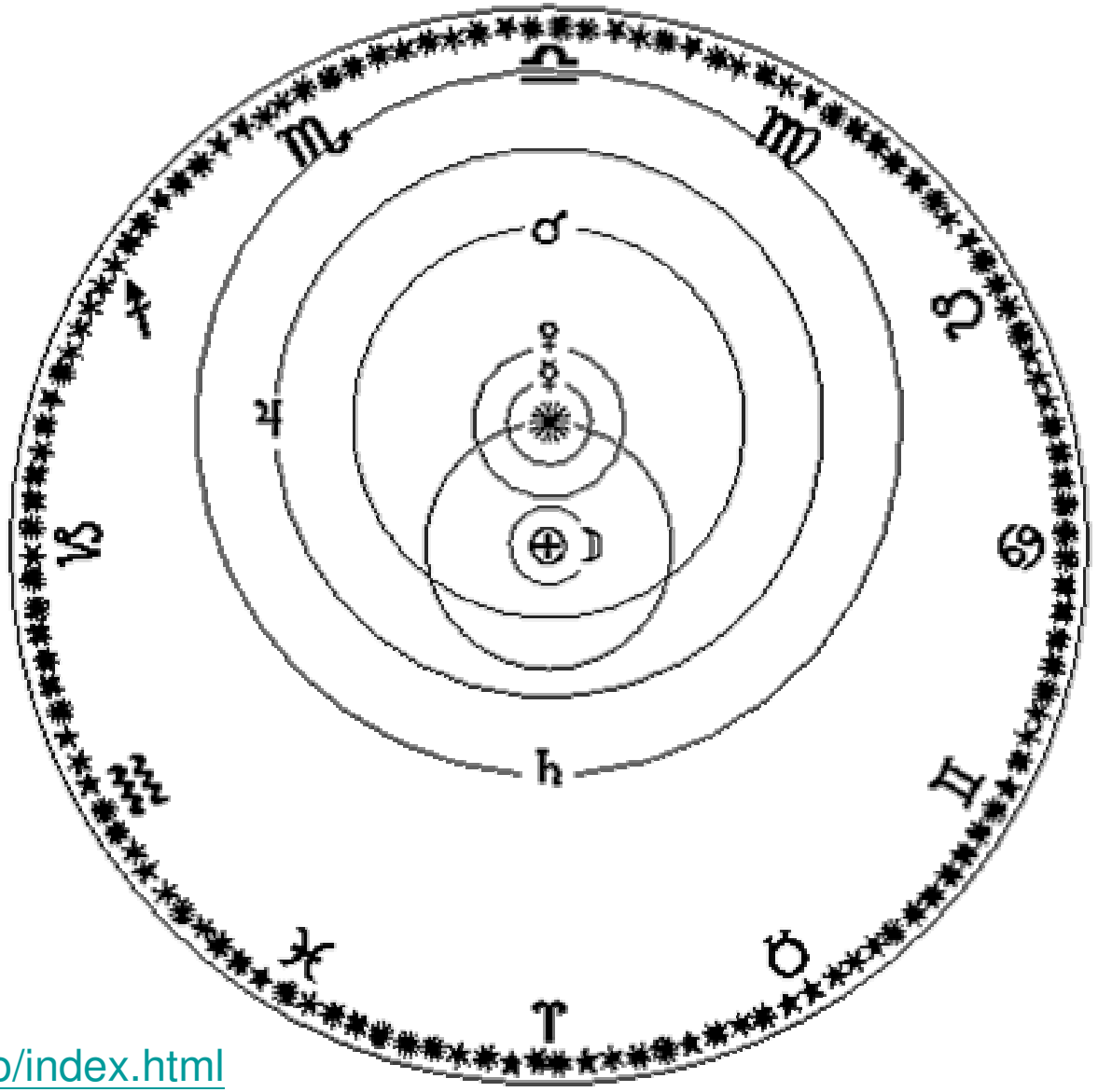
measure distance: Modern astronomers use parallax to estimate the distance of nearby stars.

Tycho's cosmology

Tycho used parallax argument against heliocentric concept.

Science is based upon proofs. Sometimes many models can exist because the experiments/observations are not precise enough to distinguish models.

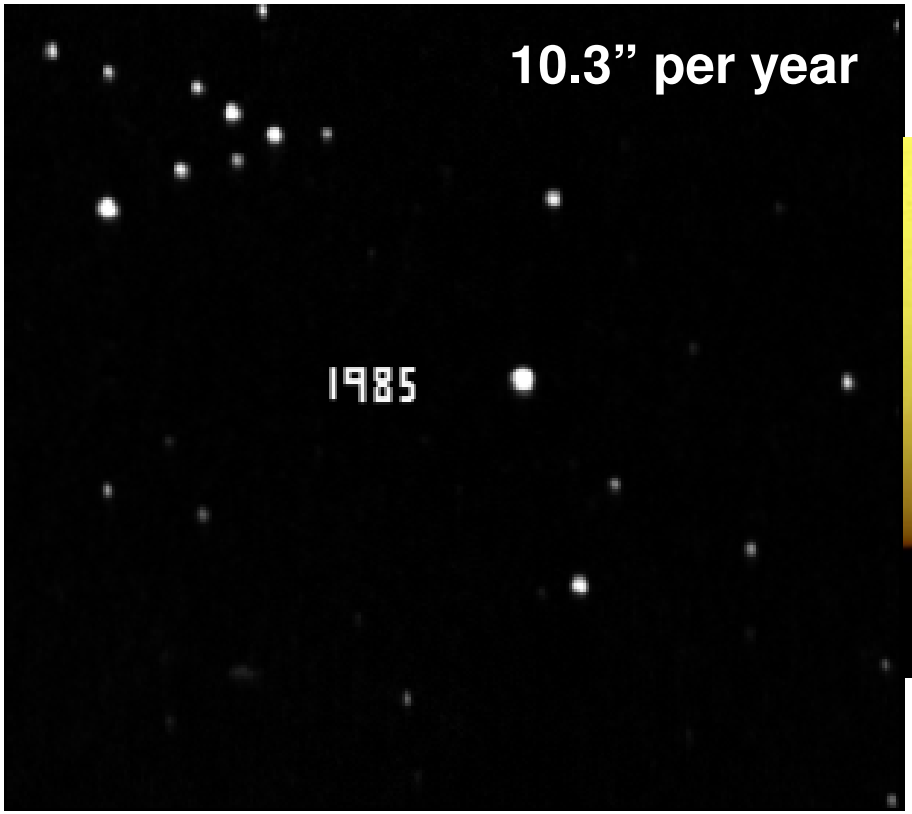


http://www.nada.kth.se/~fred/tycho/index.html

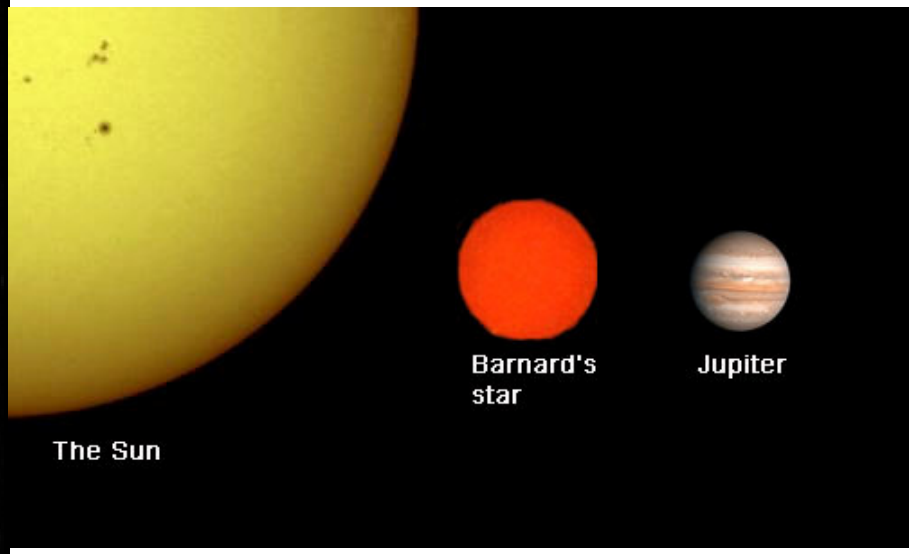
Barnard's Star (1916)

2nd closest star system (1st is alpha Centauri)

angle: 1 circle=360°　1°（度）= 60'（弧分）　1' = 60"（弧秒）



肉眼可分辨的角度下限≈ 1'

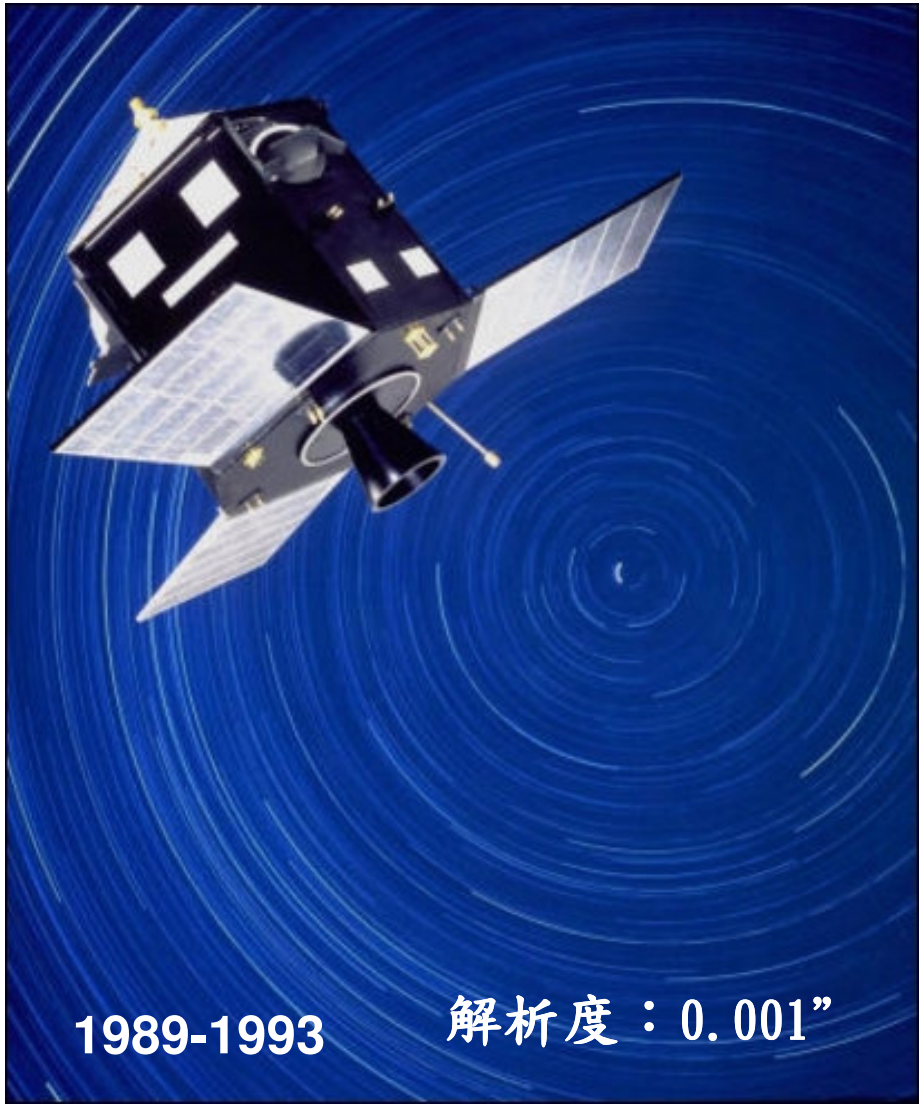


http://www.solstation.com/stars/barnards.htm

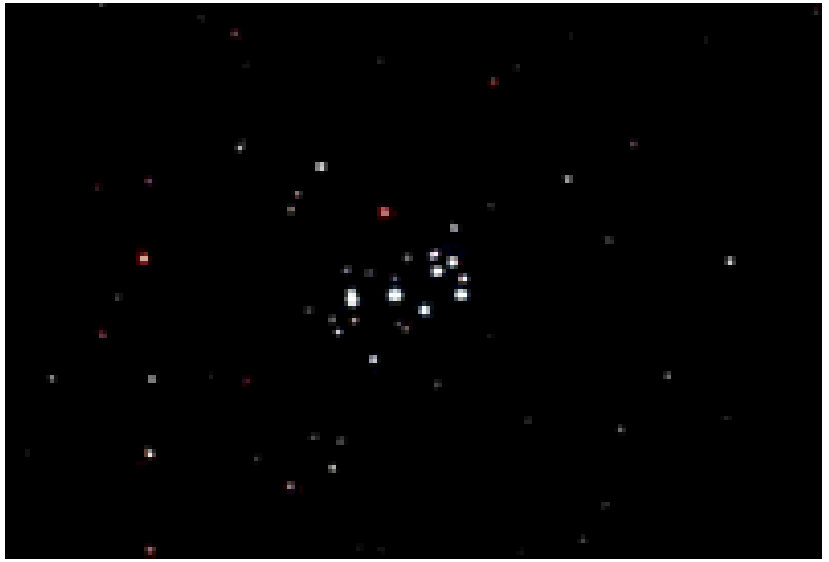
Wikipedia.org:
0.17 solar masses
5.96 light years away

Hipparcos Satellite (space astrometry)

http://www.rssd.esa.int/Hipparcos/

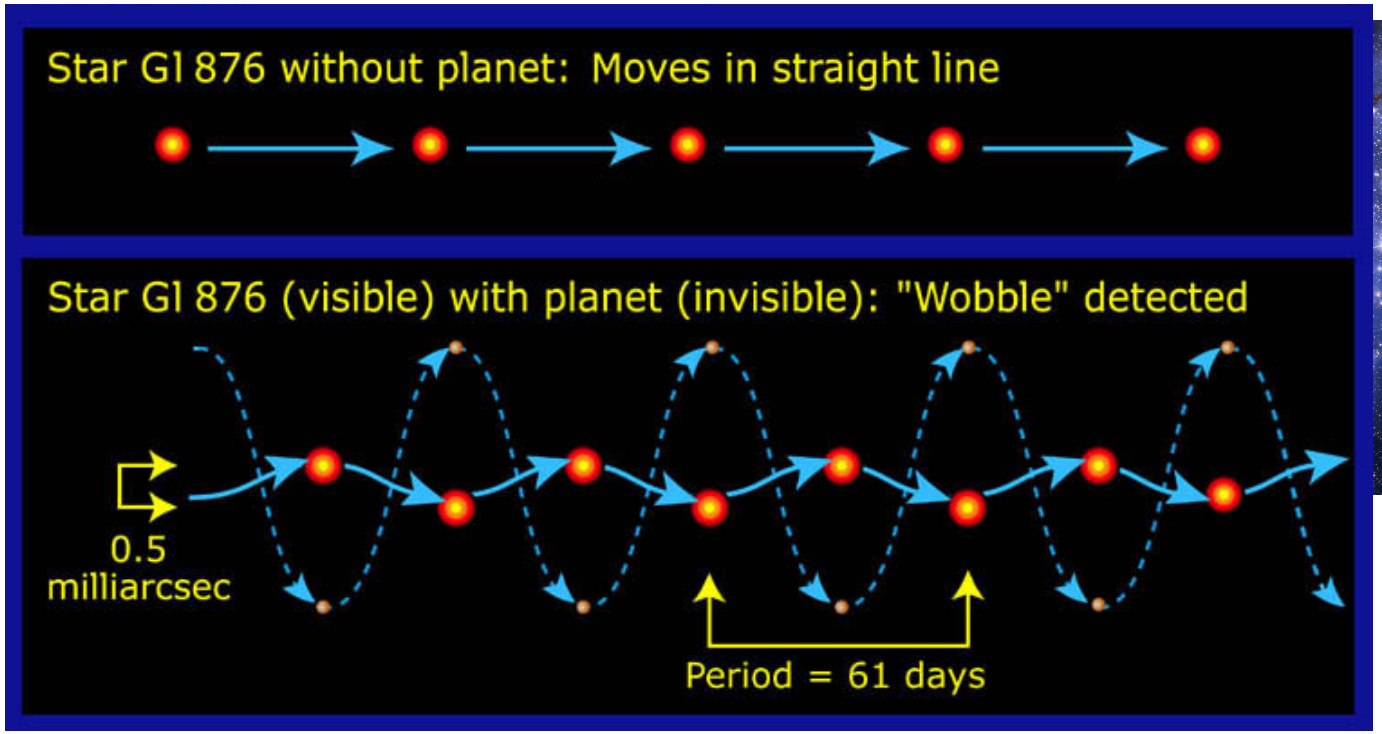


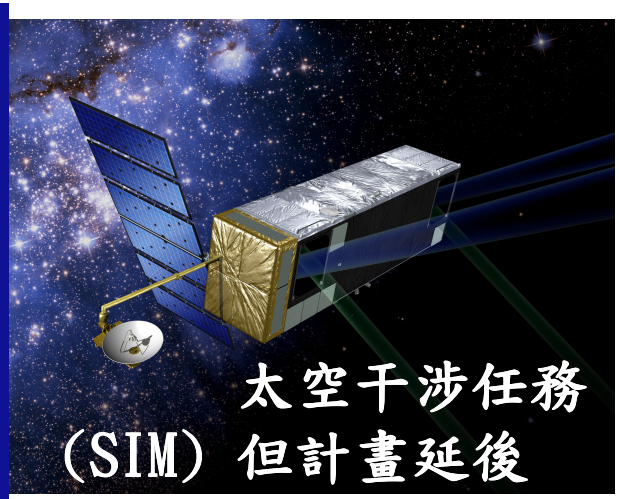
http://www.rssd.esa.int/hipparcos/Pleiades_distance.html

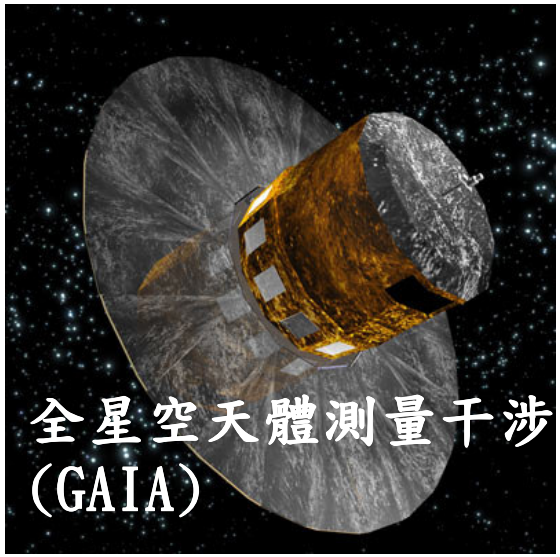


Pleiades (昴宿星團或七姐妹或 Subaru, distance=400 light years) animation generated using Hipparcos data. This is an 8x6 degree field. The movement of the stars over 120,000 years is shown.

未來超精密的天體位置測量：尋找另一個地球？







有如要從地球上解析在月球上的一隻螞蟻(解析度≈10^{-6}")，須要「干涉儀」。
可能發現在30光年距離以內，
比地球質量大若干倍的系外行星，
落在所謂的可居住帶。

Summary

- 什麼是astrometry?
- 如何描述星星在天空的位置？
- 為什麼有日？為什麼有時區？
- 為什麼有年?一年有多長?為什麼有閏年?
- 什麼是恆星和星座?
- 為什麼群星繞著不動的北極星打轉?
- 為什麼北極星隨緯度不同變化高度?
- 古埃及的北極星不是現在的北極星?
- 為什麼有四季?為什麼星座四季不同?
- 為什麼座北朝南的房子比較好？這和日晷的原理有關嗎？
- 北回歸線經過嘉義縣花蓮縣，這代表了什麼？
- 什麼是黃道12/13宮?為什麼占星學的12宮已不代表太陽在天球上的正確位置?
- 為什麼古代天文與曆法有關?農曆只是陰曆嗎?
- 什麼造成行星在天球上的逆行現象？
- Tycho 為何不採用在哥白尼(Copernicus)的地動說？
- 恆星在宇宙中實際上會不會移動？古人和我們為何在這一點有認知上的差異？