# Astronomical Observation
## 天文觀測

- To study the properties of celestial objects by means of observations

  以觀測的手段瞭解宇宙天體的性質，探討其來源、演化，以及彼此之交互作用

Star → EM radiation → Detection → Analysis

Properties of stars ← Interpretation

**宇**（上下四方）**宙**（古往今來）

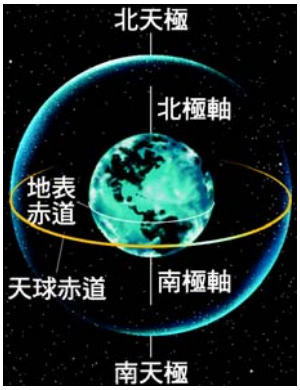
空間 — 時間

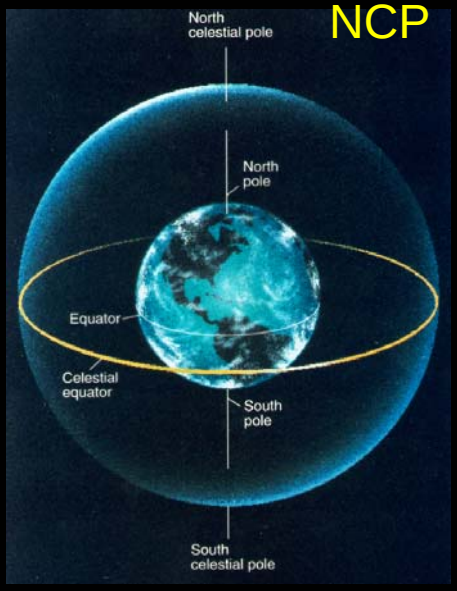
**天球** (celestial sphere)
--- 角度 (angle)

**距離**（深度、沿視線方向；徑向）

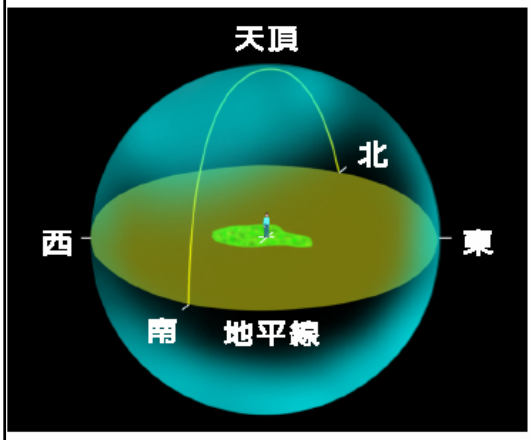
**因果關係**
(con)sequences

Action, reaction, interaction



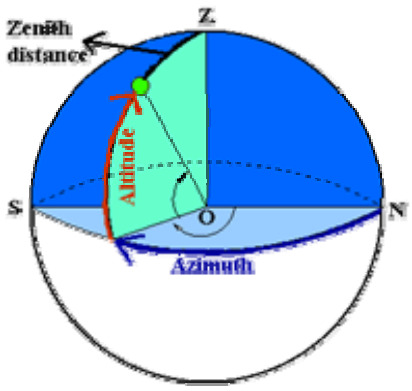



**zenith**




天底＝**nadir**

圖 2-3　通過觀測者地平南、北方，以及天頂的圓弧稱為子午線。天體在天球上的位置，可以兩個角度來描述，例如方位角與仰角。隨著地球自轉，對某個觀測者而言，某顆星的坐標隨時在改變。

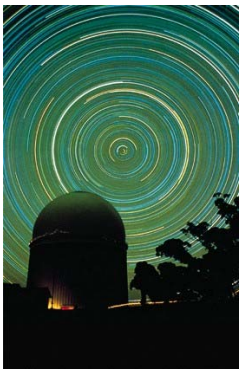



**altitude**（仰角）
(= elevation)
-90° to +90°

**azimuth**（方位角）
e.g., measured from north, clockwise
0° to 360°

**Zenith distance** = 90°-Alt

## Measuring the Sky



- Unit of distance in astronomy
  1 astronomical unit (AU) 天文單位
  =149.6 x $10^6$ km
  約一億五千萬公里
  1 light year (ly) =9.460 x $10^{12}$ km
  ~ 6x $10^4$ AU
  1 parsec (pc) = 206,265 AU 秒差距
  = 3.086 x $10^{13}$ km ~ 3.26 ly
- Unit of separation (on the sky)
  1 degree = 60 minutes of arc (arcminutes) = 60’
  1 arcminute = 60 arcseconds = 60”

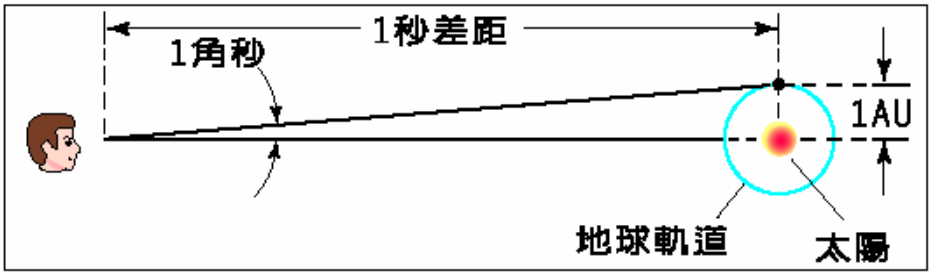
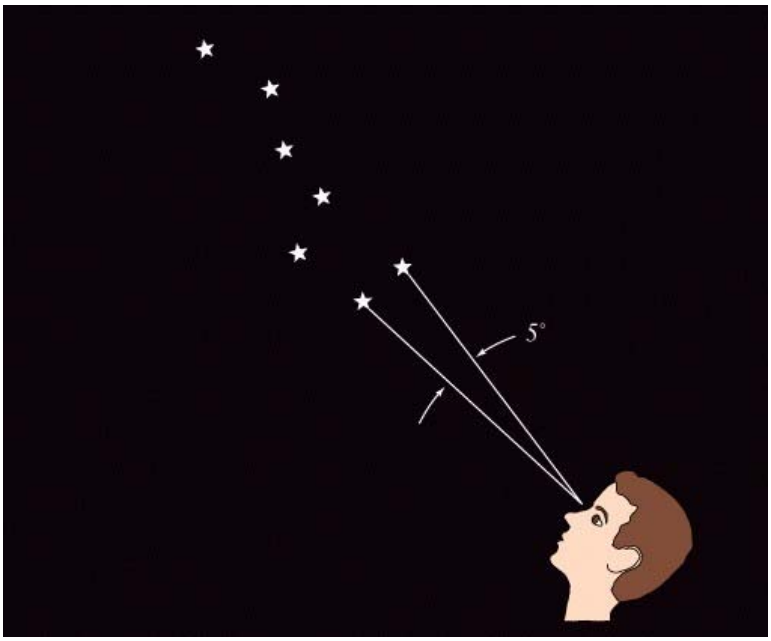



圖 2-9　當相離 1 pc 時，1 AU 的張角為 1 角秒。



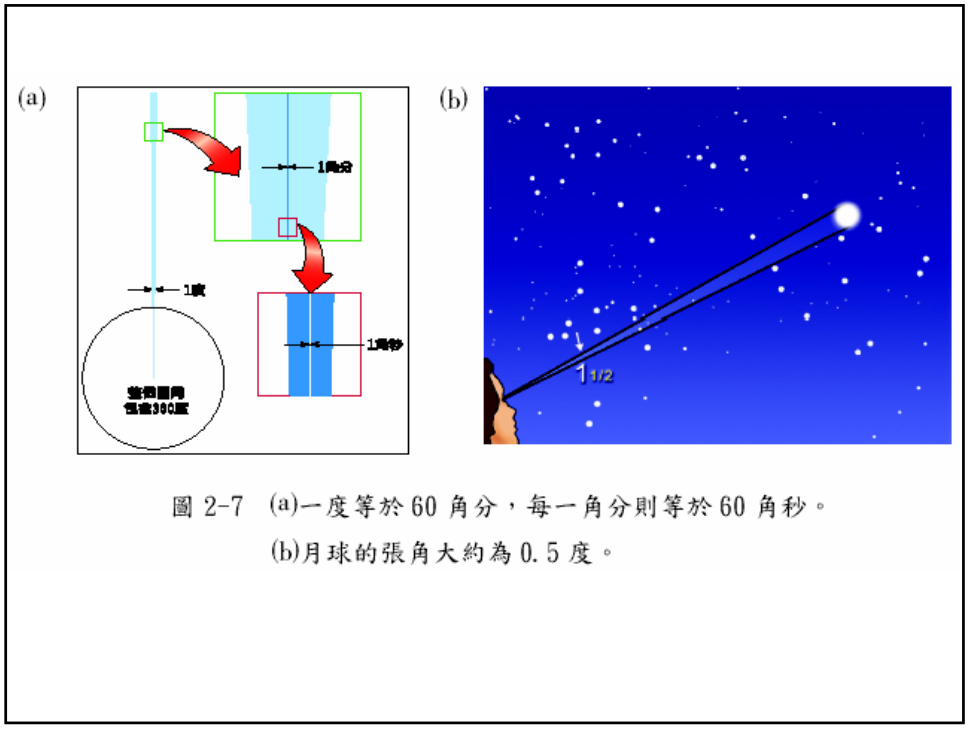
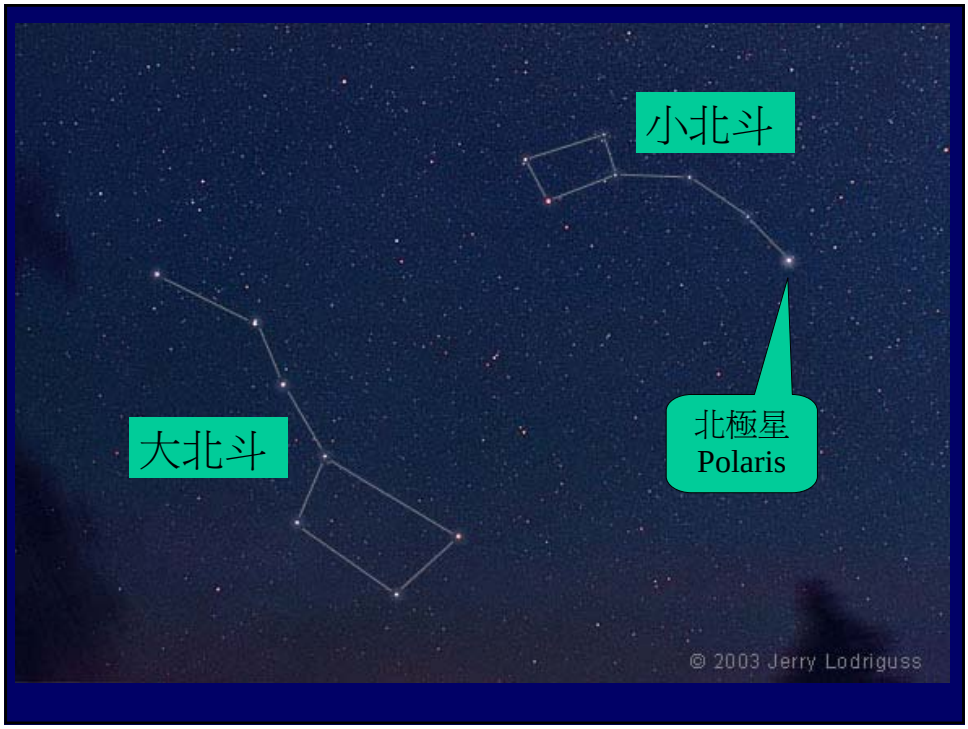
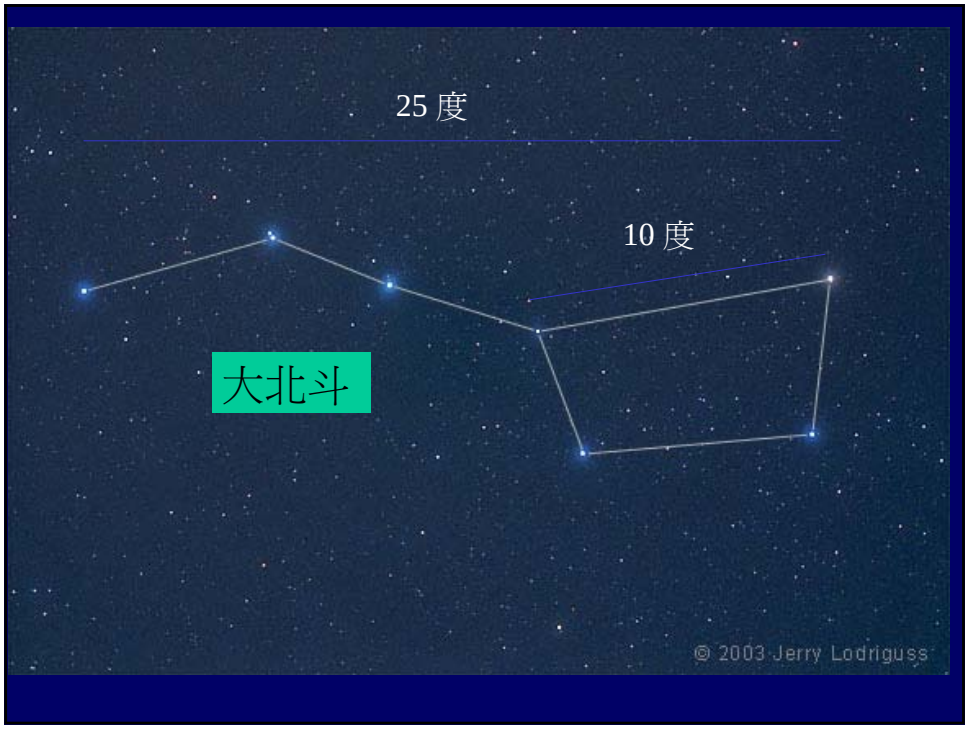
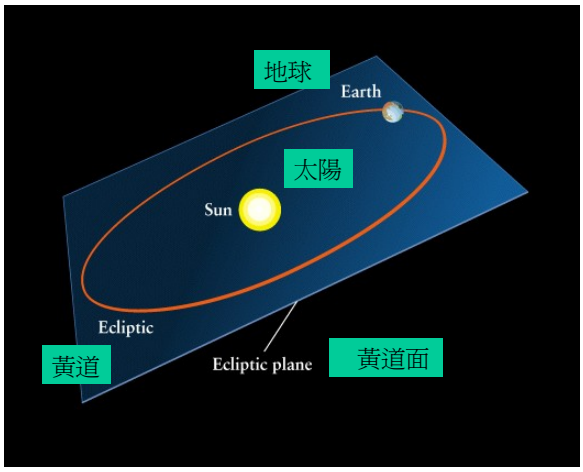



圖 2-7　(a)一度等於 60 角分，每一角分則等於 60 角秒。
(b)月球的張角大約為 0.5 度。


小北斗
北極星
Polaris
大北斗
© 2003 Jerry Lodriguss


25 度
10 度
大北斗
© 2003 Jerry Lodriguss

# Earth's Revolution 地球公轉




The Earth revolves around the Sun. The passage is called the **ecliptic** (黃道).

**黃道面**：The ecliptic plane intercepts the celestial equator with an angle of 23.4 degrees.

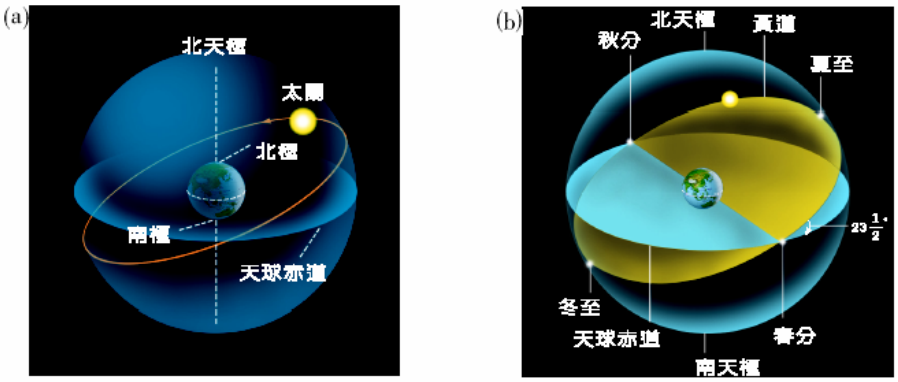



圖 2-12 (a)從地球看太陽一年當中的運動，最北時達到赤緯北方 23.5 度，然後通過天球赤道，繼續南行直到赤緯南方 23.5 度。
(b)黃道面與天球赤道成 23.5 度傾角，兩個面的交點分別稱為春分點及秋分點，黃道面最（上）北方的點稱為夏至，最南方的點則稱為冬至。

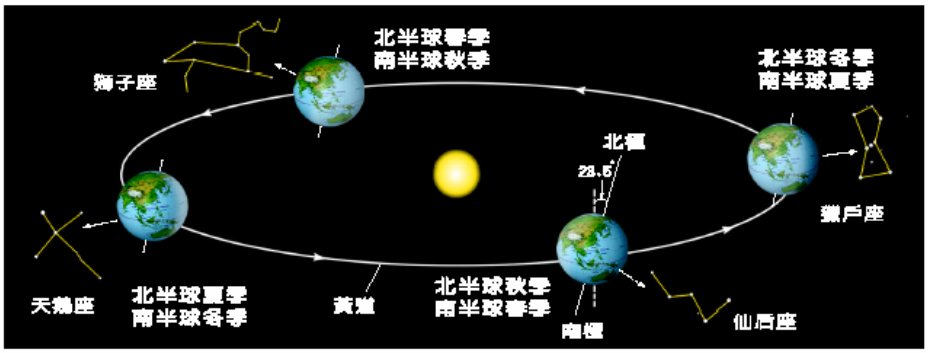


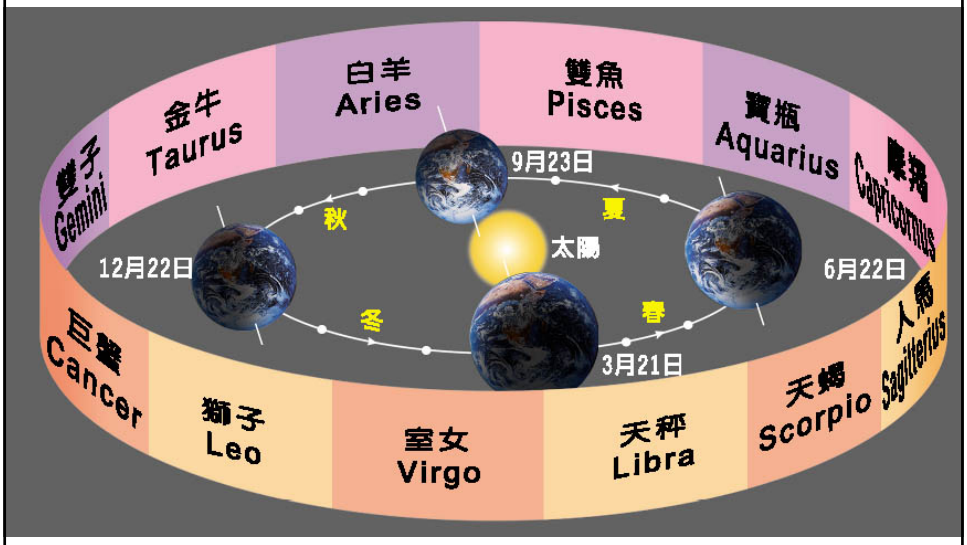

圖 2-11　黃道面與天球赤道成 23.5 度傾角，兩個面的交點分別稱為春分點及秋分點，黃道面最（上）北方的點稱為夏至，最南方的點則稱為冬至。

At different hours in a night, one sees different night sky. At different months one sees also different sky ➔ 黃道十三宮 (zodiac signs)

Table 1-1
The 13 Constellations of the Zodiac

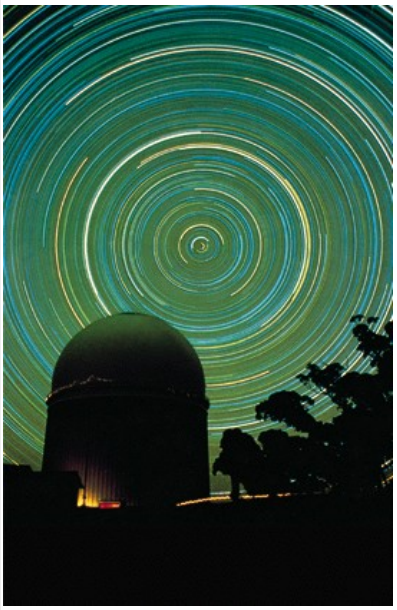
| Constellation | Dates of Sun's Passage Through |
|---|---|
| Pisces | March 13–April 20 |
| Aries | April 20–May 13 |
| Taurus | May 13–June 21 |
| Gemini | June 21–July 20 |
| Cancer | July 20–August 11 |
| Leo | August 11–September 18 |
| Virgo | September 18–November 1 |
| Libra | November 1–November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

missing

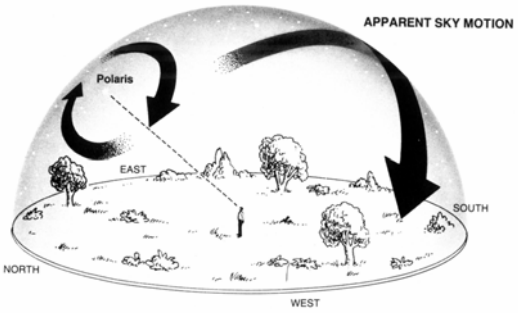



## Earth's Rotation (Spin) 地球自轉

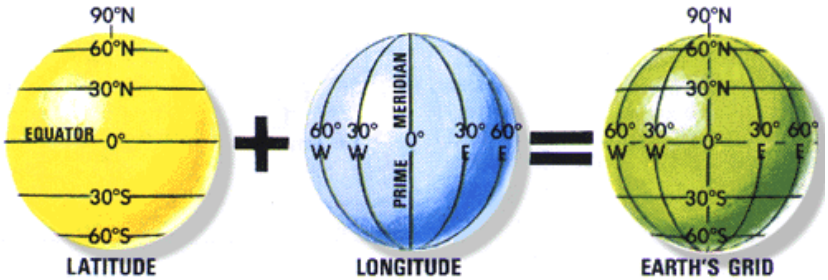
- Counterclockwise (west → east) if viewing from the above (the north pole) ➔ Sun, moon and stars rise in the east and set in the west
- Earth's orbital motion also counterclockwise
- Extending Earth's spin axis
  →天（球）北極 (**north celestial pole**; NCP)
  NCP appears not to spin; all other stars seem to move around the NCP or SCP in a day
- 北極星 (**Polaris**)：closest to NCP now (< 1°)
- Babylonians 3000 years ago 360 days
  → 360 deg in a circle



In the duration of a day, all stars seem to move around the NCP. The stars actually do not move. The Earth's spin causes the apparent motion of stars.




## The coordinate System on the Surface of the Earth — Longitude and Latitude



- **Longitude and Latitude**
  Greenwich longitude = 0
  格林威治當地時間
  (local time)
  → Universal Time
  （UT；國際標準時）

**Taiwan Time = UT + 8 hr**

赤道 latitude = 0
北極：北緯90度；
南極：90°S or –90°N

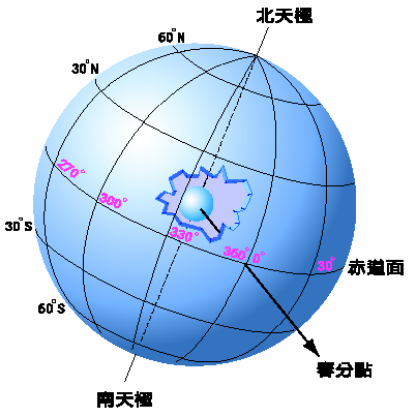
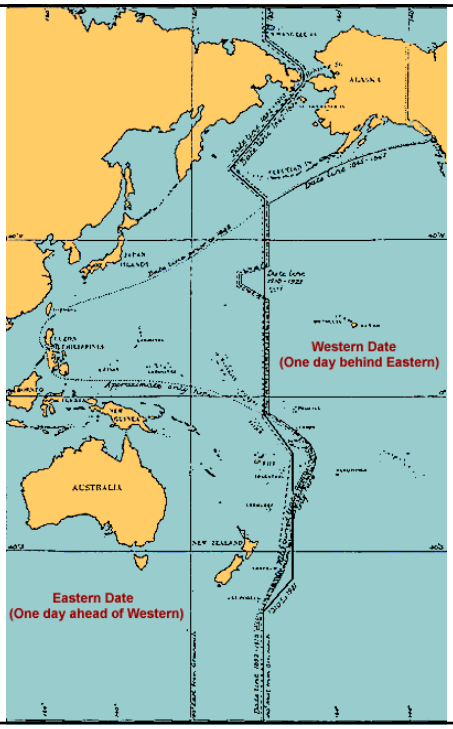
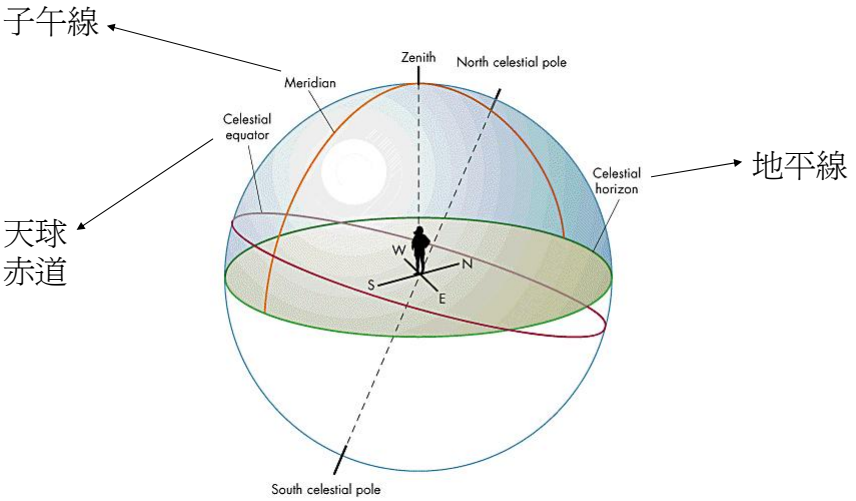


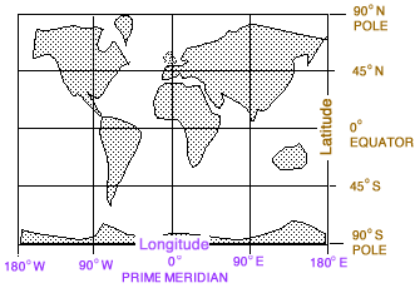

圖 2-6　把地表的經度與緯度向外擴張，便能將類似的坐標系統應用在天球上，用以描述天體的位置



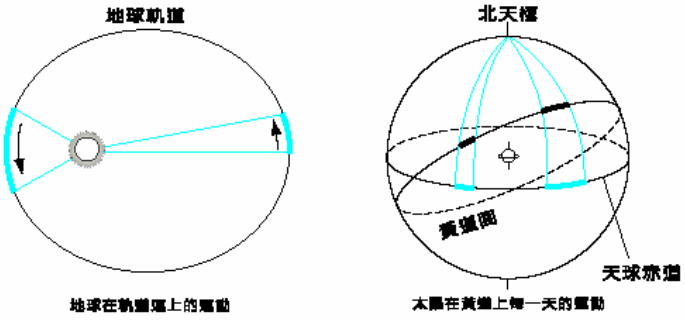

國際換日線
(date line)




Projecting the longitude and latitude onto the celestial sphere …




The Sun is not a good time keeper.



- **Sidereal Time**（恆星時）
  Time as measured by reference to the stars
  = hour angle of the **vernal equinox**
  = right ascension of stars currently on the observer's **meridian**
- **Solar Time**（太陽時）
  Time with respect to the sun
  = hour angle of the sun plus 12 hours
  **apparent solar time** → true sun, irregularly
  **mean solar time** → for timekeeping
  Solar time loses about 4 minutes a day against sidereal time; a star rises **4 minutes earlier** a day

**Q：Which is longer, a solar day or a sidereal day? By how much?**

1. Solar day; one hour
2. Solar day; 4 minutes
3. Sidereal day; one hour
4. Sidereal day; 4 minutes

- The sidereal day is 23 h 56 m 04.1 s
- Each apparent solar day in a year is different, with a variation of ~30 s
- One mean solar day, by definition, is exactly 24 hours.
- The mean sidereal day is about 4 minutes shorter than the mean solar day.
  → 相同的夜空隔天會早約四分鐘升起
- Other sidereal periods
  sidereal month for the Moon = 27.32166 d
  c.f. (mean) synodic month 朔望月=29.53059 d
  sidereal day; sidereal year

**大圓** (great circle)

從台北到洛杉磯的飛行路線？

**子午線** (meridian)

**赤經** (right ascension; RA)

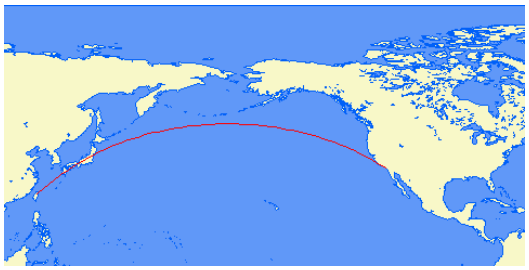
通常以時間單位表示

天球赤道與黃道交點之一 RA=0h

每年約3月21日太陽行至春分點

**赤緯** (declination; DEC)

通常以角度單位表示

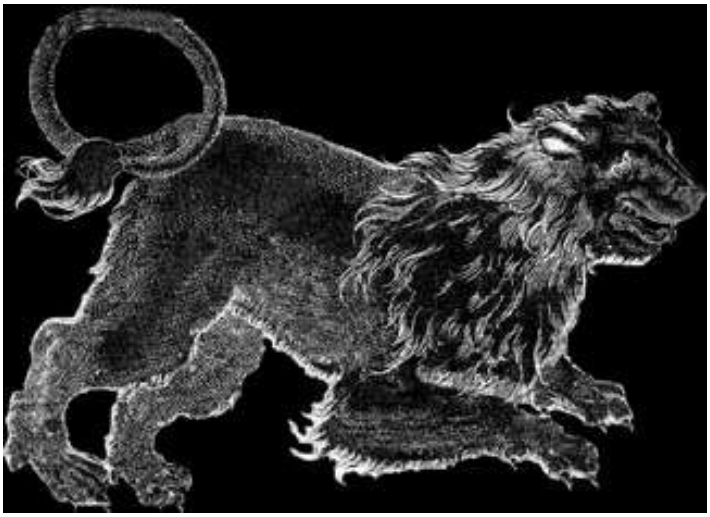


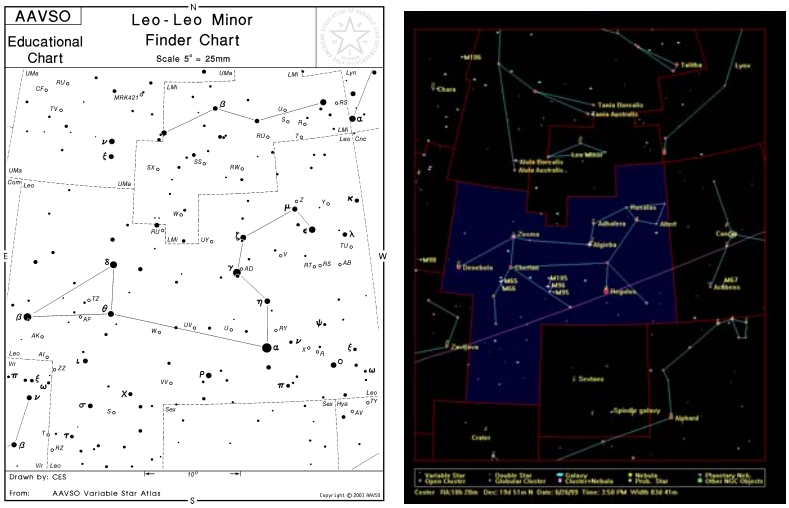
TPE-LAX

TPE-NYC

**星座 (constellation) --- Stars in a constellation may not be associated with each other. They are at different distances but merely projected onto the same part of the sky. There are a total of 88 constellations for the whole sky.**

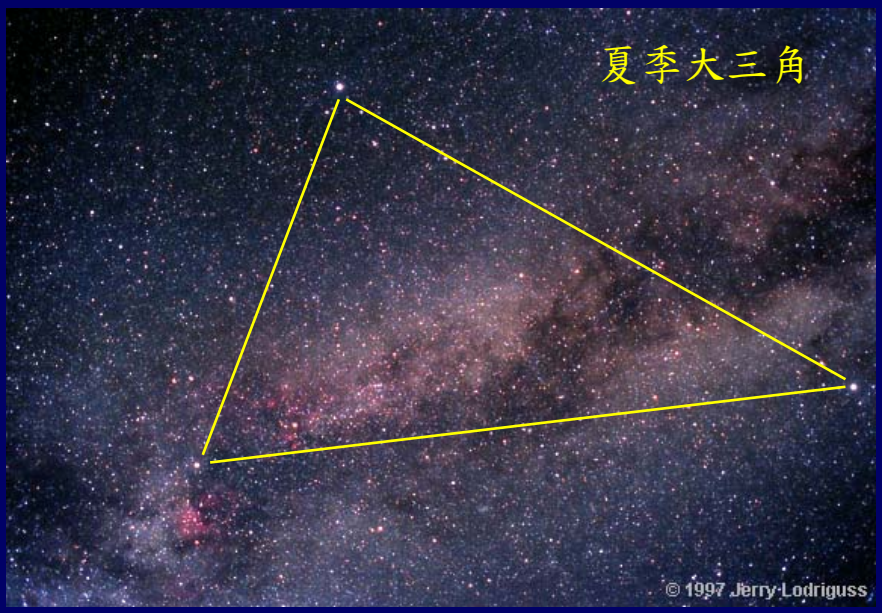
The constellation Leo “Lion” appears in the spring sky.

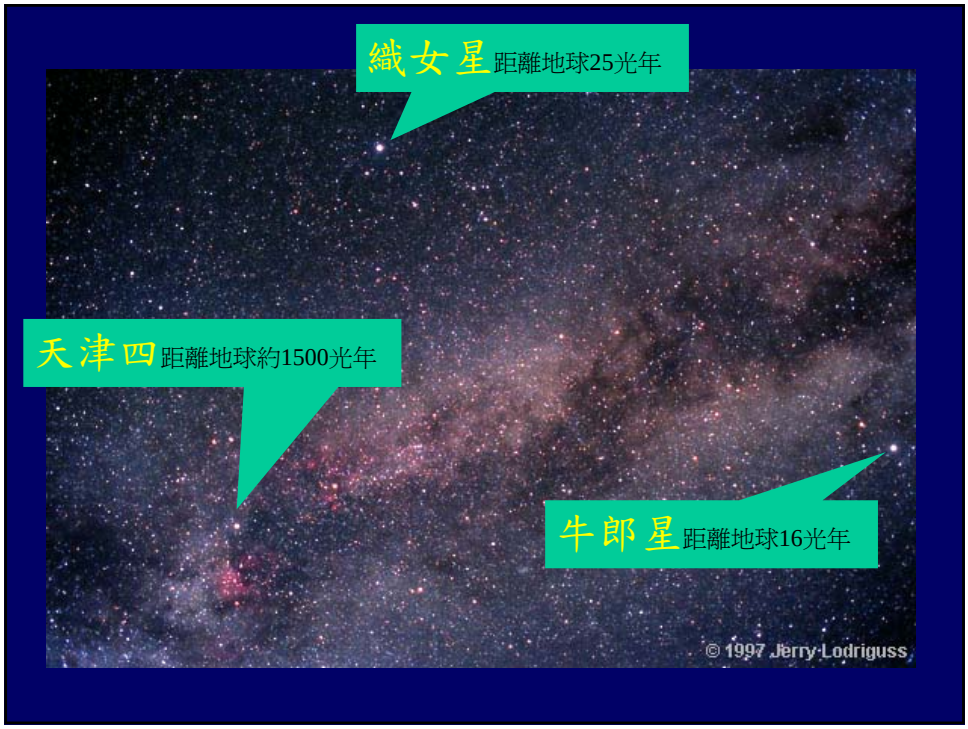


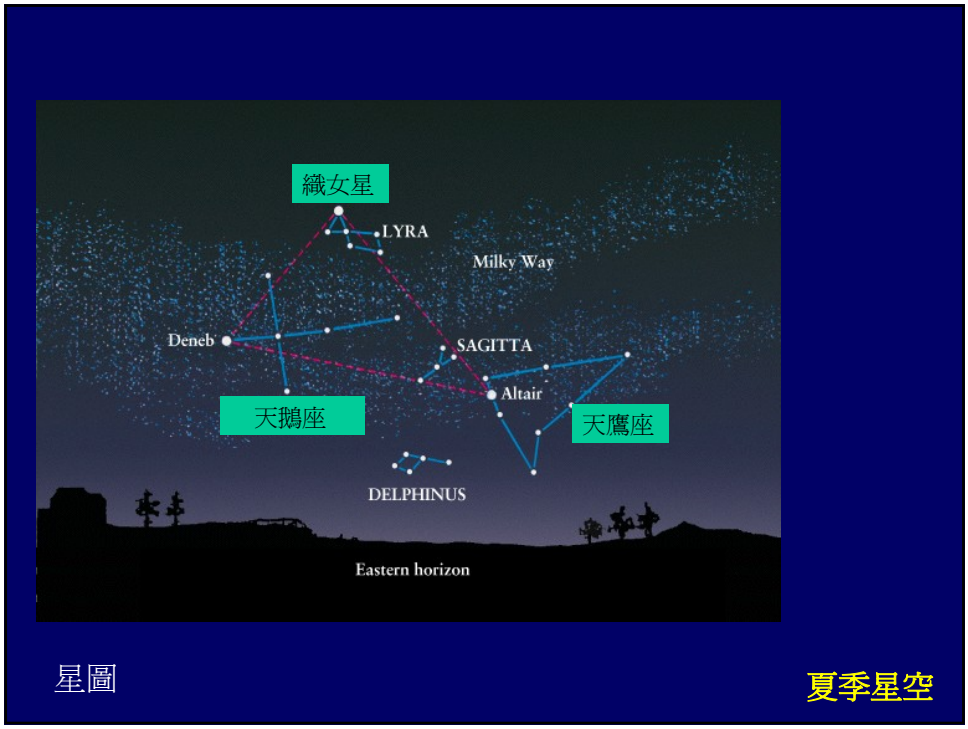



A constellation is more than a “star pattern”. It stands for a patch (region) of the sky. A star chart (星圖) shows Leo and its neighboring constellations.

**Constellation Cygnus** (photograph)

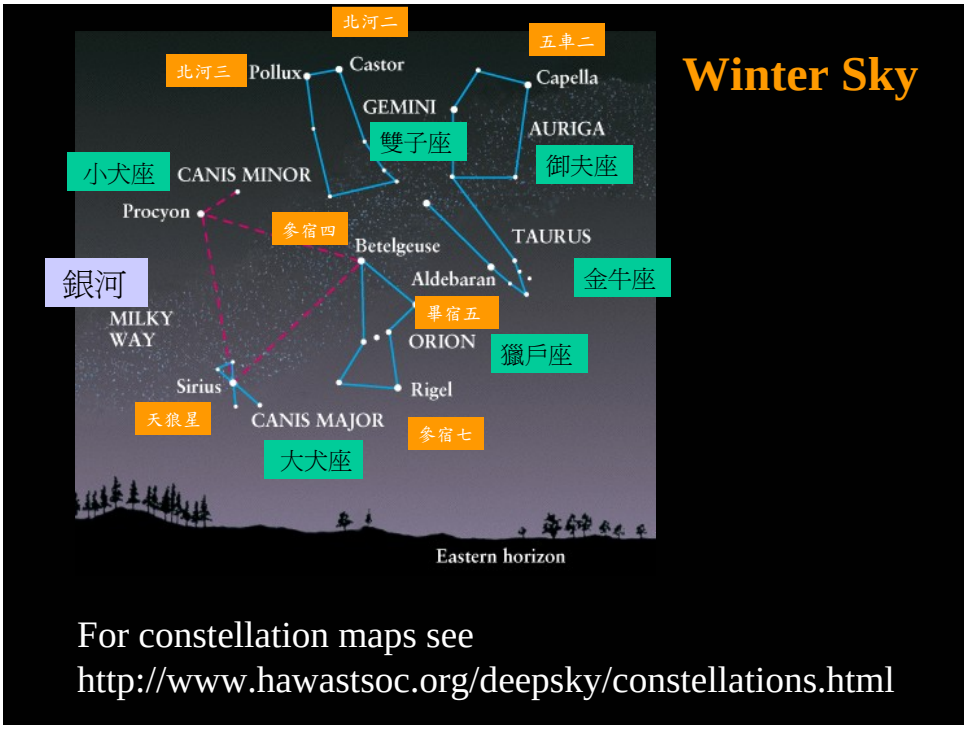


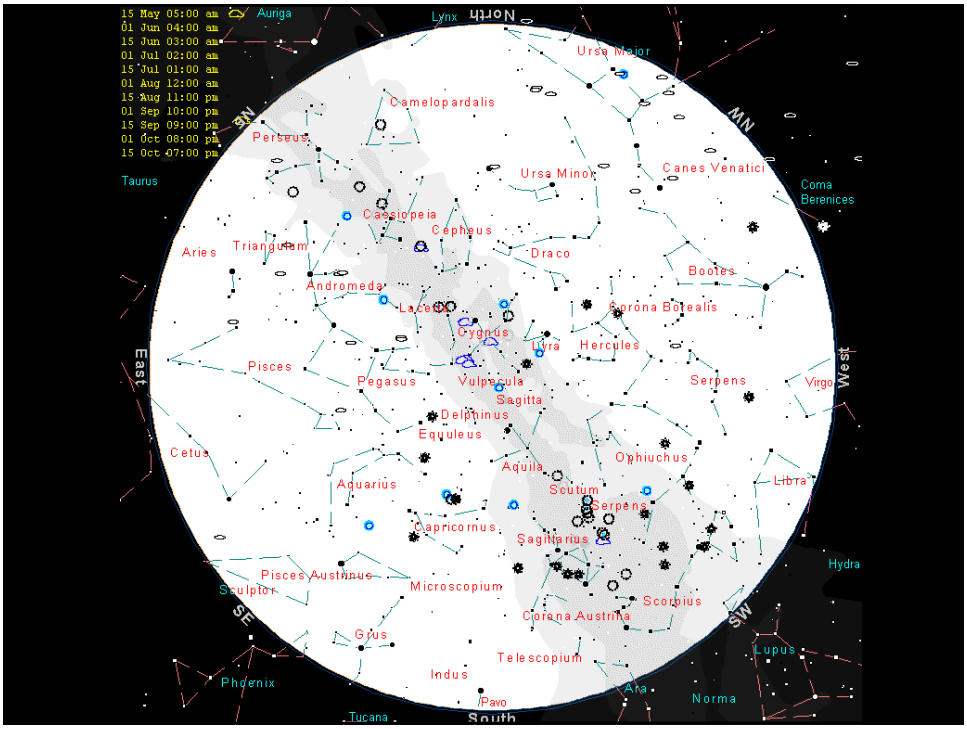

織女星距離地球25光年
天津四距離地球約1500光年
牛郎星距離地球16光年
© 1997 Jerry Lodriguss

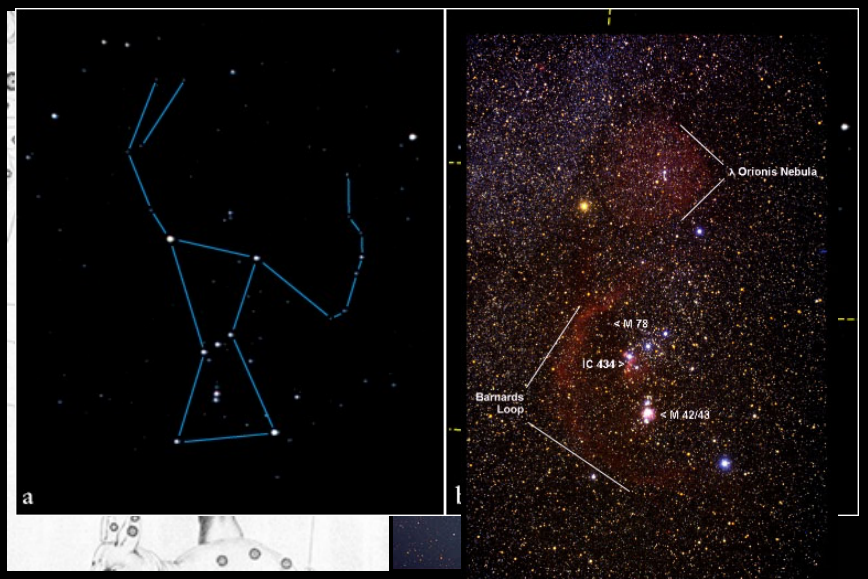

織女星
LYRA
Milky Way
Deneb
SAGITTA
Altair
天鵝座
天鷹座
DELPHINUS
Eastern horizon

星圖

夏季星空


北河二
五車二
北河三
Pollux
Castor
Capella
GEMINI
雙子座
AURIGA
御夫座
小犬座
CANIS MINOR
Procyon
參宿四
Betelgeuse
TAURUS
銀河
Aldebaran
金牛座
MILKY
WAY
畢宿五
ORION
獵戶座
Sirius
Rigel
天狼星
CANIS MAJOR
參宿七
大犬座
Eastern horizon
Winter Sky
For constellation maps see
http://www.hawastsoc.org/deepsky/constellations.html


15 May 05:00 am
01 Jun 04:00 am
15 Jun 03:00 am
01 Jul 02:00 am
15 Jul 01:00 am
01 Aug 12:00 am
15 Aug 11:00 pm
01 Sep 10:00 pm
15 Sep 09:00 pm
01 Oct 08:00 pm
15 Oct 07:00 pm
Auriga
Taurus
Lynx
North
Ursa Major
Camelopardalis
Perseus
NW
NE
Ursa Minor
Canes Venatici
Coma Berenices
Cassiopeia
Cepheus
Aries
Triangulum
Draco
Andromeda
Boötes
Lacerta
Corona Borealis
Cygnus
Lyra
Hercules
Pisces
Pegasus
Vulpecula
Serpens
Virgo
East
West
Sagitta
Delphinus
Equuleus
Cetus
Ophiuchus
Aquila
Aquarius
Scutum
Libra
Serpens
Capricornus
Sagittarius
Hydra
Pisces Austrinus
Microscopium
Sculptor
SE
SW
Scorpius
Corona Australis
Grus
Lupus
Telescopium
Indus
Phoenix
Pavo
Ara
Norma
Tucana
South

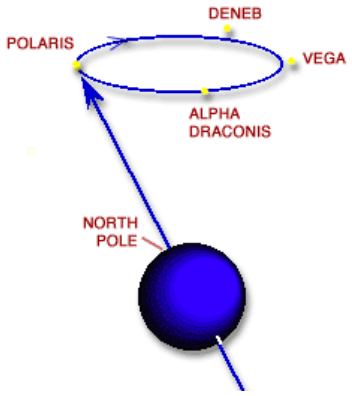



**Orion 獵戶座**

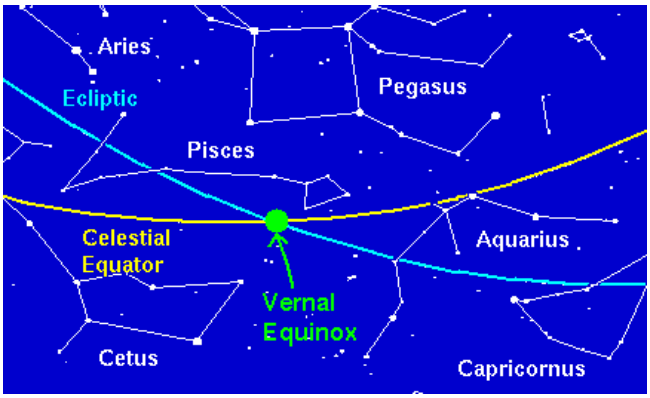
http://www.allthesky.com/constellations/orion/mainm.html

## Celestial Coordinates

- The sky position of a star is specified by its RA and DEC coordinates.
- But there is **precession of the equinox**; i.e., the position of the vernal equinox changes with time



The Earth's spin axis precesses with a period of ~ 26,000 years. By AD13,000 the Polaris will become the star Vega.




A star's RA and DEC coordinates change with time! B1950 equinox vs J2000 equinox

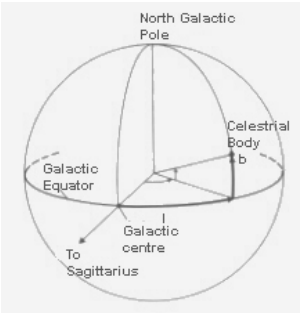
# Coordinate Systems

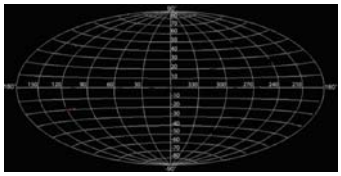
- **Horizontal (observer) system**
- **Equatorial system**

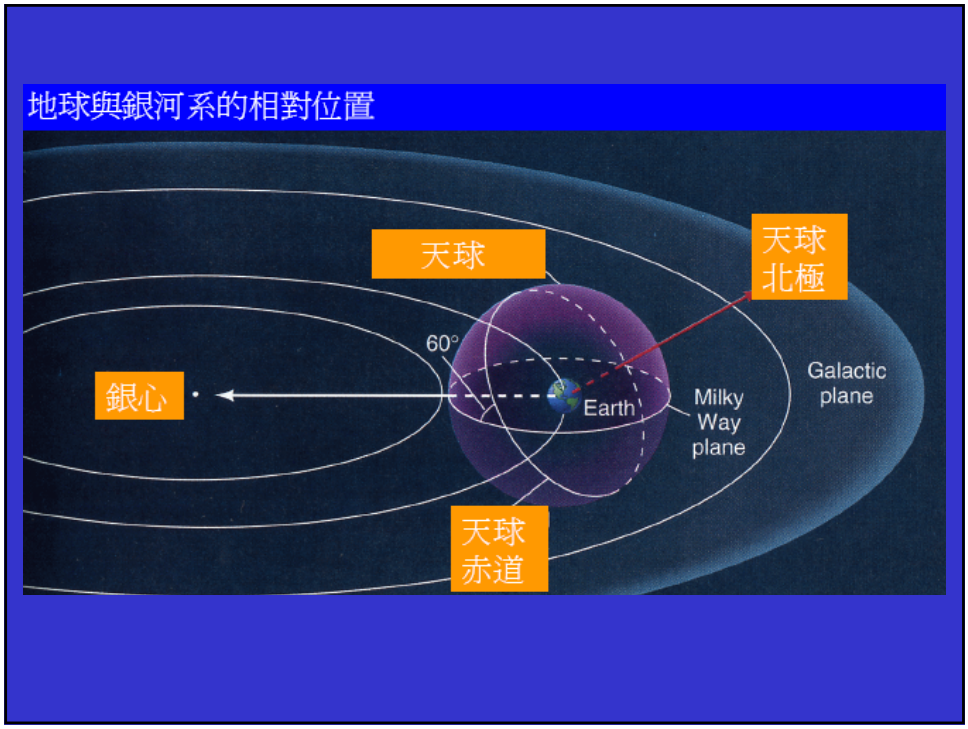
  Fundamental plane=earth's equator
- **Galactic system**

  Fundamental plane=Galactic plane
- **Ecliptic system**

  Fundamental plane=ecliptic plane






## Q：What causes the seasoning？

1. The sunspot activities on the surface of the Sun
2. Inclination of the Earth’s spin axis
3. Change of distance between the Sun and the Earth
4. Periodical changes of atmospheric turbulences

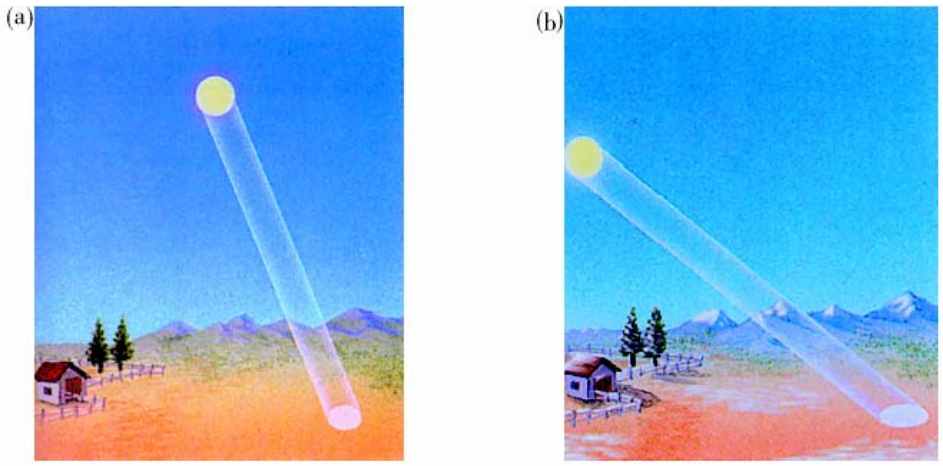
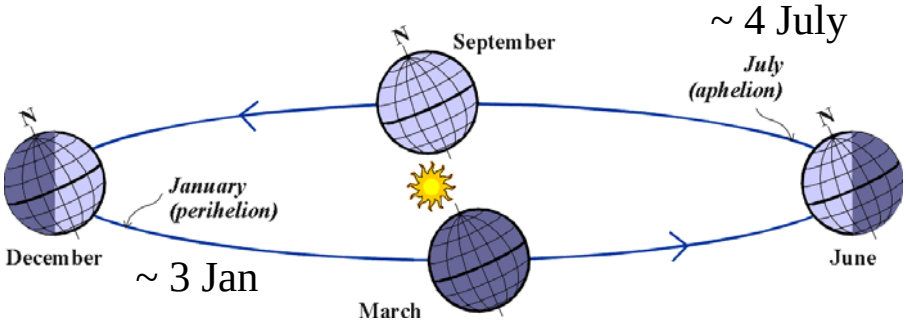



圖 2-13　(a)太陽直射時陽光分布在幾乎圓形的最小面積，(b)太陽斜射時，陽光分布在較大的橢圓面積裡，因此地面單位面積內接收到比較少的能量。(a)圖中的情形有如七、八月時，中午太陽直射北半球地面，因此北半球為夏天。(b)的情形則如一、二月時，同樣是中午，太陽在南方地平線上斜射地面，因此北半球平均溫度低，時值冬季。



- **春分 (vernal equinox)、夏至 (summer solstice)**
  **秋分 (autumn equinox)、冬至 (winter solstice)**
- Sun at vernal equinox around March 21 each year
- Direct sunshine → summer; longer days than nights
- Opposite season in southern hemisphere
- At equinoxes, same duration of day and night
- Seasoning has nothing to do with sun-earth distance (difference only 2%).
- In fact Earth at **perihelion (近日點)** in January, at **aphelion (遠日點)** in July

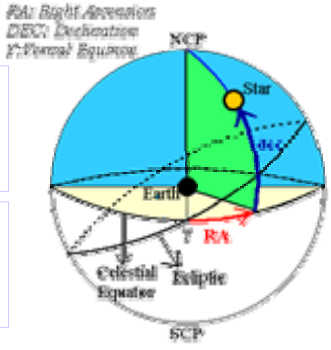
# Time and Coordinates

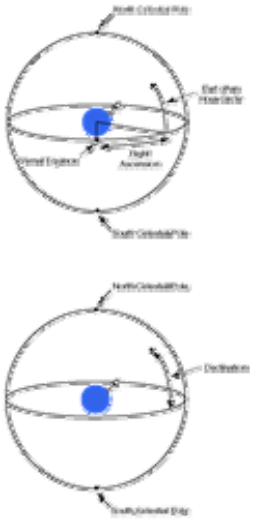
- Sun at vernal equinox on March 21
- Vernal Equinox ➔ RA＝0h
- Sun moves RA~ 2 hours each month

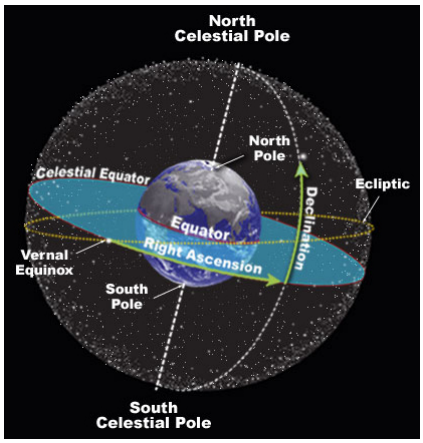
DEC ➔ 緯度

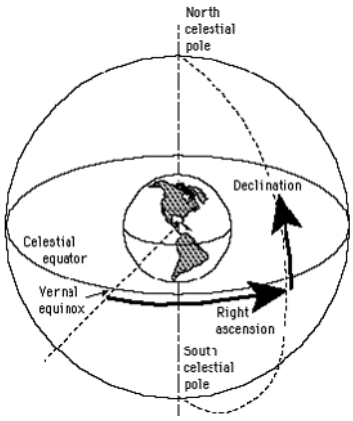
How does a star of DEC=＋25 deg move on the sky?

How about a star of DEC=＋90 deg?
DEC=－65 deg?






**Remember**: Sun at RA=0h around March 21 (vernal equinox 春分）, and moves 2 h every month.

## An exercise….

- The center of the Milky Way galaxy has the equatorial coordinates of RA~17h and DEC~－30 deg. What is the best month/season to observe the Galactic center （銀河中心） from Taiwan?
- Is it better to observe the Galactic center in Australia? If so, why? If not, why not?