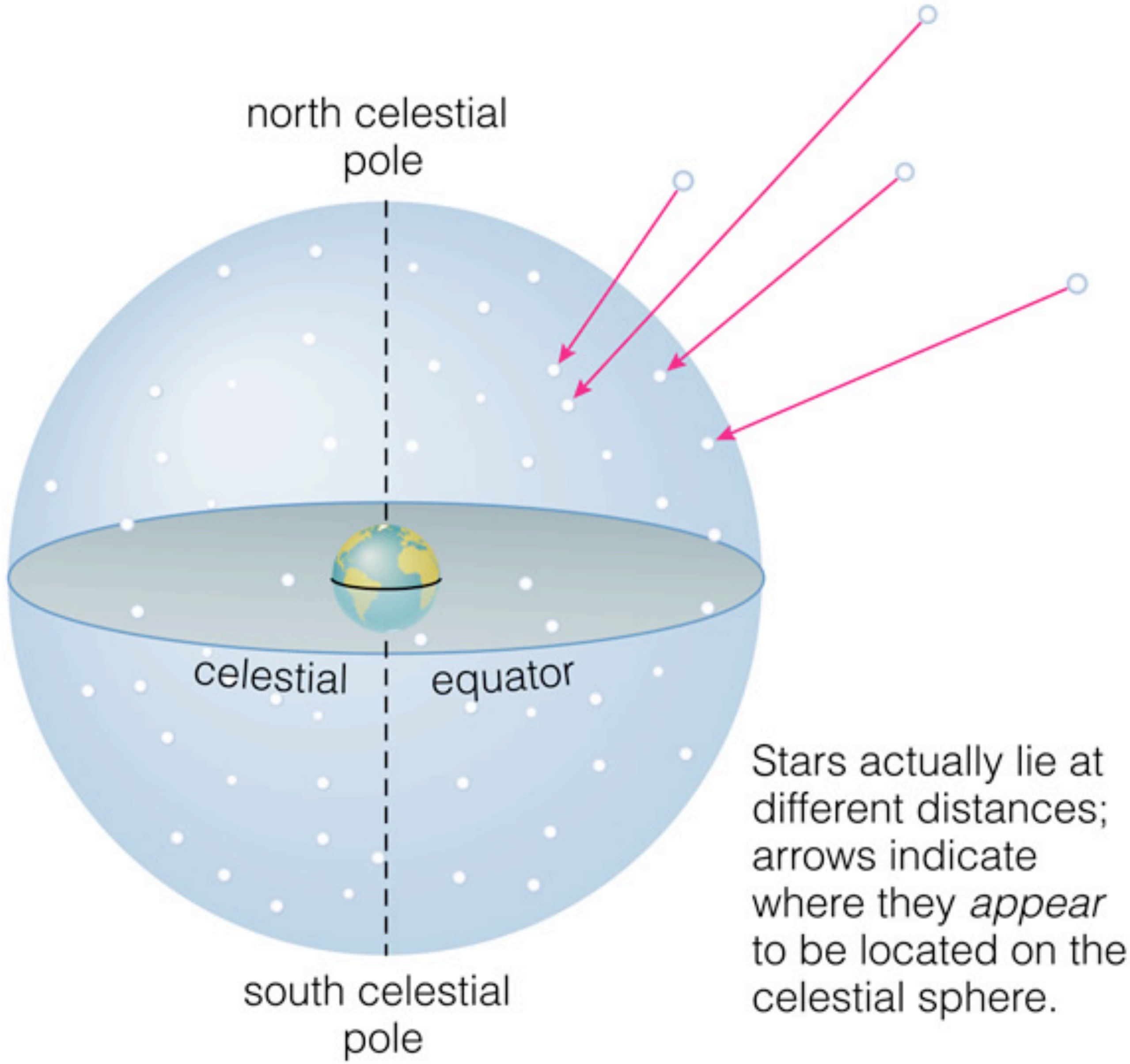
# *2. Descriptive Astronomy ("Astronomy Without a Telescope")*

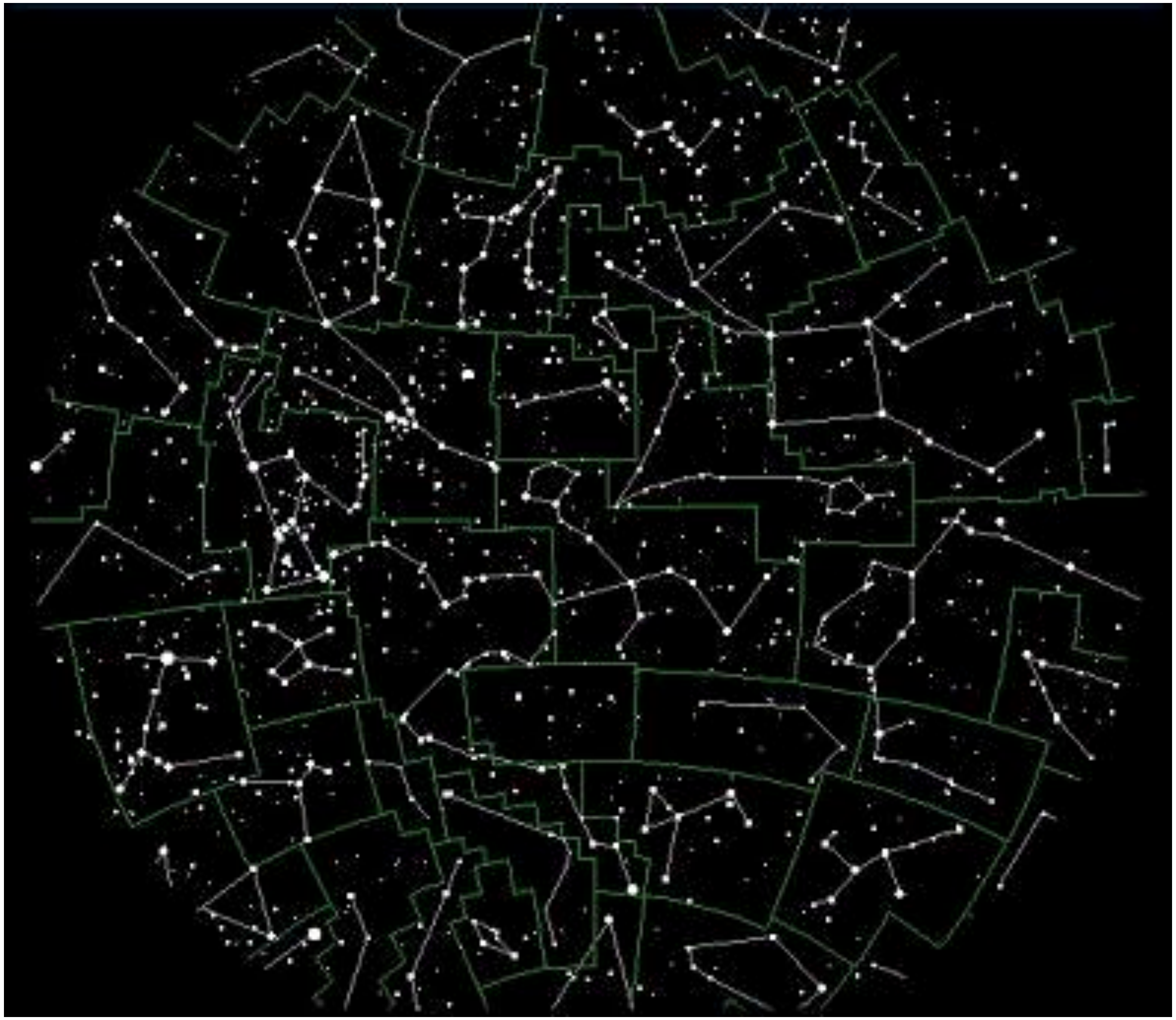
http://www.star.ucl.ac.uk/~idh/apod/

- How do we locate stars in the heavens?
- What stars are visible from a given location?
- Where is the sun in the sky at any given time?
- Where are you on the Earth?






An "asterism" is two stars that appear
To be close in the sky but actually aren't



In 1930 the International Astronomical Union (IAU) ruled the heavens off into 88 legal, precise constellations.

Every star, galaxy, etc., is a member of one of these constellations.

Many stars are named according to their constellation and relative brightness (Bayer 1603).

Sirius

$\alpha$ – Centauri, $\alpha$-Canis Majoris, $\alpha$-Orionis

Betelgeuse

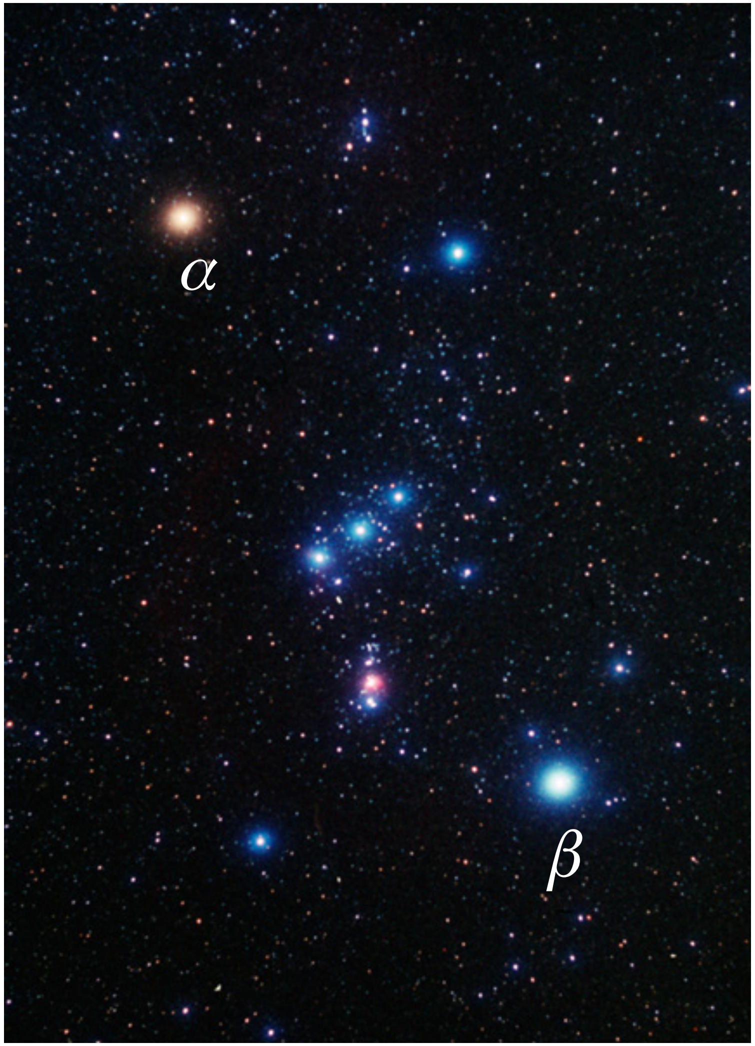
see http://calgary.rasc.ca/constellation.htm#list
http://www.google.com/sky/
http://www.seds.org/messier/ (1758 – 1782)

# Brief History

Some of the current constellations can be traced back to the inhabitants of the Euphrates valley, from whom they were handed down through the Greeks and Arabs. Few pictorial records of the ancient constellation figures have survived, but in the *Almagest* AD 150, Ptolemy catalogued the positions of 1,022 of the brightest stars both in terms of celestial latitude and longitude, and of their places in 48 constellations.

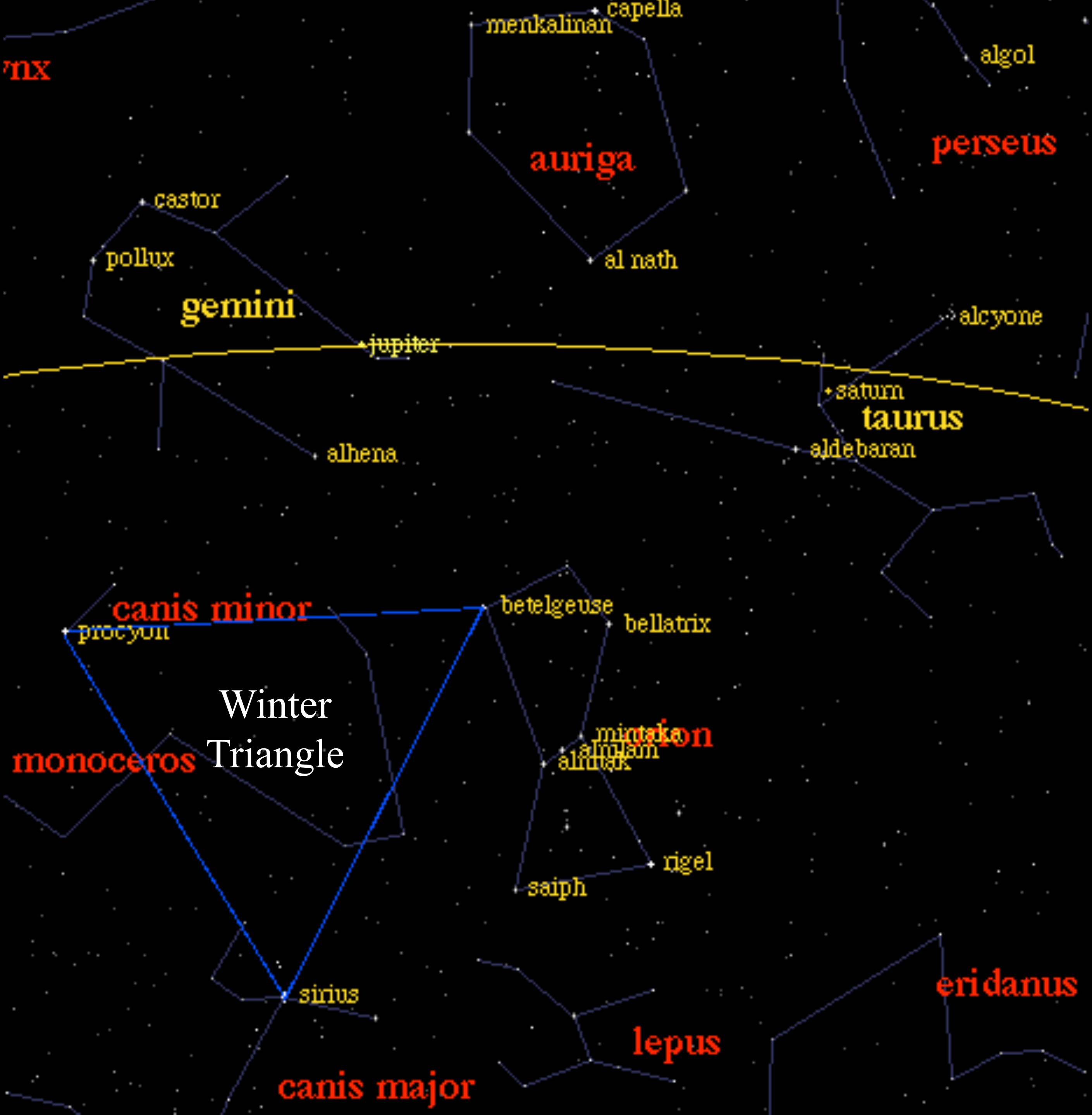
The Ptolemaic constellations left a blank area centered not on the present south pole but on a point which, because of precession, would have been the south pole *c.* 2800 BC, a fact that is consistent with the belief that the constellation system had its origin about 5,000 years ago.

# E.g., ORION




*Betelgeuse and Rigel are α – and β-Orionis*

M42 = Orion nebula
M43 = DeMairan's nebula

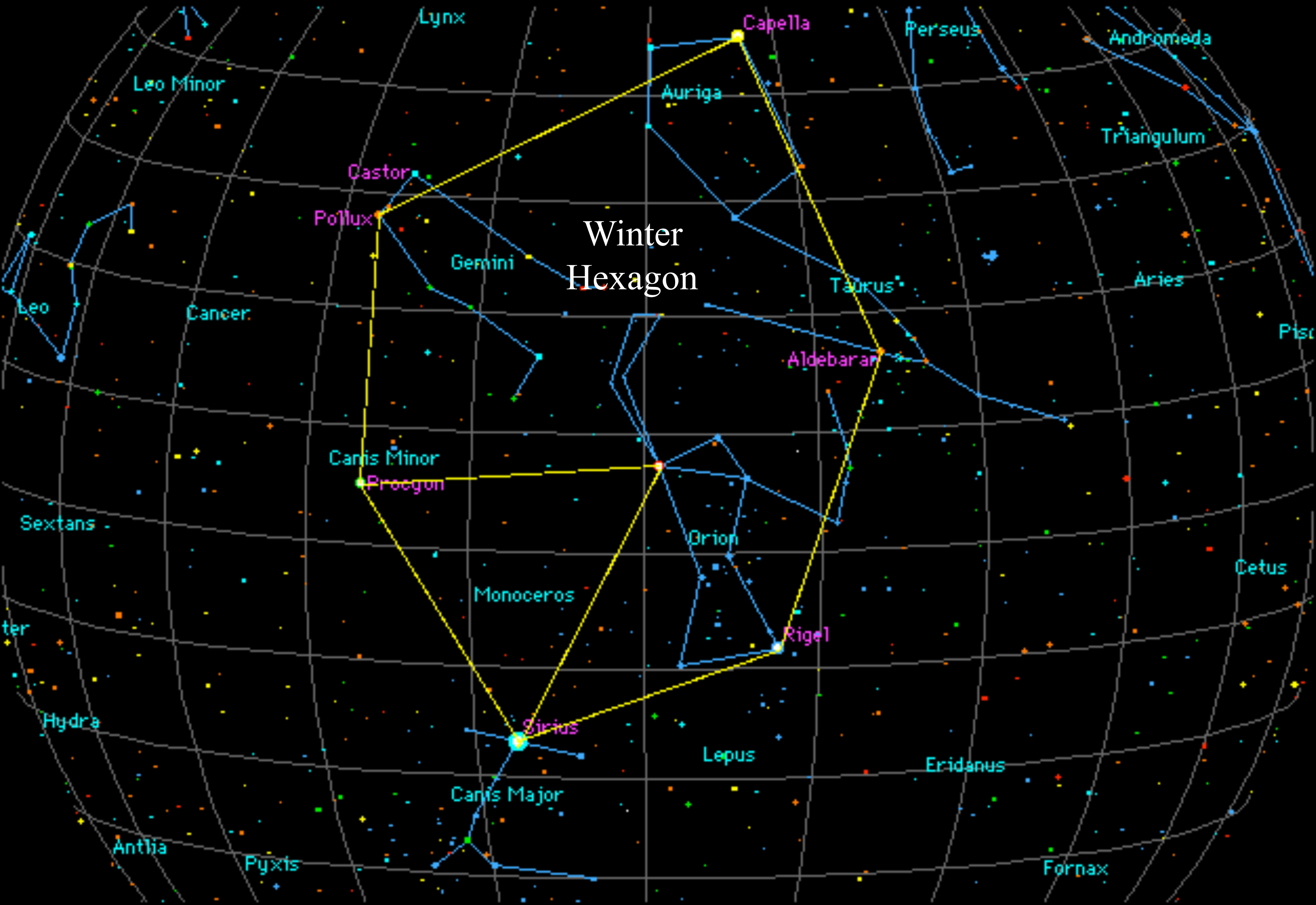


capella
menkalinan
algol
auriga
perseus
castor
pollux
al nath
gemini
alcyone
jupiter
saturn
taurus
alhena
aldebaran
canis minor
betelgeuse
bellatrix
procyon
Winter
Triangle
monoceros
rigel
saiph
sirius
eridanus
lepus
canis major

*Sirius* – brightest star in the sky – star of about twice the mass of the sun. Blue. Very luminous, very hot. A main sequence star (like the sun) but of Type A1

*Procyon* – $8^{th}$ brighest star. About 1.4 solar masses. Another main sequence star. Hotter and more luminous than the sun but not as luminous as Sirius. Type F5. May be close to finishing hydrogen burning as its luminosity is a bit high for its mass.

*Betelgeuse* – $9^{th}$ brightest star. $2^{nd}$ brightest in Orion. Betelgeuse is a red supergiant. It is not fusing hydrogen in its center. It has left the main sequence. May vary in brightness over periods of years by as much as a factor of two. About 18 solar masses and around 10 million years old.


Winter
Hexagon
Lynx
Capella
Perseus
Andromeda
Leo Minor
Auriga
Triangulum
Castor
Pollux
Gemini
Taurus
Aries
Leo
Cancer
Aldebaran
Canis Minor
Procyon
Sextans
Orion
Cetus
Monoceros
Rigel
Hydra
Sirius
Lepus
Eridanus
Canis Major
Antlia
Pyxis
Fornax

# Orion Nebula: M-42

1600 light years away in the sword of Orion, easily visible to the naked eye. 85' x 60' across and part of a larger cloud spanning 20 degrees*. Diameter ~30 ly, Mass ~ 200,000 solar masses.

*•Your fist at arm's length is about 10 degrees*

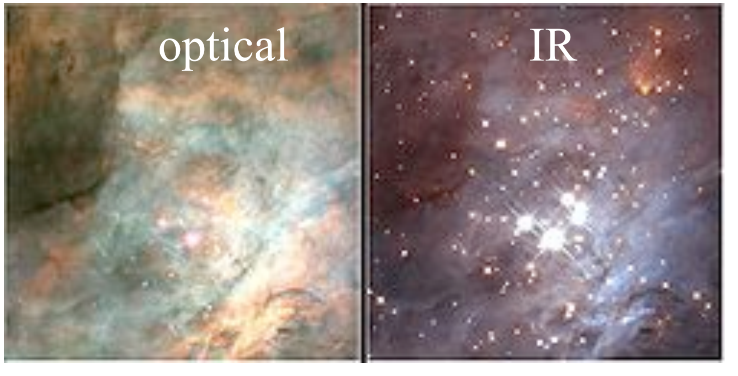

*Star Nursery*

**Betelgeuse** - red supergiant, about 20 solar masses.
May have shrunk 15% in radius since 1993.
This probably does not indicate evolution at its center. 570 ly away. Variable star.
1000 times as luminous as the sun

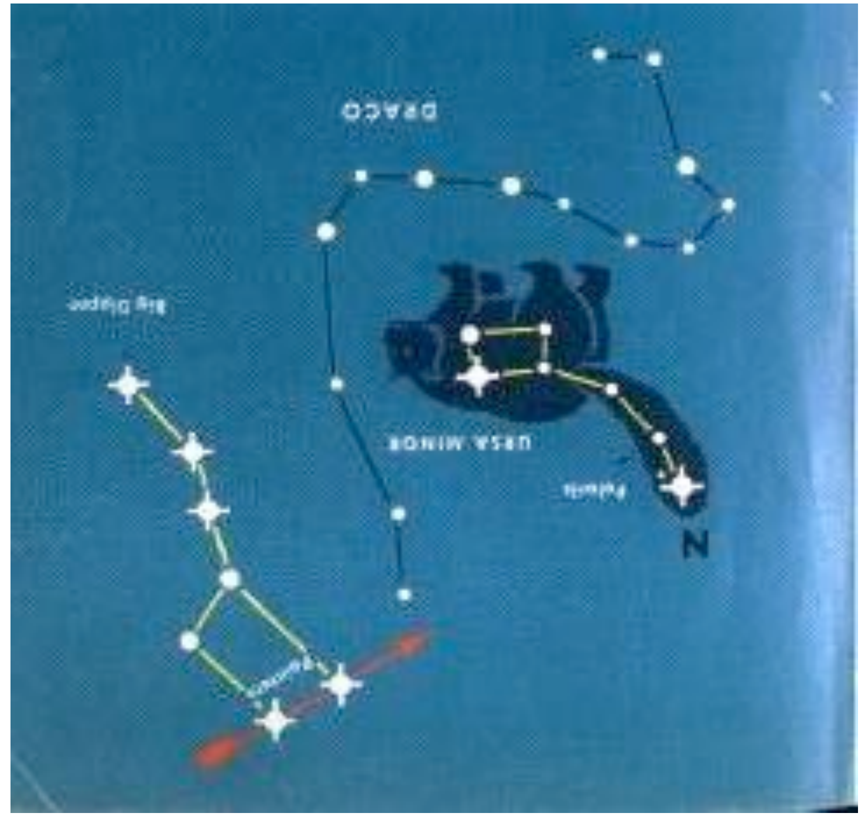
**Rigel** - brightest star in Orion by (a bit more than $\alpha$-Orionis = Betelgeuse – a variable)
7th brightest star in the sky. 770 ly. Most luminous star in our region of galaxy.
A blue supergiant star, 17 solar masses.
Brightness varies by 3 to 30%
Triple star system. A is bright. B is a binary.

**Trapezium** - an open cluster of young stars which illuminate the Orion nebula. The 5 brightest are all over 15 solar masses. Three were discovered by Galileo in 1617.

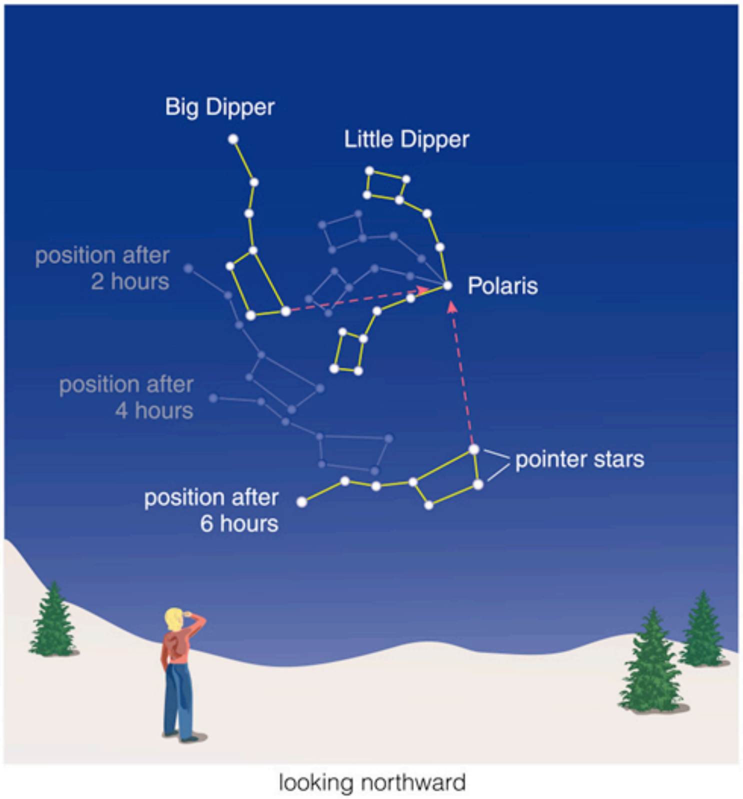
*Bayer (1603) designated the brightness of 1564 stars in his *Uranometria*



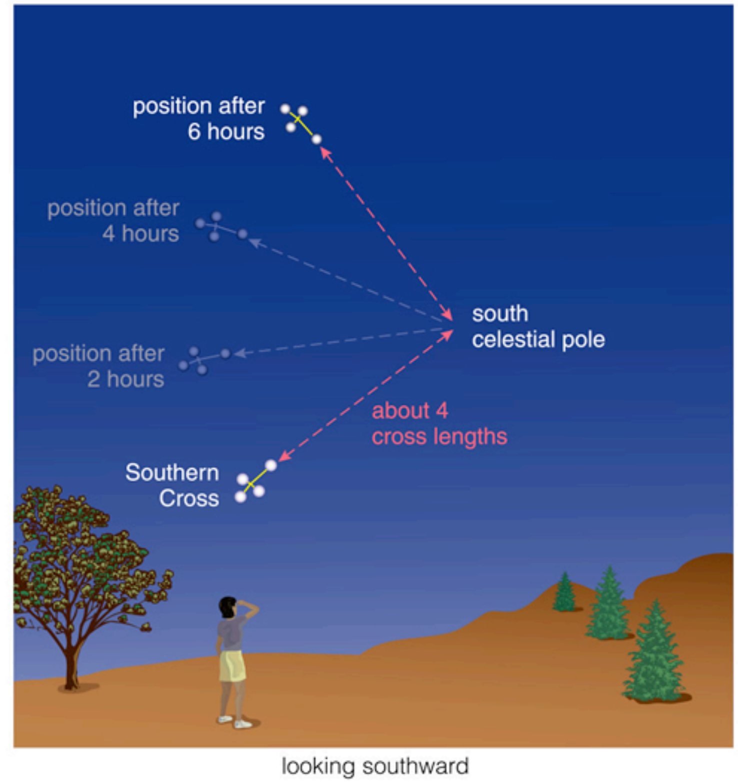

Polaris
N
URSA MAJOR
x 6
Big Dipper
Pointers


DRACO
Big Dipper
URSA MINOR
Polaris
N

# Motions of stars in the sky





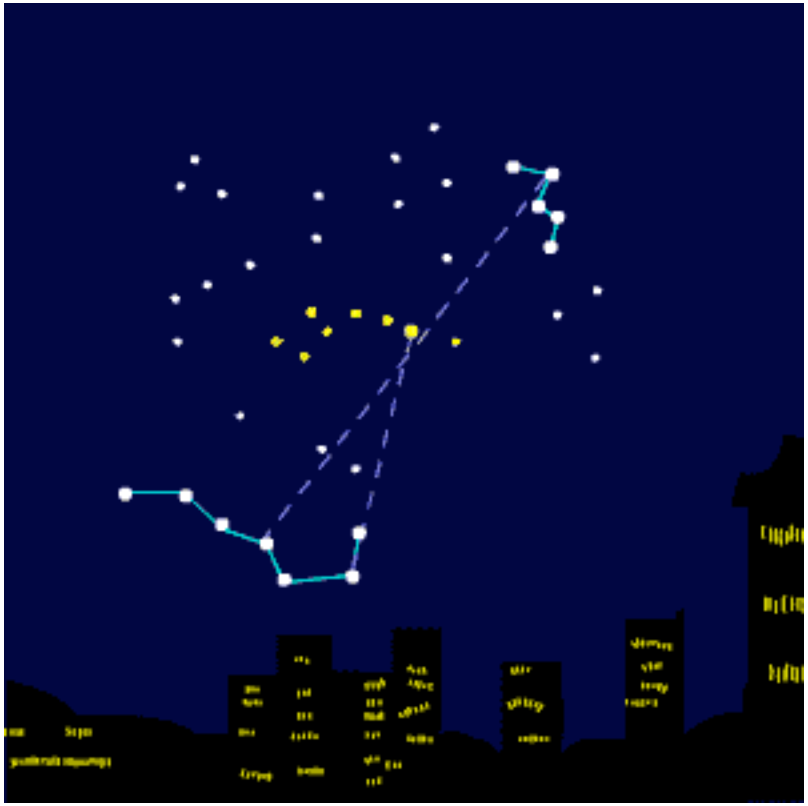




North

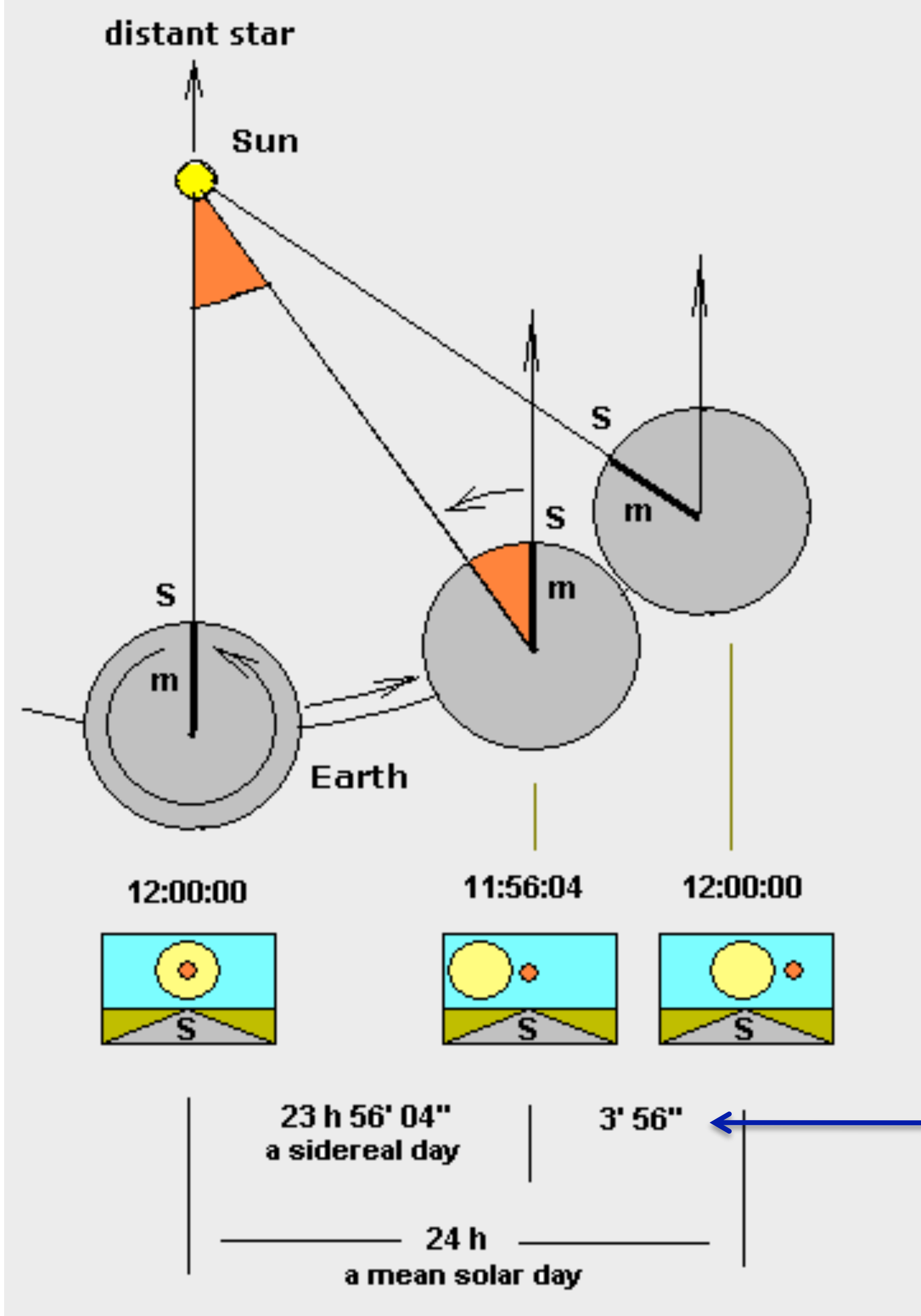
South

*Polaris is 6 times the distance between the pointers away – i.e., ~30$^{o}$.*




Can tell time this way, but

a) 24 hr clock
b) sidereal time

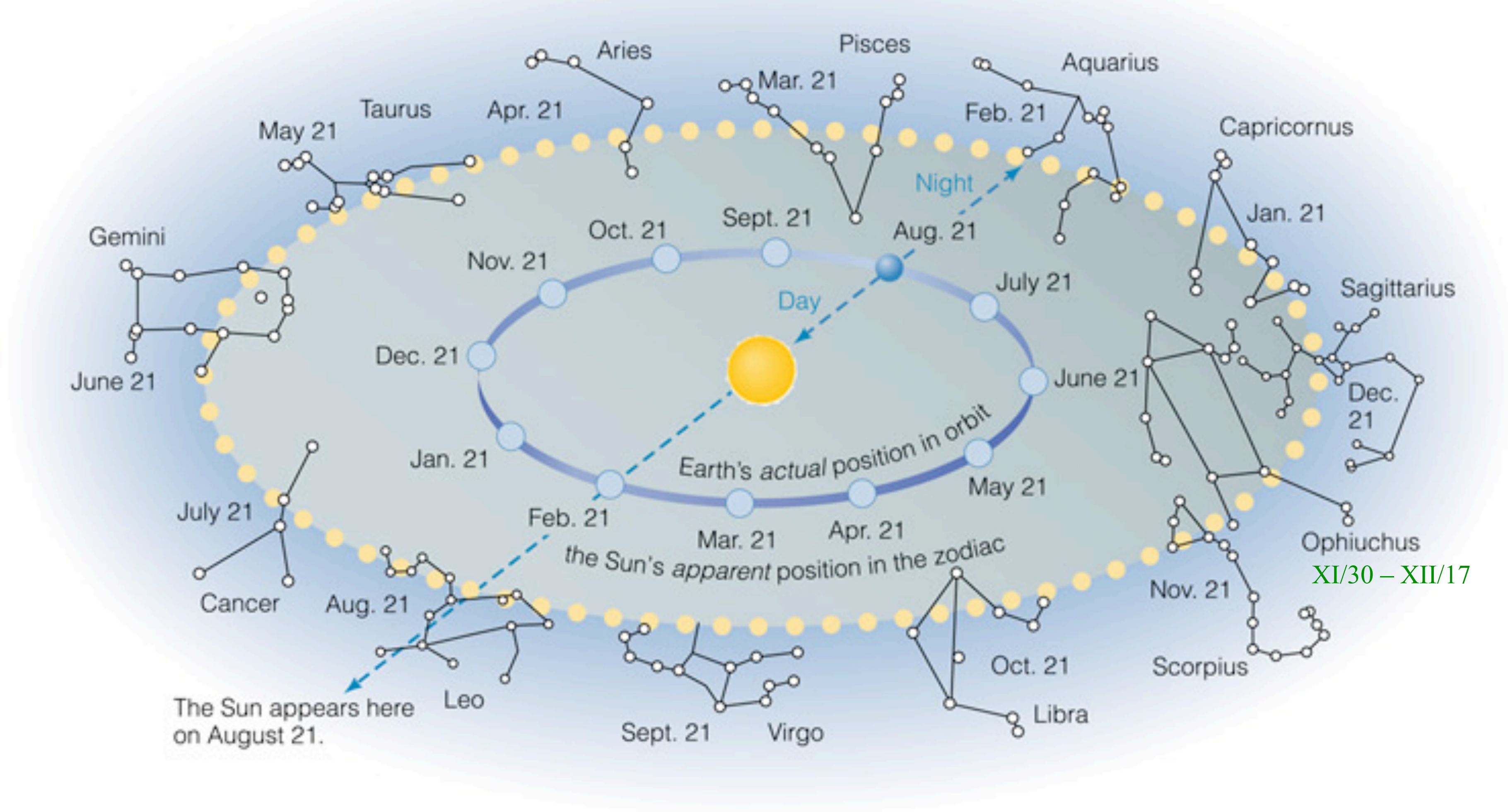



$$\frac{24\ \text{hr}}{365.25}$$

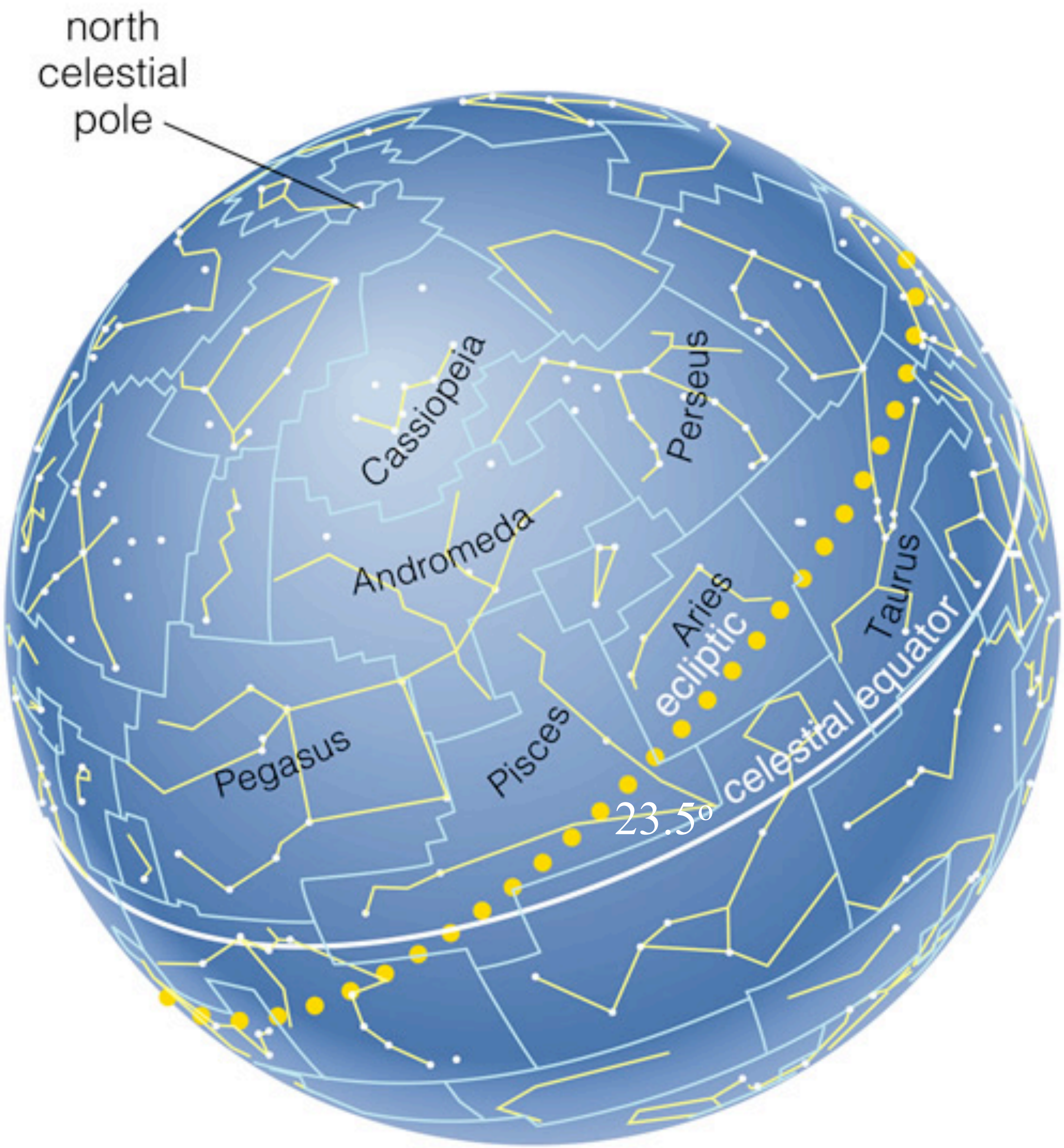
The apparent location of the sun in the sky as the earth goes round it defines a great circle in the heavens called the “ecliptic”.

The projection of the earth’s equator in the sky gives another called the “celestial equator”. Because the Earth’s rotational axis is not perpendicular to the plane containing the earth’s orbit around the sun, the two are not the same but are inclined to each other by $23.5^{o}$.

# *The path of the sun in the sky*




XI/30 – XII/17



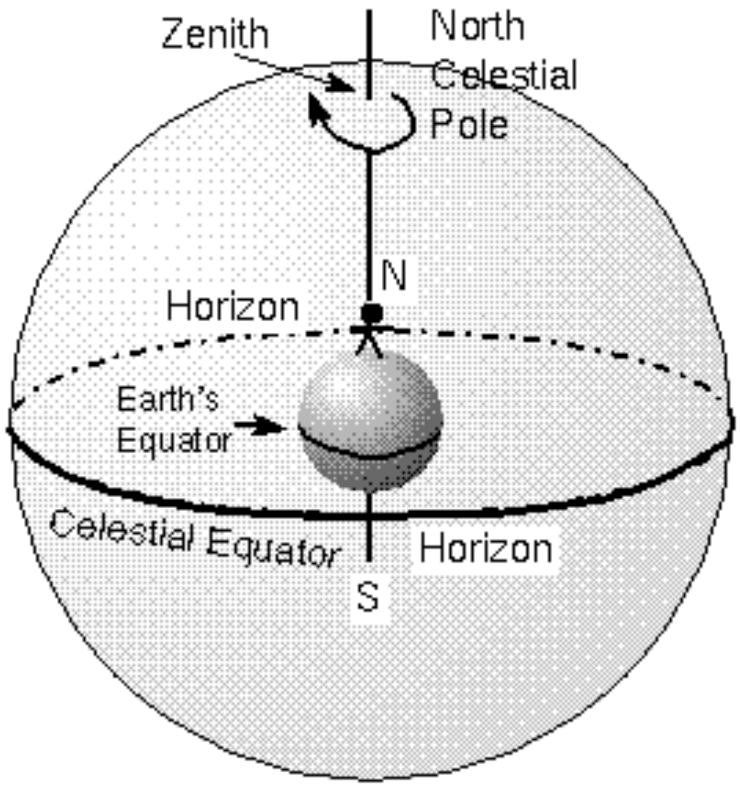



*Think of the earth as being at the center of this imaginary celestial sphere*

# Signs of the Zodiac

| | | | | | | |
|---|---|---|---|---|---|---|
| Pisces | The Fishes | March | 12 | to | April | 18 |
| Aries | The Ram | April | 19 | to | May | 13 |
| Taurus | The Bull | May | 14 | to | June | 19 |
| Gemini | The Twins | June | 20 | to | July | 20 |
| Cancer | The Crab | July | 21 | to | August | 9 |
| Leo | The Lion | August | 10 | to | September | 15 |
| Virgo | The Maiden | September | 16 | to | October | 30 |
| Libra | The Balance | October | 31 | to | November | 22 |
| Scorpius | The Scorpion | November | 23 | to | November | 29 |
| Ophiuchus** | Serpent-holder | November | 30 | to | December | 17 |
| Sagittarius | The Archer | December | 18 | to | January | 18 |
| Capricornus | The Goat | January | 19 | to | February | 15 |
| Aquarius | The Water-bearer | February | 16 | to | March | 11 |

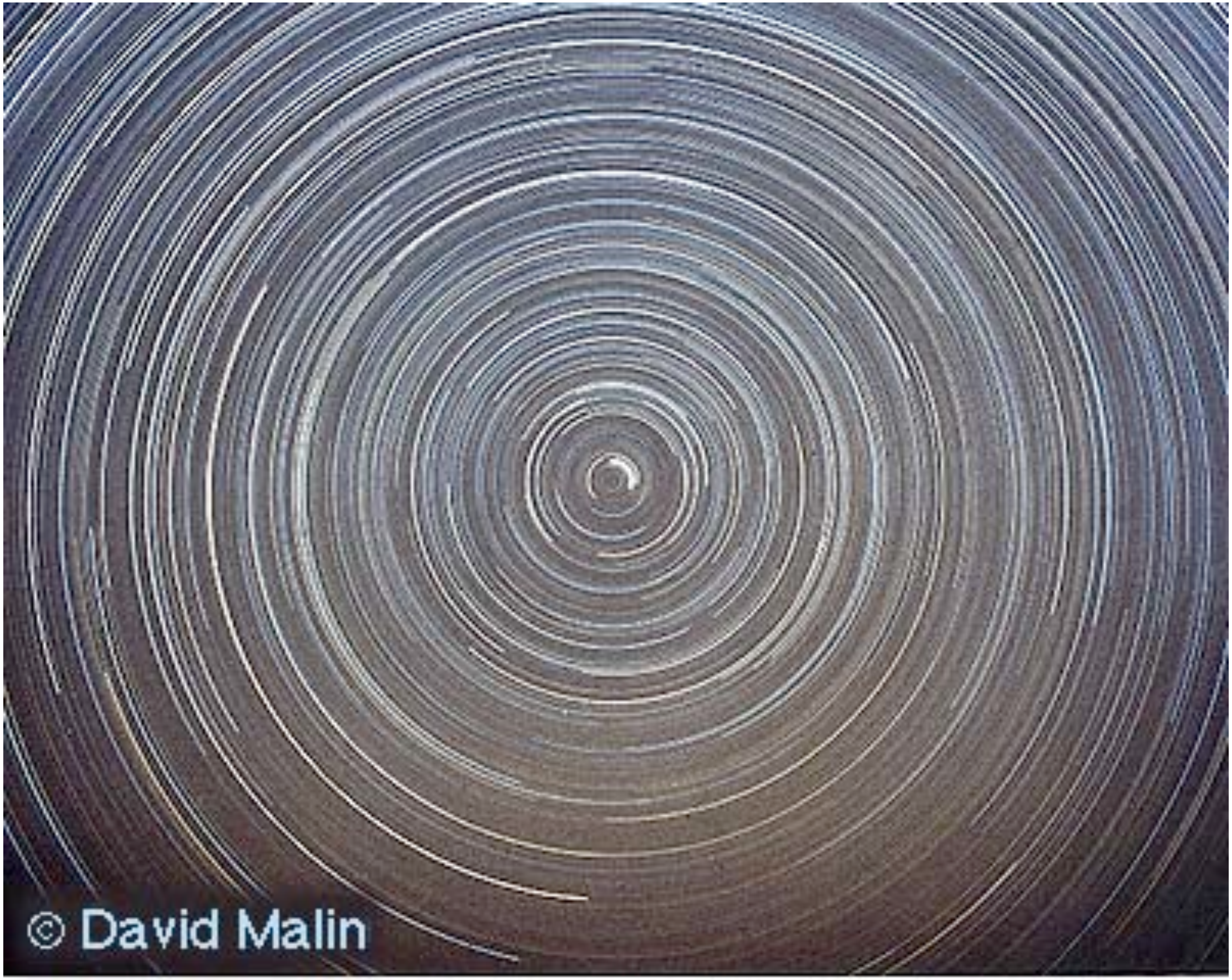
# How about the apparent motion of the stars in the sky?




If you stood at the earth's north pole, your *zenith* would be the projection of the earth's rotational axis into the sky.

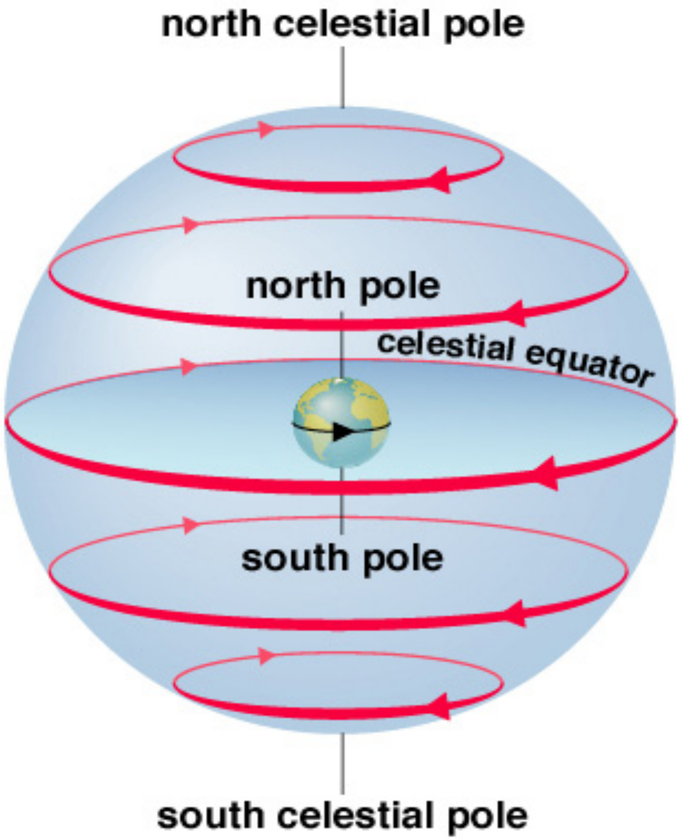
Your horizon would be the *celestial equator.*

*The celestial equator is the projection of the Earth's equator into the heavens.*




8 hr time lapse photo

# The Daily Motion

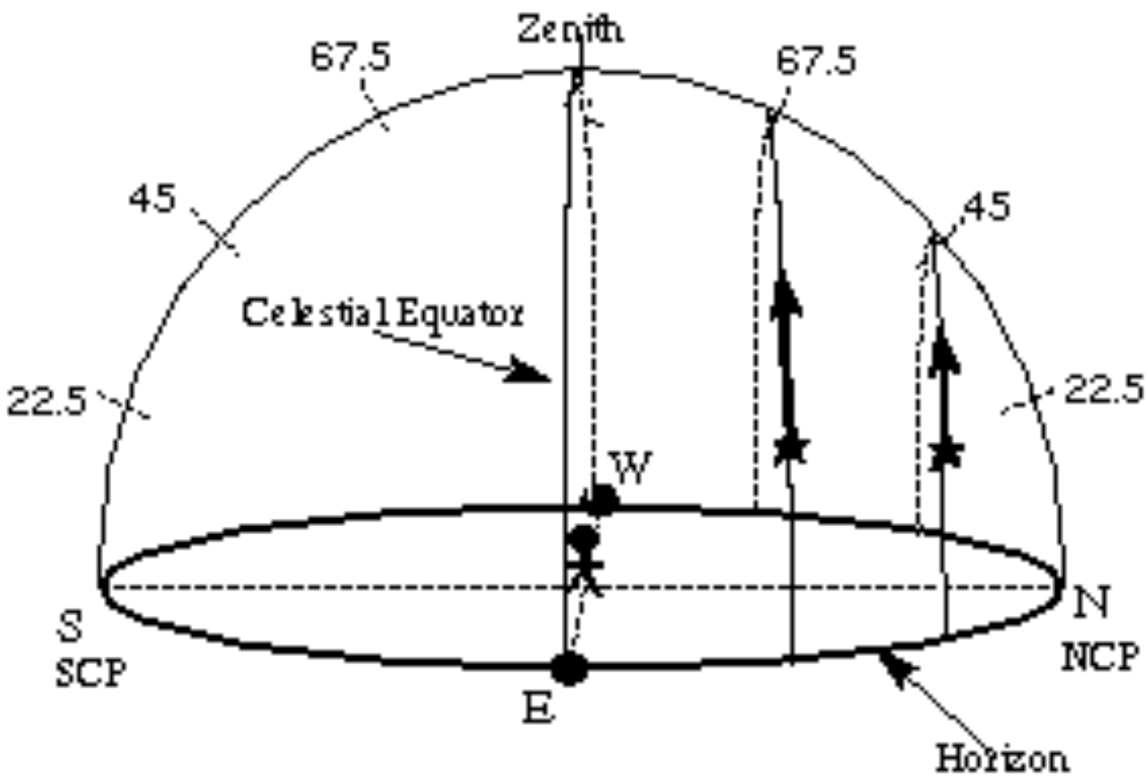





- As the Earth rotates, the sky appears to us to rotate in the opposite direction.
- The sky appears to rotate around the N (or S) celestial poles.
- If you are standing at the poles, nothing rises or sets.
- If you are standing at the equator, everything rises & sets 90$^{o}$ to the horizon.

copied from Nick Strobel's "Astronomy notes". See his website.

*At the equator, stars would all rise perpendicular to the horizon and set perpendicular to the horizon.*



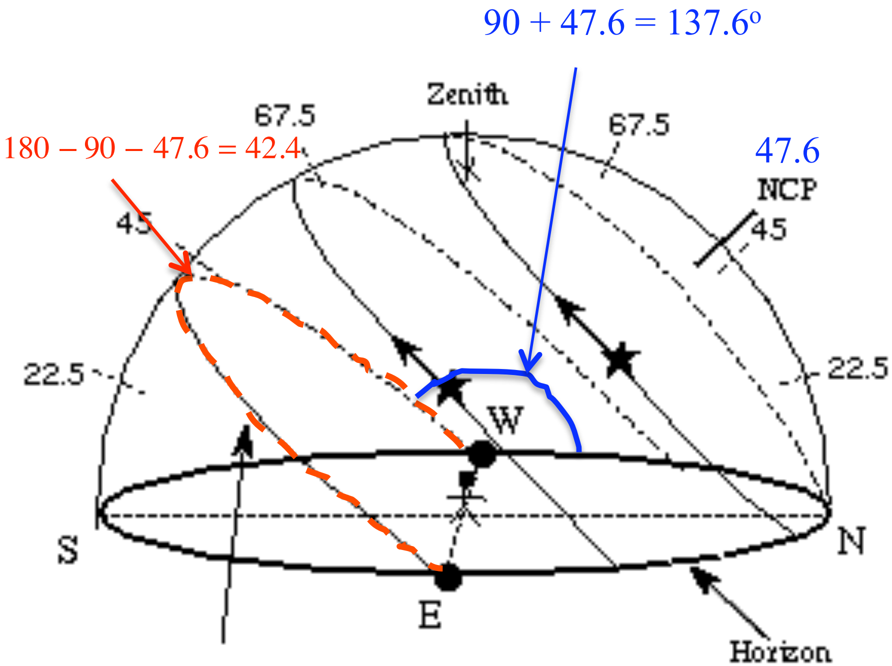

Stars motion at the Equator. Stars rotate parallel to the Celestial Equator, so they move perpendicular to the horizon here. All stars are visible for 12 hours. Both celestial poles are visible on the horizon.


Panoramic view of the African night from equatorial Kenya. The three hour long exposure was made on a clear, dark, mid November evening facing due west and covers just over 180 degrees along the horizon. So, the South Celestial Pole is at the center of the concentric arcs on the left and the North Celestial Pole is at the far right. The stars setting along the Celestial Equator leave the straight trails near the middle of the picture.

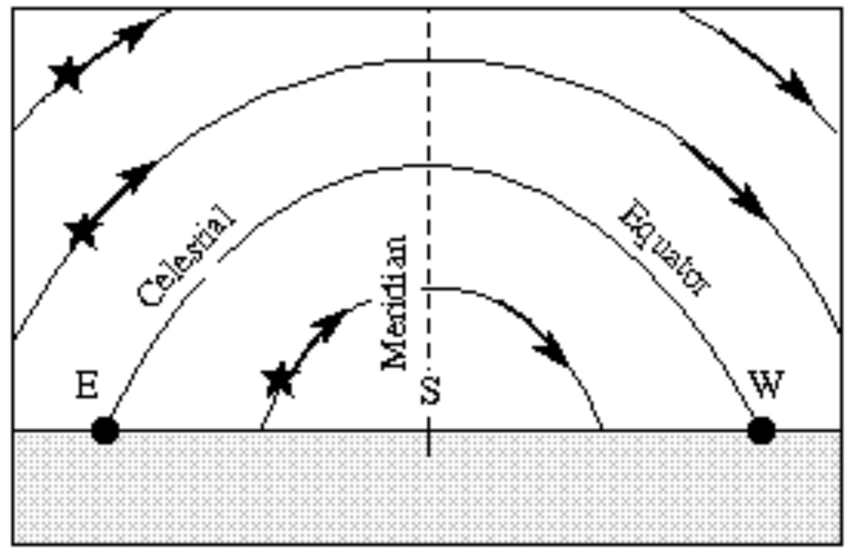
Leroy Zimmerman, Astronomy picture of the day November 15, 2002

Latitude of Seattle = 47.6 degrees

# At a lower latitude than the north pole




Stars motion at Seattle. Stars rotate parallel to the Celestial Equator, so they move at an angle with respect to the horizon here. Altitudes of 1/4, 1/2, and 3/4 the way up to the zenith are marked.




Your view from Seattle. Stars rise in the East half of the sky, reach maximum altitude when crossing the meridian (due South) and set in the West half of the sky. The Celestial Equator goes through due East and due West.

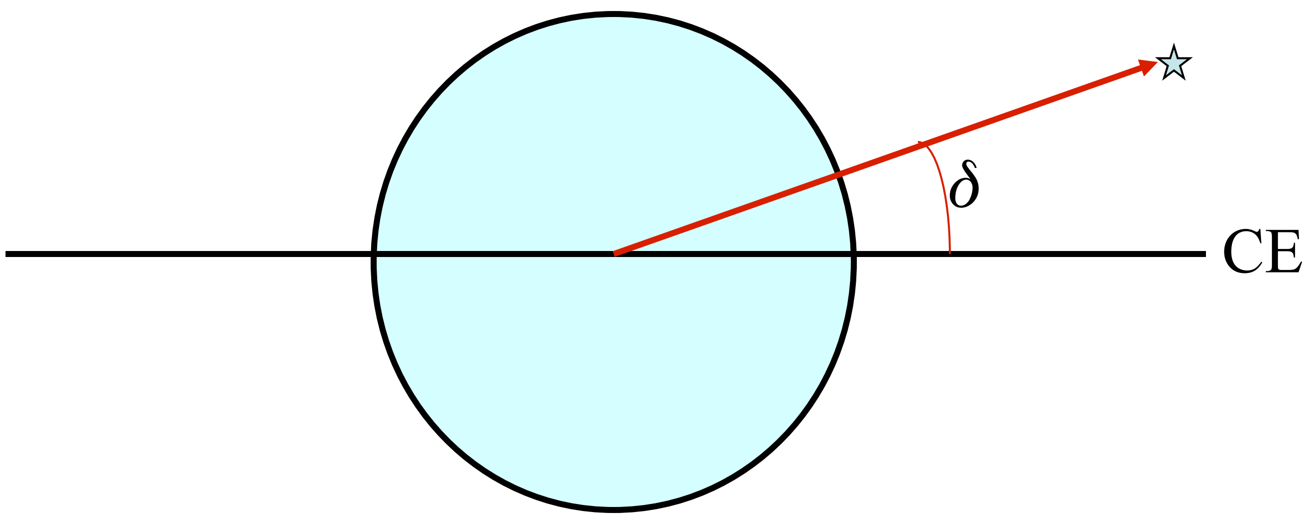
Stars within a certain angle of the north pole would go in circles around the pole and never set. Others have more complicated paths. Some near the south pole remain invisible. Only stars on the celestial equator would rise due east and set due west.

# Stellar Coordinates

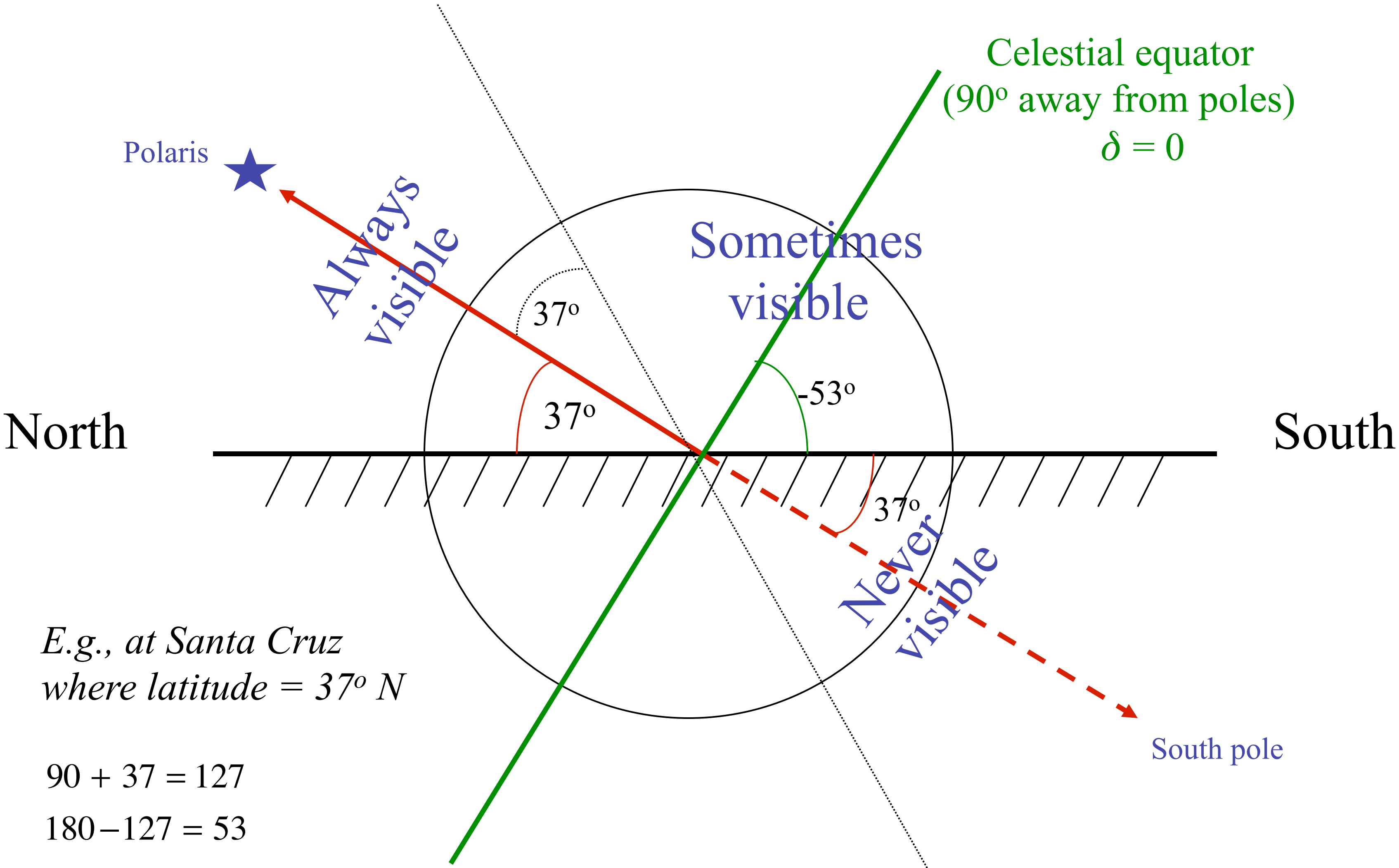
## Right Ascension and Declination

- **Celestial Equator**
  Projection of the Earth's equator into the sky

- **Declination** $-90^o \leq \delta \leq +90^o$
  The angle to a star or other object in degrees, minutes, and seconds measured north or south of the Celestial Equator



# What can be seen from a given location?




*E.g., at Santa Cruz*
*where latitude = 37° N*

$90 + 37 = 127$

$180 - 127 = 53$

The poles and the celestial equator remain fixed in the sky as the earth rotates

Stars will be "circumpolar", i.e., never set if their declination is

L = latitude

$$\delta \geq 90^o - L \qquad L > 0$$

in the northern hemisphere and

$$\delta \leq -90^o - L \qquad L < 0$$

in the southern hemisphere. Note that L is negative in the southern hemisphere. At the south pole L = -90. At the north pole L = +90.

A star will rise above the horizon sometime in a 24 hour period if

$$\delta > L - 90^o$$

$$\delta < L + 90^o$$

Where $\delta$ is the declination of the star and L is your latitude.

$$90 \geq \delta \geq -90$$

$$90 \geq L \geq -90$$

L = -90 is the south pole. L = 90 is the north pole, 37 is Santa Cruz.

- What stars are visible from Santa Cruz (Latitude 37° N)?

  Sometime each day: $\delta > 37^o - 90^o = -53^0$ L - 90

  Never: $\delta < 37^o - 90^o = -53^0$

  Always: $\delta > 90^o - 37^o = +53^o$ 90 - L

Examples:

  Sirius - $\delta = -16^o\ 39'$

  Polaris - $\delta \approx 90^o$

  $\alpha$-Centauri - $\delta = -60^o\ 38'$

- What stars are visible from the north pole?

  All with $\delta > 0$ all the time

- What stars are visible from the equator?

  All stars (including the sun) 12 hours per day

- What stars are above the horizon 12 hours per day everywhere?

  Those on the Celestial Equator

http://aa.quae.nl/en/index.html

Click on answerbook and e.g., position of the sun

# Brightest Stars

| Star | Name | M | RA | Dec |
|---|---|---|---|---|
| alpha CMa | Sirius | -1.46 | 06 45 8.9 | -16 42 58 |
| alpha Car | Canopus | -0.72 | 06 23 57.2 | -52 41 44 |
| alpha Cen | Rigil Kent | -0.01 | 14 39 36.2 | -60 50 07 |
| alpha Boo | Arcturus | -0.04 | 14 15 39.6 | +19 10 57 |
| alpha Lyr | Vega | 0.03 | 18 36 56.2 | +38 47 01 |
| alpha Aur | Capella | 0.08 | 05 16 41.3 | +45 59 53 |
| beta Ori | Rigel | 0.12 | 05 14 32.2 | -08 12 06 |
| alpha CMi | Procyon | 0.38 | 07 39 18.1 | +05 13 30 |
| alpha Eri | Archenar | 0.46 | 01 37 42.9 | -57 14 12 |
| alpha Ori | Beteigeuse | 0.50 | 05 55 10.3 | +07 24 25 |
| beta Cen | Hadar | 0.61 | 14 03 49.4 | -60 22 22 |
| alpha Aql | Altair | 0.77 | 19 50 46.9 | +08 52.6 |
| | | 0.77 | | |
| alpha Tau | Aldebaran | 0.85 | 04 35 55.2 | +16 30 33 |
| alpha Vir | Spica | 0.98 | 13 25 11.5 | -11 09 41 |
| alpha Sco | Antares | 0.96 | 16 29 24.4 | -26 25 25 |
| beta Gem | Pollux | 1.14 | 07 45 18.9 | +28 01 34 |
| alpha PsA | Fomalhaut | 1.16 | 22 57 39.0 | -29 37 20 |
| alpha Cyg | Deneb | 1.25 | 20 41 25.8 | +45 16 49 |
| beta Cru | Mimosa | 1.25 | 12 47 43.3 | -59 41 19 |

| Day | Solar Declination |
|---|---|
| March 21 | 0 |
| June 21 | 23.5º |
| September 21 | 0 |
| December 21 | -23.5º |

# The Altitude of the Sun

- The declination, $\delta$, of the sun varies from $-23.5^o$ to $+23.5^o$

  For regions above latitude $66.5^o$ or below $-66.5^o$ there are times when the sun is not visible

- What is the highest the sun rises in Santa Cruz?

  $90^o - 37^o + 23.5^o = 76.5^o$ on June 21

  gives CE

  ab on equator just = inclination of ⊕ rotation axis

- What is the lowest

  $90^o - 37^o - 23.5^o = 29.5^o$ on December 21

- When is the day 12 hours long everywhere

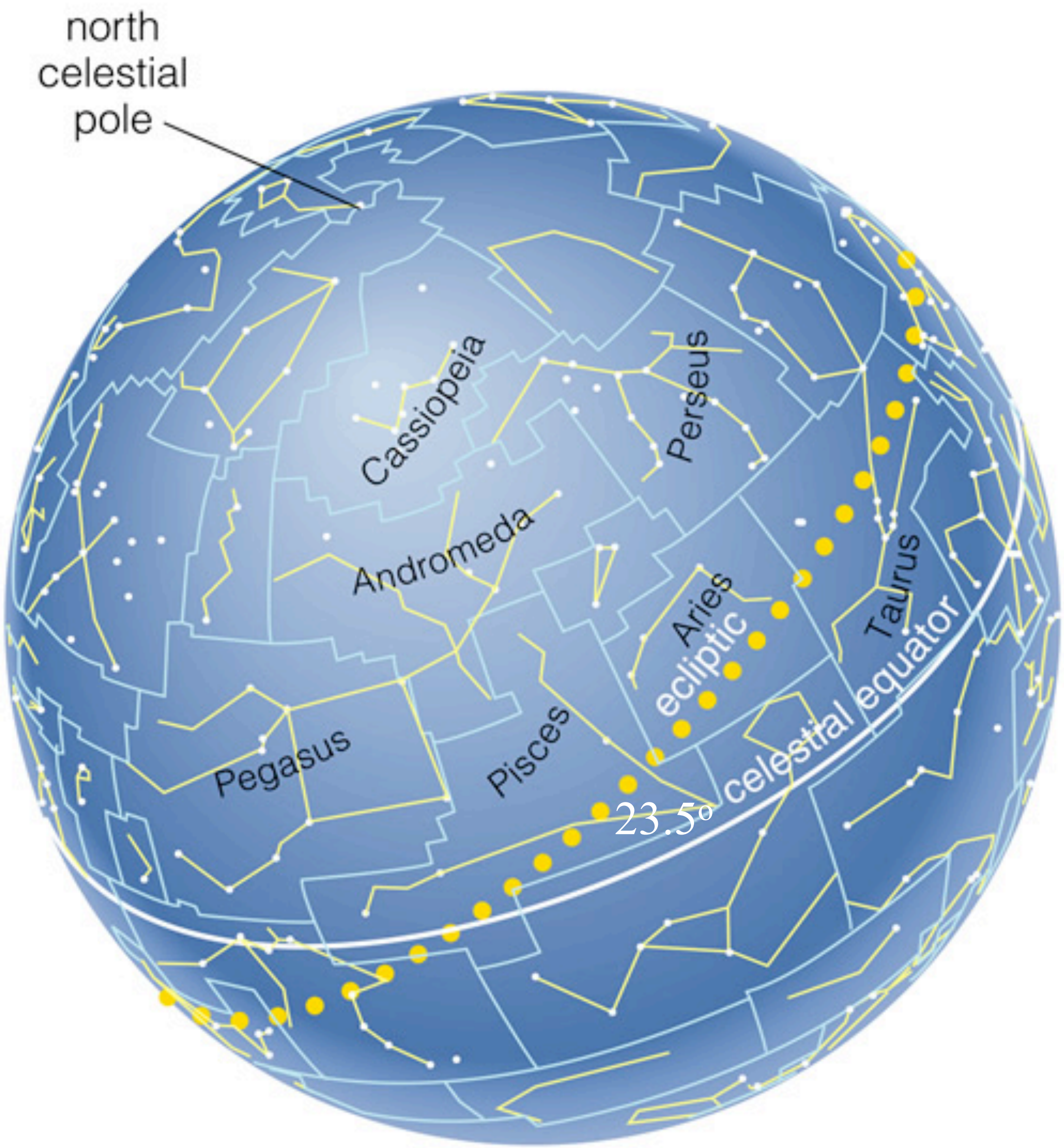
  When the sun is on the Celestial Equator, i.e., the two equinoxes

- Is the sun ever directly overhead in Santa Cruz?

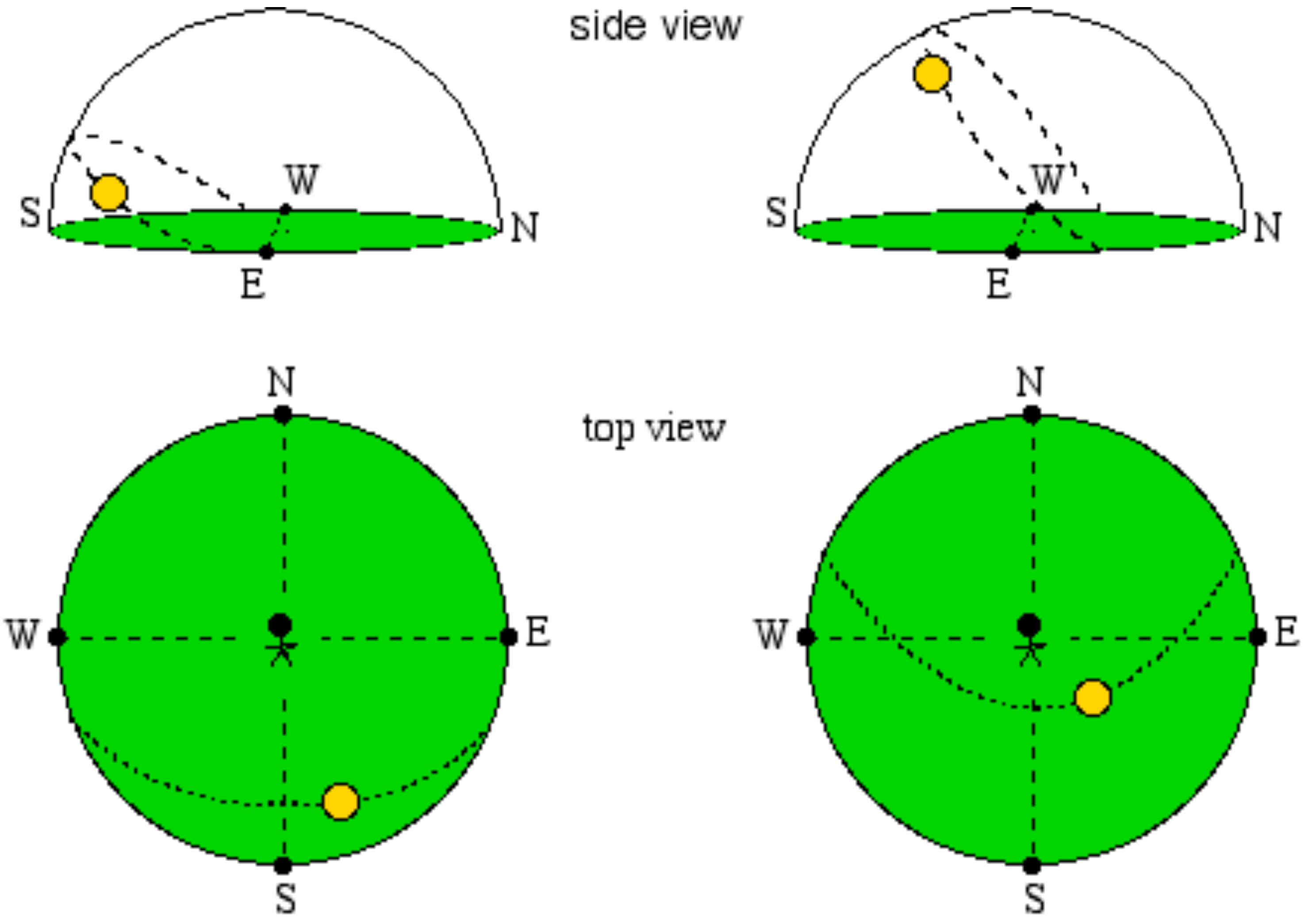
  *No*

- How far south must one go?

  To the "tropics" – latitudes below 23.5º


north
celestial
pole
Cassiopeia
Perseus
Andromeda
Aries
ecliptic
Taurus
celestial equator
Pegasus
Pisces
23.5º

copied from Nick Strobel's "Astronomy notes". See his website.



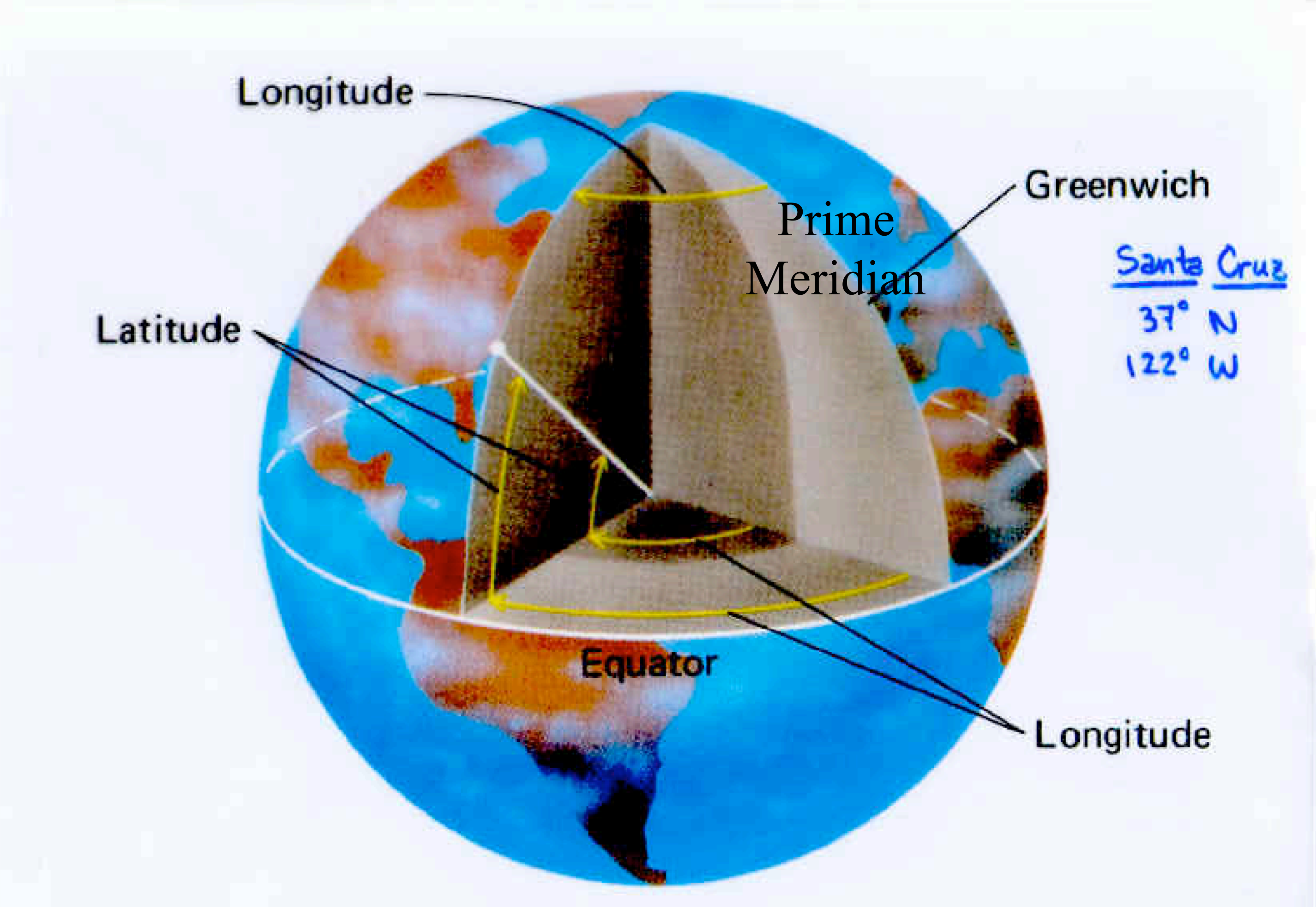

Fall + winter: short, low path.
Sunrise in southeast
Sunset in southwest

Spring + summer: long, high path
Sunrise in northeast
Sunset in northwest

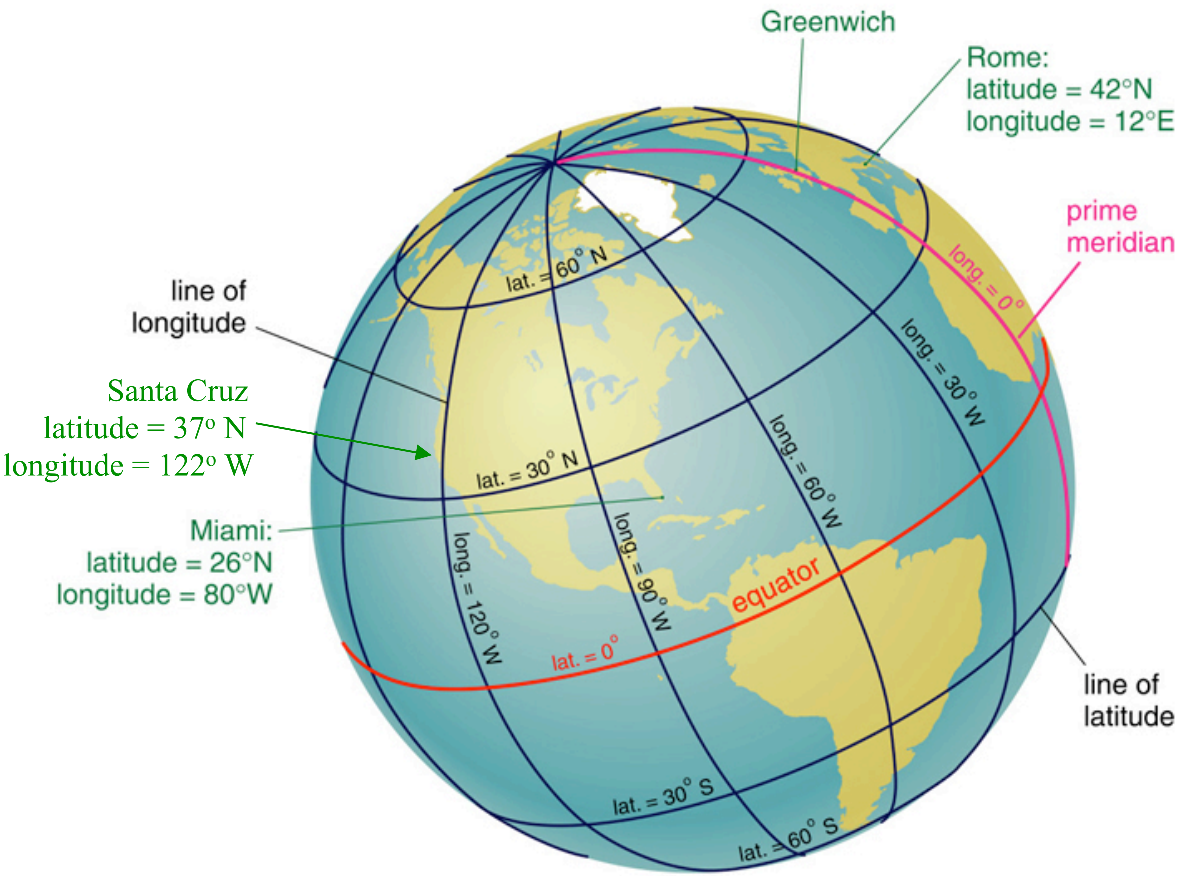
How do we assign a location to a  star in the sky?

We could say so many degrees above the horizon and so many degrees east or west from some point, like the southern direction, but a little thought shows that location would vary with location and time on the Earth.

# How we define our location on the Earth...



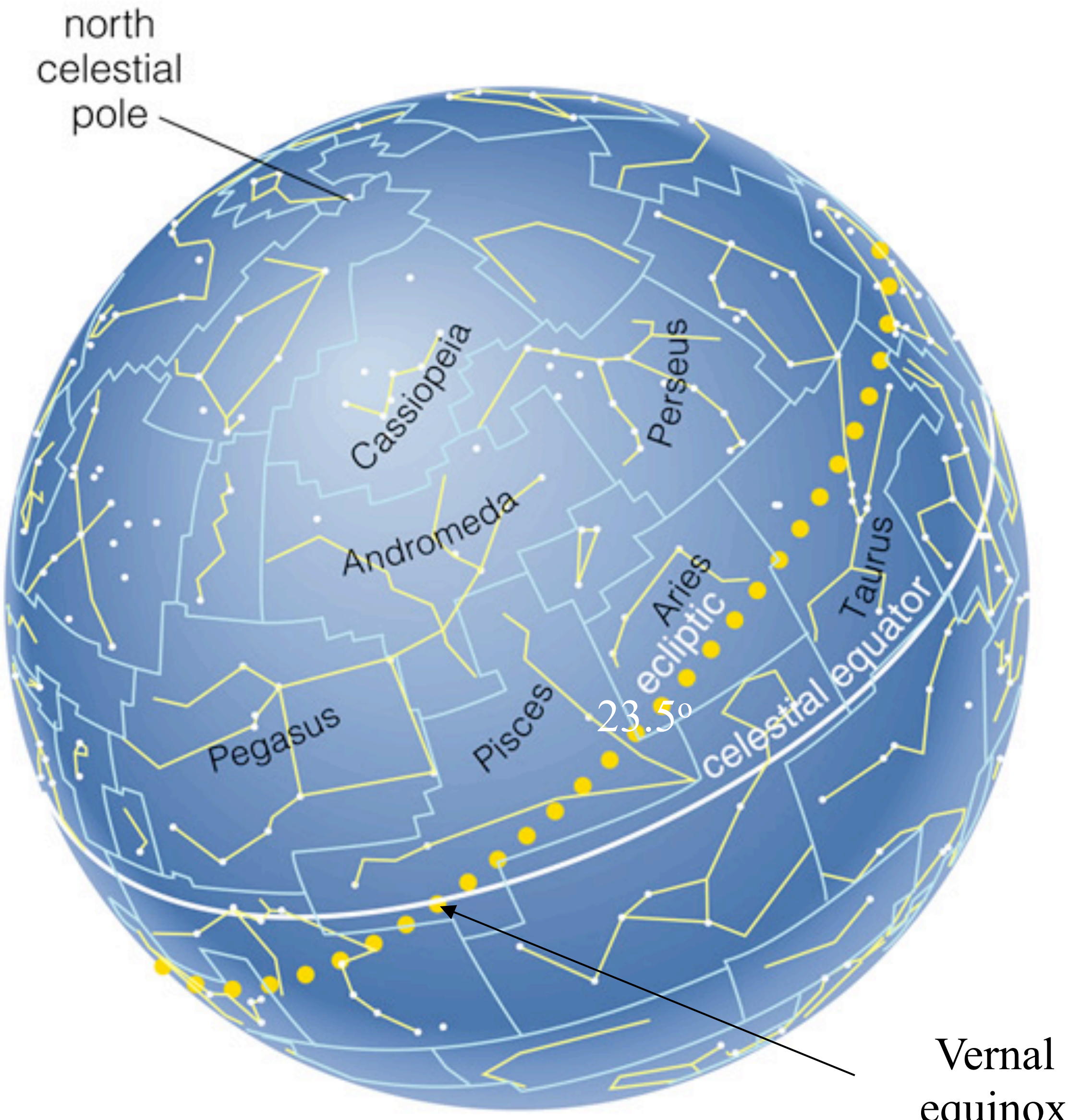

16. Abell/Morrison/Wolff: EXPLORATION OF THE UNIVERSE, 6/E


Greenwich
Rome:
latitude = 42°N
longitude = 12°E
prime
meridian
line of
longitude
Santa Cruz
latitude = 37° N
longitude = 122° W
Miami:
latitude = 26°N
longitude = 80°W
line of
latitude
lat. = 60° N
lat. = 30° N
lat. = 0°
lat. = 30° S
lat. = 60° S
equator
long. = 0°
long. = 30° W
long. = 60° W
long. = 90° W
long. = 120° W

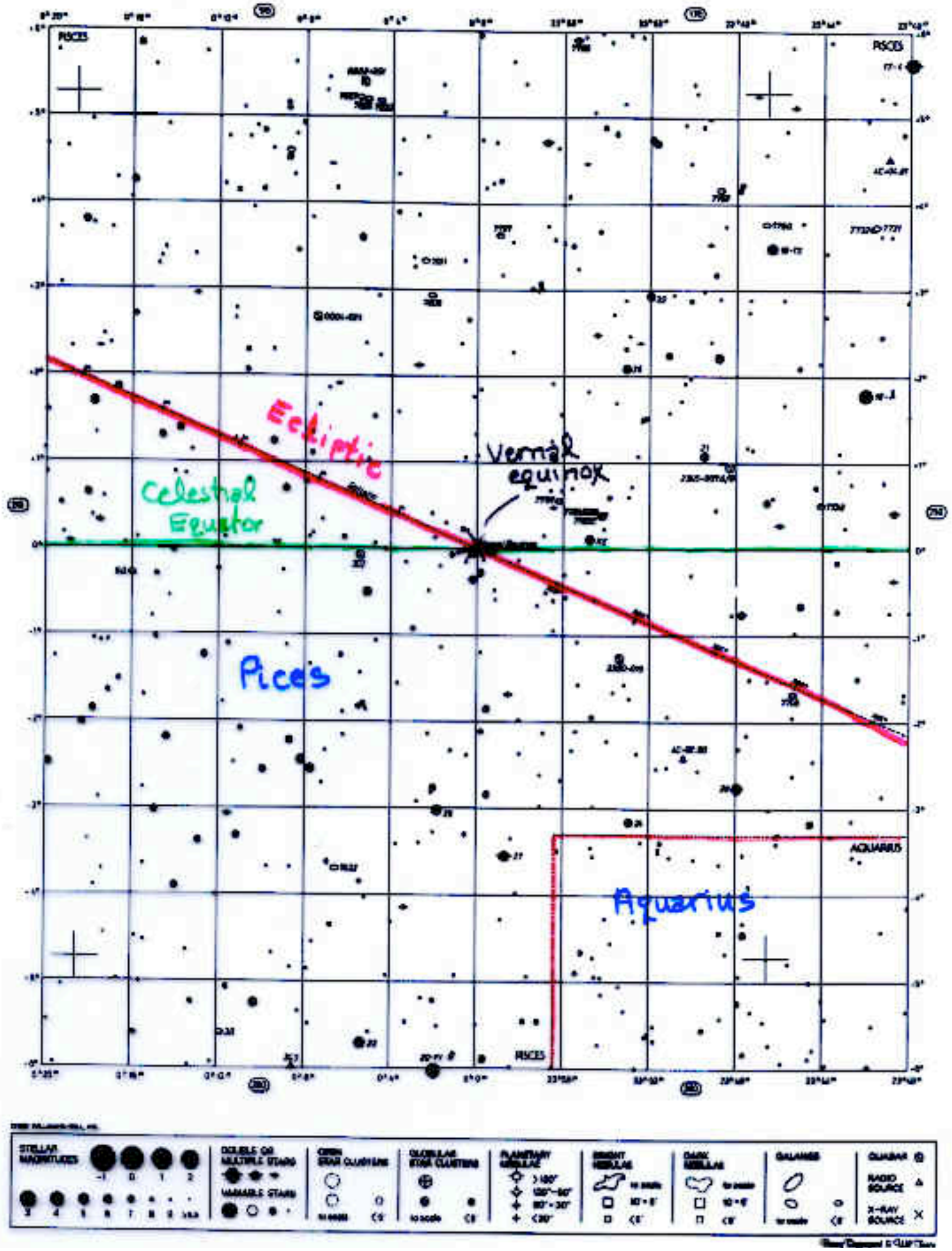


PRIME MERIDIAN
OF THE WORLD

An important location in the sky, to astronomers, is the "Vernal Equinox", where the center of the sun crosses the CE.



*The autumnal equinox is in Virgo. Astrologers would say Libra (offset by the precession of the equinoxes).*



# Stellar Coordinates

- **Celestial Equator**

  Projection of the Earth's equator into the sky

- **Declination**

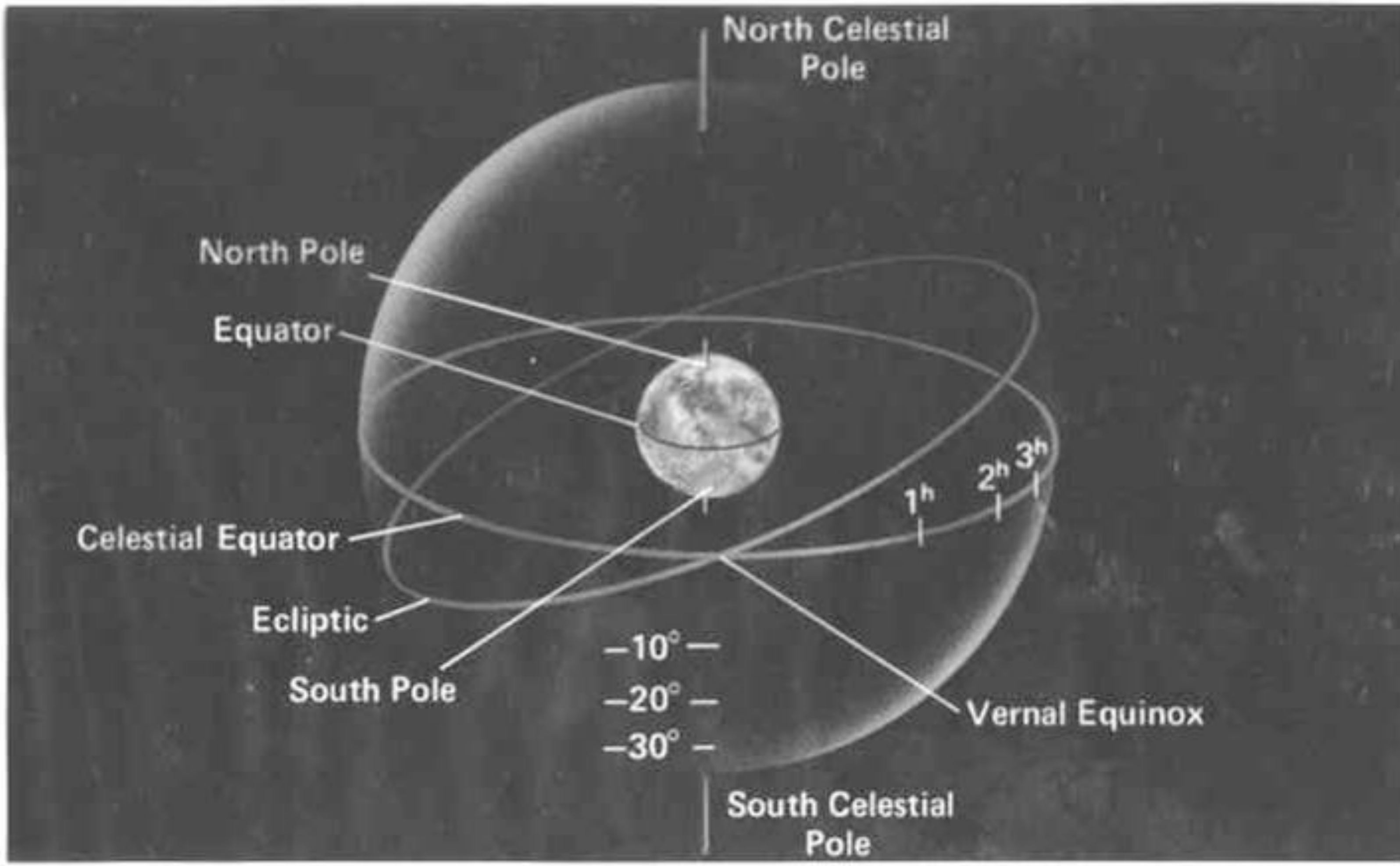
  The angle to a star or other object in degrees, minutes, and seconds measured north or south of the Celestial Equator

$$-90^o \leq \delta \leq +90^o$$

- **Right Ascension**

  The angle measured *eastwards* from the Vernal equinox along the Celestial equator to the hour circle of the star. Measured in units of time (1 hour = 15 degrees; 1 minute of time = 15' of angle)

$$0^h \leq RA \leq 24^h$$


North Celestial Pole
North Pole
Equator
Celestial Equator
Ecliptic
South Pole
−10°
−20°
−30°
$1^h$
$2^h$
$3^h$
Vernal Equinox
South Celestial Pole

# Measuring angles in units of time? A convention used in astronomy because of historical reasons.

Declination is measured in degrees (and minutes and seconds), but Right Ascension (RA) is measured in hours, minutes, and seconds.

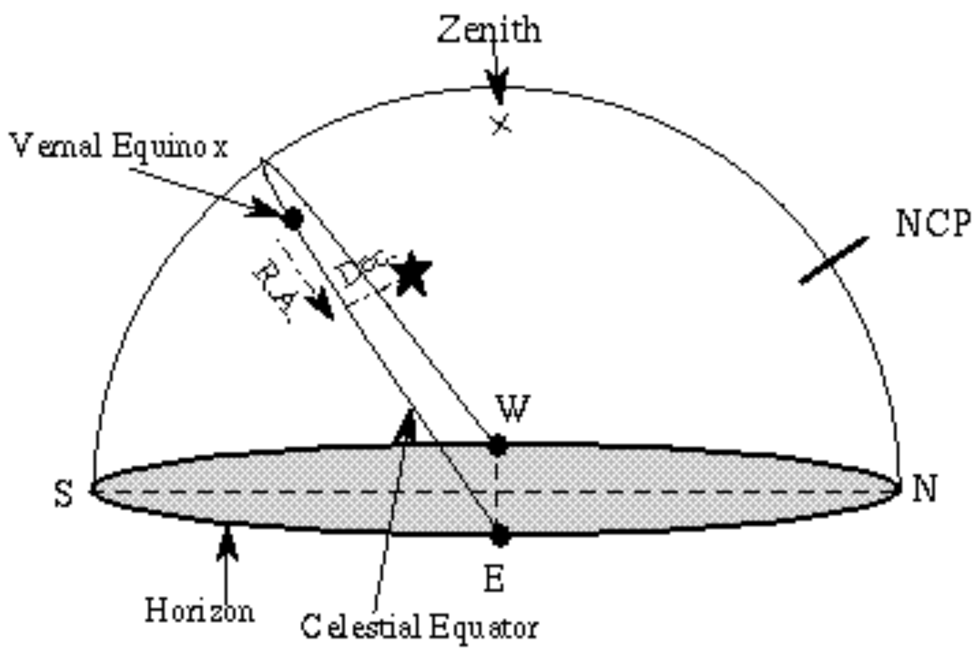
1 hr of RA = 15 degrees of ordinary angular measure (360/24)

1 min of RA = 15/60 = ¼ degree = 15 arc min of angular measure

1 sec of RA = 15/3600 = 1/240 degree = 15 arc sec

nb. 0 longitude on Earth is defined by Greenwich England.
0 right ascension in astronomy is defined by the vernal equinox

copied from Nick Strobel's "Astronomy notes". See his website.




A star's position in the equatorial coordinate system. The right ascension (R.A.)=1 hr 30 min and the declination (Dec.)=15°. The right ascension is measured in hours, minutes, and seconds in the easterly direction from the vernal equinox position on the celestial equator. The declination is measured in degrees above the celestial equator. The star's R.A. and Dec. does NOT change throughout the night—its equatorial coordinate position is fixed with respect to the stars. The star's position does depend on the location of the NCP and Celestial Equator in this system.

# Brightest Stars

| Star | Name | M | RA | Dec |
|---|---|---|---|---|
| alpha CMa | Sirius | -1.46 | 06 45 8.9 | -16 42 58 |
| alpha Car | Canopus | -0.72 | 06 23 57.2 | -52 41 44 |
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| alpha Ori | Beteigeuse | 0.50 | 05 55 10.3 | +07 24 25 |
| beta Cen | Hadar | 0.61 | 14 03 49.4 | -60 22 22 |
| alpha Aql | Altair | 0.77 | 19 50 46.9 | +08 52.6 |
| | | 0.77 | | |
| alpha Tau | Aldebaran | 0.85 | 04 35 55.2 | +16 30 33 |
| alpha Vir | Spica | 0.98 | 13 25 11.5 | -11 09 41 |
| alpha Sco | Antares | 0.96 | 16 29 24.4 | -26 25 25 |
| beta Gem | Pollux | 1.14 | 07 45 18.9 | +28 01 34 |
| alpha PsA | Fomalhaut | 1.16 | 22 57 39.0 | -29 37 20 |
| alpha Cyg | Deneb | 1.25 | 20 41 25.8 | +45 16 49 |
| beta Cru | Mimosa | 1.25 | 12 47 43.3 | -59 41 19 |

http://www.google.com/sky/

Actual Coordinates of Polaris:

Declination = $89^{o}$ $15'$ $51''$

RA = $2^{h}$ $31^{m}$ $48.7^{s}$

# Examples

Sirius: $\delta = -16^{o}\ 39'$; RA = 6 hr 42.9 min

$\alpha$-Centauri: $\delta = -60^{o}\ 38'$; RA = 14 hr 36.2 min

http://www.google.com/sky/

How many degrees is 14 hr 36.2 min?

1 hr = 15 degrees
1 min = 15'

14 hr*(15 $^{0}$/hr) + 36.2 min (15' /min) = 210 $^{0}$ 543'

but 543' /60' per degree = 9$^{o}$ with 3' left over

so 14 hr 36.2 min or RA is 219$^{o}$ 3' East of the Vernal Equinox

This is also 360$^{o}$ – 219$^{o}$ 3' = 140$^{o}$ 57' West of the Vernal Equinox

# NAVIGATION

Your Celestial Meridian is the imaginary line through your zenith and north (or south pole) from horizon to horizon.

Your siderial time is equal to the right ascension of stars on your CM.

Your longitude is the difference between your local siderial time and the siderial time in Greenwich.

To navigate in the old days your prime need was a good clock (if the sky was clear) and knowledge of the stars.

The **Longitude Prize** was a reward offered by the British government for a simple and practical method for the precise determination of a ships longitude. The prize was established through an act of Parliament (the Longitude Act) in 1714 and was administered by the Board of Longitude

E.g. RA of Betelgeuse is 05 55m 10.3053 s

Suppose Betelgeuse crosses your CM when the siderial time in Greenwich is midnight (0h 0 m)

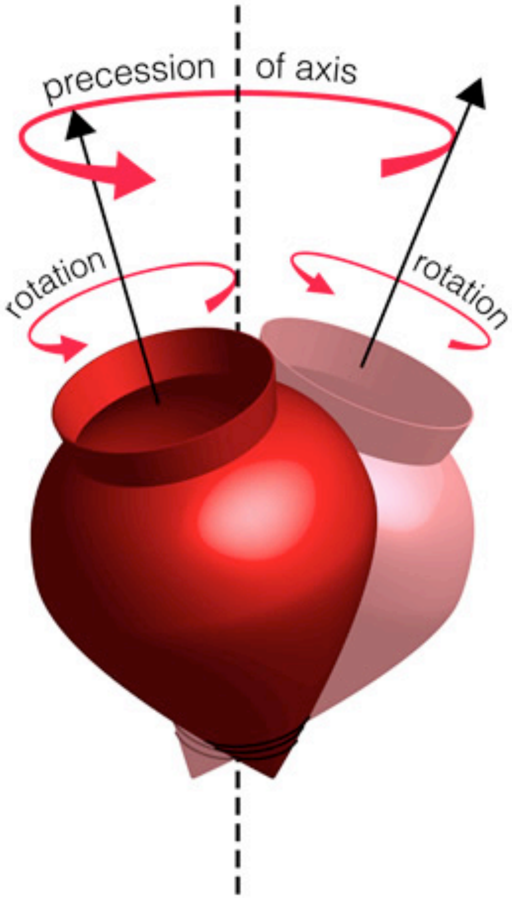
Your longitude is 5 h 55m … or 5.920 h or 88.79 degrees

You are 88.79 degrees east of Greenwich.

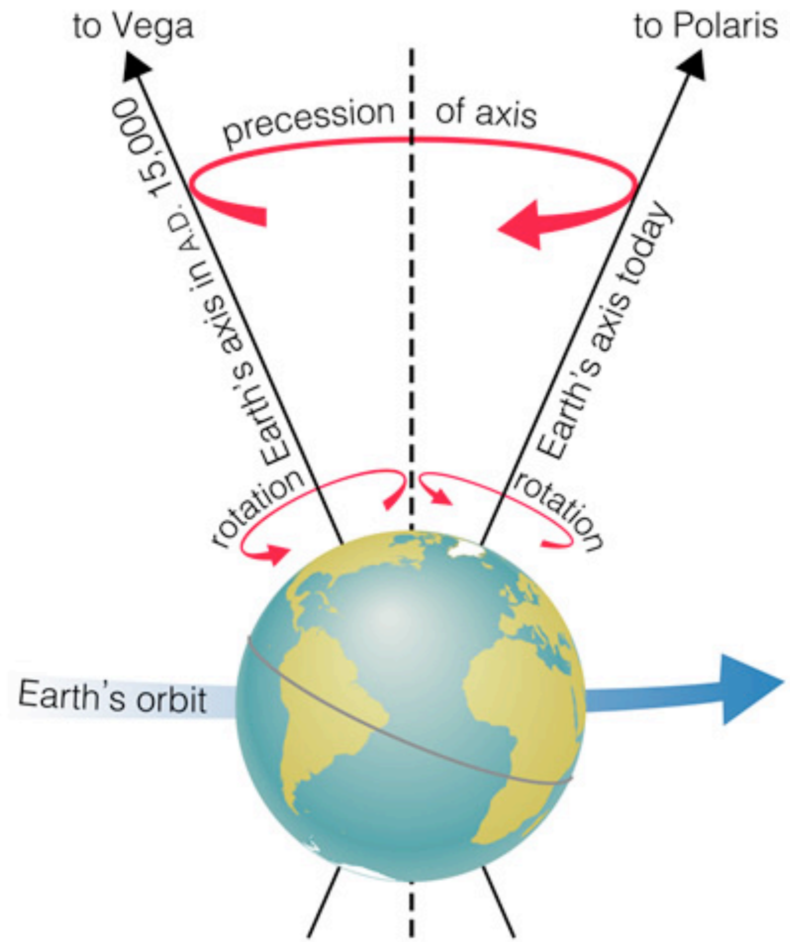
(Time is later as you go east, e.g., NY vs Santa Cruz)

Aside, the vernal equinox is on your CM at "midnight" siderial time (not necessarily at night). Siderial time is defined as the "hour angle" of the vernal equinox.

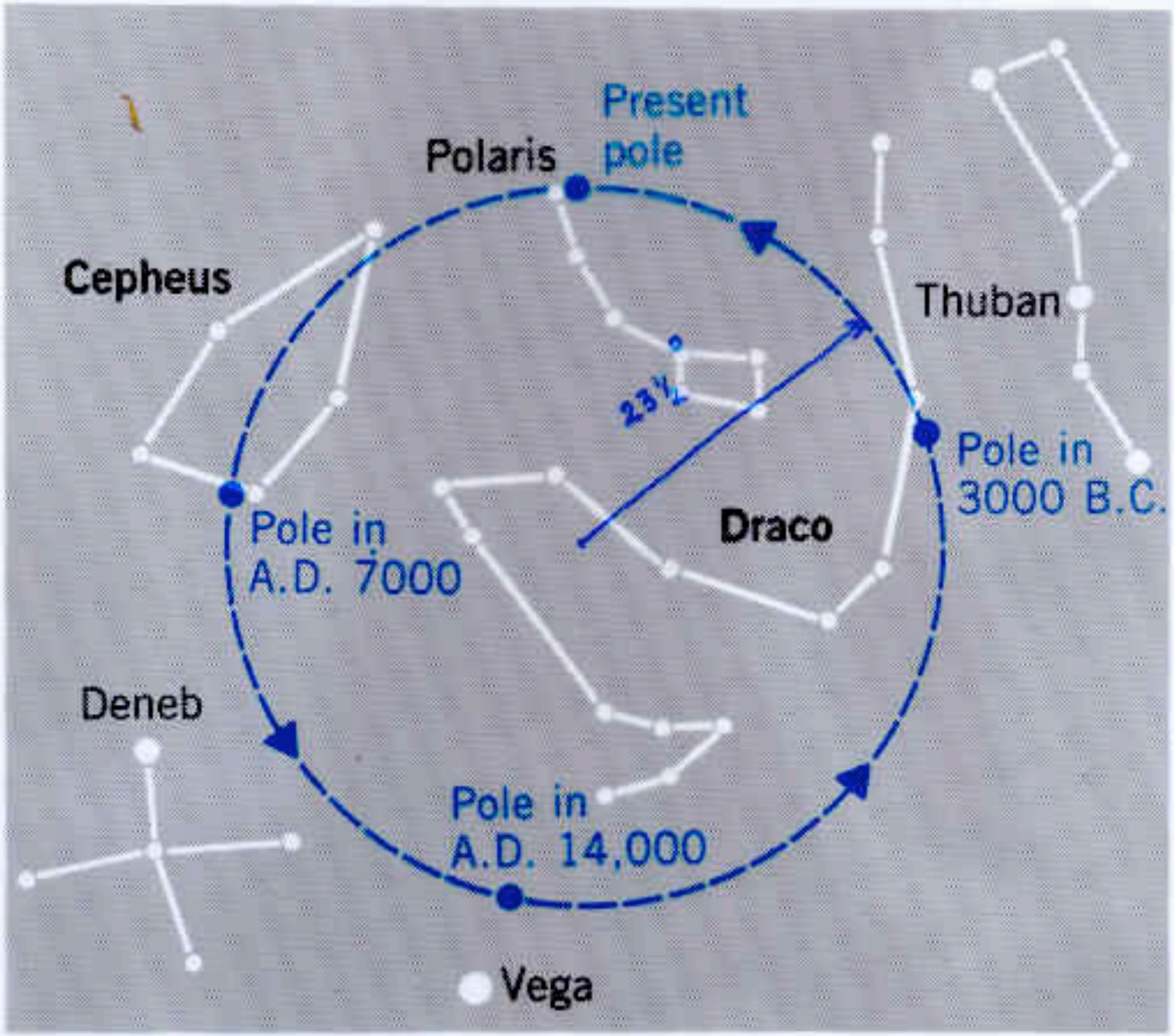
# Precession of the Equinoxes





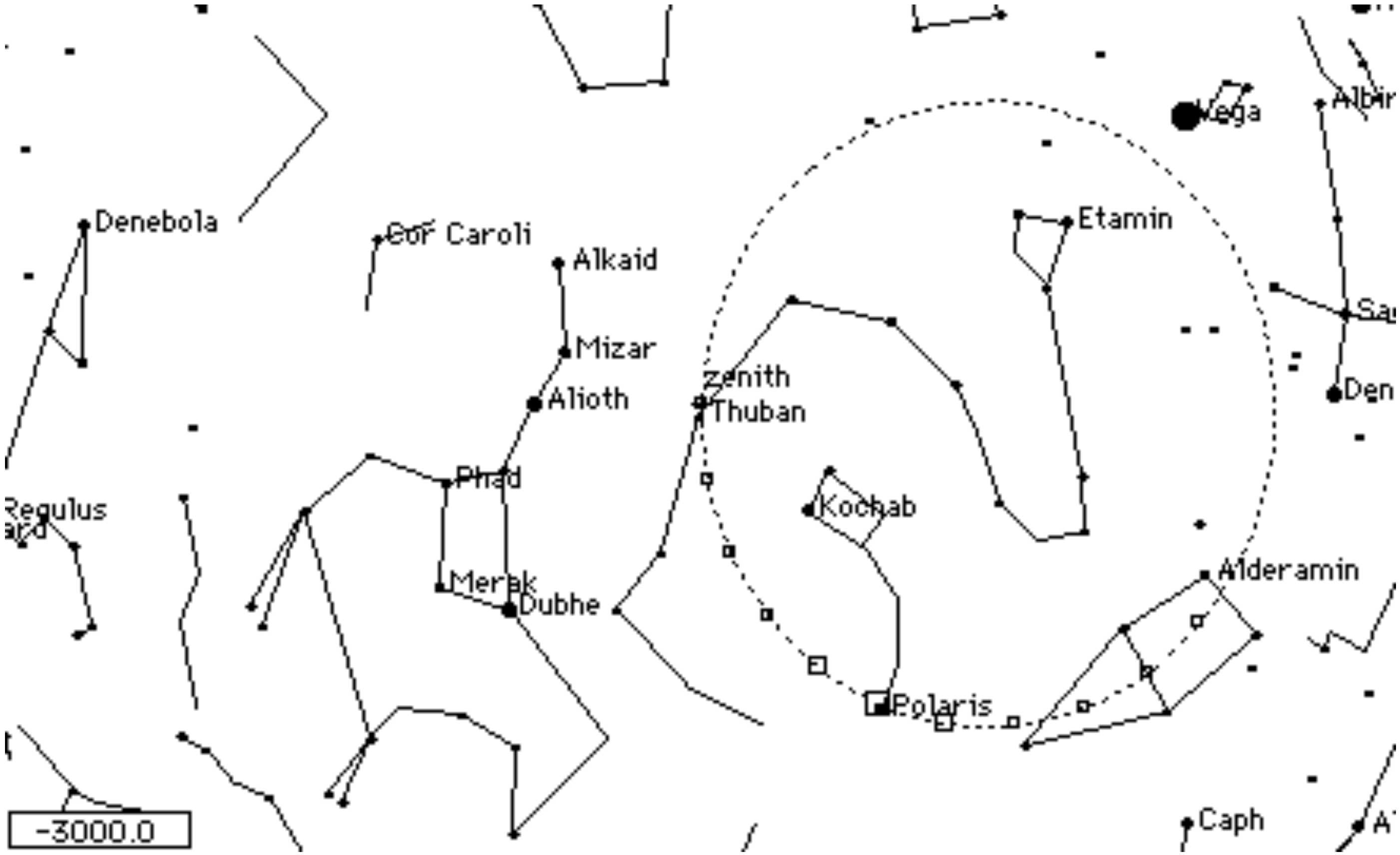



# 1.38 degrees per century




**Precession and the change of position of the north celestial pole with respect to the stars.**

$\tau_p = 26{,}000$ yr.



Denebola
Cor Caroli
Alkaid
Mizar
Alioth
zenith
Thuban
Etamin
Vega
Phad
Regulus
Kochab
Merak
Dubhe
Alderamin
Polaris
Caph
-3000.0

As a result of this precession the projection of the earth's equator into the sky - the *celestial equator* - also moves and this causes an adjustment of the equinoxes. This in turn changes the coordinate system in which a star's location is measured. The vernal equinox drifts westward along the ecliptic about an arc minute per year (actually 50.35 arc seconds).

So when a star's coordinates are given (RA and $\delta$), a date must also be given. Current tables use 2000 as a reference point.

Corrections to where to point a telescope are discussed at e.g.,

http://star-www.st-and.ac.uk/~fv/webnotes/chapt16.htm