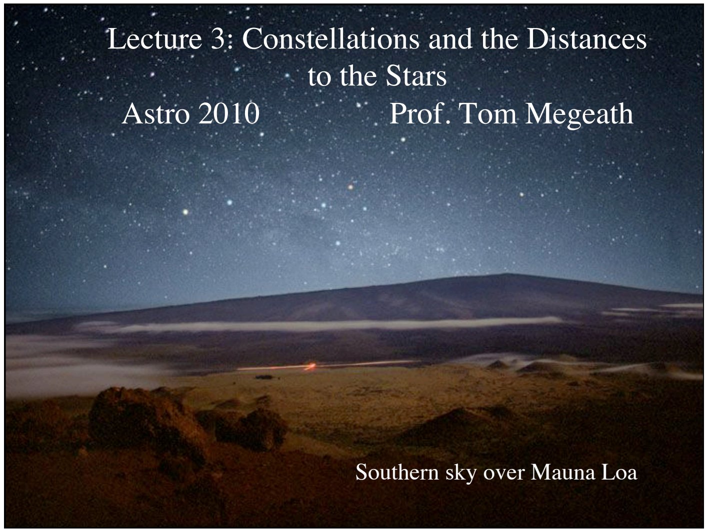


Questions for Today

How do the stars move in the sky?

What causes the phases of the moon?

What causes the seasons?

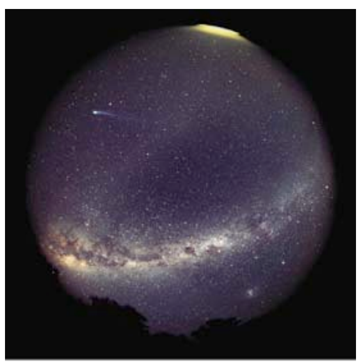
How can we measure the distances to the stars?

The Celestial Sphere

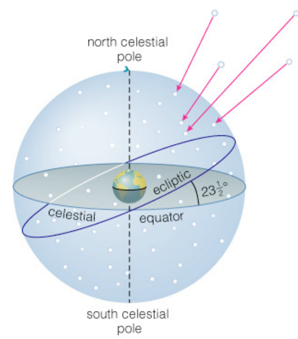
The Celestial Sphere is a map of where the stars are located in the night sky.

With the naked eye, we can see more than 2,000 stars as well as the Milky Way.

The Celestial Sphere is a way of visualizing the sky by ignoring that each star is at a different distance.



The Celestial Sphere



Stars at different distances all appear to lie on the celestial sphere.

Ecliptic is Sun’s apparent path through the celestial sphere.

The Moon and the planets are found near the ecliptic.

NASA: http://earthobservatory.nasa.gov/Newsroom/BlueMarble/

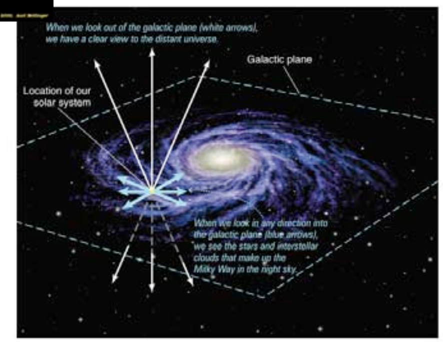
Putting a 3D Sphere on a 2D surface.

NASA via Wikipedia

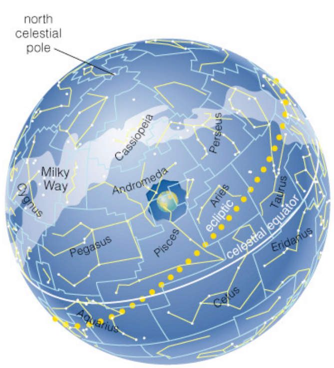
Mollweide Projection

The Milky Way in The Celestial Sphere

The Milky Way extends across the entire celestial sphere because we are in the Galaxy



Constellations in The Celestial Sphere



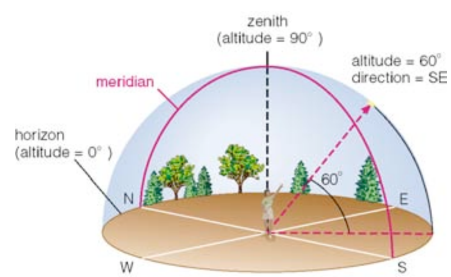
There are 88 official constellations in the celestial sphere.

The constellations have their origins from the Mesopotamian (1000 BC). These constellations were adapted by the ancient Greeks and compiled into a list by Claudis Ptolemy (90-168 AD).

The southern constellations come from Dutch navigators in the 16th century and the French astronomer de Lacaille.

Mapping Locations in the Celestial Sphere

An object's **altitude** (above horizon) and **direction** (along horizon) specifies its location in your local sky

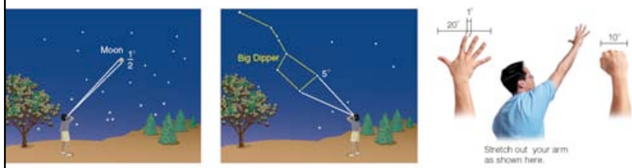


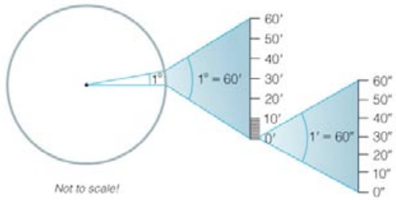
Zenith: The point directly overhead

Horizon: All points 90° away from zenith

Meridian: Line passing through zenith and connecting N and S points on horizon

We measure the sky using *angles*

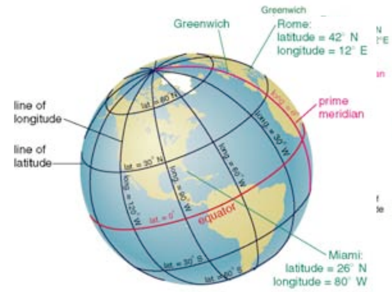




- Full circle = 360°
- 1° = 60′ (arcminutes)
- 1′ = 60″ (arcseconds)

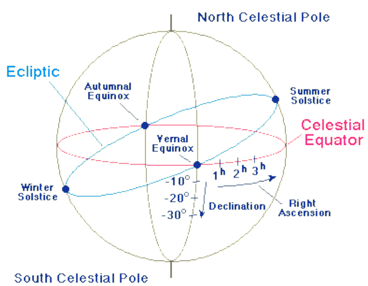
Measuring the Positions of the Stars Review: Coordinates on the Earth

- Latitude: position north or south of equator
- Longitude: position east or west of prime meridian (runs through Greenwich, England)



Longitude = 41deg 40m, Latitude = 83d 35 m

Measuring the Positions of Stars in The Celestial Sphere: Right Ascension and Declination



Every star can be located by its RA and Dec. Ra in units of hours minutes and seconds, Dec in units of degree minutes and seconds

Polaris

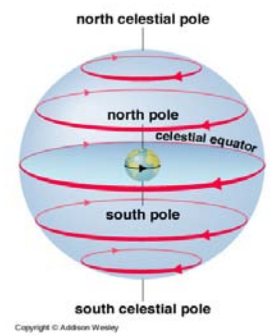
Ra = 2h 31m 49.s

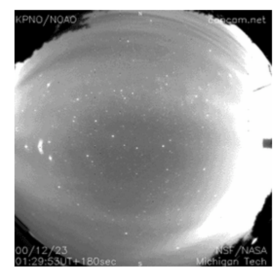
Dec = 89d 15m 51s

http://csep10.phys.utk.edu/astr161/lect/time/coordinates.html

The Motion of Celestial Bodies

1. Why do stars rise and set?



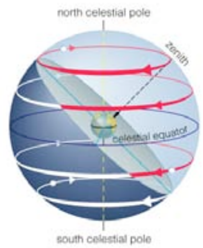


Our view from Earth:

- Stars near the north celestial pole are circumpolar and never set.
- We cannot see stars near the south celestial pole.
- All other stars (and Sun, Moon, planets) rise in east and set in west.

A circumpolar star never sets

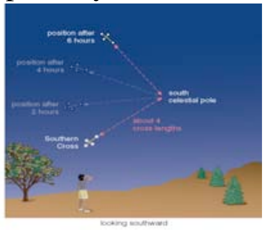
This star never rises



Celestial Equator

Your Horizon

Altitude of the celestial pole = your latitude



In the northern hemisphere, stars rotate around polaris, *the north star*. In the southern hemisphere, there is no equivalent south star.

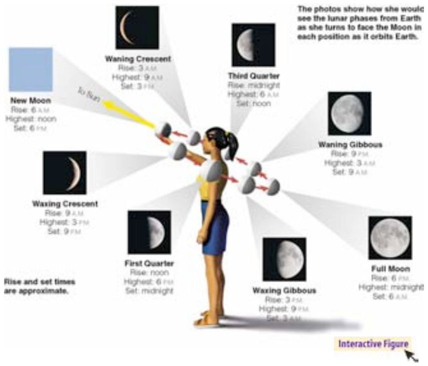
Circumpolar Motions from Ohio

From Richard Pogge

http://www.astronomy.ohio-state.edu/~pogge/Ast161/Movies/circumpolar.mov

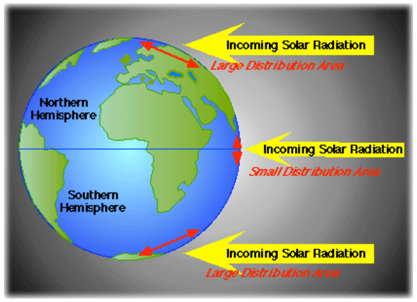
Phases of Moon

- Half of Moon is illuminated by Sun and half is dark
- We see a changing combination of the bright and dark faces as Moon orbits



The Seasons

- Sun’s rays
  - spread over large area = cooler
  - concentrate in small area = warmer
  - Warmest where sun directly overhead (at noon)

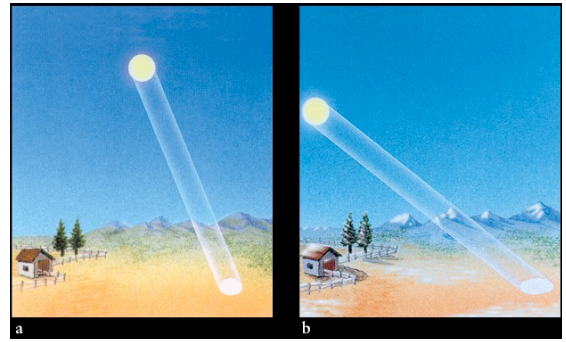


cooler

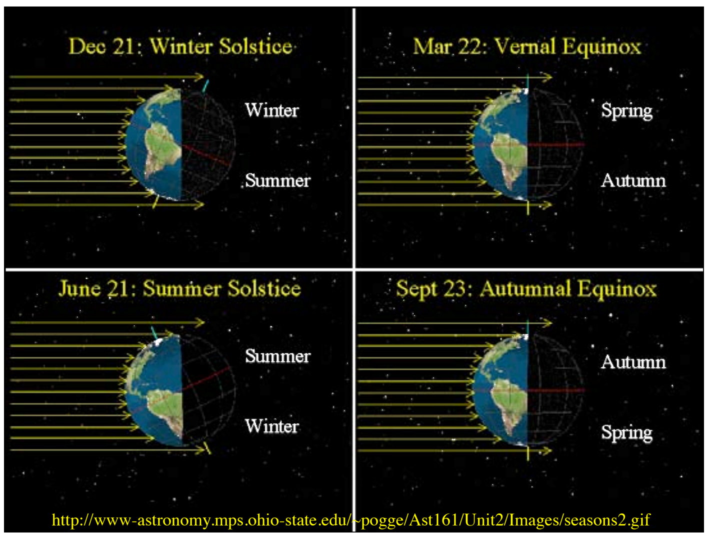
warmer

cooler

Annual Variation in Insolation

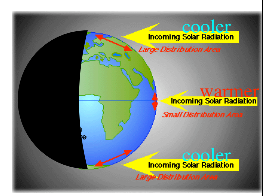


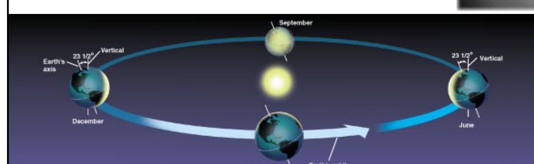
- The figures show the solar insolation during the summer on the left and during the winter on the right. The height of the sun above the horizon determines how much heat and light strike each square meter of ground. During the summer, a shaft of light at noon illuminates a nearly circular patch of ground. During the winter, that same shaft at noon strikes the ground at a steeper angle, spreading the same amt of light over a larger, oval area.

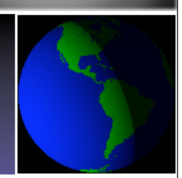


The Seasons

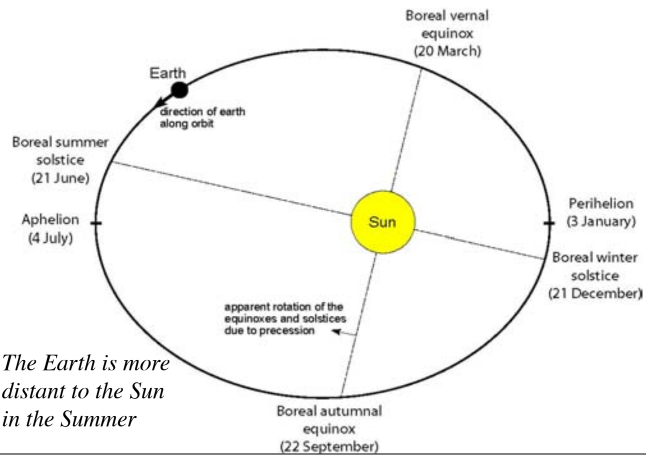
- Tilt of Earth’s Axis
- Location where sun overhead (at noon)
  - Vernal & Autumnal Equinoxes (Mar 21, Sept 21)
    - Overhead at Equator
  - Summer Solstice (Jun 21)
    - Overhead on Tropic of Cancer (23.5° N)
    - Warmer in N hemisphere; cooler in S hemisphere
  - Winter Solstice (Dec 21)
    - Overhead on Tropic of Capricorn (23.5° S)
    - Warmer in S hemisphere; cooler in N hemisphere







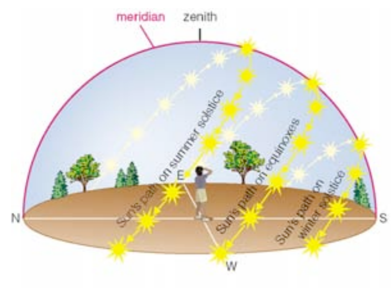
The Seasons



The Earth is more distant to the Sun in the Summer

The Seasons

We can recognize solstices and equinoxes by Sun's path across sky:



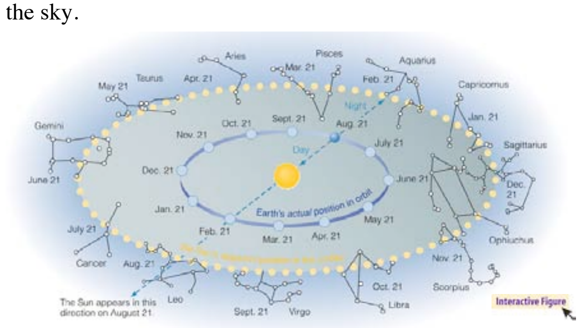
Summer solstice: Highest path, rise and set at most extreme north of due east.

Winter solstice: Lowest path, rise and set at most extreme south of due east.

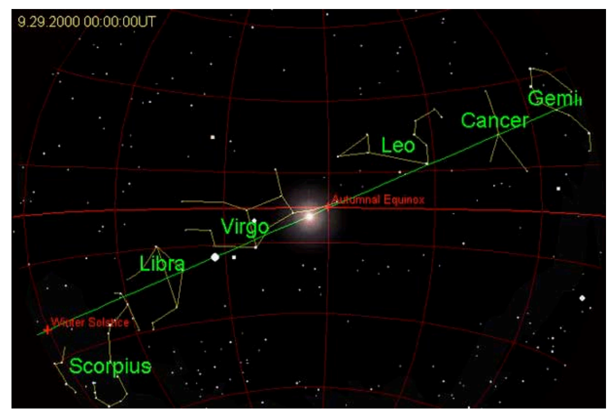
Equinoxes: Sun rises precisely due east and sets precisely due west.

The sky varies as Earth orbits the Sun

- As the Earth orbits the Sun, the Sun appears to move eastward along the ecliptic.
- At midnight, the stars on our meridian are opposite the Sun in the sky.



The Zodiac



Richard Pogge, Ohio State

http://www.astronomy.ohio-state.edu/~pogge/Ast161/Movies/zodiac.mov

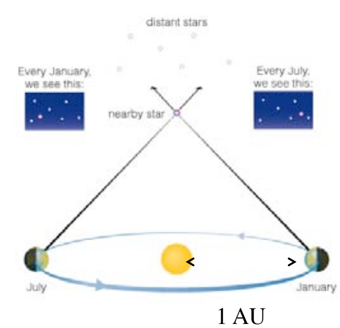
The “Fixed” Stars

Unlike the Sun, Moon and the Planets, the stars appear “fixed” in the sky. The reason is the great distances to the stars.

Because the stars are distant, they don’t appear to move and change relative to each other. Instead, all the motions that we see are due to the rotation of the Earth and the orbit of the Earth around the Sun.

However, careful observations do show that the star move.

Measuring the Distance to Stars: Parallax



However some stars show small motions, these are due again to the motion of the Earth.

An object that moves 1 second of arc in the sky (1/3600 of a degree) as the Earth moves 1 AU in its orbit in 1 parsec away

Parsec = **Par**allax of 1 **sec**ond

Distance (pc) =1/parallax (arcsec)

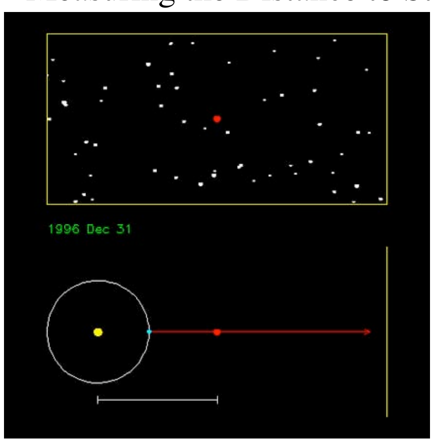
A parallax of 0.5 second implies a distance of 2 pc

1 pc = 206265 AU

1 pc = 3.26 ly

1 pc = 3.086 x 10^{13} km

Measuring the Distance to Stars: Parallax



The most distant parallaxes can be measured by satellites The *Hipparcos* satellite could measure parallaxes as small as 0.001 arcsecond

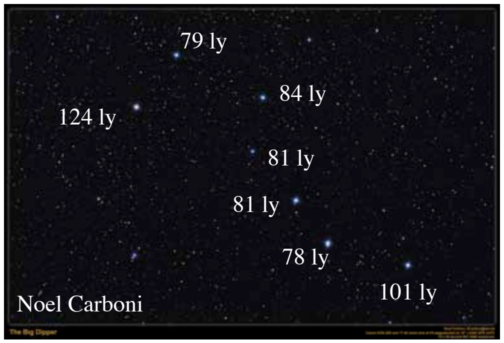
D (pc) = 1/0.001 arcsec

D = 1000 pc (3260 ly)

The *Hubble Space Telescope* can measure parallaxes to 0.0005 arcsec, or D = 2000 pc (6520 ly)

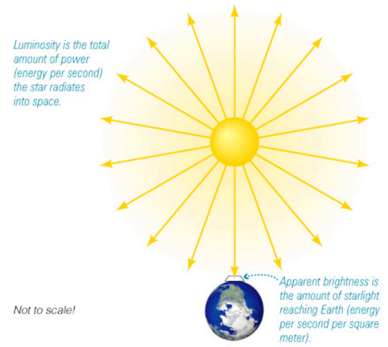
Parallax in Everyday Life

The Distances to the Stars in the Big Dipper



The patterns of stars in the sky are misleading. For example, the stars in the Big Dipper vary in distance.

Measuring The Brightness and Luminosities of Stars



Luminosity:

Amount of power a star radiates

(energy per second = Watts)

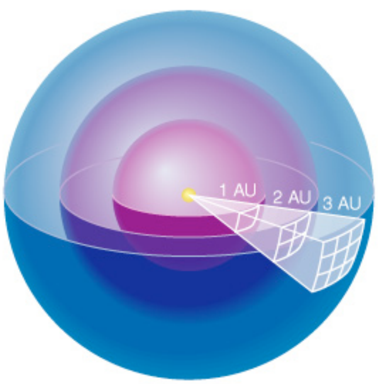
Luminosity of the Sun is 10^{26} Watts

Apparent brightness:

Amount of starlight that reaches Earth

(energy per second per square meter)

The Inverse Square Law



The total energy radiated by the star passing through each sphere is the same

Area of sphere:

$4\pi\ (\text{radius})^2$

Divide luminosity by area to get brightness

The Inverse Square Law

The relationship between apparent brightness and luminosity depends on distance:

$$\textbf{Brightness} = \frac{\text{Luminosity}}{4\pi\ (\text{distance})^2}$$

We can determine a star's luminosity if we can measure its distance and apparent brightness:

$$\textbf{Luminosity} = 4\pi\ (\text{distance})^2 \text{ x } (\text{Brightness})$$

Measuring the Brightness of the Stars: Magnitudes

Apparent magnitude: how much fainter a star is compared to the star Vega, the brightest star in the constellation Lyra. This system originated with the classical Greeks (probably Hipparchus around 150 B.C.)

1 magnitude star is 2.5 times *fainter* than Vega

2 magnitude star is $2.5^2 = 6.25$ fainter than Vega

-1 magnitude star is 2.5 times brighter than Vega

5 magnitude star is 100 times fainter than Vega

6 magnitude star if faintest star you can see with the naked eye

26 magnitude is the faintest object detected with Hubble Space Telescope

Mag = -2.5 x log(Brightness star/Brightness Vega)

(not to be confused with *orders of magnitude*)

Measuring the Brightness of the Stars: Magnitudes

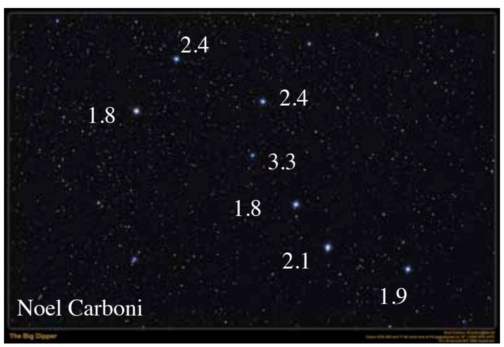
Apparent and absolute magnitude

Apparent magnitude - magnitude of star as it appears in the sky

Absolute magnitude - magnitude of a star observed at a distance of 10 parsec away.

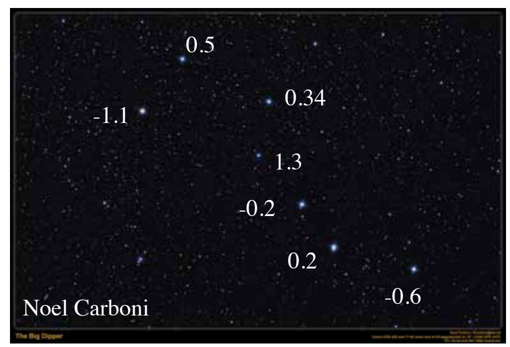
Apparent mag. = absolute mag. + 5 log (distance/10 pc)

Measuring the Brightness of Stars:
The Apparent Magnitudes to the Stars in the Big Dipper



Most of the stars are very similar in apparent brightness as measured by their apparent magnitudes

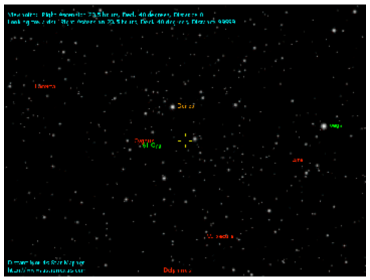
Measuring the Brightness of Stars:
The Absolute Magnitudes to the Stars in the Big Dipper



The end stars are more distant, and thus their luminosities are higher and their absolute magnitudes smaller (brighter!)

Measuring the *Proper* Motions of the Stars

The astronomer Edmund Halley in 1718 noticed that several prominent stars relative to the positions recorded by the ancient Greeks. These are nearby stars that are moving rapidly relative to the Sun.



Between 1916 and 1951

61 Cygnus aka Bessell's Stars or Piazzi's Flying Star (11 light years away)
Motion first proved by Giuseppe Piazzi in 1804
The rapidly moving star 61 Cygni has a motion of 5" per year.
http://www.solstation.com/stars/61cygni2.htm & http://astronexus.com/node/77

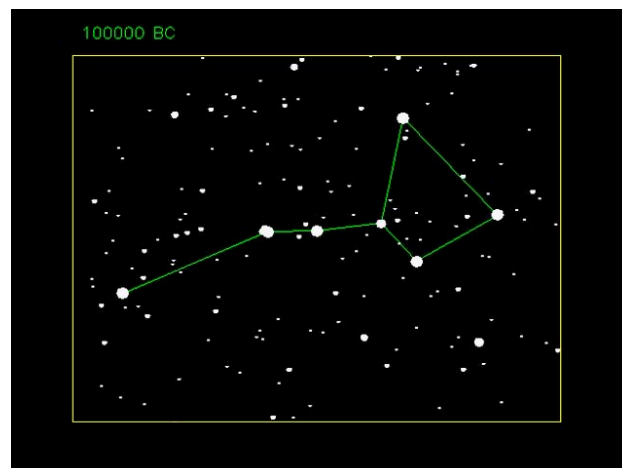
Proper Motion in Everyday Life

Measuring the Motions of the Stars

The motions of the stars come from both the random motions of the stars, as due to the Sun and stars orbiting the Galaxy.

Like looking out the window as driving, nearby stars (objects) will appear to move faster.

Measuring the Motions of the Stars



Things to know

Why we have seasons? What are the solstices and equinoxes?

Why the Moon has phases.

How the rotation of the Earth and orbit of the Earth around the Sun cause the stars to move overhead.

What are parallax and magnitudes?

What is the inverse square law?

What are proper motions?

Next Topic: Some Basic Physics

Astronomy is physics in disguise

In the next two lectures:

Laws of Motion and Gravity

Conservation of Momentum and Energy

The Nature of Light.

How do things (gases, light bulbs, etc) emit light.