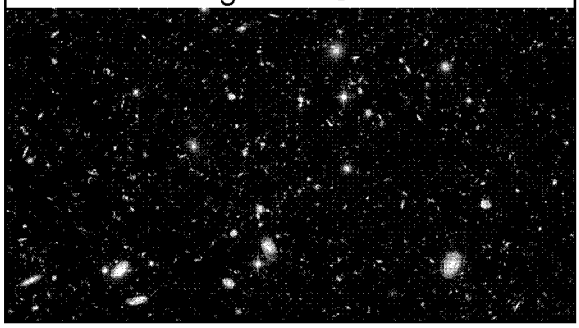
Wednesday, September 29

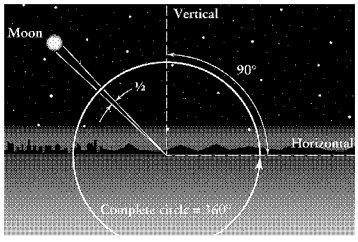
The Cosmological Revolution: How Big is the Universe?



The Cosmological Revolution Key Concepts

1) Distances within the Solar System can be measured using **radar**.
2) Distances to nearby stars can be measured using **stellar parallax**.
3) Greater distances can be measured using **standard candles**.

Angles: 360 degrees in a circle, 60 arcminutes in a degree, 60 arcseconds in an arcminute.



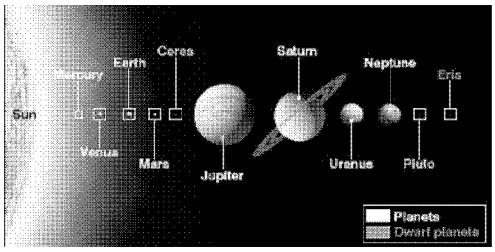
Seen from the Earth, Sun and Moon appear ½ degree across; Proxima Centauri appears 0.001 *arcsecond* across.

Climbing the
"cosmic distance ladder".

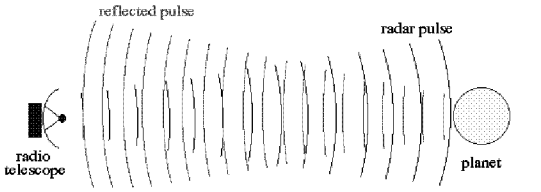
We can't use the same technique to find the distance to **every** astronomical object.

Use one technique within Solar System (1st "rung" of ladder); another for nearby stars (2nd "rung"), etc...

1st rung of the distance ladder:
distances within the Solar System.



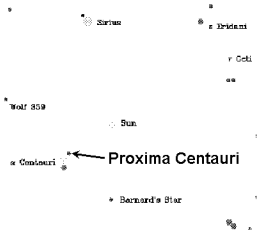
Distances from Earth to nearby planets are found by **radar**.



Bounce a radio signal from **Venus**, for instance.
Round trip travel time ÷ 2 = One-way travel time.
One-way travel time × c = distance to Venus.

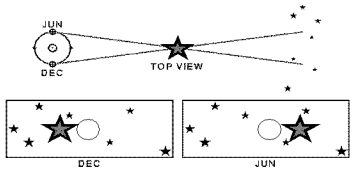
c = speed of light

2nd rung: distances to nearby stars (within a thousand light-years or so).



Distances from the Solar System to nearby stars are found by **stellar parallax**.

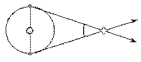
Stellar parallax = shift in apparent position of a star due to Earth's motion around Sun.



Stellar parallax was 1st measured in 1838 by Friedrich Bessel. It was difficult, since parallax angles are tiny (< 1 arcsecond).

How to find distance by measuring parallax:

Closer stars have *larger* parallaxes:



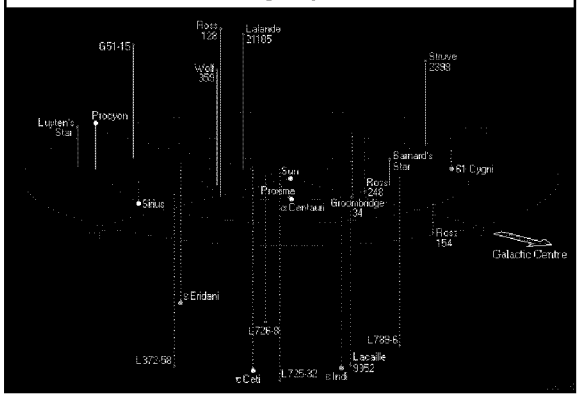
Distant stars have *smaller* parallaxes:

$$d = \frac{3.26 \text{ light} - \text{years}}{P}$$

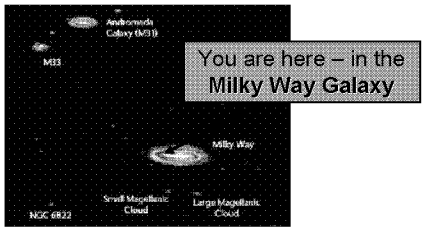
d = distance to star

P = parallax in arcseconds

Stars within 10 light-years of the Sun.



3rd rung: distances to the far reaches of our Galaxy… and beyond.

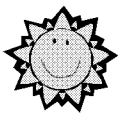


Large distances are found with **standard candles**.

"Standard candle" = a star (or other light source) of known luminosity.

Every star has a **luminosity (L)**: this the **wattage** of the star (how much energy it emits per unit time).

40 watts

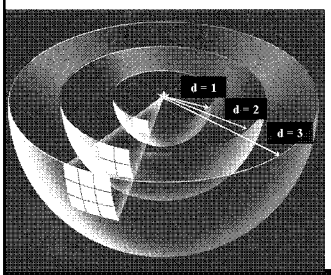


4×10^{26} watts

We **don't** directly measure a star's luminosity. We measure its **flux (f):** wattage collected per square meter of our telescope mirror.

Flux of sunlight at the Earth's location = 1370 watts per square meter

At a distance d from the star, the luminosity L is spread over an area $4\pi d^2$.

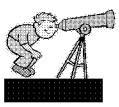


$$f = \frac{L}{4 \pi d^2}$$

Flux goes inversely as the square of distance.

Climbing the distance ladder.

1) Measure flux of two standard candles: one near, one far.



2) Find distance to near standard candle from its parallax.

3) Compute luminosity of near standard candle:

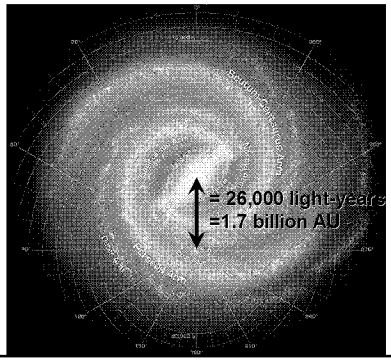
$$L = 4 \pi d^2 f.$$

4) Assume far standard candle has same luminosity as the near one.

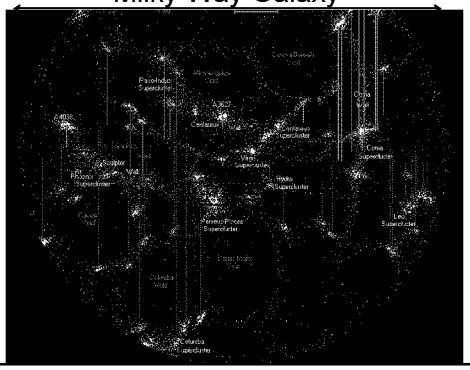
5) Compute the distance to the far standard candle:

$$d = \sqrt{\frac{L}{4\pi f}}$$

If we could see the Milky Way Galaxy face-on from outside:



Galaxies within 1 billion light-years of the Milky Way Galaxy



The Cosmological Revolution:
at once humbling and hopeful.

The Earth and Sun and Milky Way Galaxy
don't occupy a special place in the universe.

The universe is large and old;
we are small and young.

In the immensity of space and time,
perhaps we are not alone.

Tomorrow's Lecture:

Chemical Revolution:
What is **Stuff** Made of?

This week's reading:

Chapters 2 & 3