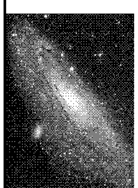
What is a Galaxy?

Friday, October 9

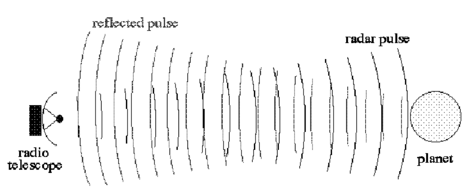
Next Planetarium Show: Tues, Oct 27

Are stars distributed uniformly through space, or do they clump together?

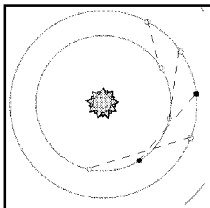


Astronomers now know that stars are in clumps called "galaxies". To find that out, they had to know how stars are distributed in 3-D.

Finding **Sun's** distance is relatively easy.



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



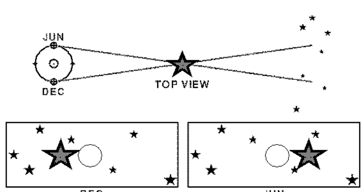
Once you've plotted the orbit of Venus, you know where the Sun is: at a focus of the elliptical orbit.

average Earth-Sun distance =
1 astronomical unit (AU) =
149,597,870.69 kilometers

Finding the distance to stars other than the Sun is difficult.

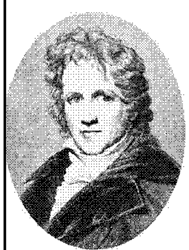
We can find the distance to (relatively) nearby stars by measuring their **parallax**.

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



Remember: the parallax is too small to be seen by the naked eye (< 1 arcminute).

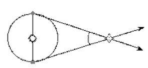
For the closest stars, the parallax is large enough to be measured with a telescope.



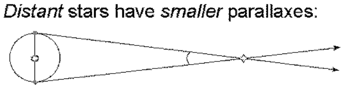
In 1838, Friedrich Bessel found a parallax of 0.3 arcseconds for a nearby star.

How to find distance by measuring parallax:

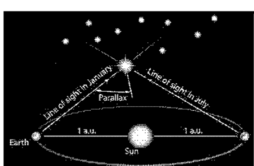
Closer stars have *larger* parallaxes:



Distant stars have *smaller* parallaxes:



Parallax and distance are related by a simple equation.



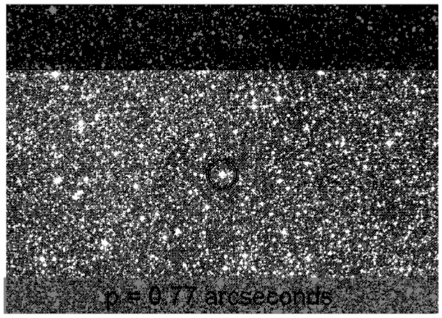
$$d = \frac{1}{p}$$

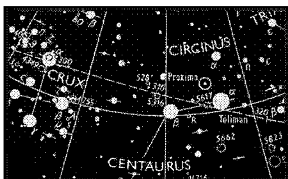
p = parallax of star (in arcseconds)

d = distance to star (in parsecs)

1 parsec = distance at which a star has a parallax of 1 arcsecond = 206,000 AU = 3.26 light-years.

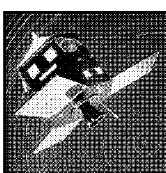
What's the nearest star?
(other than the Sun)





How far is the journey from here to Proxima Centauri?

$$d = \frac{1}{p} = \frac{1}{0.77} = 1.3 \text{ parsecs}$$



The Parallax Problem

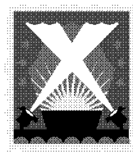
Best parallax measurements were provided by the *Hipparcos* satellite.

Parallaxes < 1/1000 of an arcsecond were too small to measure.

Distances > 1000 parsecs can't be found from parallax.

How can we find the distance to a star more than 1000 parsecs away?

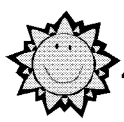
Use the "World-Famous Inverse-Square Law".



The Inverse-Square Law.

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

40 watts

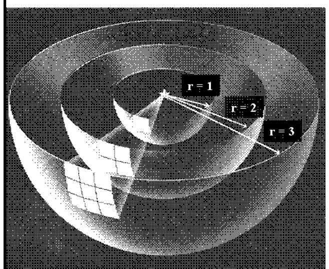


4×10^{26} watts

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

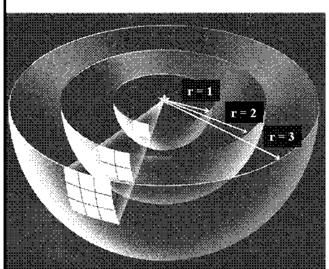
Flux of sunlight at the Earth's location = 1400 watts per square meter

Flux is related to luminosity by an inverse-square law.



What is the flux f at a distance r from a star of luminosity L?

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



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

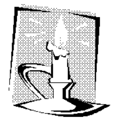
Flux goes inversely as the square of distance.

What does this have to do with finding distances to stars??

If you know the luminosity L,
and you measure the flux f,
you can compute the distance r:

$$f = \frac{L}{4\pi r^2} \Rightarrow r = \sqrt{\frac{L}{4\pi f}}$$

An object whose luminosity you know is called a "standard candle".



Alas! Stars have a range of luminosities.

Betelgeuse = high luminosity
Sun = medium luminosity
Proxima Centauri = low luminosity

For nearby stars, we can measure distance (from parallax) and flux.

We compute luminosity:

$$L = 4 \pi r^2 f$$

Eureka! Stars with identical spectra have identical luminosity!

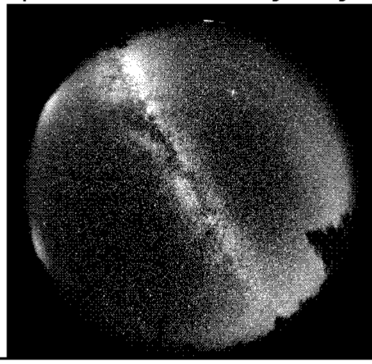
Find a star with a spectrum identical to the Sun's (for instance).

Measure the star's flux f.

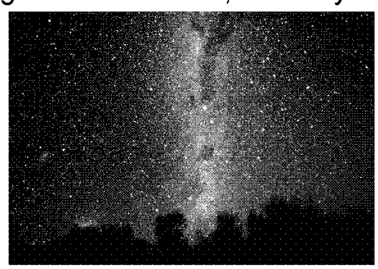
Assume the star's luminosity is the same as the Sun's ($L = 4 \times 10^{26}$ watts).

Compute the star's distance: $r = \sqrt{\frac{L}{4\pi f}}$

In the dark night sky, we see a luminous path called the **Milky Way**.

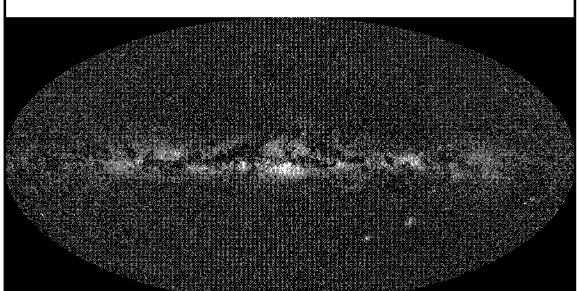


Ancient astronomers called the Milky Way the “galactikos kuklos”, or “milky circle”.

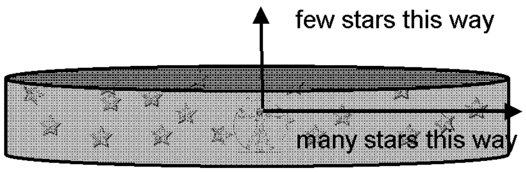


Aristotle thought the Milky Way was a glowing cloud in Earth’s upper atmosphere.

Galileo looked at the Milky Way with his telescope: he found it was made of an “immense number” of faint stars.

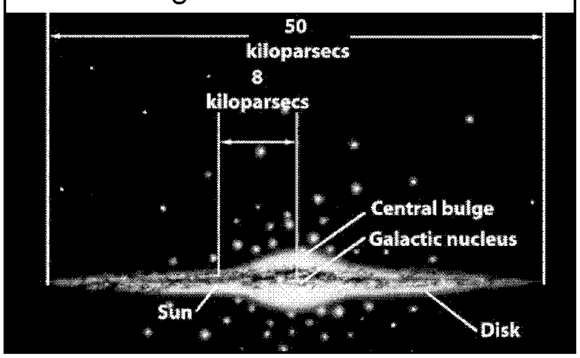


Consider a disk of stars:

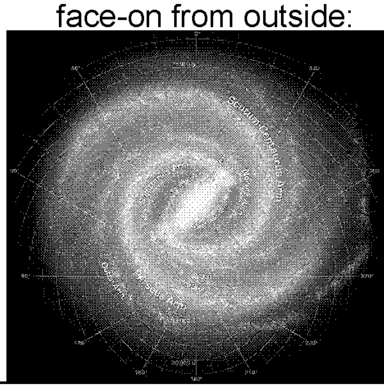


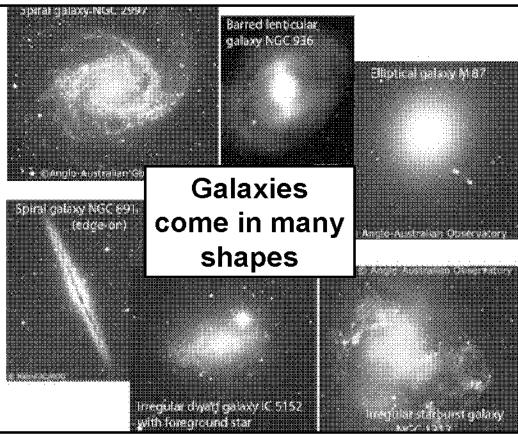
We see the “Milky Way” when we look through the disk.

If we could see the Milky Way galaxy edge-on from outside:



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





Galaxies come in many shapes

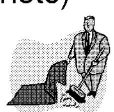
What is a galaxy?

A gravitationally bound assembly of

many stars (+ associated planets)

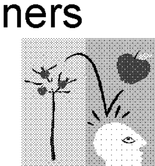
interstellar gas (+ dust)

and **dark matter**.



Monday's Lecture:

Gravity for Beginners



Reminders:

Read Chapter 4 by **Monday**.
Problem Set 2 is due **Wednesday**.
Planetarium shows **Oct 27 & 28.**