Lecture 8: Stellar Motions

Reading: Box 19-1

Key Ideas

The stars are in constant motion.

<u>Observed</u> Motions

Proper motions (motion against the background, measured in angular motion/time)
Radial velocities (motion towards or away, measured from the Doppler shift)

<u>True Space</u> Motion

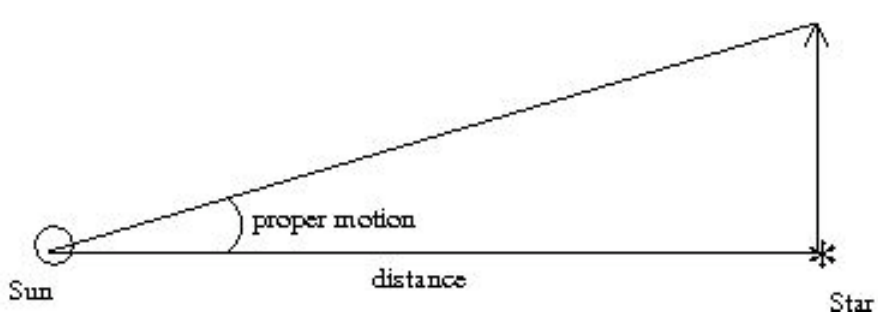
Combination of radial velocity, proper motion, and distance (important for proper motion!)

The "Fixed" Stars

Although the stars are moving, their motions across the sky are so small that to the naked eye, the stars appear "fixed" to the sky. Great distances make the amount of motion small on human lifetimes. (Of course, stars moving directly away or towards us will not to appear to move across the sky)

Proper Motions

Apparent angular motion across the sky of nearby stars with respect to distant objects. (Distant stars are used because we assume that even though they are moving through space they are so far away that from our perspective they are fixed). It is the projection of the star's true motion through space relative to the Sun.



Typical proper motion for stars in the solar neighborhood is about 0.1 arcsec/year
Largest proper motion measured is 10.25 arcsec/year Barnard's Star)

Proper motions are cumulative.

Effects build up over time. The longer you wait, the greater apparent angular motion is.

Measuring proper motions:
Compare photos of the sky taken 20 to 50 years apart
Measure how much stars have moved compared to more distant background objects (galaxies, quasars).

Example: if a star has a proper motion of 0.1 arcsec/year:

In one year, it moves 0.1 arcsec
In 10 years, it moves 10x0.1= 1 arcsec
In 100 years, it moves 100x0.1 =10 arcsec

It can take a long time for the constellations to noticeably change shape.
History: Edmund Halley

Example: the Big Dipper

Proper Motion depends on Distance

For the same actual distance traveled by a star, a star that is closer to the Sun will *appear* to move a larger angular distance.

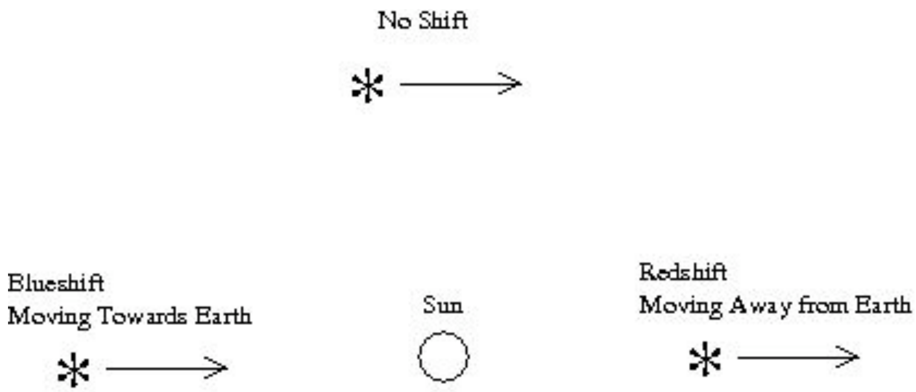
More distant stars tend to have smaller proper motions.

Can usually measure accurate proper motions out to distances of about 1000 parsecs.

Distance is not the only reason why stars with large velocities can appear to have very small proper motions.
Stars moving exactly along the line of sight have <u>no proper motion</u>.

Radial Velocity

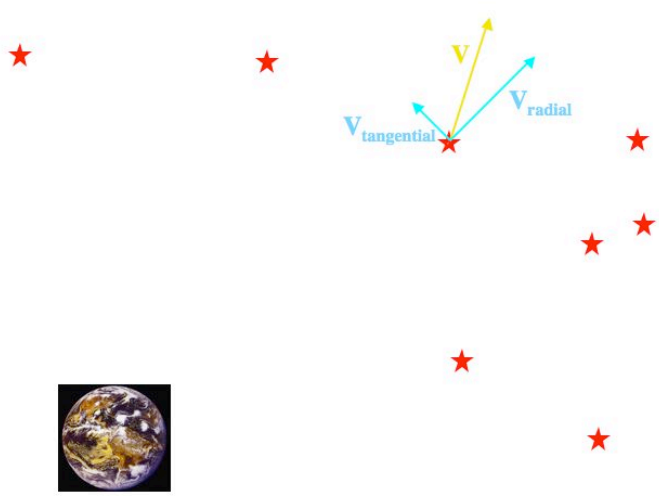
However, we can measure the speed along the line of sight using the Doppler shift.



Note that the velocity measured from the Doppler shift does NOT depend on distance. Indeed we can measure radial velocity out to the edge of the visible Universe if we get enough photons.

True Space Motion

Now that we've measured the radial velocity and the tangential velocity (proper motion x distance), we can figure out the true space motion of the object.



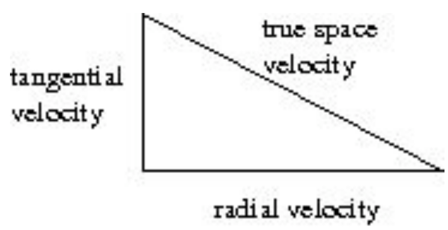
The gory details of true space motion:

Radial velocity (v_r): from Doppler Shift
Tangential velocity (v_t): from Proper Motion and Distance:

$v_t = 4.74 \mu d$

μ is the proper motion in arcsec/year
d is distance in parsecs
v_t is the tangential velocity in km/sec

Finally we can get the true space velocity from the Pythagorean Theorem



$$v^2 = v_r^2 + v_t^2$$
$$v^2 = v_r^2 + (4.74 \mu d)^2$$

Why measure space motions?

Most useful when measured for many stars.
Use the statistics of the motions to find:

- Motion of Sun through nearby space (towards the constellation Hercules)
- Location rotation of the Milky Way galaxy
- Identify odd-ball stars that move "peculiarly" relative to otherwise similar stars.
  - Kicked by explosion?
  - Visitors from outer reaches of Milky Way?

Important tool for studying the structure of the Milky Way galaxy.