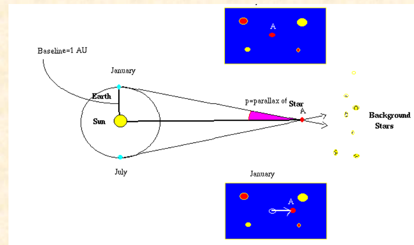
Lec #8: 9 SEP 11 Cataloging Stellar Properties. I.

- LAST TIME: Finish Basic Motions & Cycles
  - precession, nutation
  - position measurements
  - stellar catalogs
- TODAY: Cataloging Stellar Properties. II.
  - Parallax and Proper Motion
  - Apparent Brightness and Luminosity
  - Colors and Temperature
- MONDAY: Cataloging Stellar Properties. III.
  - Spectroscopic Properties
  - Spectral Classification

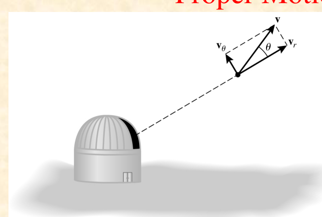
Parallax



- notice that for small angles, tan p ~ p
- 1 parsec = distance to an object with a parallax of 1 arc-sec
- parallaxes are referenced to a baseline of 2 A.U., but you can observe with a smaller baseline
- nearest star has a parallax of less than 1 arc-sec (d > 1 pc)

- Before Hipparcos
  - Gliese (Wooley) catalog of all stars within 25 pc
  - "volume-limited" sample
  - mostly M stars
  - had some glaring errors
- Hipparcos
  - goal 100,000 stars to better than 0.002 arc-sec
  - achieved >100,000 at ~ 0.001 arc-sec
  - 0.001" -> 1000 pc
  - brighter stars out to this distance
  - fainter stars only to ~100 pc

Proper Motion



- $\Delta\theta$ usually given as μ :

  $\mu = \{(\mu_\alpha \cos\delta)^2 + (\mu_\delta)^2\}^{1/2}$

  units: arc-sec/year
- Note that: $v_t = \mu d$
- Barnard's Star: 10.3 ″/y

- component of true velocity vector projected onto the "plane" of the sky
- transverse velocity not measured directly; only change of angular position with time (i.e. angular velocity)
- to get true space velocity, also need radial velocity and distance

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Doppler Shifts

- Doppler shift: $\Delta\lambda = \lambda_{obs} - \lambda_{pred}$ (can be + or -)
  - + => redshift (relative motion away from us)
- Radial velocity: $v_r/c = \Delta\lambda / \lambda_{pred}$
- Observed v. True Radial Velocity:
  - Earth rotational velocity (~0.5 km/s)
  - Earth orbital velocity (~ 30 km/s)
  - Sun's velocity (speed and direction) !!
    - How the heck do we know that???
    - From statistical studies of many stars v_r
  - "Local Standard of Rest"

Space Velocity

- LSR motion:
  - 16.5 km/s
  - l = 53° (galactic longitude)
  - b = 23° (galactic latitude)
  - ISM seems to flow in from this direction -> Doppler shifts of ISM lines
- Vector sum of proper motion (expressed in km/s) and radial velocity
  - can give us a sense of galactic dynamics if we can get out far enough (several types of orbits)
  - Pop I v. Pop II stars

4. Apparent Brightness and Flux

- Luminosity is the total power output. It can be measured in Watts (Joule/sec). In astronomy, we usually use erg/sec (1 Joule = 10^7 erg).
- Stars radiate approximately the same amount in all directions ("isotropic"). This energy propagates at the speed of light, and the total amount is conserved as it travels through space.
- But it spreads out over an ever larger surface, with an area $4\pi d^2$, where d is the distance away from the star.
- A flow through a surface : "flux" [units always per unit area]
- This is what we actually measure to determine the "Apparent Brightness".

- The surface flux at the star is $L/(4\pi R^2)$, where R is the radius of the star. Units are usually given as erg/s/cm^2.
- Apparent brightness is flux at distance, d: $L/(4\pi d^2)$.
- Therefore, if we want to know the *total energy generated* by a star, we need to measure both the APPARENT BRIGHTNESS and the DISTANCE to the star.
- For stars with measured parallax, we know the distance.
- The total energy received from the star also depends on the area of the detector you use (e.g. a large telescopes collects more light than your eye does).

Apparent Brightness

- Recall that apparent brightness depends on distance and the detector area. It also depends on the detector *sensitivity* (and spectral response).
- How do we put everything onto a common scale of W/m^2?
- Being astronomers, we don't. But we have to have something that we can all agree on. Rather than conforming to SI, we have instead taken the old irrational system of APPARENT MAGNITUDE (m) and "standardized" it.

Apparent Magnitude

- Based on visual system of Hipparchus. He categorized all the visible stars into 6 classes, with "first magnitude" being the brightest and "6th magnitude" being the faintest.
- We've quantified this such that a change of 1 magnitude corresponds to a fixed fractional change. For example, two stars differing by 5 magnitudes differ by a factor of 100 in brightness (i.e. flux): $F_2/F_1=100^{(m_1-m_2)/5}$.
- A difference of 1 magnitude corresponds to $100^{1/5}$ ~ 2.512 in flux.

- The brightest object in the sky has an apparent magnitude of about -27. The faintest things we can see have a magnitude of about 31. That's a range in brightness of $100^{58/5} \sim 10^{22}$!!
- Notice that this scale is purely relative (not absolute) and dimensionless. Fractional changes in brightness (ratios) --> differences in magnitude (log brightness); Need a zero point...
- Relative to what? Vega (m=0; sort of)

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5. Luminosity

- Since we've mucked up the apparent brightness (flux) scale, we'll need a similar scale for true brightness. We define ABSOLUTE MAGNITUDE (M) as the apparent magnitude a star would have if it were 10 parsecs away. This makes it a dimensionless measure of luminosity.
- It is not measured directly, just inferred from the apparent magnitude and distance.
- Distance Modulus: (proof left as homework)

$$m - M = 5 \log(d/10pc)$$

- Example. If the Sun were 10 pc away, instead of appearing at m=-27, it would appear to be a star with m=4.76.
- Like apparent magnitude, a difference of 5 in absolute magnitude corresponds to a difference of 100 in Luminosity.
- Example. Solar Luminosity = 4×10^{33} erg/s. A star with an absolute magnitude of -0.24 has a luminosity of 4×10^{35} erg/s.

- Why is luminosity an important # to know?