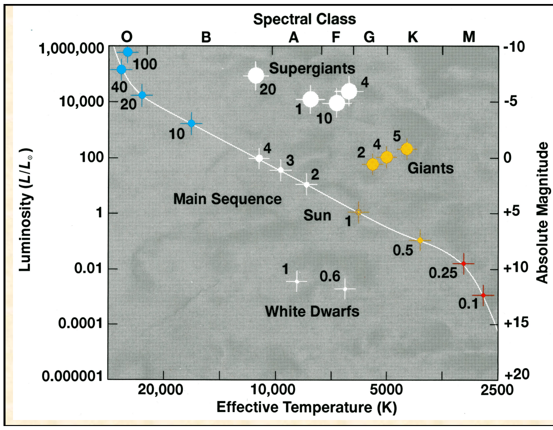
Lec #13: 21 September 2011 Fundamental Stellar Properties

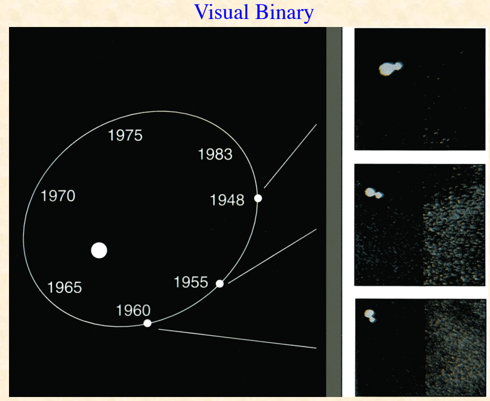
- LAST TIME: Using Spectral Line Positions
  - HR Diagram
  - Binary Stars
  - Mass Determination
- TODAY: Mass-Luminosity Relation
  - mass measurements from binary stars
  - mass-luminosity relation
  - T, L, M, R
- FRIDAY: EXAM #1 !!!



Measuring Mass Using Binary Stars

- Kepler's Third Law: $1/M_T \sim a^3/P^2$
- But we are interested in individual masses of each component, not total mass
- P is easy to measure (but for visual binaries, it can take 10's or 100's of years)
- What about a? (demo: hula hoop)

Visual Binary



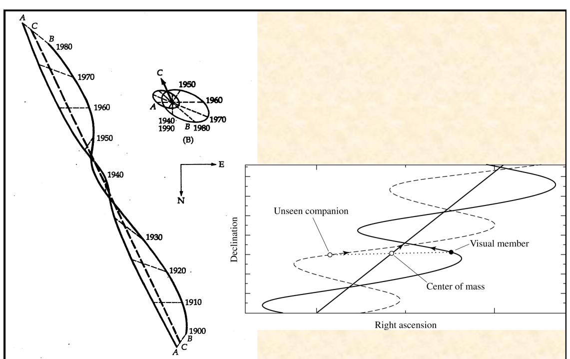


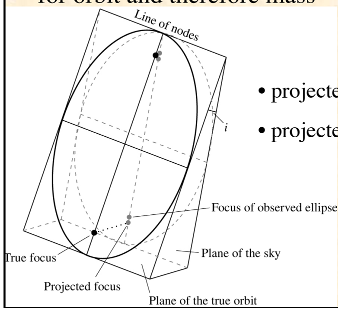
Figure 12–2 Motions of Sirius A and B. (A) The apparent motions relative to background stars of Sirius (A), its companion (B), and the center of mass of the system (C). (B) Orbital motions of Sirius A and B relative to the system's center of mass.

1) Visual Binaries

- Mass ratio given by relative semi-major axes:

  $m_1/m_2 = \alpha_1/\alpha_2$; where α=a/d
- distance not required *if* you can see both stars *and* the center of mass (just use angular separation)
- if orbit in plane of sky and distance is known, can set up 1-body problem with reduced mass $\mu=m_1m_2/(m_1+m_2)$ orbiting immobile total mass
  - $a=a_1+a_2$
  - Kepler's 3rd law gives m_1+m_2
  - combine mass ratio and mass sum ->
  - solve for m_1 & m_2 individually (2 eq., 2 unknowns)

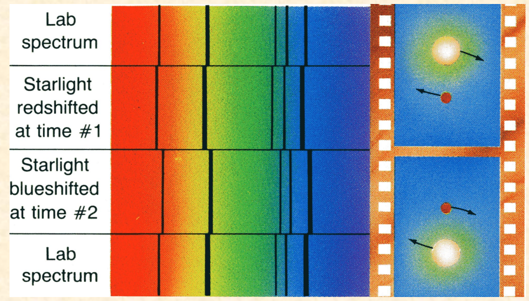
• if not in plane of sky, you can still fiddle with more careful observations (accelerations, line of nodes, longitude of ascending node, etc) to solve for orbit and therefore mass



• projected orbit still an ellipse

• projected foci not true foci

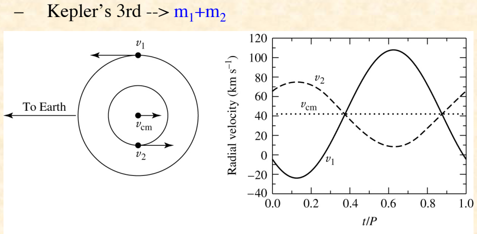
Spectroscopic Binary



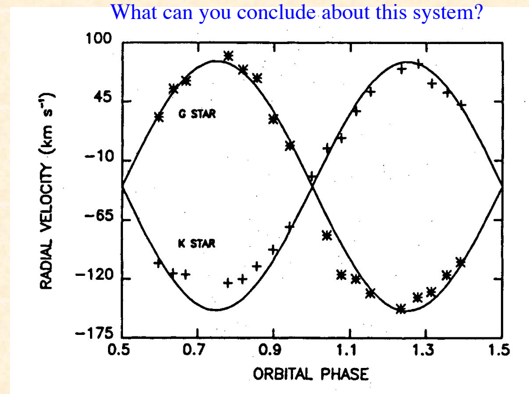
single-lined v. double-lined spectroscopic binaries

2) Spectroscopic Binaries

- Special Case: circularized; eclipsing binaries
  - eclipsing binary: sin i = 1 (i=90) circular: e=0
  - $m_1/m_2 = v_2/v_1$
  - in general v is not constant and is projected v_r
  - $v=2\pi a/P$; a=radius of circular orbit
  - Kepler's 3rd --> m_1+m_2

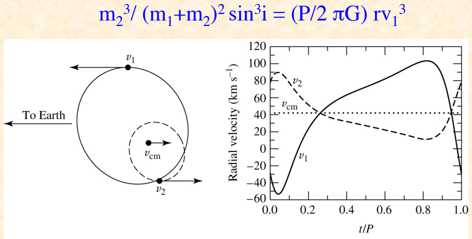


What can you conclude about this system?

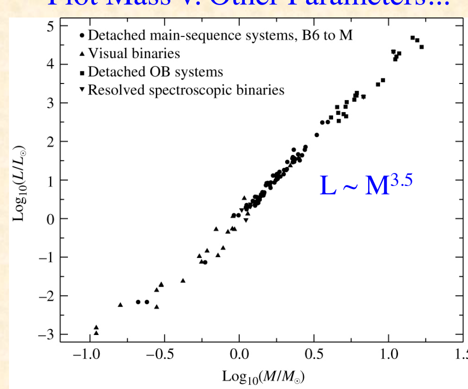


- More general case, total mass given by:
  - $m_1+m_2 = (P/2\pi G)(rv_1 + rv_2)^3 / \sin^3 i$
  - if we see both stars and know i, we can solve
  - if we see both stars but not i, only get w/in $\sin^3 i$
  - if we only see 1 star only get "mass function":

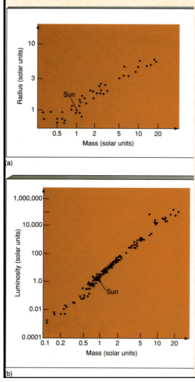
$$m_2^3/(m_1+m_2)^2 \sin^3 i = (P/2\pi G)\, rv_1^3$$



Plot Mass v. Other Parameters...



Mass-Luminosity Relation



$L \sim M^{3.5}$

- L comes from conversion of mass into energy
- so Lifetime~Mass/Luminosity

Max. Lifetime ~ $M^{-2.5}$

- Mass range .1 -> 20 $M_{\odot}$
  - M~20 25 million years
  - M~1 10 billion years
  - M~0.1 1 trillion years

Properties We Have "Measured"

- from apparent brightness, position, "color"
  - distance
  - proper motion
  - luminosity
  - effective temperature
  - radius
- from Doppler shifts of spectral lines
  - radial velocity
  - space velocity
  - mass

These measured properties cover a large range:

	min	max	range
Luminosity	10^{-4}	10^{4}	10^{8}
Radius	10^{-2}	10^{3}	10^{5}
Mass	10^{-1}	10^{2}	10^{3}
Temperature	2500	25000	10^{1}

(L, R, M in Solar Units; T in Kelvin)