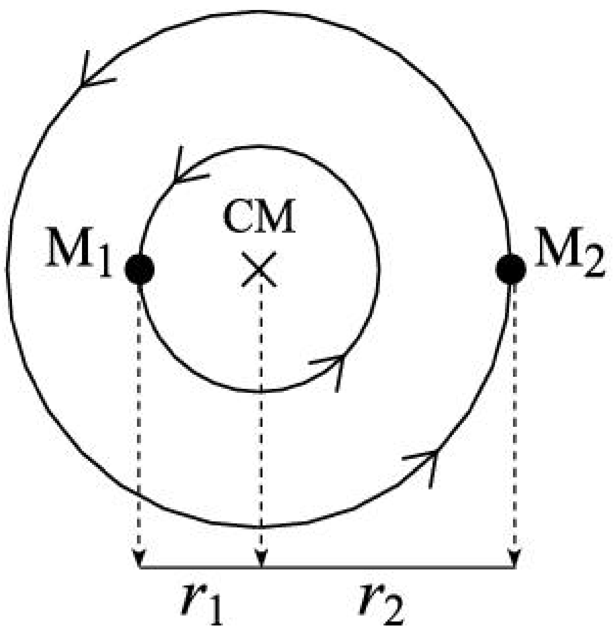
Outline

- Hand in, go over homework problems 2.2, 2.3
- Stars in binary systems

Binary Star Systems

- Observational categories:
  - Visual binaries – can see and resolve the two stars
  - Astrometric binaries – can see at least one stars and measure its orbital motion on the sky
  - Spectroscopic binaries – cannot resolve the two stars, but can detect spectral lines that shift in wavelength due to orbital motion (and Doppler effect). Can be 'single lined' or 'double lined'.
  - Eclipsing binaries – orbital plane lies near our line of sight, so stars eclipse each other.

Two Body Problem



System viewed above orbital plane

$$r_1 M_1 = r_2 M_2$$

$$a = r_1 + r_2$$

$$r_1 = a\, M_2/(M_1+M_2)$$

$$r_2 = a\, M_1/(M_1+M_2)$$

Do equations of motion from notes/book

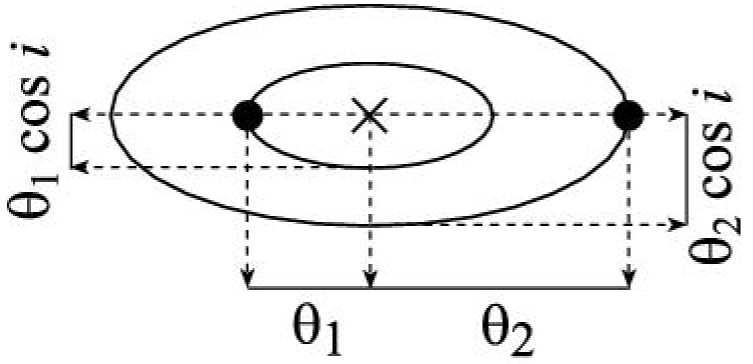
Visual Binary

System viewed at inclination *i*

Inclination is measured perpendicular to orbital plane.

Circular orbit appears as an ellipse, but major axes remain same:

$$r_1 = \theta_1 d, \quad r_2 = \theta_2 d, \quad a = (\theta_1 + \theta_2)d$$



Since $r_1 M_1 = r_2 M_2$, then $\theta_1 / \theta_2 = M_2 / M_1$

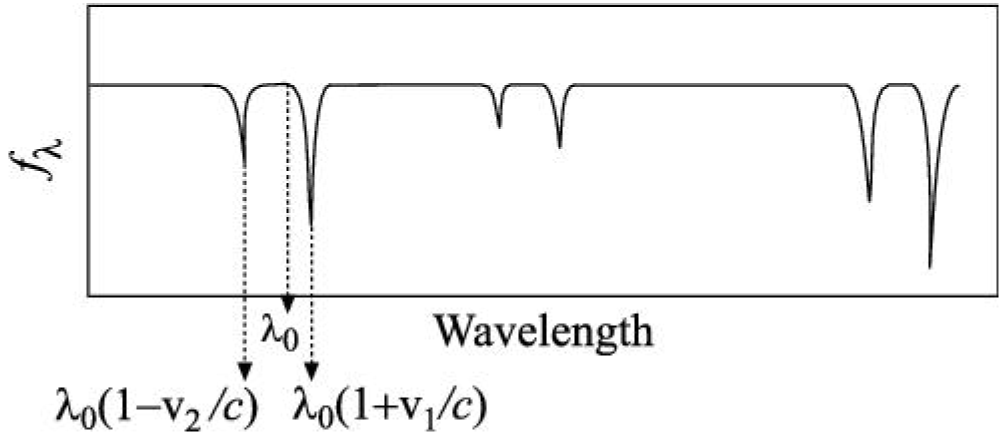
Orbital period is determined by watching the stellar motion.

If *d* is known, then we can find *a* and calculate

$$M_1 + M_2 = 4\pi^2 a^3 / G\tau^2$$

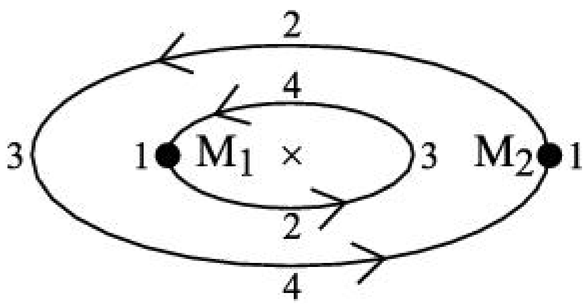
Can solve for two unknowns using two equations.

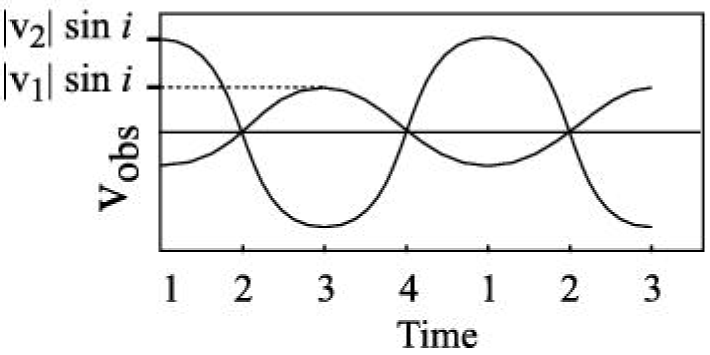
Spectroscopic Binaries



- In a double lined system, each line appears twice, once from each star.
- The lines move due to orbital motion of the star (and Doppler effect).
- Movie: http://www.astronomy.ohio-state.edu/~pogge/Ast162/Movies/spbin.mpg

Spectroscopic Binaries





- We see only the component of the velocity along our line of sight, so

  $v_{\text{obs}} = v \sin i$

- We still have $v_{1\text{obs}} / v_{2\text{obs}} = M_2 / M_1$ since the sin i cancels out.

- Separation a depends on i :

  $r_1 = \tau v_1 / 2\pi = \tau\, v_{1\text{obs}} / 2\pi \sin i, \quad a = \tau\,(v_{1obs} + v_{2obs})/2\pi \sin I$

  $(M_1 + M_2) \sin^3 i = \tau\,(v_{1obs} + v_{2obs})^3 / 2\pi G$

- Need some way to determine i.

Spectroscopic Binaries

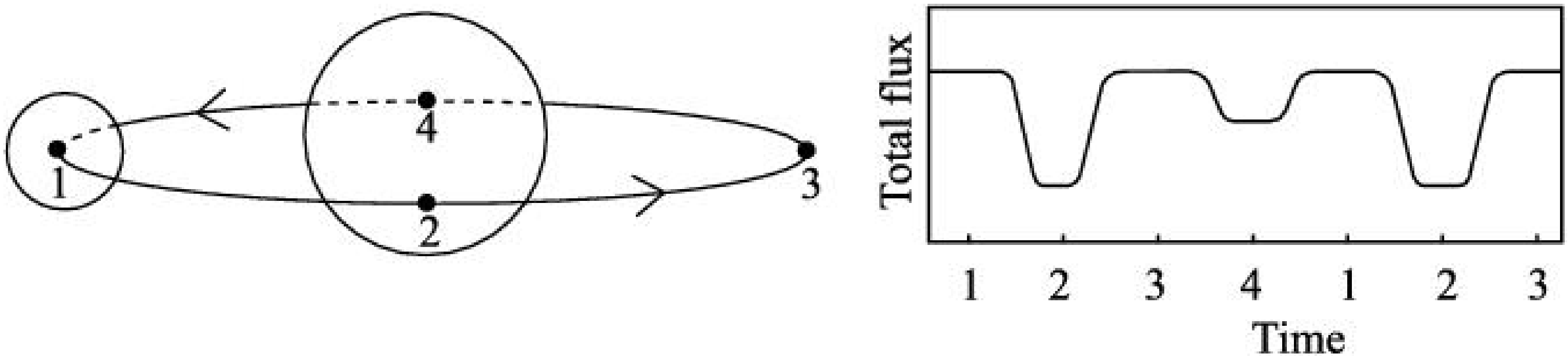
- For single line binaries, we cannot directly measure the mass ratio.
- Then Kepler's law becomes

$$M_2^3 \sin^3 i \,/(M_1 + M_2)^2 = \tau\, (v_{1obs})^3 / 2\pi G$$

- This is called the 'mass function'. It has units of mass.
- Note that $M_1 > 0$ and $\sin i \le 1$, so $M_2 \ge \tau\, (v_{1obs})^3 / 2\pi G$.

- Need some way to determine i and mass ratio.

Eclipsing Binaries



- Orbital plane must lie in or near our line of sight.
  - Provides direct constraint on orbital inclination, best mass measurements come from eclipsing systems.
- Eclipses provide means to measure orbital period.
- Eclipses provide means to measure diameters of the stars.

Homework

- For next class:
  - Problem 2-4
  - Note problem 2-5 is similar to 2-4, but is not assigned