Astronomy 404
September 9, 2013

Chapter 7. Binary Systems and Stellar Parameters

Visual binary
Astrometric binary
Eclipsing binary
Spectrum binary
Spectroscopic binary

$$m_1 / m_2 = a_2 / a_1 = v_2 / v_1 = v_{2r} / v_{1r}$$

$$P^2 = \frac{4\pi^2}{G(m_1+m_2)} a^3$$ Kepler's 3rd law

$$m_1 + m_2 \ (\text{in } M_\odot) = \frac{a^3 \ (\text{in AU})}{P^2 \ (\text{in yr})}$$ **Short cut**

$$m_1 + m_2 = \frac{4\pi^2}{G P^2} \frac{a^3}{\cos^3 i}$$

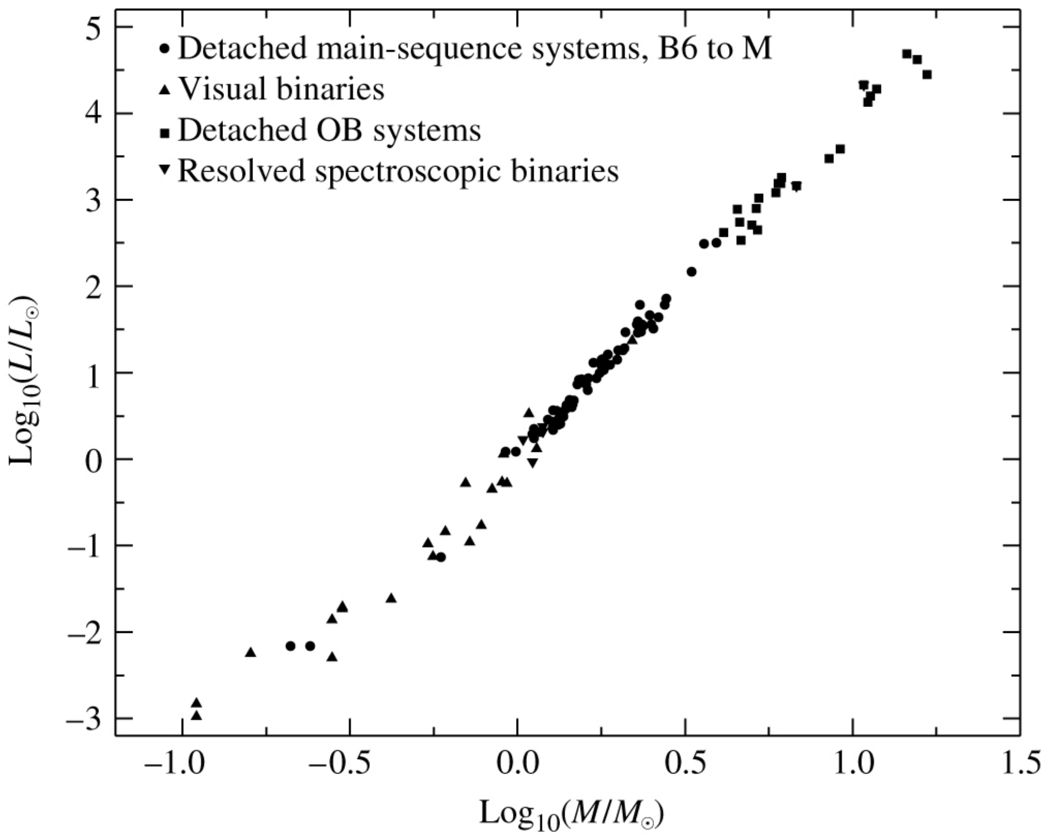
$$m_1 + m_2 = \frac{P}{2\pi G} \frac{(v_{1r} + v_{2r})^3}{\sin^3 i}$$

To determine the total mass, both v_{1r} and v_{2r} need to be known. If only one can be measured, then

$$\frac{m_2^3}{(m_1+m_2)^2} \sin^3 i = \frac{P}{2\pi G} v_{1r}^3$$ Mass Function

(lower limit of m_2)

Mass-Luminosity Relation



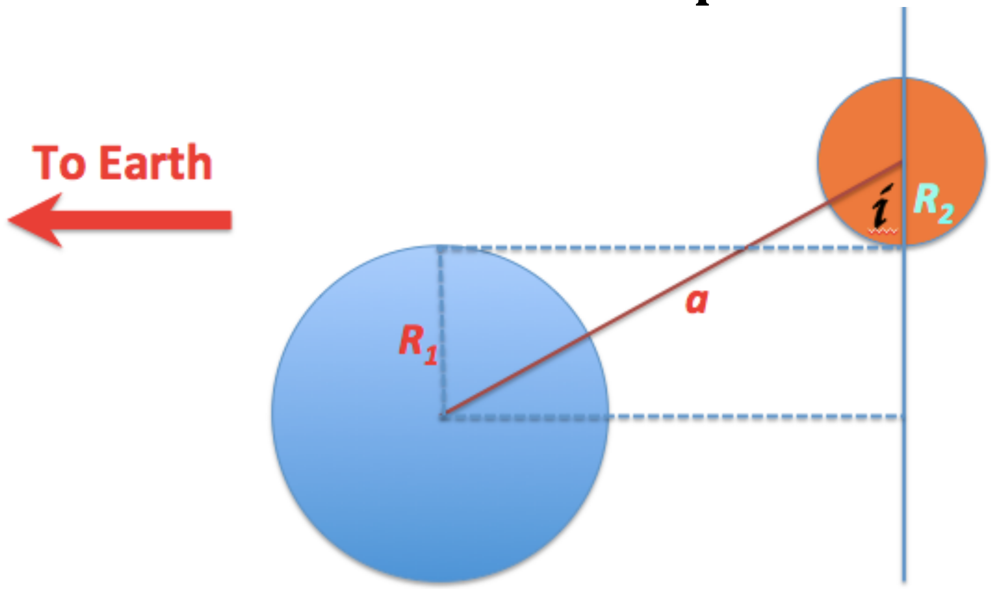
$$L \sim L_\odot \left(\frac{M}{M_\odot}\right)^5 \quad \text{for } M \leq M_\odot$$

$$L \sim L_\odot \left(\frac{M}{M_\odot}\right)^{3.9} \quad \text{for } M_\odot \leq M \leq 10\, M_\odot$$

$$L \sim 50\, L_\odot \left(\frac{M}{M_\odot}\right)^{2.2} \quad \text{for } M \geq 10\, M_\odot$$

Eclipsing Binaries

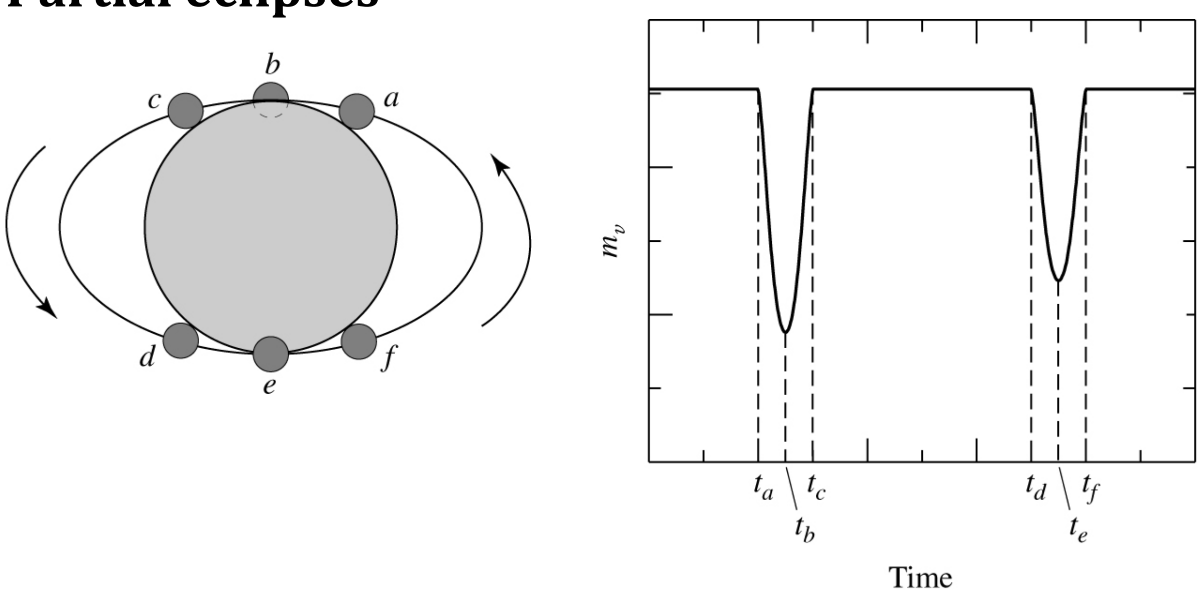
What is the minimal *i* for eclipses to occur?



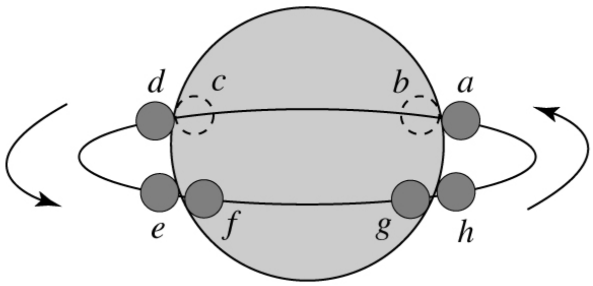
***i* has to be close to 90°. If *i* is 75°, $\sin^3 i = 0.90$, only 10% error in mass determination.**

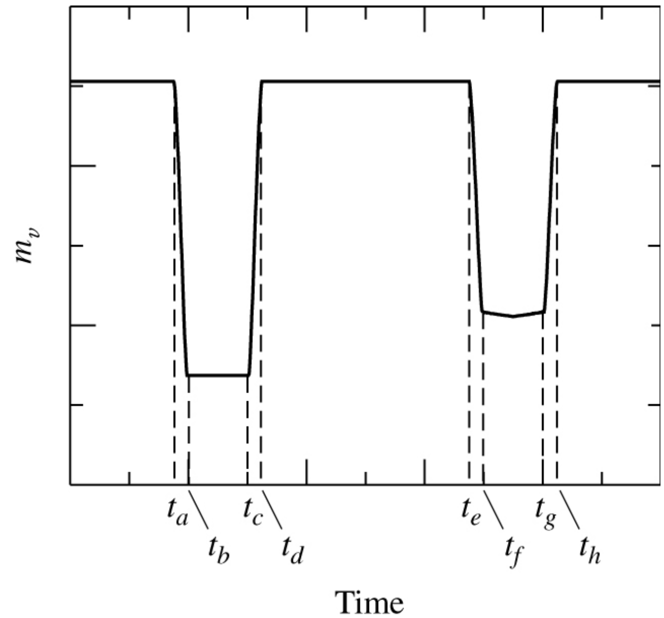
Light Curve of Eclipses

Partial eclipses



Total eclipses





$v_s = c\,(\Delta\lambda_s / \lambda_0)$ $\quad$ $\Delta\lambda_s$: maximum Doppler shift of star s

$v_l = c\,(\Delta\lambda_l / \lambda_0)$ $\quad$ $\Delta\lambda_l$: maximum Doppler shift of star l

$$r_s = \frac{v}{2}\,(t_b - t_a) \qquad \text{where } v = v_s + v_l$$

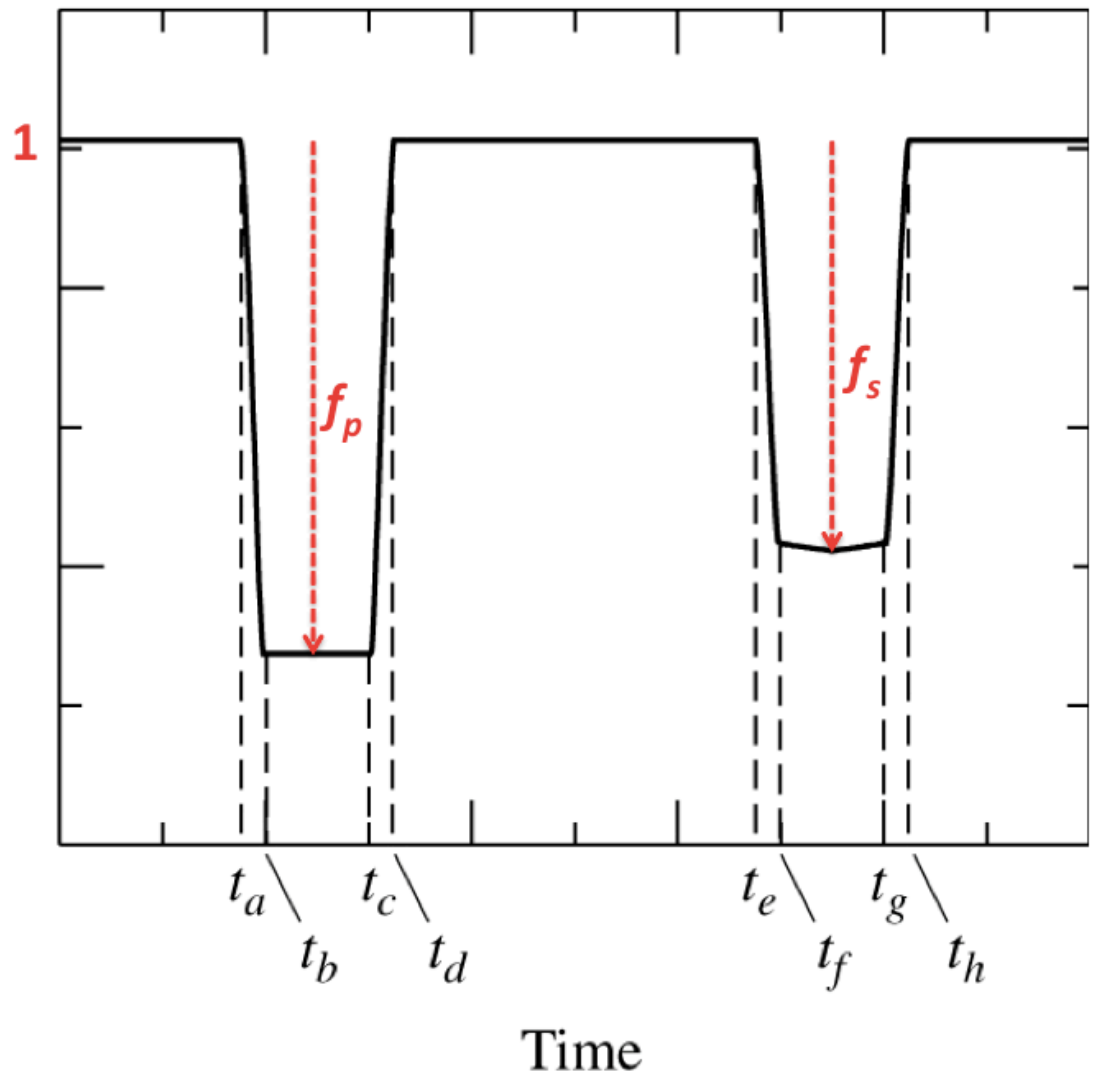
$$r_l = \frac{v}{2}\,(t_c - t_a)$$

Light curve ➔ $P, t_a, t_b, t_c, \ldots t_h$

$$m_l / m_s = v_{rs} / v_{rl} = v_s / v_l = \Delta\lambda_s / \Delta\lambda_l$$

$$2\pi a = (v_s + v_l)\,P$$

$$m_l + m_s = a^3 / P^2 \qquad m \text{ in } M_\odot,\ a \text{ in AU},\ P \text{ in yr}$$



Total light = $\pi\, r_s^2\, \sigma\, T_s^4 \;+\; \pi\, r_l^2\, \sigma\, T_l^4$

$f_p \,/\, f_s \;=\; \pi\, r_s^2\, \sigma\, T_h^4 \,/\, \pi\, r_s^2\, \sigma\, T_c^4 \;=\; (T_h \,/\, T_c)^4$

But, how do we know which star is hotter?
Assume star *l* is hotter,

$$f_s \;=\; \frac{\pi\, r_s^2\, \sigma\, T_c^4}{\pi\, r_s^2\, \sigma\, T_c^4 + \pi\, r_l^2\, \sigma T_h^4} \;=\; \frac{1}{1+(r_l\,/r_s)^2\,(T_h/T_c)^4}$$

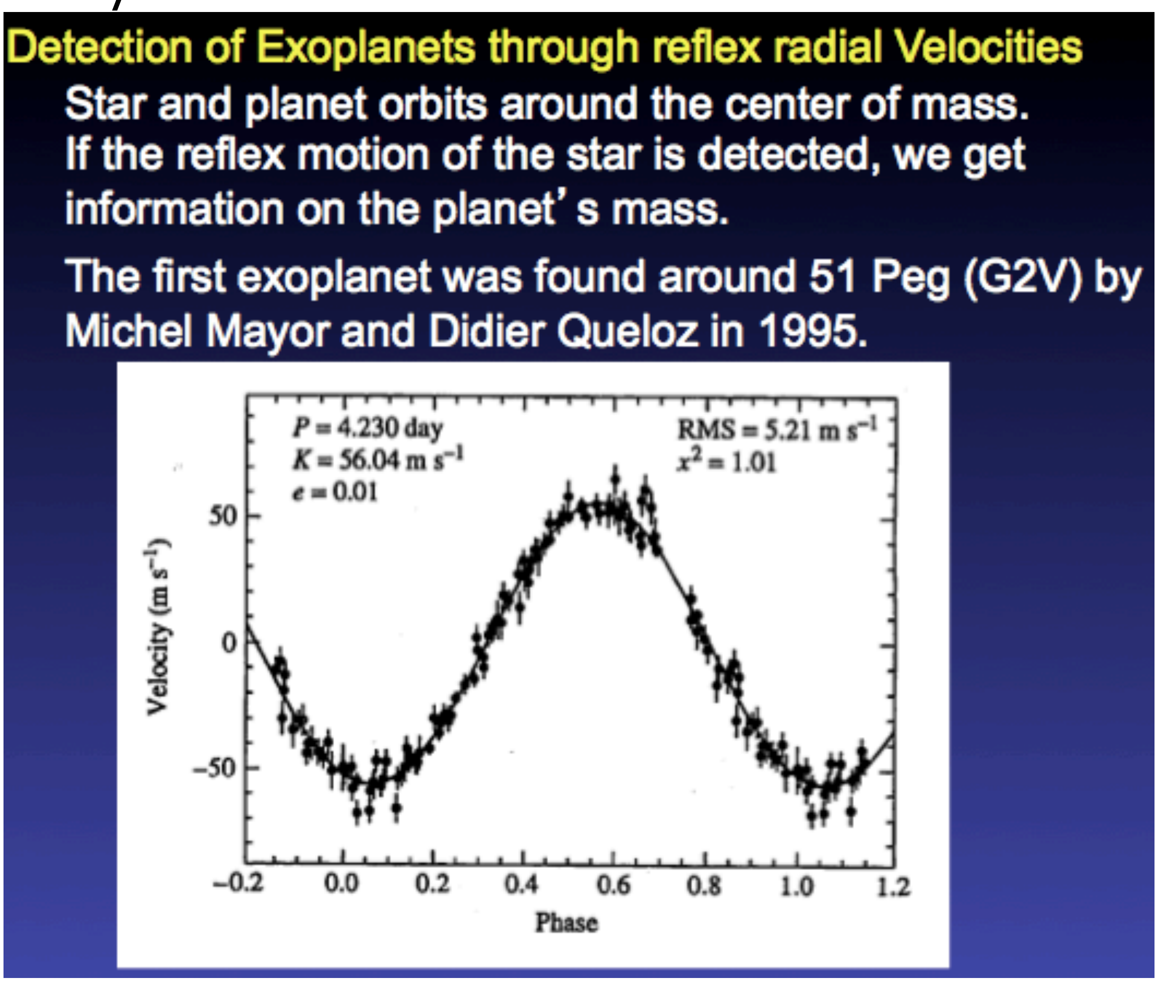
Is this f_s consistent with observation?
If yes, then star *l* is hotter.

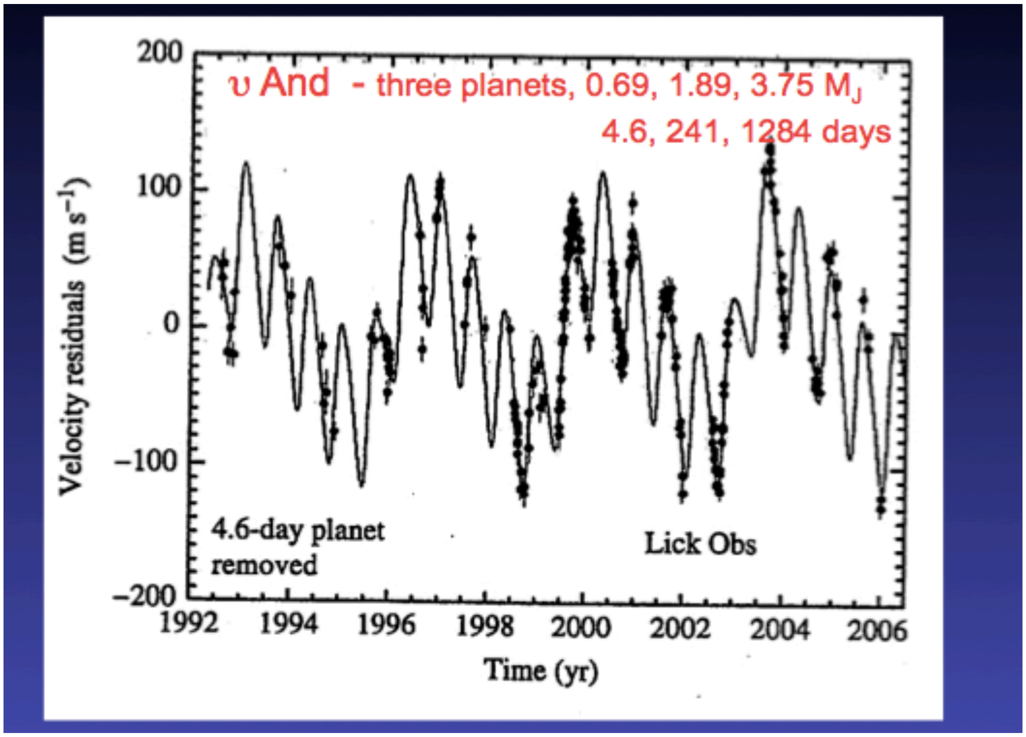
Search for Extrasolar Planets

This is a topic covered in Astr 405.

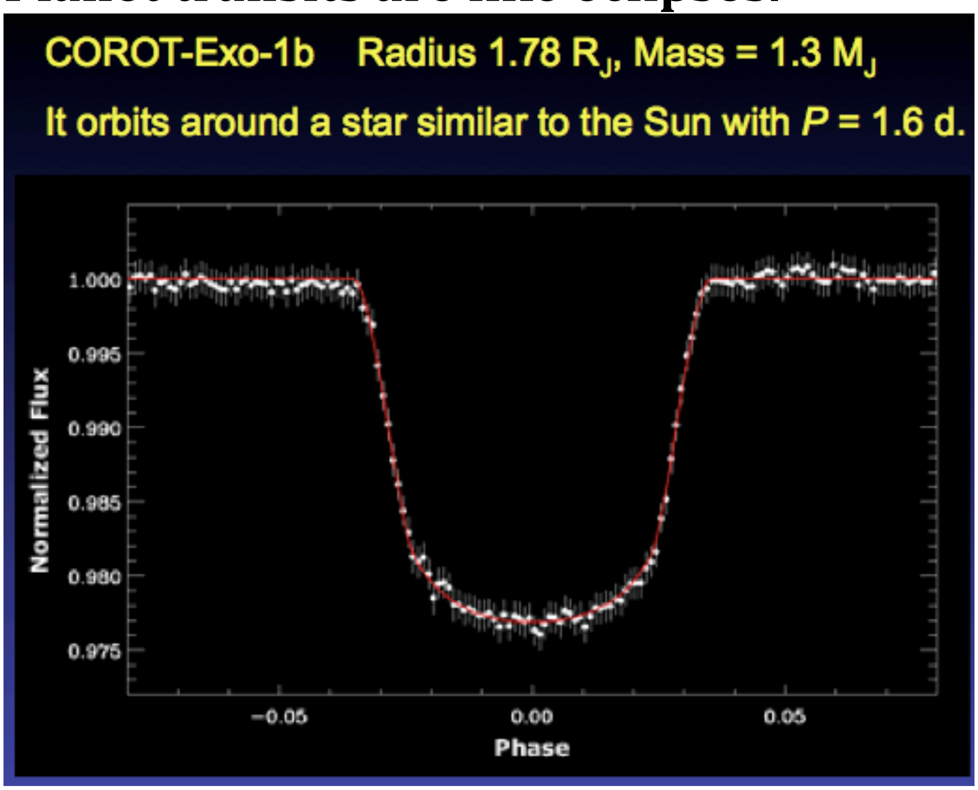
A planet orbiting around a star is just like a binary system with a large primary to secondary mass ratio.

The reflex motion of the star is small, of order of m/s. Accurate measurements are needed.





Planet transits are like eclipses.



Mercury transiting the Sun (2004)