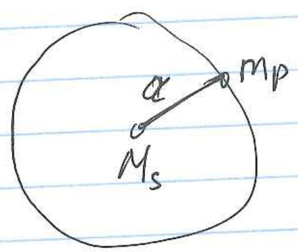
lecture 8   ~~Ext~~ Exoplanet search



$$P^2 = \frac{4\pi^2}{G(M_s+m_p)} a^3$$

$$v_p = \frac{2\pi a}{P}$$

$$v_s = v_p \frac{M_p}{M_s} = \frac{2\pi a}{P} \frac{M_p}{M_s}$$

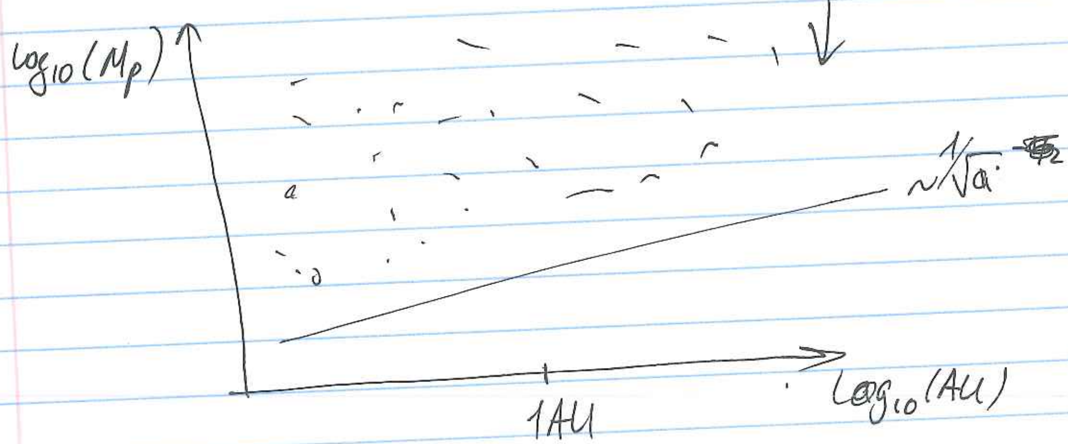
$$= 2\pi \frac{a}{\sqrt{\frac{4\pi^2 a^3}{G(M_s+M_p)}}} \frac{M_p}{M_s} =$$

$$= 2\pi \cdot \frac{1}{\sqrt{a}\sqrt{\frac{4\pi^2}{G}}} \frac{M_p}{\cancel{(M_s+M_p)}\,\frac{M_s}{\sqrt{M_s+M_p}}}$$

$$\Rightarrow \boxed{M_p \ll M_s}$$

$$= \frac{2\pi}{\sqrt{\frac{4\pi^2}{G}}} \frac{M_p}{\sqrt{a}\sqrt{M_s}}$$

Current v sensitivity 60 cm/s



Planet search.

Assume circular orbit

$v_p = \frac{2\pi a_{planet}}{p}$ $\quad v_{star} = \frac{2\pi a_{star}}{p}$

$\cancel{v_p = 2\pi}$ $\quad \frac{a_{planet}}{a_{\cancel{earth}\ star}} = \frac{v_{planet}}{v_{star}}$

~~under estimate~~

Earth motion

$v_E = \frac{2\pi \cdot 1\,AU}{1\,year} \simeq \frac{2\pi \cdot 1.5 \cdot 10^{11}}{\pi \cdot 10^7} = 3 \cdot 10^4 \approx 30\frac{km}{s}$

$v_{sun} = v_E \cdot \frac{M_E}{M_S} = 3 \cdot 10^4 \cdot \frac{6 \cdot 10^{24}}{2 \cdot 10^{30}} \simeq$

$\approx 9 \cdot 10^{-2} \approx 9\,cm/s$

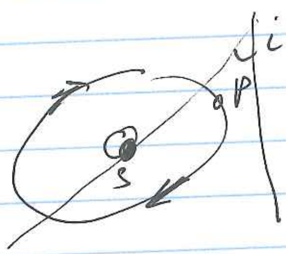
First planet report in 1996.

Overall about 860 planet reported in 2013

So far they are way heavier than Earth ≃ Jupiter like, and usually way closer to star than earth

Problem with radial velocity method

we do not know inclanation of the orbit



$v_{s\,\text{observed}} = v_s \cdot \sin i$

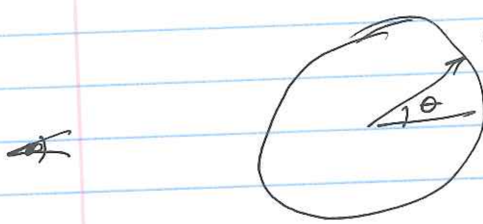
$\Rightarrow$ radial velocity alone gives only lower bound on mass of the planet

Also we do not know 'e'

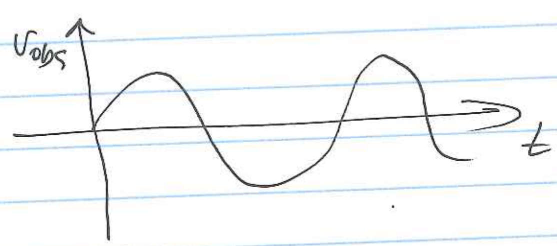
But if we can trace v_s vs t

we can deduce some things

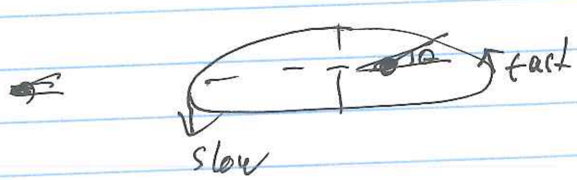
Ex. 1. circular orbit

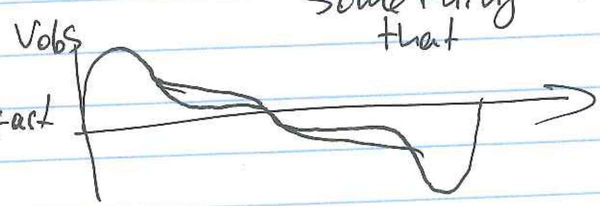


$v_{obs} \sim v \cdot \sin\theta = v \sin(\omega t)$



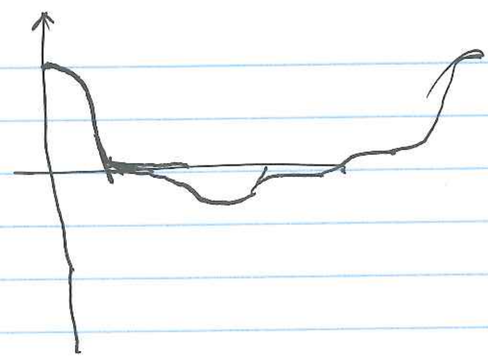
Ex. 2





something like that

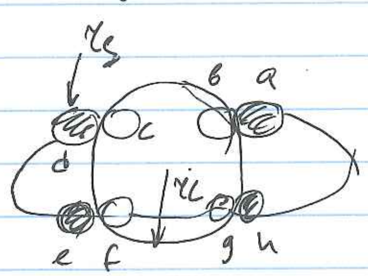
ex. 3

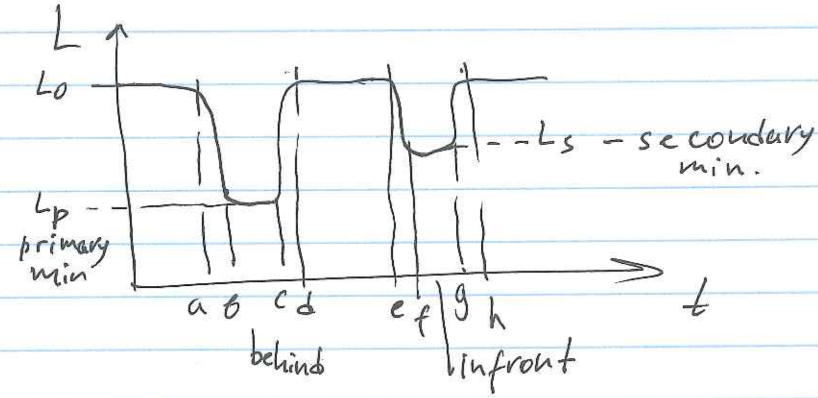


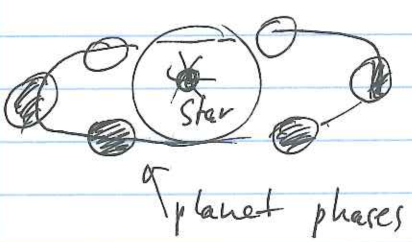
Luminocity method

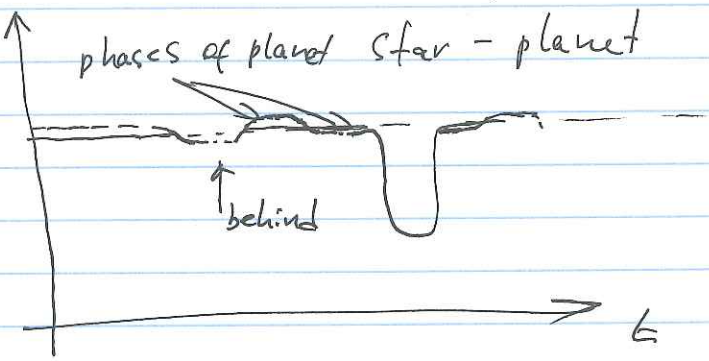
two star

τ small stars
τ lage









{ By the way - this how sun radius was measured by transit of Venus

$$r_s = \frac{v_{orb}}{2}\cdot(t_b - t_a) \qquad r_e \approx \frac{v_{orb}}{2}(t_c - t_a)$$

depends on inclanation

Relative temperatures Stefan-Boltzmann

Flux from star $\simeq A_{star}\cdot \sigma T_{star}^4$

$$L_o \approx F_e + F_s = \pi r_e^2 T_e^4 + \pi r_s^2 T_s^4$$ shade

$$L_p = \pi r_e T_e^4 \quad ; \quad L_s = \pi r_e^2 T_e^4 - \pi r_s^2 T_e^4 + \pi r_s^2 T_s^4$$

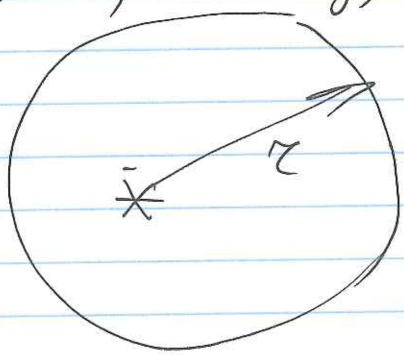
$$\boxed{\frac{L_o - L_p}{L_o - L_s} = \frac{\pi r_s^2 T_s^4}{\pi r_s^2 T_e^4} = \left(\frac{T_s}{T_e}\right)^4}$$

lecture 8 stops here

Radiant flux F (all 'normal' people call it intensity)

Energy per unit area per time

Luminocity (Energy emitted per second)



$F \cdot 4\pi r^2 = L$

$$\boxed{F = \frac{L}{4\pi r^2}}$$

inverse square law for light

If flux differs by factor of 100 we say that magnitude different by 5

i.e. $\frac{F(m+1)}{F(m)} = 100^{1/5} = 2.512$

the brighter the smaller

$$\Rightarrow \frac{F_2}{F_1} = \frac{F_0 \cdot 100^{(-m_2)/5}}{F_0 \cdot 100^{-m_1/5}} = 100^{(m_1-m_2)/5} = 10^{\frac{2}{5}(m_1-m_2)}$$

$$\log_{10}\frac{F_2}{F_1} = \frac{2}{5}(m_1 - m_2) = \cancel{\log_{10}(100^{(m_1-m_2)/5})} =$$

$$= \cancel{10}\ \cancel{\log_{10}(10^{2\cdot(m_1-m_2)/5})} =$$

$\Rightarrow$

$$\boxed{m_1 - m_2 = -2.5\log_{10}\frac{F_1}{F_2}} = \cancel{\frac{2}{5}\log_{10} 10^{\frac{2}{5}(}}$$

Absolute magnitude

Flux from star at distance of 10pc

$$F = \frac{L}{4\pi d^2} \Rightarrow F_{10pc} = \frac{F \cdot d^2}{10pc^2} = F\left(\frac{d}{10pc}\right)^2$$

$$\frac{F_{10}}{F} = 100^{(m-M)/5}$$

$$m - M = +2.5 \log\left(\frac{d}{10pc}\right)^2 = +5\log\left(\frac{d}{10pc}\right)$$

$$M = m - 5\log\left(\frac{d}{10pc}\right)$$

$$\Rightarrow F = \frac{L}{4\pi d^2}$$

$$\frac{F}{F_\odot} \text{ at 10pc} = \frac{L_s}{L_\odot} = 100^{(M_{sun} - M_{st})/5}$$

$$\Rightarrow \boxed{M = M_{sun} - 2.5\log_{10}(L/L_\odot)}$$