ASTR2050 Spring 2005

Lecture 10am 8 February 2005

Please turn in your homework now!

In this class we will cover “Binary Stars”:

- Kinds of binary stars
- Binary star orbits
- Measuring the masses of stars
- Measuring the sizes (radii) of stars

Binary star systems provide most of what we know about the structure and properties of stars!

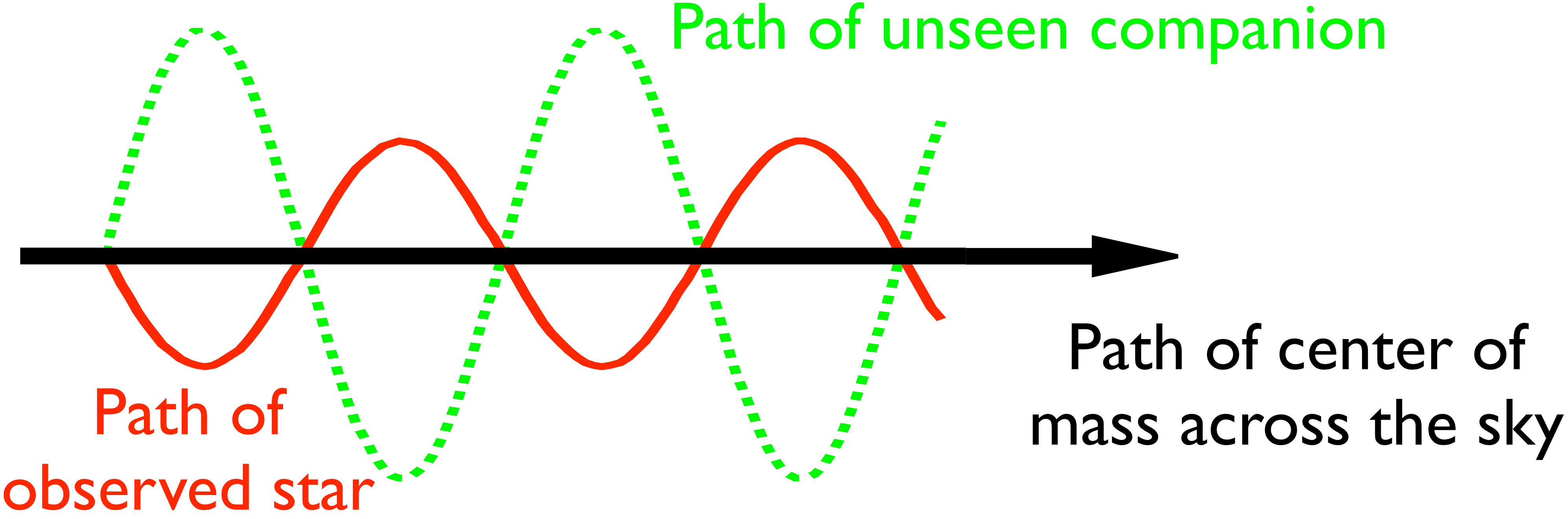
Kinds of binary stars

- Visual binary: See two stars orbit each other
- Composite spectrum binary: Two stellar spectra
- Eclipsing binary: Information from "light curves"
- Astrometric binary: Watch a "single" star wobble
- Spectrographic binary: Doppler shifted spectrum

Movie demonstrations thanks to
http://www.astronomy.ohio-state.edu/~pogge/Ast162/Movies/

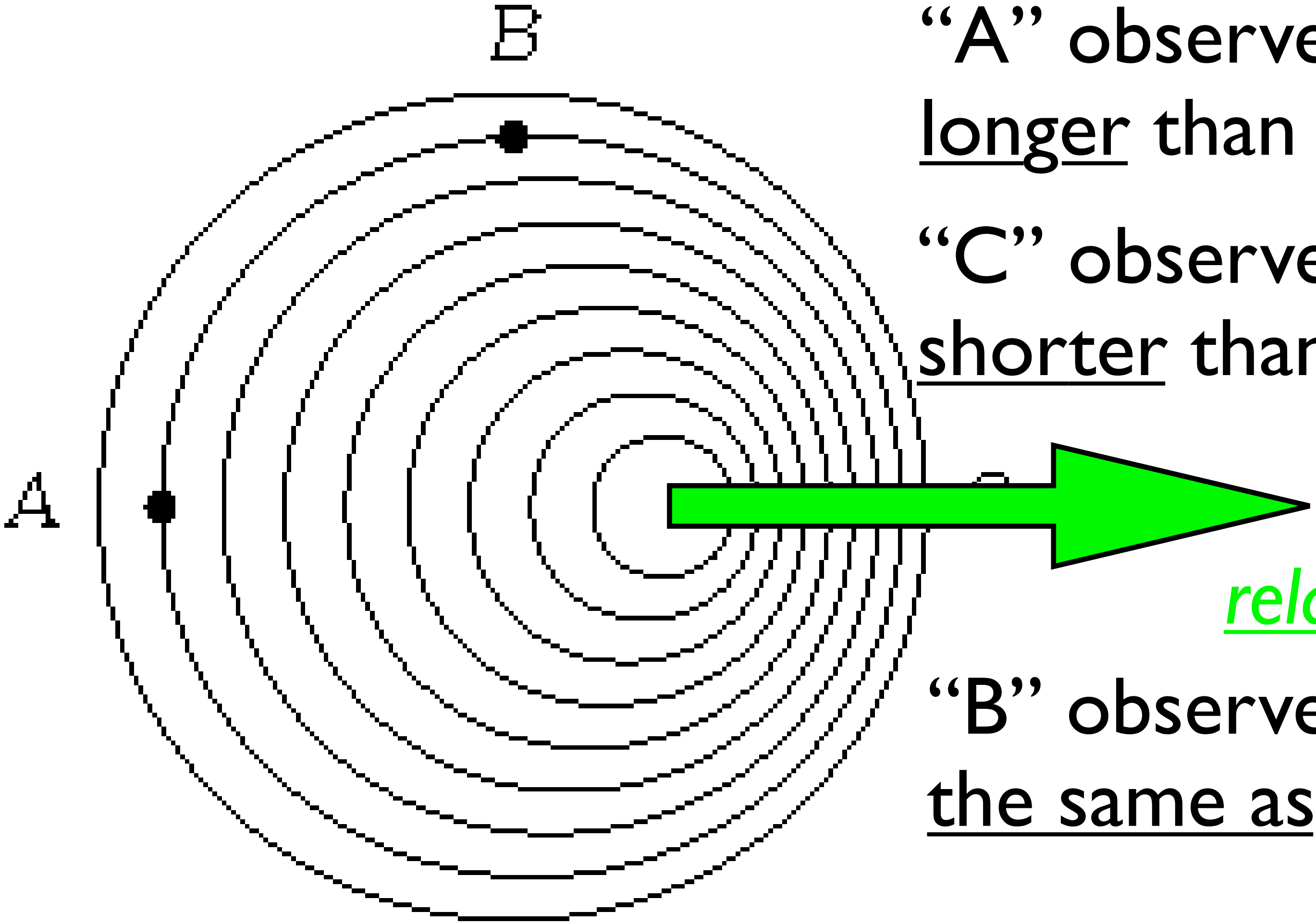
Astrometric Binary

See Kutner Figure 5.2



Only possible for stars with large "proper motion"

Review: Doppler Shift



"A" observes a wavelength longer than if source at rest.

"C" observes a wavelength shorter than if source at rest.

Source velocity relative to the observer!

"B" observes a wavelength the same as source at rest.

Note: The speed of the wave is a property of the medium through which it propagates, and independent of the source velocity.

The nonrelativistic Dopper shift

Speed of recession: v Speed of "light": c

Rest wavelength: λ_0

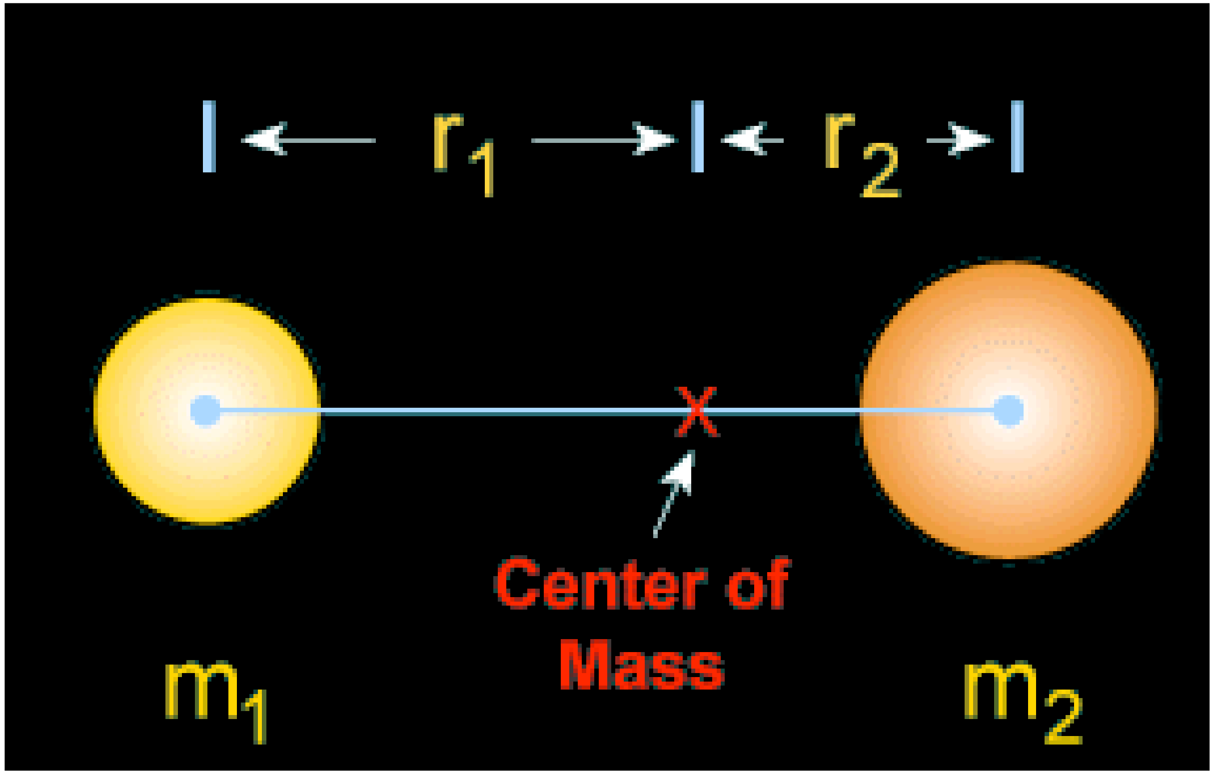
Wavelength shift: $\Delta\lambda = \lambda - \lambda_0 > 0$

$$v/c \ll 0 \Rightarrow \Delta\lambda/\lambda_0 = v/c$$

Also: $\lambda\nu = c \Rightarrow \lambda d\nu + d\lambda\nu = 0 \Rightarrow d\lambda/\lambda = -d\nu/\nu$

The fractional change in wavelength is positive if the source and observer are receding, and its size is given by the ratio of the recession speed and the speed of light.

Binary Star Orbits

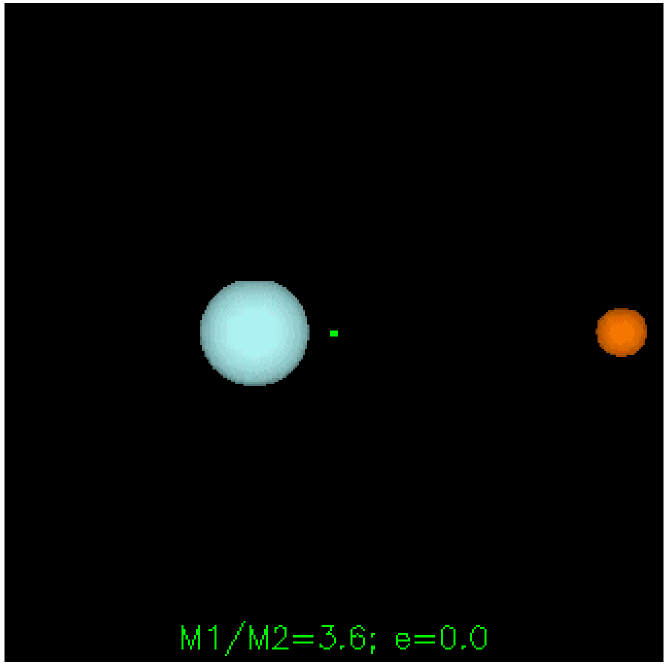


Each star orbits about *its own* center of mass

$$m_1 r_1 = m_2 r_2$$

Gravity: $F = G\frac{m_1 m_2}{R^2}$ *where* $R = r_1 + r_2$

Circular orbits of binary stars



$$\frac{m_1 v_1^2}{r_1} = G\frac{m_1 m_2}{R^2} = \frac{m_2 v_2^2}{r_2}$$

Separate information from the velocity of each star!

However, we can write this in terms of the period in a way valid for both stars! *See Kutner Eq.5.20* ***and typo!***

$$\frac{4\pi^2 R^3}{G} = (m_1 + m_2)P^2$$

Example: The mass of the Sun

The mass of Sun is much greater than the planets, so...

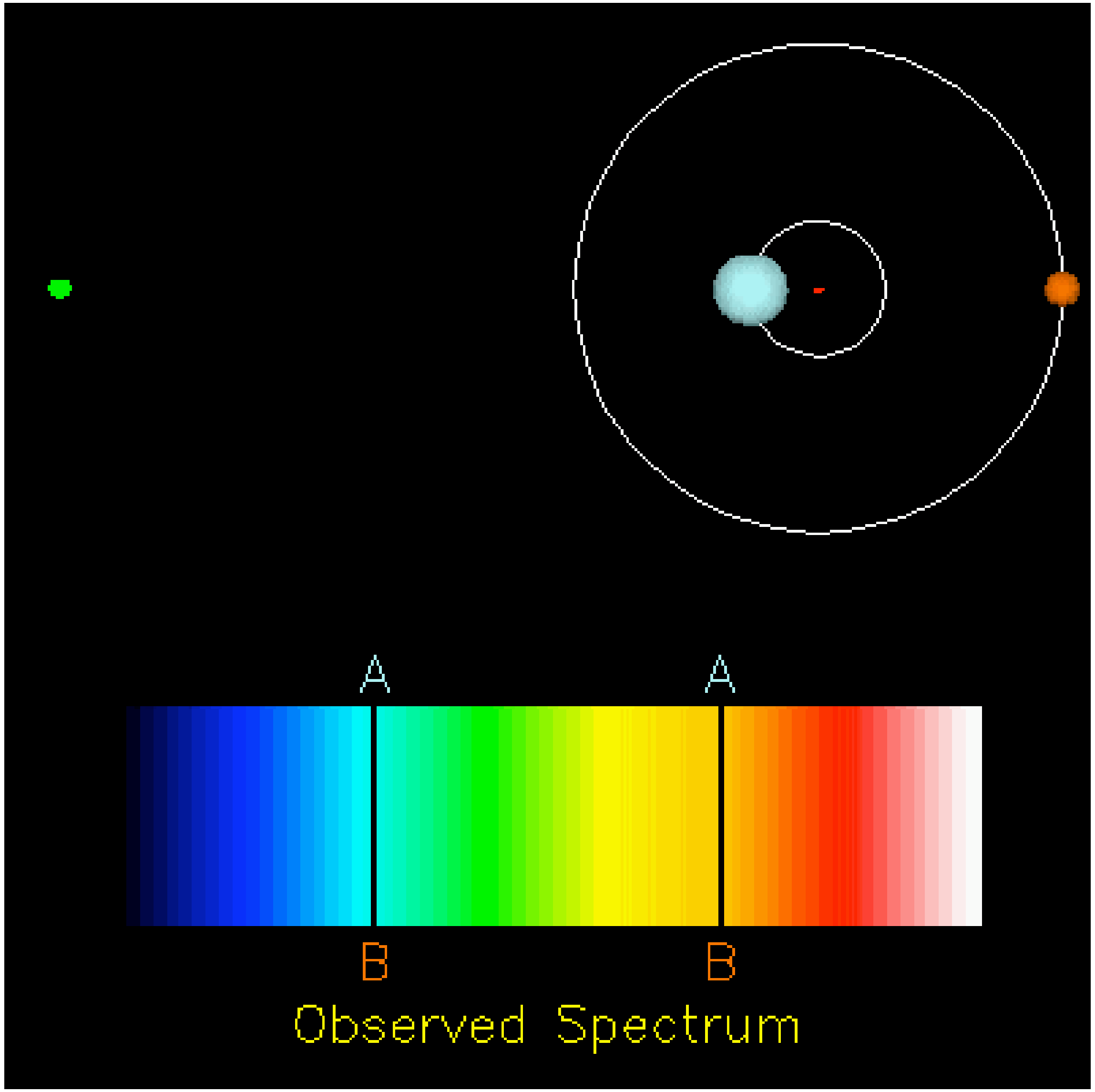
$$\frac{4\pi^2 R^3}{G} = M_\odot P^2$$

(Recall first week's studio laboratory)

This suggests some useful units:

$$\left[\frac{R}{1\,AU}\right]^3 = \left[\frac{m_1 + m_2}{M_\odot}\right]\left[\frac{P}{1\,yr}\right]^2$$

Spectrographic Binary Stars



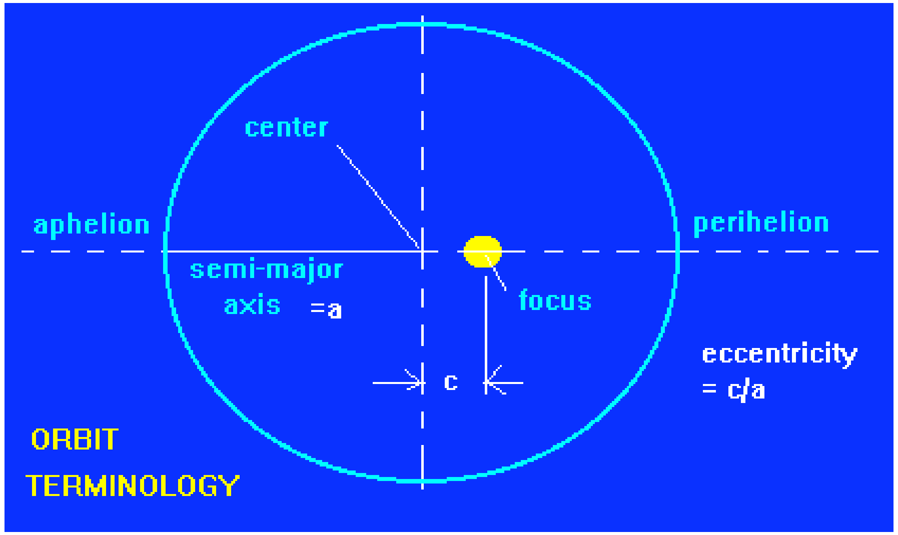
The Doppler shift of each star tells us its own orbital velocity.

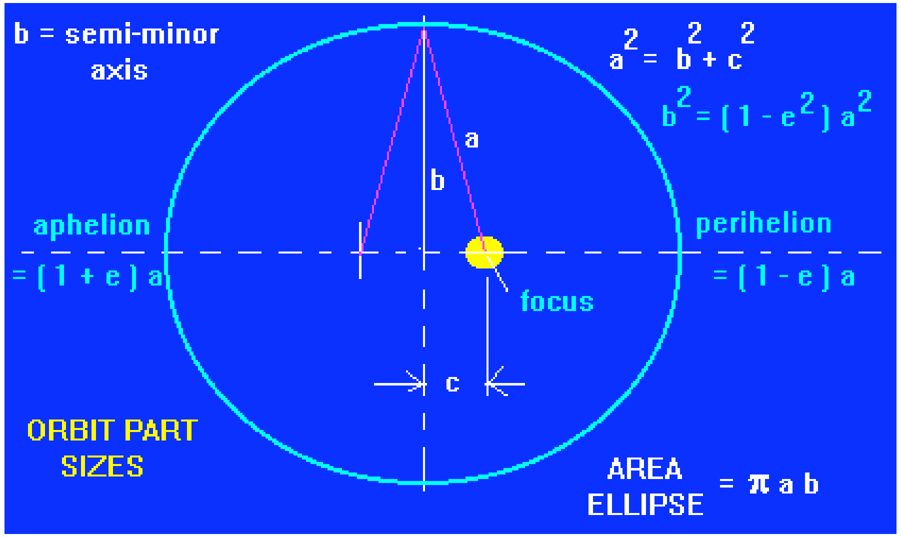
If we know r_1 and r_2 we can find the mass of the other star:

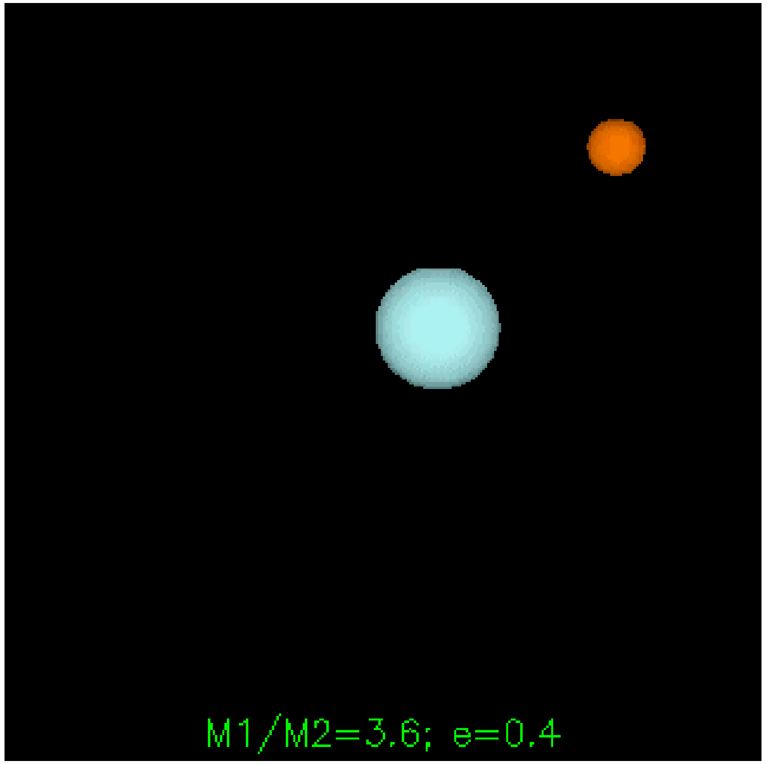
$$\frac{m_1 v_1^2}{r_1} = G\frac{m_1 m_2}{R^2} = \frac{m_2 v_2^2}{r_2}$$

Beware of the "inclination angle"!

Elliptical orbits of binary stars







(See Kutner for details.)

Physics note: Newton’s laws (including gravity) allow any orbit that is a “conic section”, i.e. circles, ellipses, parabolas, or even hyperbolas.

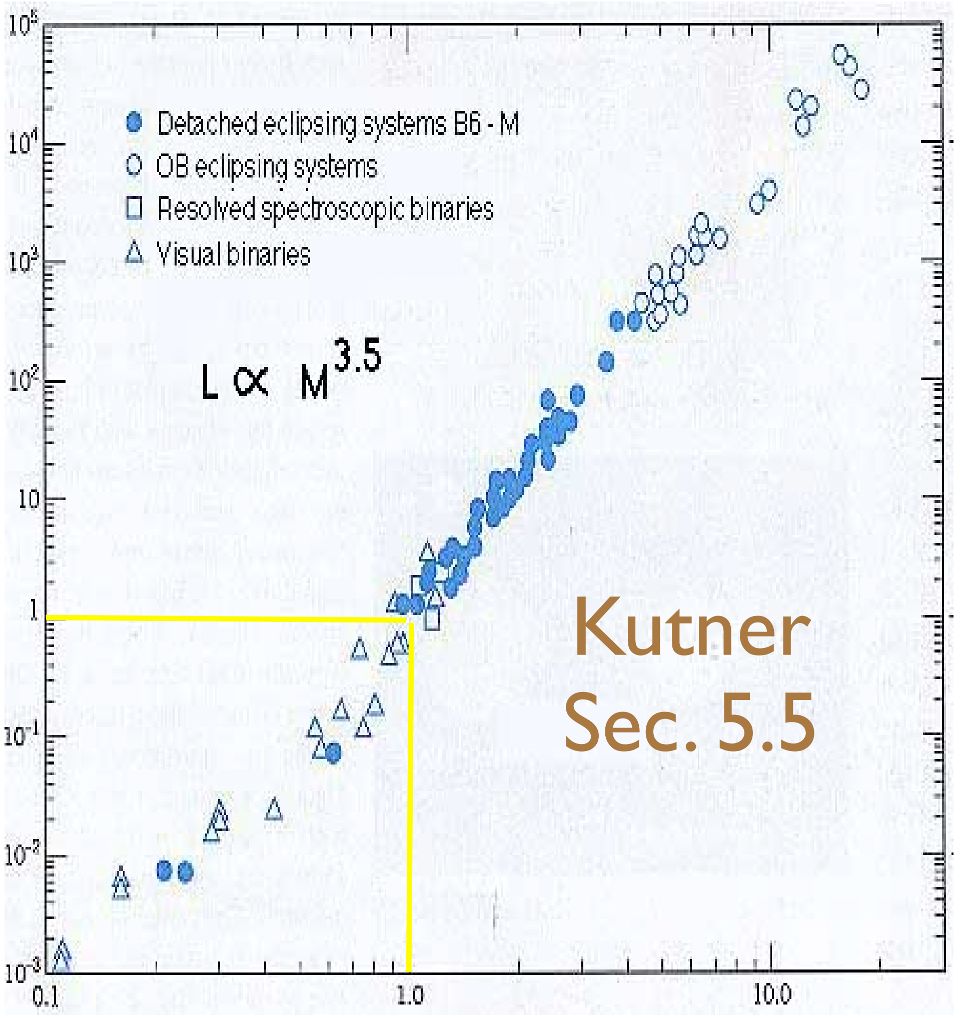
What we learn: The masses of stars

Solar masses of main sequence stars

O5	40.0
B5	7.1
A5	2.2
F5	1.4
G5	0.9
K5	0.7
M5	0.2

Kutner Tab.5.1

“Mass Luminosity Relation”

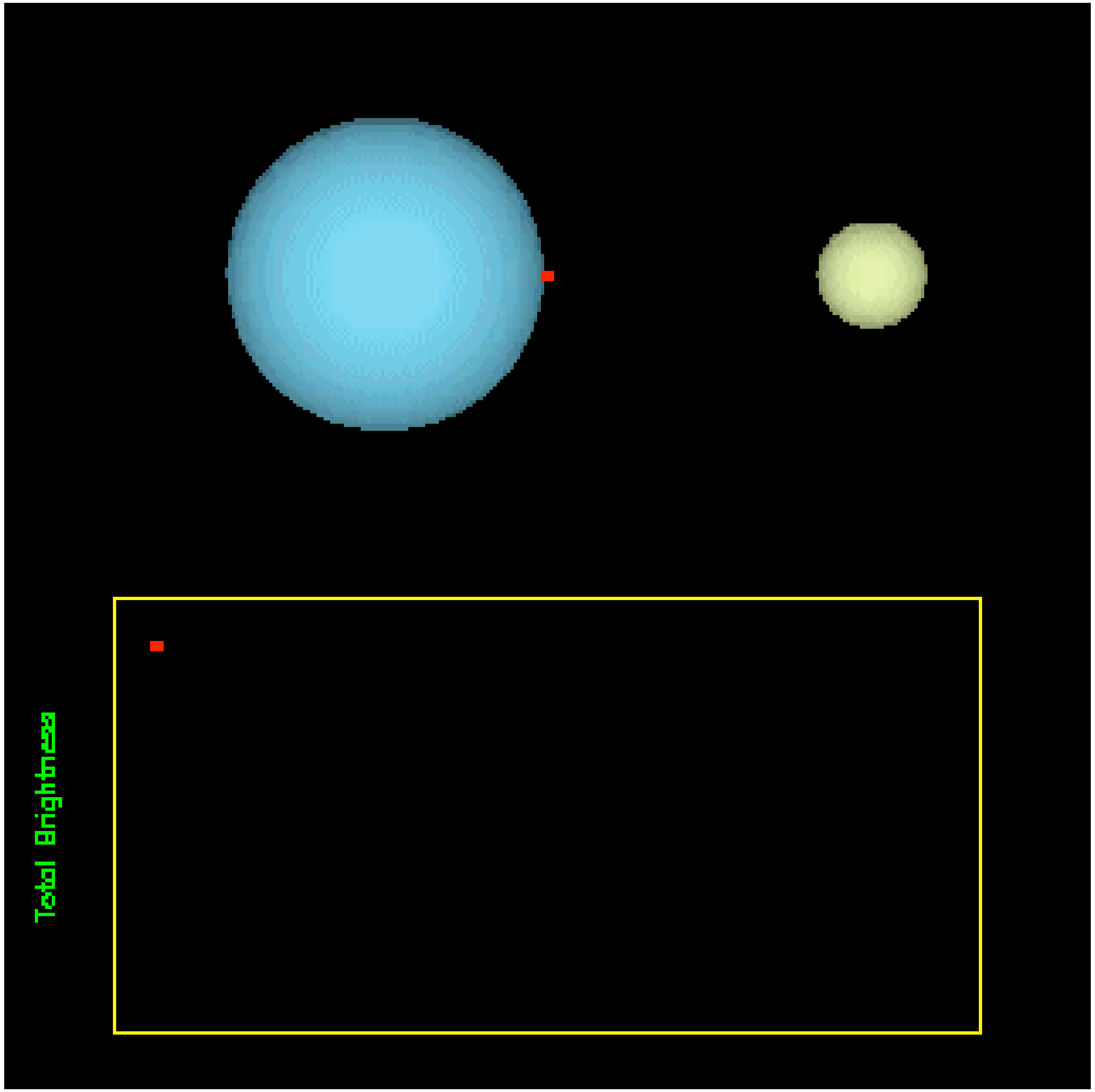


Kutner Sec. 5.5

Luminosity (in solar luminosity)

Mass (in solar masses)

Stellar Radii from Eclipsing Binary Stars



The "light curve" can be used to deduce the sizes of the stars if we know other parameters of the binary star orbit.