Binary Stars

Most stars come in pairs: *binary stars*

Sometimes we can measure their orbital period (P) and separation [semi-major axis] (a).

- Since they are held in orbit by gravity, they obey Kepler's 3rd law: $P^2 = [k]\, a^3$

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- But now the constant **k** is not equal to 1:

we need to use Newton's full version of Kepler's 3rd law:

$$P^2 = [\, 4\pi^2 / G(M_1+M_2) \,]\, a^3$$

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However, we can use a simpler version if we use units of solar masses $M_\odot$, years, and AU:

$$P^2 = a^3 / (M_1+M_2)$$

$$P^2 = a^3/(M_1+M_2)$$

Thus by measuring **<u>P</u>** and separation **<u>a</u>**, we can measure the masses of the stars!

But how do we get “a” ?

For some nearby binary stars, we can directly measure their orbits on the sky.

But for most binaries, the stars are too far away to measure the separation "a".

But we can use spectroscopy and the Doppler effect to measure the radial velocity.

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- As stars orbit, they move toward then away from us; hence a **Doppler shift**
- Motion of the spectral lines tells us period and velocities → we can estimate the stars' masses
- ***"radial velocity curve"*** is plot of *velocity* vs. time

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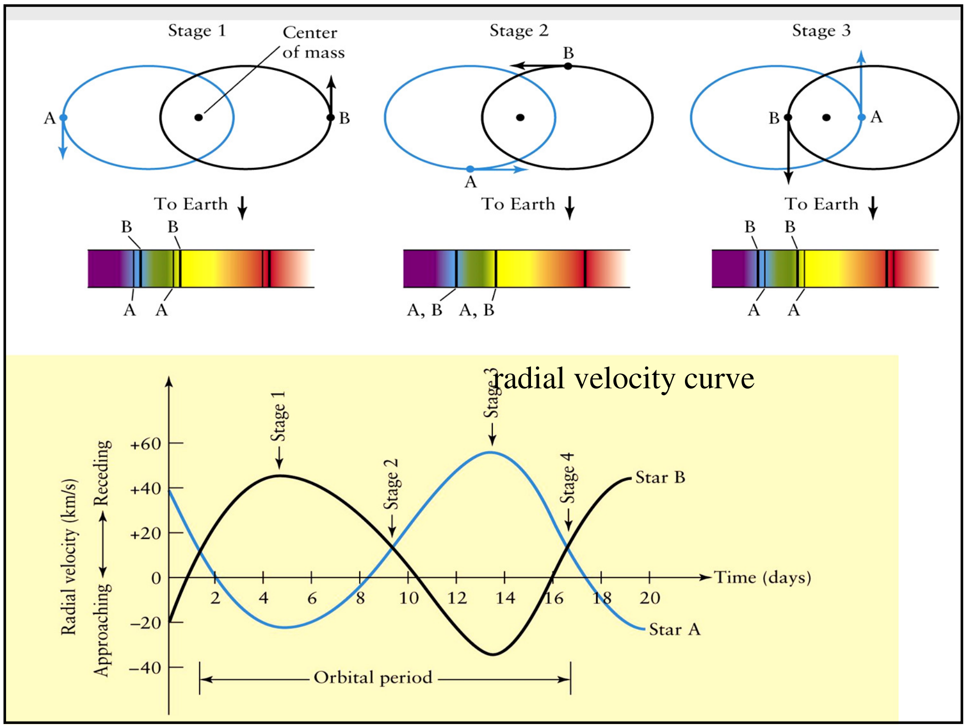
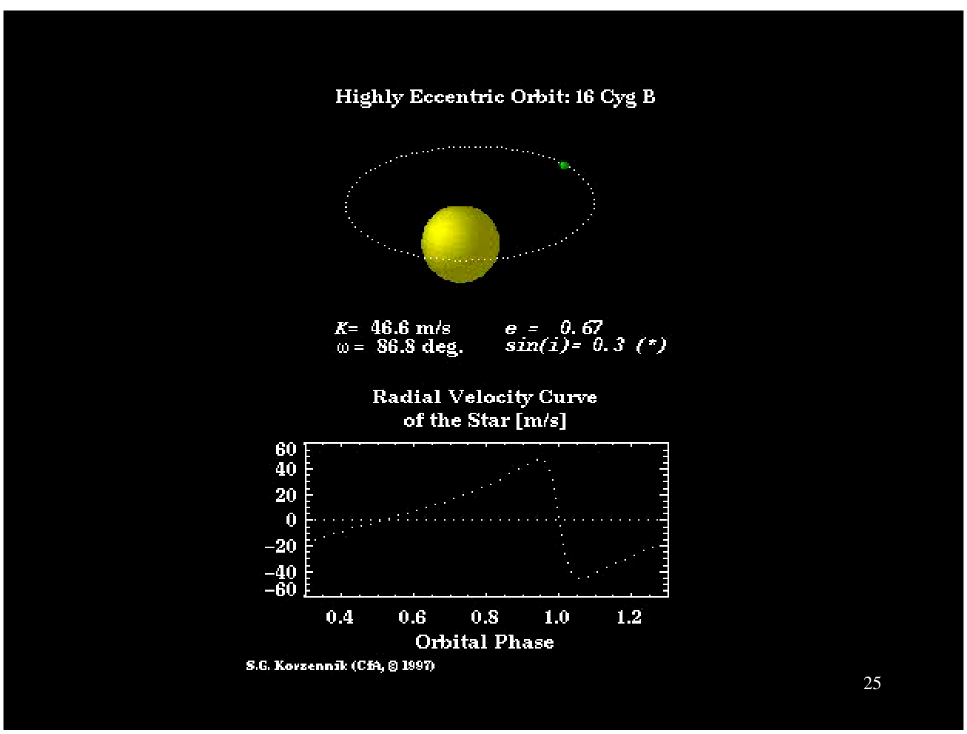


Stage 1
Center of mass
Stage 2
Stage 3
To Earth
radial velocity curve
Radial velocity (km/s)
Approaching
Receding
Star B
Star A
Time (days)
Orbital period



Highly Eccentric Orbit: 16 Cyg B
K= 46.6 m/s
e = 0.67
ω = 86.8 deg.
sin(i)= 0.3 (*)
Radial Velocity Curve of the Star [m/s]
Orbital Phase
S.G. Korzennik (CfA, © 1997)
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$P^2 = 4\pi^2 a^3 / G(M_1+M_2)$

Using the Doppler effect to measure the radial velocity allows us to get "a":

For a circular orbit, $v = 2 \pi a / P$

which can be rewritten $a = v P/2\pi$.

Hence Kepler's law then becomes:

$$(M_1+M_2) = v^3 P/ (2\pi G)$$

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A "***light curve***" is a plot of brightness vs. time

- If properly aligned (by chance), stars eclipse.
- Eclipses tell us the size of stars (radii):
  - in general, the wider and deeper the eclipse, the larger the star.

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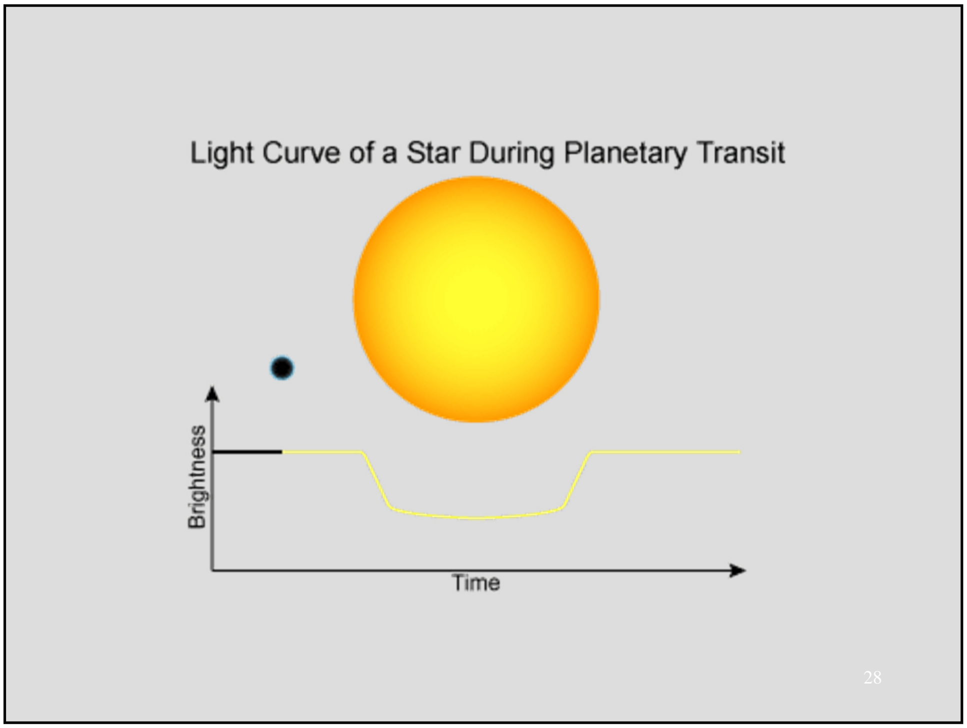
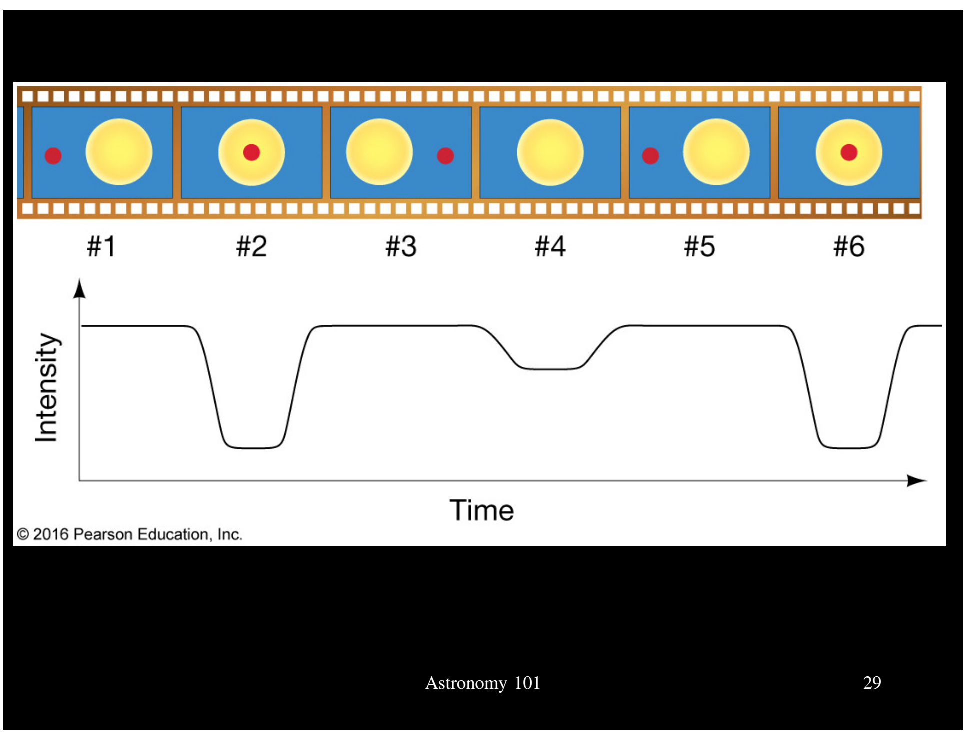

Light Curve of a Star During Planetary Transit
Brightness
Time
28


#1
#2
#3
#4
#5
#6
Intensity
Time
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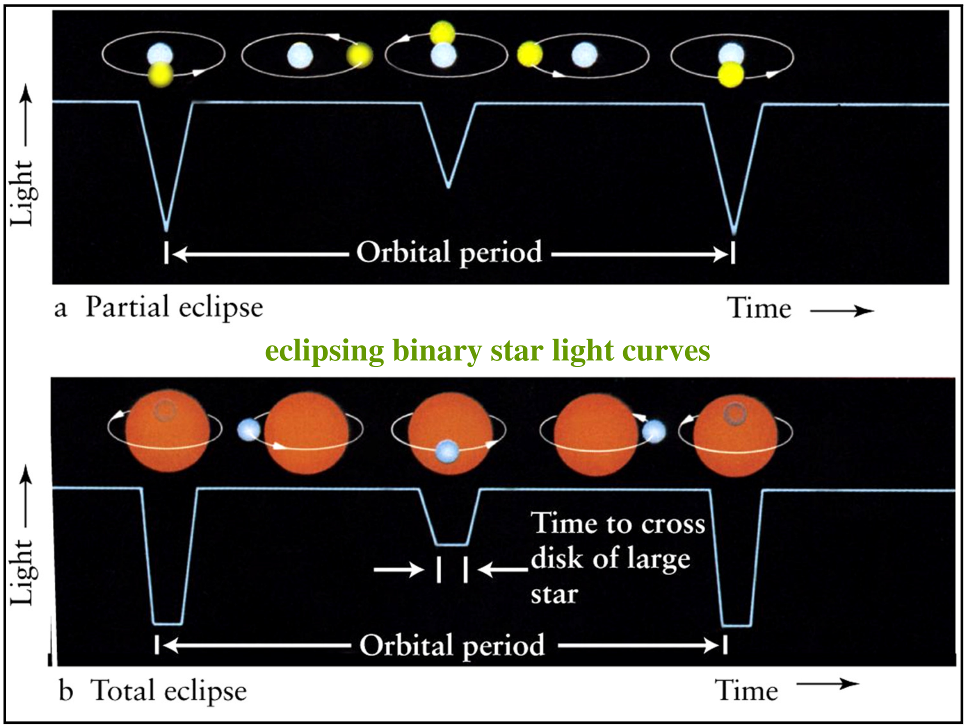

* Binary stars are important because they allow us to measure the masses and radii of stars.

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