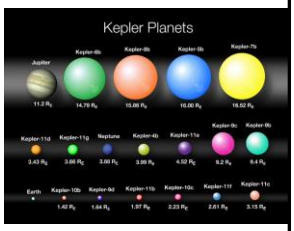
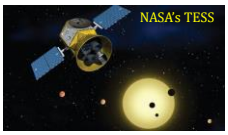
Today's Class: Exoplanets

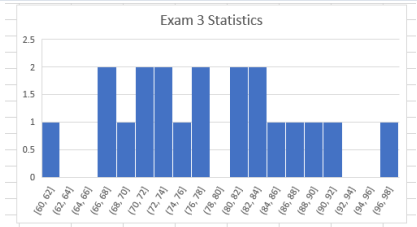
- Reading for *The Search for Life* in Chapter 24 of Cosmic Perspective.
- Complete FCQs by Wednesday!
- Final paper due on Dec. 7.





1

Exam #3 Results



# points	100.00
Std Deviation	9.74
Mean	76.51
Median	76.50
Average	77.13636

2

Today's Class

- Exoplanet detection
  - Doppler shift
  - Transits
- What properties can we measure?
  - Mass
  - Size
  - Density
  - Atmosphere composition

3

Preparing for Interstellar Travel: Telescopic Observations of Exoplanets

4

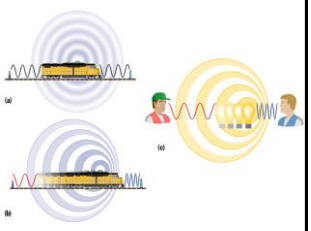
Planet Detection

- **Direct:** pictures or spectra of the planets themselves
- **Indirect:** measurements of stellar properties revealing the effects of orbiting planets
- Major Challenge: A Sun-like star is 10^9 brighter than reflected light from planets!

5

Measuring velocities with the Doppler Shift

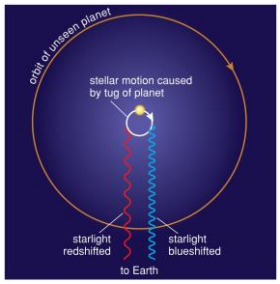
- Familiar shift in pitch of SOUND: higher when approaching, lower when receding
- Similar shift in frequency of light: higher (blueshift) when approaching, lower (redshift) when receding: $\frac{V}{c} = \frac{\Delta\lambda}{\lambda}$, where V = radial velocity, c = light speed, λ = wavelength, Δλ = shift in wavelength.



Doppler video

6

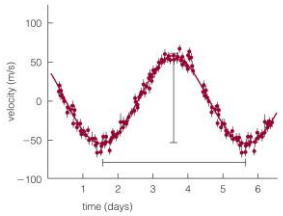
Doppler Technique for Exoplanet Detection



- Measuring a star's Doppler shift can tell us its motion toward and away from us.
- Current techniques can measure motions as small as 1 m/s (walking speed!).

7

First Extrasolar Planet



a A periodic Doppler shift in the spectrum of the star 51 Pegasi shows the presence of a large planet with an orbital period of about 4 days. Dots are actual data points; bars through dots represent measurement uncertainty.

- Doppler shifts of the star 51 Pegasi indirectly revealed a planet with 4-day orbital period.
- This short period means that the planet has a small orbital distance.
- This was the first extrasolar planet to be discovered around a Sun-like star (1995).

8

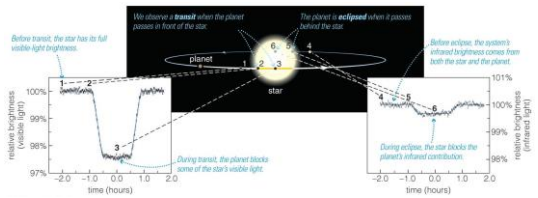
First Extrasolar Planet

b Artist's conception of the planet orbiting 51 Pegasi, which probably has a mass similar to that of Jupiter but orbits its star at only about one-eighth of Mercury's orbital distance from the Sun. It probably has a surface temperature above 1000 K, making it an example of what we call a hot Jupiter.

- The planet around 51 Pegasi has a mass similar to Jupiter's, despite its small orbital radius around the star.

9

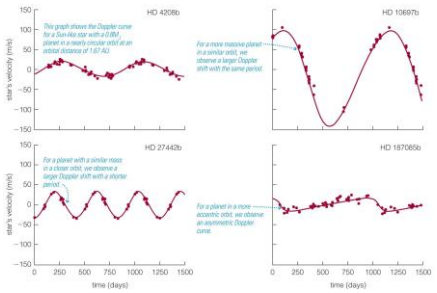
Transits and Eclipses (Kepler)



- A **transit** is when a planet crosses in front of a star.
- The resulting eclipse reduces the star's apparent brightness and tells us planet's radius.
- No orbital tilt: accurate measurement of planet mass.
- **Results from Kepler:** 2662 exoplanets confirmed. Several are rocky & in habitable zone.

10

What can Doppler shifts tell us?



- Doppler shift data tell us about a planet's mass and the shape of its orbit.

11

Class Exercise

Suppose you found a star with the same mass as the Sun moving back and forth with a period of 16 months. What could you conclude? (1 AU = distance between Earth & Sun, astronomical unit)

a) It has a planet orbiting at less than 1 AU.
b) It has a planet orbiting at greater than 1 AU.
c) It has a planet orbiting at exactly 1 AU.
d) It has a planet, but we do not have enough information to know its orbital distance.

12

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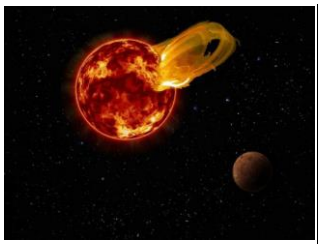
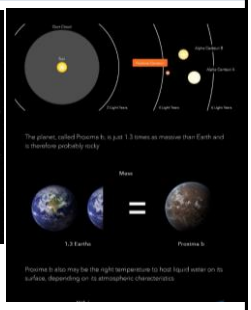
13

Proxima b

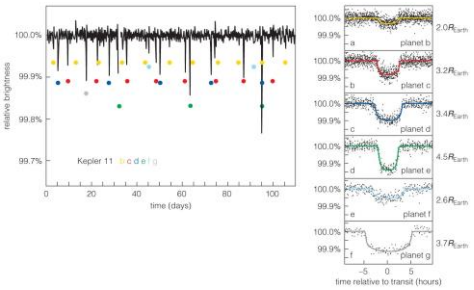


Artist's illustration of a powerful flare erupting from the red dwarf star Proxima Centauri.



14

The Kepler 11 system

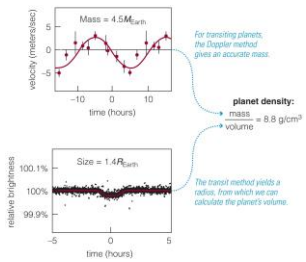


- The periods and sizes of Kepler 11's 6 known planets can be determined using transit data.

15

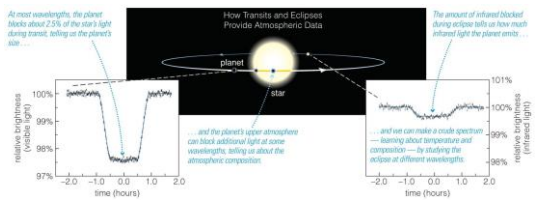
Calculating density

- Using mass, determined from the Doppler technique, and size, determined using the transit technique, density can be calculated.



16

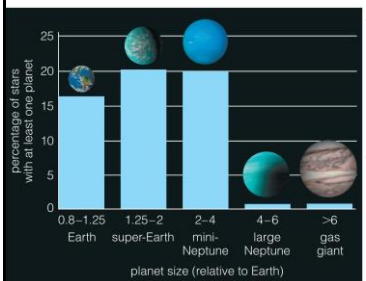
Spectrum During Transit



- Change in spectrum during a transit tells us about the composition of planet's atmosphere.

17

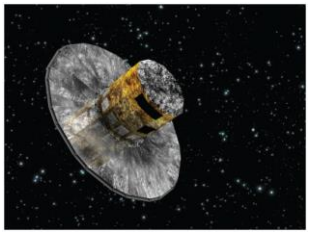
Orbits of Extrasolar Planets



- Most of the planets detected by *Kepler* have lower mass than Jupiter.
- These percentages will certainly go up as we get better at discovering planets with longer periods.

18

ESA's *GAIA* mission



- *GAIA* is a European mission that measures precise motions of a billion stars. Exoplanets will be uncovered by monitoring tiny changes in a star's position and motion caused by the gravitational pull of one or more planets around it, and by looking for dips in the stellar light caused by a planet transiting in front of its parent star.

21