Planets

Monday, November 30

Wed, Dec 2: Life
Problem Set #8 due

Fri, Dec 4: Past, Present, & Future
Problem Set #8 returned (I hope).

Tue, Dec 8, 9:30 am
Final Exam
Comprehensive
Same format as midterm

What is a planet?

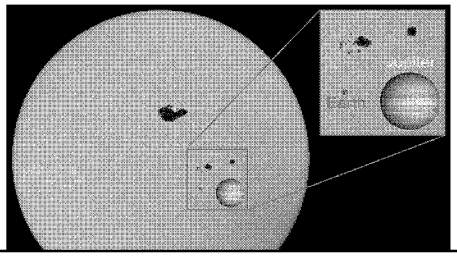
A ball of gas, liquid, and/or solid,

orbiting a star,

whose size is neither too big
nor too small for a planet.

Planets are smaller than stars.

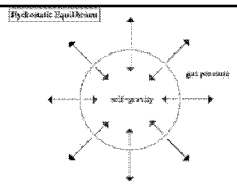
Within the Solar System,
the mass of the Sun is
1000 × the mass of Jupiter.



How small can a ball of gas be and still qualify as a **star**?

A star has **nuclear fusion** occurring in its interior.

Fusion of hydrogen to helium requires T > 10 million Kelvin.

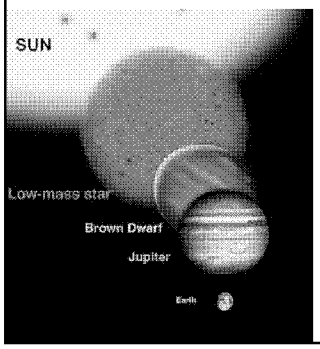


A star is in **hydrostatic equilibrium**.

The **smaller** a ball of gas, the **lower** the pressure & temperature needed for hydrostatic equilibrium.

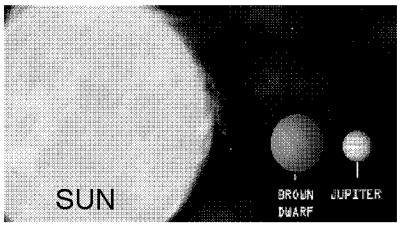
If star's mass < 0.08 Sun's mass, central temperature < 10 million K.

A ball of gas with less than 8% of the Sun's mass is **not** a star.



It is what astronomers call a **brown dwarf**.

Brown dwarf = "failed star".
Like a star, it's a ball of gas.
Like a star, it radiates light.
Unlike a star, it doesn't have a fusion "engine", so it cools down.



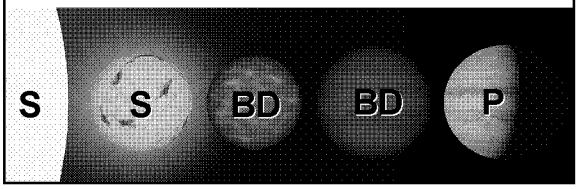
How does a planet differ from a brown dwarf?

Planets are not completely gaseous.

Planets are differentiated (layers of different chemical composition).

Planets are lower in mass.

Object	Mass
star	> 80 Jupiters
brown dwarf	13 to 80 Jupiters
planet	< 13 Jupiters



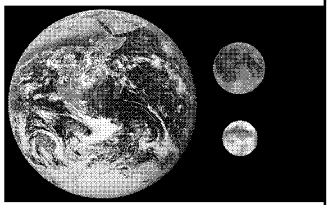
Upper limit on a planet's mass is 13 Jupiters.
What's a sensible **lower limit** for a planet's mass?

The Sun is orbited by lots of small junk: asteroids, comets, dust grains, etc…

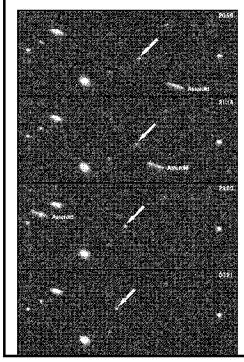
Where do we draw the line?

For decades, Pluto was called the "9th planet"… but a very unusual planet.

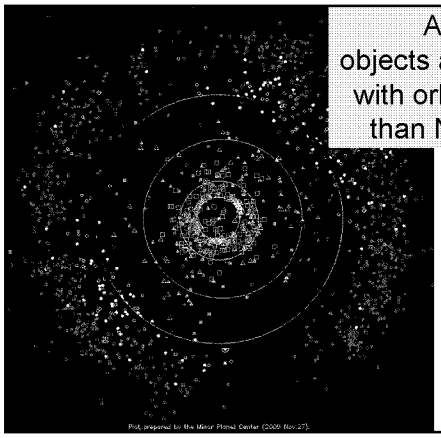
High orbital eccentricity.
Large orbital tilt (inclination).
Very small!



Around 1990, searches began for more objects in the region beyond Neptune.

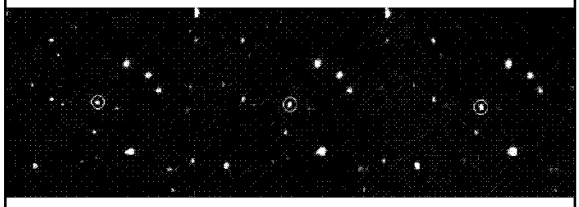


Technique: look for faint objects that move at the appropriate rate.



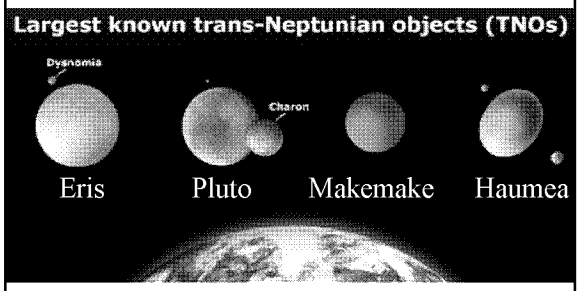
About 1100 objects are known with orbits bigger than Neptune's.

Largest "trans-Neptunian" object yet known: discovered in 2005.



Given the name **Eris**.

Eris is slightly larger than Pluto.



If Pluto is a planet, then Eris is too.

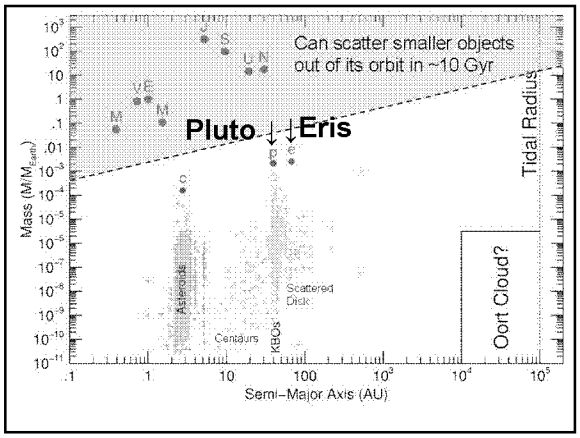
Are Pluto and Eris planets?

International Astronomical Union definition of "planet":

1) Orbits the Sun (or other star)

2) Is big enough to be spherical

3) Has cleared its orbit of smaller objects.



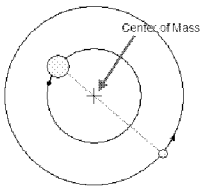
It's useful to place Eris, Pluto, Makemake, & Haumea in a new category: "**dwarf planets**"

Orbiting the Sun, roughly spherical, but not massive enough to dominate their neighbors.

Until fairly recently, nothing was known about "**exoplanets**" (planets around stars other than the Sun).

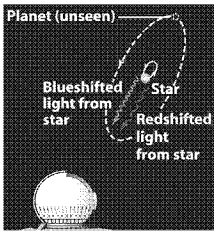
Now, it's a hot topic of research.

Planets can be detected from the **Doppler shift** of their parent star.



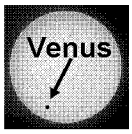
Jupiter & the Sun each orbit the center of mass of the Sun – Jupiter system.

Sun's orbital speed = 0.001 × Jupiter's orbital speed = 12.5 meters/sec.



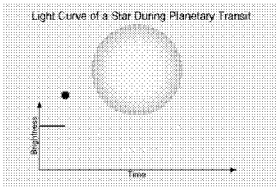
Look for variations in the **Doppler shift** of the Sun's light!

Planets can be detected when they eclipse (or **transit**) their parent star.



During a **transit of Venus** across the Sun, the Sun's flux dips slightly.

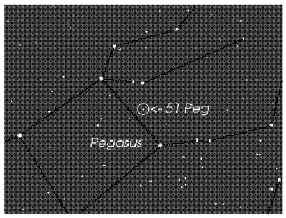
When a distant star is transited by one of its planets, its brightness drops slightly.



Time between transits tells us planet's orbital period.

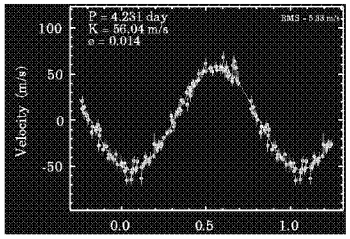
Amount of dimming tells us size of planet.

The first exoplanet discovery was in 1995.



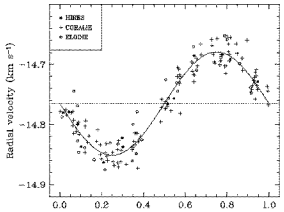
Found by radial velocity method, orbiting 51 Pegasi, a Sun-like star.

Radial velocity "wobble" of 51 Pegasi.



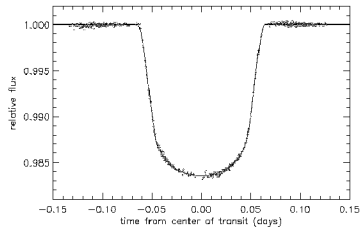
Planet mass ≥ ½ Jupiter
P = 4.2 days
a = 0.05 AU

A star with a well-studied exoplanet: HD 209458



After the star was found to have variations in its Doppler shift, it was found to have dips in brightness.

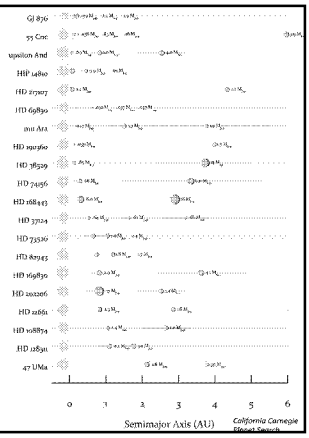
Transit of HD 209458 by its planet:



Mass of planet = 0.69 × Jupiter
Radius = 1.35 × Jupiter
Density = 1/3 that of water

Over 400 planets have been found around stars other than the Sun.

including multiple planet systems →



Wednesday's Lecture:

Life

Reading:

Chapters 13 & 14