Planetary Overview

Courtesy: NASA

Inventory

- 1 Sun, containing 99.9% of mass
- 8 planets; 5 dwarf planets, and counting
- 15 moons over 1000 km in diameter
  - many smaller moons
- ~100,000 asteroids
- probably billions of Kuiper belt objects, scattered disc objects and Oort cloud objects
  - including billions of potential comets
- billions of meteorites, meteoroids and debris
- solar wind
- magnetic field

Bode's Law of Planetary Distances

- Empirical relationship (discovered by Titius!), with no basis yet in theory
- If a is the average distance of a planet to the Sun, then:

$$a = \frac{3n+4}{10}\,\text{AU} \quad , \; n = 0, 1, 2, 4, 8, 16, 32$$

$n = 0$ *for Mercury*

$n = 1$ *for Venus*

$n = 2$ *for Earth*

$n = 4$ *for Mars*

$n = 8$ *for?* – Ceres (1801)

$n = 16$ *for Jupiter*

$n = 32$ *for Saturn*

$n = 64$ *for?* – Uranus (1784)

How the Planets fit Bode's Law

- After K & K chapter 7 table

n	Bode's Law Prediction	Today's Measured Distance (AU)	Object
0	0.4	0.39	Mercury
1	0.7	0.72	Venus
2	1	1	Earth
4	1.6	1.52	Mars
8	2.8	2.8	Ceres
16	5.2	5.2	Jupiter
32	10	9.54	Saturn
64	19.6	19.19	Uranus
		30.06	Neptune
128	38.8	39.4	Pluto

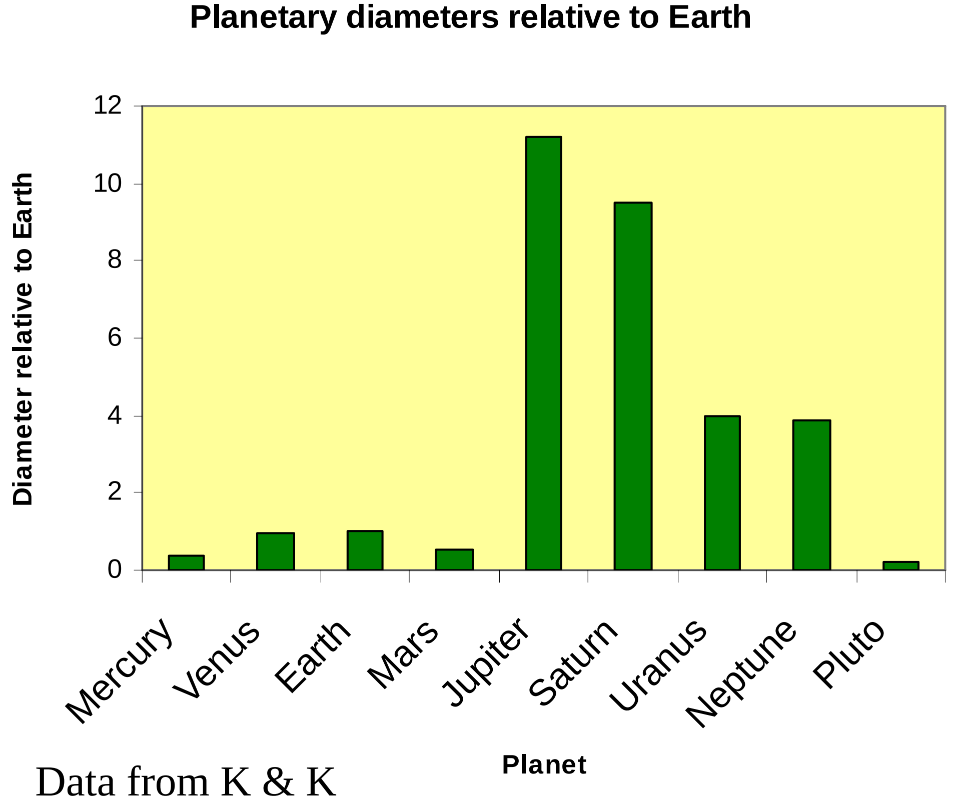
Masses and Densities

- Masses of all planets with moons are obtained through Kepler's 3rd Law
- Densities are calculated from ratio

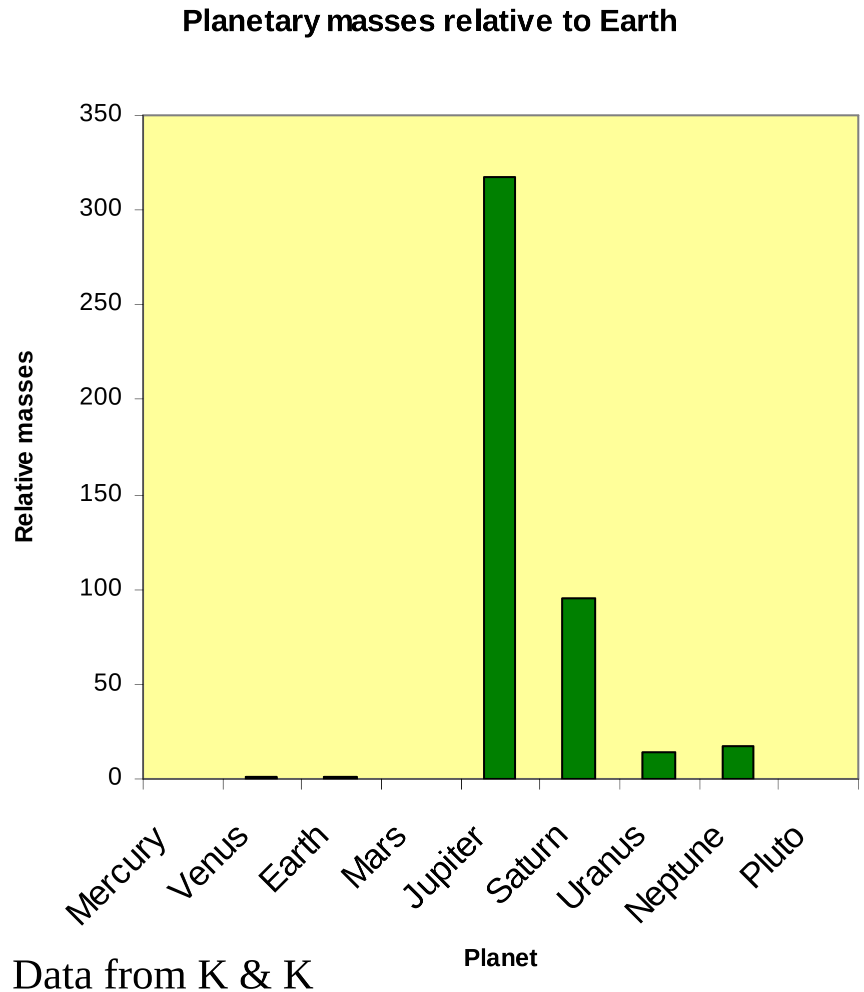
$$density\ (kg\ m^{-3}) = \frac{mass(kg)}{volume(m^3)}$$

- **Terrestrial** planets are mainly rocky matter, with a molten core
- **Jovian** planets are mainly gas and liquid, with a rock core

Diameters & Masses

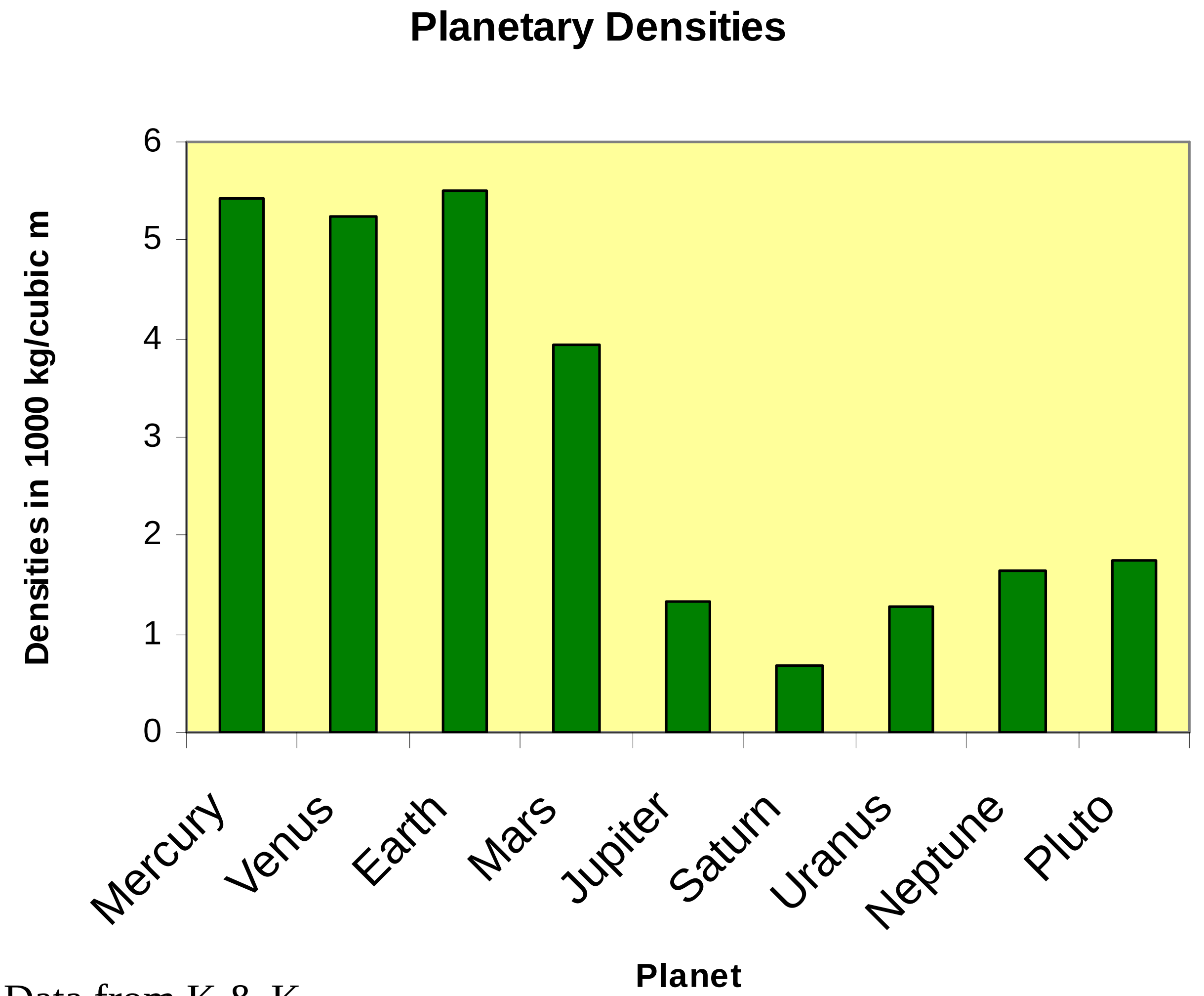


Data from K & K



Data from K & K

Planetary Densities



Data from K & K

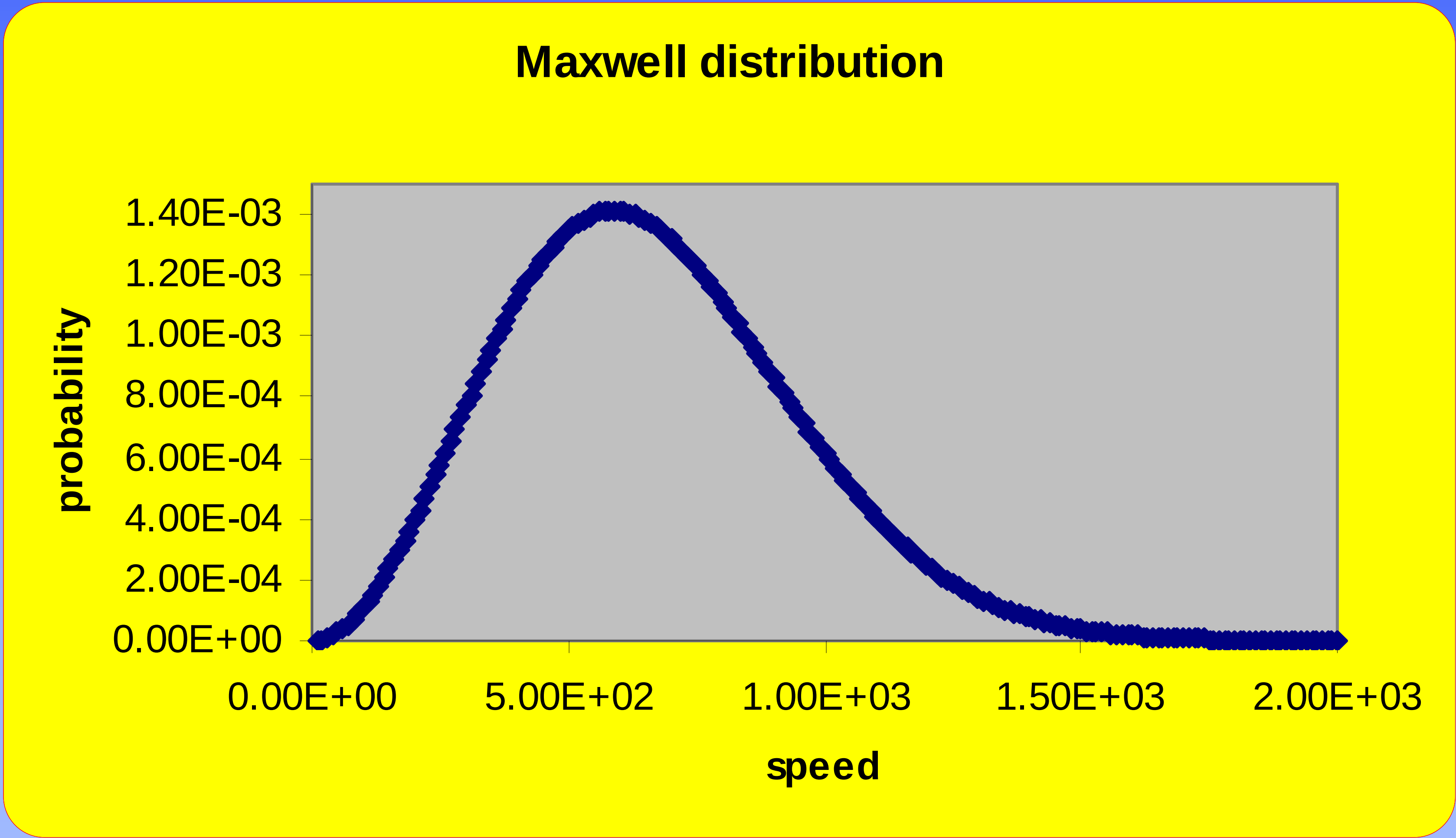
Orbits and Satellites

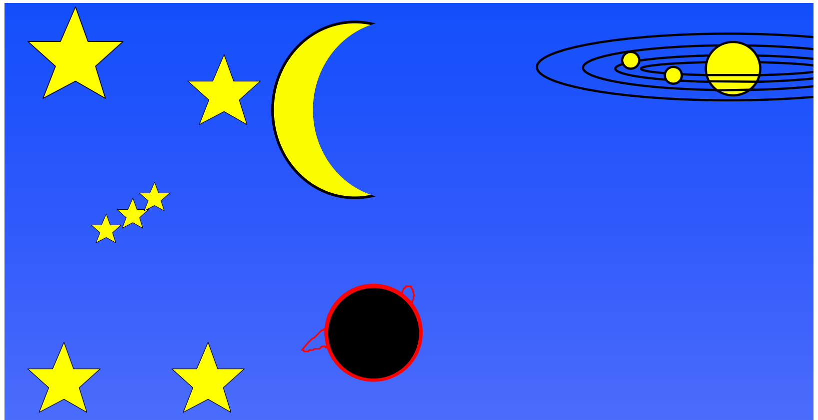
- Rotation is generally in the same direction:
  - rotation of Sun (equator rotates faster than polar regions)
  - rotation of planets about their axes (except Venus, Uranus and Pluto)
  - orbits of planets about Sun
  - orbits of moons about planets
    - >100 named moons
- Most orbits nearly circular and in same plane
- All Jovian planets have ring systems

Atmospheres

- Average energy ($\frac{1}{2}mv^2$) of molecules $\propto$ temp
  - lighter molecules therefore move faster
- In a gas there is a wide range of molecular speeds, called the Maxwell distribution $\rightarrow$ [next slide]
  - a significant number of molecules travel at more than 10 times the average speed
  - if they reach the escape velocity without colliding any more, they will escape
- The Earth has lost its primitive H_2 and He

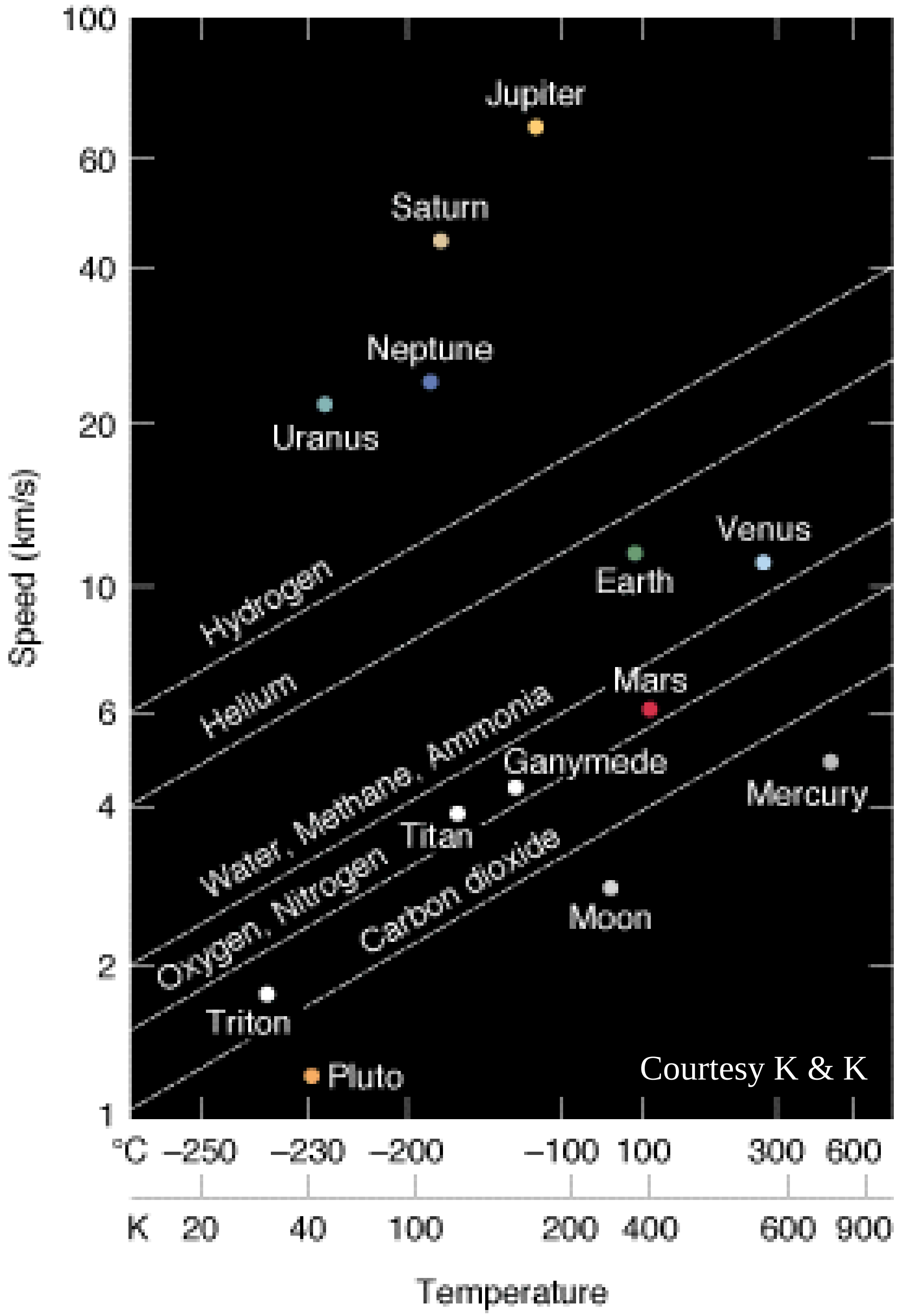
Maxwell Distribution





How Molecular Speeds Depend on Temperature

Each planet is plotted at its atmospheric temperature and escape velocity



Features of the Solar System

- system nearly planar
- angular momentum mostly in outer regions
- spacing of planets increases with distance from Sun
- chemical composition of planets
- cratering everywhere
- ring systems on Jovian planets
- presence of asteroids, comets & meteorites

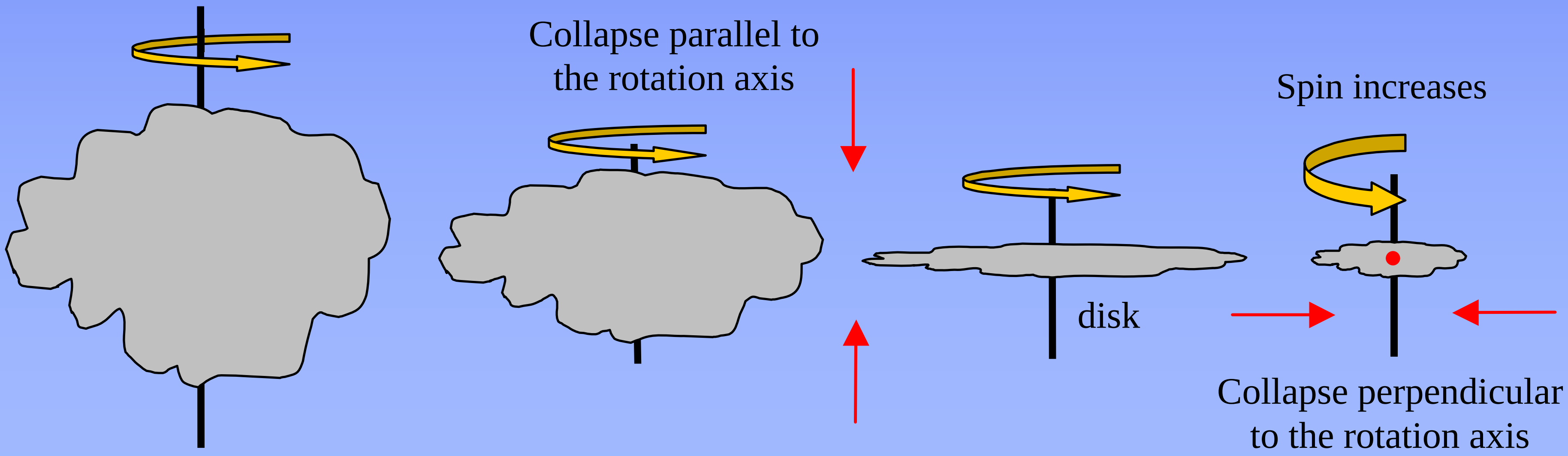
Planetary systems likely to be common around other single stars – prediction prior to planet discoveries

Formation of Solar System

- **Catastrophe** theories consider the Solar system pulled out from a star
  - the physics and chemistry of catastrophe theories cannot be made to produce the observed features
- **Evolutionary** theories describe formation from an initial large cloud of rotating gas
  - gravitational attraction along with conservation of angular momentum gives the condensing cloud a disk shape

Collapse of a rotating gas cloud

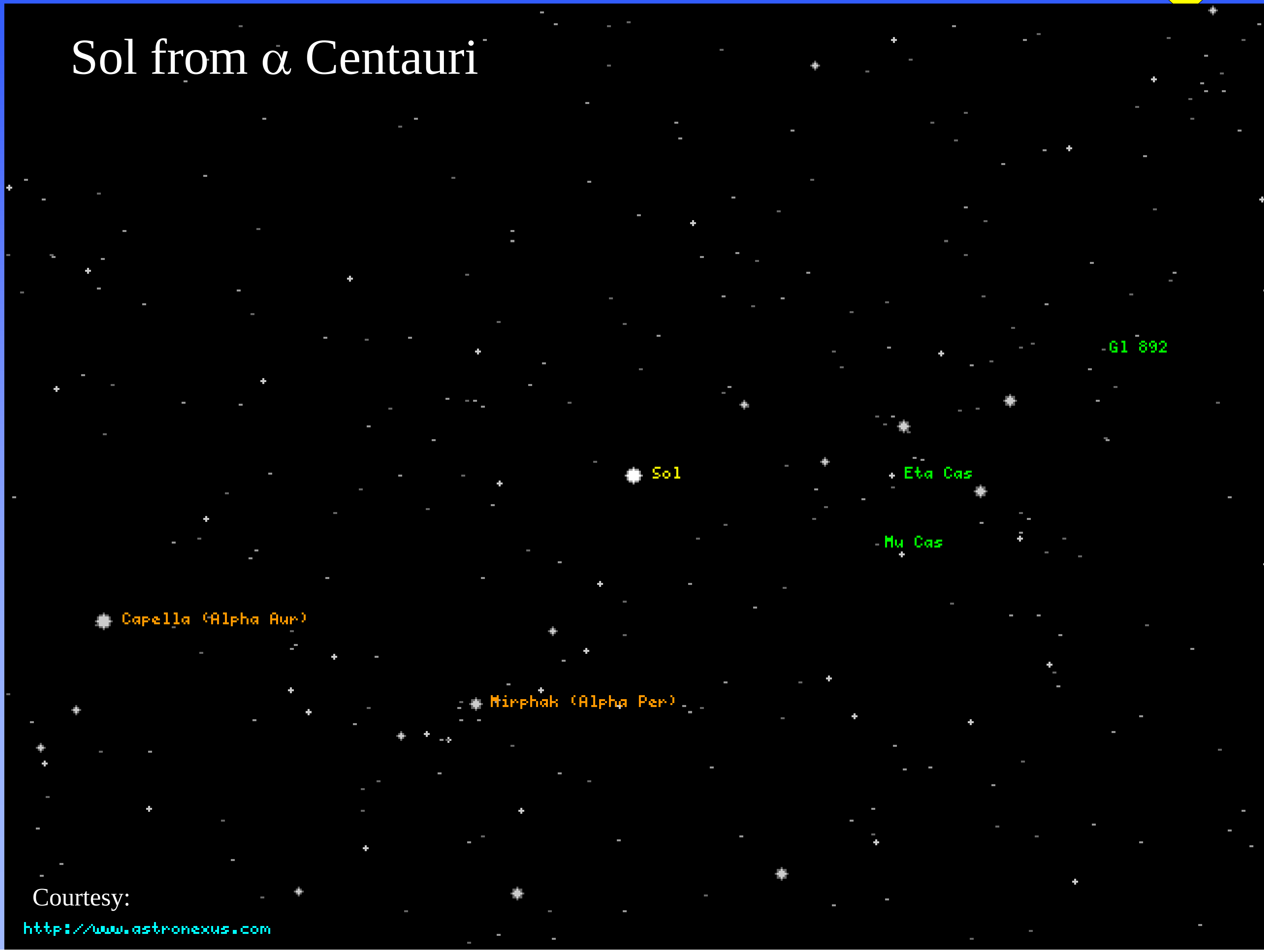
- Collapse parallel to the rotation axis does not re-distribute angular momentum
- Collapse perpendicular to the rotation axis causes the cloud to spin faster



Modern Evolutionary Theory

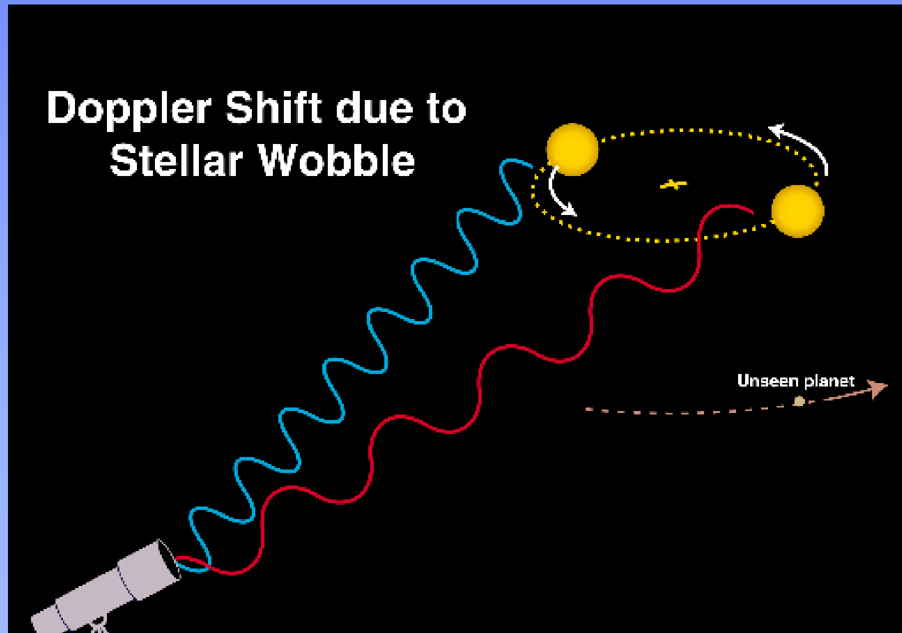
- von Weizäcker's analysis of a rotating gas condensing around a *protosun* showed that the gas would form eddies, with larger eddies further from the centre
- *Planetessimals* slowly formed by collision
  - asteroids are remnant planetesimals that failed to join together due to the stirring influence of Jupiter
- The expected fast rotation of the Sun was slowed by the influence of its magnetic field on the ionised gas it created

Planets around stars



Extrasolar Planet Search

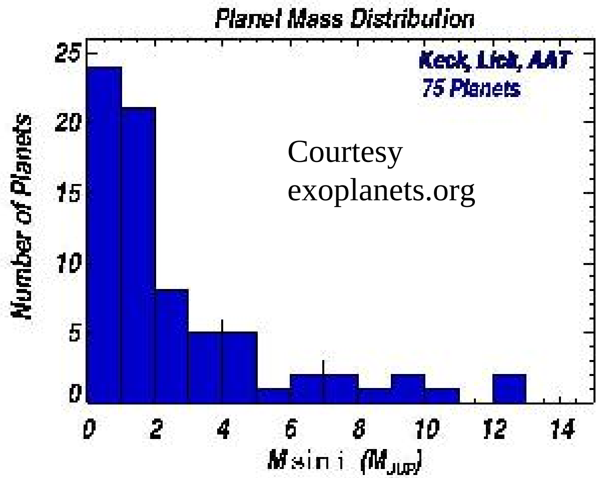
- Some 300 stars now have confirmed planets
- All candidates within ~100 LY of Earth have been examined
- Most common technique is to detect very small Doppler shifts of spectral lines from parent stars

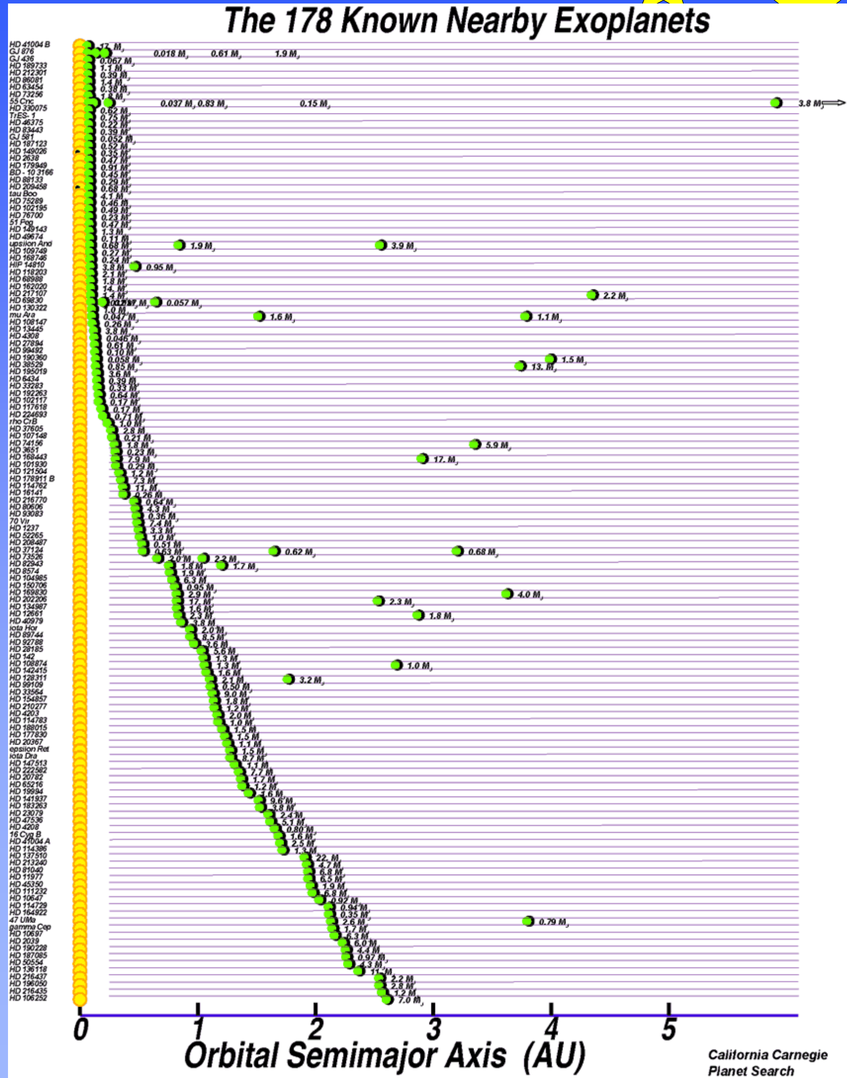


Courtesy G. Marcy

Extrasolar Planet Properties

- Most planets detected are
  - close to their stars
  - have masses like Jupiter
  - are in eccentric orbits

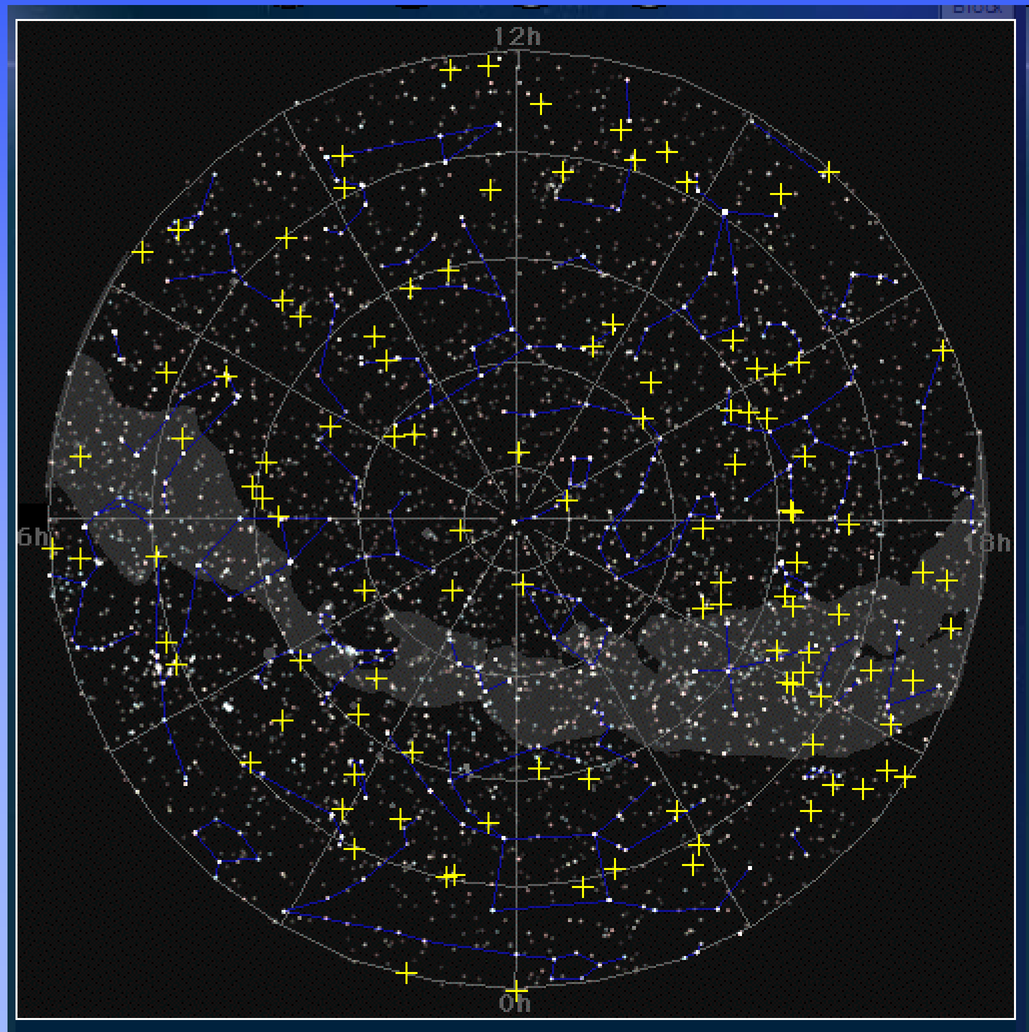




Courtesy: http://exoplanets.org/massradiiframe.html

Where are they?

- Everywhere!
- N celestial hemisphere →
- For 3D skymap
  - http://media4.obspm.fr/exoplanets/base/carte3d.php



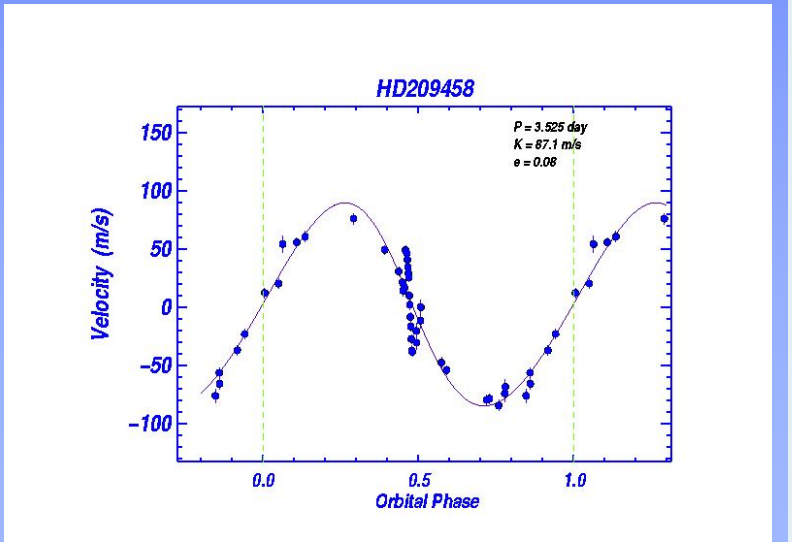
Courtesy: http://media4.obspm.fr/exoplanets/base/carte.php

A Shift in Expectations

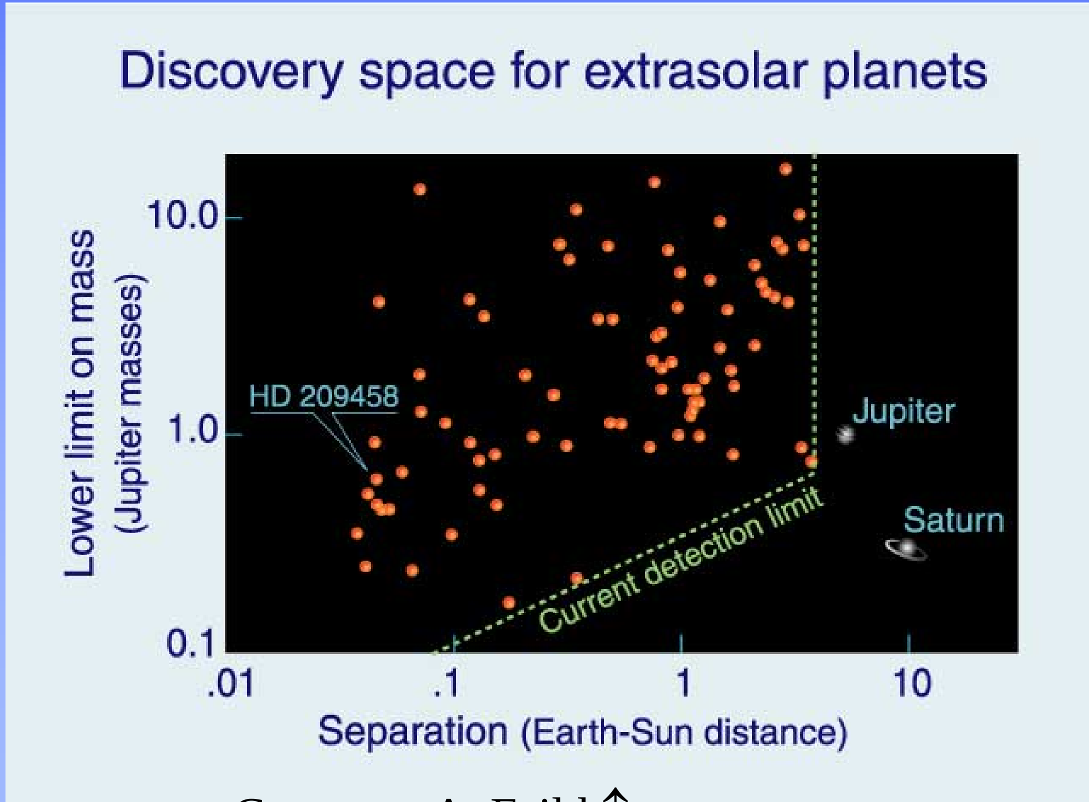
- Large planets provide the biggest wobble of their parent stars
  - the closest large planet in the solar system (Jupiter) orbits in ~12 years
  - looking for changes in stars over times as long as this requires patience and instrument stability
- The new perception is the discovery that large planets that circle their parent in only a few days exist around some stars
  - planetary systems like these are unlike the solar system

Example of HD209458

- HD209458 is a Sun-like star 150 LY distant in the constellation of Pegasus
  - it has a planet $0.7M_{Jup}$ orbiting in 3.5 days



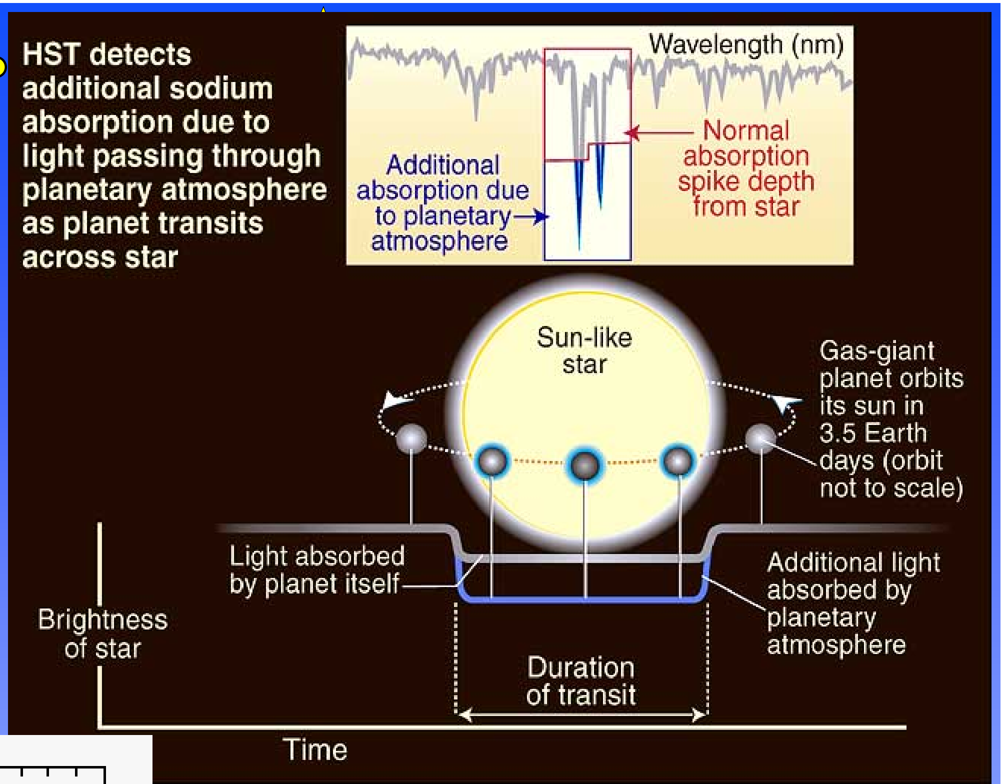
Courtesy: Geoff Marcy ↑



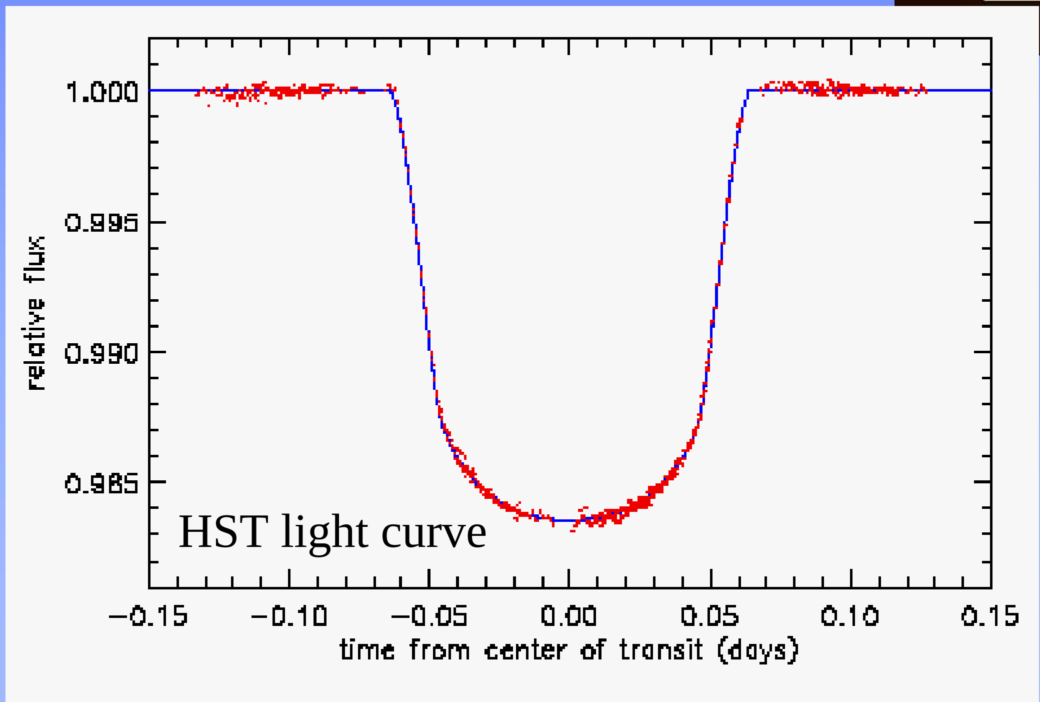
Courtesy: A. Feild ↑

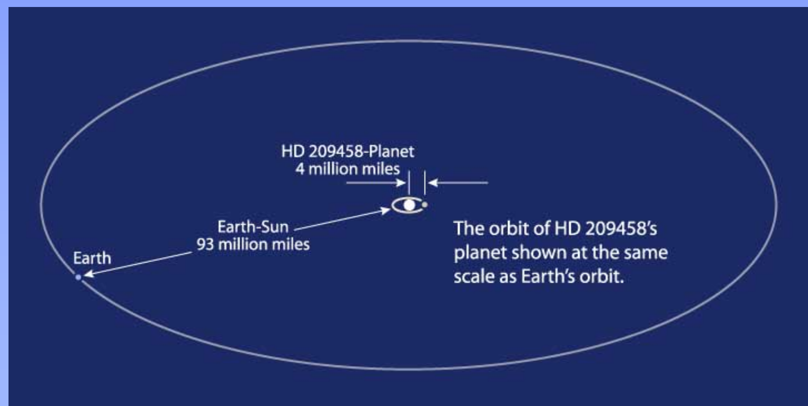
Transit of HD209458

- The planet transits the star, affecting the light received
- The planet is bigger than Jupiter



Courtesy: A. Feild ↑

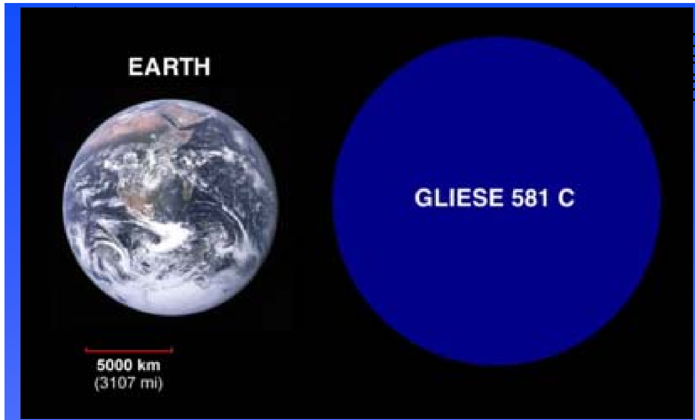




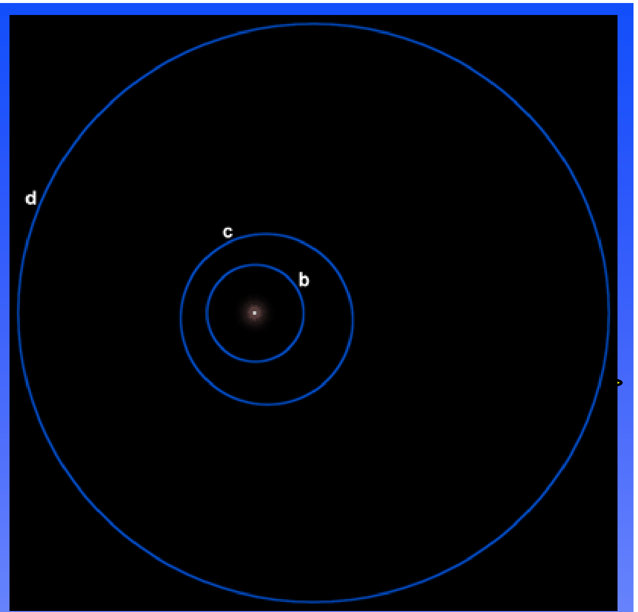
Courtesy: Z. Levay ↑

Looking for Earth-like Planets

- Giant planets close in to their parent stars will have temperatures of over 1000ºC facing the star
- Detecting Earth-like planets will not be easy
  - 47 UMa has at least 2 giant planets in circular orbit at a distance of several AU
  - a new era in astronomy has dawned
  - new instruments, including giant mirrors and custom designed space probes
  - new techniques such as looking for the dip in light as a planet transits its parent star

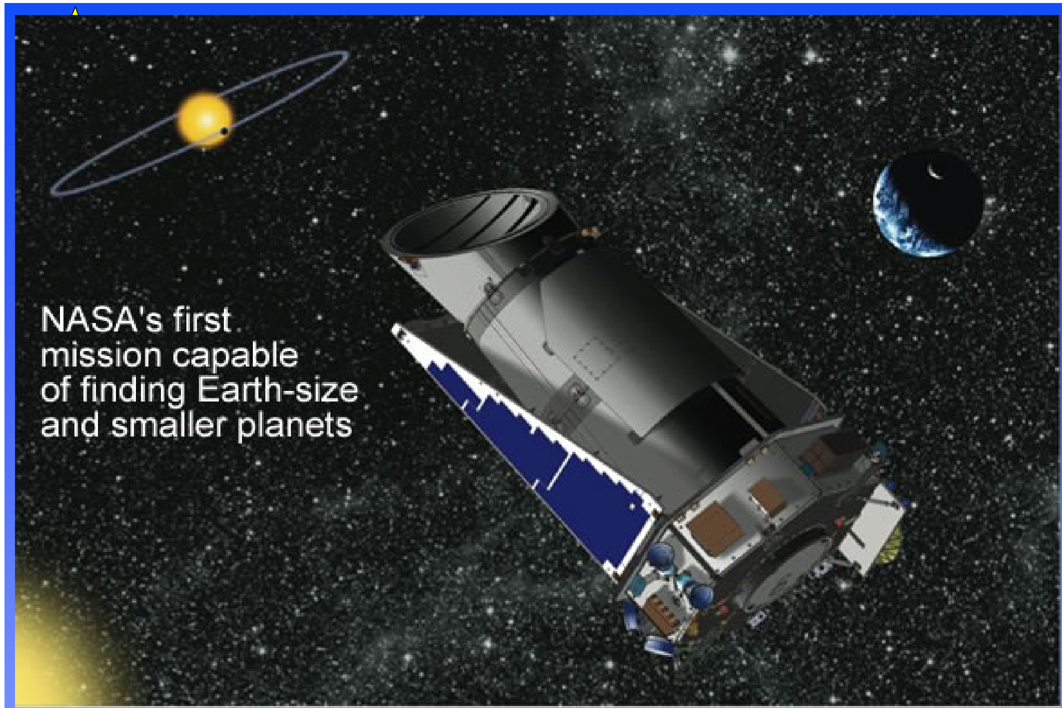


Gliese 581



- Nearby star: 20 LY distance
- Red dwarf star; m = 10.5; T ~ 3500 K; ~1% output of Sun; mass ~0.3$M_\odot$
- 3 planets discovered by wobble technique
- Outer 2 (Gliese 581 c & Gliese 581 d) discovered in 2007 at either edge of habitable zone; both larger than Earth
- May be most Earth-like planets found; may be more like large Venus and large Mars, too hot and too cold

Kepler Mission



- Mission to look for Earth-like planets using the transit dimming technique
- Monitoring light emission from 100,000+ stars to a precision of 20 ppm in a fixed area of sky for 4 – 6 years
- Launch Feb 2009 into Earth-trailing heliocentric orbit