Lecture 36

Strange New Worlds:

The Properties of Exoplanets

Astronomy 141 – Winter 2012

This lecture describes the properties of the exoplanets discovered thus far

760 planets known to date, most discovered by the Radial Velocity and Transit methods.

"Hot Jupiters" – giant gas planets very close to their parent stars – are a big surprise.

Many of the planets are on very eccentric (elliptical) orbits, unlike in our Solar System

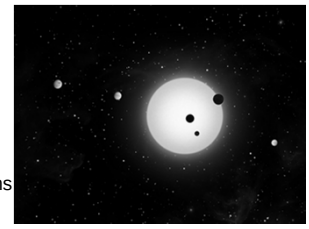
Planetary Migration is a way to explain how gas giants can be so close to their stars and on eccentric orbits.

Current techniques are mostly biased against finding systems like our own, but that is starting to change.

As of 2012 Feb 14, we have found 760 planets around 609 stars by various methods

469 by the RV method
230 by the transit method
31 by direct imaging
14 by microlensing
16 by pulsar timing

100 are multi-planet systems

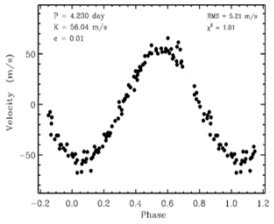


Kepler 11: 6 planets, G6 star

Only a handful so far look anything like our Solar System…

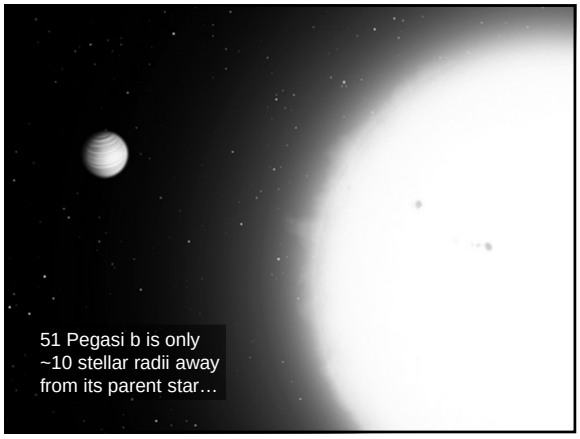
51 Pegasi b, a 0.5 $M_{Jupiter}$ planet only 0.05 AU from its parent star, is the prototype "Hot Jupiter"

A surprise when discovered in 1995:
- 4.23 day period
- 0.05 AU semi-major axis
- Gas giant like Jupiter

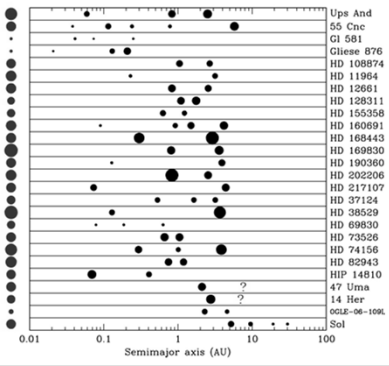


The surprise was what it was doing so close to its parent star…

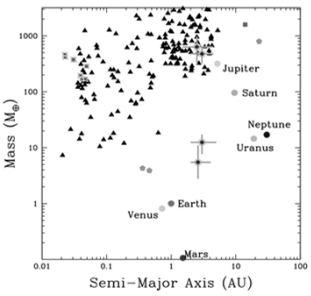
Gas giants in our Solar System are distant, out beyond the "Ice Line" where stable ices can exist.



A selection of multi-planet systems



The properties of the known exoplanet systems show a great deal of diversity…



Planet Masses
~1 M_{Earth} – 13 $M_{Jupiter}$

Semimajor Axes
0.02 AU – 8 AU

Eccentricities
0.0 – 0.93

Host Masses
0.3 – 5 M_{sun}

Distances
10 – 21,000 light years

Surprise #1:
Many Jupiters within 5 AU of their parent stars

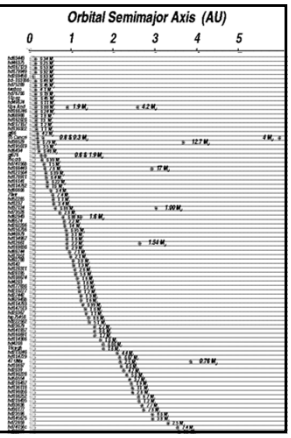
Orbital Periods < 10 days

Inside the orbit of Mercury

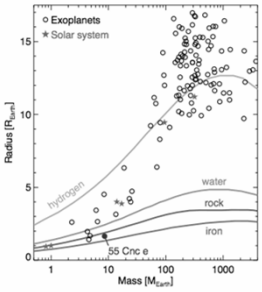
Densities like Jupiter and Saturn, so they are gas giants.

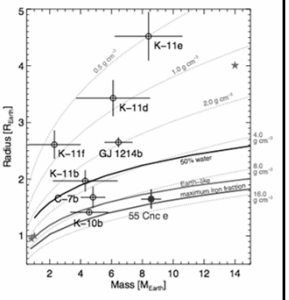
Selection effect?

How does a Jupiter-size gas planet get so close to its parent star?



Most known exoplanets are Gas Giants, but a few are ice giants or rocky super Earths



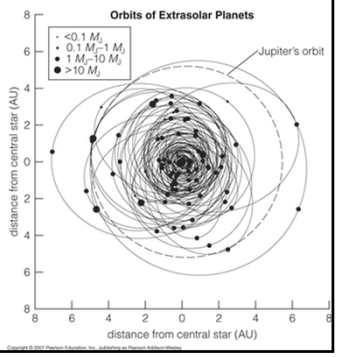


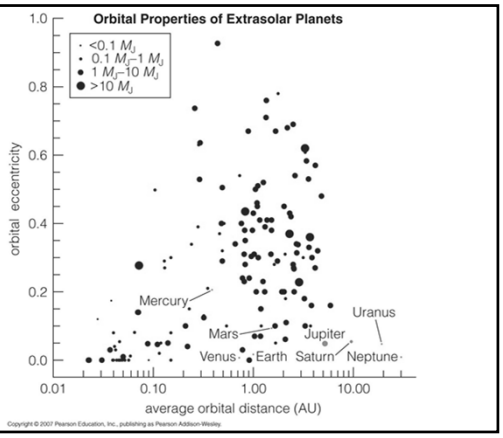
Surprise #2: A large number of gas giants have very eccentric (elliptical) orbits.

In our Solar System Jovian & Terrestrial orbits are nearly circular

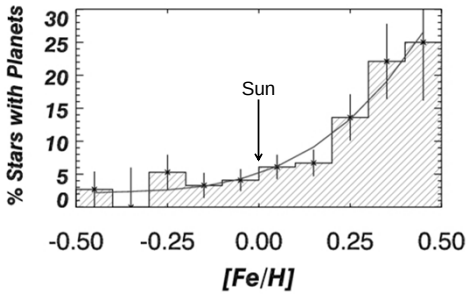
Among Exoplanets very elliptical orbits are common!

Some as elliptical as comets…





Planets are preferentially found around stars that are rich in metals.



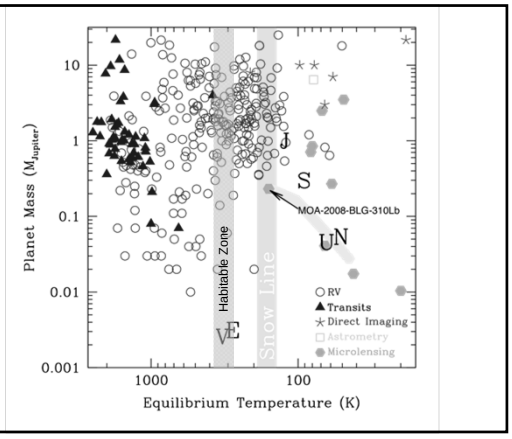
With one exception, none of the systems found so far resembles the Solar System

The large orbit eccentricities are very hard to explain.

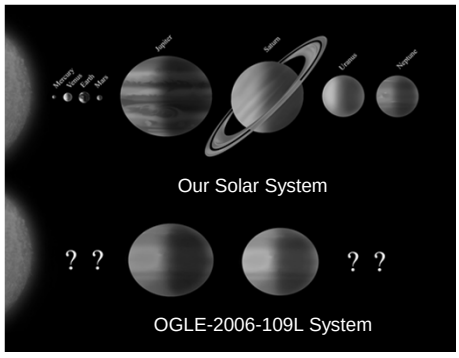
The biggest surprise is Jupiter-sized planets so close to their parent stars.

Most are deep inside the "Ice Line" where Jupiter-sized planets should not be able to form.

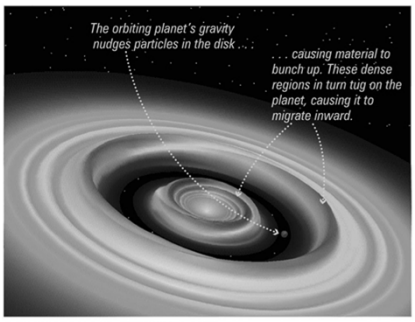
What is going on?



OGLE-2006-109L, found by gravitational lensing, is the first true Solar System analog discovered.



Did the gas planets formed far out then migrate inwards by interacting with the protoplanetary disk?

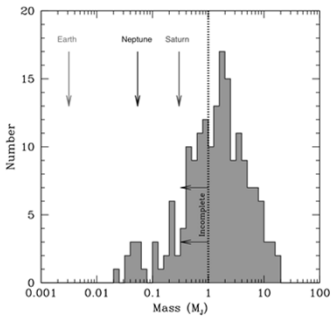


All planet searches thus far are just becoming sensitive to finding Earth-sized planets

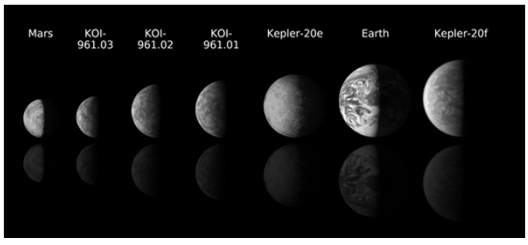
RV method needs to be ~10x more precise.

Transit method is just now finding Earth-sized planets.

Microlensing is very promising, but a few years away.

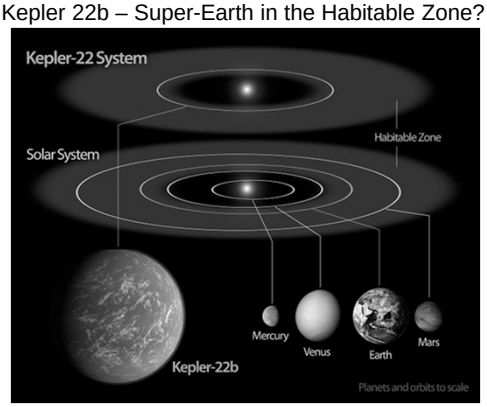


Kepler-20:
5 planets, 2 near-Earth sized around G star closer than the star's habitable zone

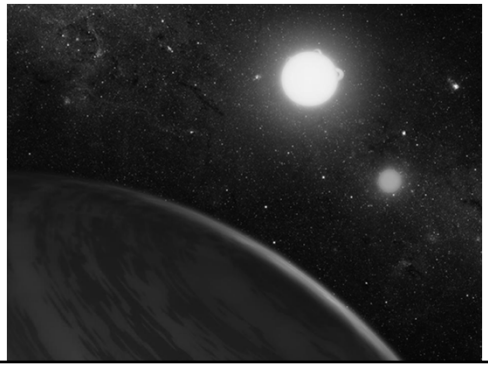


KOI-961:
3 planets, Earth to near-Mars sized around an M star closer than habitable zone (hot planets)

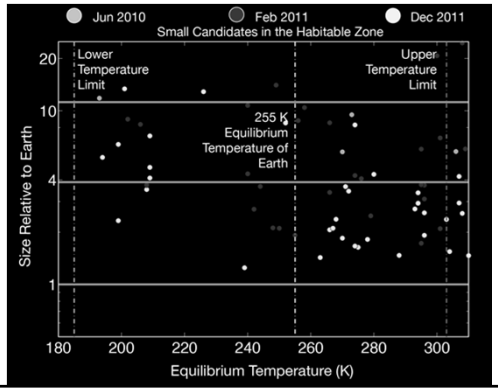
Kepler 22b – Super-Earth in the Habitable Zone?



Kepler 16:
$0.3M_J$ planet orbiting a binary star (K and M star)



Candidates in the Habitable Zone as of Dec 2012



The hunt is still on for Earth-like planets in the habitable zones of their parent stars…

Continuing the search for other planetary systems using many complementary methods.

We want to find more systems like our own…are we unusual?

How common are planets?

Ultimately want to find other Earth's capable of harboring life