Extrasolar Planets

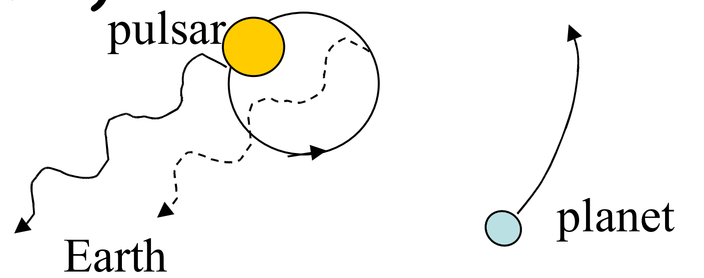
Extra-Solar Planets

- A very fast-moving topic (~330 confirmed 6/12/08)
- How do we detect them?
- What are they like?
- Are they what we would have expected? (No!)

How do we detect them?

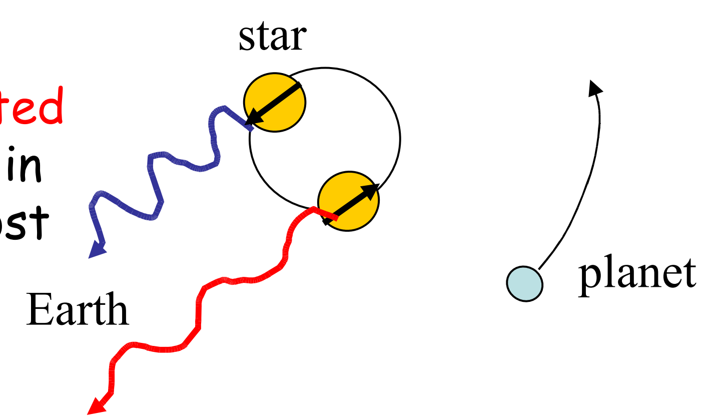
- The key to most methods is that the star will move (around the system's centre of mass) in a detectable fashion if the planet is big and close enough
- Pulsar Timing (first one in 1992)

A pulsar is a very accurate clock; but there will be a variable time-delay introduced by the motion of the pulsar, which will be detected as a variation in the pulse rate at Earth



Radial Velocity

Spectral lines in star will be Doppler-shifted by component of velocity of star which is in Earth's line-of-sight. This is easily the most common way of detecting ESP's.



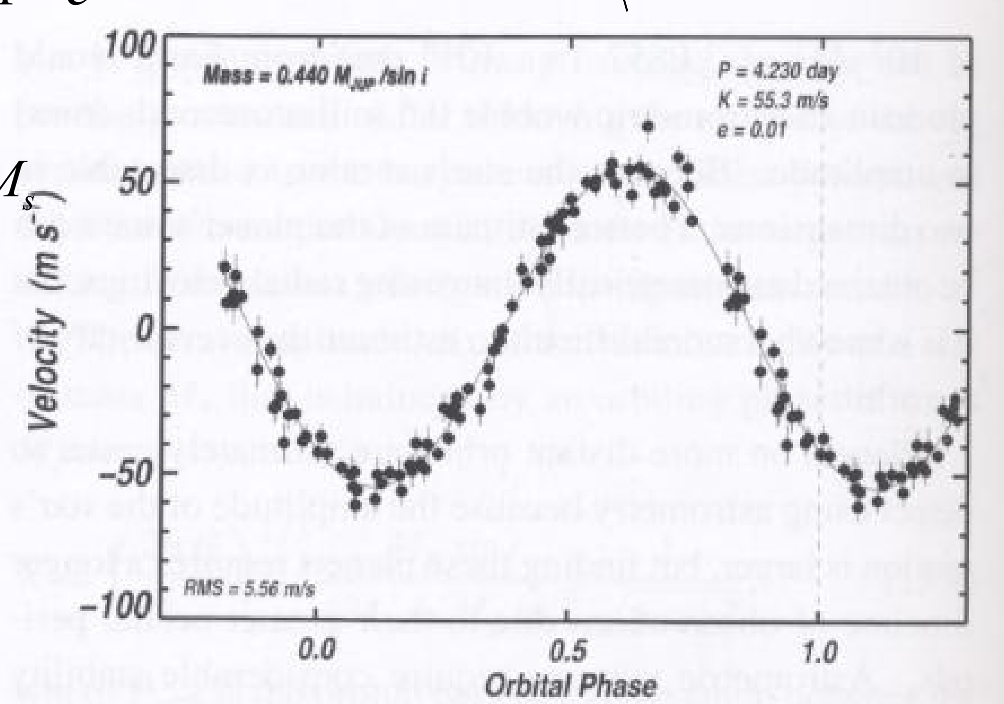
How do we detect them? (2)

- Radial Velocity (cont'd)

The radial velocity amplitude is given by Kepler's laws and is

$$v = \left(\frac{2\pi G}{P_{orb}} \right)^{1/3} \frac{M_p \sin i}{(M_s + M_p)^{2/3}} \frac{1}{\sqrt{1 - e^2}}$$

Note that the planet's mass is uncertain by a factor of sin *i*. The $M_s + M_p$ term arises because the star is orbiting the centre of mass of the system. Present-day instrumental sensitivity is about 3 m/s; Jupiter's effect on the Sun is to perturb it by about 12 m/s.

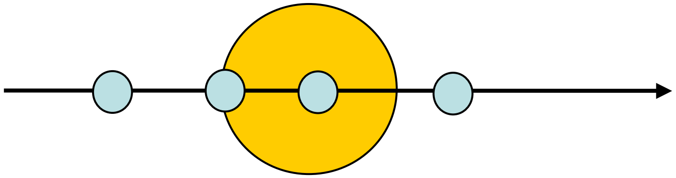


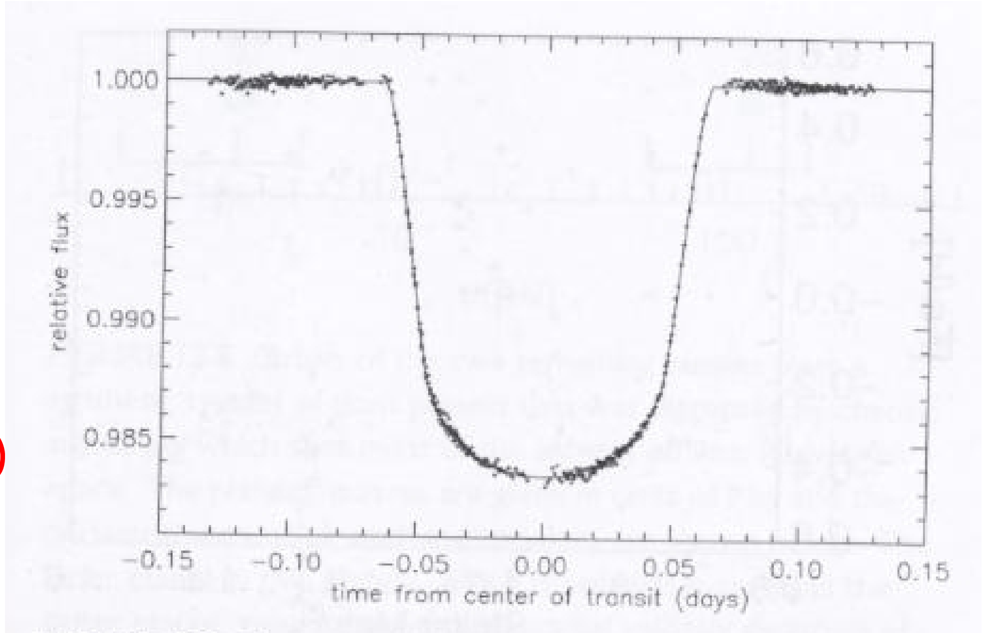
From Lissauer and Depater, *Planetary Sciences*, 2001

How do we detect them? (3)

- <u>Occultation</u>

- Planet passes directly in front of star. Rare, but very useful because we can:
- Obtain *M* (not *M* sin *i*)
- Obtain the planetary radius (*R*)
- Obtain the planet's spectrum (!)

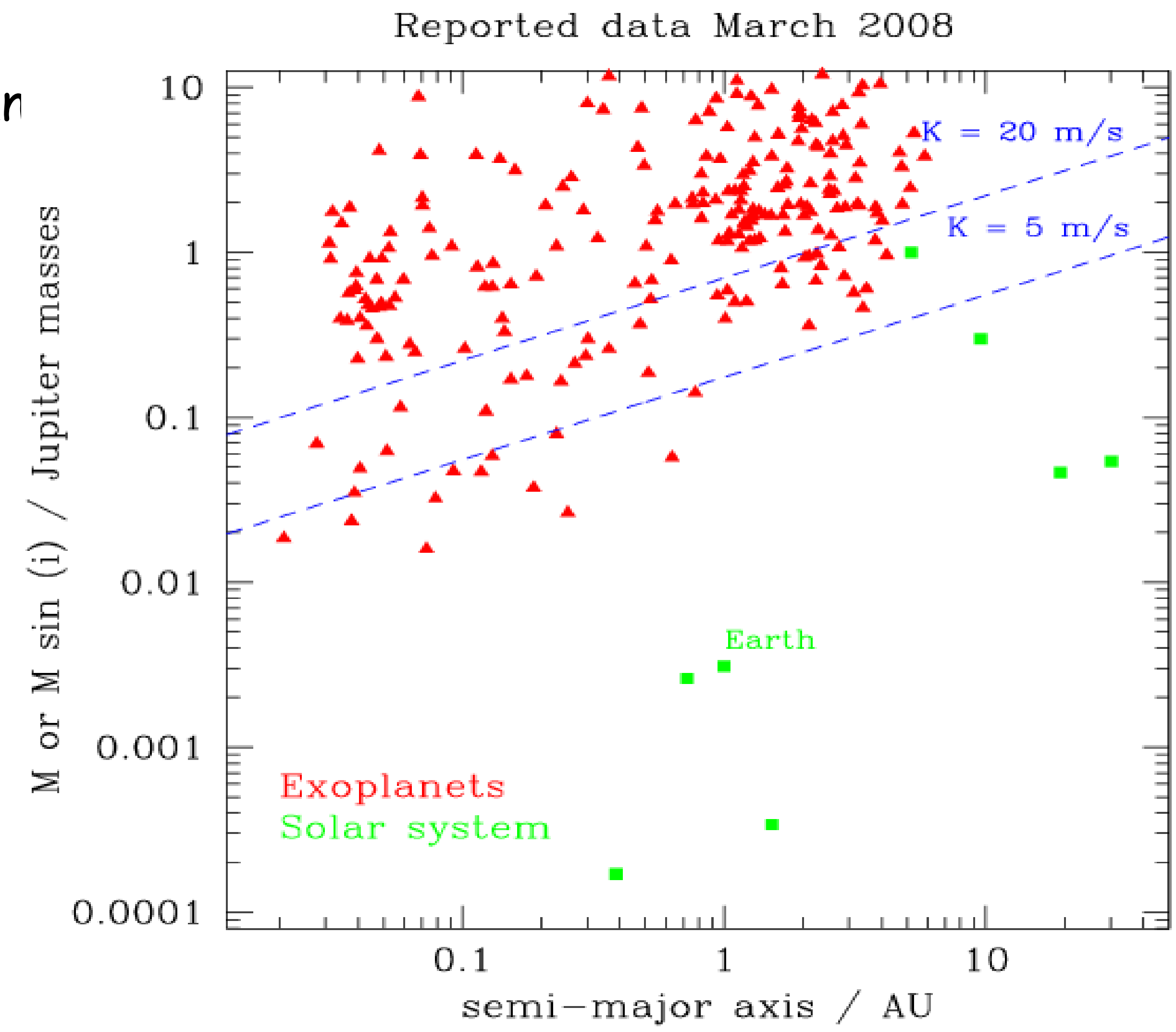




Light curve during occultation of HD209458.
From Lissauer and DePater, *Planetary Sciences*, 2001

Masses and Orbits

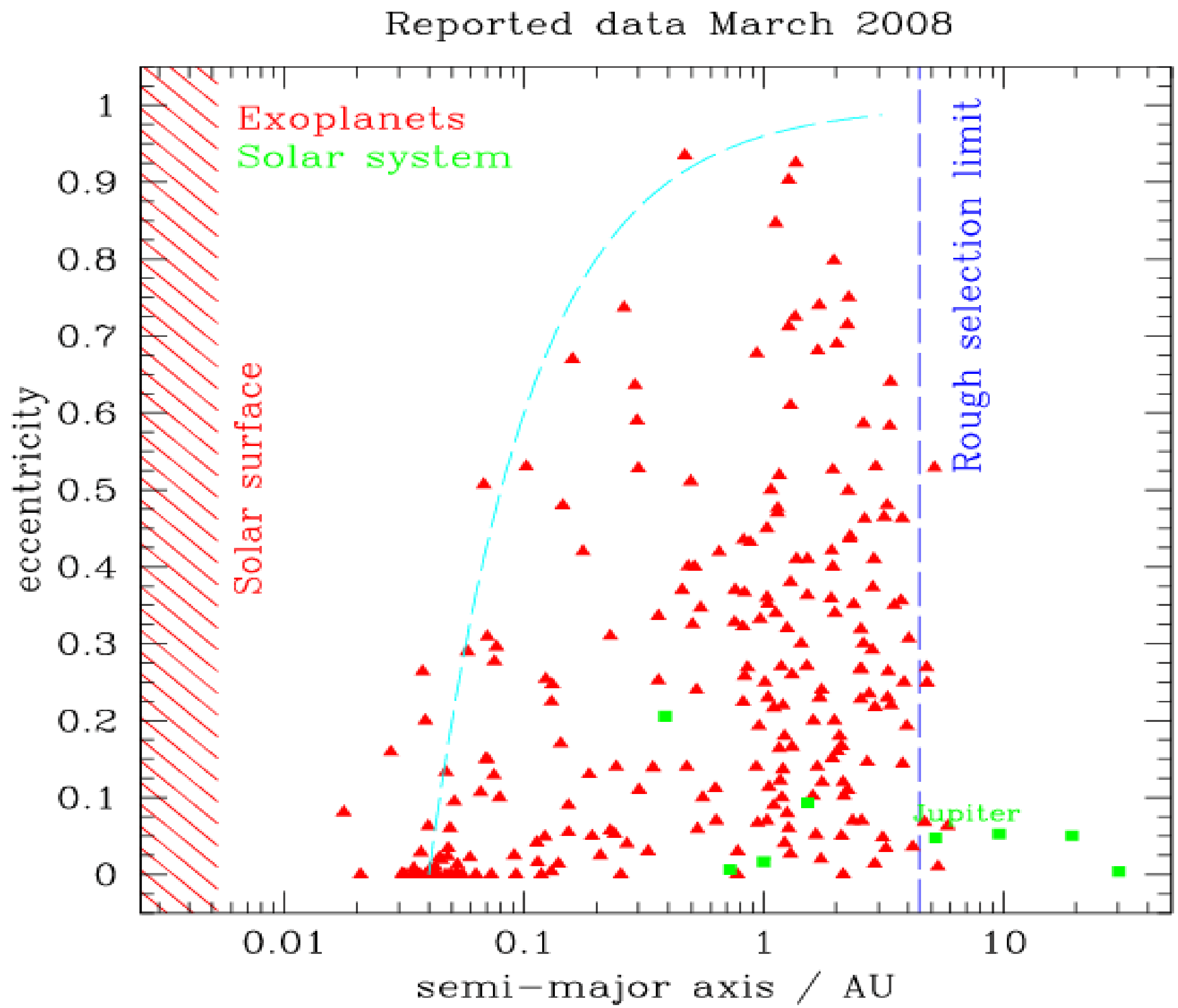
Massive, Close-in Plan
`Hot Jupiters'



Semimajor axes and Eccentricity

Note small e at small a?

Similar to regular satellites?



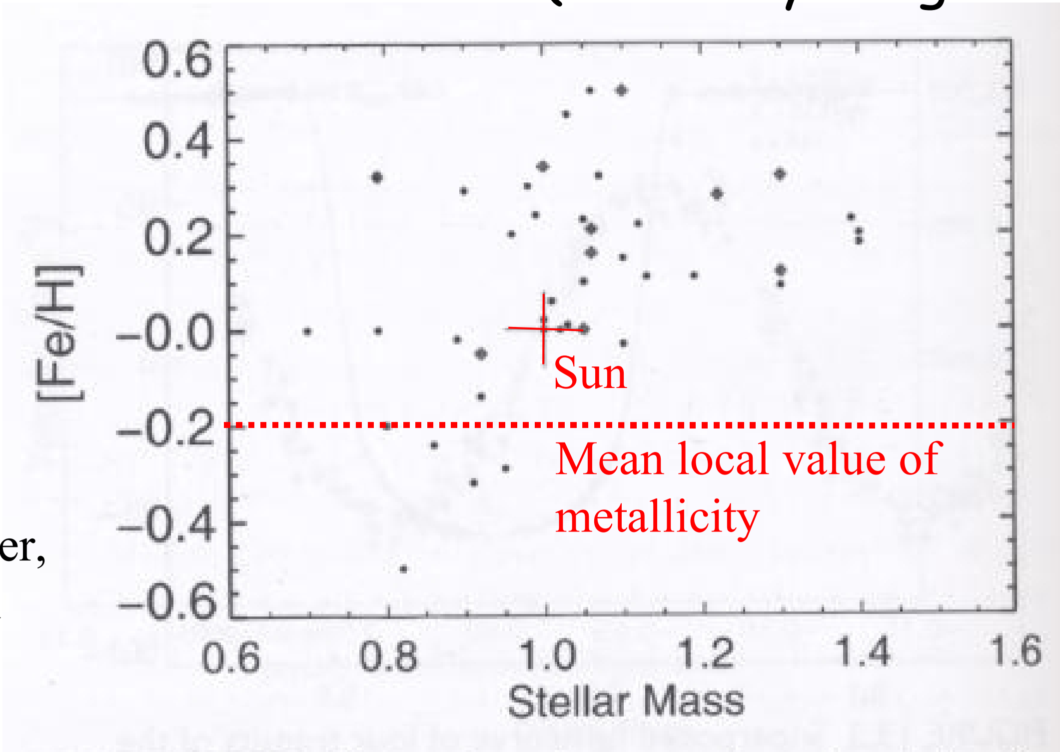
Physical Properties

- *Big*, *close*, and often highly *eccentric* – “hot Jupiters”
- What are the observational biases?
- Some are more dense than theoretical models suggest – Larger cores? (70Me cores?)
- Some are less dense than models suggest – additional heating and inflation?

What are they like (2)?

- Multiple planet systems have been found with up to 7 planets
- Several pairs of planets have been observed, often in 2:1 resonances
- (Detectable) planets seem to be more common in stars which have higher proportions of “metals” (i.e. everything other than H and He)

There are also claims that HD179949 has a planet with a magnetic field which is dragging a sunspot around the surface of the star . . .



From Lissauer and DePater, *Planetary Sciences*, 2001

Puzzles

- 1) Why so close?
  - Inwards migration due to presence of nebular gas disk (which then dissipated)
  - They don't fall into the star is because the disk is absent very close in, probably because it gets cleared away by the star's magnetic field. An alternative is that tidal torques from the star (just like the Earth-Moon system) counteract the inwards motion
- 2) Why the high eccentricities?
  - Gravitational scattering off other planets during inwards migration?
  - Resonant interaction with gas disk?
- 3) How typical is our own solar system?
  - Not very, but current observations are biased

Consequences

- What are the consequences of a Jupiter-size planet migrating inwards?
- Systems with hot Jupiters have likely witnessed planetary migration – dynamical instability
- So the timing of gas dissipation is crucial to the eventual appearance of the planetary system (and the possibility of habitable planets . . .)
- What controls the timing?
- Gas dissipation is caused when the star enters the energetic T-Tauri phase – not well understood (but inferred to take around 1-10Myr)
- So the evolution (and habitability) of planetary systems is controlled by stellar evolution timescales

Summary

- Giant planets primarily composed of H,He with a ~10 M_e rock-ice core – probably accreted first
- They radiate more energy than they receive due to gravitational contraction (except Uranus!)
- *Many* (~500) extra-solar giant planets now known
- Many are close to the star or have high eccentricities – are unlike our own solar system
- Nebular gas probably produced inwards migration (if true – migration occurred in first few Myr of system history)

Puzzles

Where are the habitable worlds? - small planets - moons...