Results of radial velocity searches

Since the planet is not directly detected, only information is that which can be derived from the radial velocity curve:

- `mass' - actually M_p sin(inclination)
- orbital period / orbital radius
- eccentricity of the orbit

Can also measure some properties of the host star, such as its mass and *metallicity* - normally expressed as the abundance of elements heavier than helium relative to the abundance in the Sun.

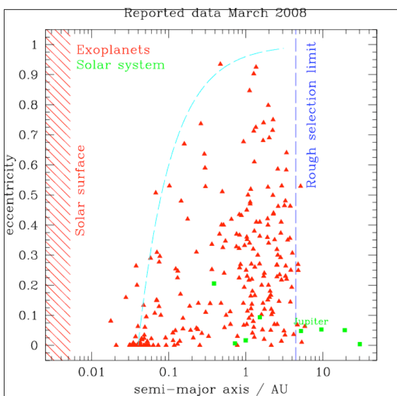
Selection effects / biases

You see first what's easiest to see…

For a particular mass star, the planets that produce the largest radial velocity signal are those that are (a) massive and (b) orbit at small distance from the star…

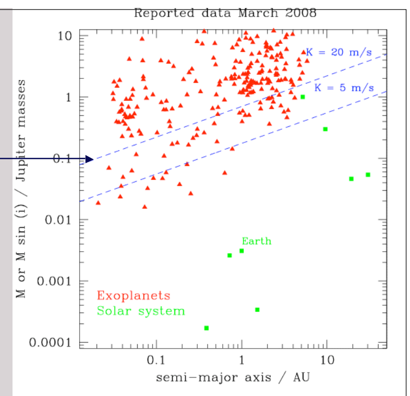
$$v_* = \frac{M_p}{M_*}\sqrt{\frac{GM_*}{a}}$$

Also, need to detect the whole orbit of the planet around the star, so need to monitor the star for a long time. Recall the orbital period of Jupiter… about 10 years.



More than 200 known extrasolar planets found to date…

line of constant v_* - i.e. line of roughly equal detectability



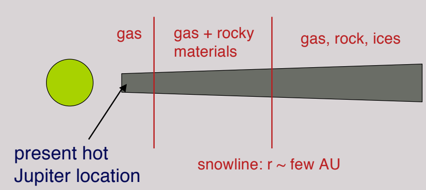
Massive (gas giant) planets are reasonably common - at least 5-10% of Solar mass stars have detectable planets and there are probably many more that currently elude detection.

But… **two major surprises**

- giant planets in ultrashort period orbits (sometimes just a few days, a < 0.1 AU). These planets, which orbit closer to their stars than Mercury does to the Sun, are called **hot Jupiters**
- giant planets with (often) very eccentric orbits - some known extrasolar planets have e > 0.9, which in the Solar System is an orbit more typical of a comet than a planet

Why are hot Jupiters surprising? Recall: for the Solar System we argued that giant planets form in the outer Solar System beyond the snowline - where icy materials can condense due to low temperature

The disk at ~0.05AU is too hot for even dust to survive, so how did the cores of hot Jupiters form?



Why are eccentric planets surprising?

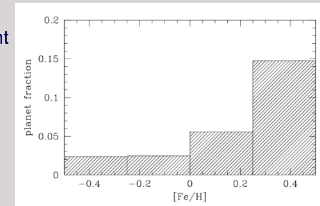
- all the major planets in the Solar System have close to circular orbits
- planets form from protoplanetary disks, in which the gas is likely to have near-circular orbits

Note: if *terrestrial* (rocky) planets also often have very eccentric orbits, implications for habitability…

Is the theory of giant planet formation wrong?

Some theoretical expectations are confirmed:

Frequency of planets vs stellar metal content

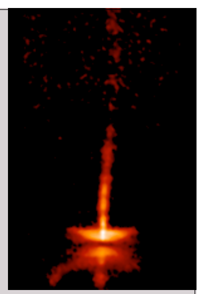


More heavy elements means more planetesimals - expect cores of giant planets to form more quickly so it is more likely to form a giant planet in time before the gas in the disk is lost

Planetary migration

Most popular theory for origin of the hot Jupiters

- planets *formed* at `normal' location in disk - beyond the radius of the snowline
- planets lost energy (and angular momentum) to the gas in the disk
- planets spiraled in to the small radius where they're now seen



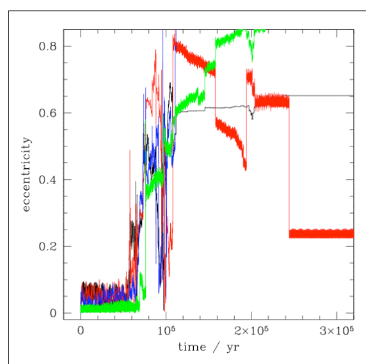
Idea was proposed before extrasolar planets were found, seems to match the main properties of the hot Jupiters

Planet formation may be less efficient than we thought before - whole generations of planets may be swallowed by their stars as a result of migration…

Origin of the eccentric orbits?

Also quite uncertain…

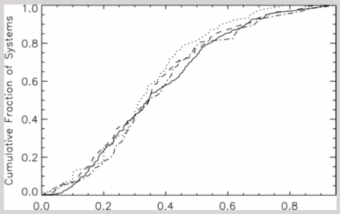
- perhaps the typical outcome of the giant planet formation process is several massive planets that orbit too close together to be stable for long time periods
- planets interact gravitationally and *scatter*
- least massive planets are ejected
- survivors are left with eccentric orbits



Violent and very chaotic process

Close to the star, scattering often results in physical collisions between planets!

Many planets are ejected into interstellar space



Not proven to be the answer, but the distribution of eccentricity resulting from such a model is a good match to the one that is observed…