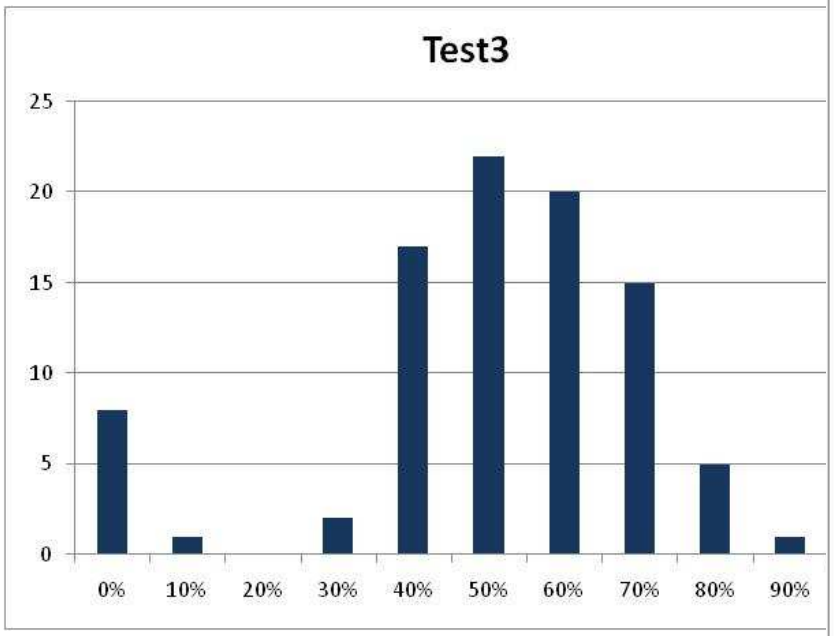
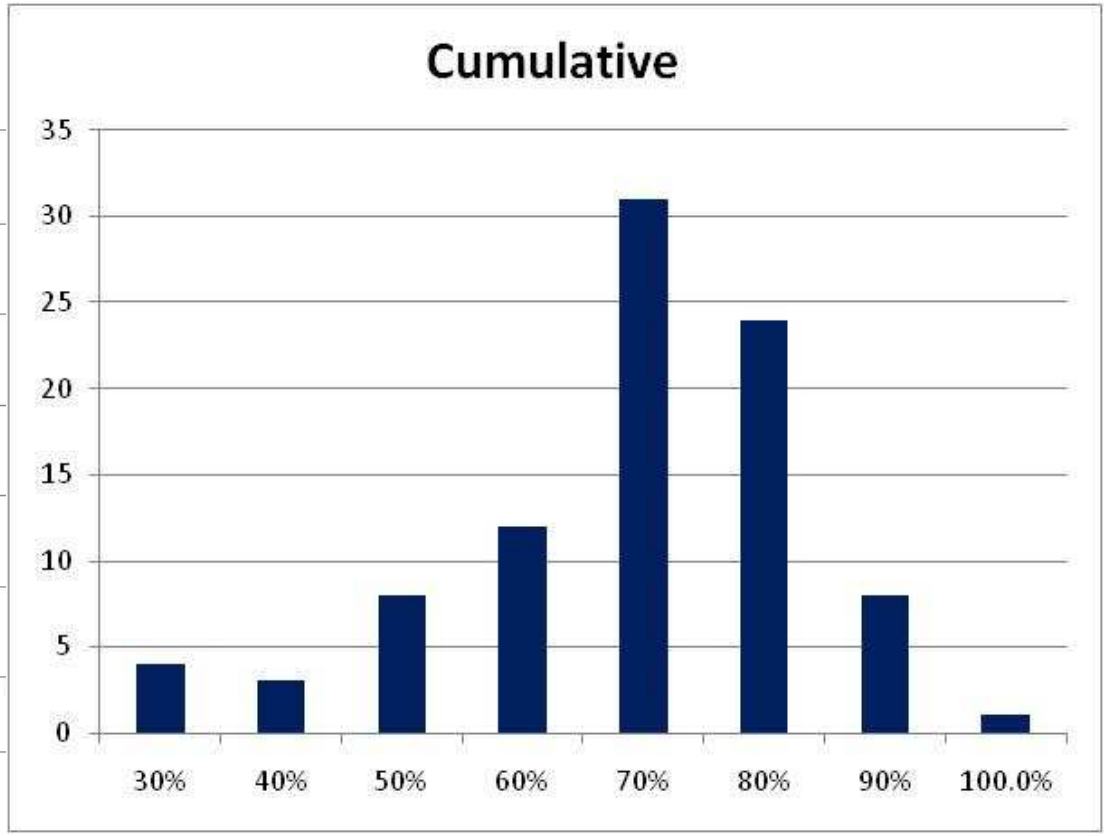




Max = 300

Range = 60 – 288 (20% - 96%)
Mean = 183 (61%)
Median = 177 (59%)

Max = 1050

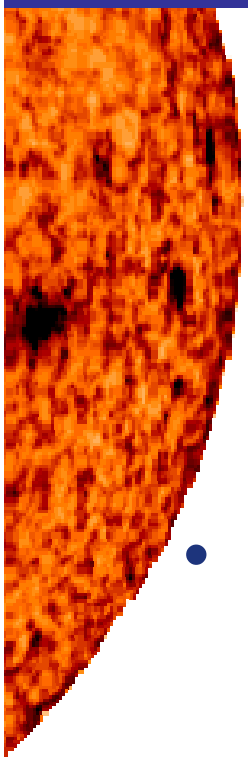
Range = 343 – 1056 (33% - 101%)
Mean = 775 (74%)
Median = 798 (76%)

So, we're in the final stretch. Keep your focus and work hard for the next few days!

What We Will Learn Today

- Do the patterns of our Solar System extend to other solar systems?
- What are the observed patterns of exoplanet systems discovered to-date?
- Do the observed exoplanets support or challenge the nebular theory of Solar System formation?
- Is our Solar System rare?

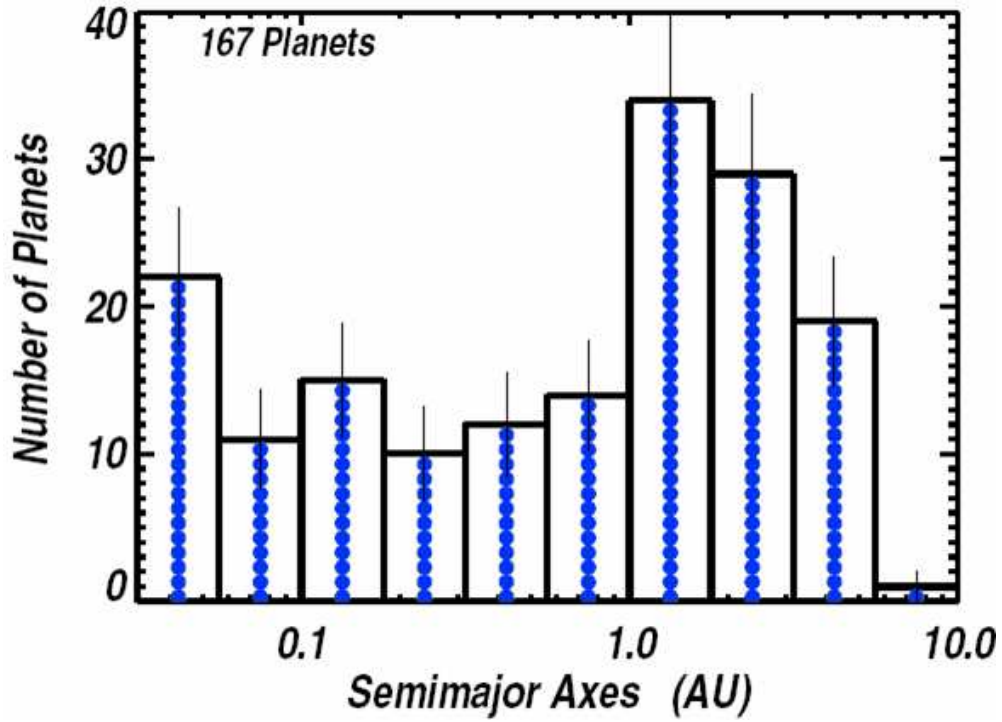
Early Discoveries: “Hot Jupiters”



- Selection Effect
  - More massive planets cause higher star velocity, so more easily detected
  - Closer planets ➔ Shorter period ➔ Detected early
- So, are all other solar systems weird? Is ours unique?

Most Exoplanets are not so “Hot”!

- Closer planets are easier to find, but aren’t as numerous!

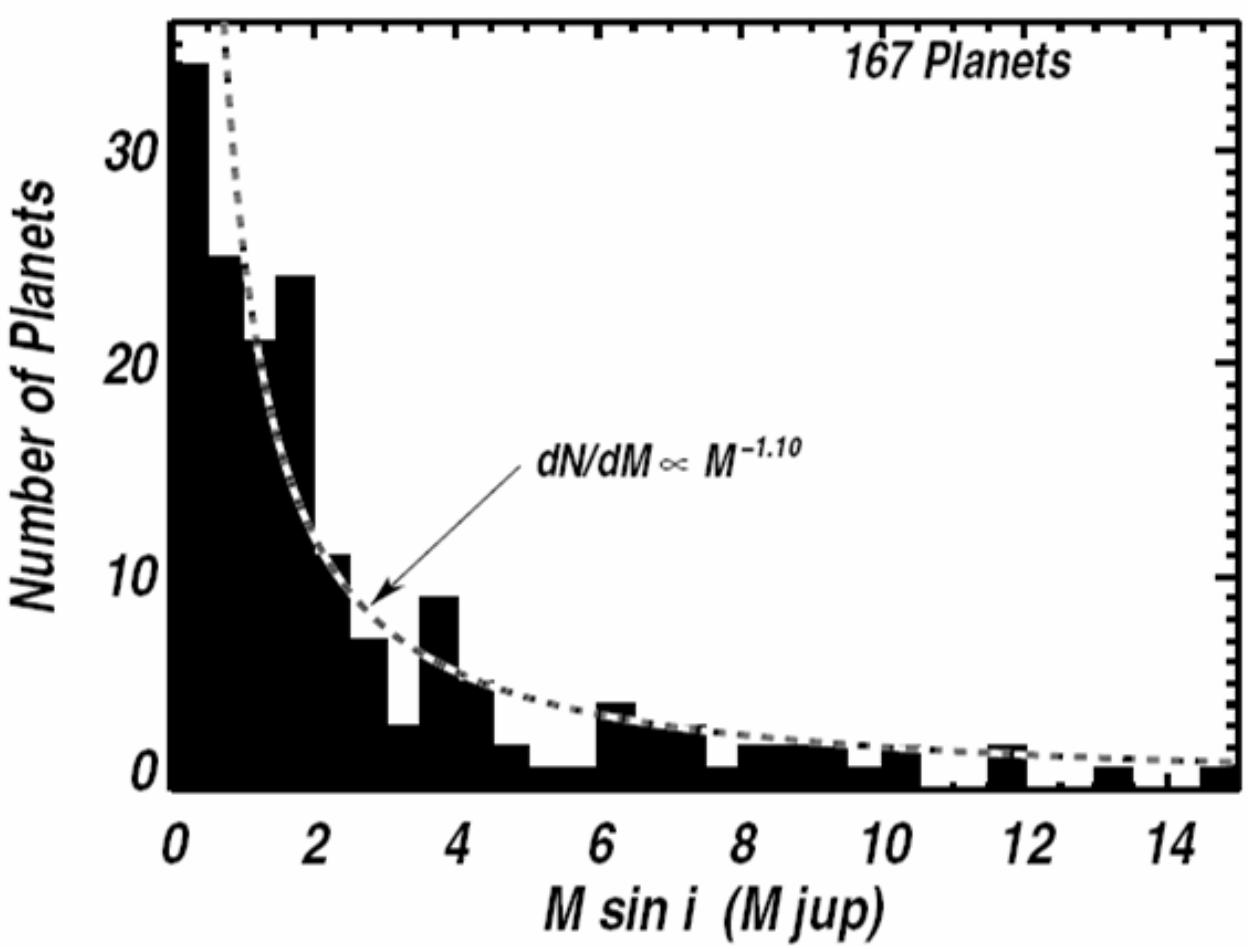


Source: http://exoplanets.org

- Space beyond 3 AU not fully probed, likely to find many more planets farther out

Smaller Planets Rule!

- Massive planets are easier to detect, but aren't as numerous!

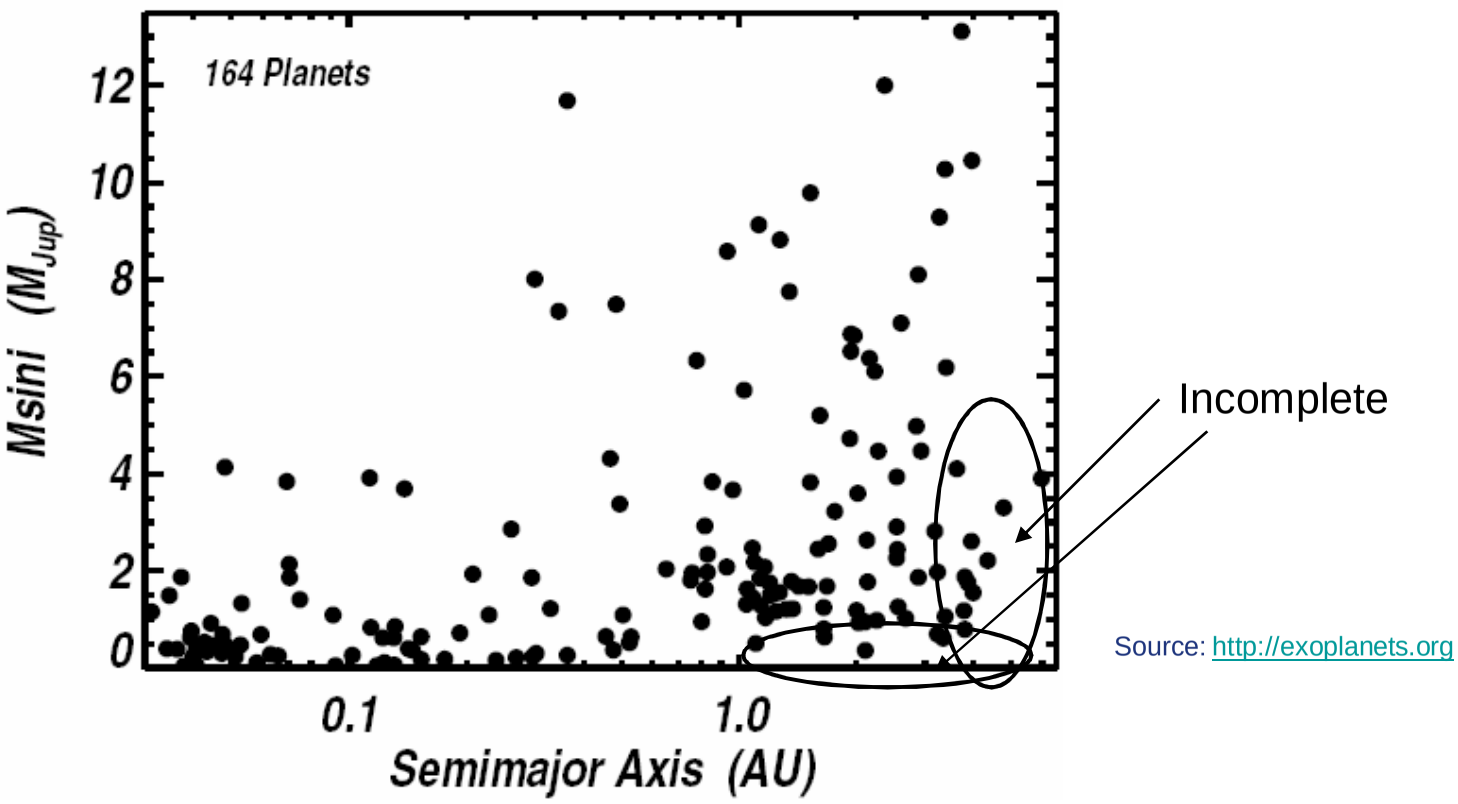


Source: http://exoplanets.org

Similar to Fig 13.12

Massive Planets Are Farther

- Hot Jupiters are easier to detect, but aren't as numerous!

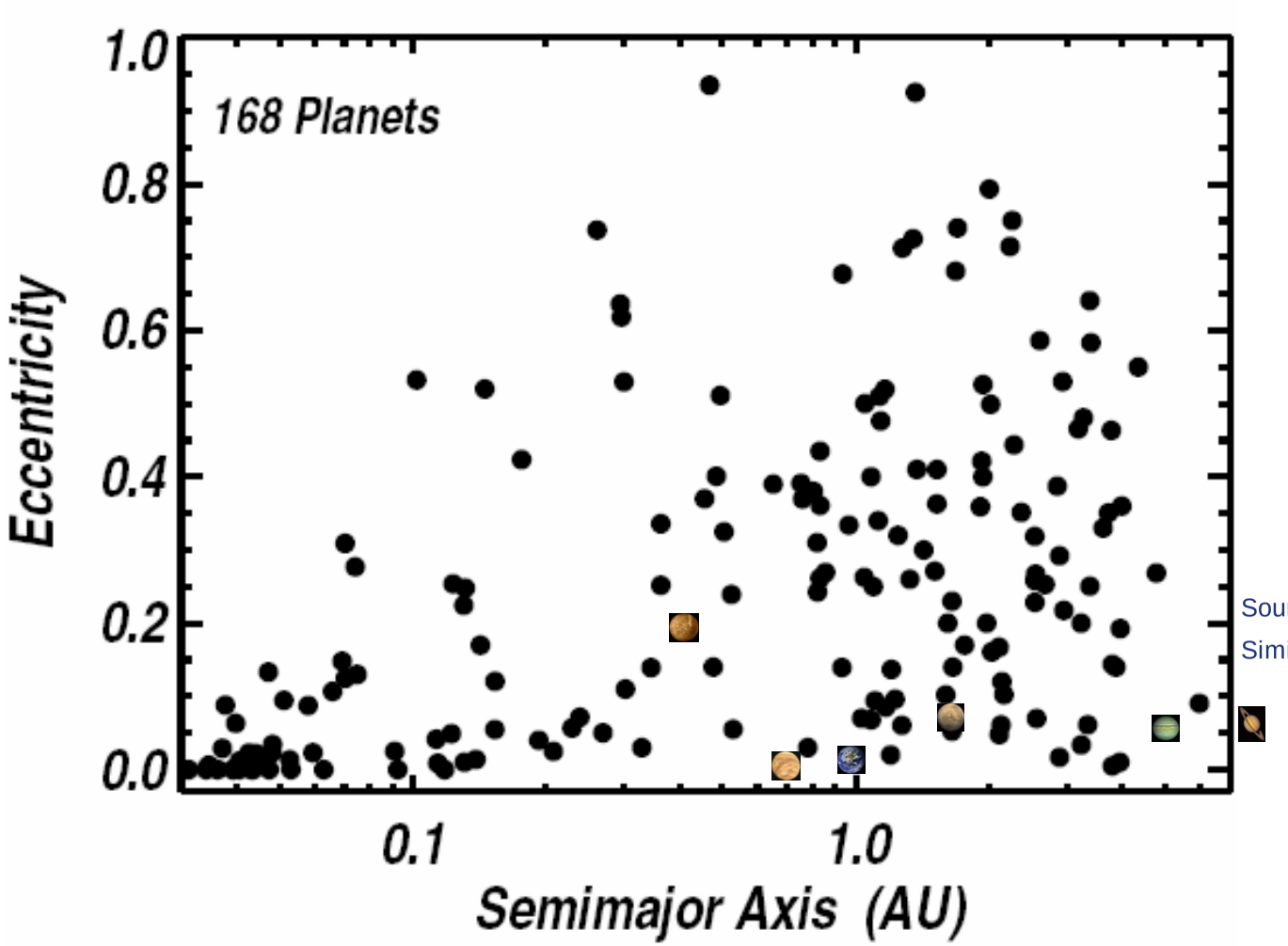


Source: http://exoplanets.org

- Multi-planet systems preferentially have more massive planets farther out

Exoplanets Are More Eccentric

- Our Solar System appears unique in this respect!



Source: http://exoplanets.org

Similar to Fig 13.10 a

Consistent With Nebular Theory?

- All exoplanets found are Jovian planet mass
  - Sub-Neptune mass (6 Earths) to 10 Jupiter Mass
  - Only a few have known size (why?), and their densities are consistent with Jovian planets
  - Jovian planets form beyond the frost line
  - So, how do they get so close to their Sun?
- Planetary Migration
  - Propagation of waves in nebula lead to planet migration inwards
  - In our solar system, Sun cleared the nebula before significant migration could take place

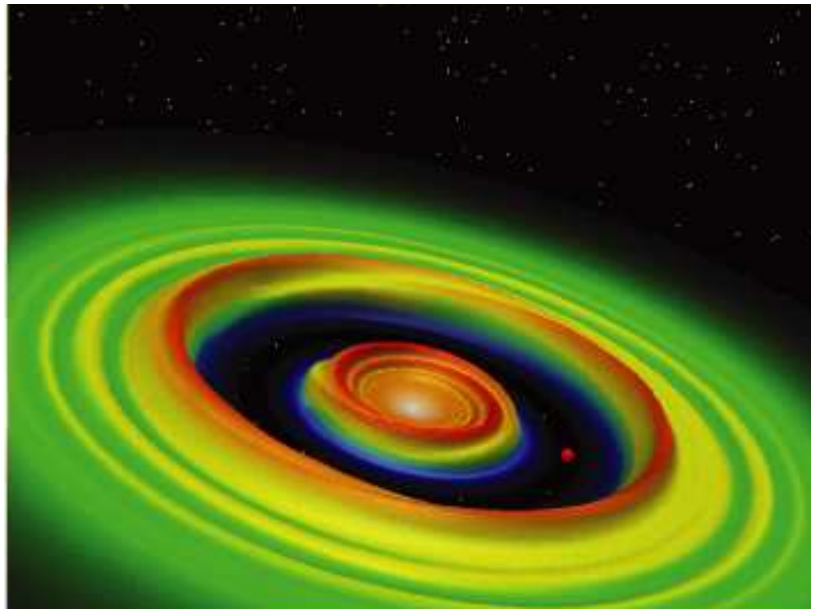


Fig 13.14

Planet Encounters and Resonances

- Mutual gravitational interactions
  - One planet flung out of the solar system
  - The other planet ends up with an eccentric orbit
- Multiple small perturbations
  - Comets flung into Oort cloud
  - Jovian planets migrate a bit inward as a result
- Resonances observed in many multi-planet exoplanet systems
  - Consistent with resonances observed in our Solar System

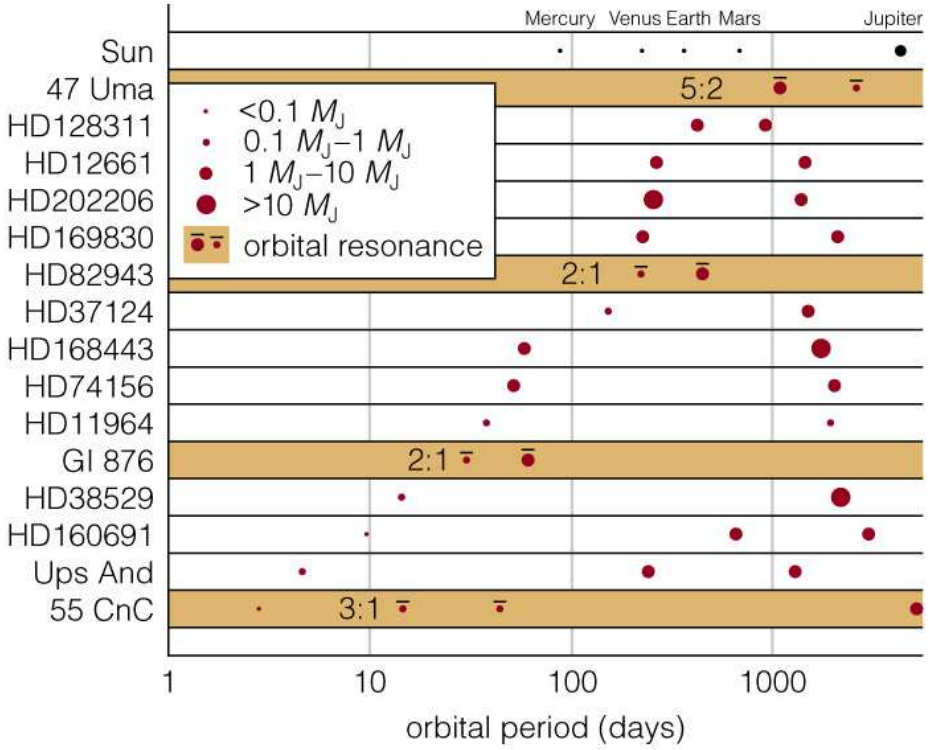
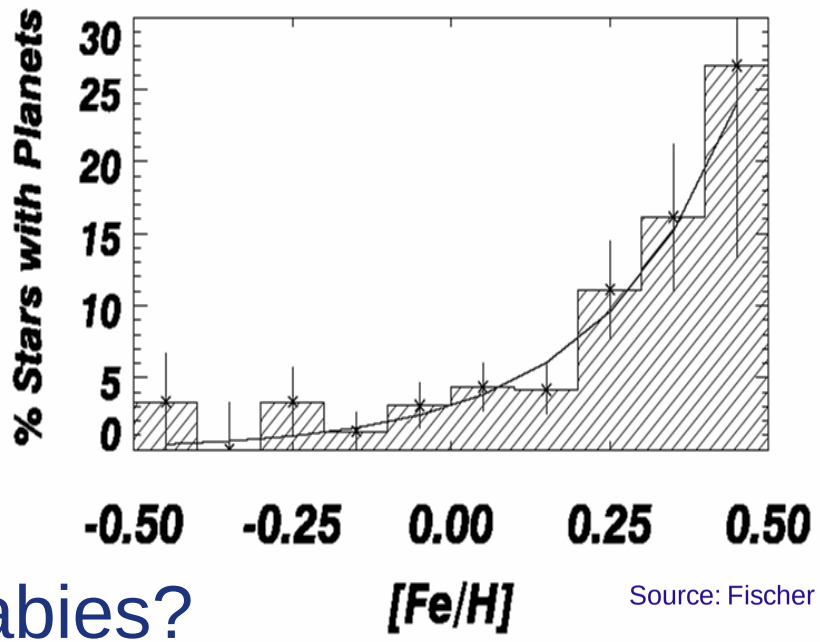


Fig 13.11

- Nebular theory probably OK, but needs modification
  - Only one in ten stars studied have planets seen around them
  - Are solar systems rare, or have we only seen the tip of the iceberg?
  - Hot Jupiters are easier to detect, Earths are beyond detection yet

Metal-rich Stars Have More Planets

- Is it due to:
  - More metals ➔ Planet formation favored
  - Stars with planets eat some, and hence have more metals



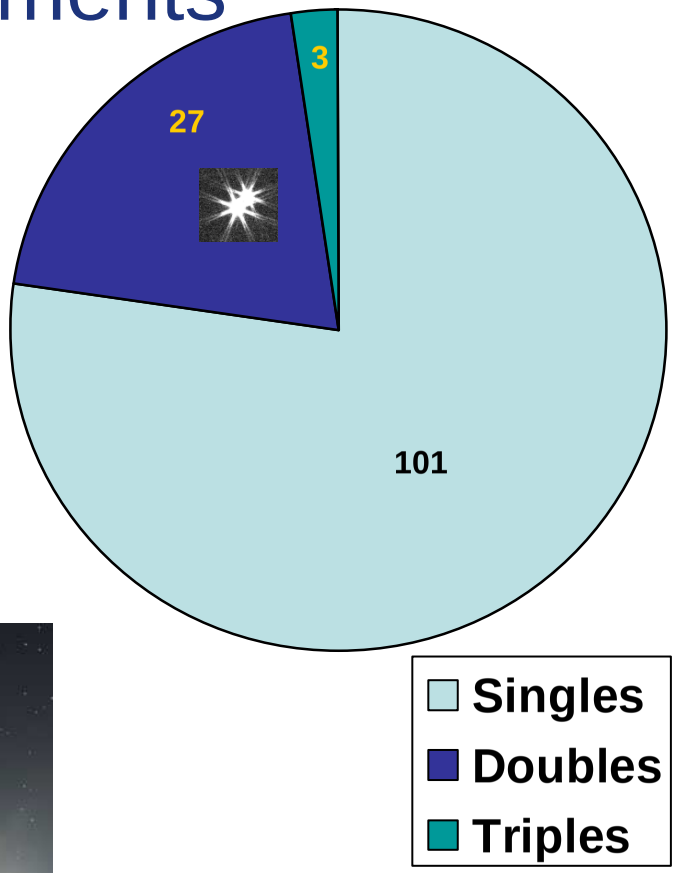
Source: Fischer & Valenti 2005

- Do stars eat their babies?
  - Some may, but not responsible for metallicity correlation
- Higher metallicity provides more condensates
  - Encourages planet formation

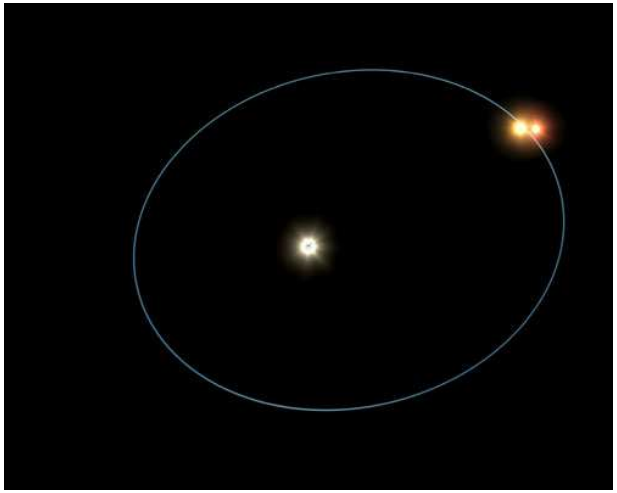
So, Are All Stellar Parents Single?

Almost ¼ of the planetary systems reside in multiple star environments

- Remarkable because:
  - We only look for planets around "single" stars
  - Contrary to expectations
  - Shows that planets are very "hardy"
  - Two/Three Suns in the Sky!

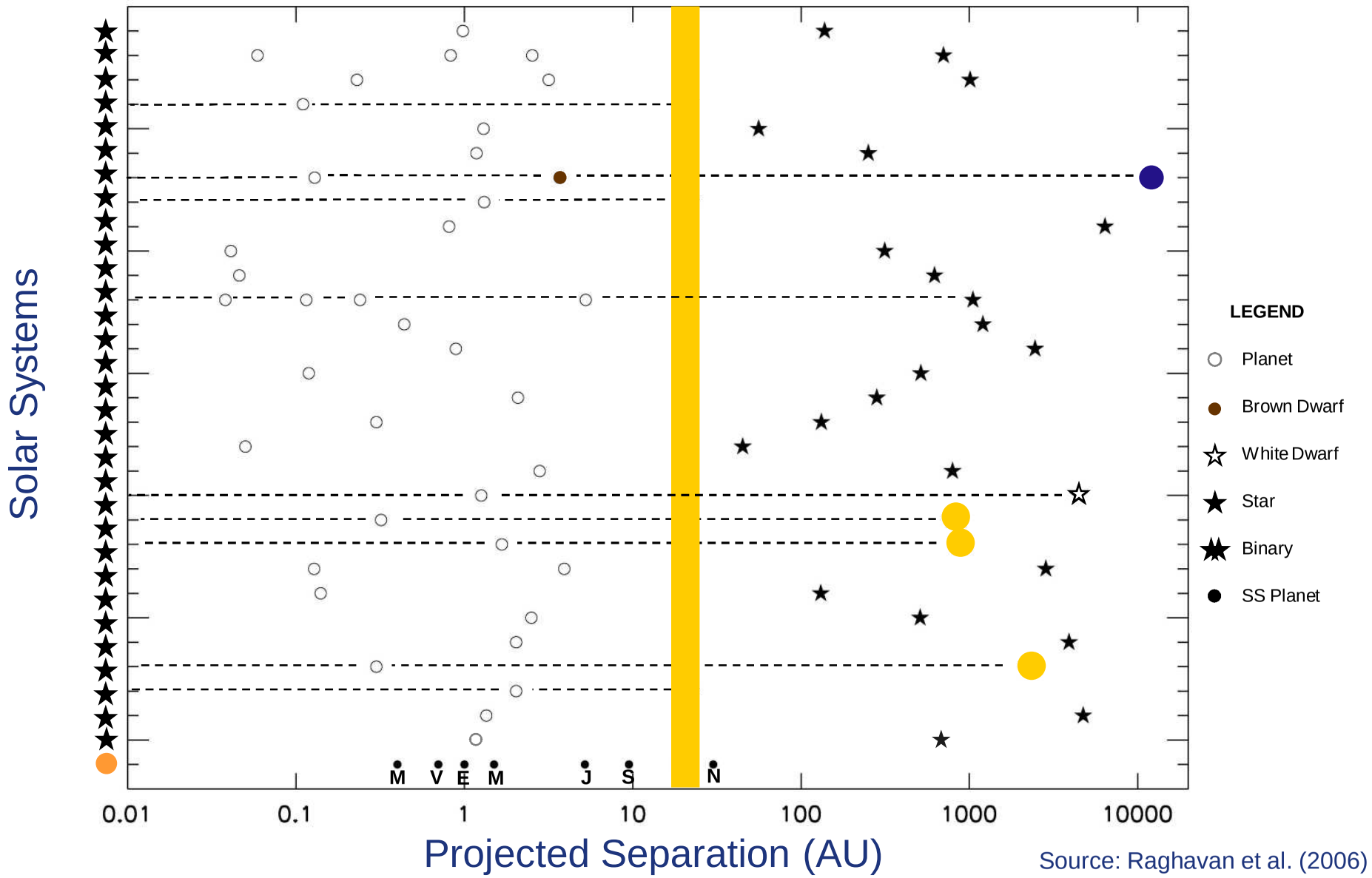


Source: Raghavan et al. (2006)



NASA/JPL animations

Solar Systems with Multiple Stars



Source: Raghavan et al. (2006)

Ever Wonder about other worlds?