



DARA Basic Training

NAMIBIA-BOTSWANA 2019

UNIT 1: INTRODUCTION TO ASTROPHYSICS

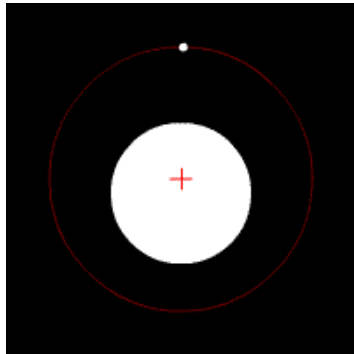
Windhoek, 7 –18 January 2019

Extra-solar Planet Detection

- Radial Velocity Technique
- Transit technique
- Direct Imaging

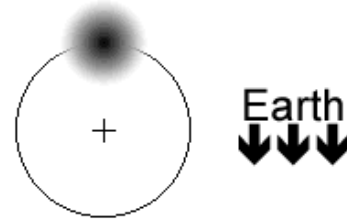
Radial velocity technique

- Use same single line spectroscopic binary technique but more accurate

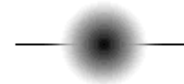


Observation of Stellar Motions Due to Presence of Extra-Solar Planet

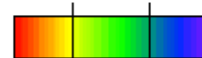
Orbit of Star Around System's Center of Mass
(Viewed from above)



Astrometric Displacement
(Detects movement across line of sight)



Doppler Shift
(Detects movement along line of sight)



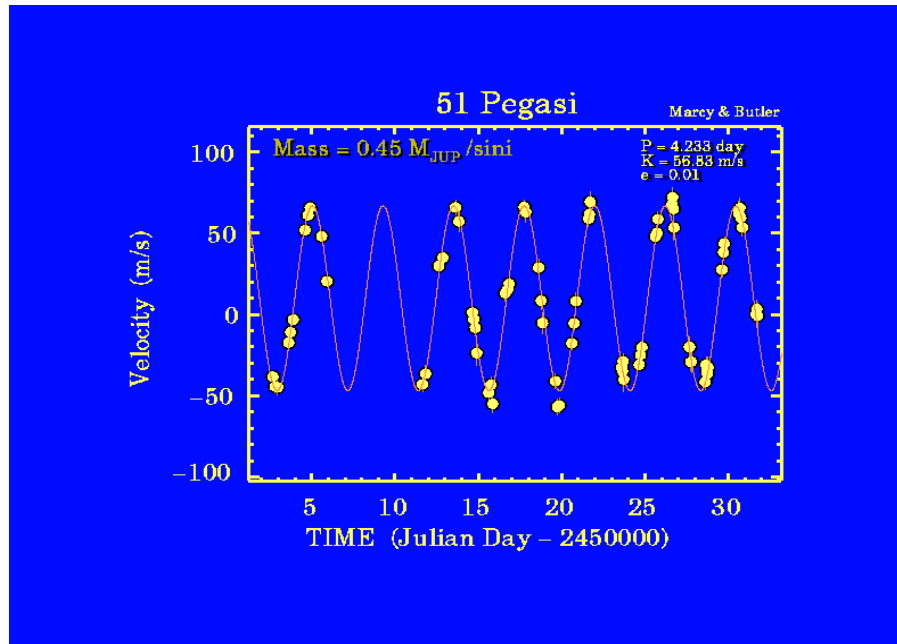
When $M_2 \ll M_1$ the single-lined spectroscopic binary formula becomes

$$\frac{M_2^3 \sin^3 i}{M_1^2} = \frac{Pv_{r1}^3}{2\pi G}$$

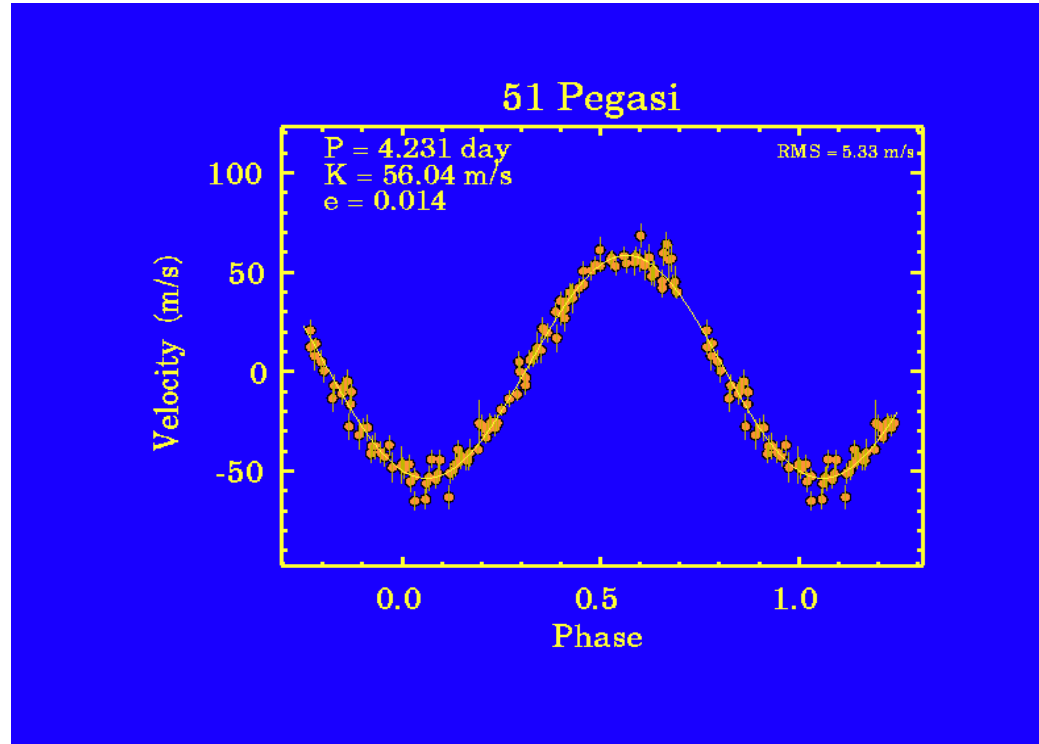
$$M_2 \sin i = \left(\frac{PM_1^2}{2\pi G} \right)^{\frac{1}{3}} v_{r1}$$

51 Pegasi b – the first exo-planet

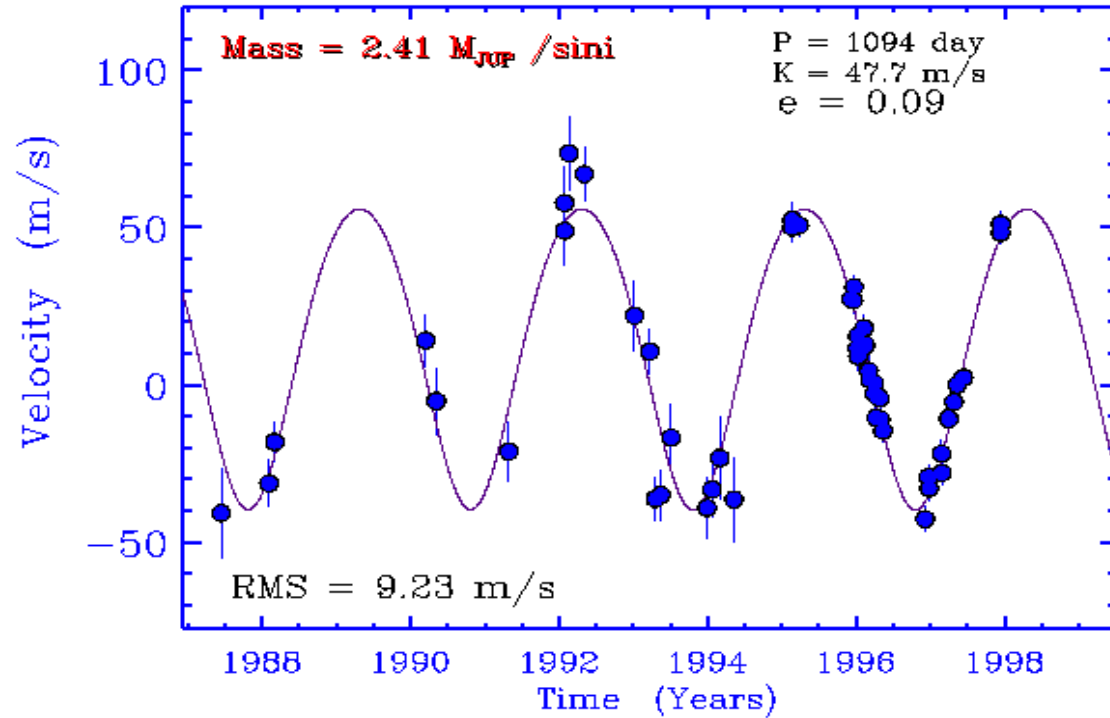
- The radial velocity curve



- The folded radial velocity curve (against orbital phase)

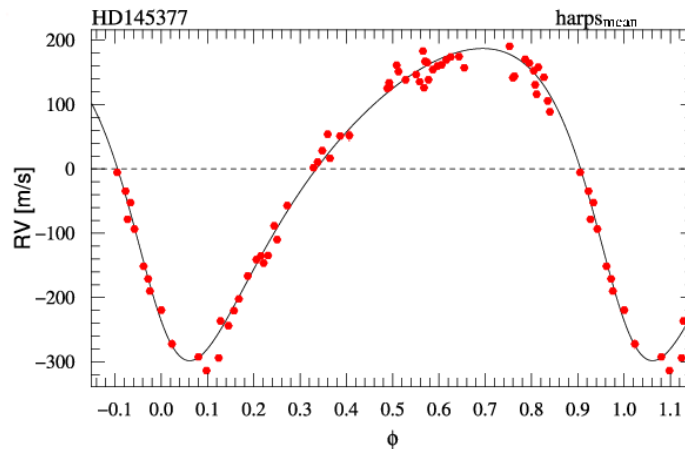
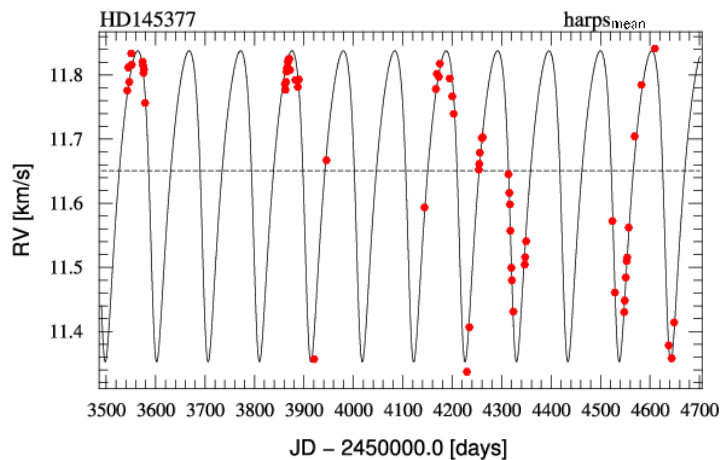


Long Period Planets: 47 UMa b



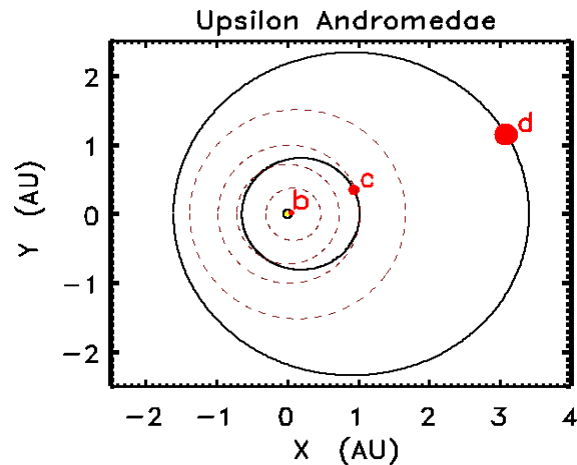
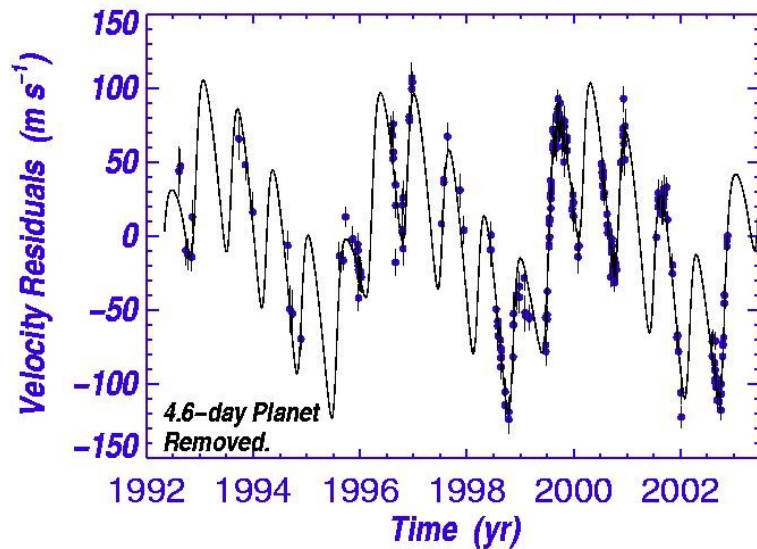
Eccentric Orbits

- Non-sinusoidal shape is due to an eccentric orbit.

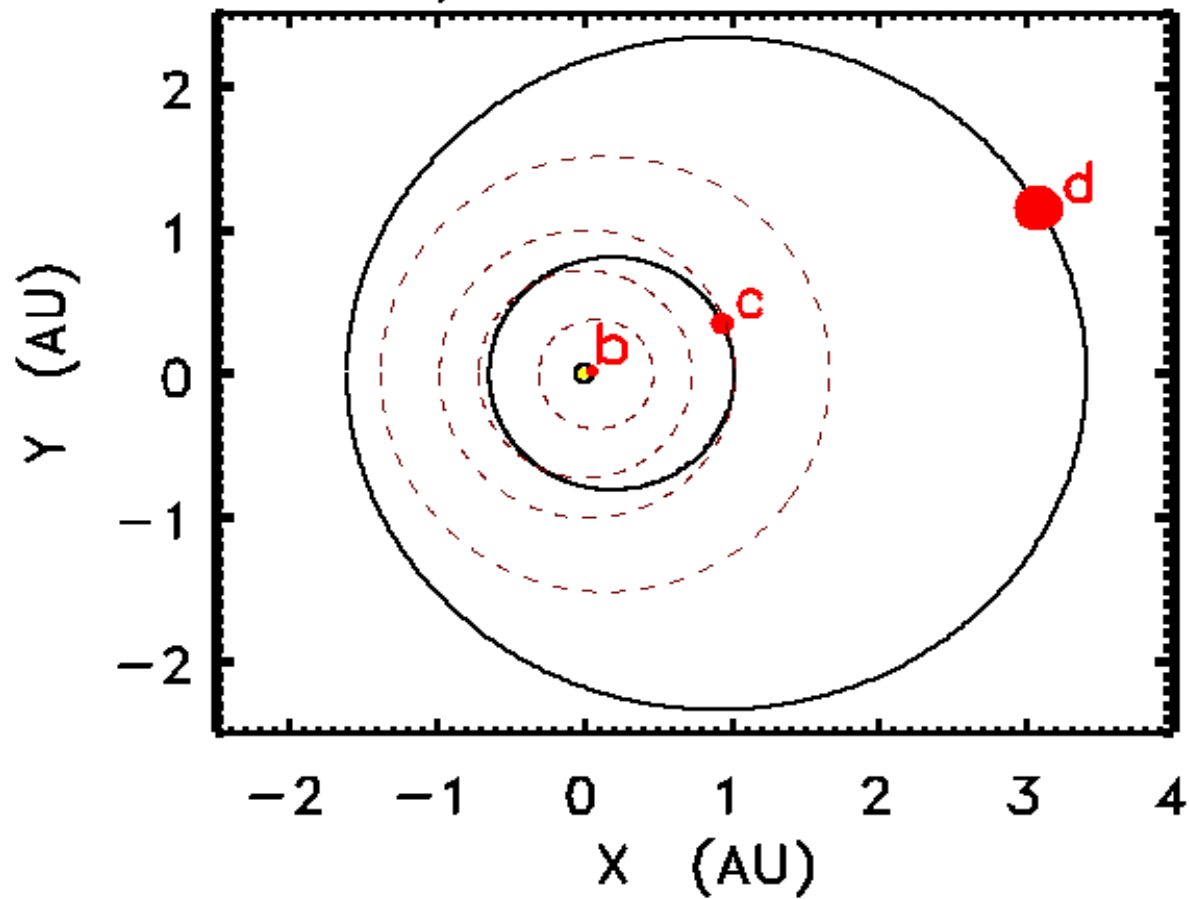


Multiple Planet systems

- If more than one period and amplitude is seen in the radial velocity curve it shows that multiple planets are present



Upsilon Andromedae



- Radial velocity measurements are most sensitive to massive planets close to their host star

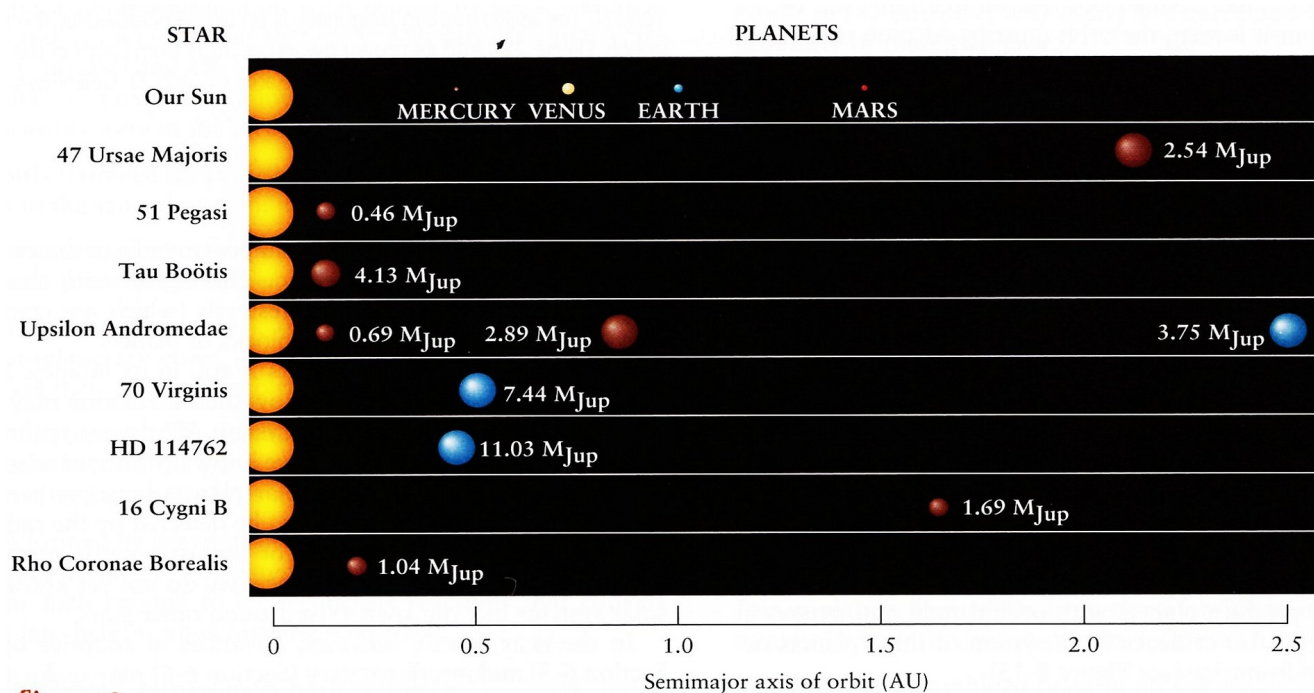
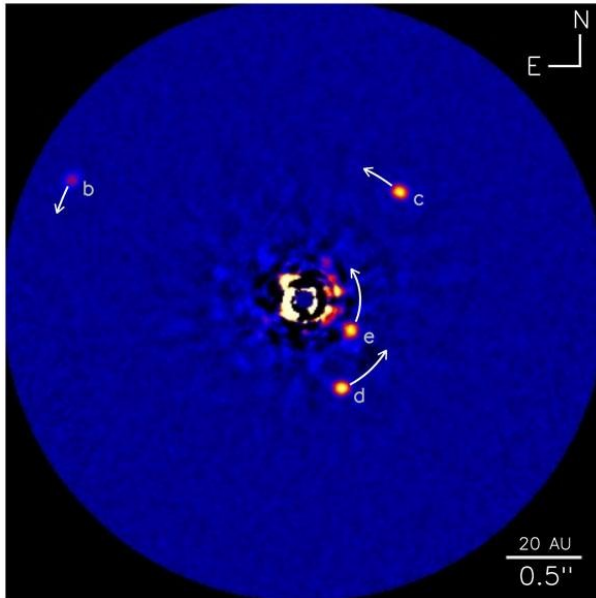


Figure 9.10

Direct imaging

- Imaging has been used to find large planets far from host star



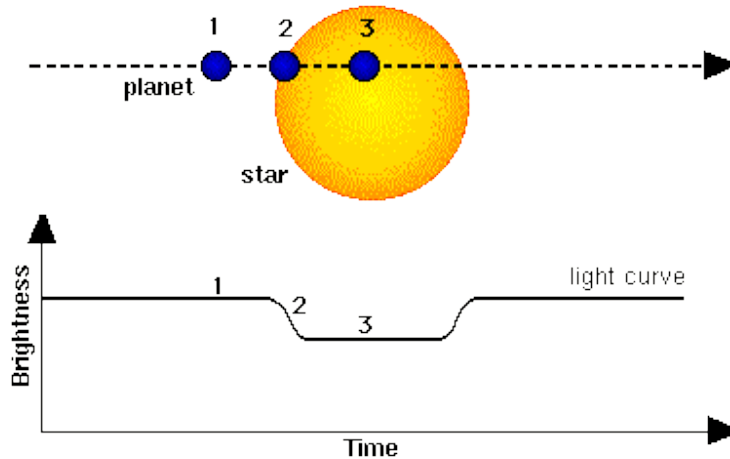
Four planets orbiting the solar-like star HR 8799 seen in the infrared image

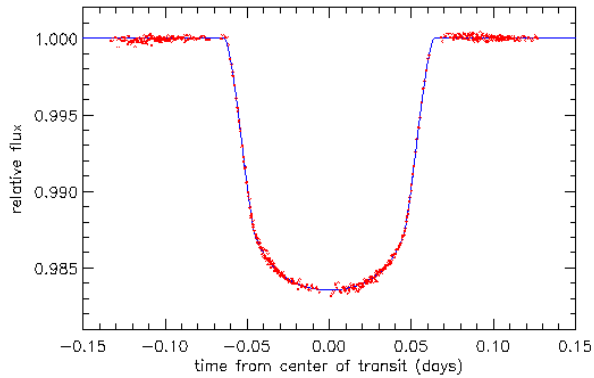
Credit: NRC-HIA, C. Marois & Keck Observatory

www.nature.com/nature/journal/v468/n7327/full/nature09684.html

Transits

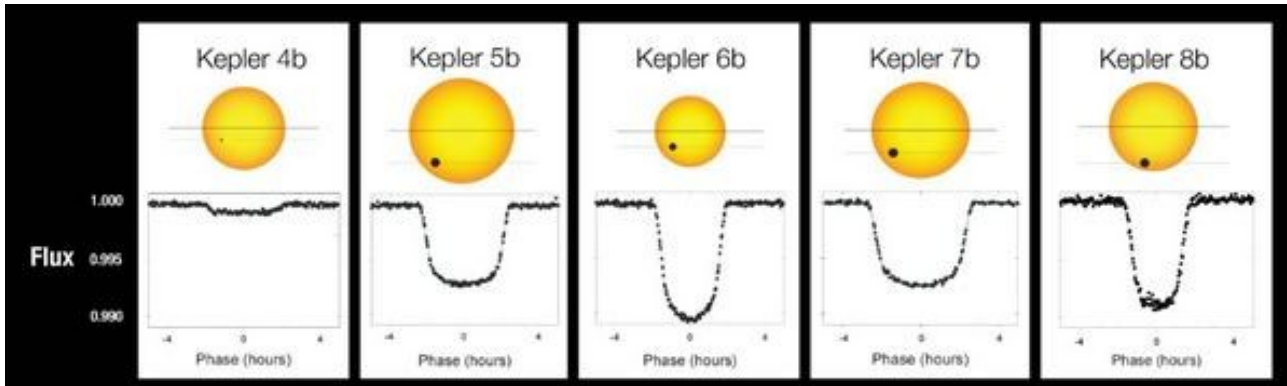
- A transit occurs when a planet crosses in front of the disc of the star
- Like a mini-eclipse it causes the star to dim slightly during the transit



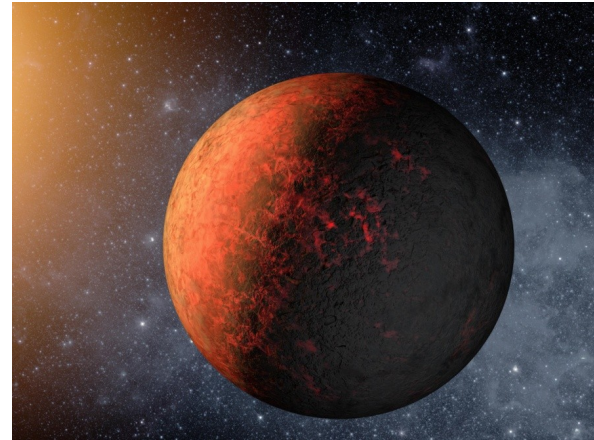
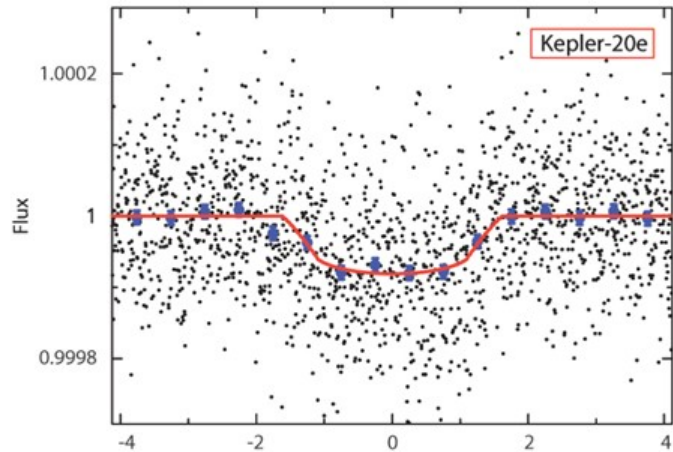


HST measurement of the dip in HD209458

- Depth of the transit is determined by the relative size of the planet to the star



- Kepler mission has discovered Earth-sized planets

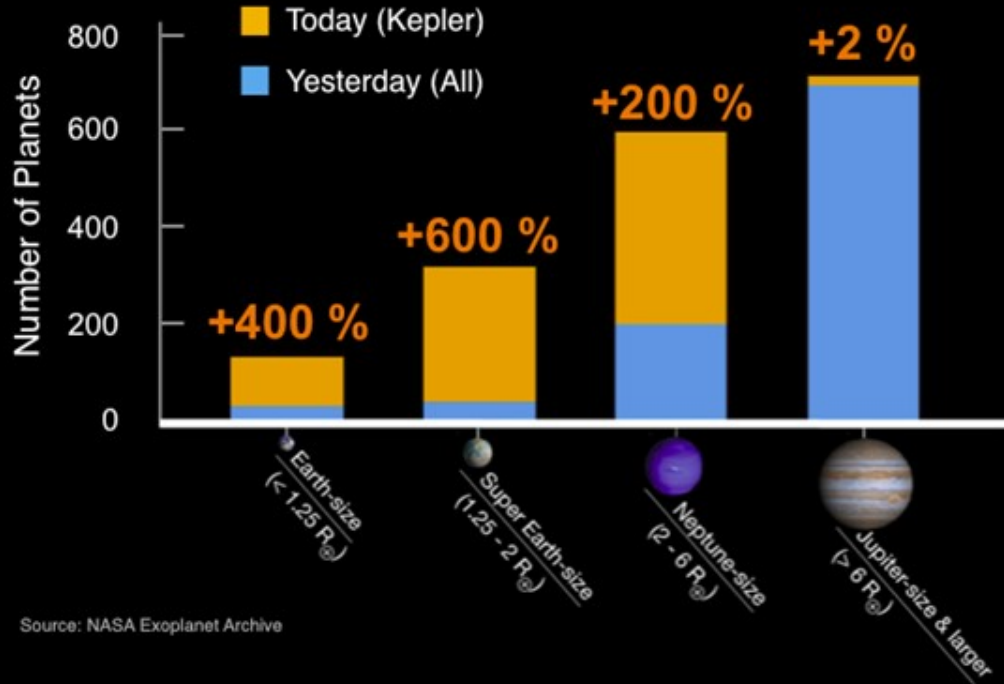


Kepler



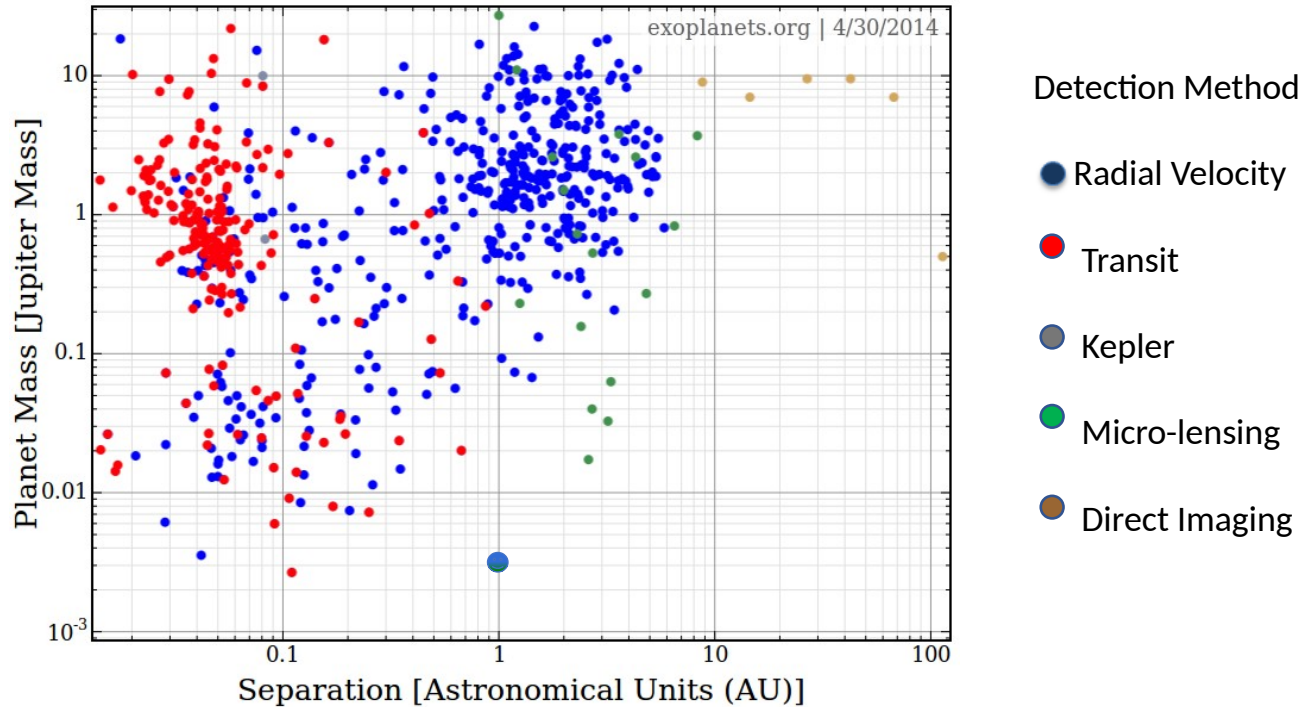
Sizes of Known Exoplanets

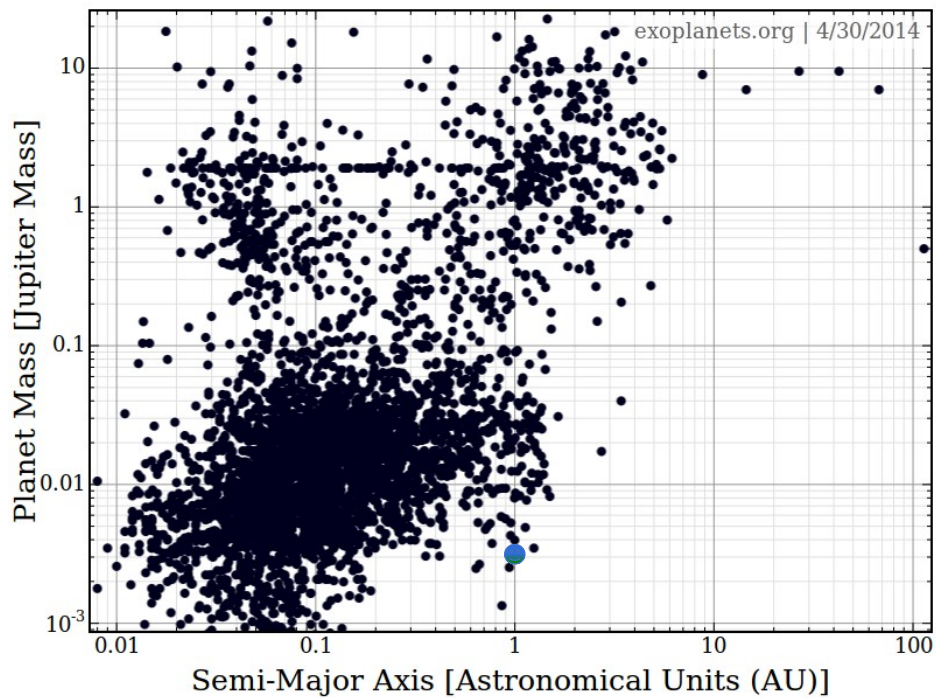
As of February 26, 2014



Source: NASA Exoplanet Archive

Mass and Separation

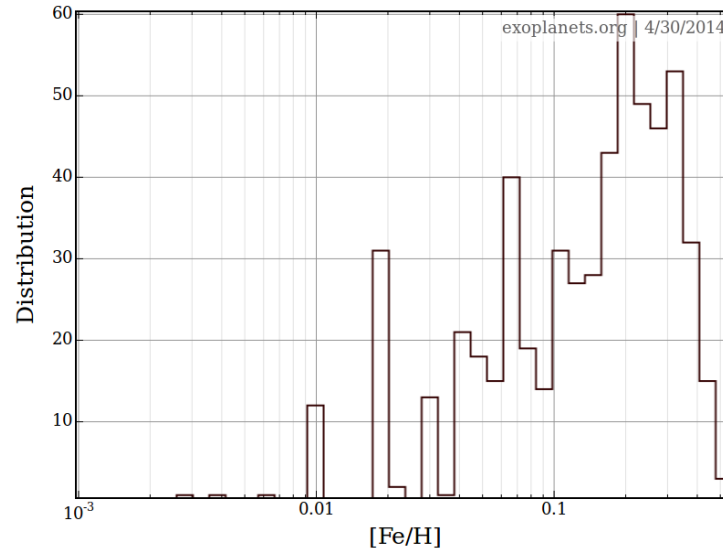




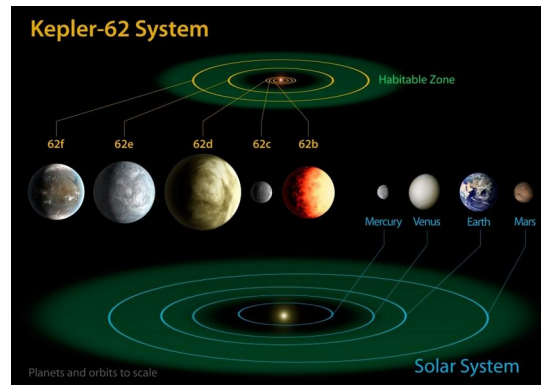
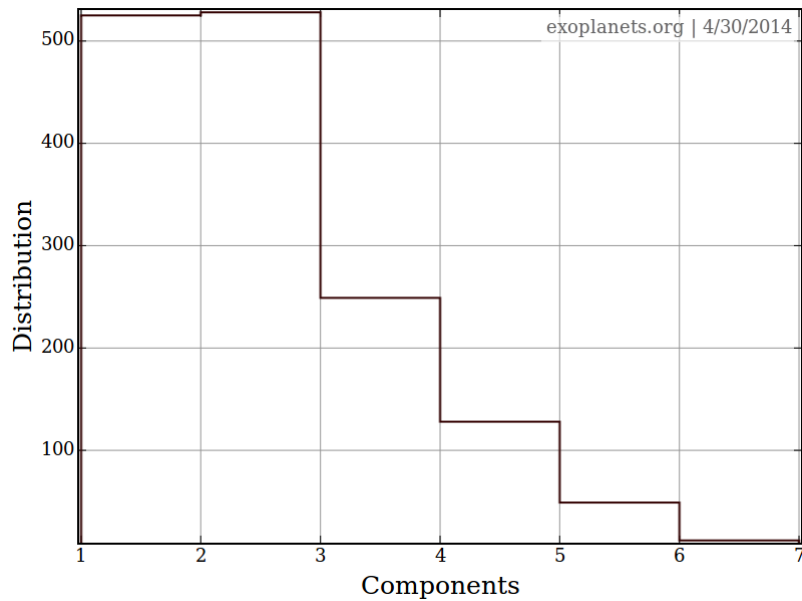
This plot contains
Kepler candidate
planets with
masses
estimated from
the measured
radius

Heavy Element Abundance

- Planets more likely to be found around stars with more heavy elements in them
- Support for core accretion model



- Multiple planet systems are common



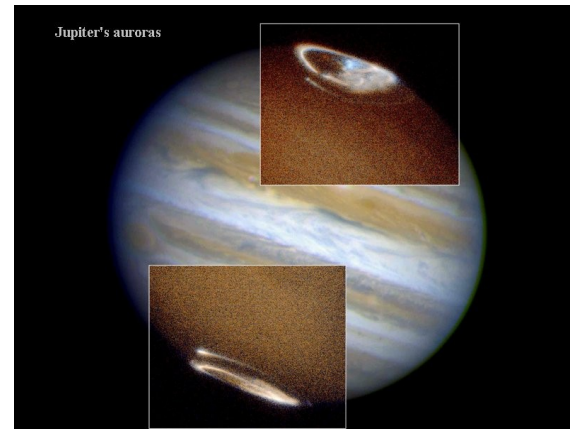
Planetary Migration

- Interactions between the planet and gas disc cause the planet to migrate inwards



Planetary Magnetic Fields

- Solar winds interacting with planetary magnetic fields and atmospheres create aurorae
- These produce very long wavelength radio emission



Summary

- Radial velocity technique delivers the mass and orbital radius of exoplanets
- Transits deliver radius of the planets and hence average density
- Kepler mission has shown that most stars have planets
- Planetary migration can explain 'hot Jupiters' and the eccentric orbits in many planetary systems