Lecture 35

Exoplanets: Planets Around Other Stars

Astronomy 141 – Winter 2012

This lecture describes the search for exoplanets: planets orbiting other stars.

Direct detection is very challenging, but now becoming possible with new technologies.

Indirect methods rely on effects of the planet upon its star to detect an otherwise unseen planet.

Radial Velocity (RV) and Transits are the most successful methods to date.

Gravitational Microlensing and Direct Imaging are finding an increasing number of interesting planetary systems.

As of 2012 Feb 14, we know of 760 planets around 609 stars.

There are two basic ways to search for planets around other stars

Direct Detection:
Take pictures of planets orbiting other stars.

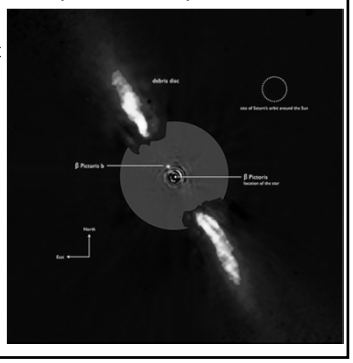
Indirect Detection:
Orbital motions ("wobbling") of the star because of the planet's gravity.

Observe the transits of planets crossing the disks of their parent star

Gravitational microlensing of a background star by the planet.

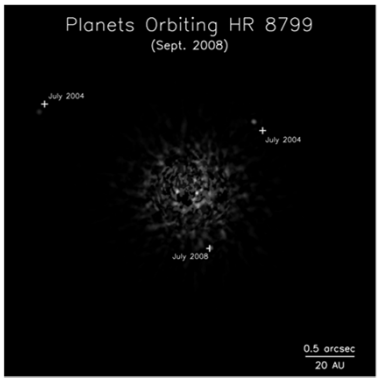
Direct Detection has only recently become possible with adaptive optics and space telescopes.

Challenge is finding a faint planet in the bright glare from the parent star.



27 planetary systems (31 planets) discovered via direct imaging to date.

Some are probably brown dwarf stars.

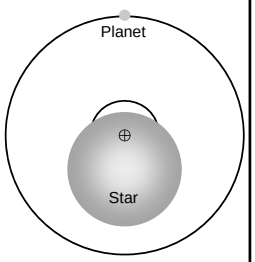


Keck Telescope, Mauna Kea – Adaptive Optics Imaging

Planets and Stars orbit each other about their common center of mass.

The parent star orbits *closer* to the center of mass because it has more mass.

The star's orbital speed is *smaller*, in proportion to the planet-to-star mass ratio.



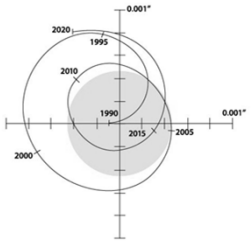
Observed from afar, the star appears to "wobble" around the center-of-mass of the star-planet system.

Astrometric Wobble is when a star wobbles back & forth on the sky relative to distant background stars.

The wobble is *very* small

From 18 light years away, the Sun's astrometric wobble is <0.001 arcseconds.

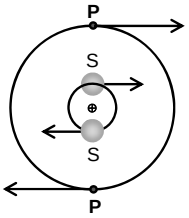
Combined motion due to Jupiter and Saturn.



Possible with future space missions like GAIA.

The Doppler Wobble or Radial Velocity (RV) method looks for orbital motions using the Doppler Effect

Star's spectrum Doppler shifts redward then shifts blueward



Measuring the orbital speed and period gives an estimate of the unseen planet's mass.

The greater mass of the star makes its orbital speed very small and thus challenging to measure.

Sun & Jupiter
Jupiter: 13 kilometers / second
Sun: 13 meters / second (30 mph)

Sun & Earth
Earth: 30 kilometers / second
Sun: 10 *centimeters* / second (0.22 mph)

Need to measure speeds with *extremely* high precision.

Current state-of-the-art is <1 meters/sec, but not yet cm/sec.

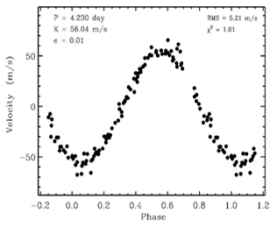
In 1995, 51 Pegasi became the first Sun-like star with a planet detected by the RV method.

Michel Mayor & Didier Queloz (Geneva Observatory)

~40 ly away in Pegasus

Orbital speed of 56 m/sec

Orbits every 4.23 days!



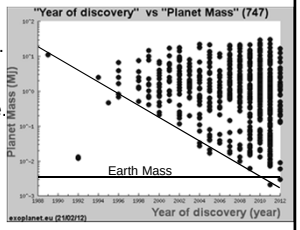
The period and speed make this is a 0.5 Jupiter-mass planet orbiting only 0.05 AU from its parent star!

To date most of known exoplanets have been discovered using the RV method.

Most sensitive to big planets around relatively nearby stars.

Sensitivity increases with time.

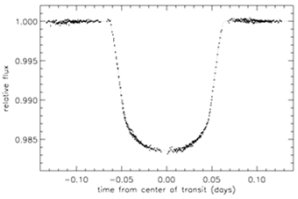
State of the Art is now below 1 meter/sec precision.

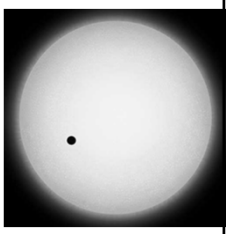


Only now approaching the sensitivity to detect Earths…

Planetary Transits occur when the planet's orbital plane is aligned with our line of sight.

The planet periodically crosses (*transits*) its parent star, briefly dimming it





193 transiting systems known, many more on the way

The transit depth measures the ratio of the areas of the planet and the star.

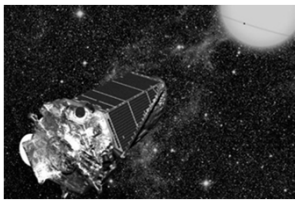
Jupiter: 0.1 R_{sun}
1% Transit Depth

Earth: 0.01 R_{sun}
0.01% Transit Depth

The latest techniques can detect Earth-sized planets...

Most transiting planets to date have been discovered by the Kepler spacecraft

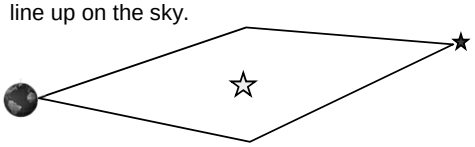
Launched in 2008, main goal is to find and Earths In the habitable zones of FGKM type parent stars.



It find lots of other planets, strange binary and triple star systems, etc.

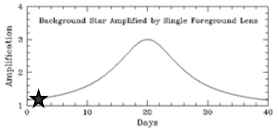
Unusually sensitive to close-in planets.
Has discovered a number of multi-planet systems
Closing in on Earth-sized planets...

Gravitational Microlensing occurs when two stars line up on the sky.



Light from the background star gets amplified by the gravity of the foreground star.

Brief brightening of the background star by the foreground lensing star



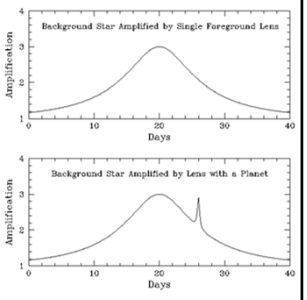
If there is a planet around the lensing star, it will also amplify the background star a little bit.

Get a small "bump" of extra magnification by the planet.

Method invented by OSU astronomer Andy Gould.

So far, 9 planets have been discovered this way

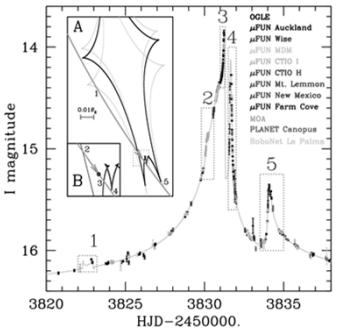
Most by OSU's Microlensing Follow Up Network (MicroFUN)



OGLE-2006-109bc is the first true Solar System analog found so far.

Jupiter and Saturn sized planets in similar orbits scaled to the parent star.

OSU-led discovery enabled by our network of amateur astronomers.



As of February 2012, we have found 760 planets around 609 stars.

Most are single planets

A large number of multi-planet systems have been found.

Most are Jupiter-mass or larger

A few Neptune-mass planets and an increasing number of "super Earths".

Found the first candidate Earth-mass and smaller planets...