Extrasolar Planets: *Planets Around Other Stars*

See “Life in the Universe” Ch. 10 and the “Extrasolar planets” section of Class Website

For most of human history, we knew of 5 planets (M,V,M,J,S)
By 1600 there were 6: the Earth!
By 1930 there were 9 (...if you count Pluto)
As of spring 2006, there are over 192! Over 184 of these orbit other stars.

Too faint and small to be directly “seen” (lost in the glare of their star); ten billion to one contrast in optical light!

We find them through indirect techniques:

- astrometry
- Doppler shift
- transits
- gravitational microlensing

Astrometry & Doppler Indirect Detection Methods:
The gravity of a star pulls on a planet; the planet must also pull on the star (“equal and opposite forces”). So both the planet and star orbit around the center of mass of the system (the balance point). Thus the star “wobbles” in the sky.

Wobble motion can be detected two ways:

1. Astrometry: the position of the star on the sky. Very challenging to do, but space missions are being built that can measure the reflex motion of the star (SIM, GAIA).
2. Doppler effect: star’s velocity changes as it orbits: sometimes coming towards us (blueshift) sometimes moving away (redshift)

Measuring the Doppler shift is hard, but it is being done....
with great success: >180 planets! (as of May 2006)
18 multiple planet systems have been found.

In general, these new planets are NOT like planets in our Solar System:
- some orbit very close to their star, so they are hot: called “hot Jupiters”
- very short orbital period: their “years” are only days!
- many have eccentric (highly elliptical) orbits

Transit Method: A “transit” is a partial eclipse
If a planet passes in front of its star, it creates a shadow; brightness of the star decreases.
Transits are very important because they give the relative radius and mass of the planet.

e.g. for HD 209458b
Mass = ~ 0.65 $M_{Jupiter}$ (no inclination sin i problem)
Radius = ~1.35 $R_{Jupiter}$
Density → definitely a gas giant planet: a “Hot Jupiter”

As of 2007 we know of seven transiting planets:

HD 209458 - the brightest and best studied
TrES-1 - discovered in the summer 2004
HD 149026 - discovered in the summer 2005
HD 189733 - discovered in fall 2005
OGLE-TR-56 + 2 more "OGLE" planets

No new planets have been detected via transits, but many are expected with new searches. As of 2001 we know of one transiting planet: HD 209458

Gravitational Microlensing: Einstein's general relativity tells us that gravity can bend space. Therefore light paths are bent too. A large mass can bend space, creating a lens effect.

Objects behind the lens are magnified and multiple images are seen. If a star passes in front of another star, it will magnify the brightness of the background star.

If the foreground star has a planet, it will cause additional brightening.

We measure brightness of stars to find planets; we can detect very small planets this way, even Earth size.

But few planets discovered to date via this method, due mostly to limited resources (lack of coordinated telescopes, weather).

2004 April 15:Gravitational microlens discovery of an extrasolar planet: OGLE-2003-BLG-235
mass ~ 1.5 $M_{Jupiter}$ orbit ~ 3 AU

Caution: There is a strong bias in exoplanet discoveries.

Current technology can only detect massive planets that are close to their stars;
"hot Jupiters" are easy to find, "cold Earth's" are every hard.
We are not able to detect a planetary system like the Solar System... ...yet.
Most of the stars that have been searched are:

- nearby (< 600 light years)
- Sun-like (FGK type stars)

because this optimizes success (bright, and lots of sharp spectral lines)
Many more planets remain to be found.
But already we know something amazing:

About 5% of Sun-like stars have planets! Planets are not rare!

Interesting point: Some of the extrasolar planets discovered orbit their star in the "habitable zone". **Habitable zone:** region around a star where the temperatures on a planet are such that liquid water can exist. Assumed to be the most likely place for life.