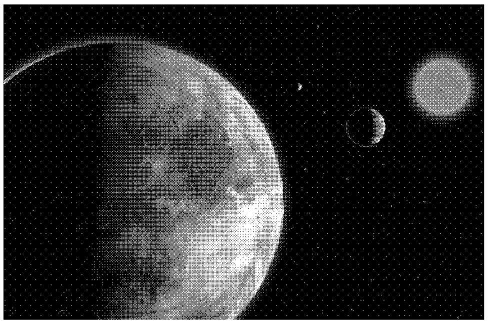
Monday, November 15

Exoplanets



Exoplanets
Key Concepts

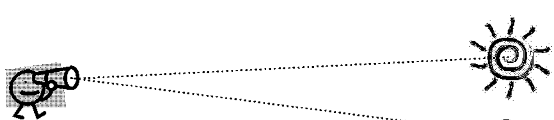
1) Direct detection of exoplanets (planets around stars other than the Sun) is extremely difficult.

2) The most useful methods for indirect detection are the Doppler technique & transit technique.

3) So far, about 500 exoplanets have been found orbiting other stars.

Direct detection of “exoplanets” is difficult.

Imagine: an astronomer orbiting Proxima Centauri wants to find planets orbiting the Sun (4.24 light-years away).

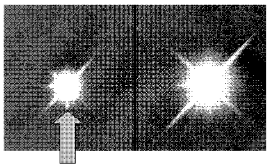


Jupiter has the best chance of being seen.
(It’s biggest, and reflects the most light.)

Seen from Proxima Centauri, the Sun & Jupiter are at most 4 arcseconds apart. (This angle is resolvable with a small telescope).

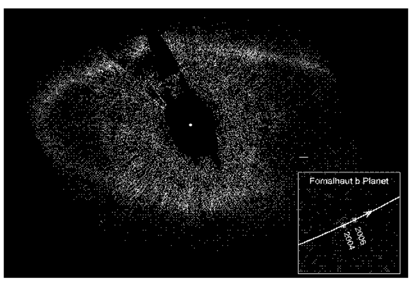
However, Jupiter is 1 billion times fainter than the Sun: it's lost in the glare!

Short exposure



Long exposure

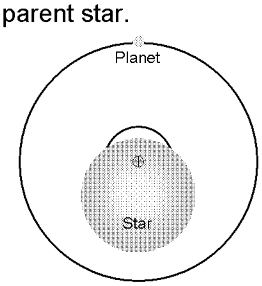
Only a few exoplanets, orbiting far from their parent star, have been directly detected.



Example: a planet has been seen orbiting 115 AU from the star Fomalhaut.

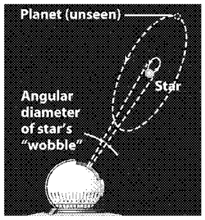
Indirect "Doppler technique": planets can be detected by the Doppler shift they produce in their parent star.

Jupiter and the Sun each orbit the center of mass of the Sun – Jupiter system.



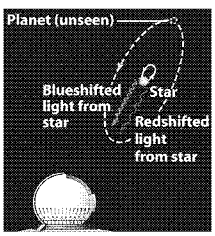
Mass of Sun = 1000 × mass of Jupiter

Sun's orbit = 0.001 × size of Jupiter's orbit



Seen from Proxima Centauri, the Sun's orbit is 0.004 arcseconds in radius; this is too small to be easily measured.

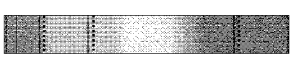
Sun's orbital speed = 0.001 × Jupiter's orbital speed = 12.5 meters/sec.



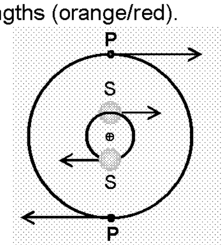
Variations in a star's speed lead to variations in the **Doppler shift** of the star's light!

Doppler effect:
A light source moving toward you has its light shifted to shorter wavelengths (blue/violet); moving away, its light is shifted to longer wavelengths (orange/red).

Star's spectrum Doppler shifts redward



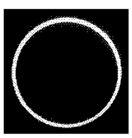
Star's spectrum Doppler shifts blueward



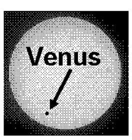
A shortcoming of the "Doppler technique":

It works *only* if the star's speed is large enough to be measured. This happens when the planet is
(1) massive and
(2) close to the star.

Indirect "transit technique":
planets can be detected when they eclipse (or **transit**) their parent star.

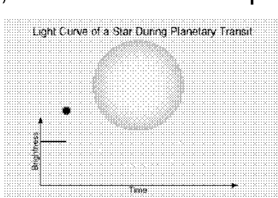


During a **solar eclipse**, the Moon passes between the Earth and Sun: the Sun's brightness dips greatly.



During a **transit of Venus**, Venus passes between the Earth and Sun: the Sun's brightness dips slightly.

When a distant star is transited by one of its planets, its measured flux drops slightly.



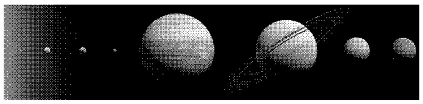
The time between transits tells us the planet's orbital period.

The amount of dimming tells us the size of planet.

A shortcoming of the "transit technique":

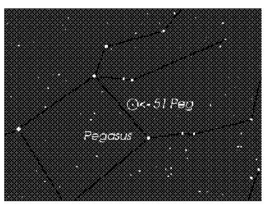
It works *only* if the dimming of the star is large enough to be measured.

This happens when the planet is big.



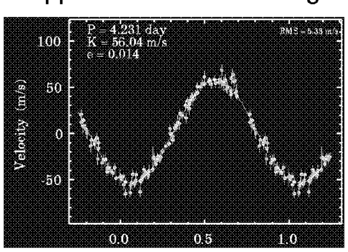
Terrestrial bad, Jovian good.

First discovery of an exoplanet using the Doppler technique was in 1995.



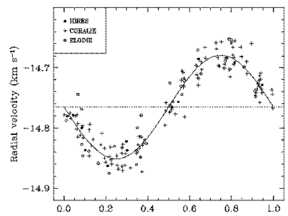
The exoplanet was found orbiting 51 Pegasi, a Sun-like star.

Doppler "wobble" of 51 Pegasi:



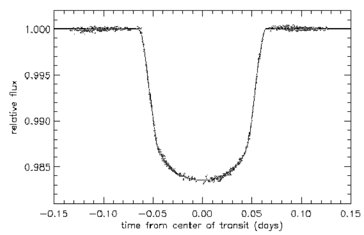
Planet mass ≥ ½ M_{jup}
P = 4.2 days
a = 0.05 AU

A star with a well-studied exoplanet:
HD 209458



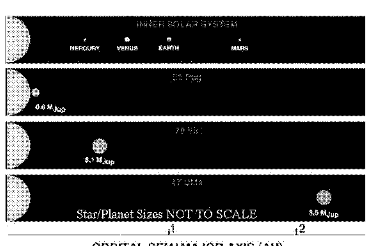
After the star was found to have variations in its Doppler shift, it was found to have dips in brightness.

Transit of the star HD 209458 by its planet:



Mass of planet = 0.685 M_{jup}
Radius = 1.42 R_{jup}
Density = 0.3 grams/cm^3

Count as of today: 497 exoplanets have been discovered around 419 stars (some stars have multiple planets).



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