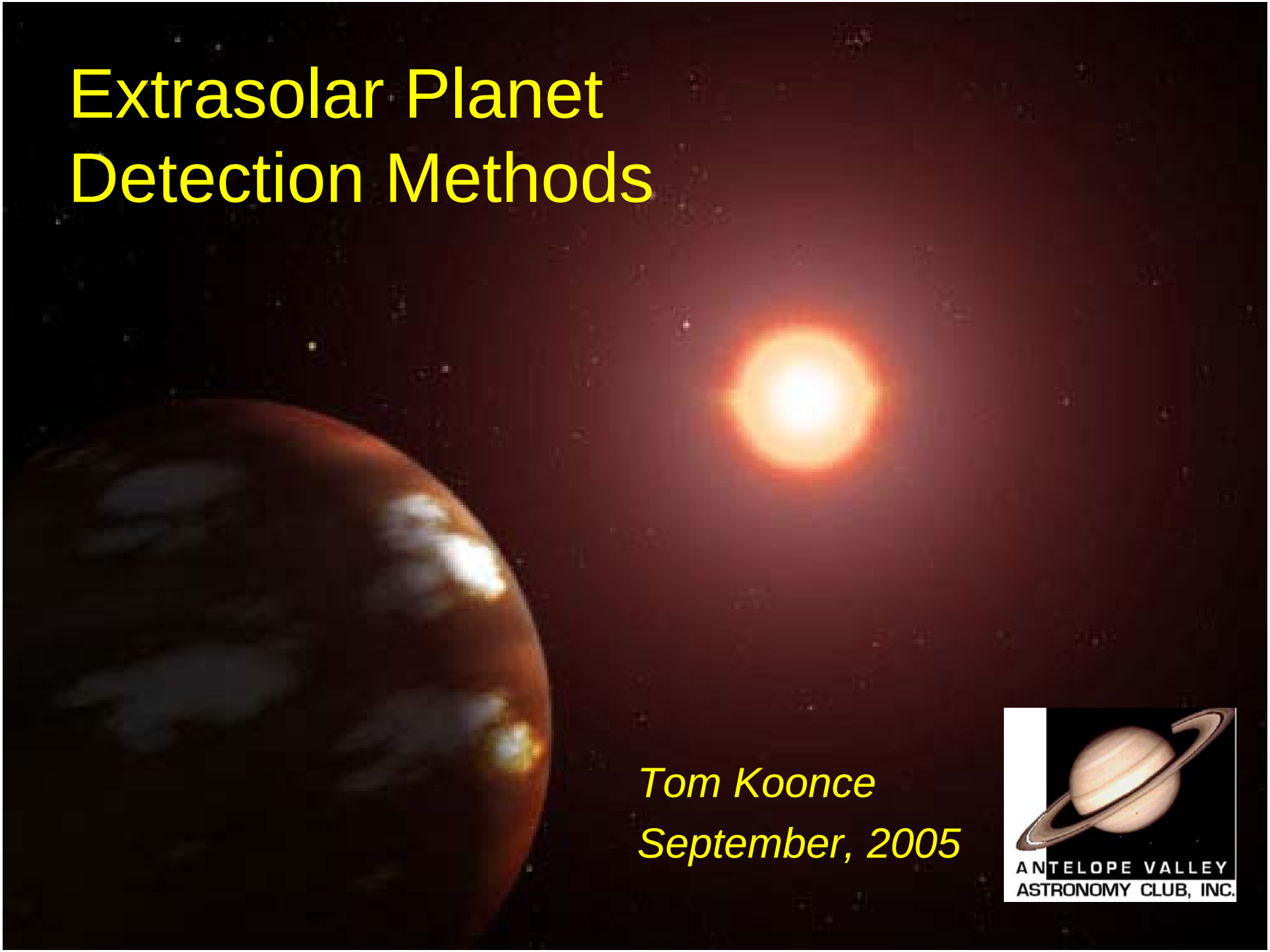
Extrasolar Planet Detection Methods



Tom Koonce

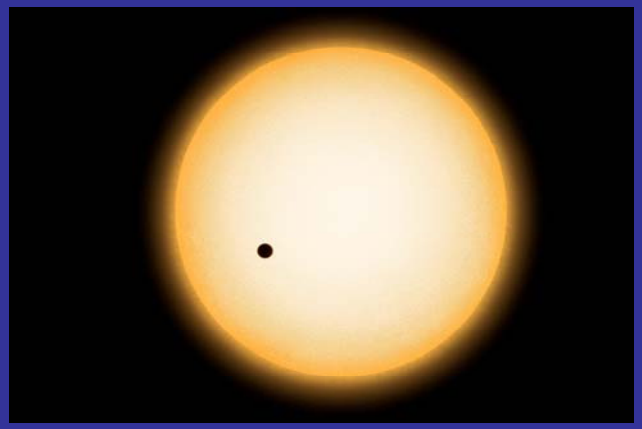
September, 2005

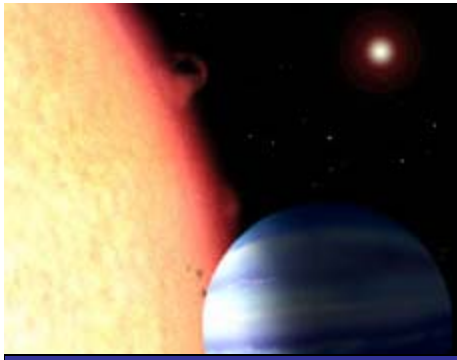
ANTELOPE VALLEY ASTRONOMY CLUB, INC.

Planets Around Other Stars?

How is it possible to see something so small, so far away?

- If everything is aligned perfectly, we can see the light of the star dim if a planet passes in front of it
- We can see the effects of an orbiting body on the parent star by looking carefully at the star's light spectrum





Planet Finding Methods:

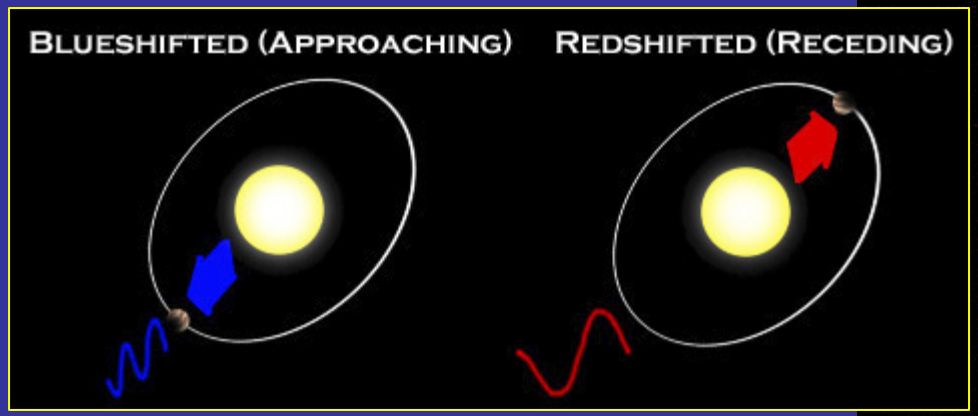
- ‘ Light Curve’ Analysis
  - ‘Doppler Wobble’ of star (red shift / blue shift of spectra)
  - Decreased light from star ‘Planetary Eclipsing’
  - Gravitational ‘Microlensing’
- Gravitational Waves (Not demonstrated yet)
- Optically (Not demonstrated as of 09/10/05)

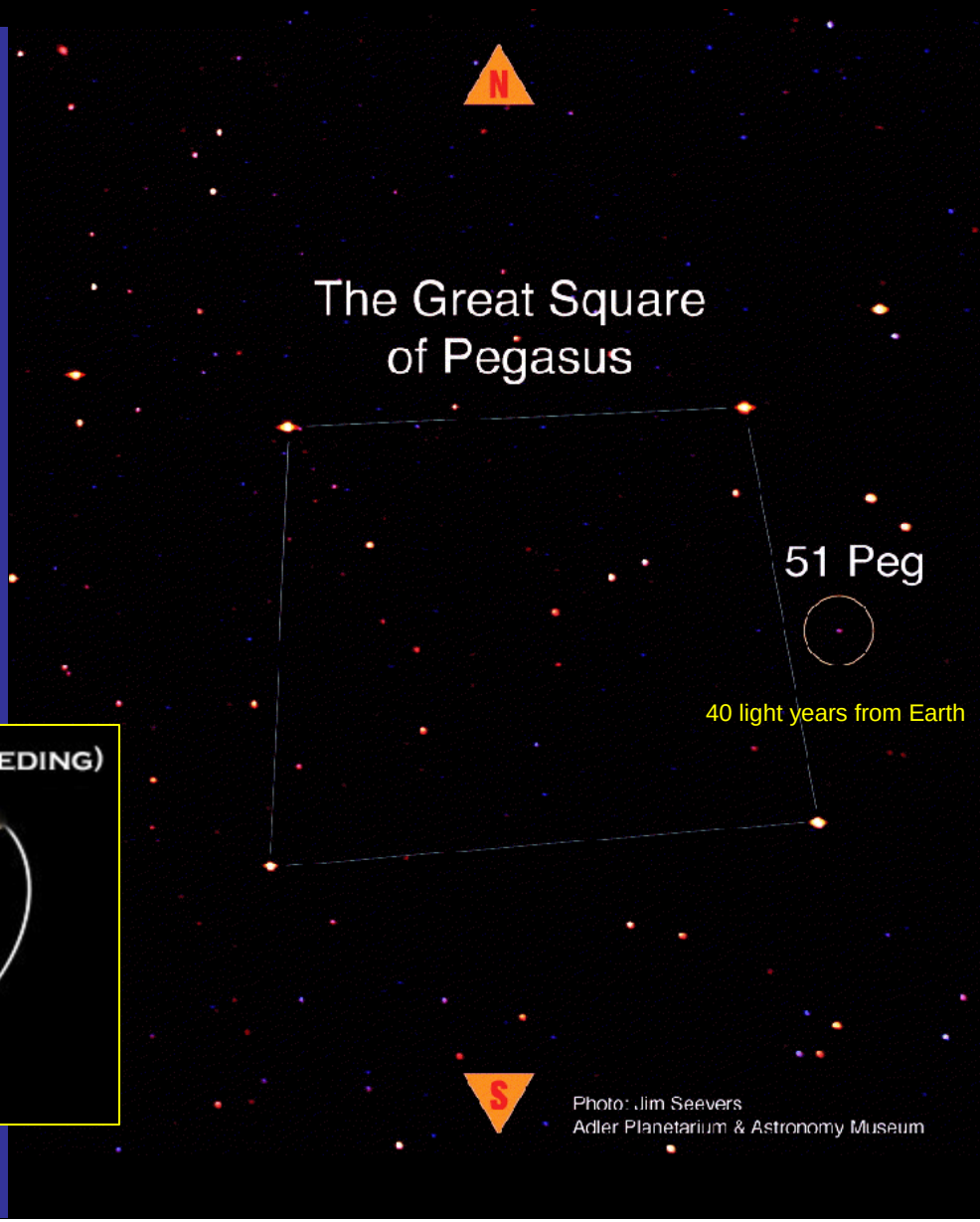
Discovery of a Planetary Orbit around 51 Pegasi

October 6, 1995:

Michel Mayor and Didier Queloz from Geneva Observatory reported the discovery of a Jupiter--mass planet in orbit around the solar--type star 51Pegasi.

The claim was based on 18 months of precise Doppler measurements done with a spectrograph

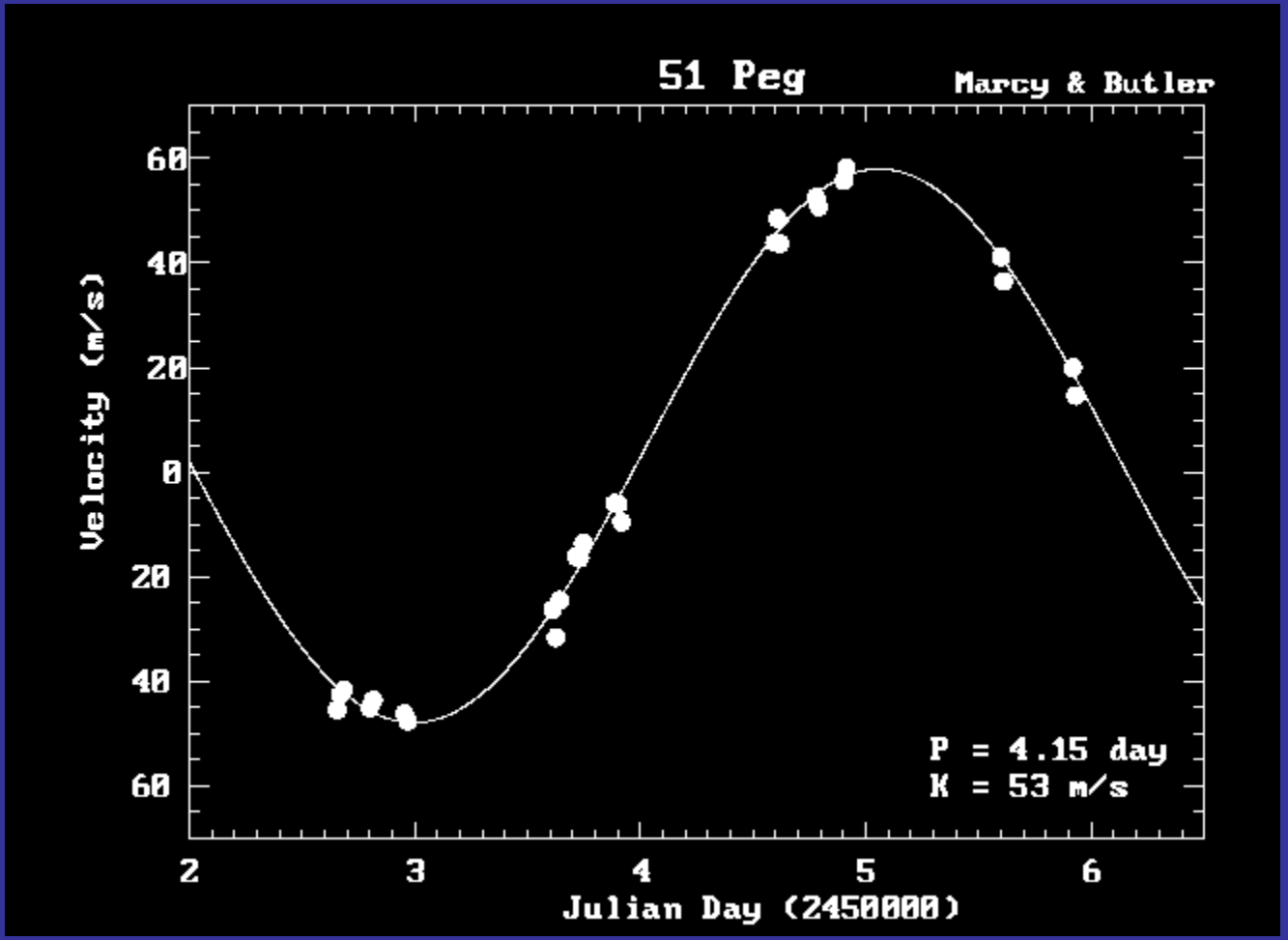




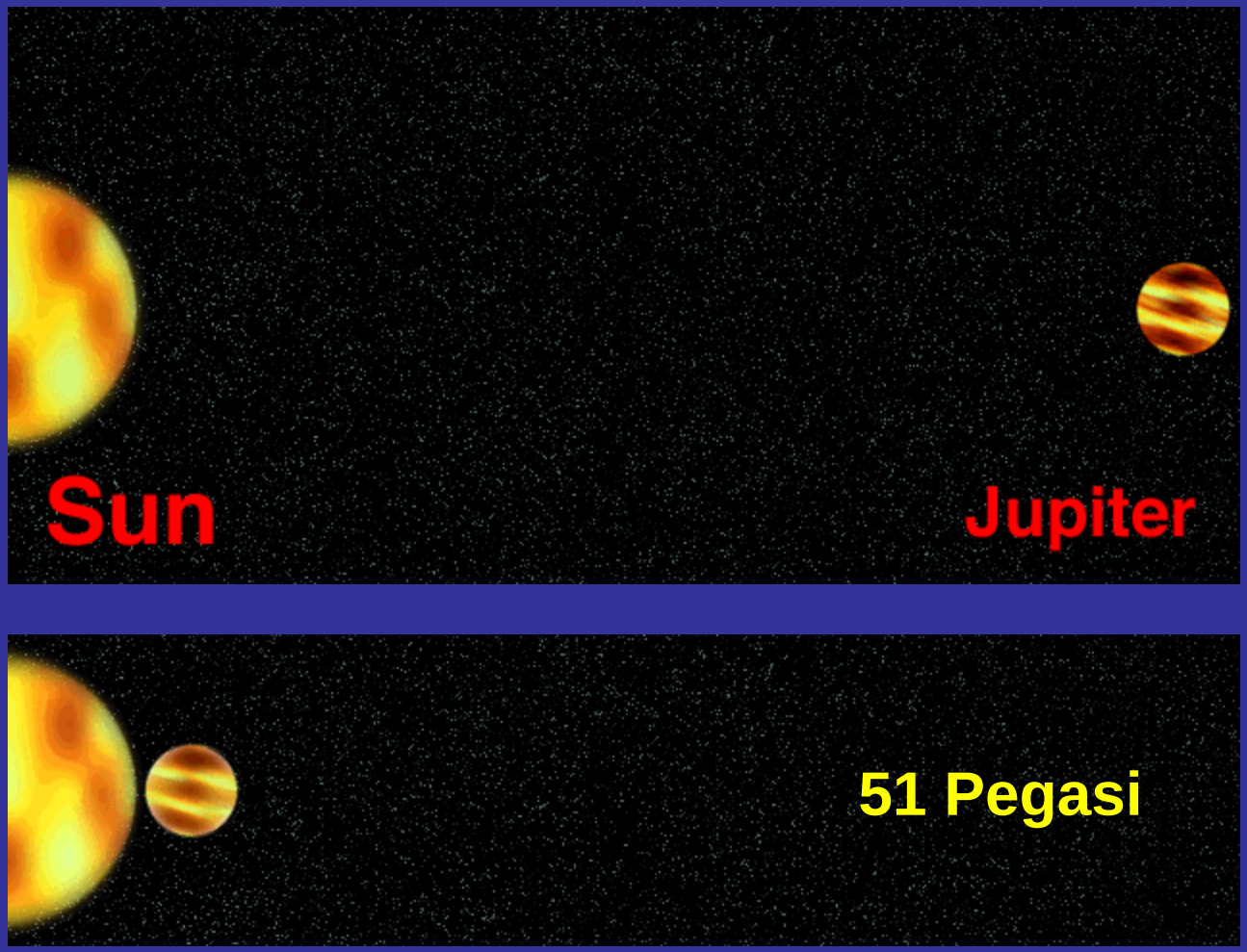
Doppler Analysis of Light Curve

Results

- Body orbits 51 Pegasi in just 4.2 days
- Semi-major axis 0.05 AU
- Probable mass of 0.5 Jupiters



Big and Close = Big Wobble



Artist's Conception

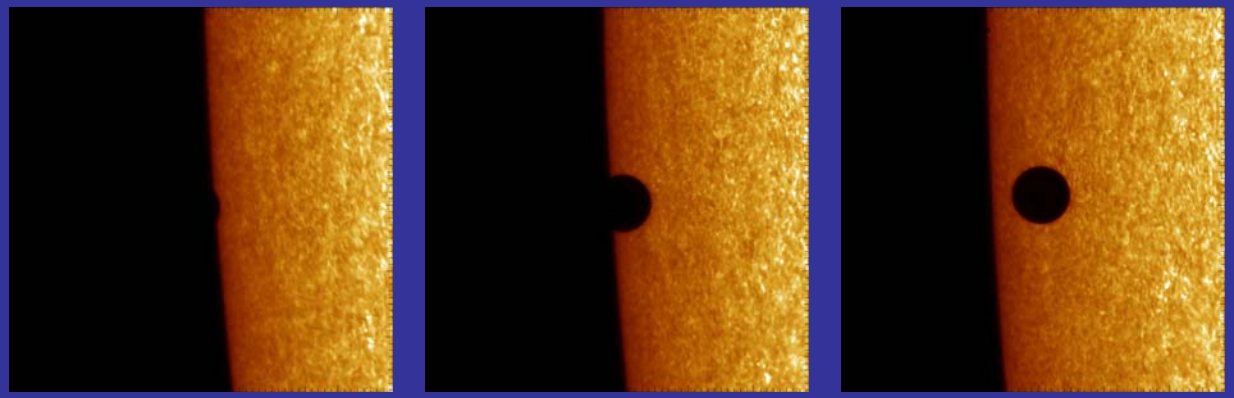
Planets Discovered

Planets Discovered Using “Doppler Wobble”

- 136 (UPDATE)
- Why the largest percentage?
  - Imaging systems and computers are very efficient at looking at multiple spectra simultaneously
  - Hubble recently identified 100 more candidate planets!
  - Amateurs have detected planets around other stars using this method using commercial off the shelf equipment
  - The Doppler Wobble method does not depend on the distant planet being in near-perfect alignment with the line of site from the Earth, and can be applied to a far greater number of stars. It provides an accurate estimate of a planet's mass, and not just a minimum figure

Another Method: Planetary Eclipsing

Mercury Transit May 7, 2003



Venus Transit
June 8, 2004

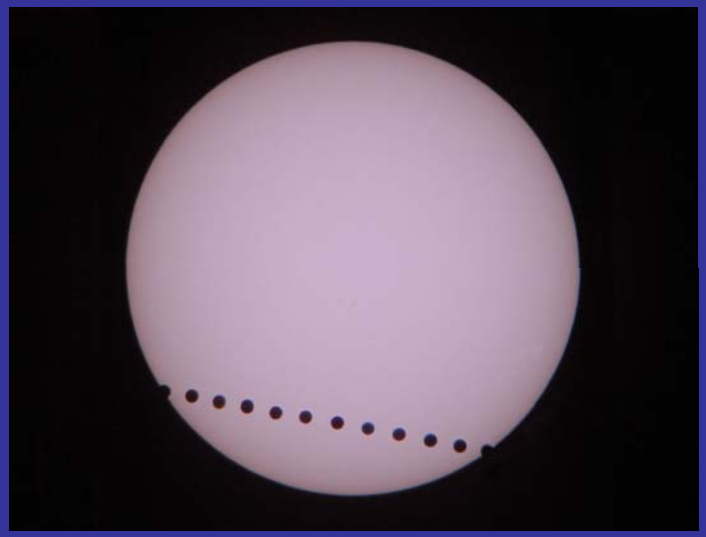
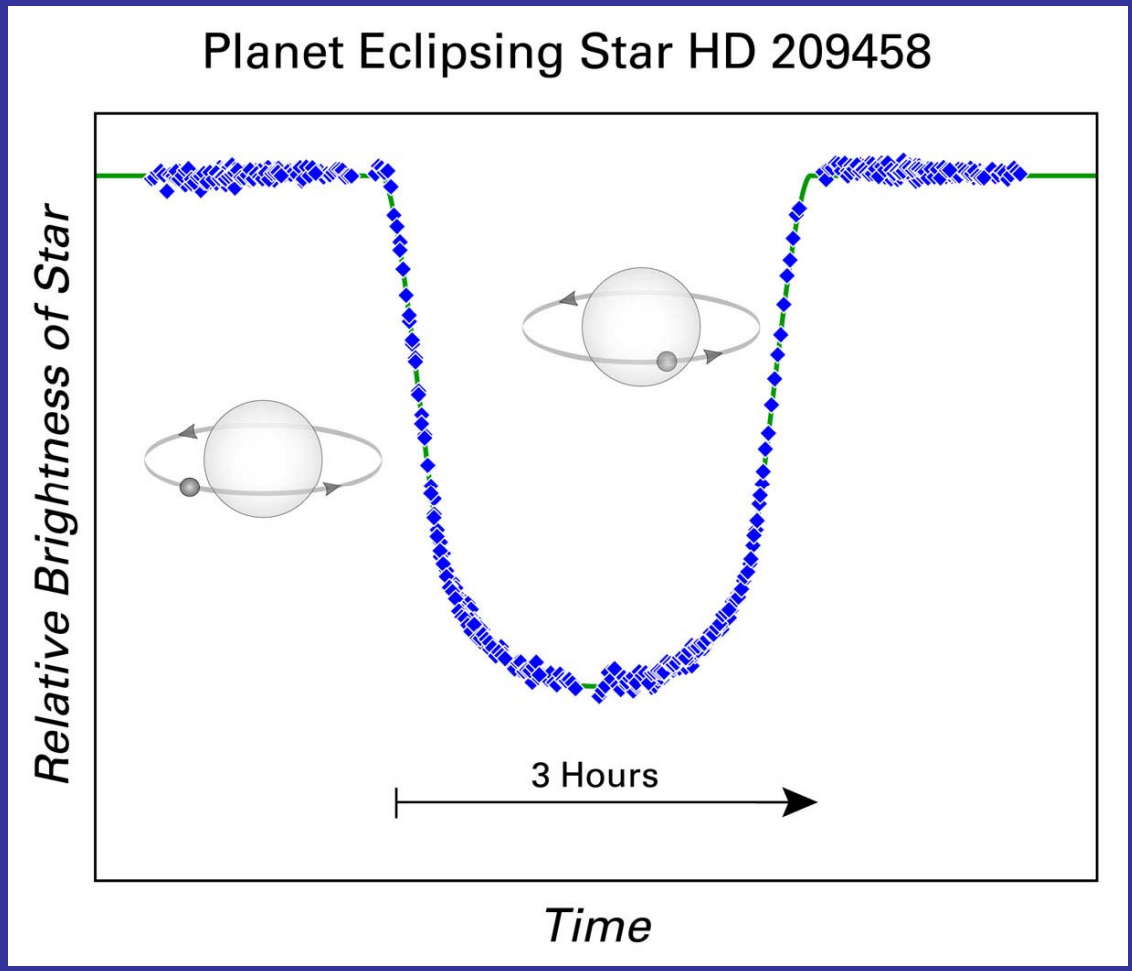


Photo Credit: The Swedish 1-m Solar Telescope (SST) of the Royal Swedish Academy of Sciences on the Canary Islands

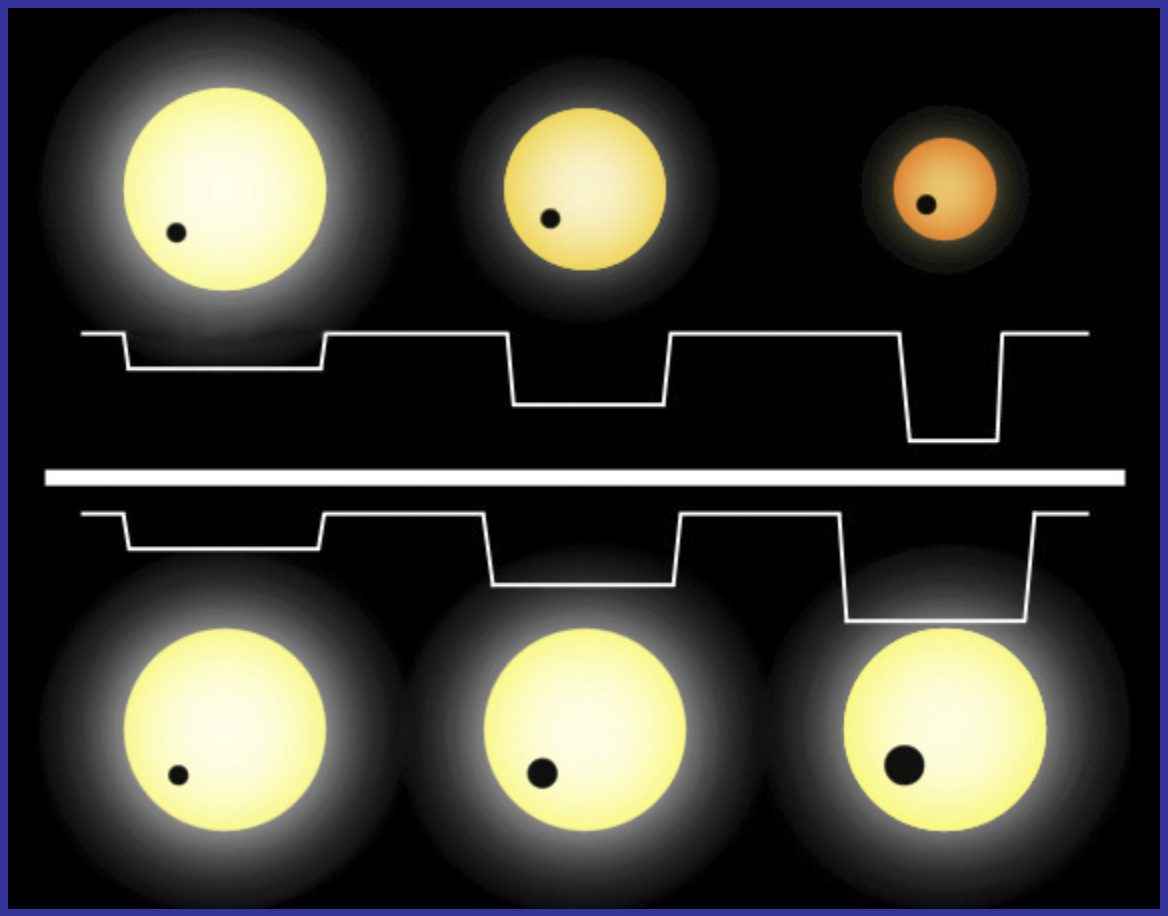
Planetary Eclipsing

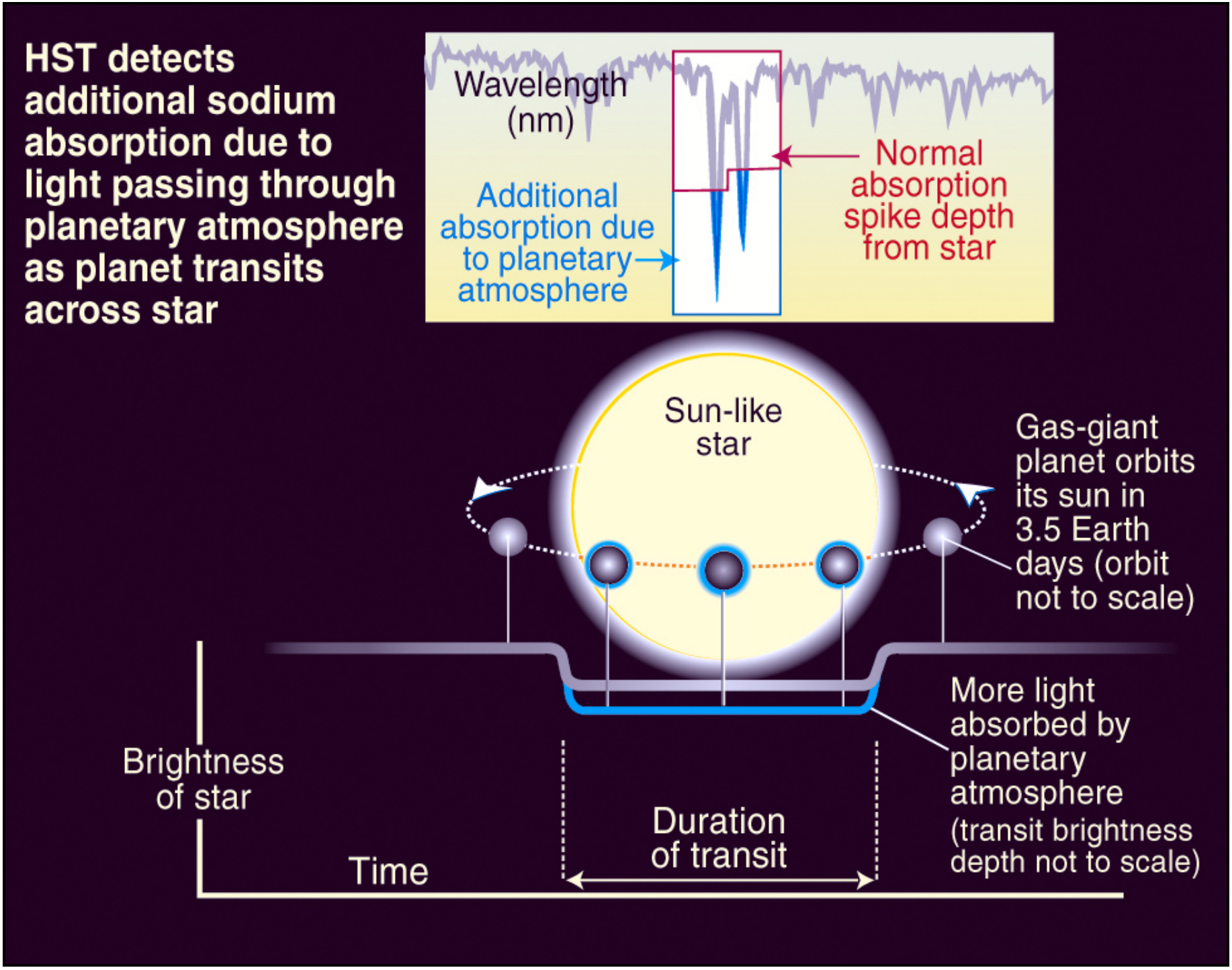
If we are well aligned with the extrasolar planetary system, it is possible to measure the reduction in light coming from a star as a planet transits.



Planetary Eclipsing

Reduction in light depends upon the size of the star and the size of the eclipsing body




HST detects additional sodium absorption due to light passing through planetary atmosphere as planet transits across star
Wavelength (nm)
Additional absorption due to planetary atmosphere
Normal absorption spike depth from star
Sun-like star
Gas-giant planet orbits its sun in 3.5 Earth days (orbit not to scale)
More light absorbed by planetary atmosphere (transit brightness depth not to scale)
Brightness of star
Time
Duration of transit

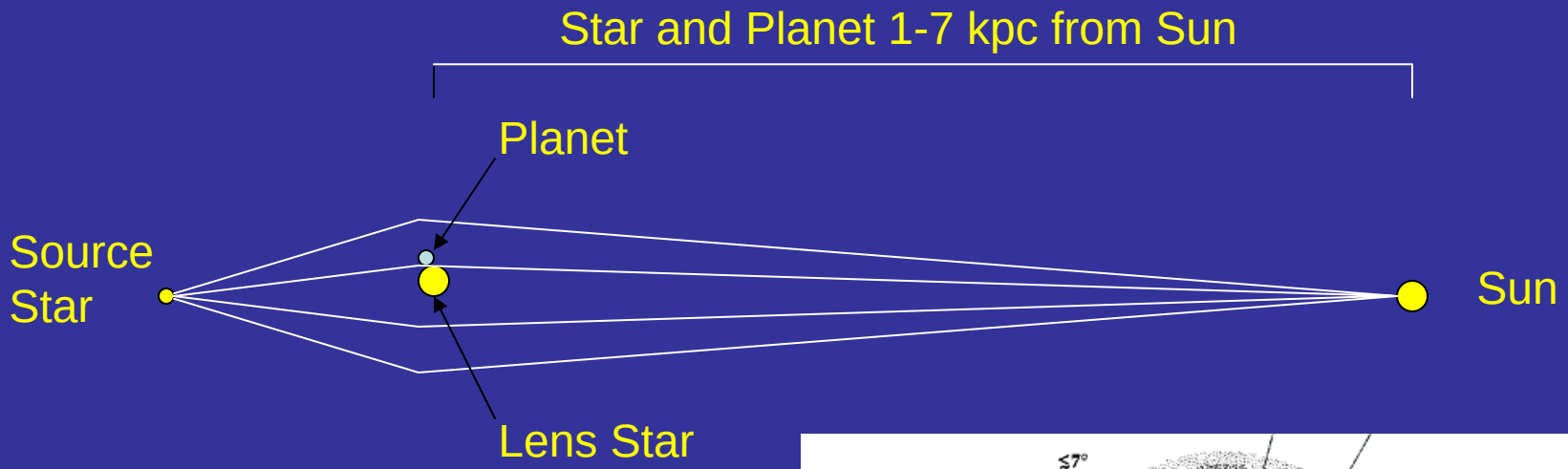
Planets Discovered

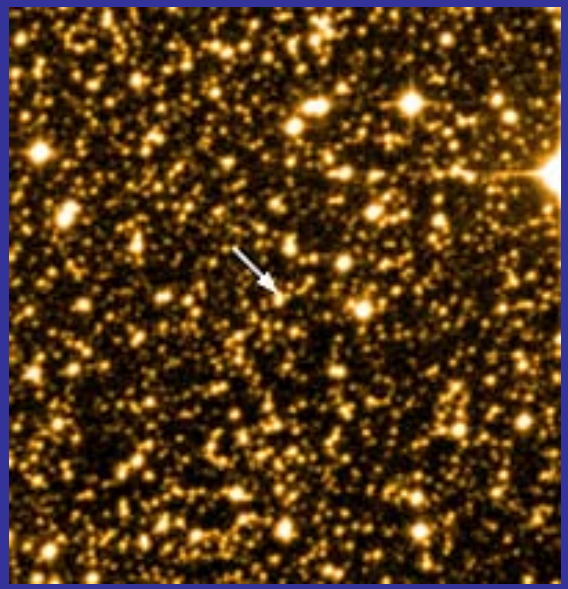
Planets Discovered Using the Planetary Eclipsing Method: 20 (UPDATE)

Why so few?

- The extrasolar orbit must be perfectly aligned with us for us to witness the eclipse.
- Can be misled by very cool brown dwarf stars in orbits around the primary star. The Dwarfs can have their own spectra overwhelmed by the larger star. Long term observation can rule this out.

Microlensing



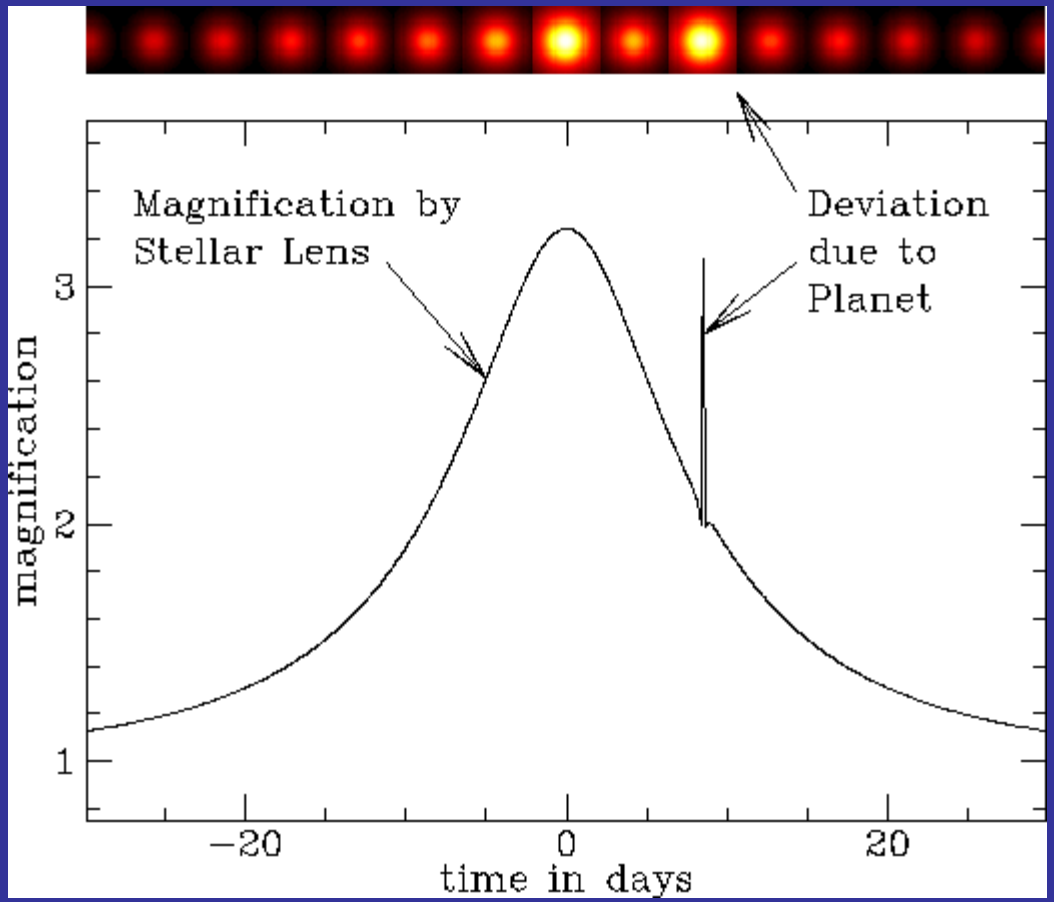


Observations must be made of dense star clusters to improve the chances of exact alignment and detection.

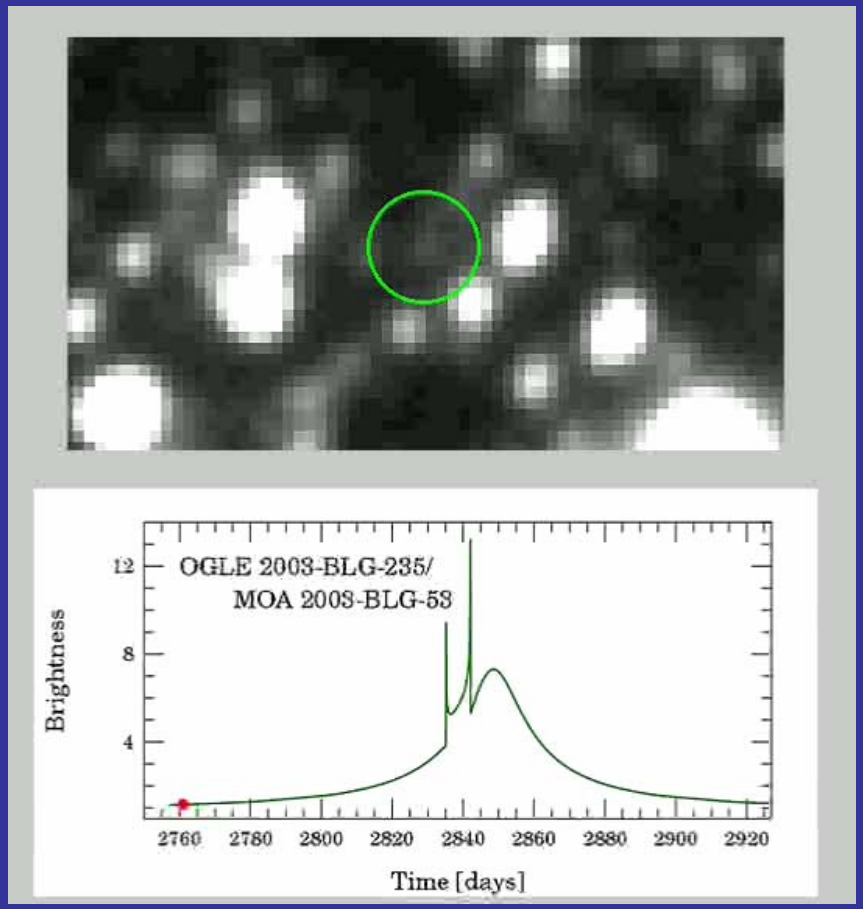
http://researchnews.osu.edu/archive/nuplanet.htm

Planetary Microlensing

- A planetary microlensing event light curve resembles a single lens light curve most of the time.
- But, if one of the lensed images approaches the location of a planet, then the light curve can dramatically increase.



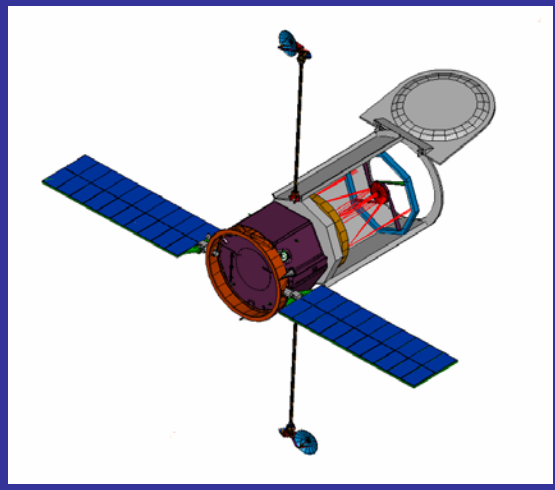
Planetary Microlensing



Galactic **E**xoplanet **S**urvey **T**elescope (**GEST**)

Microlensing - The Basis for **GEST**

- M_{planet}/M_{*} and separation are directly measured
- Planets are detected rapidly, even in ~20 year orbits
- 100,000,000 main sequence stars must be surveyed towards the Galactic bulge
- The only method sensitive to old, free floating planets



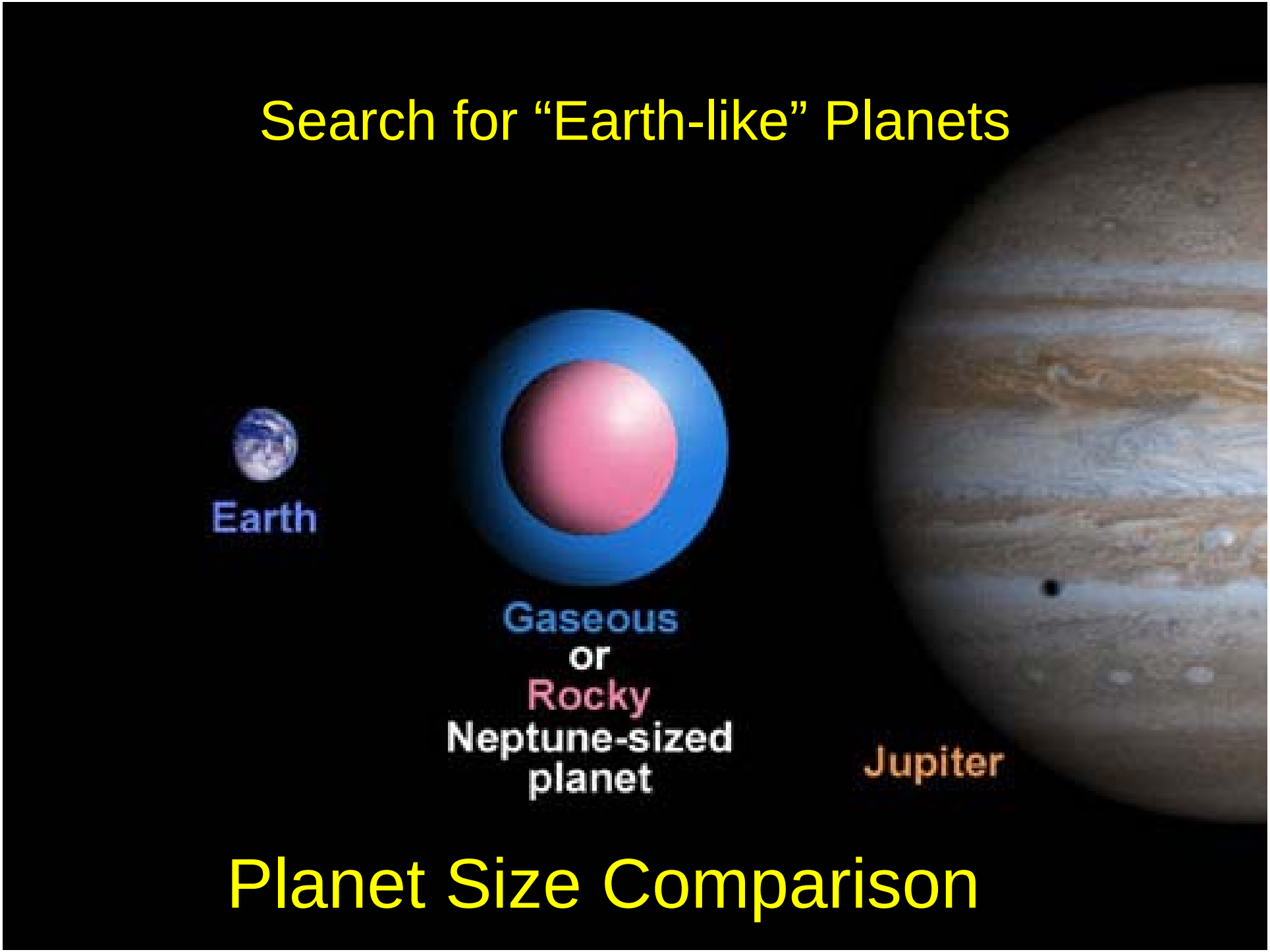
- Can be done with current technology!

Planets Discovered

Planets Discovered Using the Microlensing Method: 3 (UPDATE)

- The extrasolar orbit must be perfectly aligned with the intervening mass and the Earth for us to witness the microlensing event.

Search for “Earth-like” Planets

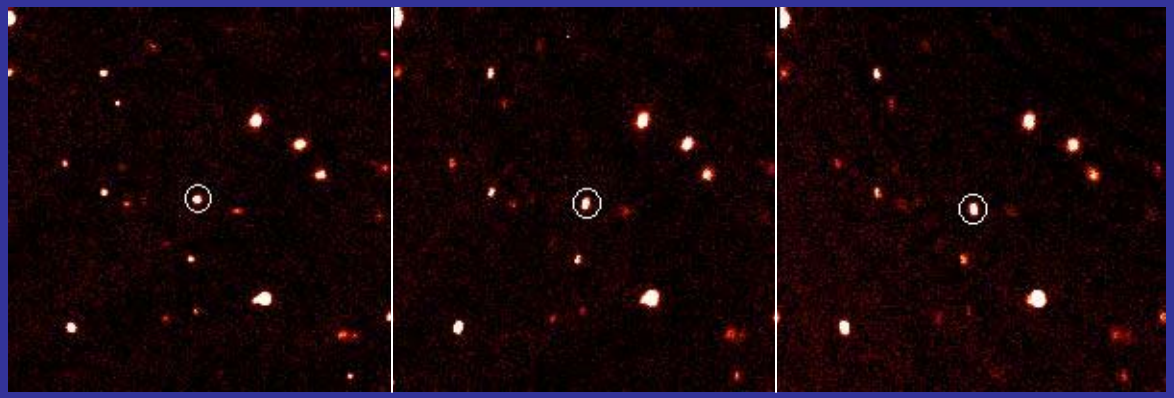


Planet Size Comparison

Advanced Techniques and Equipment

- Astronomers are detecting smaller and smaller planets as techniques develop.
- Dedicated space observatories are planned to take advantage of very long baseline measurements. The technologies are being developed to enable multiple spaceborne telescopes to work together as one super-telescope.

10th Planet Discovered

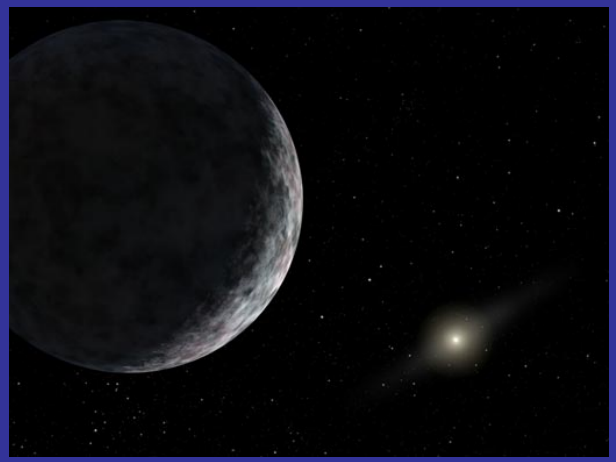


Scientists did not discover that the object in these pictures was a planet until January 8, 2005

These are time-lapse images of a newfound planet in our solar system, called 2003UB313, taken on Oct. 21, 2003, using the Samuel Oschin Telescope at the Palomar Observatory near San Diego. The planet, circled in white, is seen moving across a field of stars. The three images were taken about 90 minutes apart.

Based on the amount of light it reflects and its orbit, the new planet is *larger* than Pluto.

The planet has a 557 year, highly elliptical, orbit and is now at the point furthest from the Sun.



10th Planet

The object is inclined by a whopping 45 degrees to the main plane of the solar system, where most of the other planets orbit.

Still undiscovered: A Mars sized planet is expected.

Latest News: Super-Earth

6/13/05

“A newly-discovered super-Earth orbits the star Gliese 876, located just 15 light years away in the direction of the constellation Aquarius. This star also possesses two larger, Jupiter-size planets. The new planet whips around the star in a mere two days, and is so close to the star's surface that its temperature probably tops 400 to 750 degrees Fahrenheit (200 to 400 degrees Celsius) oven-like temperatures far too hot for life as we know it.

Nevertheless, the ability to detect the tiny wobble that the planet induces in the star gives astronomers confidence that they will be able to detect even smaller rocky planets in orbits more hospitable to life.

"This is the smallest extrasolar planet yet detected and the first of a new class of rocky terrestrial planets," said team member Paul Butler of the Carnegie Institution of Washington. "It's like Earth's bigger cousin."

Minimum mass for the planet of 5.9 Earth masses, orbiting with a period of 1.94 days at a distance of 0.021 astronomical units (AU), or 2 million miles.

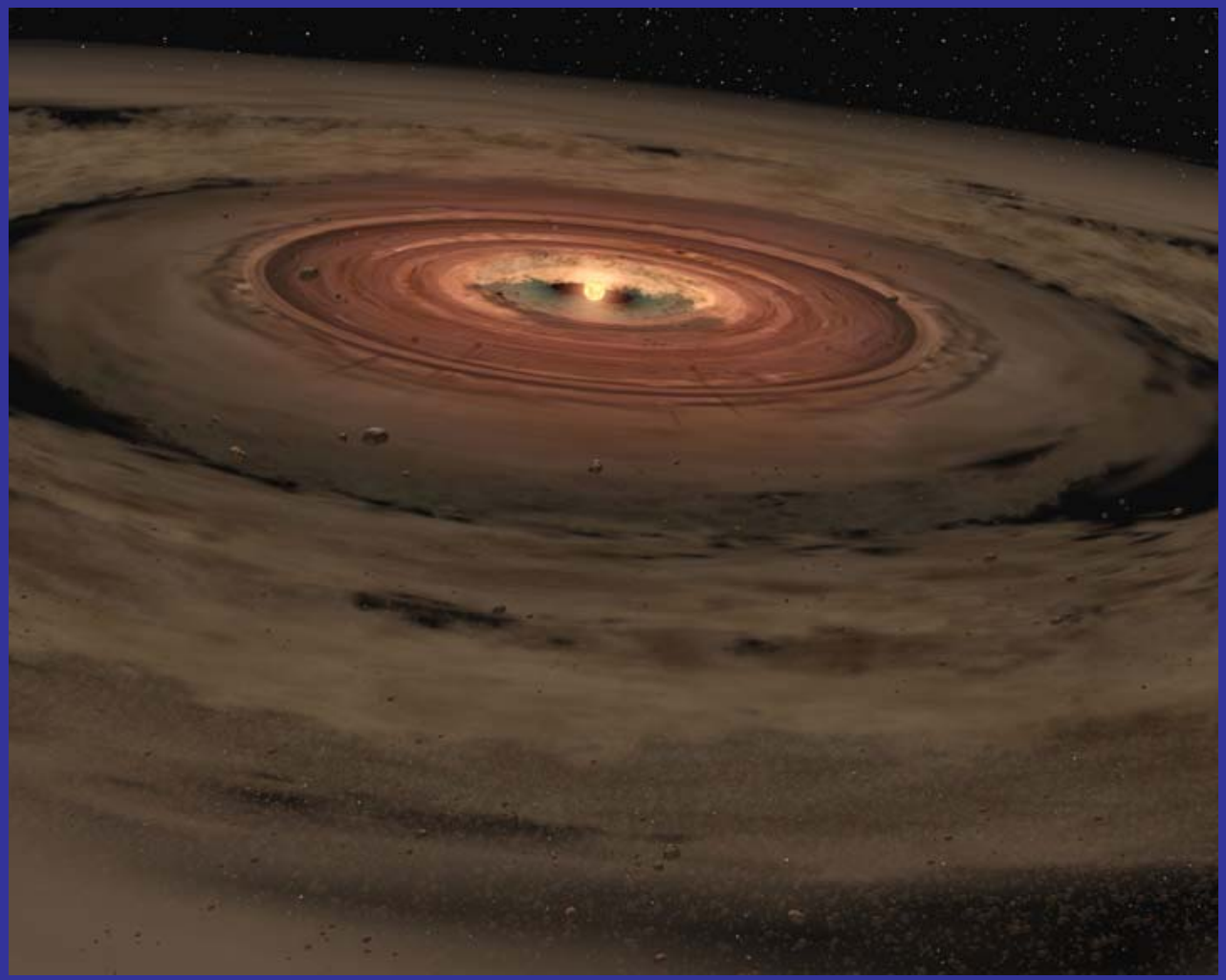
http://exoplanets.org/

Artist's Conception

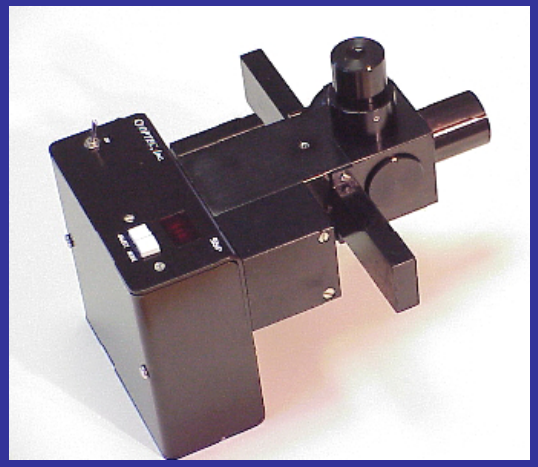
"Super Earth" orbiting Gliese 876

Trent Schindler, National Science Foundation

More are forming every day …



Equipment Needed to Detect a Planet



Permanent Pier

Telescope >8”

Mount

Accurate Drive

Observatory

A good finder scope

Photometer

Computer

http://www.planetary.org/

http://www.aavso.org/observing/programs/pep/manual.html