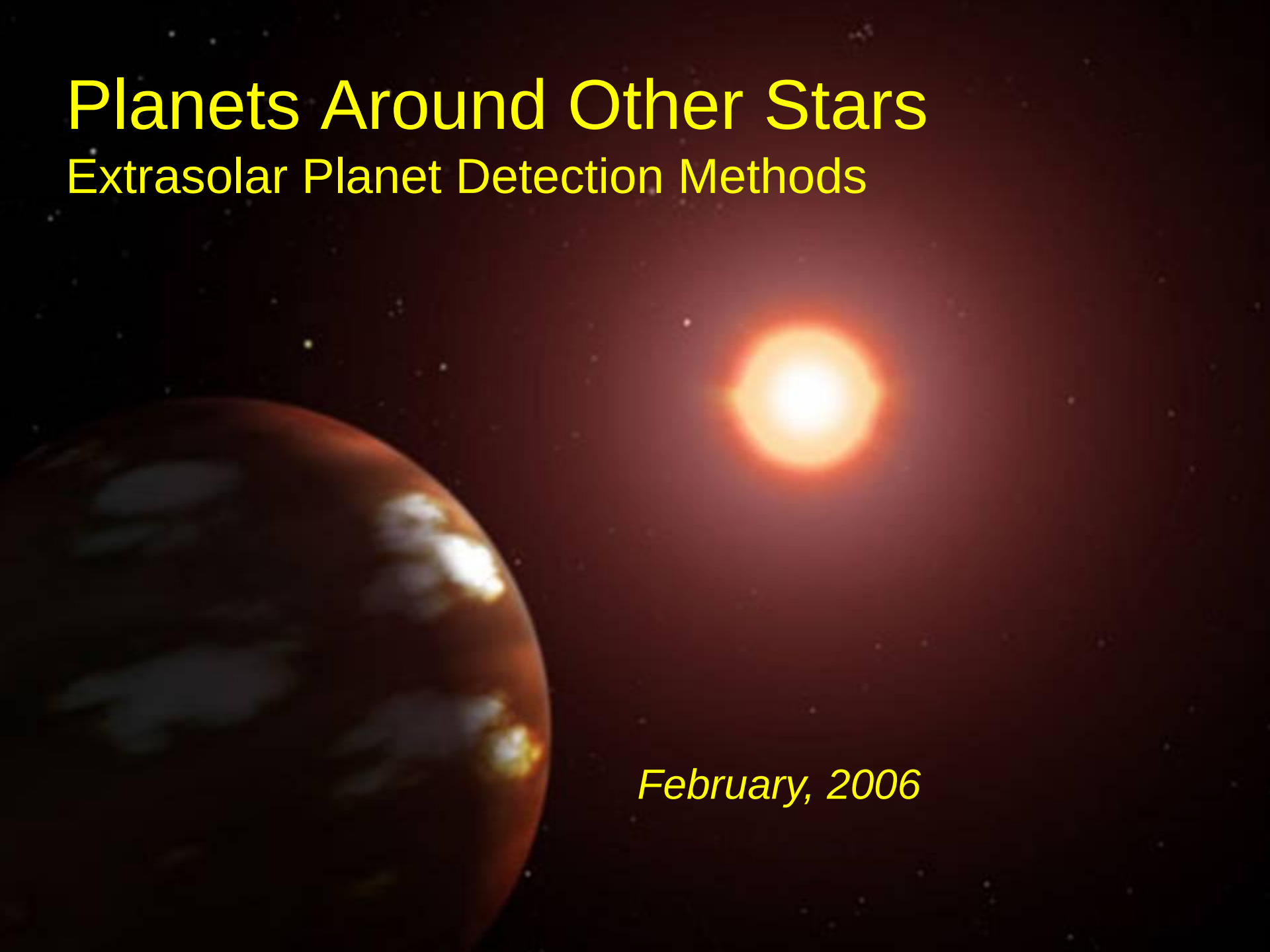
Planets Around Other Stars

Extrasolar Planet Detection Methods



February, 2006

Distribution of this File

Extrasolar_planet_detection.ppt

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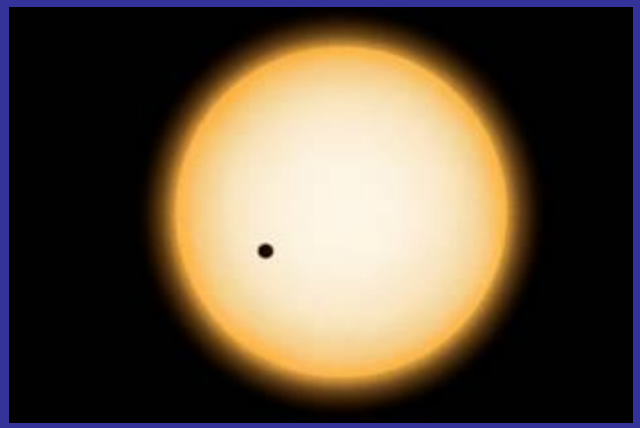
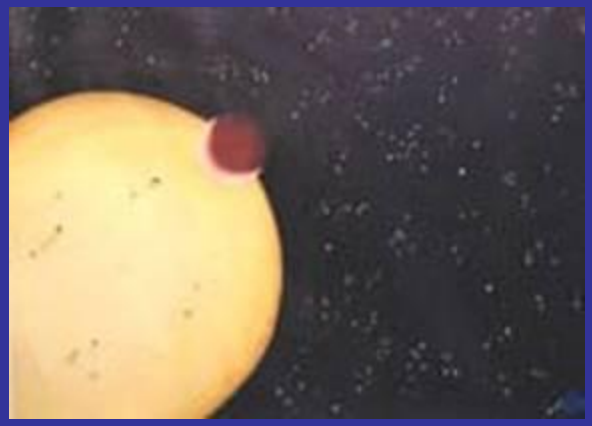
Planets Around Other Stars?

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:

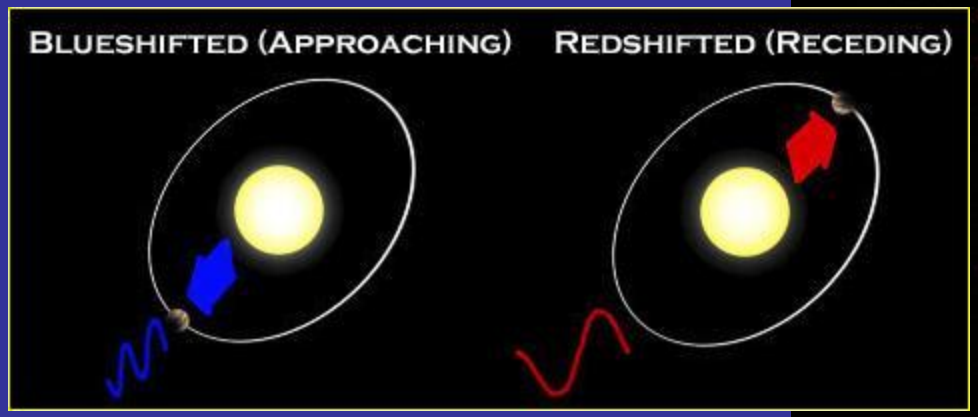
- February 10, 2006: 180 Planets Found, 167 Planetary Systems
  - http://planetquest1.jpl.nasa.gov/atlas/atlas_index.cfm
  - http://vo.obspm.fr/exoplanetes/encyclo/catalog.php
- 'Light Curve' Analysis
  - 'Doppler Wobble' of star (red shift / blue shift of spectra)
  - Decreased light from star 'Planetary Eclipsing'
  - Gravitational 'Microlensing'
- Gravitational Waves (Not demonstrated yet)
- Direct Observation (Not confirmed as of 2/10/06)

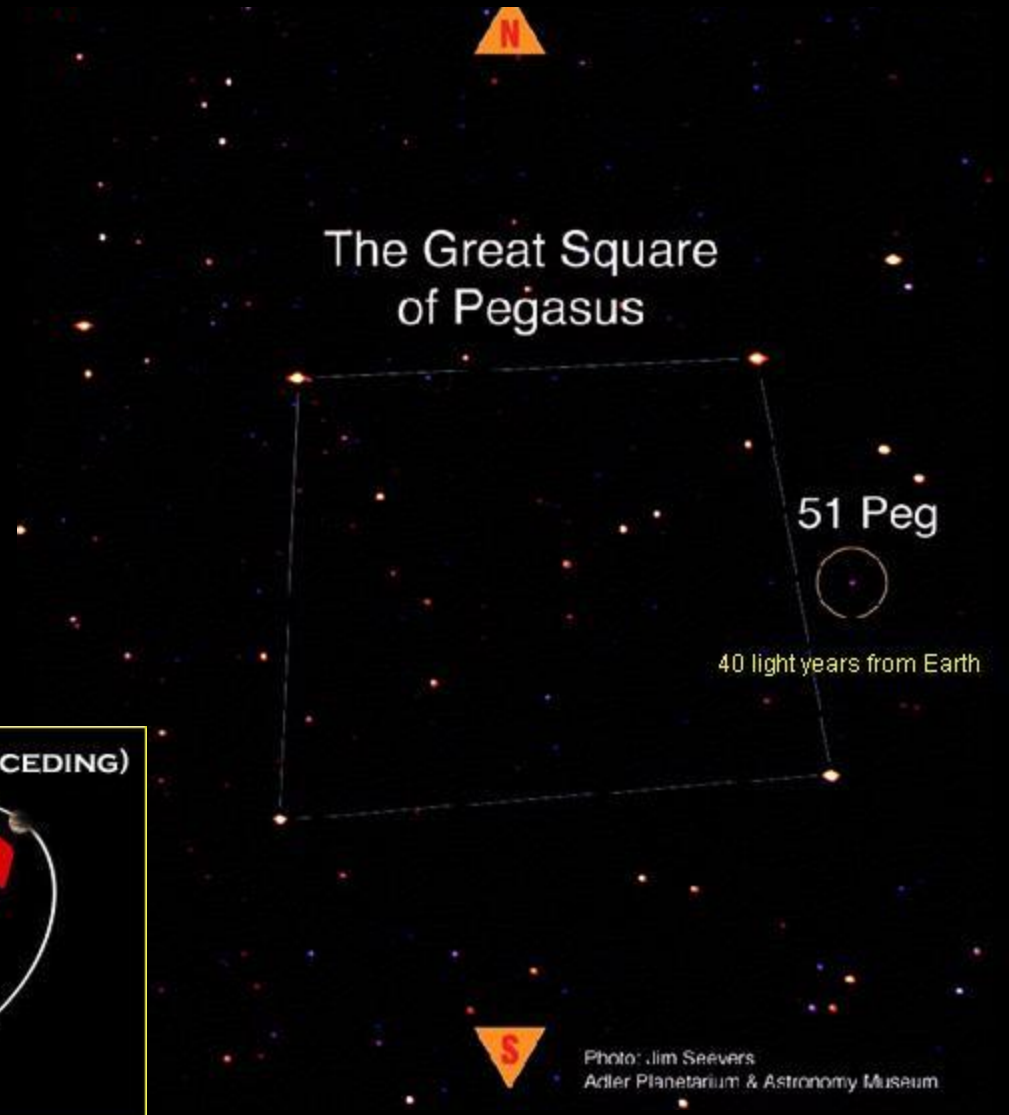
Discovery of a Planetary Orbit around 51 Pegasi

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

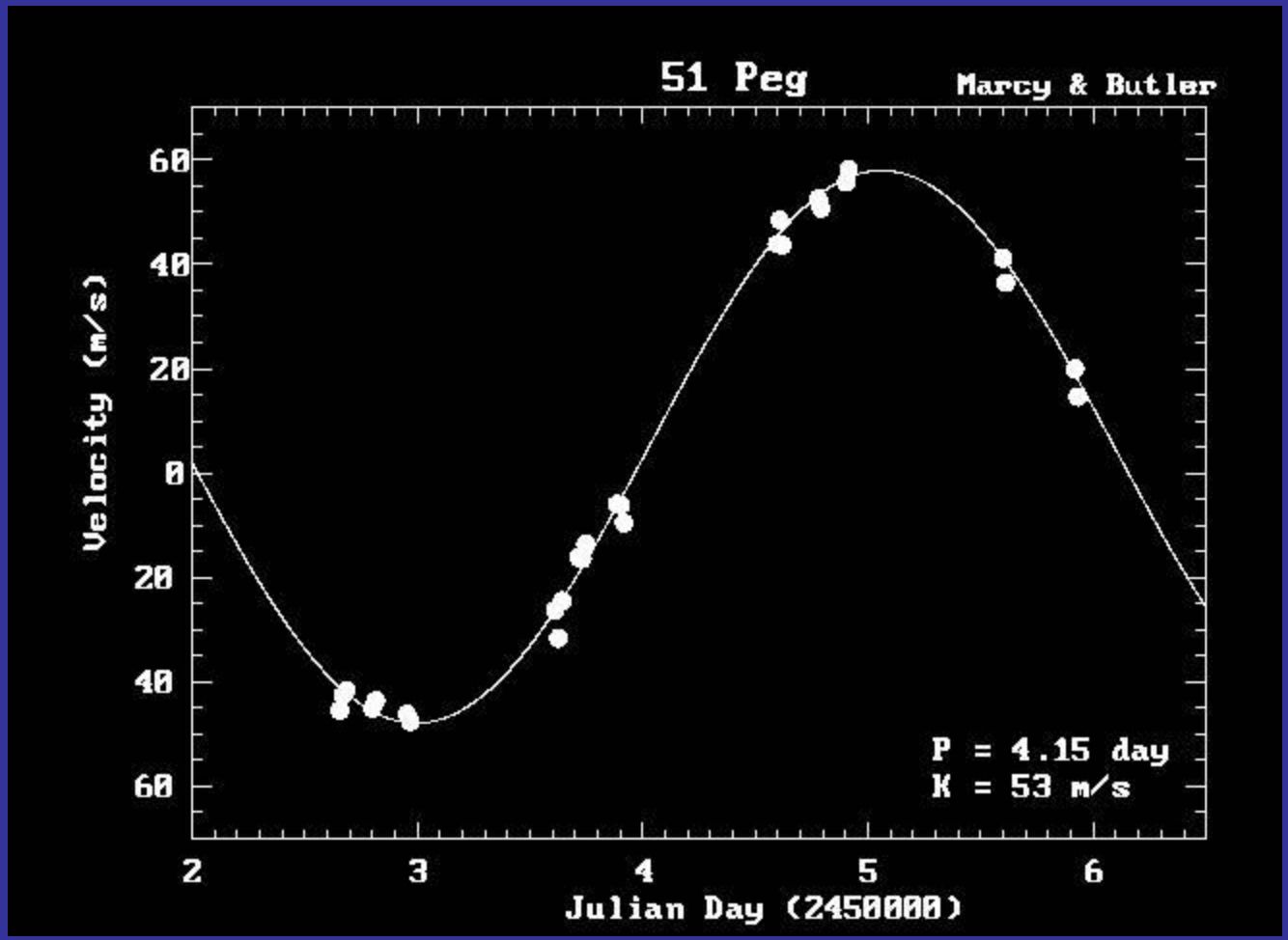




Doppler Analysis of Light Curve

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

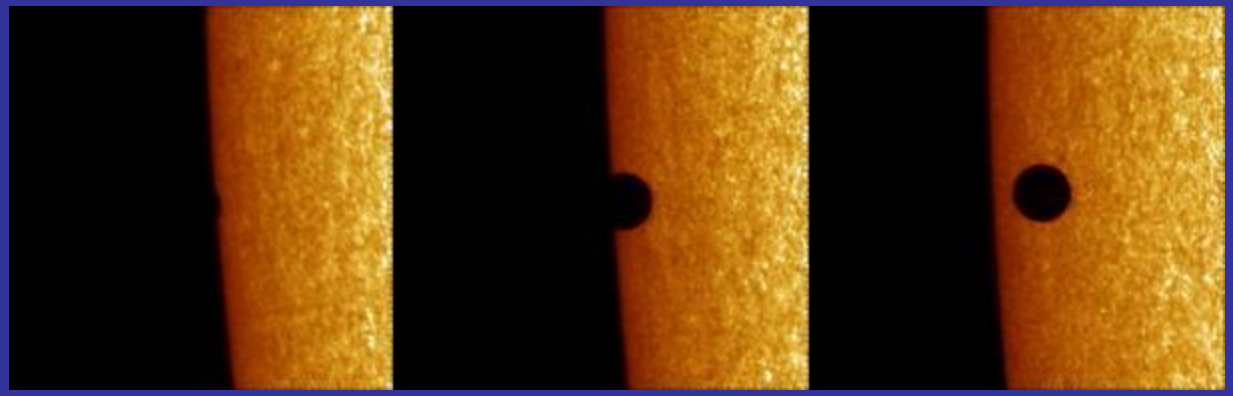
Planets Discovered

Planets Discovered Using “Doppler Wobble” (also called Radial Velocity method and Doppler Spectroscopy)

- ~ 90%
- 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. Only works out to about 160 ly.

Another Method: Planetary Eclipsing

Mercury Transit May 7, 2003



Venus Transit
June 8, 2004

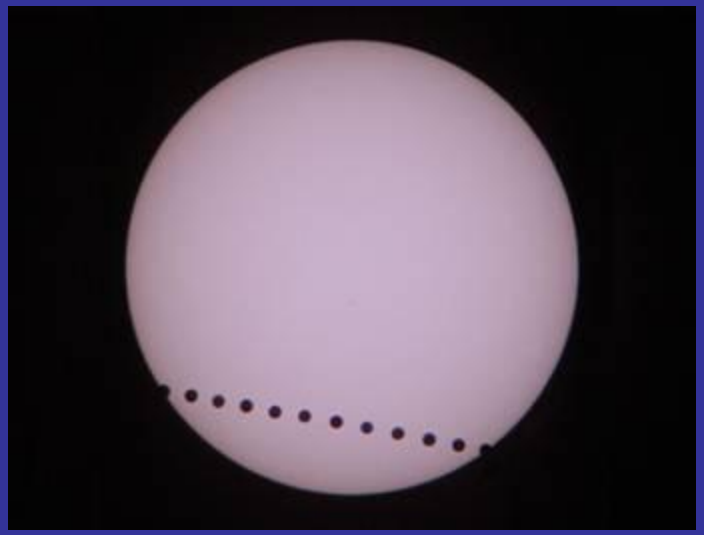
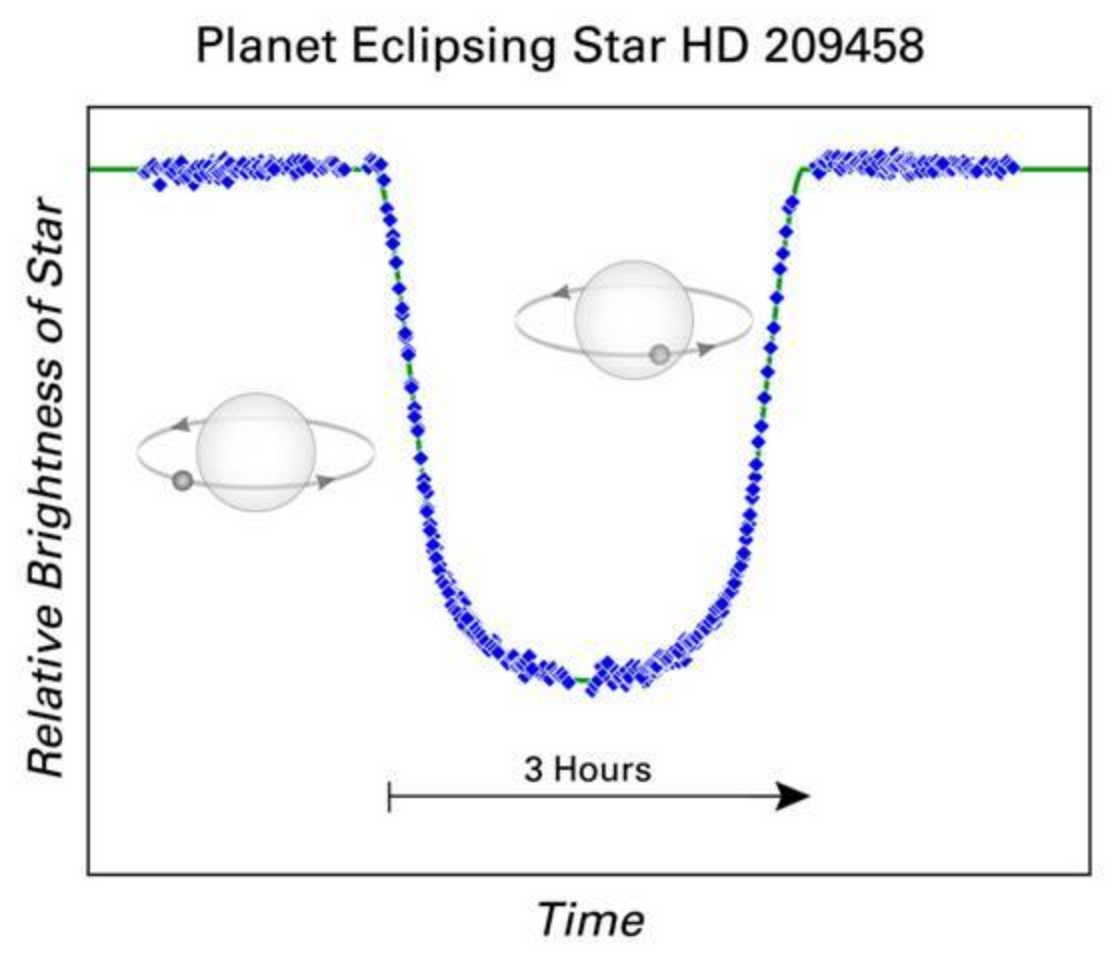


Photo Credit: The Swedish 1-m Solar Telescope (SST) of the Royal Swedish Academy of Sciences on the Canary Islands

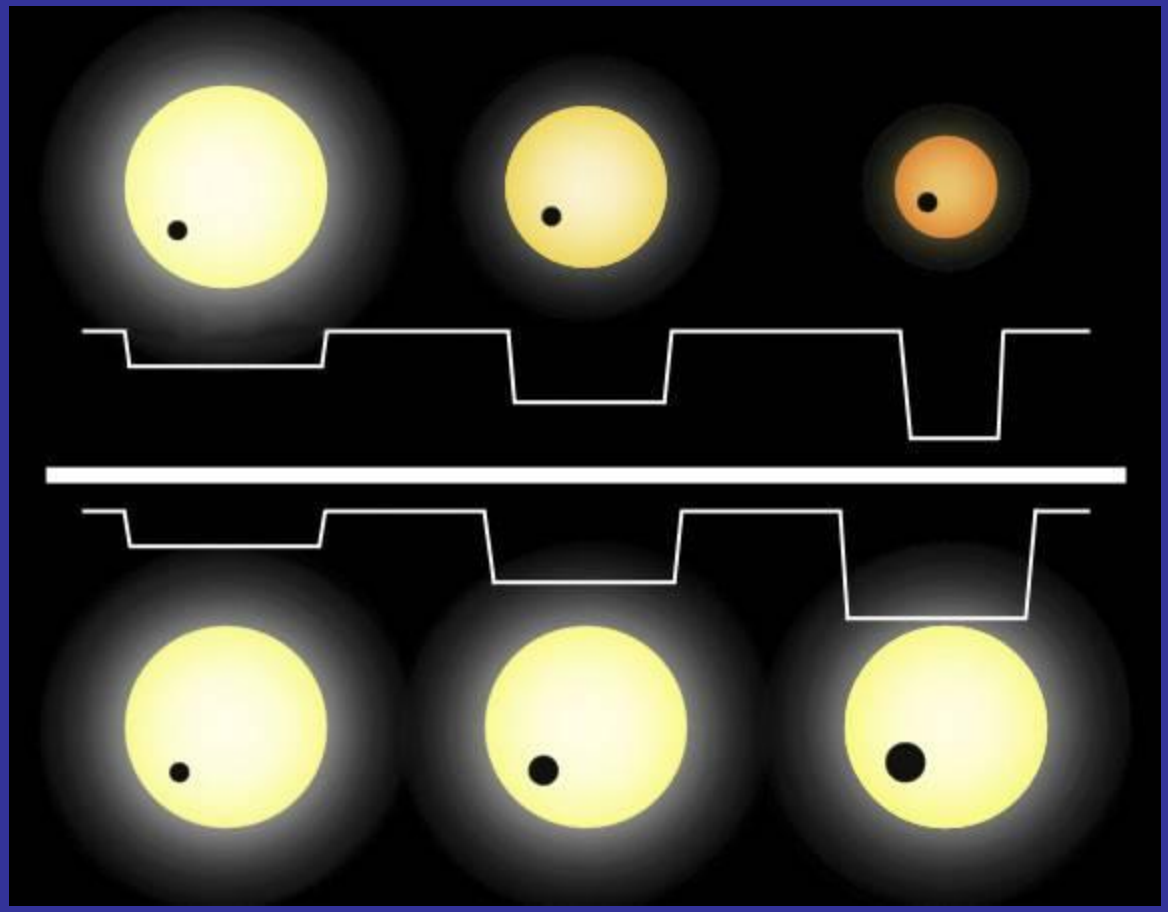
Planetary Eclipsing

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.



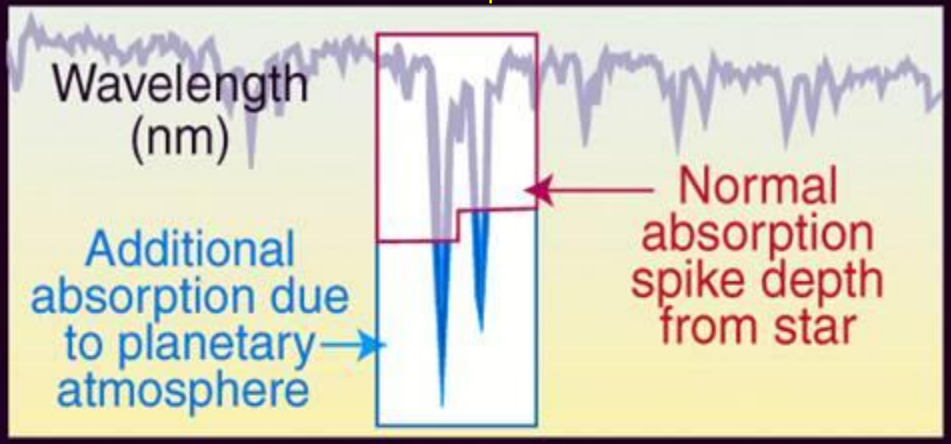
Planetary Eclipsing

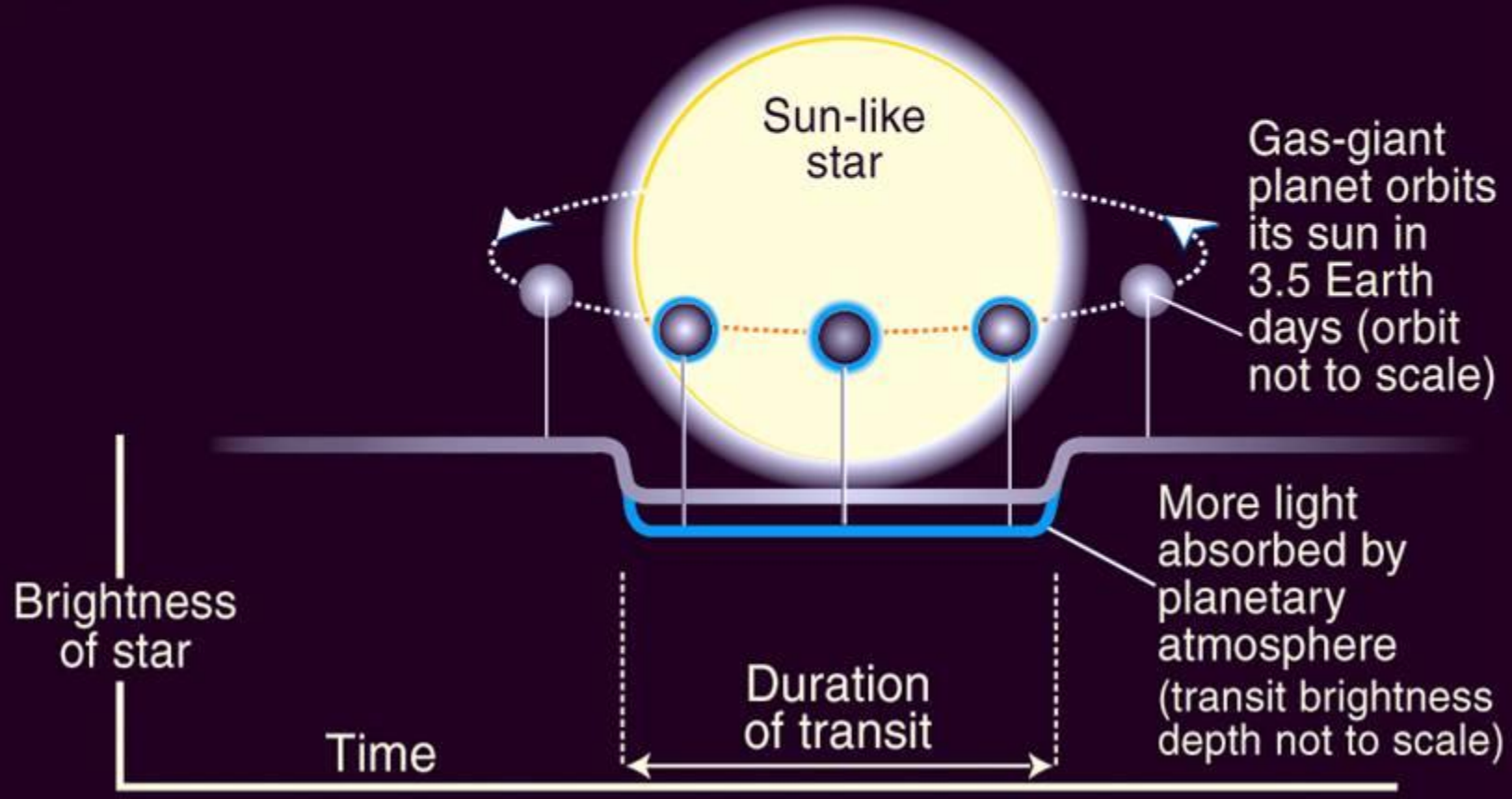
Reduction in light depends upon the size of the star and the size of the eclipsing body



Sodium Absorption Line

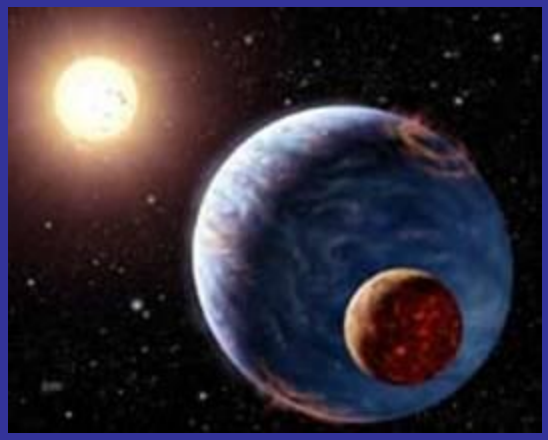
HST detects additional sodium absorption due to light passing through planetary atmosphere as planet transits across star





Planets Discovered

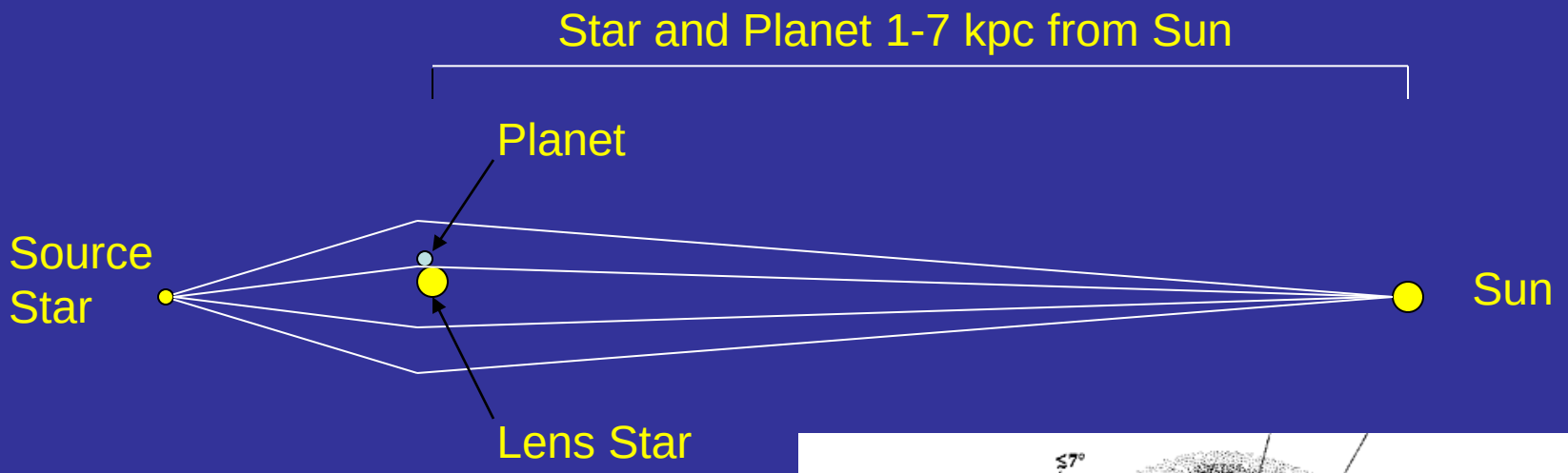
Planets Discovered Using the Planetary Eclipsing Method: ~9%

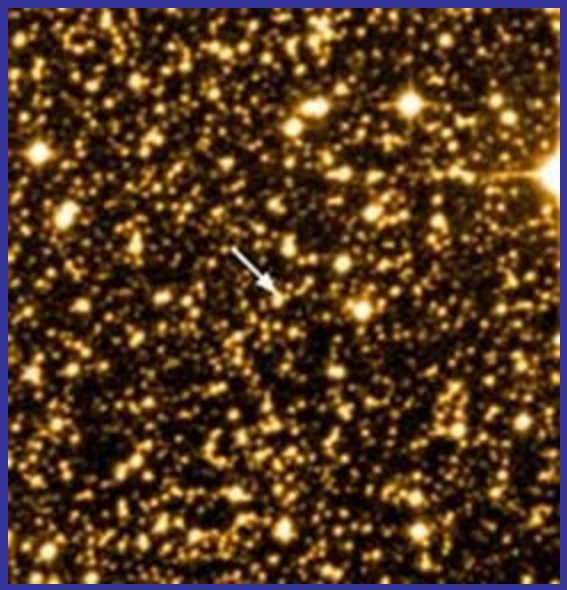


Why so few?

- 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.

Planetary Microlensing



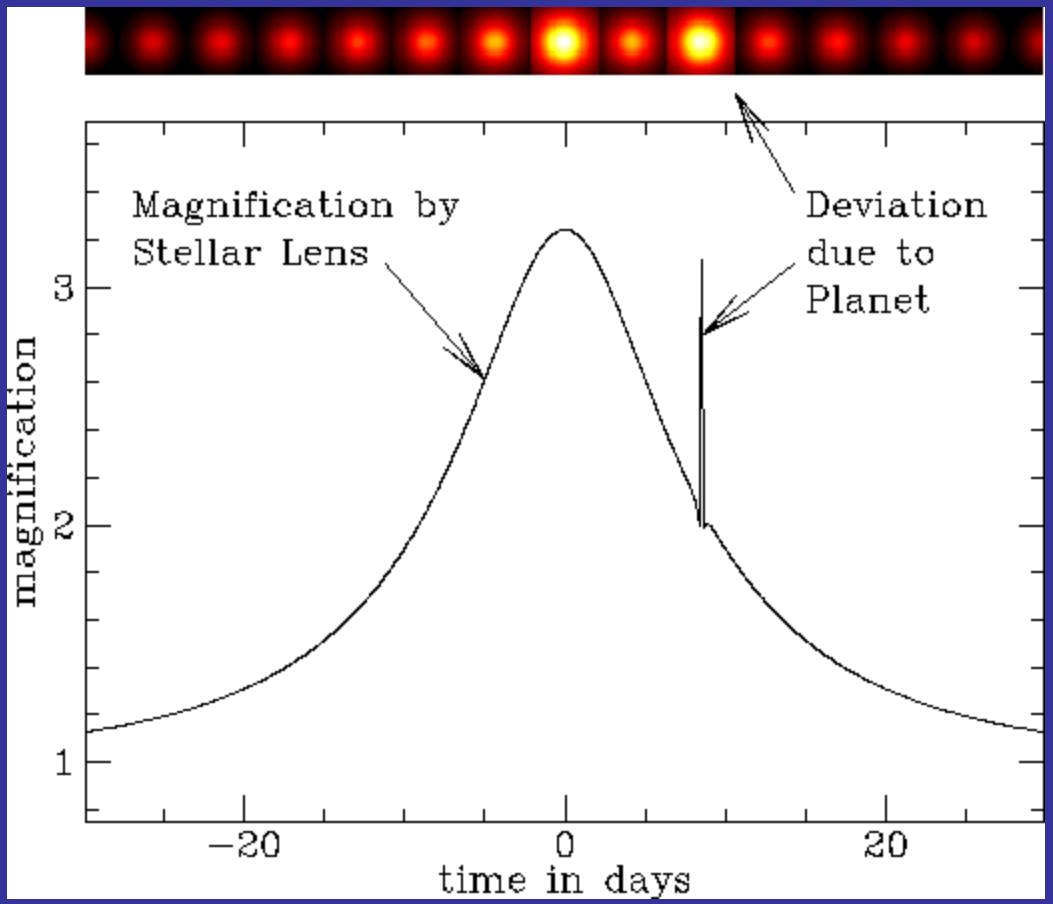


Observations must be made of dense star clusters to improve the chances of exact alignment and detection.

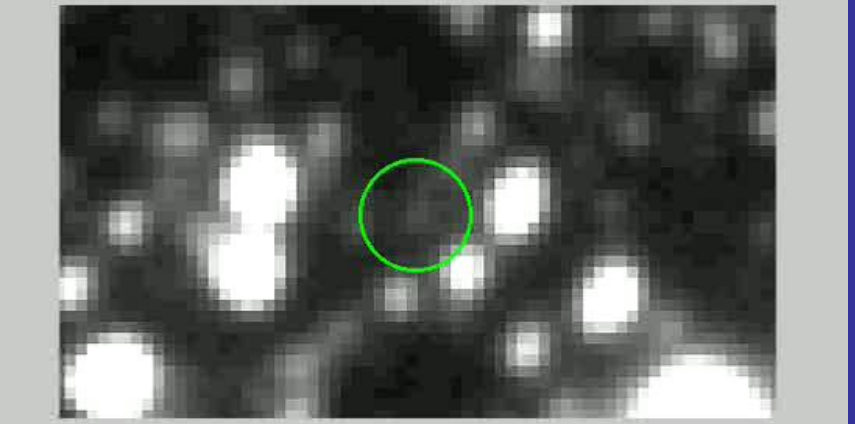
http://researchnews.osu.edu/archive/nuplanet.htm

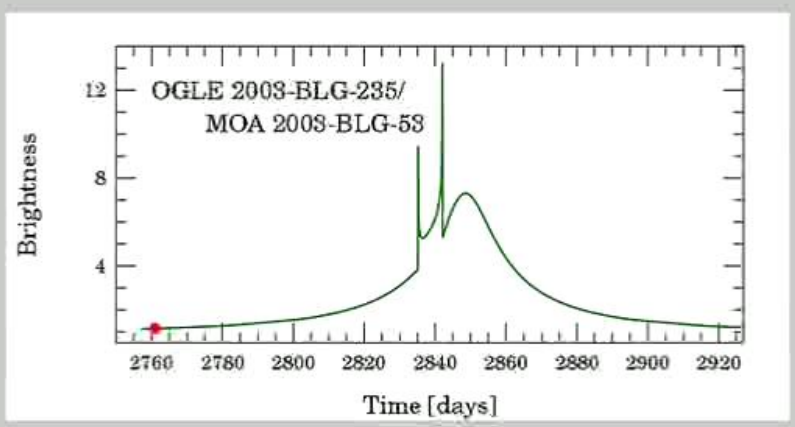
Planetary Microlensing

- 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

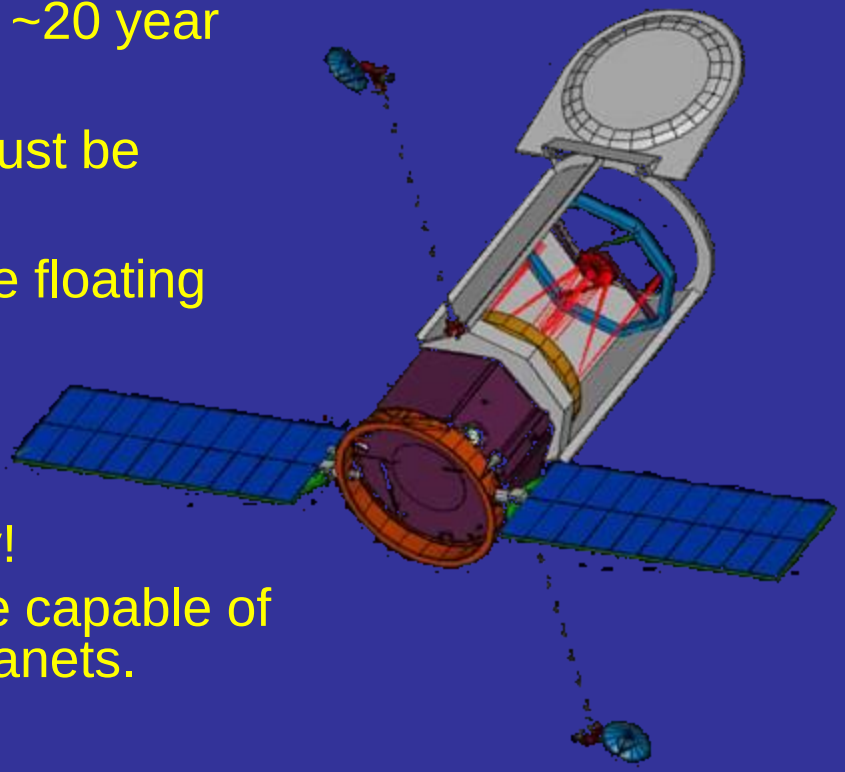




Microlensing Planet Finder (MPF)

Microlensing - The Basis for **MPF**

- 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

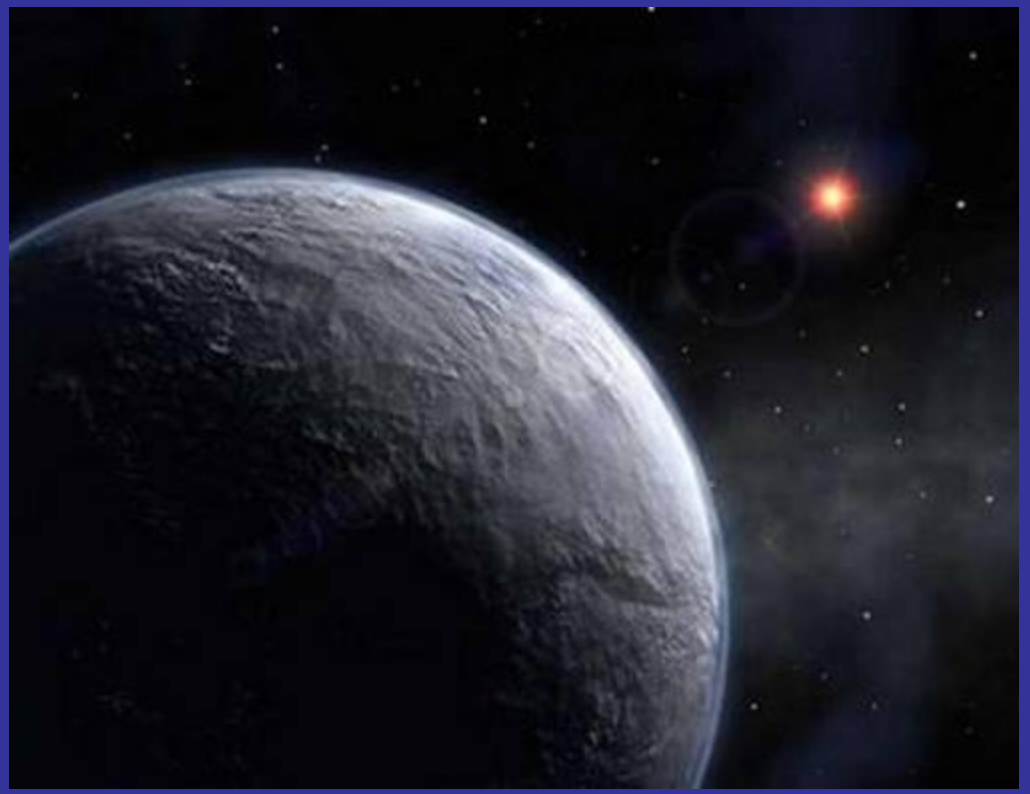


- Can be done with current technology!
- Currently, there is no other technique capable of detecting low-mass and Earth-like planets.

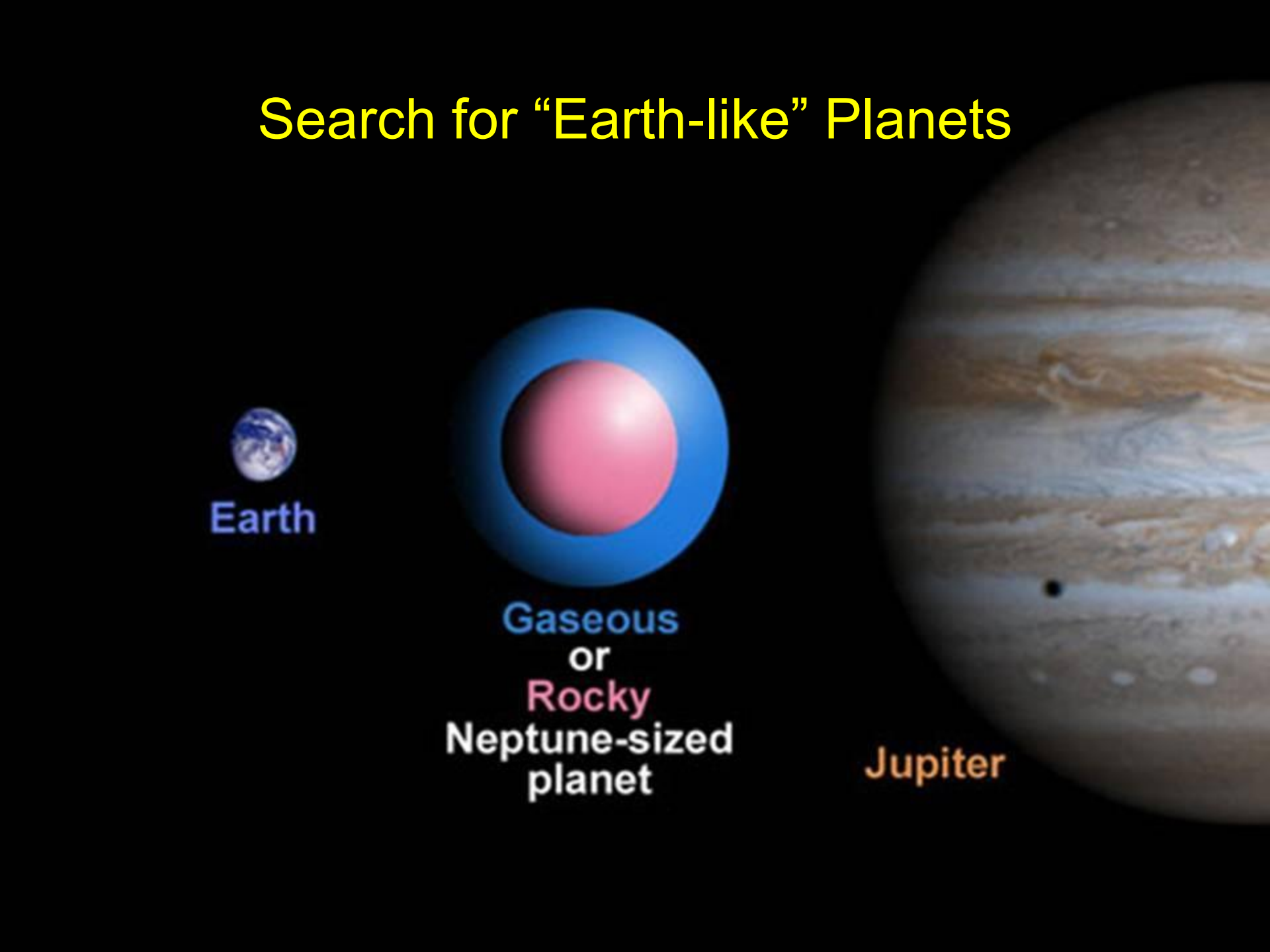
Planets Discovered

Planets Discovered Using the Microlensing Method: ~1% (2/10/06, 3 planets) Orb Dist: to 3 AU

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



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

Doppler Wobble

Recent 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.…

…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/

Doppler Wobble

Artist's Conception

"Super Earth" orbiting Gliese 876

Trent Schindler, National Science Foundation

Recent News: Six New Planets Reported

Six New Planets Reported

August 30, 2005 (PLANETQUEST)

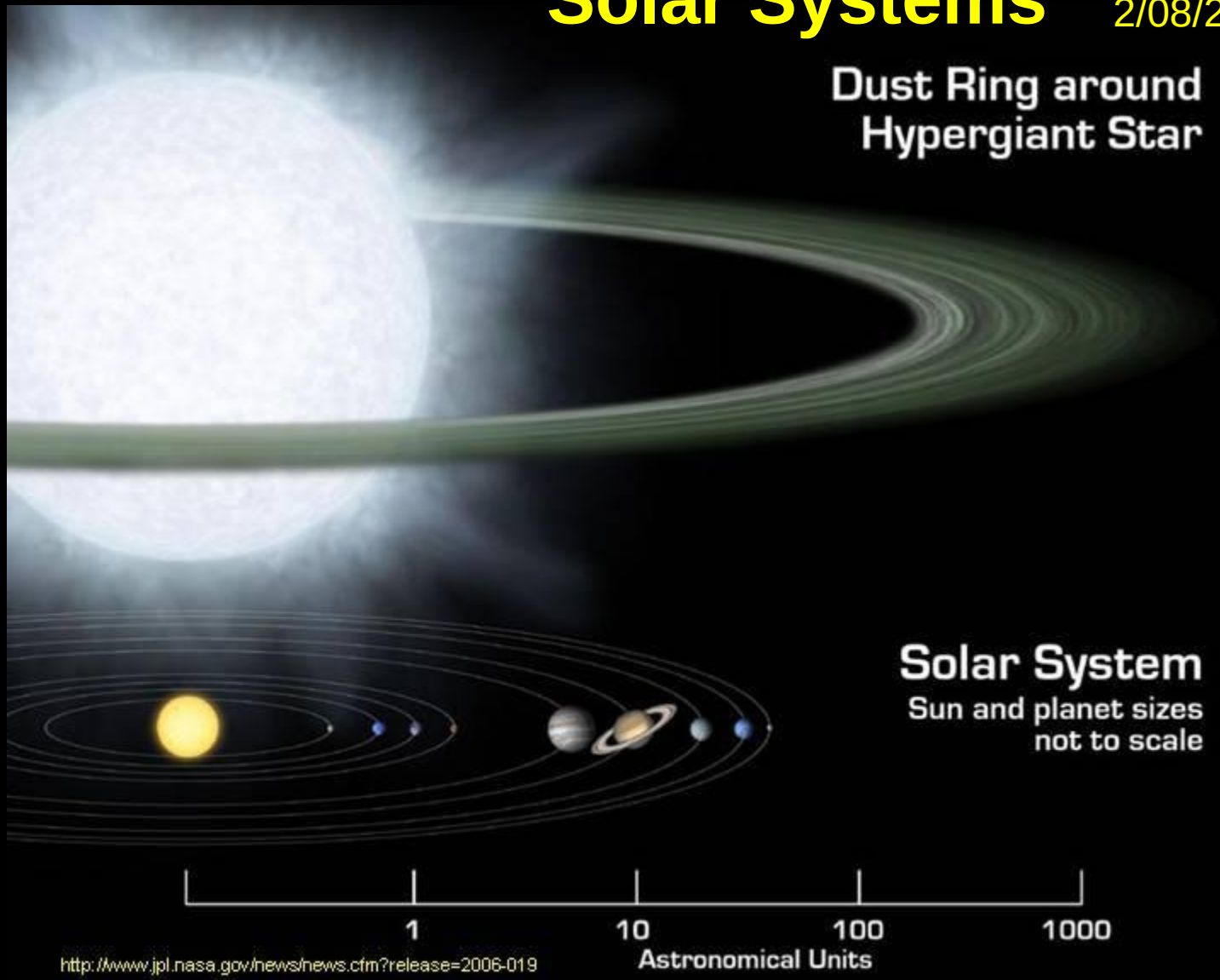
Scientists announced the discoveries of six new extrasolar planets during the latter half of August, found at distances ranging from 20 to 289 light-years from Earth, according to information posted on the Extrasolar Planets Encyclopedia website.

The largest is about 1.6 times as massive as Jupiter. The smallest is about as massive as Uranus, or about 14 times the mass of Earth. The planets orbit their parent stars at distances ranging from 10 million to 3 million miles (16 million to 5 million kilometers) -- much closer than the distance at which Mercury orbits our sun.

The new planets are described in papers submitted to the European journal Astronomy and Astrophysics.

http://planetquest.jpl.nasa.gov/news/sixPlanets.html

NASA's Spitzer Uncovers Hints of Mega Solar Systems 2/08/2006



Dusty disks around stars are thought to be signposts for present or future planetary systems

http://www.jpl.nasa.gov/news/news.cfm?release=2006-019

Recent News

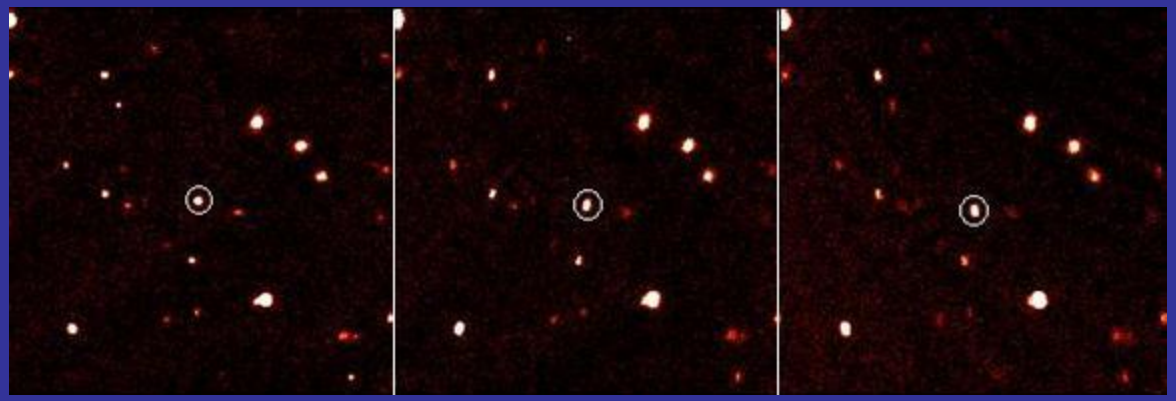
Astronomers Find Small, Distant Planet

By MALCOLM RITTER
AP Science Writer *Thu Jan 26, 2006, 8:01 PM ET*
NEW YORK –
Astronomers say they've found what may be the smallest and most distant planet known to be orbiting a star outside our own solar system.

The work suggests that such small rocky or icy planets may be more common in the cosmos than Jupiter-sized gas giant planets, researchers said. The discovery also indicates the power of a relatively new method of finding such "exoplanets."

http://planetquest.jpl.nasa.gov/news/sixPlanets.html

Related News - 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.

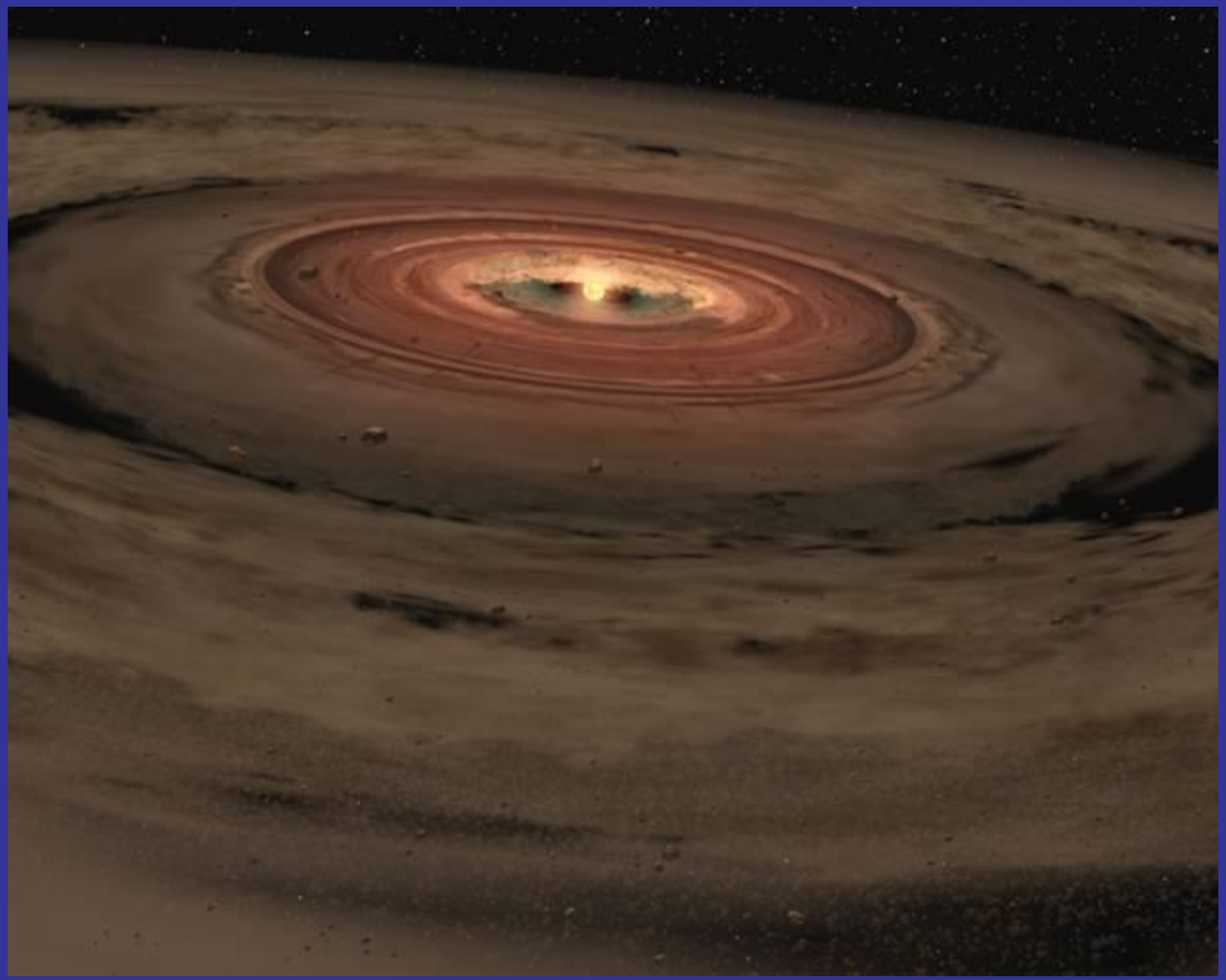
The planet has a 557 year, highly elliptical, orbit and is now at the point furthest from the Sun.

10th Planet

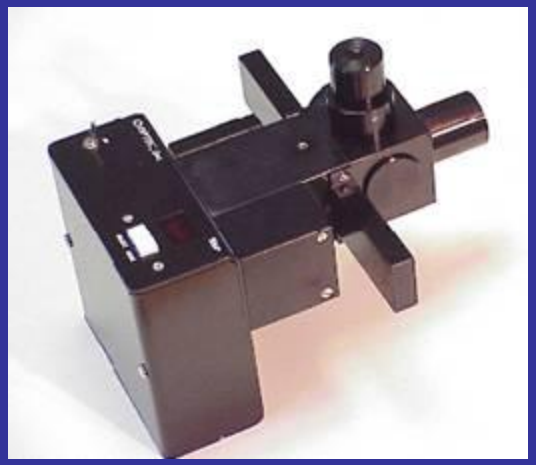
The object is inclined by a whopping 45 degrees to the main plane of the solar system, where most of the other planets orbit.

Still undiscovered: A Mars sized planet is expected.

More are forming every day …



Amateur Equipment Needed to Detect a Planet



- **Permanent Pier**
- Observatory
- Telescope >8”
- Solid Mount
- *Accurate* Drive
- A good finder scope
- Photometer
- Computer
- Patience

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