Astronomy 330:

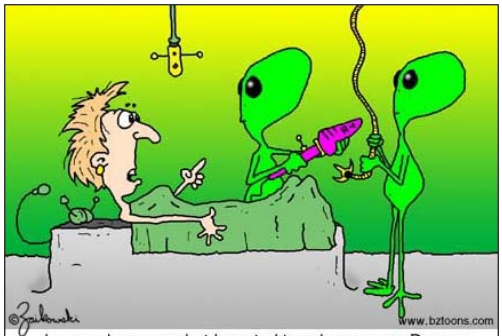
Extraterrestrial Life

This class (Lecture 11):

Planets for Life
Itamar Allali
Brian Campbell-Deem

Next Class:

Planets for Life
Zoe Richter
Tara Chattoraj



I remember now what I wanted to ask you guys. Do you know how to go about setting the clock on a VCR?

Music: *We Are All Made of Stars*– Moby

HW #4 due Sunday night.

HW #2

Connor Bailey
http://www.ufoabduction.com/telepathy4.htm
Fancy title"International Center for Abduction Research" and an editor with a PhD. However, everything on the website is anecdotal or otherwise unscientific

Kevin Brenner
https://usahitman.com/cc-cracked/
Crop circles have weird effects on their surroundings such as causing insects to refuse entering into them and causing scientists to grow faint when standing in them

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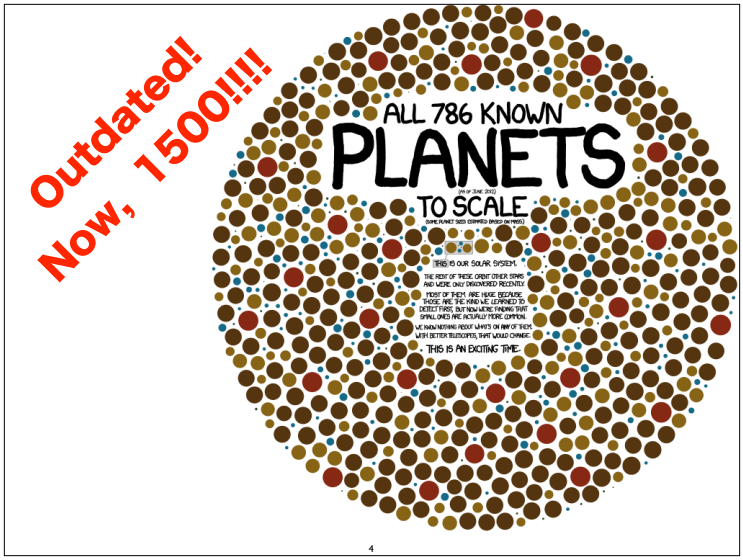
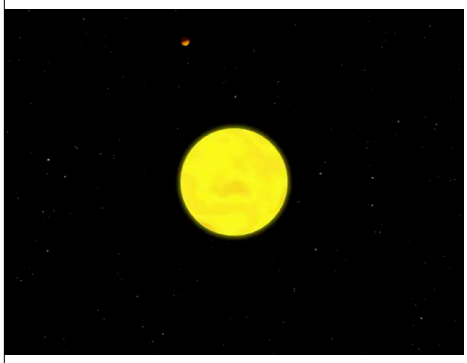
For 1 solar mass star, process takes about 10 million years. Density increase, temperature increases until fusion can occur. Blows away most of its natal circumstellar material. Becomes a hydrogen burning star



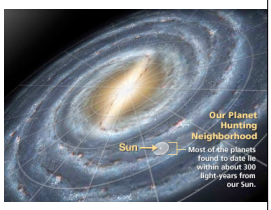
4

XKCD
http://exoplanets.org

ExoPlanets



1. Transit Technique
2. Astrometric
3. Radial Velocity
4. Direct Detection
5. Microlensing

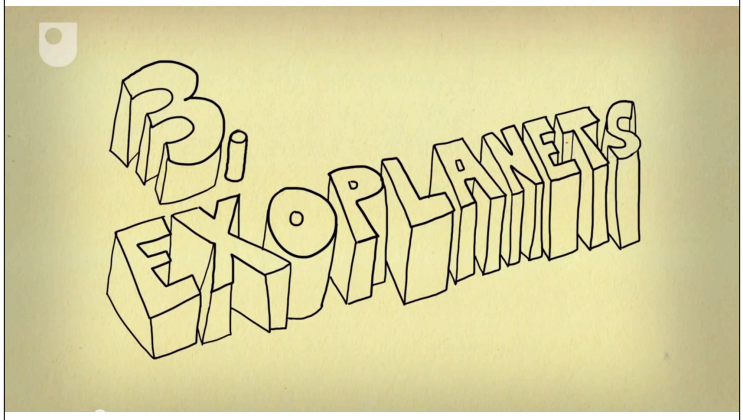


Extra-Solar Planet = Exoplanet

5

By far the most successful technique is the transit method.

ExoPlanets



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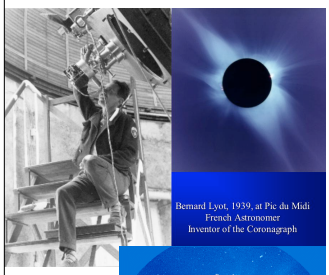
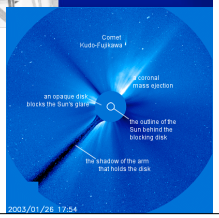
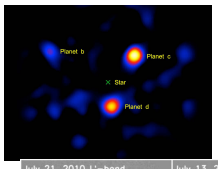
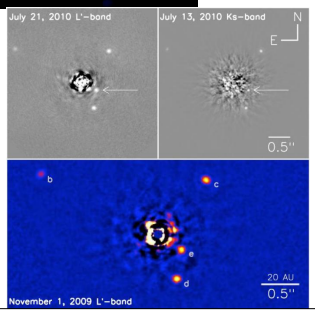
Direct Imaging



Bernard Lyot, 1939, at Pic du Midi
French Astronomer
Inventor of the Coronagraph







Direct image of exoplanets around the star HR8799 using a Vortex coronagraph on a 1.5m portion of the Hale telescope

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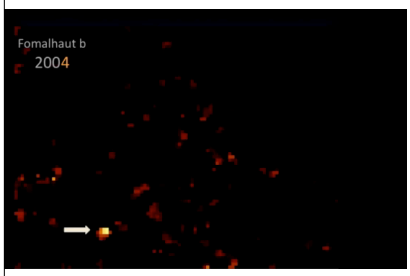
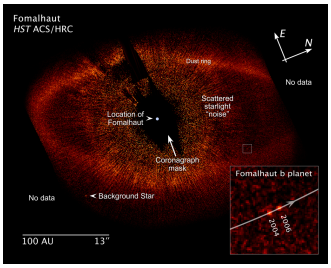
Planet Direct Imaging

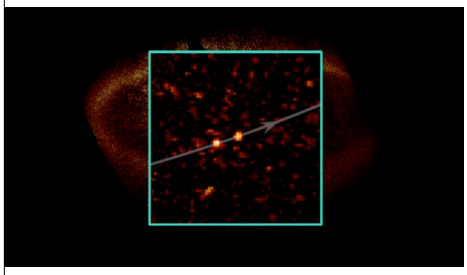


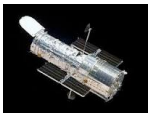
Controversy

Candidates
versus
Confirmations

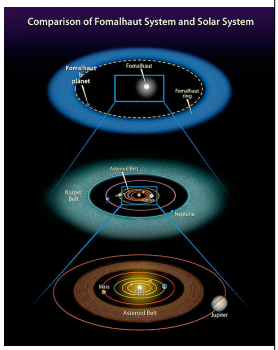


Planet Direct Imaging





Confirmed



From Wikipedia: http://en.wikipedia.org/wiki/Fomalhaut

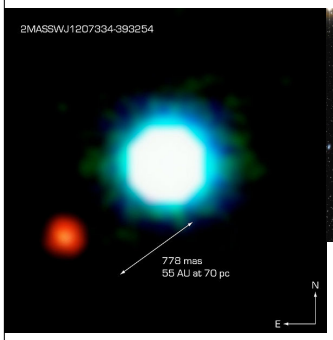
On November 13, 2008, astronomers announced an object, which they assumed to be an extrasolar planet, orbiting just inside the outer debris ring. This was the first extrasolar orbiting object to be seen with visible light, captured by the Hubble Space Telescope. A planet's existence had been previously suspected from the sharp, elliptical inner edge of that disk.[27] The mass of the planet, Fomalhaut b, was estimated to be no more than three times the mass of Jupiter but at least the mass of Neptune.[28] There are indications that the orbit is not apsidally aligned with the dust disk, which may indicate that additional planets may be responsible for the dust disk's structure.

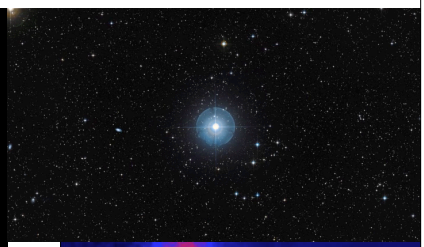
However M-band images taken from the MMT Observatory put strong limits on the existence of gas giants within 40 AU of the star[30] and Spitzer Space Telescope imaging suggested that the object Fomalhaut b was more likely to be a dust cloud.[31] In 2012, two independent studies confirmed that Fomalhaut b does exist; but it is shrouded by debris, so it may be a gravitationally-bound accumulation of rubble rather than a whole planet.

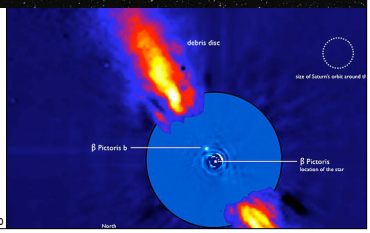
Herschel Space Observatory images of Fomalhaut reveal a large amount of fluffy micrometer-sized dust is present in the outer dust belt. Because such dust is expected to be blown out of the system by stellar radiation pressure on short timescales, its presence indicates a constant replenishment by collisions of planetesimals. The fluffy morphology of the grains suggests a cometary origin. The collision rate is estimated to be approximately 2000 kilometre-sized comets per day.

Observations of the star's outer dust ring by the Atacama Large Millimeter Array point to the existence of two planets in the system, neither one at the orbital radius proposed for the HST-discovered Fomalhaut b. If there are additional planets from 4 to 10 AU, they must be under 20 MJ; if from 2.5 outward, then 30 MJ.

Direct Imaging







Infrared Image

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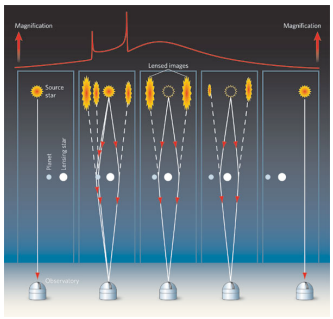
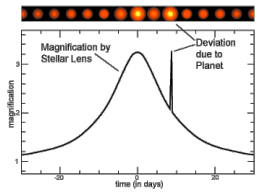
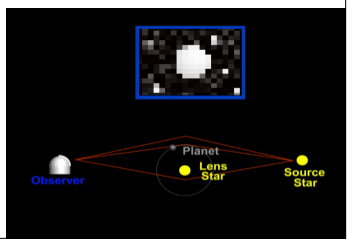
Planet Microlensing







Can detect free-floating planets!

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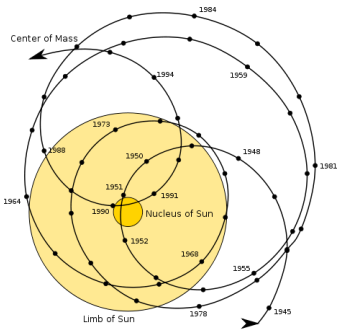
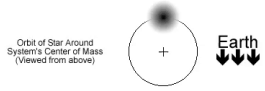
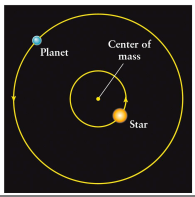
Astrometric



Observation of Stellar Motions Due to Presence of Extra-Solar Planet





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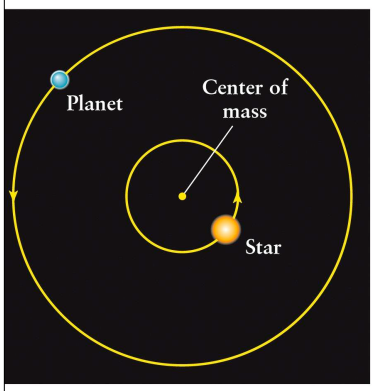
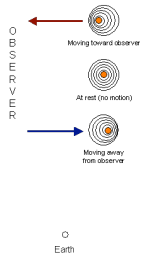
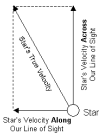
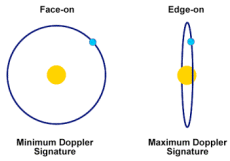
Radial Velocity





Period
Semi-Major Axis
Minimum Mass



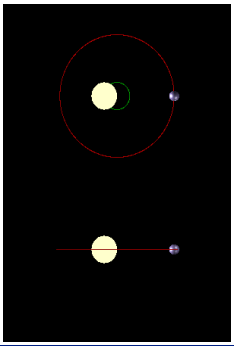


13

Wobbling Stars

Planet's gravity "tugs" the parent star

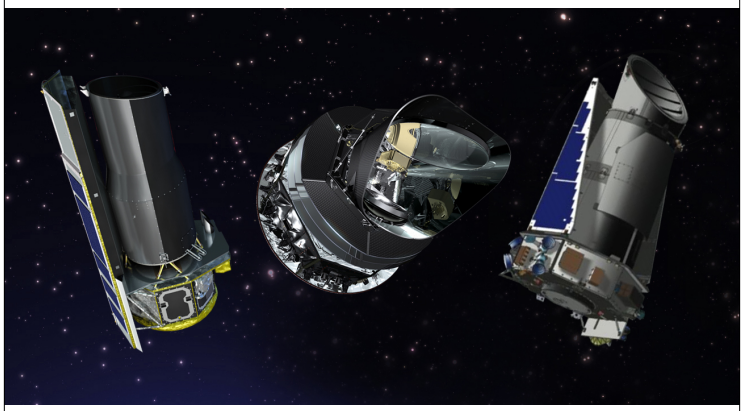
As planet orbits the star, the tugs make the star "wobble"



Star and planet each orbit around their mutual *center of mass*

Astronomers have generally had to resort to indirect methodsInstead of detecting the planet, they infer its existence by observing the effects that it has on its parent star.

NASA's Kepler Mission



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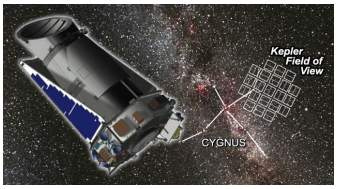
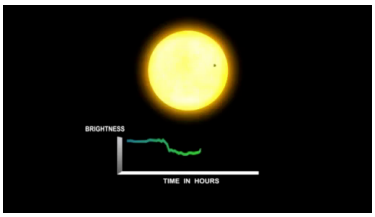
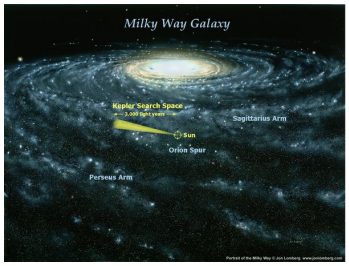
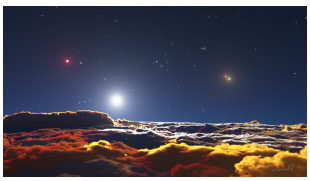
NASA's Kepler Mission





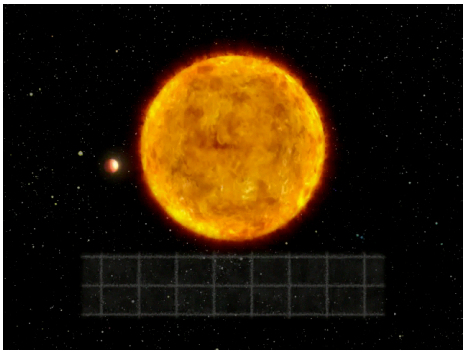




16

4 minutes

Planet Transit

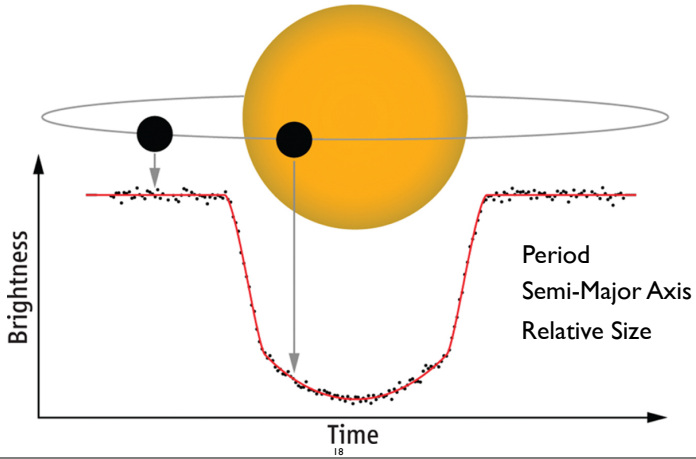


Extremely small variations

17

12 seconds

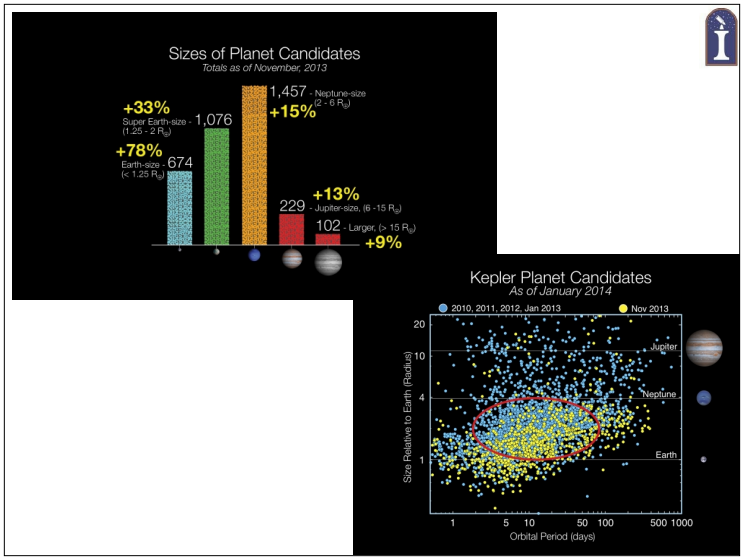
Transit Method

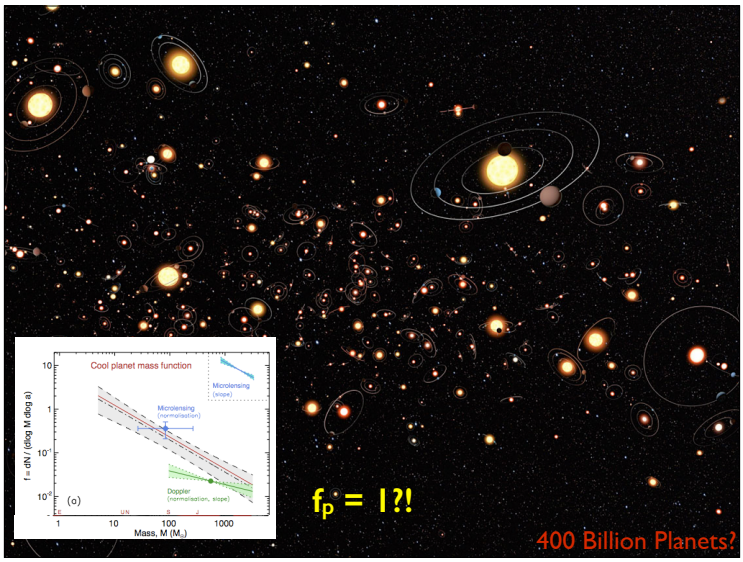


18

Fraction of starlight blocked tells us planet's size. Time between transits gives us orbit period. A Jupiter-sized planet transiting a Sun-like star would cause a 1% brightness drop. Best method to find Earth-like planets.

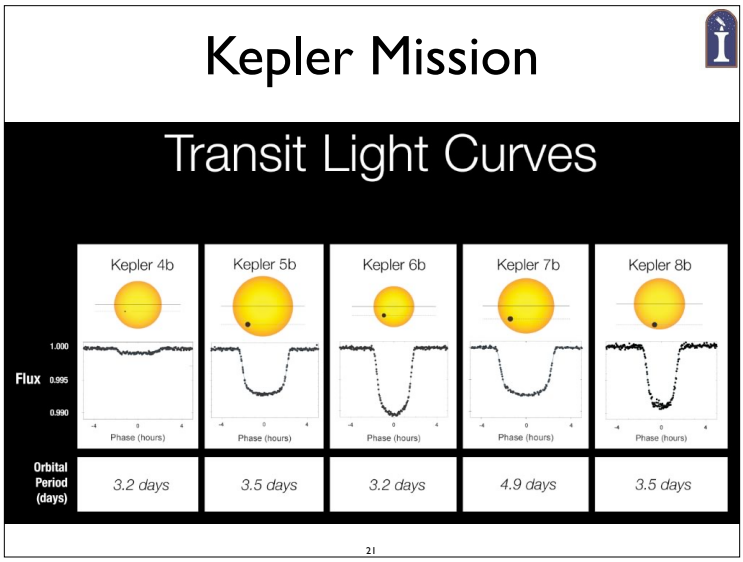
Must have planet block some of the star's light. Playing probability game as random orbits must intersect our line of sight. For Earth, the chance of this happening is 0.465%. If ALL stars have Earths, would see 678 Earths. But, Kepler group won't call objects candidates until they see the dip three times.. not yet enough time for Earth's at 1 AU.





Using the Kepler data and other data (micro-lensing), groups have estimated that on average every star in the Galaxy has 1.6 planets. Planets more common than stars! That means fp = 100%!

From Cassen et al. Nature 2012
17+6% of stars host Jupiter-mass planets (0.3- −910 MJ, where MJ= 318 M⊕ and M⊕ is Earth's mass). Cool Neptunes (10-30 M⊕) and super-Earths (5-10 M⊕) are even more common: their respective abundances per star are 52+22% and 62+35%. We conclude that stars are orbited by planets as a rule, rather than the exception



NOte that Kepler is sensitive to short period planets.

Kepler 10b

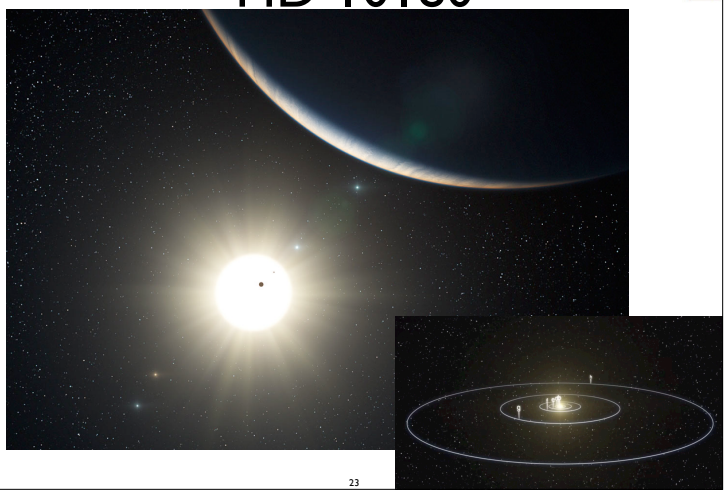
First rocky exoplanet.
Based on mass and size

3.3 Earth masses
but 5x closer than Mercury
so lava planet

22

Kepler could find closest planets fastest— it transits more often.

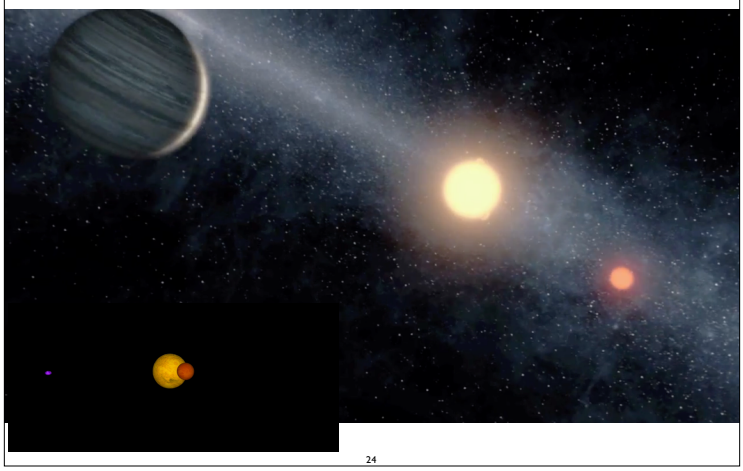
HD 10180



23

The most confirmed planets — 7 and maybe 9, which would make it the largest number of planets including our Solar System!

Kepler 16b



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First confirmed planet in a binary star system!

Kepler 47b

25

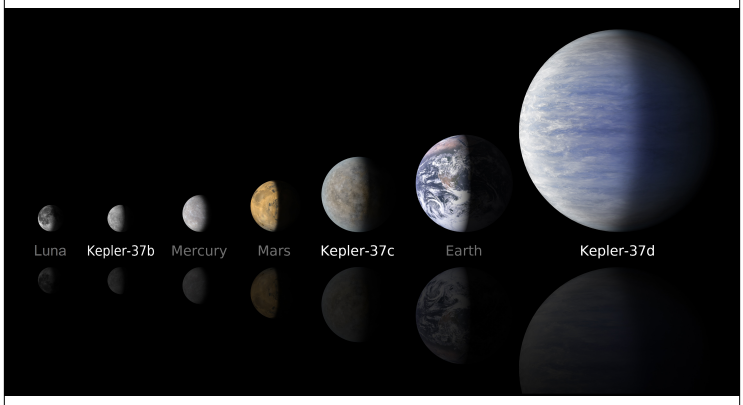
Another circumbinary planetary system— but with at least 3 planets.

Kepler 37b

26

Artist's concept of Kepler-37b. The planet is slightly larger than our moon, measuring about one-third the size of Earth. Credit:

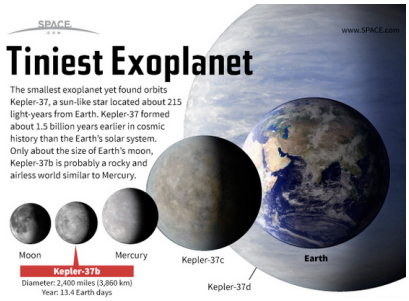
Kepler 37b

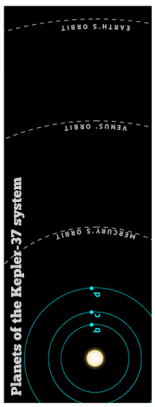


27

NASA's Kepler mission has discovered a new planetary system that is home to the smallest planet yet found around a star like our sun, approximately 210 light-years away in the constellation Lyra. Credit: NASA/Ames/JPL-Caltech

Kepler 37b





28

NASA's Kepler mission has discovered a new planetary system that is home to the smallest planet yet found around a star like our sun, approximately 210 light-years away in the constellation Lyra. Credit: NASA/Ames/JPL-Caltech

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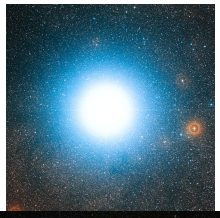
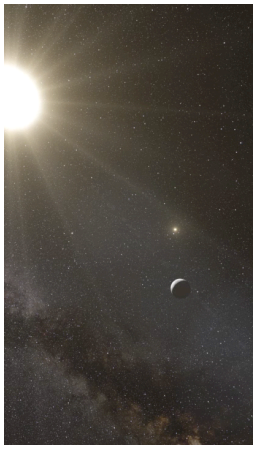
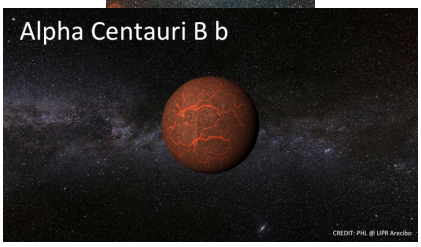
Alpha Centauri







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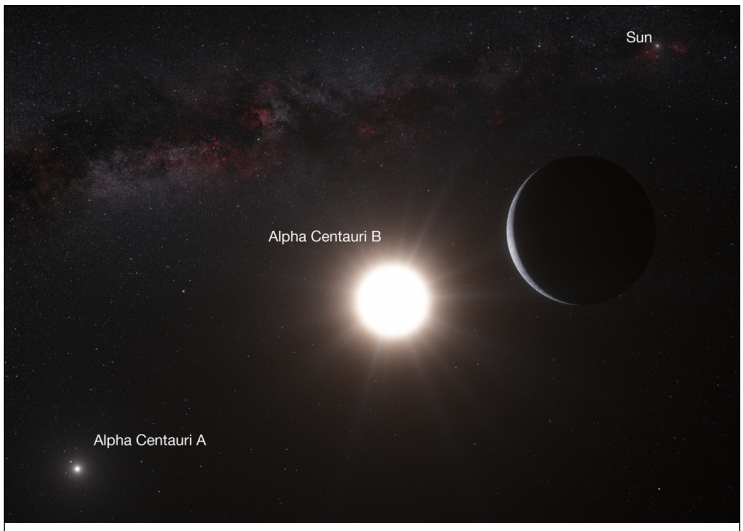
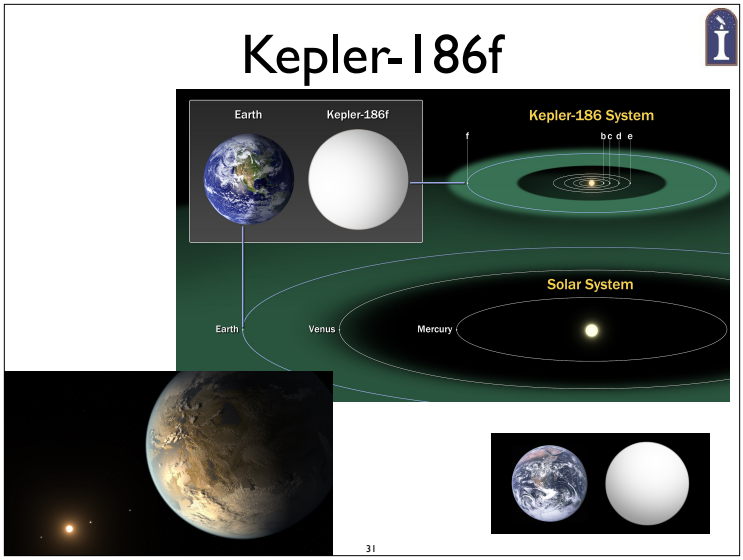
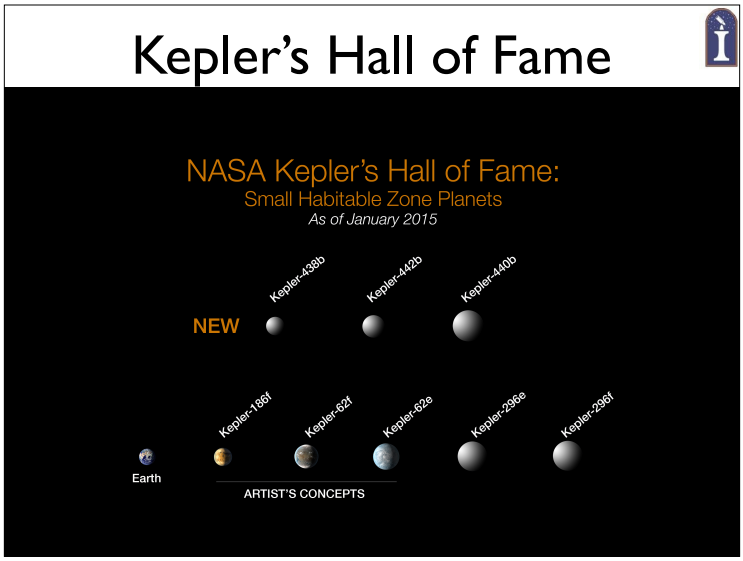
The bright star Alpha Centauri and its surrounding. If confirmed will be the closest exoplanet!

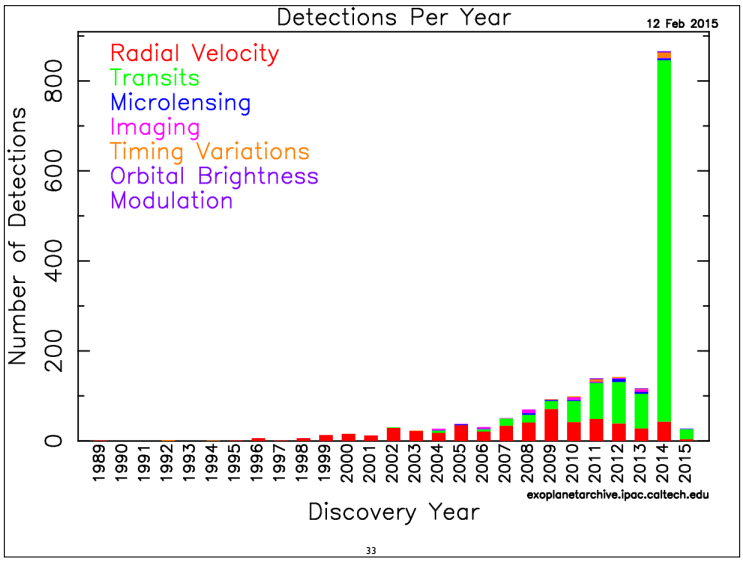


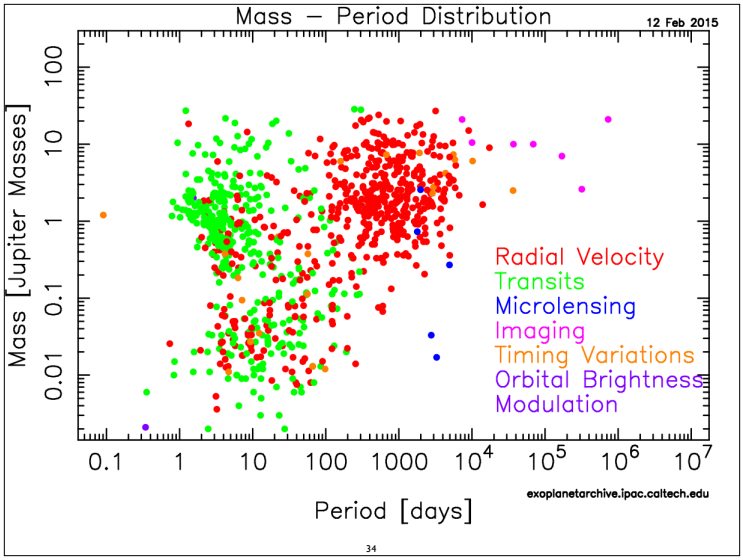
30



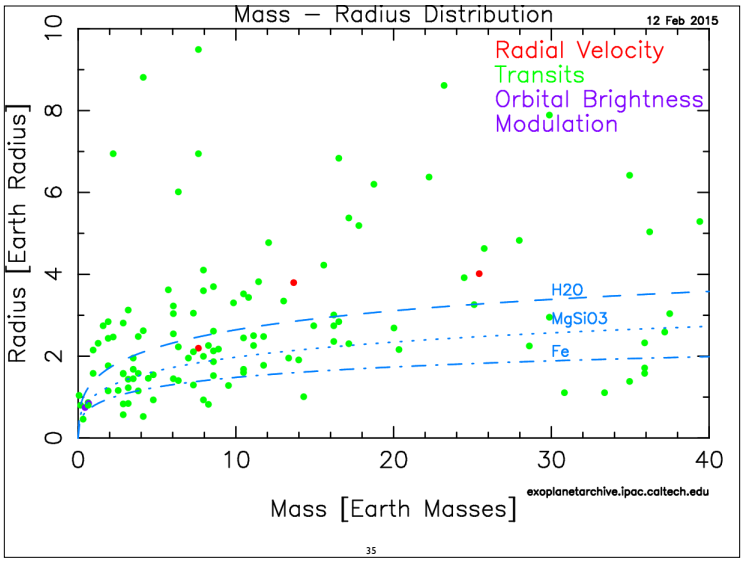
First Earth-like planet in habitable zone— red dwarf star has closer habitable zone.







Updated Weekly



Updated Weekly