Hunting extra-solar planets 400 years after Galilei

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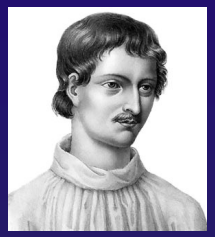
Galileo Galilei

2000

„...and hence the universe is endless in extent,
and the worlds are innumerable..“

Giordano Bruno



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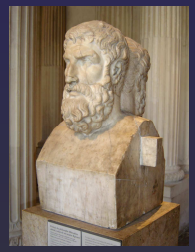
„Are there many worlds, or is there only one?
This is one of the noblest and most elevated questions in
the studies of nature.“

Albertus Magnus

„It has to be proven whether are worlds
other than ours.“

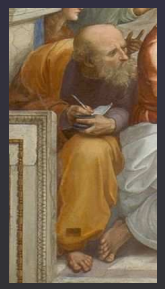
Aristoteles

Chr.



„There are worlds not limited in number,
some of them similar, some dissimilar to
ours..“

Epikur



„There are infinitely many worlds,
successively and in parallel.“

Anaximander

Thales v. Milet

Galilei's detection of Jupiter's moons

2inch telescope

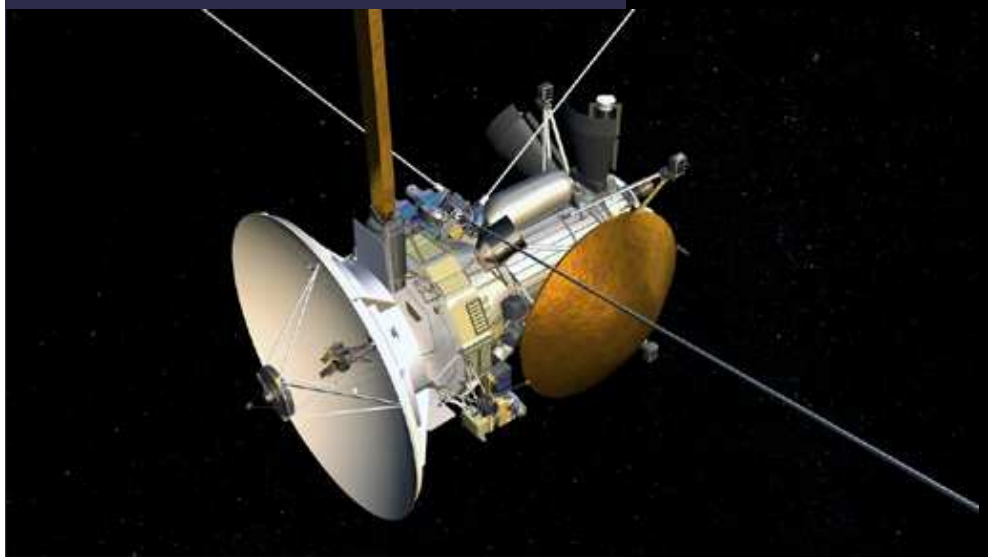
Galilei's discovery

not everything is orbiting Earth…

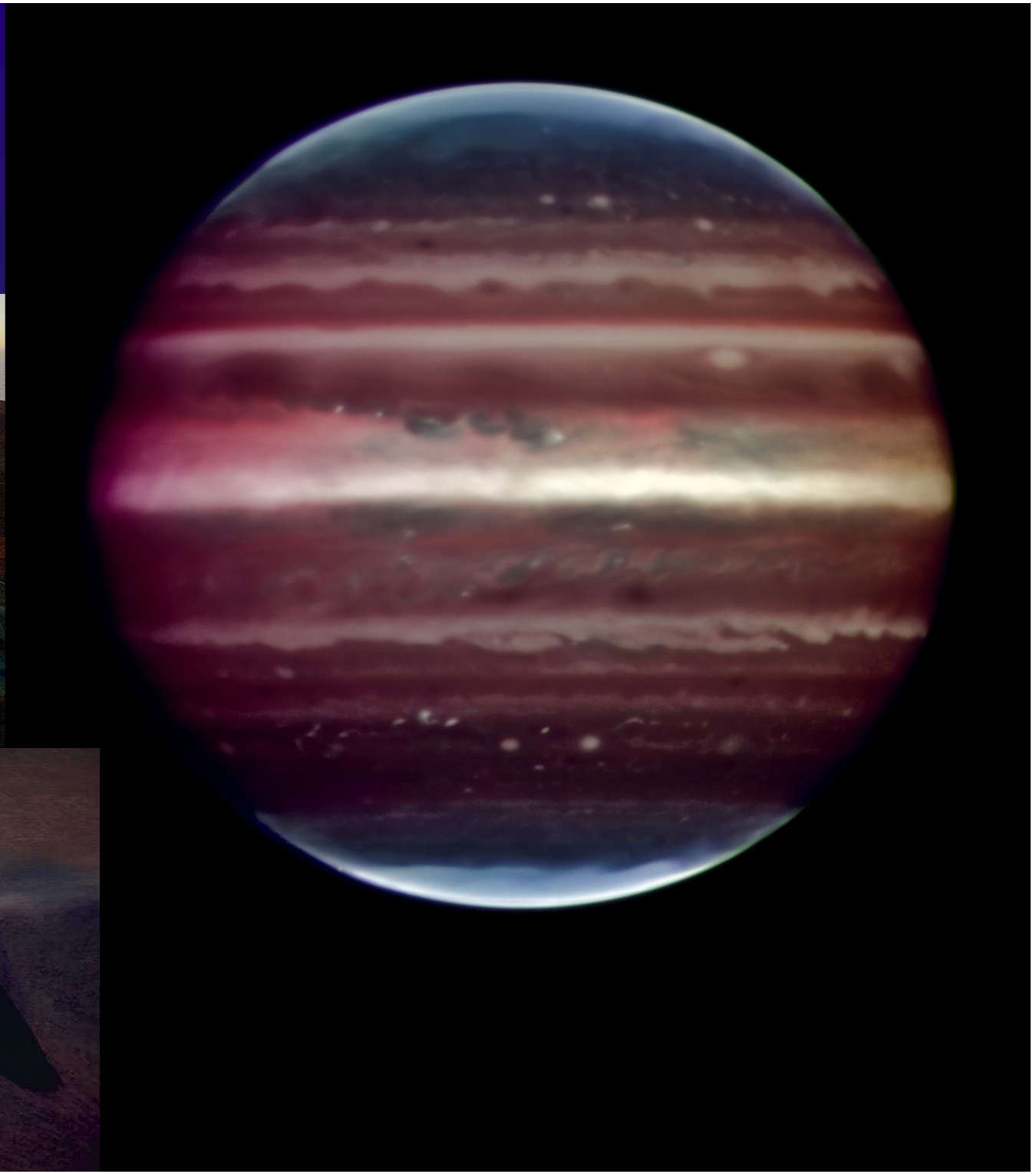
Today:

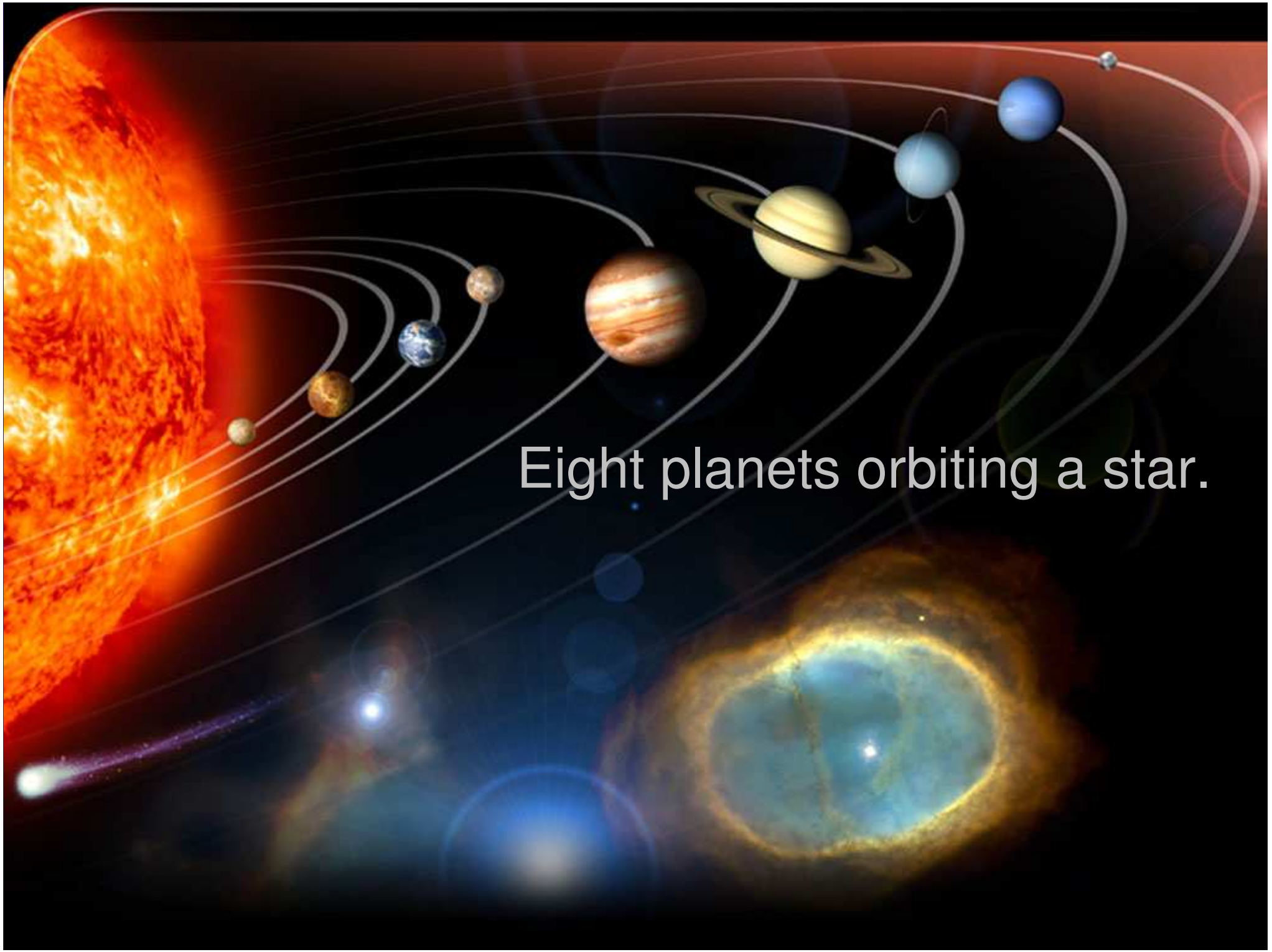
From HST…

…from the Cassini satellite…



…and from the ground.




Eight planets orbiting a star.


Stars are several billion times brighter...


...than their planets.

What to do?

Start with indirect methods:

1. Timing Method
   (first clear planet detection)
2. Radial velocity method
   (most important)
3. Transit method
   (upcoming surveys)
4. Micro-lensing
   (niche)

First detection of an extra-solar planet:

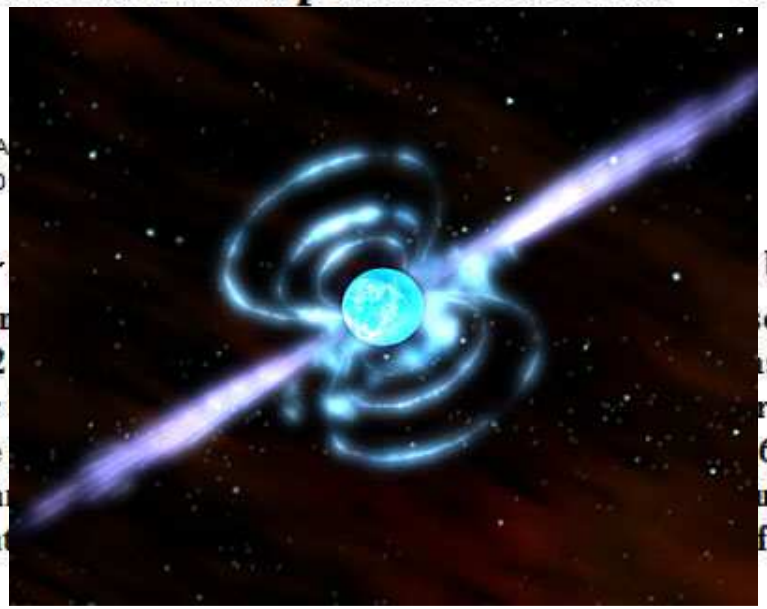
letters to nature

Nature **355**, 145 - 14 (09 January 1992) doi:10.1038/355145a0

A planetary system around the millisecond pulsar PSR1257 + 12

A. WOLSZCZAN* & D. A. FRAIL†

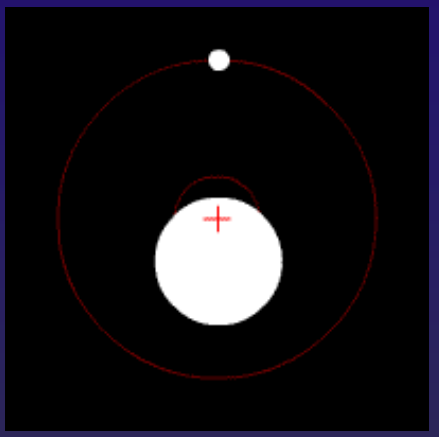
*National Astronomy and Ionosphere Center, Arecibo Observatory, A
†National Radio Astronomy Observatory, Socorro, New Mexico 8780



MILLISECOND radio pulsars, which are old (~ be spun up usually found in binary systems with other deger cope to ma recently discovered 6.2-ms pulsar PSR1257 +12 ssociated v planet-sized bodies. The planets detected so far re $M_\oplus$ is th pulsar are 0.47 AU and 0.36 AU, and they move 66.6 days. be present in this system. The detection of a pla utron star, to the pulsar PSR1829–10 (ref. 3) raises the tant f neutron st like bodies.

1. The timing method

variations in the pulsar's period induced by the star's motion due to the planet



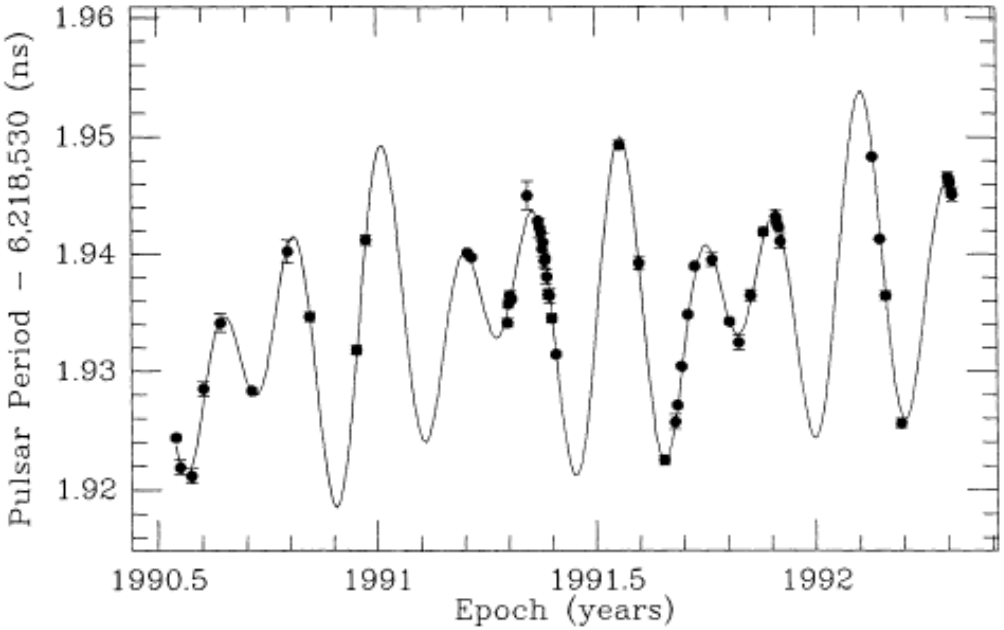
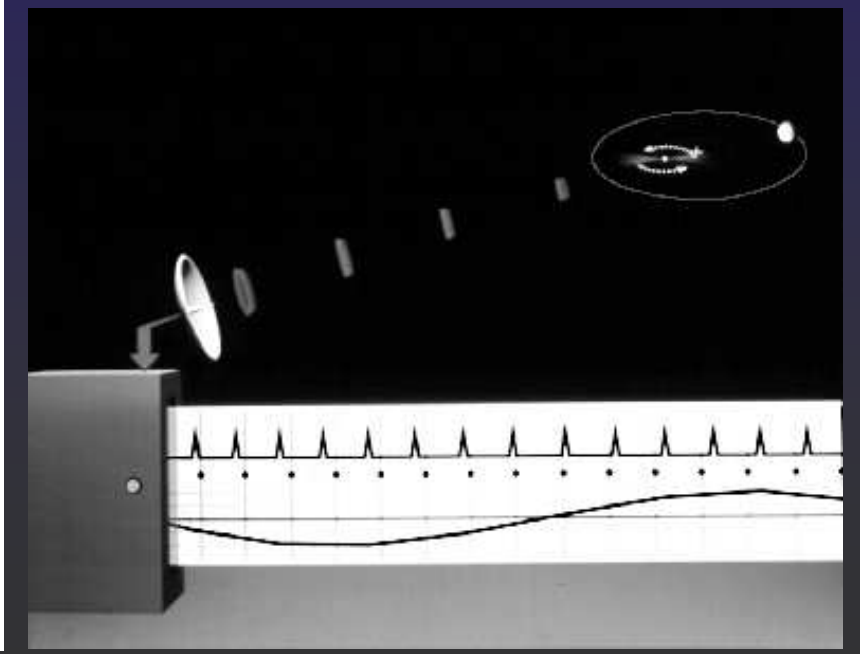
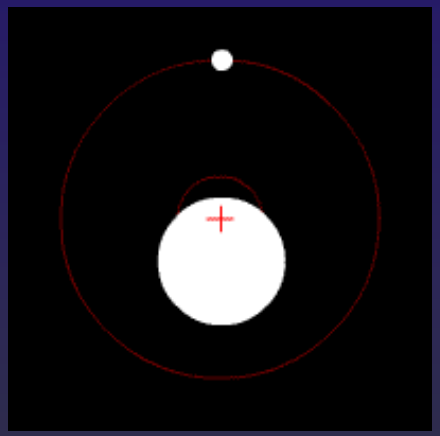
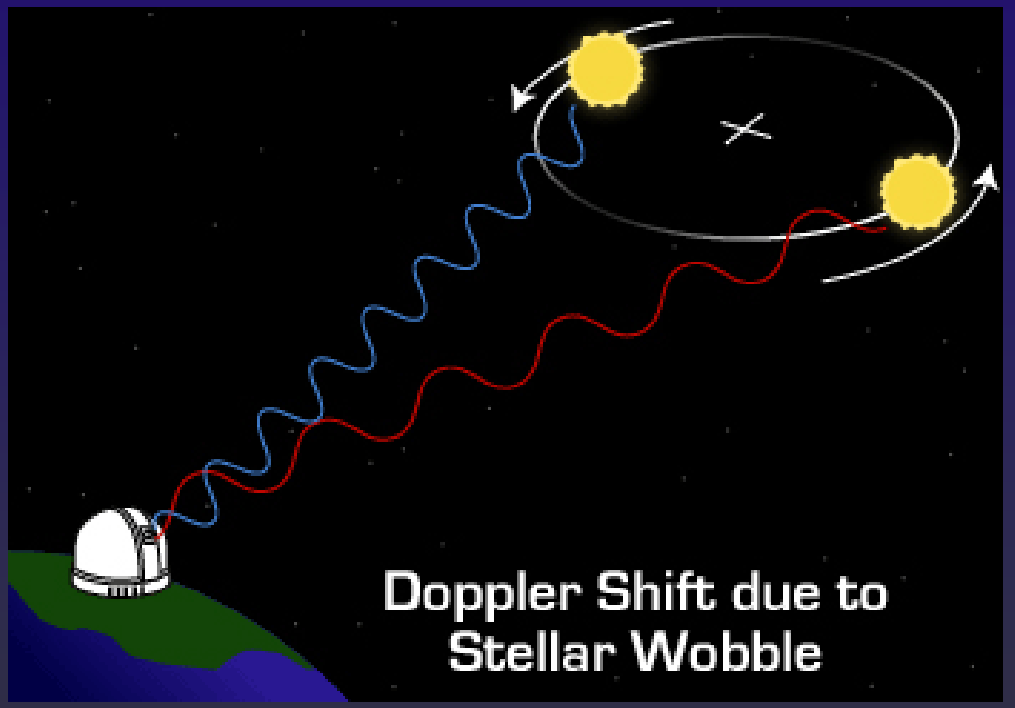


FIGURE III Period variations of PSR1257+12. Each period measurement is based on observations made on at least two consecutive days. The solid line denotes changes in period predicted by a two–planet model of the 1257+12 system.



2. The radial velocity method





$$\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$$

i.e., 100 km/s = 0.22 nm @ 656 nm

What reflex motion does a planet introduce?

Examples:

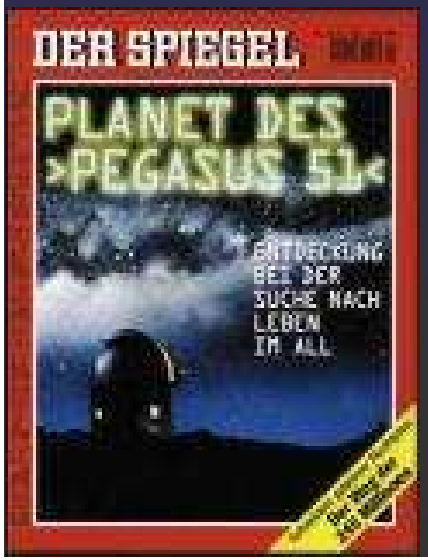
	velocity	period
Earth around Sun:	9 cm/s	1yr
Jupiter around Sun:	11 m/s	11yrs
Jupiter ar. Sun on Earth orbit:	25 m/s	1yr

A Jupiter-mass companion to a solar-type star

Michel Mayor & Didier Queloz

Geneva Observatory, 51 Chemin des Maillettes, CH-1290 Sauverny, Switzerland

The presence of a Jupiter-mass companion to the star 51 Pegasi is inferred from observations of periodic variations in the star's radial velocity. The companion lies only about eight million kilometres from the star, which would be well inside the orbit of Mercury in our Solar System. This object might be a gas-giant planet that has migrated to this location through orbital evolution, or from the radiative stripping of a brown dwarf.



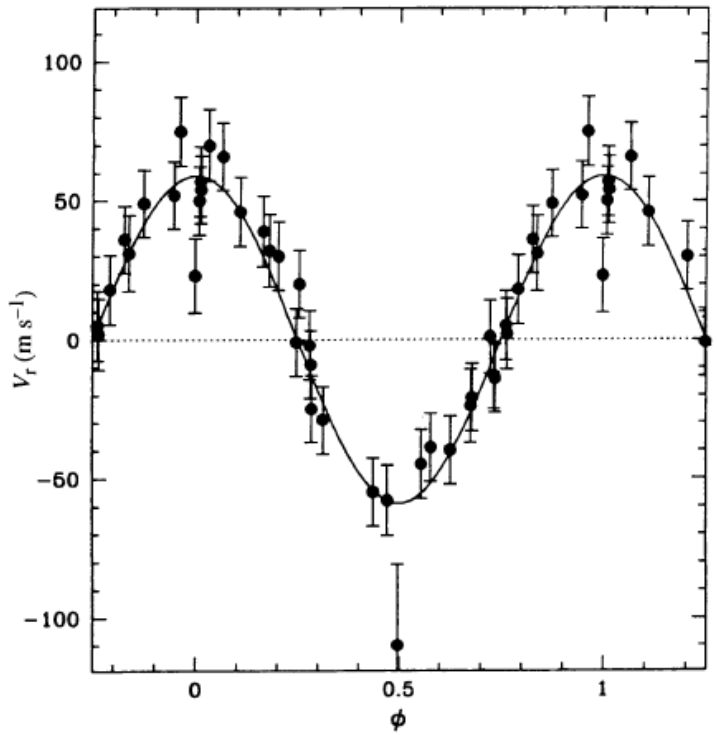


FIG. 4 Orbital motion of 51 Peg corrected from the long-term variation of the γ-velocity. The solid line represents the orbital motion computed from the parameters of Table 1.

M sin$i$ = 0.45 M_J

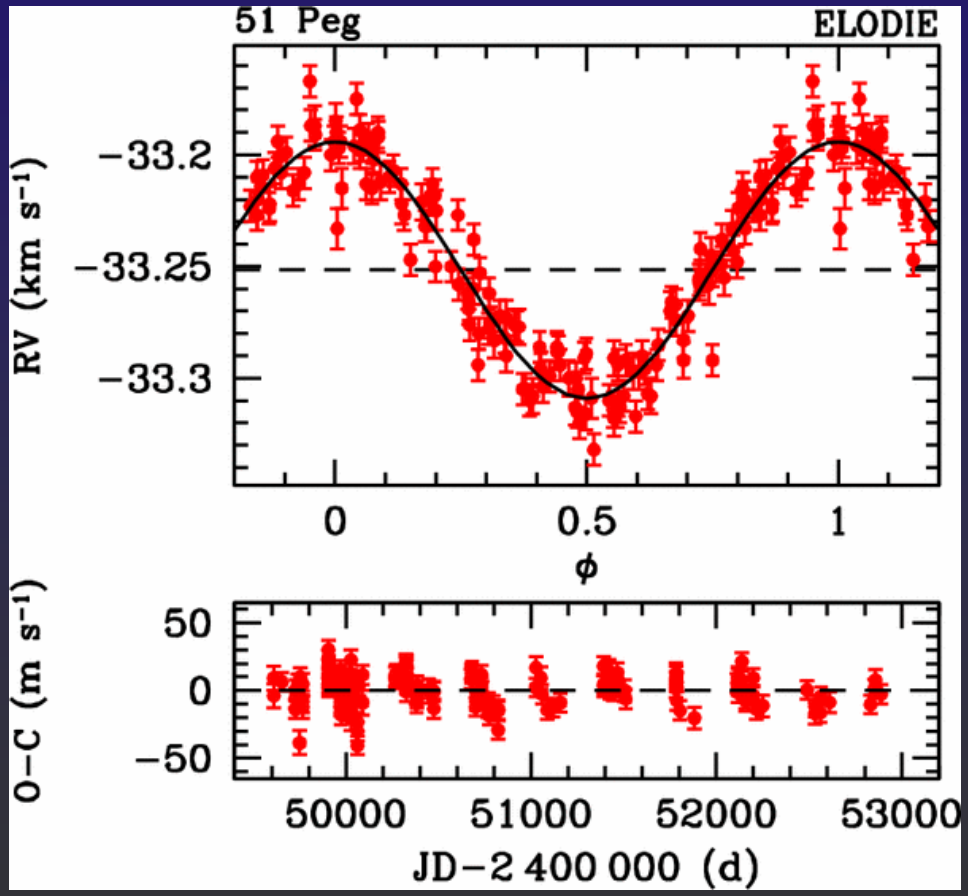
P = 4.2 d

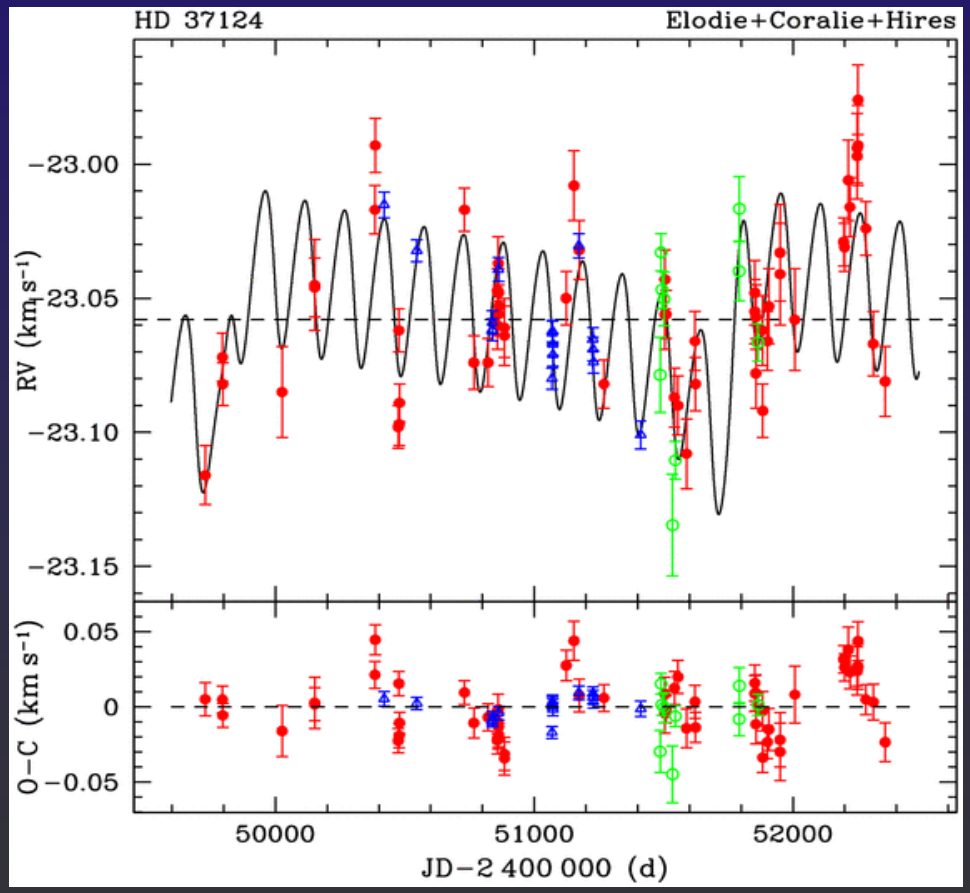
d = 0.05 AU

K = 55 m/s

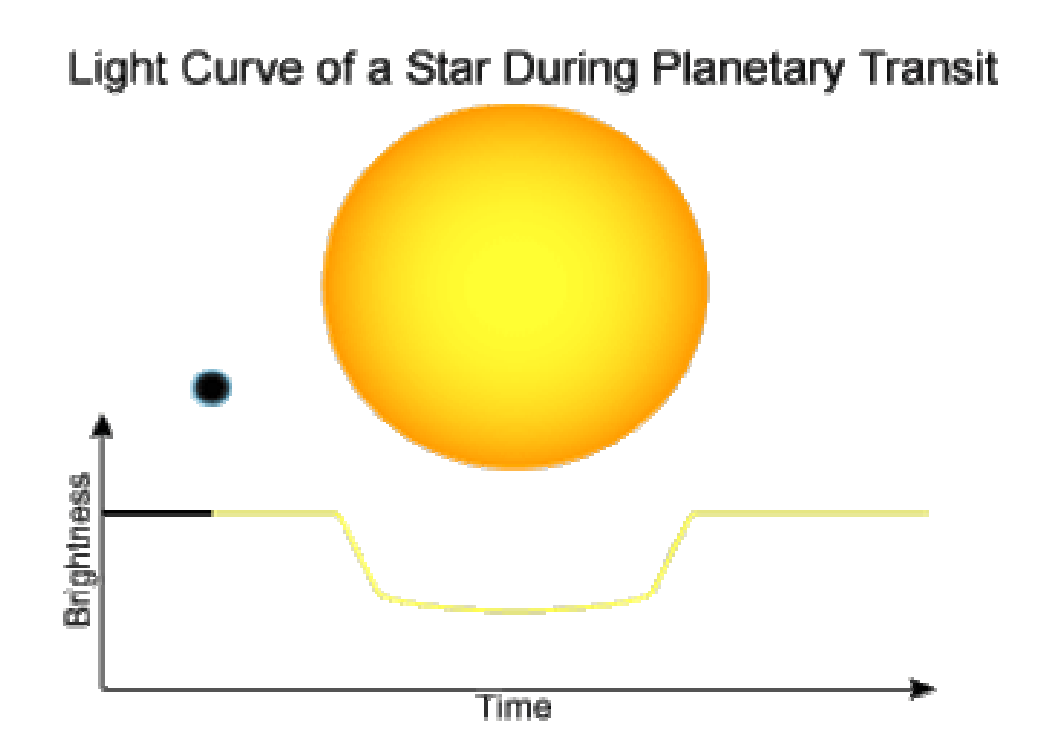
Mayor & Queloz, 1995, Nature

Examples for radial velocity detections

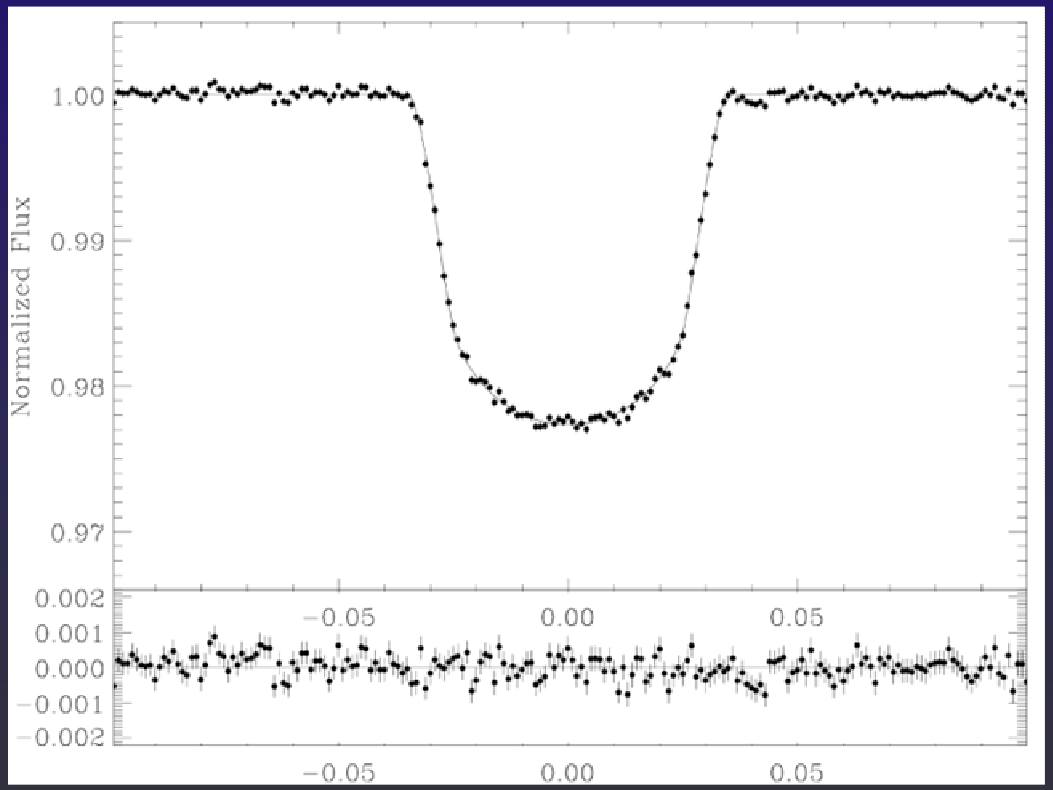




3. Transit method

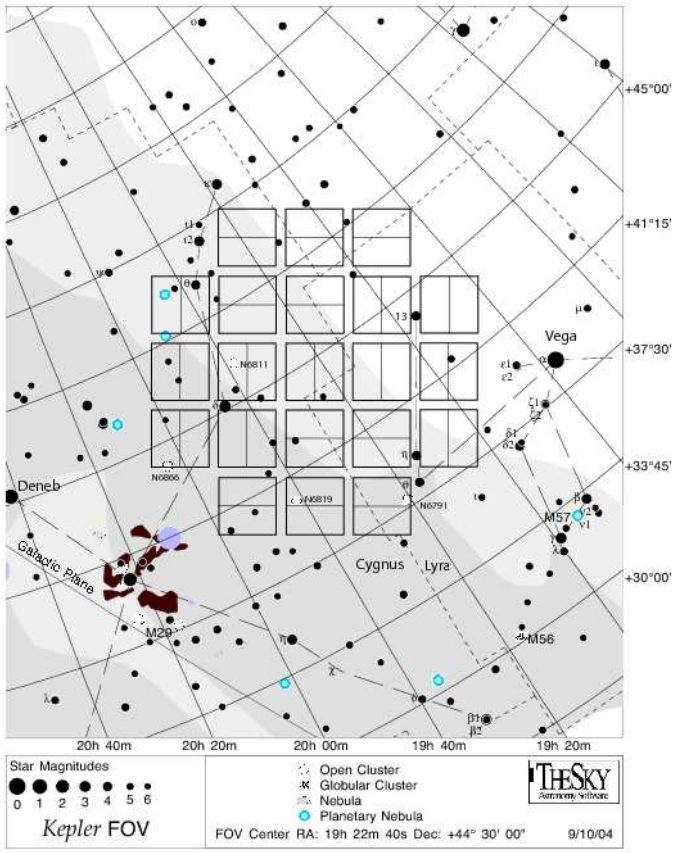


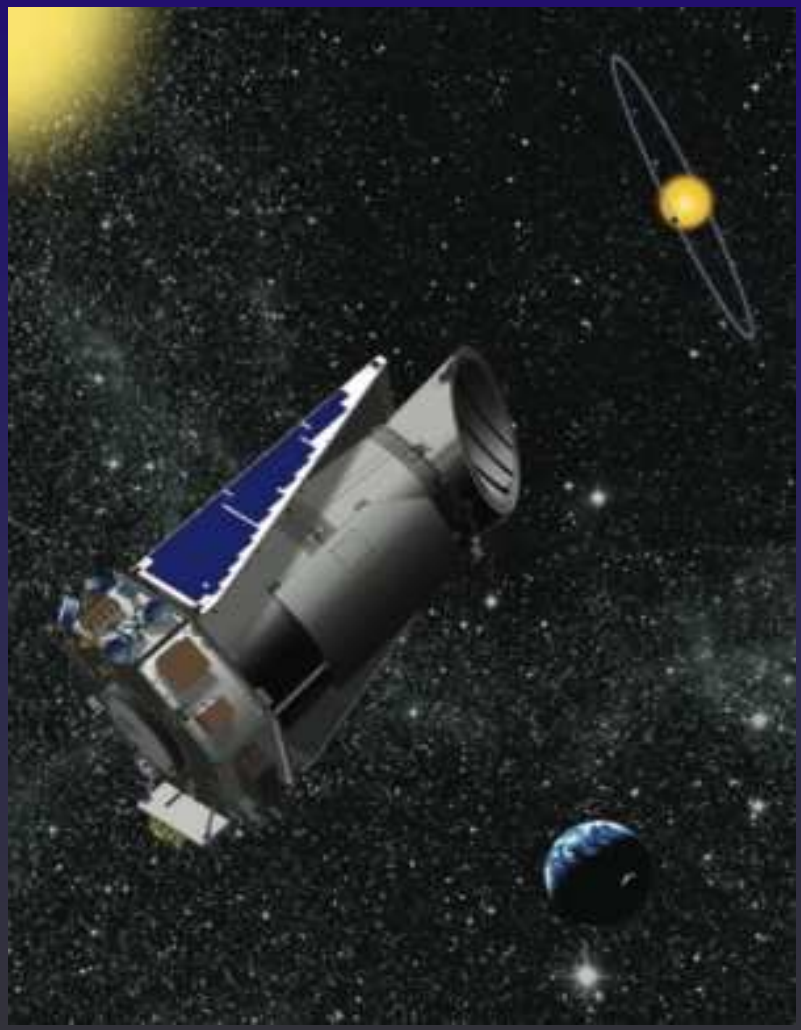
Transit detections – space-borne science



1st transit detected with CoRoT

Coming soon: Kepler



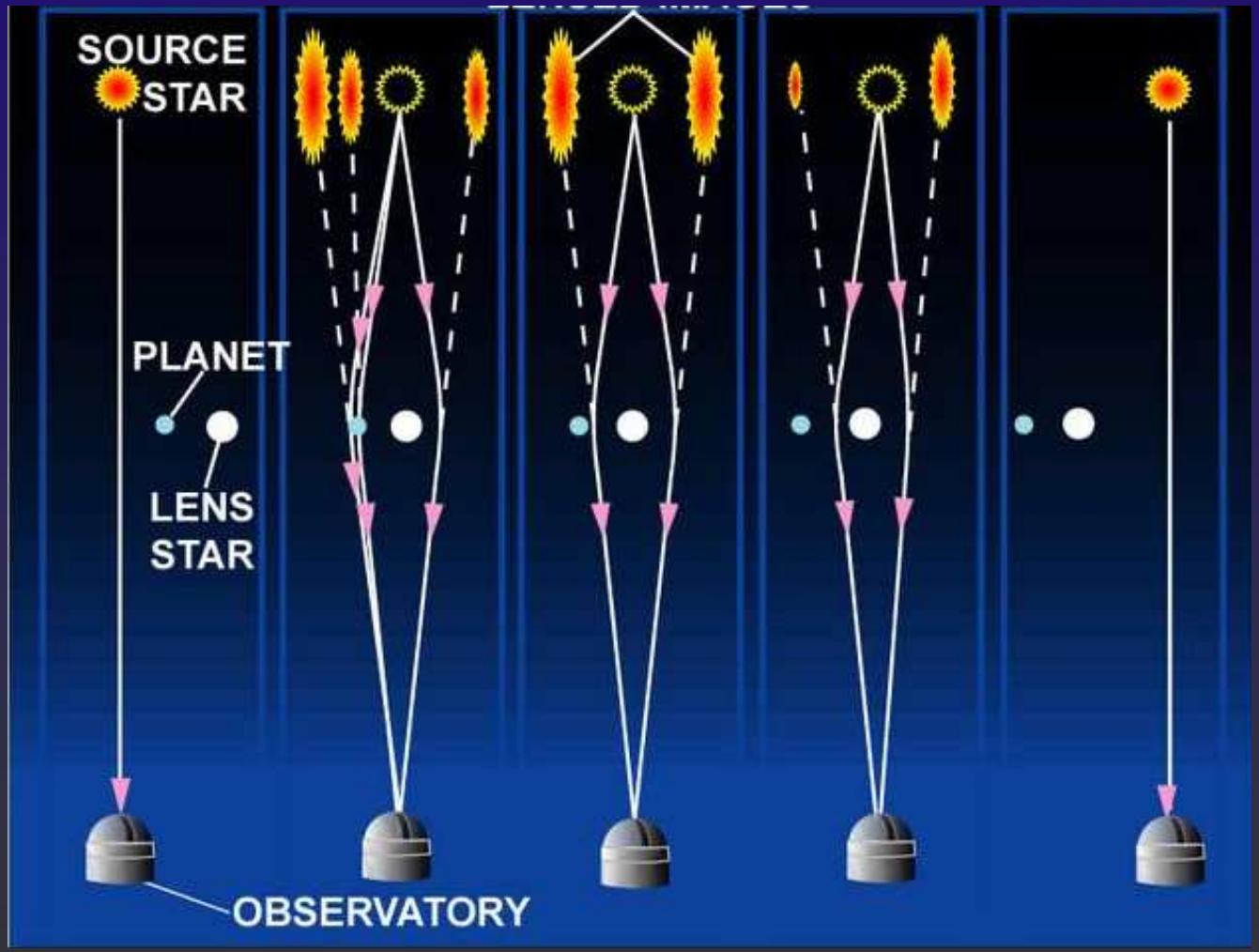


Stare at the same field for 4yrs – designed to detect an Earth around a Sun
~ 170 000 stars surveyed

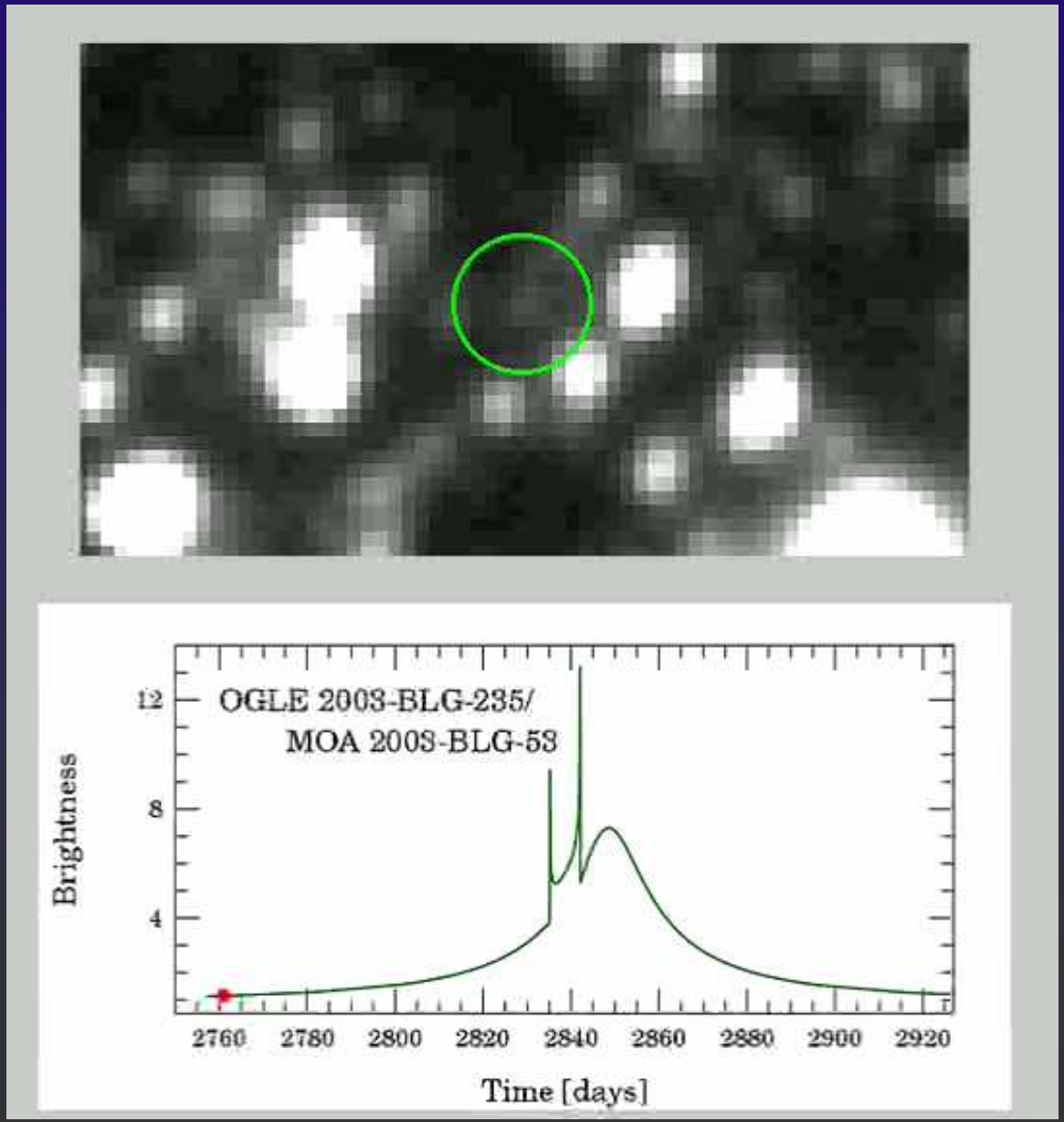
Coming soon: Kepler

Launch: March 6th 2009 03:48:43 UT (subject to change)

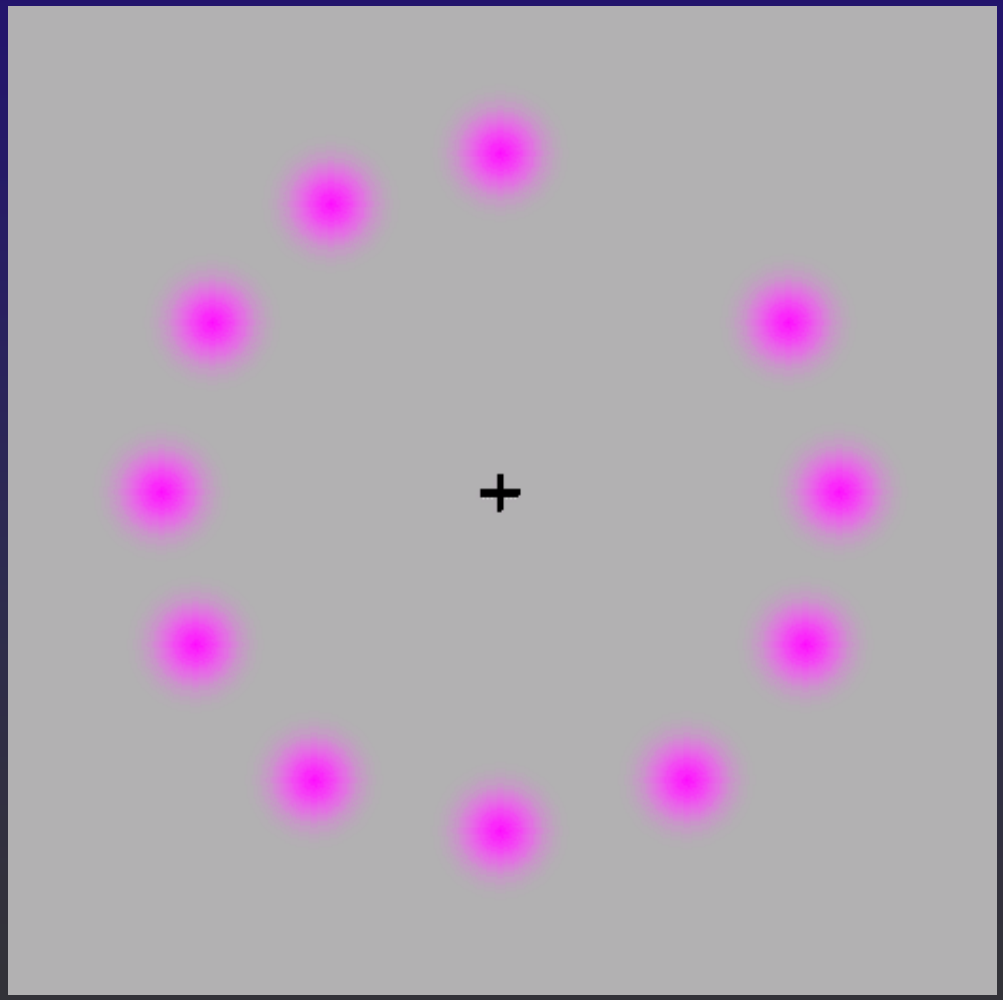
4. Micro-lensing



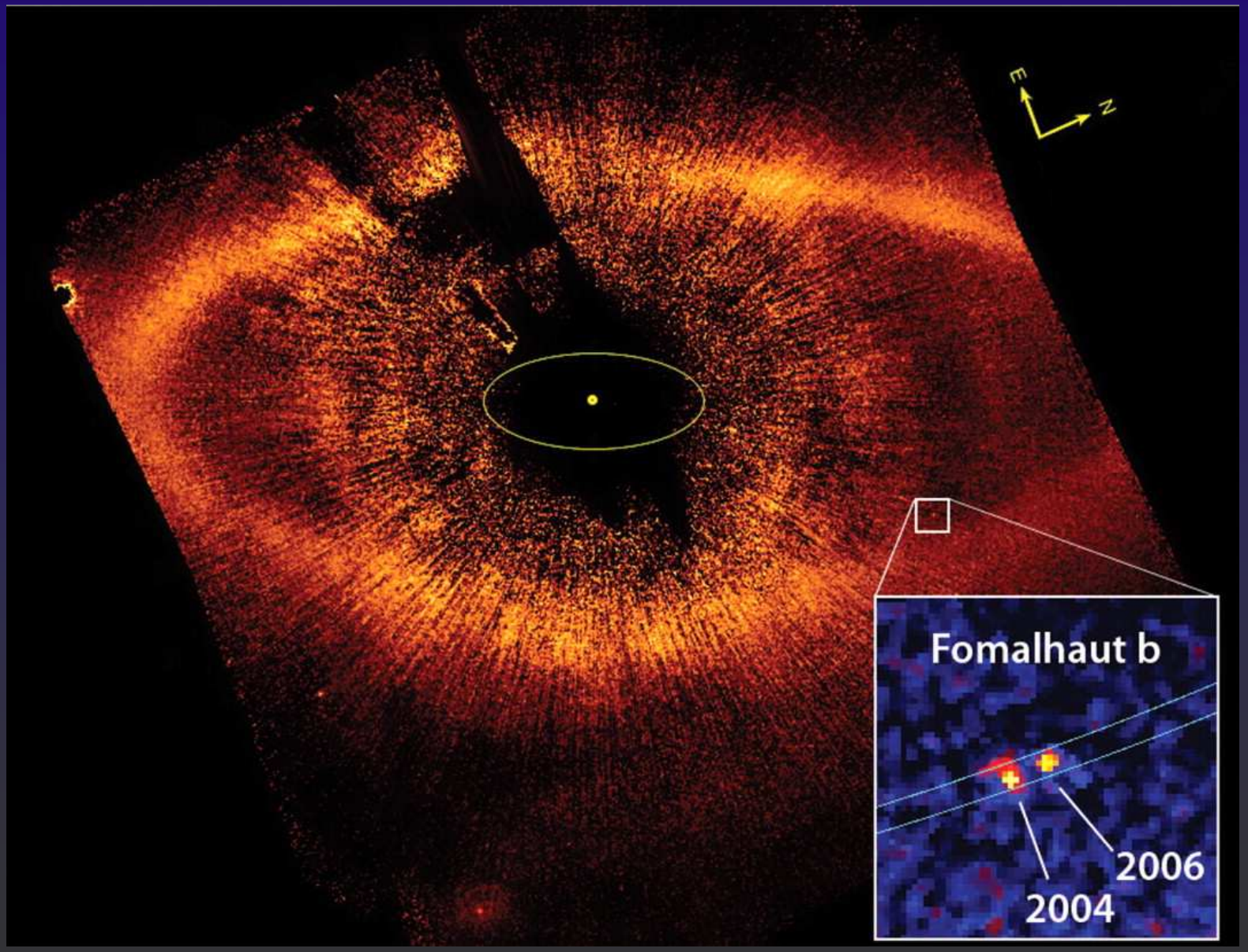
4. Micro-lensing



Well, it would be nice to SEE a planet!

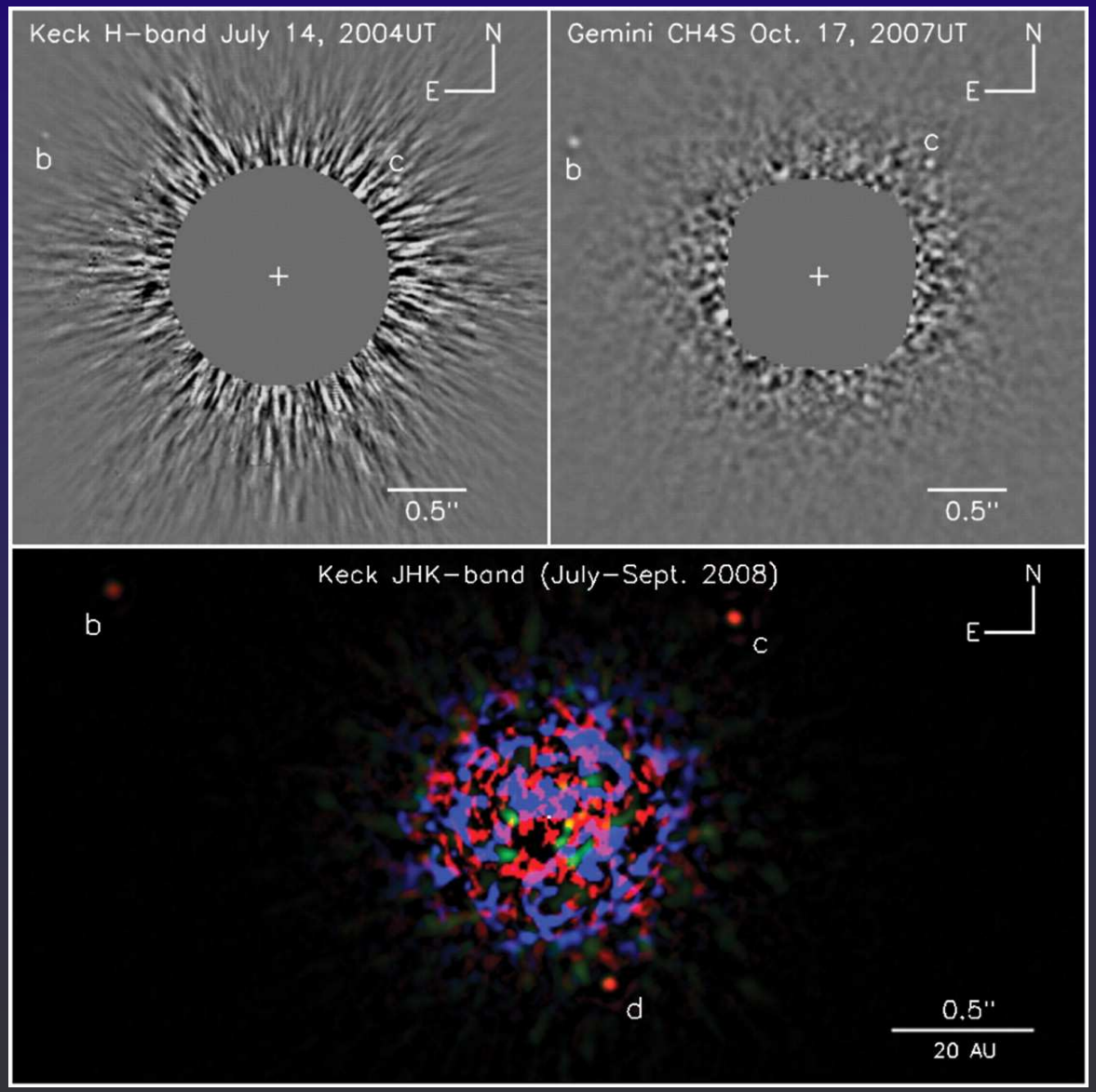


Seeing is believing: The first images of exo-planets



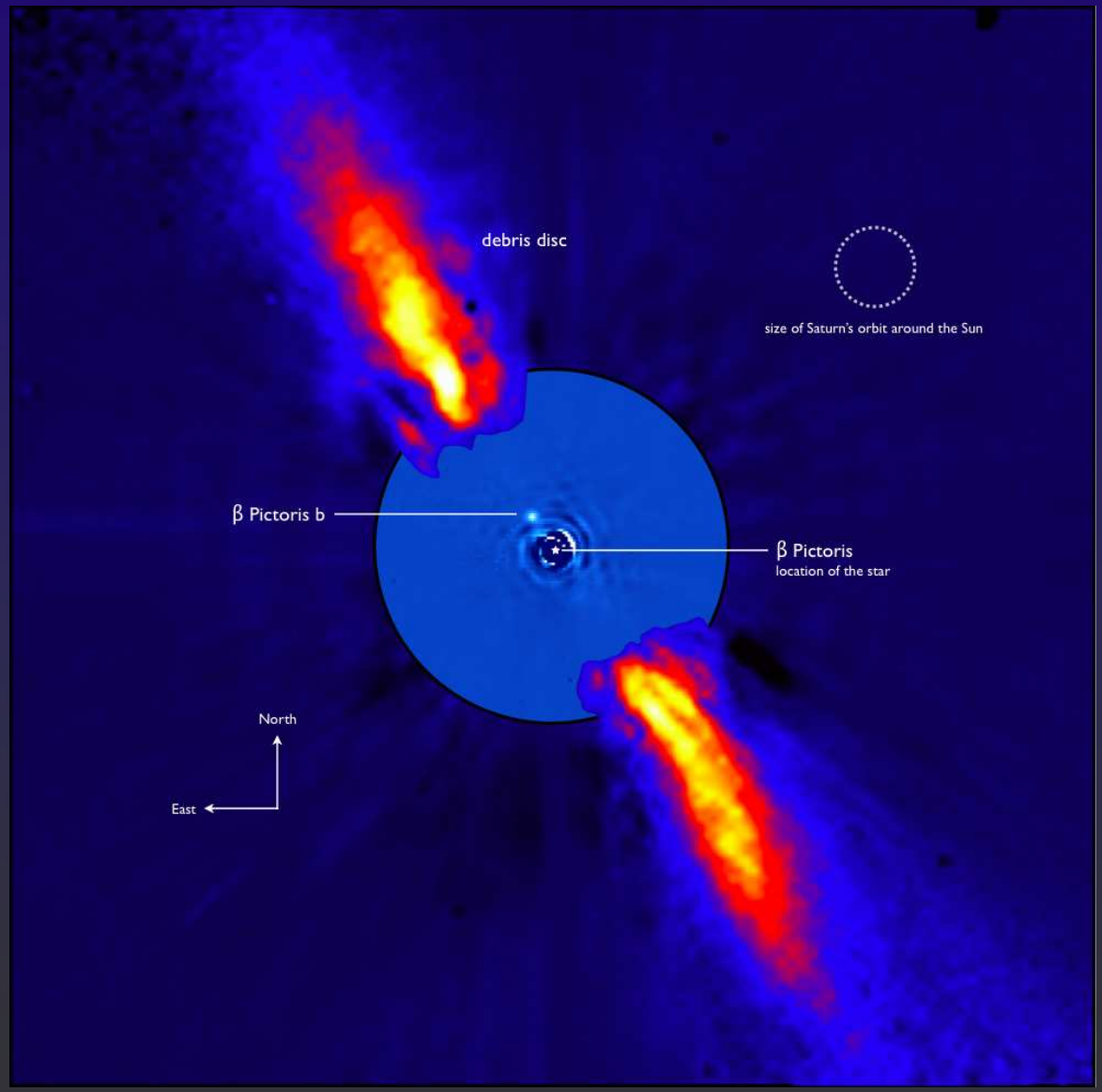
Kalas et al., 2008

Seeing is believing: The first images of exo-planets



Marois et al., 2008

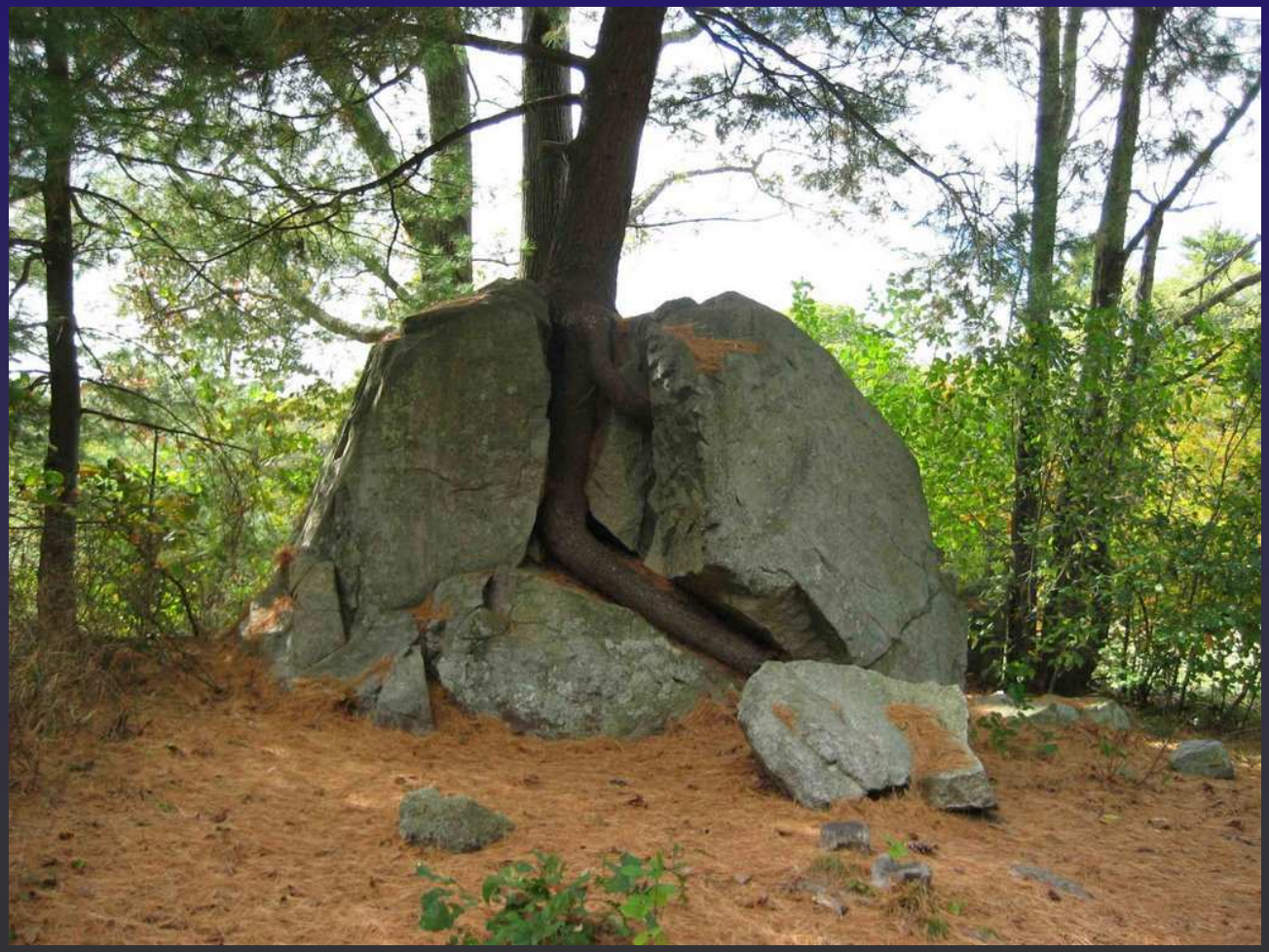
Seeing is believing: The first images of exo-planets



Lagrange et al., 2008

Back to the old question:

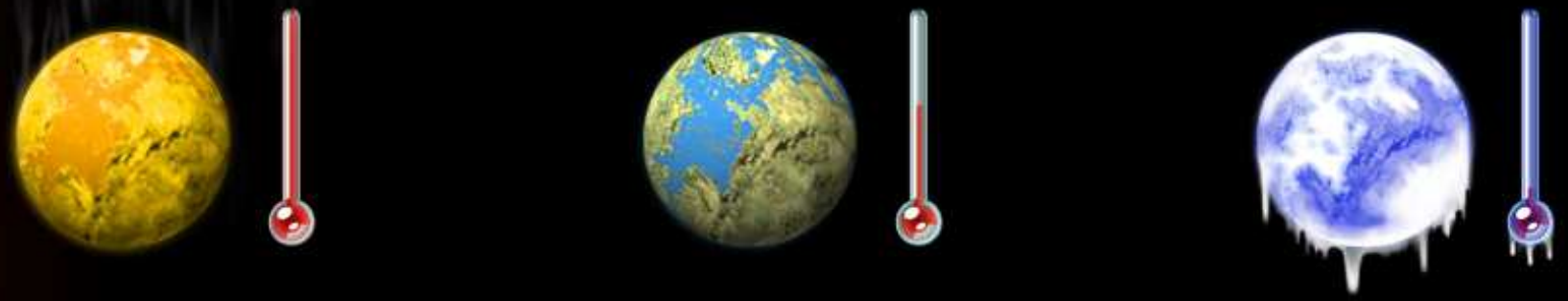
Could there be life?



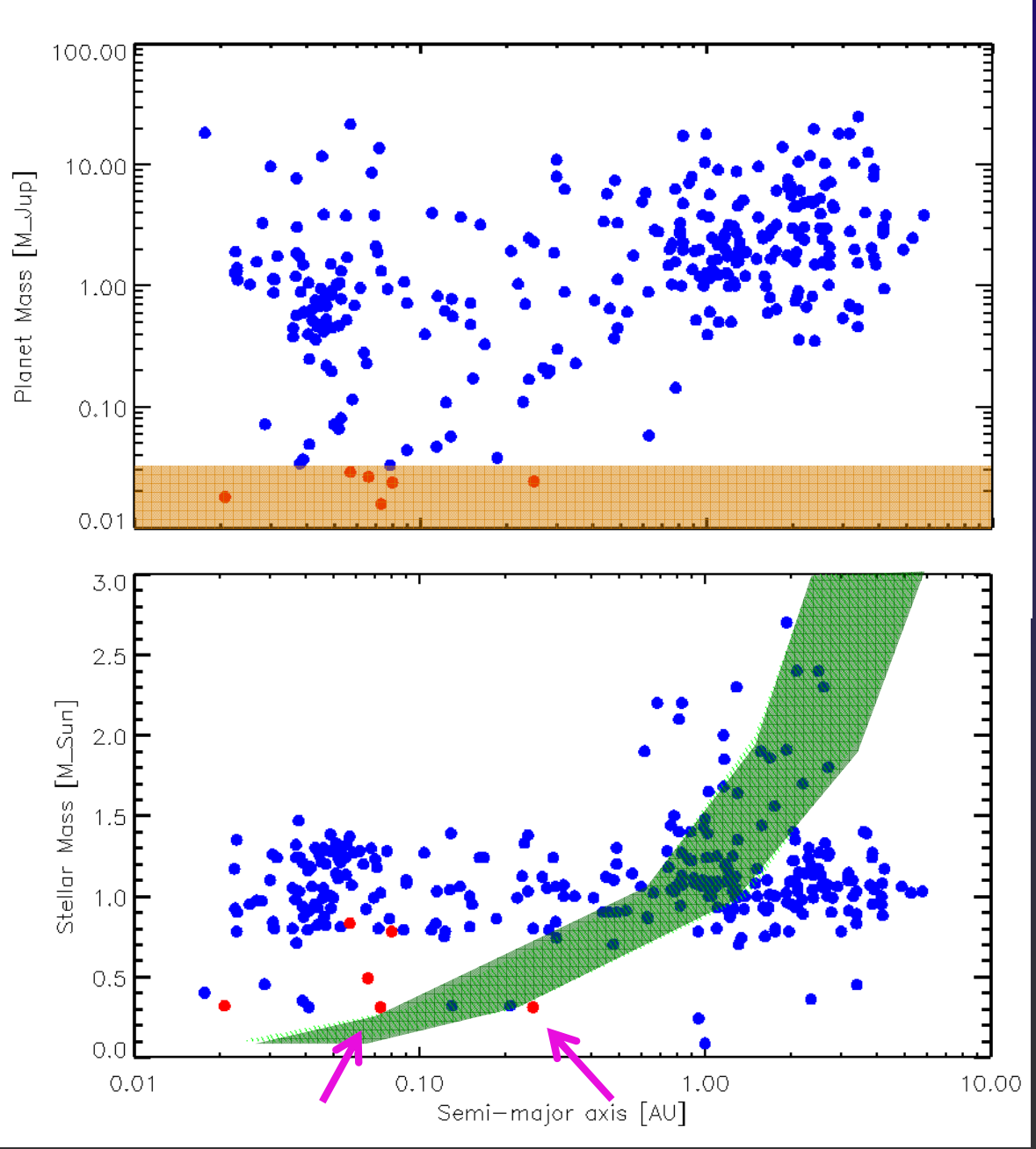
Life on other planets:

1. The planet should have a crust (no gas-giant)
2. Habitable zone:

   Area where liquid water can exist



Inventory



Planets have "solid" crust

"habitable" zone

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THE SEARCH FOR A HABITABLE PLANET Font: - +

Researchers May Have Found Earth's Twin

By Markus Becker

Astronomers may have found their holy grail. A team working out of Geneva say they have discovered a planet which may be capable of supporting life.

The Planetary System in Gliese 581
(Artist's Impression)

ESO Press Photo 22a/07 (25 April 2007)

A *super-Earth* inside the habitable zone

A summary of the last 2500 years

- 500 B.C.: white paper: “There must be infinitely many worlds”
- 1611: Detection of moons around Jupiter
- 1992: First detection of a planet around a star
- 1995: First detection of a planet around a sun-like star
- 2007: First detection of a planet in the habitable zone
- 2008: First image of an extra-solar planet

INTERNATIONAL YEAR OF ASTRONOMY 2009

THE UNIVERSE : YOURS TO DISCOVER

IAU

GERMANY
NATIONALES KOMITEE