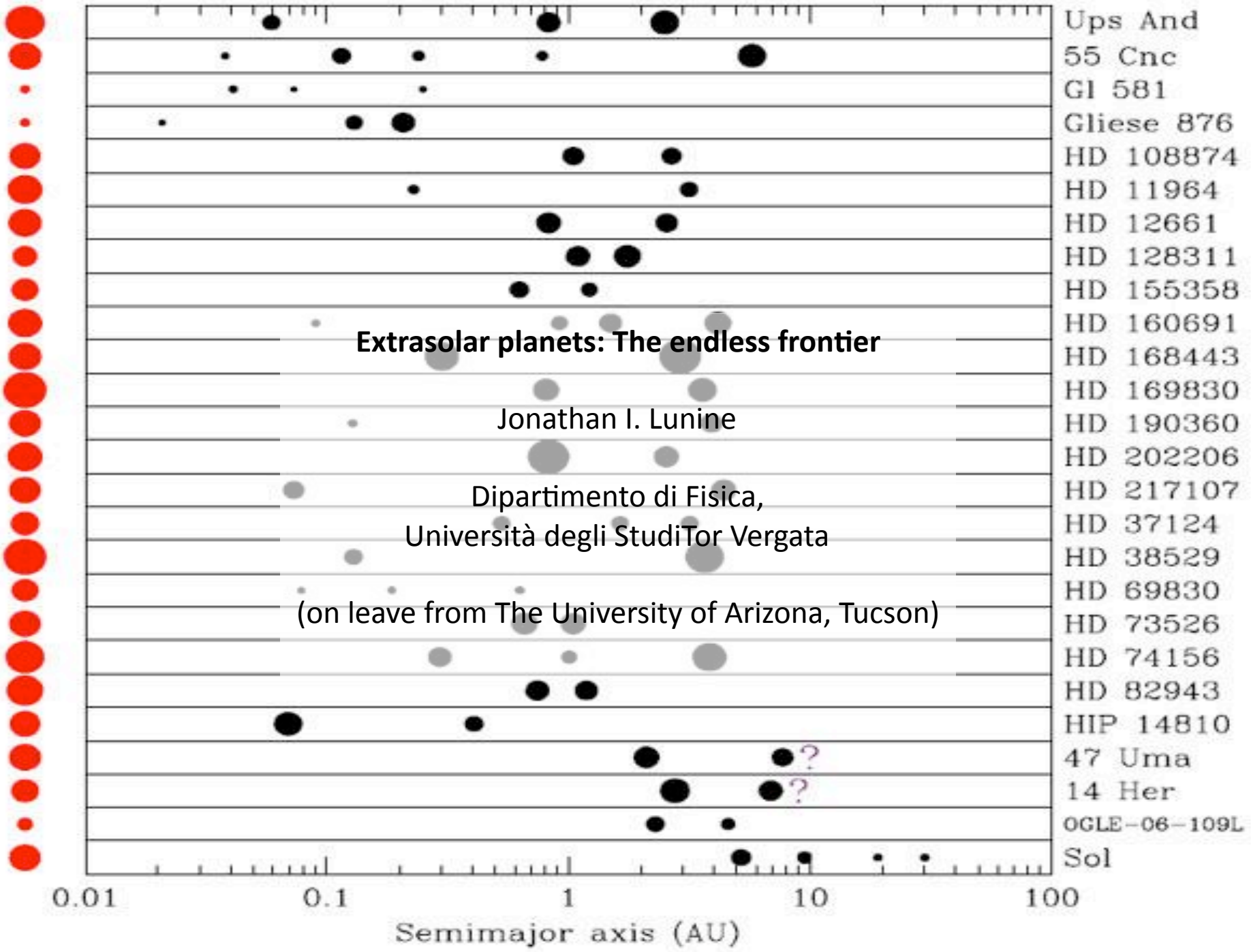
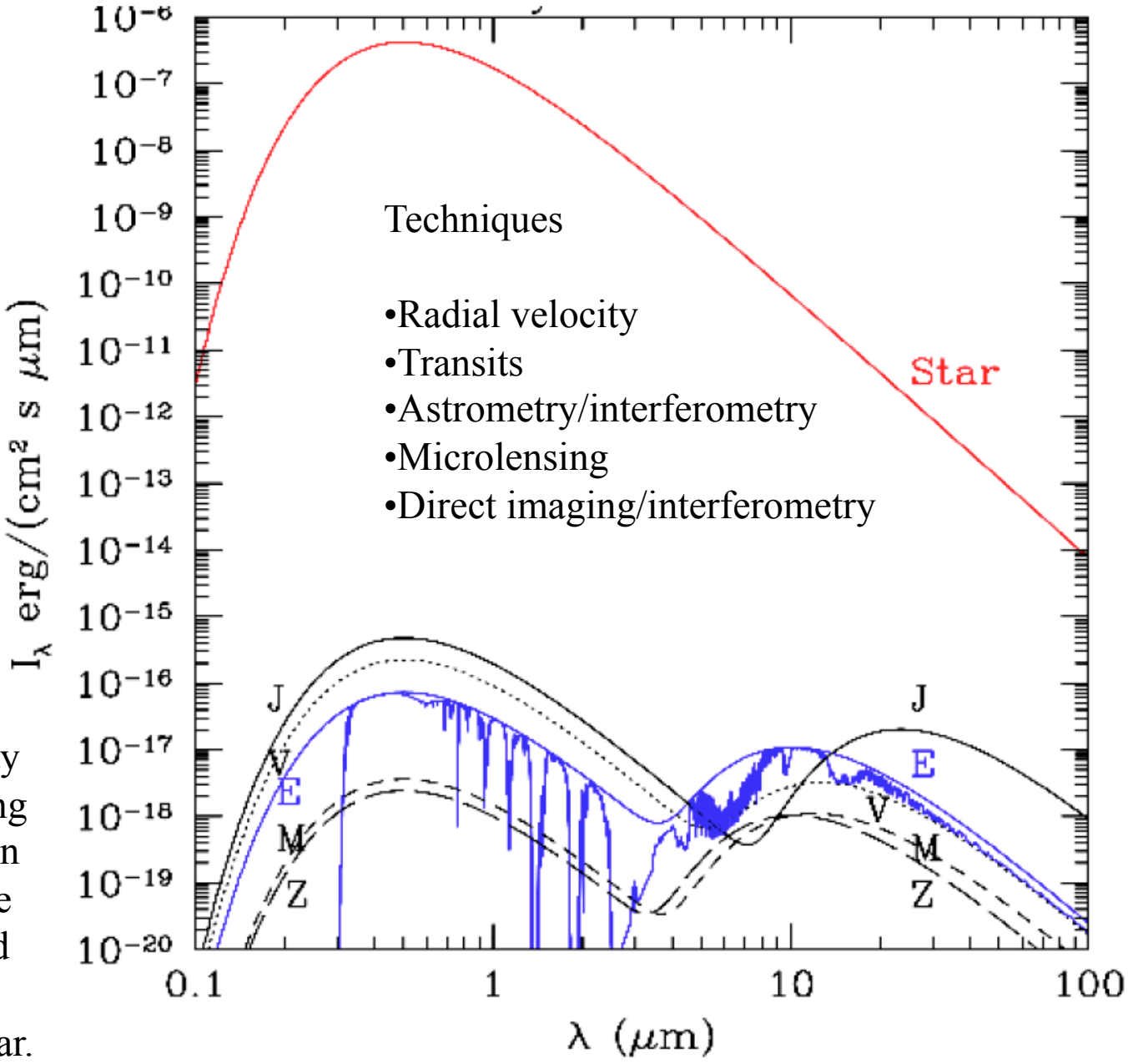


Extrasolar planets: The endless frontier

Jonathan I. Lunine

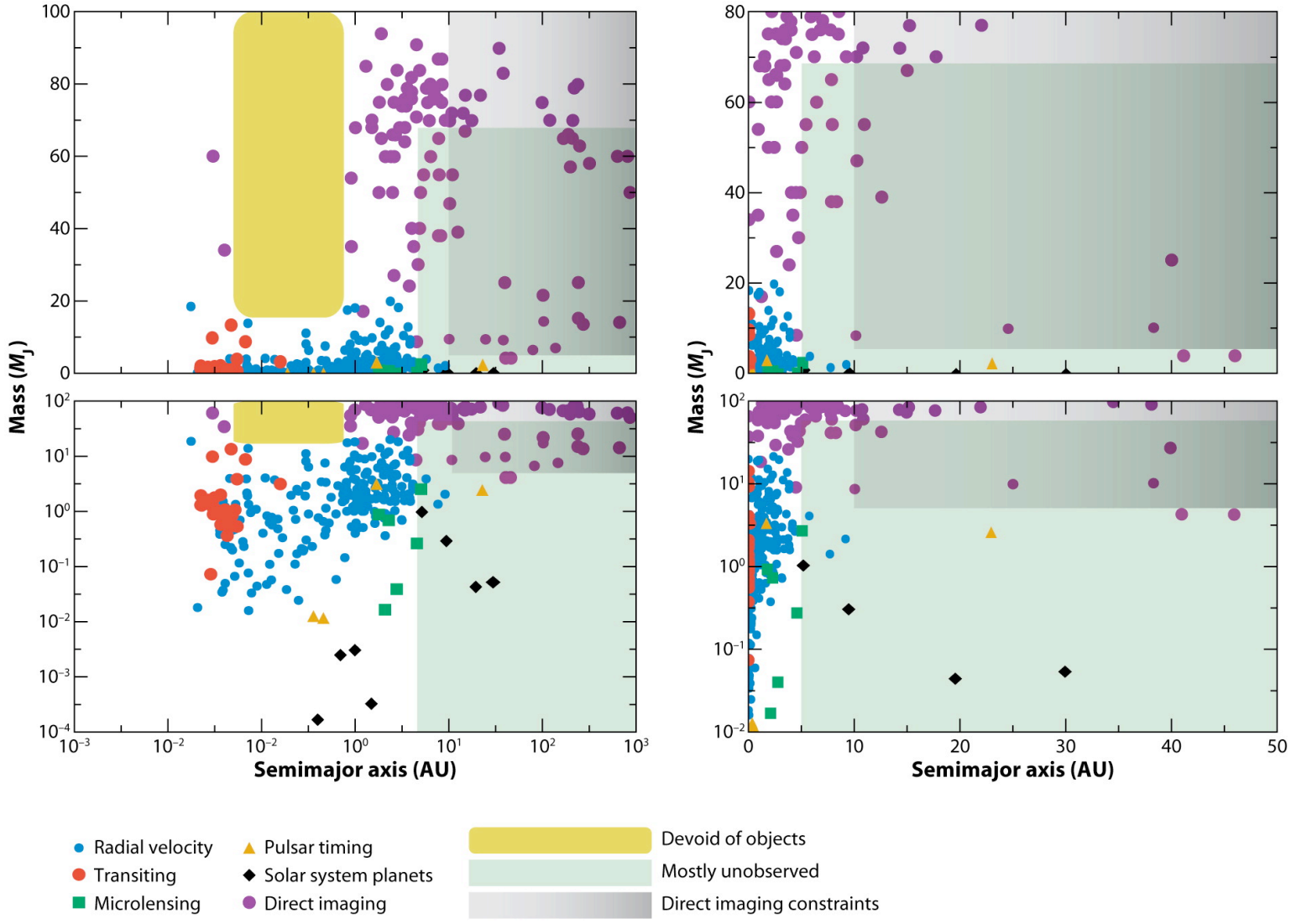
Dipartimento di Fisica,
Università degli StudiTor Vergata

(on leave from The University of Arizona, Tucson)



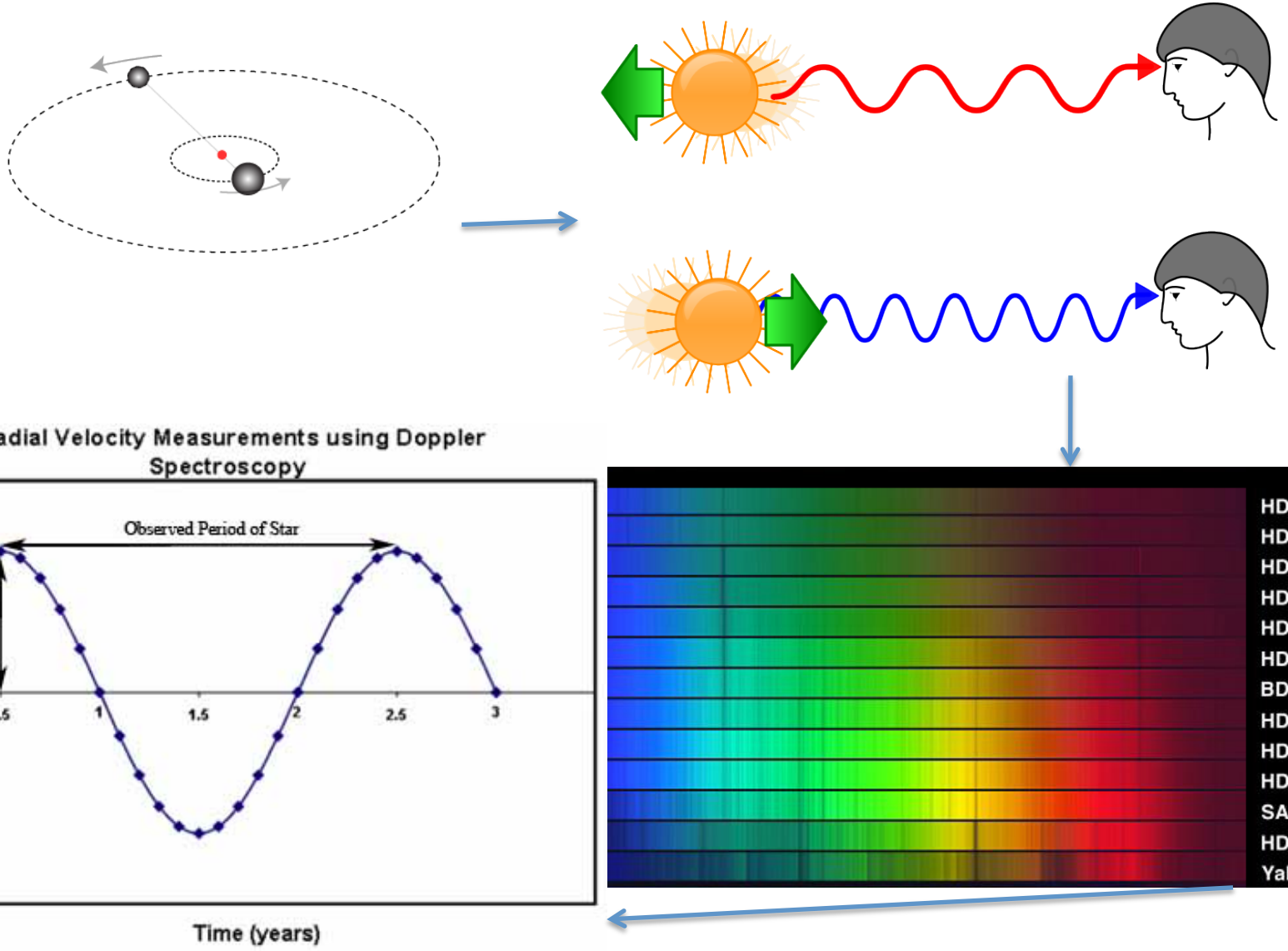
The difficulty with detecting planets lies in their extreme faintness and proximity to the parent star.

Radial Velocity has found the bulk of the 494 planets discovered to date

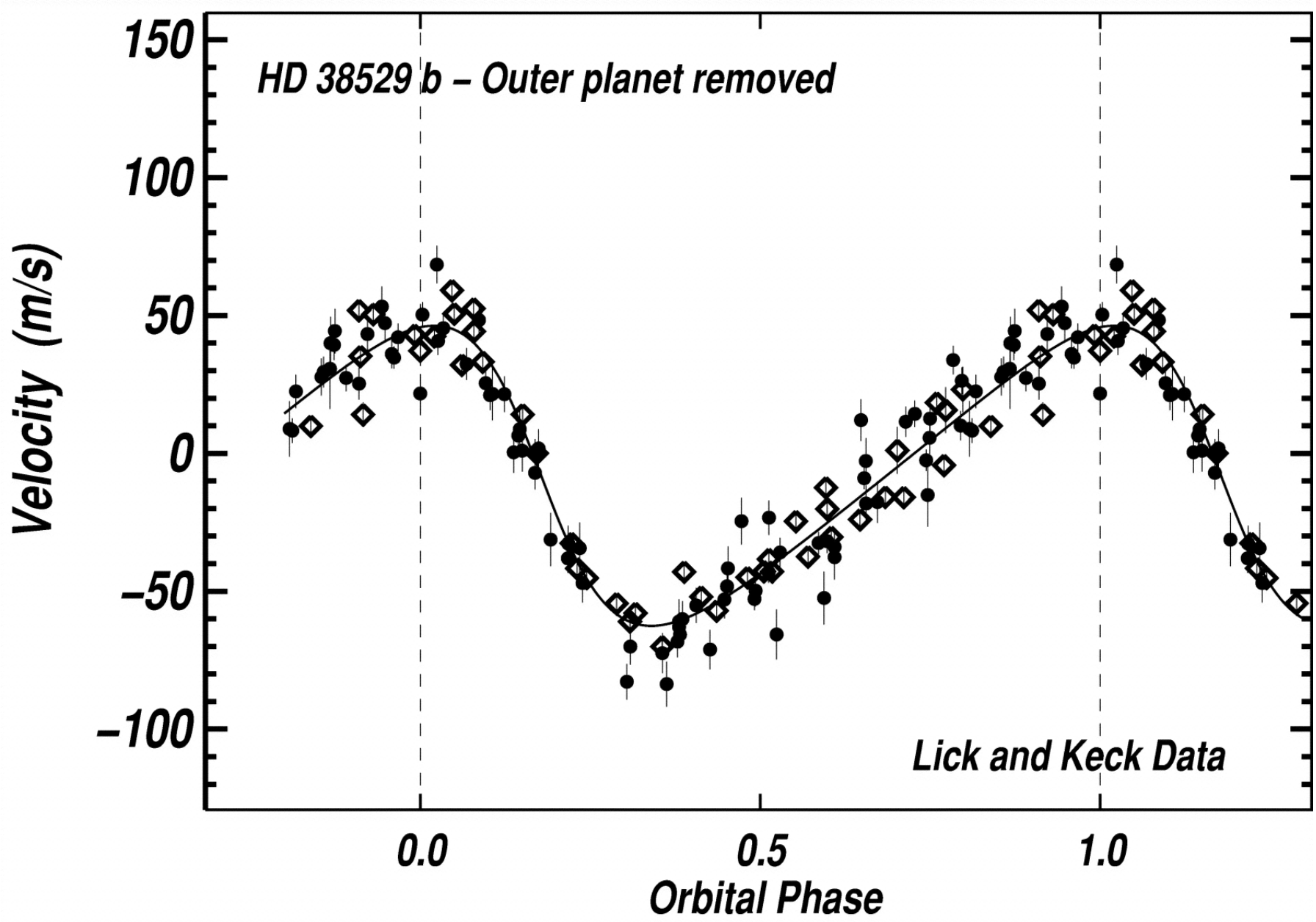


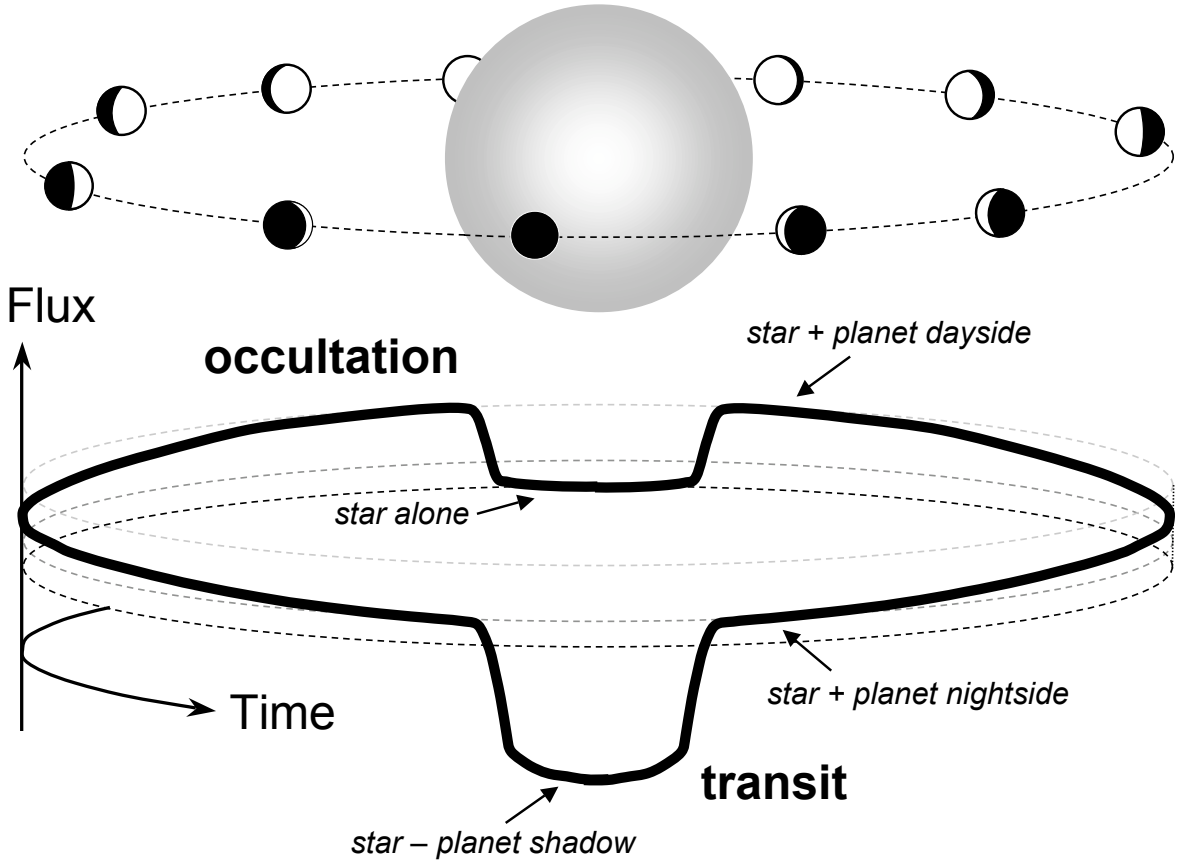
Oppenheimer BR, Hinkley S. 2009.
Annu. Rev. Astron. Astrophys. 47:253–89

Doppler shift diagnoses the stellar radial motion



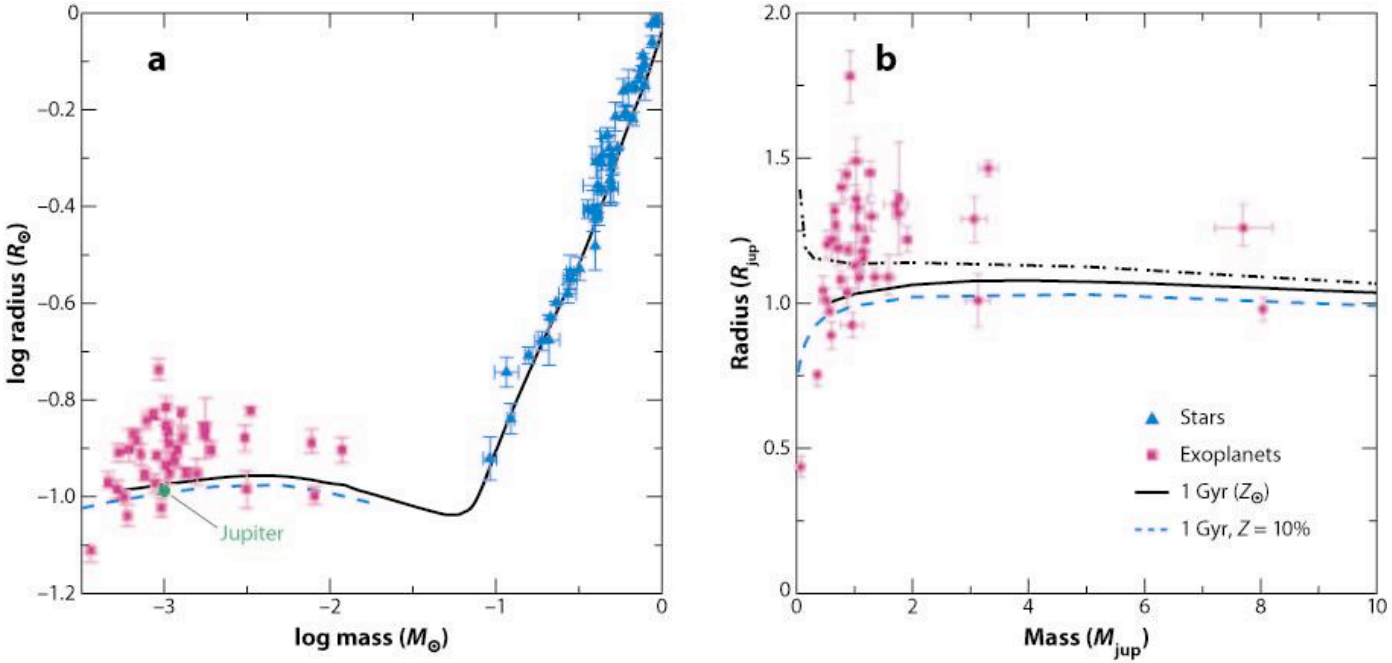
Marcy et al. 2005, ApJ 619, 570.





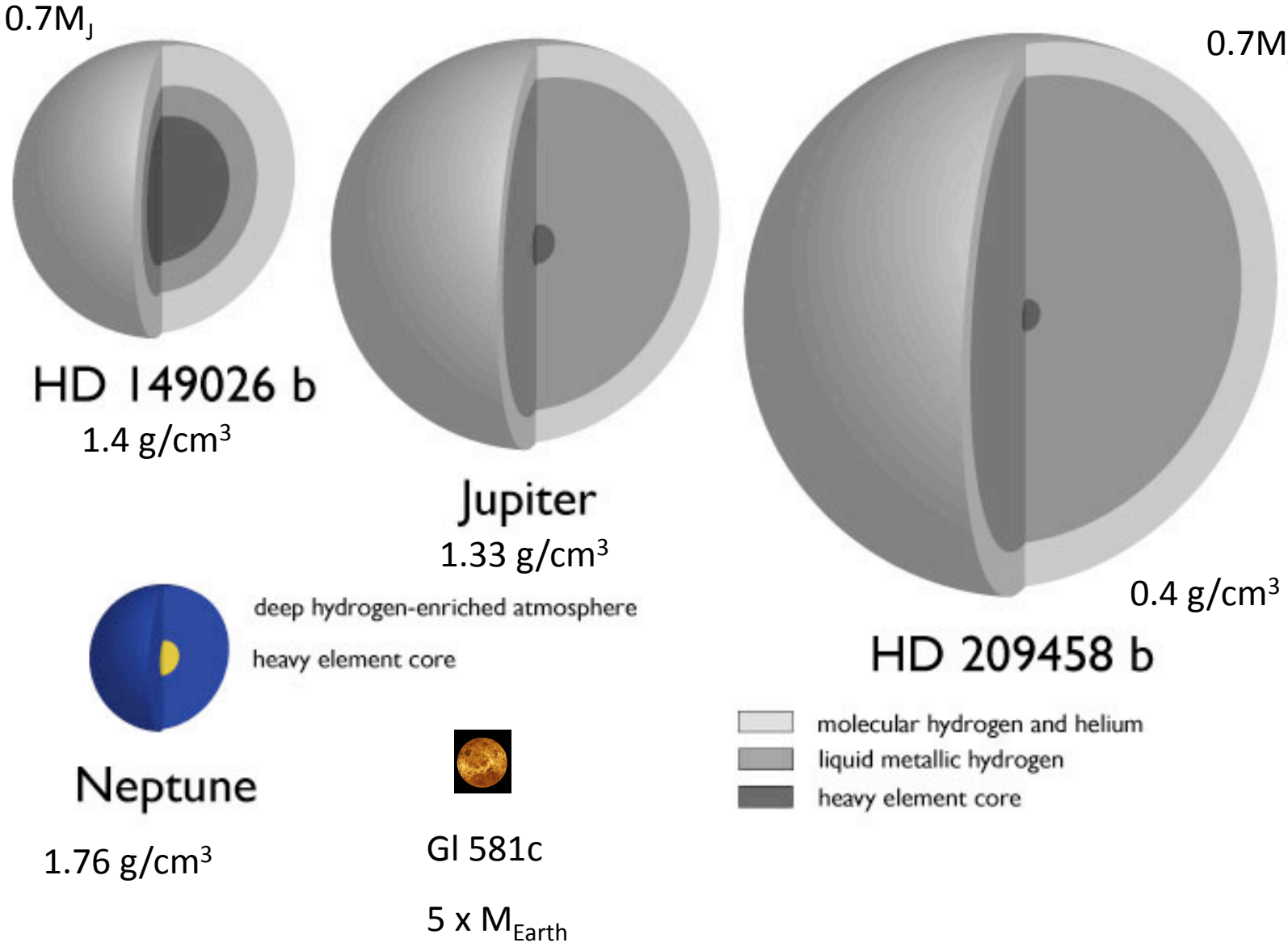
J. Winn, 2010, arXiv:1001.2010v2

Properties of exoplanets



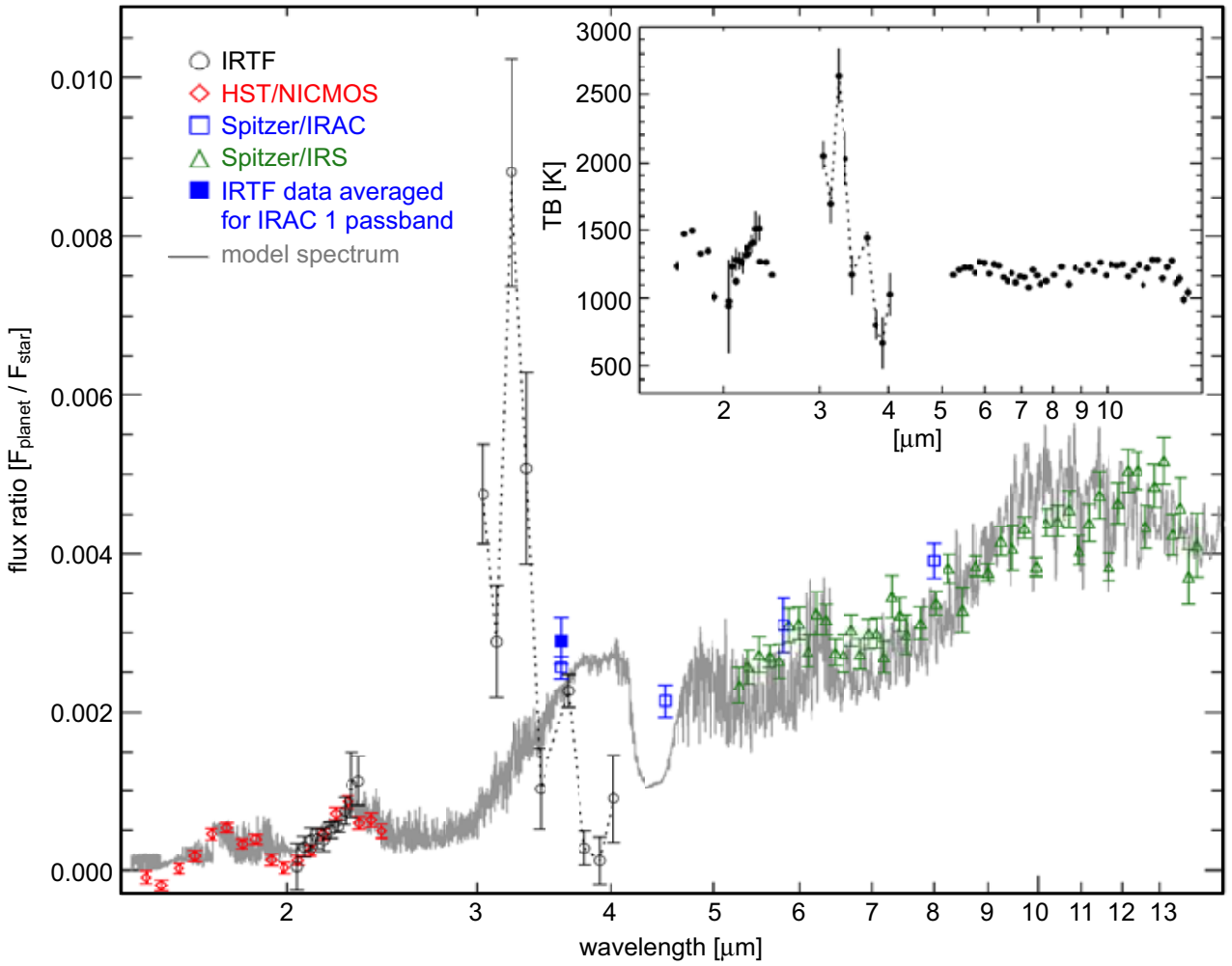
Oppenheimer BR, Hinkley S. 2009.
Annu. Rev. Astron. Astrophys. 47:253–89

Annual Reviews



Properties of planets: variable in density and composition.

Spectrum of a giant exoplanet Gl189733b from transits (Swain et al 2010)

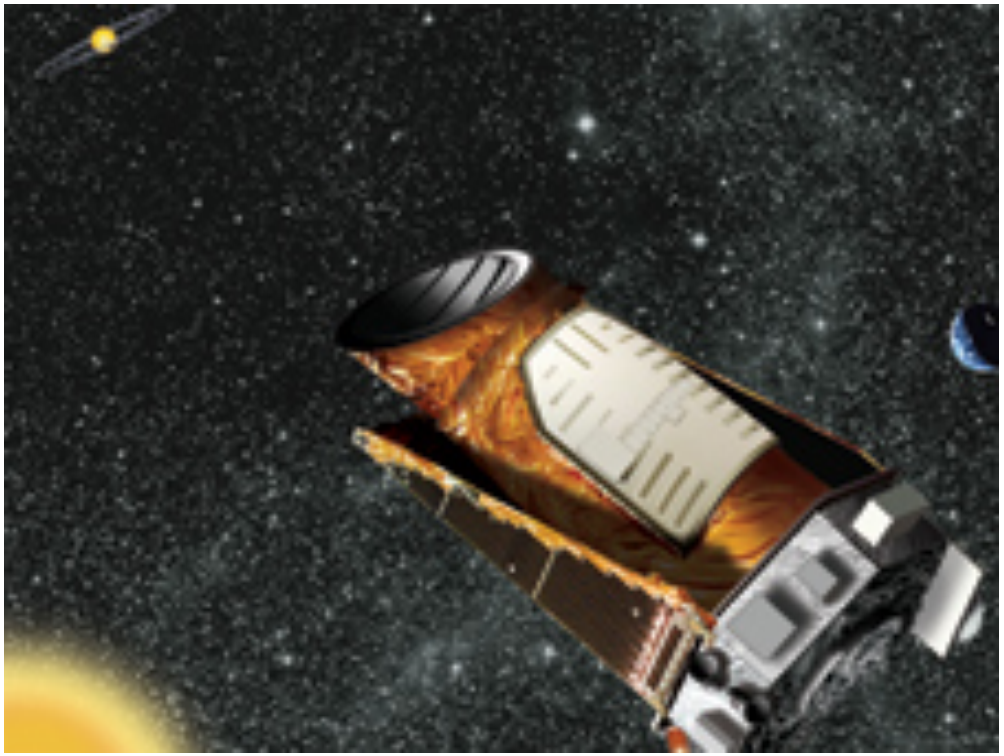


Dayside spectrum ([planet_out-planet_in] occultation)

Kepler: A spacecraft that detects Earth-sized planets by transit

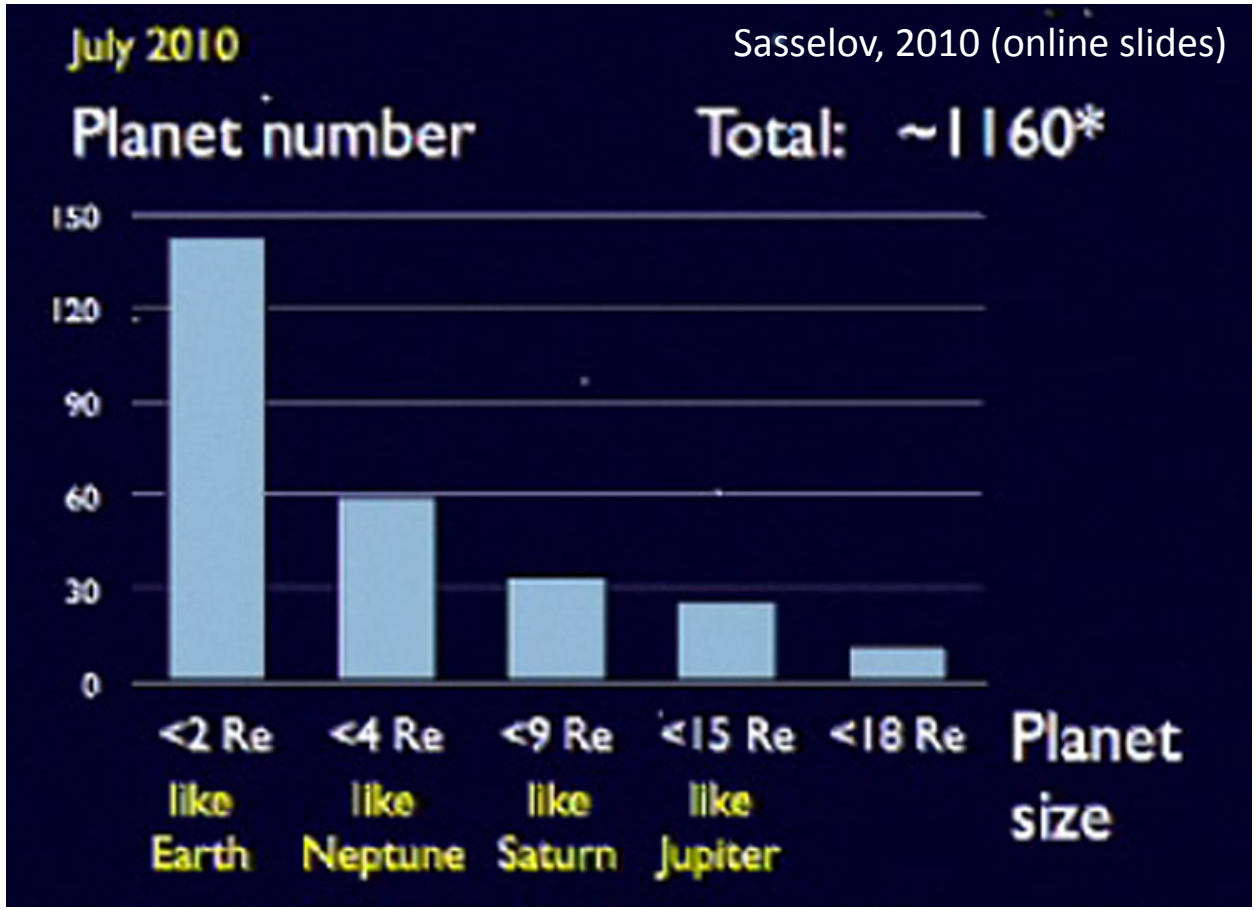
June 15, 2010: Kepler potentially expands the number of known planets with ~ 300-700 candidates (need to be confirmed by further observations)

N.B.: Analysis done on short segments (10 days, 33 days) of Kepler data—close-in Earths only.

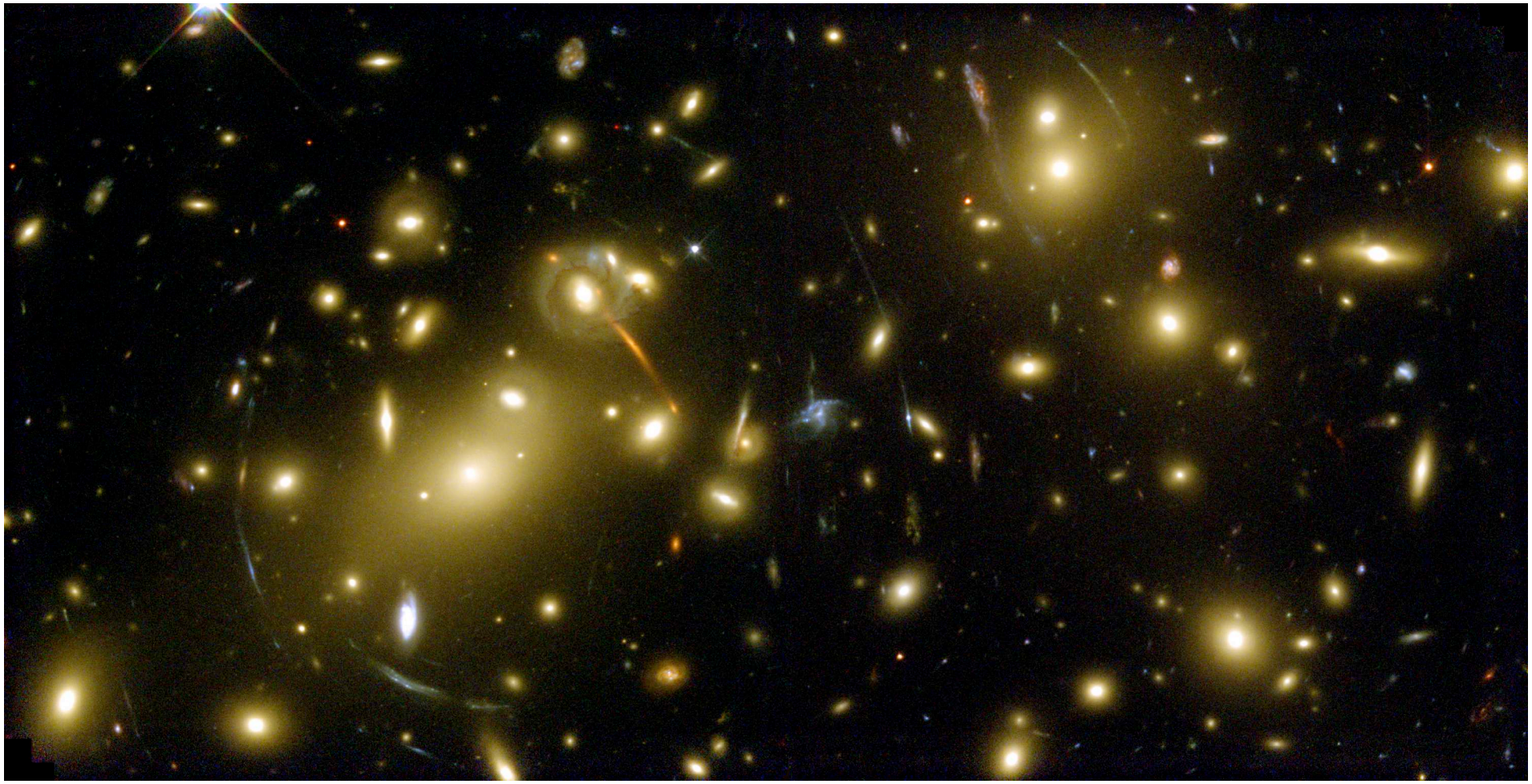


Kepler observes 150,000 stars→ 1,500 planets for case of 1 close planet/star.

The data imply that one of ten Sun-like stars has a close planet with an Earth-like radius

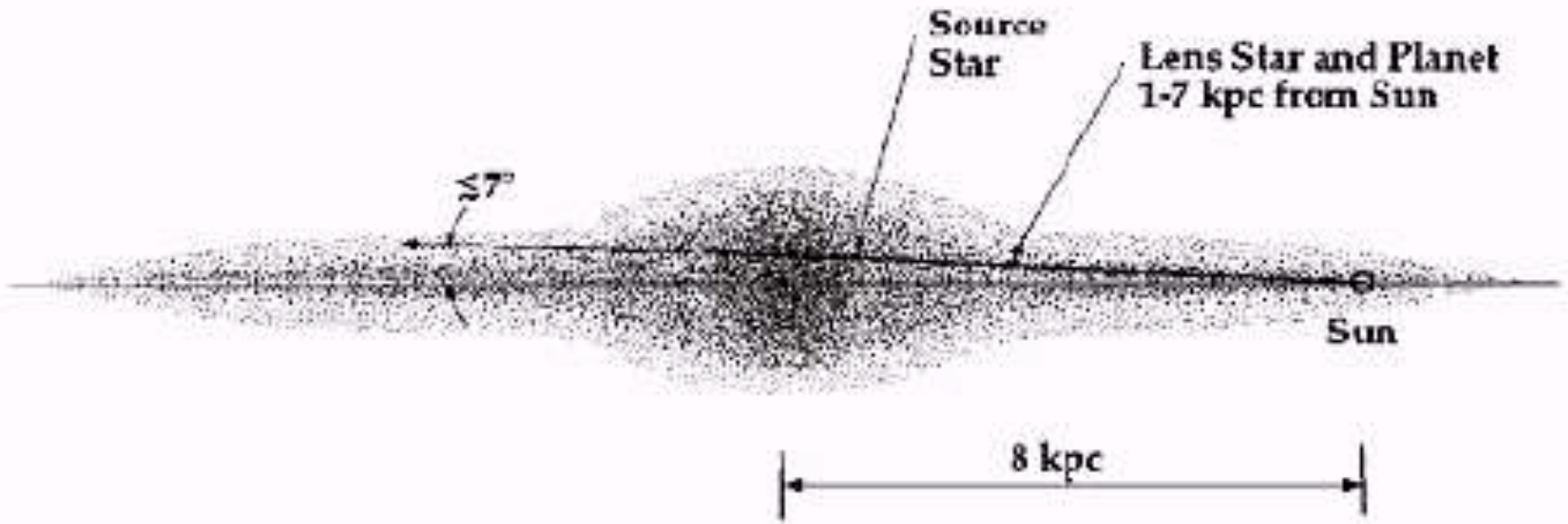


Gravitational lensing is the bending of light from a source by the gravitational force of a foreground mass

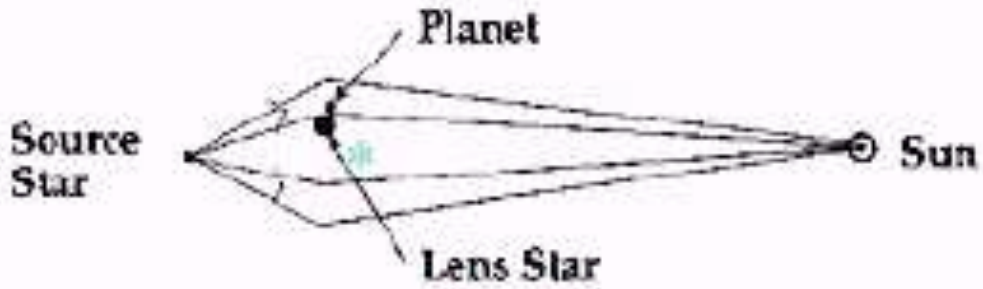


HST image, Space Telescope Science Inst.

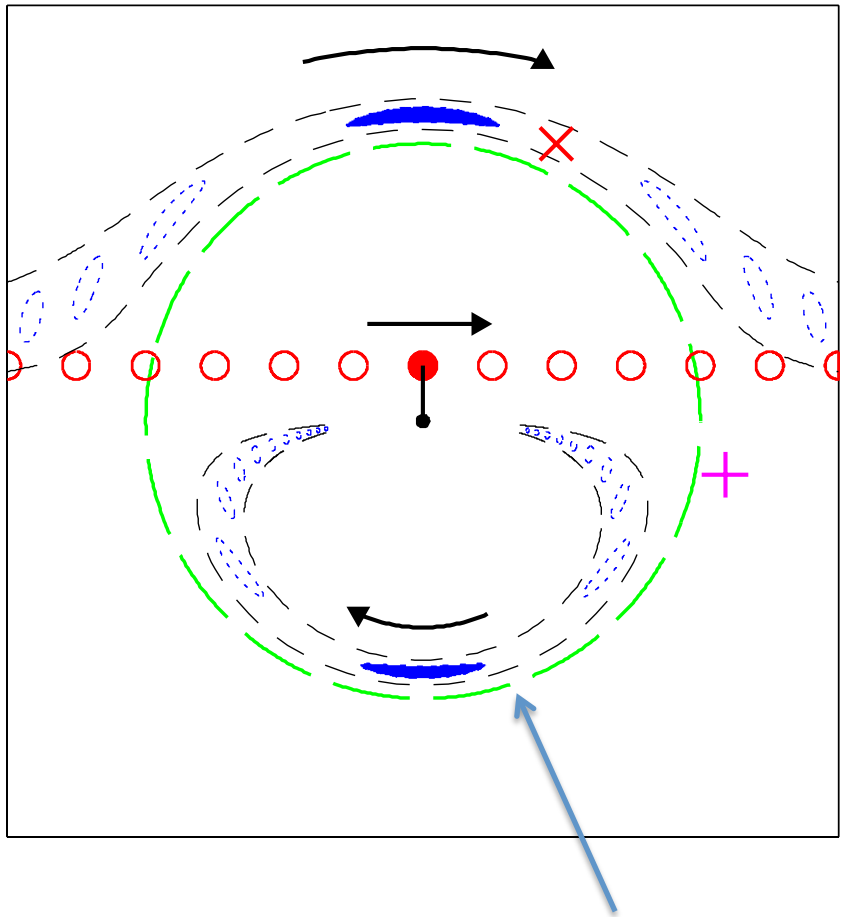
Microlensing= lensing where the multiple images are separated by less than milliarcsec and so are unresolved.



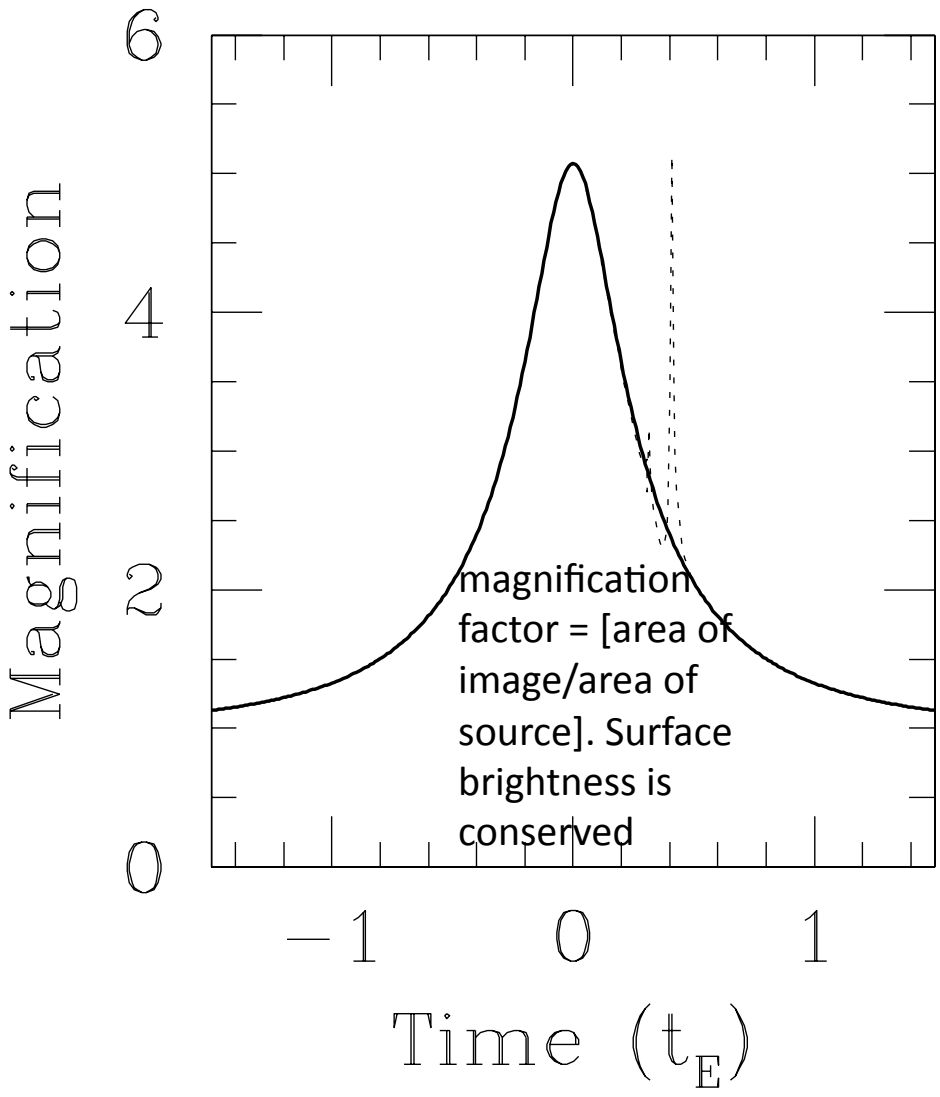
Side View



*binary lenses give 3 or 5 images - not 4



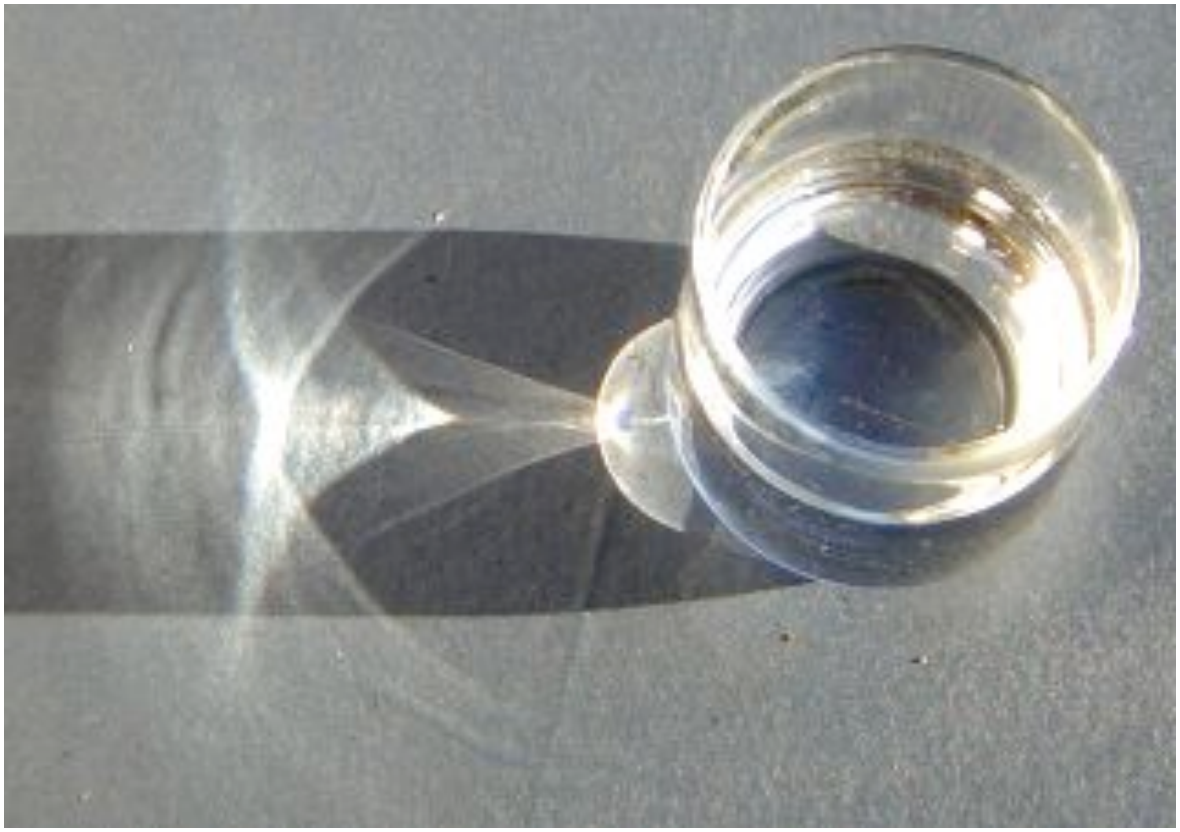
Einstein ring



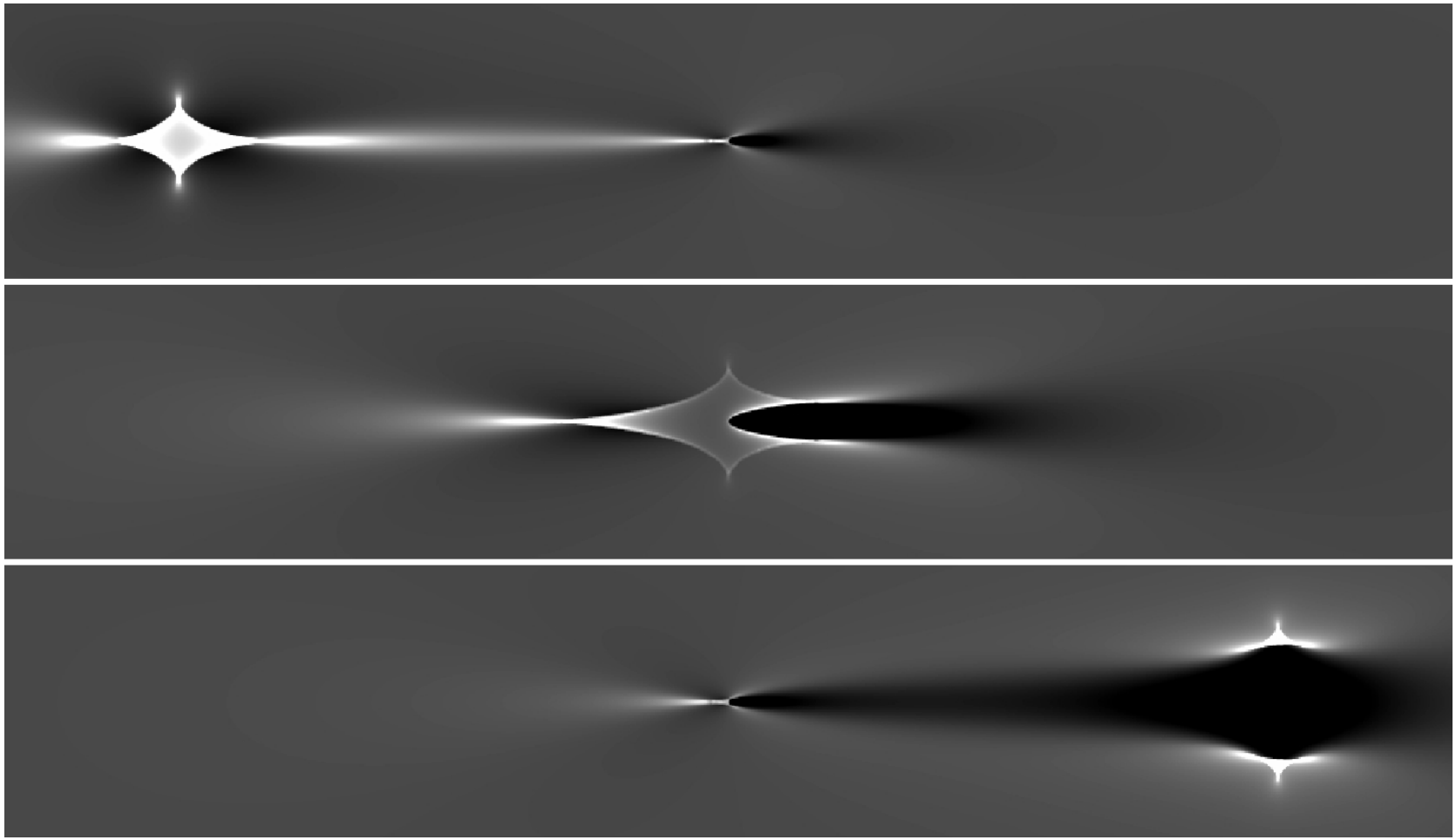
Lens: Black dot. Source: Red circles. x: place where planet causes the above perturbation

Gaudi, S. 2010 arXiv:1002.0332v2

Lensing in a Glass of Water



Caustic is a curve or surface to which each of a bundle of refracted light rays are tangent, which define the boundary of a envelope of rays as curves of concentrated light.



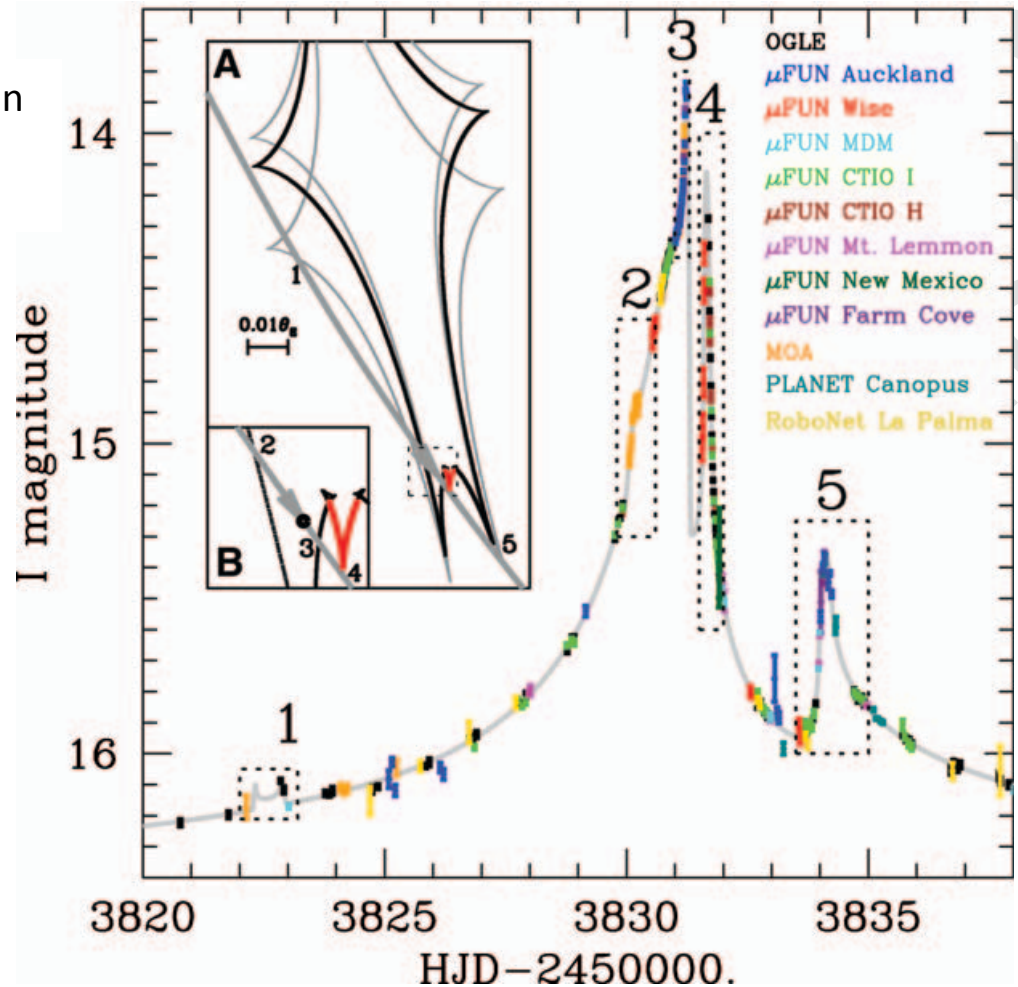
The greyscale shading denotes $2.5\log(1+\delta)$, where δ is the fractional deviation from the single-lens (i.e., no planet) magnification.

mass ratio = 0.001; separation (in units of Einstein ring) 1.25, 1 and 0.8 (top to bottom)
Gaudi, S. 2010 arXiv:1002.0332v2

www.sciencemag.org **SCIENCE** *2008, 319, 927-930*

Strong microlensing event with caustics.

Peak 4 is not expected in the caustics associated with a single planet.



Masses of ~0.71 and ~0.27 times the mass of Jupiter and orbital separations of ~2.3 and ~4.6 astronomical units orbiting a primary star of mass ~0.50 solar masses at a distance of ~1.5 kiloparsecs.

Beaulieu et al. 2010 arXiv:1001.3349v1

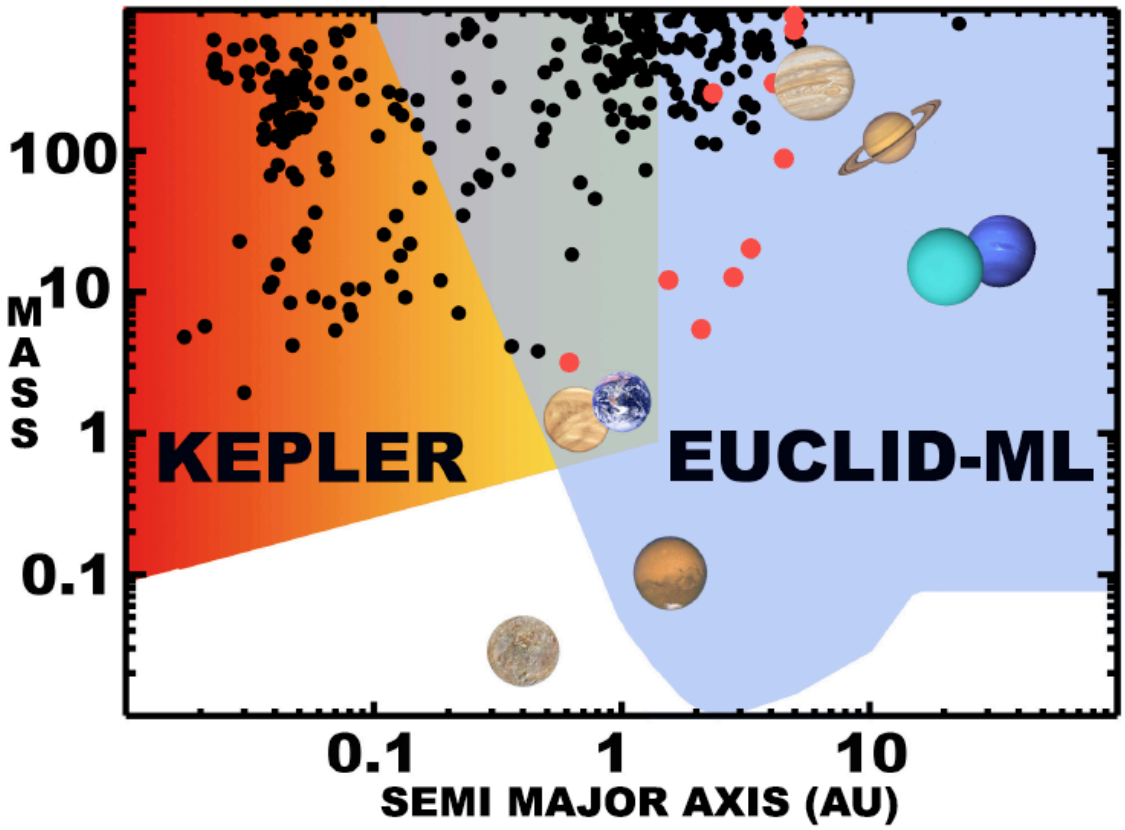
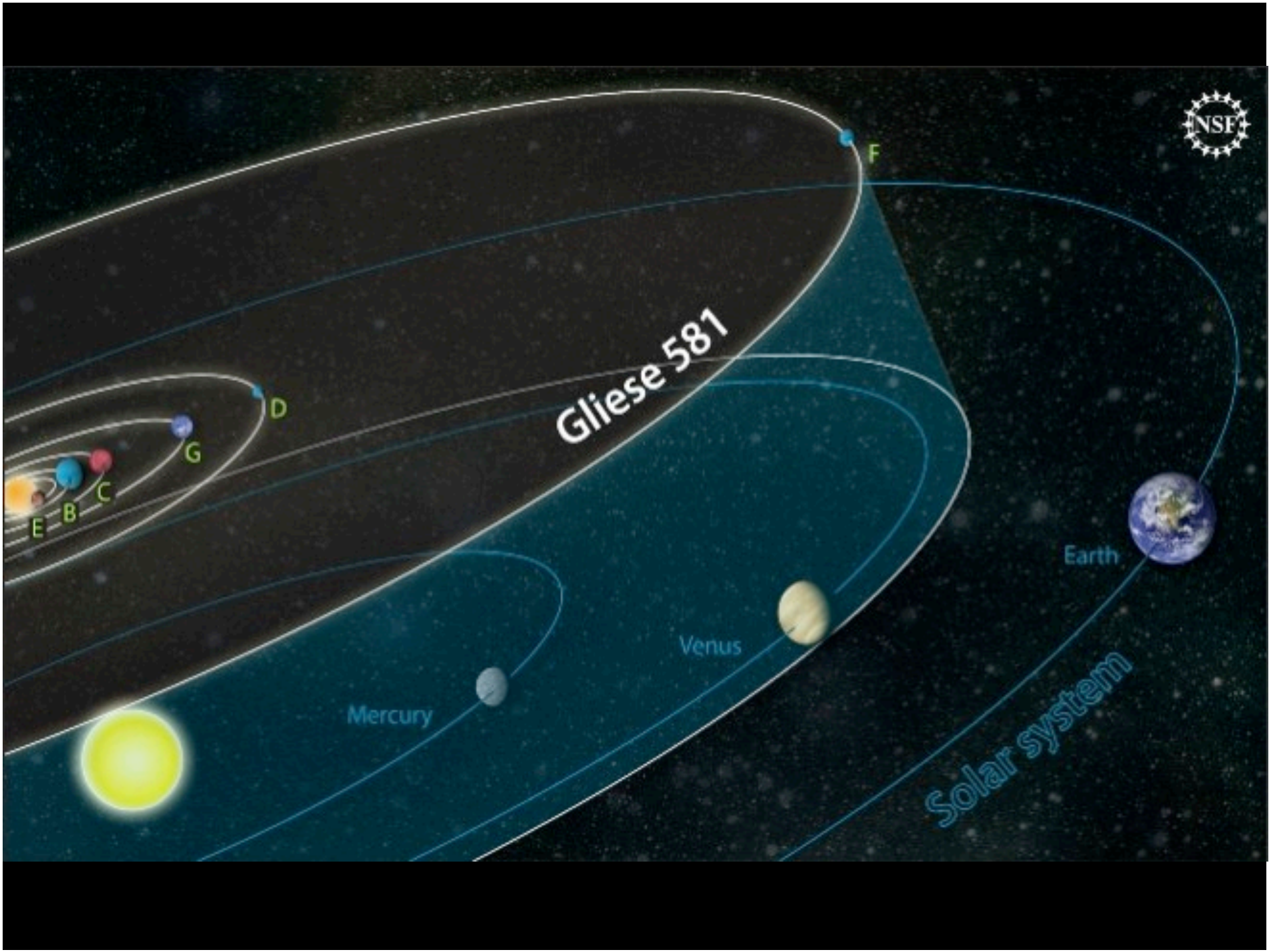


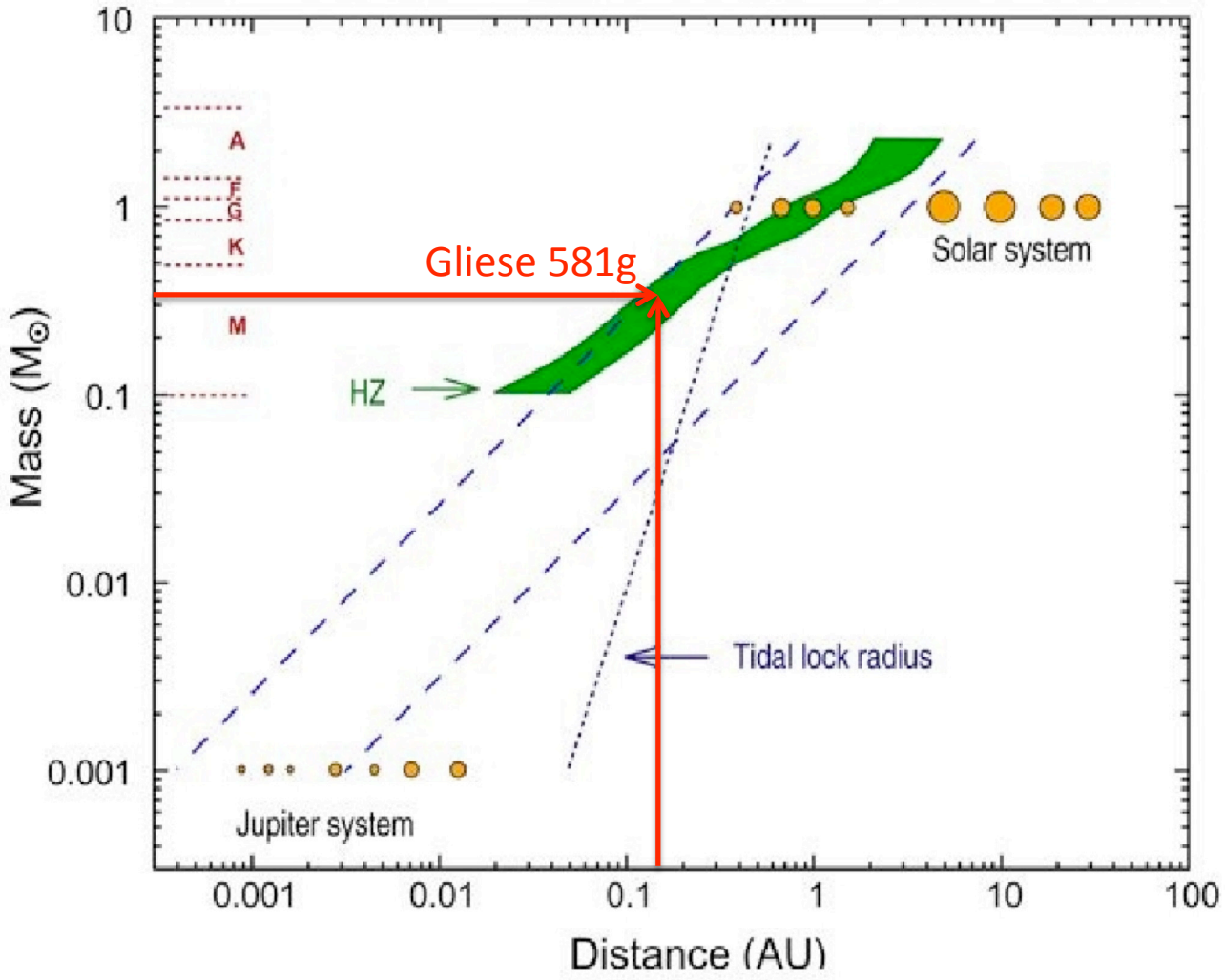
Figure 1. Semi major axis as a function of mass for all exoplanets discovered as of September 2009 (microlensing planets are plotted as red dots) and the planets from our solar system. We also plot the sensitivity of KEPLER and of space based microlensing observations.

Two actual“super-Earths”

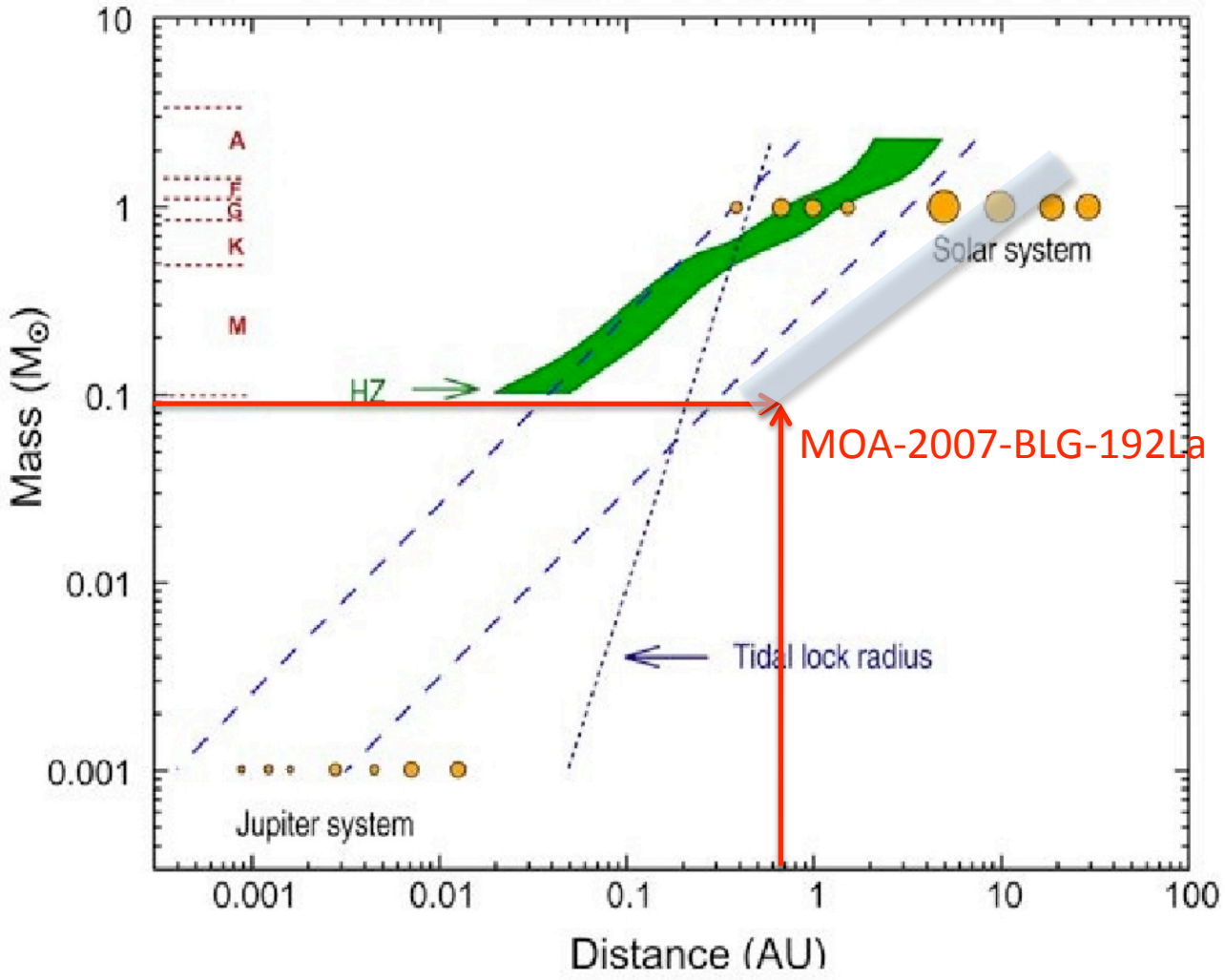
- Gliese 581 g: A habitable world between 3 and 4 times the mass of the Earth (Vogt et al).
- MOA-2007-BLG-192La: A frozen world between 2 and 8 times the mass of the Earth (Kubas et al.)

- Both planets orbit cool, “M-dwarf” stars.
- Both planets are examples of what JWST might be able to observe for other, transiting, M-dwarf planet systems.


NSF
F
Gliese 581
D
G
C
B
E
Earth
Venus
Mercury
Solar system



Gleise 581g is in the classical “habitable zone” where liquid water is stable

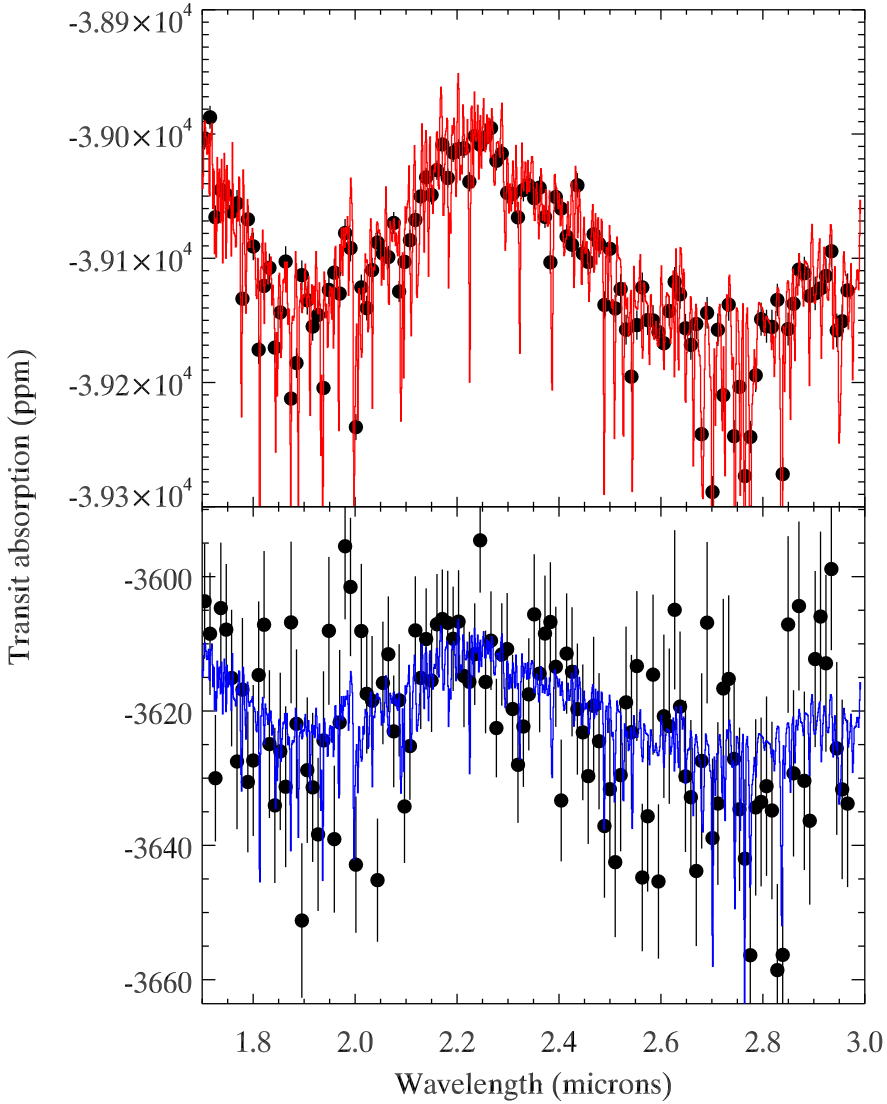


MOA-20070BLG-192La is beyond the classical “habitable zone”, but liquid methane/nitrogen might be stable

James Webb Space Telescope

...will provide the first information on composition of transiting superEarths.

Simulations of JWST transit spectra for M-dwarf planets.

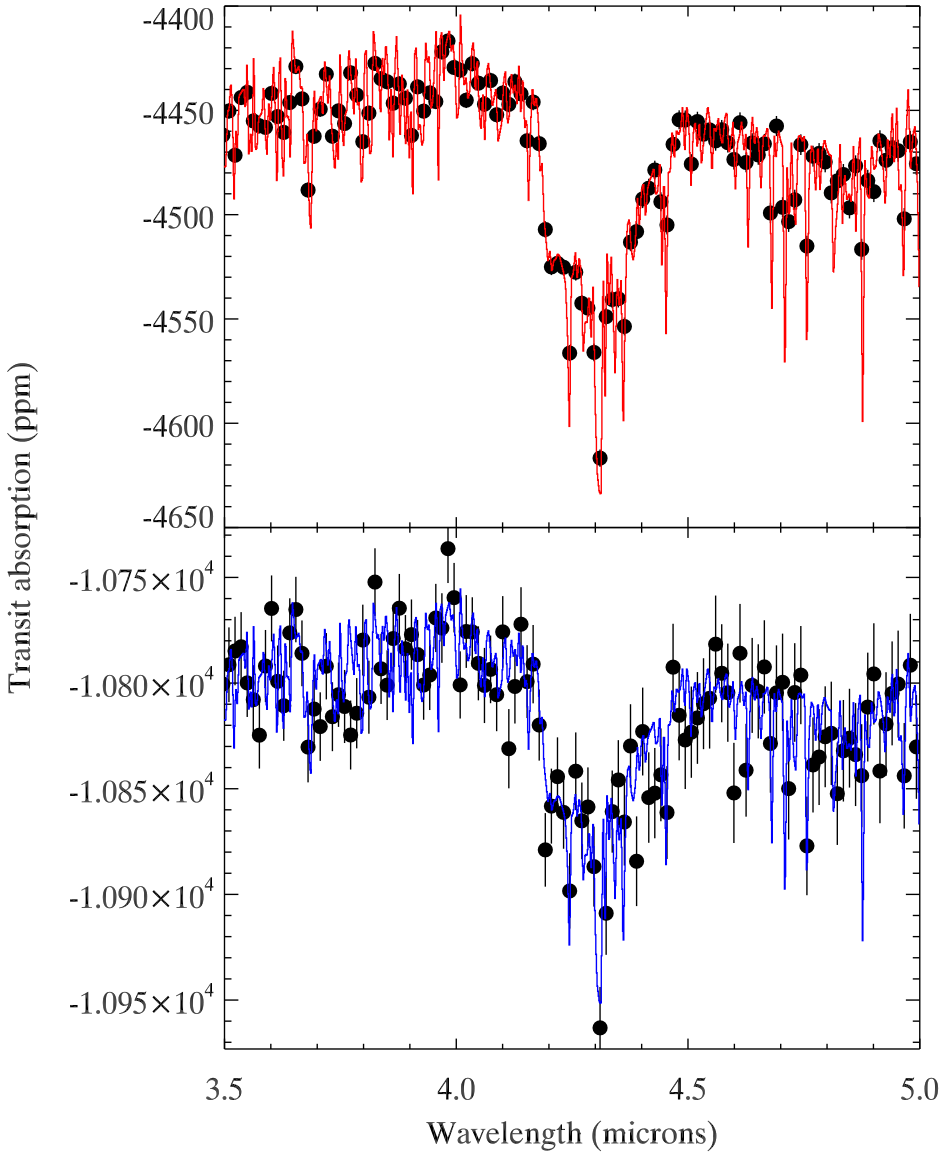


Synthetic spectra of H_2O absorption in a hot (T ~500K) superEarth with twice Earth's radius. 300 hour integration. 30 parsecs distance.

Synthetic spectra of H_2O absorption in a habitable (T ~300K) superEarth with twice Earth's radius. 5 day integration. 20 parsecs distance.

Deming, Seager et al 2009.

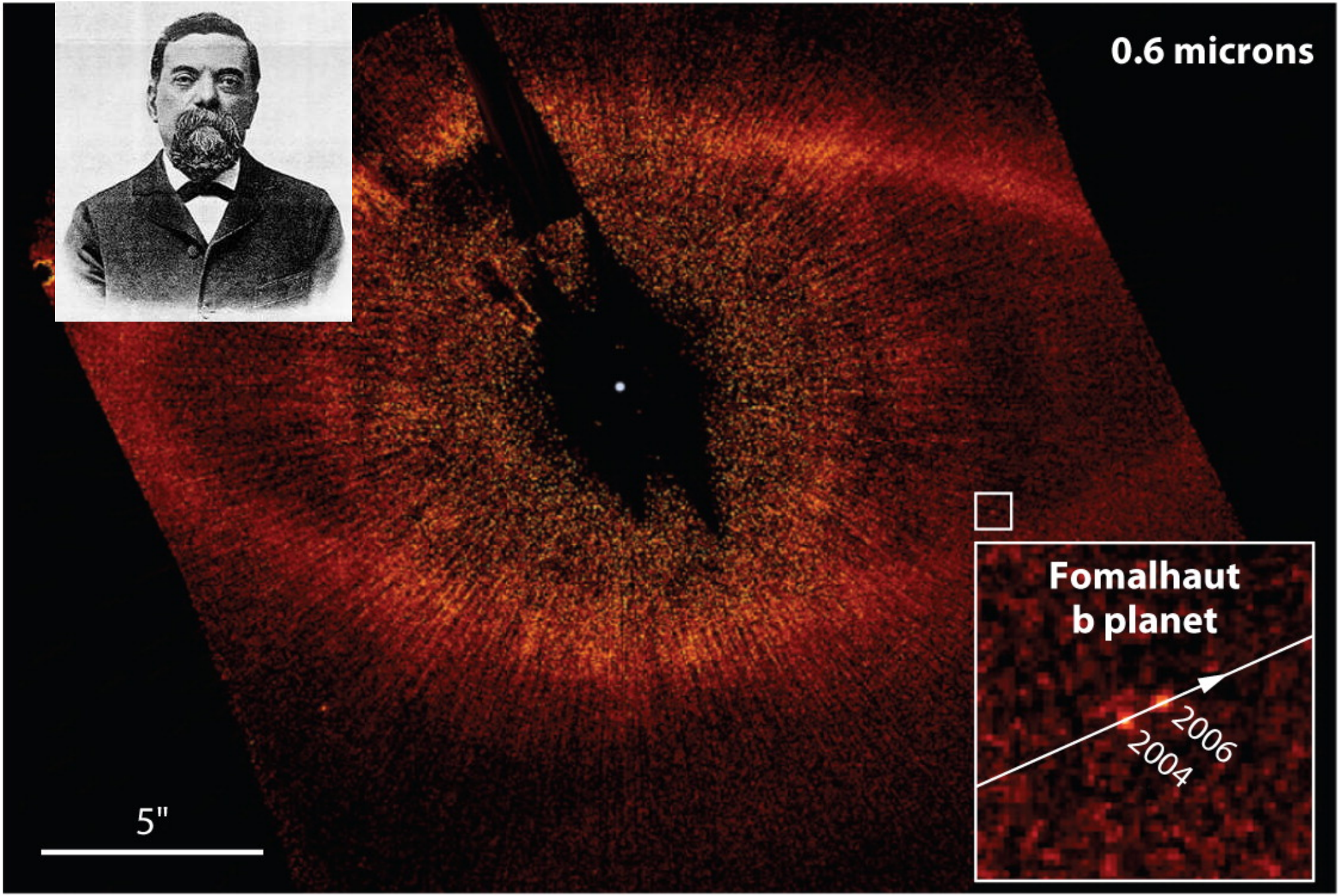
Simulations of JWST transit spectra for M-dwarf planets.



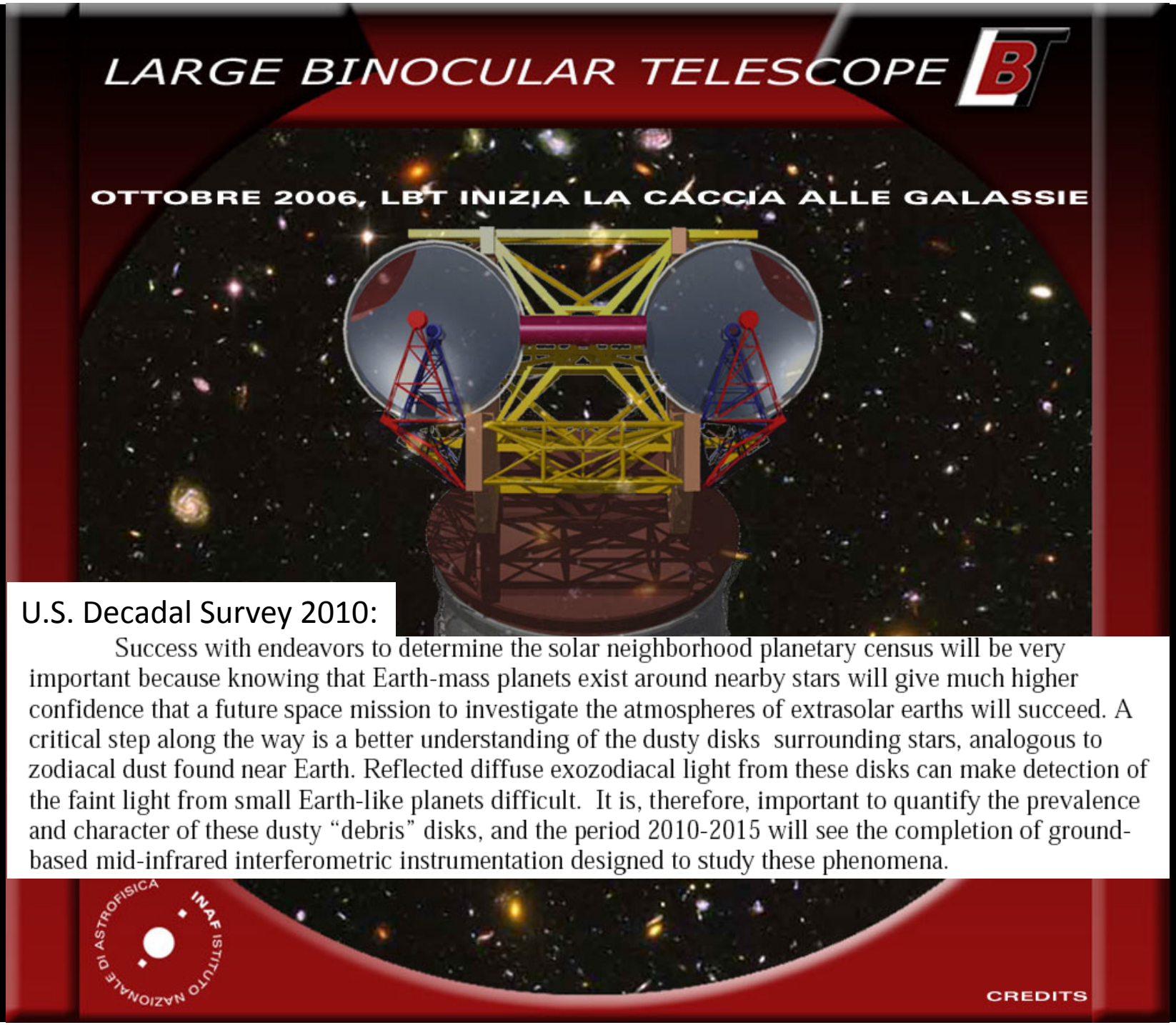
Synthetic spectra of H_2O absorption in a hot (T ~800K) superEarth with twice Earth's radius. 20 day integration. 20 parsecs distance.

Synthetic spectra of H_2O absorption in a habitable (T ~300K) superEarth with twice Earth's radius. 4 day integration. 20 parsecs distance.

Deming, Seager et al 2009.



Oppenheimer BR, Hinkley S. 2009.


LARGE BINOCULAR TELESCOPE
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OTTOBRE 2006, LBT INIZIA LA CACCIA ALLE GALASSIE
U.S. Decadal Survey 2010:
Success with endeavors to determine the solar neighborhood planetary census will be very important because knowing that Earth-mass planets exist around nearby stars will give much higher confidence that a future space mission to investigate the atmospheres of extrasolar earths will succeed. A critical step along the way is a better understanding of the dusty disks surrounding stars, analogous to zodiacal dust found near Earth. Reflected diffuse exozodiacal light from these disks can make detection of the faint light from small Earth-like planets difficult. It is, therefore, important to quantify the prevalence and character of these dusty "debris" disks, and the period 2010-2015 will see the completion of ground-based mid-infrared interferometric instrumentation designed to study these phenomena.
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CREDITS

Is Earth --as a planet which has played host to complex life for billions of years-- unique in the cosmos?