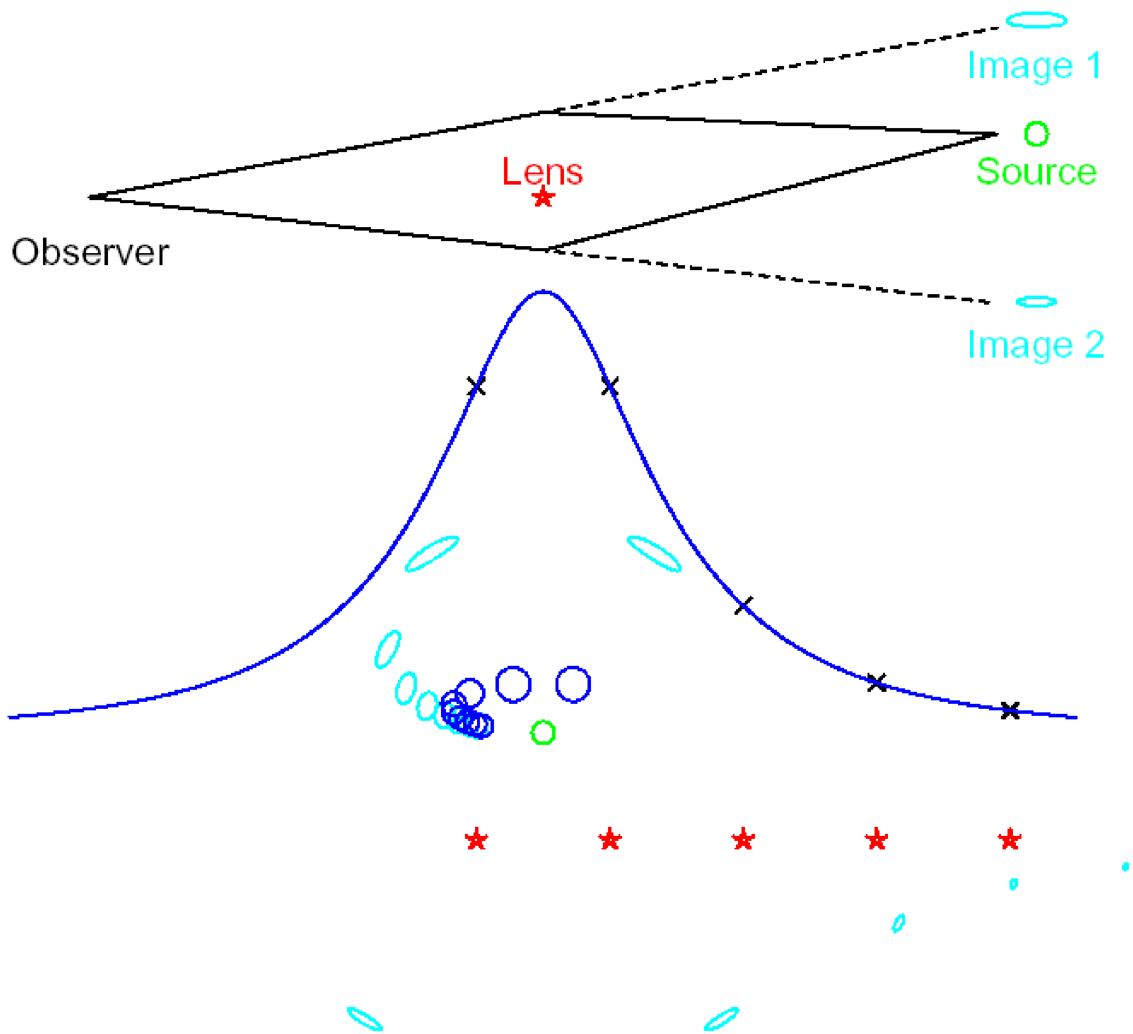
μFUN Planet Detections

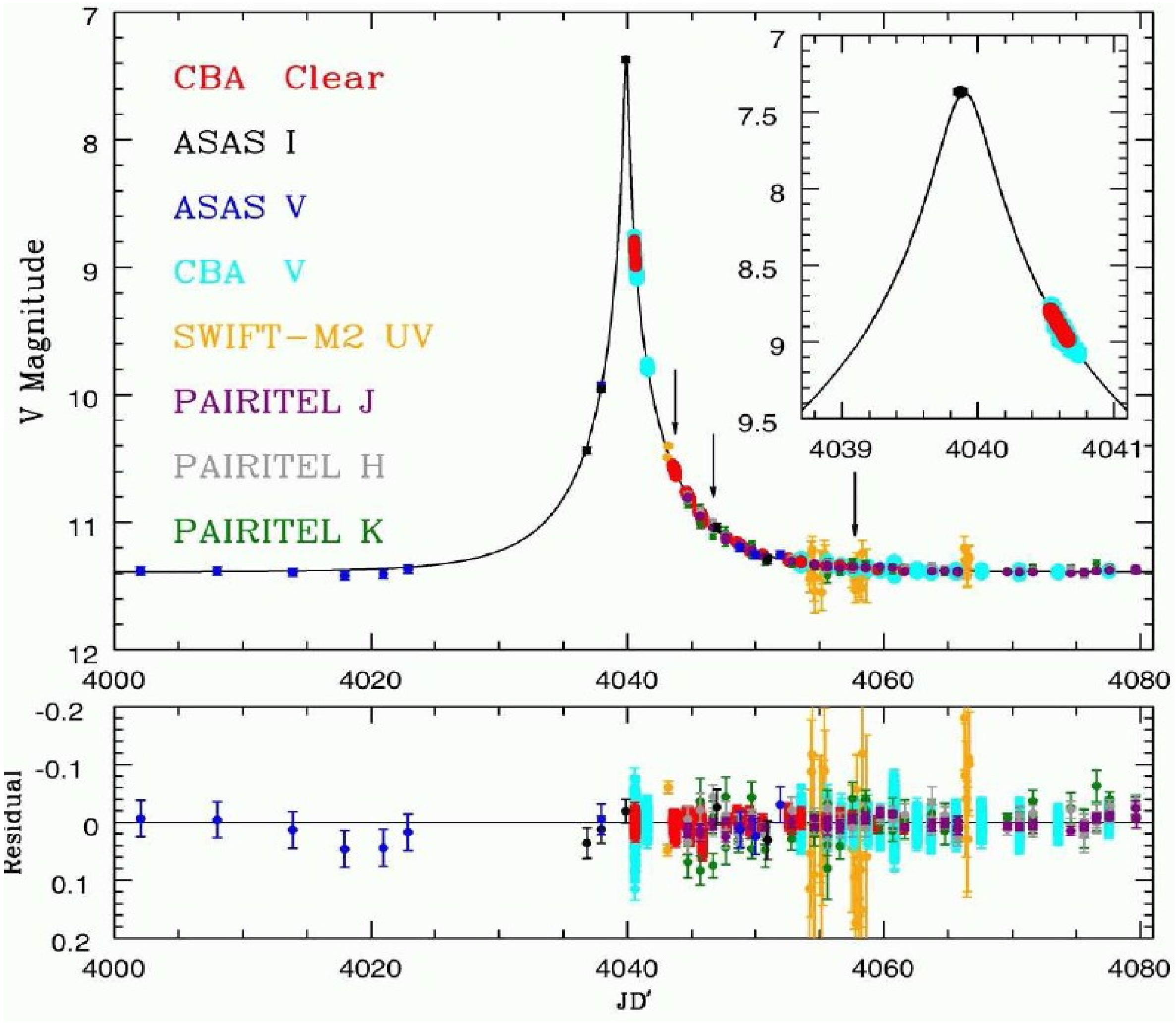
2005-2008

Andy Gould (Ohio State)



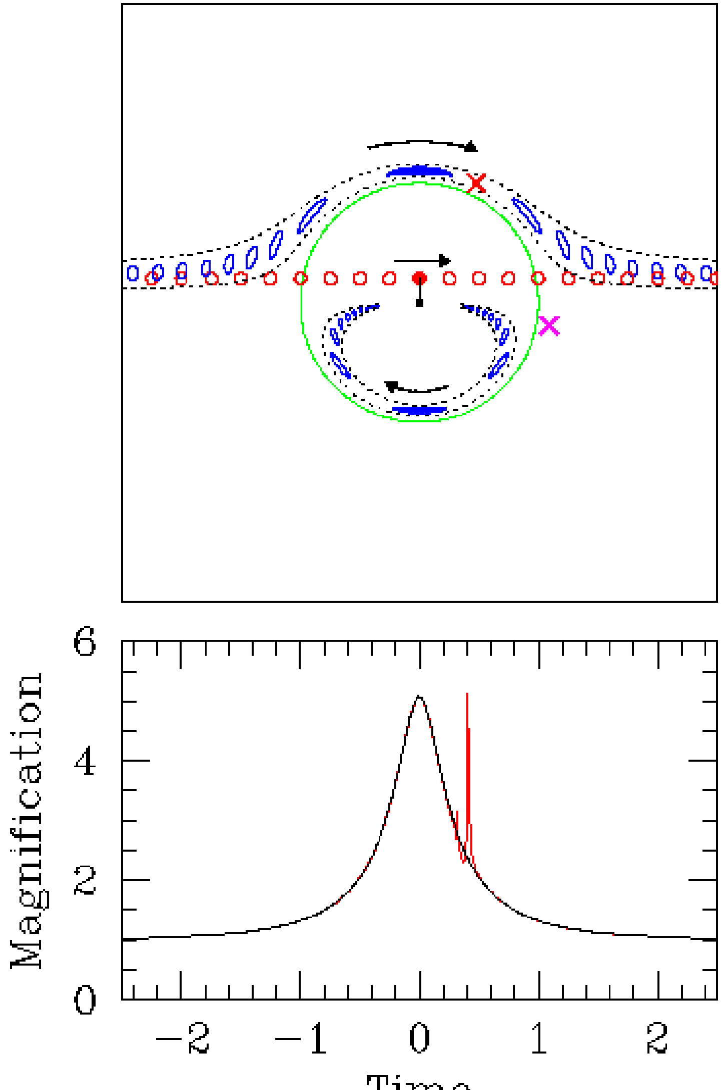
A0 star GSC 3656-1328

A=40, V=7 at 1 kpc



Gaudi et al. 2008, ApJ

How Microlensing Finds Planets



Mao & Paczynski

Microlens Planet Searches

GRAVITATIONAL MICROLENSING BY DOUBLE STARS AND PLANETARY SYSTEMS

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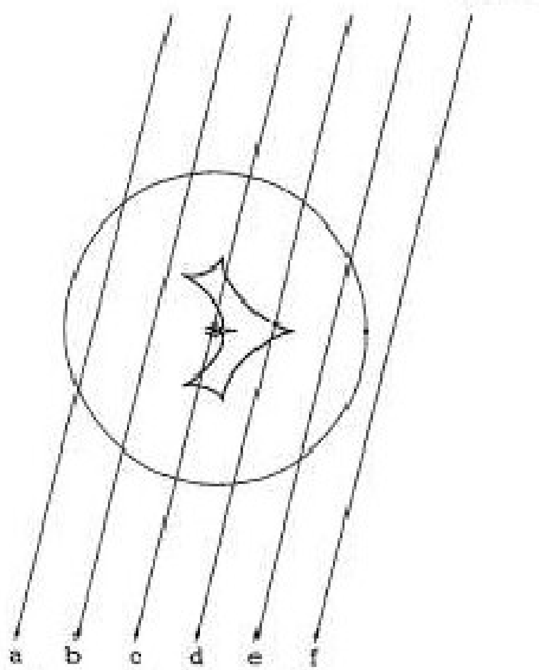
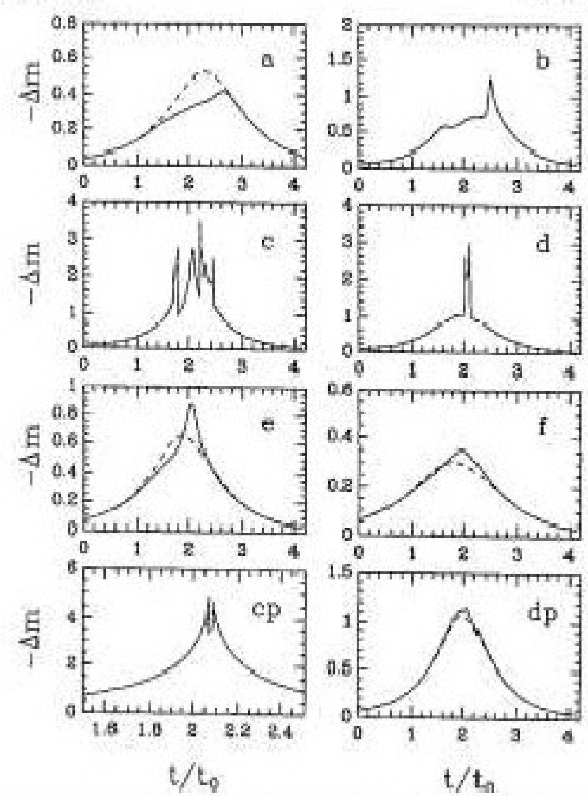
Princeton University Observatory, Princeton, NJ 08544
Received 1991 March 12; accepted 1991 April 2



. 1.—Geometry of microlensing by a binary, as seen in the sky. The y star of 1 $M_\odot$ is located at the center of the figure, and the secondary of , or 0.001 $M_\odot$ is located on the right, on the Einstein ring of the y. The radius of the ring is 1.0 mas for a source located at a distance of 8 d the lens at 4 kpc. The two complicated shapes around the primary are



the lens. The effect is strong even if the companion is a planet. A massive search for microlensing of the Galactic bulge stars may lead to a discovery of the first extrasolar planetary systems.

Survey + Follow-Up

DISCOVERING PLANETARY SYSTEMS THROUGH GRAVITATIONAL MICROLENSES

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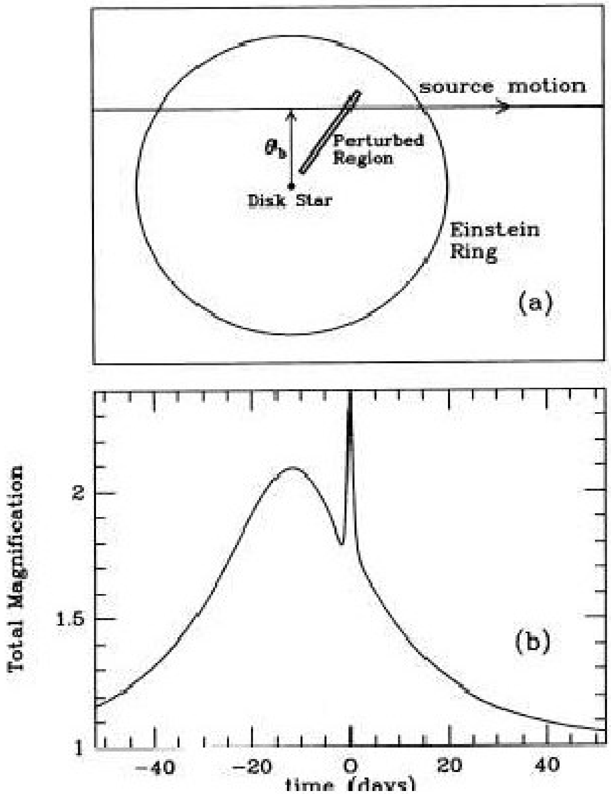
Received 1991 December 26; accepted 1992 March 9



5. OBSERVATIONAL REQUIREMENTS

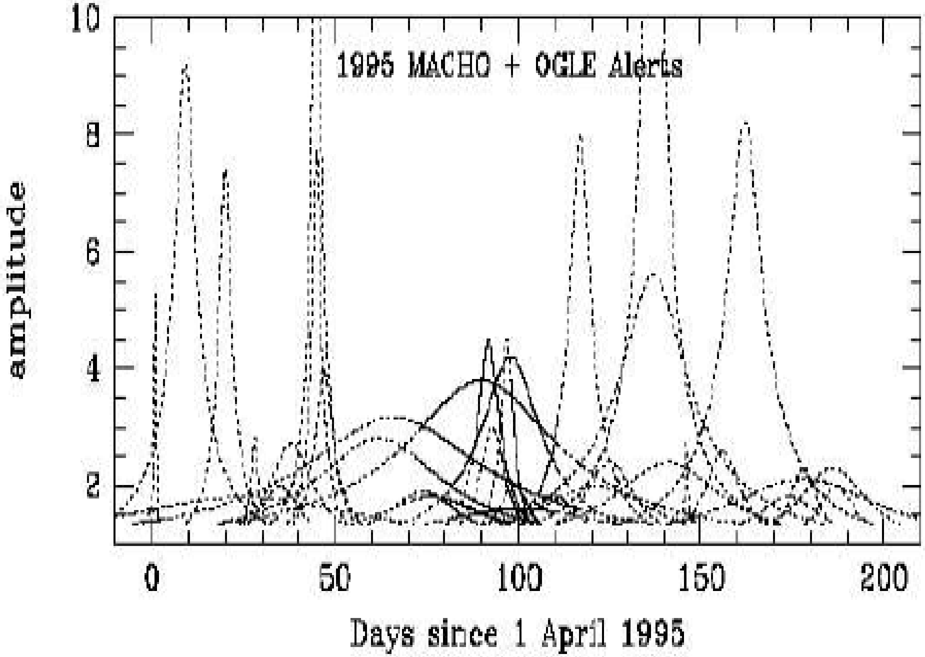
Two distinct steps are required to observe a planetary system by microlensing. First, one must single out a disk star which happens to be microlensing a bulge star. Second, one must observe this star often enough to catch the deviation in the light curve due to the planet. The first step involves the observation of millions of bulge stars on the order of once per day. The second step involves the observation of a handful of stars many times per day. In the following we give a rough outline of what is required for each of these steps.

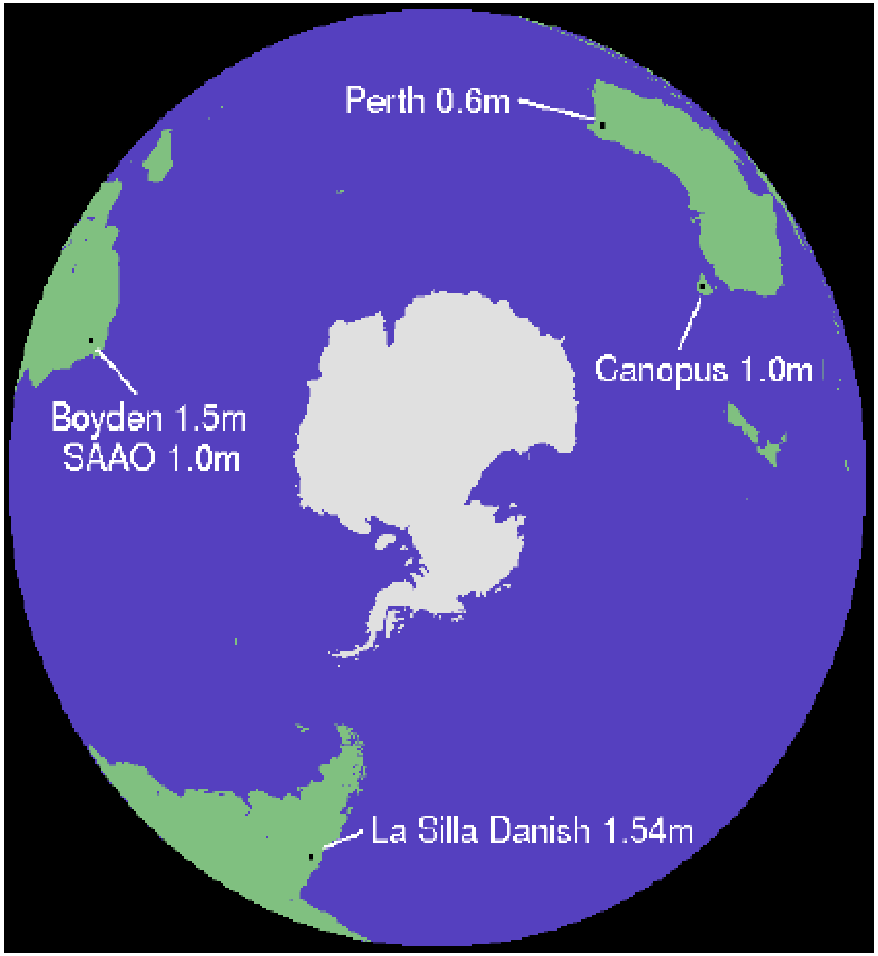
While observations from one site would be useful, there are advantages to be gained by observing from several sites. First,

two telescopes that were totally committed. Third, in view of the fleeting nature of the events, it would seem prudent to build in some redundancy in case of bad weather at a particular site. Thus, the optimal scheme would employ, say, a dozen telescopes. Each of these would be committed to carry out two observations per night. During the near-December season,

1995 PLANET Pilot Season

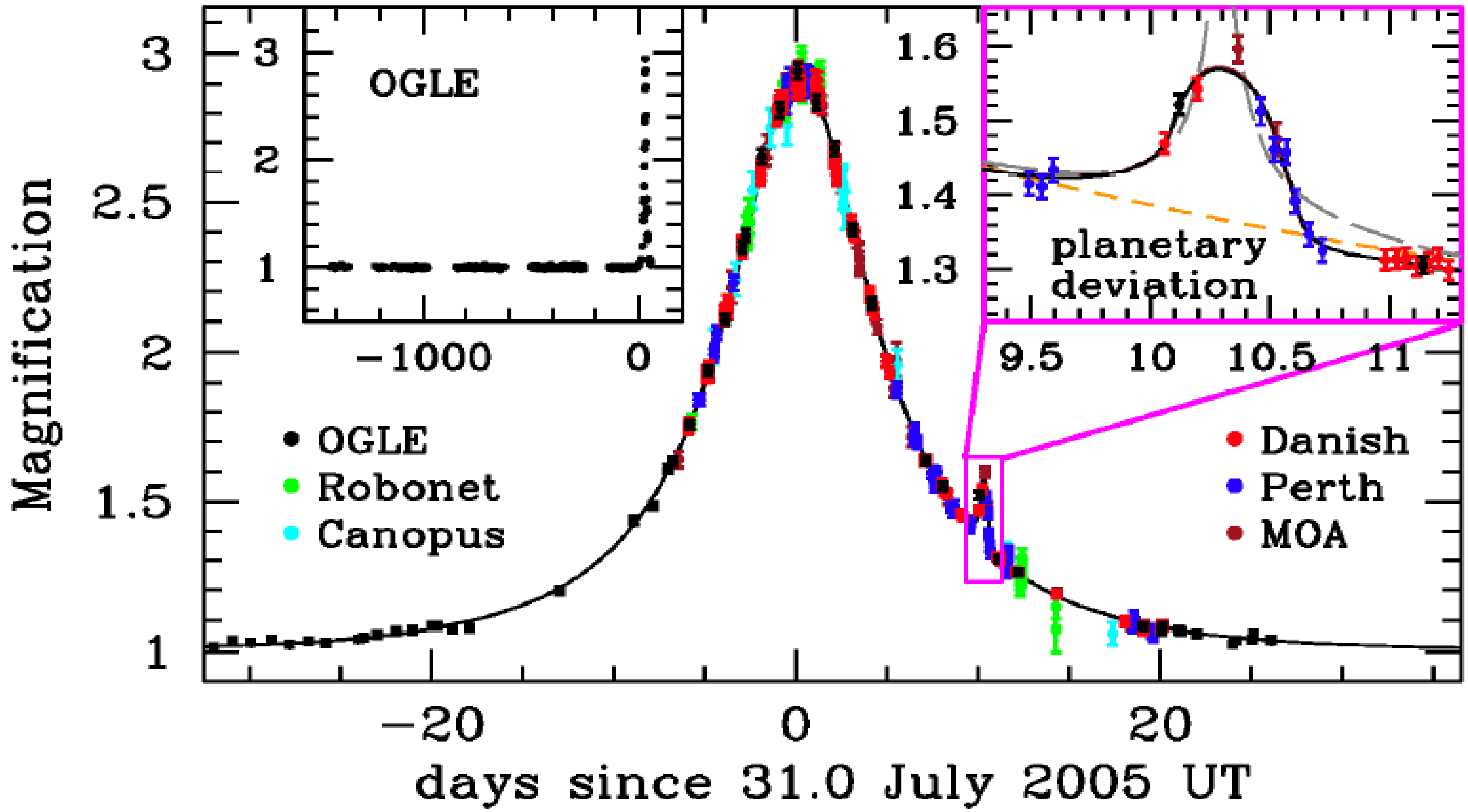
- Albrow et al. 1998
  ApJ, 509, 687





OGLE-2005-BLG-390

“Classical-Followup” Planetary Caustic

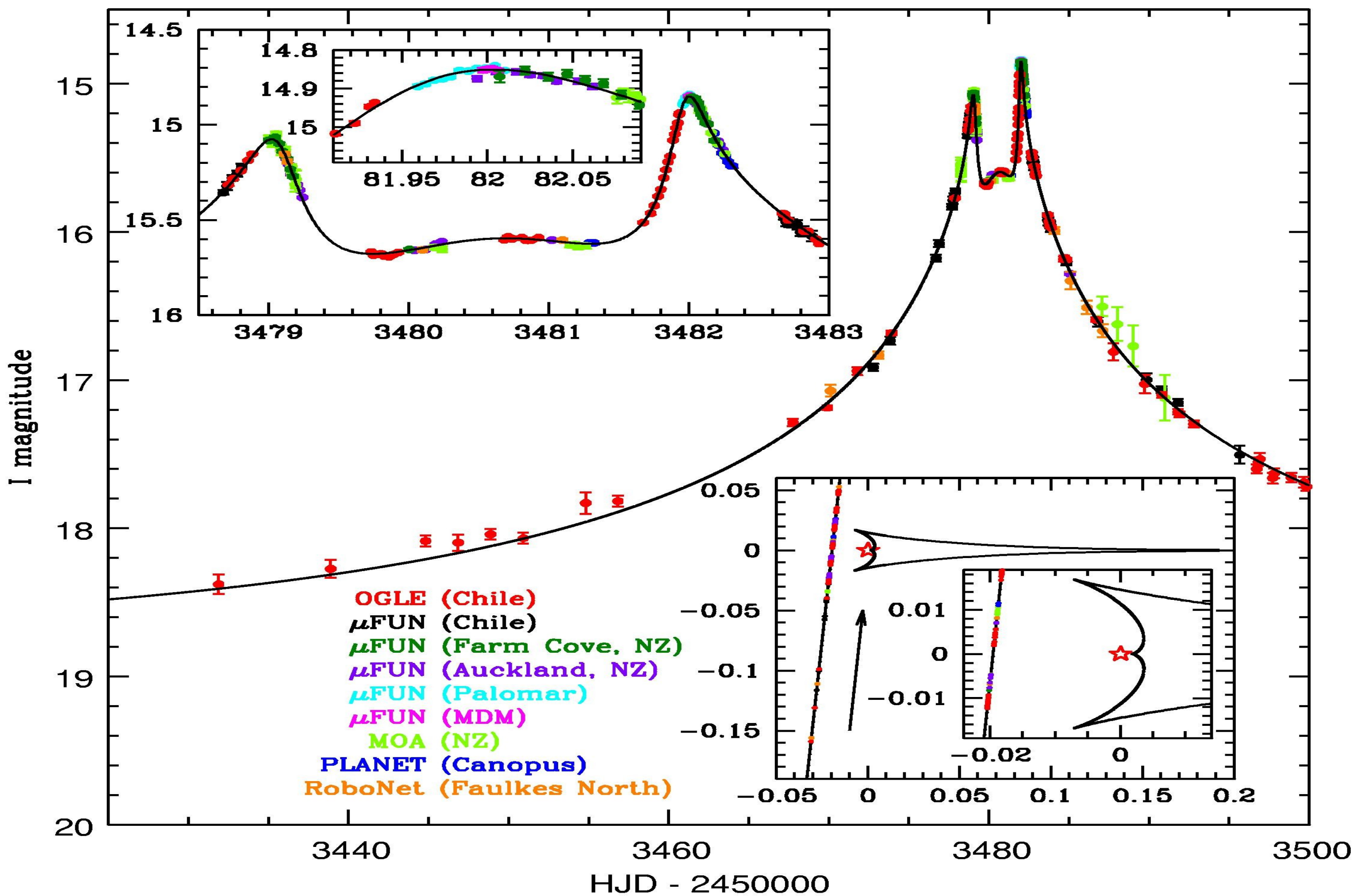


Beaulieu et al. 2006, Nature, 439, 437

OGLE-2005-BLG-071

1st μFUN Planet:

Super-Jupiter around M dwarf



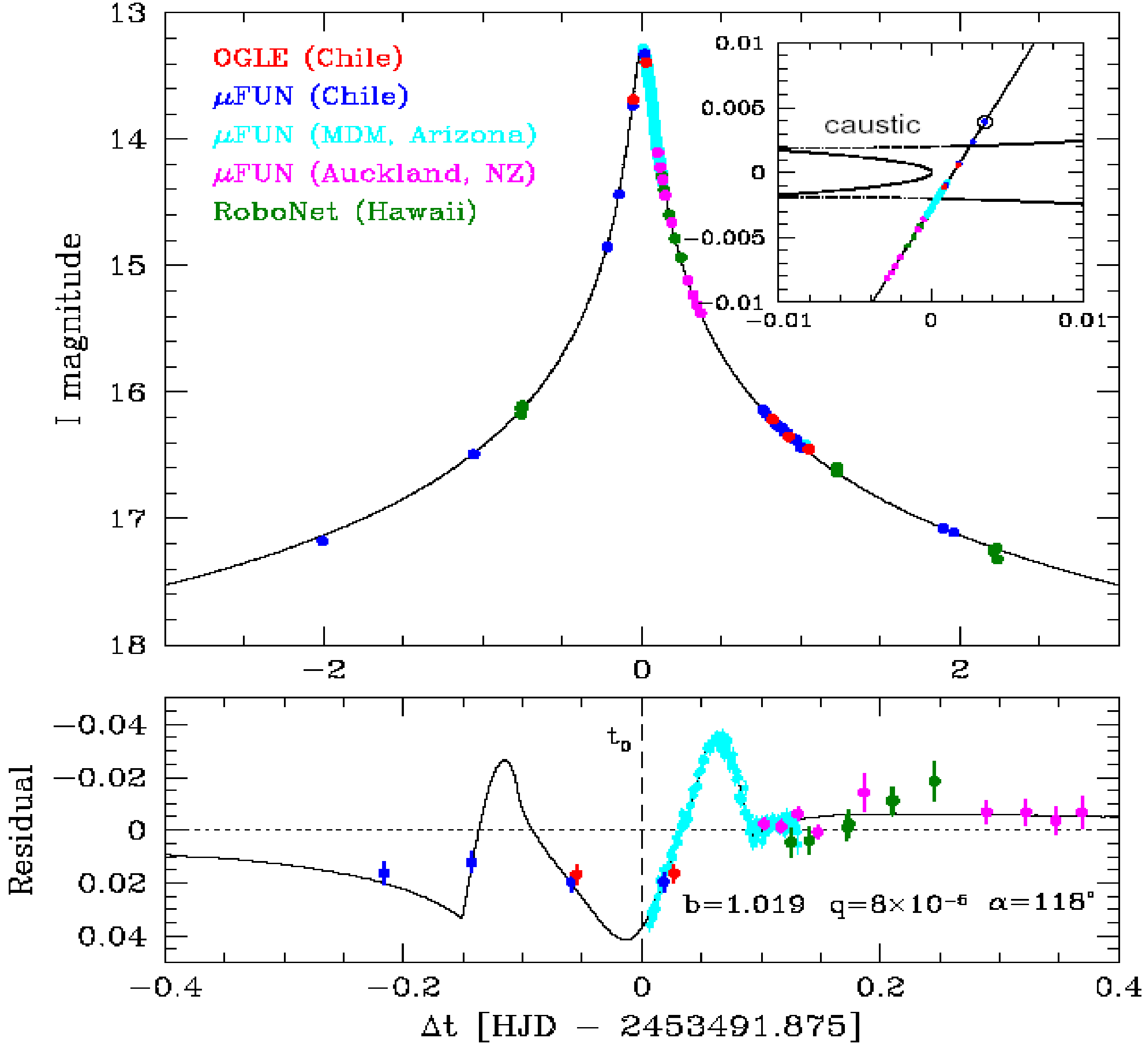
Udalski et al. 2005, ApJ, 628, L109

Amateurs + Professionals

Grant, Ian, Jennie, Phil

OGLE-2005-BLG-169:

Second μFUN Planet: Cold Neptune



Deokkeun An


ASTRONOMY TODAY
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Tale of Two Planets

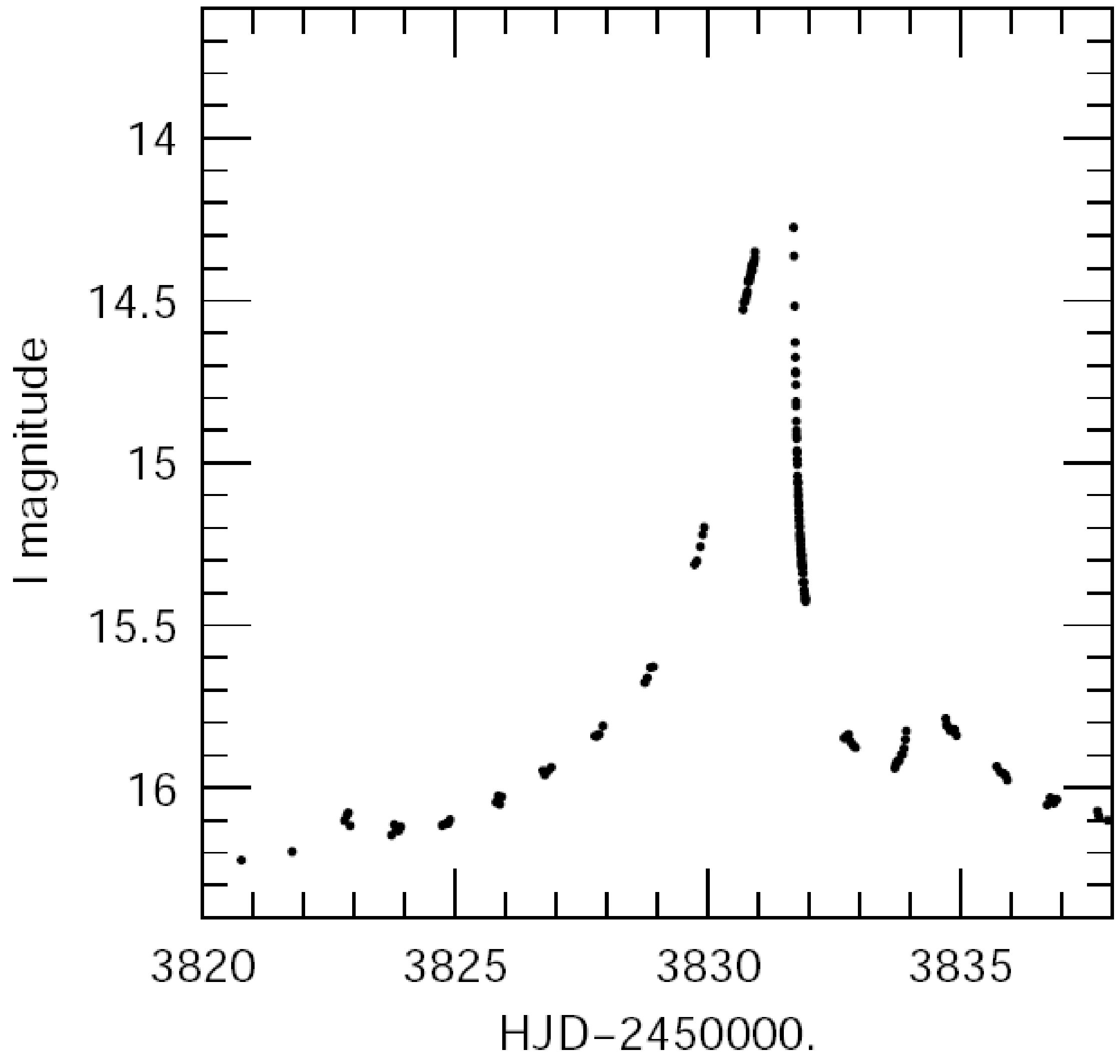
OGLE-2005-BLG-390

- q = 8e-5
- M_* = 0.2 M_sun
- M_p = 5.5 M_earth
- D = 7 kpc
- a = 3 AU
- T = 50 K
- Low-mag Event
- (1 det)/(4.4 probed)

OGLE-2005-BLG-169

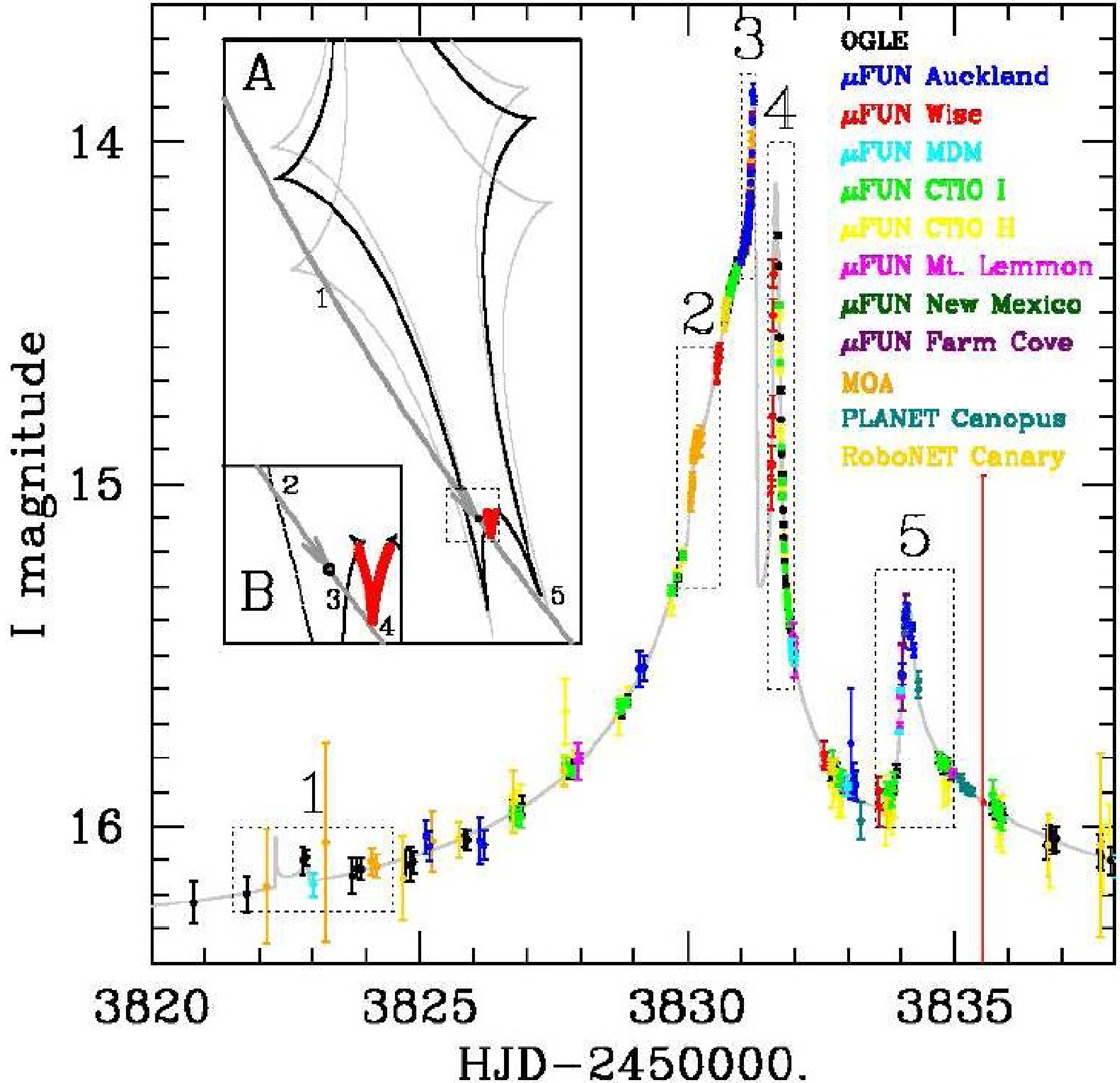
- q = 8e-5
- M_* = 0.5 M_sun
- M_p = 13 M_earth
- D = 3 kpc
- a = 4 AU
- T = 70 K
- High-mag Event
- (1 det)/(2.25 probed)

OGLE-2006-BLG-109:
Without Followup Observations



OGLE-2006-BLG-109

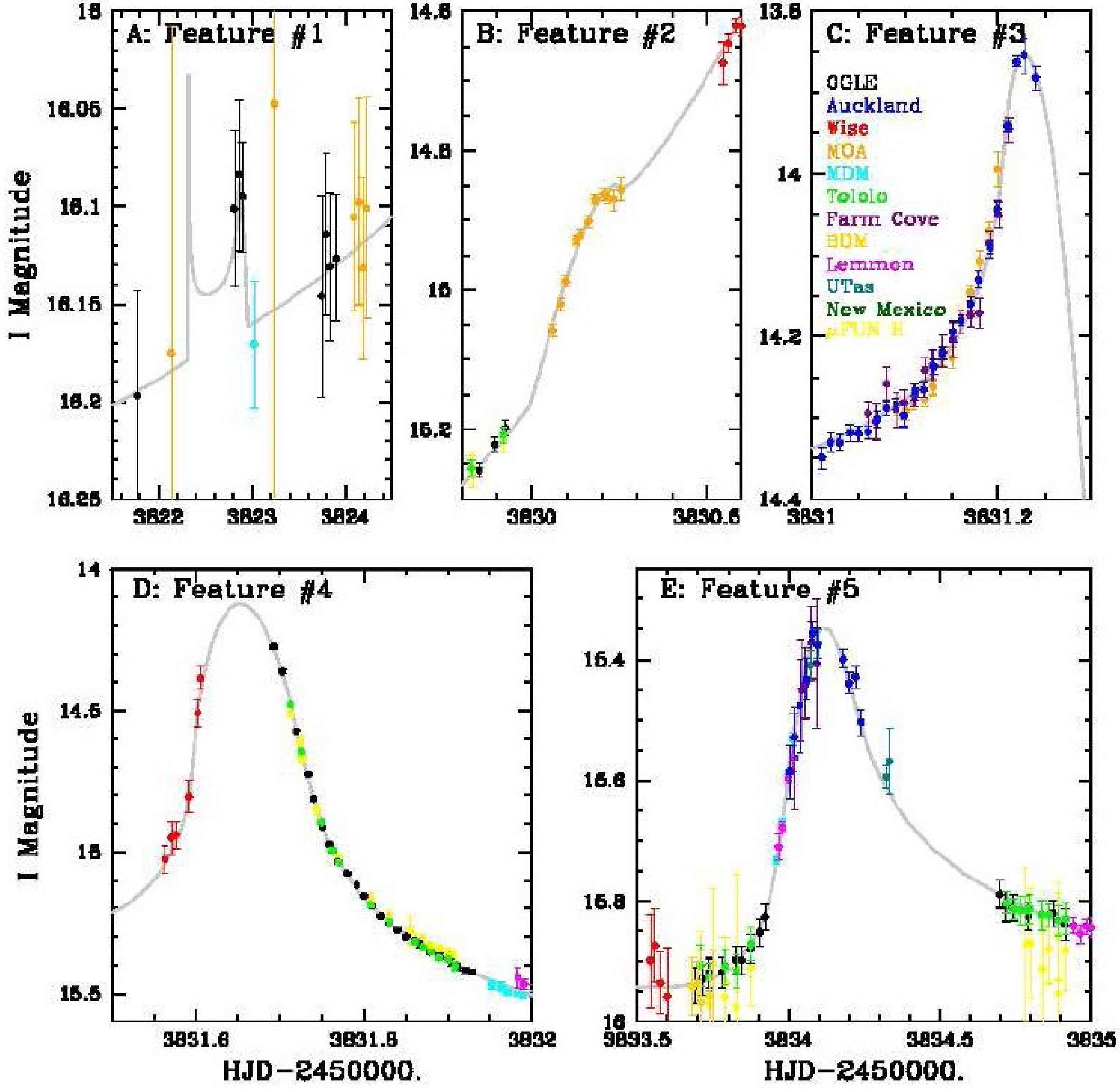
μFUN Planets 3+4: Jupiter+Saturn System



Gaudi et al. 2008, Science, 319, 927

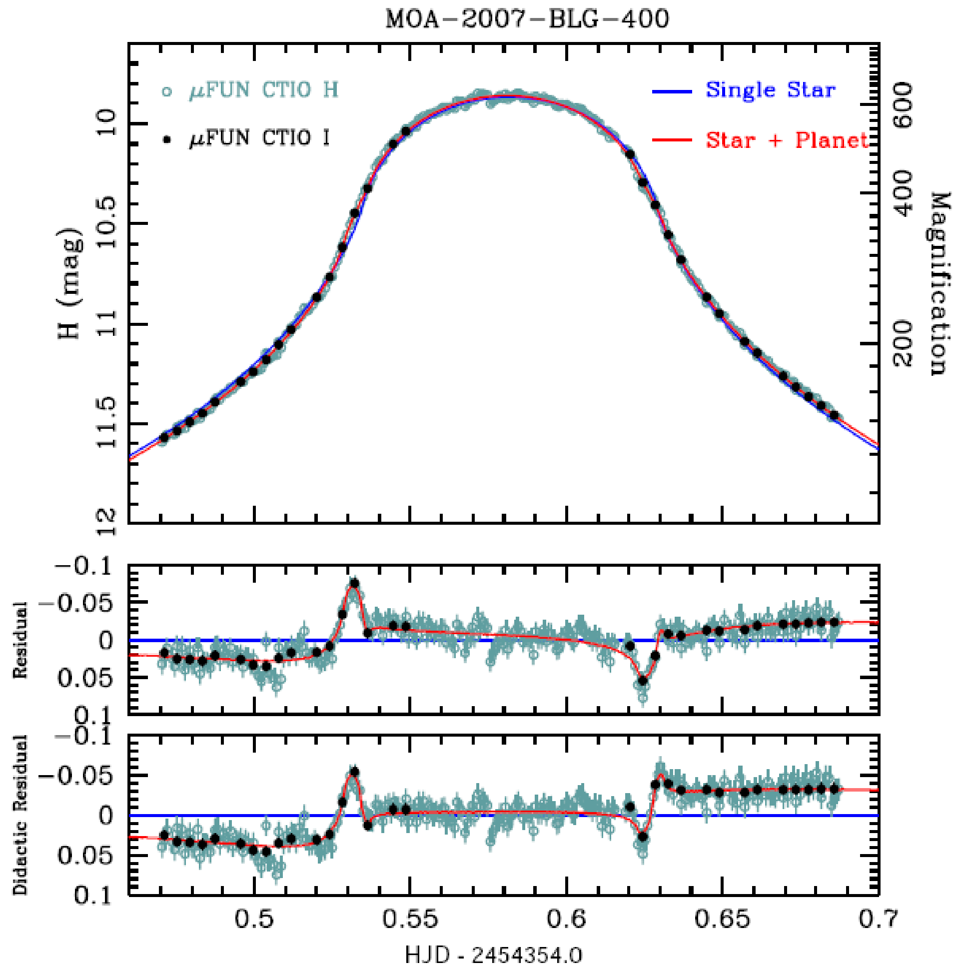
Five Lightcurve Features

1+2+3+5=Saturn 4=Jupiter

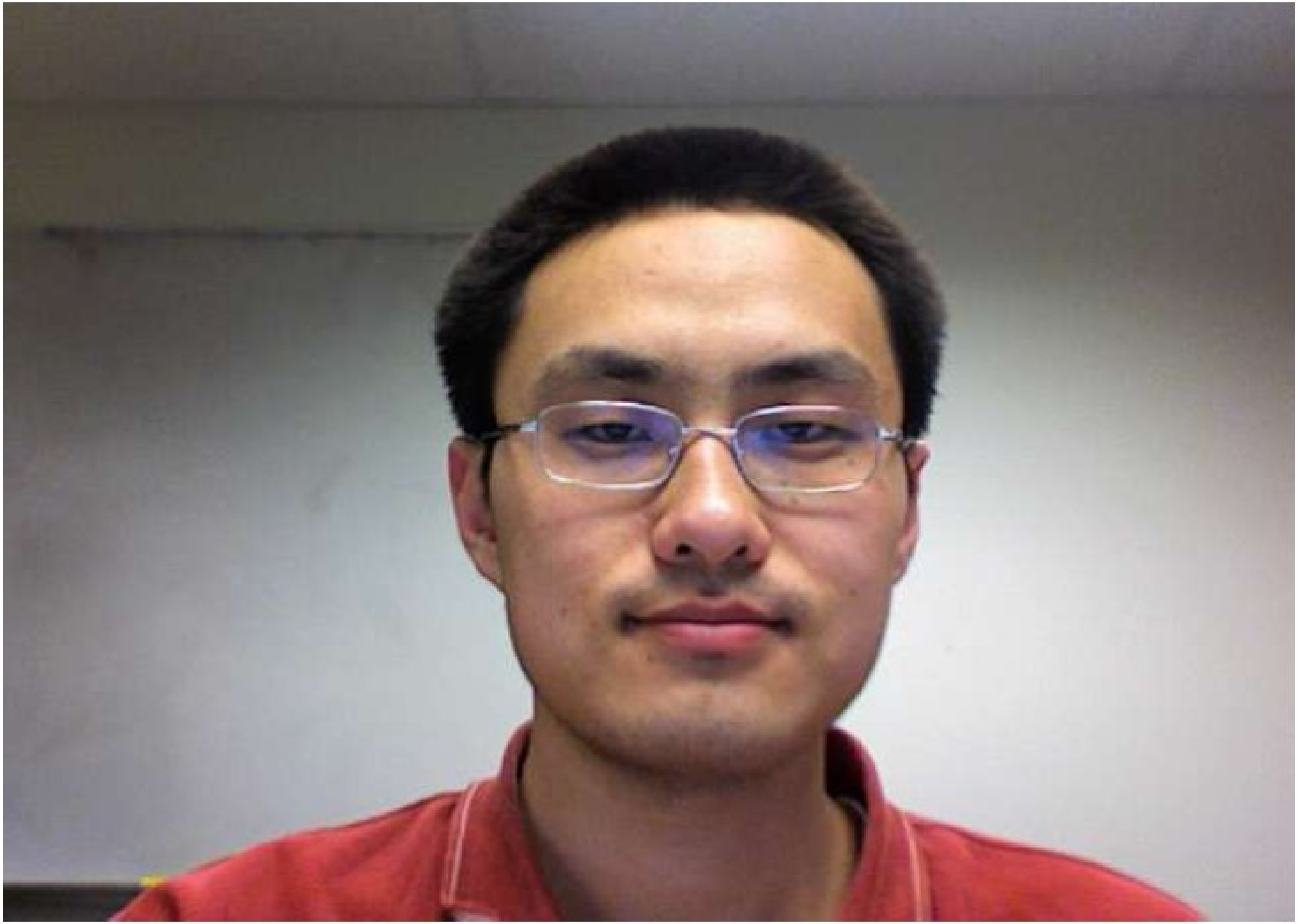


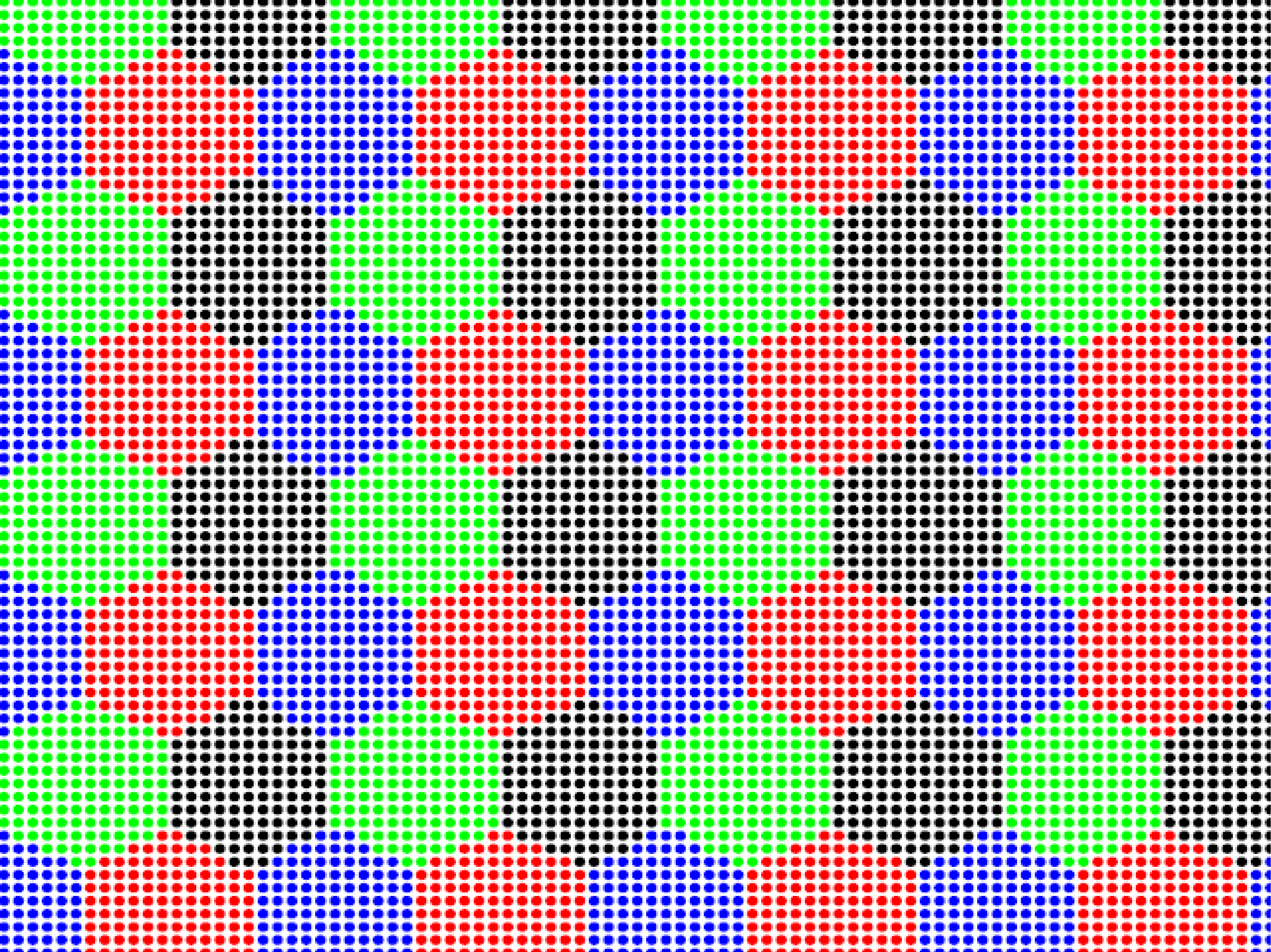
MOA-2007-BLG-400

Fifth µFUN Planet: "Buried" Jupiter

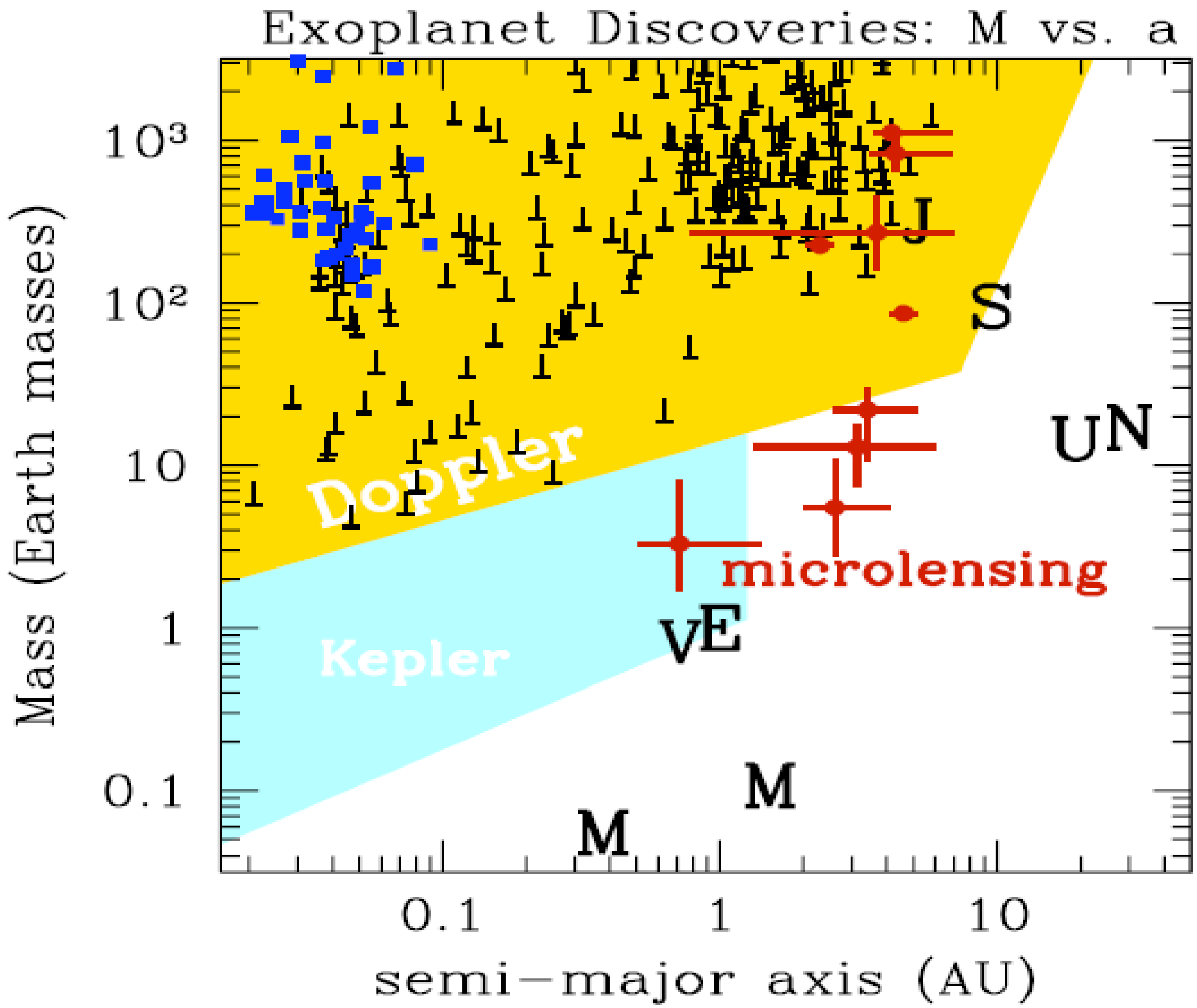


Subo Dong

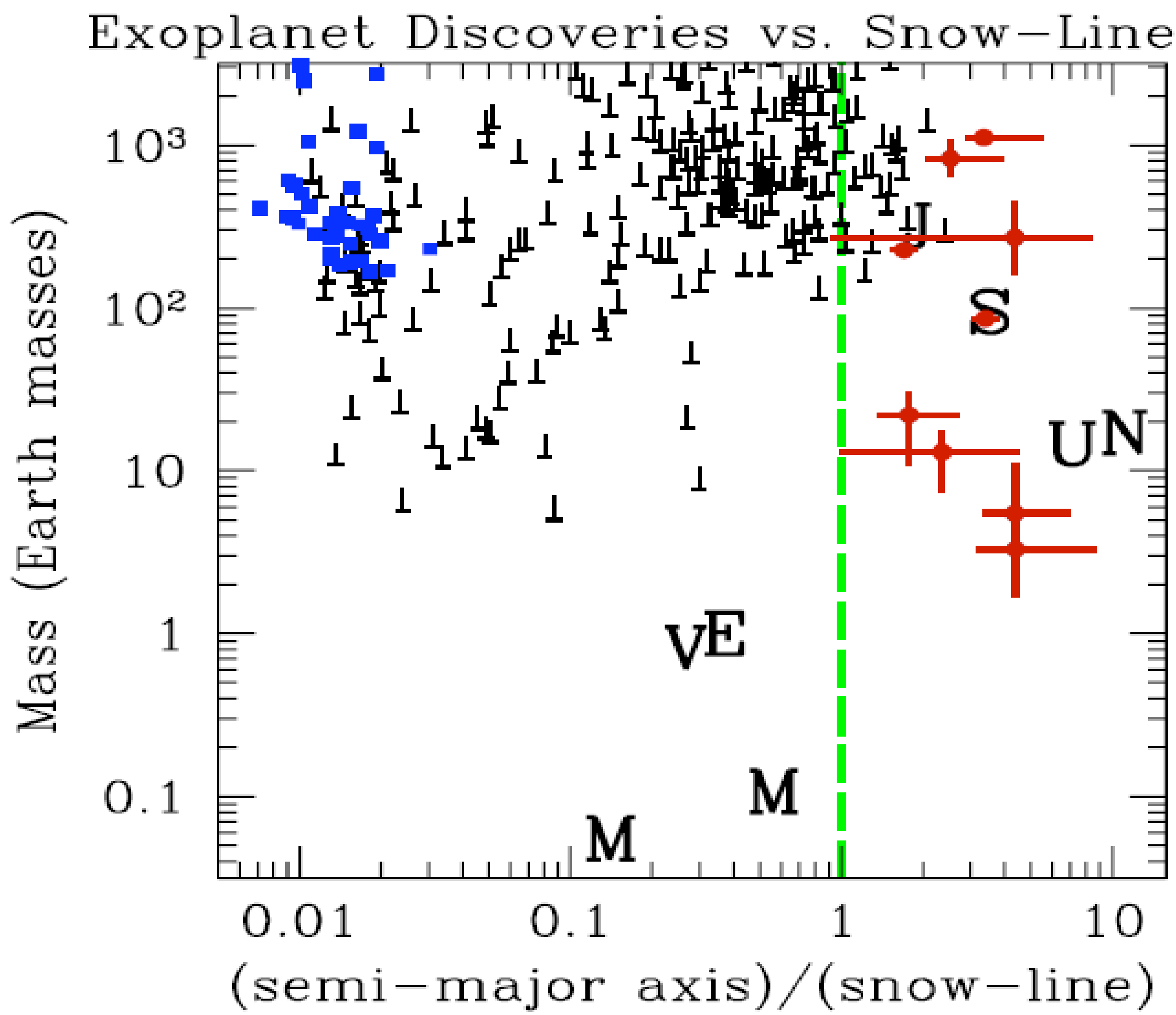




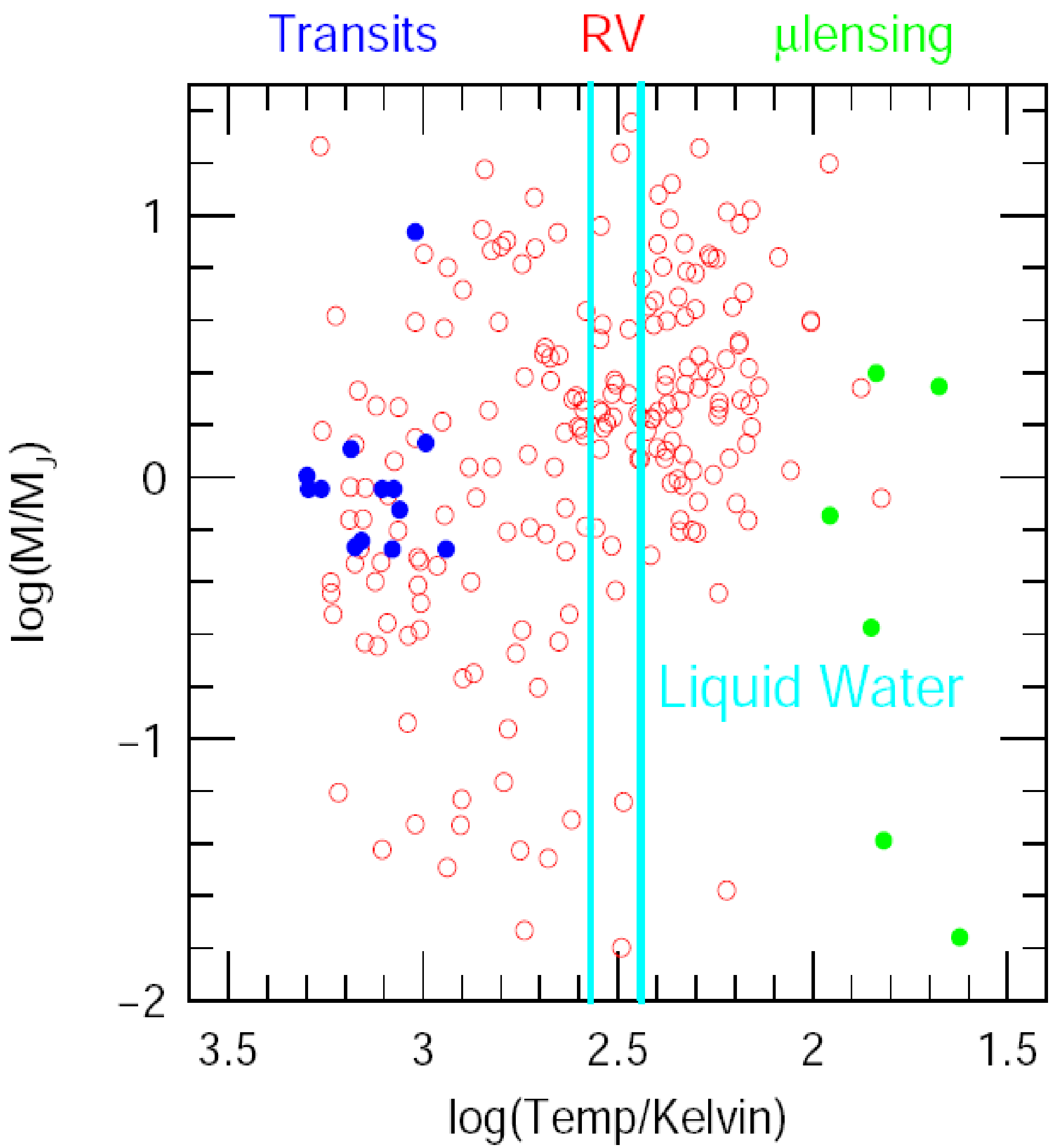
Microlensing vs. Other Methods



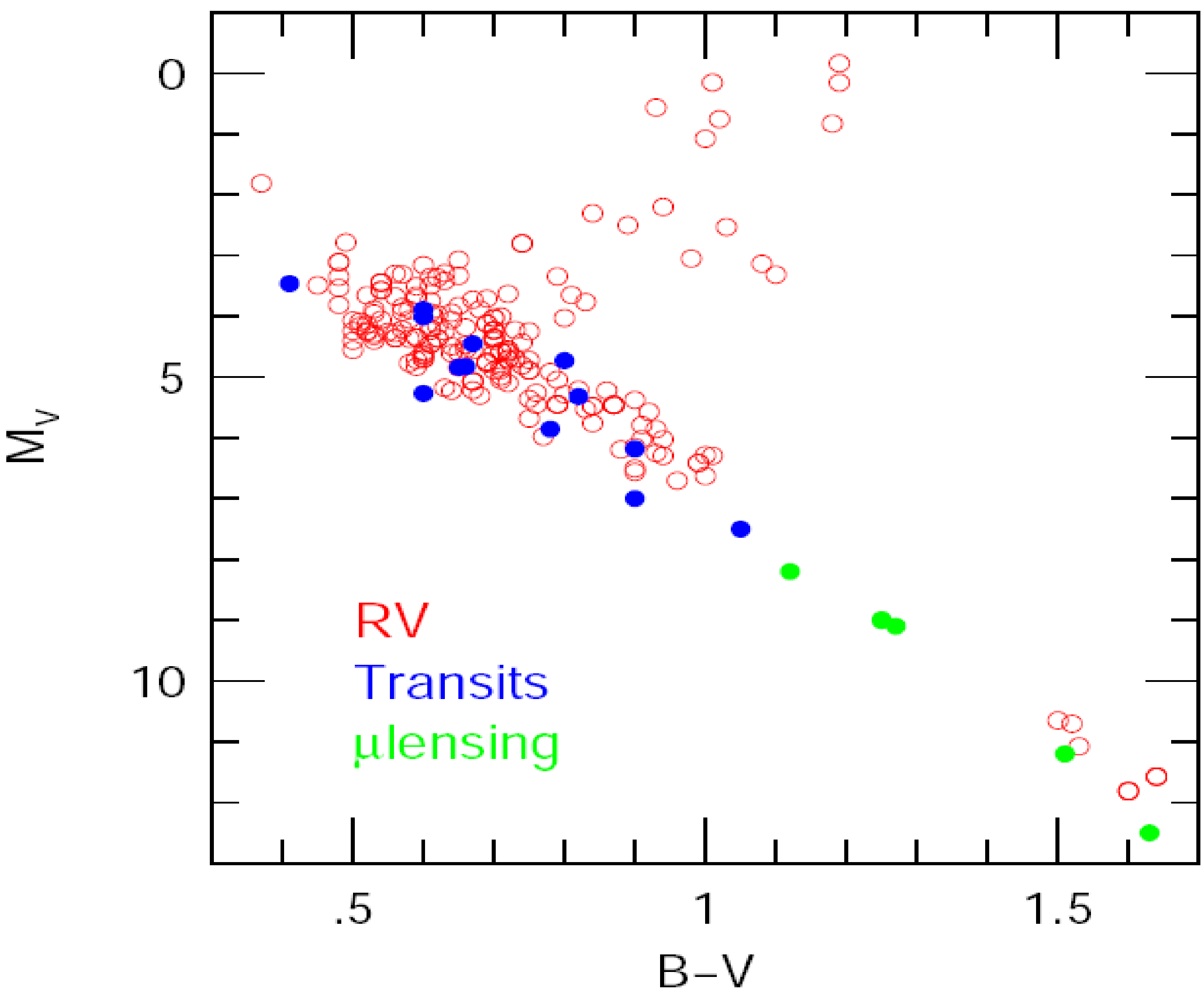
Microlensing and the "Snow Line"



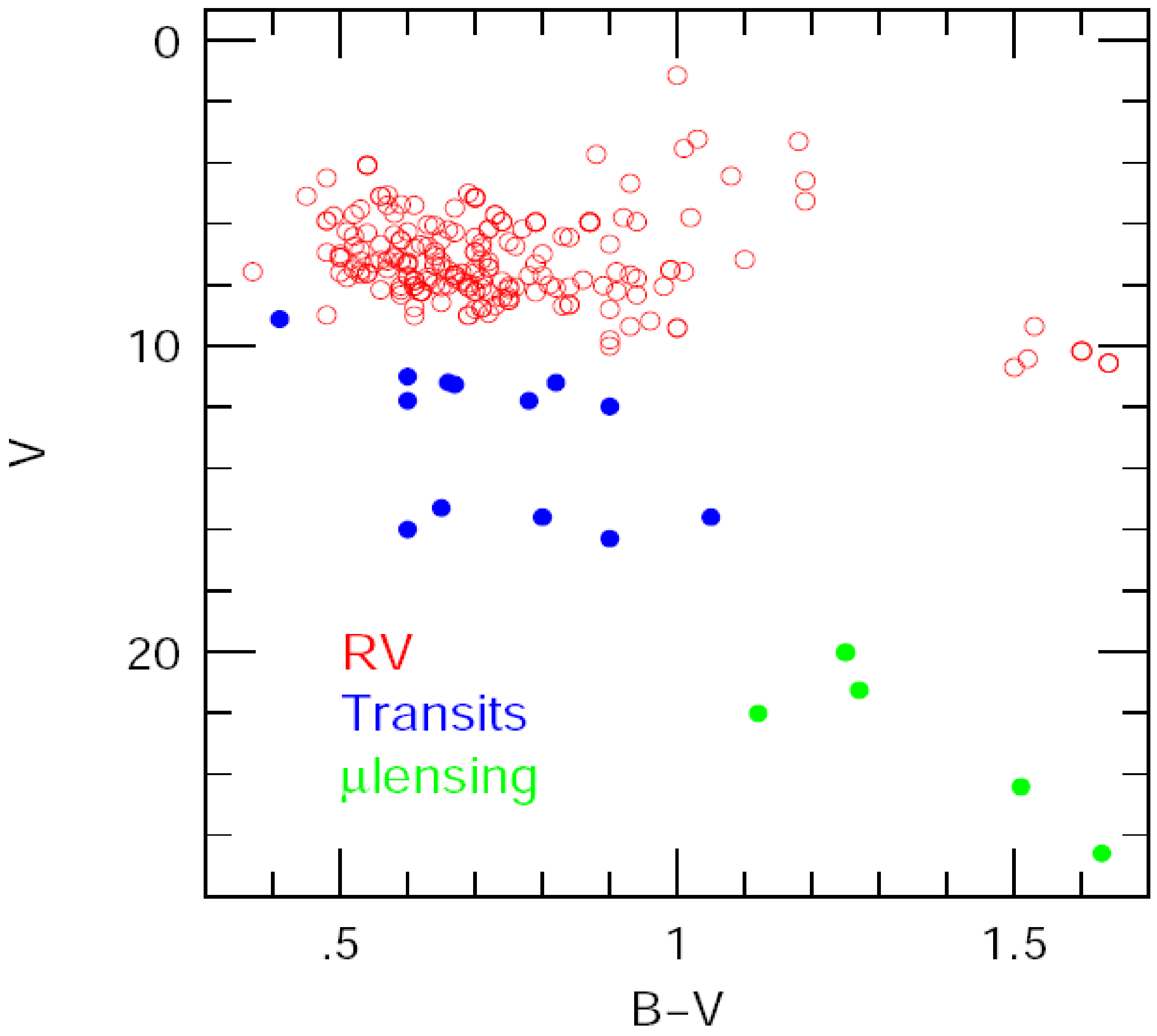
Equilibrium Temperature



CMD (Absolute mags)

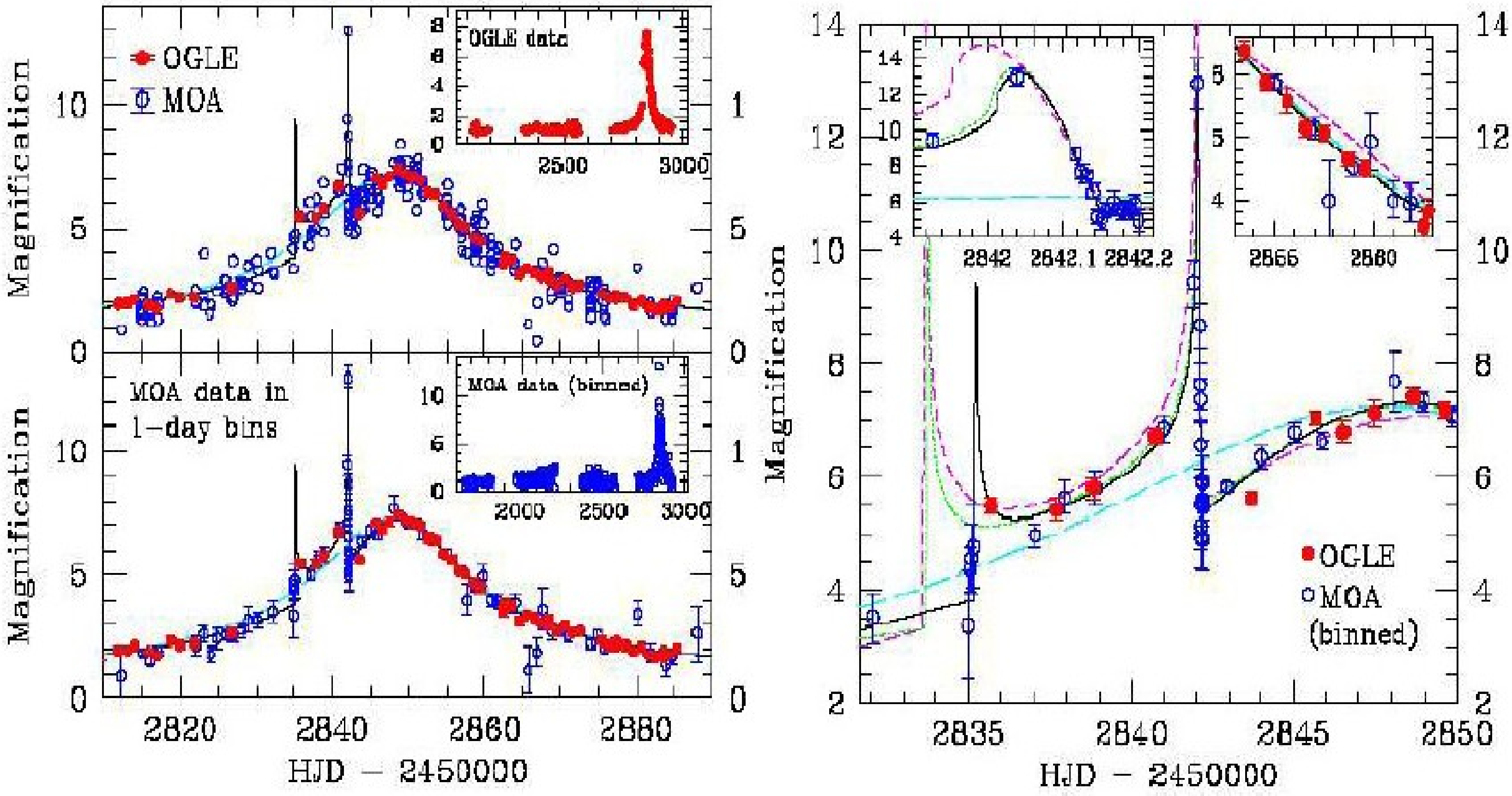


CMD (Apparent Mags)



OB-03-235/MB-03-053: 5.5 kpc

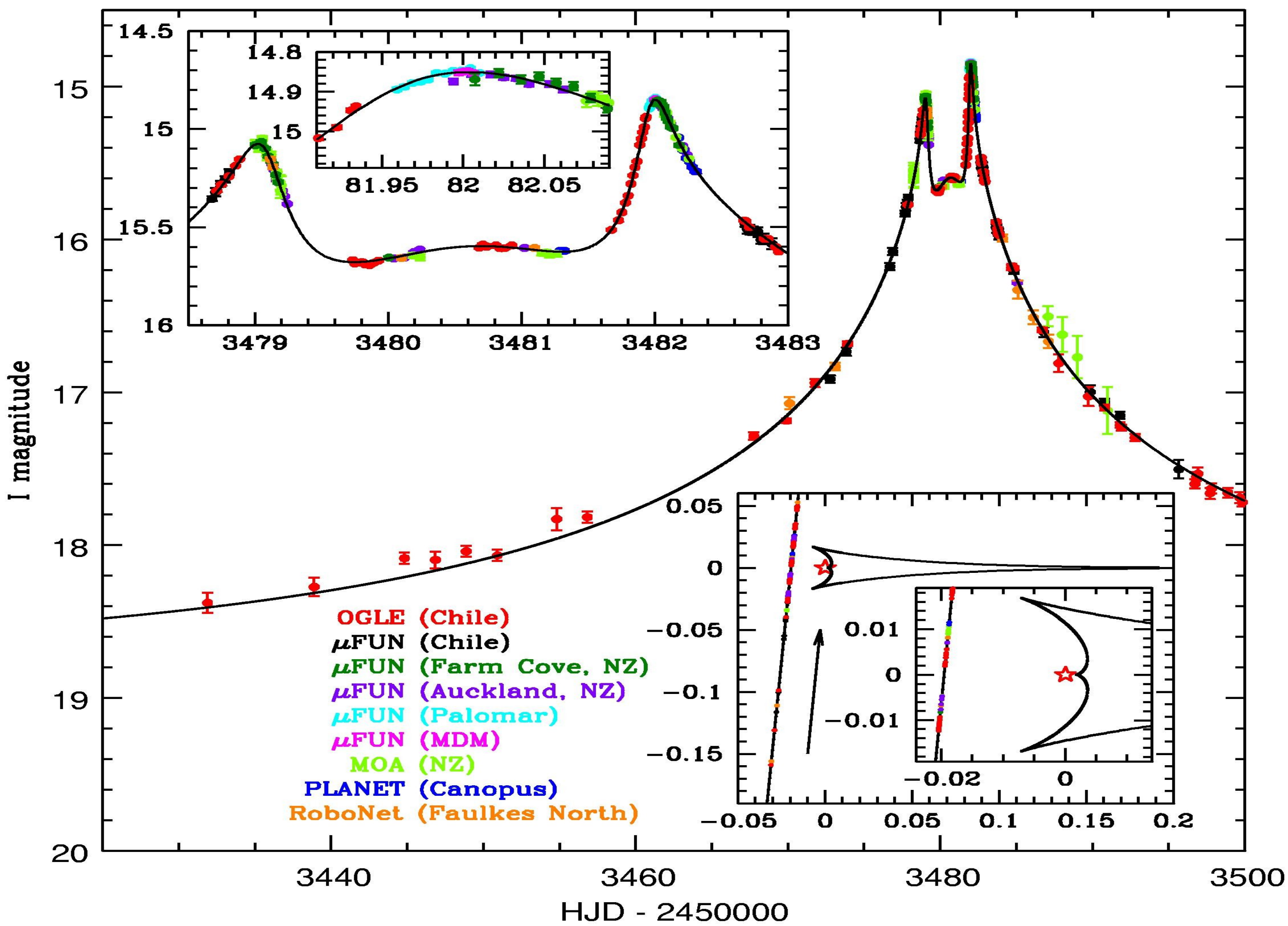
Finite Source + Centroid Motion



Bennett et al. 2006, ApJ, 647, L171

OGLE-2005-BLG-071: 3.3 kpc

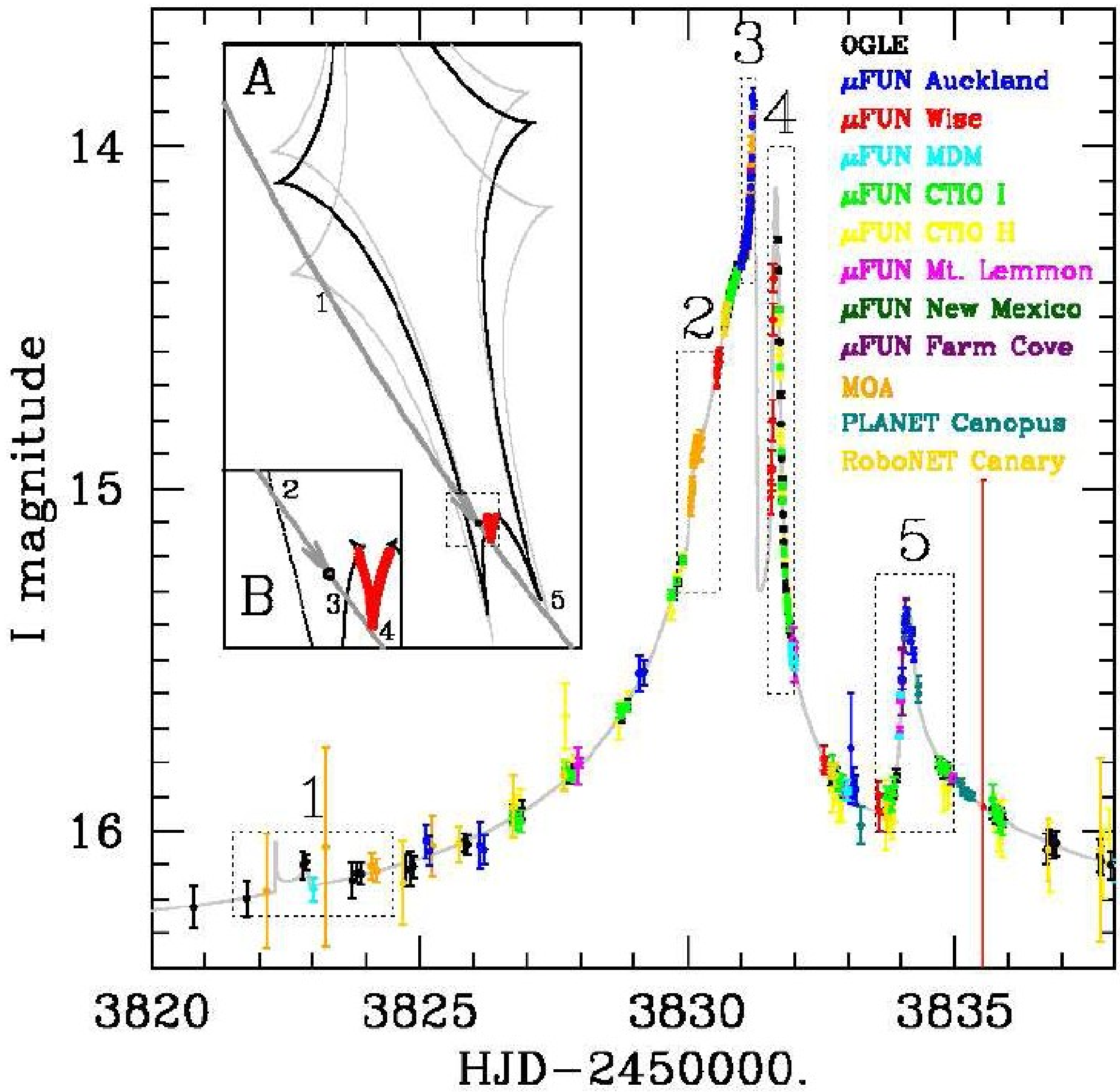
Parallax + Finite Source + Centroid Motion



Dong et al. 2009, astroph/0804.1354

OGLE-2006-BLG-109: 1.5 kpc

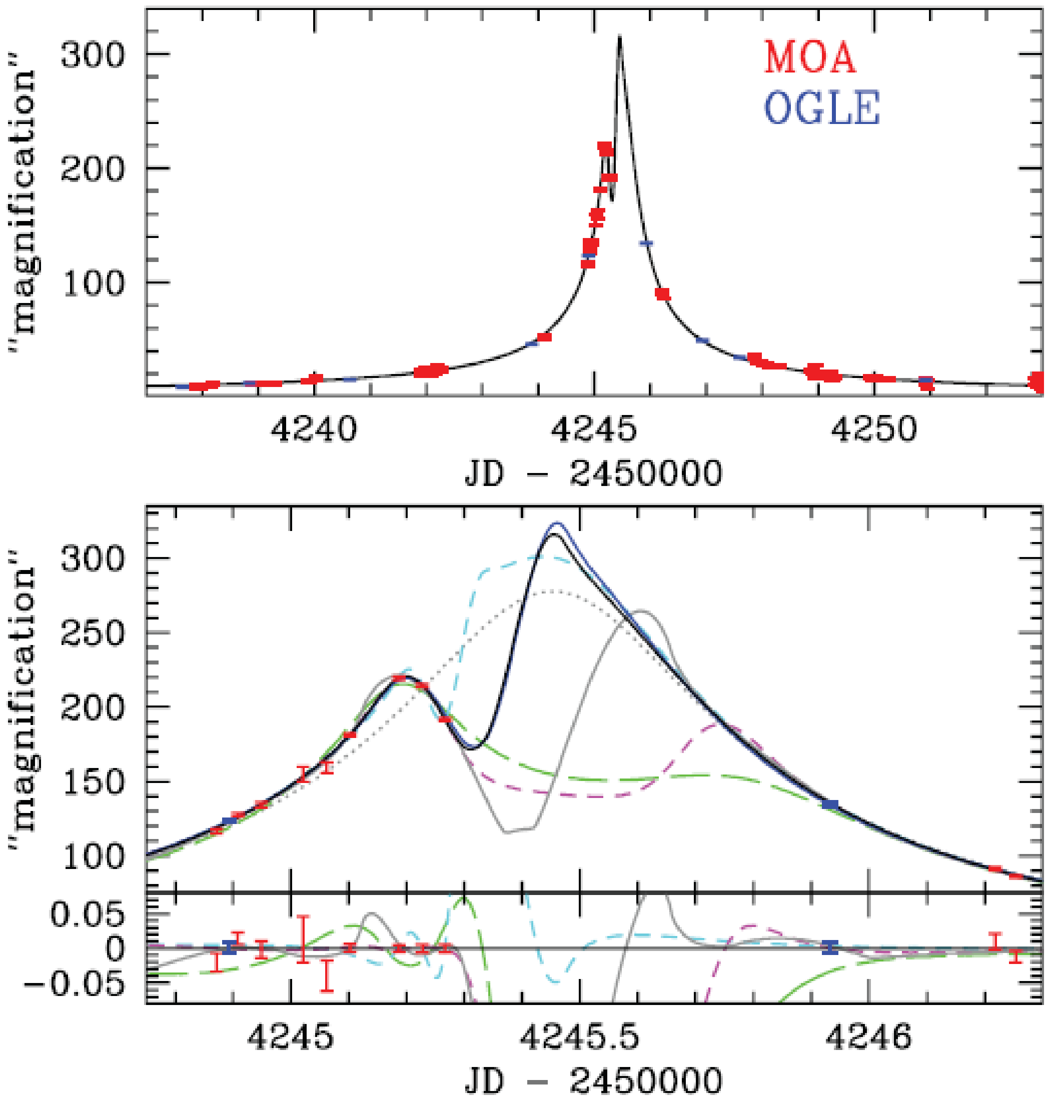
Parallax + Finite Source + Blend



Gaudi et al. 2008, Science, 319, 927

MOA-2007-BLG-192: 1.5 kpc

Parallax + Finite Source



Bennett et al. 2008, ApJ, 684, 663

Conclusions

- μFUN has played a major role in the discovery of 9 extrasolar planets
  - 2005 (2), 2006 (2), 2007 (2), 2008 (3)
- Many planet distances are measured
  - Most in Disk
- Microlensing planets are cold
  - Great Probe Beyond the "Snow Line"