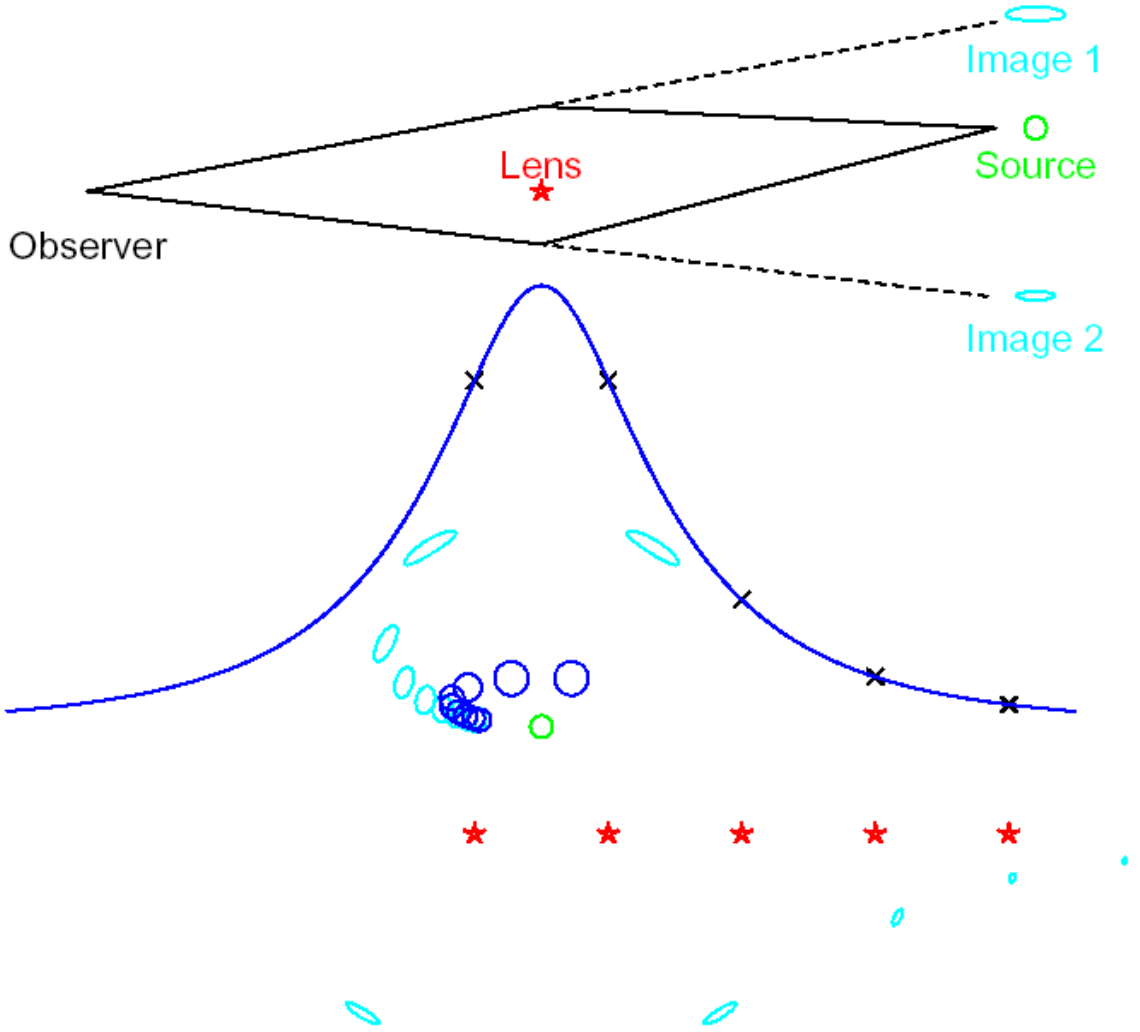
μFUN 2005-2012

8 Years of Planet Detections

Andy Gould (Ohio State)

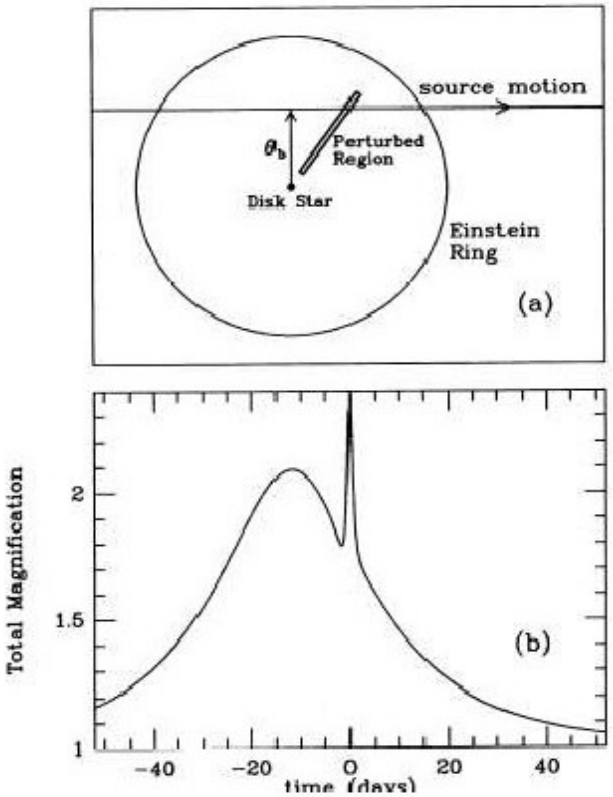


Gould & Loeb

1992

DISCOVERING PLANETARY SYSTEMS THROUGH GRAVITATIONAL MICROLENSES

ANDREW GOULD AND ABRAHAM LOEB
Institute for Advanced Study, Princeton, NJ 08540
Received 1991 December 26; accepted 1992 March 9



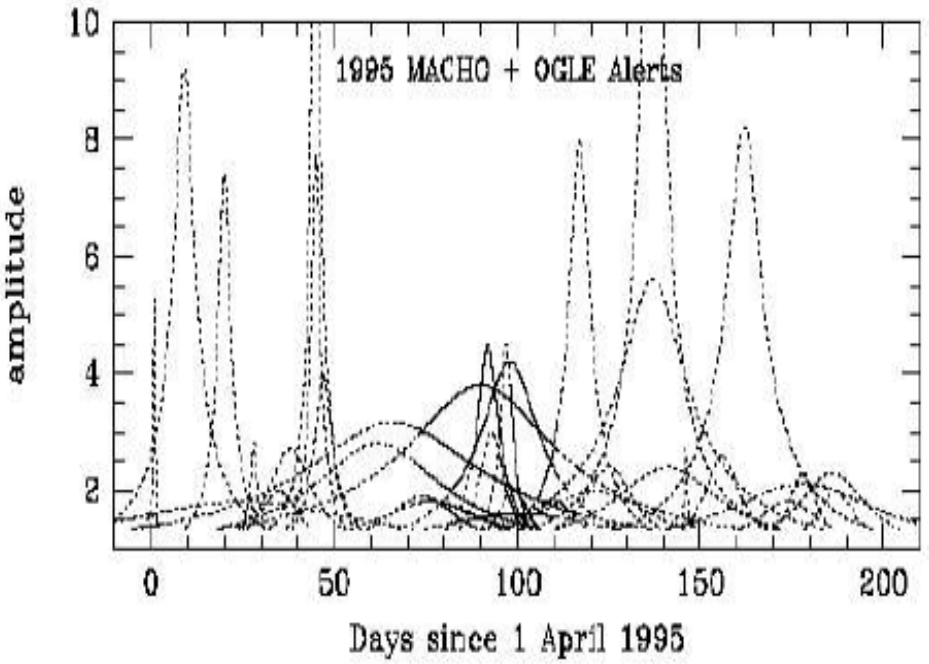
5. OBSERVATIONAL REQUIREMENTS

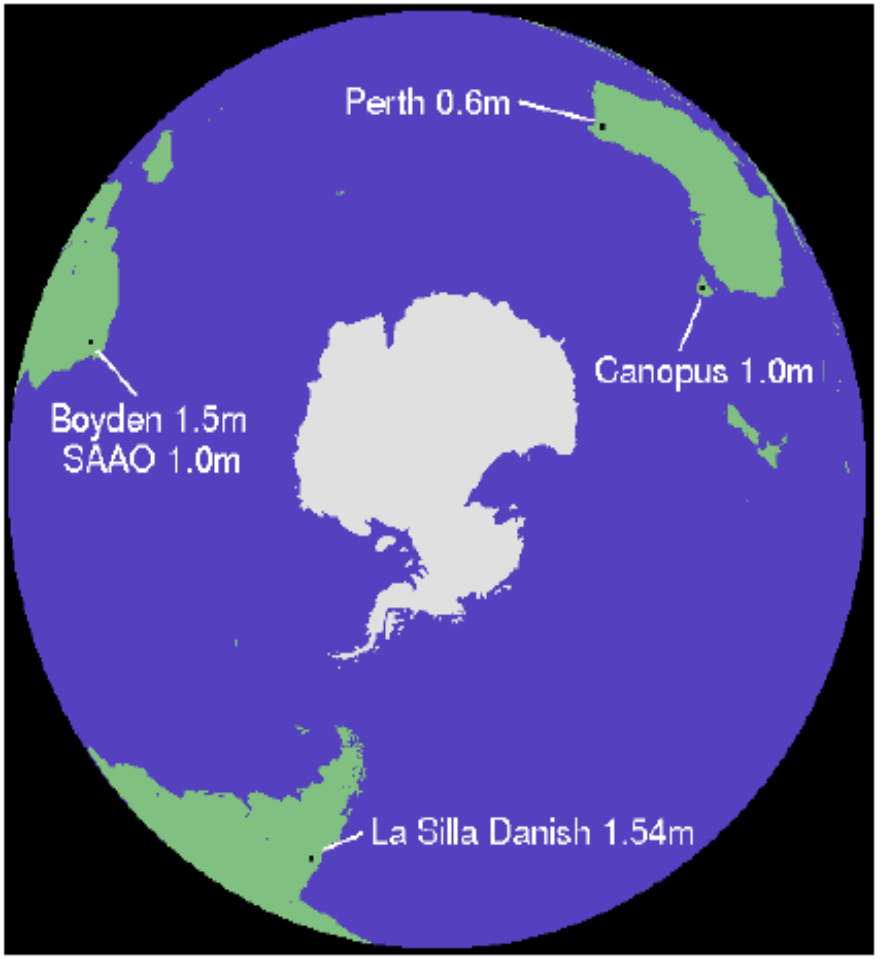
Two distinct steps are required to observe a planetary system by microlensing. First, one must single out a disk star which happens to be microlensing a bulge star. Second, one must observe this star often enough to catch the deviation in the light curve due to the planet. The first step involves the 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,

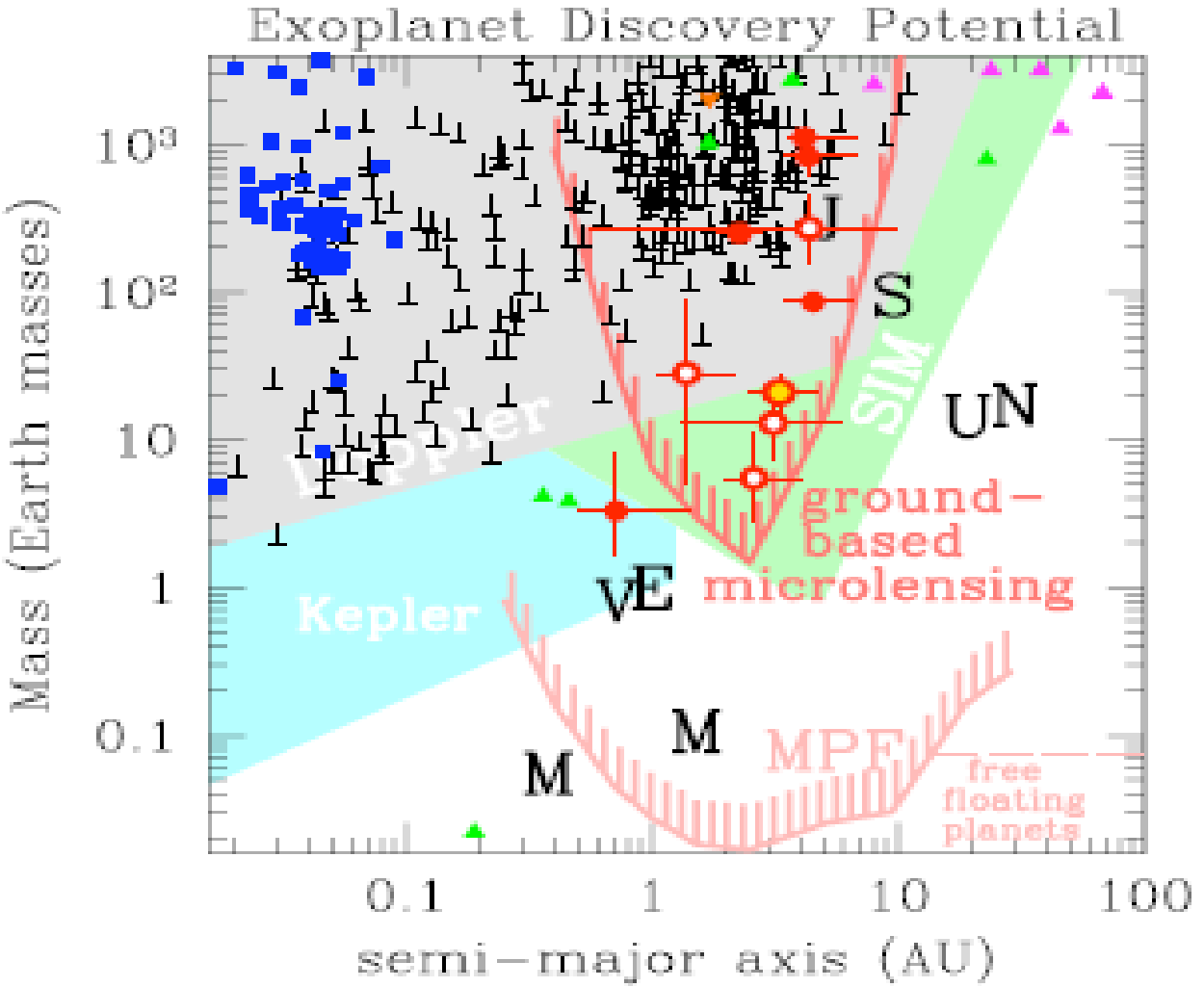
1995 PLANET Pilot Season

- Albrow et al. 1998 ApJ, 509, 687





Planets 2010



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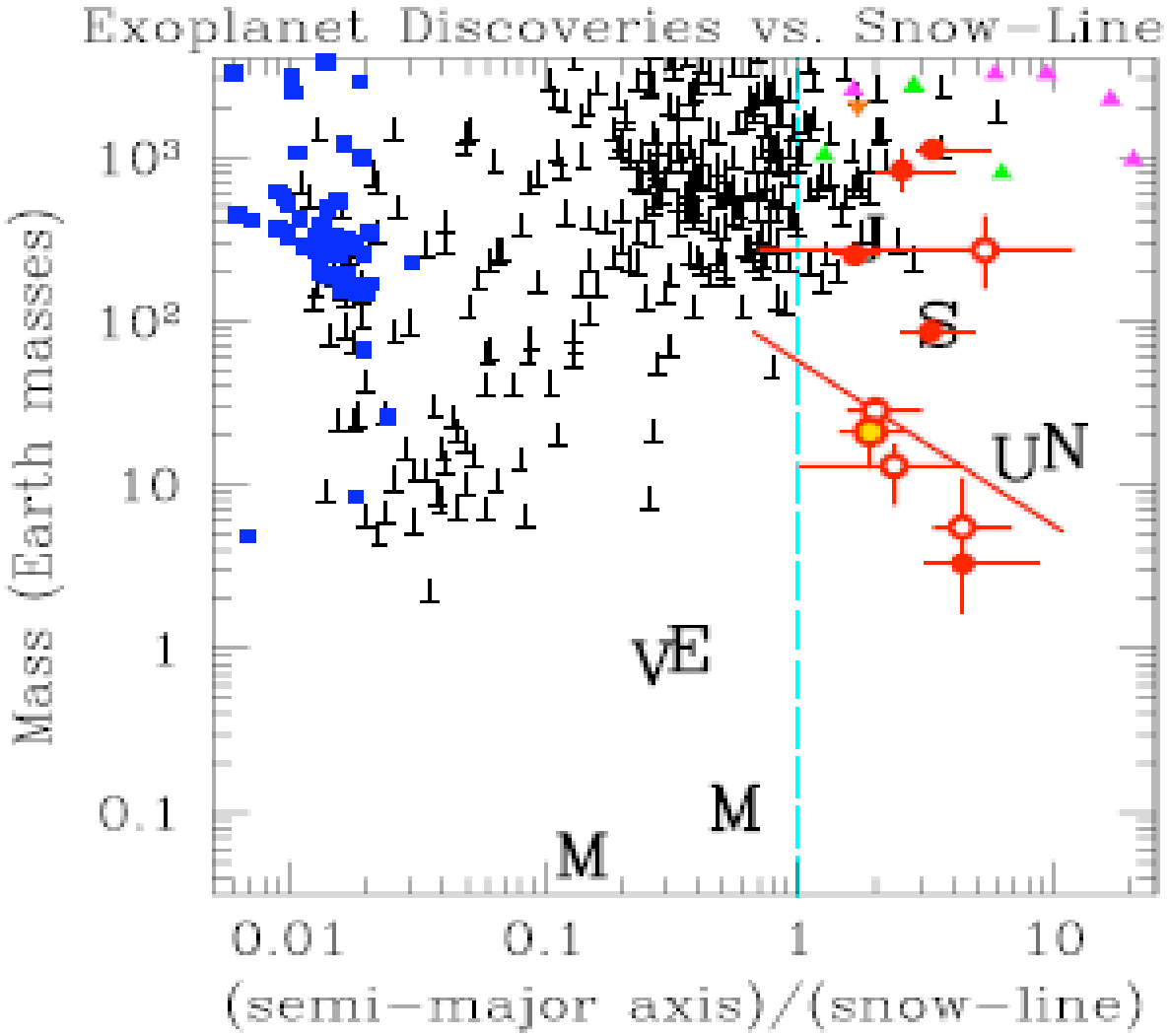
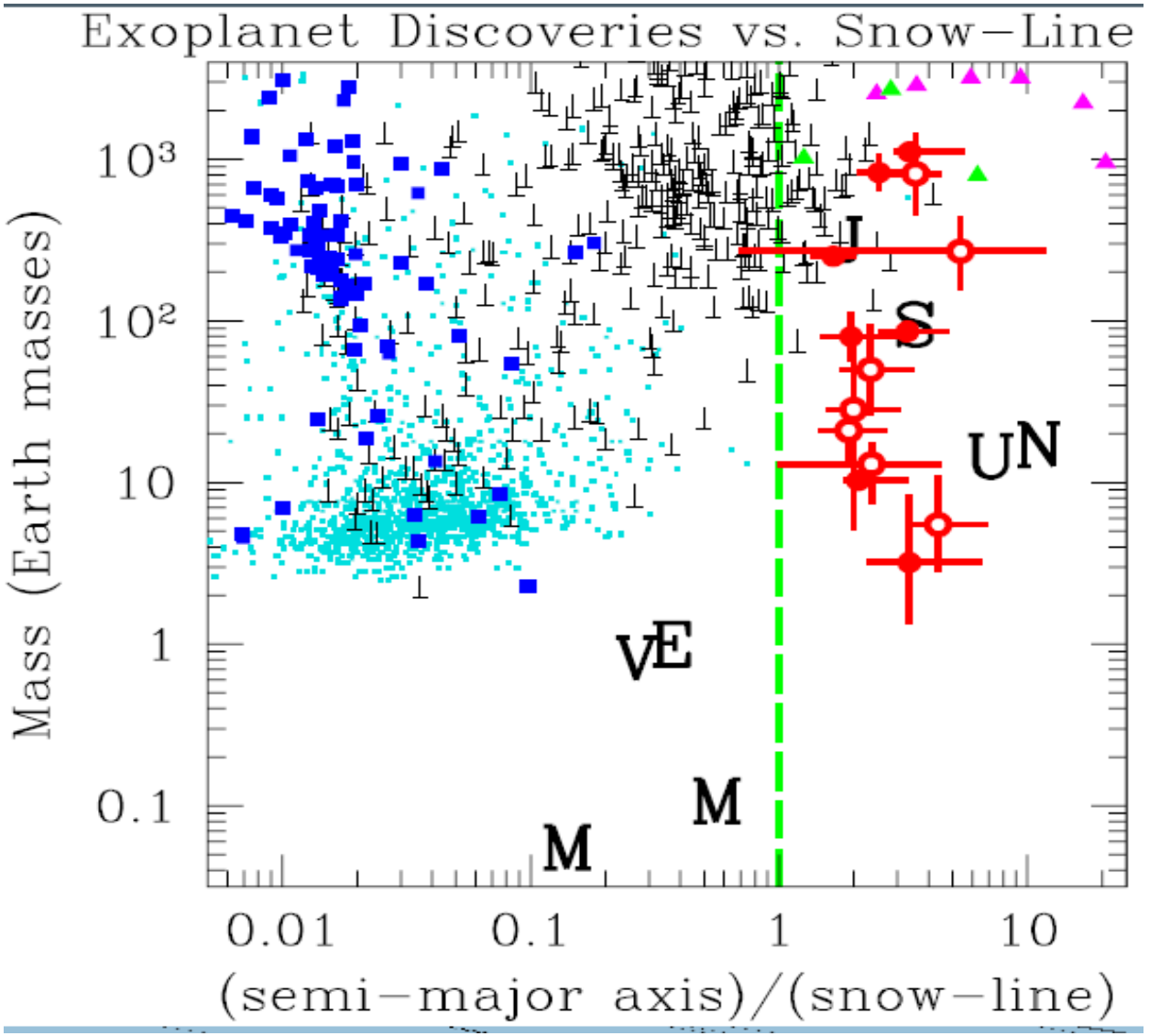
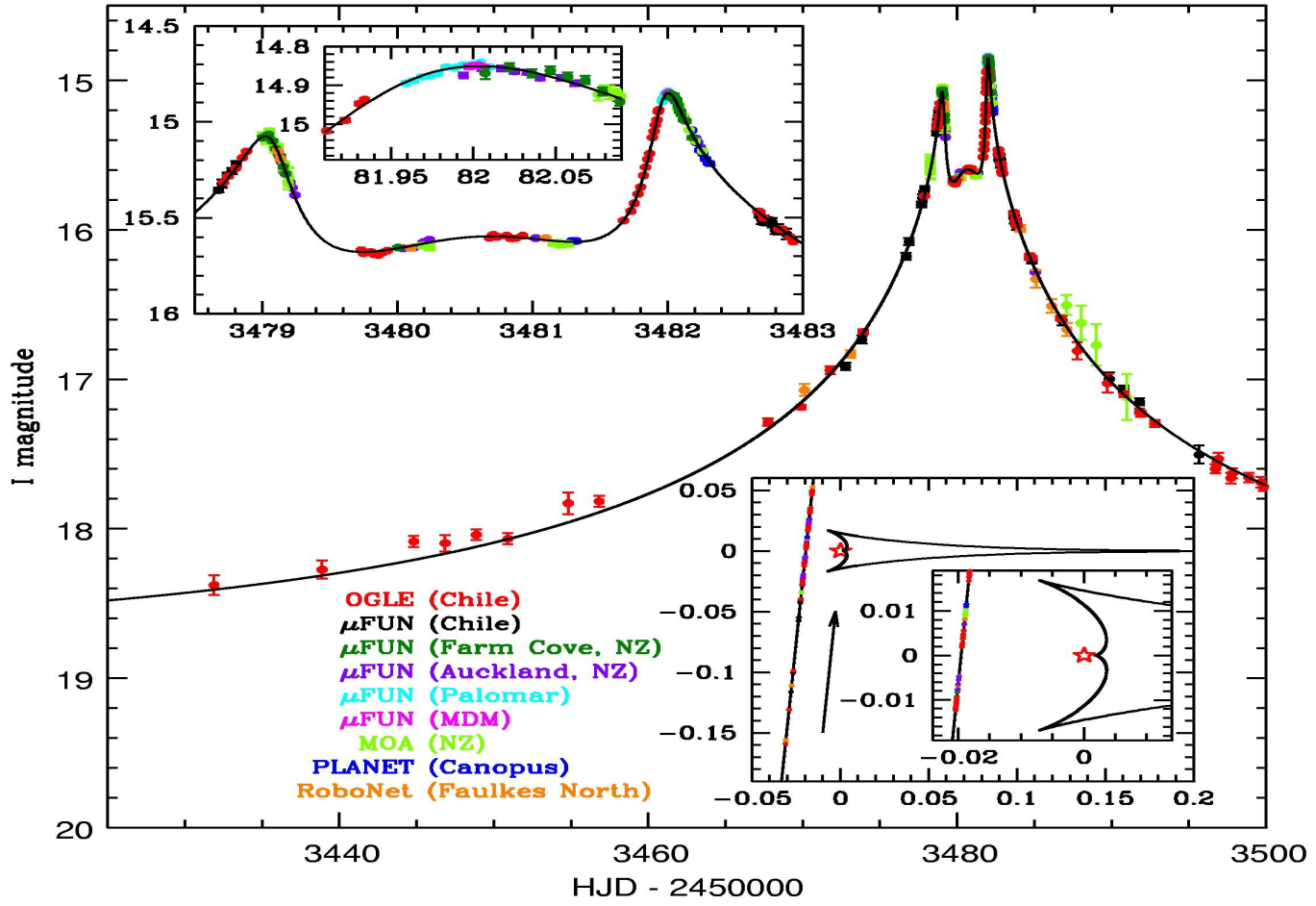


Planets 2011



OGLE-2005-BLG-071

1st High-Mag, 1st μFUN, 2nd Planet



Udalski et al. 2005, ApJ, 628, L109

Major Discoveries

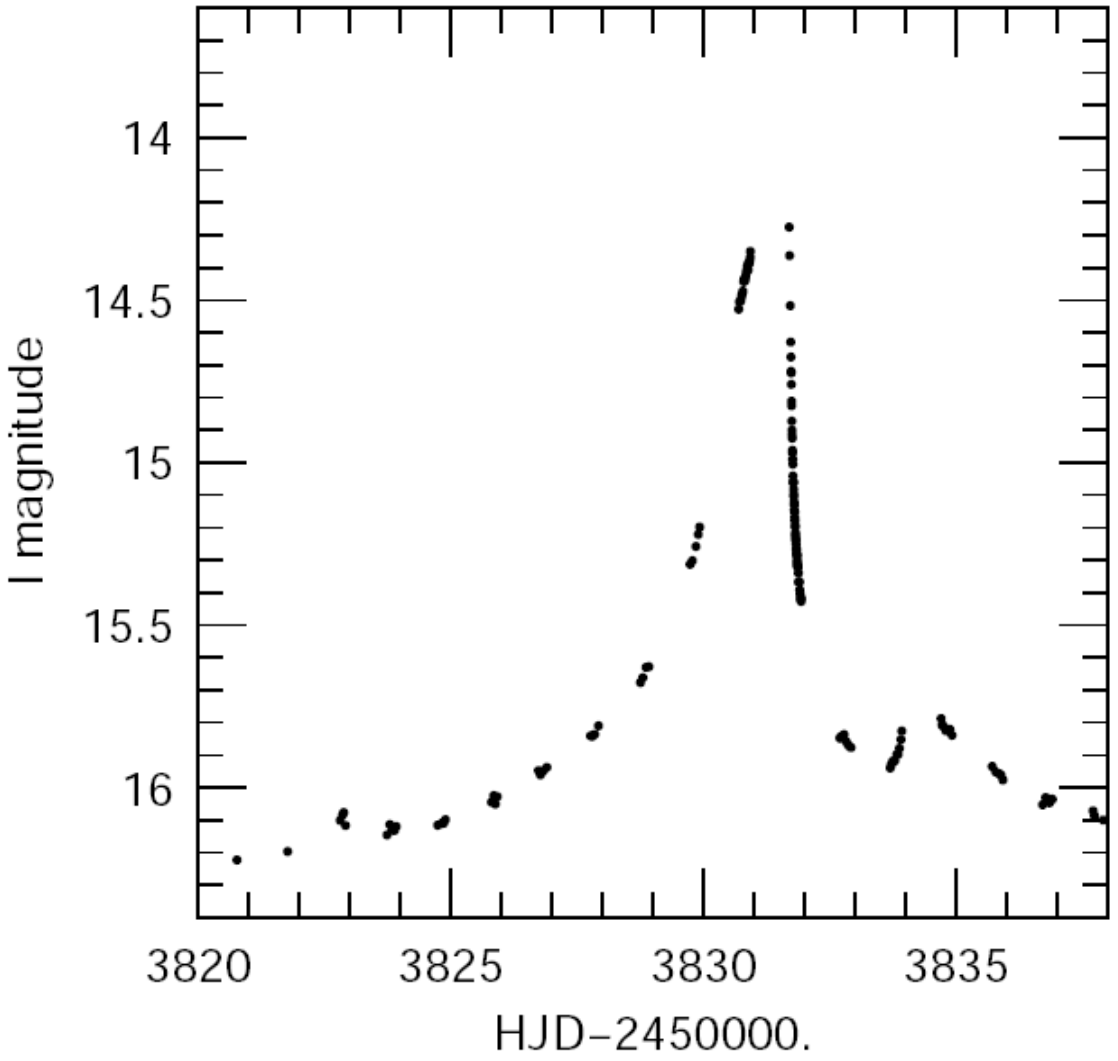
- Two-Planet Systems
- Terrestrial Parallax
- Super-Jupiters orbiting M dwarfs

Two-Planet Systems

- OGLE-2006-BLG-109Lb,c

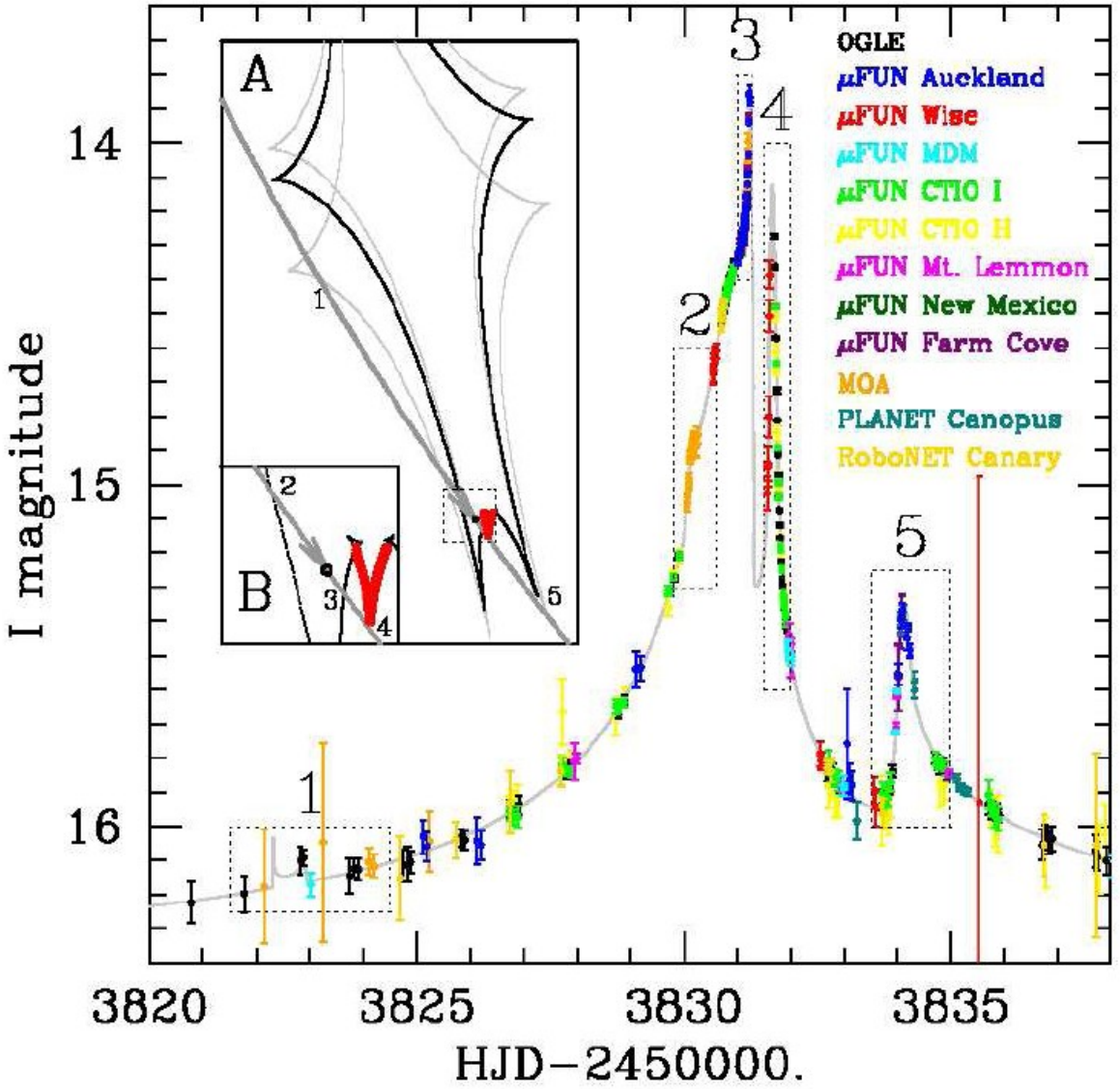
OGLE-2006-BLG-109:

Third High-Mag Event (OGLE only)



OGLE-2006-BLG-109

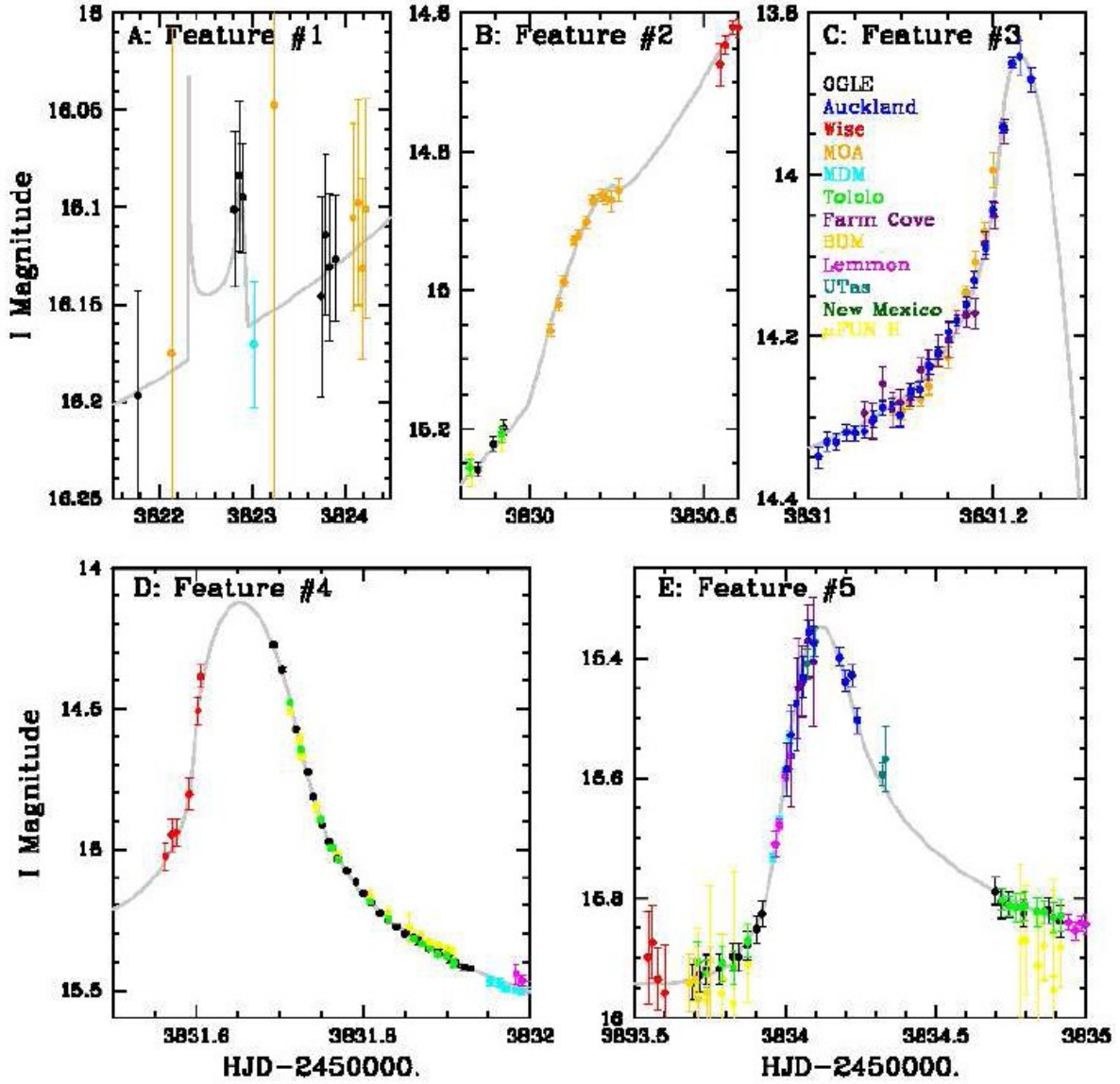
Parallax+Finite-Source+Rotation+Blend



Gaudi et al. 2008, Science, 319, 927

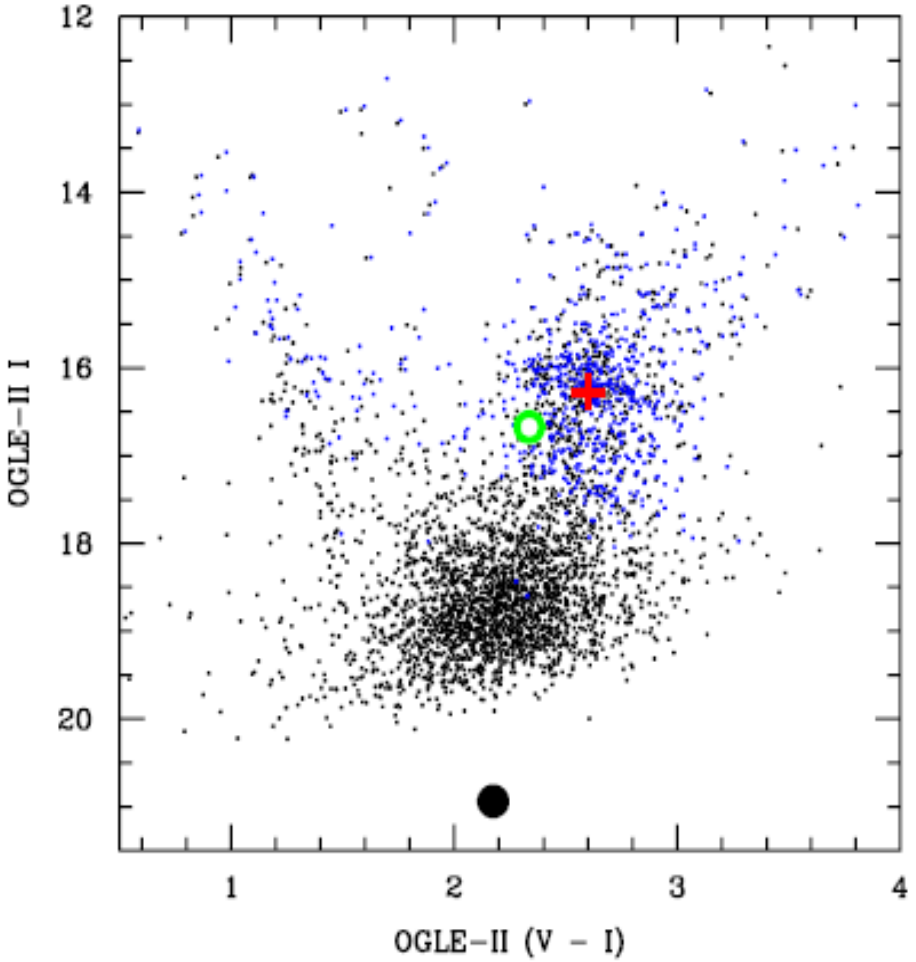
Five Lightcurve Features

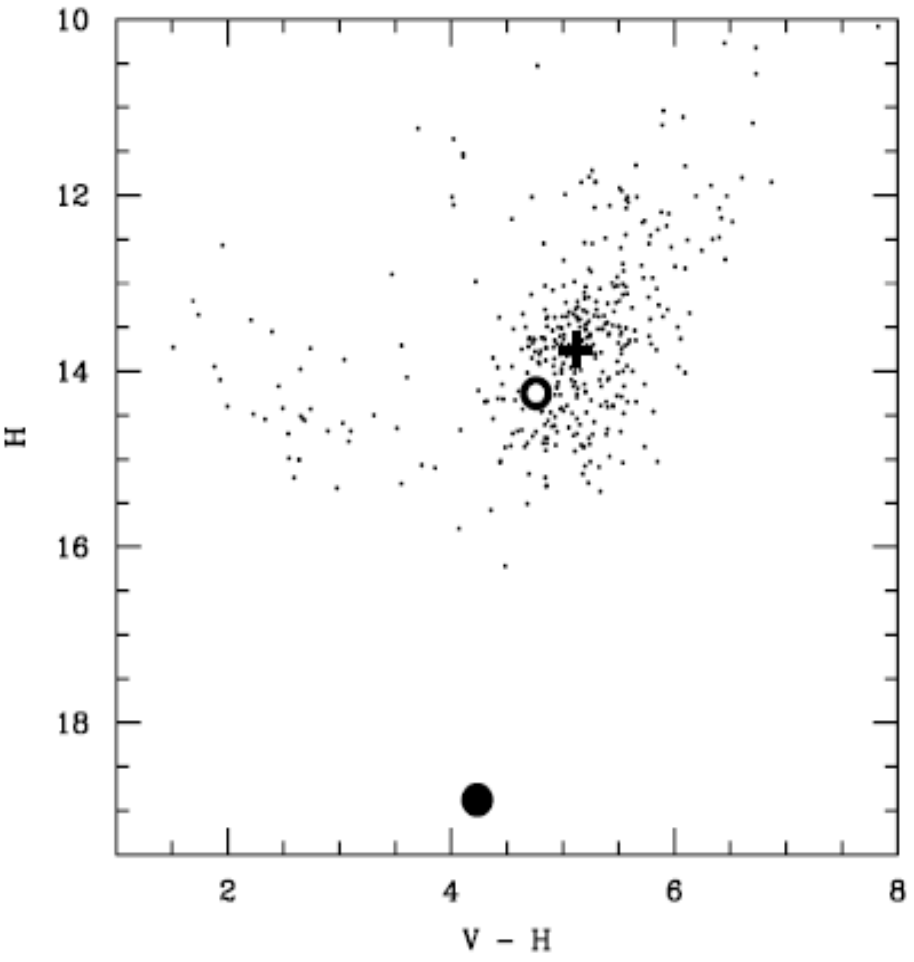
1+2+3+5=Saturn 4=Jupiter



OGLE-2006-BLG-109

Source (MSTO) & Blend (Clump?) on CMD

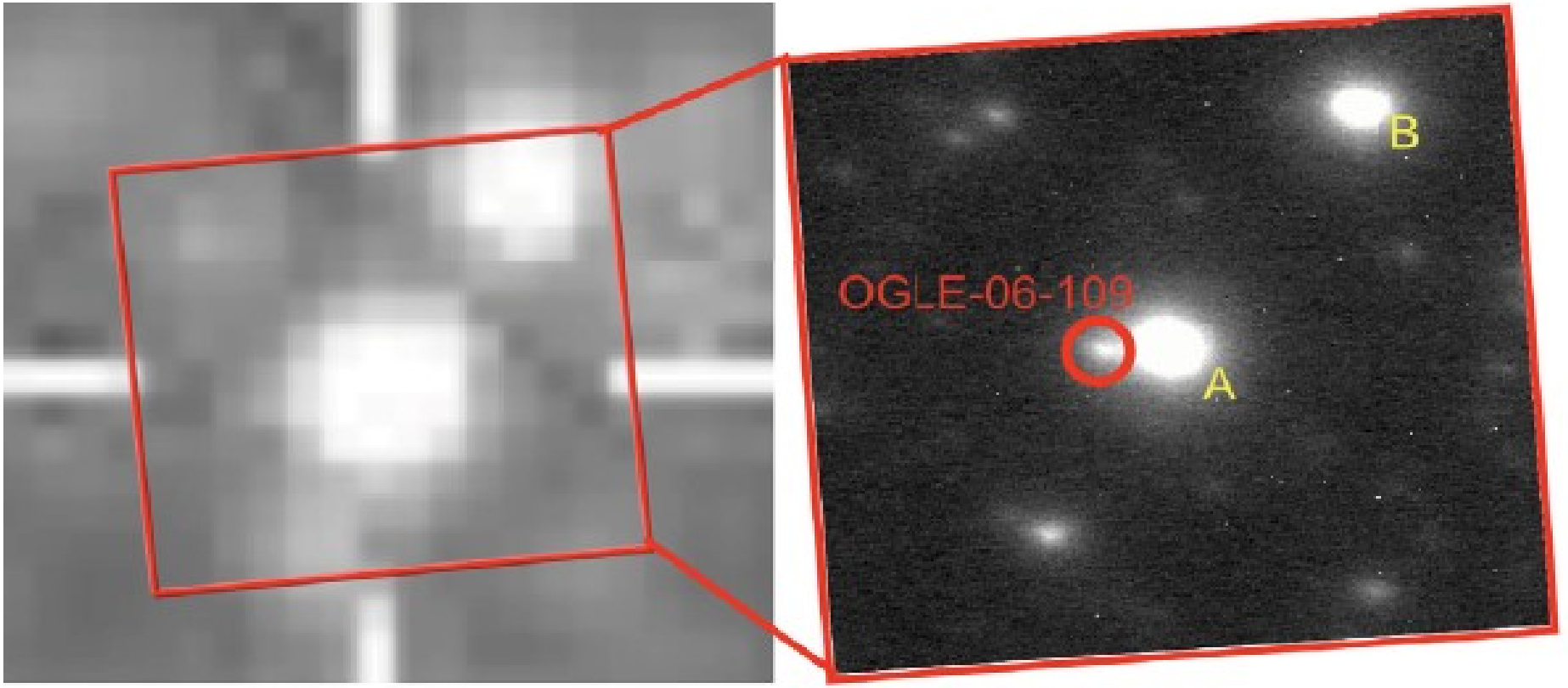




Bennett et al. 2010, ApJ, 713, 837

OGLE-2006-BLG-109

Keck: Source+Blend Much Fainter than clump



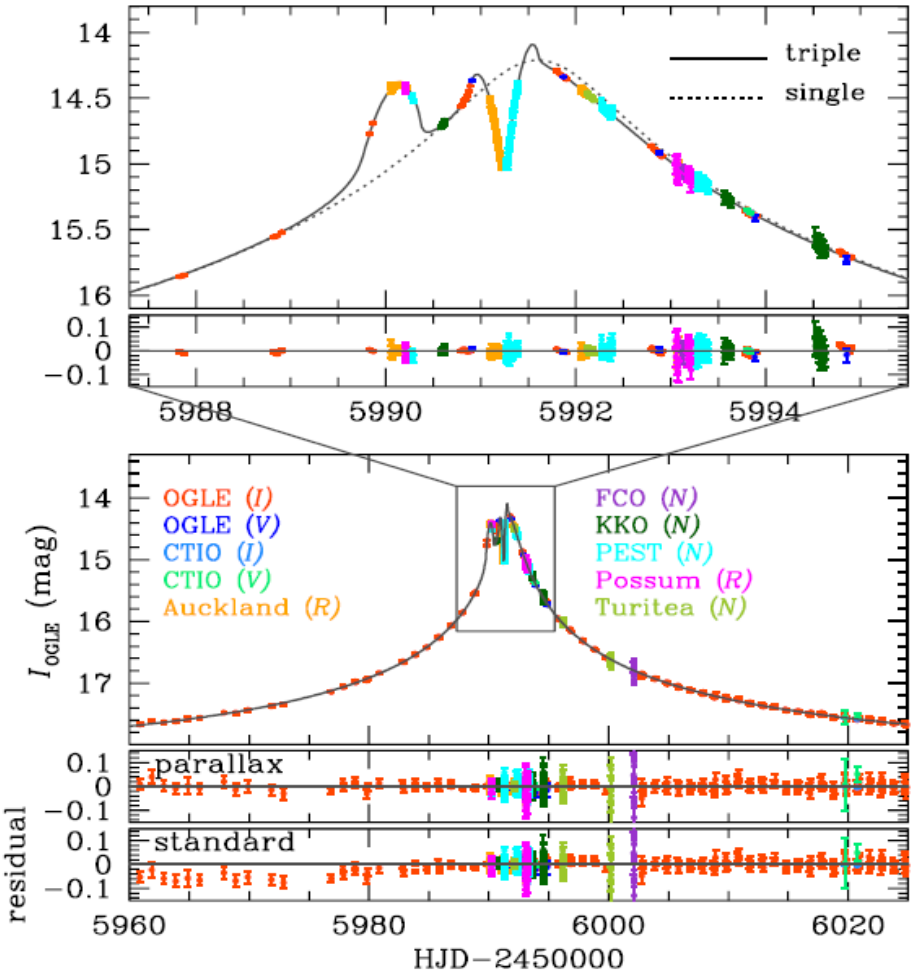
Bennett et al. 2010, ApJ, 713, 837

Two-Planet Systems

- OGLE-2006-BLG-109Lb,c
- OGLE-2012-BLG-0026Lb,c

OGLE-2012-BLG-0026

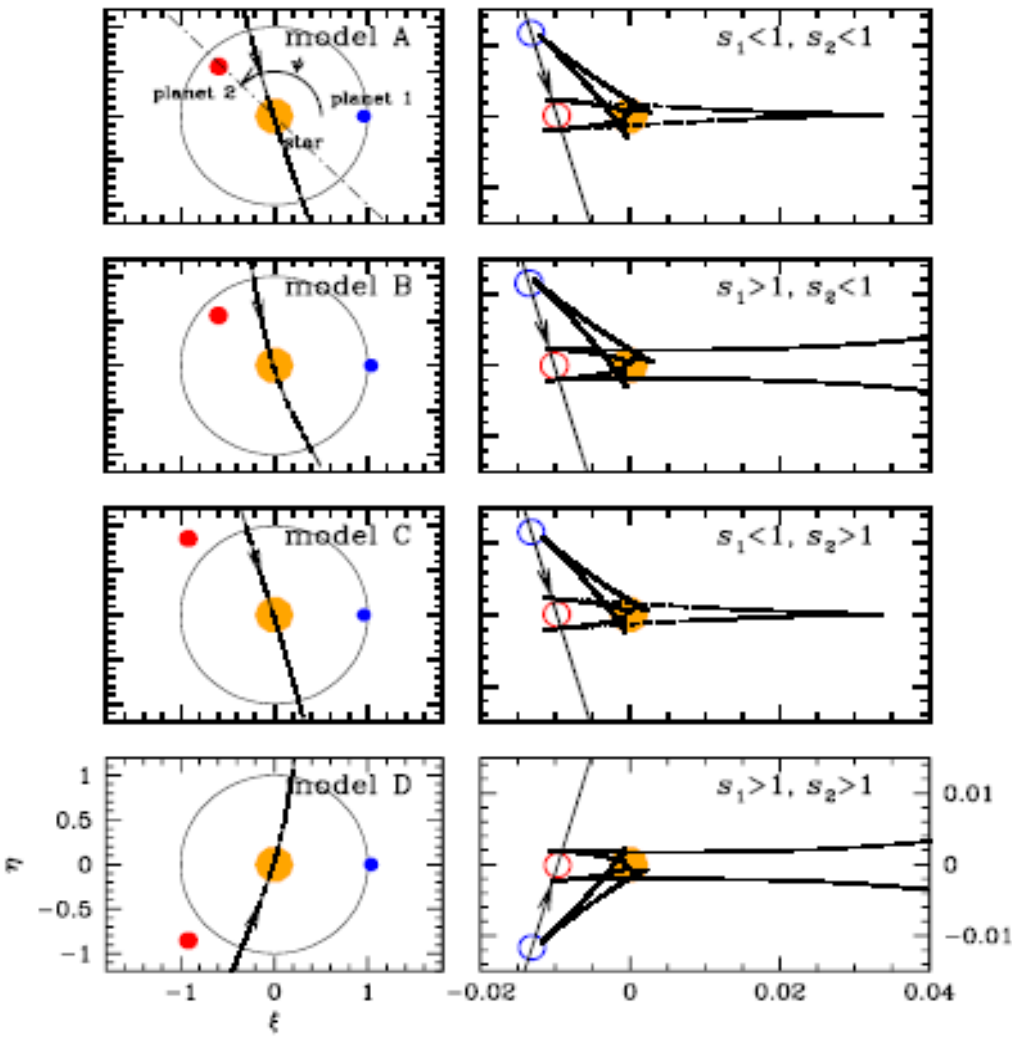
Second 2-planet system

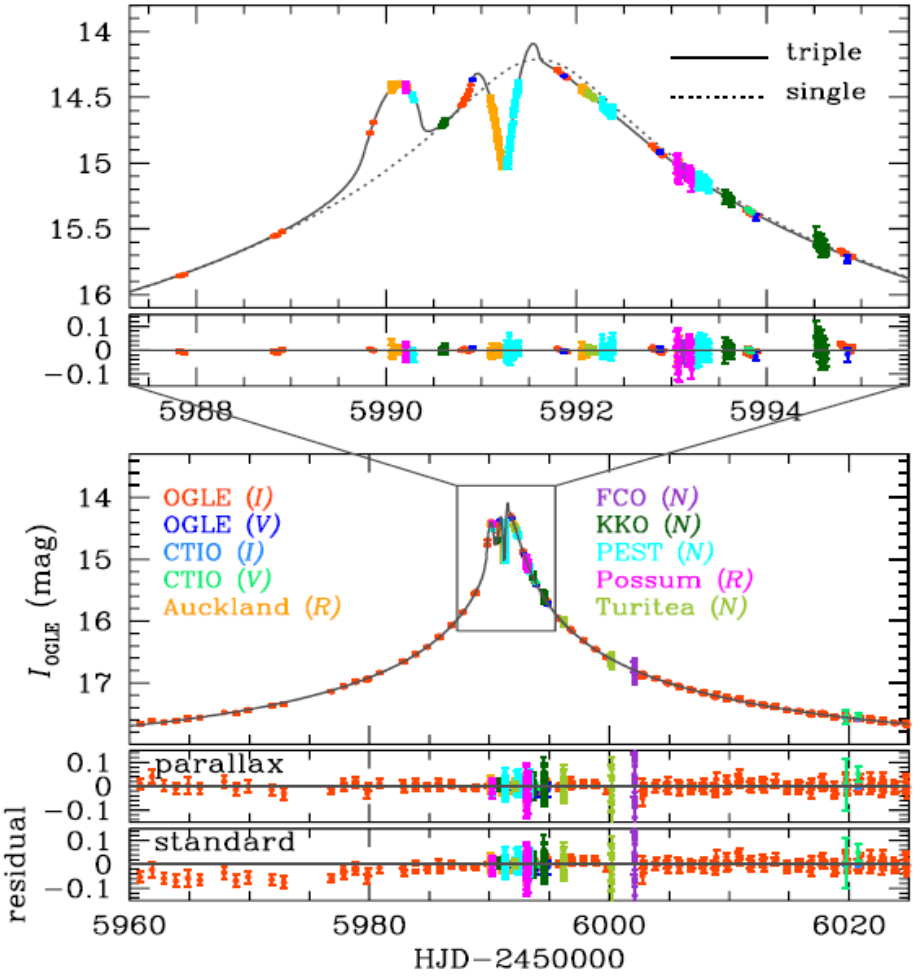


Han et al, ApJL, in press

OGLE-2012-BLG-0026

4-fold degeneracy: Unstable?

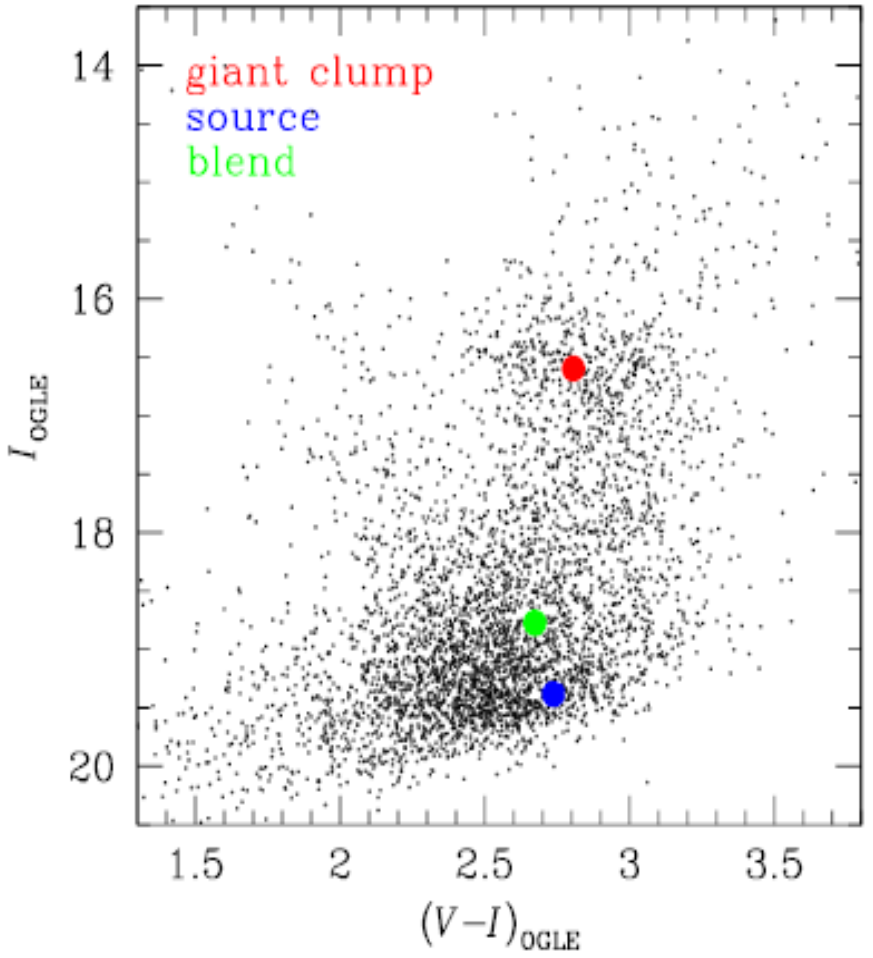




Han et al, ApJL, in press

OGLE-2012-BLG-0026

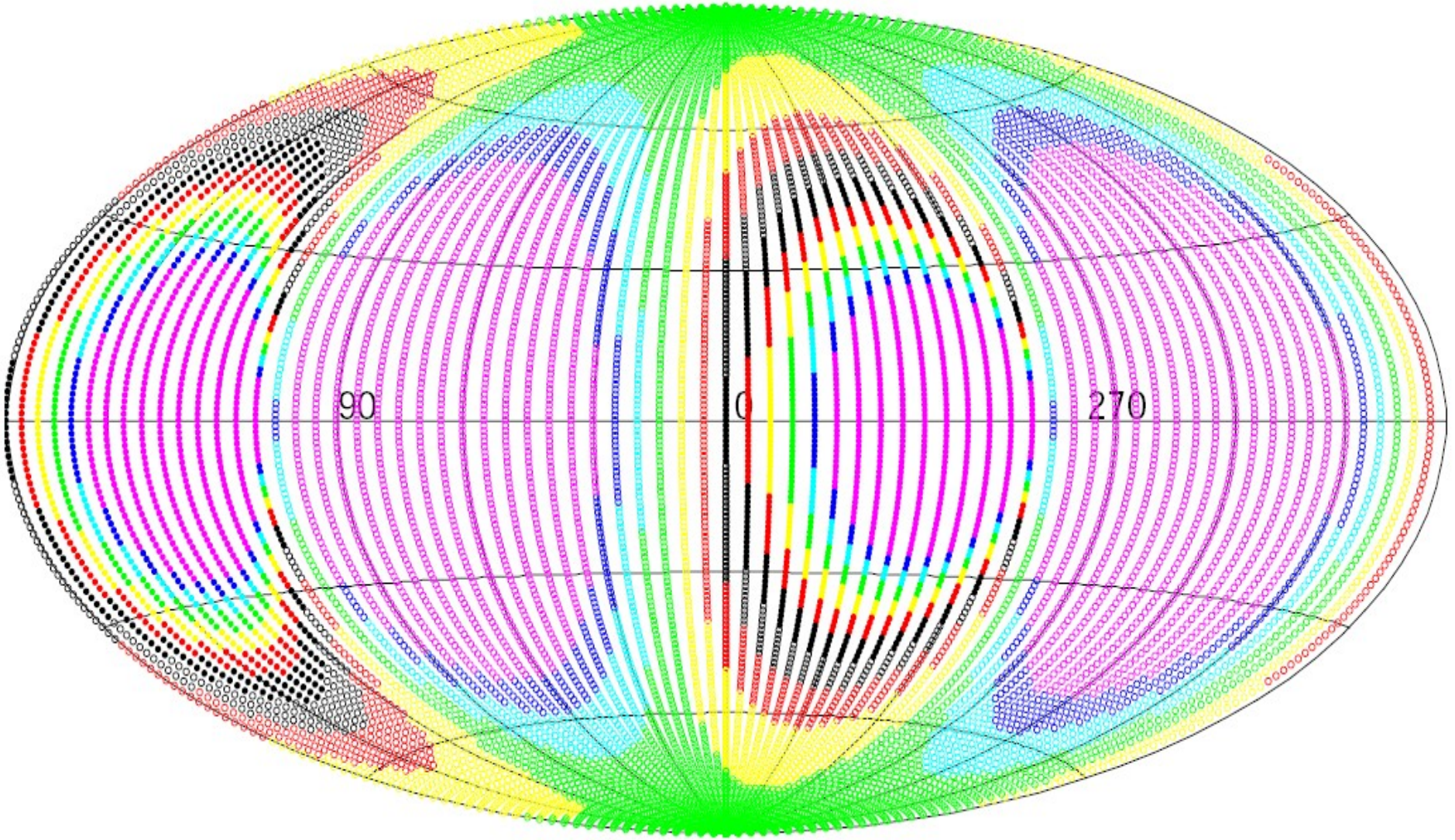
Lens Detected?



Han et al, ApJL, in press

OGLE-2012-BLG-0026: Stability Analysis

$$|a_1-a_2|/[(a_1+a_2)(q_1+q_2)^{1/3}/2]>2.4$$

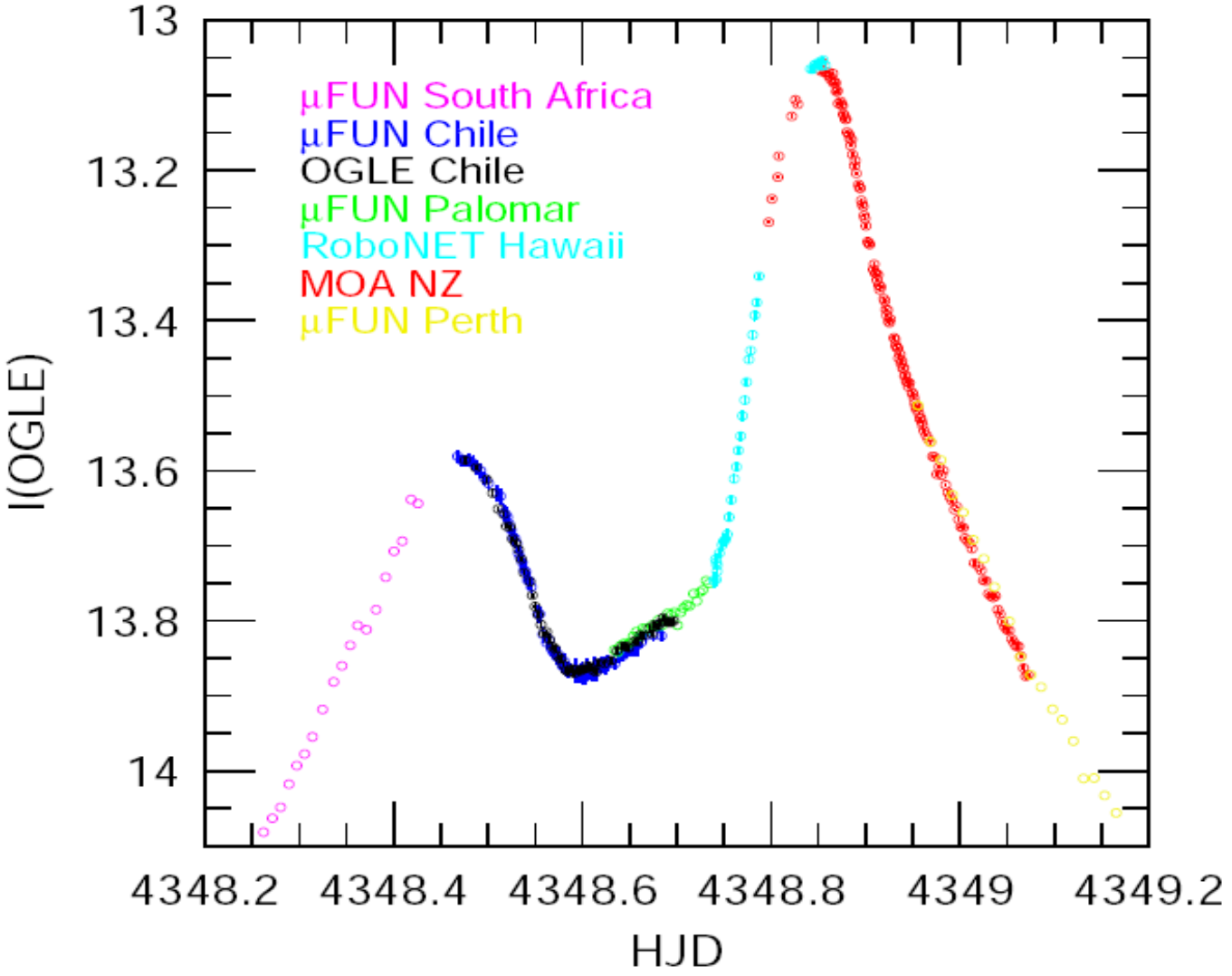


Two-Planet Systems

- OGLE-2006-BLG-109Lb,c
- OGLE-2012-BLG-0026Lb,c
- OGLE-2007-BLG-349(?)

OGLE-2007-BLG-349:

Saturn Mass-Ratio Planet +



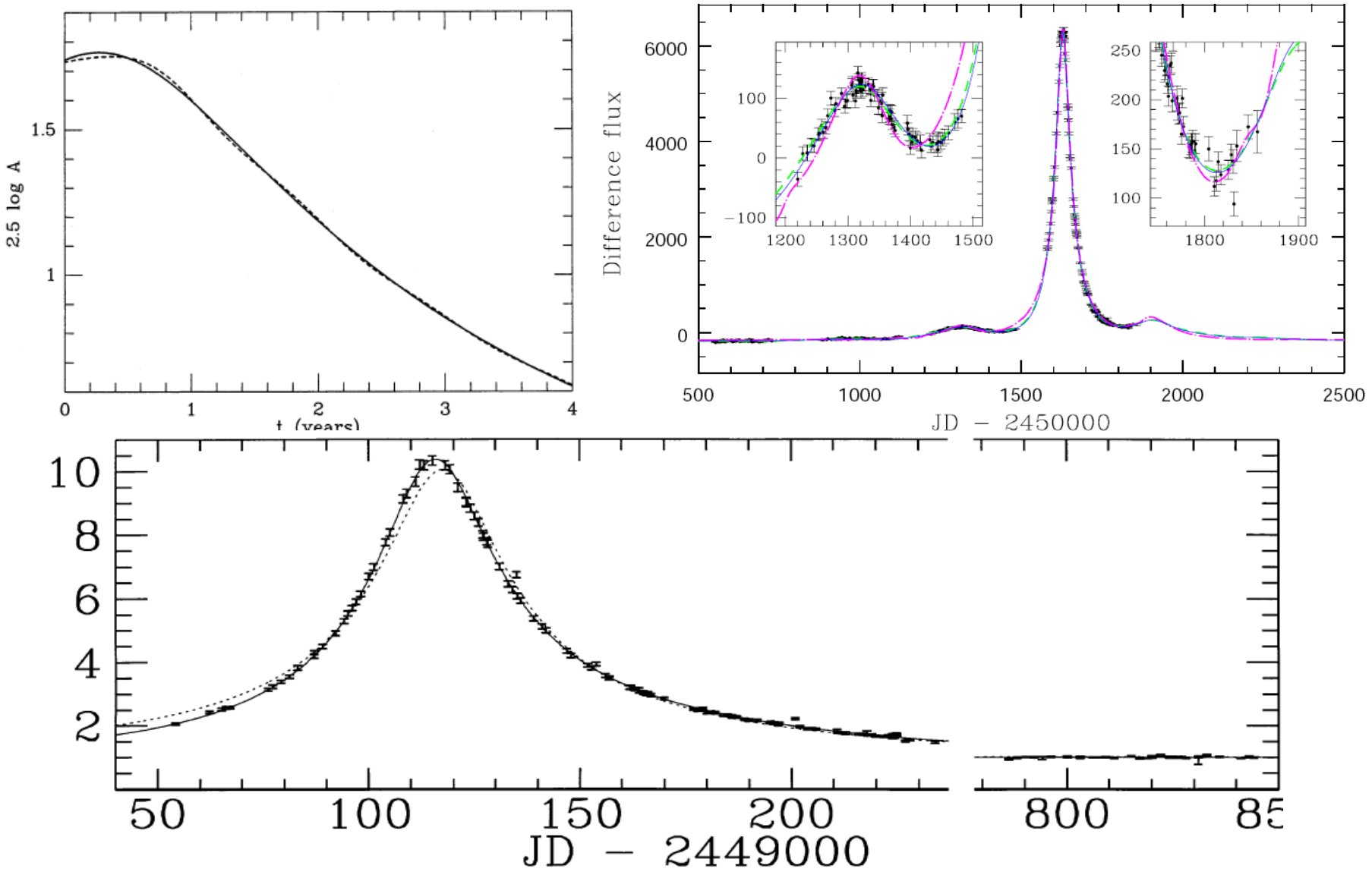
Dong et al. 2013, in prep

Terrestrial Parallax

- OGLE-2007-BLG-224

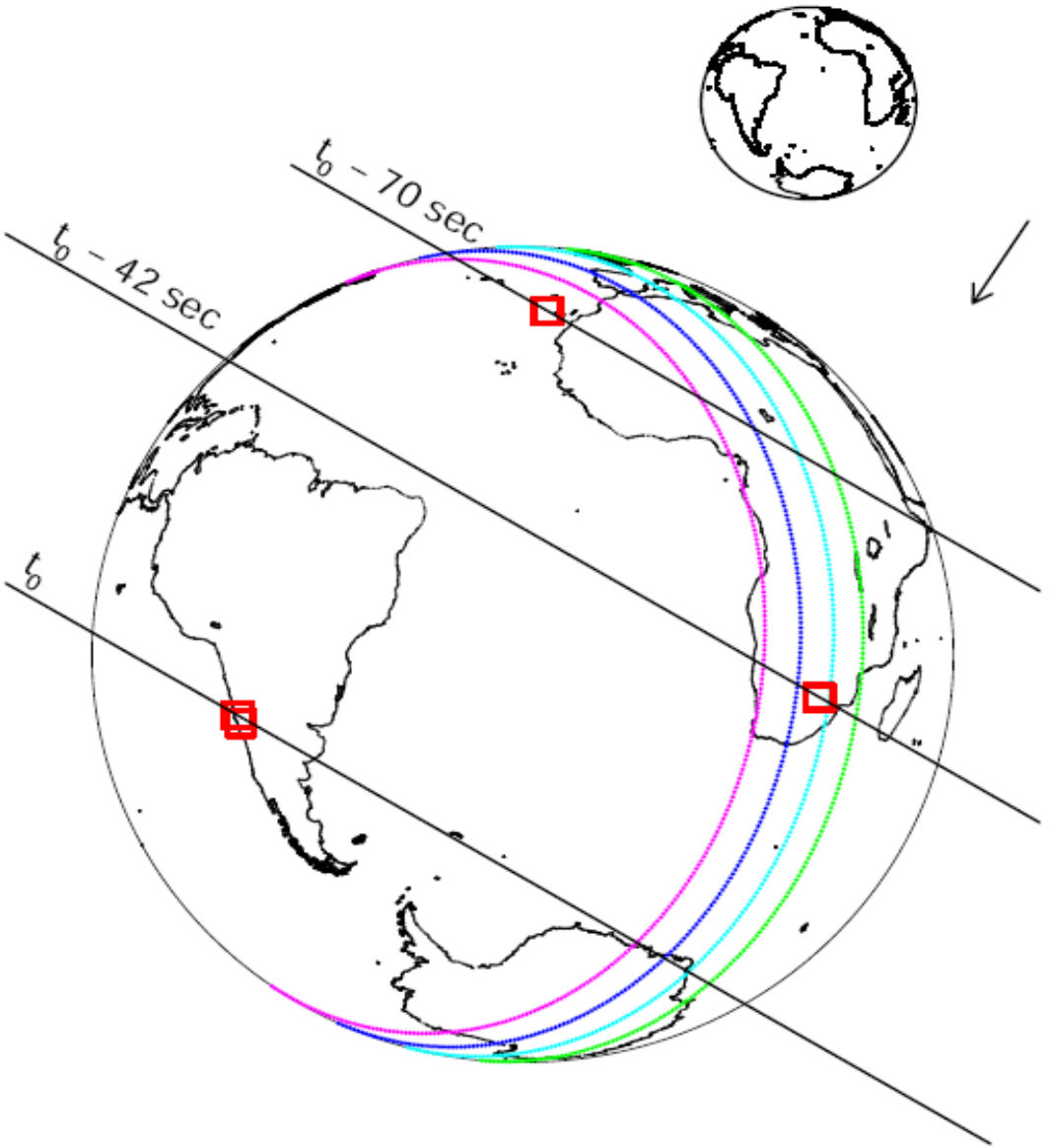
To measure parallax:

Standard Observer-Plane Rulers



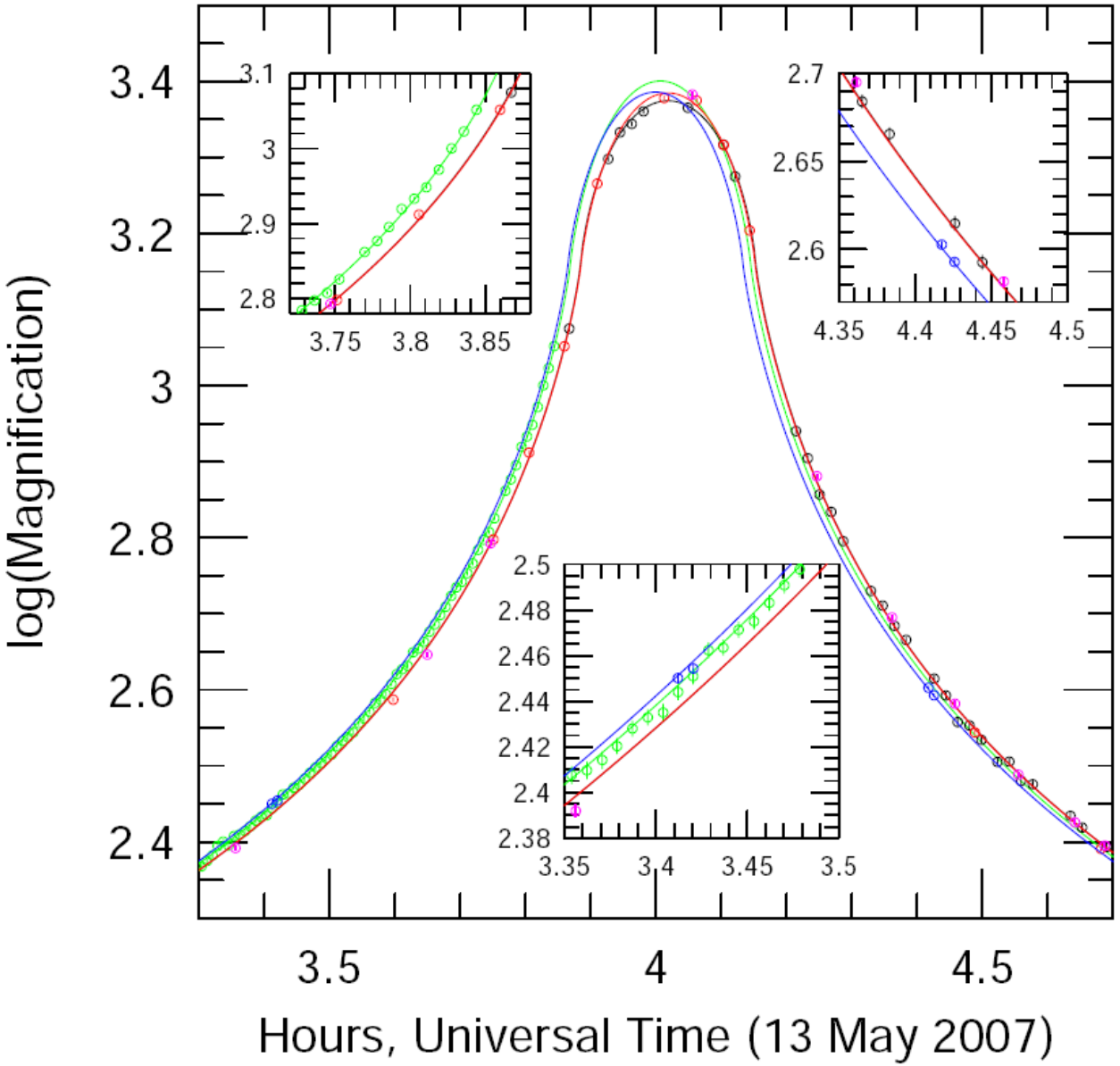
Terrestrial Parallax:

Simultaneous Observations on Earth



OGLE-2007-BLG-224

Canaries South Africa Chile



First Isolated Brown Dwarf Mass

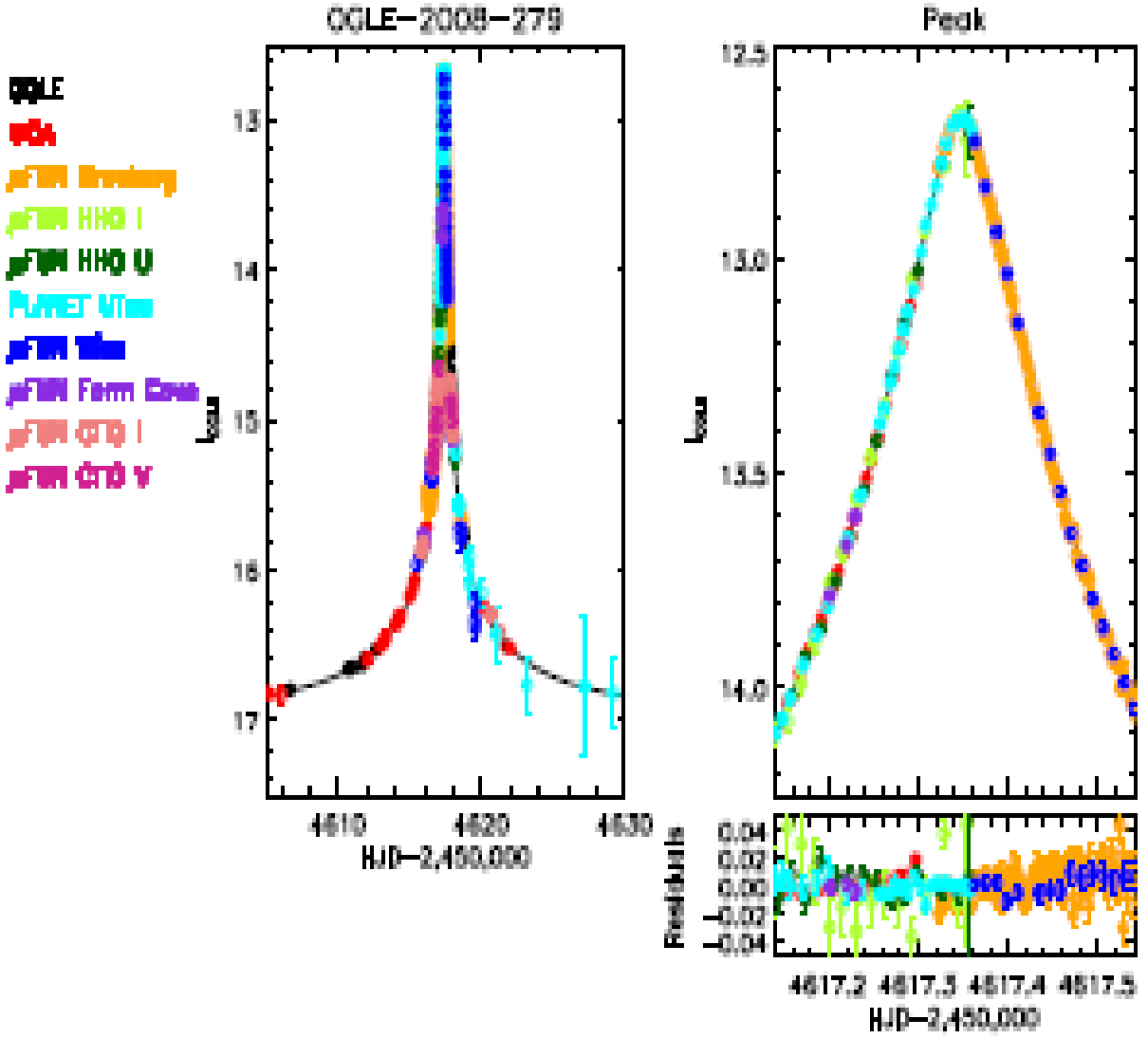
- $M = 0.056 +/- 0.004\ M_{sun}$
- $D = 525 +/- 40$ pc
- $v_{perp} = 113 +/- 21$ km/s
- ==> "thick disk BD"

Terrestrial Parallax

- OGLE-2007-BLG-224
- OGLE-2008-BLG-279

OGLE-2008-BLG-279:

A = 1600



Yee et al. 2009, ApJ, 730, 2082

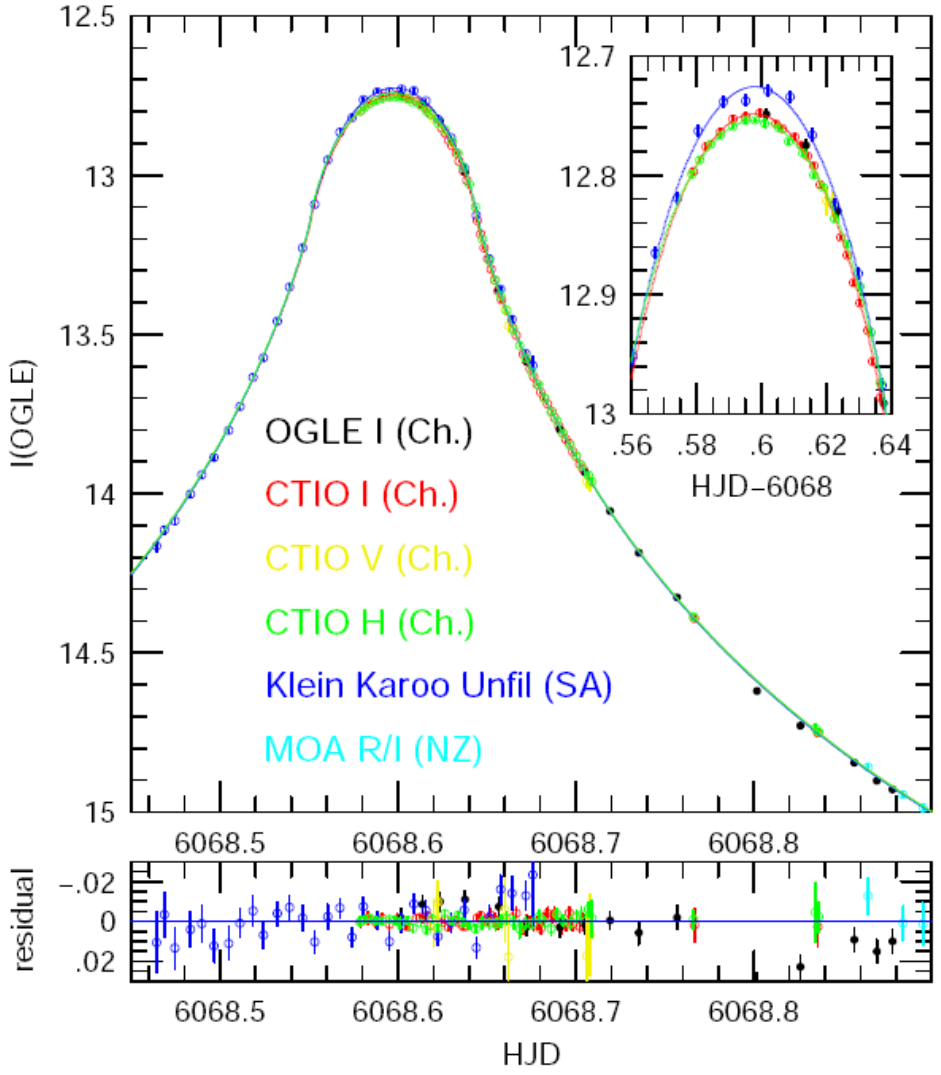
Second Isolated Star Mass

- $M = 0.64 +/- 0.10\ M_{sun}$
- $D = 4.0 +/- 0.6$ kpc

Terrestrial Parallax

- OGLE-2007-BLG-224
- OGLE-2008-BLG-279
- OGLE-2012-BLG-0617(?)

OGLE-2012-BLG-0617

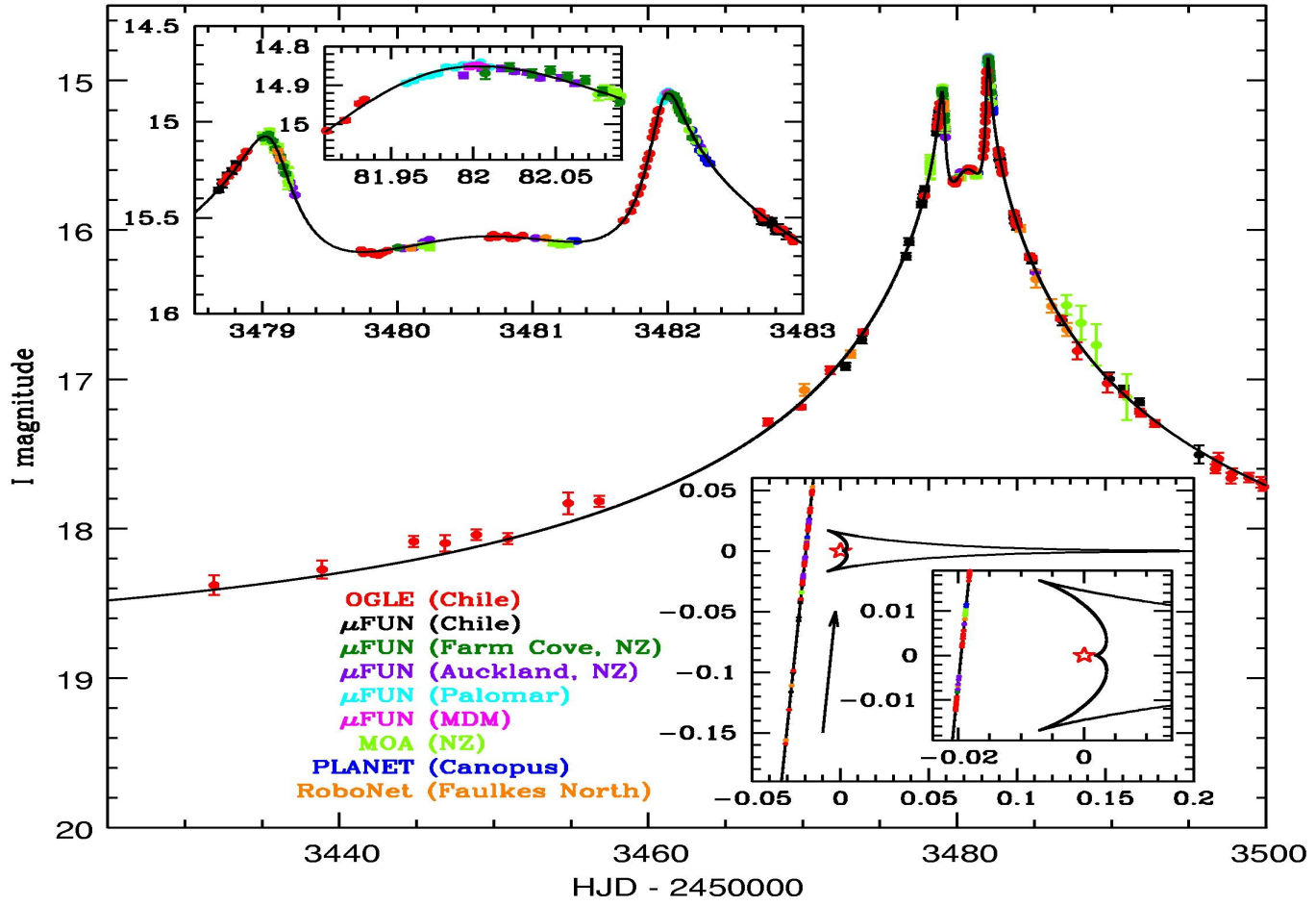


Jupiters Orbiting M dwarfs

- OGLE-2005-BLG-071

OGLE-2005-BLG-071

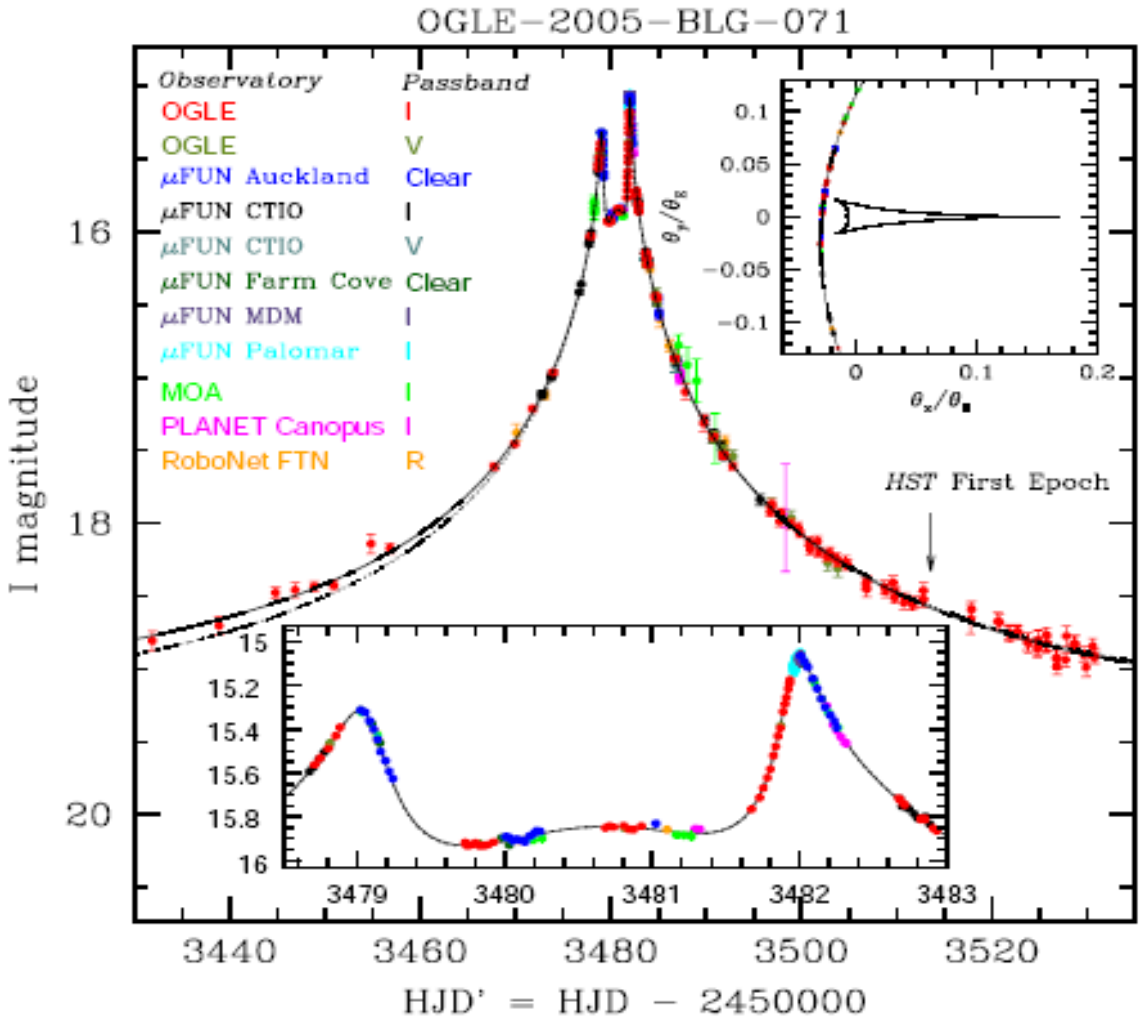
1st High-Mag, 1st μFUN, 2nd Planet



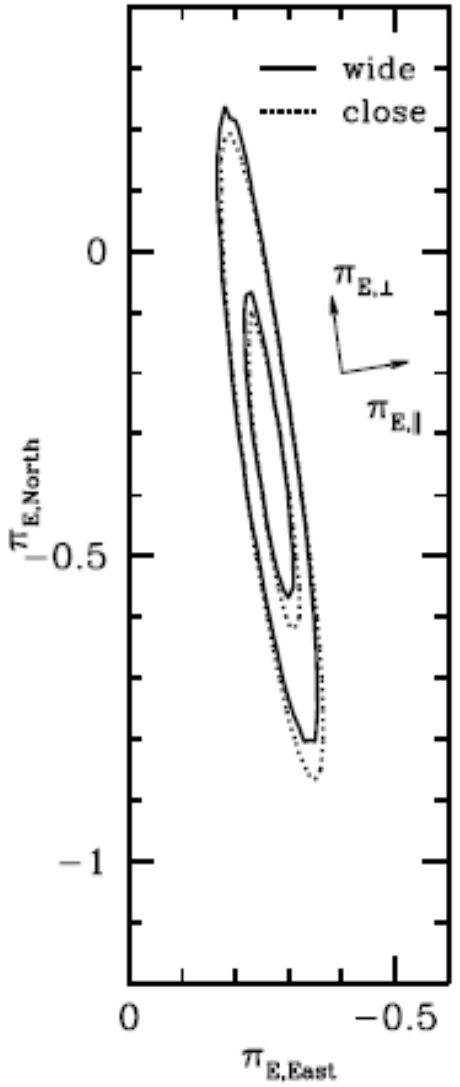
Udalski et al. 2005, ApJ, 628, L109

Multiple Partial Information

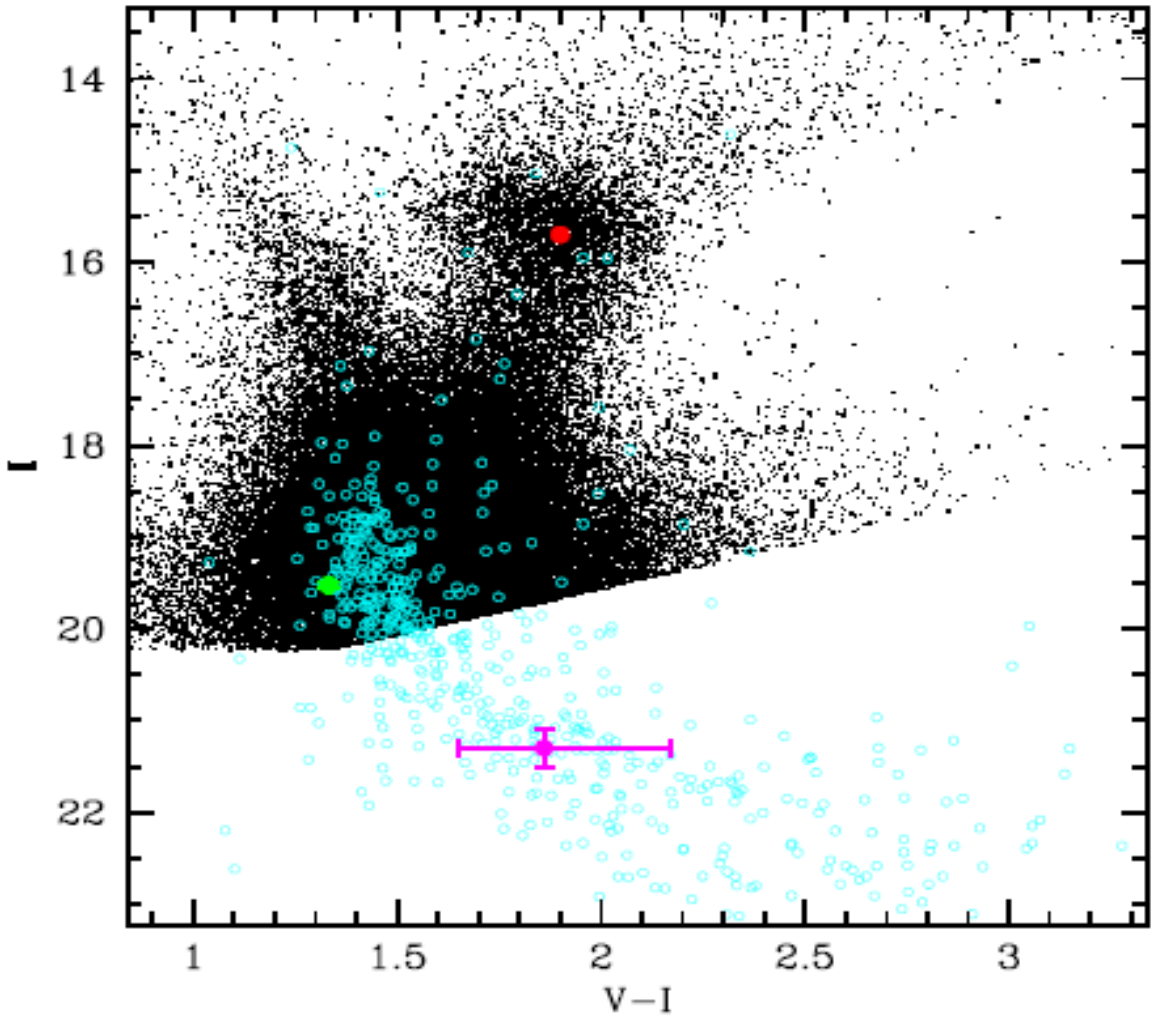
OGLE-2005-BLG-071 (Dong et al)



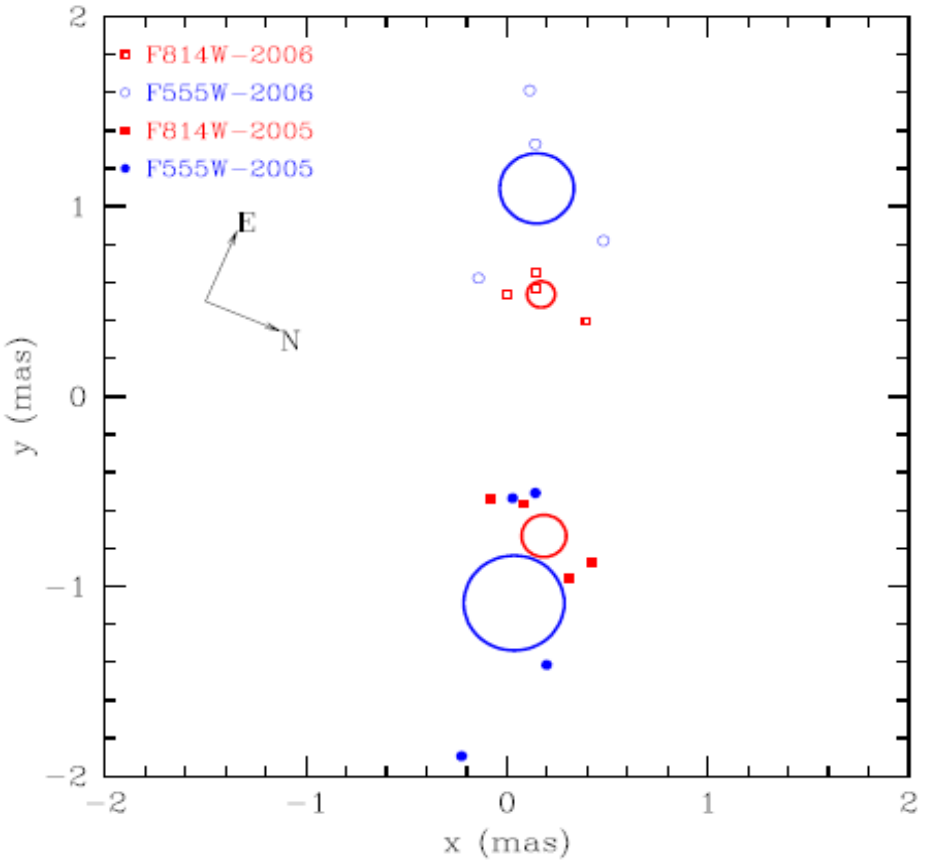
1-D Parallax Measurement



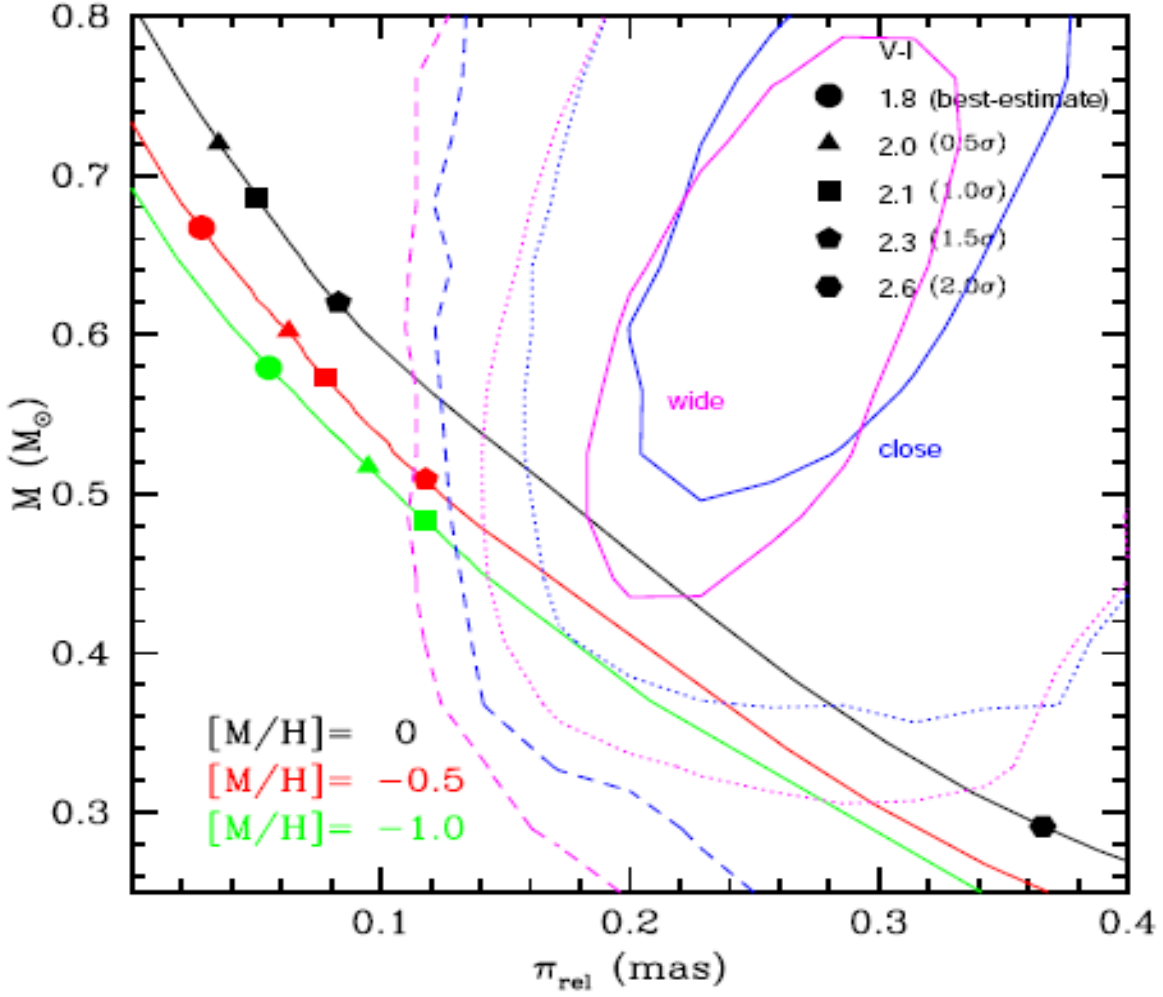
Blended Light Detected with HST



Differential V/I source+blend proper motion from 2 HST epochs



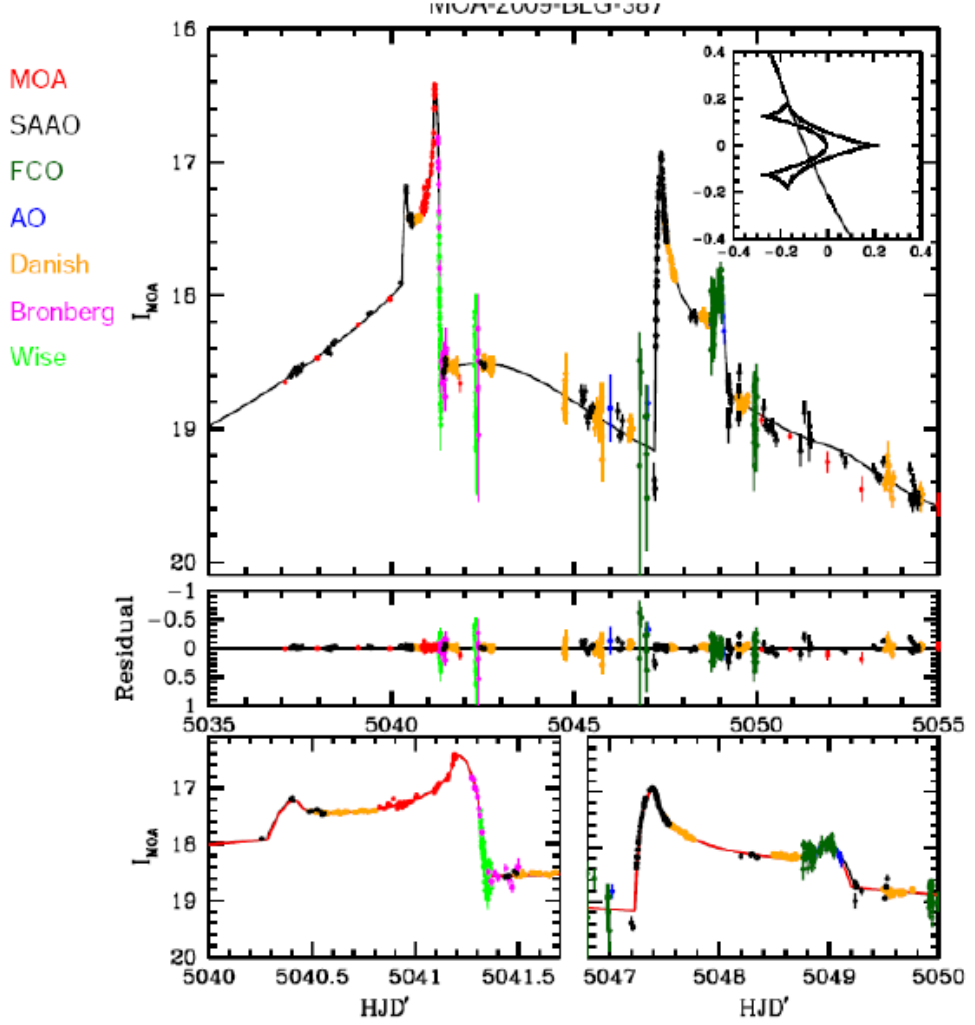
Most Likely:
M dwarf + Super-Jupiter



Jupiters Orbiting M dwarfs

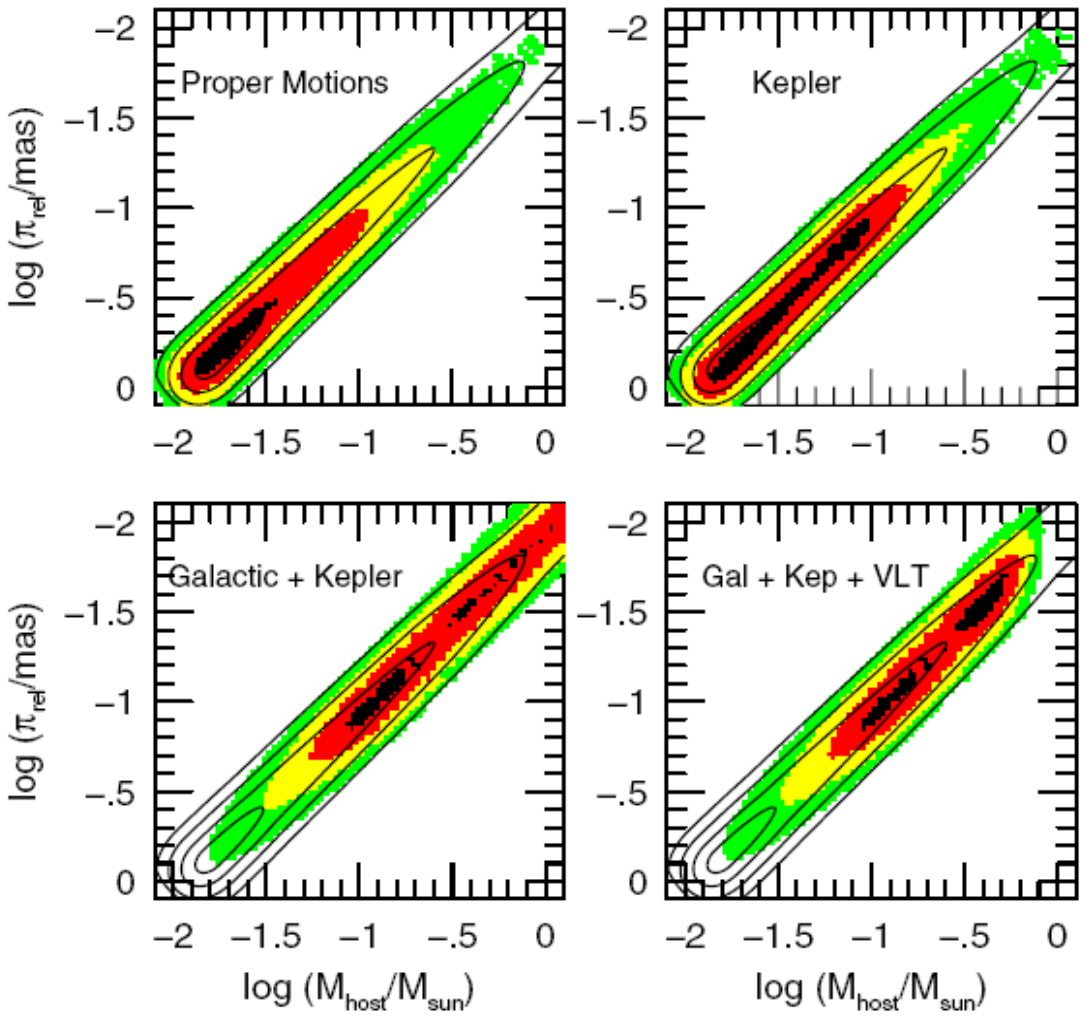
- OGLE-2005-BLG-071
- MOA-2009-BLG-387

MOA-2009-BLG-387



Batista et al. 2011, A&A 529 102

MOA-2009-BLG-387:
M dwarf + Super-Jupiter



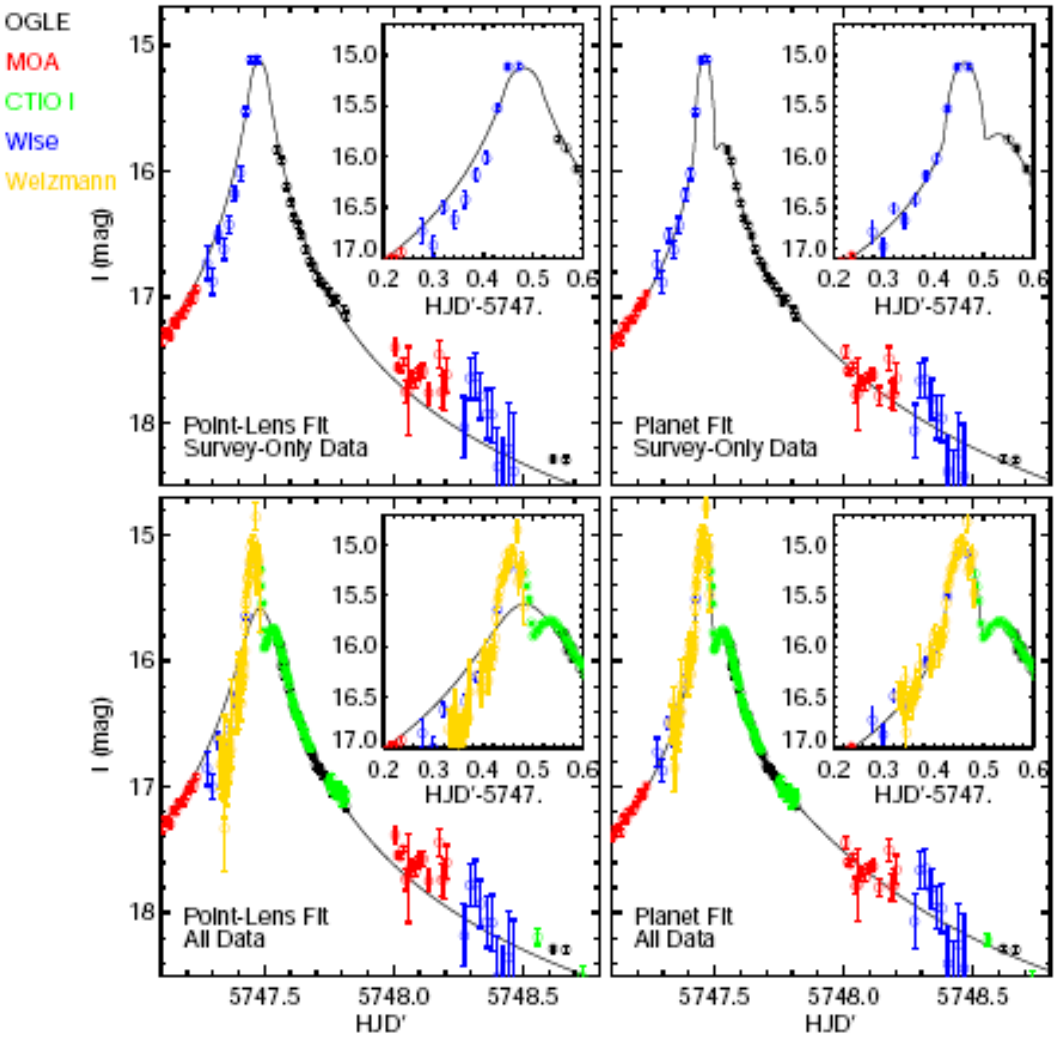
Batista et al. 2011, A&A 529 102

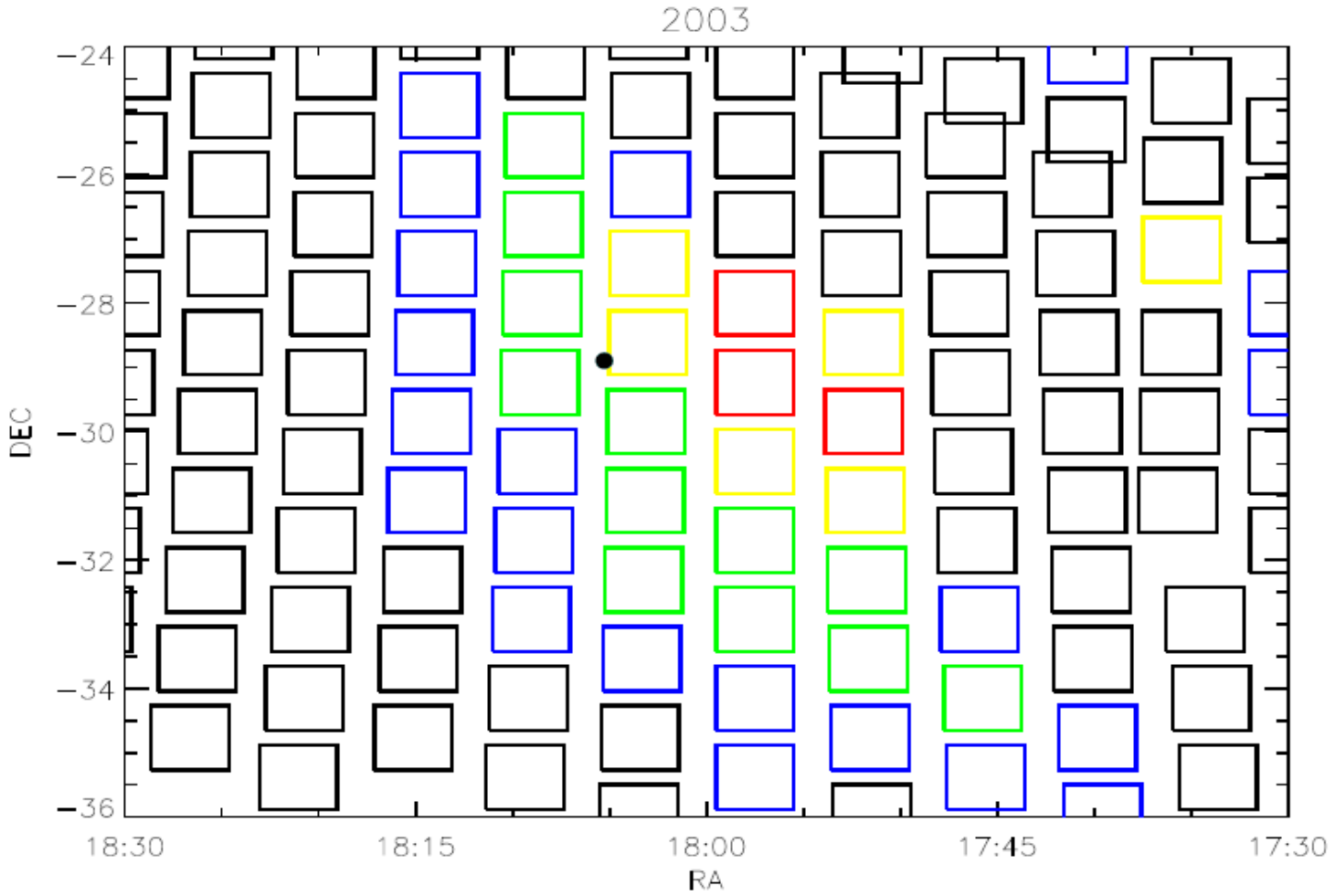
Jupiters Orbiting M dwarfs

- OGLE-2005-BLG-071
- MOA-2009-BLG-387
- MOA-2011-BLG-293(?)

Possible M-dwarf with Super-Jupiter

MOA-2011-BLG-293

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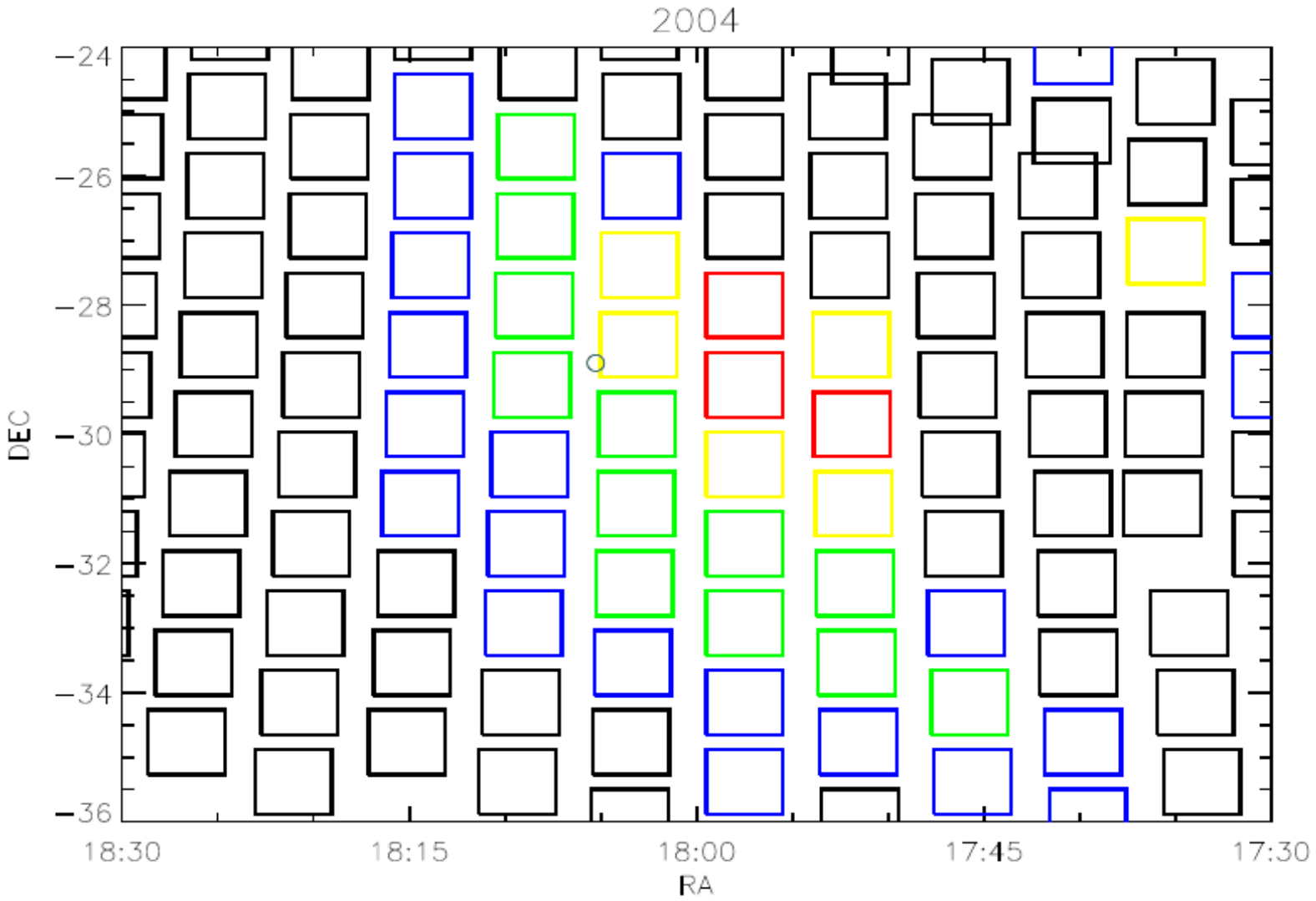
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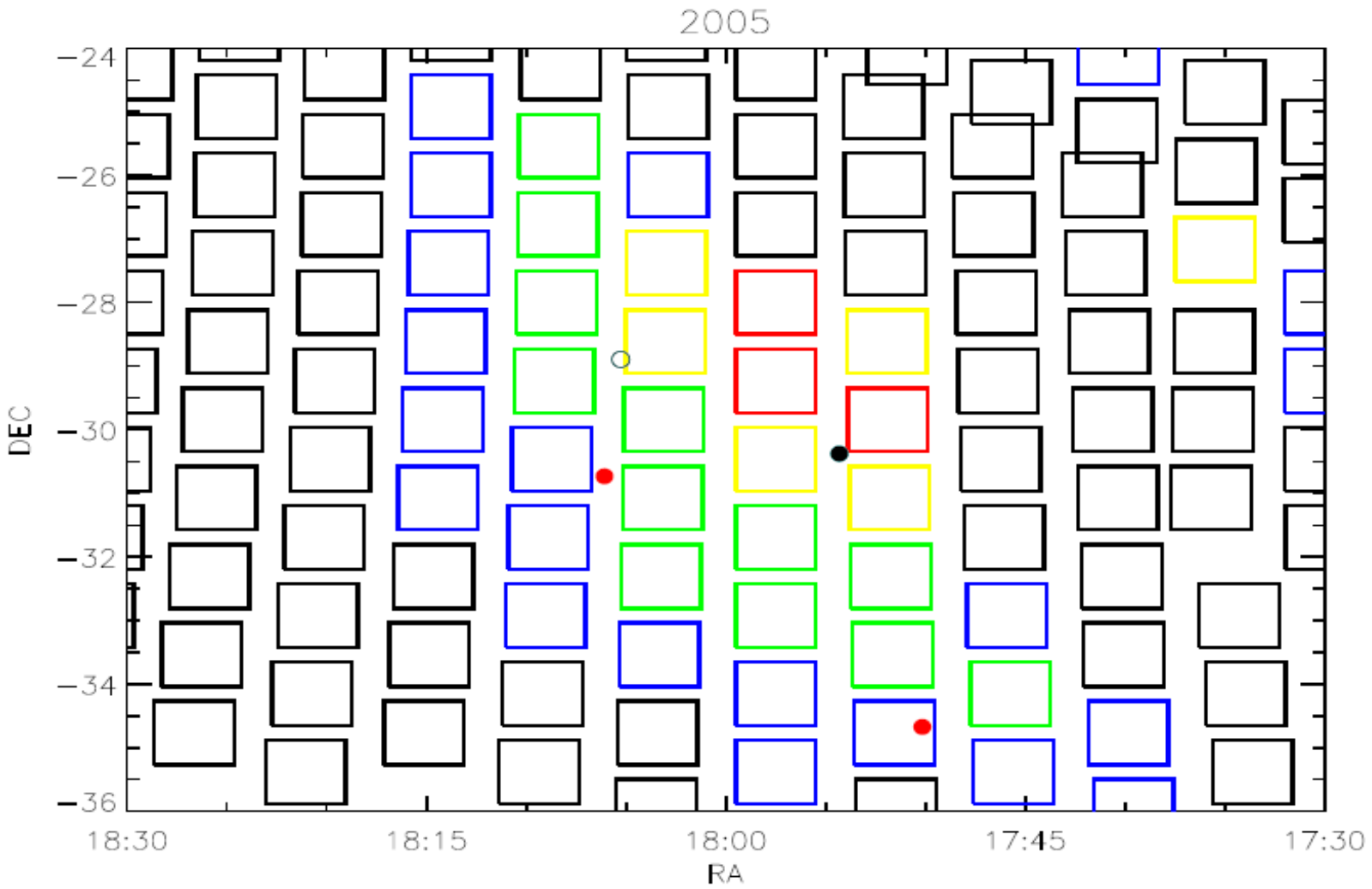
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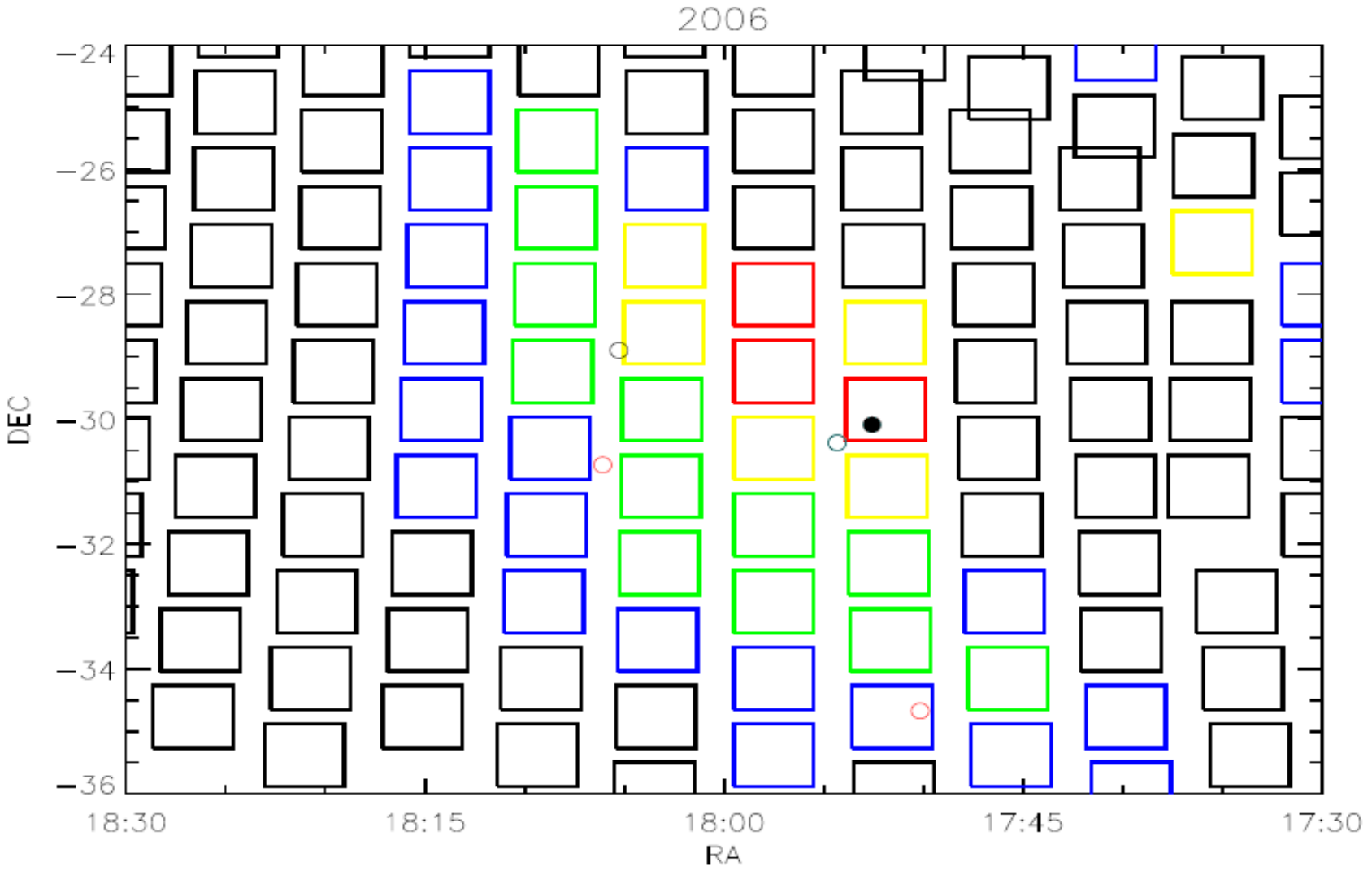
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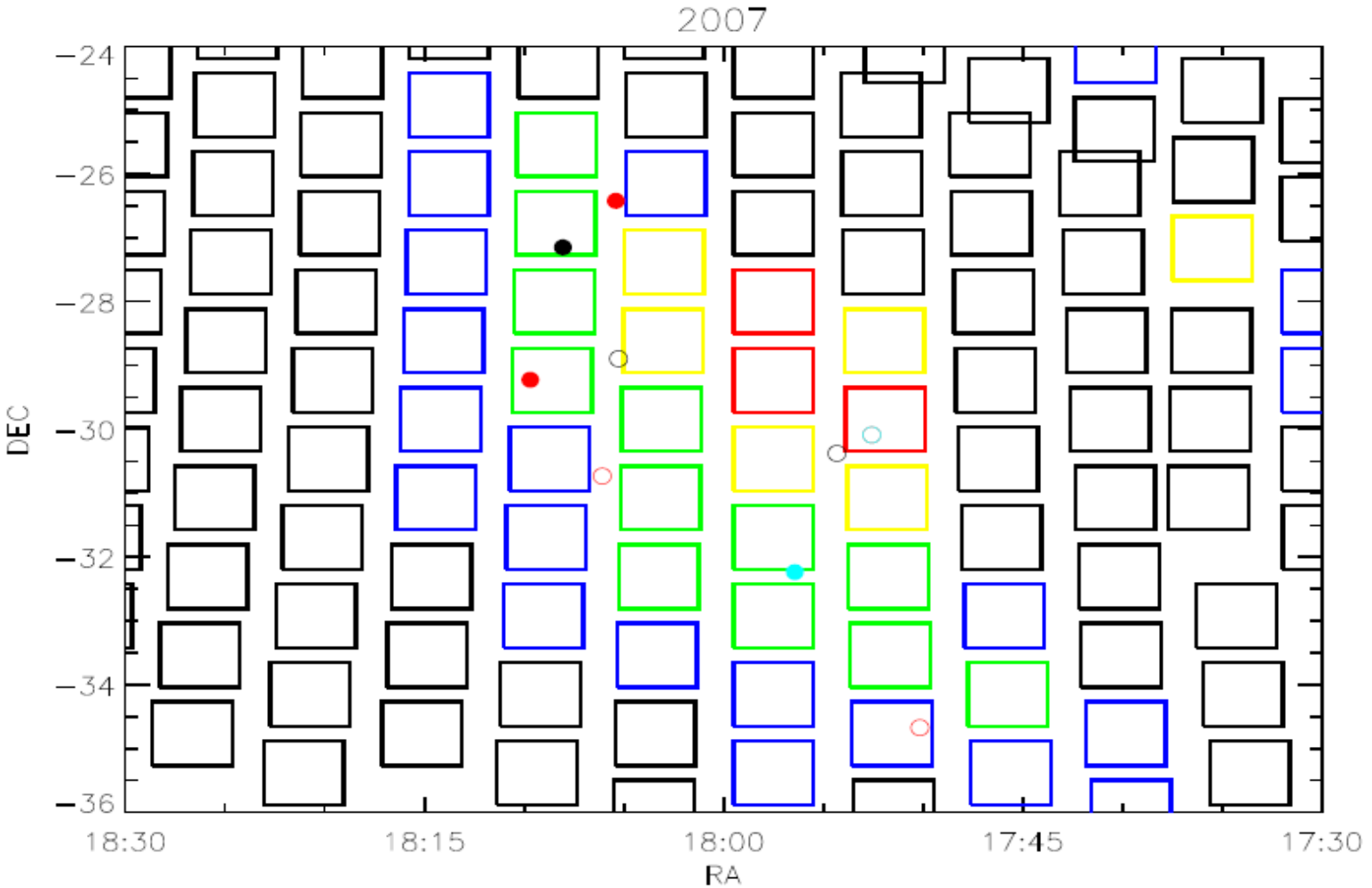
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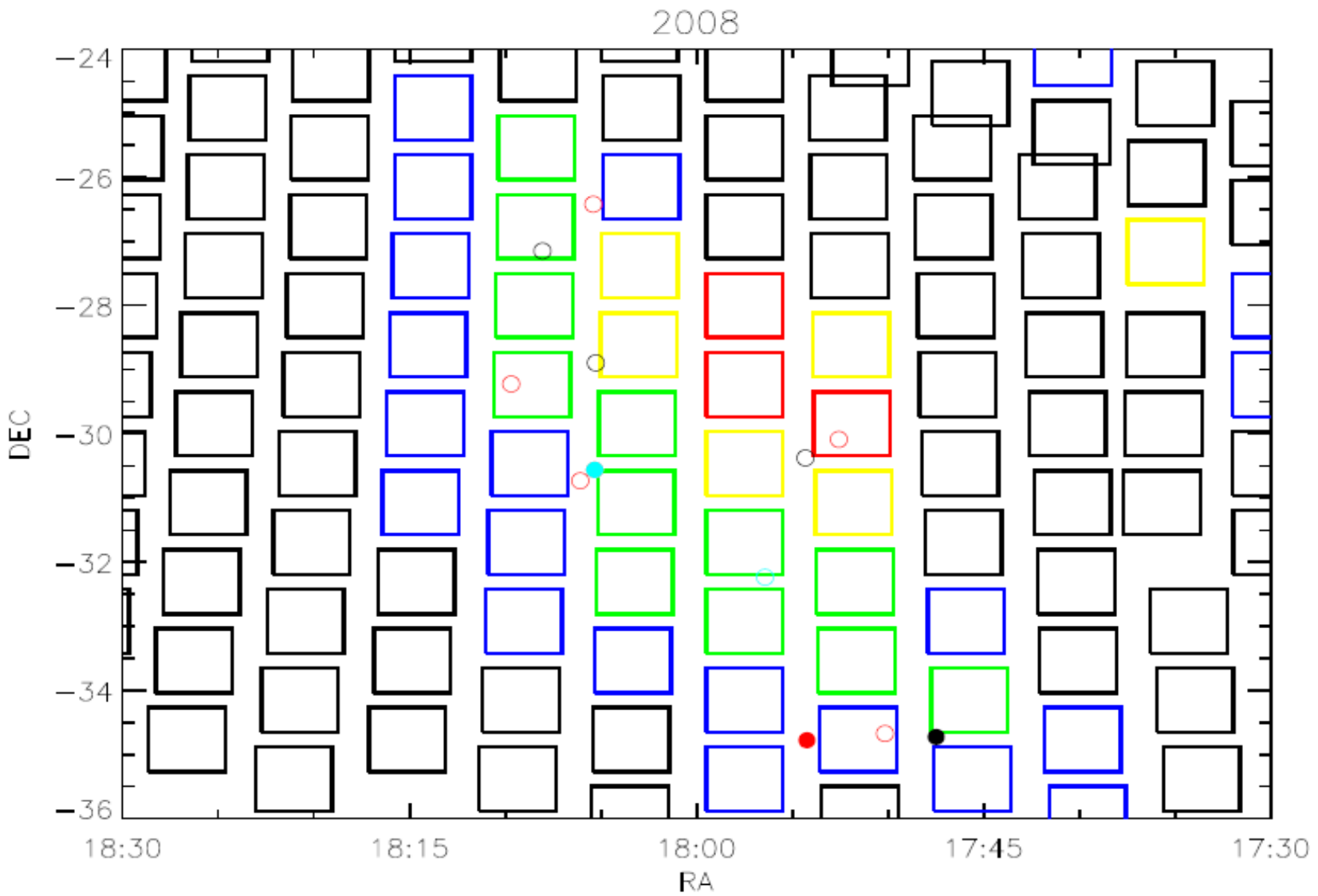
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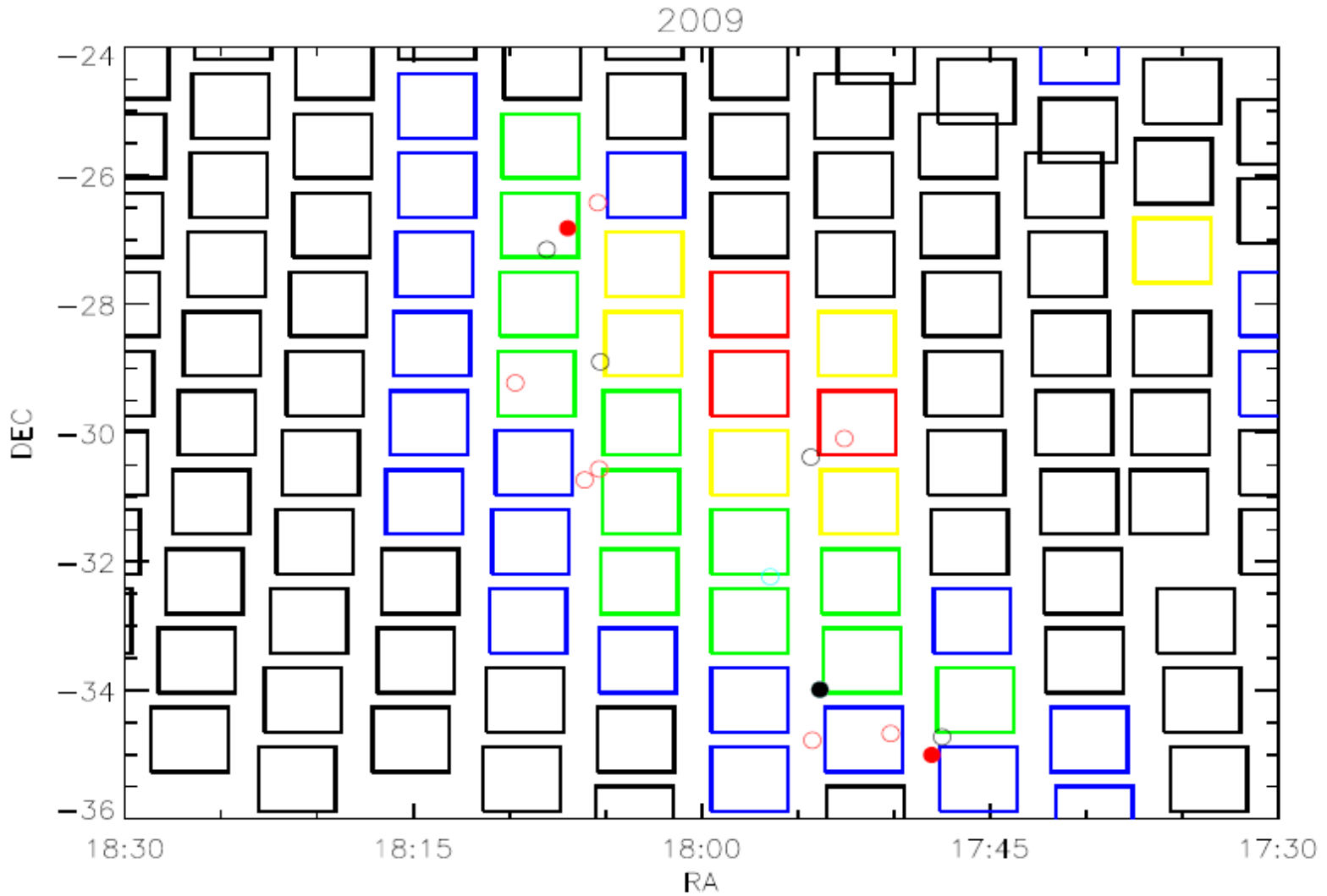
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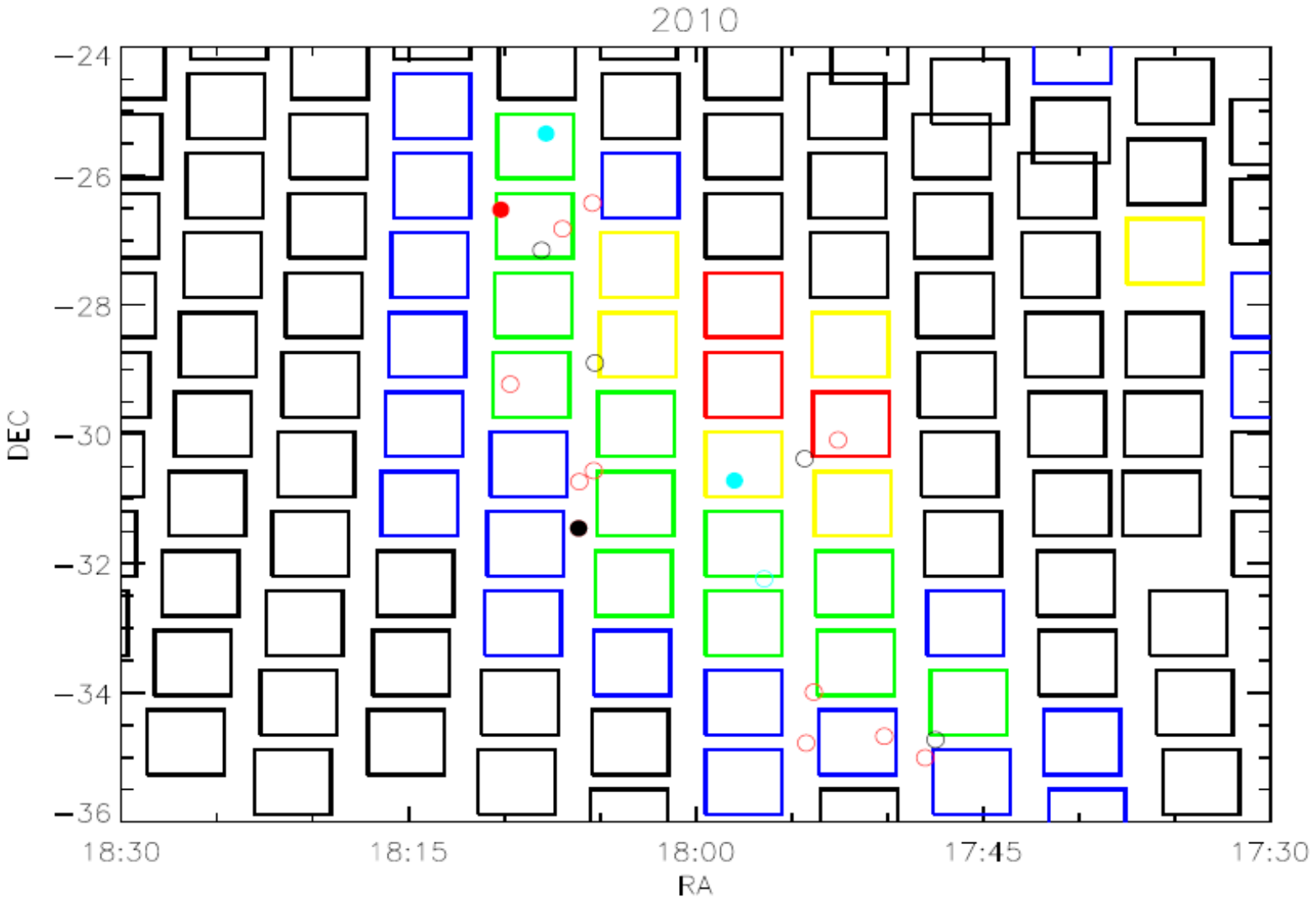
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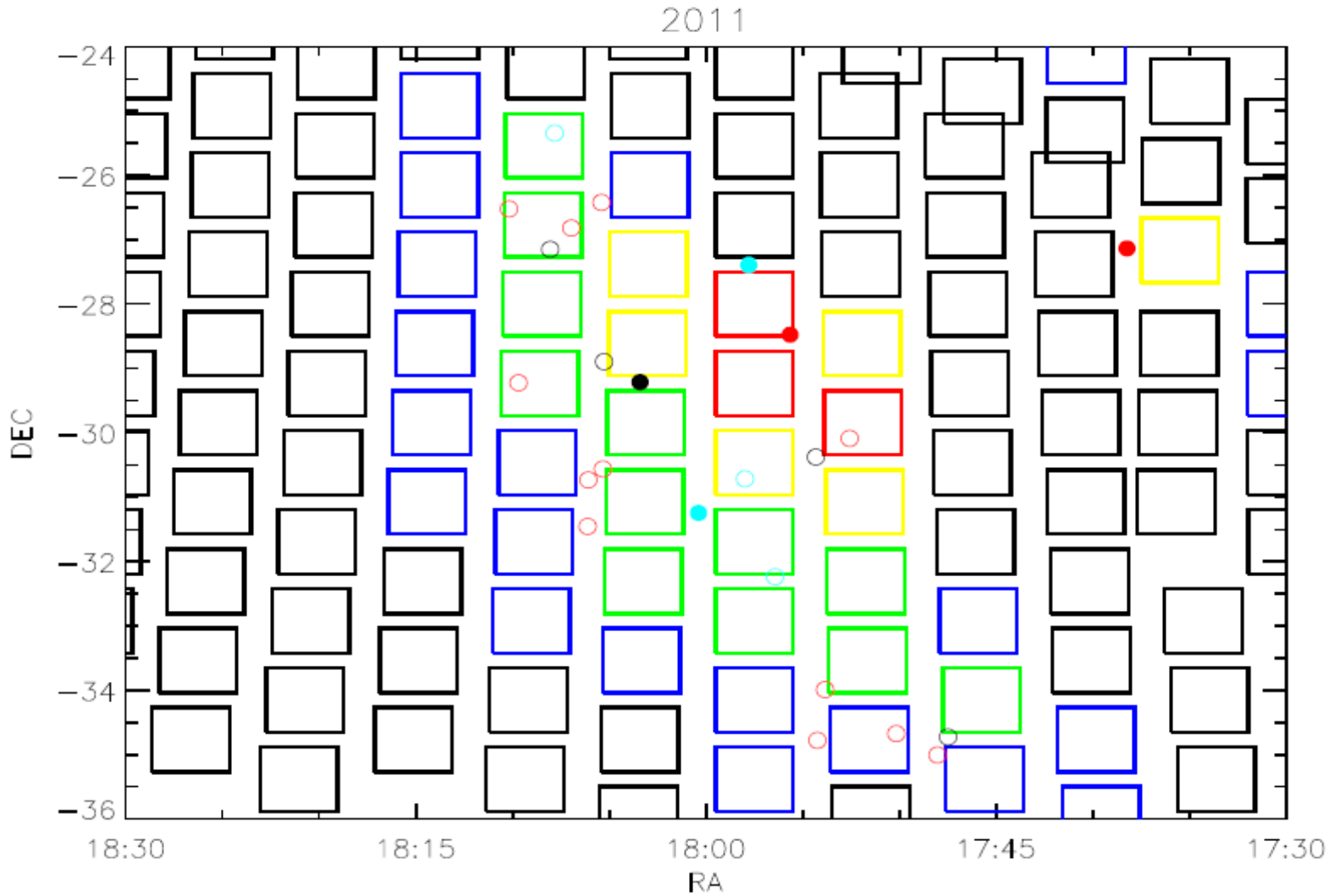
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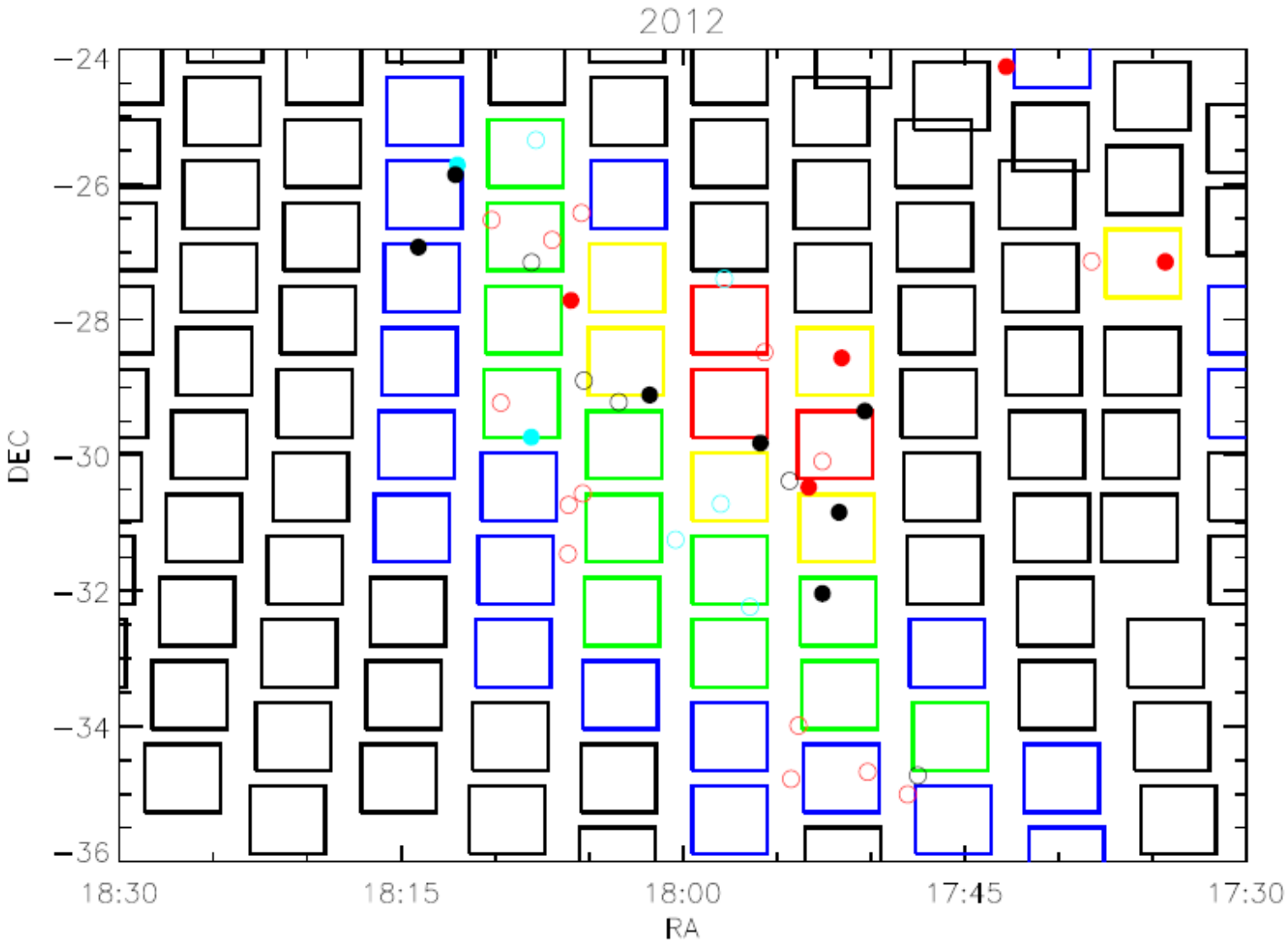
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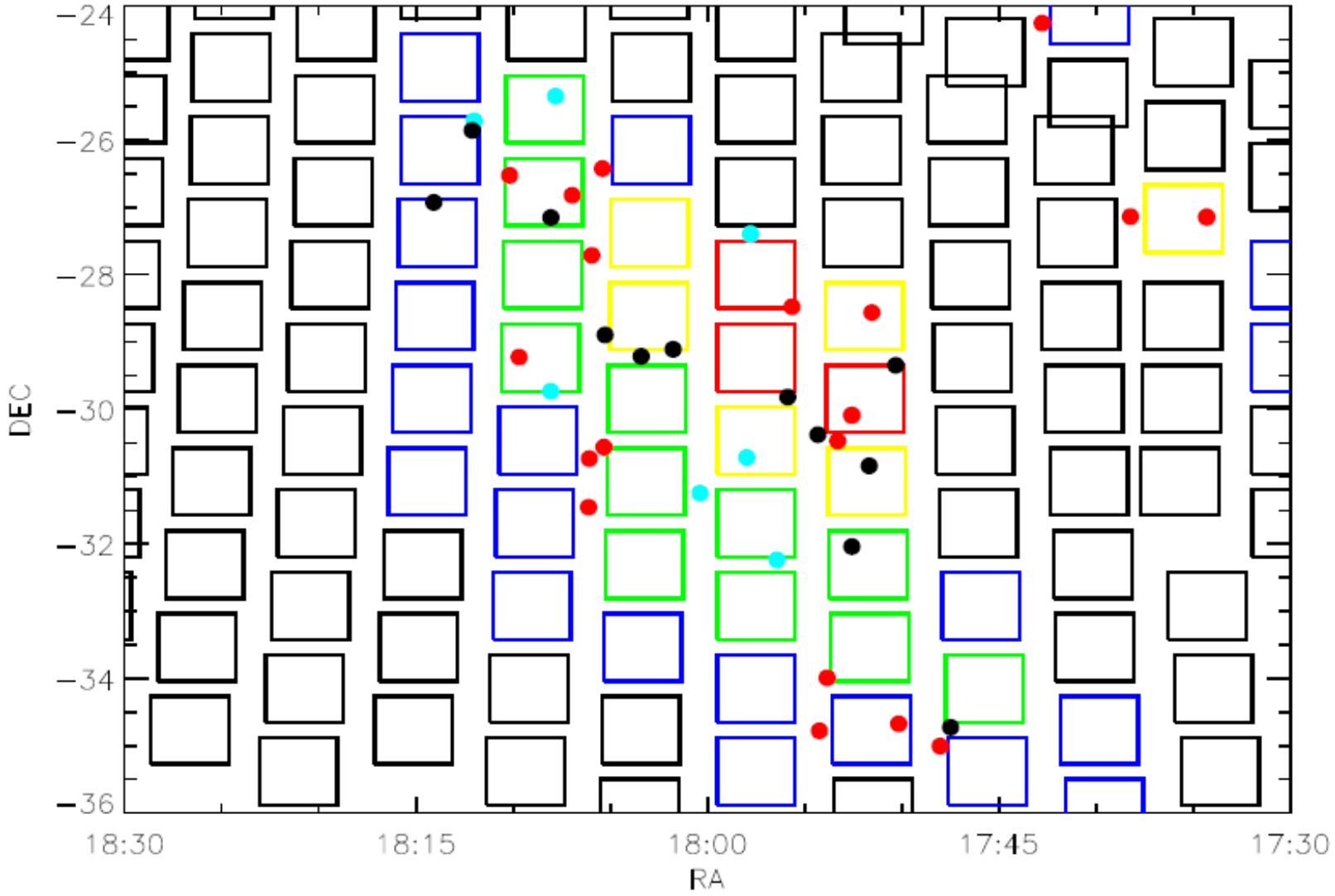
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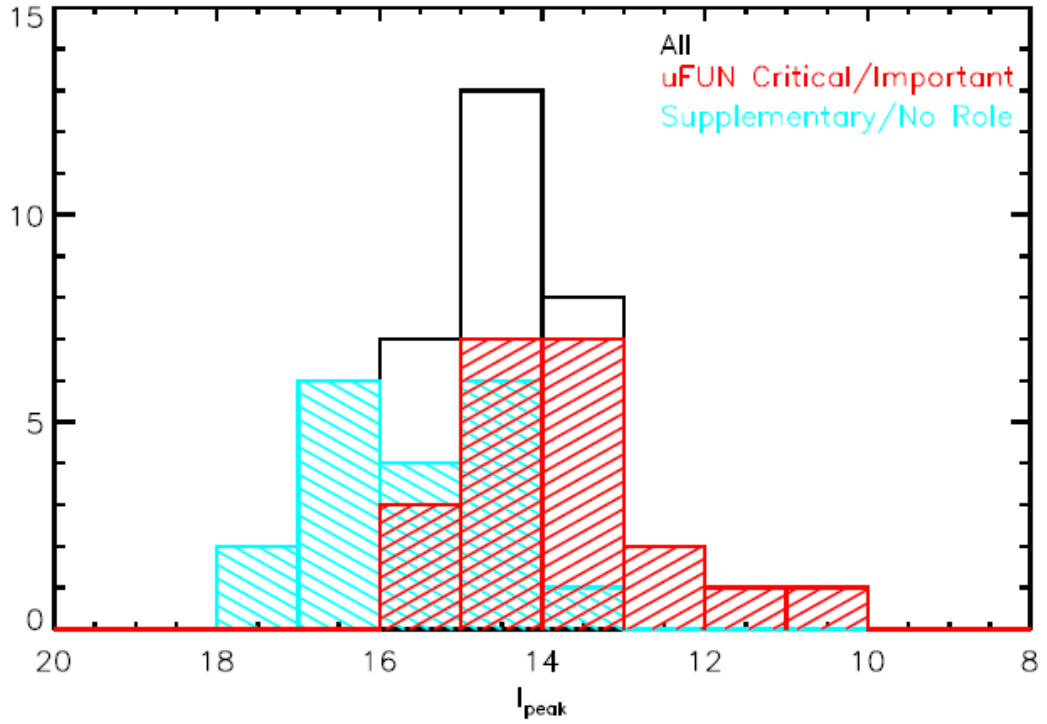
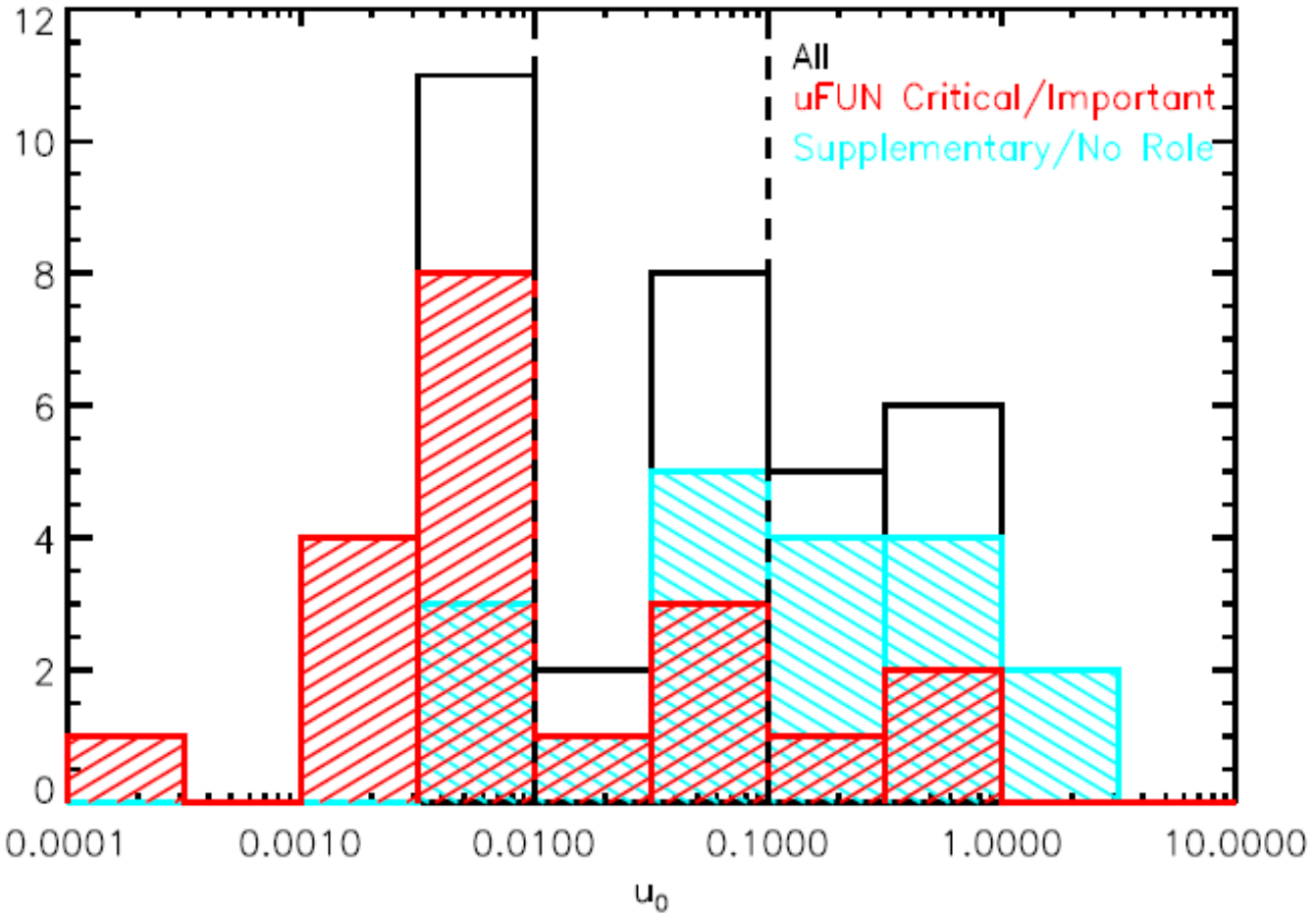
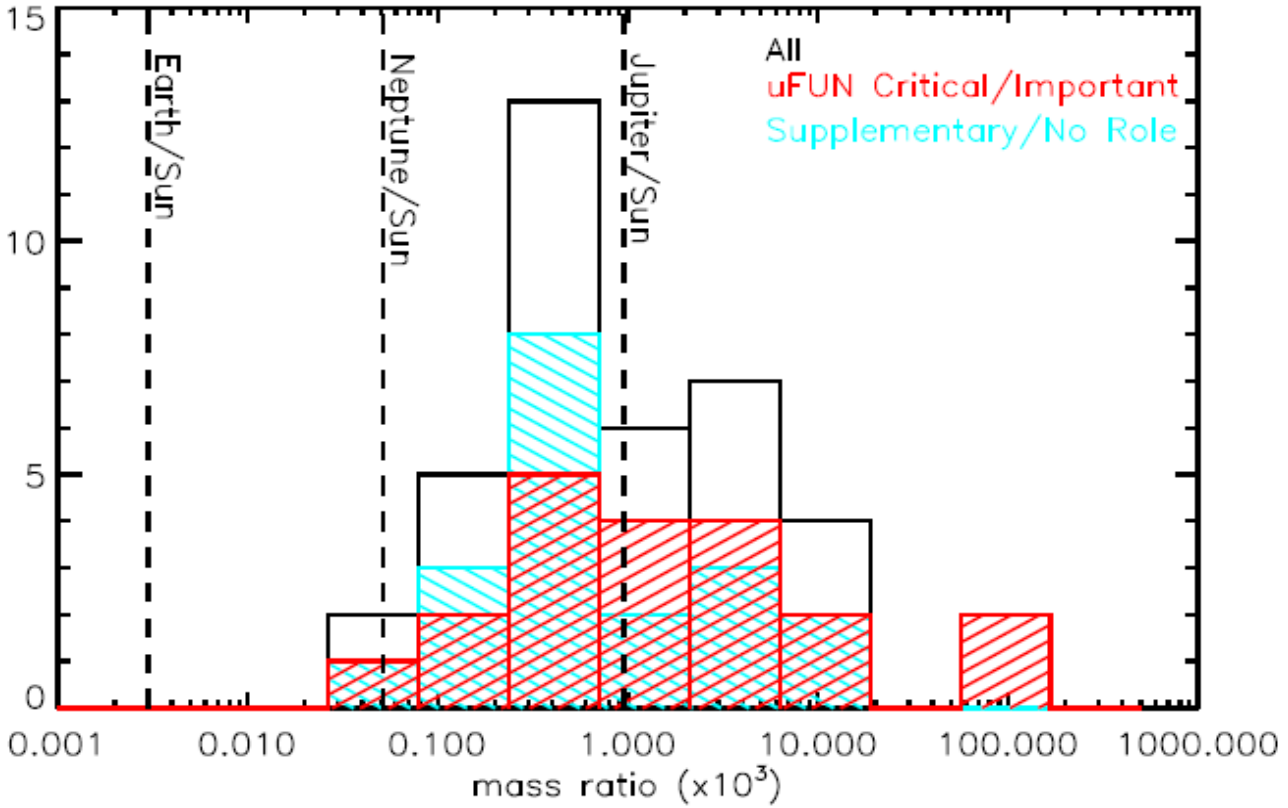
Planetary events by peak magnitude



Planetary events by impact parameter



Planetary events by mass ratio



Planetary events by publication delay