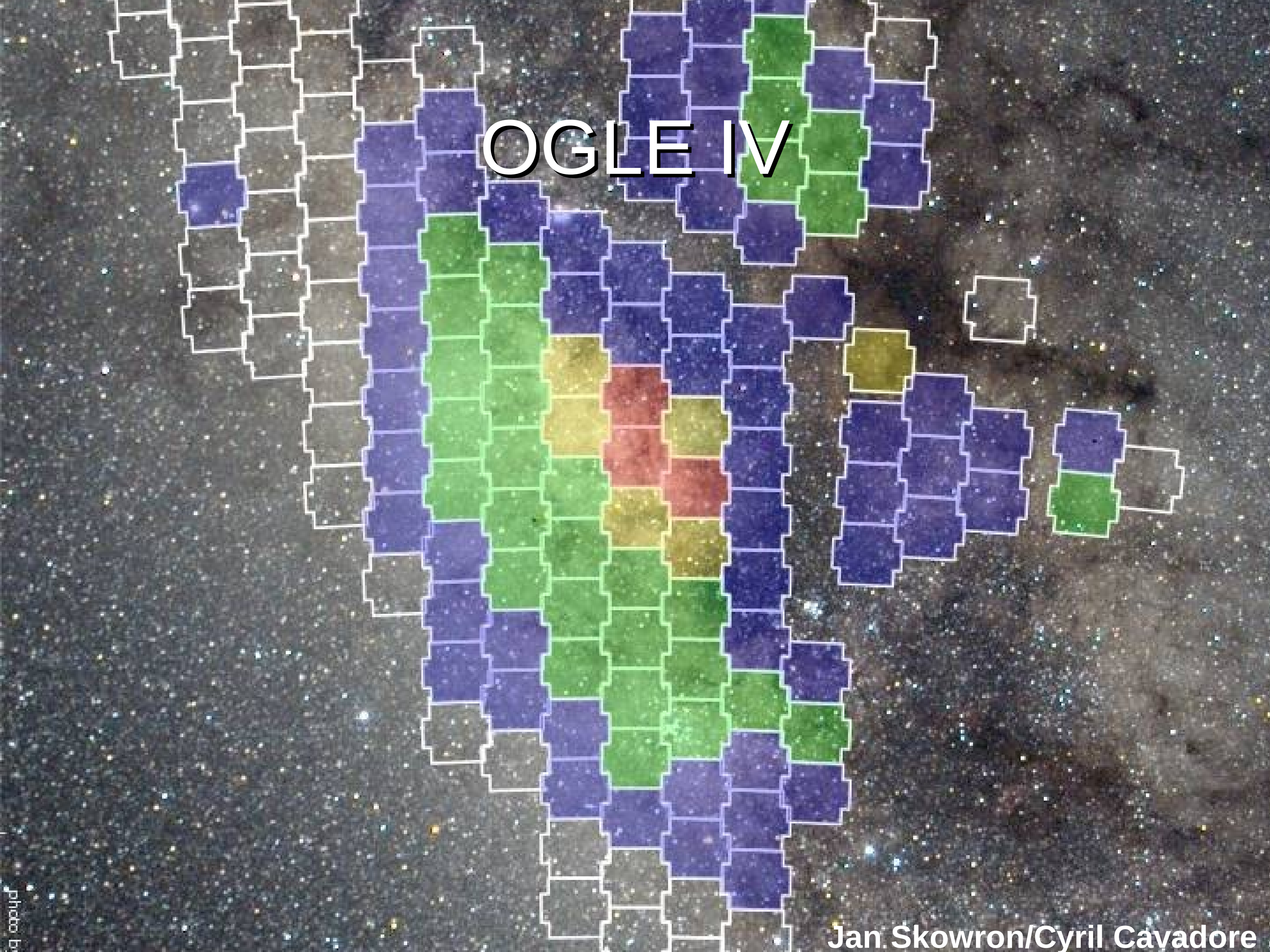
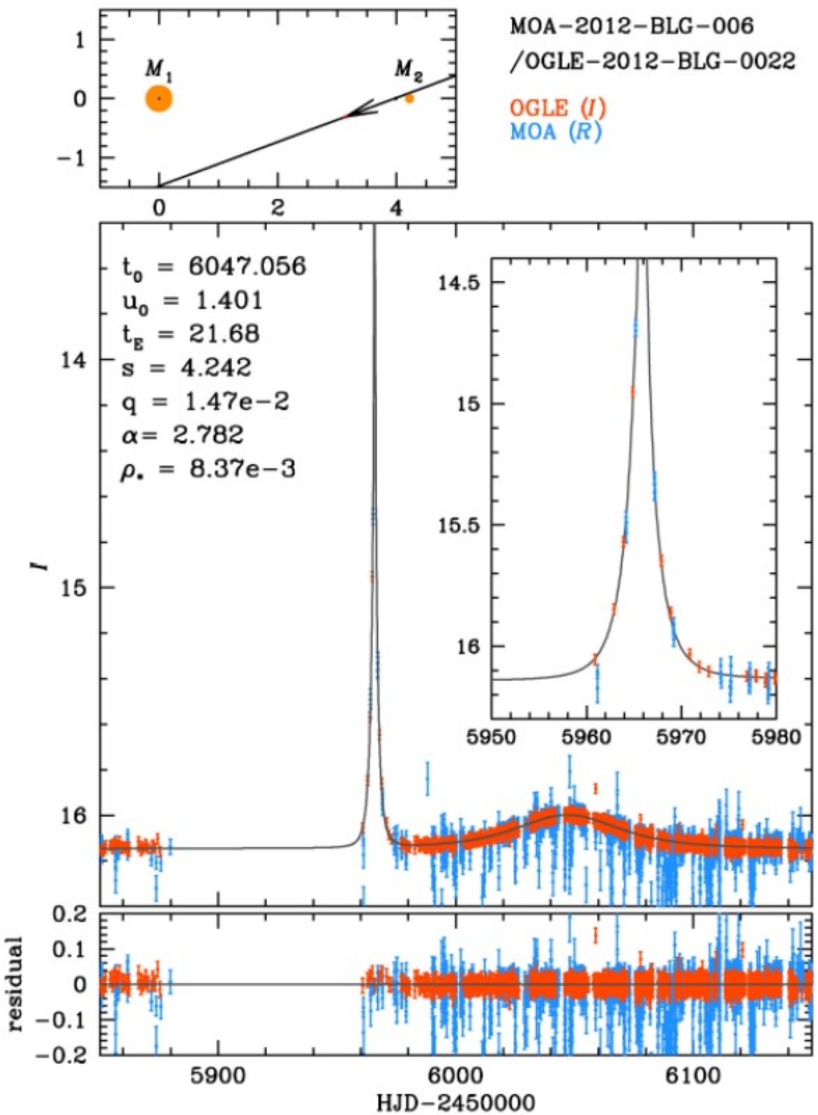
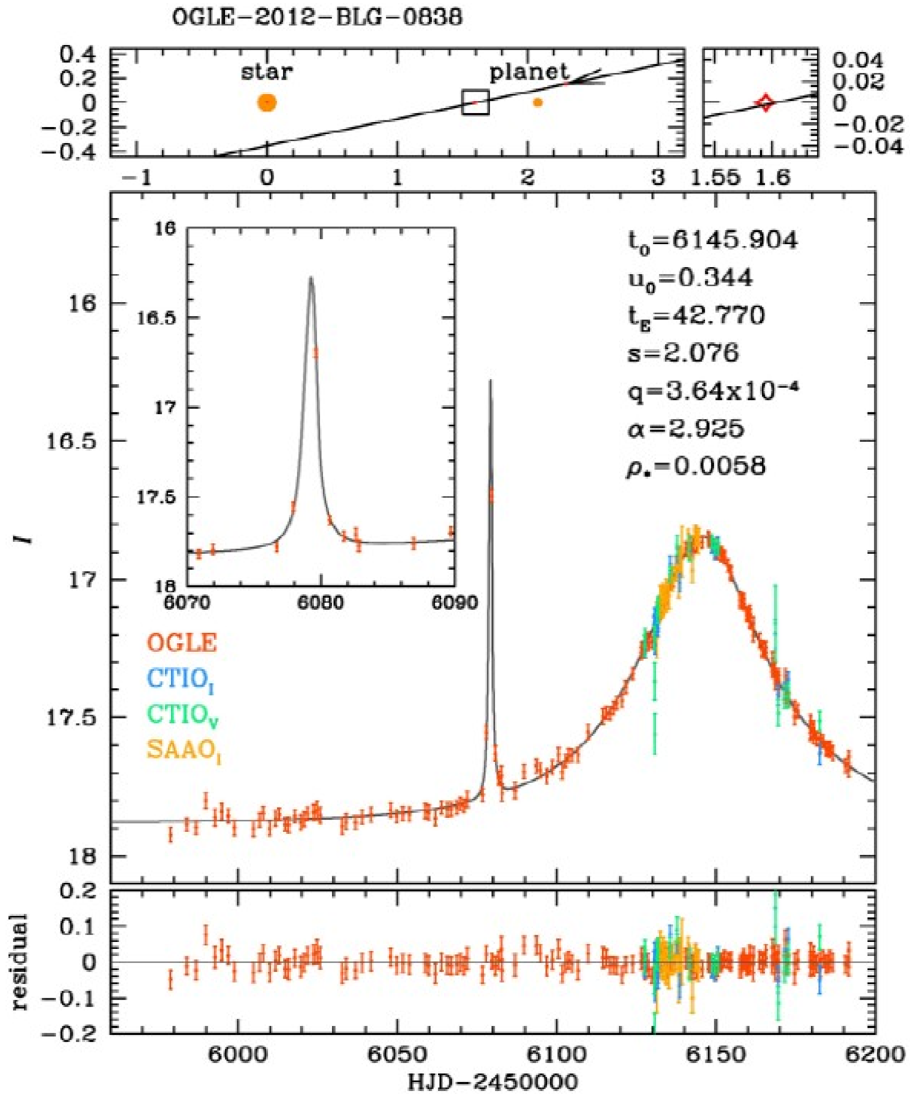
Microlensing Followup in the Era of Second-Generation Surveys

Surveys cover a large fraction of the sky and are now able to find planets without followup.


OGLE IV
Jan Skowron/Cyril Cavadore



MOA-2012-BLG-006
/OGLE-2012-BLG-0022
OGLE (I)
MOA (R)
M1
M2
t0 = 6047.056
u0 = 1.401
tE = 21.68
s = 4.242
q = 1.47e-2
α= 2.782
ρ* = 8.37e-3
I
residual
HJD-2450000

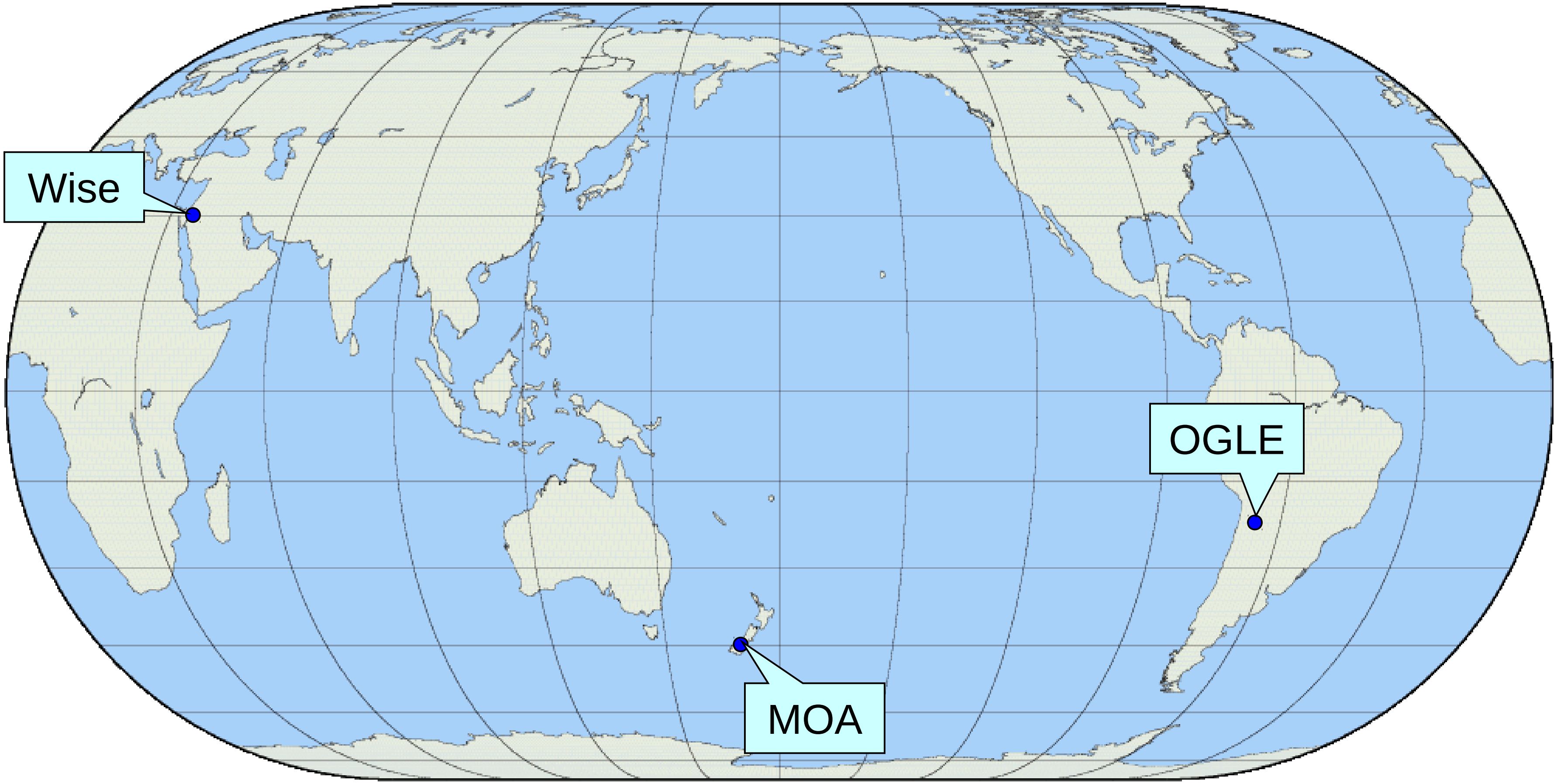


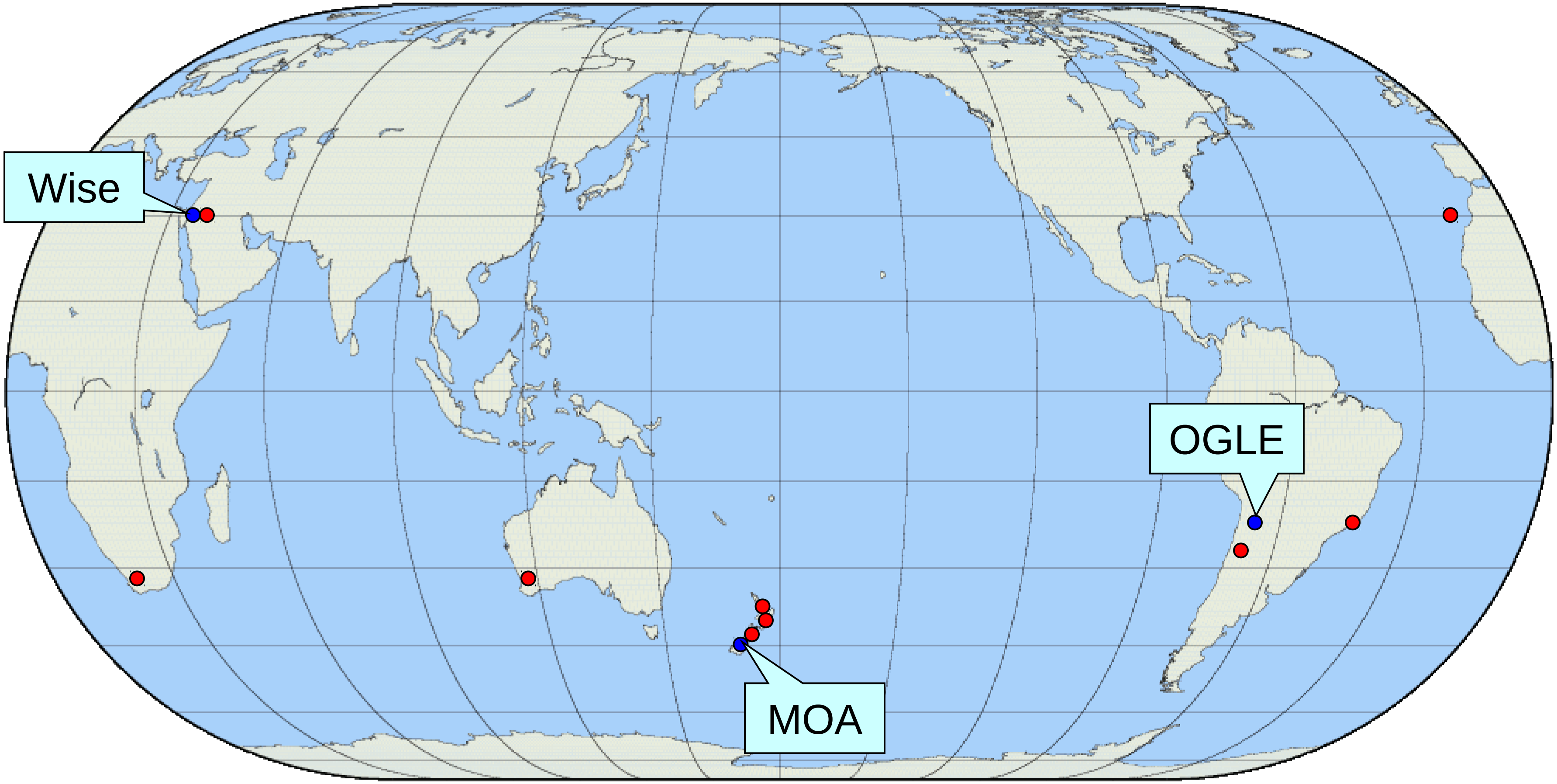
OGLE-2012-BLG-0838
star
planet
t0=6145.904
u0=0.344
tE=42.770
s=2.076
q=3.64x10−4
α=2.925
ρ*=0.0058
OGLE
CTIO_I
CTIO_V
SAAO_I
I
residual
HJD-2450000

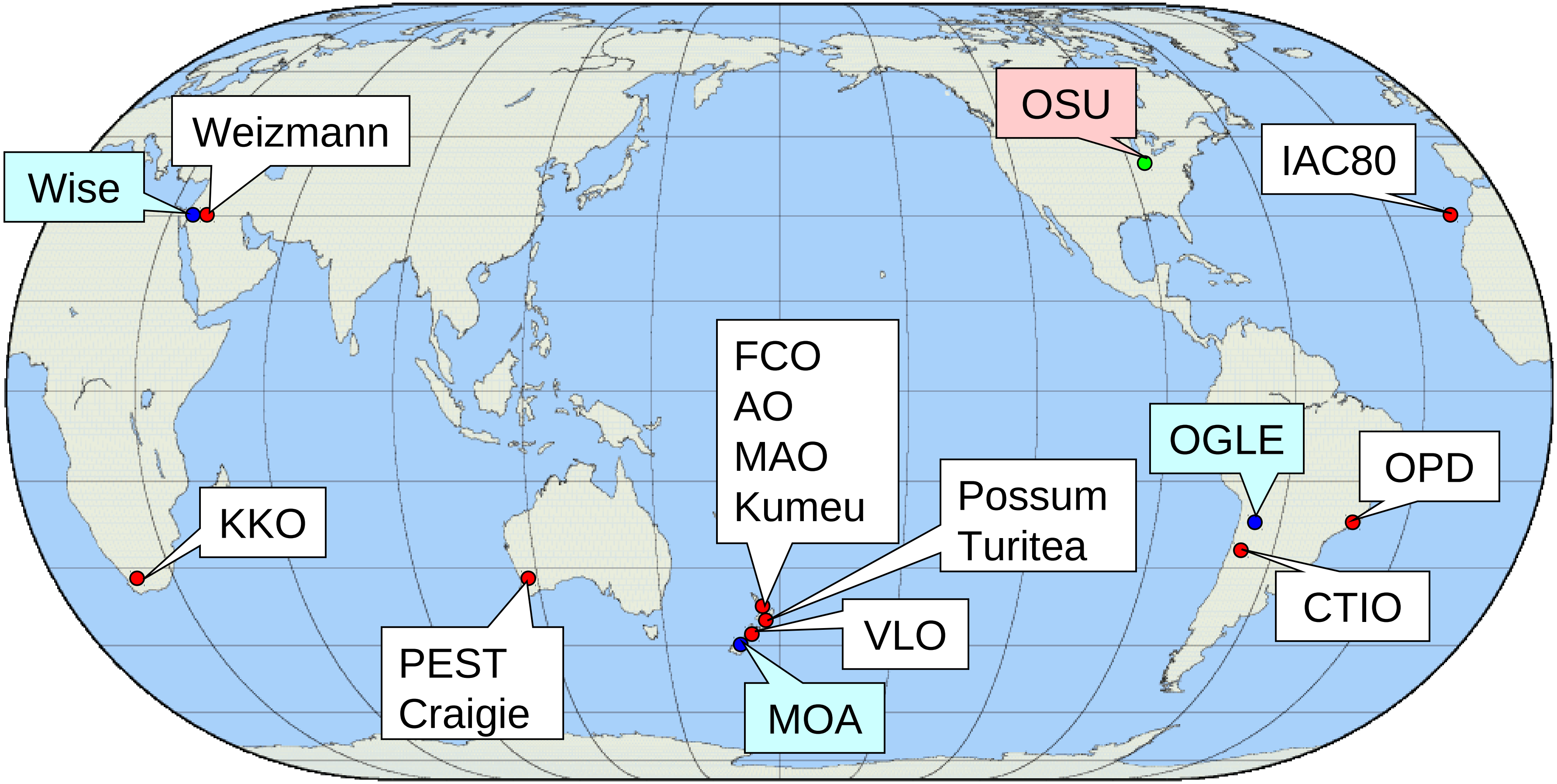
MicroFUN Advantages

- Cadence
- Sky Coverage
- Redundancy
- Longitudinal Coverage
- H-band

MicroFUN has much better longitudinal coverage than surveys alone.

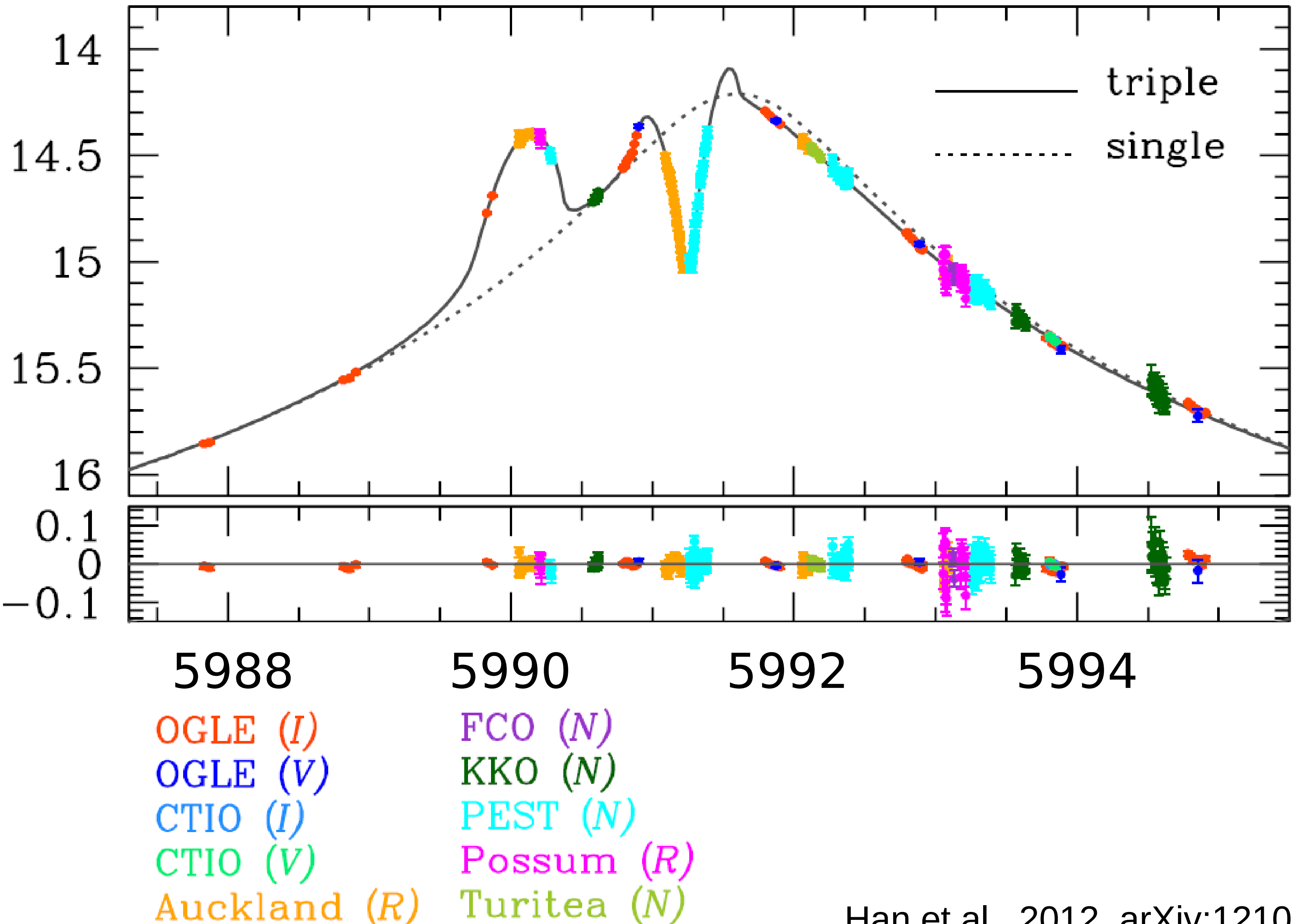

Wise
OGLE
MOA


Wise
OGLE
MOA


Weizmann
Wise
OSU
IAC80
FCO
AO
MAO
Kumeu
Possum
Turitea
OGLE
OPD
KKO
CTIO
VLO
PEST
Craigie
MOA

This was important for OGLE-2012-BLG-0026, which peaked when the Bulge was only visible for a few hours from each site.

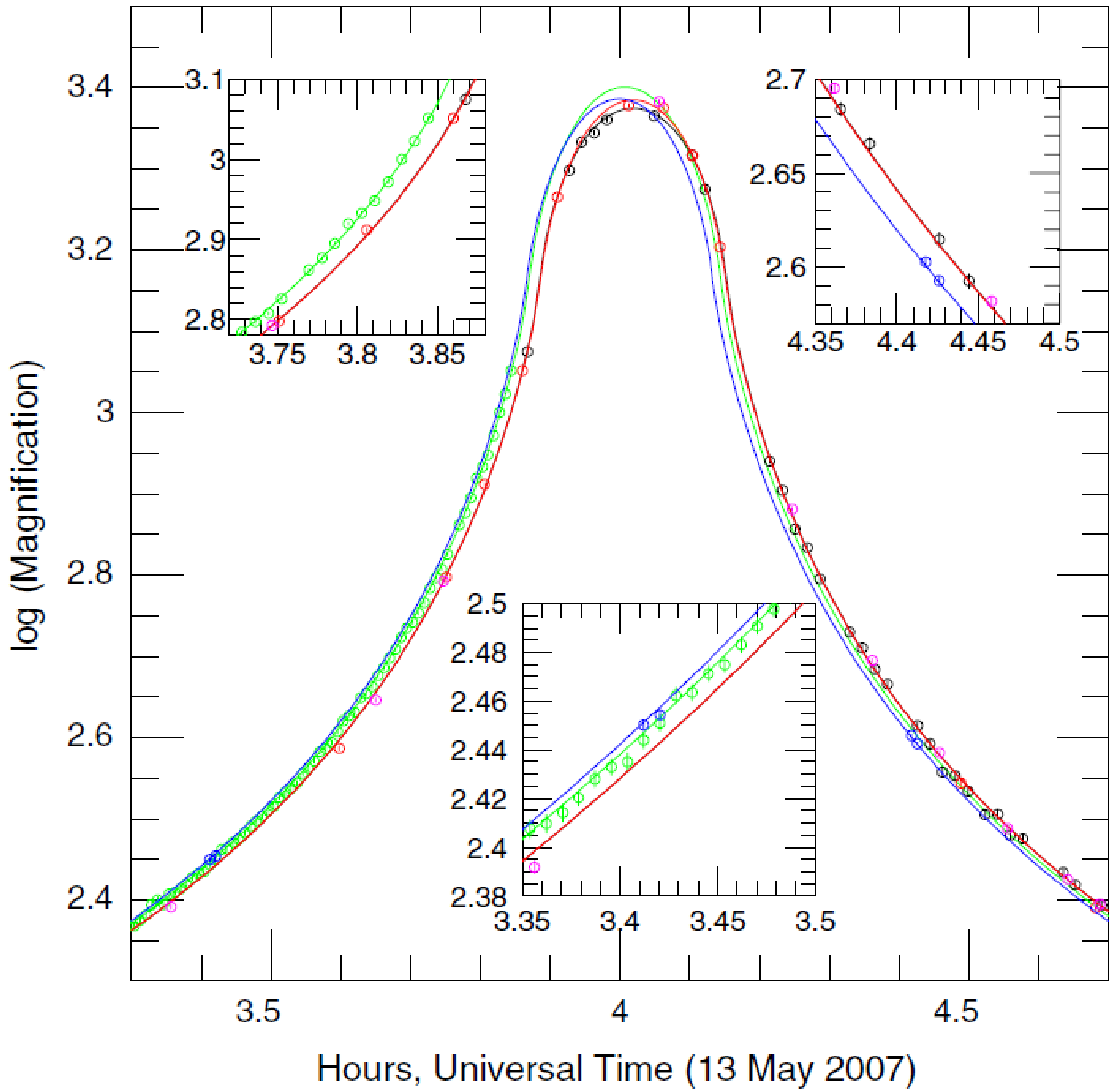
OGLE-2012-BLG-0026



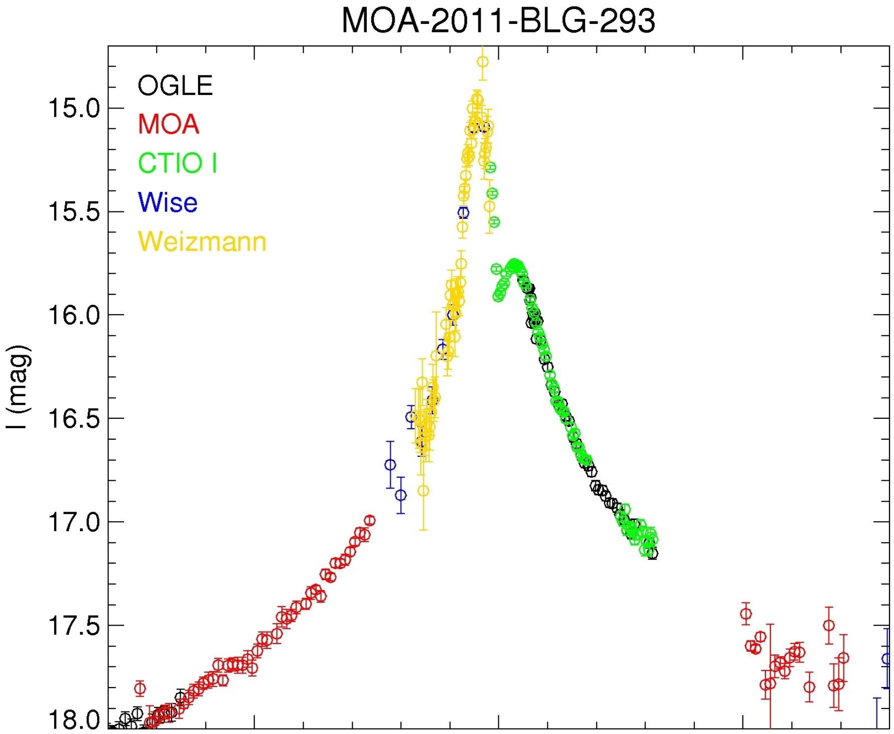
Han et al., 2012, arXiv:1210.4265

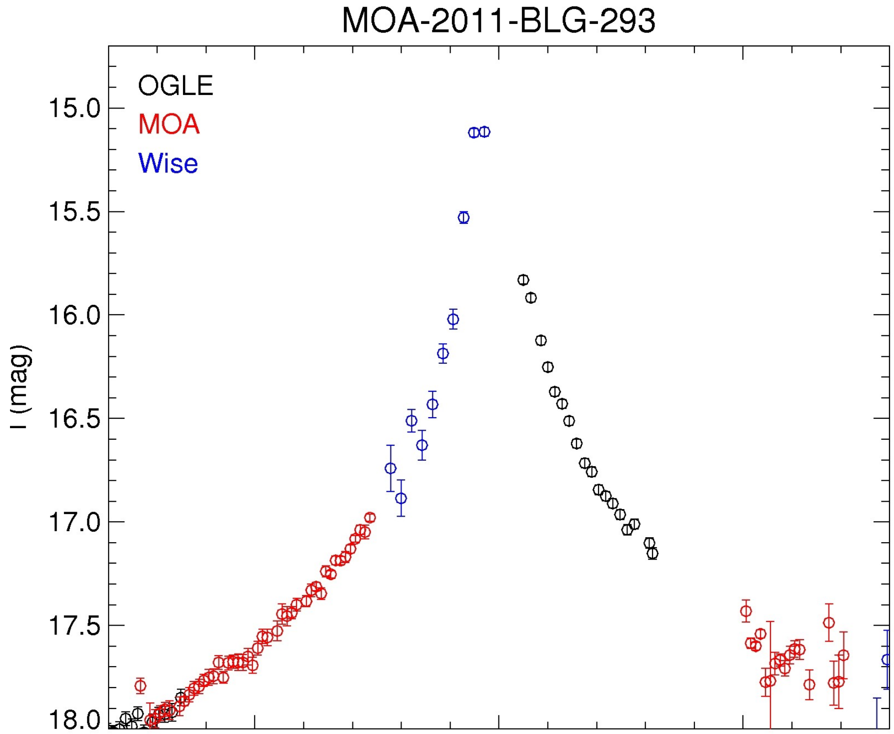
Logitudinal coverage is also important for observing terrestrial parallax.

OGLE-2007-BLG-224



It is also important if there is bad weather at some sites, because the weather can't be bad everywhere!

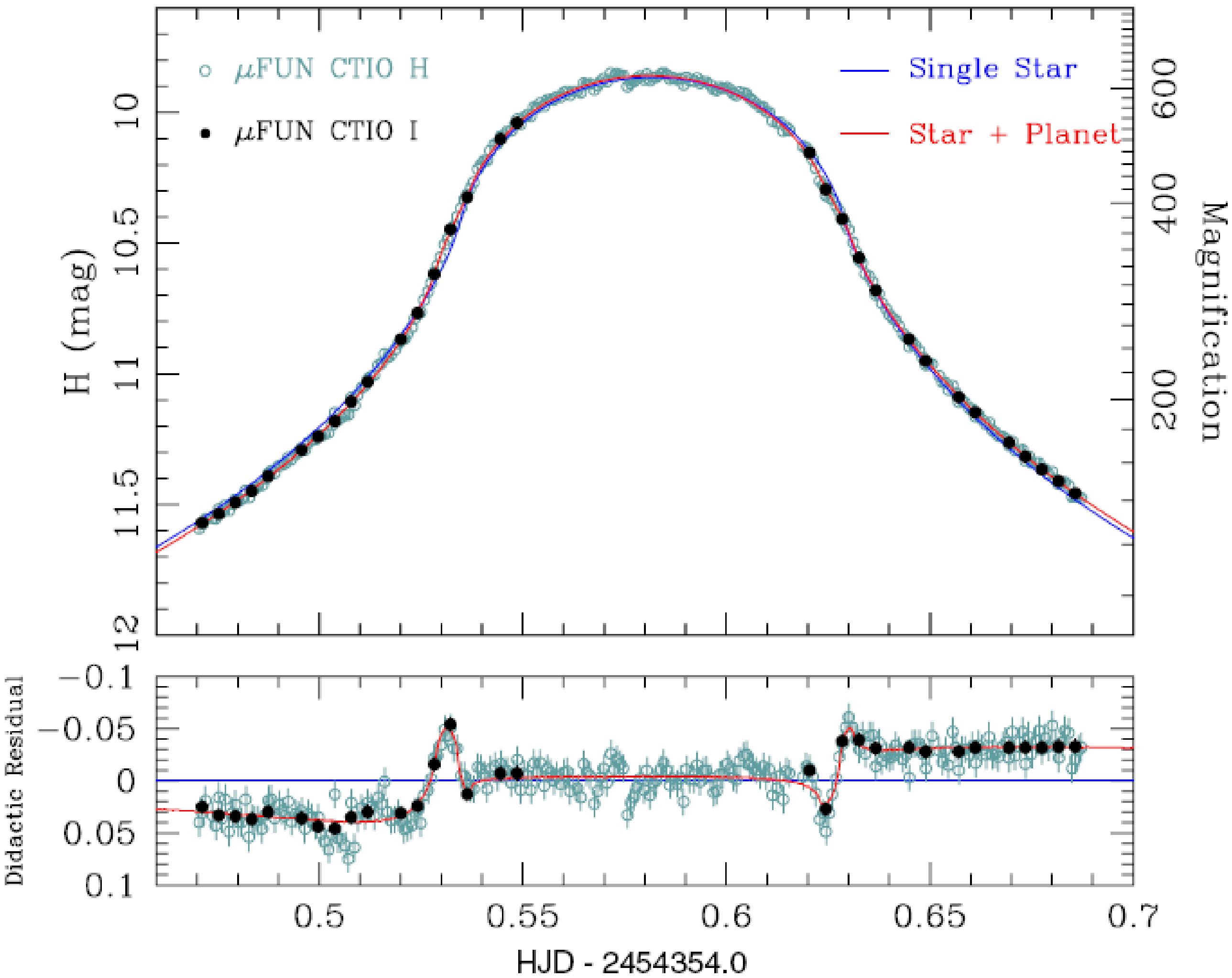




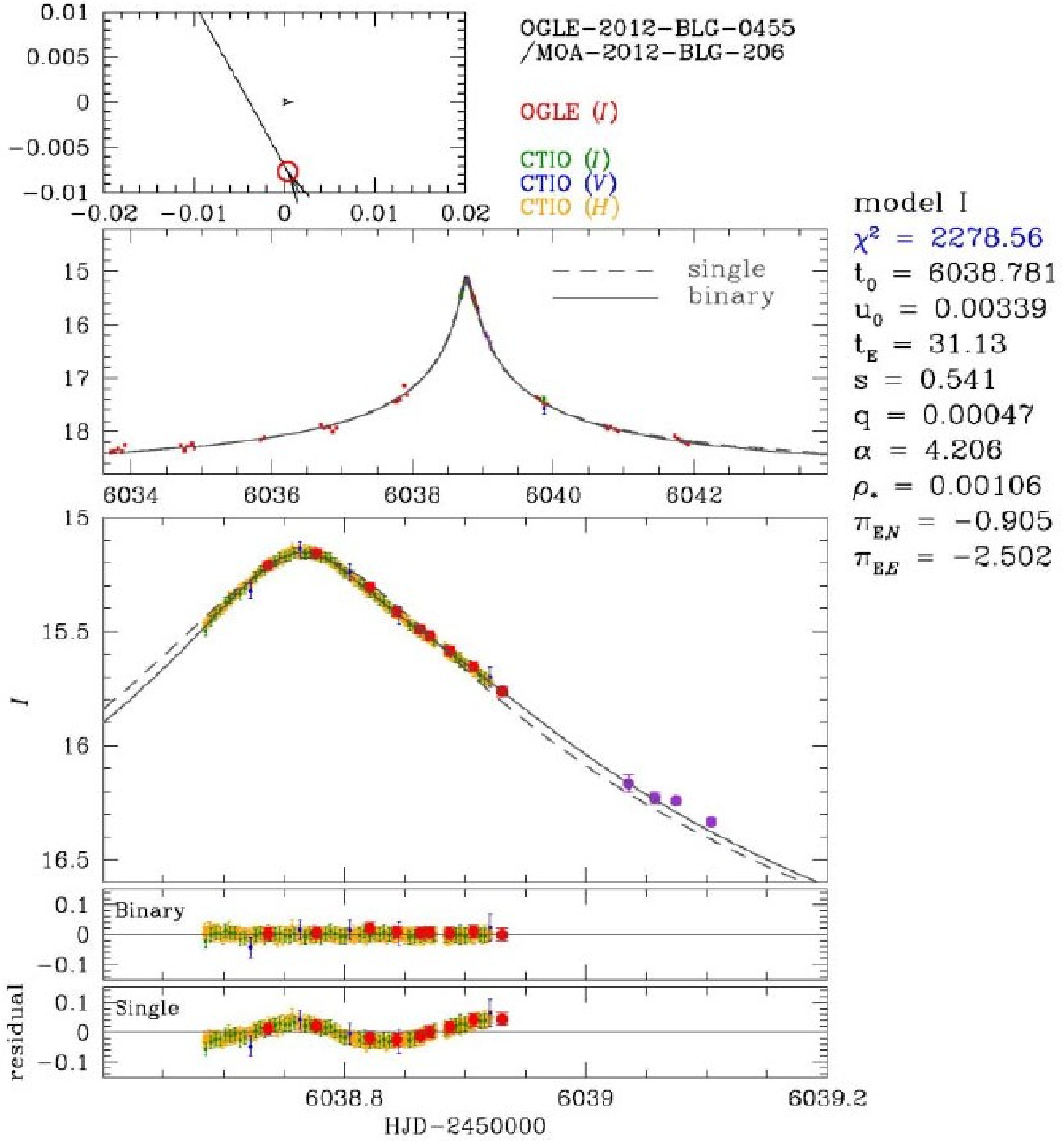
Yee et al. 2012, ApJ, 755, 102

MicroFUN data are continuous leading to better characterization of planetary signals.

MOA-2007-BLG-400

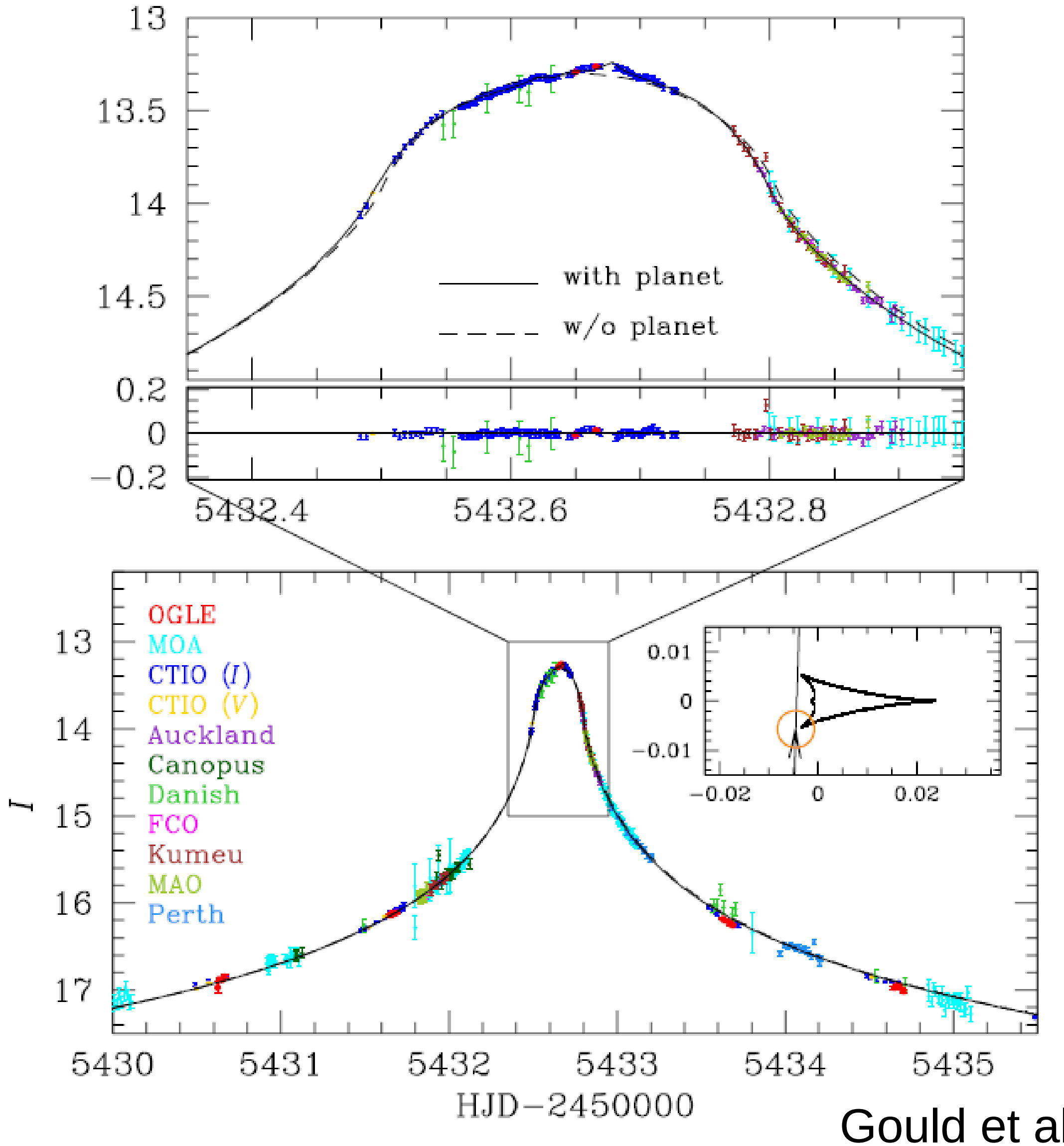


Dong et al. 2009


OGLE-2012-BLG-0455
/MOA-2012-BLG-206
OGLE (I)
CTIO (I)
CTIO (V)
CTIO (H)
single
binary
model I
χ² = 2278.56
t0 = 6038.781
u0 = 0.00339
tE = 31.13
s = 0.541
q = 0.00047
α = 4.206
ρ* = 0.00106
πE,N = −0.905
πE,E = −2.502
I
Binary
Single
residual
HJD−2450000

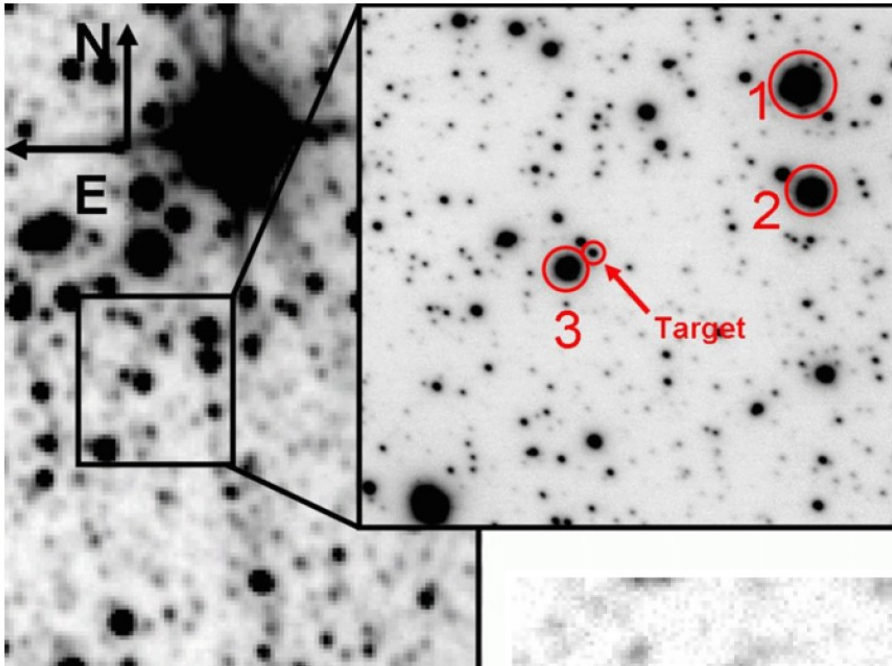
Followup H-band data can be important for identifying non-microlensing effects (such as magnified starspots) and for comparison to adaptive optics images used to identify the lens stars.

MOA-2010-BLG-523



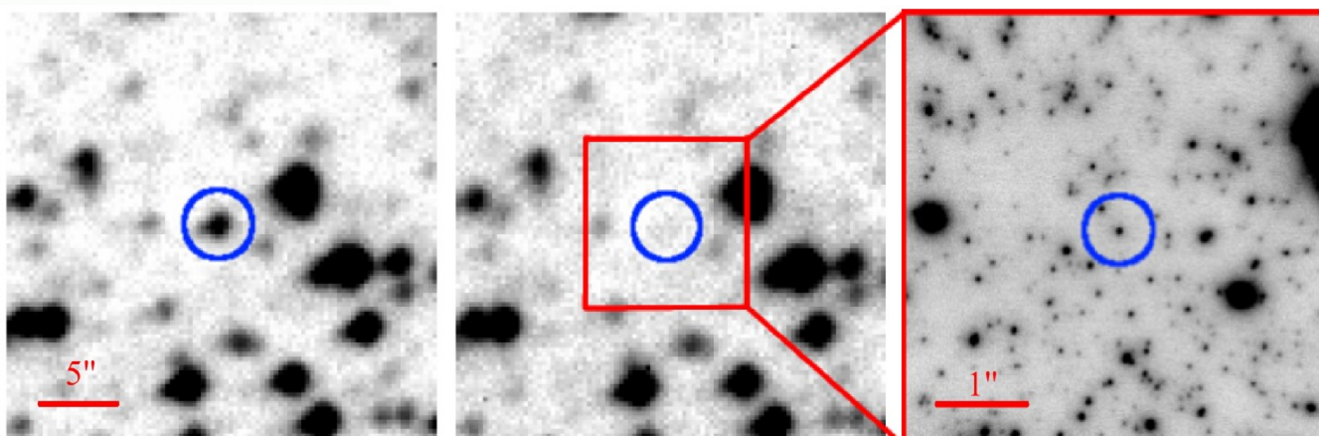
Gould et al. 2012 ApJ, in press

AO Followup



MOA-2008-BLG-310

MOA-2011-BLG-293

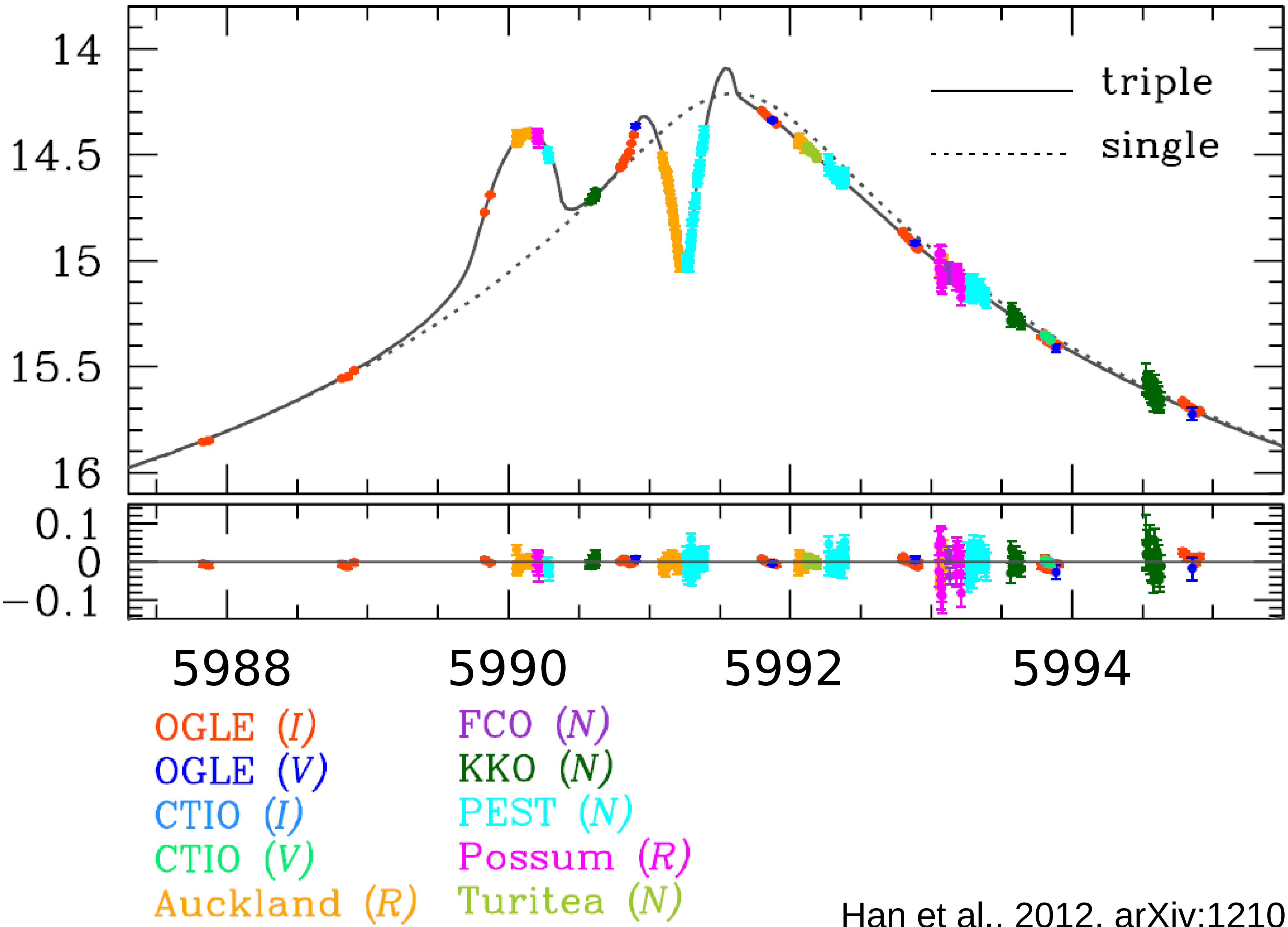


Where can we make the most impact going forward?

Science Potential

- **Wings of the Season**
- Low-cadence Fields
- High-Magnification Events
  - More data are needed
  - Extreme sensitivity to planets
  - Terrestrial and satellite parallax
  - Spectra of source stars

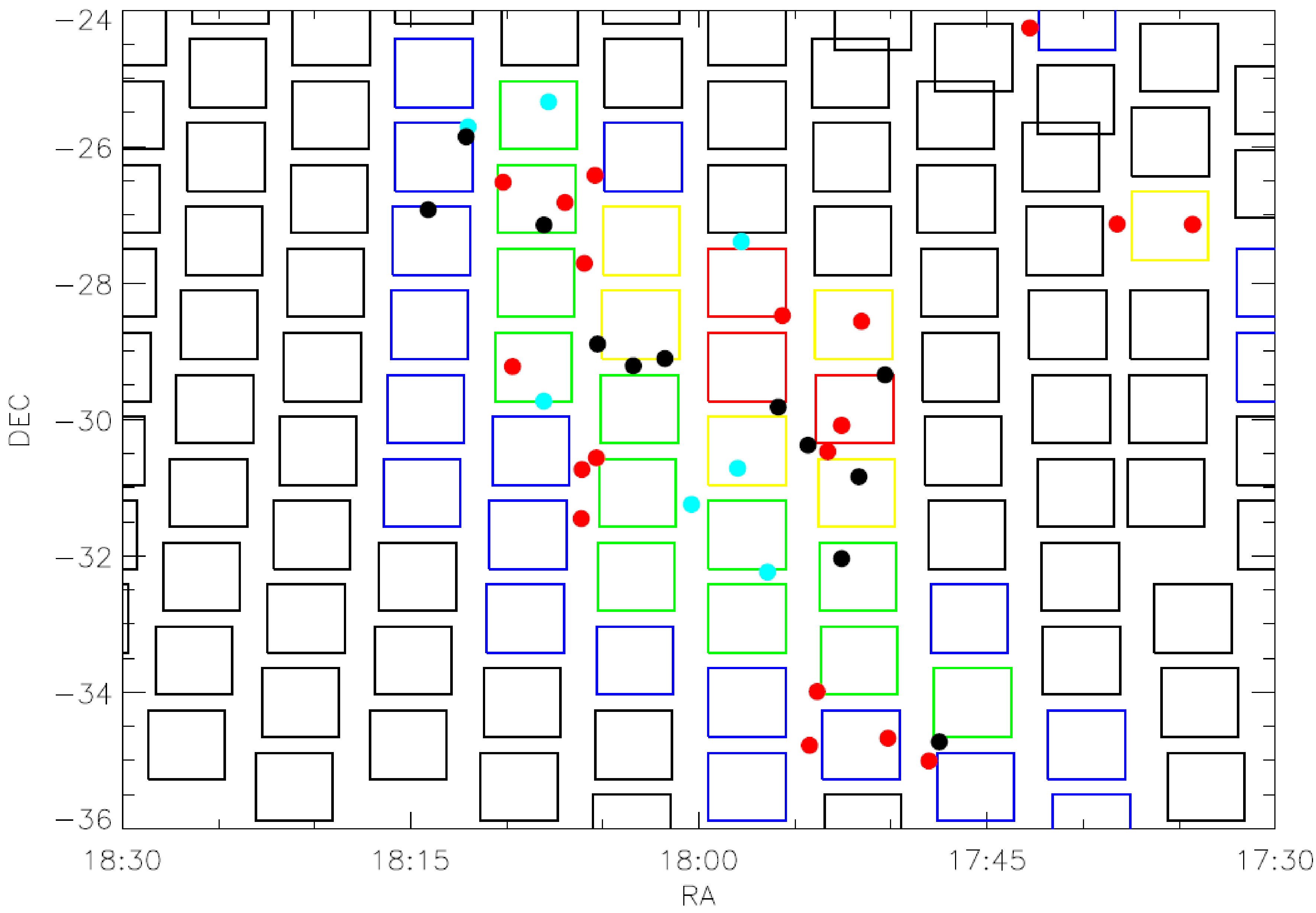
OGLE-2012-BLG-0026



Han et al., 2012, arXiv:1210.4265

Science Potential

- Wings of the Season
- **Low-cadence Fields**
- High-Magnification Events
  - More data are needed
  - Extreme sensitivity to planets
  - Terrestrial and satellite parallax
  - Spectra of source stars

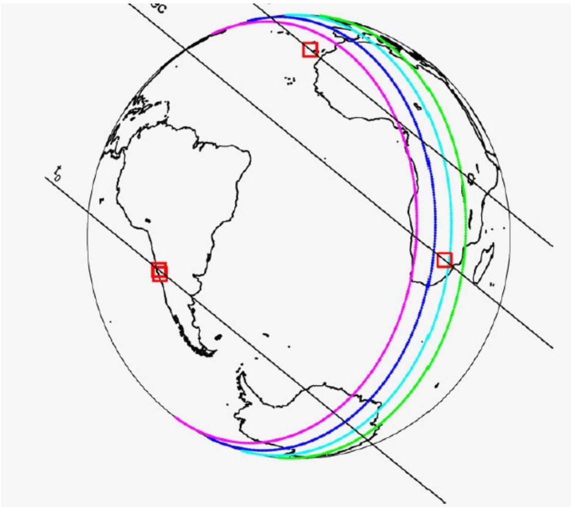


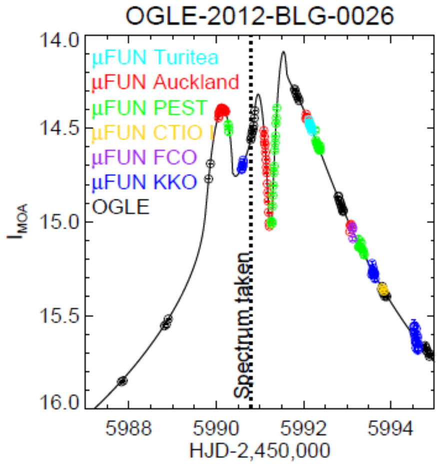
−24
−26
−28
−30
−32
−34
−36
DEC
18:30
18:15
18:00
17:45
17:30
RA

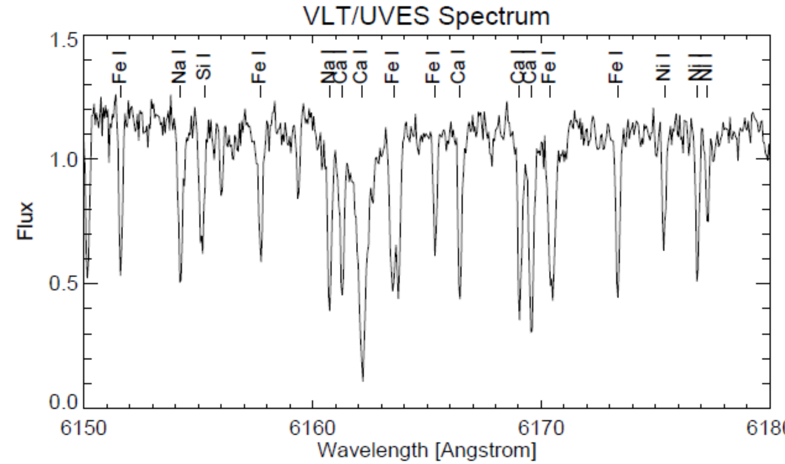
Science Potential

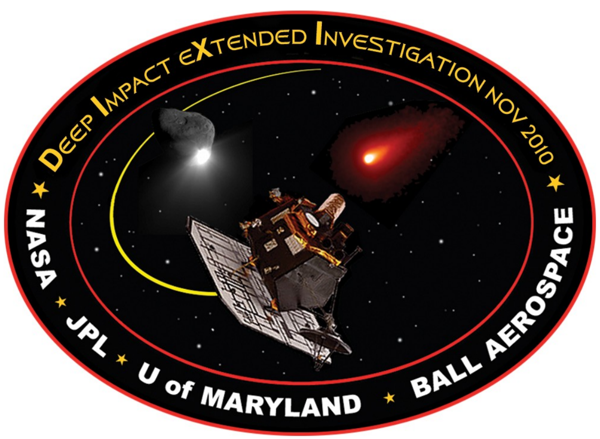
- Wings of the Season
- Low-cadence Fields
- **High-Magnification Events**
  - More data are needed
  - Extreme sensitivity to planets
  - Terrestrial and satellite parallax
  - Spectra of source stars

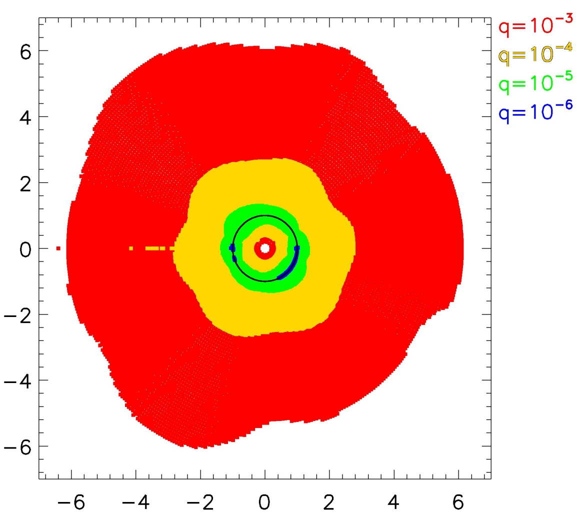
High-Magnification Events

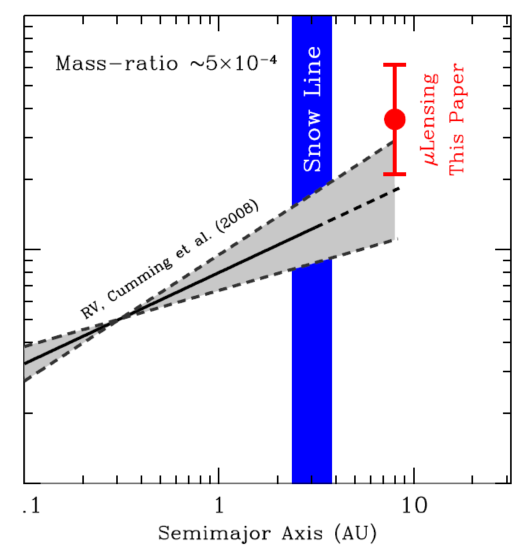




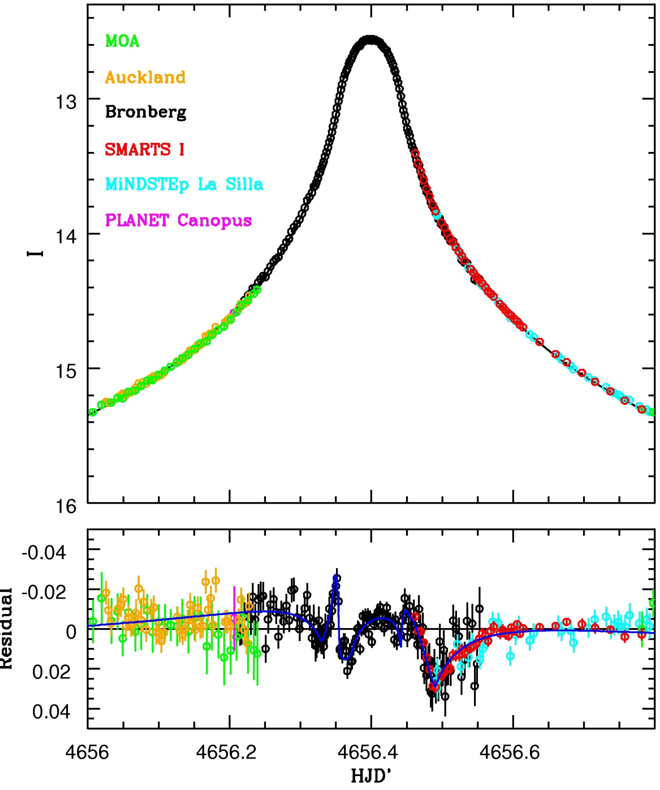


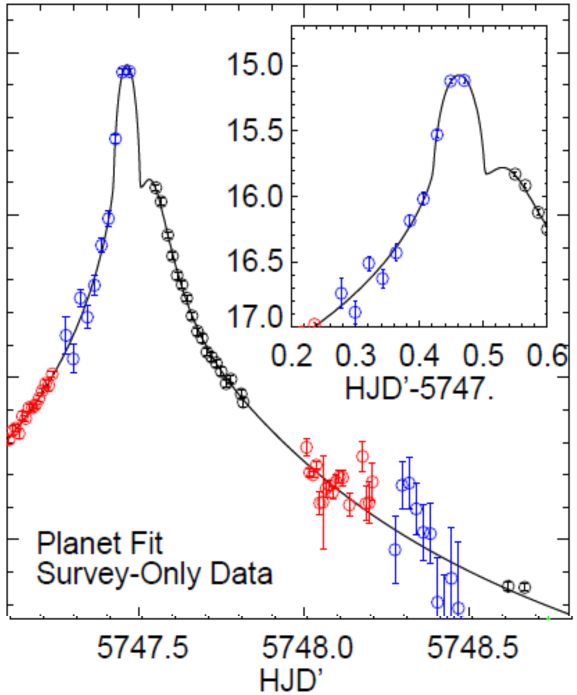


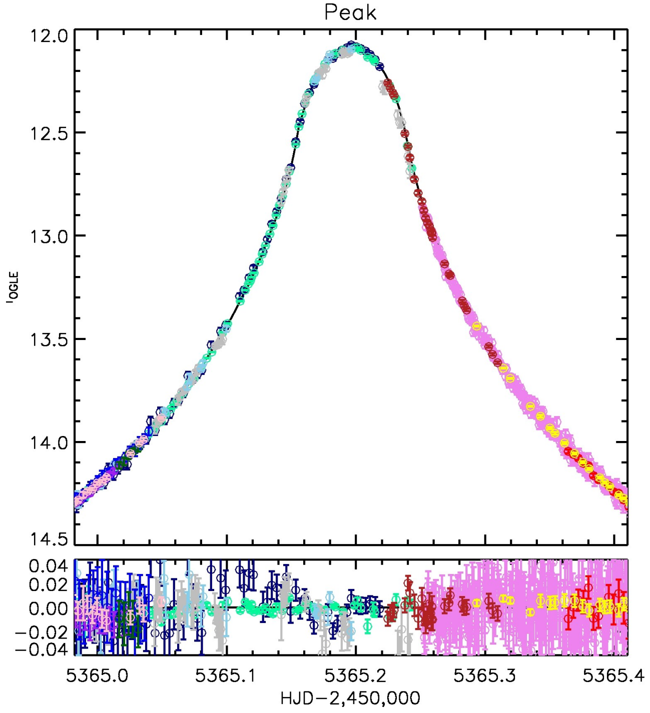




Detection Threshold

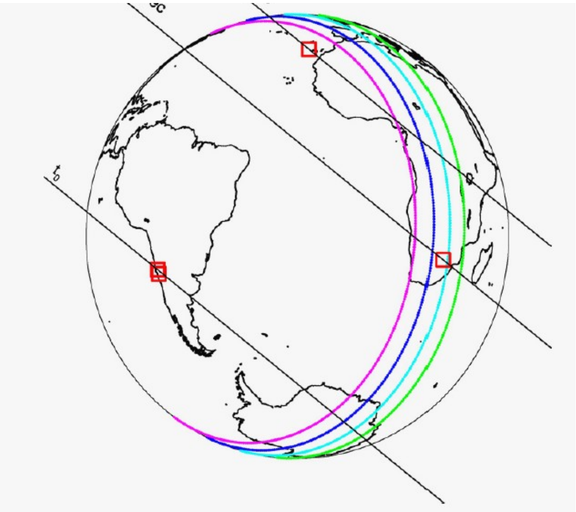


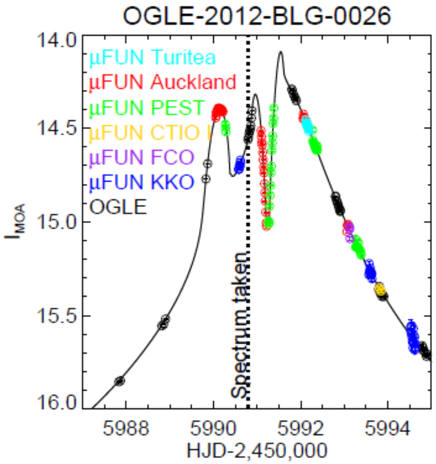


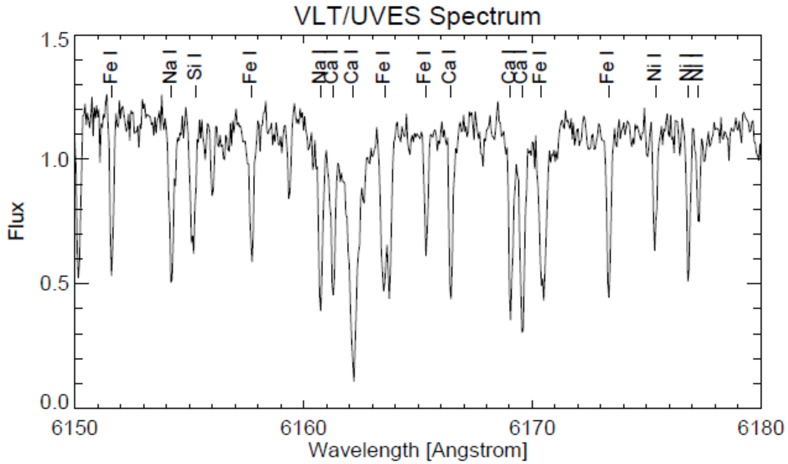


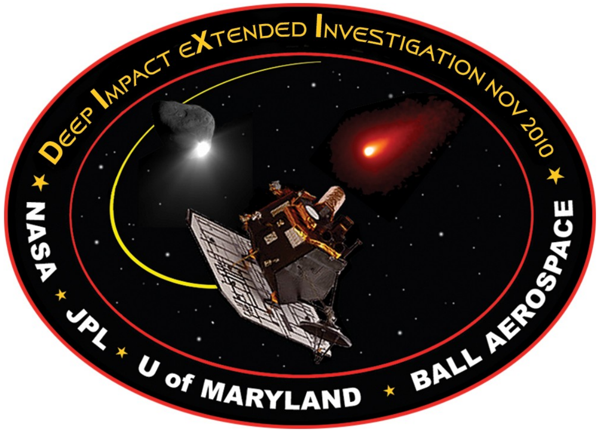
$\Delta\chi^2 = 880$ $\Delta\chi^2 = 500$ $\Delta\chi^2 = 140$

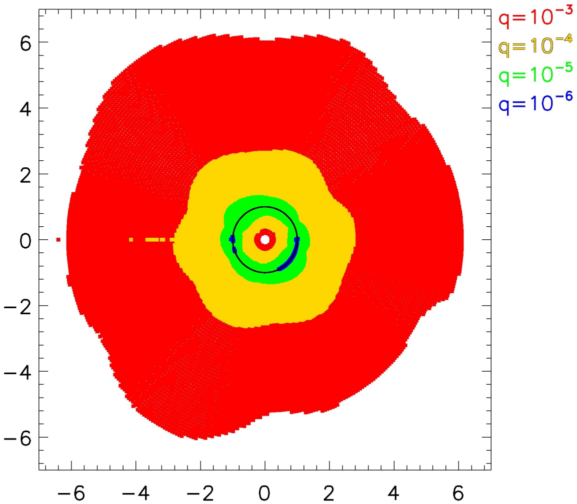
High-Magnification Events

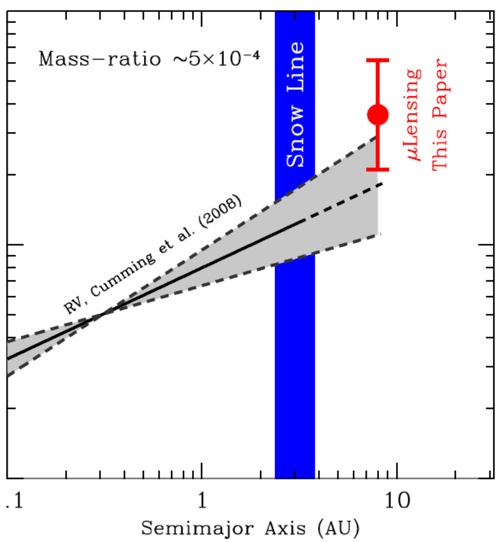










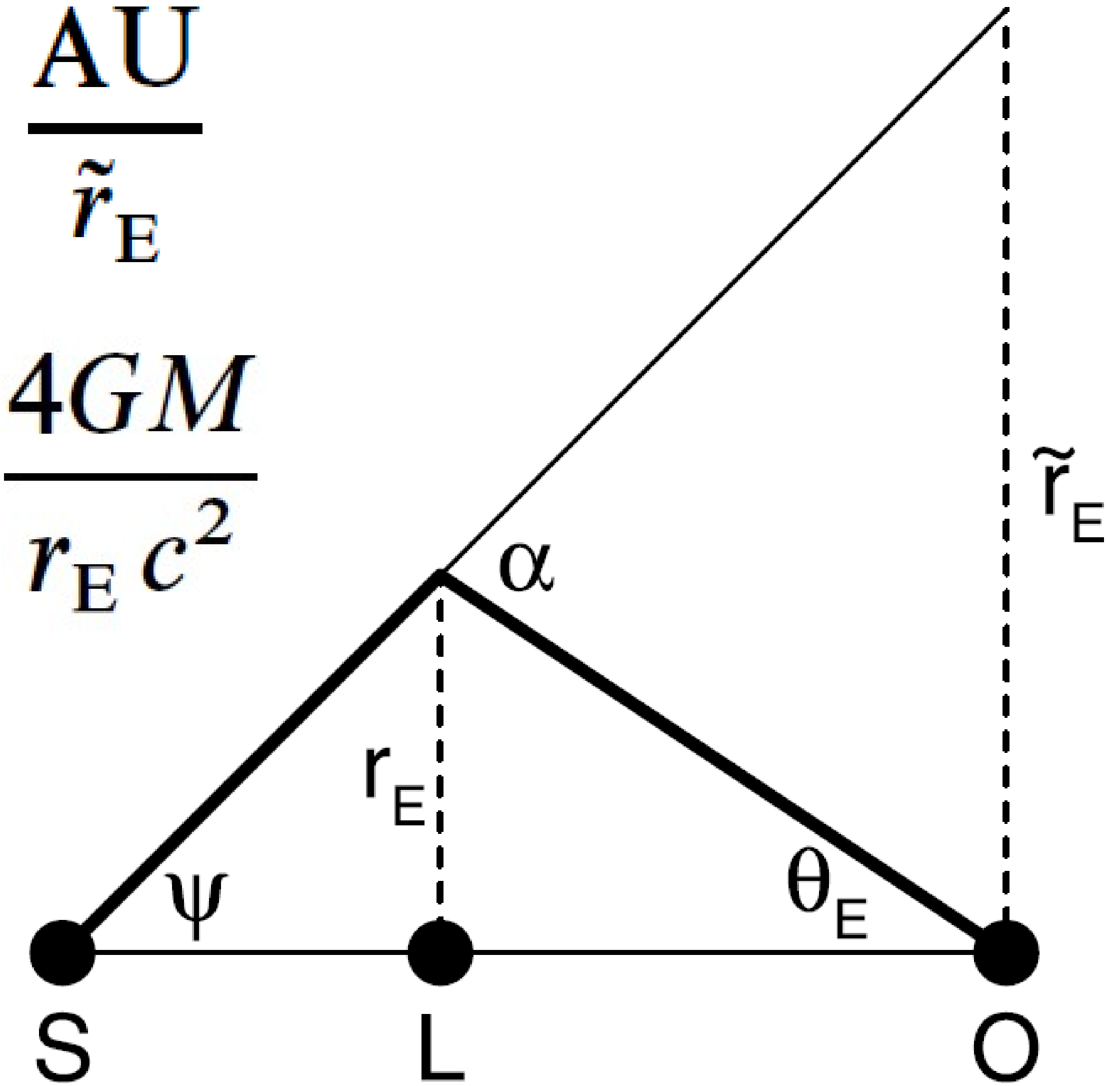


Terrestrial Parallax

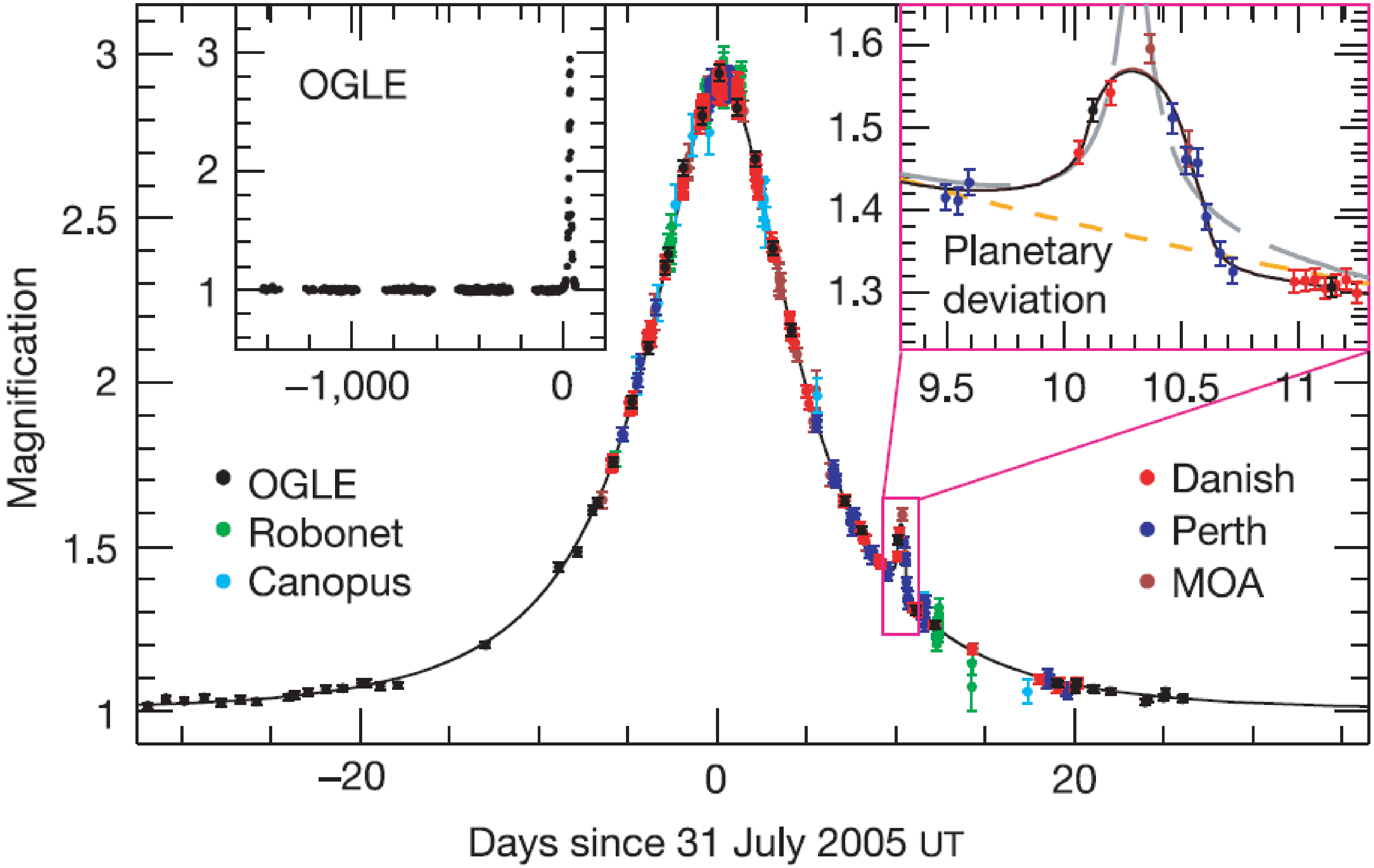
Terrestrial parallax can be used to measure the mass of the lenses. This also requires a measurement of finite source effects (the source size must be resolved by the event). Finite source effects are almost always measured in planetary events because the source crosses the caustic, but in point lens events is only measured if the lens star crosses the face of the source.

$$\pi_E \equiv \frac{\mathrm{AU}}{\tilde{r}_E}$$

$$\alpha = \frac{4GM}{r_E c^2}$$

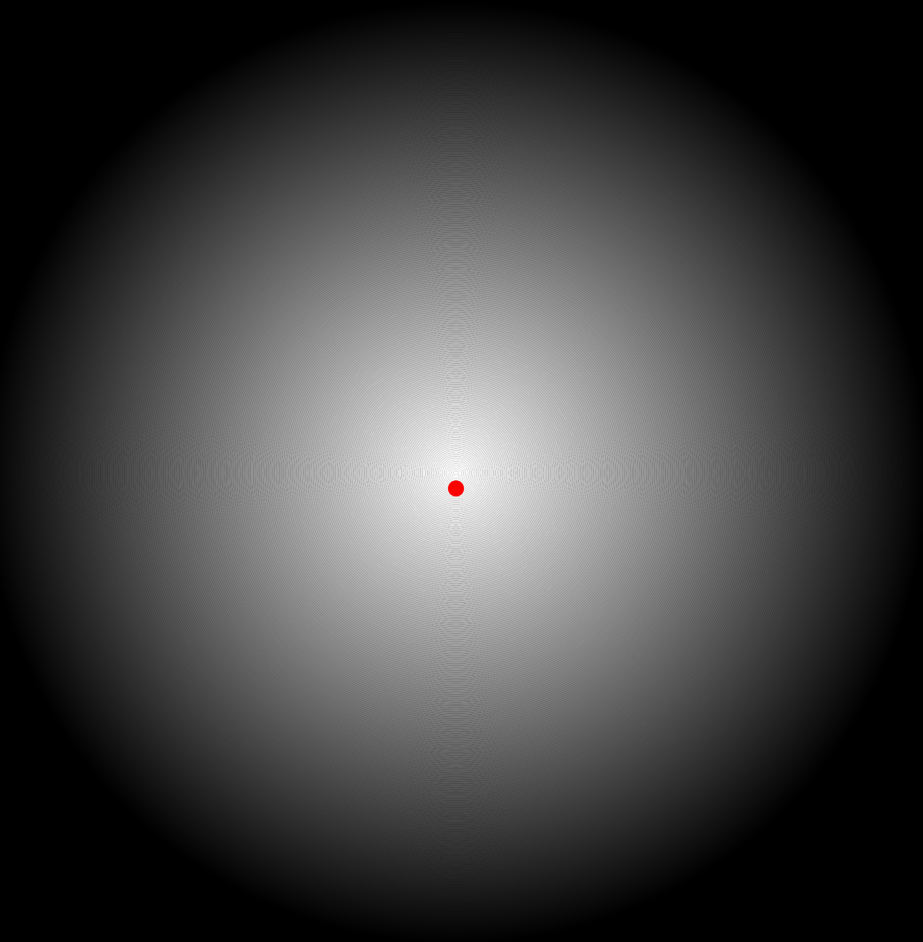


OGLE-2005-BLG-390

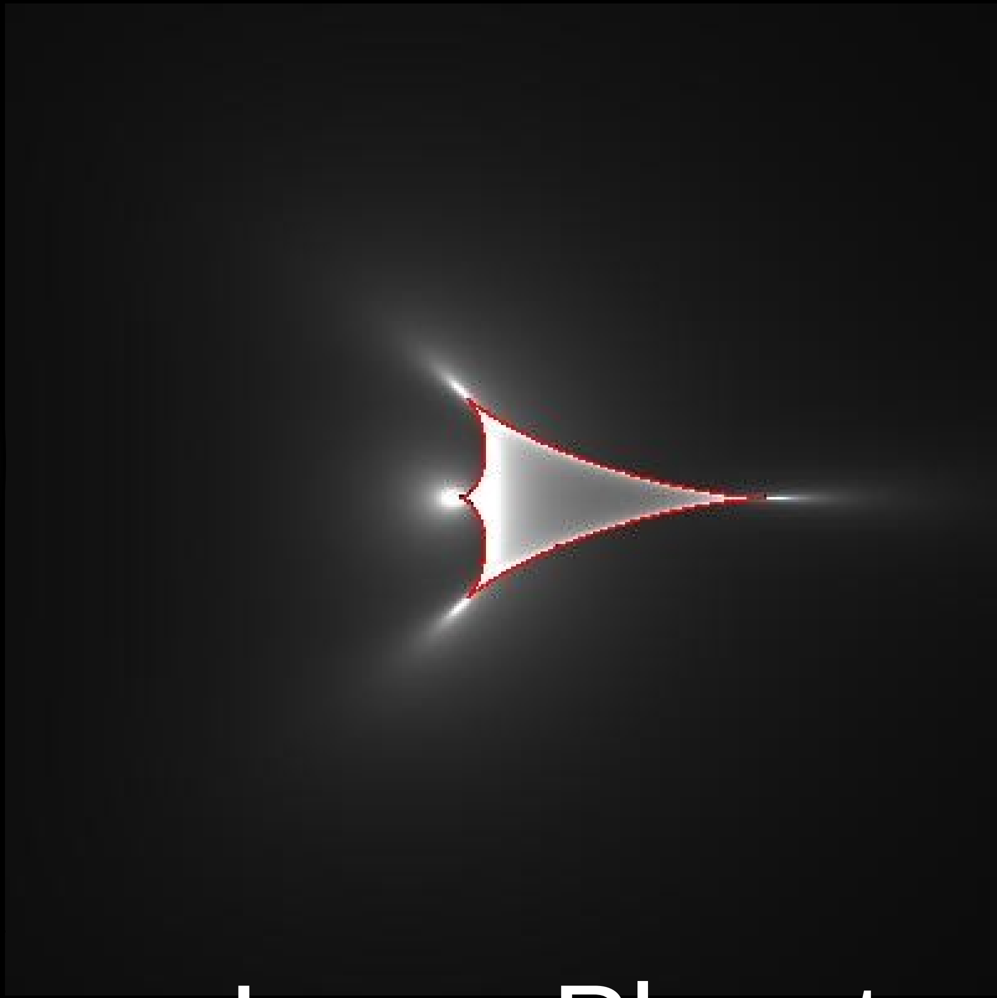


Beaulieu et al. 2006, Nature, 439, 437

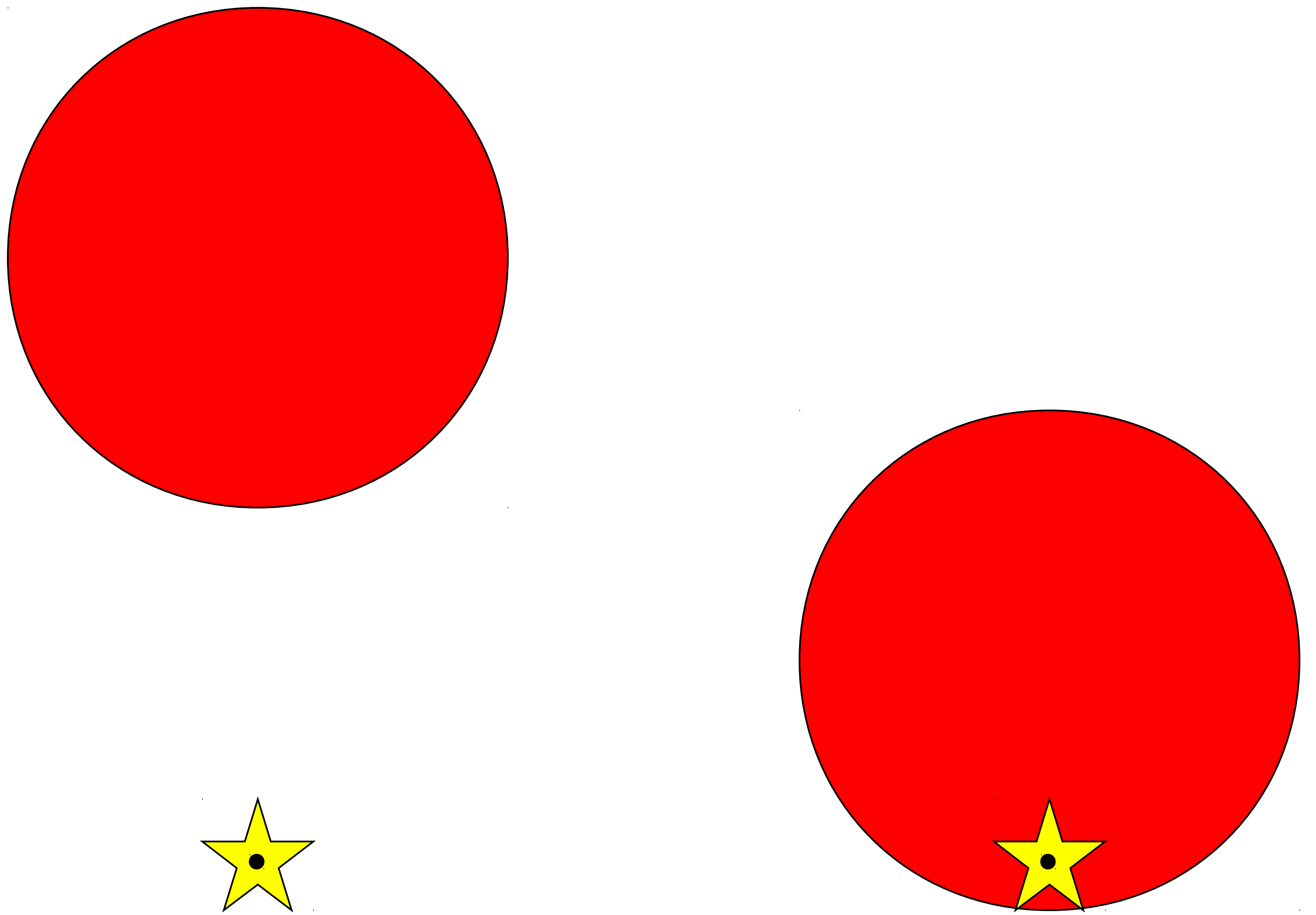
Magnification Map

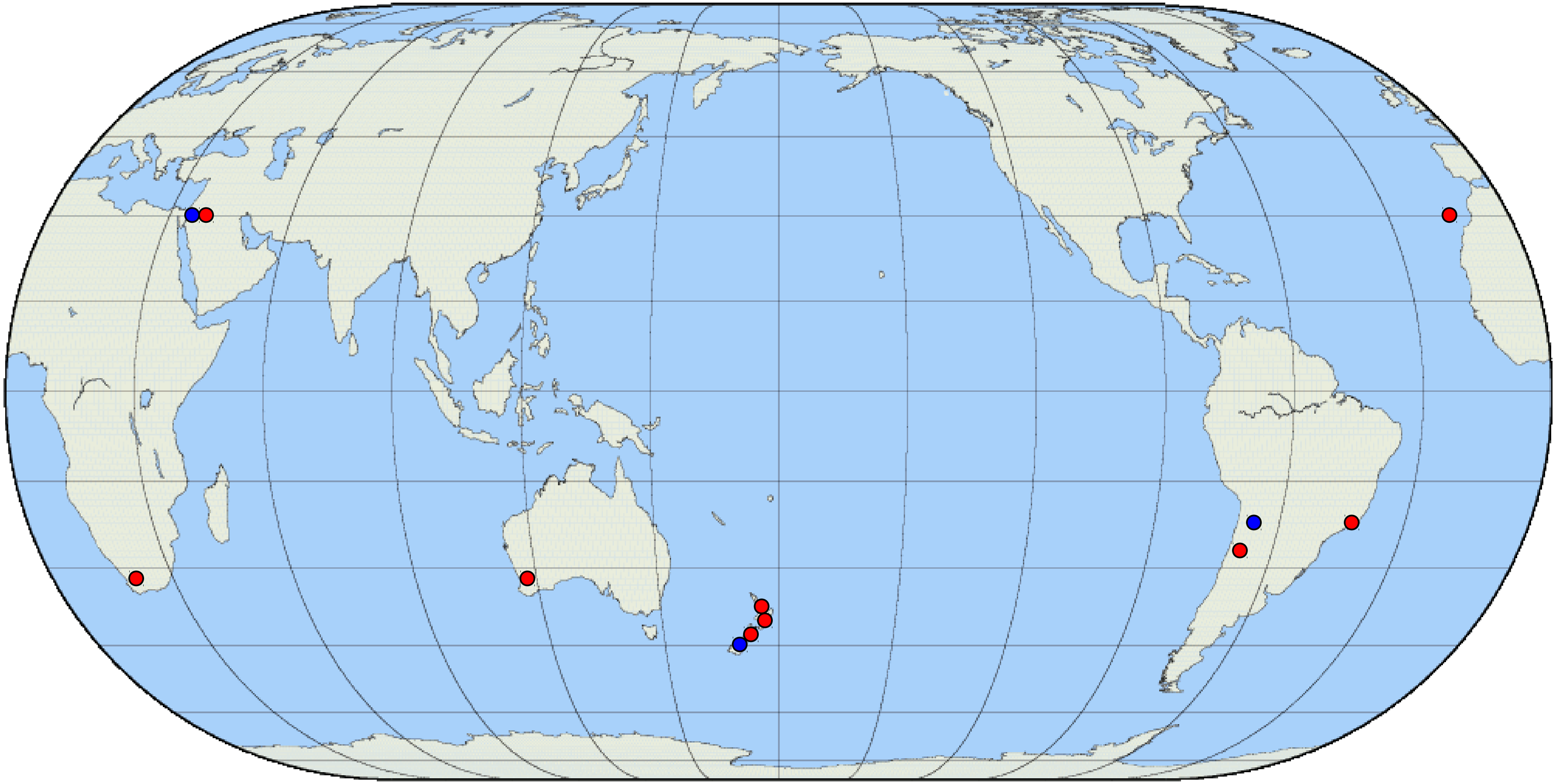


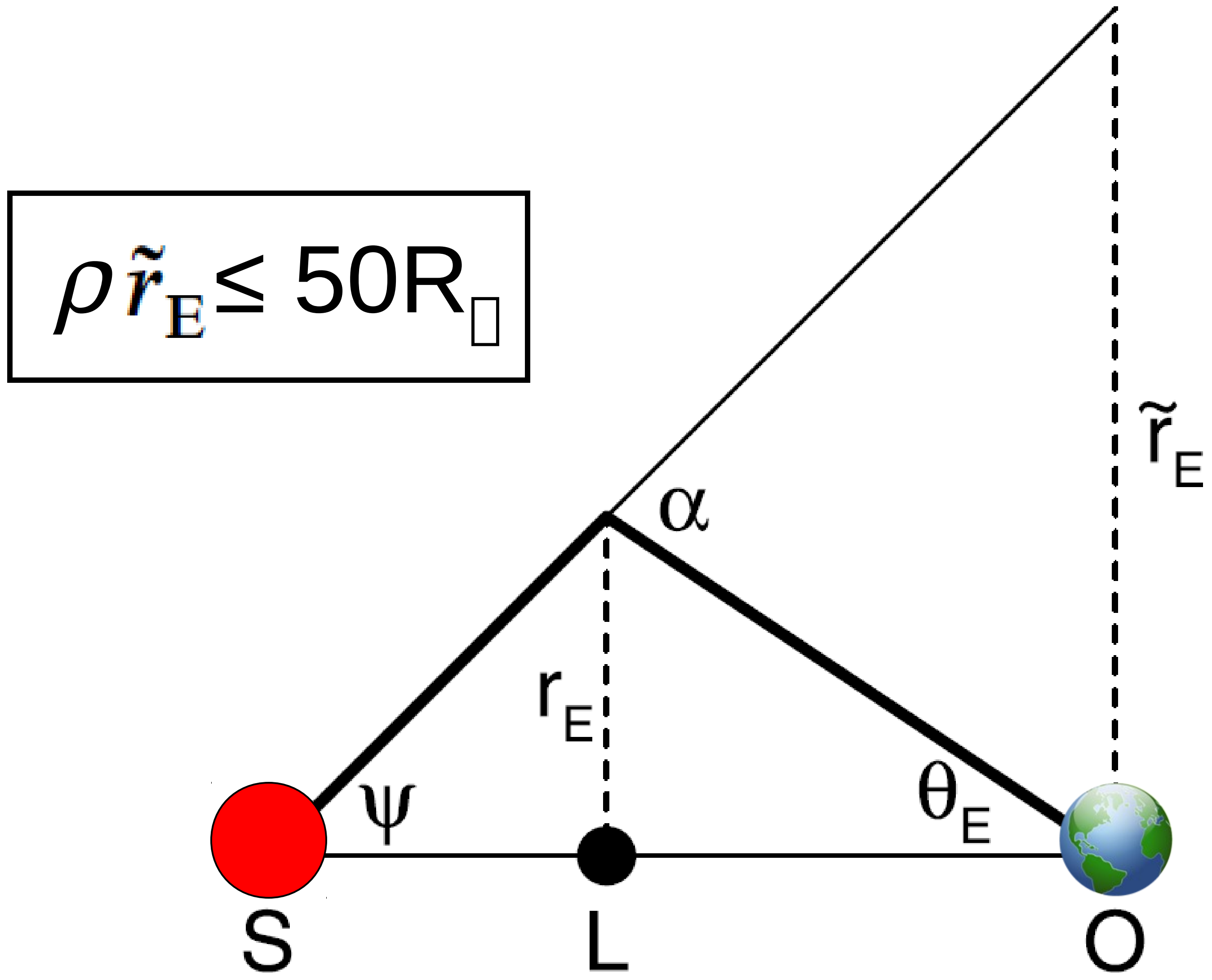
Point Lens



Lens+Planet

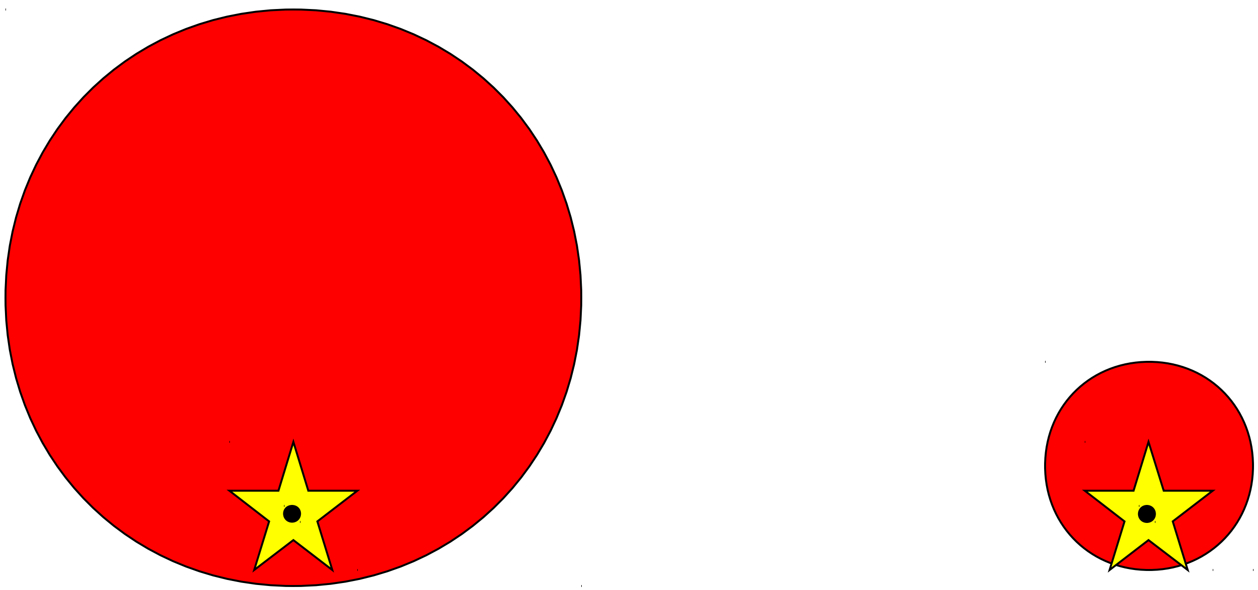






$\rho \tilde{r}_E \leq 50R$
$\tilde{r}_E$
α
r_E
ψ
θ_E
S
L
O

$$\rho\, \tilde{r}_{\mathrm{E}} \leq 50\mathrm{R}_{\square}$$



$$\rho\,\tilde{r}_{\mathrm{E}} \leq 50\mathrm{R}_{\square}$$