Harvard-Smithsonian
Center for Astrophysics

Microlensing Surveys: Techniques and Results

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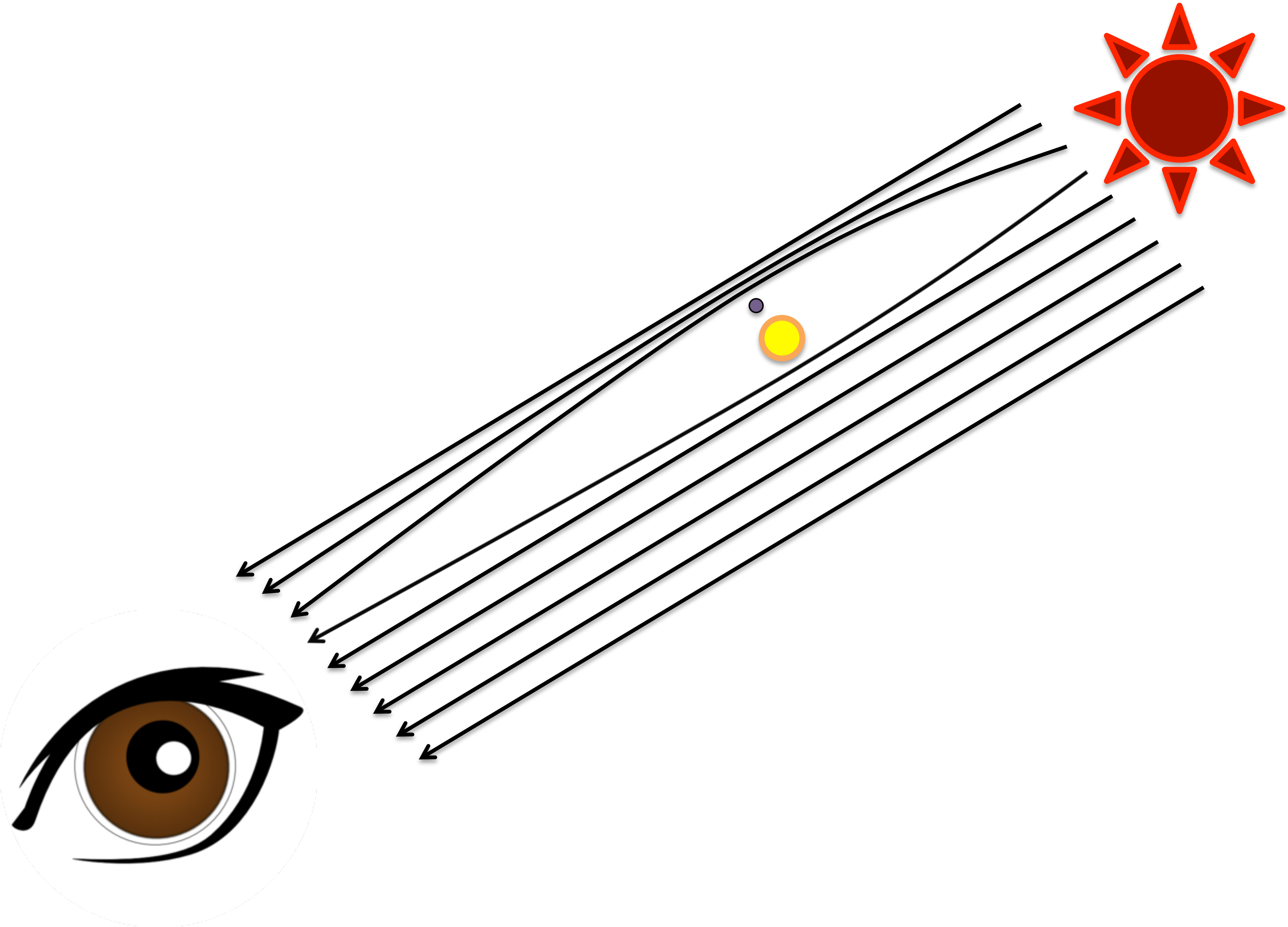
OGLE
MOA
SPITZER SPACE TELESCOPE
KOREA MICROLENSING TELESCOPE NETWORK

LCOGT.net
PLANET
Probing Lensing Anomalies NETwork
MiNDSTEp
MicroFUN
Microlensing Follow-Up Network



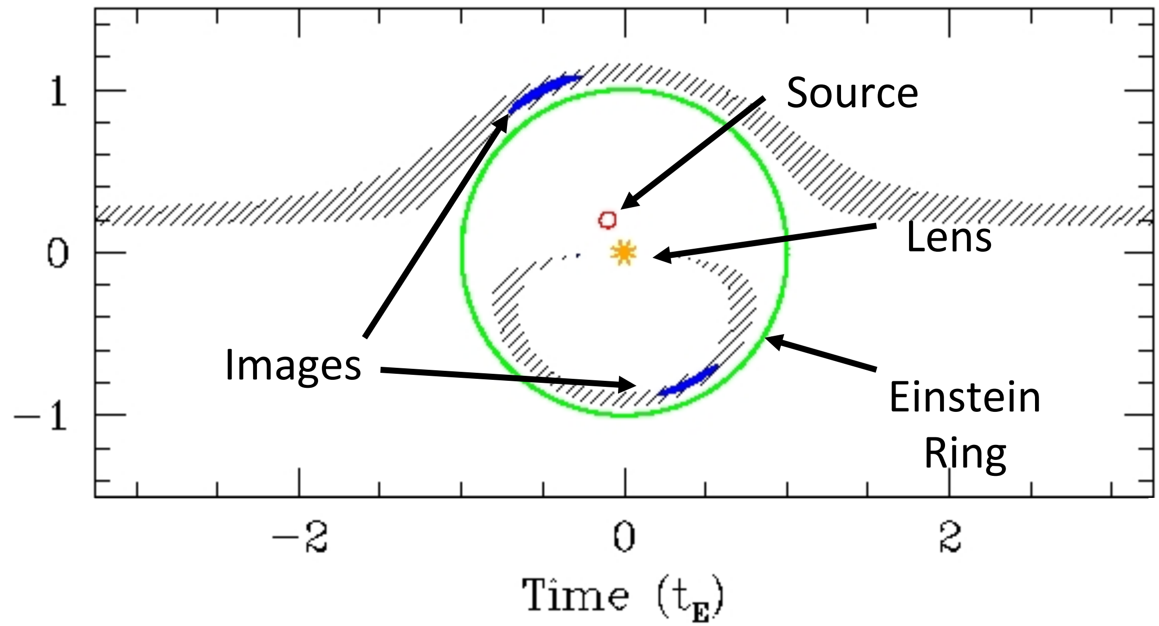
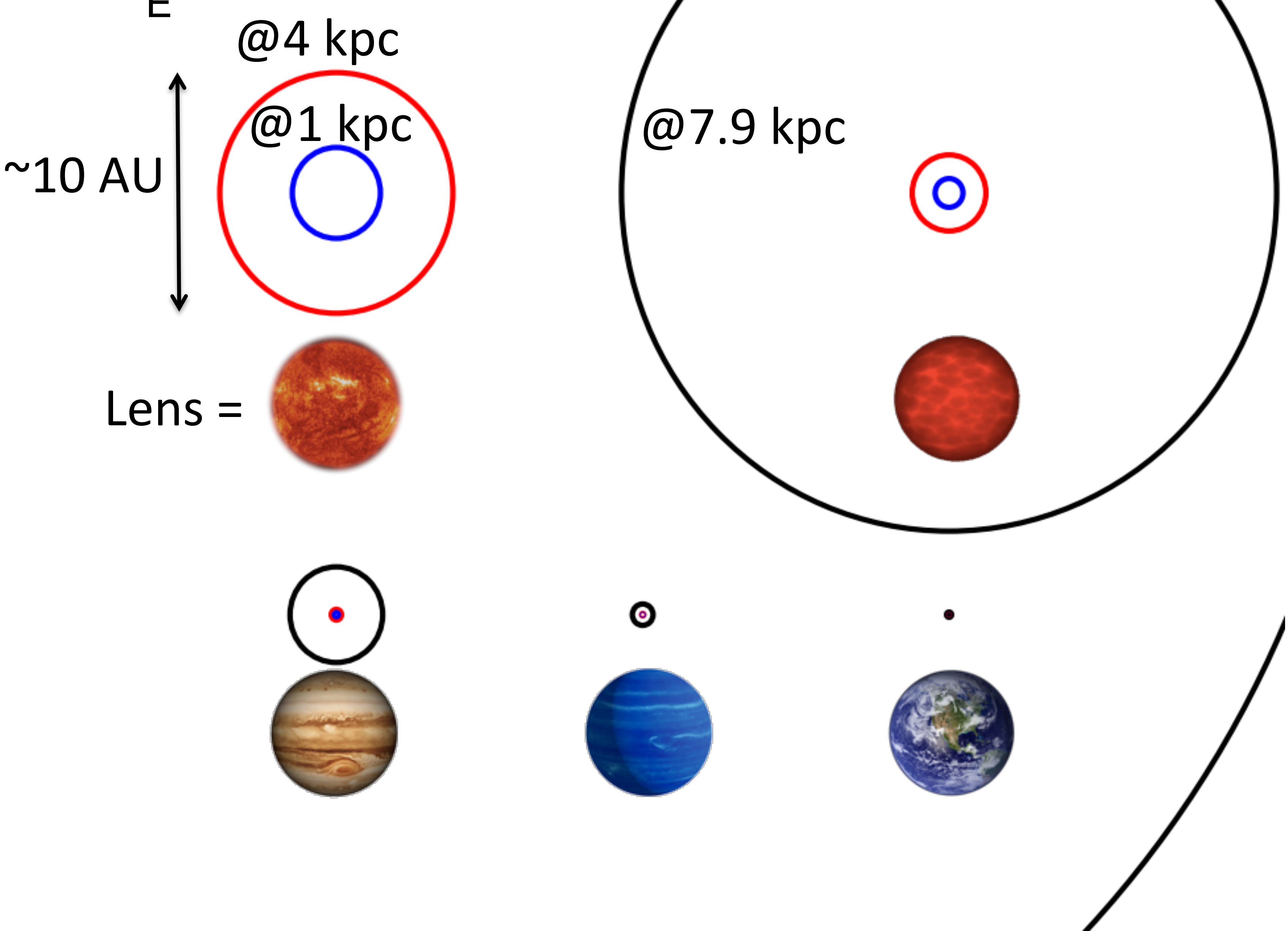


Image courtesy of B. Scott Gaudi
http://www.astronomy.ohio-state.edu/
~gaudi/movies.html

$\tilde{r}_E$ (and θ_E) depends on M_L and D_L



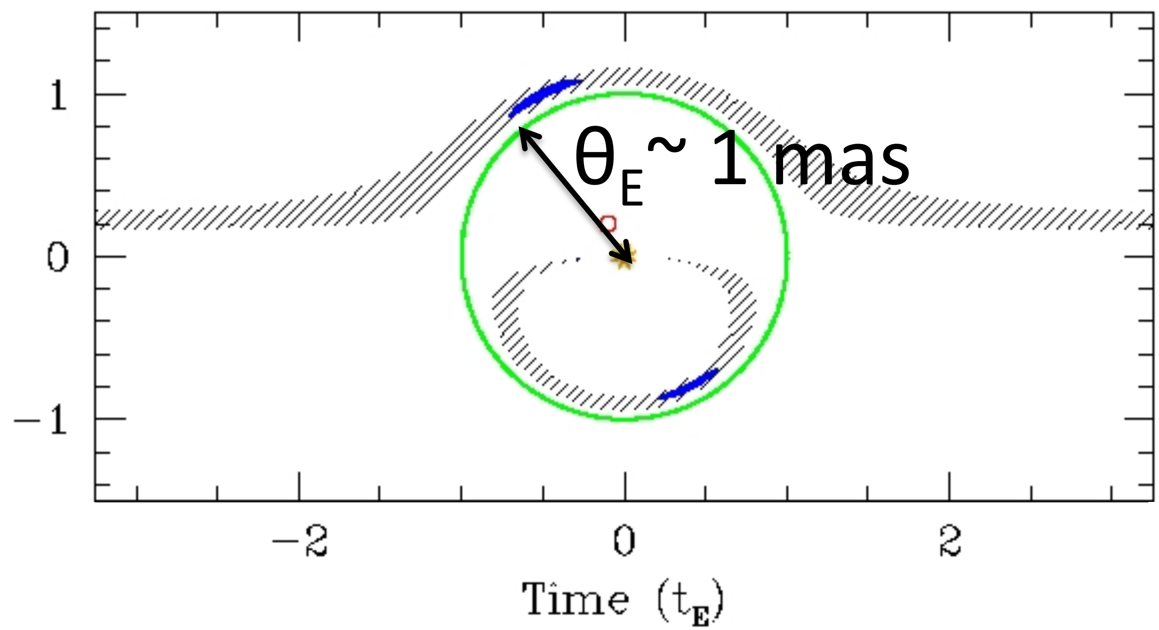


Image courtesy of B. Scott Gaudi
http://www.astronomy.ohio-state.edu/~gaudi/movies.html

Even in the most favorable cases … there is no great chance of observing this phenomenon.

– Albert Einstein 1936

Because θ_E~1 mas…

1. Microlensing should "never" occur.

2. The images can’t be resolved.

Because θ_E~1 mas…

1. Microlensing should "never" occur.

   → Never say “never.”

2. The images can’t be resolved.

   → Lensing also *magnifies* the source.

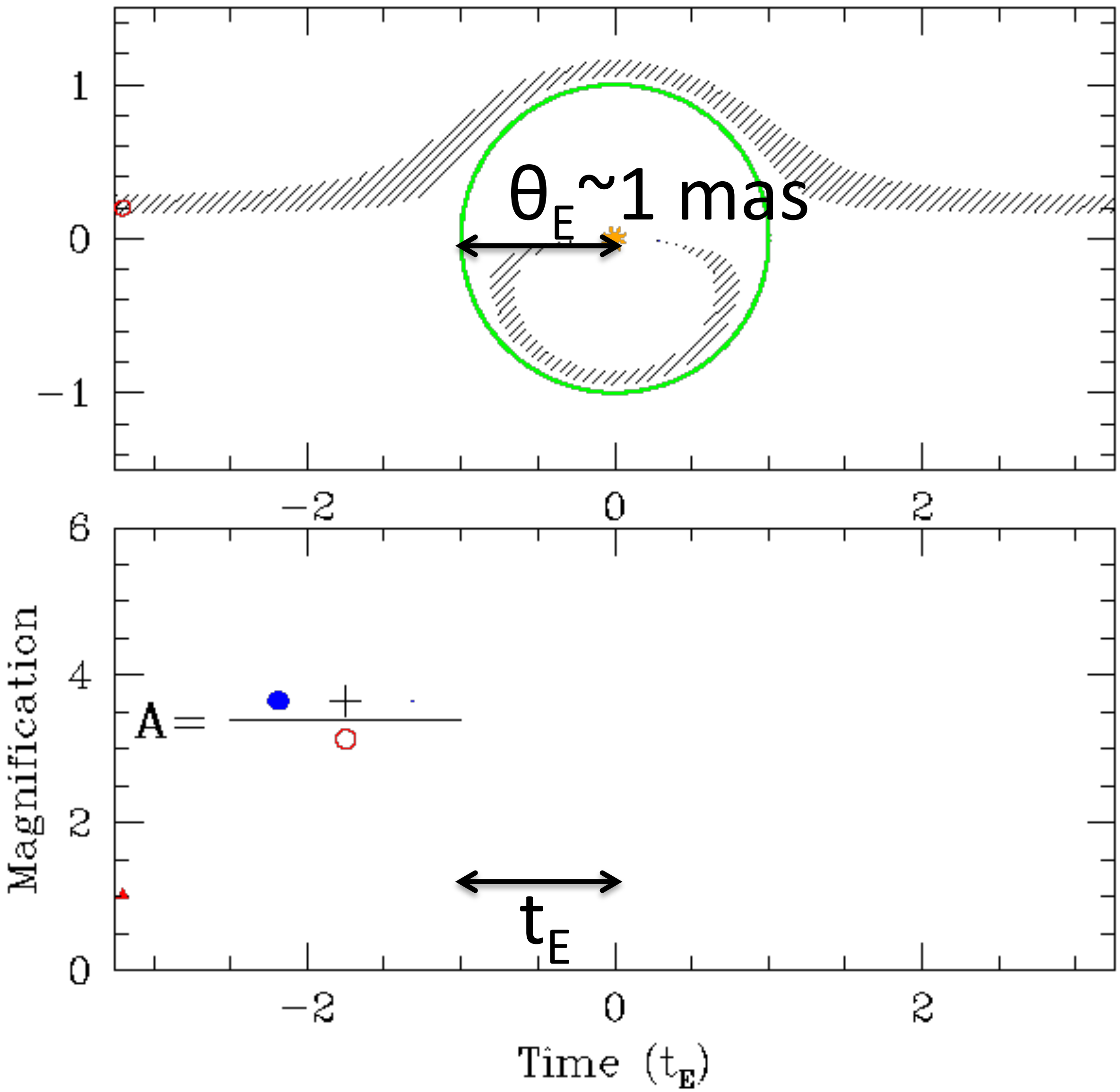
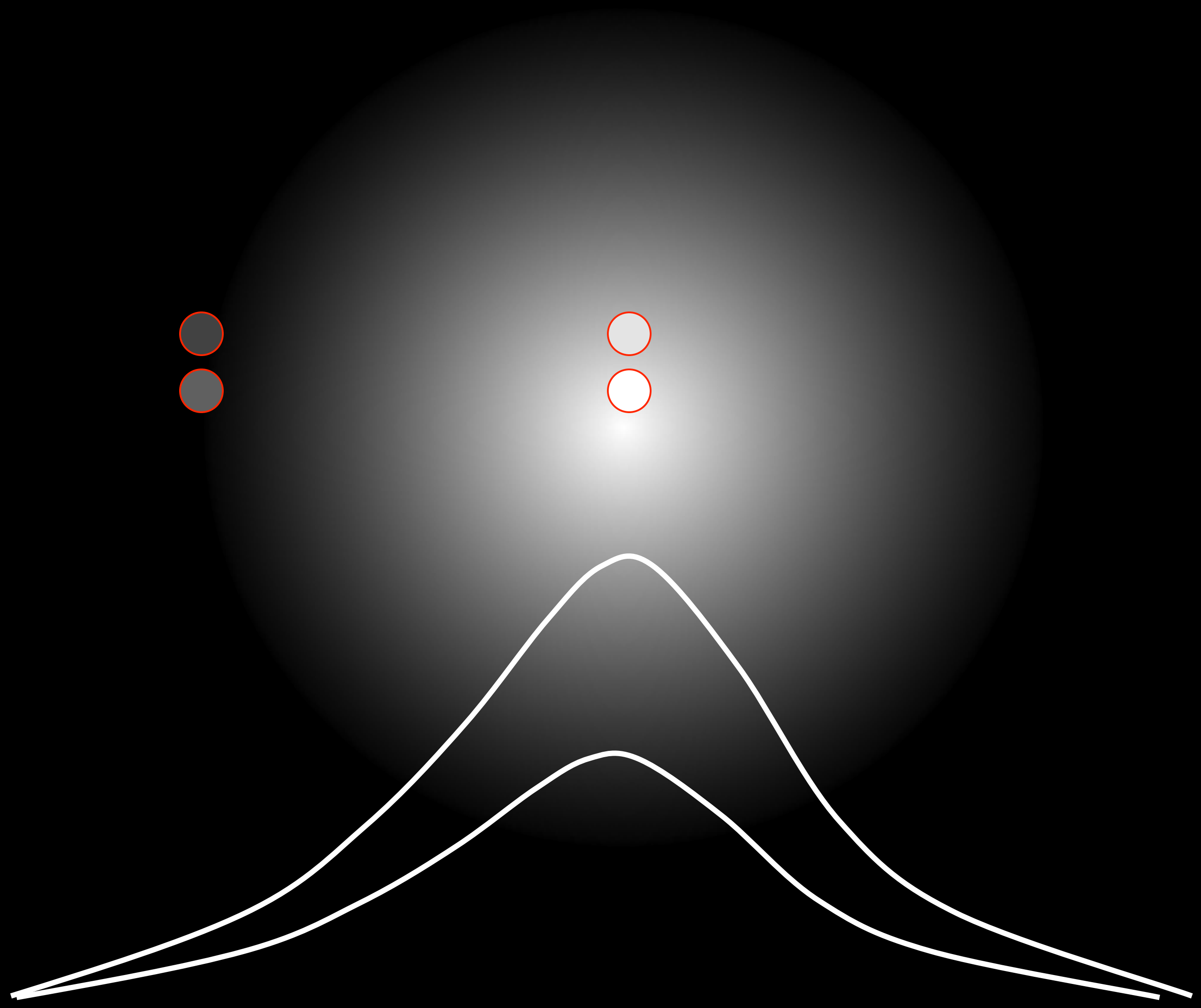
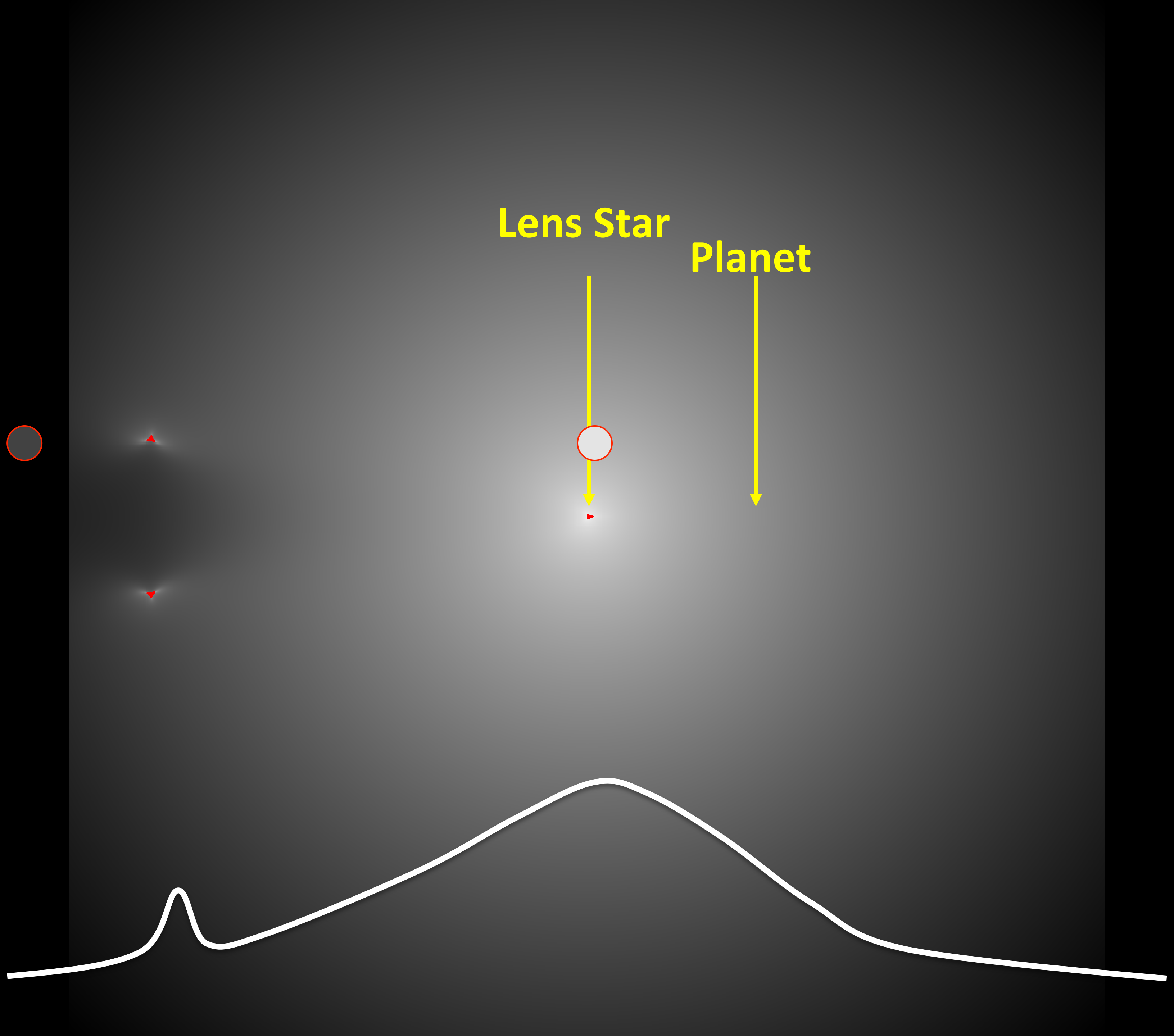


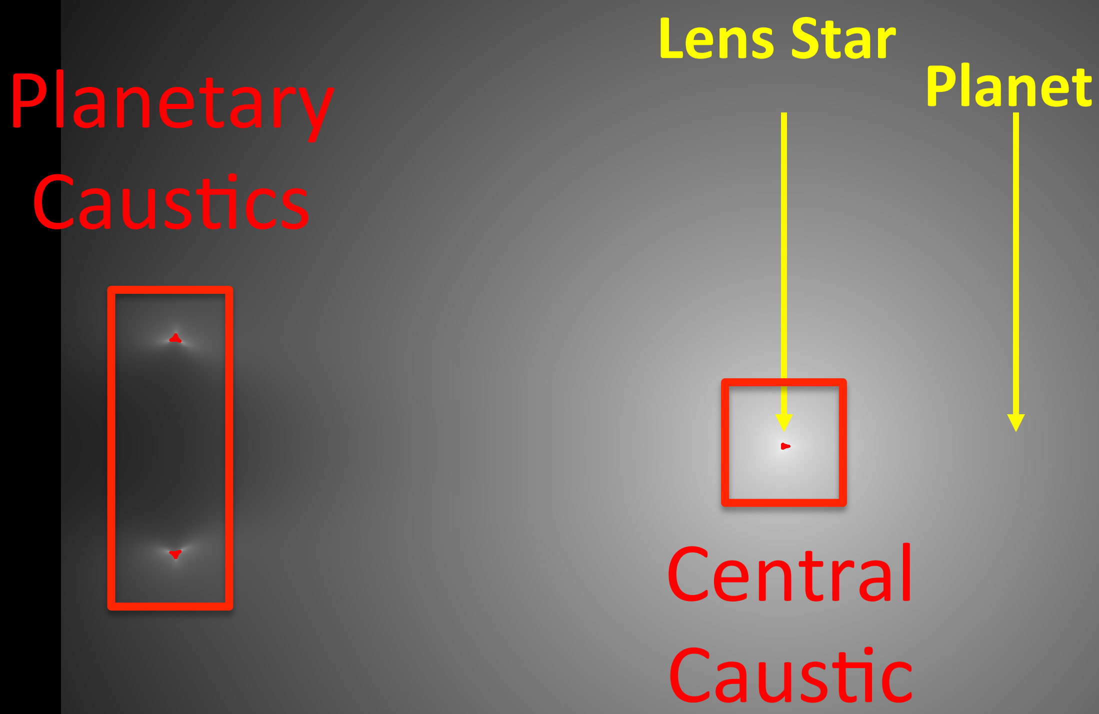
Image courtesy of B. Scott Gaudi
http://www.astronomy.ohio-state.edu/~gaudi/movies.html

Magnification Map

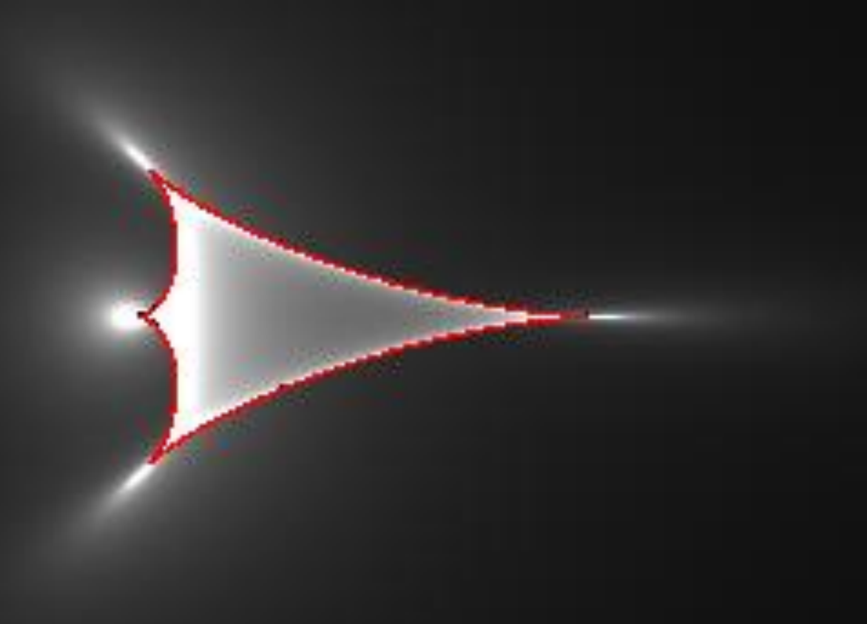


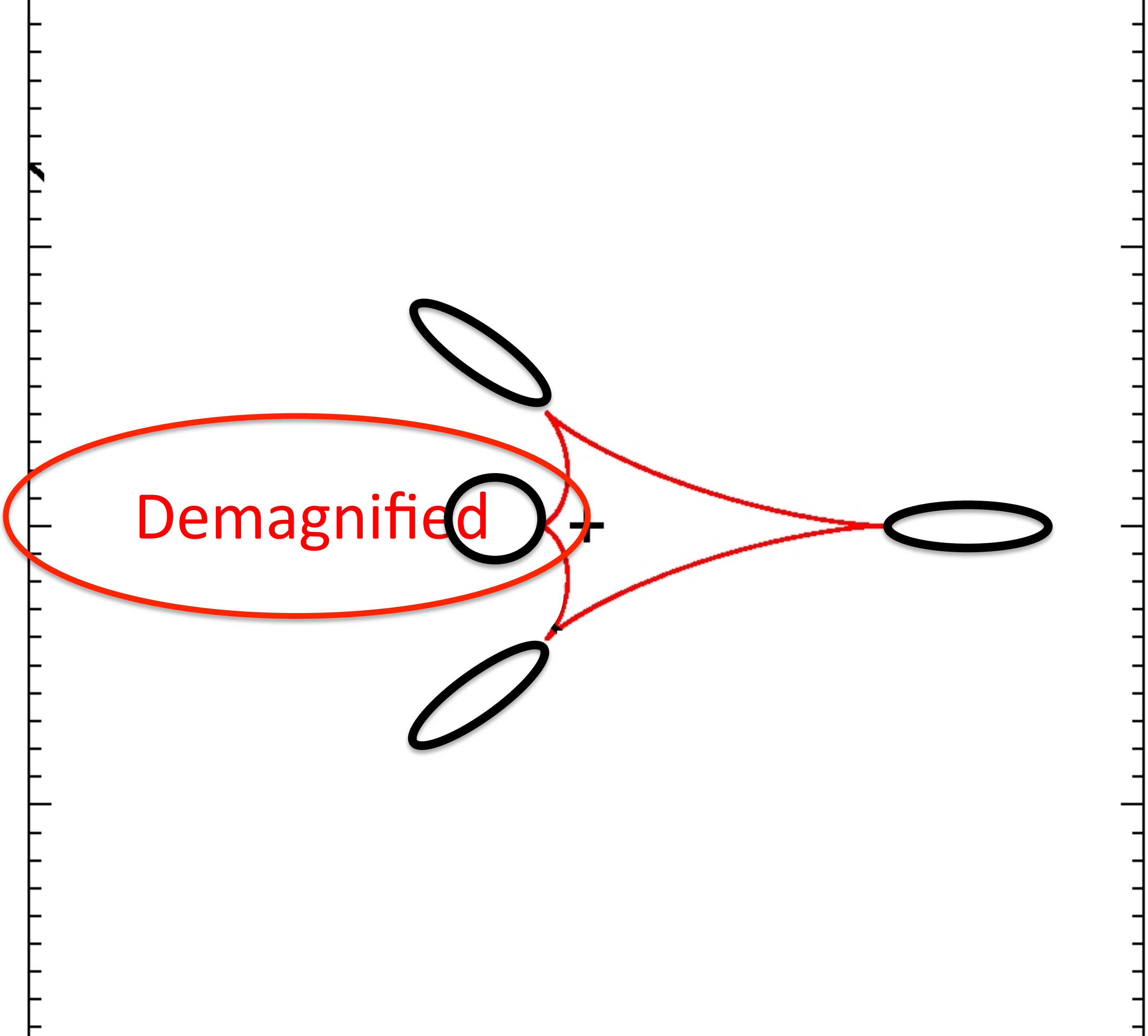

Lens Star
Planet

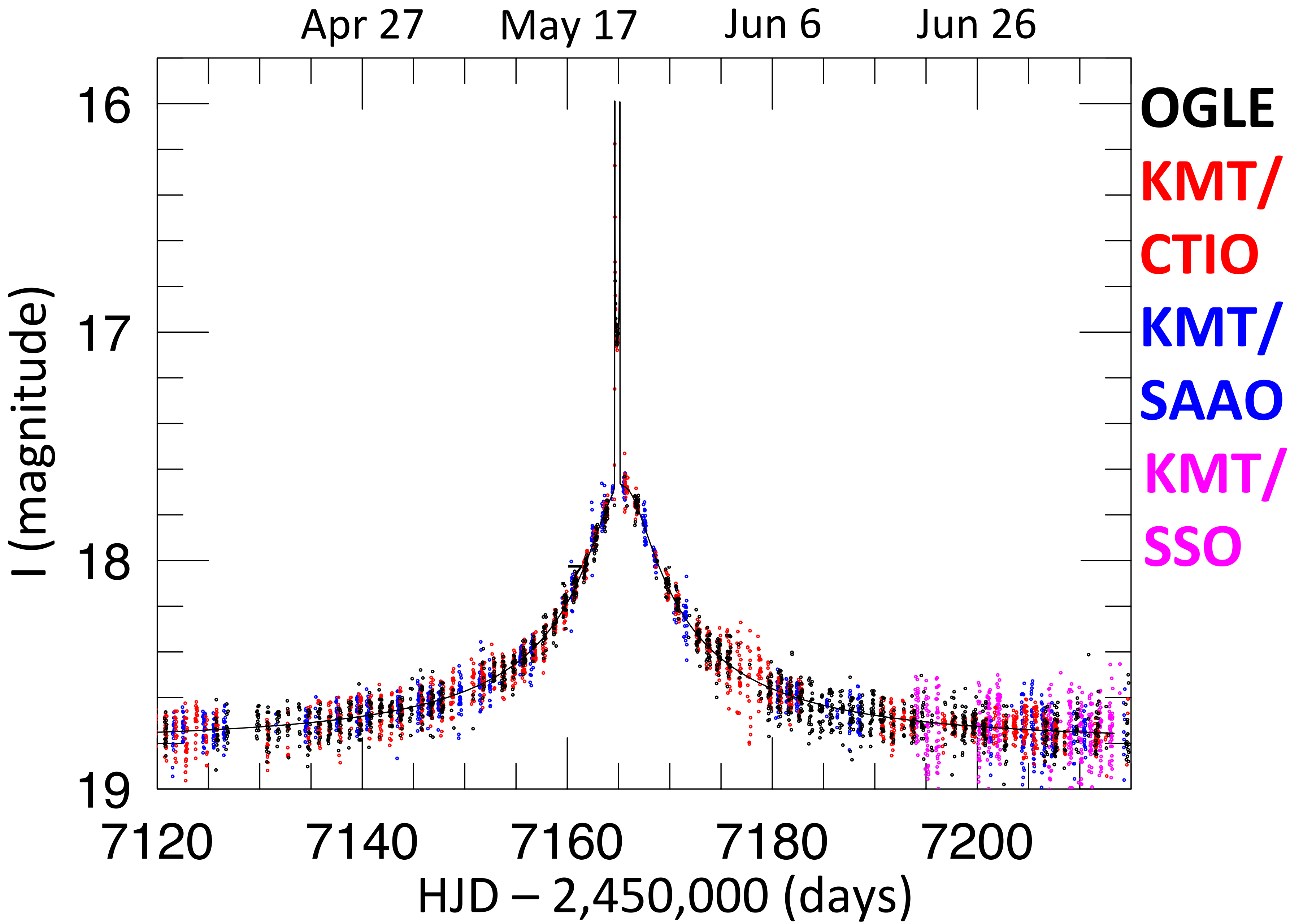
A planet makes 2 sets of caustics



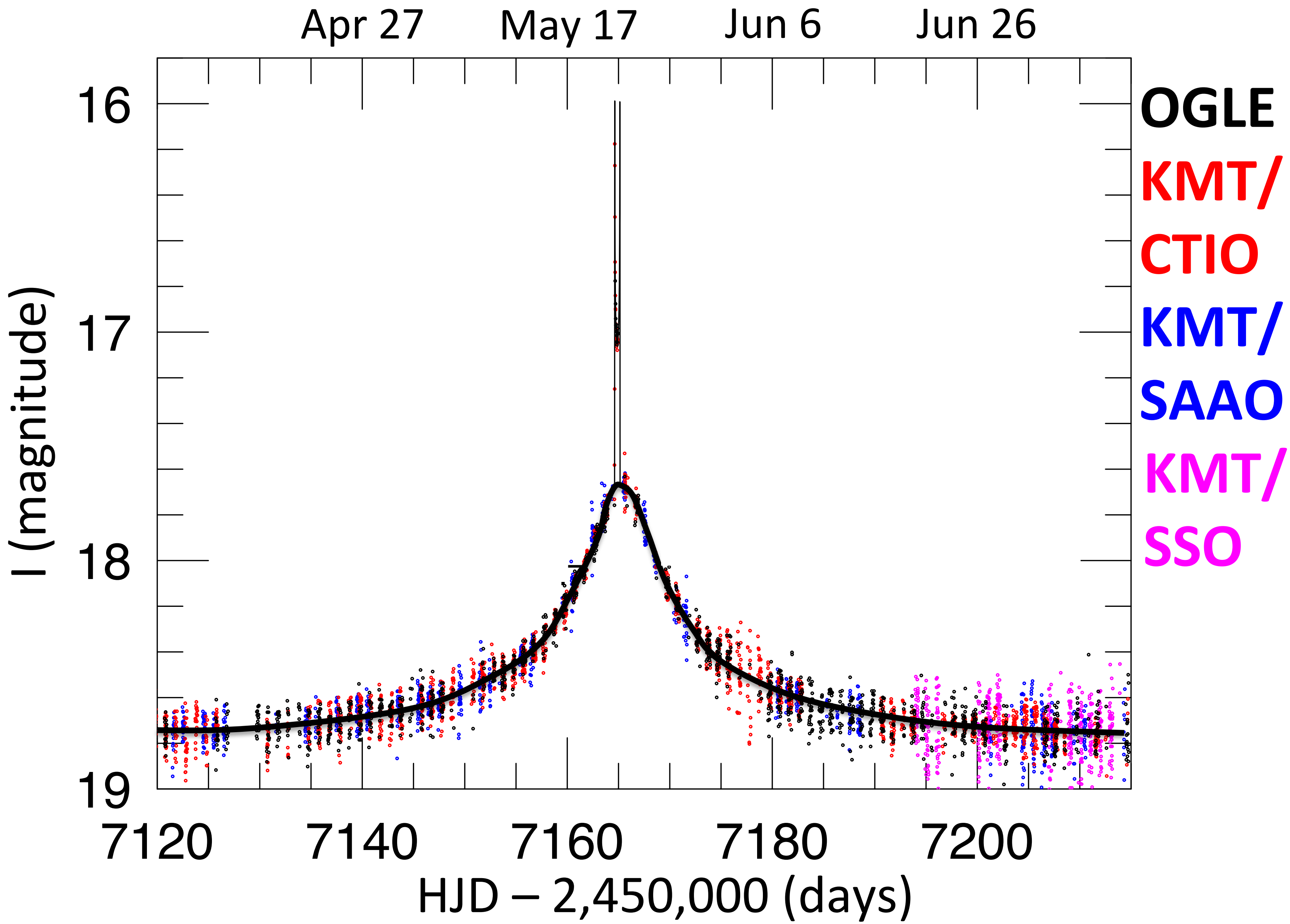
The magnification diverges to infinty at a caustic.



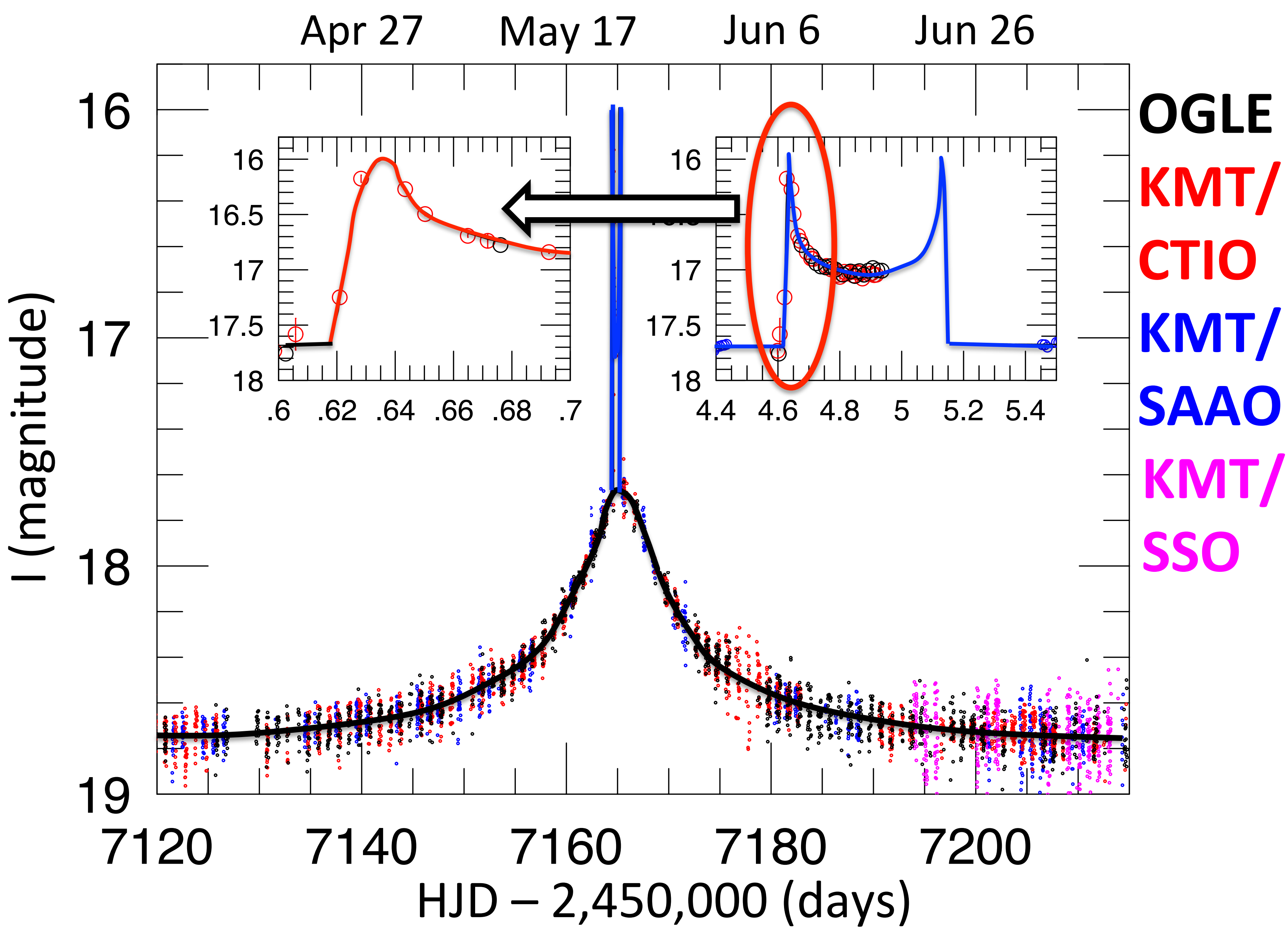

Demagnified



Shin et al. 2016, JKAS, in press

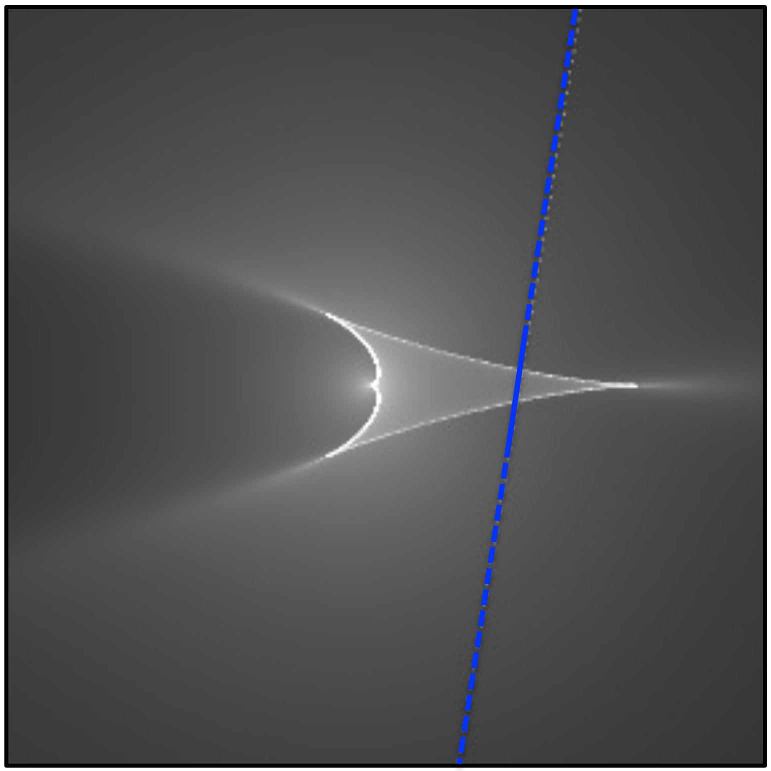


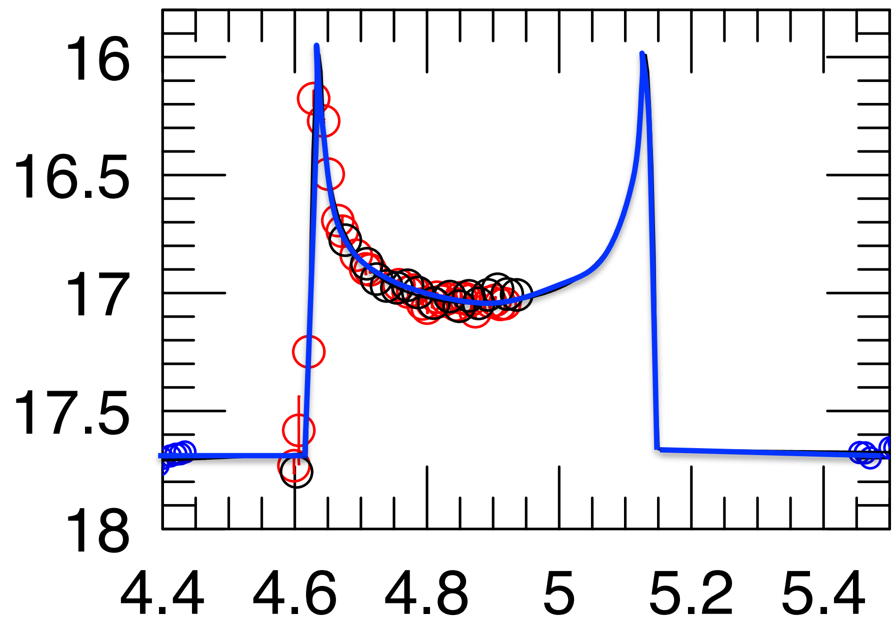
Shin et al. 2016, JKAS, in press

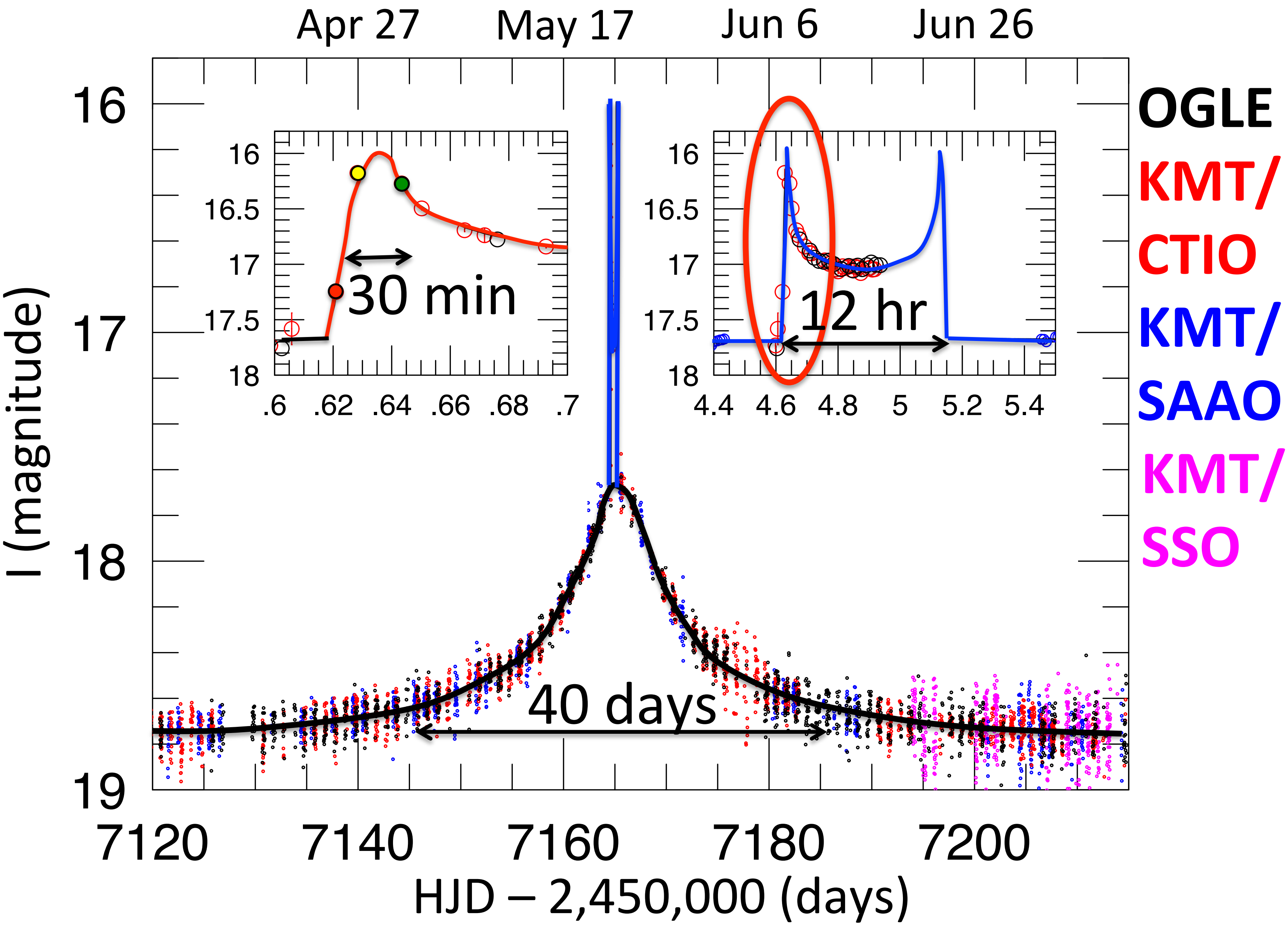


Shin et al. 2016, JKAS, in press

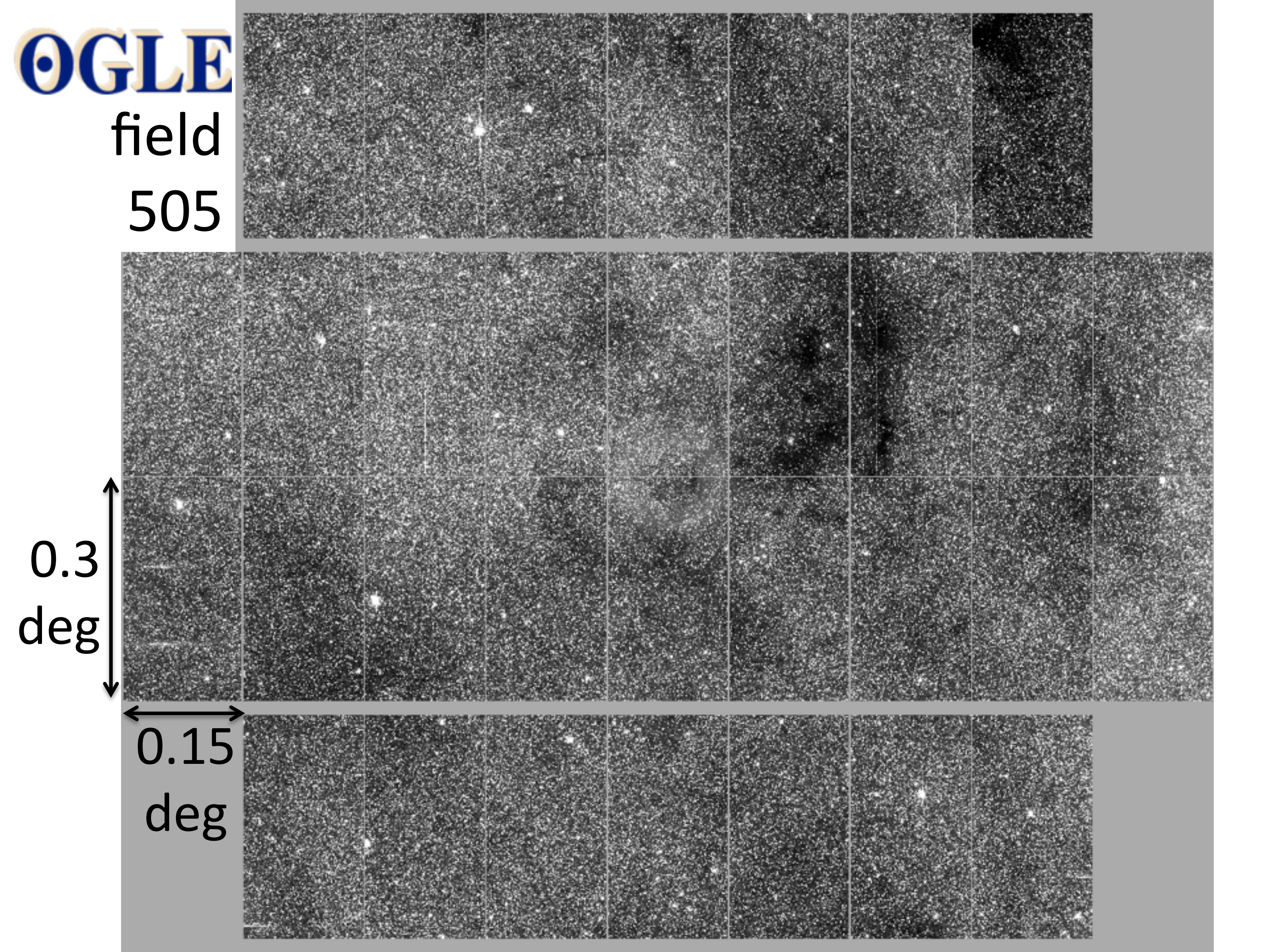
The magnification map reflects the distortion due to the lens



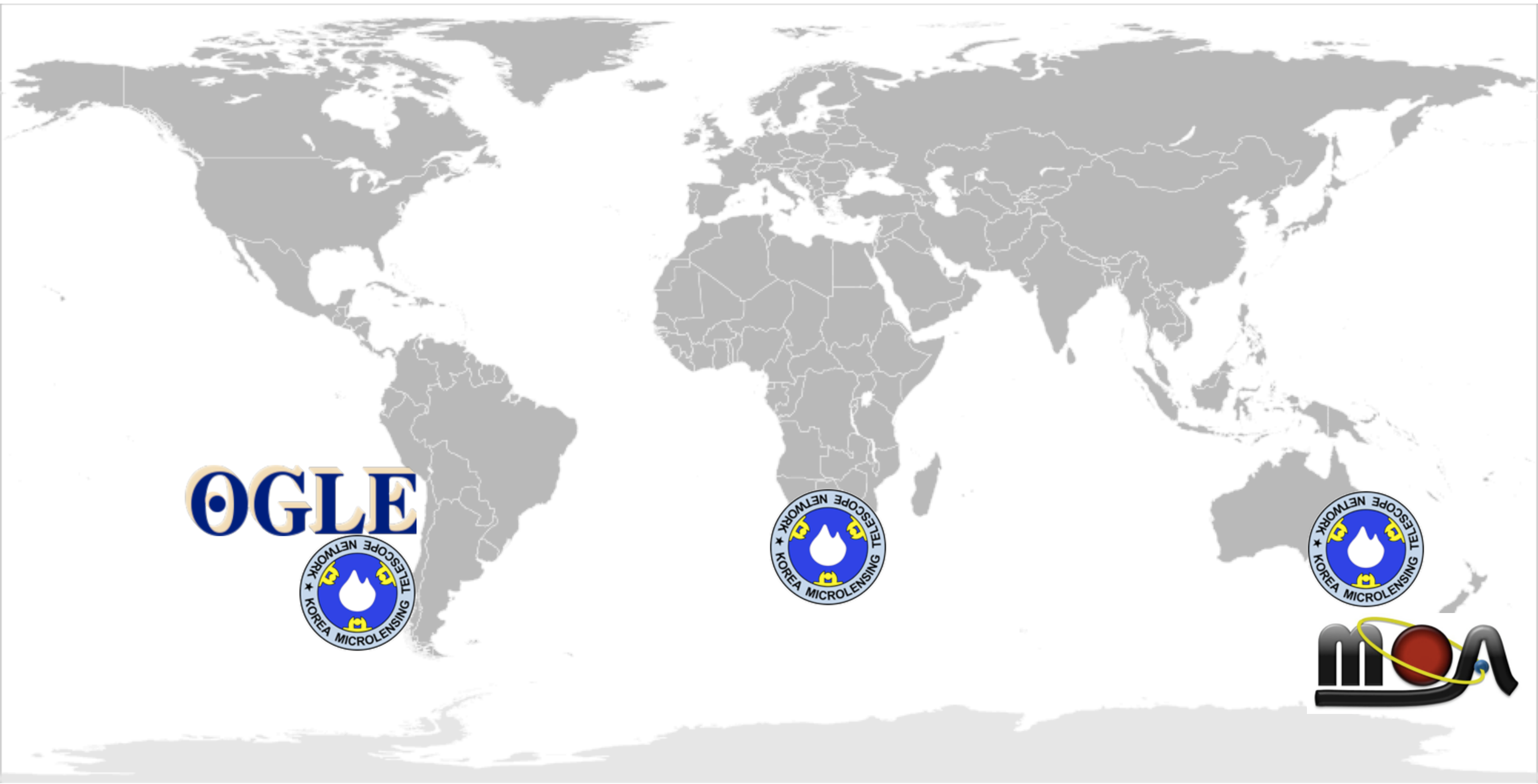




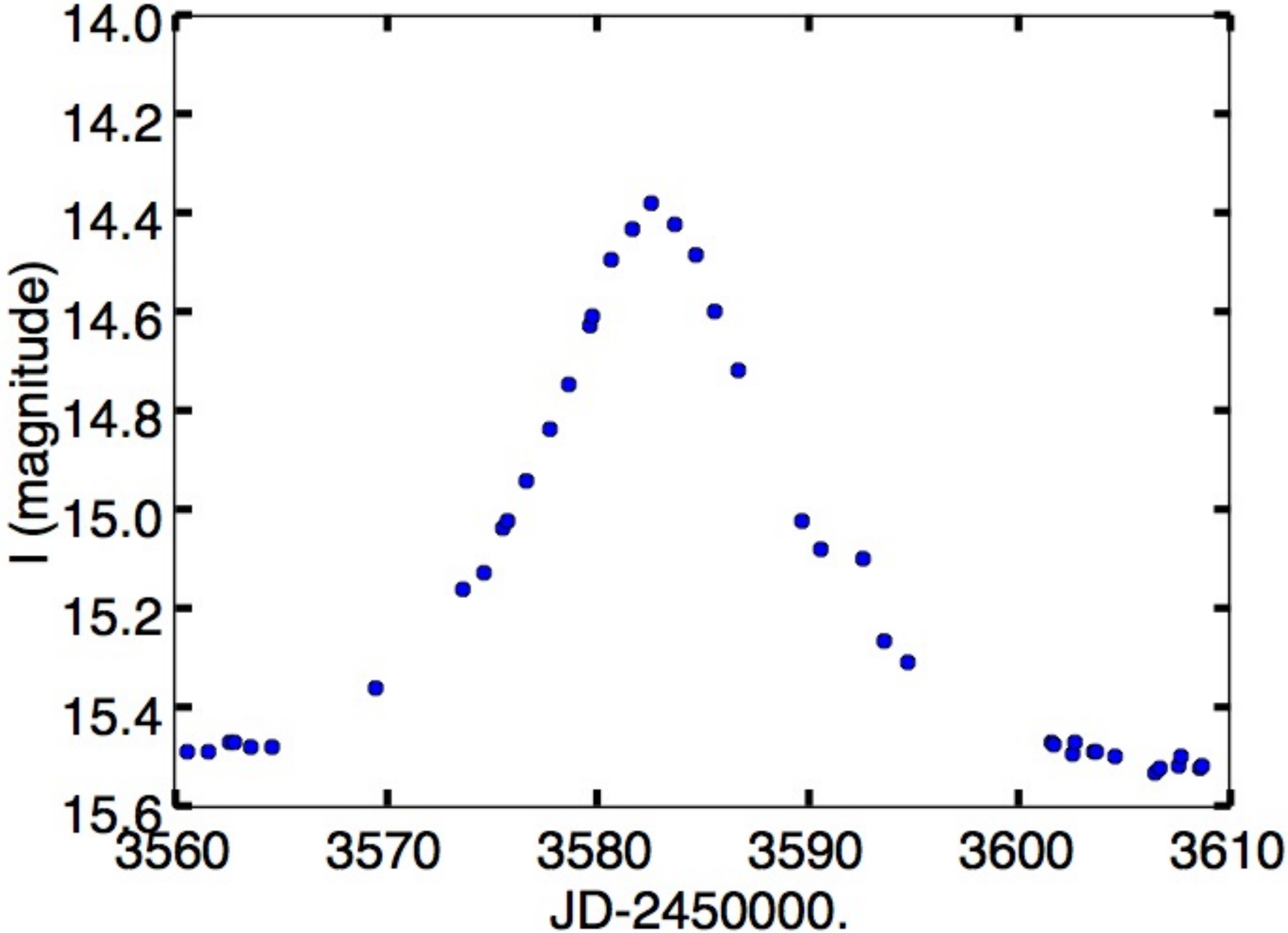
Shin et al. 2016, JKAS, in press


OGLE
field
505
0.3
deg
0.15
deg

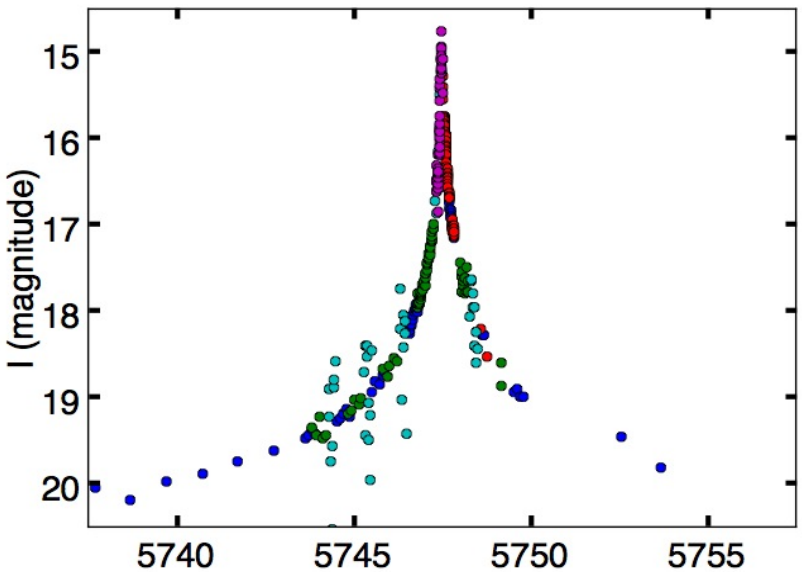
Main Wide-Field Microlensing Surveys

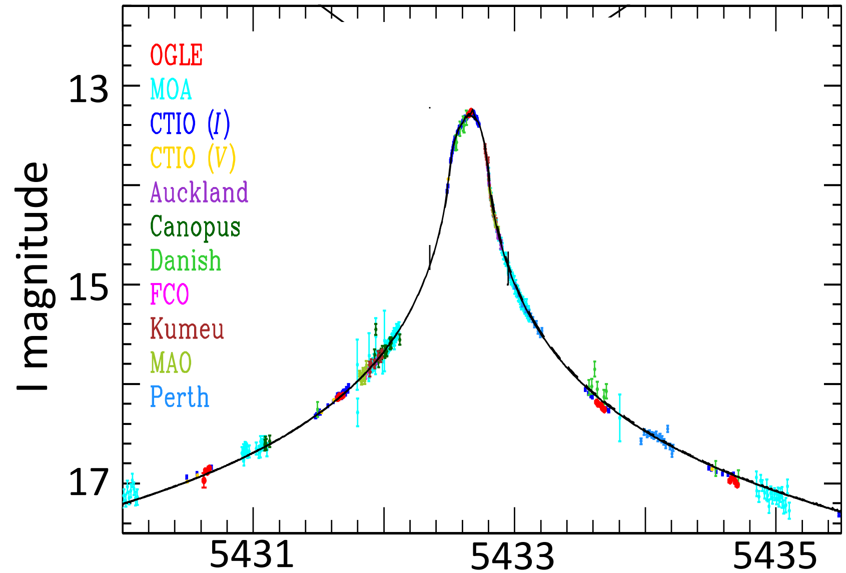


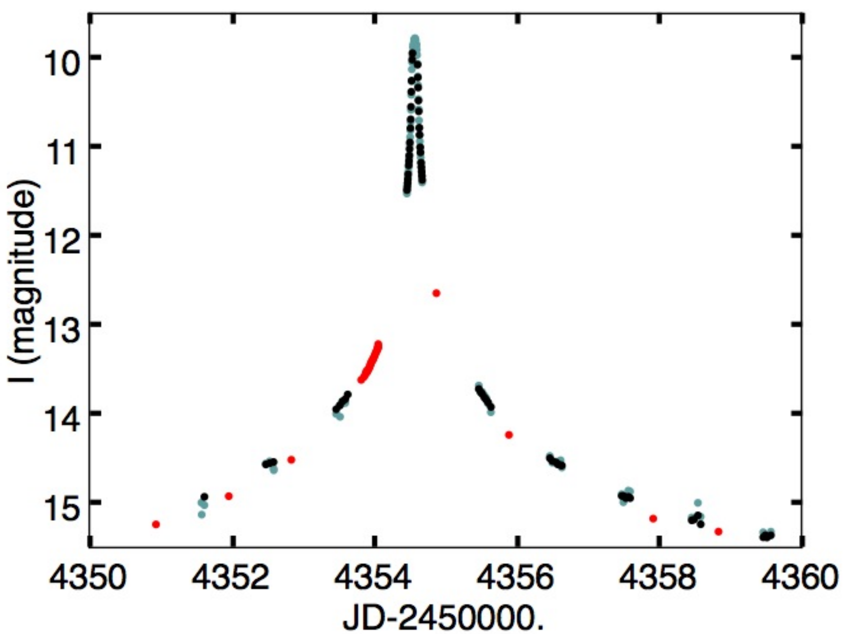
Is there a planet in my data?

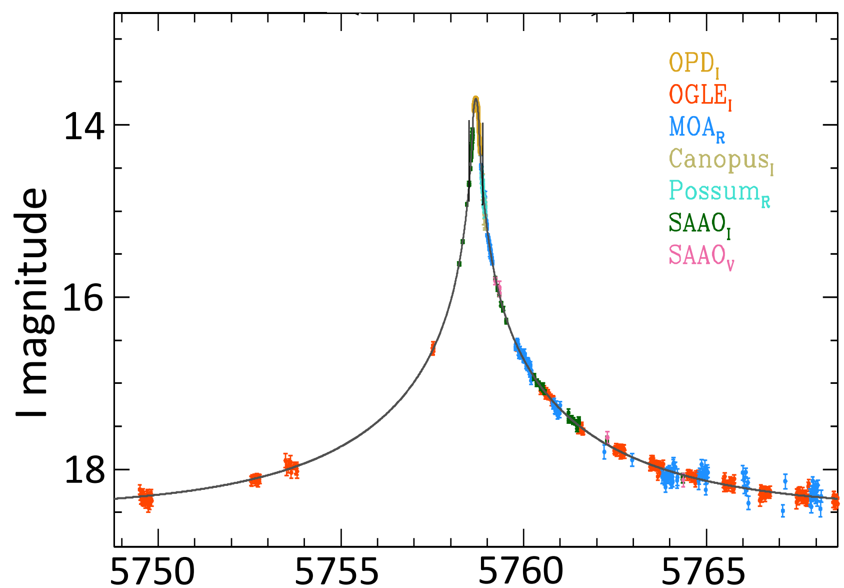


How many planets?

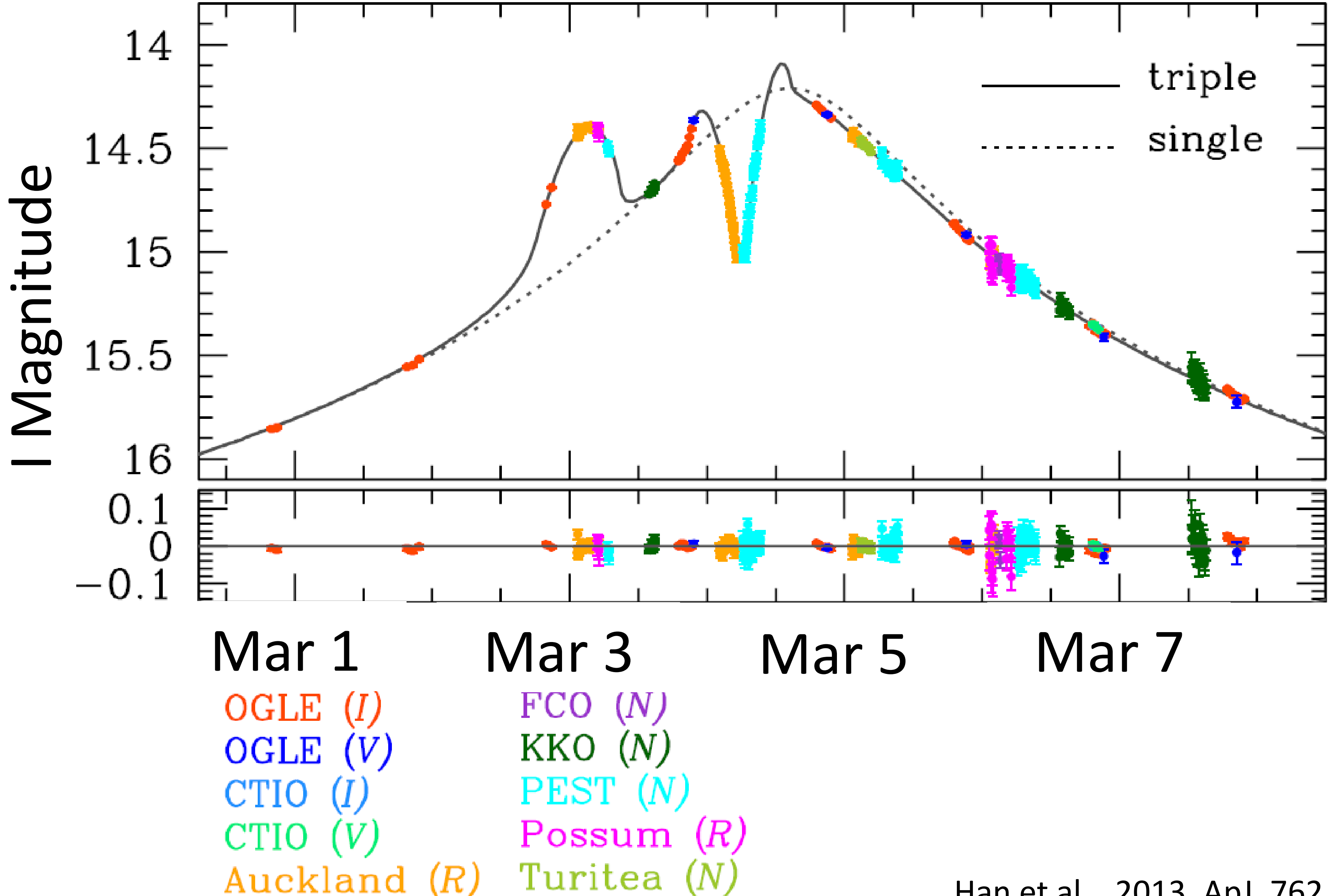








How many planets?



Han et al. , 2013, ApJ, 762, 28

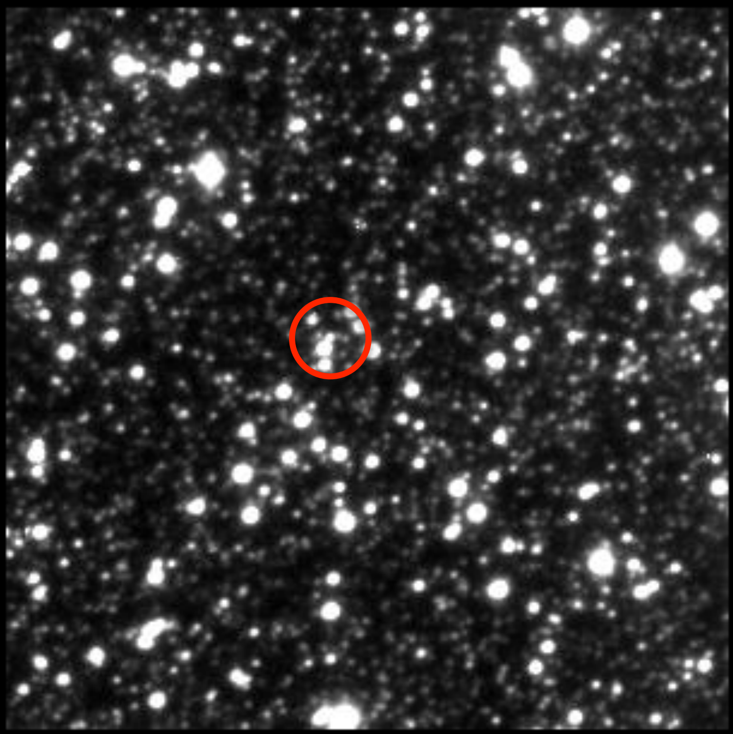
Planetary Observables Are Measured *Relative* To the Host Star

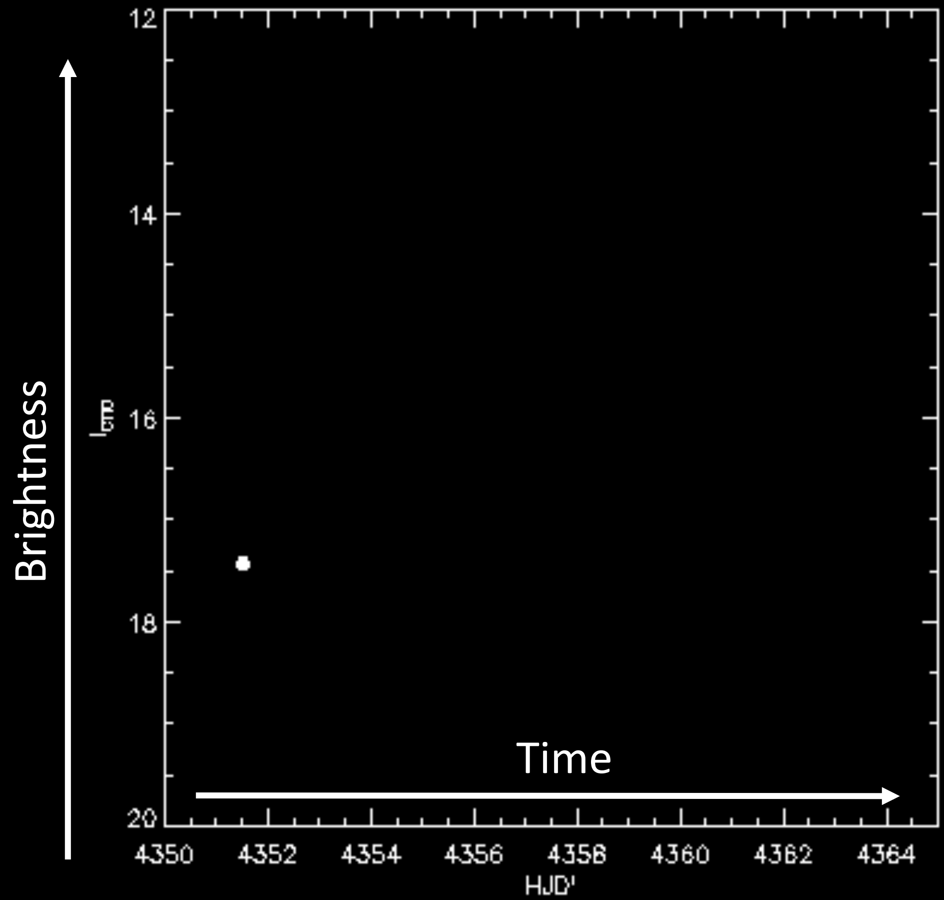
Microlensing $$q = \frac{m_p}{M_*}$$

Radial Velocity $$K \propto \frac{m_p \sin i}{M_*^{2/3}}$$

Transits $$\delta = \left(\frac{r_p}{R_*} \right)^2$$

Microlensed photons are from the source!

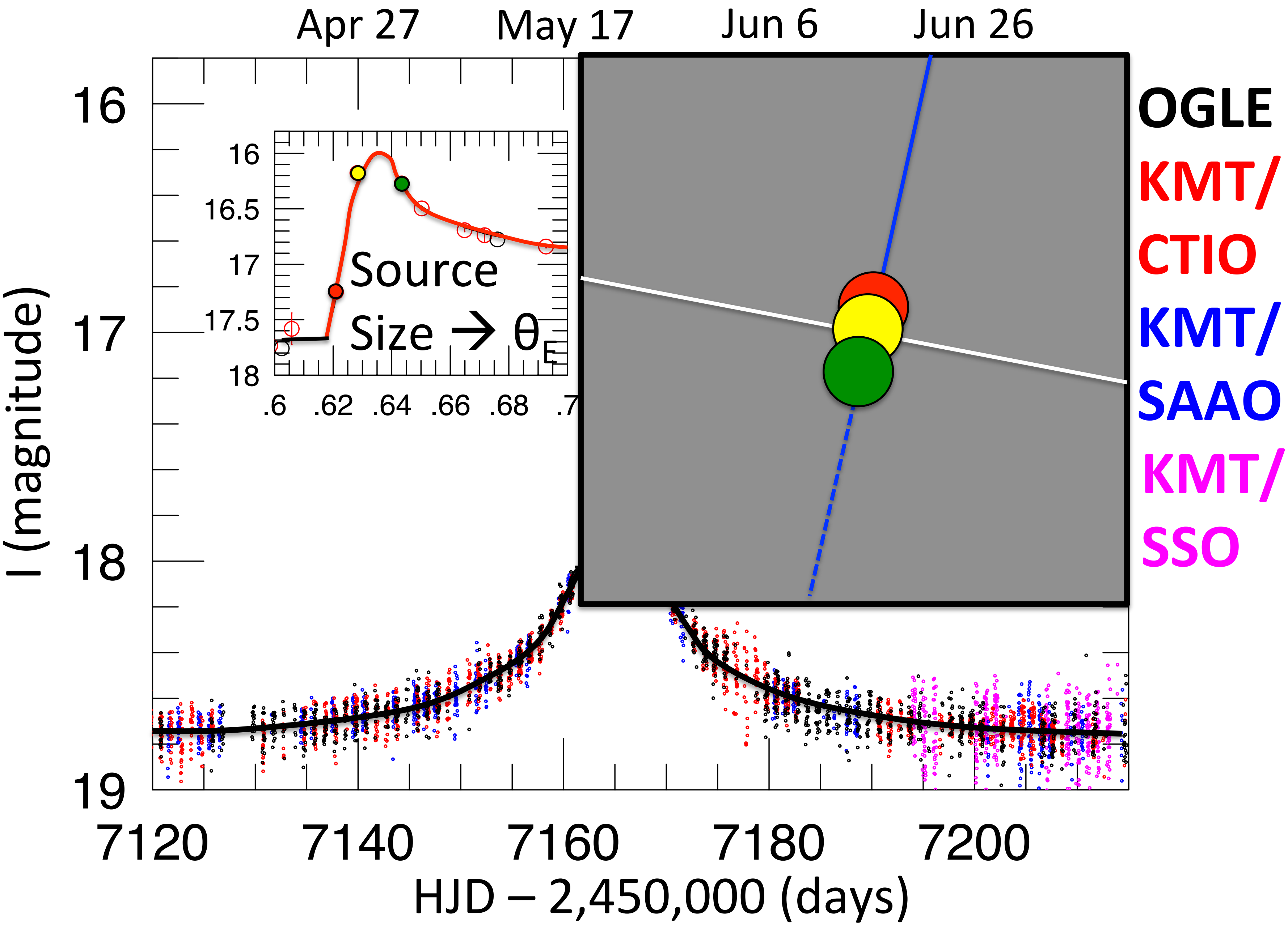




More Information is Needed

$$t_E = \theta_E/\mu$$

$$\rightarrow t_E(M_{star}, D_{lens}, \mu)$$



Shin et al. 2016, JKAS, in press

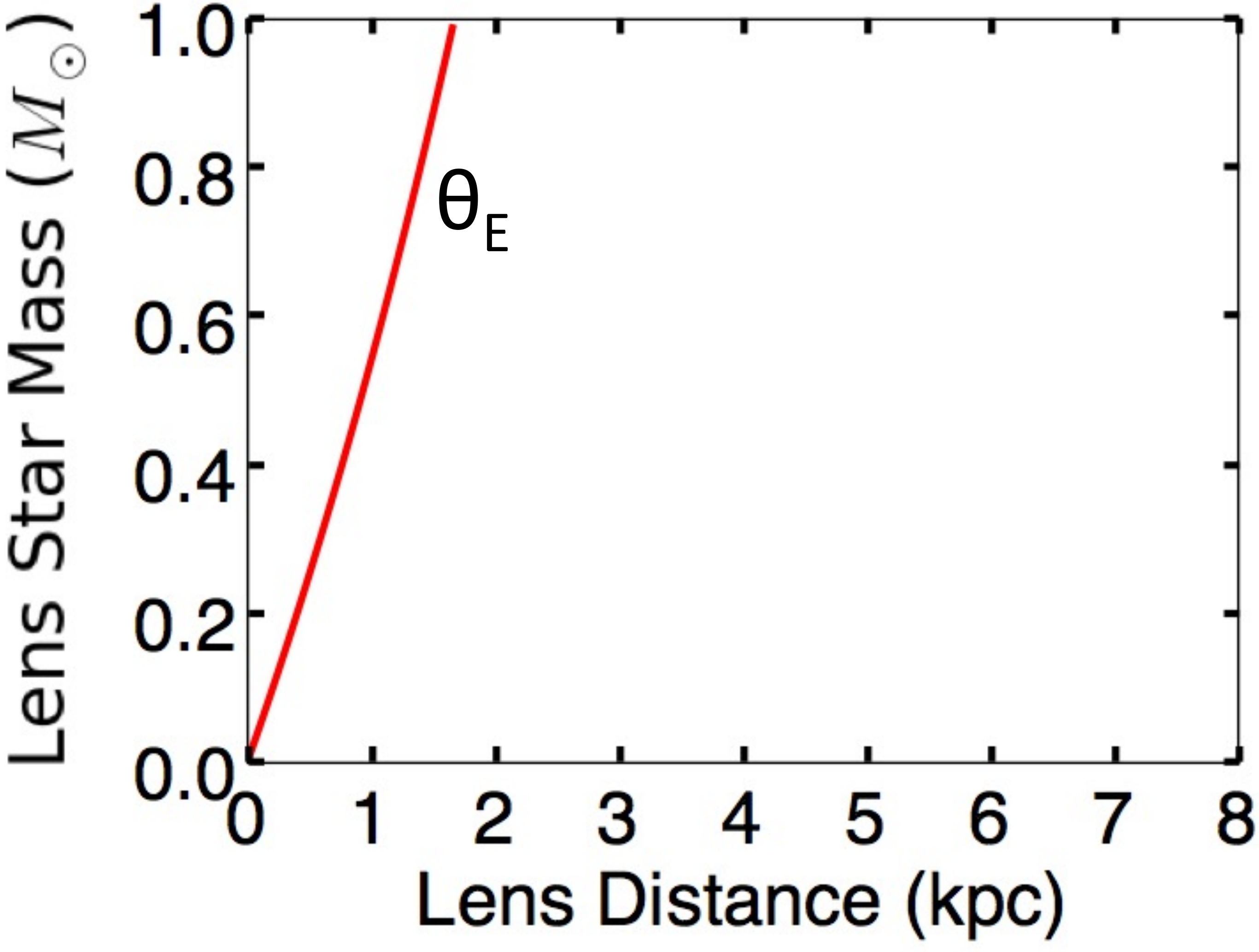
Angular Size of Einstein Ring

Microlens Parallax

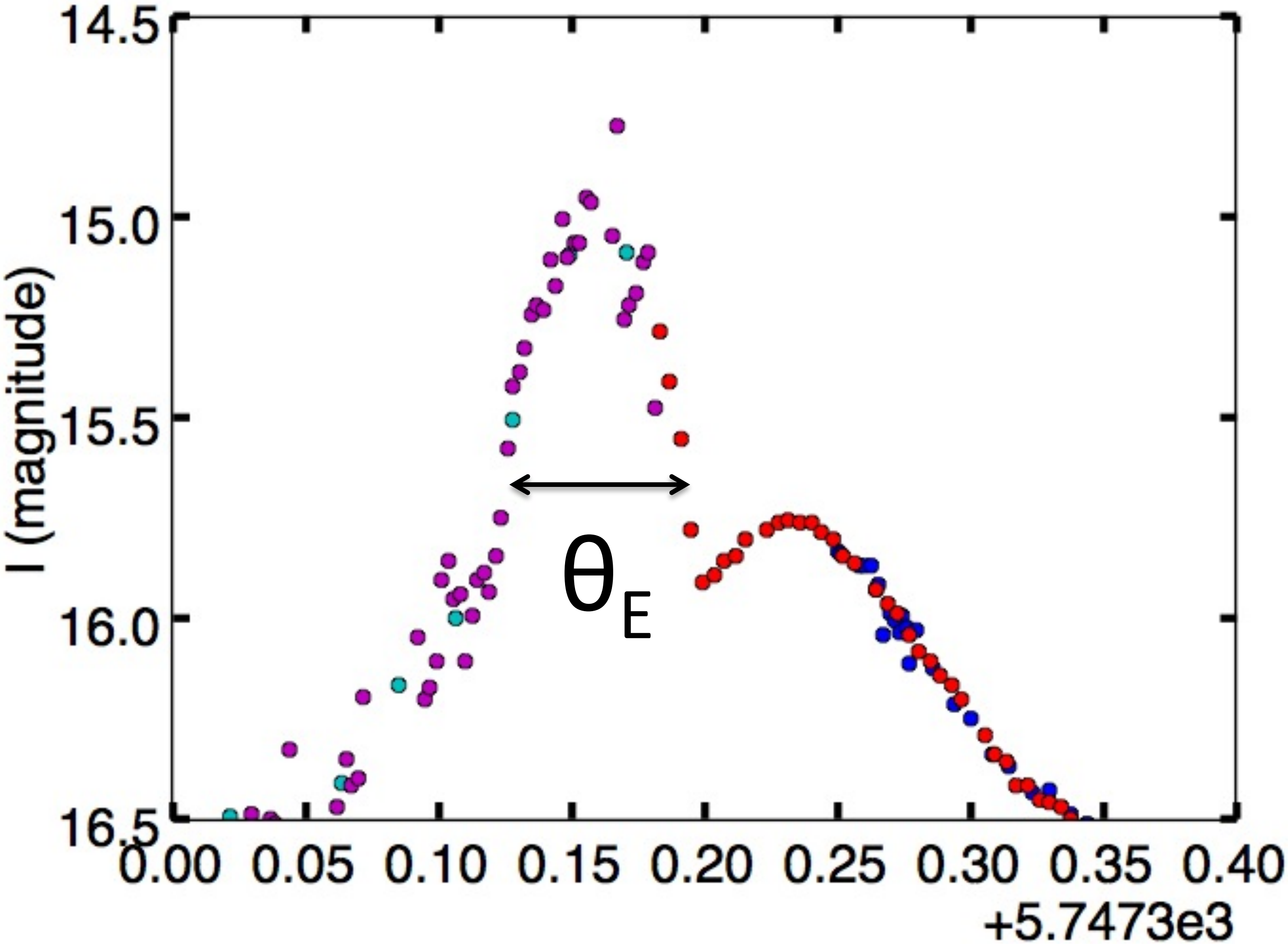
$$M_{star} = \theta_E / (\kappa \pi_E)$$

κ = constant

θ_E → nearby lens

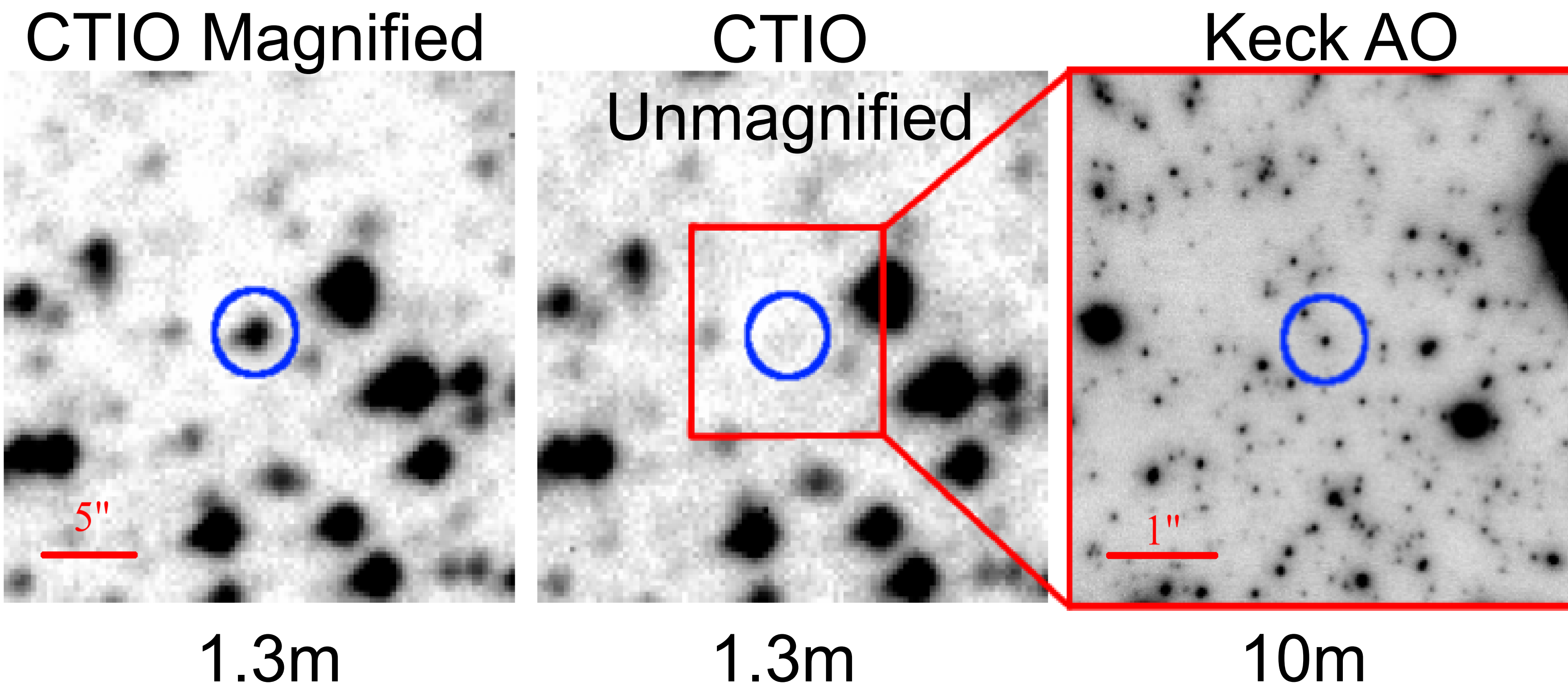


θ_E is half the necessary information



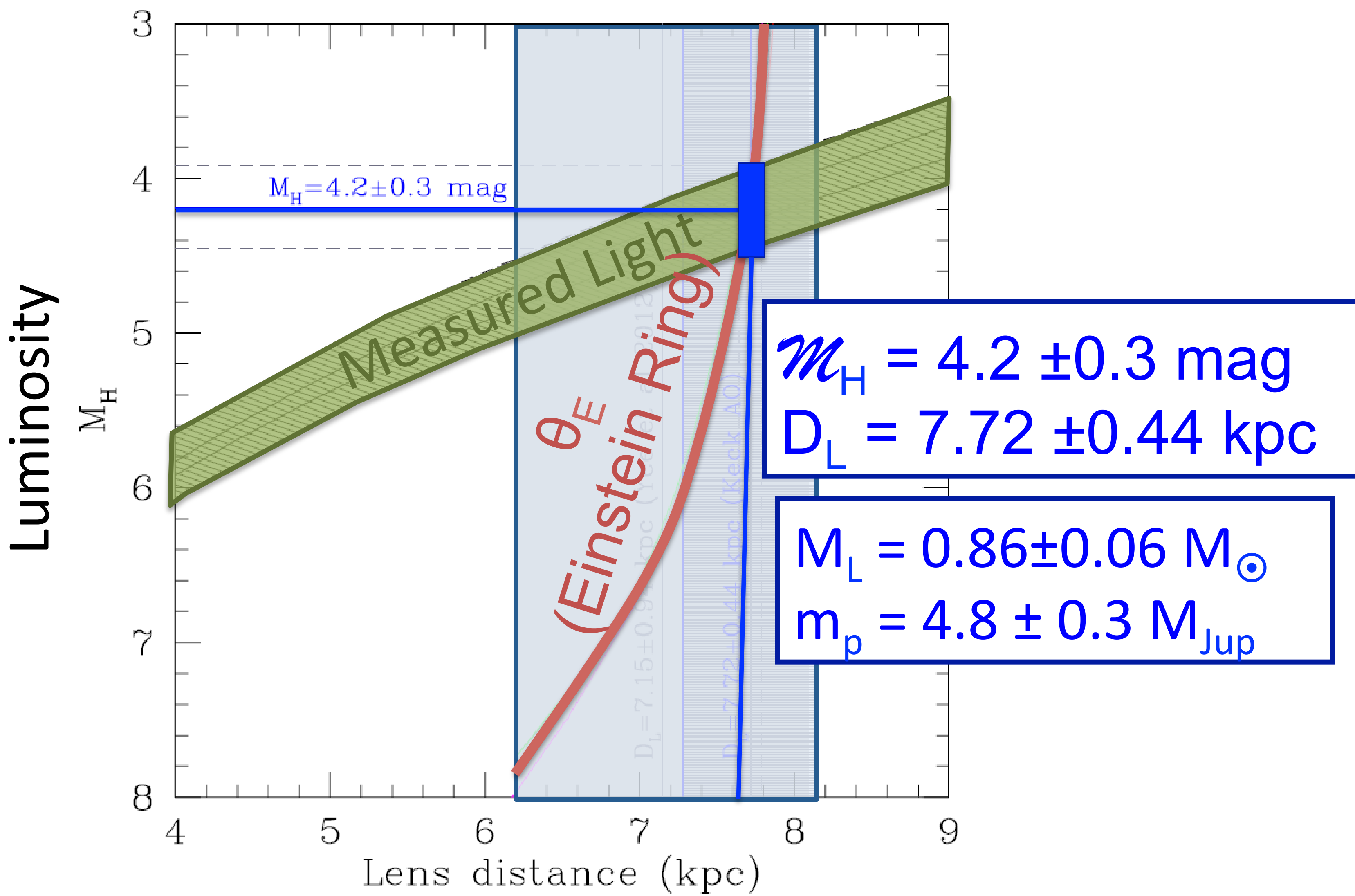
Yee et al. 2012 ApJ 755, 102

Measuring the Lens Flux is Hard



Batista et al. (incl. Yee) 2014, ApJ, 780, 54

AO Mass Constraints - 293



Distance

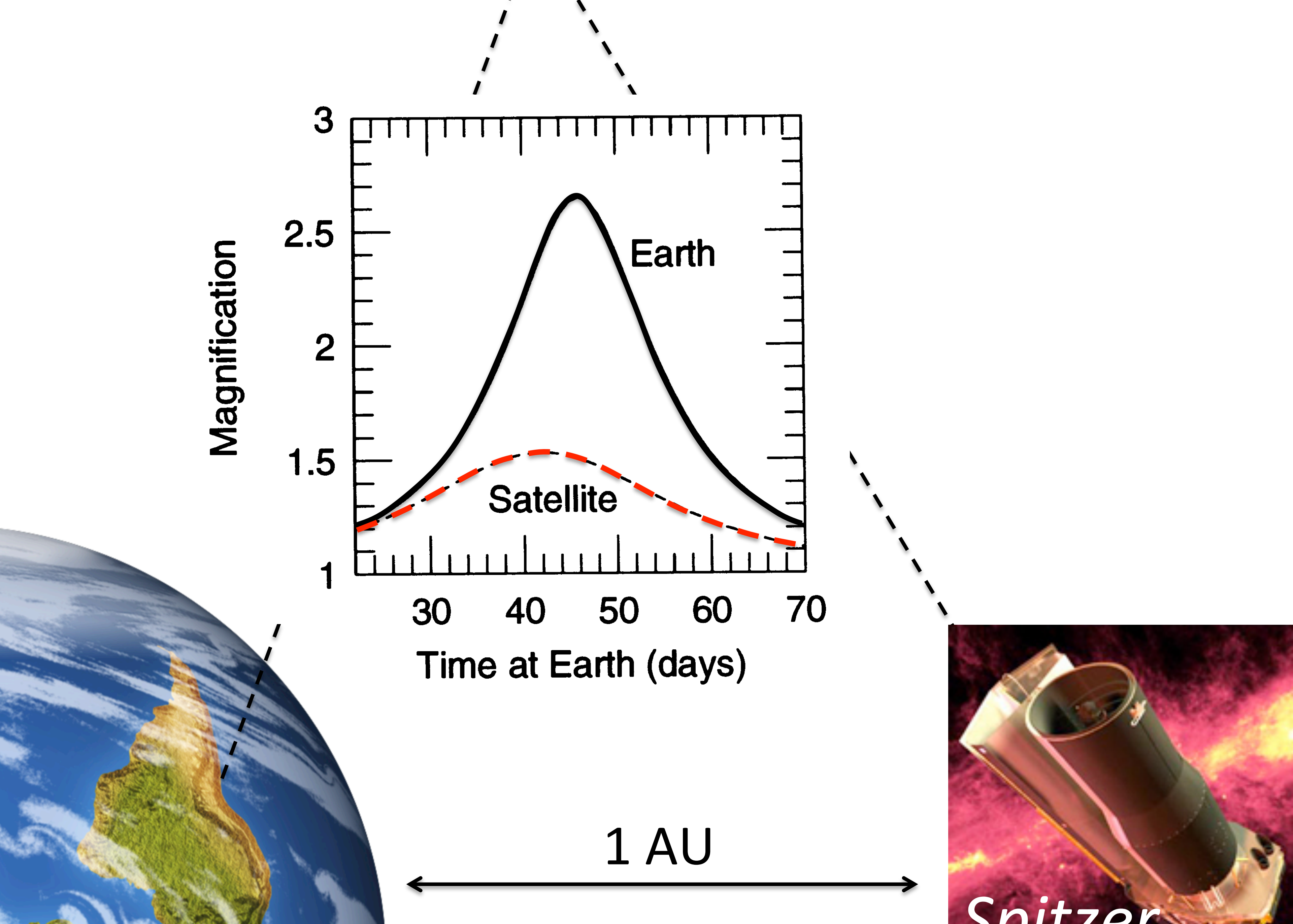
Batista et al. (incl. Yee) 2014, ApJ, 780, 54

Angular Size of Einstein Ring

Microlens Parallax

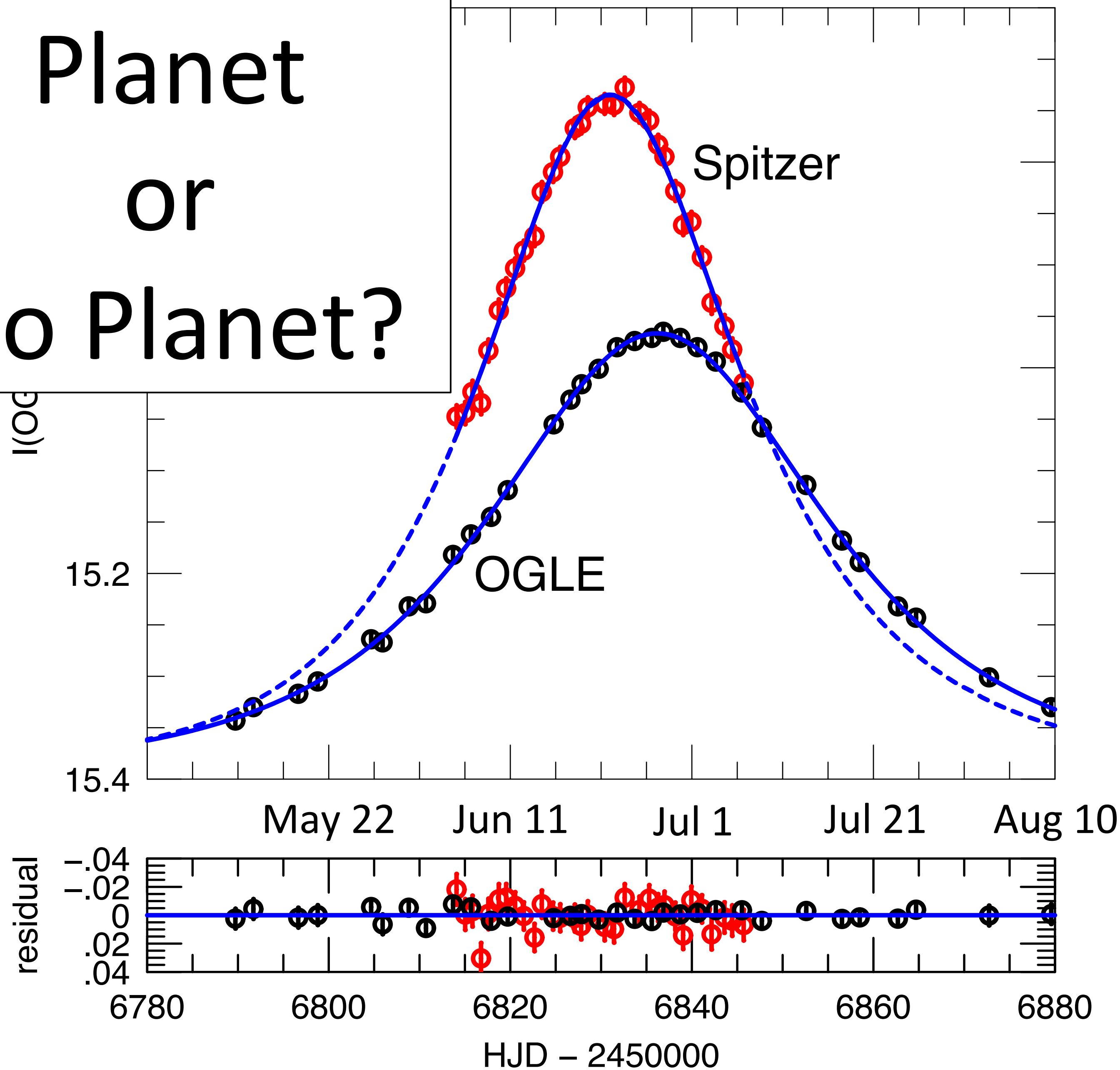
$$M_{star} = \theta_E / (\kappa \pi_E)$$

κ = constant

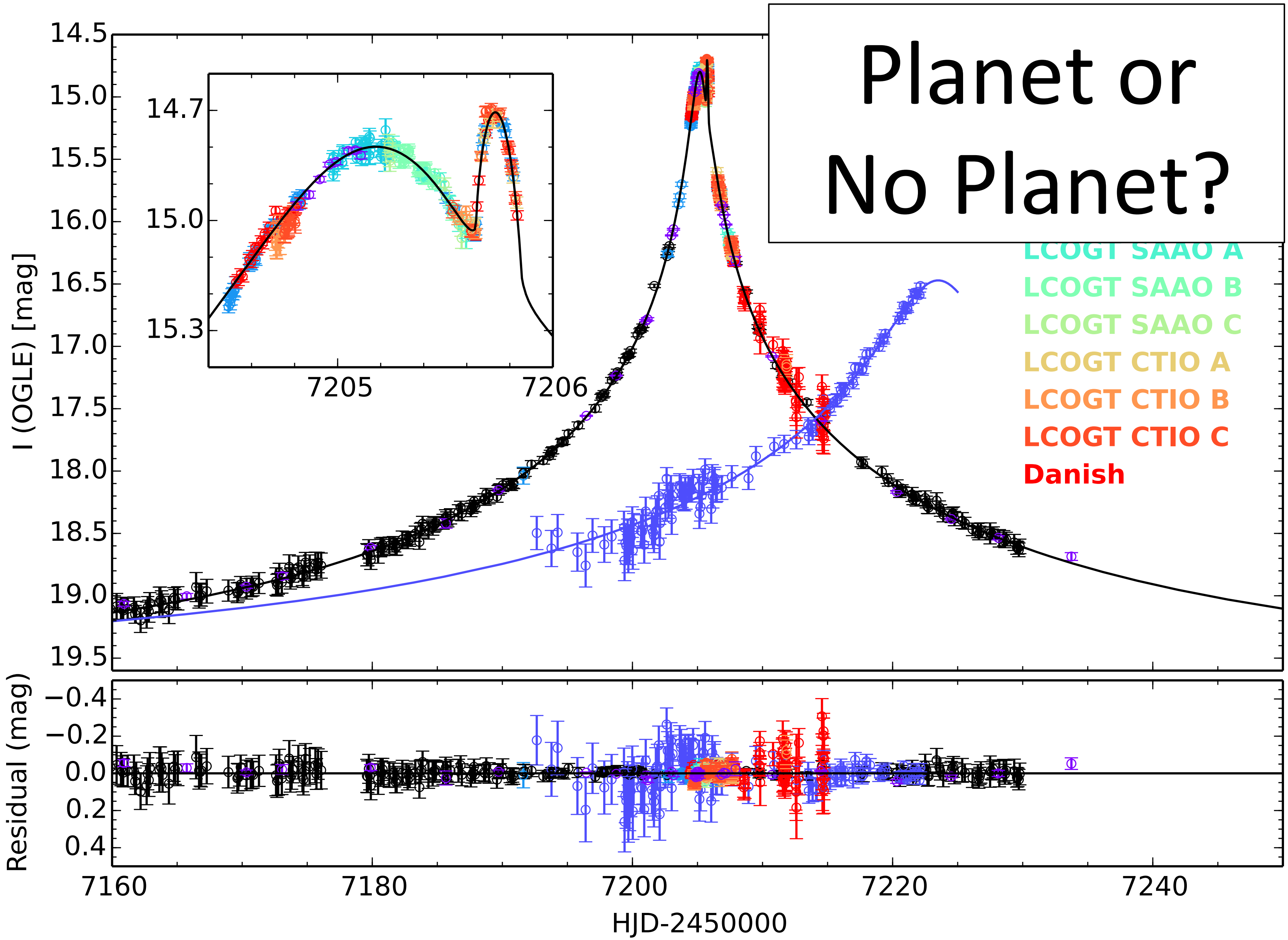


Gould 1994 ApJL, 421, 75

Planet or No Planet?

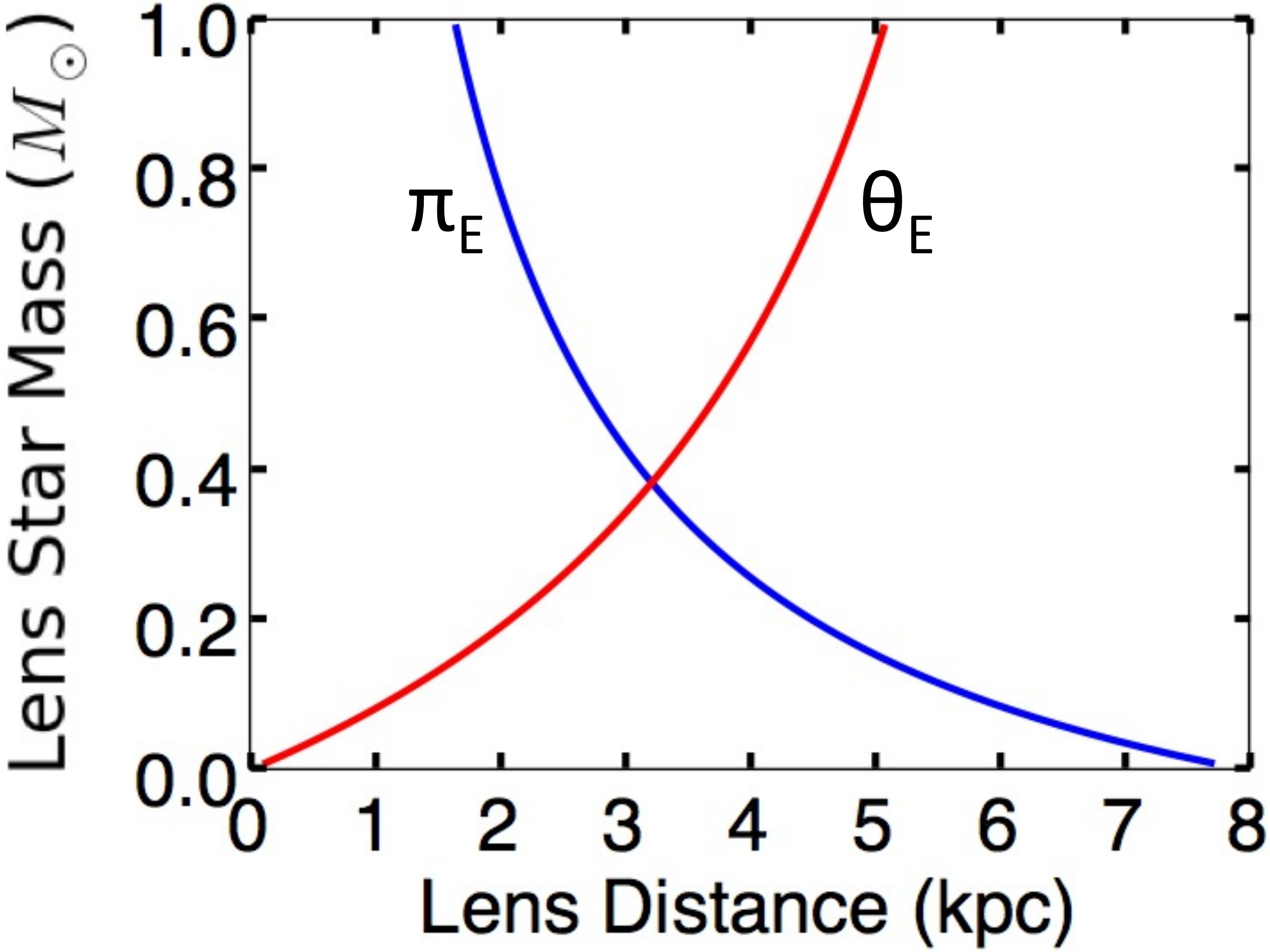


Yee et al. 2015, ApJ 802, 76

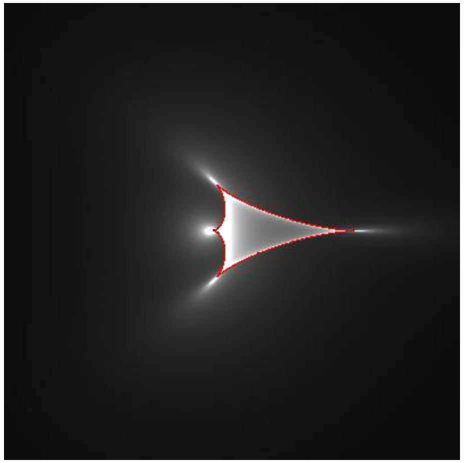


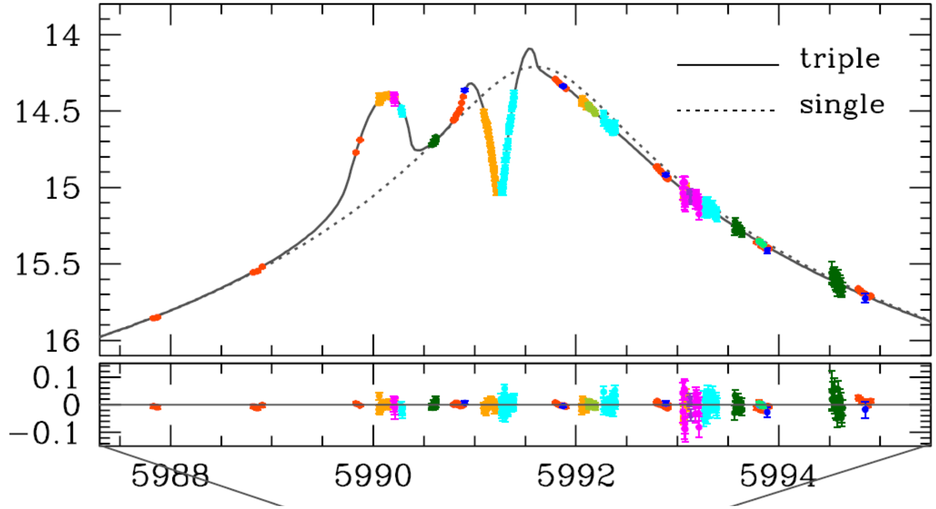
Street et al. 2016, ApJ, 819, 93

θ_E + π_E = precise mass and distance

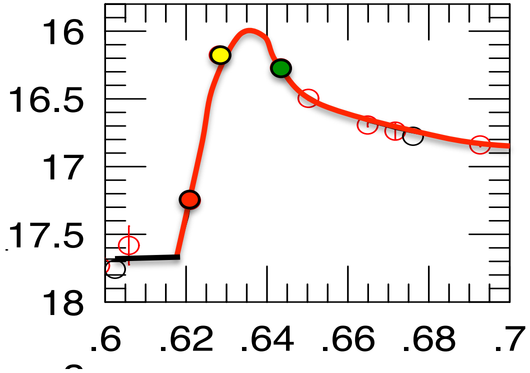


The caustics determine the lightcurve:

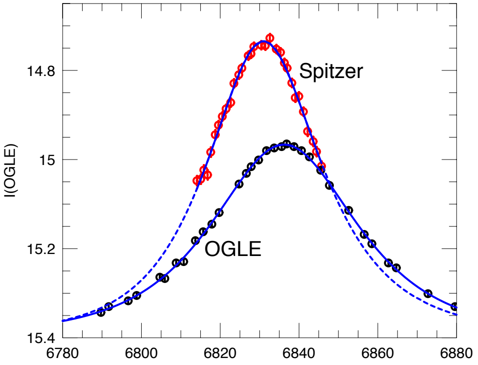




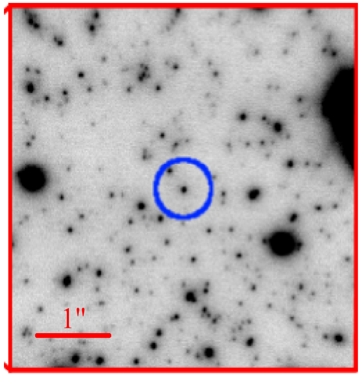
Three ways to constrain the lens mass:



θ_E



π_E



flux

Resources:

Introduction to Microlensing (shortest first):

Yee, J.C. Section 7 of "Exoplanet Detection Techniques" in Protostars and Planets VI, eds. Beuther, Klessen, Dullemond, Henning

Gaudi, B. S. "Microlensing by Exoplanets" in Exoplanets, ed. Sara Seager

Gaudi, B. S. 2012 ARAA 50, 411

Wambsganss, J. "Gravitational Microlensing" in Gravitational lensing: strong, weak, and micro, ed. Schneider

Classic Papers:

Einstein, A. 1936 Science 84, 506

Liebes, S. 1964 Phys Rev. 133, 835

Refsdal, S. 1964 MNRAS 128, 295

Mao, S. &Paczynski, B. 1991 ApJL 374, 37

Gould, A. & Loeb, A. 1992 ApJ 396, 104

Gaudi, B.S. & Gould, A. 1997 ApJ 486, 85