Exoplanetary Microlensing science with WFIRST

Yossi Shvartzvald & Calen Henderson
NPP Fellows @ JPL
Sebastiano Calchi Novati

photo by Cyril Cavadore

WFIRST Microlensing Primer Series

I. Basic Introduction to the Methodology and Theory of Gravitational Microlensing Searches for Exoplanets

W, 21/Sept , Yossi Shvartzvald

II. Lens Companion Detection and Characterization

W, 28/Sept , Yossi Shvartzvald

III. Results from and Future Directions for **Ground**-based Microlensing Surveys

W, 12/Oct , Calen Henderson

IV. Results from and Future Directions for **Space**-based Microlensing Surveys (including *WFIRST*)

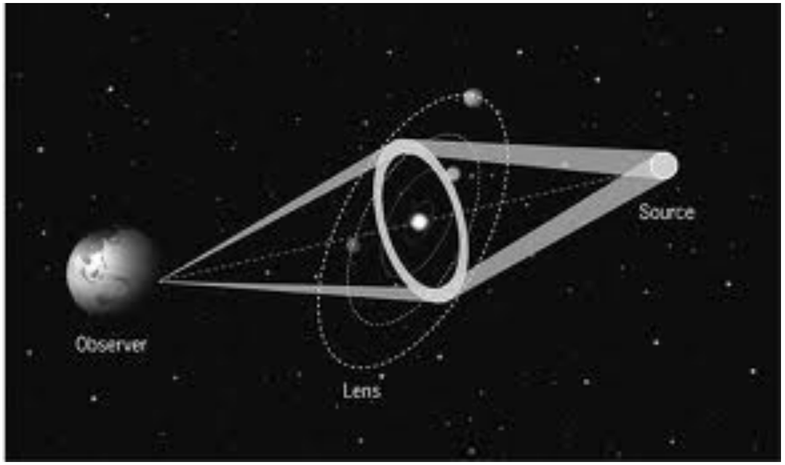
W, 19/Oct , Calen Henderson

Microlensing basics

Microlensing basics

Amplification = $\frac{\text{image area}}{\text{source area}}$

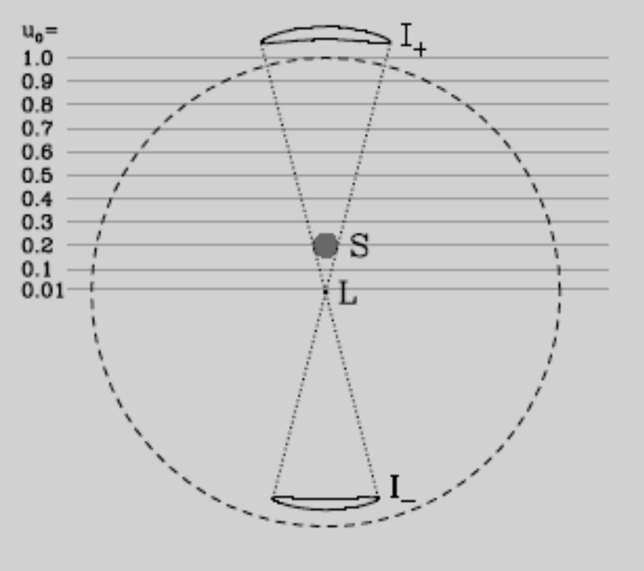
$$A(u) = \frac{u^2+2}{u\sqrt{u^2+4}}$$



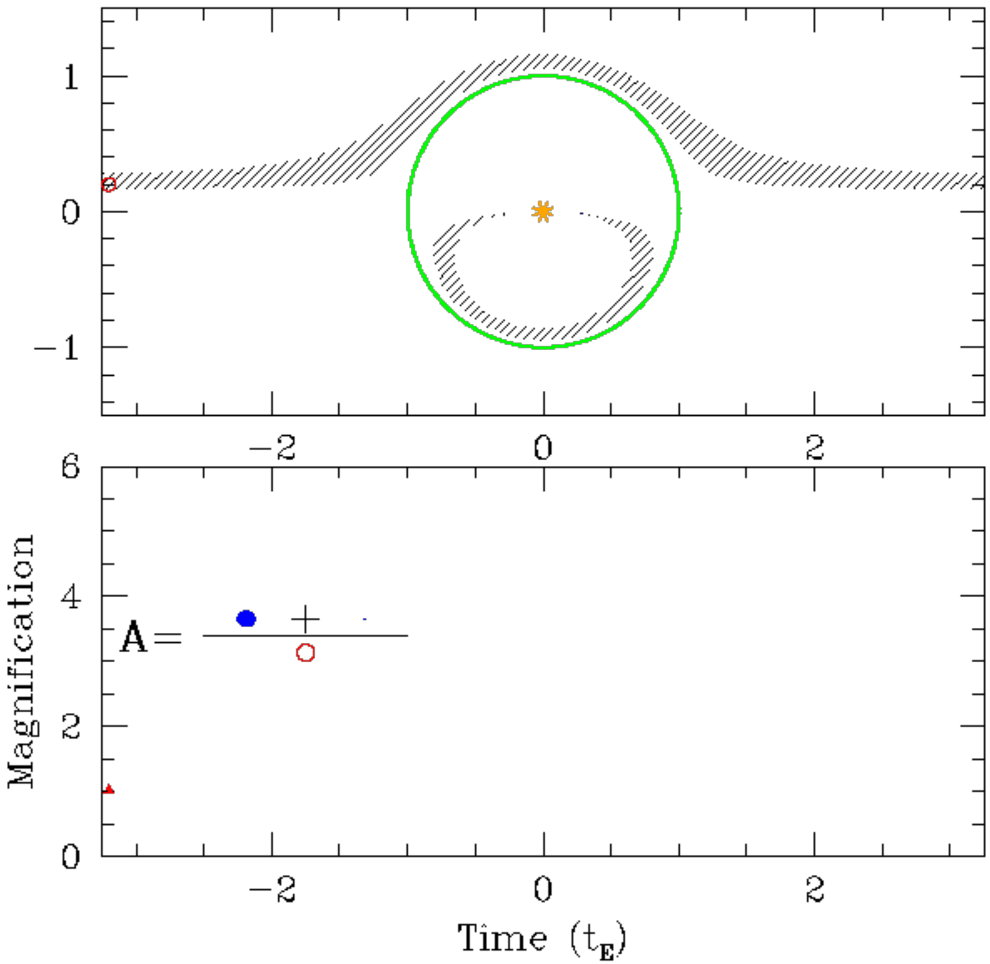
<u>Einstein angle:</u>

$$\theta_E = \sqrt{\frac{4GM_L}{c^2}\left(\frac{1}{D_L}-\frac{1}{D_S}\right)}$$

~milliarcsec

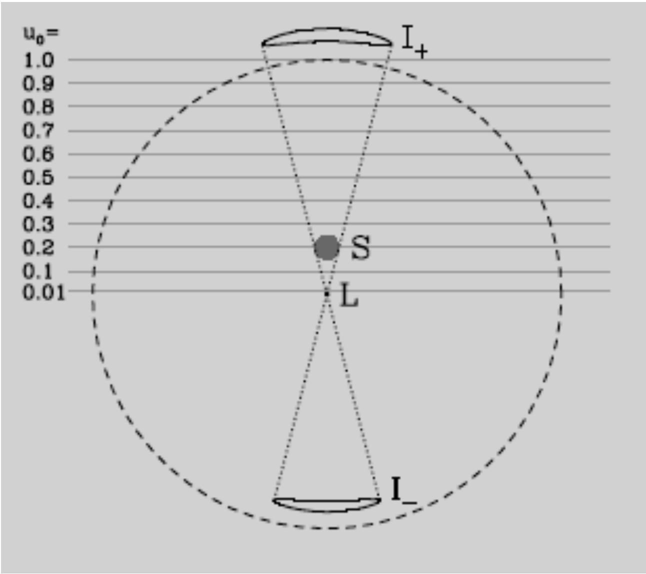


Microlensing basics



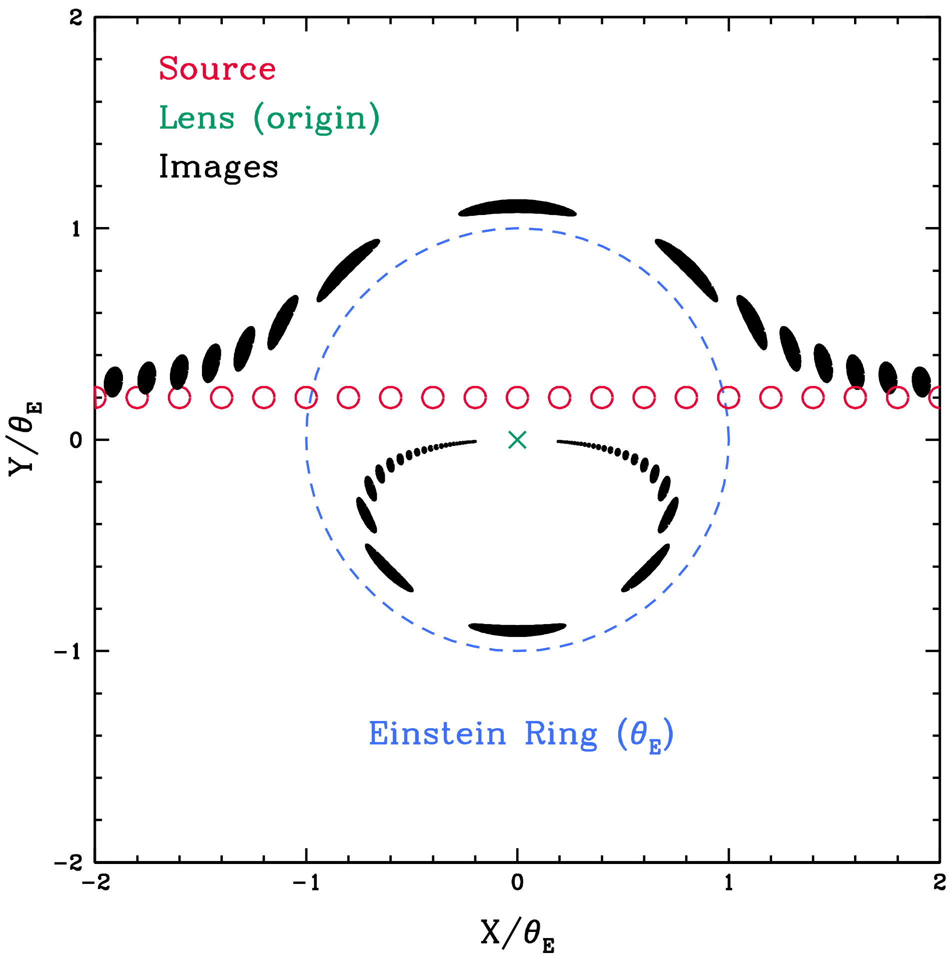
$$A(u) = \frac{u^2 + 2}{u\sqrt{u^2 + 4}}$$

$$u(t) = \left[u_0^2 + \left(\frac{t - t_0}{t_E} \right) \right]^{1/2}$$



S. Gaudi

Microlensing basics



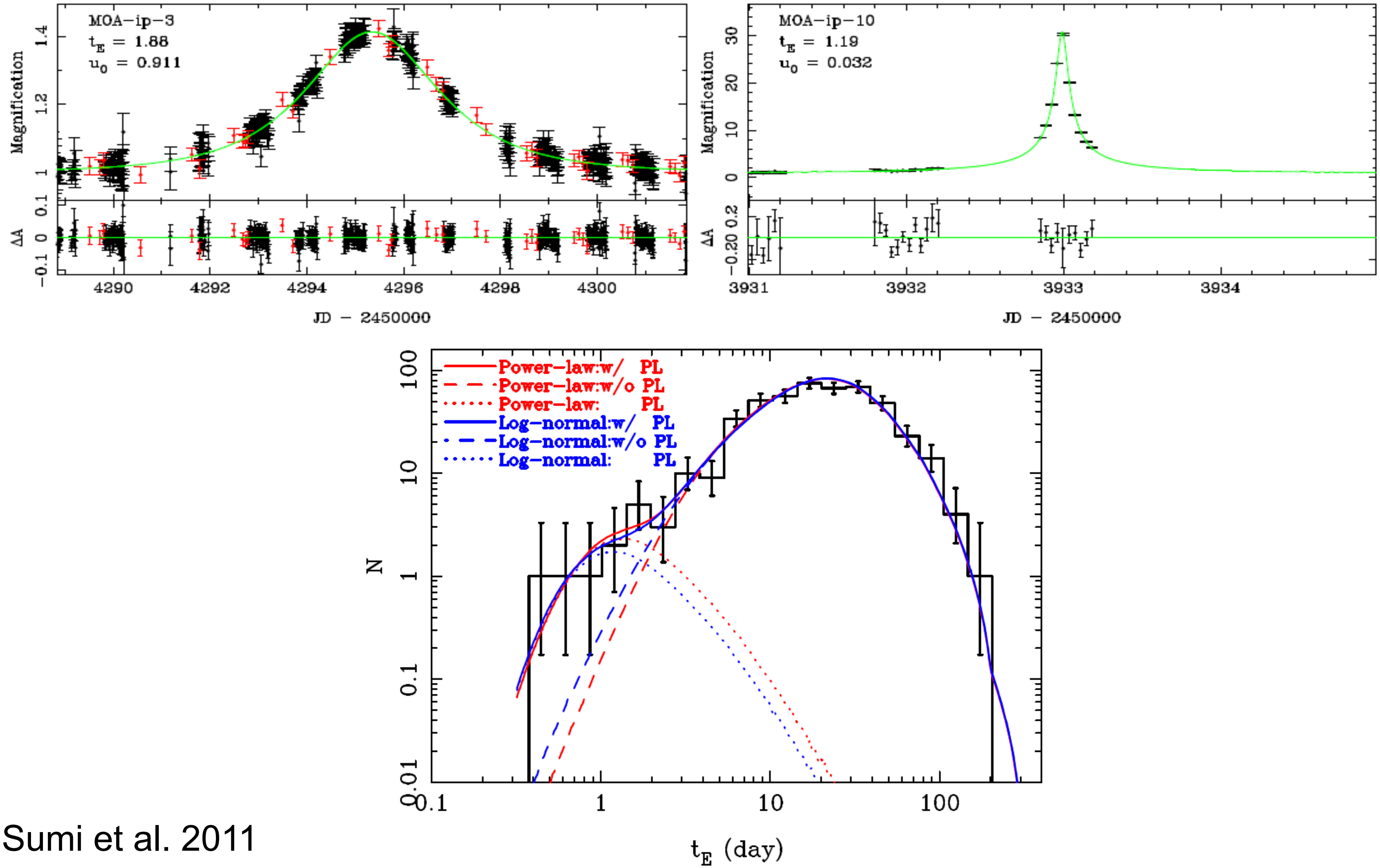
Event timescale

$t_E(M_L, D_L, D_S, \mu_{rel}) =$

$\approx$20 d for $0.3 M_\odot$

$\approx$1 d for M_J

Free floating planets



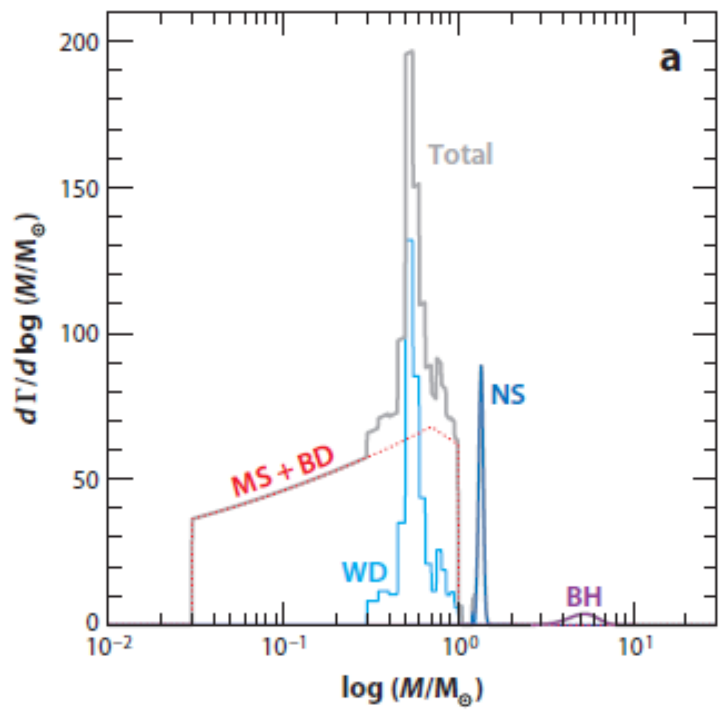
Sumi et al. 2011

Free floating planets

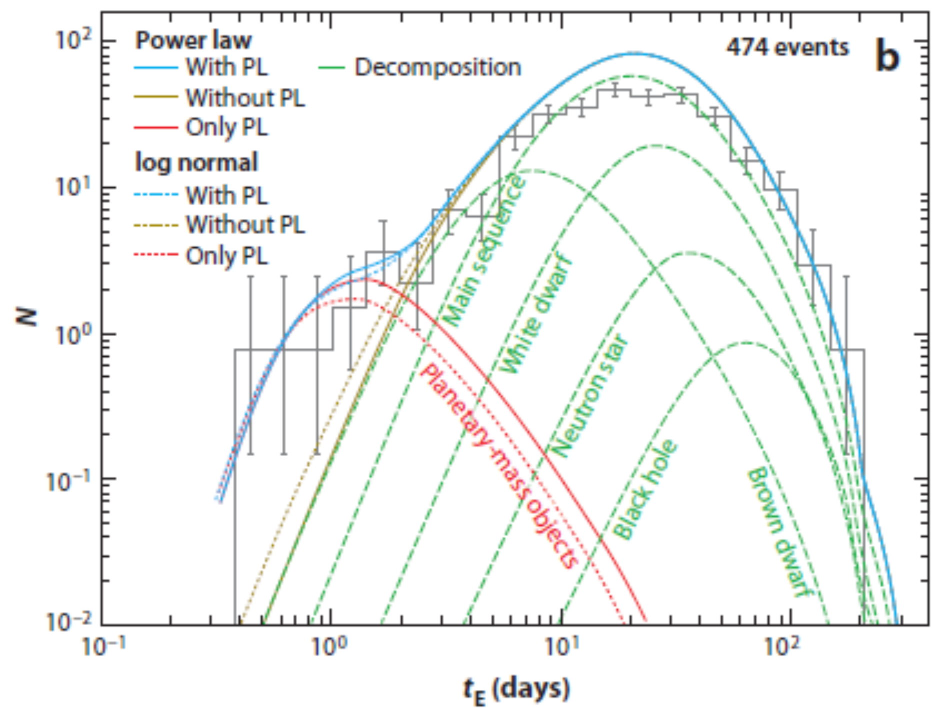
<u>Sumi et al. 2011:</u>

Unbound or distant Jupiters are twice ($1.8^{+1.7}_{-0.8}$) as common as main sequence stars

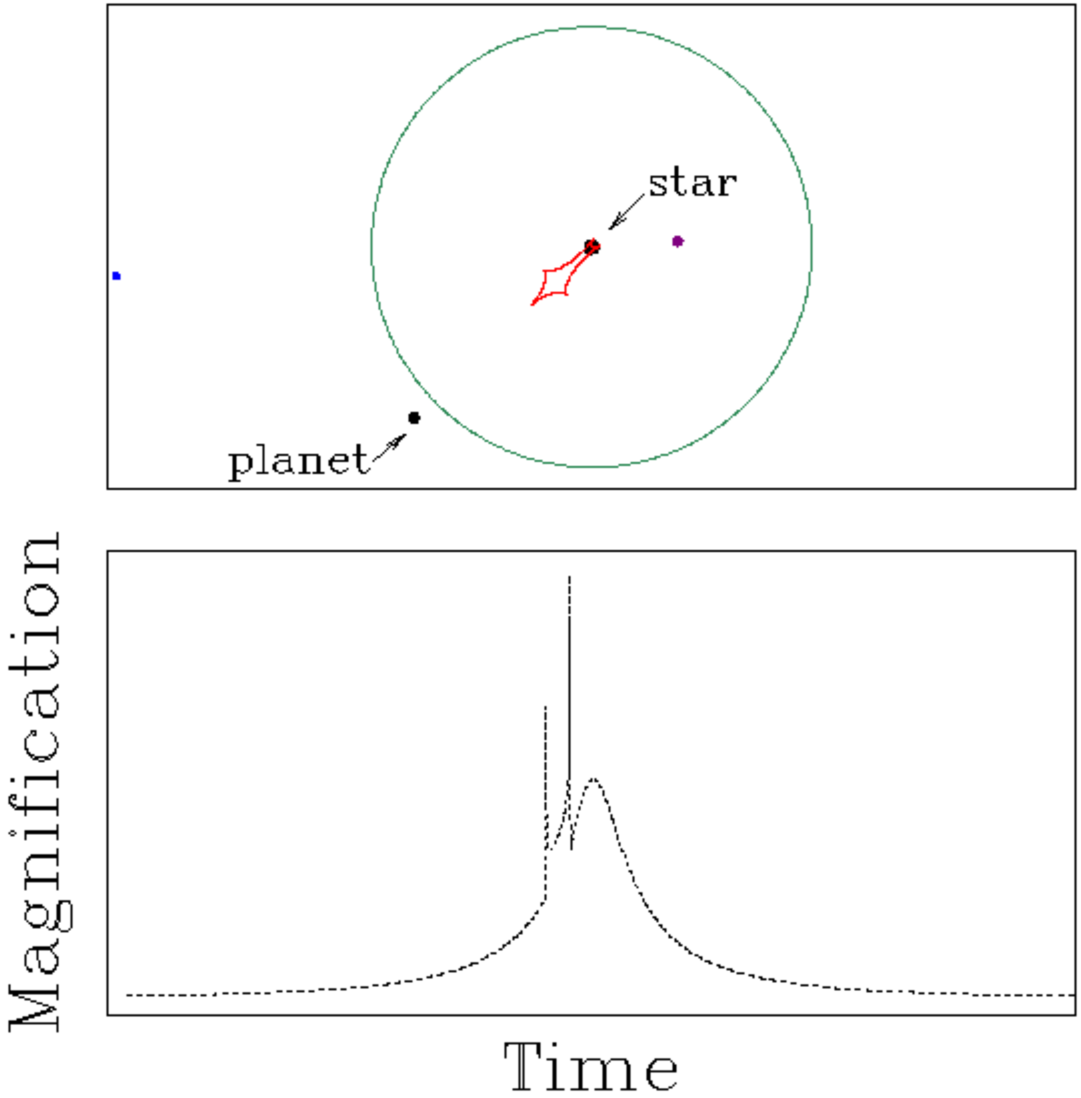
Gould 2000



Sumi et al. 2011



Microlensing basics



S. Gaudi

Microlensing basics

Planet-Star mass ratio

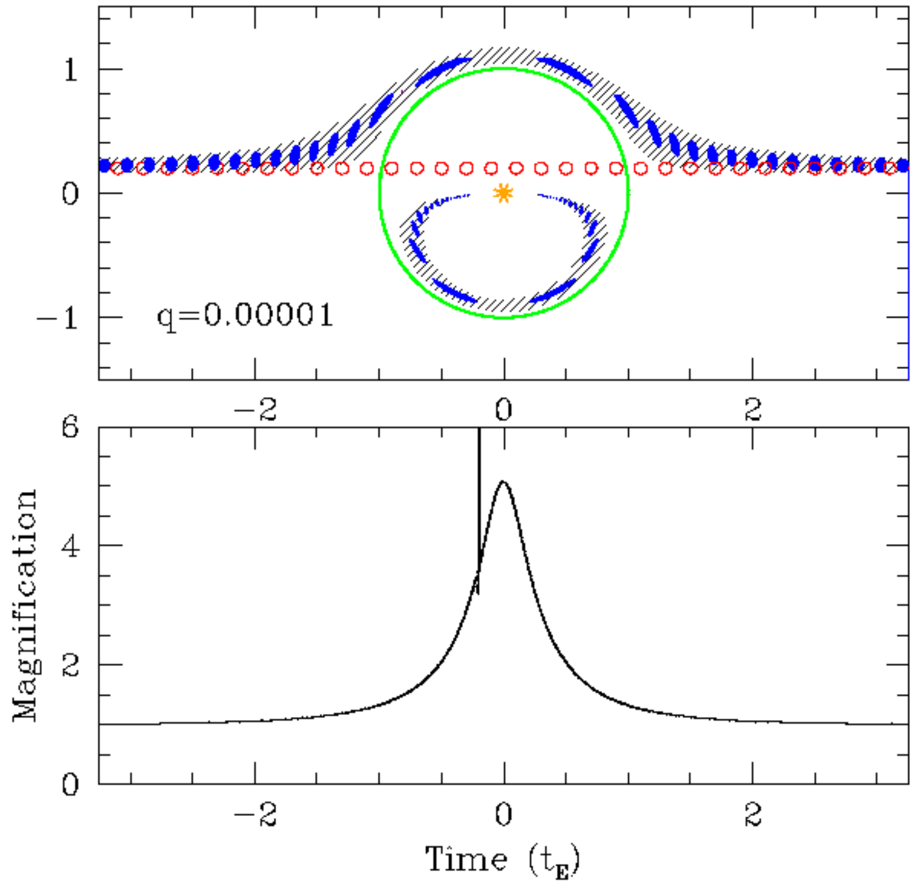
$$q = \frac{M_P}{M_L}$$

Planet-Star separation

$$s = \frac{a_\perp}{r_E}$$

Event timescale

$$t_E\left(M_L, D_L, D_S, \mu_{rel}\right) = \frac{\theta_E}{\mu_{rel}}$$

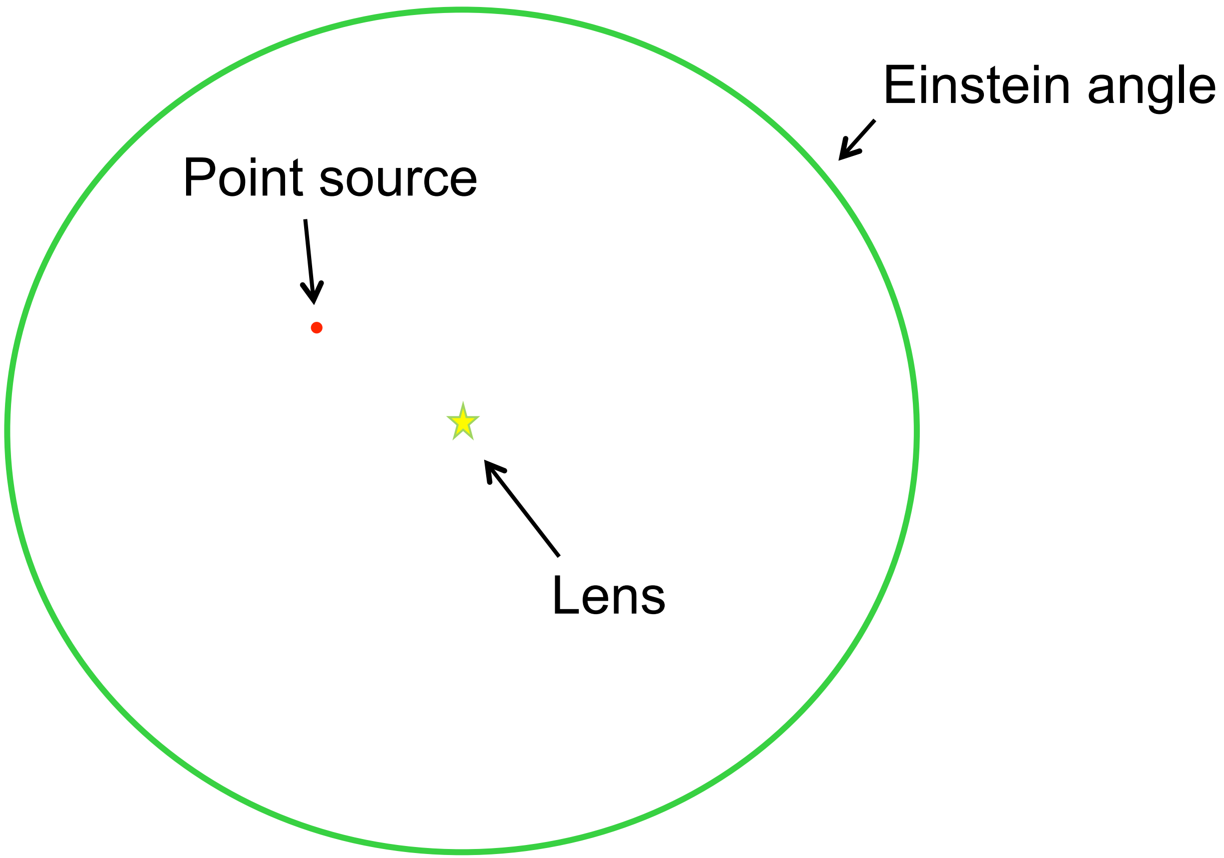


S. Gaudi

From lensing observables to physical parameters

High order effects:

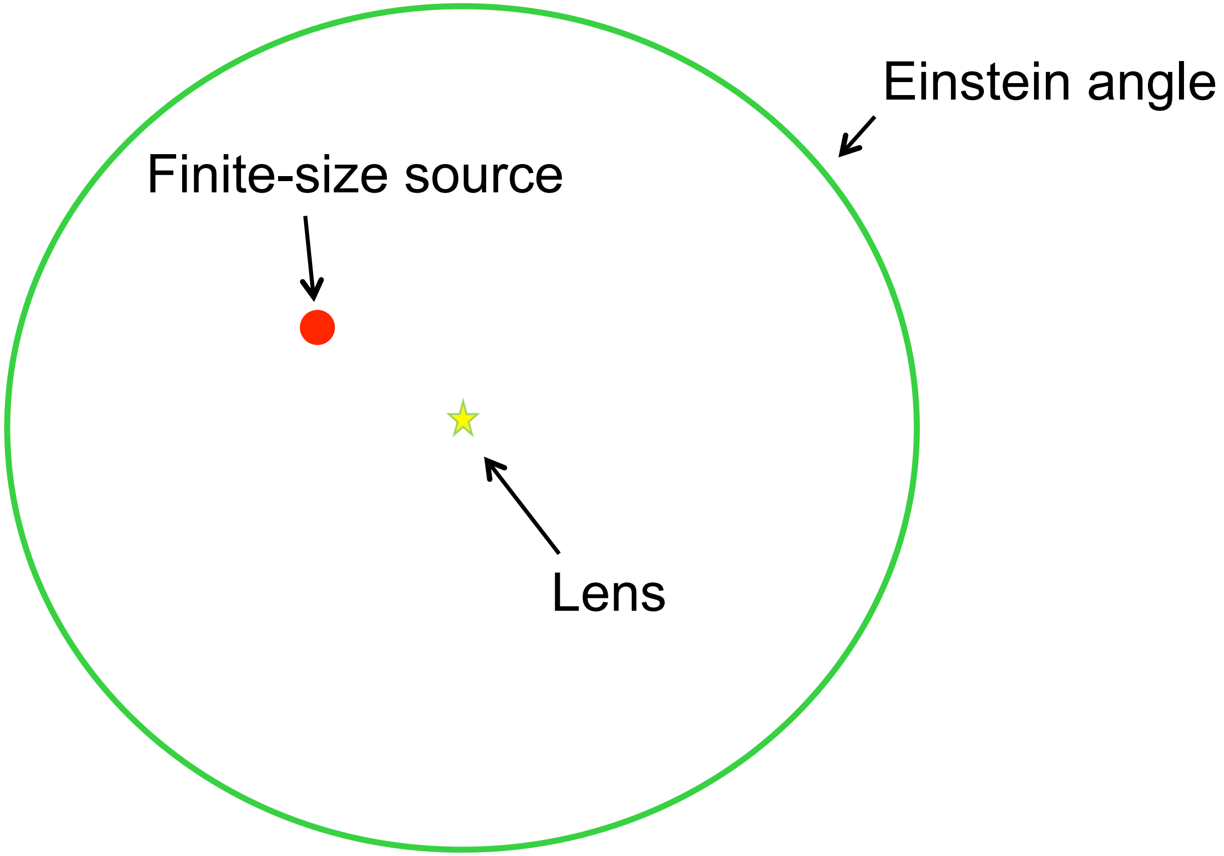
- Finite source size $\rho_* = \frac{\theta_*}{\theta_E}$



From lensing observables to physical parameters

High order effects:

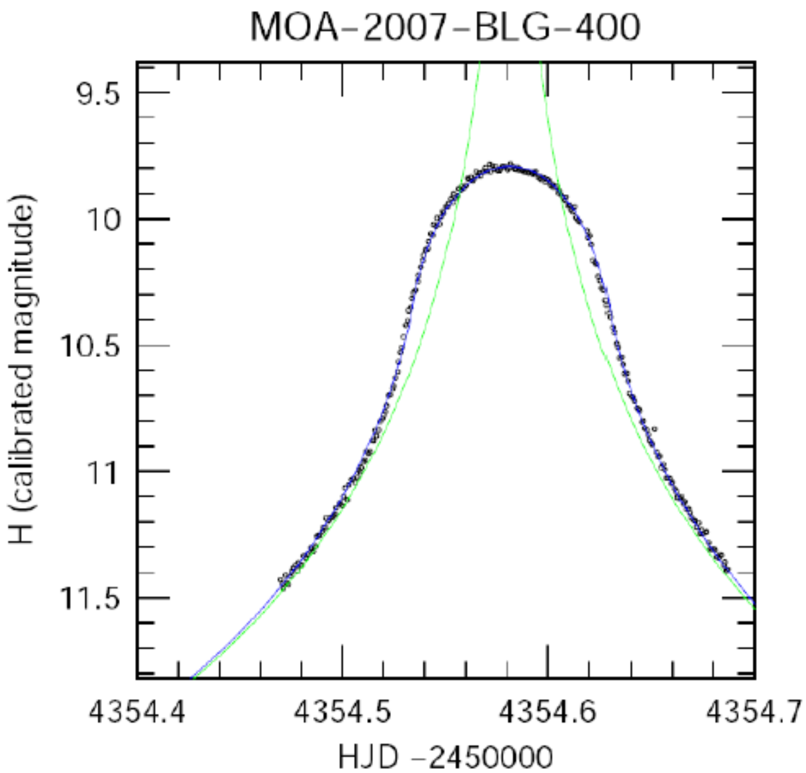
- Finite source size $\rho_* = \dfrac{\theta_*}{\theta_E}$

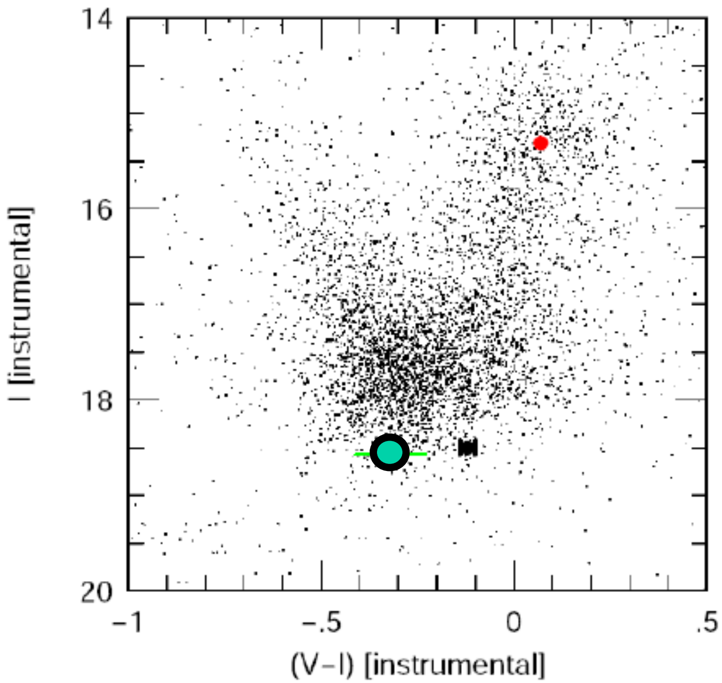


From lensing observables to physical parameters

High order effects:

- Finite source size $\rho_* = \dfrac{\theta_*}{\theta_E}$





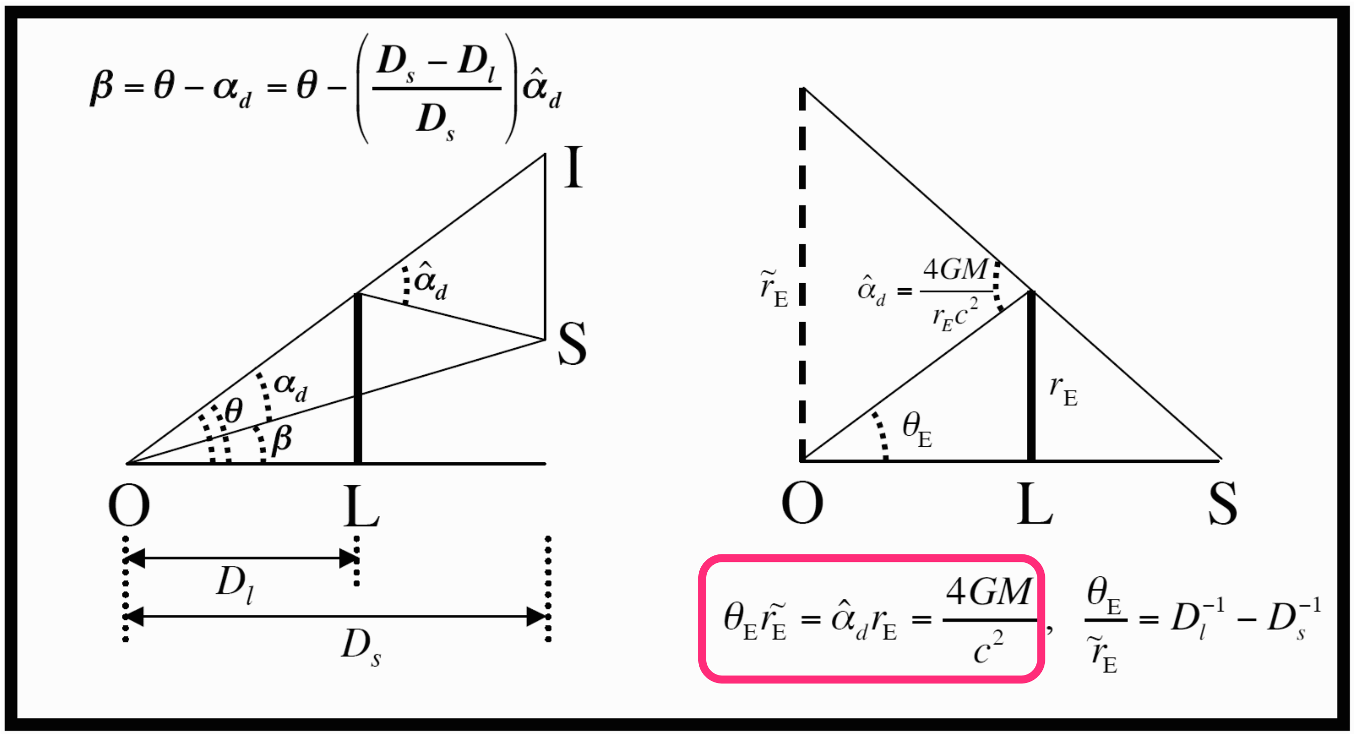
From lensing observables to physical parameters

High order effects:

- Finite source size $\rho_* = \frac{\theta_*}{\theta_E}$

- Microlens parallax

$$\pi_E = \frac{AU}{\tilde{r}_E}$$



From lensing observables to physical parameters

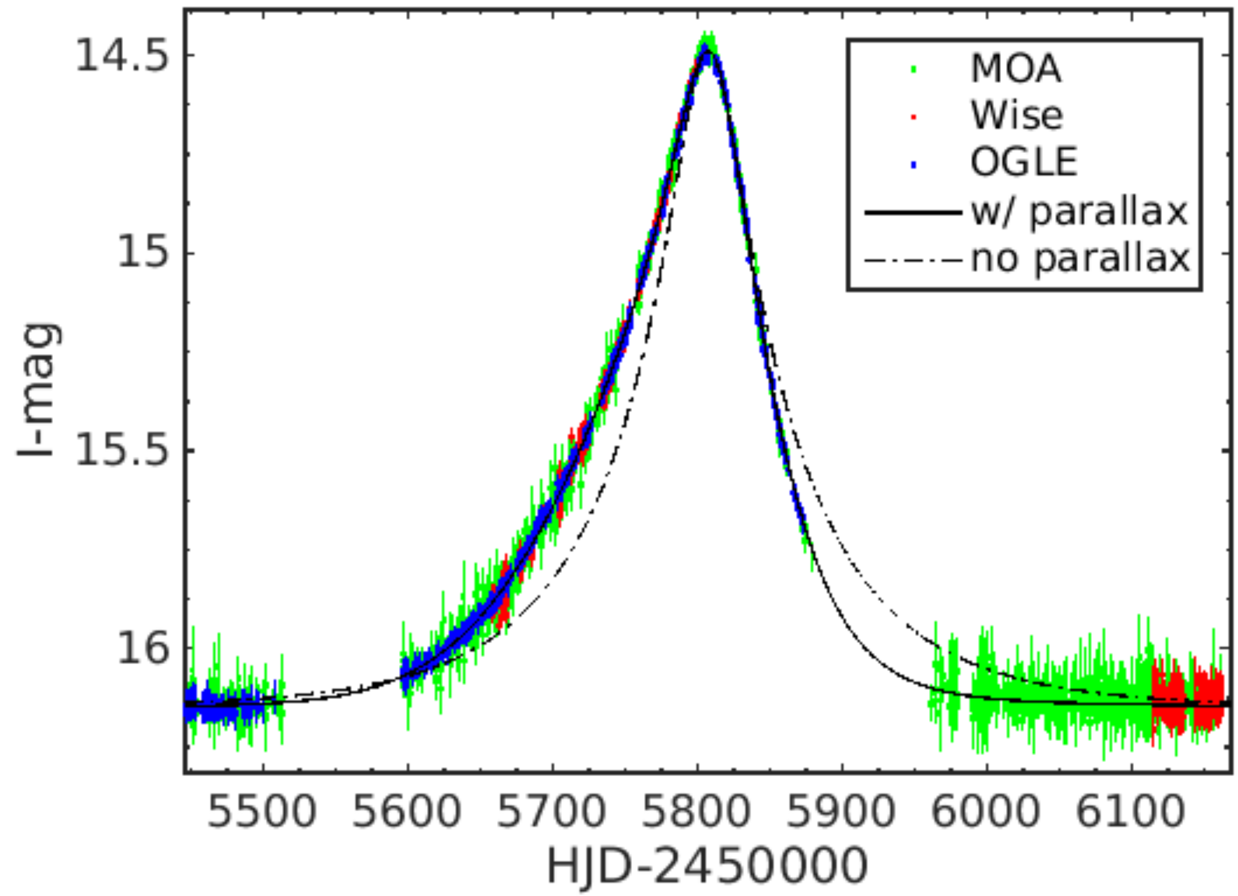
<u>High order effects:</u>

- Finite source size

- Microlens parallax

$$\pi_E = \frac{AU}{\tilde{r}_E}$$

Orbital parallax



From lensing observables to physical parameters

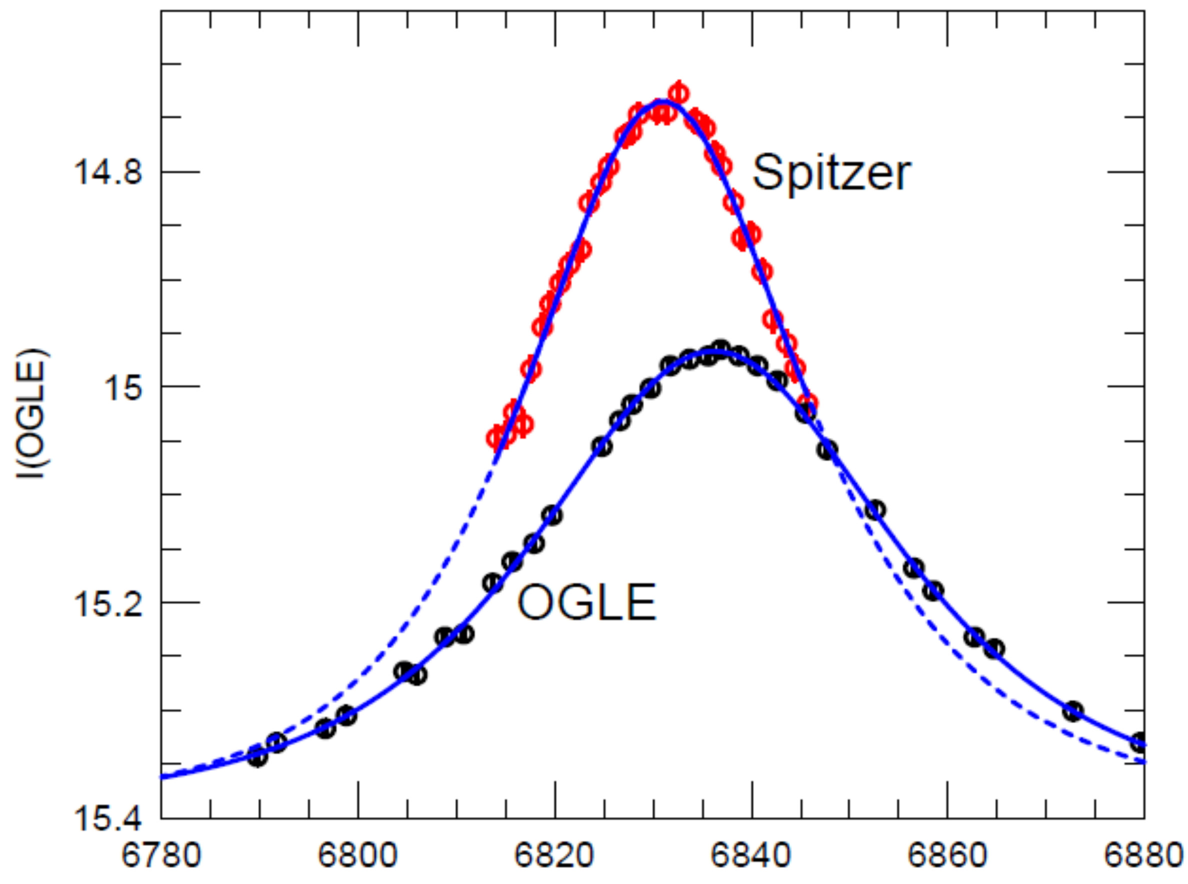
<u>High order effects:</u>

- Finite source size

- Microlens parallax

$$\pi_E = \frac{AU}{\tilde{r}_E}$$

“Trigonometric” parallax



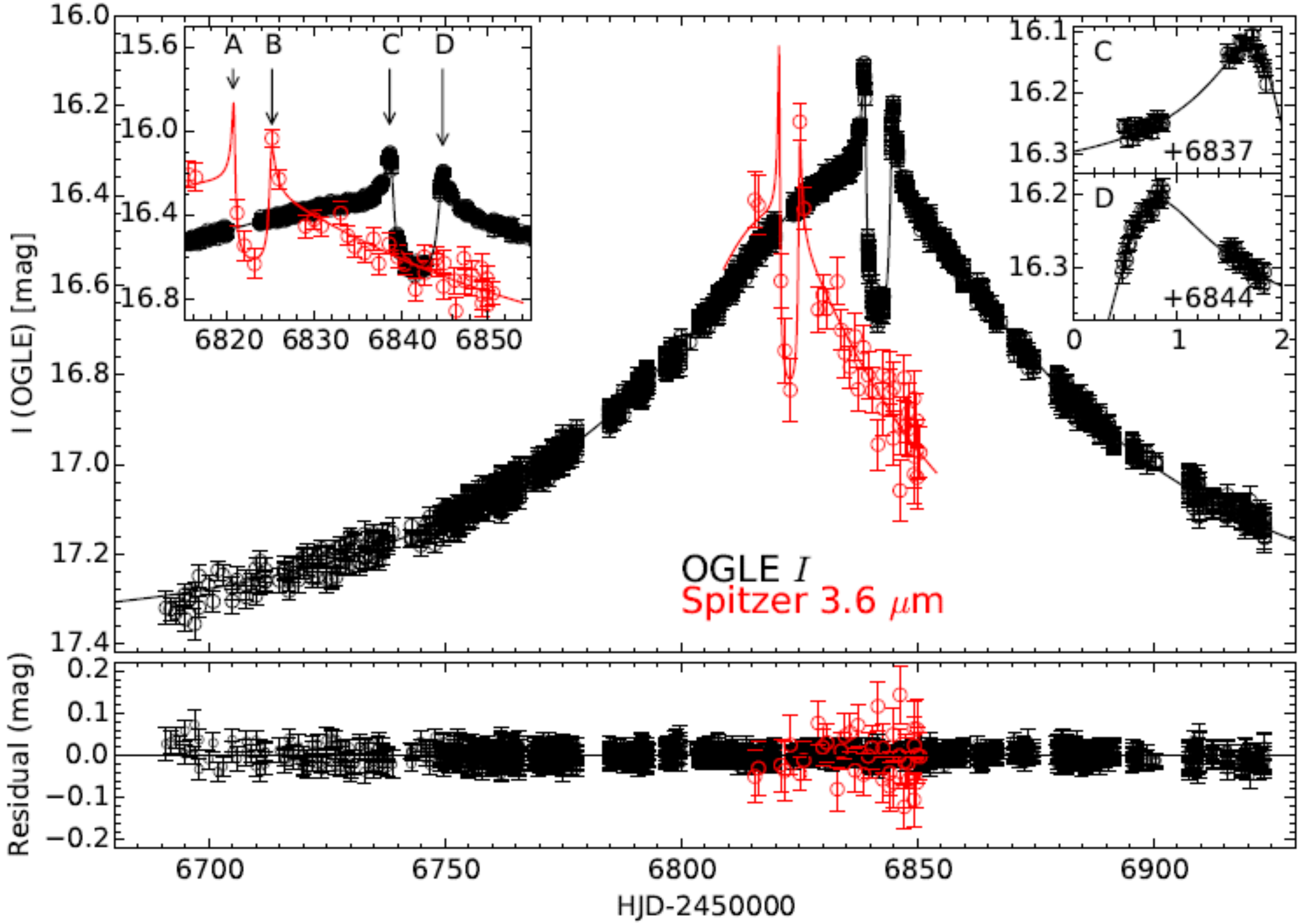
Yee et al. 2014

From lensing observables to physical parameters

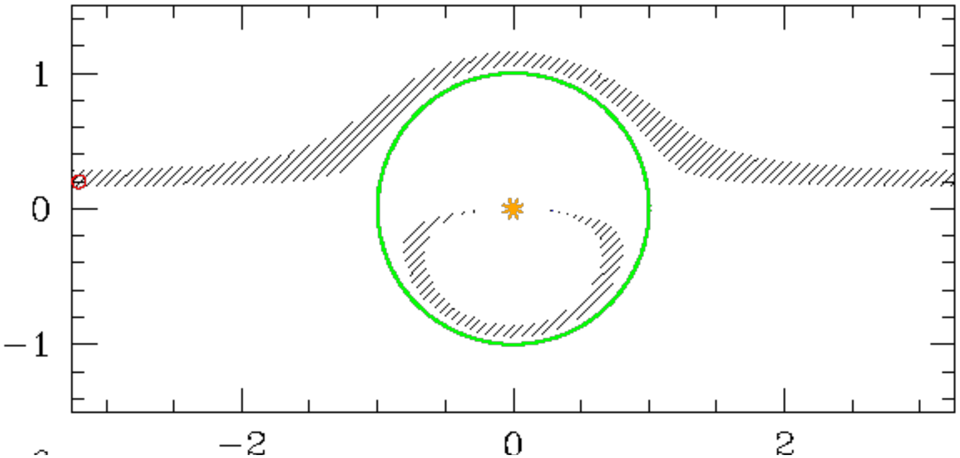
$$M_P = 0.51 \pm 0.16\, M_J$$
$$a_\perp = 3.11 \pm 0.49 \text{ AU}$$
$$M_L = 0.71 \pm 0.22\, M_e$$

Udalski et al. 2014

OGLE-14-0124

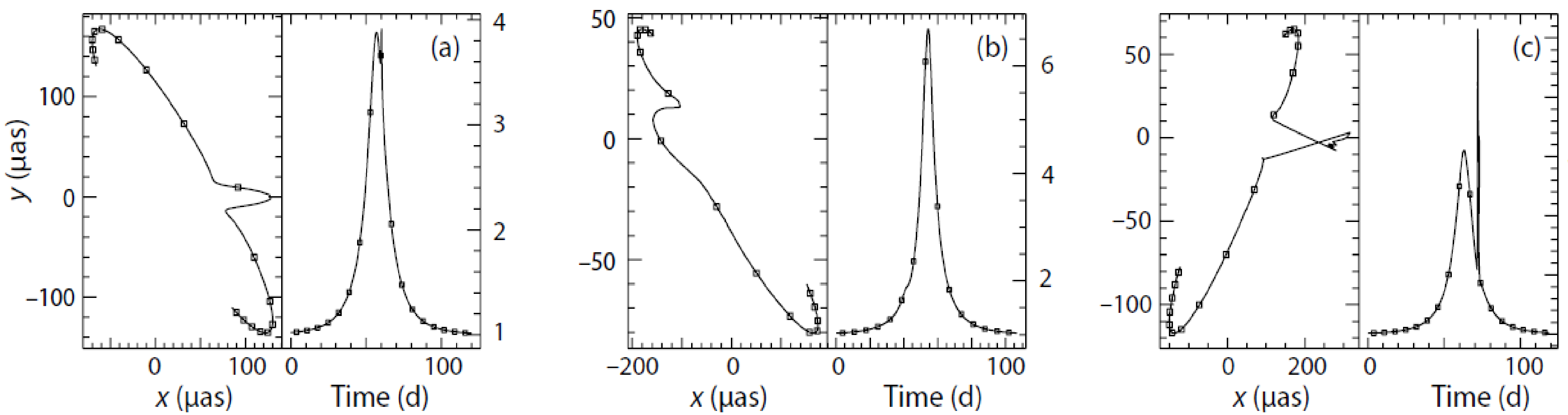


Astrometric microlensing



Astrometric microlensing:

- Typical max shifts - 0.1 mas



S. Gaudi