Finding Neutron Stars and Black Holes with Microlensing

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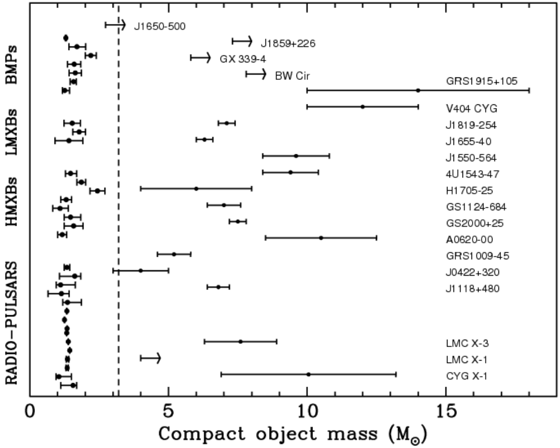
Where (and why) is the NS-BH valley?



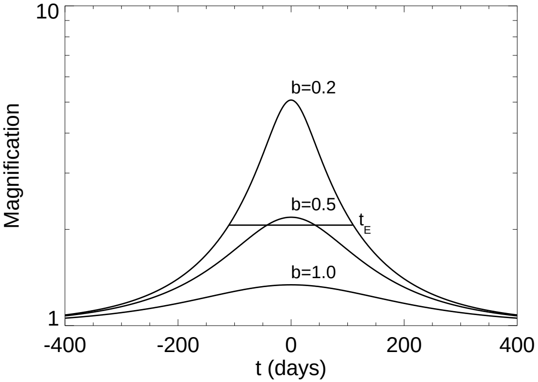
Classic point mass lens

photometric light curve gives us the Einstein crossing time:

$$t_E = \sqrt{\frac{4GM}{c^2}}\sqrt{\frac{D_S - D_L}{D_L D_S}}\frac{D_L}{v}$$

and the magnification:

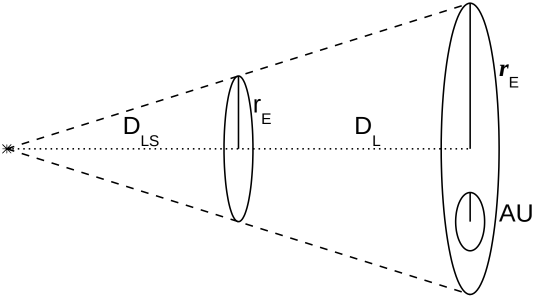
$$\mu_{\max} = \frac{b^2+2}{\sqrt{b^2(b^2+4)}}$$



Photometric parallax

Earth's parallax give the *projected* Einstein radius:

$$\tilde{r}_E = \sqrt{\frac{4GM}{c^2}}\sqrt{\frac{D_L D_s}{D_S - D_L}}$$



Binary lens

introduces many new parameters:

- mass ratio $q = M_2/M_1$
- semimajor axis a
- eccentricity e
- inclination i
- ascending node Ω
- argument of pericenter ω
- epoch of pericenter T_p

but also some new observables:

- orbital period $T_{\rm orb}$
- orbit crossing time $T_a \equiv a/v$

A complete solution is possible (in principle)

$$t_{\mathrm{E}} = \sqrt{\frac{4GM}{c^2}}\sqrt{\frac{D_S - D_L}{D_L D_S}}\frac{D_L}{v}$$

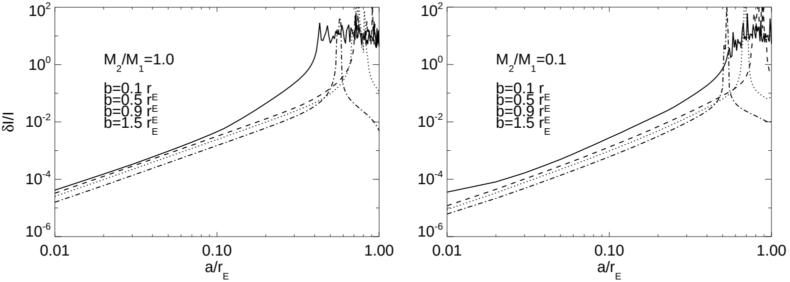
$$\tilde{r}_{\mathrm{E}} = \sqrt{\frac{4GM}{c^2}}\sqrt{\frac{D_L D_s}{D_S - D_L}}$$

$$T_{\mathrm{orb}} = 4\pi^2\sqrt{\frac{a^3}{GM}}$$

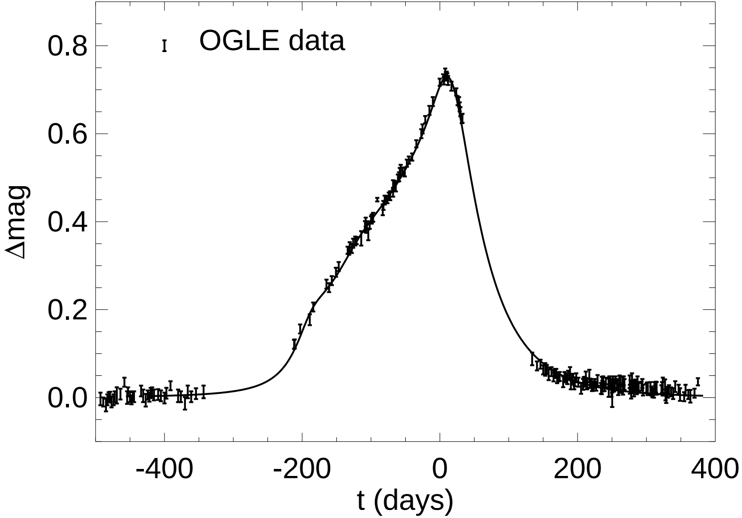
$$T_a = \frac{a}{v}$$

How well can we measure $T_{\rm orb}$ and T_a ?

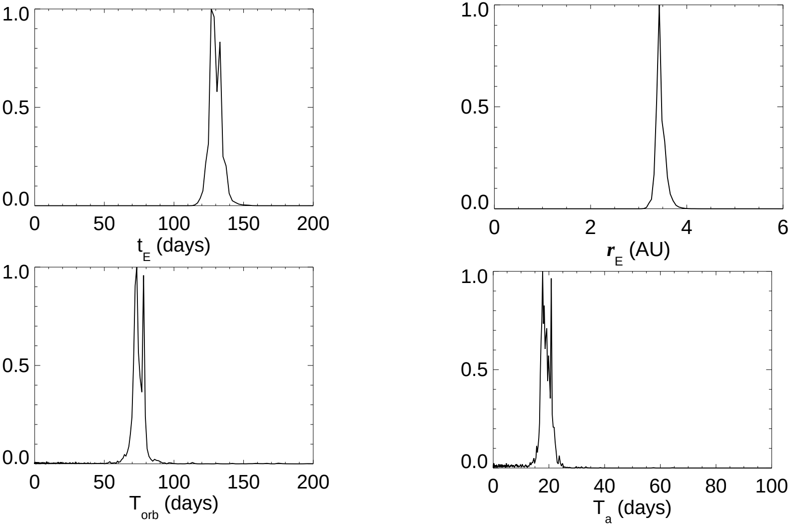
want to minimize $T_{\rm orb}$ and maximize $a/r_{\rm E} = T_a/T_{\rm E}$



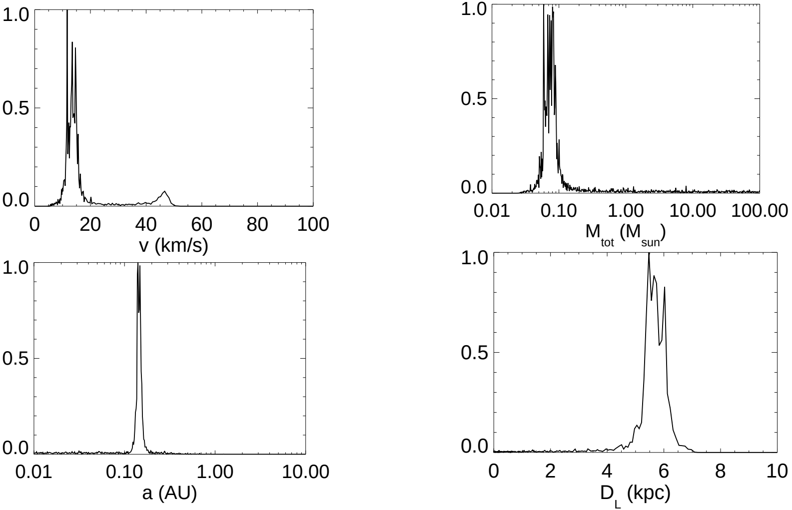
Test case: OGLE-2003-BLG-032



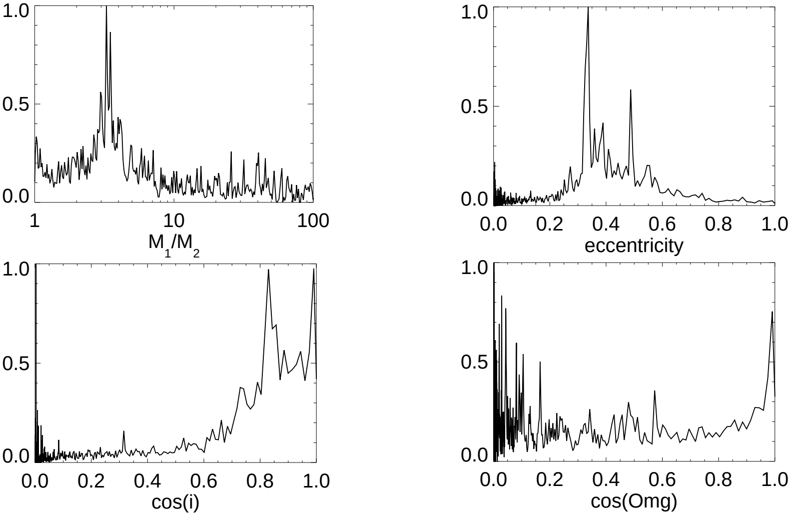
MCMC parameter estimation: observables



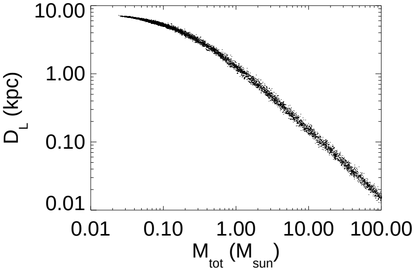
MCMC parameter estimation: inferables

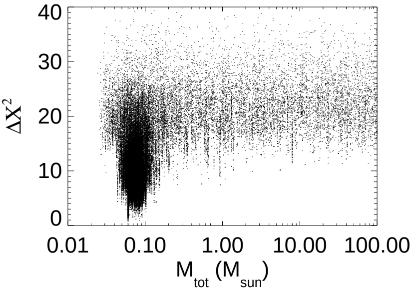


MCMC parameter estimation: inferables



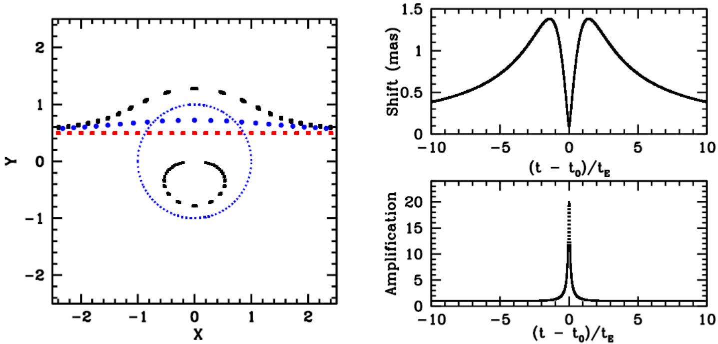
Degeneracies still important





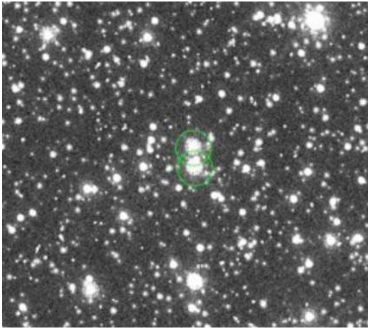
Astrometry can help break degeneracy

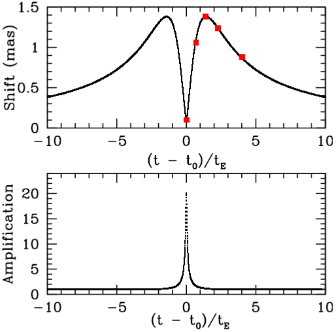
$$\delta = \frac{b\theta_E}{b^2+2}$$



HST GO-11707, PI: Kailash Sahu

follow-up OGLE/MOA triggers of ongoing, long-duration microlensing events

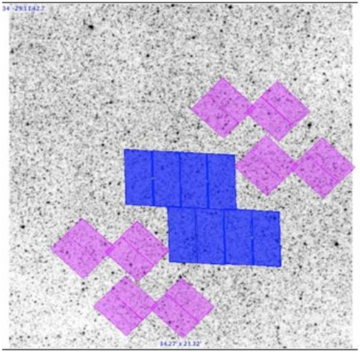




HST GO-12586, PI: Kailash Sahu

follow-up OGLE/MOA triggers of ongoing, long-duration microlensing events

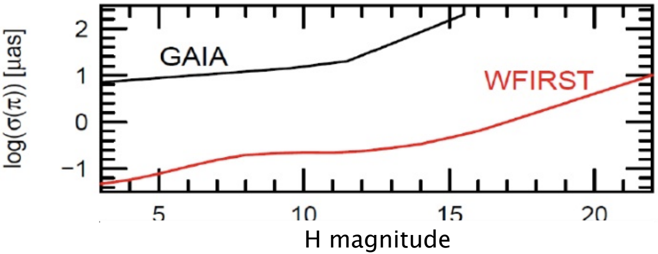
- 192 HST orbits
- 1.7 million stars, 50% w/ astrometry
- 2-week cadence for 3 years
- supplemened by GEMINI observations for parallax measurements
- will give unbiased distribution of NSs, BHs in disk
- began in March 2012



WFIRST-AFTA astrometry

WFIRST SDT telecon, Gaudi 10/31/2014

WFIRST–AFTA Parallaxes.



- H<14.0; $\sigma(\pi)$ < 0.3 μas; 1,000,000 stars
- H<19.6; $\sigma(\pi)$ < 3.7 μas; 40,000,000 stars
- H<21.6; $\sigma(\pi)$ < 10 μas; 120,000,000 stars

Gould et al. (2014)

Science Applications

- FREE SCIENCE! black holes can be found in planetary graveyards
- new probe of the high end of IMF
- mass distribution of end state of stellar evolution
- SN kick distribution
- binary evolution (common envelope, mass transfer, etc.)