Astrometric and photometric microlensing with Gaia and OGLE

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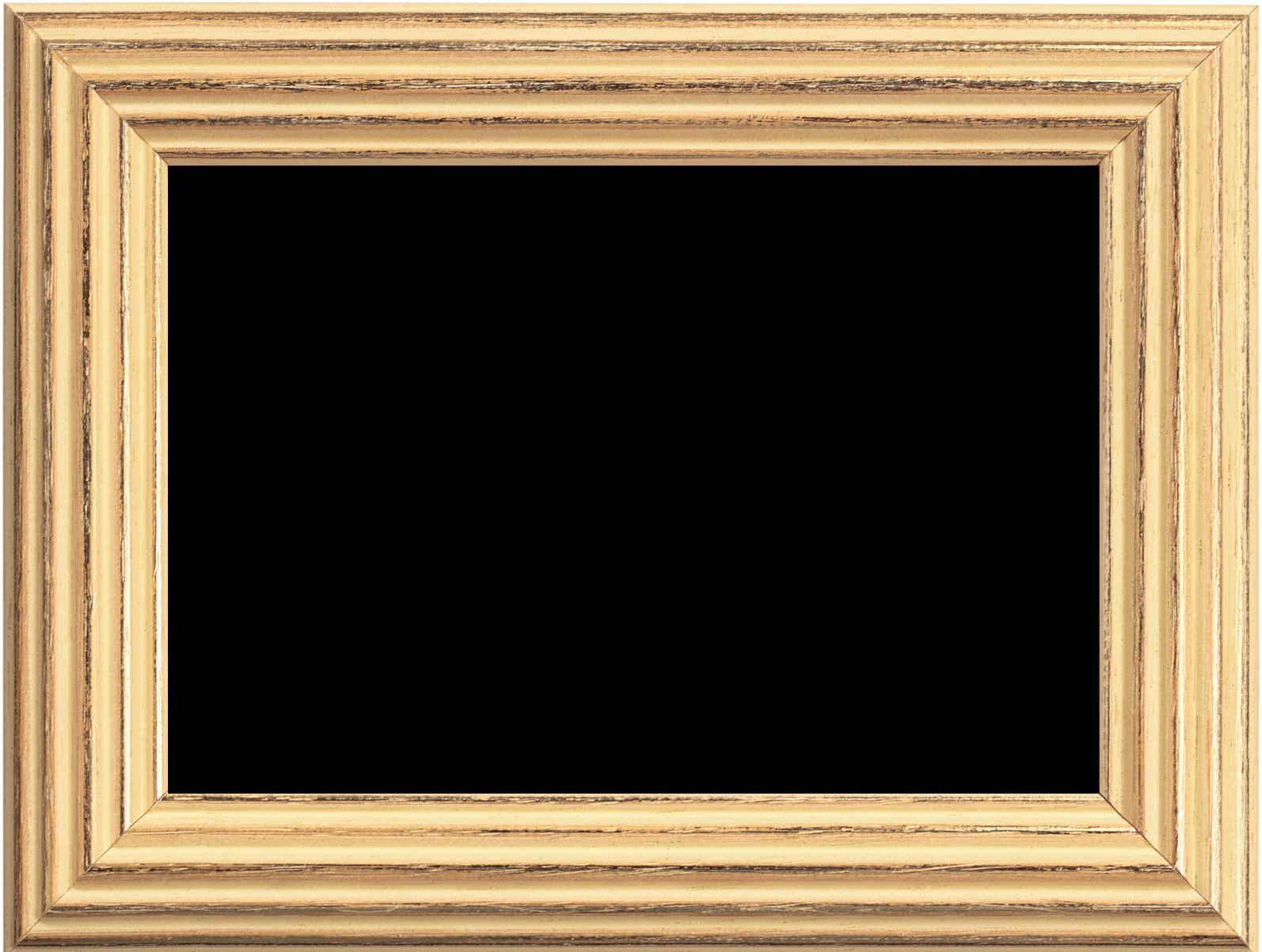
How does single stellar mass BH look like?



Motivation

- According to IMF (Kroupa & Weidner 2003), about 0.5 promil of all stars should be BH
- Final stages of the evolution of masive stars not understood well
- Mass measurement of single BH hard (impossible?) to detect without microlensing

Photometric and astrometric microlensing

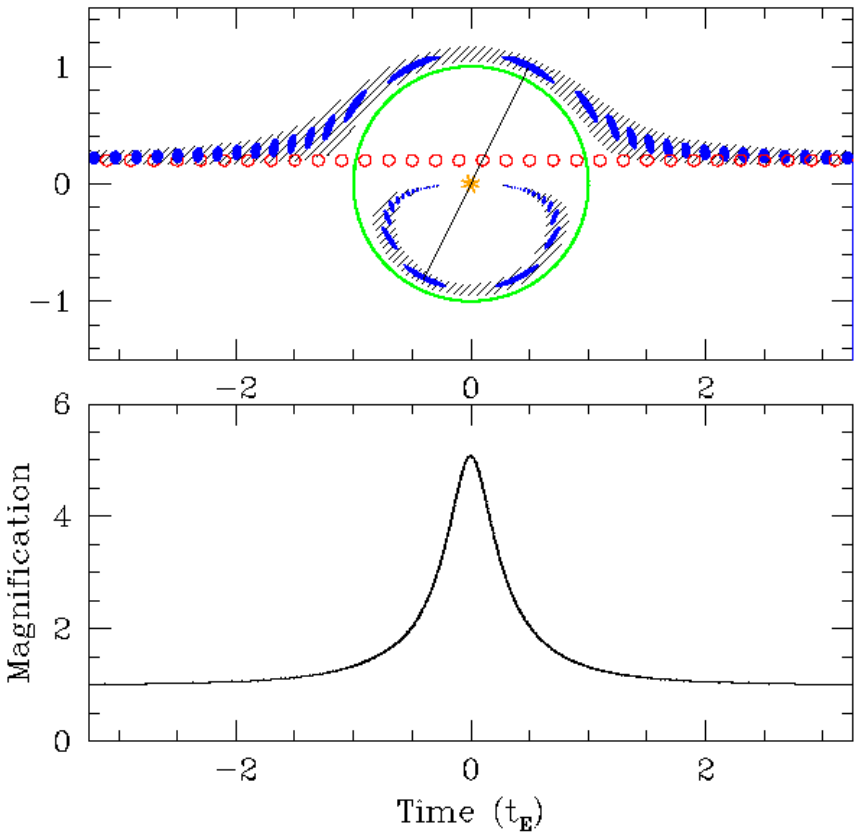
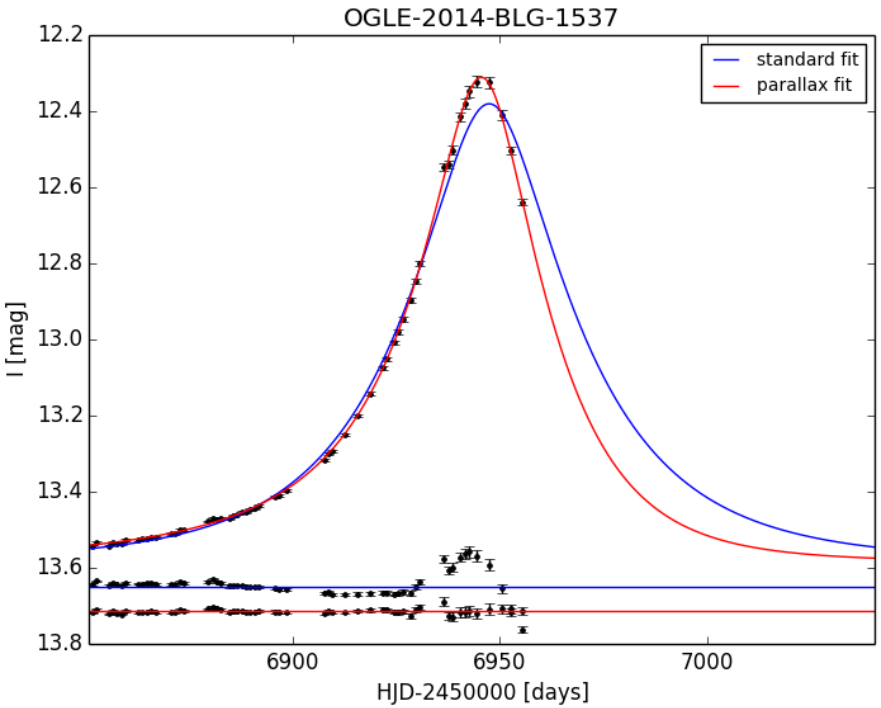


image credit: Scott Gaudi

Microlensing parallax and mass



Parallax:

$$\pi_{rel} = \frac{1}{D_l} - \frac{1}{D_s}$$

$$\pi_{rel} = \theta_E \pi_E$$

Mass formula:

$$M = \frac{\theta_E}{\kappa \pi_E} = \frac{\mu_{rel} t_E^{helio}}{\kappa \pi_E}$$

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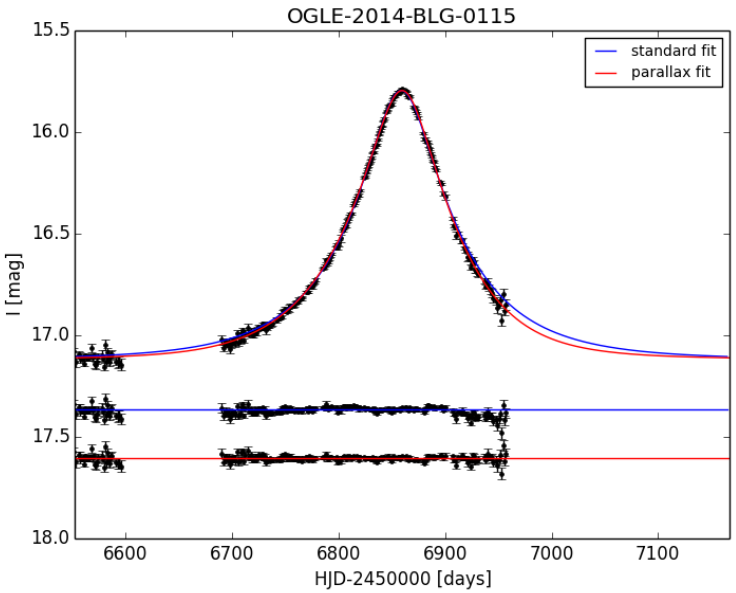
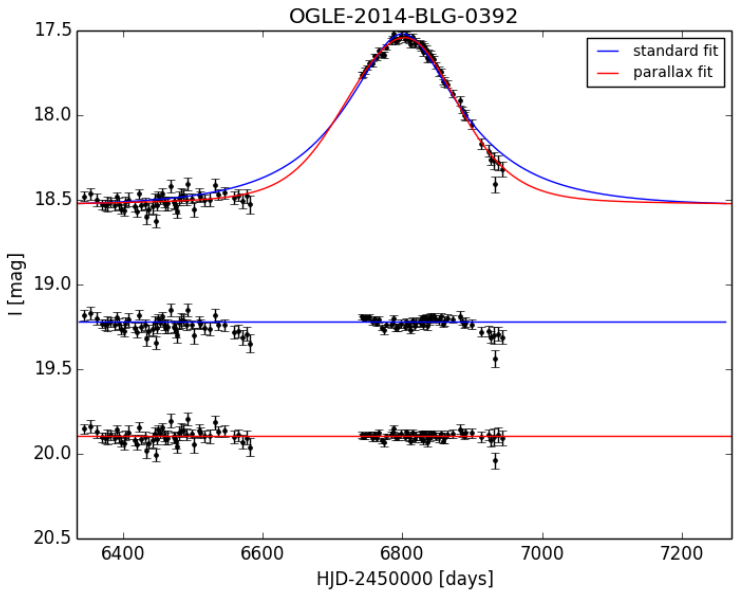
Events selection

- Long timescale: $t_{E_{std}} > 50$ days
- Gaia and OGLE observations overlap
- Parallax signal essential for mass determination
- Fit goodness

Lightcurve fits





$t_0, t_E, I_0, f_s, u_0, \pi_{EN}, \pi_{EE}$: 7 parameters from parallax model!

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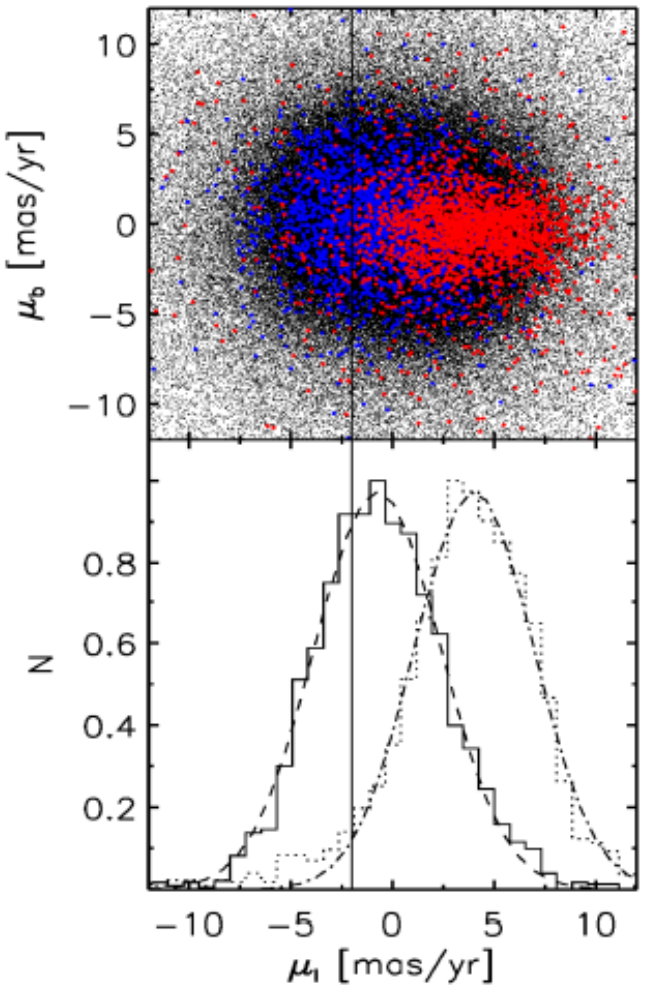
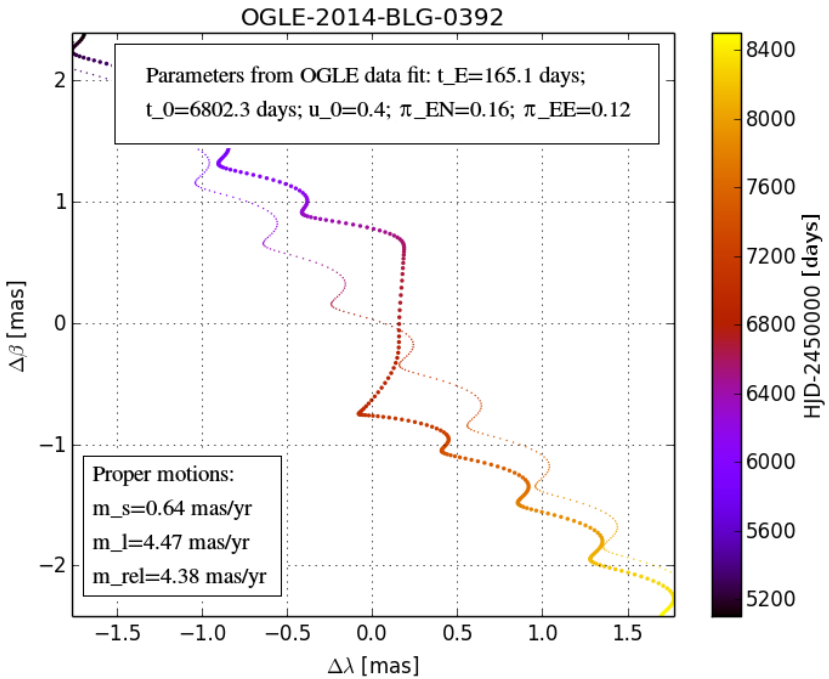
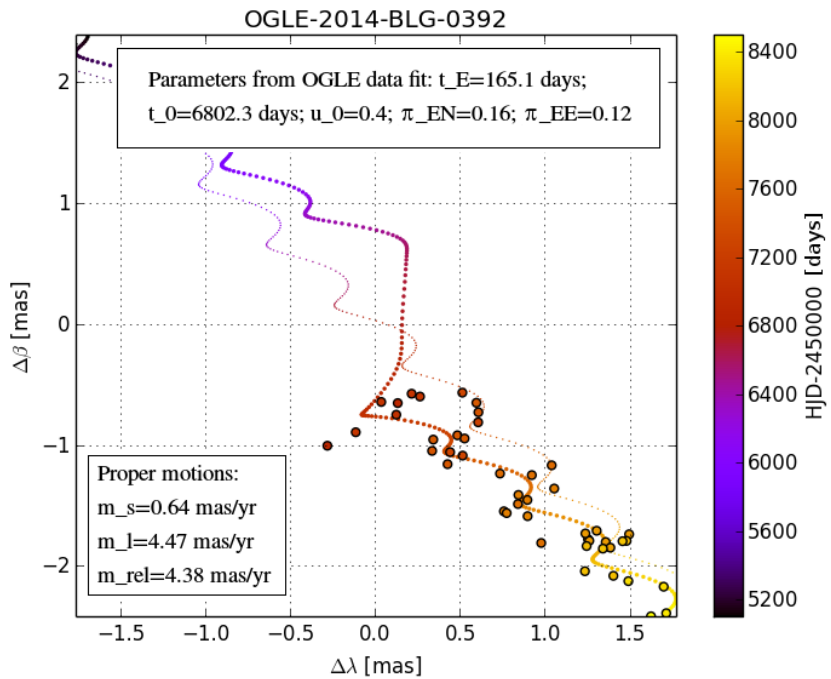
Proper motions

- PM bulge and disc distributions (Calamida et al. 2014)
- Proper motions: μ_{lens} and μ_{src}
- $\frac{\pi_{EN}}{\pi_{EE}} = \frac{\mu_{rel_y}}{\mu_{rel_x}}$
- $D_s = 8kpc$!!
- We could stop now: Wyrzykowski et al. 2015



Generating trajectory and Gaia data simulations



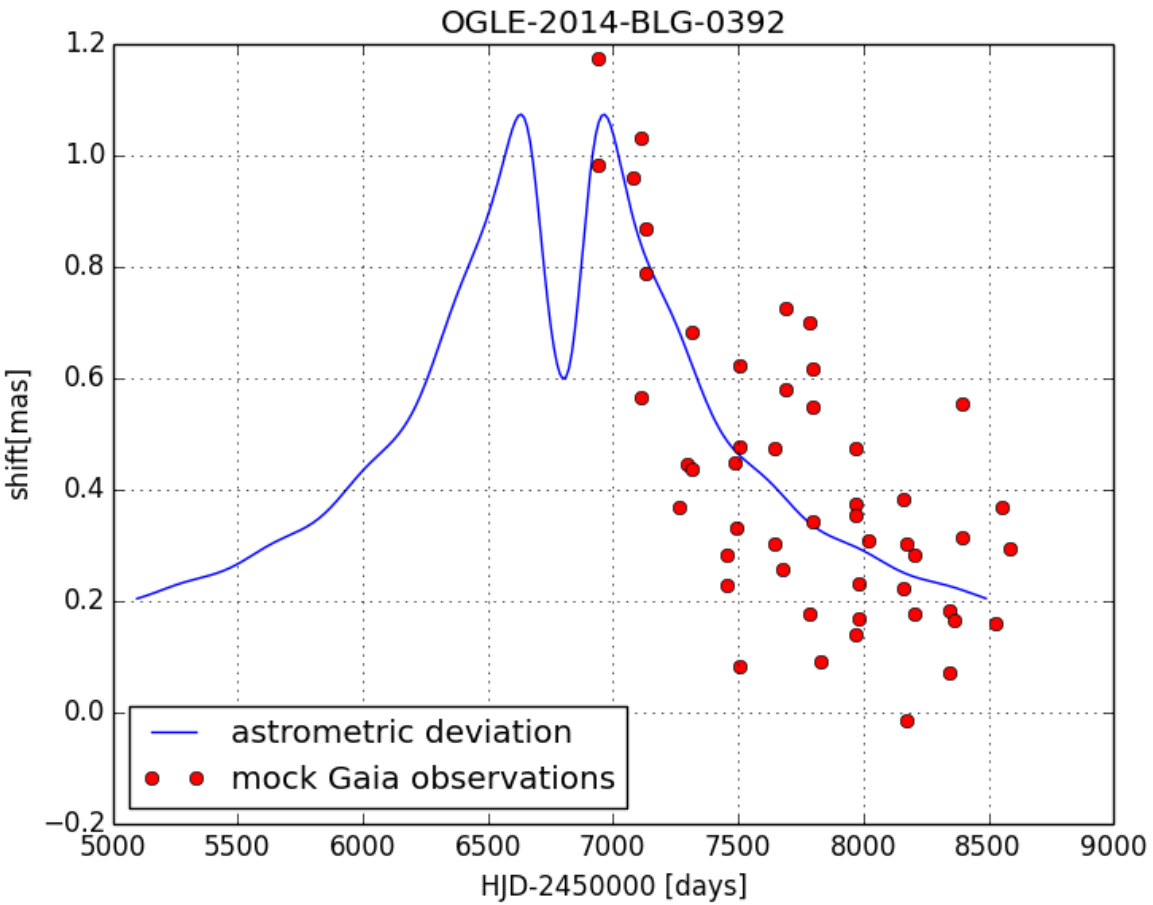


Gaia performance

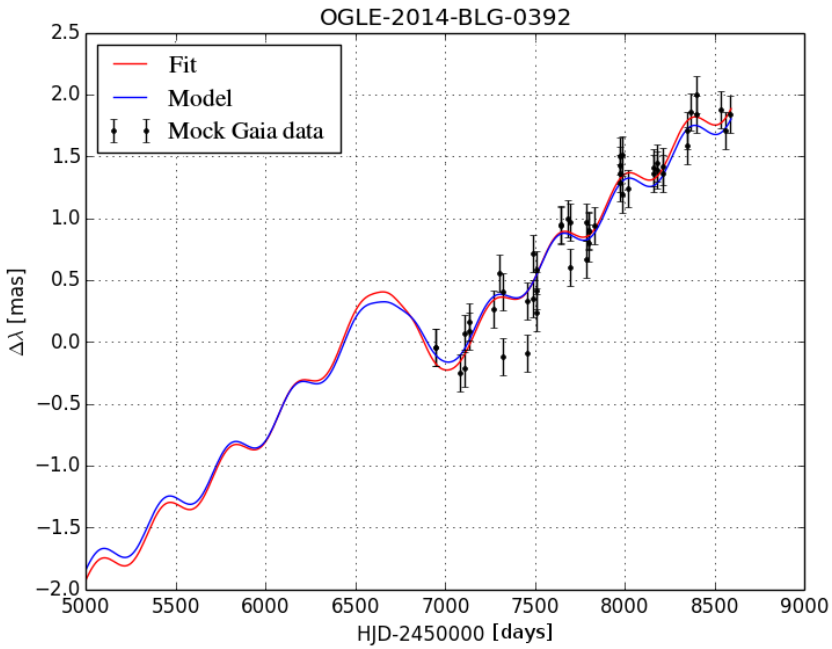
G [mag]	3–12.09	13	14	15	16	17	18	19	20
σ_0 [μas]	5.0	7.7	12.3	19.8	32.4	55.4	102	208	466
σ_ϖ [μas]	6.7	10.3	16.5	26.6	43.6	74.5	137	280	627
σ_μ [μas yr^{-1}]	3.5	5.4	8.7	14.0	22.9	39.2	72.3	147	330

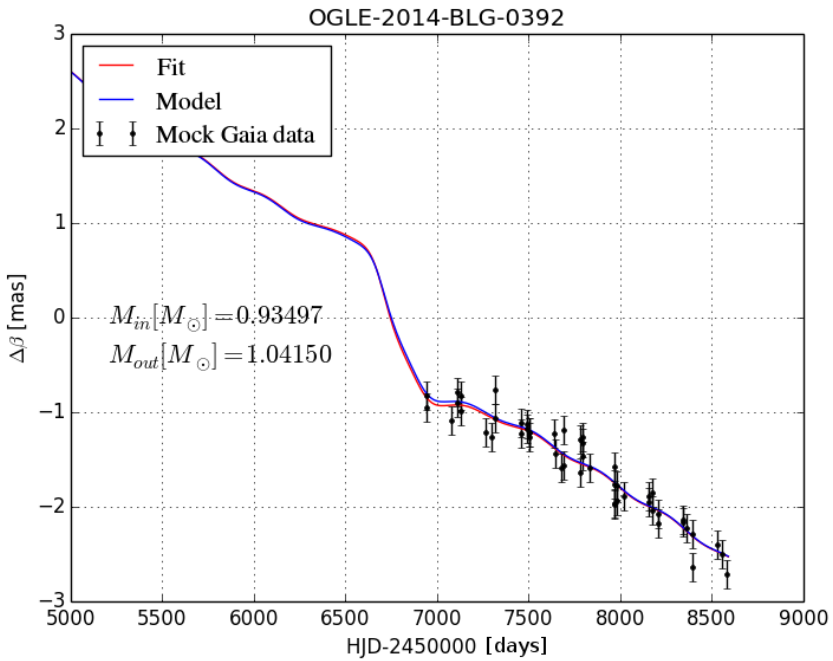
Figure: Gaia astrometric science performance - post-launch predictions (J.H.J. de Bruijne 2015)

Absolute shift vs t



Fitting trajectory





Only proper motions values are fitted, rest of the parameters are assumed to be known from the lightcurve!

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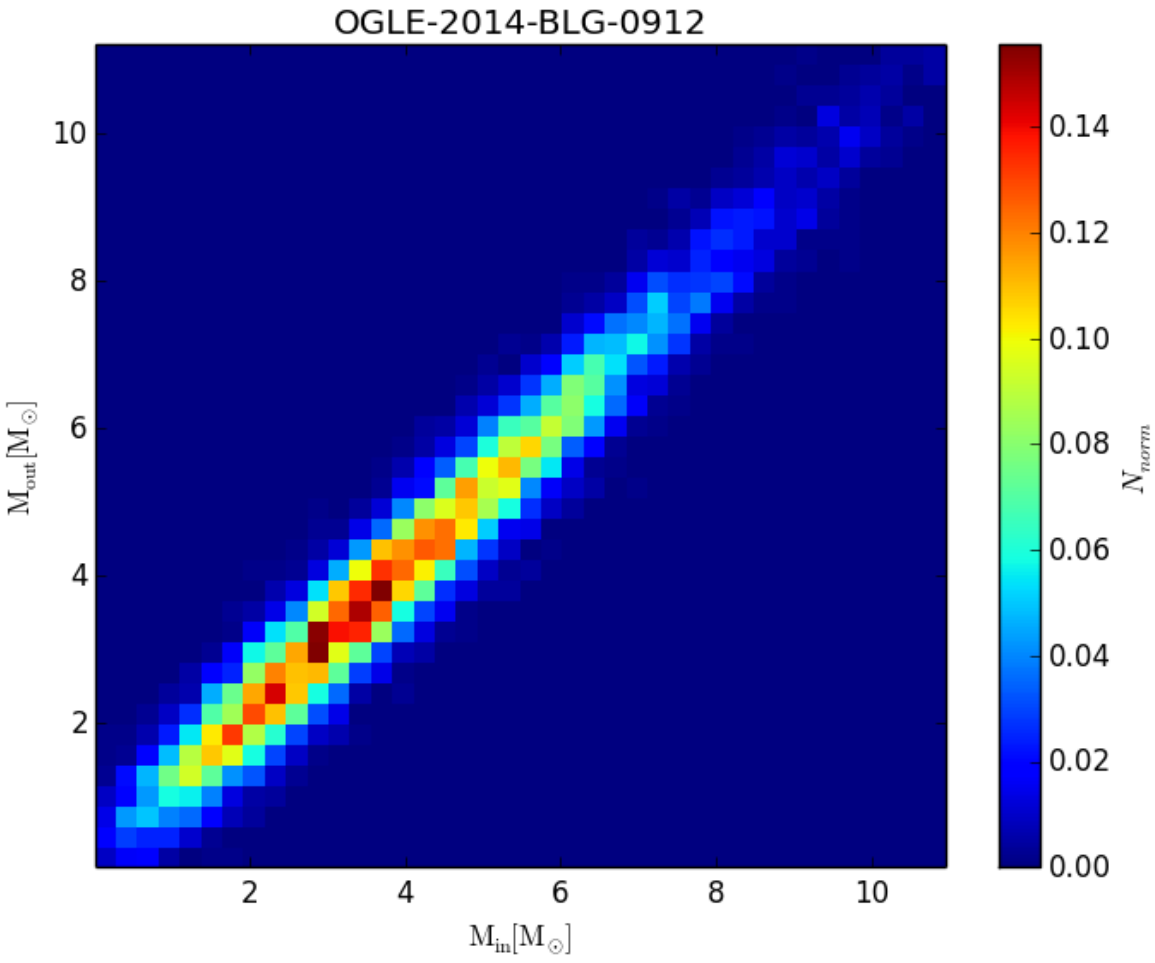
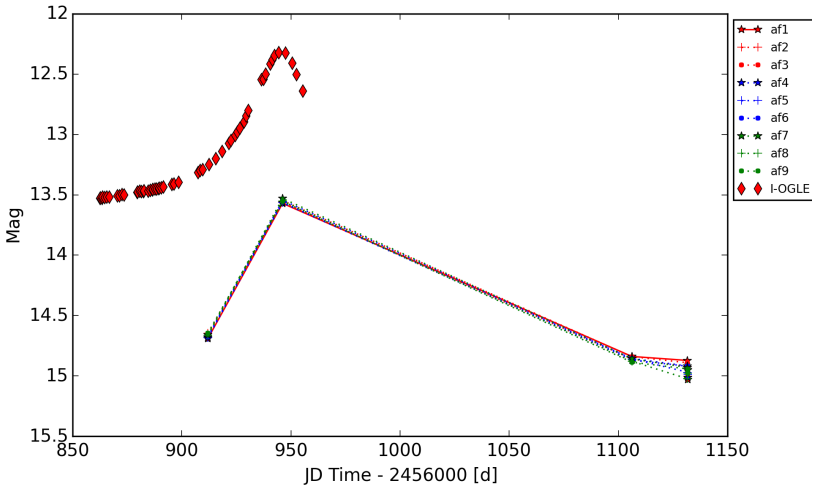
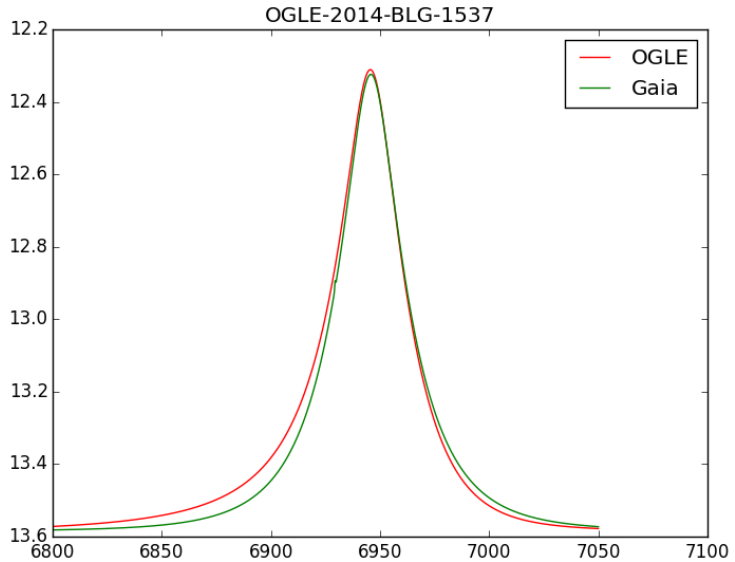
M_{in} vs M_{out}


OGLE-2014-BLG-0912
10
8
6
4
2
$M_{out}[M_\odot]$
2
4
6
8
10
$M_{in}[M_\odot]$
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
N_{norm}

*Parallax from space





Summary

- Having empirical distributions of proper motions we can derive probability function for lens mass
- With Gaia astrometry and OGLE photometry it will be possible to measure mass of the lens
- Measurement of space parallax may be possible with Gaia

The only way to derive masses of single, dark stellar remnants like neutron stars or black holes