Is the Distribution of Einstein Crossing Times of Galactic Microlensing Events Bimodal ?

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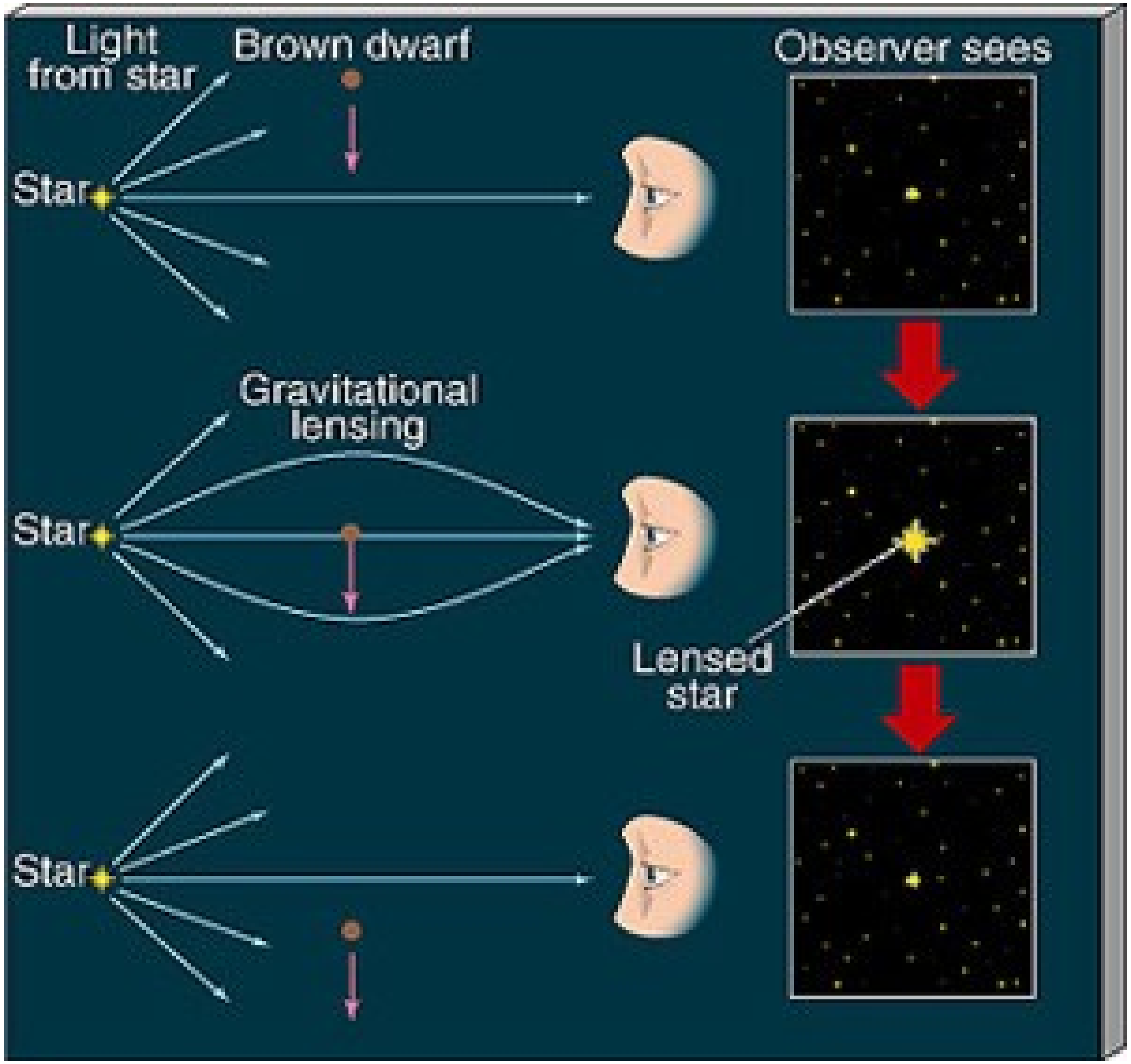
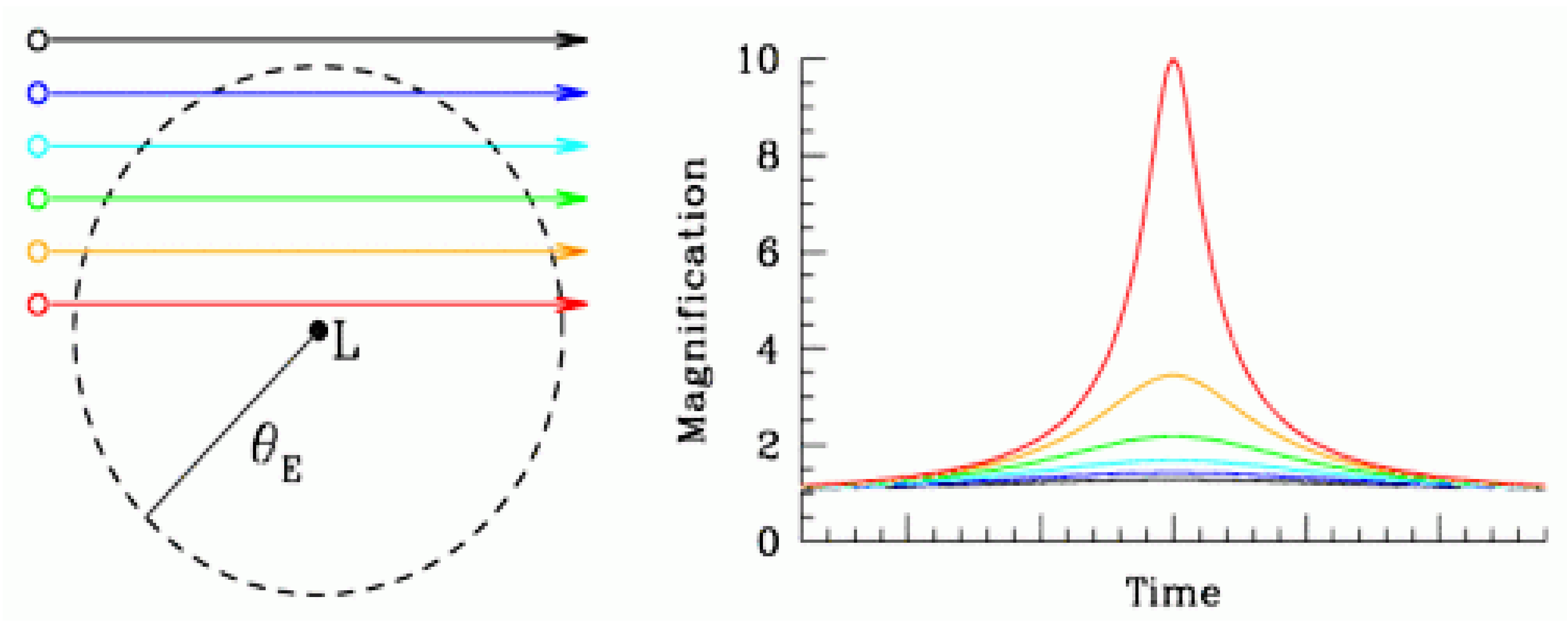
Microlensing cartoon



Computed microlensing light curves
- one time event & achromatic;
t_E is parameter defining width of curve

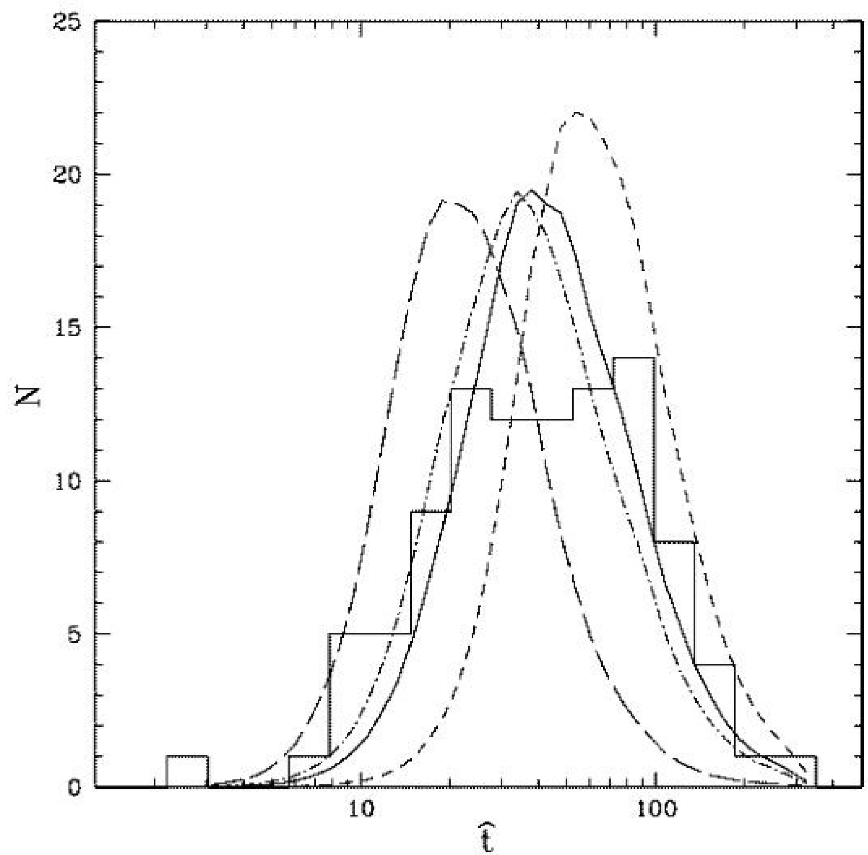
(Paczyński, 1986)



MACHO distribution of Einstein crossing times, t_E

Fig. 10. The timescale ($\hat{t}$) of the 99 candidate microlensing events compared to predictions from four mass models, normalised to the observed number of events. The mass functions are: a δ function at $0.1 M_\odot$ (long-dashed line); a δ function at $1 M_\odot$ (the short-dashed line); a Scalo (1986) PDMF (solid line); the Han & Gould (1996) power-law model with $\alpha = -2.3$ and $m_{lo} = 0.1$ (dash-dotted line).

MACHO: Alcock et al. 2000, ApJ, 541, 734



Sample & Method

Our sample: above paper which gives blending corrected t_E distributions and detection efficiency curves, supplemented by similar data from other microlensing projects:

MOA: Sumi et al. 2003, ApJ, 591, 204
OGLE: Sumi et al. 2006, ApJ, 636, 240

Out of ~ 400 events, only 160 satisfy these criteria.

$$t_E = 78.163 \left(\frac{M}{M_\odot}\right)^{\frac{1}{2}} \left(\frac{D_d}{10\mathrm{kpc}}\right)^{\frac{1}{2}} \left(1 - \frac{D_d}{D_s}\right)^{\frac{1}{2}} \left(\frac{v}{200\mathrm{km/s}}\right)^{-1} \text{ days}$$

Method: generate t_E via Monte Carlo simulations assuming density and velocity distributions for Galactic bar and disk, with stellar masses selected from known distributions of both Main Sequence and white dwarf samples.

Galactic bar & disk model

D_s and D_d selected from both bar & disk:

$$\nu(r_s) = \nu_0 \exp\left(-\frac{1}{2} r_s^2\right) 10^9 L_\odot \,\mathrm{pc}^{-3},$$

where

$$r_s = \left\{ \left[\left(\frac{x'}{x_0}\right)^2 + \left(\frac{y'}{y_0}\right)^2 \right]^2 + \left(\frac{z'}{z_0}\right)^4 \right\}^{\frac{1}{4}}$$

$$\rho_D = \rho_0 \exp\left[-\frac{|z'|}{h} + \frac{R_0 - s}{s_D} \right]$$

Orbital speeds from standard galactic rotation model (Han & Gould 1995)

Main sequence & white dwarf mass distributions

Main sequence (Scalo 1986 & Kroupa, Taut & Gilmore 1993):

$$\xi(M) \propto \begin{cases} M^{-2.35} & \text{for } M > 10M_\odot, \\ M^{-3.27} & \text{for } 1M_\odot < M < 10M_\odot, \\ M^{-2.2} & \text{for } 0.5M_\odot < M < 1M_\odot, \\ M^{-1.2} & \text{for } 0.2M_\odot < M < 0.5M_\odot, \\ M^{-1.85} & \text{for } 0.1M_\odot < M < 0.2M_\odot. \end{cases}$$

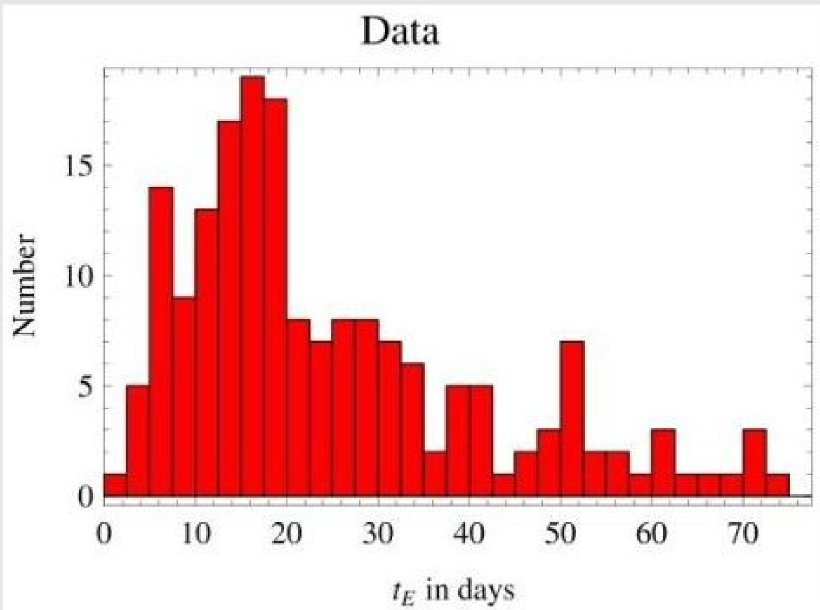
Have not modeled alternative mass function [log-normal distribution] for low-mass stars per Chabrier (2003) or Bochanski (2008), nor included sample of events with $t_E < 2$ days, implying mass component of Jupiter-like interstellar planets (Sumi et al. 2011).

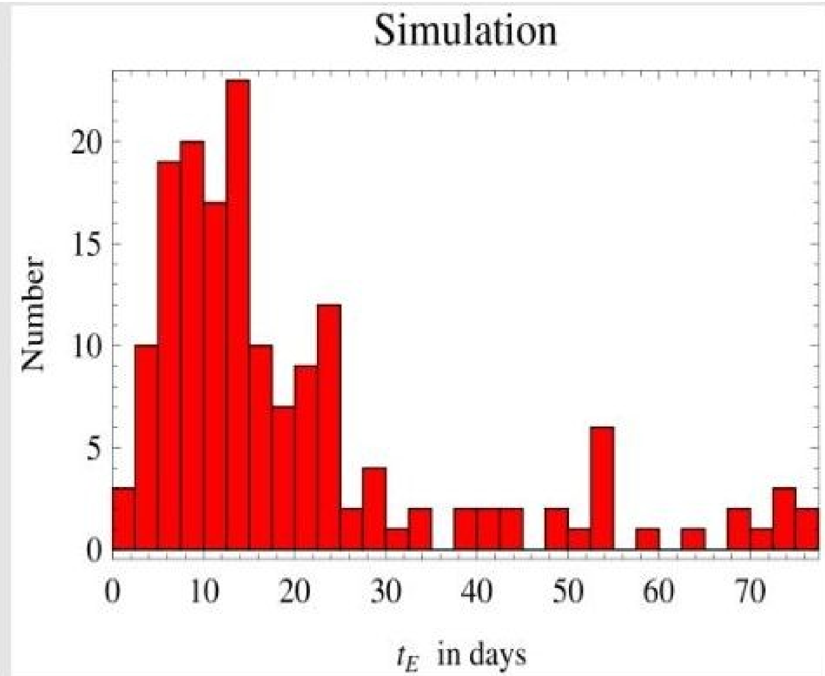
White dwarfs from two Gaussian distributions (Kepler et al. 2007, from SDSS data):

DA: $\langle M \rangle = 0.593\ M_\odot$, $\sigma_M = 0.11\ M_\odot$

DB: $\langle M \rangle = 0.711\ M_\odot$, $\sigma_M = 0.09\ M_\odot$

Results for our sample





K-S one sample tests show observed and computed distributions agree at 97% significance level for:
75% MS, 25% WD (86% DA, 14% DB)
Sources: 90% in bar, 10% in disk
Lenses: equally from bar & disk