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ARE THE EINSTEIN CROSSING TIMES OF GALACTIC MICROLENSING BIMODAL?

T Wickramasinghe*and J Nieusma
Department of Physics, The College of New Jersey, Ewing, NJ 08628, USA
E-mail: wick@tcnj.edu

M Struble
Department of Physics & Astronomy, University of Pennsylvania, Philadelphia, PA 190108, USA
E-mail: struble@sas.upenn.edu

The OGLE data [1] for Einstein ring crossing times, t_E, for microlensing events toward the galactic bulge are analyzed. The analysis shows that the crossing times are bimodal, indicating that two populations of lenses could be responsible for observed microlensing events. Given the possibility that microlensing in this direction can be due to both main-sequence stars and white dwarfs, we analyze and show that the observed bimodality of t_E can be derived from the accepted density distributions of both populations. Our Kolmogorov-Smirnov (KS) one sample test shows that that a white dwarf population of about 25% of all stars in the galaxy agrees well with the observed bimodality with a KS significance level greater than 97%.

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*Speaker.

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1. Introduction

The Einstein crossing time (measured in days) of a galactic microlensing event can be written as [2]

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

where M is the mass of the lens, v the relative orbital speed of the lens and the source, and D_d the distance of the lens, and D_s the distance of the source.

OGLE data for 190 events (Fig. 1) show a certain bimodality in the Einstein crossing times. In order to reproduce this bimodality, we use Eq. (1) with respective galactic mass distributions of main-sequence stars and white dwarfs. Once we have chosen all the relevant parameters satisfying their respective density distributions, we carry out a Monte Carlo simulation to obtain a distribution for t_E. This distribution is then tested against the observed distribution utilizing the KS one sample test to investigate the agreement.

2. Analysis

For our statistical analysis, the parameters in Eq. (1) were chosen as follows. About 90% of D_s values were chosen from the galactic bar. The density profile of the bar was assumed to be [3]

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

where

$$r_s = \left\{\left[\left(\frac{x'}{x_0}\right)^2 + \left(\frac{y'}{y_0}\right)^2\right]^2 + \left(\frac{z'}{z_0}\right)^4\right\}^{\frac{1}{4}} \tag{3}$$

and $\nu_0 = 3.66\times 10^7 L_\odot$ kpc^{-3}. The scale lengths are $x_0 = 1.85$ kpc, $y_0 = 0.62$ kpc, and $z_0 = 0.43$ kpc, respectively. In these coordinates, the galactic center is at the origin. The rest of D_s values were chosen from a disc population, whose density profile is given by

$$\rho_D = \rho_0 \exp\left[-\frac{|z'|}{h} + \frac{R_0 - s}{s_D}\right] \tag{4}$$

where ρ_0 is the mass density in the local solar neighborhood, h the scale height, and s and z' form a system of cylindrical galactocentric coordinates.

The lens distances D_d were chosen only from the disk. The orbital speeds v were chosen from a standard galactic rotation model.

Both main-sequence stars and white dwarfs were used for masses. For main-sequences masses, a combination of Scalo initial mass function [4] and a rapidly falling three-power law form due to Kroupa, et al.[5] was used as follows:

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

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Both DA and DB types of white dwarfs were used in our simulations. Their masses obey normal distributions such that $< M_{DA} >= 0.593 \pm 0.016 M_{\odot}$ and $< M_{DB} >= 0.711 \pm 0.009 M_{\odot}$ respectively.[6][7]

3. Analysis and Results

Figure 1 shows the OGLE data and our simulated values of Einstein crossing times. The KS one sample test was used to see if the two distributions had been drawn from the same parent distribution. For any acceptable agreement, two different mass distributions were essential. In our calculations, these masses were chosen from both main-sequence stars and white dwarfs including both types DA and DB. We find that the white dwarf contribution should be as high as about 25% to explain the data well. Out of this contribution, for a better agreement, we needed about 86% of DA and about 14% of DB dwarfs.

There was only very poor agreement if all the source stars were chosen only from the bar. This is contrary to the findings of Alcock et al.[8][9] who had taken all the sources to be in the bar. Our analysis shows that 90% of the sources could come from the bar while the rest must be drawn from a disk population. Excellent agreement was obtained for all the lens distances chosen equally from the disk and bulk populations.

The KS test indicate that our simulation agrees with the observed distribution with significance level greater than 97%. Our analysis shows that the possible bimodality of t_E could be due to a high percentage of white dwarfs($\sim$ 25%) and main-sequence stars.

References

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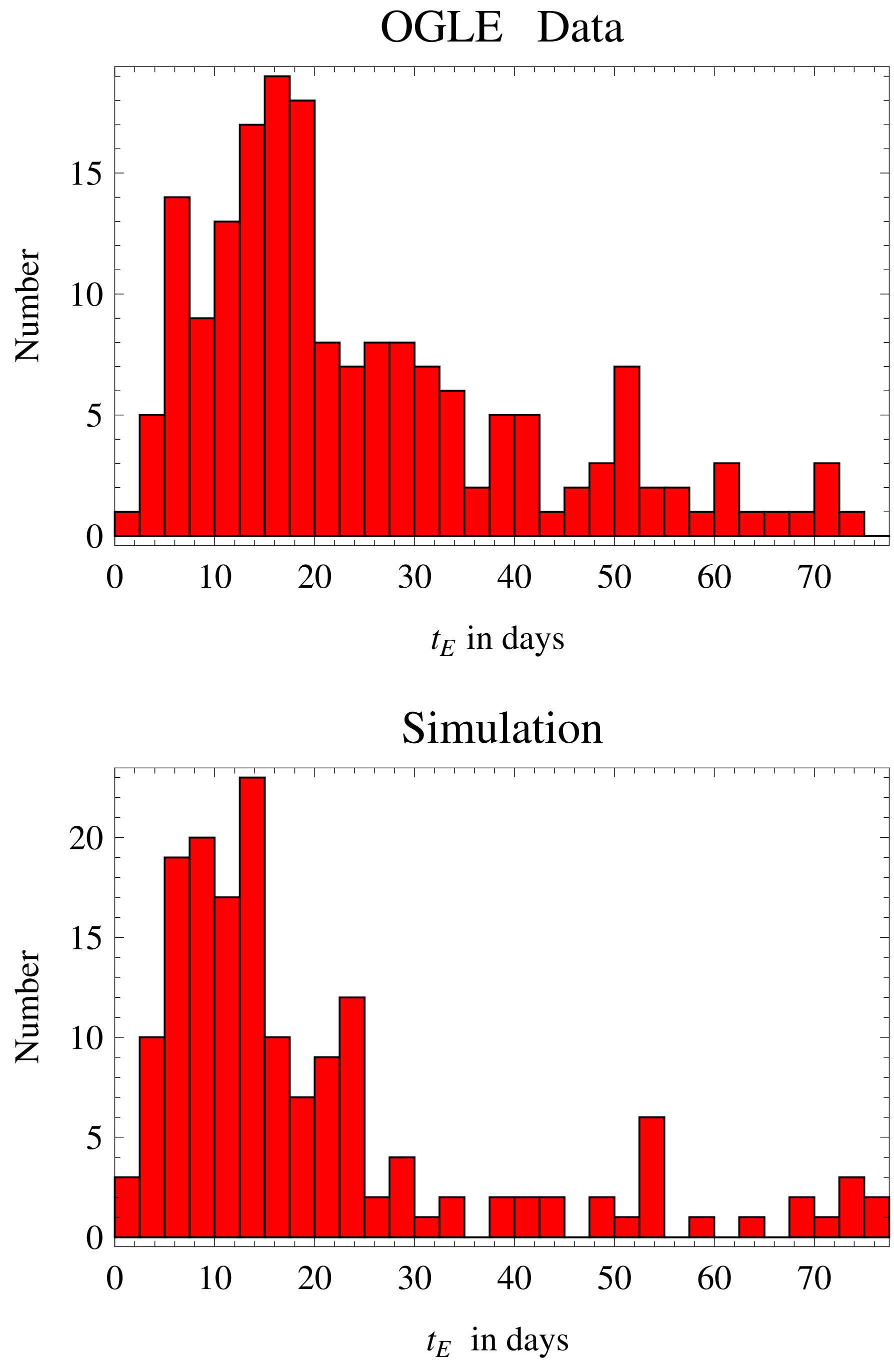

Figure 1: The data and simulated values for t_E. Kolmogoroff - Smirnoff one sample test gives that the two sets of data agree with a confidence level greater than 97%. This is an excellent agreement with our hypothesis that micolensing may be due to both main-sequence stars and white dwarfs in the galactic disk.