Binary Source Lensing and the Repeating OGLE EWS Events

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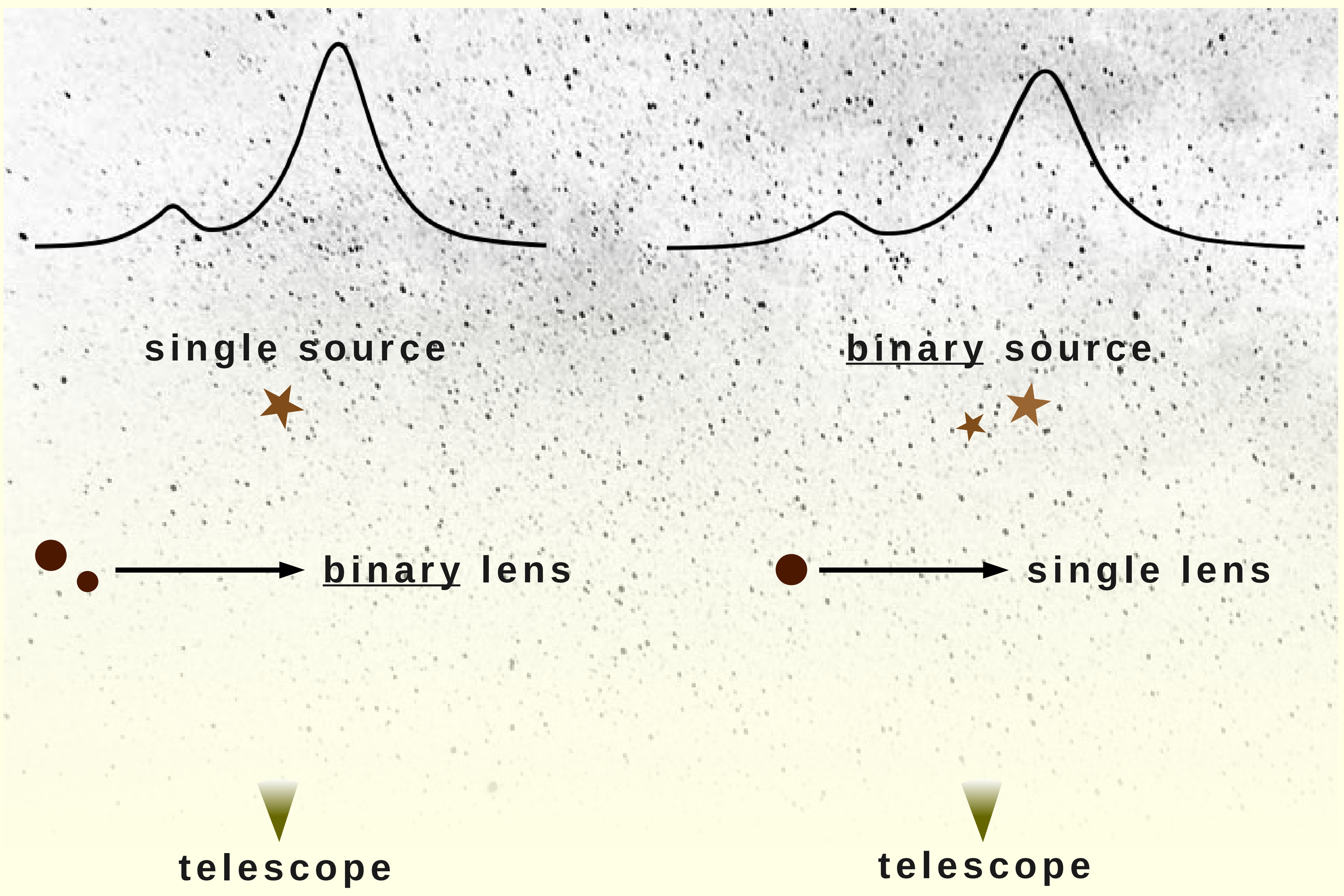
Abstract

A microlensing event may exhibit a second brightening when the source and/or the lens is a binary star. Previous study revealed **19** such repeating event candidates among **4120** investigated microlensing light curves of the Optical Gravitational Lensing Experiment (OGLE). The same study gave the probability **~ 0.0027** for a repeating event caused by a binary lens. We present the simulations of binary source lensing events and calculate the probability of observing a second brightening in the light curve. Applying to simulated light curves the same algorithm as was used in the analysis of real OGLE data, we find the probability **~ 0.0018** of observing a second brightening in a binary source lensing curve. The expected and measured numbers of repeating events are in agreement only if one postulates that all lenses and all sources are binary. Since the fraction of binaries is believed to be ≤ 50%, there seems to be a discrepancy.



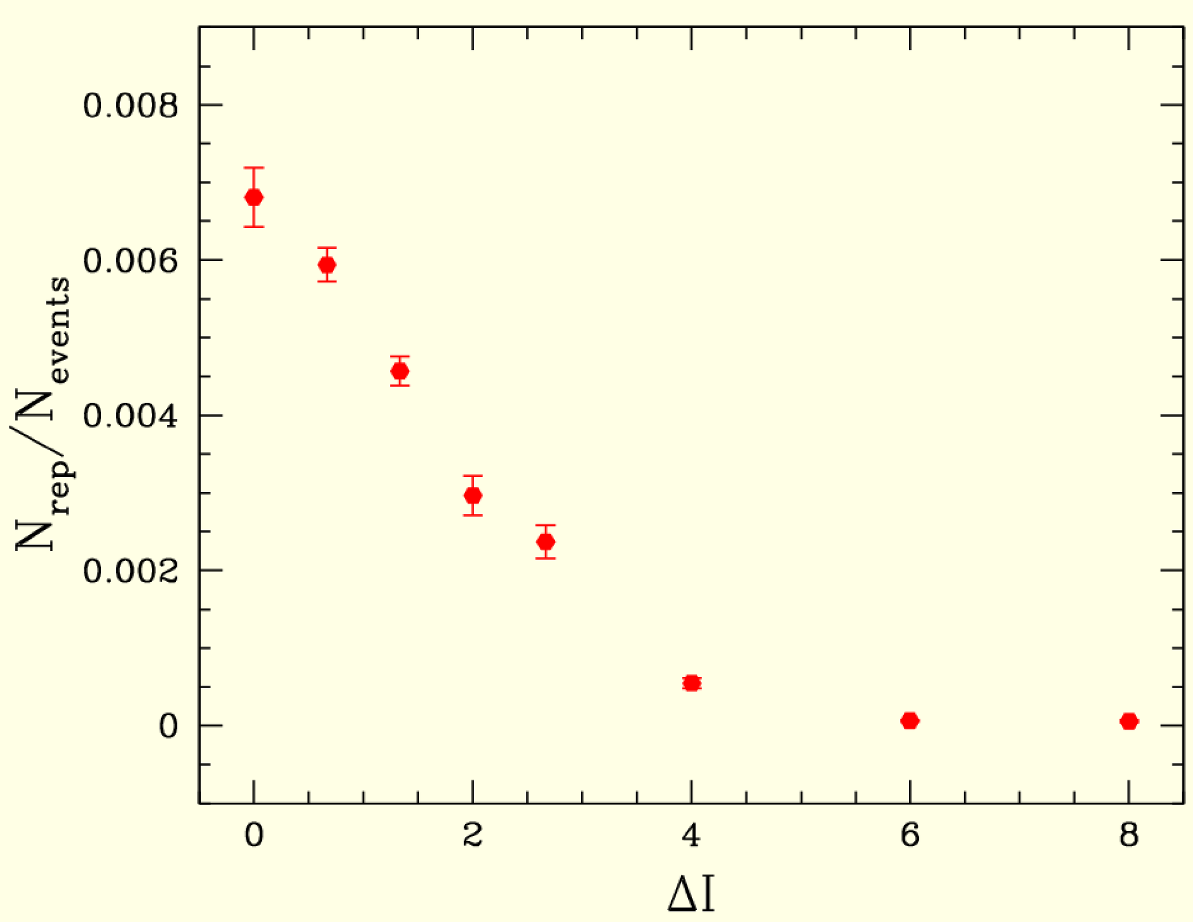
Both, binary sources and binary lenses can cause *repeating* microlensing event, i.e. two episodes in the light curve separated by drop to the baseline.
With similar separations, angles and impact parameters, light curves are very lookalike when mass ratio (in case of binary lens) is same as light ratio (in case of binary source).

Simulations

We simulate the microlensing light curves with binary sources to find probability of producing a *repeating* event. Our aim is to obtain realistic light curves, and we include several details typical for the OGLE team observations, like sampling rates, observational errors and their dependence on observed luminosity, span of observations etc.

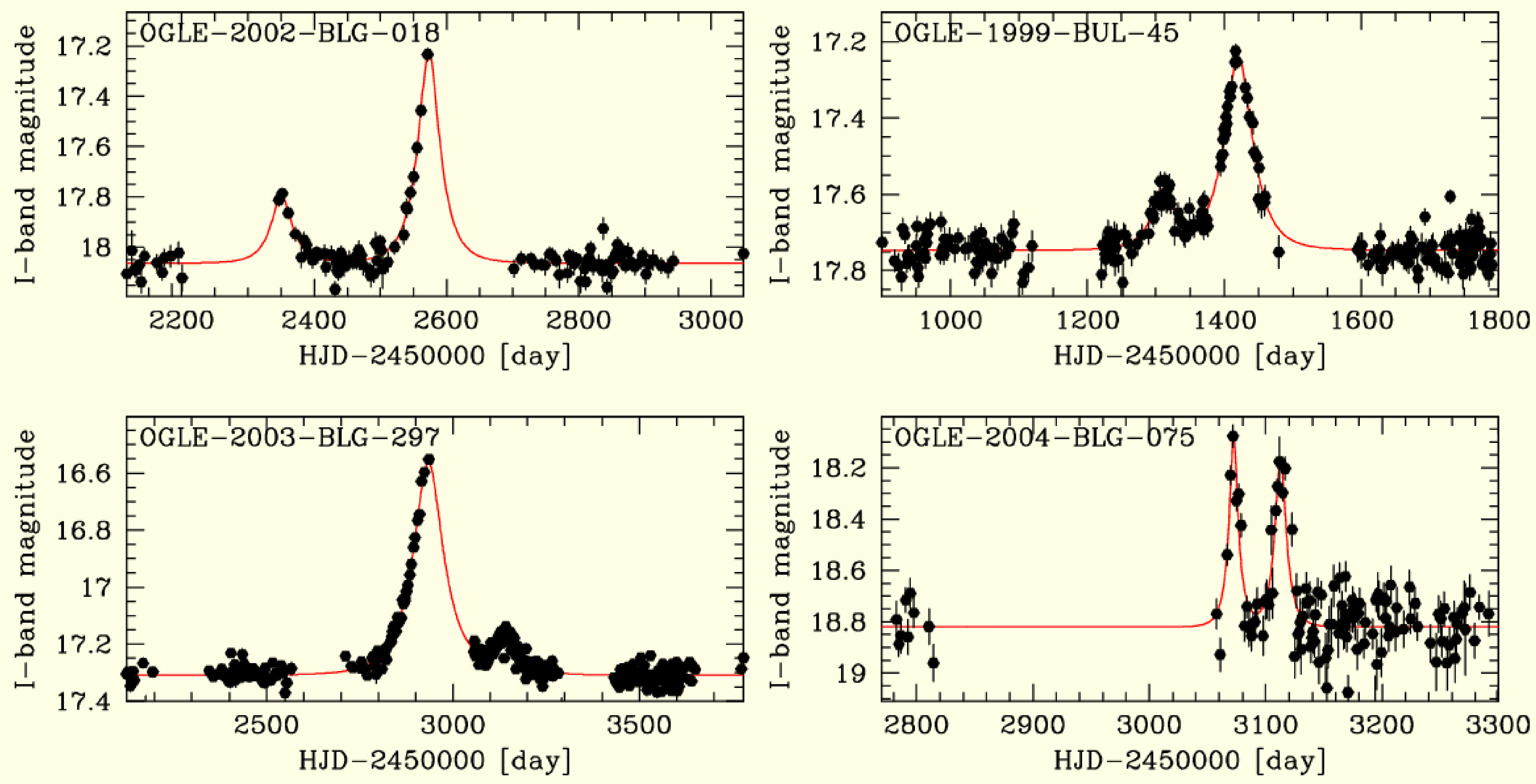
After constructing a microlensing model based on the simulations of the Galaxy structure and known properties of the binaries, we prepare an OGLE-like light curve and classify it with automated algorithm based on the one used in Skowron *et al.* (2009). Basically we fit Paczyński model (point-source point-lens) to identify a microlensing episode and mask it out from the light curve. Subsequently we seek for another episode by once again fitting Paczyński model. If second peek is found and the light curve returns to baseline between them, the event is classified as *repeating*.

We store the number of microlensing events identified in the simulated light curves, as well as the number of events classified as *repeating*. We use those values to calculate the effectiveness of finding a repeating events among large number of events caused by binary sources.



The effectiveness of discovering a repeating microlensing event as a function of the flux ratio of the binary source components. The flux ratio is expressed in stellar magnitudes ($\Delta I = |2.5 \log(F_1/F_2)|$).

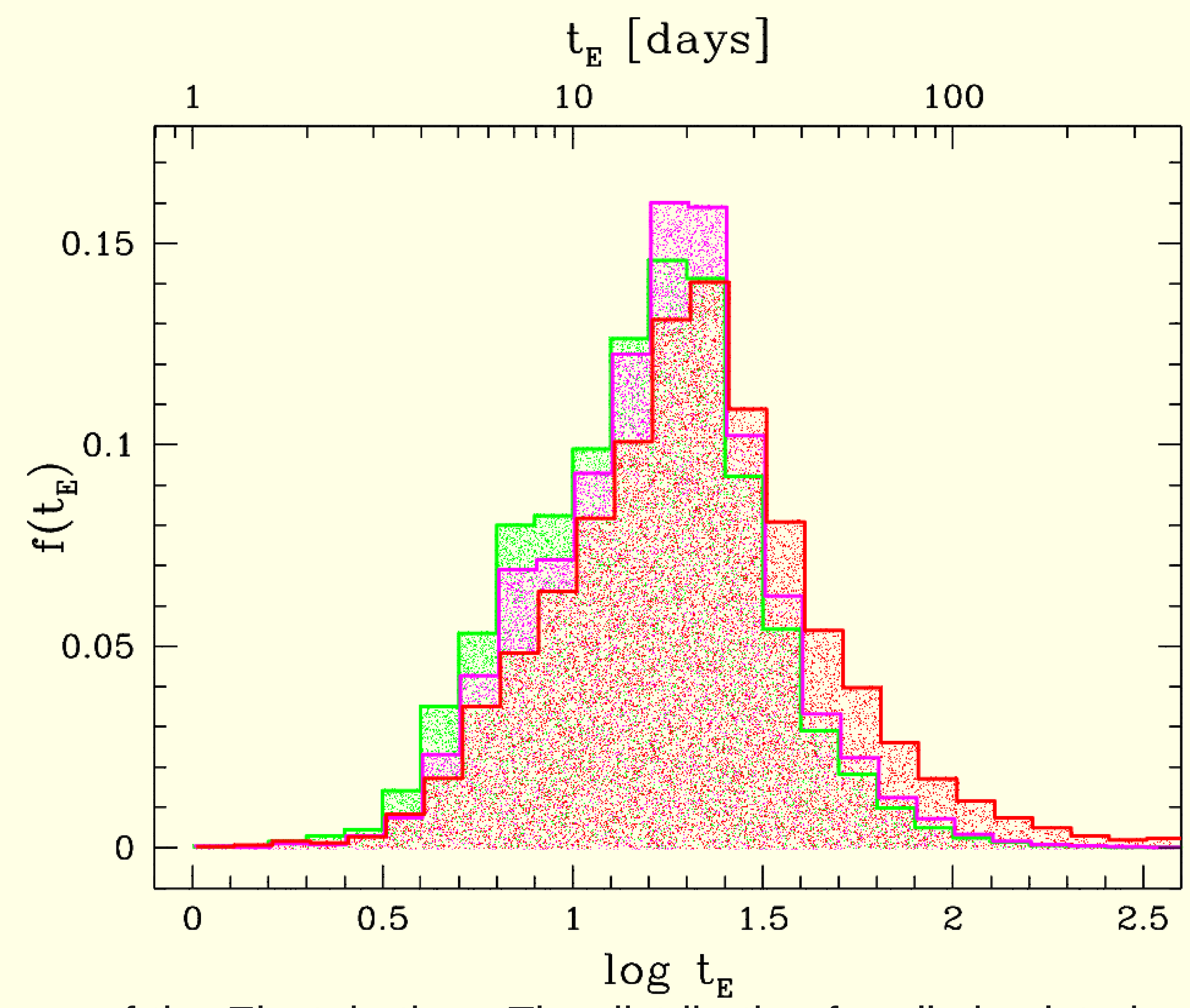
Some examples of repeating events observed by the OGLE Team.



Comment on time-scales

Our Galaxy model gives the intrinsic distribution of Einstein times for all would-be lenses with mean logarithm corresponding to ≈14 days. The subsample of microlensing candidates has the average corresponding to ≈18 days, where the simulation parameter values are used. Finally, the average for parameters fitted to the same subsample corresponds to ≈22 days. The three distributions are shown below. Note that these are presented on logarithmic scale and all mean values are calculated in logarithms, as mean time-scale calculated in days can be mis-guiding.

It is interesting that the logarithmic means for OGLE II and OGLE III EWS events (Udalski, 2003) are ≈22 days and ≈18 days respectively, in good agreement with our results.



The histogram of the Einstein time. The distribution for all simulated models is shown in green. Also the distribution of model parameters is shown in magenta but it is limited to cases accepted as microlensing events. The distribution of fitted parameter values for accepted models is shown in red.

Results

Using the described methods we have simulated few millions of binary source lensing light curves. About one third to one half of the simulated cases have been classified by our algorithm as microlensing event candidates, while the other have been rejected because of too weak or missing microlensing signatures.

We have calculated the probability of observing a *repeating* microlensing event among the sample of OGLE EWS events toward the Bulge, caused by the binary nature of the source star. The effectiveness (shown on the left) averaged over the interval of eight stellar magnitudes is 0.18%.

If all the sources included in the sample were binary, there should be 4120·0.0018≈7 repeating microlensing events of this kind, where the estimate is done for the 4120 events investigated by Skowron *et al.* (2009).

Analogous calculation by Skowron *et al.* (2009) shows that if all the lenses causing OGLE sample events were binary, they should produce another 4120·0.0027≈11 repeating events. The analysis of light curves from the sample by the same authors gives 19 repeating events, 12 probably due to binary lenses, 6 possibly due to binary sources.

Since not all stars belong to multiple systems, there seems to be a problem with the interpretation of the repeating events.

References

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