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DETECTION LEVEL ENHANCEMENTS OF GRAVITATIONAL MICROLENSING EVENTS FROM LIGHT CURVES: THE SIMULATIONS

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ABSTRACT

Microlensing can be seen as a version of strong gravitation lensing where the separation angle of the image formed by light deflection by a massive object is too small to be seen by a ground based optical telescope. As a result, what can be observed is the change in light intensity as function of time; the light curve. Conventionally, the intensity of the source is expressed in magnitudes, which uses a logarithmic function of the apparent flux, known as the Pogson formulae. In this work, we compare the magnitudes from the Pogson formulae with magnitudes from the Asinh formulae (Lupton et al. 1999). We found for small fluxes, Asinh magnitudes give smaller deviations, about 0.01 magnitudes smalller than Pogson magnitudes. This result is expected to give significant improvement in detection level of microlensing light curves.

Key words: gravitational lensing: micro; methods: data analysis

1. INTRODUCTION

A research group which routinely provides early indication of the occurrence of gravitational microlensing is the Optical Gravitational Lensing Experiment (OGLE) group. This group built an early warning detection system for gravitational microlensing events and provide photometrically reduced data Udalski (1994). In general, the brightness of an astronomical object is defined by its apparent flux (hereafter referred to as flux). The flux is converted into apparent brightness using the Pogson formulae for magnitude (m). We know very well how the Pogson formulae works, and it gives reliable magnitude errors for large fluxes. Conversely, for a small flux, with low S/N, the error in the magnitude will be very large. Therefore, Lupton et al. (1999) proposed a new set of equations to define object magnitudes, using the Inverse Hyperbolic Sine function (hereafter referred to as Asinh magnitude) that works well in low the S/N regime.

2. OBJECTIVES AND METHODOLOGY

We want to determine whether Asinh magnitudes can give better results in terms of the errors of magnitudes for small fluxes. Later, we want to increase the detection level of gravitational microlensing from light curves by using Asinh magnitudes. For the initial work, we performed a simulated magnitude calculation from inputs such as the temperature range, size, and distance of the source. In this work, we use stellar radii in the range 1-3 $R_\odot$ and star temperatures between 3000–11000 K, corresponding to stars of spectral classes A to M, and observations at visual wavelengths of ($\lambda = 550$ nm). In addition, we also adopt one value for source distance, $d = 8.5$ kpc. Magnitudes from the simulations will be converted to Asinh magnitudes. Later, we apply Asinh magnitudes to OGLE photometric reduced data with magnitudes brighter than 19m, selected using the Microlens Priority Generator from RoboNet Planet Search for the 2013 and 2014 seasons. The photometric data from the Early Warning System OGLE (EWS-OGLE) does not provide flux information. Therefore, we used the transformation equations from Bessel et al. (1998), to calculate the flux and its error.

3. DATA

We choose one microgravitational lensing event for each season, with input parameters of the Las Campanas Observatory $\phi = 29^\circ\ 00'\ 36.9''$ S, $\lambda = 70^\circ\ 42'\ 5.1''$ W and using the 1.3-m Warsaw Telescope. The midpoint of the early data starts at at HJD = 2456840.727. The selected events are OB130723 and OB140042.

4. RESULTS

In Figure 1, we present the simulation results for for R = 1 $R_\odot$. We can see that the Asinh formulae gives smaller

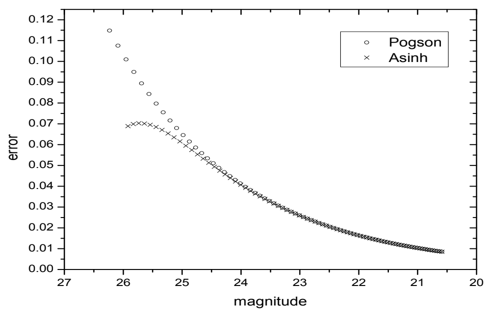

Figure 1. Error magnitude versus magnitude for 1 $R_\odot$.

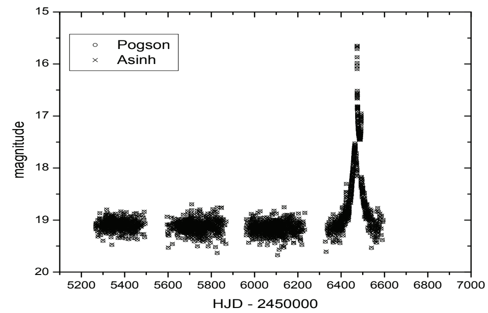

Figure 2. The light curve for event OB 130723

errors than Pogson for small fluxes. We also obtain a mean of the error difference for all the simulations of about 0.003 (for R = 1 $R_\odot$), 0.001 (R = 2 $R_\odot$), and 0.0002 (R = 3 $R_\odot$). The error difference (δ) is defined as the difference between the two magnitude formulae.

After we recalculated the magnitudes with Asinh formulae, we reconstructed the light curve of each event. The light curve is a plot of the brightness of events computed by Pogson magnitudes and Asinh magnitudes against time. Figure 2 shows the light curves for the selected event OB130723. The circle is for Pogson magnitudes and the cross for Asinh magnitudes. If we look carefully, we can see some slight difference between them. This can be seen more clearly in the results given in Figure 3. The error difference of the two magnitude systems can be seen more clearly. There is a tendency that the error difference for smaller fluxes will be larger. We performed curve fitting using the form

$$\Delta = C \times e^{(A \times m)} \quad (1)$$

where the value of C and A respectively are constants and coefficients of the regression. The results are shown in Table 1. Using the mean of the error difference and Equation (1) to fit each event, we propose a magnitude value where it is appropriate to use to the Asinh formulae instead of the Pogson formulae. This is shown in Table 2.

5. CONCLUSIONS

The conclusion that we obtained from this study are:

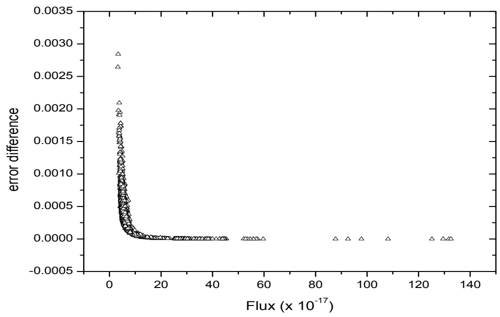

Figure 3. Error difference versus flux for event OB130723

Table 1
Coefficients and constants of regression

Event	A	C	adj. R^2
BLG130723	3.288	2.07×10^{-31}	0.76
BLG140042	3.035	2.50×10^{-29}	0.87

Table 2
Suggested starting point

Event	M_{limit}
BLG130723	19.10
BLG140042	19.76

1. For large fluxes, there is no significant difference between Pogson and Asinh. For small fluxes, there appears to be some difference in magnitude. The Asinh formulae give smaller deviations than the Pogson formulae.
2. We strongly suggest using Asinh magnitude for photometry of sources with magnitudes fainter than 19^m.

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