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Exoplanet detection capability of microlensing observations

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Abstract

The exoplanet detection capability of microlensing observations is compared for several telescopes. As a part of our studies, we consider the models for sky brightness and seeing, calibrated by fitting to data from the OGLE survey and RoboNet observations in 2011.

1. Introduction

Microlensing is unique in its sensitivity to wider-orbit (i.e. cool) planetary-mass bodies, allowing to find planets with masses down to the mass of the Moon. Below we compare the exoplanet detection capability of microlensing observations for several telescopes. Time intervals during which events are observable are identified by accounting for positions of the Sun and the Moon, and other restrictions on telescope pointing. Based on the approach presented by Horne et al. [1], at each time step for different events we calculate the detection zone area and the exoplanet detection capability. The event with a maximum capability at a time step is chosen for observations.

We considered the following 13 telescopes numbered from N_t=1 to N_t=13:

1. 2 m FTS - Faulkes Telescope South - Siding Spring Observatory, Australia.
2. 2 m FTN - Faulkes Telescope North - Haleakela, Hawaii, USA.
3. 2 m LT - Liverpool Telescope - La Palma, Canary Islands, Spain.
4. 1.3 m OGLE - The Optical Gravitational Lensing Experiment - Las Campanas, Chile.

5-7. Three 1 m CTIO - Cerro Tololo Inter-American Observatory, Chile.

8. 1 m MDO - McDonald observatory, Texas, USA.

9-11. Three 1 m SAAO - South African Astronomical Observatory, South Africa.

12-13. Two 1 m SSO - Siding Spring Observatory.

2. Models for sky brightness

Models for sky brightness and seeing (based on [2]) have been developed for FTS, FTN, LT, and OGLE. They were calibrated by fitting to *I*-band data from the OGLE survey and RoboNet observations in 2011. The models are part of our work on construction of the simulator which maximizes the planet detection zone area for a search with the use of the microlensing method. We used χ^2 optimization for analysis of observations. The values of seeing for FTN were almost twice less than those for the other three telescopes considered (FTS, LT, and OGLE). The obtained *I*-band sky brightness at the zenith was 19.0, 18.7, 19.6, and 18.1 mag arcsec^{-2} for FTS, FTN, LT, and OGLE, respectively. At the same airmass, the typical sky brightness near different microlensing events (different regions of sky) usually varied by less than 1 mag if we analyze images with the Moon below the horizon. Most of sky brightness residuals relative to the best fit model for each event (observations minus χ^2 optimization which is different for different events) are in a small range (-0.4 to 0.4 mag) even for all Moon and Sun positions; for the Moon below the horizon there are many values in the range [-0.2, 0.2], but the absolute values of some residuals can be much greater (up to 4 mag if we consider all observations). The influence of solar elevation on sky brightness began to play a role at solar elevation θ_{Sun}>-14^o, and was considerable at θ_{Sun}>-7^o. If we consider FTS observations with the Moon below the horizon, then sky brightness residual s_{br} can be up to -3 mag at -8^o<θ_{Sun}<-7^o, s_{br}>-1 mag at θ_{Sun}<-8^o, and s_{br}>-0.4 mag at θ_{Sun}<-14^o.

3. Exoplanet detection capability of observations

Our simulator suggests what events it is better to observe at specific time intervals with a specific telescope in order to increase the detection capability of finding new exoplanets based on microlensing observations. For estimates of the detection capability, for best events (i.e., events selected for observations at a current time) we considered the value of w_{sum}. Its calculation is discussed in http://star-www.st-and.ac.uk/~si8/doha2013s.ppt. In Fig. 1 for 13 telescopes, we present the values of $r_{wsumt}=(w_{sum}/w_{sumOGLE})/(t_{sum}/t_{sumOGLE})$, where t_{sum} is the total time during considered time interval when it is possible to observe at least one event ($t_{sumOGLE}$ is the value for OGLE).

The obtained results show that, for a search for exoplanets based on already discovered events, a 2 m LCOGT telescope (FTS, FTN, or LT) is more effective (per unit of time of observations) than OGLE, and the efficiency of a 1 m telescope with the Sinistro CCD often is about 0.8 of that of OGLE, but in some runs it was greater than that of OGLE (see Fig. 1). The ratio r_{wsumt} of values of w_{sum} per unit of time for the 2-m telescopes to that for OGLE often is in the range of 1.2-2.1, but in some calculations r_{wsumt}>3. The ratio of the values of w_{sum} for FTS and SSO (the telescopes are at the same site) usually was about 2. For the SBIG CCD, the values of w_{sum} were smaller by a factor of ~1.2 than those for the Sinistro CCD. The value of w_{sum} was typically proportional to the diameter of the mirror.

Analysis of our calculations shows that during most of the time it is better to observe different events using different telescopes located at the same site than to observe the same event with two or three telescopes, but at a time close to a light-curve peak often it is better to observe the same event with all telescopes located at the same site. For 1562 events (110001-111562) and 90-day (or larger) time interval, a considerable (often greater than 50%) contribution to w_{sum} was during short time intervals corresponding to peaks of light curves if this telescope is allowed to observe all events. Our code can be used for planning various observations (not only observations of microlensing events).

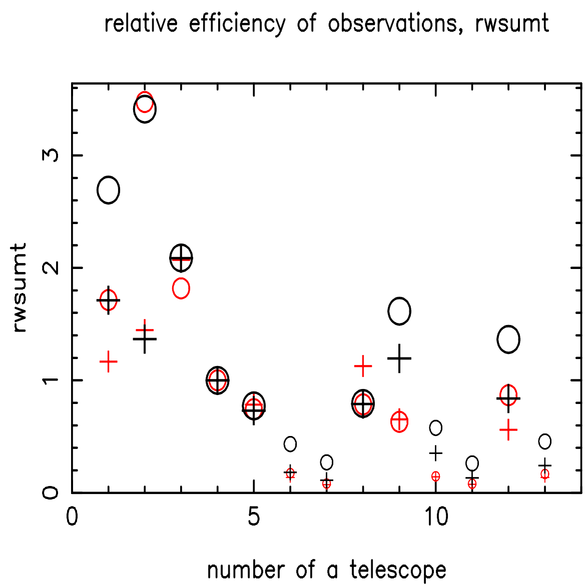

Figure 1: The values of r_{wsumt}, which characterize the exoplanet detection capability of microlensing observations in the case of 1562 events (110001-111562) available for observations, vs. the number N_t of a telescope (see N_t in Section 1) in the case when 1 m telescopes (equipped with the Sinistro CCD) located at the same site observe different events at the same time. Crests and circles are for the 90-day time interval beginning from May 2 and August 1 2011, respectively. The signs for calculations with actual values of t_o (the time corresponding to the peak of a light curve) and with random values of t_o are black greater and red smaller, respectively. Small signs are for non-priority telescopes. For random values of t_o, the number of light curve peaks was greater.

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