Gravitational microlensing as a tool to study the Galaxy

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Gravitational microlensing, a very rare, but powerful phenomena, allows us to study a range of compact objects like extrasolar planets, stars or black holes. By means of this application we can study the structure of the Galaxy in a unique way. We present new results from the Optical Gravitational Lensing Experiment (OGLE), which are related to the structure of the Milky Way's inner parts and the halo.

1 Introduction

Gravitational microlensing is caused by the light deflection in the gravity of a massive compact object. The microlensing event occurs when a foreground star is close enough to the line of sight of a background star whose light is then bent by the gravity of the foreground star (the lens). It causes a temporal brightening of the background star, which we can see as a bump in the otherwise flat light curve.

OGLE has been running since 1992 at the University of Warsaw (Poland). Since 1996, it has been using a dedicated 1.3 m telescope located in the Las Campanas Observatory in Chile. The main aim of the project is to continuously monitor hundreds of millions of stars down to 21 mag towards the Galactic Centre and the Magellanic Clouds in order to detect gravitational microlensing events (Paczyński, 1996).

2 Dark Matter in the Halo

The main scientific goal of the OGLE and other sky surveys at their very beginnings was to verify the hypothesis that MACHOs, the compact dark matter objects, compose the bulk of the dark matter in the Galactic Halo. The long-standing debate was fuelled by contradictory results from different surveys regularly monitoring the Magellanic Clouds. Only recently a combination of the OGLE-II and OGLE-III data (nearly 14 years of data) yielded in a conclusion that there is very little or none of MACHOs with masses below 1 $M_\odot$ in the halo (Wyrzykowski et al., 2011).

3 Structure of the inner Galaxy

OGLE-III covered about 90 square degrees towards the Galactic bulge for 8 years with a typical sampling of one visit every 3-4 days. Archival data were searched for microlensing events and about 3600 standard events were selected. It made the largest homogenous set of events ever created, perfect for verification of the models of the inner Galaxy. The event time-scale depends on the combination of lens and source distances, velocities and mass of the lens. Large statistical samples help reveal the overall differences due to different mixture of stellar populations with different kinematics. The map of the observed mean time-scale of the events is in good agreement with the most recent models from Kerins et al. (2009), which relied on the Besançon Galaxy model. The asymmetry due to near–far bar configuration is plainly visible in the OGLE-III data. Extension of such microlensing studies to lower |b| is essential for understanding the structure of the inner central parts of the Galaxy – this will be achieved with the infrared surveys like VVV or WFIRST.

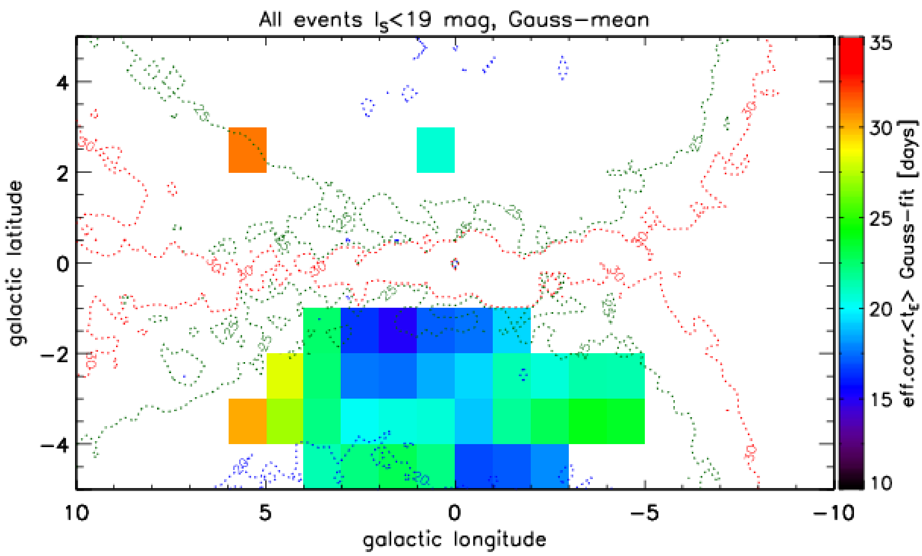

Fig. 1: Map of the mean time-scale for 3600 events found in the OGLE-III data, indicating clear asymmetry due to near–far bar orientation.

4 Coping with the dense stellar images

It was microlensing which primarily motivated the development of the difference imaging techniques (DIA, Woźniak, 2000), capable of providing superb photometric time-series from images containing sources blending with each other. Comparing the OGLE and HST images in the same location of the sky blending parameter can be derived using observational luminosity function. A consideration of the blending parameter is very important because it allows to interpret the time-scale of the event correctly and determine the efficiency of detection of the events.

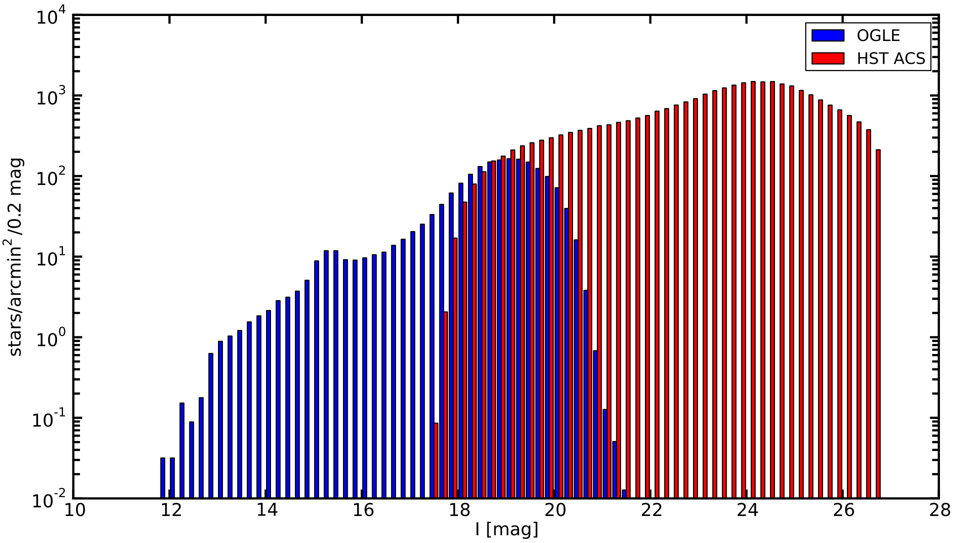

Fig. 2: Observational luminosity function toward the Galactic bulge from the OGLE and HST data. (Based on observations made with the NASA/ESA Hubble Space Telescope, obtained from the data archive at the Space Telescope Science Institute. STScI is operated by the Association of Universities for Research in Astronomy, Inc. under NASA contract NAS 5-26555.)

5 The next decade: OGLE, Gaia, LSST

The OGLE project is expected to continue its operation for a long time. OGLE-IV phase (since 2010) takes full advantage of field-of-view of the 1.3m telescope in Las Campanas and provides about 2000 of events per year, also with the planetary signatures. Such large sample of events will be unique in studies of the Galaxy.

For the next 5 years Gaia, which is the European Space Agency's mission, will be monitoring a billion of stars down to V=20 mag. During this time Gaia can discover over one thousand of events in the whole sky, additionally providing crucial astrometric data. It will allow to determine the masses and distances of the lenses, and hence the galactic mass function. Combination of the Gaia data with the OGLE data could also lead to a discovery of free-floating black holes (Wyrzykowski et al., 2012).

In the next decade, the Large Synoptic Survey Telescope (LSST), which will monitor stars down to V=24 mag over with 8 m telescope with large field-of-view, might contribute to the microlensing studies, provided the observing strategy will include the densest regions of the sky.

References

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