Pixel-lensing and search for extrasolar planets in Andromeda galaxy

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During the first half of the nineties two new branches of astrophysics were born. On 1993 the first two gravitational microlensing events have been observed by the EROS and MACHO Collaborations towards the Large Magellanic Cloud (LMC). On 1995 the first extrasolar planets was discovered by radial velocity method: it was the first (of the many to come) "hot Jupiter" with half of the mass of Jupiter orbiting at only 0.05 AU around a solar-type star located 13.7 pc away. After about 15 years of continuous monitoring of millions of stars we have more than 3000 gravitational microlensing events (most of them towards the Galactic Bulge and the Magellanic Clouds) and 342 extrasolar planets with 35 planetary systems containing two or more planets (see the web page at http://exoplanet.eu that is continuously up-graded). Both branches of astrophysics have revolutionized much of our previous knowledge in these subjects of research. Nowadays, most of the research in gravitational microlensing goes mainly in two directions: *i*) dark matter studies investigating other lines of sights, in particular towards the Andromeda galaxy, which offers the advantage of having many more target stars, thus allowing the search of dark matter in form of MACHOs (Massive Astrophysical Compact Halo Objects) in both galactic halos and *ii*) the search for extrasolar planets through the induced perturbations on the light curves with respect to that expected for a single lens.

Since 2006, the PLAN (Pixel Lensing towards ANdromeda) Collaboration (see the web page at http://plan.physics.unisa.it/) is conducting pixel-lensing searches towards the Andromeda galaxy using the Loiano (BO) telescope and the TT1 telescope at Toppo di Castelgrande (PZ). At variance with microlensing searches, the analysis is complicated in this case by the fact that the microlensed stars are not resolved - hundreds of stars fall within a single pixel of the telescope CCD - and it is necessary to make use of the so called pixel-lensing technique to reliably discover microlensing events. We have established an automatic pipeline for the detection and the characterization of microlensing variations, carrying out a complete simulation of the experiment, and evaluated the expected signal, including the efficiency of our pipeline. As a result in the 2007 Campaign (the observations of the 2008 Campaign are being currently analyzed), we have been able to select 1-2 candidate microlensing events, according to different selection criteria. This result is in agreement with the expected rate of self-lensing events for which both sources and lenses are stars in the bulge and/or disk of the Andromeda galaxy. However, the available statistics is still too low to draw definitive conclusions about the lensing contribution due to MACHOs in the galactic halos (for details see [1,2]).

Within the PLAN Collaboration, the Lecce group has developed a Monte Carlo code for the analysis of pixel-lensing observations obtained by our and other Collaborations. An important result is that only for extreme models for the Andromeda stellar distribution it is possible to explain the observed number of events by self-lensing. Moreover, the distribution of the observed events, much more extended with respect to that expected for self-lensing events, makes even more difficult to accept the no MACHO hypothesis (for details see [3–5]).

More recently, the attention of the scientific community working on gravitational microlensing is moving towards the detection of extrasolar planets by microlensing observations. Indeed, of the four methods currently used to search for extrasolar planets - i.e. radial velocity methods

(316 planets discovered), transits (58 planets discovered), direct imaging (11 planets) and gravitational microlensing (8 planets), only the last one is capable of revealing extrasolar planets in the whole mass range (i.e. since 0.1 Earth masses to 10 Jupiter masses) and in particular in the so-called "habitable zone" of about one Earth mass. Indeed, the lowest mass extrasolar planet (about 5 Earth masses) discovered by now has been found by gravitational microlensing. Moreover, gravitational microlensing has an enormous advantage with respect to the other techniques: it allows in principle to detect extrasolar planets around stars at arbitrary distance from Earth, even in other galaxies! We have explored by a Monte Carlo study the possibility of detecting extrasolar planets in pixel lensing observations towards the Andromeda galaxy. To this aim, one has to consider that only bright sources (i.e. giant stars) can give rise to detectable microlensing events. This implies that finite size effects cannot be neglected (see e.g. [6]). Until now, only about a dozen microlensing events have been observed towards the Andromeda galaxy by the POINT-AGAPE [1] and MEGA collaborations [7] and in one case a deviation from the standard Paczynski shape has been observed and attributed to a secondary component orbiting the lens star [8]. However, new observational campaigns towards the Andromeda galaxy have been undertaken and hopefully a few planets might be discovered in the future, providing a better statistics on the masses and orbital radii of extrasolar planets. It is in fact expected, and supported by observations and numerical simulations, that almost any star has at least a planet orbiting around it. In other words, the rate of single lens events towards the Andromeda galaxy may suffer of a strong contamination of binary lensing events, most of which are expected to be due to extrasolar planets. Therefore, it is important to address the question of how to extract information about planetary lensing events, occurring in the Andromeda galaxy, from the observed microlensing light curves. Since planetary perturbations last from hours to few days, a monitoring program with suitable sampling must be realised, in order to avoid missing these perturbations. The feasibility of such research program has been already explored in [9,10]. They have considered the possibility to detect planets in the bulge of Andromeda galaxy by using the observations taken with a global network of 2 m class telescopes and a monitoring frequency of about five observations per day. The analysis for planet detection, however, has been performed by using a fixed configuration of the underlying Paczynski light curve. At variance with that analysis we use, instead, a Monte Carlo approach [11,12] by considering the multi-dimensional space of parameters for both lensing and planetary systems. Taking into account finite source effects and limb darkening, and using the residual method we can select the simulated light curves that show significant deviations with respect to a Paczynski like light curve, modified by finite source effects. The advantage of the Monte Carlo approach is that of allowing us a complete characterization of the sample of microlensing events for which the planetary deviations are more likely to be detected as a function of the telescope size and the sampling time.

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