The PLAN collaboration. M31 pixel lensing PLAN campaign: MACHO lensing and self lensing signals

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1. Introduction

We present the final analysis of the observational campaign carried out by the PLAN (Pixel Lensing towards ANdromeda) Collaboration to detect a dark matter signal in form of MACHOs (Massive Astrophysical Compact Halo Objects) through the microlensing effect. The campaign consists of about 1 month/year observations carried out during 4 years (2007-2010) at the 1.5m Cassini telescope in Loiano (Astronomical Observatory of BOLOGNA, OAB) plus 10 days of data taken in 2010 at the 2m Himalayan Chandra Telescope (HCT) monitoring the central part of the M31 galaxy (two fields of about $13' \times 12.6'$).

We evaluate the expected signal (number of events) through a full Monte Carlo simulation of the experiment completed by an analysis of the detection efficiency of our pipeline. We consider both theself lensing and MACHO lensing contributions to the total microlensing rate. We find that the the total number of events is compatible with the expected self-lensing rate. Specifically, we evaluate an expected signal of about 2 self-lensing events. As for MACHO lensing, for full 0.5 (10^{-2}) $M_\odot$ MACHO halos, our prediction is for about 4 (7) events. The comparatively small number of expected MACHO versus self lensing events, together with the small number statistics at disposal, do not enable us to put strong constraints on that population. Rather, the hypothesis, suggested by a previous analysis, on the MACHO nature of OAB- 07-N2, one of the microlensing candidates, translates into a sizeable *lower limit* for the halo mass fraction in form of MACHOs of about 15%.

Gravitational microlensing is the tool of choice for the investigation of the dark matter content of galactic halos (Strigari 2013) in form of MACHOs. Since the original intuition of Paczynski (1986), observational campaigns have been undertaken to this purpose towards the Magellanic Clouds, as a probe of the Milky Way halo, and towards the nearby galaxy of Andromeda (M31). Although there is an agreement in excluding that MACHOs can fill up the dark matter halos, some tension remains based on the difficulty to fully disentangle the lensing signal from known (stellar) population (self lensing) as opposed to the dark matter signal (MACHO lensing). The EROS and more recently the OGLE collaboration, out of observations towards the Large and Small Magellanic Clouds (LMC and SMC), put rather robust upper limits (at 95% CL) on the halo mass fraction in form of MACHO, f, below 10% up to 1 $M_\odot$ MACHOs (and down to below 5% around 10^{-2} $\mathrm{M}_\odot$ objects). On the other hand, the MACHO collaboration had reported a MACHO signal towards the LMC of about f $\simeq$ 20% within the mass range (0.1-1) $M_\odot$.

Alternative hypotheses have also been discussed, in particular proposing non-standard models of the LMC/SMC which may somehow enhance the expected self-lensing rate. The main bonus of the line of sight towards M31 is that, being an external galaxy, we can fully map its own dark matter halo (roughly, at parity of MACHO mass function and halo fraction, one expects about 2/3 of the MACHO signal, if any, to belong to the M31 halo, with the rest to the MW halo along that line of sight). Because of the large (about 770 kpc) distance to the sources, we enter here the "pixel lensing" regime of microlensing. In particular, among other specificities, we recall the further degeneracy in the lensing parameter space between the physical event duration, the Einstein time, t_E and the impact parameter, u_0, which makes reliable, in most cases, only a determination of the full-width-half-maximum duration, $t_{1/2}$ of the event. Additionally, as further addressed below, it results that the ratio of the expected self lensing over MACHO lensing rate is larger with respect to that expected towards the LMC/SMC (quantitatively this depends on the field of view and on the assumed MACHO mass function) and this further complicates the physical interpretation of the data towards M31. Indeed, the analysis of the self-lensing signal appears to be at the origin of the disagreement between the POINT-AGAPE collaboration, who reported an evidence for a MACHO signal, and the MEGA collaboration who concluded that their signal could be fully explained by the expected self-lensing rate.

A detailed report on the results from the PLAN collaboration is given in Calchi-Novati et al. [1].

REFERENCES

1. S. Calchi Novati, ApJ, in press (2014).