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1405:EROS-II Status Report

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Abstract. EROS-II is a second generation microlensing experiment. The experimental setup, in operation at the European Southern Observatory (ESO) at La Silla (Chile) since mid-1996 is briefly described together with its scientific objectives. Preliminary results concerning our microlensing searches towards the Small Magellanic Cloud (SMC) and the Galactic plane are presented. We conclude by overviews of the semi-automated supernovae search and the cepheid studies being pursued in parallel.

1 Introduction

The microlensing effect was proposed ten years ago by B. Paczynski[1] as a unique experimental signature of MACHOs. Dark compact baryonic objects (MACHOs) are plausible components of the galactic dark matter. The flux of an observed star is gravitationally deflected if one of these objects passes close to the line of sight. If the image distorsion is undetectable one is left with a transcient amplification of the total flux.

Few years later, several occurrences of the microlensing amplification of stars were observed in two different directions, the LMC (Large Magellanic Cloud)[2] [3] and the Galactic Bulge [4]. This field is now entering a more quantitative era. EROS-I has isolated 2 candidates over 3 years of running[5]. The Macho collaboration has taken data from 1993 until now and has a handful microlensing candidates towards LMC[6]. These observations indicate a total halo MACHO mass fraction within a factor of two from the total required to explain the Galactic rotation curve. In addition the time scales associated with these events indicate large MACHO masses, which is difficult to accomodate with known stellar populations.

To address these questions, EROS started as early as 1993 to build a new apparatus, which started observations in June 1996. It is outlined in this paper and first results of some of its programs are also presented.

2 The instrument

The EROS-II[1] instrument is a 1m diameter telescope, the MarLy, which has been specially refurbished and automated to enable a reliable microlensing

[1] participating institutes : CEA-Saclay, IN2P3-CNRS, INSU-CNRS

survey. It is in operation at the European Southern Observatory at La Silla (Chile). The optics include a dichroïc beam splitter allowing simultaneous

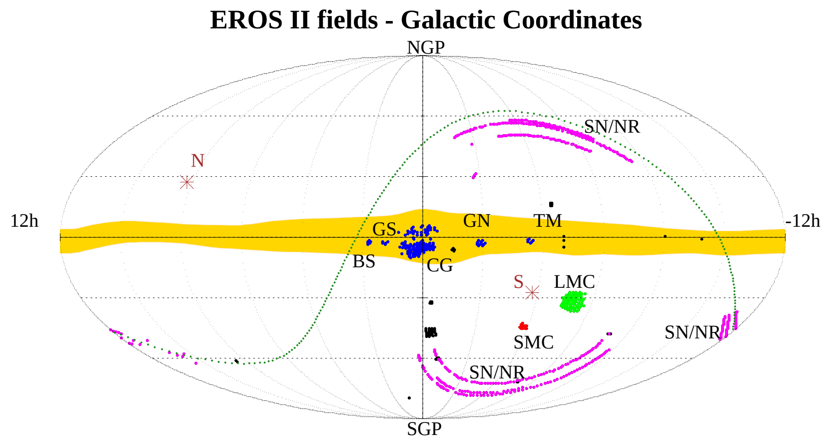

Fig. 1. All-sky view of our fields (equatorial coordinates). The shaded areas represents our Galaxy. We indicated the celestial equator and poles (N and S). fields from specific programs are labelled respectively CG (Galactic Center), LMC and SMC (Magellanic Clouds), SN/NR (SN or red dwarves search).

observations in two wide pass-bands (a blue and a red one). The field of the instrument is observed in each band by a mosaic of 2×4 Loral $2k \times 2k$ pixels thick CCDs. The total usable field is $.7 \times 1.4\,\mathrm{deg}^2$. The median seeing (FWHM of the signal from a point-like source) is about 2. arcsec. CCDs from each mosaic are readout in parallel by DSPs. The total readout time is 50s. The data acquisition is controlled by two VME crates (one per camera). Images are analyzed in the CCIN2P3 in Lyons. We are also developing an alert capability by monitoring on site, the day following the observation, a sample of stable stars from the microlensing fields.

3 The EROS-II programs

EROS-II is primarily aimed at giving a better understanding of the matter distribution in the Galaxy using microlensing. In order to achieve this, a number of directions are currently studied : the Magellanic Clouds (60 fields for the Large, 10 for the Small), the Galactic Center (80 fields) and 4 areas within the Galactic plane ($\approx$ 6 fields each). We are currently giving the highest priority to the microlensing search in new line of sights (the Small

Magellanic Cloud and the Galactic plane fields), from which we present some preliminary results.We also address other cosmologically important programs, such as a systematic study of Cepheids, a search for high proper motion stars and a semi-automated supernovæ search. These programs use images from different regions in the sky, as shown on figure 1. The schedule of each night optimizes the observation conditions for each program.

4 SMC data analysis

The analysis of the SMC data from our first running year is now completed ; more details can be found elsewhere[7]. The SMC was observed from July 1996 to February 1997 and then after July 1997 (our analysis includes data up to August 1997). A hundred images of each field are usable for subsequent analysis. In total more than 5.10^6 light-curves could be analyzed. They were searched for microlensing events. This selection is described in [7]. The cuts are designed to select light curves with a unique and achromatic amplification, a sufficient S/N ratio and no known variable star contamination. The global selection efficiency is about 15%. In our data 10 light-curves passed all cuts and where checked visually, one being finally selected : it is shown in figure 2. This event has also been seen by the Macho Collaboration[8]. Both groups

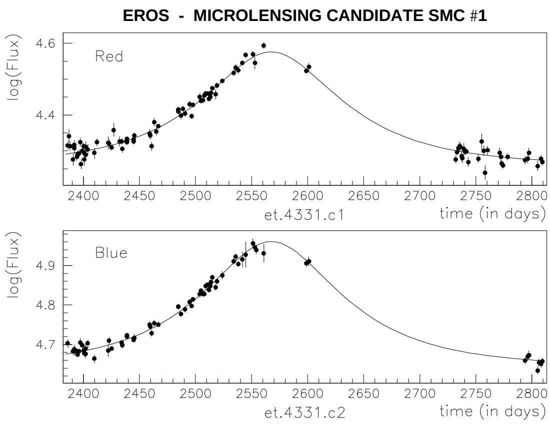

Fig. 2. The SMC-1 candidate light-curve with a standard microlensing fit superimposed (no blending assumed). Our time origin is Jan 0,1990.

signal that the amplified star is a superposition of two stars with close line of sight with flux ratios of 70% and 30% . Only the brightest of these two stars is amplified. EROS also reports a periodic modulation of the combined flux with a period of 5.128 days and an amplitude of about 3% of the brightest flux.

Using a simulation to compute our efficiency we also reported a first measurement of the Galactic halo optical depth τ (instantaneous probability that a given star be magnified by more than a factor 1.34) towards SMC: $\tau \simeq 2.2\ 10^{-7}$. This value is similar to that measured towards the LMC. Comparisons with several halo models show that this sole event contributes by at least 40% of the optical depth due to the halo of our Galaxy. However, the absence of parallax effect (caused by the modulation of the Earth velocity) in this long duration event tends to imply a heavy lens (a few $M_{\odot}$) or a deflector near the source. This event may in fact also be interpreted with both deflector and source lying within the SMC, with a lens mass of order $.1 M_{\odot}$. In that case, we derive $\tau_{SMC-SMC} \simeq 1.3\ 10^{-7}$ which does not conflict with the SMC structure[7].

5 The Galactic Plane

Measuring optical depths in various directions in the Galactic plane would help constraining the different Galactic components to the Bulge and LMC or SMC optical depths. We chose several directions to look at, grouped respectively near galactic longitudes of 25^o (5 fields), 30^o (6 fields), 310^o (6 fields) and 320^0 (12 fields). A feasibility study of a microlensing search in these directions[9] showed that we were able to monitor about 10 million stars in these directions, 50% of these with a photometric precision better than 10%. The stellar content of our fields could be qualitatively understood with the help of a simulation of the evolution of a star population. It agrees with what we expect of 10^8 year old stars located at $8 kpc$ (within 10%). This rather small distance range is essential for the microlensing search.

We are currently processing our first year data in these directions with a twofold objective, searching for distance indicators such as cepheids and for microlensing candidates. First results should come by the beginning of next year.

6 The supernovæ search

EROS-II has also started a semi-automated supernova (SN) search. It is aimed at discovering in a programed way batches of supernovæ. Spectrography and photometry observations may thus be planned in order to classify and study them accurately. Supernovæ are rare phenomena ($\approx$ 1 per century and per galaxy) and study a large ($\approx$ 100) number of them offers interesting cosmological perspectives, for example measuring their rate, or study type Ia SN. Systematic surveys for nearby SNe have tackled to their usability as distance indicators (with $\approx$ 20 SNe)[10]. This could be well studied in a intermediate redshift search such as that of EROS. Our detection threshold is estimated to be about a 22d magnitude, corresponding to a redshift

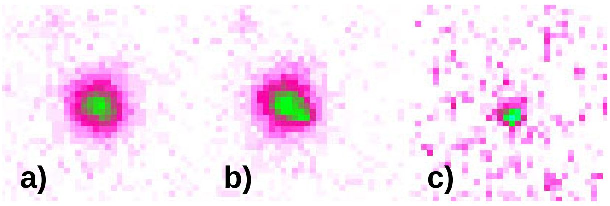

Fig. 3. Pictorial view of the discovery of sn1997bl. The image (a) is our reference image, taken on 03/02/97, (b) is the discovery image taken on 07/03/97, showing the SN superimposed onto the host galaxy. (c) is the difference between (b) and (a), on which the supernova was detected.

of 0.2. Such systematic studies are also essential in extracting cosmological informations from the distant SNe searches[11][12].

Our program goes as follows. Using the EROS-II instrument, we take images near two new moons. The more recent (current) image is compared to the older one (reference) during daytime to search for SN, as shown on figure 3. This program was tested in spring 1997. Three supernovae were discovered, in good agreement with our estimated discovery rate of .1 $SN.\deg^{-2}$. A more intensive campaign has started this autumn. We obtained follow-up time on the ESO 1.5m Danish telescope, and have also few spectroscopic nights on the ARC 3.5m telescope (New-Mexico, USA). In October we discovered 5 new SN (within $55\,\deg^2$) and 4 up to November 28^{th}. We do also follow these SN on our own instrument.

7 Magellanic cepheids

EROS-I reported a possible metallicity effect on the period-luminosity relation for SMC and LMC cepheids[13]. We pursued last year a specific program in order to study this effect more accurately. Two fields in LMC and two in SMC were taken each night. These data were then searched for cepheids. Our new sample contains about 300 cepheids in LMC and 600 in SMC.Being observed with the same instrument and in similar conditions will also reduce systematics. Results from this analysis will come by the end of the year.

8 Conclusion

EROS-II started taking data more than one year ago. During this period, the detector has run quite well. We present a first measurement of the galactic halo microlensing optical depth towards SMC based on one event. This event could however as well be interpreted as due to a lens lying within SMC, and presents some intriguing properties. We demonstrated the feasibility of a microlensing search towards the galactic plane, and expect first candidates to be isolated soon. Our SNe search has been quite intense this autumn, leading to the discovery of ≈ 10 SNe that are being followed on our instrument and others. We are also analysing a large LMC and SMC cepheids database to check for systematic effects on the distance scale deduced from them. These subjects are only a subsample of the rich physics outcome that is to be expected soon from EROS-II[14].

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