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Microlensing observations with the 4-m International Liquid Mirror Telescope

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Abstract. The 4-m International Liquid Mirror Telescope (ILMT) is a zenithal telescope dedicated to a direct imaging survey in two broad spectral bands. It will be located in the Atacama desert and will become operational two years from now. At such geographical latitudes and due to the rotation of the Earth, the field of view of the ILMT will scan the Galaxy from the Southern Pole to the bulge and the central regions. Very precise photometric and astrometric data of millions of stars will be obtained in the drift scan mode night after night, so that microlensing events will inevitably be detected towards the bulge of the Galaxy.

1. Introduction

It is well known that the surface of a liquid spinning in a constant gravitational field takes the shape of a perfect paraboloid, which can be used as the primary mirror of a telescope. However, such a telescope cannot be pointed in the sky, except to the zenith, and can not even track the stars. Nevertheless, Borra et al. (1993) showed that the image quality required for astronomy could be achieved with such mirrors. On the other hand, technology can circumvent the tracking problem by moving the charges on the CCD at the apparent speed of the stars in the field (this is known as time delay integration (TDI) or drift scan mode). This technique was first demonstrated by Hickson et al. (1994) with a 2.7-m diameter liquid mirror telescope.

Despite the restricted access of the sky to a narrow strip and the fixed exposure time, a liquid mirror telescope remains very attractive! Indeed, first it is much cheaper than a conventional telescope: there is no need for a rotating dome nor for a precise mount, as a simple tripod suffices to support the CCD camera and the lens corrector at the prime focus (see Fig. 1). Secondly, it also allows specific scientific goals to be achieved, thanks to precise and regular photometry and astrometry measurements of each object present in the strip. Detection of microlensing events represents such a potential application.

After briefly presenting the 4-m International Liquid Mirror Telescope project, we discuss the rate of microlensing events expected from such observations.

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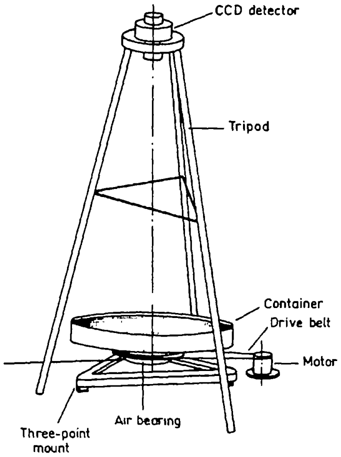

Figure 1. A liquid mirror telescope.

2. The 4-m International Liquid Mirror Telescope (ILMT)

The 4-m International Liquid Mirror Telescope (ILMT) project is conducted by an international consortium of European, Argentinian, Canadian and Chilean astronomers. Detailed information on the project, the participating institutions and the numerous scientific drivers may be found at the Internet address: http://vela.astro.ulg.ac.be/lmt. Here, we describe some important ILMT specifications in the context of microlensing observations.

ILMT specifications related to microlensing:

- Located in a high quality astronomical site, in the Atacama desert (Chile), at latitude $\varphi \simeq -22.5°$ (El Toco) or $\varphi \simeq -29°$ (La Silla, European Southern Observatory).
- Field of view: $30' \times 30'$. For $\varphi = -29°$, this corresponds to a strip of sky of $\simeq$140 sq. degrees, with $\simeq$ 100 sq. degrees at high galactic latitudes and one crossing of the Galactic plane is very close to the Galactic center.
- Detector: mosaic of thinned high quantum efficiency 2048 × 2048-pixel CCDs, equivalent to a 4096 × 4096 chip; scale: $0.4''$/pixel.
- Survey: at least two bands (equivalent to B and R), down to a limiting magnitude of about 23 per scan.
- Effective integration time: the time delayed integration (TDI) is equivalent to $\simeq$ 140 sec for one channel or $\simeq$ 70 sec for two channels. A semi-classical, on-axis corrector must be installed to remove the TDI distortions.
- On line detection of photometric variations and possible follow up with a small robotic telescope.

- First light at the end of 2001 and operation of the telescope for at least 5 years.

3. Microlensing with the ILMT

3.1. Modellling

Qualitatively, microlensing events are expected within the ILMT observations because the field of view is going to cross the bulge very close to the Galactic center and because each detected star will be monitored every night, for about 120 consecutive nights. This will lead to well-sampled light curves for lensing masses in the range $10^{-3} - 4\,\mathrm{M}_{\odot}$. This mass range is known to be responsible for the majority of the observed microlensing events (e.g. Alcock et al. 1997, 2000).

To obtain more quantitative results, we proceed in two steps:

1. The *star counts* are estimated along each galactic direction (l, b) scanned by the ILMT ($\varphi = -29°$ or $\varphi = -22.5°$), as a function of their distance and magnitude using the Besançon model (Robin et al. 1995), which takes into account the contributions from the halo, the thick and the thin disks; mean galactic extinction is used. A conservative limiting magnitude is computed by requiring a $S/N \geq 10$, as this should allow a significant ($\geq 3\sigma$) detection with the image subtraction technique (Alard & Lupton 1998; Alard 2000) of all lensing events with impact parameters smaller than the Einstein radius. First empirical estimates indicate that the limiting magnitude will be 0.5 mag brighter in the crowded fields.

2. *Modelling the Galaxy:* the Galaxy is assumed to be entirely composed of dark compact objects. The optical depth for microlensing along the direction (l, b) is computed from the Galactic matter density distribution and the latter is estimated by the addition of three components: the *halo* (Griest 1991), the *disk* (Peale 1998; Bahcall & Soneira 1980) and the *bulge* (Peale 1998; Zhao 1996).

3.2. Predicted results

Simulations have been performed for a transverse velocity $v_t = 200$ km/s and a lensing mass $M = 1\,\mathrm{M}_{\odot}$. Observations are assumed to be done in the B band (where stars counts are the lowest) with the 4-m ILMT located either at latitude $\varphi = -29°$ or at $\varphi = -22.5°$ and with a S/N=10, a FWHM=0.8$''$ and an exposure time t = 70s or t = 140s. The resulting total number of stars is estimated to be between 15 and 19 million for the different locations and exposure times ($B_{\mathrm{lim}} \simeq 22.5$).

As expected, both the star counts and the optical depth have a maximum towards the bulge and the Galactic center. Consequently, the rate of microlensing events also has a maximum in that direction, as can be seen from its distribution as a function of Right Ascension (or Sidereal Time of the observations) in Figure 2. On the basis of an observing time of 8 hours per night, the efficiency of the ILMT is simply approximated to 33% for every star brighter than B_{lim}.

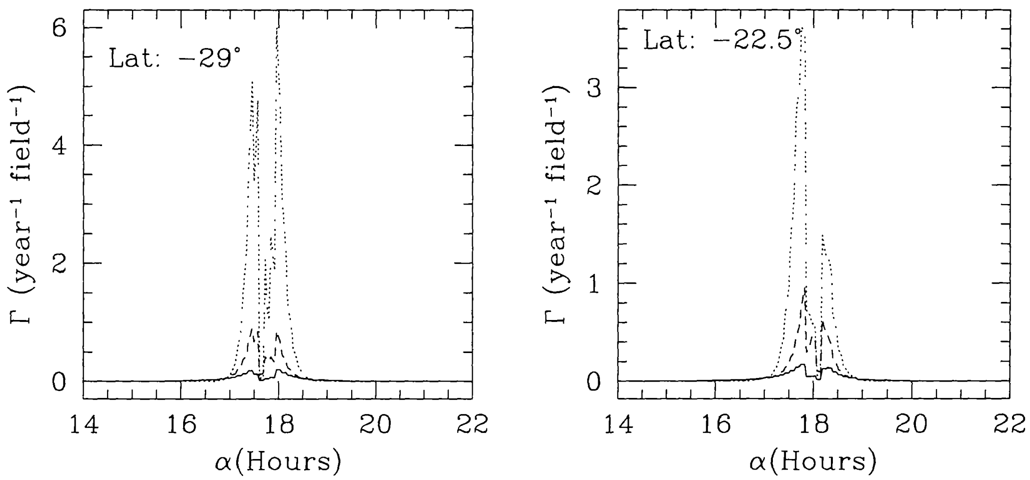

Figure 2. Number of events per year and per field as a function of Right Ascension for La Silla ($\varphi = -29°$; left) and El Toco ($\varphi = -22.5°$; right); $t = 70$ s. Individual contributions are represented for the halo (thick lines), the disk (dashed lines) and the bulge (dotted lines).

The total number of observed microlensing events per year amounts to approximately 30, with 75% due to the bulge, 20% to the disk and only 5% to the halo.

4. Conclusions

Conservative estimates predict the detection of approximately 30 microlensing events per year due to 1 $M_\odot$ lenses among the ILMT observations. By their nature, the latter will scan all southern galactic latitudes b, so that the number of microlensing events as a function of b will probably help in constraining the Galactic structure. The bulk of events is indeed expected towards the bulge.

Finally, let us also note that the ILMT observations might constitute a precious contribution to the detection of microlensing events in the near future when the EROS and MACHO experiments are over.

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Discussion

Graff: Since your telescope is so cheap, it seems you could easily build more, or larger ones, to cover a wider area and go dimmer.

Claeskens: Yes, of course!! This technique may be applied by individual groups or institutions, with dedicated scientific projects. However, considering area and depth the quantity of data is already 10 Gbytes per night and co-addition of frames will allow us to reach 26th magnitude for extragalactic research. On the other hand, a better corrector lens will soon provide a corrected field of view of a few tens of degrees.... So, a single LMT is already a very good source of data.

Vermaak: Is there any fundamental limit to the size of the "mirror"?

Claeskens: Not to my knowledge, at least for the 6- to 8-m class. A 4-m mirror is the largest for which technology already exists (container, air-bearing), so that no R&D is needed.

Zinnecker: Did you talk to ESO to get permission to put your LMT on La Silla (or El Toco)?

Claeskens: Yes, contacts with ESO have been established to get permission to install the LMT at La Silla. We should receive a definite answer in the very near future.

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