The 4-m International Liquid Mirror Telescope project

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Abstract

The International Liquid Mirror Telescope (ILMT) project is a scientific collaboration in observational astrophysics between the Liège Institute of Astrophysics and Geophysics (Liège University, Belgium), the Aryabatta Research Institute of Observational Science (ARIES, Nainital, India) and several Canadian universities (British Columbia, Laval, Montréal, Toronto, Victoria and York). Meanwhile, several other institutes have joined the project: the Royal Observatory of Belgium, the National University of Uzbekistan and the Ulugh Beg Astronomical Institute (Uzbekistan) as well as the Poznan Observatory (Poland).

The Liège company AMOS (Advanced Mechanical and Optical Systems) has fabricated the telescope structure that has been erected on the ARIES site in Devasthal (Uttarakhand, India). It is the first liquid mirror telescope being dedicated to astronomical observations. First light has been obtained on 29 April 2022 and commissioning is going on at the present time.

In this poster, we describe and illustrate the different components of the ILMT and their functions. We also present some preliminary scientific results based upon observations collected in October-November 2022.

Introduction

Taking advantage of the best seeing conditions and atmospheric absorption towards the zenith, the ILMT performs a deep survey consisting of high S/N photometric and astrometric observations in the SDSS g, r or i spectral bands of a narrow strip of sky (22' in declination) passing over the zenith. In combination with an efficient 4kx4k CCD camera and a dedicated optical corrector, the images are being secured at the prime focus of the telescope using the Time Delayed Integration (TDI) technique. The singly scanned CCD frames correspond to an integration time of 102 sec, corresponding to the time an object's image crosses the active area of the detector. The ILMT presently reaches V ~ 22 mag (i-band) in a single scan but this limiting magnitude can be further improved by co-adding the nightly recorded images.

The uniqueness of good cadence (one day) and deeper imaging with the ILMT make it possible to detect and characterize artificial satellites and space debris (see Hickson et al.'s ILMT poster, hereafter ILMTP), solar system (see Pospieszalska-Surdej et al.'s ILMTP), galactic (see Grewal et al.'s ILMTP) and extra-galactic objects (see Akhunov et al. + Sun et al. + B. Kumar et al.'s ILMTPs). The field covered by the 4m ILMT during a full year is represented in equatorial, ecliptic and galactic coordinates in the ILMTP by Dubey et al.

The fast f/D ~2.4 ratio of this telescope is particularly well adapted to the detection and characterization of low surface brightness objects (see Fu et al.'s ILMTP). Several examples of very extended and faint galactic nebulae observed with the ILMT are presented.

An image subtraction technique is also being applied to the nightly recorded observations in order to detect transients, objects exhibiting variations in flux or position (see P. Kumar et al.'s ILMTP).

ILMT data acquired during the fall of 2022 are being made freely available to the scientific community (see Kuntal et al.'s ILMTP).

Following a campaign of observations that took place during the first commissioning period of the 4m ILMT in October-November 2022, an astrometric and photometric pipeline has been developed to reduce and analyse the data (see Ailawadhi et al. + Dukiya et al. and Negi et al.'s ILMTPs). We present some preliminary scientific results based upon these observations.

After briefly reviewing the working principle of a liquid mirror, we describe and illustrate in the present poster the different components of the telescope.

Technologies used for the ILMT

The technology of liquid mirrors has been developed by the teams of Prof. E. Borra at Laval University and Prof. P. Hickson at the University of British Columbia (UBC). Liquid mirror Telescopes are relatively simple. Three components are required (see Fig. 2): a fixed metallic structure, an upper hand comprising a TDI optical corrector, a CCD camera and alignment mechanisms, and a mirror. The latter is made of a dish containing a reflecting metal liquid (mercury), an air bearing that supports the mirror, and a drive system. The choice of an air bearing system has been made in order to avoid as much as possible the transmission of vibrations from the turntable to the mercury. The air bearing is driven by a synchronous motor controlled by a variable-frequency AC power supply stabilised with a crystal oscillator. It has to support the weight of the mercury (~ 650 Kg). To avoid transitory effects in the mercury, the rotation speed must be very stable (relative variations in the rotation period must be smaller than typically 10^{-6}).

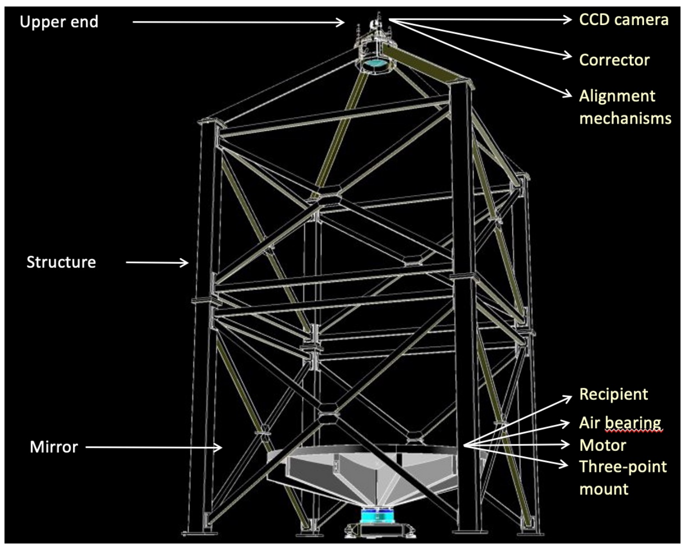

Fig. 2: The main components of a liquid mirror telescope: the mirror, the metallic structure and the upper end installed at the level of the prime focus.

Working principle of the ILMT

A perfect reflective paraboloid represents the ideal reference surface for an optical device to focus a beam of parallel light rays to a single point. This is how astronomical mirrors form images of distant stars in their focal plane. In this context, it is amazing that the surface of a liquid rotating around a vertical axis takes the shape of a paraboloid under the constant pull of gravity and centrifugal acceleration, the latter growing stronger at distances further from the central axis. The parabolic surface occurs because a liquid always sets its surface perpendicular to the net acceleration it experiences, which in this case is increasingly tilted with distance from the central axis. The focal length F is proportional to the gravity acceleration g and inversely proportional to the square of the angular velocity ω (see Fig.1). In the case of the ILMT, the angular velocity ω is about 8 turns per minute, resulting in a focal length of about 8m. Given the action of the optical corrector, the effective focal length f of the D=4m telescope is about 9.44m, resulting in the widely open ratio f/D ~ 2.4. In the case of the ILMT, a thin rotating layer of mercury naturally focuses the light from a distant star at its focal point located at ~ 8 m just above the mirror, with the natural constraint that such a telescope always observes at the zenith.

Thanks to the Earth's rotation, the telescope scans a strip of sky centred at a declination equal to the latitude of the observatory (+29°22′26″ for the ARIES Devasthal observatory). The angular width of the strip is about 22′, a size limited by that of the detector (4Kx4K) used in the focal plane of the telescope. Since the ILMT observes the same region of the sky night after night, it is possible either to co-add the images taken on different nights in order to improve the limiting magnitude or to subtract images taken on different nights to make a variability study of the corresponding strip of sky. Consequently, the ILMT is very well-suited to perform variability studies of the strip of sky it observes. While the ILMT mirror is rotating, the linear speed at its rim is about 5.6 km/hr, i.e., the speed of a walking person.

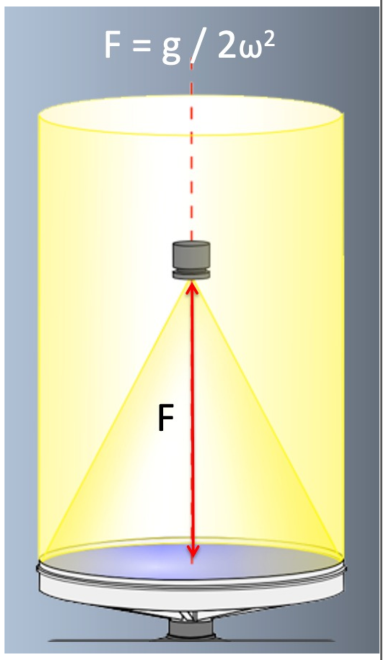

Fig. 1: Mercury placed in a circular recipient spinning around the vertical axis focuses a beam of parallel light rays in the focal plane at a distance F from the vertex of the mirror (see text).

Figure 3 shows a top view of the 4m ILMT. We see the mirror filled with mercury and covered with a very thin film of mylar in order to prevent any friction between the mercury and the ambient air that could produce ripples at its surface. Figure 4 shows the filter tray placed just under the CCD camera inside the SOCABELEC interface at the prime focus. This interface is equipped with mechanisms to focus the stellar images on the CCD and also to eventually translate and rotate the camera in the focal plane.

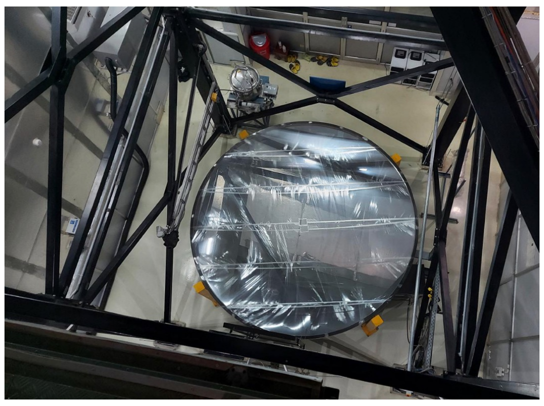

Fig. 3: Top view of the ILMT structure and mirror filled with mercury and covered with mylar

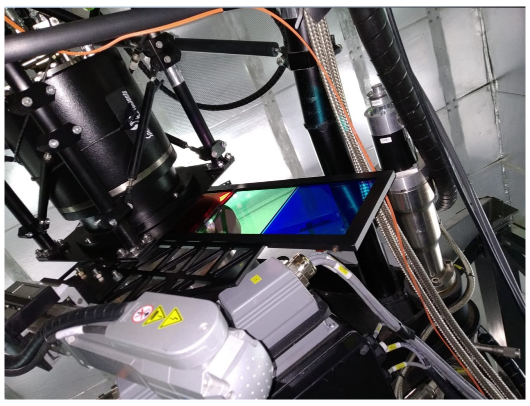

Fig. 4: The Sloan filters installed in a tray just below the Spectral Instruments CCD camera

Based upon ILMT observations that have been collected during 9 consecutive nights in October-November 2022 through the Sloan g, r and i spectral filters, composite CCD frames have been produced after correction for dark current, flat field, cosmic rays. They have been astrometrically and photometrically calibrated. Preliminary investigations have led to the following results: hundreds of transients and known asteroids have been identified and more than 80 space debris streaks have been detected. Very nice extended nebulae have also been imaged (see Figs. 5-9).

Fig. 5: *Streaks by Meridian 3, an old Russian satellite.*

Fig. 6: ILMT composite image of the planetary nebula NGC 2371.

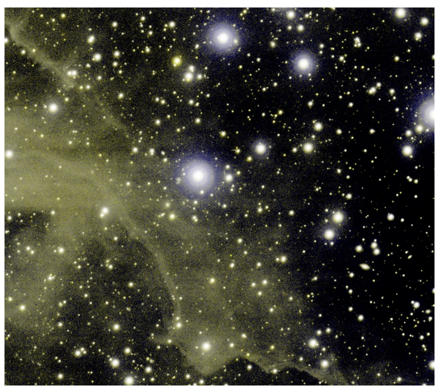

Fig. 7: ILMT composite image of a diffuse nebula.

Fig. 8: ILMT composite image of a reflecting nebula.

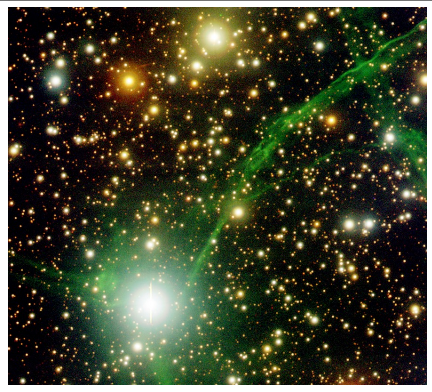

Fig. 9: ILMT composite image of an emission-line nebula.

All the above pictures result from the composition of g, r and i CCD frames

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