THE ILMT (INTERNATIONAL LIQUID MIRROR TELESCOPE) AND MONITORING OF GRAVITATIONAL LENSES

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KEY WORDS: Instrumentation, CCDs, gravitational lenses.

ABSTRACT

An international consortium has been set up to construct a telescope with a liquid mirror of 4m diameter (making use of the concept that a spinning liquid takes the shape of a paraboloid and can be used as primary mirror of a telescope). The choise of the site (the Atacama Desert in Chile), the acqusition equipment (2 or 4 CCD's totalling 4Kx4K), the methodology of observing (time-delay integration), and the scientific aims (comprising survey, detection, photometric monitoring and astrometric measurement) are commented upon. The monitoring of gravitational lenses is one of the main scientific interests of the National Observatory of Athens, of the Royal Belgian Observarory and of the Liège Institute of Astrophysics and Geophysics.

1. The liquid mirror telescope

The surface of a uniformally rotating liquid takes the shape of a paraboloid. If the liquid is reflective, it can be used as the primary mirror of a telescope (Borra 1982, Borra 1997). The most conclusive application so far is the NODO (NASA Optical Debris Observatory) 3m liquid mirror astronomical telescope constructed by NASA, with a thin layer of Mercury used for the spinning liquid. See e.g. Hickson and Mulrooney (1998), giving specifications of the mirror and describing scientific results derived from LMT observations. The principle of such a telescope is shown in figure 1.

2. The ILMT project

An international consortium has been set up to build and operate a 4m liquid mirror telescope (Table 1: Participants to the International Liquid Mirror Telescope project).

Having to do with zenith-pointing telescope which cannot be tilted, tracking is performed in TDI-mode (see section 3).

It may be mentioned that the cost of this telescope is at least a factor of 20 times lower than a "classical" 4m-telescope - thanks to the simple mounting and minimal requirements for building facilities. For the CCD's, a good (but not the highest) quality will be chosen.

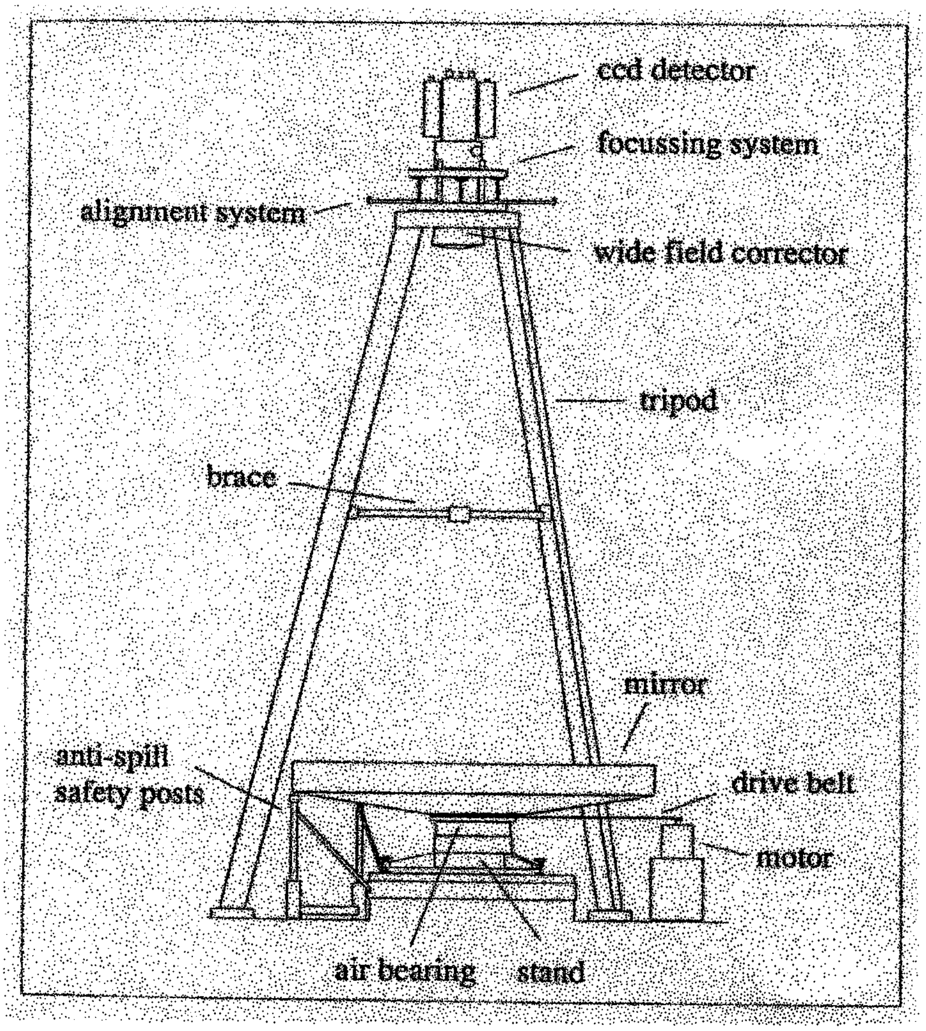

Figure 1: Schematic view of a fully equiped (mounting, CCD camera, corrector lens) Liquid Mirror Telescope.

The site chosen will be at -23.5° latitude: the most intensively investigated site is a location on a high plateau in the Chilean Atacama desert (at an altitude of nearly 5000m), not far from the ALMA site (cf. The Messenger Nr.94, p.13, 1998). An operational ground basis will probably be stationed in the somewhat lower lying village of San Pedro de Atacama (2400m). The transparency, photometric and image quality at the projected ILMT site are of the same standards as for the well praised VLT.

With the f/2 focal ratio opted for, the strip of sky covered will be some 28' wide. The detector configuration of either 2 CCD's of 2Kx4K, or 4 CCD's of 2Kx2K will allow to observe in two wide spectral bands: one fixed (R), for consistent monitoring, one changeable (B or I), according to the programme that during that night is given priority. Pixel size will be around 0.4". The limiting magnitude is estimated 23.5 in B, for one single scan.

It is not excluded that the project will be extended to more than one liquid mirror telescope. Scientific projects are for the moment counting on the one telescope that is being prepared for installation.

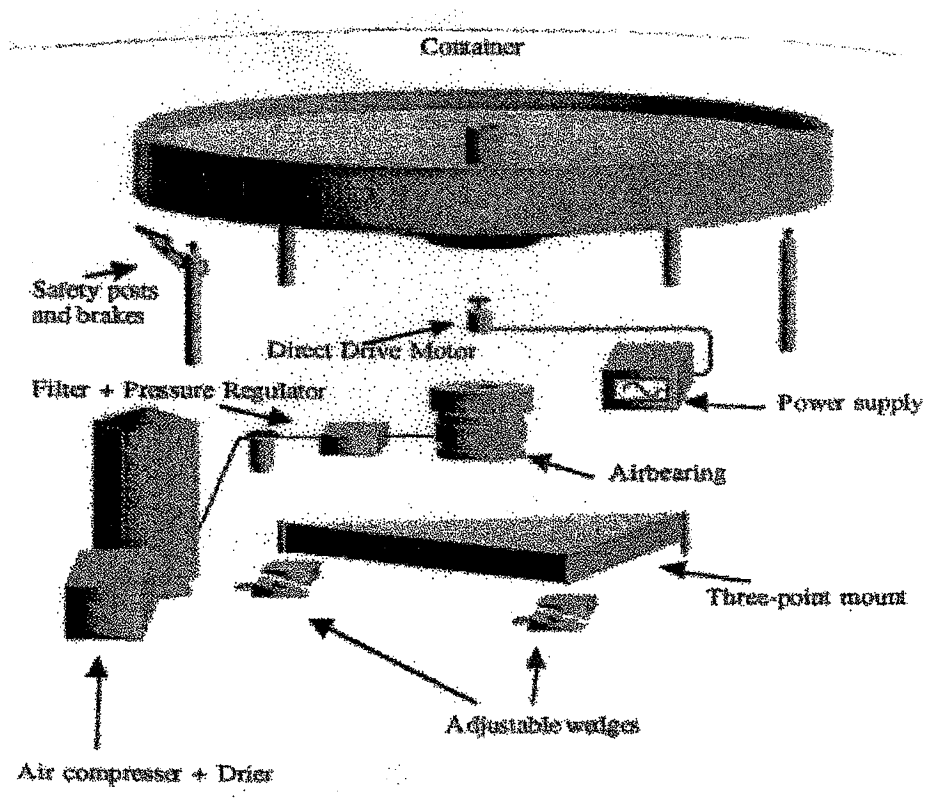

Figure 2: Detail of the basic mirror set-up.

3. Operation

The observations will consist of a succession of 2min CCD scans (integrating 4K columns). Images will be stored on disk and the night observations can be used for quick examination (recognition, identification, detection) and for later analysis, frames being co-added with known and to be developed techniques to obtain long integration times. The scientific programme contains a survey and detection part, and a monitoring part (cf. section 4).

On the TDI mode: With a conventional telescope, CCD observations are performed by pointing to a target and taking a sucsession of digital images, each one having a predicted exposure time. In our case, where the telescope can only observe at zenith, such a method cannot be used; a LMT "sees" a long and narrow strip of the sky, at a constant declination. The *drift scan mode*, or TDI (*Time Delay Integration*) is a relatively new technique applied when stars passing by have to be monitored (see Gibson-Hickson 1992, Viateau et al. 1999).

* The rows of the detector are aligned with the E-W direction so as to follow the daily motion of objects.
* The electric charges of the detector in one column are moved to the next one at a speed equal to the linear velocity of the images on the CCD chip and are added to the signal in the next column. The total integration corresponds to the time taken for an object to drift the length of the CCD.
* As soon as the images transit the last column of the detector, the electrical charges are collected by reading out, registering one column after the other.

4. Scientific aims

The scientific research objectives consist of surveys and detection on one hand, monitoring and measuring on the other. Different programmes for the members of the consortium will be accommodated:

* QSO survey, identification on the basis of colour and photometric variability, detection of gravitational lens candidates, to be followed by monitoring.
* Detection of low-surface brightness and star-forming galaxies, observational studies of large-scale structures, studies of dark matter.
* Search for supernovae at high redshift, monitoring.
* Detection of distant RR Lyrae stars in the galactic halo.
* A wide and differential range of variability studies (photometry of stars as well as of variable AGN) over day to year time scales.
* Detection of white dwarfs, brown dwarfs (based upon their proper motions or trigonometric parallaxes).
* Astrometry of faint nearby objects, studies of multiple stars (measurement of astrometric and photometric parameters, statistics).
* Identification and orbit determination of minor planets.

In general:

* Providing targets for the VLT, Gemini etc. for further studies.
* Being on the look-out for serendipitous phenomena, that can lead to unexpected breakthroughs in astronomical research.

For the survey projects, the aspect of completeness - which is imposed, since a well defined strip of the sky is searched for- is very important for statistical research.

5. Monitoring of gravitational lenses

The observing strategy consists in first surveying a sky strip as deep as possible (B~24) for quasar candidates and then select gravitational lens candidates among them (several members of the consortium have shown their interset in this survey).

As concerns the case of multiply imaged quasars, Surdej and Claeskens (1997, cf. the Web page http://vela.astro.ulg.ac.be/grav_lens.html) have calculated that after less than six weeks of effective operation, some 50 new gravitational lens systems are likely to be detected. The teams of the Royal Observatory of Belgium, the National Observatory of Athens and the Liège Institute of Astrophysics and Geophysics have decided to photometrically monitor as many as possible of these, to establish light curves of the multiple images of the lensed quasars and to record microlensing events.

The first result aimed for with these light curves is a statistical determination of the Hubble parameter, on the basis of the time delays between the components of the quasar mirage. [As a reminder: H_0 is inversely proportional to the delay between the arrival times, which is a consequence of the different paths the light follows through the foreground galaxy to form a multiple image (Refsdal 1964)]. The consistently continued observations of the sources present an unprecedented asset for studies of micro-lensing [differential amplifications of the different components, resulting from small "fields of view" - from one or several stars - within the galaxy].

Follow-up research, e.g. with high-resolution spectroscopy, will be engendered by the ILMT investigations, to obtain a consistent image of the systems (the quasars and their distance, the medium along the lightpath) and finally to set constraints on other cosmological parameters.

Table 1: Participants to the ILMT project (in alphabetical order):

Centre Spatial de Liège and AMOS industry (B)
Durham University (UK)
Institut d'Astrophysique, Université de Liège (B)
National Observatory of Athens (GR)
Observatoire de Bordeaux (F)
Observatoire de la Côte d' Azur (F)
Royal Observatory of Belgium
Royal Observatory of Edinburgh (UK)
Universidad Catolica de Chile
Universidad de Cordoba -I.A.T.E. (ARG.)
Université de Laval (CA)
Universiteit Maastricht (NL)

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Viateau, B., Réquième, Y. et al, 1999. The Bordeaux and Valinhos CCD meridian circles. A&AS, 134, pp. 173-186.