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The 4-m International Liquid Mirror Telescope Project (ILMT)

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Abstract. The working principle of liquid mirror telescopes (LMTs) is first reviewed along with their advantages and disadvantages over classical telescopes. For several reasons (access to regions near the south galactic pole, galactic center, good image quality, etc.), an excellent site for such an LMT is the Atacama desert. A deep (B$\sim$24 mag) LMT survey at latitudes near -22° – -29° will cover $\sim$90 square degrees at high galactic latitude and be especially useful for gravitational lensing studies, for the identification of various classes of interesting extragalactic objects (cf. clusters, supernovae, etc. at high redshift) and for subsequent follow-up observations with 8 m-class telescopes. A short description of the handling of data products is also presented.

1. Telescope Technical Description

The surface of a rotating reflecting liquid takes the shape of a paraboloid which is the ideal surface for the primary mirror of an astronomical telescope. The focal length F of the mirror is related to the gravity g and the angular velocity of the turntable ω by means of the relation $F = g/2\omega^2$. The container and the bearing rest on a three-point mount that aligns the axis of rotation parallel to the gravitational field of the Earth (Figure 1). The container must be light and rigid. A thin layer (0.5 mm to 1 mm) of mercury is then spread on the container.

Figure 2 shows the entire telescope system. Comparing the LMT to a conventional telescope, we see that they are similar with the exception of the mount. The top parts, consisting in a focusing system and a detector, are identical, but there is some cost saving in the upper end structure since it does not have to be tilted. The largest savings accrue due to the simple tripod mount.

While an LMT can only observe a zenith strip of constant declination, its observing efficiency compared to that of a classical telescope is very high (no slew, no field acquisition, no lost readout time). The tracking will be done with the Time Delay Integration technique (TDI, also known as the drift scan technique), and low-resolution spectroscopy can be carried out with interference

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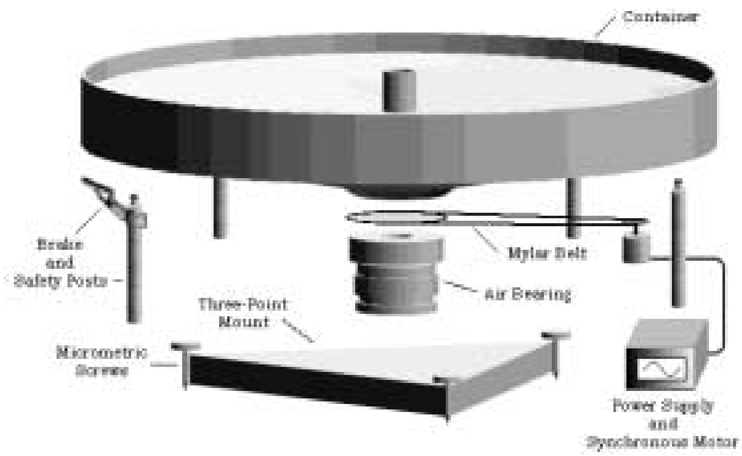

Figure 1. Exploded view of the basic liquid mirror telescope setup.

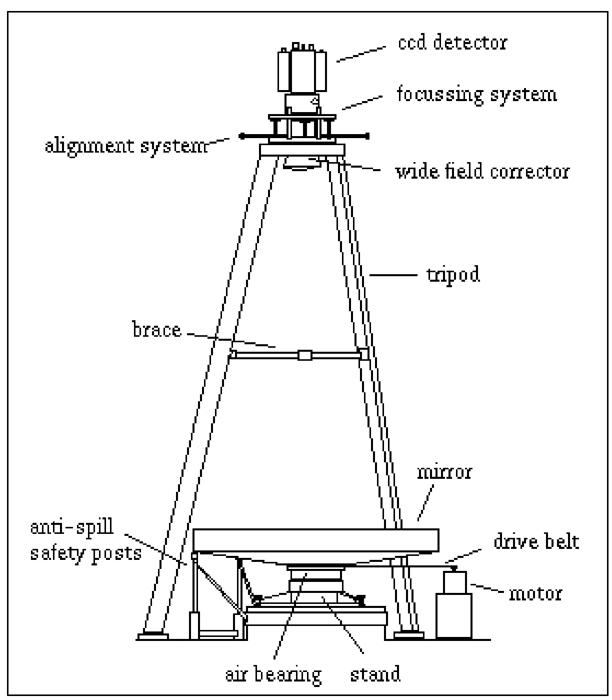

Figure 2. Entire liquid mirror telescope system.

filters. A semi-classical on-axis glass corrector capable of about $30' \times 30'$ degree field will be used to remove the TDI distortion. With a classical corrector, the TDI technique degrades the images since the technique moves CCD pixels at a constant speed in a straight line, while fixed-sky elements appear to move at different speeds along slightly curved trajectories. This latitude-dependent deformation is zero at the equator and increases with increasing latitude.

2. Science with the International Liquid Mirror Telescope

The observational strategy for studies of gravitational lensing effects with a LMT consists in first surveying a sky area as deeply and broadly as possible for interesting targets (e.g., quasar candidates using color and variability criteria) and then selecting gravitational lens candidates among them. The field of view is primarily determined by the number and/or the size of the thin CCDs placed at the LMT prime focus. For the case of multiplely imaged quasars, we find that direct imagery with the 4 m International Liquid Mirror Telescope (ILMT) will lead to the detection of approximately 50 new gravitational lens systems ($\Omega_0 = 1$, $\Lambda_0 = 0$). The natural possibility of photometrically monitoring these at daily intervals with a great accuracy offers a unique opportunity to define a sub-sample of interesting lenses with reliable geometrical parameters, time delay measurements and/or micro-lensing signatures for further astrophysical and cosmological studies. Such a survey will also provide unique data for studies of the galactic structure and stellar populations, including the detection of micro-lensed galactic objects, accurate measurements of stellar proper motions and trigonometric parallaxes useful for the detection of faint red, white and brown dwarfs, halo stars, etc. The ILMT will be located in the Atacama desert and should be operational in 2002. With the ILMT field of view at its geographical latitude, the Earth's rotation will scan the Galaxy from the Southern Pole to the bulge and central regions. Very precise photometric and astrometric data for millions of stars will be obtained in the drift scan mode night after night, permitting the detection of microlensing events toward the galactic bulge.

3. Data Analysis and Computational Aspects

3.1. Data Acquisition

The overall ILMT software architecture can be described briefly as follows: The acquisition of the 4 K×4 K CCD data flux relies on C++ software running on a WinNT4 platform housing custom electronic PCI cards with real-time multi-channel acquisition capabilities. This system (a Pentium PC) will be located in a booth that will be part of the telescope building. The collected data stream will then be sent through a microwave data link to a lower altitude remote site where the main processing and analysis will take place. This will allow dedicating a whole system for reliable data acquisition, temporary storage, archiving, observation scheduling and network transactions, thereby enabling data reduction to be performed at the same data rate in a remote data processing location. The integration of CCD captors, TDI mode CCD controller, data acquisition PCI electronic cards, WinN4 PCI software drivers and data acquisition application software is currently undergoing testing. Completion of quality assurance tests related the whole data acquisition chain is expected in early summer 2001.

3.2. Data Processing and Reduction Pipeline

From the data analysis point of view, such a project requires sophisticated algorithms and a massive, reliable computation and storage infrastructure in order to generate an exhaustive catalog of detected sources. Fortunately, modern computer science and artificial intelligence techniques (i.e., pattern recognition using neural networks, fuzzy logic, decision trees, etc.) can permit accurate categorization of the objects and of their photometric and astrometry history (time series). Furthermore, management and analysis of catalog/image databases will be accomplished with powerful data-mining tools. With an appropriate on-line data analysis policy, the survey is likely to yield many short duration events/targets that in turn could be of major interest to large southern hemisphere observatories, such as the ESO/VLT, and to the Virtual Observatory project. Powerful computational resources are needed for the demanding CPU-intensive processes and large number of database transactions. Sun Microsystems has been chosen as hardware manufacturer partner for its UltraSparc III processor technology (running the Solaris 8 Unix-like operating system). Ideally, one TB of Fiber Channel RAID storage should be considered as a minimum after one year of ILMT telescope operation. Storage requirements would increase if an array of such ILMT's should be deployed (with individual telescopes being dedicated to specific spectral bands). On the database side, investigations are still underway to determine which RDMS software vendor best fits the ILMT project's needs. At the time of this writing, Oracle, Informix and Sybase are being considered as potential RDMS's. Given the amount of public domain astronomical image processing software available, it is clear that some de facto standards have already emerged (e.g., SExtractor, IRAF, MIDAS, Drizzle, etc.). Integration of as many existing software solutions as possible seems desirable in building the ILMT data processing pipeline. Another alternative would be to adapt an existing data reduction pipeline to meet the project's requirements: this possibility is still under assessment.

4. The ILMT Project in Detail:

A more detailed description of the ILMT project is available at: http://vela.astro.ulg.ac.be/lmt/.