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Cosmology with Liquid Mirror Telescopes

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Liquid mirrors provide an exciting means to obtain large optical telescopes for substantially lower costs than conventional technologies. The liquid mirror concept has been demonstrated in the lab with the construction of a diffraction limited 1.5m mirror (Borra et al. 1989). The mirror surface, using liquid mercury, forms a perfect parabolic shape when the mirror cell is rotated at a uniform velocity. An $f/1.9$ 2.7m liquid mirror observatory is now nearing completion at a site near Vancouver, B.C.. The *UBC/Laval liquid mirror observatory* is expected to begin a survey of quasars and galaxies in the fall of 1992. The successful demonstration of the 2.7m observatory may usher in an era of 4-8m liquid mirror telescopes (LMTs).

The primary disadvantage of liquid mirrors is their inability to point, being restricted to observations at the zenith. The use of large format CCD's, read out using the time-delay and integrate (TDI) technique (McGraw et al. 1986) compensates for the earth's rotation as the image crosses the telescope's field of view. The telescope then has access to the strip of sky that passes overhead over the course of a year. The disadvantage of being restricted to observations at the zenith is mitigated in cosmological studies, where surveys of any strip of sky can provide valuable information.

A liquid mirror must be able to support a heavy mercury load with minimal flexure and have a fundamental resonant frequency that is as high as possible, to suppress the amplitude of surface waves caused by small vibrations transmitted to the mirror. To minimize the transmission of vibrations to the liquid surface, the entire mirror rests on an air bearing. This necessitates the mirror cell being lightweight, due to the limited load capabilities of the air bearing. The mirror components must also have physical characteristics which minimize the effects of thermal expansion with ambient temperature fluctuations in the observatory. In addition, the 2.7m mirror construction is designed so that the techniques used may be readily extended to the construction of larger mirrors.

To attain the goals of a lightweight, rigid mirror, a composite laminant construction (such as is found in the aerospace industry) was used (Hickson et al. 1992). The mirror consists of a foam core cut to the desired parabolic shape, with an accuracy of a few mm. An aluminium hub serves as an anchor for the foam and skin, and allows precise centering of the mirror on the air bearing and drive system. Several plies of Kevlar, covered in an epoxy matrix, are then applied to the foam. A final layer of pure epoxy is formed by spin casting. This final layer is parabolic to within a fraction of a mm. An aluminium ring bonded to the circumference of the mirror retains the mercury, and incorporates stainless-steel hard-points for the attachment of balance weights.

The mirror cell is covered with a 1-2mm layer of liquid mercury. A transparent monomolecular layer on the surface of the mercury suppresses surface waves and virtually eliminates evaporation. The reflectivity of mercury is about 79% from 3100 \rightarrow 8700Å as compared to 92% for a fresh aluminium layer in the visible. However, it is pointed out

that the aluminium coating deteriorates as it oxidizes, while mercury oxidizes very slowly and is easy to clean (Borra et al. 1992).

To obtain high image quality, the angular velocity of rotation must be uniform to within 10^{-7} . This is achieved by driving the mirror with a synchronous motor, controlled by a quartz-oscillator.

A preliminary survey is expected to begin in the fall of 1992. The total survey area will be approximately 20 deg^2 , consisting of a strip of sky $21'$ wide, at a declination of $49^\circ 04'$. A Loral 2048×2048 CCD will be used, read out using the TDI technique clocked at the sidereal rate (Gibson et al. 1992). This will provide an integration time of approximately 2 minutes per filter.

Spectrophotometry will be obtained by multiband imaging through a series of 40 intermediate band filters, each with a bandwidth of $\Delta\lambda/\lambda_c \approx 0.046$, uniformly sampling the entire optical spectrum: $14.87 \leq \log \nu_c \leq 14.48$ ($4000 \rightarrow 10000 \text{ \AA}$) where the filter central wavelength separation is $\Delta \log \nu_c = 0.01$. A different filter will be used each night, building up over a two-year period spectral energy distributions (SEDs) of all detectable objects down to a limiting magnitude of $V \sim 21.4$ ($S/N \approx 3$). Theoretically this will yield SEDs for ~ 20000 galaxies and ~ 1000 QSOs. Photometric calibration will be derived from a sequence of secondary spectrophotometric standards in this region of the sky. The SEDs may then be used for determining redshifts and morphological type.

References

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