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The Multi–Telescope Telescope Project: An Inexpensive Spectroscopic Facility

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ABSTRACT: We have constructed a new facility at the Georgia State University Hard Labor Creek Observatory, consisting of a telescope and a fiber–fed spectrograph and detector. The Multi–Telescope Telescope (MTT) is an inexpensive one–meter light–collecting telescope whose 'primary' mirror consists of nine 33.3 cm mirrors. Each mirror of the MTT focuses light into a separate optical fiber, thus avoiding light losses of conventional fiber bundles. The optical fibers feed a modified 'slightly' off–plane Ebert–Fastie spectrograph. The detector is a CCD with low thermal noise characteristics, cooled to 200 K. The CHARA spectroscopic facility will be used for high precision radial velocity observations of binary orbits, tomographic separation of binary spectra, and observations of nonradial pulsations of Be stars.

1. INTRODUCTION

This new CHARA spectoscopic facility consists of a fiber–fed spectrograph, detector, and a novel Multi–Telescope Telescope (MTT). The MTT Project grew out of a need for a local spectroscopic facility with at least a 1-m aperture, which would be used primarily for time–critical observations of Be-stars, radial velocities of resolved binaries with $\leq$1 yr periods, and tomographic separation of composite binary spectra.

The MTT comprises a 1-m aperture (largest in the Southeast) with nine individual 33.3-cm mirrors coupling light to separate fibers at each mirror focus. The MTT is like a bundle of smaller telescopes (see Figure 1), hence its name. An advantage of this design is potentially higher throughput, as much as 1.8 times that of a conventional telescope/fiber bundle arrangement, due to higher light transmission through the optics (only one reflection, high reflectivity coatings, a minimal aperture obscuration, and no light loss "between the cracks" in a fiber bundle). The trade–off for low primary mirror cost and weight, only $2300 and 49 kg respectively, is the need for a control system for individual mirror alignment.

The spectrograph is a fiber–fed 'slightly' off–plane, Ebert–Fastie design (Furenlid & Barry, in preparation). The camera/collimator mirror is a 20 cm. aperture, f/5 sphere. The asymmetric coma produced by a parabola is thus avoided, and a nearly constant point–spread function across the spectrum is achieved. The resolution is about 0.083 or 0.223 Å/pixel, with coverage of 96 or 256 Å at the 298$\times$1152 pixel CCD detector for gratings with 1200 and 600 grooves mm^{-1} respectively. The limiting magnitude is about 8 for 1000 sec integrations at SNR=100 at 0.083 Å/pix.

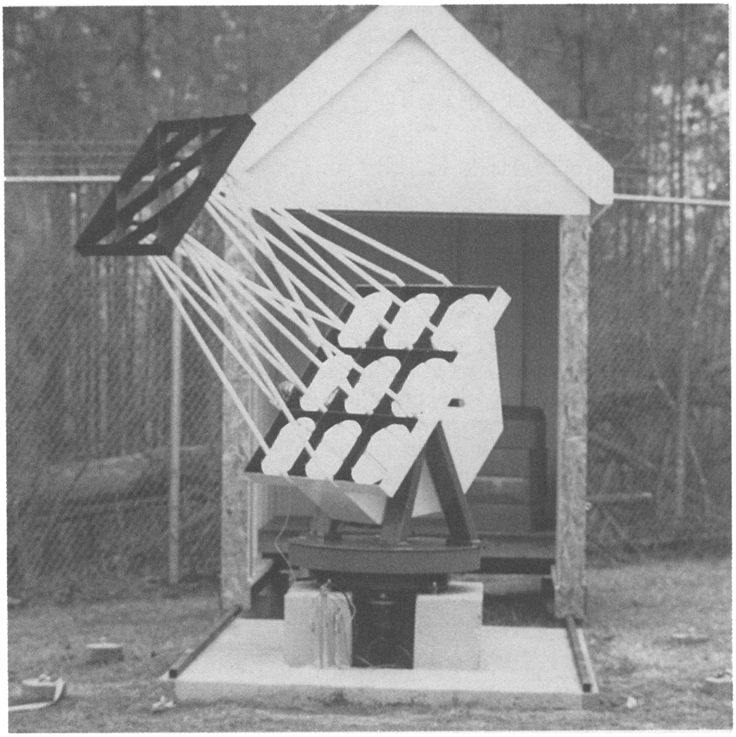

FIGURE 1. The Multi-Telescope Telescope is shown above

2. MTT DESIGN SPECIFICATIONS

- 1.0-m aperture telescope, fiber–fed modified Ebert–Fastie spectrograph
- Height: 2.4 m, Weight: 350 kg
- Barlow lenses for f/11 fiber coupling 100 μm optical fibers convey light to spectrograph. Six similar guide fibers surrounding science fiber (hexagonal packing) send error signals to mirror tilt control.
- Low overall moving weight allows less expensive bearings
- Calculated static deflection $\leq 2''.5$ due to gravity and 20 mph wind.
- Minimal aperture obscuration
- Individual mirrors on mechanical 9-point supports
- Alt–Az design with reduced azimuth yoke width from CG behind mirrors
- Ball bearings for altitude and azimuth
- Compumotor microstepper motors with large speed range coupled in line to axes with Harmonic 200:1 gear reduction
- Acquisition: Pointing accuracy $\leq 30''$. Central mirror re-imaged onto small CCD camera for acquisition and tracking.

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- Slew rate of 5°/sec, "set" speed for acquisition, and basic 15 arcsec/sec equatorial tracking to within 1° of zenith
- Tracking signal from acquisition camera or guide fibers of central mirror. Tracking rate 1 Hz.
- Mirror alignment from 8 outer mirrors relative to center. Each mirror has six 100 μm "guide" fibers surrounding the "science" fiber. Guide fiber outputs re-imaged into small cooled CCD camera. Digitized image polled for significant light from guide fibers. Mirror alignment rate 0.2 Hz.
- Control software in C. Four controller boards move 16 small stepper motors controlling tilt of 8 mirrors. (1 step = $0''.15$).
- The 6 'guide' + 1 'science' fiber bundles are located at the focus of each sub-telescope. The science fibers convey the light to the spectrograph, located in the control room 10-m away, via a fiber slit assembly. The guide fibers convey light to nine 6-fiber bundles imaged into a control CCD at the telescope. Fiber diameters are 100/110/120 μm.
- Housed in a rolled away shelter at GSU Hard Labor Creek Observatory 55 miles E of Atlanta

3. CURRENT STATUS AND FUTURE PLANS

The fiber connections are the major uncompleted portion of the project, and we have drawn up plans for the three major fiber connections. [These are: the 7-fiber bundles at each sub-telescope, the guide fiber focal plane at the control CCD, and the spectrograph slit assembly.] We plan to get 'first lights' through the spectrograph in summer 1992.

Possible future upgrades to the MTT facility are: (1) a new thinned detector chip with twice the d.q.e., (2) a second telescope with 17.5 – 20-in (44 – 51 cm) mirrors, and (3) automation.

A possible extension of this technology is the Multi– Multi– Telescope–Telescope (or "Mighty MuTT"). Facility would consist of 8 MTT's clustered around a small building containing the spectrograph and control room. Each MTT would contain nine 25-in mirrors (the limit of current inexpensive 'amateur size' mirrors). Total aperture is about 5.4-m (roughly equivalent to a 6-m conventional telescope in light). Estimated cost is about $1.04 M, including $720 K for telescopes and shelters, $200 K for spectrograph and detector, and $120 K for the building.

4. ACKNOWLEDGMENT

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