

# CTIO/CERRO TOLOLO

INTER - AMERICAN OBSERVATORY

## Tololo Key Pathfinder for Thirty Meter Telescope Site Testing

Bob Blum

In March of this year, the Thirty Meter Telescope (TMT) sites group began a campaign on Cerro Tololo to test and further develop the complete suite of in-situ testing equipment and methods to be deployed on the TMT candidate sites. The sites group is a collaboration between TMT personnel based at Caltech and the AURA New Initiatives Office (NIO) personnel based in Tucson and Chile. The latter group has participation from both Gemini and NOAO.

Both Matthias Schöck, the TMT sites group leader, and Warren Skidmore have spent many weeks on Cerro Tololo this fall and winter setting up, debugging, and running the sites equipment. The CTIO sites group, as part of the AURA-NIO team, has been helping them at each stage. Engineers Edison Bustos and Juan Sequel, computer specialist David Walker, and sites technician Joselino Vasquez have worked many long nights on Tololo alongside Matthias and Warren.

Many visitors to Tololo in this time will fondly recall many interesting stories (everything from near-death scuba diving exploits to “running into” President Bill Clinton on the Royal Saint Andrews golf course) heard at the dining table from that “British guy.” In addition, they may recall seeing that “crazy German” running between Cerros Tololo and Pachón for a bit of exercise during the long campaign (a feat, I believe, only matched by Todd Henry of Georgia State some years ago). Thanks to the dedication of this eclectic group, the perception of the noise emitted by the Sound Detection and Ranging (SODAR) equipment evolved from a harsh distraction to a reassuring soft “ping.”

Aside from demonstrating that work on Tololo can be interesting and fun, the sites campaign is a key element in the site selection process for the TMT. The campaign consists of a comprehensive plan to test the atmosphere above a select number of candidate sites in the United States, Mexico, and Chile. Considerable effort is going into probing the ground layer (0–30 meters), low levels (0–500 meters), and most of the free atmosphere

(0.5–20 kilometers). Side by side tests of similar and different DIMMs (differential image motion monitors) are being carried out to fully verify that the integrated seeing measured by such instruments is the same.

Early in the testing, a sounding balloon campaign was made to obtain the necessary input conditions to computational fluid dynamics (CFD) models. This was executed by a team from the Large Synoptic Survey Telescope (LSST) project including Gary Poczulp and Jacques Sebag, along with key support from the TMT group. The balloons are standard meteorological equipment

that carry a few hundred grams payload (a “radiosonde”) consisting of a GPS tracker and temperature, humidity, and pressure sensors. The data are relayed in real time by radio transmitter to a ground tracking station. Figure 1 shows a balloon being filled with Helium just before launch. The balloon and simultaneous ground data are being analyzed by Konstantinos Vogiatzis, whose CFD models are intended to provide predictive power in modeling the atmosphere above remote sites.



Figure 1. Joselino Vasquez and Gary Poczulp prepare a balloon for launch. The payload consists of sensors and a transmitter/receiver and is carried on a 60-meter tether. The balloons ascend to an altitude of 20–25 kilometers before bursting (with a diameter of ~10 meters).

A detailed set of safety procedures, including real-time communication between the launch team and the Chilean civil air authorities, was put in place before the launches started, which worked very well throughout the campaign. Thus, possible tragedy was averted early on when a launch of balloons was delayed at the last minute that would have occupied the airspace of the Chilean national soccer team returning from a triumphant match in Bolivia.

The balloon launches were only the beginning of the campaign effort. Simultaneous measurements were made with the CTIO MASS-DIMM instrument, two SODARs, and a set of microthermal probes developed at the University of Nice in France. The ongoing campaign seeks to further verify and develop all these sensors.

The Nice microthermal probes are based on a resistive circuit design, but are quite fragile (the key element is a 5-micron wire). The TMT group is testing three other sets of thermal probes to

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## Tololo Key Pathfinder for TMT Site Testing continued

judge their ability to accurately characterize the component of atmospheric turbulence in the first 30 meters from the ground. Thirty meters is a compromise between the likely elevation of the TMT primary and a freestanding tower that can be reliably deployed in remote locations. The thermal probes are located at various altitudes on the tower. Along with thin wire probes like the Nice model (which are also fragile), the TMT group is developing sonic anemometers. These probes measure the sound speed at high frequency and, from this, microthermal variations in a small volume of air. The microthermal variations (as for all the thermal probes) are converted into index of refraction variations, and then “seeing” over the 30-meter column.

Ascending beyond 30 meters, the atmospheric column is probed by the SODAR and Multi-Aperture Scintillation Sensor (MASS) units. SODAR is an acoustic profiler that transmits strong and directional sonic pulses upward. The pulses are backscattered from the interfaces between turbulent cells with different temperatures. The duration between transmitted and received signals and the strength of the backscattered signal allows a vertical profile to be reconstructed. The TMT group is testing two units that reach altitudes of about 200 meters and 800 meters, respectively.

The MASS is a profiler that resolves the free atmosphere seeing (0.5–20 kilometers) into contributions arising from six layers. While the vertical resolution is low, the MASS provides valuable information about the main contributing layers of turbulence above a site and is intrinsically insensitive to the ground layer turbulence, which produces no scintillation. It is compact and can be deployed in an integrated unit with a DIMM on a small telescope. (The MASS-DIMM implementation is described in Andrei Tokovinin’s March 2004 *NOAO/NSO Newsletter*.) During the CTIO TMT campaign, two independent MASS-DIMM units have been deployed and found to be in excellent agreement. A third, MASS-only instrument was briefly run and also agrees with the other two. The MASS-DIMM is one of the primary TMT tools, and one unit is already operating at a remote site.

The TMT MASS-DIMM has been operating on Tololo since mid-April and has already become a familiar site to visiting astronomers. The telescope is fully robotic, opening, observing, and closing each night through a set of software programs distributed over three computers in a local area network and managed by UNIX cron jobs. The operation still requires daily “care and feeding,” but this is typically routine and involves only quick checking through a Web interface that the operation has begun normally, that the

dome is closed in the morning, and that all data have been backed up on remote computers. The software programs check current weather conditions and close the telescope during the night if conditions warrant it. Operation begins again when the weather improves. Web cams allow visual confirmation that the dome is closed during the day as well as providing additional information on daytime conditions.



*Figure 2. The 30-meter microthermal tower rising above the USNO and Columbia domes on Cerro Tololo. As many as 50+ probes were simultaneously mounted at 10 altitudes on the tower to measure microthermal variations (and hence seeing). The 6.5-meter tower to the right of the 30-meter is the ATST DIMM tower. The tubular tower next to the USNO dome contains the CTIO MASS-DIMM telescope.*

The TMT MASS-DIMM telescopes will use a tower developed for the Advanced Technology Solar Telescope (ATST). The Tololo equipment is currently running on such a tower (see figures 2 and 3). This 6.5-meter tower is meant to place the DIMM above the first few meters of ground turbulence. The 6.5-meter height is as high as possible while still allowing the DIMM to operate without excessive windshake. Since the DIMM measures the total seeing, the combination MASS-DIMM can be used to infer the ground-layer contribution (in this case everything below the MASS lower layer of about 500 meters). Of great interest to the TMT group will be the eventual cross-calibration of the various instruments working at overlapping layers.

Another novel aspect of the TMT DIMM is its drift scan mode of taking the usual dual spot images used in measuring image motion. In the TMT implementation, the CCD is read out in drift scan mode, compressing one dimension into a row of pixels. The spot centroids are thus measured only in one direction. This readout mode is very fast and allows for many more samples to be taken in a shorter time than with traditional DIMMs. While the traditional method provides

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### *Tololo Key Pathfinder for TMT Site Testing continued*



*Figure 3. The TMT Halfmann telescope. The 35-centimeter telescope can just be seen through the bottom of the enclosure. The black object to the left on the same tower is a portable Meade telescope/DIMM. The tower to the left is the ATST tower on which the TMT MASS-DIMM telescope will be deployed on remote sites. The final major component of the TMT site testing suite is, of course, the DIMM (deployed as a MASS-DIMM).*

two independent measures of the differential image motion variance (and hence seeing), the TMT method has been shown to give the same results. A series of tests were run on sets of Tololo DIMM images, compressing the data and piping it through the TMT software. The seeing computed from the Tololo DIMM and TMT algorithm were in excellent agreement.

Throughout the campaign, the TMT and Tololo DIMMs have been taking data on as many clear nights as possible.

The resulting database of information forms one of the most detailed data sets to test standard DIMM theory and operation ever taken. A third DIMM has been run alternately next to (on the same tower; see figure 3) the TMT DIMM and the Tololo DIMM (mounted in the same tower; see figure 2). The preliminary comparison among the three is very encouraging. A “quick” look at the data through early May suggests agreement to better than 0.1 arcsec between the TMT and Tololo DIMMs, and less than 0.05 arcsec for the portable and TMT DIMMs when run on the same tower. It is believed that a more careful analysis, including effects of the logged focus behavior of the Tololo DIMM and derived ground layer, will improve the comparison and point to methods and procedures that will be helpful in taking similar data with other DIMMs.

The TMT site selection is on a fast track and one MASS-DIMM unit has already been deployed in Northern Chile. The equipment on Tololo will soon be deployed on a second Chilean peak as the Tololo campaign winds down. A final push is under way to test two Halfmann MASS-DIMMs side by side and to finalize the testing of the microthermal probes. The hard work of assessing the data obtained over the last months on Tololo from three DIMMs, two MASS units, two SODARs, four flavors of thermal probes, and the balloon launches has begun. A complete technical description of the equipment described in this article and preliminary results from the Tololo campaign is given by Skidmore et al. (to appear shortly in the proceedings of the 2004 SPIE meeting, Glasgow, Scotland).

Besides the TMT sites group team members deservedly mentioned in this article, there are many others who have made essential contributions to the early success of this project. On Cerro Tololo, the entire Telops team has been a great help and, in particular, Gale Brehmer has been a constant source of assistance and advice during the campaign. Paul Gillett is in charge of all the sites logistics and infrastructure and has made key contributions to the deployments, both remote and on Tololo. The AURA Observatory Support Services (AOSS) group provided invaluable help with the balloon launches and communications with the Chilean civil air authorities.



## Goodman Spectrograph Arrives in Chile

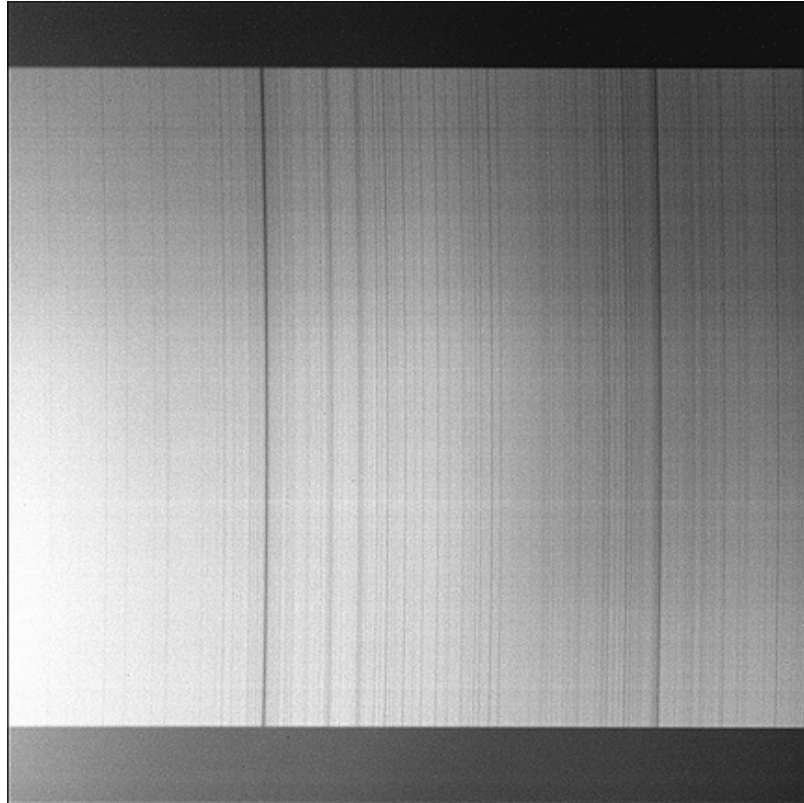
*Chris Clemens (University of North Carolina)*

The Goodman Spectrograph was shipped from Chapel Hill, North Carolina, to La Serena in June. As the instrument principle investigator, I was in Chile with University of North Carolina (UNC) students Adam Crain and Matt Bayliss through August for testing and integration.

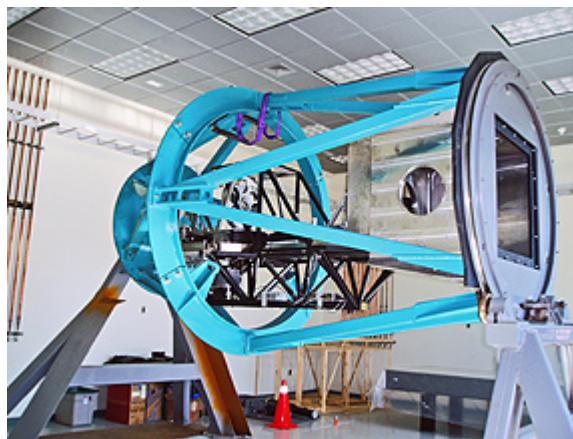
The Goodman Spectrograph is the first major instrument produced by the UNC Goodman Laboratory. It is an all-refracting imaging spectrograph that incorporates transmission volume phase holographic gratings. The instrument is designed to be used on the 4.1-meter SOAR telescope.

All of the optical, mechanical, and electronic systems delivered are functioning as expected thus far, and the spectrograph has taken spectra of ambient sunlight in the Gemini instrument laboratory. Tests of the instrument flexure show that it is repeatable and within the range of the active compensation system built into the spectrograph. Remaining work includes final integration of the dewar and Lincoln Lab CCDs in the CTIO workshops. Meanwhile, the instrument is operational using a modified 2Kx2K pixel Apogee camera.

A more detailed description of the instrument, and software tools for potential observers, are available at the Goodman Laboratory Web site ([www.physics.unc.edu/~clemens](http://www.physics.unc.edu/~clemens)).



*First Engineering Image from the Goodman Spectrograph. When installed on the SOAR telescope later this year, the spectrograph will provide very high throughput imaging and spectroscopy from 320 to 850 nanometers, with  $R \sim 1000-10,000$ .*



*The Goodman Spectrograph and SOAR Nasmyth cage in the Gemini South instrument laboratory.*



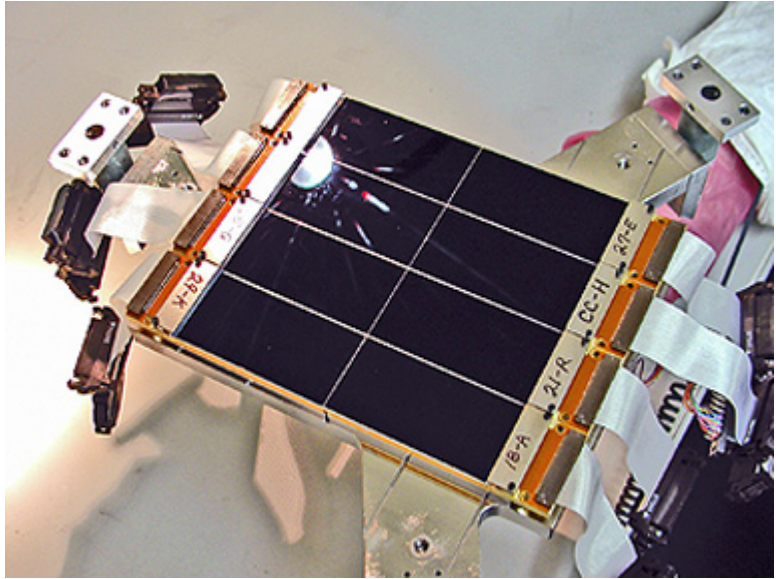
## Mosaic II Detector Replacement

*Tim Abbott*

The Mosaic II imager suffered a failure September 2003 that resulted in the production of serious amplifier glow in one of its CCDs (CCD#3). Despite valiant efforts by CTIO staff, it proved impossible to resolve this problem and we were forced to disable this CCD entirely to avoid compromising the imaging quality of the rest of the array.

For several months, observers could only observe with this 7/8ths mosaic while we sought and acquired a replacement detector. Though the SITe 2Kx4K CCDs employed in the NOAO mosaics are no longer in production and supply is very limited, we were able to obtain a replacement through Chris Clemens at the University of North Carolina's Goodman Laboratory. Moreover, this replacement had two functioning amplifiers (perhaps the last such device!), which meant that performance of the Mosaic II camera would not be compromised after all.

A collaborative effort by NOAO North and South—primarily Ramon Gálvez, Ricardo Schmidt, and Tom Wolfe—saw



*The reassembled Mosaic II focal plane array with the replacement detector identified by "CC-H".*

the replacement safely installed in the cryostat in April 2004, and observations with Mosaic II resumed

in May. The new detector performs, if anything, slightly better than the original.

## Blanco Telescope Shutdown 2004

*Tim Abbott*

When its dome shutter failed in February 2003 (see the June 2003 *NOAO/NSO Newsletter*), the Blanco 4-meter telescope fell victim to a freak hailstorm. While no lasting damage was done, the primary mirror did get wet and degraded sufficiently that we decided to accelerate the aluminizing schedule. We therefore shut down observing operations for two weeks in June and July of this year and removed the primary mirror for adjustment and recoating. In preparation for this, we had upgraded our aluminizing chamber to match the changes already made to the chamber at the Mayall telescope on Kitt Peak.

While the first coating failed as the result of a minor misunderstanding, the second was gratifyingly successful, resulting in a significantly more uniform coating than before. We also took the opportunity to repair the two radial supports that had broken since the last shutdown (see the December 2002 *NOAO/NSO Newsletter*) and made significant progress in tuning this complex and delicate system. Finally, the telescope's hydrostatic bearing oil was completely drained and replaced for, we think, the first time since the telescope was commissioned!



## Other Happenings @ CTIO

*Alistair Walker*

I am very happy to announce that the CTIO scientific staff has been augmented by two new appointments. Rachel Mason, NOAO Postdoctoral Fellow working for the NOAO Gemini Science center (NGSC), arrived in La Serena on June 15, after having spent the first several months of her appointment in Tucson. Apart from supporting Gemini infrared (IR) instrumentation via NGSC, she expects to continue her research on interstellar dust using GNIRS and T-ReCs. In early August, Chris Miller from Carnegie Mellon University took up an Assistant Astronomer position. His recent work has involved using the Sloan Digital Sky Survey for a number of extragalactic studies, and his expertise with large databases will be put to good service by his participation in the NOAO Data Products program (DPP).

In early September we bid farewell to Jim de Buizer, who has been at CTIO as a Postdoctoral Fellow for three years, plus a year “loaned” to Gemini South where he helped in the TReCs commissioning. Jim is not moving very far though, having accepted a position as a Gemini Science Fellow at Gemini South. Jim is an expert on star formation and mid-IR instrumentation, and the facilities and opportunities at Gemini should be a perfect match to his talents. We all wish him well in his new job!

In response to an announcement of opportunity for proposals to partner in building a major new facility instrument for the Blanco telescope, a proposal was received on July 15 from a Fermilab-led consortium to construct a new prime focus CCD imager and corrector with 2.2-degree diameter field. The consortium plans to deliver the instrument in 2009, and then use 30 percent of the Blanco time over five years to undertake the Dark Energy Survey. The survey data products will be made available for public use, while the instrument itself will provide an order-of-magnitude increase in capability over Mosaic II. The proposal was reviewed by the Blanco Instrumentation Partnership Panel in August 2004.

See the Observational Programs section of this *Newsletter* for a list of telescope-instrument combinations at CTIO available for NOAO users in 2005A. For the first time, SOAR instruments appear on this list. Details will appear on the proposal Web page at the start of September, after a review of telescope and instrumentation readiness.

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### *Notable Quotes*

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“There are so many surprises in store for us that we can’t even anticipate yet, and that is the glory and magic of exploration, of discovering the unknown.

The heavens above us, the stars that light the night sky, we look up and marvel and we don’t know much about it. It is a mystery and has been to humanity throughout the centuries.”

—*Legendary space artist Robert McCall, quoted in an Arizona Republic story on early Cassini spacecraft images of Saturn’s rings, written by Judd Slivka and Amanda J. Crawford, 2 July 2004*