R
cent scientific output from
CTIO continues to receive
favorable reviews. Users and
staff of CTIO have a long tradition
of significant contributions to our
understanding of stellar populations and
their evolution, through studies in our
galaxy (particularly its central and bulge
regions), the Magellanic Clouds and local-
group galaxies. Newer staff members
have brought an emphasis on synoptic
astronomy and even astrometry! Two
groups using the facilities at Tololo have
recently detected and then measured a
remarkably high space density of white
dwarfs in the halo of our galaxy, with
implications for the nature of dark matter
in that region of our galaxy and for the
form of the stellar mass function in the
early history of the Galaxy.

In support of such work, Tololo has
always had a strong instrumentation
program. This has resulted from a
combination of carefully chosen new
instruments and prioritized upgrades,
i.e., new spectrograph cameras and new
CCDs. Lately, much of the scientific
emphasis has been on observational
cosmology, as reflected in the work on
Type Ia supernovae which has revealed
an apparent acceleration of the expansion
of the Universe, and on observational
probes of large-scale structure through
weak lensing and the study of MgII
absorbers.

With the arrival in Chile of the VLT,
Gemini South, and the Magellan
telescopes, it is once again necessary to
accelerate the process of change at CTIO.
Our Web site illustrates the short-term
changes we have already made. For the
intermediate and longer term, we are in
the middle of an intense process that will
likely produce substantial change within
CTIO. We are currently exchanging ideas
with our users and outside committees.
This is a tricky moment to be writing
about the precise direction we are headed.
Given the stimulating requirements of the
Decadal Survey and the lack of significant
additional funding from the NSF to carry
out these requirements, it is clear that
beyond the process of prioritization and
re-organization within NOAO, searches
for additional, non-traditional funding
will be necessary -- probably through
existing and new partnerships. This will
help create sufficient resources to respond
to these new challenges, while continuing
to supply our user community with high
quality, open observing access to the
Southern Hemisphere skies.

Under Jeremy Mould’s leadership,
NOAO’s process of prioritization and
reorganization is underway, and CTIO is
ready to do its part. Indeed, the staff is
already making substantial contributions
to many of the newer areas of NOAO
activity. Brooke Gregory is working 2/3
of his time on the GSMT. Alistair Walker
is leading a staff group in a major survey
of sites in various places, including the
whole area of Northern Chile between
-30 and -20 degrees latitude. Others are
working closely with Celine d’Orgeville
and her team from Gemini using two
of the small telescopes on Tololo to
characterize the nature of the sodium
layer above Tololo (and Pachón) in
preparation for development of adaptive
optics for Gemini South and SOAR.
(See cover image and the article by
A. Tokovinin in this newsletter.) As
reported in the last newsletter, several
members of the staff have been working
with Cornell University to survey in
greater detail the 17,000-foot mountains
around the ALMA site near Chajnantor.
Bob Schommer is moving to Tucson
in order to set up the NOAO Gemini
Science Center. Patrice Bouchet, Stefanie
Wachter, Bob Blum, and Chris Smith
have all helped with the operations of
Gemini North in Hawaii, thereby gaining
the expertise necessary to help in a
similar way on Cerro Pachón and in La
Serena. Chris Smith and Ron Lambert
are working with Gemini and SOAR to
improve the communications bandwidth
to AURA’s observatory here (see article in
this newsletter). Steve Heathcote is now
the Director of SOAR and is returning
to Chile after a year in Tucson with
the SOAR construction project team.
The entire former business and logistics
division of CTIO, under Enrique
From the Director continued

Figueroa’s leadership, is now devoted to the support of all of AURA’s operations in Chile (Gemini South, SOAR, and the telescopes on Cerro Tololo).

Once the commissioning of SOAR is completed, we expect significant shifts of effort within our engineering and technical services group towards support of some of NOAO’s new activities. Many former members of the CTIO engineering and technical staff have transferred to the international Gemini project and are making major contributions there, while several young, highly talented, new staff members have arrived to take their place. The next two years will see the assembly, integration, test, and commissioning of SOAR over on Cerro Pachón. We are experimenting with ways to use our new communications bandwidth to enable new styles of observing at the Blanco 4-m telescope. Don’t be too surprised to find that you are eventually observing from La Serena or from home -- it is mainly a matter of bandwidth. We are currently consulting with our users to see how we can transfer responsibility for the smaller telescopes on Tololo to university consortia as an option superior to that of closure, given the excellent site conditions on Tololo.

Continuing to improve our high standards through a period of such intense change and under likely conditions of substantially reduced funding is challenging. Please do not hesitate to send your comments or advice to me at: msmith@noao.edu and/or to the chairman of NOAO’s Users’ Committee.

SOAR’s Tip/Tilt Tertiary Nears Completion

Steve Heathcote

The control system for the Tip/Tilt Tertiary that forms the heart of SOAR’s Adaptive Optics system was completed in April, while the mirror itself is now nearing completion.

SOAR’s tip/tilt system consists of a 470 × 655 mm fast steering mirror, made from ULE glass, that can be wobbled about two axes driven by voice coil actuators. Pairs of position and velocity sensors, coupled to the mirror, provide the feedback needed to close the control loop with a bandwidth of greater than 50 Hz. During observations, an outer control loop, closed by a fast readout (500 Hz frame rate) CCD camera, continued

The mechanism and control system for SOAR’s Tip/Tilt Tertiary is put through its paces at the BF Goodrich facility in Albuquerque, New Mexico. For these tests an aluminum surrogate was used in place of the actual mirror.
**SOAR's Tip/Tilt continued**

will drive the mirror so as to null the motion of a guide star thus correcting for atmospheric tip/tilt and wind-shake. The entire mirror assembly can be rotated about its axis to direct the light to any of the five (two Nasmyth and three folded Cassegrain) focal stations.

*The rear of the SOAR tertiary mirror blank is shown following completion of the light weighting process that reduced its mass by 80%.*

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### Not Enough Stars In The Sky?

*Andrei Tokovinin*

**N**owadays, most large ground-based telescopes are equipped with Adaptive Optics (AO) systems to compensate for atmospheric turbulence and achieve better angular resolution. To measure the perturbed wave fronts in real time, AO systems need guide stars that are bright enough and close enough to the scientific target. However, such stars are often not available, which is why astronomers want to implement artificial laser guide stars (LGSs). Furthermore, when using several LGSs, it will even be possible to do tomographic reconstruction of the instantaneous turbulent volume and to compensate it in three dimensions, a capability planned for the 8-m Gemini South telescope at Cerro Pachón.

LGSs must be high in the sky to properly simulate natural stars. The best choice is to use the glow of sodium atoms in the mesosphere, excited by a powerful laser beam. The mesospheric sodium layer has a typical altitude of 90 km and a typical thickness of 10 km. This sodium layer is known to be highly variable on time scales from minutes to months. Sometimes strong ‘sporadic’ layers with increased concentration of sodium appear and then slowly degrade. The properties of the sodium layer (total number of atoms, vertical profile) need to be known for a proper design of an AO system. Unfortunately, the available information is not sufficient, especially for the Southern Hemisphere, where most of the sodium LGSs are being planned.

The Gemini team took the initiative to organize a systematic campaign to measure the sodium layer in Chile. This is a collaborative project involving ESO, CTIO, and the Imperial College of London; the partners each provide financial support and each will benefit from the results. The team is chaired by Celine d’Orgeville (PI) from Gemini and consists of Gelys Trancho (Gemini), a group from CTIO (Brooke Gregory, Maxime Boccas, Andrei Tokovinin), and researchers from the Imperial College of London (Chris Dainty, John Quartel, Nick Wooder, and Laurent Michaille) who built the laser equipment and contributed their experience gained during previous sodium measuring campaigns (e.g., at La Palma, see Mon. Not. RAS, 318, 139, 2000).

The sodium experiment at CTIO is actually a small-scale simulation of the future LGS. The beam of a dye laser tuned to the Na D2 line is launched vertically into the atmosphere. Some light is scattered in the lower layers (0-30 km), making the beam visible even to the naked eye when standing close to the 50-cm launch telescope (see cover image). This so-called “Rayleigh cone” is not useful for AO, but its intensity is very sensitive to a presence of any additional scattering, e.g., to cirrus clouds. The sodium star has a magnitude of about 13 for the laser power of 0.4 W used in this experiment. In future systems with laser optical power of several W, stars of 10°–11° will be lit in the sky.

*continued*
Not Enough Stars continued

The dye laser and its 7-W argon-ion pump laser are located in a utility building below the Blanco 4-m. The beam is launched through a circular hole in the roof. The sodium star is observed at the 0.9-m telescope with its standard CCD, through an interference filter for a better contrast against the sky. In this way, we see the mesospheric column of excited atoms “from the side” and we can measure the altitude distribution of sodium from the brightness profile of the observed stripe. The telescope is fixed, so stellar images in the field leave trails during the 10-30 second exposures. To measure the absolute height of the layer, simultaneous exposures are taken at the Curtis Schmidt telescope, and the displacement of the sodium stripe relative to the star trails permits us to do something like a triangulation.

The first run of this campaign took place on 12-20 February 2001. Data were taken successfully and are now being processed. Four more runs are planned until February 2002 to sample the sodium layer in different seasons. It is known already that there is important seasonal variability.

An image of the sodium stripe (left, artificial colors) and the temporal evolution of the sodium profile during one night (right).

The sodium experiment is a combination of excitement (after all, it’s something unusual) and routine (monotonous data taking when everything goes smoothly), although it does not run smoothly all the time. The laser is very complex; sometimes it looses the lock on the sodium line, and sometimes additional experiments are conducted. Overall, it is a rather complicated endeavor involving three distinct locations on the mountain, many people from different organizations, and specific data processing. We hope that the results will be worth the effort, paving the road to LGS-assisted astronomical adaptive optics. Special thanks go to all CTIO staff who made this experiment possible by installing the optical table, drilling the hole in the roof, and enabling a water and power supply for the laser.

Improved Performance of the f/14.8 Tip/Tilt Secondary System at the Blanco 4-m Telescope

Patrice Bouchet and Ron Probst

The CTIO Tip/Tilt System provides first-order wavefront correction and image stabilization for infrared imaging and spectroscopy on the Blanco 4-m telescope. The system consists of a f/14.8 Tip/Tilt Secondary, driven under closed loop control by three piezoelectric activators and an accompanying controller purchased from Physik Instrumente GmbH. The Tip/Tilt Secondary serves as limiting telescope stop to reduce the thermal background. It is mounted in the prime focus cage and swings out of the beam when access to the prime focus is needed. A detailed description of the system is given by Probst et al. and Perez & Elston (SPIE, 3352, 1998).

continued
Improved Performance continued

Since the first description of the tip/tilt system the following improvements have been made:

- The CCD guide sensor. We are now using a small-field, high-speed, low-noise EEV 39B CCD. This is a 80×80 CCD with a nominal read noise of 4 electrons, and a frame rate of up to 2 KHz (for a 2×2 pixels frame without binning; standard set-up is 9×9 pixels without binning, which gives an actual correction frequency of 315 Hz). This gives a faster framing and thus allows a higher degree of correction, while lower read noise allows the use of fainter stars.

- The PC processing speed. We have acquired a Pentium P5-120 MHz processor.

- The telescope collimation. We are now operating the active primary of the Blanco 4-m telescope with a lookup table appropriated to the f/14.8 focus, whereas we used to adapt the f/8 lookup table.

- The algorithm used for the tip/tilt corrections. We have been testing various algorithms in order to optimize the corrections. Experience has shown that the so-called “centroid algorithm” gives better results than the other ones (“momentum” and “brightest pixel”; see CTIO Users’ Manual).

Two nights were devoted to the final characterization of the system (16-17 March 2001) and to determining the best setup parameters. Once these parameters were adjusted, we obtained images between 2 to 3 pixels (0.16 arcsec/pixel) with tip/tilt correction, while imaging the same fields without correction (but with guiding) just before and after usually gave a Moffat value of 4 to 5 pixels. Obviously, the achieved correction varies with the atmosphere, and the better the “seeing,” the better the correction. However, typical conditions now deliver a “dome + outside” seeing of 0.6 to 0.8 arcsec, which translates to images in the near infrared (even in J!) regularly from 0.3 to 0.5 arcsec. The best images obtained during our engineering nights were 0.32 arcsec in H and 0.26 in K, in both cases with an exposure time of 15 minutes. The worst images were around 4 pixels (0.64 arcsec). It must be emphasized that the seeing was highly variable during these nights. Unfortunately, the CTIO seeing monitor was out of order, so we could not compare our results with it.

We found that we can obtain a fairly good correction closing the loop on a 16.5m star (actual correction frequency of 10 Hz). Obviously a better correction is achieved for a 10-13m star, for which we can close the loop up to a real frequency of 310 Hz. Considering the FOV of the stage range (the “panoramic” field is about 19×19 arcsec and can be displaced over a 6 arcmin² range), most of the science-targets fields would include a bright enough guiding star. We could not see any dependence on the angular separation between science target and reference star out to the limit of the accessible field.

In conclusion, we have now a very reliable and efficient tip/tilt system at the Blanco 4-m telescope. Both technical and user documentation exist, and reports on the final characterization are available on the web at: www.ctio.noao.edu/instruments/ir_instruments/tiptilt/. Last but not least, the CTIO operators are now very continued
Since February, the scientific staff of CTIO and Gemini have been getting together for journal club. We meet in the conference room every Wednesday morning at 10:30 am to discuss recent literature. Please feel free to join these discussions whenever you are in La Serena.

With the help of a grant from the National Science Foundation, CTIO and Gemini together have recently installed a new network link connecting the La Serena offices to the telescopes on Cerro Tololo and Cerro Pachón. The new system provides a 155 Mbps “OC-3” link using new radio dishes mounted on a tower in La Serena, on the side of the Blanco 4-m, and on a small tower on Cerro Pachón. The connection will be shared between the Gemini South telescope on Cerro Pachón and NOAO-operated installations on both mountaintops (SOAR on Pachón, CTIO telescopes on Tololo). This jump in bandwidth will enable a new generation of remote support and operations from La Serena, opening exciting possibilities of remote observer support with parallel audio-video and computer connections and perhaps eventually remote observing from La Serena. Gemini and CTIO have now turned their attention to the relatively slow international link, in hopes of upgrading it soon to provide remote support and observing capabilities for both observatories from Tucson, Hawaii, and other locations in the US and around the world.

Thanks to the hard work of many people, in particular Tom Ingerson and Roger Smith, a camera designed especially for use with the Hydra-CTIO Bench Spectrograph has been installed. The new camera produces significantly sharper images than the interim Air Schmidt, allowing use of all ~130 available 2” fibers in a single observation. Its SITE 2K×4K detector also has lower read noise (3 e⁻) than the Loral 3K×1K CCD used with the Air Schmidt. The low read noise is especially important for faint object spectroscopy.

Prospective users of Hydra-CTIO should be aware that it is a demanding and complex instrument. Advice on producing accurate astrometry and preparing observing fields can be found at: www.ctio.noao.edu/spectrographs/hydra/hydra.html. We encourage observers to plan to be on the mountain one night early if they are new to the instrument.

On April 26, NOAO Director Jeremy Mould, KPNO Director Richard Green, and other Tucson staff met with La Serena Mayor Adriana Peñafiel, Pedro Sanhueza, Director of the Office for the Protection of the Quality of the Sky of Northern Chile, Enrique Piraino, a lighting engineer with the Universidad Catolica de Valparaiso, and CTIO Director Malcolm Smith to discuss dark-sky issues and joint public outreach possibilities.