

CTIO/CERRO TOLOLO

INTER - AMERICAN OBSERVATORY

PROMPT Progress

Dan Reichart (University of North Carolina at Chapel Hill)

The University of North Carolina (UNC) at Chapel Hill is currently building the Panchromatic Robotic Optical Monitoring and Polarimetry Telescopes (PROMPT) on Cerro Tololo, on the ridge between the GONG and 1.3-meter telescopes. PROMPT's primary objective is rapid and simultaneous multiwavelength observations of gamma ray burst (GRB) afterglows, some when they are only tens of seconds old. In addition to measuring redshifts by dropout, and early-time spectral flux distribution (SFDs) and extinction curves of sufficiently bright afterglows in unprecedented detail, PROMPT will facilitate quick response observations at 8.1-meter Gemini South and 4.1-meter SOAR telescopes. PROMPT will also serve as a platform for undergraduate and high school education throughout the state of North Carolina.



Four of the six PROMPT enclosures have already received 12-foot diameter clamshell domes built by Astro Haven. The remaining two enclosures will receive domes in September 2005. Live images of PROMPT can be viewed at www.physics.unc.edu/~evans/promptcam/promptcam.html.

When complete in late 2005, PROMPT will consist of six 0.41-meter Ritchey-Chrétien telescopes built by RC Optical Systems on rapidly slewing ($9^\circ/\text{sec}$) Paramount ME mounts by Software Bisque, each under a clamshell dome by Astro Haven. Five of these telescopes are being outfitted with rapid-readout (<1 sec) Alta U47+ cameras by Apogee, which make use of E2V CCDs. The sixth is being outfitted with an LN₂-cooled Micro-Cam by Rockwell Scientific for near-infrared (NIR) imaging. Each mirror and camera coating combination is optimized for a different wavelength range, including a u-band optimized telescope. Although other filters will be available, PROMPT will automatically observe GRB localizations in ugrRizYJH, six of them simultaneously. The R-band telescope



From left to right, the PROMPT-5, -3 and -2 telescopes. We have been using three 0.36-meter Schmidt-Cassegrain telescopes from Celestron while our final optics are being prepared. In September 2005, we will upgrade to six 0.41-meter Ritchey-Chrétien telescopes by RC Optical Systems.

will additionally measure polarizations. The polarimeter is being designed and built at UNC-Chapel Hill's Goodman Laboratory for Astronomical Instrumentation.

PROMPT is being built in two phases: Phase I, funded by \$130,000 from UNC-Chapel Hill and a \$100,000 gift from alumnus Leonard Goodman, began in September 2004 and is now complete. Phase I consisted of enclosure construction and assembly of temporary 0.36-meter Schmidt-Cassegrain telescopes from Celestron, with the goals of establishing reliable and robust operations, and testing software. Phase II, funded by \$912,000 from NSF's MRI and PREST programs, begins in September 2005 and will consist of upgrading to final optics: the NIR camera, and the polarimeter.

Although early science technically does not begin until after the September trip, PROMPT has already observed nine GRB localizations, two within minutes of the burst, and two with detected afterglows. These results are being prepared for submission to the *Astrophysical Journal* in combination with Follow-Up Network for Gamma-Ray Bursts (FUN GRB) Collaboration data from SOAR, the 3.5-meter ARC, 1.5-meter Kuiper, and 0.9-meter SARA telescopes. PROMPT collaborating institutions (see list on next page) will gain access to 30 percent of PROMPT's time beginning in January 2006. The broader US astronomical community will be invited to apply for 10 percent of PROMPT's time, with awards beginning in Semester 2006B.

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PROMPT Progress continued

“Skynet,” a prioritized queue scheduling system under development at UNC-Chapel Hill, controls PROMPT. This queue scheduling system, written in LabVIEW, runs on a computer at UNC-Chapel Hill’s Morehead Observatory. Skynet interacts with MySQL databases and commands dumb-by-design “Terminator” programs at each telescope. Images are automatically transferred back to a 1.1-terabyte RAID 5 with tape backup at Morehead Observatory, making use of communication libraries written for remote use of SOAR. Users can submit jobs and retrieve data from any location via a PHP-enabled Web server that interacts with the MySQL databases. GRBs receive top priority, and are added automatically to the queue via a socket connection.

Furthermore, we have written Terminator very generally to allow any mount that can be controlled by “The Sky” and any camera that can be controlled by MaxIm DL, or mounts and cameras that are ASCOM compliant, to be easily integrated into Skynet. On this note, work is underway to integrate a few half-meter-class facilities across the United States this academic year, supported in part by an NSF CAREER grant. Skynet will then synchronize GRB observations across these telescopes, which makes interpreting SFDs much easier, especially if the afterglow is not fading as a power law at early times. When not chasing GRBs, which is most of the time, network members will be able to queue jobs on each other’s telescopes, including PROMPT, at a guest priority level, giving them access to additional facilities and instrumentation, not to mention sky coverage and weather flexibility.

Between HETE-2, Integral, and now Swift, we expect PROMPT to observe GRB localizations on the rapid timescale about once every three months, and on longer timescales about once every week. Given our best estimates about the star-formation rate at high redshifts, we might observe $z > 5$ GRBs on the rapid timescale as often as once per year, and $z > 7$ GRBs on the rapid timescale perhaps once every two to three years. PROMPT’s ability to observe afterglows simultaneously in many filters, including near-IR filters, and to do so quickly before the afterglow fades away, will allow it to “promptly” pick out record-breakers.

Record-breaker or not, we will use PROMPT to facilitate our quick response programs on Gemini South and SOAR, which are only one mountaintop away. UNC-Chapel Hill and the FUN GRB Collaboration, in a coalition with the US/UK Gemini GRB Collaboration, have been awarded 21 hours of quick-response time on Gemini South in Semester 2005B. Additionally, UNC-Chapel Hill has a three-year commitment from the SOAR Board to interrupt on the rapid timescale. Both telescopes are capable of near-IR and optical spectroscopy and imaging, and are able to switch instruments within minutes. A trained GRB observer will help coordinate PROMPT, SOAR, Gemini South, and FUN

GRB Collaboration efforts from UNC-Chapel Hill’s new Henry Cox Remote Observing Center each night.

PROMPT will also be used by undergraduate and high school students from across the state of North Carolina for a wide variety of projects. In addition to UNC-Chapel Hill, PROMPT Collaboration institutions include Appalachian State University, Elon University, Fayetteville State University, Guilford Technical Community College, North Carolina Agricultural and Technical State University, UNC-Asheville, UNC-Charlotte, UNC-Greensboro, UNC-Pembroke, Western Carolina University, and Hampden-Sydney College just across the state line in southern Virginia. Each of these institutions will have about 420 hours per year of observing time distributed among the six PROMPT telescopes, giving them guaranteed access to a professional observatory and the southern sky.



UNC students Matt Bayliss and Melissa Nysewander, with PROMPT-2’s temporary telescope in the background. Nysewander is the lead graduate student on PROMPT. Bayliss is writing GRBFAST, general-purpose software for afterglow and extinction curve modeling for PROMPT and other FUN GRB telescopes.

Furthermore, since PROMPT is fully robotic, none of these institutions will have to raise additional money to send students to Chile to use the telescopes — a very expensive proposition. Rather, students will simply submit observing requests to Skynet using the Web interface.

Finally, UNC-Chapel Hill’s Morehead Planetarium and Science Center (MPSC) will have about 2,300 hours per year for K-12 education and public outreach. MPSC hopes to bring PROMPT into every high school in the state of North Carolina. Funded by a \$50,000 NASA/STScI IDEAS grant, MPSC is developing a curriculum for high school science classes allowing them to submit observing requests to Skynet using the same interface that the undergraduate college students will use. This curriculum will also satisfy new statewide graduation requirements.



Charon Occultation Observed at SOAR and CTIO

Leslie Young, Cathy Olkin, Trina Ruhland, Eliot Young (Southwest Research Institute), Dick French (Wellesley College), Kevin Shoemaker (Shoemaker Labs), Ramon Galvez & Brooke Gregory (NOAO)

How can we measure the size of Pluto's moon, Charon, when it subtends only one-twentieth of an arcsec? Even with the Hubble Space Telescope or adaptive optics, imaging cannot resolve Charon. One solution was to observe Pluto and Charon during Pluto's equinox, when the two bodies eclipsed and transited each other, but this method gave conflicting radius measurements ranging from 593 to 620 kilometers (Tholen & Buie 1990, BAAS 22, 1129; Young & Binzel 1994, Icarus 108, 219).

A more direct method is to measure stellar occultation by Charon passing in front of a star, as seen by observers within the shadow path on Earth. If the velocity of Charon is known, then a chord length can be derived from the duration of the star's disappearance.

Combining observations from multiple sites gives a raster scan across Charon, revealing its shape and size. One Charon occultation has been observed previously, in 1980 by current CTIO Director Alistair Walker (MNRAS 192, 47), but with one chord across Charon, this observation only set a lower limit to the radius.

An accurate value of the radius of Charon would improve our understanding of the Pluto-Charon system. Charon's energy budget and spectral modeling depend on its radius through its albedo. Charon's surface gravity, escape velocity, and density depend on its radius, which affects our models of Charon's composition and formation. The current uncertainty in Charon's radius allows for Charon densities ranging from 1.6 to 1.8 grams per cubic centimeter. Finally, an occultation is capable of detecting even a tenuous atmosphere, if one is present.

In the summer of 2004, three groups coordinated plans to observe the predicted 11 July 2005 (UT) occultation by Charon: a group from Meudon, France, led by Bruno Sicardy; a group from MIT/Williams College led by Jim Elliot; and our group, from SwRI/Wellesley College/Lowell Observatory, led by Leslie Young. Our group observed at SOAR, the CTIO 4-meter Blanco and the CTIO 0.9-meter telescope.

The location of these telescopes, on two mountaintops next to each other, simplified logistics and provided redundancy in case of equipment problems. This coordination was crucial, as the maximum duration of the occultation was predicted to be only 56 to 58 seconds. Everything needed to be working for one critical minute near 11:36 p.m. on July 10 (local time).

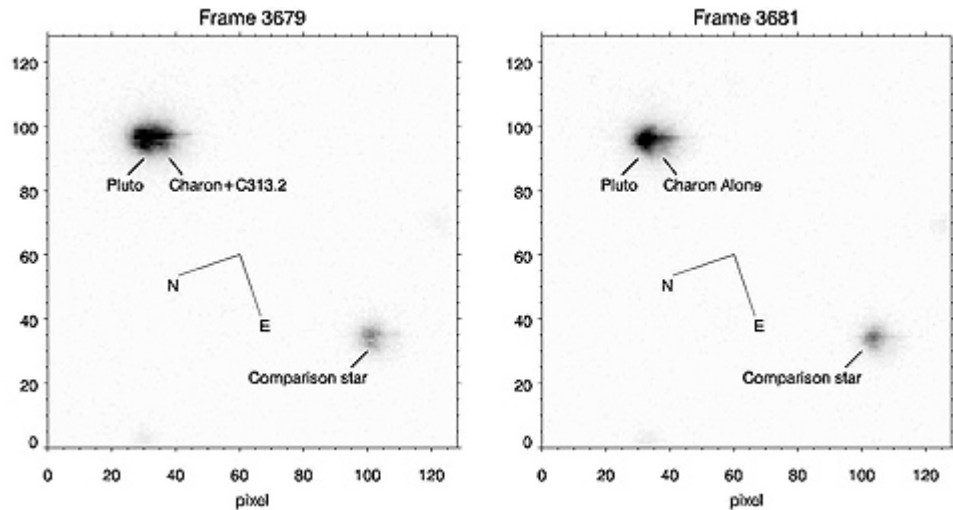


Figure 1. Two frames from the 7200-frame event sequence from SOAR/PHOT: pre-event (left) and during the event (right).

For the SOAR observations, we used one of our Portable High-speed Occultation Telescope (PHOT) cameras, a new camera and timing system that had not been mounted on SOAR before. The observers were Eliot Young, who leads the PHOT development, and Kevin Shoemaker, who designed and built the GPS-based timing unit for PHOT.

Thanks to sterling support from SOAR and NOAO, including Steve Heathcote, Hugo Schwarz, Clark Enterline, Patricio Schurter, Daniel Maturana, Esteban Parkes, Herman Diaz,

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Charon Occultation Observed continued

and Sergio Pizaro, we were able to get first light with SOAR/PHOT on Eliot and Kevin's first evening on Cerro Pachón, July 7. The camera, a Princeton Instrument MicroMAX:512BFT from Roper Scientific, is a 512×512 frame-transfer CCD with essentially no dead time. We mounted with no reimaging optics, so our 13-micron pixels gave us a field of view of only 21 arcsec. For the event, we ran at 0.2-sec integrations from the GPS-slaved timing unit, binning 4×4 on-chip for an effective plate scale of 0.16 arcsec/pixel. Figure 1 shows two frames from the event sequence, with Pluto-Charon-C313.2 and our comparison star. These observations are the first science results from these new, NSF-funded cameras.

Dick French and Brooke Gregory, who had observed Uranus occultations in the infrared, together at CTIO a decade earlier, observed the two half-nights dedicated to this program (June 8 and 10) at the CTIO 0.9-meter using the Tek2K #3 CCD. The High-Speed Photometry (HSP) mode written by Roger Smith was used, which allows high-speed readout of two selectable Regions of Interest (ROIs) next to the serial register by alternately erasing, exposing, and then reading the same small number of rows during a long sequence. This is precisely the mode needed for occultations.

In practice, this rarely used mode needed considerable "dusting off," but with the help of Rolando Cantarutti, David Rojas, Javier Rojas, Enrique Schmidt and Humberto Orrego, we managed to get the HSP mode up and running before the observing run. During the practice night, Dick, Brooke, and Ramon Galvez (with Cathy Olkin, Trina Ruhland, and Leslie Young) were able to rotate the CCD to align the ROIs with the serial register and set up ROIs on both C313.2 and the comparison star USNO B1.0 0749-0387850.

Brooke, Dick, and Ramon spent much of July 8, 9 and 10 exercising the system and running tests that will allow us to confirm absolute timing. During the morning of July 9, we were facing two instrument problems: a time-out error for integration sequences longer than about four minutes, and a limit on the number of total rows recorded in one file, in effect a limitation on the number of exposures. This situation was problematic in light of a large change in the predicted shadow path released by the MIT group that morning.

Although the update altered our predicted miss distance more than our event times, we took this as an indication of the level of uncertainty, suggesting the time of the event could plausibly be off by 60 seconds. We were facing difficult choices: at one extreme, we could save only four rows per image with 1.5 arcsec per pixel binned resolution, compromising our photometry; while at the other extreme, we could run for only two minutes, risking missing either ingress or egress entirely.

Thanks to the intervention of old Arcon-hand Steve Heathcote, who came over from Cerro Pachón, both problems were solved by the afternoon of July 10.

We were able to choose our observing mode to maximize our science. For the event, we ran a ten-minute sequence at 0.5-second exposures, with 38×20 pixel ROIs (14.9 arcsec × 7.8 arcsec), binned by two in rows (see figure 2).

The observations at the CTIO Blanco 4-meter telescope with the Mosaic II CCD were the most challenging. Since the readout time of Mosaic II is 100 seconds, longer than the maximum event duration, we instead used the technique of trailing

the images. By driving the telescope at a nonsidereal rate, the merged Pluto-Charon-C313.2 image was smeared out, letting us use location along the trailed image as a proxy for time.

Observers Cathy Olkin, Trina Ruhland, and Leslie Young had only the hours before the event to make some critical decisions: What filter to use? Which of Mosaic II's eight CCDs to use? What direction to trail, and at what speed? How long to trail? This last was the most complex of the questions. A trail with a shorter angular length has less overlap between stars, but needs either a short duration (which might miss the event) or slow rates (which makes us more sensitive to pointing errors from tracking or seeing).

We had an idea of our optimum choices from the Mosaic II exposure time calculator, and simulated trails we had made from images taken at SOAR in I and R, but they had to be confirmed at the telescope. Further, we needed to work out a scheme to assure ourselves of the timing of the images. With the support of Knut Olsen, Tim Abbot, Mauricio Fernandez, and Hernan Tirado, we were able to work out a timing scheme (comparing the time of the audible

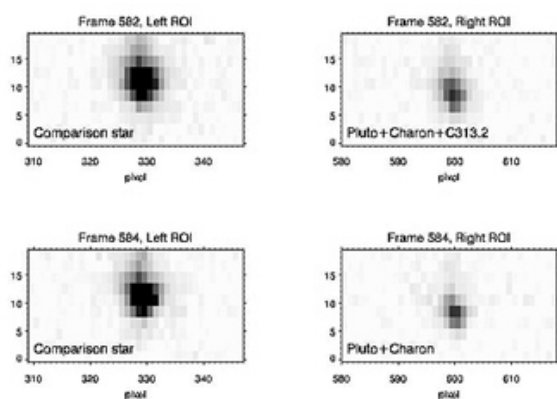


Figure 2. Two frames from the 600-frame event sequence from CTIO 0.9-meter telescope: pre-event (top) and during the event (bottom).

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Charon Occultation Observed continued

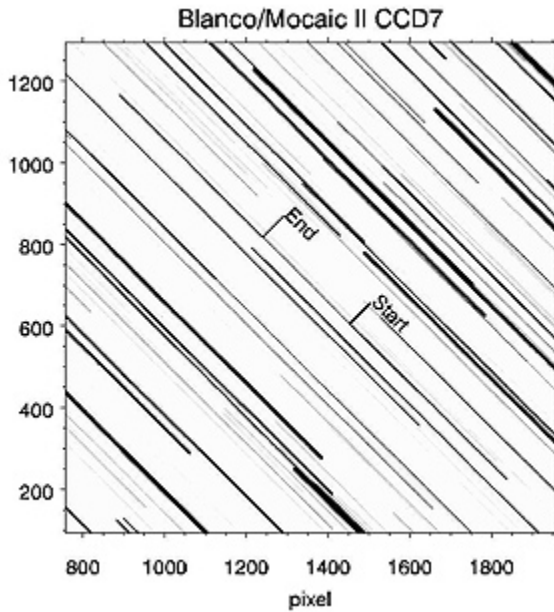


Figure 3. The occultation image obtained at the CTIO 4-meter telescope. Between "Start" and "End," the trail has only Pluto and Charon, while the rest of the trail also has C313.2.

operation of the pneumatic pump that opens the shutter with the header information). We were also able to get familiar enough with the data viewing and quick-analysis software to decide to use I-band to slew the telescope at 1.5-arcsec-per-second trailing to the North-West (see figure 3).

The weather on the night of the event was photometric, with 0.5- to 0.6-arcsec seeing. All three telescopes observed the event, with sequences immediately before and after, and observations taken an hour or more before and after, when Pluto-Charon and C313.2 were clearly separated.

Within a half-hour of the event, observers at all three telescopes reported a successful observation of Charon, with estimated durations near 55 seconds (see figure 4), and no evidence of an atmosphere. We will use the three chords together to confirm the absolute timing of the event, as each instrument used a different scheme to establish the timing, to give a more accurate duration of the event, and to place tighter limits on a Charonian atmosphere.

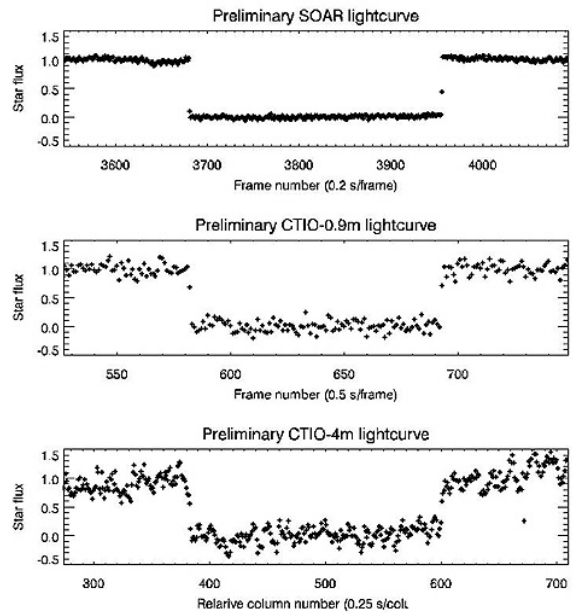


Figure 4. Preliminary lightcurves from SOAR (reduction by Eliot Young), CTIO 0.9-meter (reduction by Dick French) and CTIO 4-meter (reduction by Cathy Olkin).

SMARTS 2

Alistair Walker

NOAO-NSO Newsletter 83

The SMARTS consortium has been operating the small telescopes, regarded by all as an unqualified success, at CTIO since February 2003. As a consortium member, NOAO provides three of the four telescopes (the fourth is the Yale 1.0-meter) and some of the instruments, in exchange for 25 percent of telescope time for the general community. Other consortium members provide instruments and operations funding, plus day-to-

day operations support. Members also schedule the telescopes under the leadership of the SMARTS Principal Scientist, Charles Bailyn of Yale University.

One of the reasons for the success of SMARTS has been that it has NOT been running as a cut-price operation! The telescope operators employed by SMARTS are considered full members of the CTIO TelOps group, and the two observer support

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SMARTS 2 continued

specialists, Edgardo Cosgrove and Arturo Gomez, are long-time CTIO employees with much small telescope experience. CTIO engineering staff is on-call, responding to instrument and telescope faults; rapid response is also provided by Ohio State University and the University of Montreal for their instruments, holding the downtime to a very low level. Consortium resources have allowed for installation of new instrumentation, with a variety of observing modes offered: queue scheduled service observing on the 1.3-meter, mixed service-classical on the 0.9-meter and 1.5-meter, and classical on the 1.0-meter. This coordination of resources has allowed for a great variety of programs to be efficiently carried out by consortium members and the NOAO community, from synoptic programs requiring a few minutes per night to large multi-night surveys.

The SMARTS agreement expires at the end of 2005, and we hope to continue the program. We have dubbed this phase SMARTS 2, but plan to carry on with only a few changes from the original SMARTS program. All the present consortium members would like to continue, although some members' contribution level will change. There are prospective new consortium members, and space for more participants. We also plan to make SMARTS 2 consortium membership a bit more flexible. It will no longer be necessary to make a three-

year commitment—institutions will be able to join, and then drop out when their scientific/financial needs require, as long as they give adequate notice so a replacement partner can be found.

What will it cost to become a member of the SMARTS 2 consortium? Cash contributors should use the algorithm of one night (service observing) = 1.5 nights (on-site observer) = \$1,400 for planning purposes.

What telescope/instrument combination will be part of SMARTS 2? We plan to continue with CCD imaging on the 0.9-meter (SITE 2K CCD, 13.5-arcmin square field) and the 1.0-meter (Fairchild 4K CCD, 20-arcmin field), and the simultaneous CCD-infrared (IR) imager ANDICAM on the 1.3-meter. For the 1.5-meter, we expect to begin with a combination of IR imaging alternating CPAPIR (30-arcmin field) with CCD spectroscopy using the RC spectrograph. Much of the IR time in 2006 will be used to complete a SMARTS consortium program. For more details, see www.ctio.noao.edu/telescopes/smarts.html.

We are excited about the potential of SMARTS 2, and appreciate any comments you would like to provide (awalker@noao.edu). We would also be very pleased to talk to potential new participants!

Other Happenings at CTIO

Staffing Changes at NOAO South

Patrice Bouchet left on July 1 to take up a position at Paris Observatory, after eight years as a CTIO staff scientist. Patrice supported infrared (IR) instrumentation on the Blanco telescope and, more recently, Gemini IR observers via the NOAO Gemini Science Center, particularly for the mid-IR imager/spectrometer T-ReCS. Patrice's research focused primarily on study of the environment of Supernova 1987A, by monitoring evolution of the interaction between the ejecta and the circumstellar ring. Patrice also found time to participate fully in outreach, and is well known throughout Chile as a speaker for schools and the general public.

Also leaving us recently were Gustavo Rahmer and Rafael Hiriart. As a senior electronic engineer, Gustavo was a key developer of the Monsoon detector controller system. Gustavo is taking a position at Caltech. Rafael resigned recently for an opportunity to work on the Atacama Large Millimeter Array at the National Radio Astronomy Observatory in Socorro, NM. While at NOAO, he worked as a computer programmer in the Data Products Program, leading pipeline development.

New SMARTS Instrument

The 4K CCD imager for the 1.0-meter telescope has finally arrived! Regular operations began July 11, after Darren DePoy and associates from the instrumentation group of the OSU astronomy department commissioned the Ohio State University-built camera. The heart of the camera is a thinned, back-illuminated Fairchild 486 CCD, which has back-surface treatment and antireflective coating applied by Mike Lesser of the Steward Observatory Imaging Technology Laboratory. The CCD has a 4096×4096 format with 15-micron pixels and four readout amplifiers operated with an Astronomical Research Cameras GenIII Controller. In particular, the CCD has superb U-band quantum efficiency, and excellent cosmetics. More details are available at www.astronomy.ohio-state.edu/Y4KCam. For a description of all the SMARTS instruments and other information relating to the SMARTS operation, see www.ctio.noao.edu/telescopes/smarts.html.