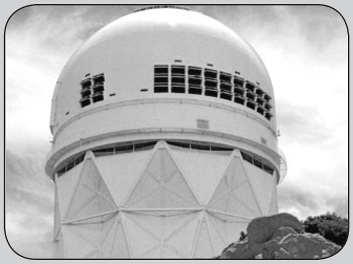

# KPNO
## Operations

# WIYN to Operate the Kitt Peak 0.9-meter Telescope: NOAO Users to Gain Continuing Access to Mosaic

*Richard Green*

A panel of reviewers met last September to review proposals submitted to operate the Kitt Peak 0.9-m telescope. They found that the proposal submitted by the WIYN Consortium was superior in the opportunities it offered for scientific research and education, as well as in the management of refurbishment and operations. As of this writing, agreements with AURA and NSF are in the approval process. The proposal effort was guided strongly by the university partners in WIYN and additional participants that teamed with the WIY members. Of course, NOAO was not a co-proposer, abstained from the WIYN, Inc., deliberations, and constituted an external review panel to consider the transfer of operations. We were, however, approached by WIYN to make the following arrangement.

A key aspect of the operations plan is that NOAO will loan CCD cameras to WIYN in exchange for observer access. In particular, the Mosaic camera will continue to be scheduled on the 0.9-m when there is a sufficiently long block of other instrument use on the 4-m. Consistent with the WIYN agreement, NOAO users will receive 40% of the available Mosaic time on the 0.9-m.

The first stage of WIYN operations will be a long-needed refurbishment of the telescope control system. The WIYN 0.9-m partners are targeting a return to operations for this coming summer. NOAO will therefore accept proposals for observing with the Mosaic CCD camera on the 0.9-m during Semester 2001B. The probability of time being available will no doubt be higher toward the end of the semester. There are two potential risks in such proposals. One is that the refurbishment takes much longer than currently anticipated, so that scheduling for scientific use becomes very limited. The other is that we might make Mosaic available prior to full interoperability with the new telescope control system. There may be restrictions on header coordinate information, *mosdither*, or other telescope control from the instrument. Imaging performance with Mosaic is anticipated to be unchanged from previous semesters.

We believe that the new arrangement will be mutually beneficial for KPNO observers and for WIYN and its partners. KPNO observers retain access to the highly demanded 1-degree field of view of Mosaic on the 0.9-m, the telescope receives a critical performance upgrade to a maintainable modern control system, and the over-stretched support staff is relieved of operations responsibility. WIYN and its partners gain access to Mosaic for imaging science and as a match to the WIYN/Hydra field. The remaining time will be scheduled with a 2K × 2K CCD, which provides for synoptic observations, photometric calibrations, and educational opportunity. NOAO use of a 2K-square CCD will begin in Semester 2002A.

Ata Sarajedini (Florida) is the Telescope Scientist leading the refurbishment effort. Bob Mathieu (Wisconsin), Chair of the WIYN Board of Directors, assembled the expanded proposal partnership and led the proposal preparation effort. The successful outcome will be continuing productive use of the unique wide-field combination of the 0.9-m and Mosaic on Kitt Peak.

# FLAMINGOS Successful Commissioning

*Jay Elias and Richard Green*

FLAMINGOS, an IR imager and multi-object spectrometer developed as a user instrument by the University of Florida with collaboration and support from NOAO, had successful commissioning runs on the Kitt Peak 2.1-m and 4-m telescopes in December 2000. The runs enabled us to determine instrument performance in imaging mode and to get positional data to enable testing of the instrument's multi-slit mode early in 2001. They were also valuable for initial science for scheduled projects proposed by astronomers at Florida. FLAMINGOS is scheduled for 60 nights on Kitt Peak in the current semester (2001A), for both imaging and spectroscopic projects.

The faintest sources visible in the first light image of the Orion nebula are at least $17^{th}$ magniude. One can compare this image to the 2MASS Orion data (*http://www.ipac.caltech.edu/2mass/gallery/orionatlas.jpg*) to see the greater depth achieved by FLAMINGOS with longer integration time and a larger telescope. The FLAMINGOS image is assembled from eight dithered 30-second exposures, totaling about 4 minutes of exposure time. The composite image was trimmed to have the same dimensions as a single frame, 21′.

## *FLAMINGOS Imaging Performance*

Measured values for imaging performance are given in the table on the next page. Prospective users need to remember that near-infrared background varies by a factor of three or more. For the K and Ks filters, where the background is mainly thermal emission, the background is correlated with temperature and therefore quite seasonal. At J and H the background is primarily OH airglow and levels are unpredictable. A detailed discussion of background variation is provided in the SQIID manual (*http://www.noao.edu/kpno/sqiid/sqiidmanual.html*), which is equally applicable to FLAMINGOS.

The 2.1-m background data were taken at relatively high airmass and warm (for December) temperatures; the 4-m data were taken at zenith and with ambient several degrees colder. The 4-m night was not completely photometric, so the count levels may be revised in the future. The Ks filter was not present in the instrument, but when installed it should provide roughly half the background of K (more like H) and 90% of the signal on a star. The instrument gain is between 4 and 4.5 electrons/ADU.

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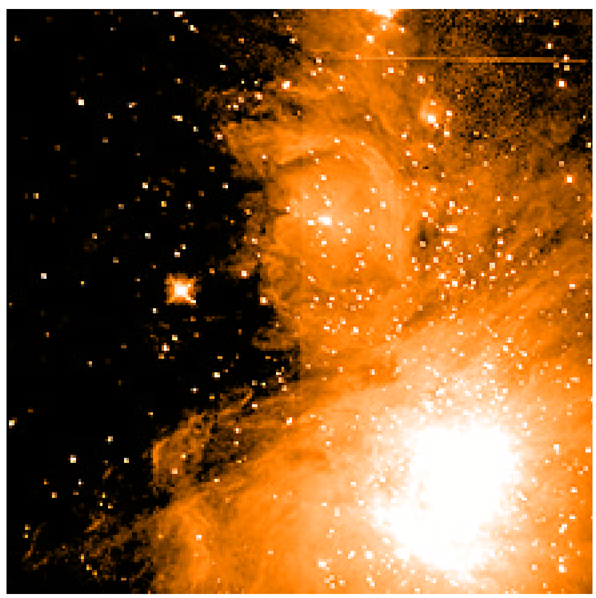

*This K-band image of the Orion nebula taken on the 2.1-m telescope represents more than "first light" for FLAMINGOS. In fact, it is the first astronomical picture taken with a 2K x 2K IR array anywhere. The Trapezium is at the center of the bright emission region; the image is saturated there due to the limited gray scale available. The bright region at the extreme top edge of the image is OMC2. The picture measures 21′ on a side. North is at the top; east is at the left.*

## *FLAMINGOS continued*

### Imaging Performance

| | 4-m telescope | | | 2.1-m telescope | | |
|---|---|---|---|---|---|---|
| Filter | J | H | K | J | H | K |
| ADU/sec from 10th mag star | 69,000 | 89,500 | 87,000 | 21,000 | 26,300 | 26,100 |
| Sky, ADU/pixel/sec | 37 | 241 | 497 | 67 | 563 | 806 |
| Sky, mag/arcsec$^2$ | 15.5 | 13.8 | 12.8 | 15.1 | 13.1 | 12.7 |

The data to accurately determine sensitivity have been obtained only at the 2.1-m, and have not been completely analyzed. Preliminary estimates indicate that one can expect to reach 17th magnitude at K (5σ) in one minute of integration time; H performance should be a few tenths of a magnitude better; and J performance possibly as much as a magnitude better. These represent data taken in "reasonable" seeing; the large pixels on the 2.1-m mean that sensitivity is not a strong function of seeing. The sensitivity on the 4-m will depend much more on seeing. For good seeing—0.6″ FWHM or so—the 4-m sensitivity should scale about as the relative collecting area (1.1 mag). For seeing around 1″ FWHM, the 4-m sensitivity gain over the 2.1-m will be around 0.6 mag.

Updated values for typical backgrounds and sensitivities will be available on the NOAO FLAMINGOS Web site by mid-March (*http://www.noao.edu/kpno/manuals/flmn*).

The instrument overhead is quite short—less than 2 seconds to read out the array and write the data to disk—so for most observing programs, the time between images is determined by telescope overheads involved in dithering or rastering. For short offsets, the offset and settling times combined should be around 10 seconds. For short exposures, overhead will significantly reduce efficiency. The engineering array in the instrument has one bad amplifier out of 32. This means that a "slice" of the image 1024 x 128 pixels is missing, and complete coverage of an area requires dithering by at least 128 pixels total. The delivery date for the science-grade array is an unknown; observers with scheduled time and proposers should assume that they will be using the engineering array.

The detector full-well is large enough that maximum exposure times at K are around 30 seconds (at least in the winter) and a minute or more at J and H. As noted above, the overhead in writing to disk is modest, but for deep observation sequences (many frames at the same location) observers may want to co-add to save disk space.

### Predicted Spectroscopic Performance

The spectroscopic performance has not yet been measured; data will be taken (weather permitting) in February. The results of the February run will also be posted in mid-March on the FLAMINGOS Web site (*http://www.noao.edu/kpno/manuals/flmn*).

Based on the imaging performance, the spectroscopic throughput should be roughly half that of CRSP. This implies exposure times will be roughly double—but of course, with several times as much spectral coverage and the ability to observe multiple objects. The assumption is that the FLAMINGOS grism efficiency is roughly comparable to that of the CRSP gratings, which is

*continued*

*FLAMINGOS continued*

reasonable but not yet established. It should be noted that FLAMINGOS can image through the slit (or without the slit), which will greatly simplify acquisition.

### Availability for 2001B

FLAMINGOS will be in the Southern Hemisphere (Gemini South) starting in late May, and will not return north until the end of October. It will most likely be first scheduled at KPNO starting in early November 2001. FLAMINGOS will then be available for the first part of 2002A, after which it will again go south to Gemini.

The multi-slit mode is *not* supported during the current semester (2001A), but will be supported when FLAMINGOS returns from Gemini South. NOAO will arrange for slit masks to be made for observers. The details of the process are not yet well defined, but should be established well before December. In outline, though, users must plan on the following:

- Masks will be made from user-supplied celestial coordinates (differential $\alpha,\delta$). These will need to be provided to NOAO at least six weeks in advance of the observing run.
- The coordinates will need to be accurate enough to ensure that objects are centered on the slit (a 2-pixel slit is ~0.6″ on the 4-m, double that on the 2.1-m).
- The slitlet orientation on the 2.1-m will be *fixed*, with the slits running EW (dispersion NS). Rotation of the instrument will be possible on the 4-m, but users should plan on substantial overhead (several minutes) for this process. The default orientation there will also be with slitlets oriented EW. The slit wheel allows for *fine* adjustment of the slit masks, which is enough to correct for rotator and mask installation tolerances.
- The slit mask field is 3′ × 10′ on the 4-m (roughly double that on the 2.1-m), with the field long axis running along the slits (i.e., EW on the 2.1-m).
- The mask wheel holds 11 masks; cycling the sub-dewar containing the mask wheel takes a good part of the day, so one is limited to 11 MOS fields per night.

## Upgrading the Cryogenic Camera

*Sam Barden, Arjun Dey, Roger Lynds, Rich Reed, Bill Ditsler, and Charles Harmer*

The Cryogenic Camera sprung a leak early last year and was removed from service. As a result, it was decided that, unless it could be significantly improved in performance, Cryocam would be permanently retired. Fortunately, we are very pleased to announce that we did identify areas for significant improvement and have been pursuing the repair and upgrade of Cryocam during the past several months. We present here the enhancements and predicted performance of the instrument, along with a timeline of when Cryocam might be back in service. These enhancements should equate to an overall efficiency gain of 1.5 over the previous peak performance and a gain of factors of 2 to 10 redward of 8000Å.

First and foremost, the leak has been found and confidence is high that it can be repaired. Obviously, this was a primary requirement before proceeding with the rest of the upgrades. We identified the following items to enhance the performance of Cryocam:

- Implementation of a 300-µm thick, high-resistivity, p-channel CCD from Lawrence Berkeley National Laboratory, similar to LB1A described in "Red Hot CCDs at KPNO" in this newsletter. The format is 1980 × 800 with 15-µm pixels.

*continued*

## Cryogenic Camera continued

- Fabrication of a Volume-Phase Holographic (VPH) grism by Kaiser Optical Systems, Inc. This new VPH grating with 450 lines $mm^{-1}$ will be sandwiched between two prisms for use as a grism. The grating is designed for an undeviated wavelength of 8057Å, which will also coincide with the peak in the CCD efficiency curve. Resolving power will be about R = 1000, roughly 8 Å resolution, which is nearly a factor of two higher than that achieved with the older set of red grisms. The VPH grism contains an OG550 filter as one of the glass elements, so there will be no need to utilize an additional filter when observing.

- Recoating the Schmidt camera mirror with a high-efficiency, reflective silver coating by Lawrence Livermore National Laboratory. This coating, which is more robust than most available overcoated silver coatings, should be 95% to 98% efficient compared to the measured average efficiency of 90% for the coating that was on the Cryocam mirror.

- A new chip mount that has significantly less obscuration due to the CCD.

- Implementation of a new field flattener lens to fill the larger format of the new CCD. The selection of the new lens was made to improve the wide-field imaging performance of the camera.

- Implementation of a Telescope Nod/Charge Shuffle observing mode (see following article).

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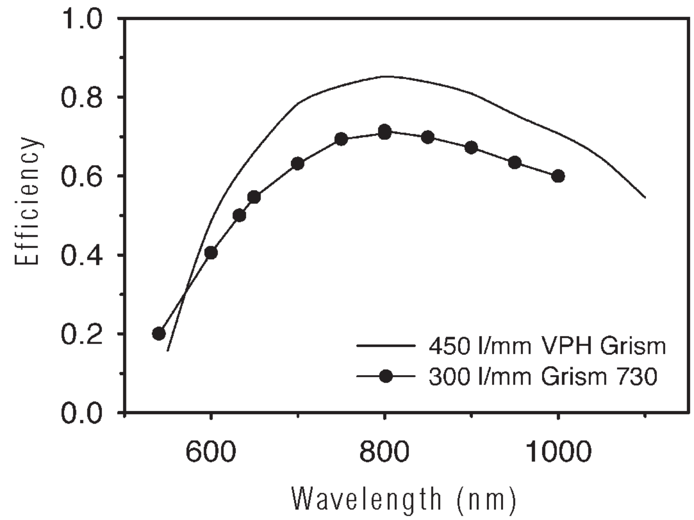
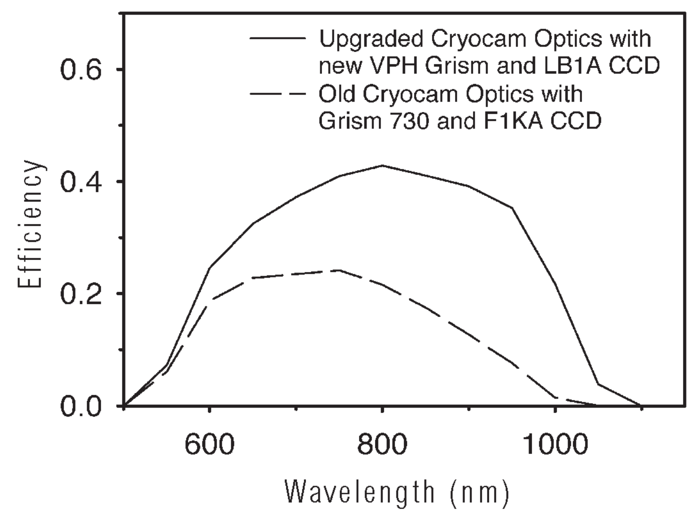



*The overall efficiency of the new VPH grism is greater than Grism 730 (300 lines $mm^{-1}$ grating), an original Cryocam grism. Spectral coverage will extend from 5900 through 10400 Å for all available field angles provided by the instrument.*




*The overall gain in the far red of all of these improvements are nearly equivalent to putting the old Cryocam on an 8-m telescope. The overall expected efficiency for the upgraded Cryocam calculated here includes the telescope, instrument, grism, and detector.*

## *Cryogenic Camera continued*

Due to other engineering commitments, the Cryocam upgrade is a low-priority project. Since resources cannot be scheduled in an optimum manner, it is difficult to predict when the project will be finished. Despite this limitation, general public access will likely begin in the 2002A observing semester. Several milestones will be reached over the next few months. The grating has been fabricated and the prisms are currently under fabrication. The mirror should be returned from LLNL by the time this newsletter is distributed. Testing and engineering time has currently been assigned at the end of July 2001. If, however, the upgraded instrument is ready prior to 2002A, observers using the RC spectrograph during the 2001B semester may be given the option of switching to Cryocam.

# Red Hot CCDs at KPNO

*Arjun Dey, Rich Reed, and Roger Lynds (NOAO); Steve Holland and Don Groom (LBNL); and Richard Stover, Mingzhi Wei, and Bill Brown (UCO/Lick)*

Through a cooperative program with Lawrence Berkeley National Laboratory (LBNL), KPNO will offer a CCD with peak DQE of nearly 90% at far-red wavelengths. Beginning in 2001B, the new CCD, which will be designated LB1A, will be available in a shared-risk mode for use with the Mayall 4-m RC spectrograph.

LB1A, which has 1980 × 800 pixels, is one of the new 300-µm thick, high-resistivity, p-channel CCDs being manufactured at LBNL. These CCDs have much greater sensitivity at wavelengths shortward of the Si band gap than any of our existing detectors. At wavelengths beyond 8500Å, the gain over T2B is more than a factor of two. The read-out noise and dark current on LB1A are approximately 6 $e^-$ and 70 $e^-$/hour, respectively. The device does not exhibit any noticeable fringing and is cosmetically clean, with the exception that 58 columns at one end are unusable. We are in the process of obtaining a second CCD that may prove to have better dark current and cosmetics.

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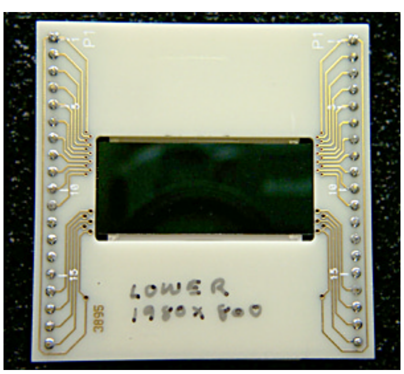
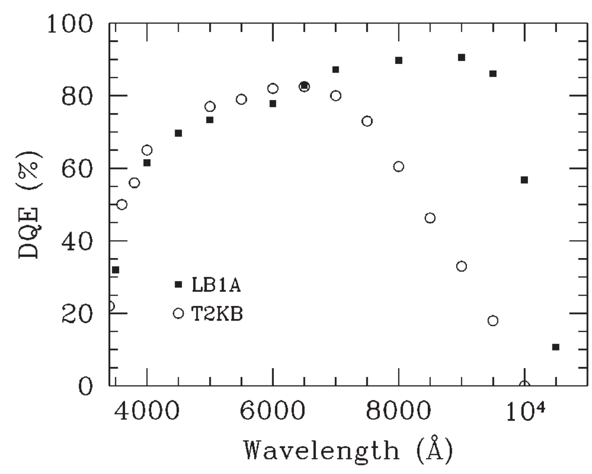



*The 198 × 800 LBNL CCD, which will be available for use with the Mayall RC spectrograph, has the highest red sensitivity of any of the CCDs we offer.*



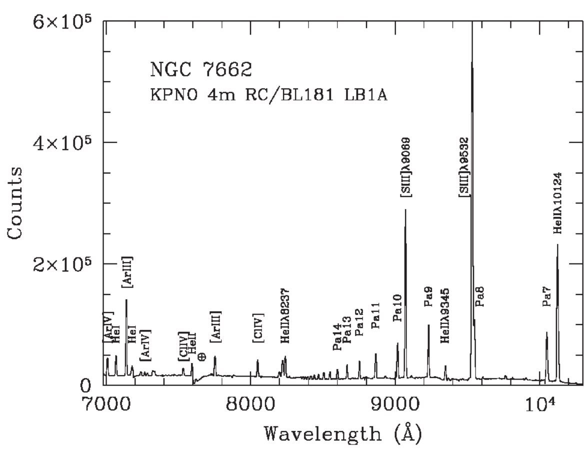

*At wavelengths beyond 8500Å, the new CCD LB1A shows a twofold gain over T2KB. Both detectors are currently available for use with the RC spectrograph.*



## *Red CCDs continued*

| ***Characteristics of LB1A:*** | |
|---|---|
| Format | 1980 × 800 |
| Pixel Size | 15 µm |
| Pixel Scale on RC | 0.43″ |
| Read Noise | 6 $e^-$ |
| Dark Current | 70 $e^-$/hour |

The gain in DQE comes with some cost: the 300-µm thickness of the CCD results in significantly more pixels lost to cosmic ray and background radiation events. Preliminary tests at the KPNO 4-m suggest that there are 1.1–1.7 particle events $cm^{-2}$ $min^{-1}$, and that typically 1–1.5% of the pixels are affected by particle events every hour. As a result, it is best to use multiple exposures per target to help remove the particle events.




The following references have detailed information on these CCDs: S. E. Holland et al. (1996, *IEDM Technical Digest*, 911-914), R. J. Stover et al. (1999, "A 2K × 2K High Resistivity CCD," to appear in *Proc. 4th ESO Workshop on Optical Detectors for Astronomy*, Garching, Germany, 13–16 September 1999); Groom (2000, *SPIE* **4008**, 634-645). Additional information can be found on the LBL Web site at *http://ccd.lbl.gov*.

KPNO acknowledges the generosity of the LBNL CCD development team and the Detector Development Laboratory at UCO/Lick Observatory in providing LB1A to KPNO for use by the community on the Mayall 4-m. The CCD development effort was supported by the US Department of Energy (Contract No. DE-AC03-76SF00098), by the National Science Foundation (grant NSF/ATI 9876605), and by the National Aeronautics and Space Administration (grant NRA-99-01-SPA-040).

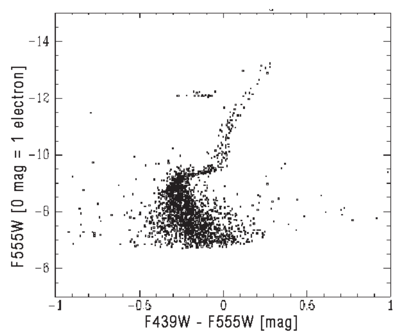
*A ten-minute spectrum (through clouds) of the planetary nebula NGC 7662 obtained using LB1A with the RC Spectrograph and the BL181 grating on the KPNO 4-m.*

# Quick & Dirty CCD Stellar Photometry

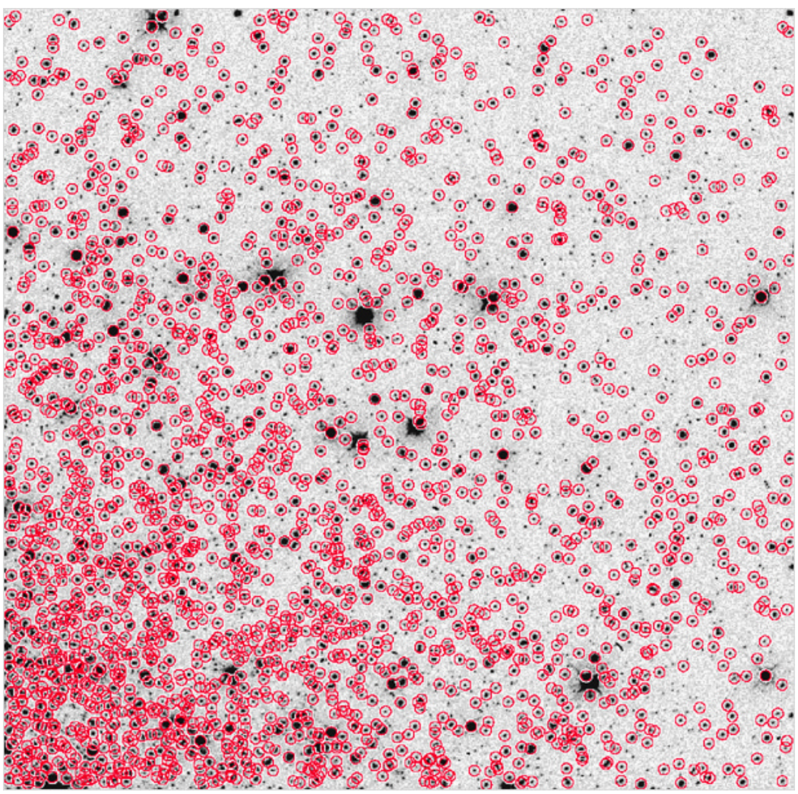
*Kenneth J. Mighell*

Quick & Dirty Photometry (QDPHOT) is a new CCD stellar photometry IRAF task to produce quality photometric reduction of two CCD images of a star field in a very short time. QDPHOT is designed to be a data mining tool for finding high-quality stellar observations in the data archives of the proposed National Virtual Observatory. For example, QDPHOT takes just a few seconds to analyze two Hubble Space Telescope WFPC2 frames containing thousands of stars in Local Group star clusters. QDPHOT is also suitable for real- time data-quality analysis of ground-based CCD observations, where on-the-fly instrumental color-magnitude diagrams can be produced at the telescope between CCD read-outs.

Information for the MXTOOLS package, including QDPHOT, is given at the MXTOOLS Web site (*http://www.noao.edu/staff/mighell/mxtools*). Once the parent MX-TOOLS package has been installed, a short QDPHOT demonstration can be seen by typing '`demoqdphot`' (don't forget first to open an image display tool, e.g., '`!ximtool &`' and then to load the MXTOOLS package by typing '`mxtools`' at the *cl* prompt).




*The instrumental color-magnitude diagram of NGC 362 calculated by the QDPHOT demonstration task.*



*QDPHOT found the circled stars on the HST F555W-filter observation of the globular star cluster NGC 362 in just a few seconds (1 to 5 seconds, generally, depending on the speed and configuration of your computer). Selection criteria can be set within QDPHOT to photometer the uncircled stars, which are generally fainter.*

This demonstration analyzes two HST WFPC2 observations of the Galactic globular cluster NGC363. On both of the two HST images, 2267 stars are found with a signal-to-noise ratio of eight or greater. Many more stars can be photometered in this field simply by reducing the minimum acceptable signal-to-noise ratio. Finding additional faint stars comes at the cost of increasing the computation time.

New options for QDPHOT are being planned for future releases. An article describing QDPHOT in detail is currently being written and will be posted to the QDPHOT Web page when it is submitted for publication. Suggestions for improving QDPHOT should be sent to *mighell@noao.edu*.

This research is supported by a grant from the National Aeronautics and Space Administration (NASA), Order No. S-67046-F, which was awarded by the Long-Term Space Astrophysics Program (NRA 95-OSS-16).

# Did You Ever Feed the Coudé?

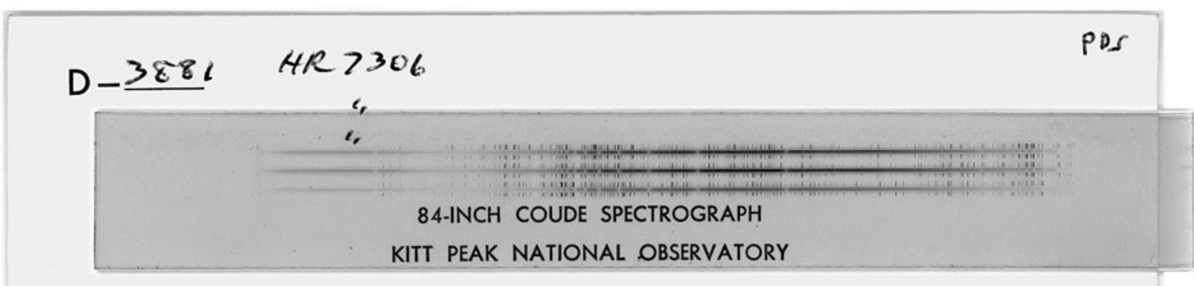
*Caty Pilachowski*

The Kitt Peak Coudé-Feed Telescope saw "first light" in the fall of 1973. Prior to the feed's opening, the coudé spectrograph was used with the Kitt Peak 84-in telescope, but was only scheduled about a third of the nights. An auxiliary feed was constructed to allow more frequent usage of this high-dispersion spectrograph. The scientific productivity of the KPNO coudé spectrograph paid dividends over and over again for this modest initial investment and the small, incremental improvements that followed.

The design of the new telescope was described in a 1971 KPNO Quarterly Report. Helmut Abt was the first observer on 12/13 September 1973, when he took two plates of the star HR 7306 to establish the proper exposure times in comparison to the coudé focus of the 84-in telescope. He then turned the feed telescope over to Thomas Margrave for further observing. Saul Adelman followed a few nights later to observe ι Peg and δ Cas.

Over the years, many refinements have been added to the coudé-feed telescope and coudé spectrograph. Observers no doubt appreciated the slit-viewing TV and the auto-guider, and—after photographic observing was phased out—conversion of the adjacent darkroom into a modern control room.

A new spectrograph camera (no. 5) was added in 1976, under the leadership of Judy Cohen, from an optical design by Jorge Simmons, to accommodate image tubes and following generation of digital detectors. This folded two-mirror camera with an aspheric corrector provided both adequate back focal distance and good image quality over a 9-cm detector field. Camera 5 quickly became the most popular of the coudé cameras. When CCDs arrived at the coudé in the early 1980s, Camera 5 was ready and waiting. A few coudé observers may remember with some discomfort our first painful experiences with CCDs, but the detectors soon matured to produce spectra of outstanding signal-to-noise ratio and linearity.




*Helmut Abt took test exposures of HR 7306 in September 1973 to establish the relative efficiency of the newly completed coudé-feed telescope relative to the 84-in. The unique combination of a dedicated telescope and a high-dispersion spectrograph, particularly in its echelle/grism mode, yielded many scientific papers on stars, stellar physics, and the interstellar medium over the next nearly three decades of productive use.*

Additions to the coudé spectrograph's stable of gratings further enhanced the telescope's performance. The arrival of the large "A" grating from (by then) Milton-Roy allowed wider slits and higher dispersions, and a new echelle grating ruled by NOAO staff on the Harrison "C" engine in Tucson provided high spectral resolution. When Jorge Simmons and Daryl Willmarth realized the potential of the 4-m Cryogenic Camera

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## *Feed the Coudé continued*

grisms to provide cross-dispersion for the echelle grating, we had available not only high resolution, but excellent spectral coverage as well. This was soon enhanced by the arrival of the Ford 1K × 3K CCD chip.

Early observers may remember the original PDP and paper-tape based control system at the feed telescope, and how much the new control systems, added under the leadership of Richard Wolff and Kim Gillies, improved observing efficiency. The most recent control system, installed in the early 1990s, made the feed the easiest and most efficient telescope to operate on Kitt Peak. And the most reliable, too.

The first journal paper based on data from the feed appears to have been the work of W. R. Beardsley and M. W. King in the publications of the Astronomical Society of the Pacific in 1976, on the binary $\kappa$ Peg. Robin Clegg obtained the first Ph.D. based on coudé-feed data for his work on carbon and nitrogen abundances in F- and G-type stars. Other, more recent theses based on coudé feed data include those of Hector Castaneda, James Grigsby, Margaret Chester, Scott Horner, Lewis Jones, Anthony Kaye, and Debra Burris, among others.

In the last five years, more than 100 papers have been published based on coudé-feed data, more than 50% of them in the *Astrophysical Journal* and *Astronomical Journal*. The most prolific recent authors are Frank Fekel, Saul Adelman, Klaus Strassmeier, Claude Lacy, and Helmut Abt. The list of "first authors" in the last five years includes nearly 60 astronomers.

The coudé feed has made many important contributions to the study of stars and stellar physics over nearly three decades of productive work. The feed has excelled both in synoptic studies of variable stars and binaries, and in spectroscopic surveys. In recent years, the feed has made possible groundbreaking work on the interstellar medium from its high throughput, high-resolution echelle/grism mode.

The last scheduled observer at the Coudé feed was Dave Soderblom, on 31 January 2001. He repeated Abt's first exposure with a new CCD spectrum of HR 7306.

# Optical Spectroscopy Learns the Nod-and-Shuffle

*Arjun Dey, Roger Lynds, Rich Reed, Rob Seaman, Nigel Sharp, Jim DeVeny, Bob Marshall, Dave Mills, Doug Williams, and Tom Wolfe*

Sky subtraction is one of the major limitations to faint-object spectroscopy, especially at wavelengths where OH emission lines begin to dominate the sky spectrum (lambda > 6500Å). The 'Nod-and-Shuffle' observing mode, pioneered at the AAO by K. Glazebrook and J. Bland-Hawthorn, provides the ability of approaching the shot-noise limit for spectroscopy by greatly improving the sky subtraction over traditional techniques. The nod-and-shuffle technique has now been implemented at the KPNO 4-m, where it is available for use with the T2KB and LB1A CCDs on the RC Spectrograph in a shared-risk mode during 2001B.

The nod-and-shuffle technique is described in detail by Glazebrook and Bland-Hawthorn (2001, *PASP*, in press; astro-ph/0011104), and interested readers are directed to this paper for a thorough discussion of the technique's pros and cons. In brief, the technique involves measuring the sky and object spectra quasi-simultaneously by offsetting (i.e, 'nodding') the telescope between object and sky positions while synchronously shifting ('shuffling') the charge on the CCD between the illuminated region and storage buffers (i.e., the unilluminated parts of the CCD). Since the charge can be 'shuffled' quickly and

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## *Optical Spectroscopy continued*

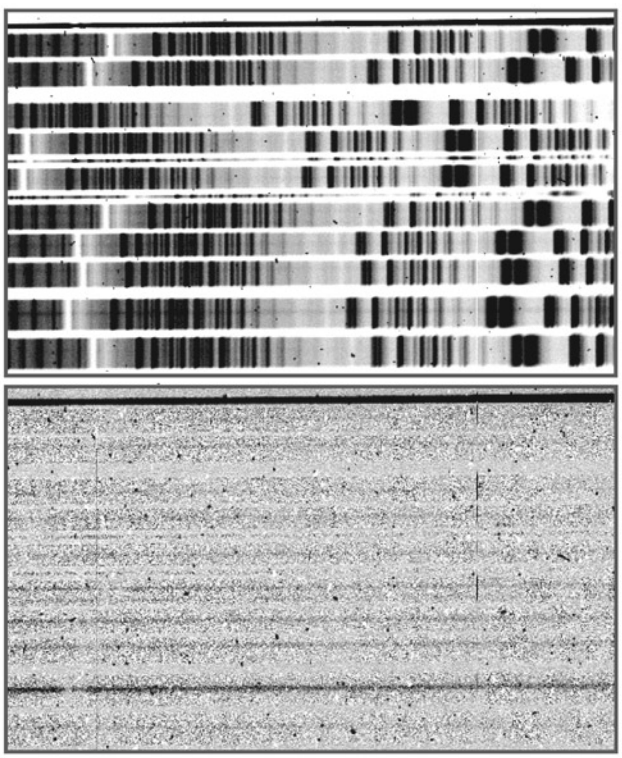
non-destructively, many short observations of object and sky spectra can be recorded alternately, thus allowing the observer to sample the sky on timescales short enough to follow its variations. Moreover, the technique results in both object and sky spectra being recorded on the same pixels, through the same slitlets, and through the same optical path. This results in identical slit variations for both sky and object spectra, enabling a better sky subtraction than is possible by traditional interpolation techniques. The nod-and-shuffle technique is also useful for spectroscopy of large extended objects (i.e., objects that fill a large fraction of the spectroscopic slit) where accurate sky subtraction is desired.

The penalty in using this mode is twofold—the noise in the sky estimate for each row is increased by root-two, and the observing time overhead is larger due to the extra time spent observing sky plus the time spent nodding the telescope. However, the technique allows the observer to fill a slitmask with a large number of small slitlets, or, alternatively, to observe large extended objects without being limited by sky subtraction errors. In the multislit mode, the gain in the number of objects per mask and the improvement in sky subtraction jointly outweigh the loss due to the observing overheads and the larger sky noise. See Glazebrook and Bland-Hawthorn (2001) for details.

On the KPNO 4-m RC spectrograph, the nod-and-shuffle observing mode is available with the T2KB and LB1A CCDs. The T2KB CCD is more than three times larger than the field of view of the RC Spectrograph, and the full field is therefore available to the nod-and-shuffle mode. Hence, in principle, the 312″ diameter slitmask can accommodate as many as 50 3.0″ long slitlets with the minimum recommended 0.4-mm (2.65″) inter-slit spacing. Note that the slitlet lengths need only be the size of an object (or its seeing profile) in the nod-and-shuffle mode.

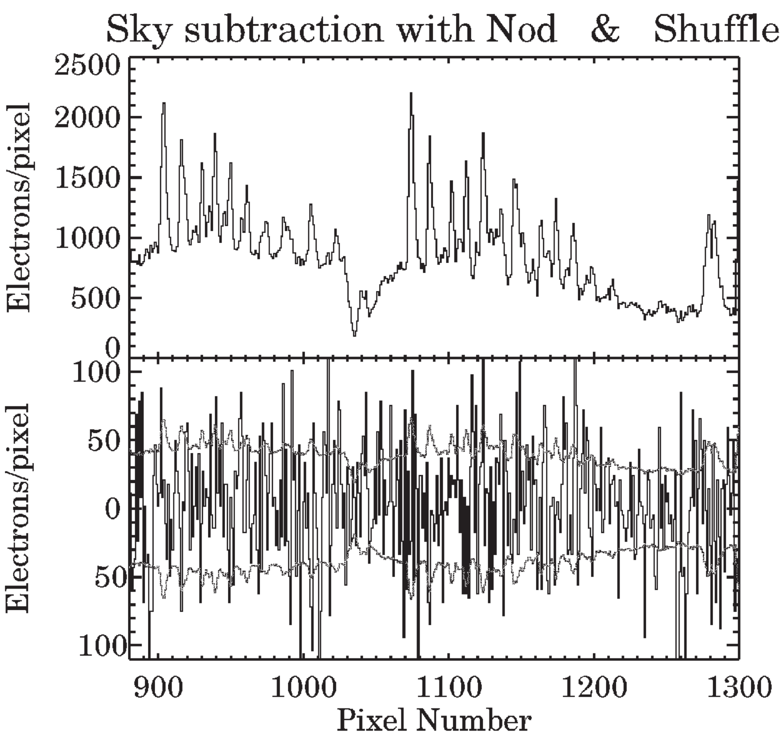
The LB1A CCD, which is currently available in shared-risk mode with the RC spectrograph (see "Red Hot CCDs at KPNO!" in this newsletter), has a small format (1980 × 800) which requires a reduction in the number of simultaneously targetted objects. The observer can either use an

*continued*



*The upper panel shows a subsection of the raw CCD frame produced by the nod-and-shuffle mode. The lower panel shows the result of simply shifting the image by the shuffle offset and subtracting the shifted version from the original.*

*Optical Spectroscopy continued*




*The effectiveness of the nod-and-shuffle technique is seen in a region of strong OH telluric emission (approx. 7180 - 8340 Å). The upper panel shows a single row of the raw CCD frame with strong OH features. The lower panel shows the same row after sky subtraction. Poisson noise from the sky is overplotted. The OH emission has been completely subtracted and the remaining "spectrum" is all sky noise.*

FOV of 110″ and densely pack slitlets as described above, or alternately, use the full FOV of 312″ and leave dead space between slitlets for the storage region. Hence, although LB1A will provide far better red sensitivity than T2KB, the user will only be able to target between one-third and one-half the number of objects when using the nod-and-shuffle mode.

As of late January, the time overhead incurred by using this mode is large, since the overhead added by each telescope offset and guider acquisition is 15 sec. Hence, a 30-min exposure on target, subdivided into 60-sec integrations, takes a total of 75 min (not including the 2-min readout time of the T2KB CCD). We are currently investigating ways of reducing this overhead and will also implement the nod-and-shuffle mode with the new KPNO 4-m guider.

We are offering this observing mode on a shared-risk basis for the 2001B semester. Users interested in using this mode should contact Arjun Dey (*dey@noao.edu*) prior to their runs for the latest information.