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NIFS and Gemini North Adaptive Optics in 2006A

Robert Blum

A good deal of activity is taking place at Gemini North in 2006A to enhance existing adaptive optics (AO) facilities and to deploy new ones, including instruments that depend critically on the corrected wavefront to achieve their scientific goals.

The Near-infrared Integral Field Spectrograph (NIFS), built by the Research School for Astronomy and Astrophysics at the Australian National University (ANU), is being commissioned on Mauna Kea in 2005B. NIFS was almost completely destroyed in the tragic wildfire that swept over Mount Stromlo in January 2003. Having risen literally from the ashes to be rebuilt by the Australian aerospace firm AUSPACE, NIFS is now mounted on the Frederick C. Gillett Gemini North telescope and undergoing on-sky commissioning. Figure 1 shows an image of the NIFS cryostat and associated electronics cabinets.

Figure 1. NIFS mounted on the up-looking port of the Gemini North telescope. The hexagonal cryostat is a copy of the NIRI design. The electronics for instrument control, the detector, and the on-instrument wavefront sensor are deployed in the two blue environmental cabinets mounted with the cryostat. The Altair facility adaptive optics system is mounted on a side port above NIFS (Photo credit: Peter McGregor and Gemini).

At the same time, Gemini has been installing and testing the Altair facility AO Laser Guide Star (LGS) system, as well as optically reconfiguring Altair to improve its off-axis performance. Earlier in 2005, a 14-Watt solid-state laser, beam transfer optics, and a launch telescope were installed at Gemini North. The system produces a bright laser "star" by exciting the atmospheric sodium layer at an altitude of 90 kilometers and has achieved first laser light. The technical staff at Gemini North has been commissioning the laser to integrate it fully with Altair and the telescope. While the initial results and performance are looking good, there is an issue with the launch telescope that should be resolved by early 2006A. At that time, it is hoped that the laser system and NIRI (the facility infrared imager) will be offered to the community for System Verification observations.

Independent of the laser, a new field lens was adapted to Altair to reconjugate its deformable mirror to the ground from the original design altitude of 6.5 kilometers. This change dramatically improves the off-axis performance of Altair by decreasing the effects of anisoplanatism across the corrected field (in most atmospheric turbulence conditions). Prior to the fix, the off-axis Strehl ratio dropped precipitously at distances of ~5 arcseconds (arcsec) from the natural guide star.

With the new field lens, the areal coverage of good image quality is increased by a factor of as much as 20 to 30. The Strehl reduction at 10 arcsec from the guide star may be reduced to a loss of only ~10 percent from 45 percent or more previously. The field lens currently deployed is temporary and is not anti-reflection coated, resulting in an 8 percent loss of throughput. The permanent version will be coated. With this current limitation, on-axis programs (with roughly 5 arcsec or less distance between the guide star and target) may choose not to use it. The lens may be moved in or out of the beam, and users can specify which mode they prefer in the Phase II observing plan. The field lens is offered with Altair in 2006A. Interested users should visit the Gemini Altair pages for more information.

The addition of an LGS system and improvements to Altair are good news for NIFS. The integral field spectrograph was designed to take advantage of a near diffraction-limited point spread function (PSF) from the 8-meter Gemini telescope. NIFS is a fully cryogenic near-infrared spectrograph. It will deliver a spectral resolution of 5,300 (two-pixel sample) and the full J, H, or K band in each image. Its real strength, however, is in spatially sampling the spectrum over a 3 arcsec × 3 arcsec field of view. NIFS produces a 3-D spatial-spectral data cube by slicing up the input field into 29 0.1-arcsec slitlets, each of length 3 arcsec. The spatial dimension of each slitlet is sampled at approximately 0.04 arcsec per pixel. The optics reformat the 29 slits into a long "staircase" slit, which is passed to a conventional spectrograph. The

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spectra corresponding to the different 0.1-arcsec × 3-arcsec slitlets are imaged onto a 2048 × 2048 Rockwell HAWAII-2RG HgCdTe detector.

As of this writing, NIFS has been mounted on the up-looking port at Gemini North, with first light achieved on October 18. On-sky commissioning of the instrument has begun, and it will be fully integrated into the Gemini observing system. Standard observing sequences are developed with the Observing Tool (OT) and then executed through the seqexecutor like other Gemini facility instruments. IRAF data reduction tools tailored for NIFS and IFU images exist and are in use to reduce the commissioning data. The reduction tools will be available to the community as part of the Gemini IRAF package.

The author gratefully acknowledges the input of Peter McGregor and Tracy Beck in the writing of this article.

TEXES Arrives at Gemini in 2006

Dan Jaffe & John Lacy (University of Texas)

One strong recommendation coming out of Gemini's 2003 "Aspen" future instrumentation process was for Gemini to develop a capability for high-resolution, mid-infrared (IR) spectroscopy. Gemini North will offer a new and unique capability to the user community, beginning in 2006B, in response to the recommendation: R=100,000 spectroscopy at 5–25 microns. The University of Texas group has modified TEXES, the Texas Echelon Cross-Echelle Spectrograph (Lacy et al., 2002, PASP, 114, 153) for use at Gemini in order to make this capability available. TEXES has been in regular use at the NASA Infrared Telescope Facility (IRTF) on Mauna Kea since fall 2000, and will be shared between the IRTF and Gemini.

The high background at mid-infrared wavelengths means that ground-based spectrometers are still limited by background noise, even with very large resolving powers. Greater resolving power is then an advantage when lines are narrow, where the line-to-continuum ratio is low, or where the line shapes contain astrophysically useful information. The Aspen Report lists some of the many areas where high-resolution spectroscopy in the mid-IR can help solve important astronomical problems. The following examples of science results from TEXES at the IRTF illustrate areas where the community can reap substantial scientific benefit from the superior spatial and spectral resolution of Gemini/TEXES, as well as the better sensitivity that Gemini will provide.

Protostellar Disks: The pure rotational lines of H_2, of which the S(1), S(2), and S(4) lines at 17.0, 12.3, and 8.0 microns are regularly accessible from Mauna Kea, should be good probes of the anthropically interesting region of protoplanetary disks at a radius of 1-10 Astronomical Units (AU). These

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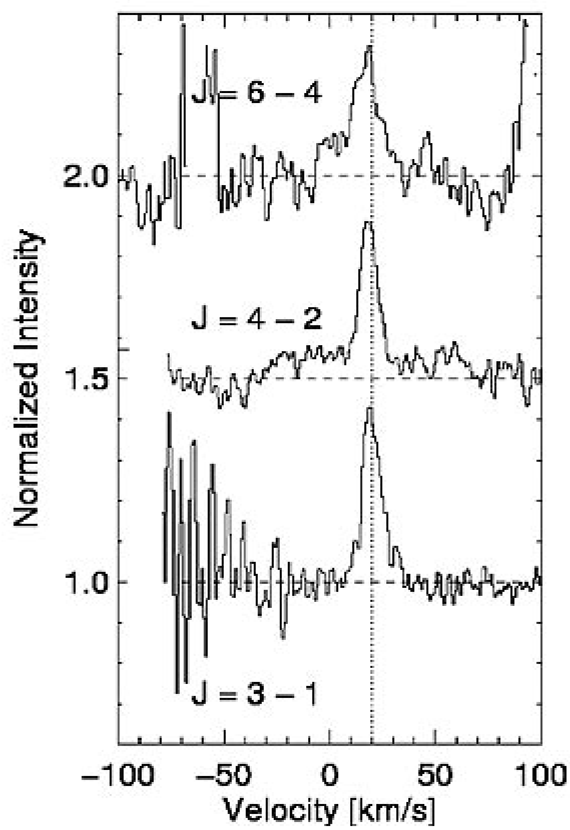

Figure 1: Observations of H_2 ground-state rotational transitions toward T Tau (Richter et al. 2006). These observations were made with TEXES at the 3-meter NASA IRTF.

TEXES Arrives at Gemini in 2006 continued

transitions should be thermalized, optically thin, and adequately excited at temperatures found at these disk radii. Measurements of the intensities and Doppler profiles of the three lines can provide information about the temperature and distribution of the emitting gas. The superior sensitivity available at Gemini will make several hundred Young Stellar Objects (YSOs) available for study, including not only the optically thick sources like T Tau studied at the IRTF (figure 1), but also optically thin Class II and even Class III YSOs. Lines of other molecules may provide information about disk chemistry as well.

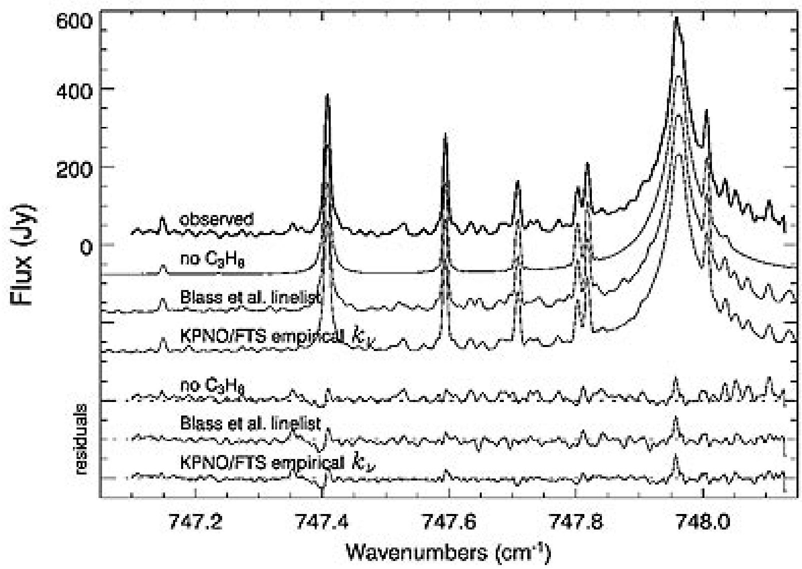

Figure 2: A section of Titan's 13-micron spectrum observed by TEXES. The strong emission features are due to C_2H_2 and HCN. These are modeled in the curve labeled "no C_3H_8". Propane (C_3H_8) contributes the many weak features, as demonstrated by the Blass et al. and KPNO/FTS fits. This observation was the first to unambiguously resolve propane features from other stratospheric emissions originating in the atmosphere of Titan. (From Roe et al. 2003, ApJ, 597, L65).

Outer Planets and Planetary Moons: Even on a 3-meter telescope, it has been possible to make some path-breaking observations of the outer planets and their moons. These observations include the detection of propane in Titan's atmosphere (Roe et al. 2003, figure 2); the detection of H_2O_2 in the atmosphere of Mars (Encrenaz et al. 2004); studies of the rotational quadrupole lines of H_2 toward Uranus (Trafton et al. 2003); and observations of SO_2 above volcanoes on Io (Spencer et al. 2002). Gemini will provide improved spatial resolution and better sensitivity for the smallest objects.

Ultra Compact HII Regions: Radio continuum and recombination line observations of ultra compact HII regions have not been able to resolve the puzzle of why, despite their small sizes and high internal pressures, these regions last as long as they appear to. Using TEXES to observe the 12.8 micron [NeII] line (Jaffe et al. 2003, Zhu et al. 2005), it has been possible to map the kinematics of several UCHII regions and to conclude that their gas motions are dominated by surface flows rather than expansion, at least alleviating the "lifetime problem."

Observing Opportunities: Gemini is still forming plans for the integration of TEXES into the observing schedule. We expect an engineering run to occur in February 2006, followed by a science verification run in summer 2006, and a longer science run in fall 2006. The opportunity to propose for both 2006 science runs will be announced in the Gemini 2006B Call for Proposals and/or via a special Demonstration Science or other call (that would be advertised on the Gemini and NGSC Web pages).

Observations with TEXES will be made in collaboration with one or more instrument team members. The TEXES team will provide complete support for users, including assistance in proposal preparation, operation of the instrument, pipeline data reduction, and collaboration in data interpretation.

For further information about proposing or observing with TEXES, contact John Lacy (*lacy@astro.as.utexas.edu*).

bHROS Update

Verne V. Smith

The High-Resolution Optical Spectrograph (bHROS) has now been commissioned and is available for use on Gemini South. The spectrograph underwent initial on-sky commissioning in July 2005 and began Demonstration Science observations in August 2005. bHROS is a fiber-fed, bench-mounted, cross-dispersed echelle spectrograph located in the pier of the Gemini South telescope.

bHROS is designed to operate at very high spectral resolution, R=150,000 with 3-pixel sampling. Of course, lower spectral resolution can be obtained by pixel binning. There are two observing modes: the first uses two 0.7-arcsecond-diameter fibers separated by 20 arcseconds to observe object and sky spectra simultaneously; the second uses one fiber for object only, with a fiber diameter of one arcsecond. Image slicers are employed to maximize throughput at high spectral resolution while maintaining a relatively compact instrument. As a result, the imaged echelle orders consist of adjacent bands from the slicer. The operational wavelength coverage is from approximately 400 nanometers to 1,000 nanometers. The detector is a 2048 × 4608 CCD with 13.5-micron pixels. Wavelength coverage is not complete. For a setting centered on H-alpha, seven or eight orders will fall on the CCD, with about 6.0 nanometers of spectral coverage from each order. A graphical observing tool on the Gemini Web site can be used for fine-tuning the grating angles to place the desired wavelengths on the CCD array.

The approximate sensitivity of bHROS is illustrated in figure 1. Currently, the limiting magnitude is set by detector read noise (5.3 electrons) and background within the instrument enclosure. Acquisition strategy for placing the target on the input fiber,

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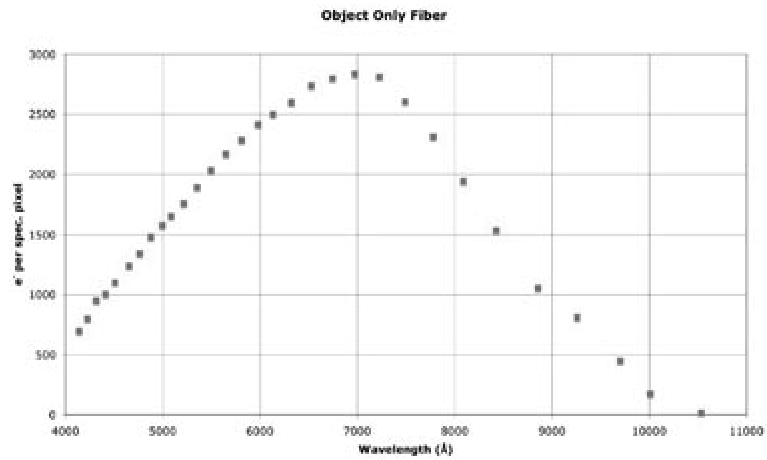

Figure 1: Electrons per pixel versus wavelength for a monochromatic magnitude 15 source, after a total integration time of 10,000 seconds at spectral resolution R=150,000.

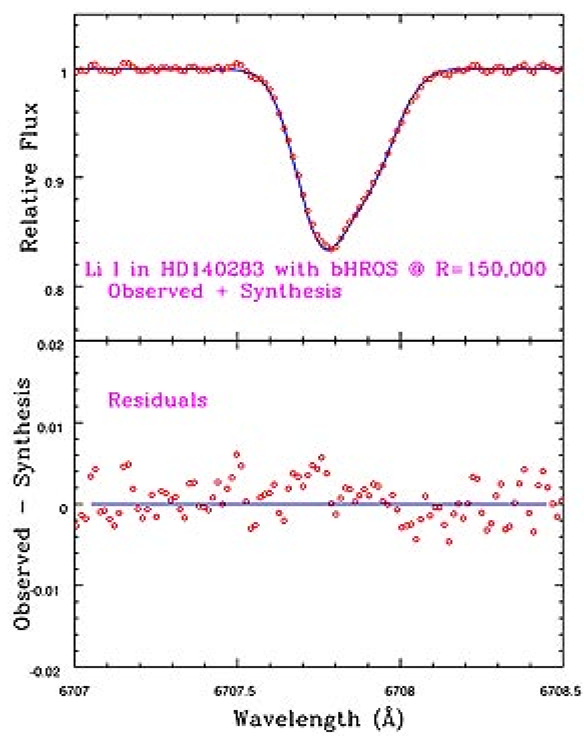

Figure 2: Demonstration science data for HD 140283 illustrating the Li I feature in this old, metal-poor halo star. Top panel: data (open symbols), synthetic fit (solid curve). Bottom panel: differences between observed and synthetic data (open symbols).

bHROS Update continued

critical for maximizing sensitivity, is evolving as well.

A Demonstration Science data sample is shown in figure 2. The illustrated section of spectrum is the 6707.8 Å neutral lithium line in the metal-poor halo subgiant HD140283 ([Fe/H] = -2.5). The data result from two 20-minute integrations and have an unsmoothed signal-to-noise ratio of about 1,000 at R=150,000. A demonstration of the quality of the spectrum is seen in the residuals (bottom panel) to the synthetic spectral fit (solid line). Spectra of this quality can be used to study the abundances of the stable lithium isotopes, Li-6 and Li-7, in stars and interstellar gas. Detection of the wavelength shift between Li-6 and Li-7, about 0.16 Å, requires very high resolution. In the case of HD140283, the synthetic fit contains no Li-6. A stringent upper limit to the fractional amount of Li-6 to total lithium content of the star can be set at about 1%.

For additional details on the status of bHROS or instrument specifics, see the Gemini Web site at *www.gemini.edu/sciops/instruments/hros/* or contact Verne Smith (*vsmith@noao.edu)*.

Electronic Distribution of Gemini Data

Tom Matheson

The Gemini Observatory has recently changed its mechanism for data distribution. In the past, the principal investigator (PI) had to wait patiently by the mailbox for CDs or DATs to be delivered. Data will now be available for electronic download from the Gemini Science Archive (*www2.cadc-ccda.hia-iha.nrc-cnrc.gc.ca/gsa*).

Use of the Gemini Science Archive (GSA) requires that a user account be established to download any data. User accounts are created by selecting '*Register*' on the GSA home page. The GSA uses this account information to contact you via e-mail when the data you request are ready for download. In addition to proprietary data, publicly available data and calibrations are also accessible through the GSA.

After data quality assessment, the data are transferred to the GSA. A weekly process generates a package of data for the PI. This includes the science data, calibrations, and any other relevant information, such as weather images and observing logs. An e-mail will notify the PI, as well as the National Gemini Office (NGO) and Gemini contact scientists, when the data are available in the GSA. Once the data are in the GSA, the PI may retrieve it at any time. Access to proprietary science data requires the Gemini program identification number as well as the Phase II program key.

The new observing classes that were implemented in the most recent release of the Gemini Observing Tool (OT) facilitate the association of calibration data with a particular science program. When designing a Phase II, be careful to assign each observation an observing class. This controls how time is charged for the program, as well as helping to ensure that calibrations are connected to the proper science observations. Observing class is set on the Observing Tool "Observing Sequence Component" page.

If a PI is unable to download the data from the GSA, it is still possible to request that it be shipped. The new formats for shipped data are DVDs or DATs. Such a request should be made through the Gemini Helpdesk (*helpdesk.gemini.edu*). This direct shipment will produce delays in receipt of the data, and possible complications if international shipping is required. Gemini Observatory and the NOAO Gemini Science Center strongly encourage PIs to use the electronic distribution system for all Gemini data.

More information may be found in the Gemini PI electronic data distribution announcement (*www.gemini.edu/sciops/data/PhaseII-GSA.html*).

NGSC Instrumentation Program Update

Taft Armandroff & Mark Trueblood

The NGSC Instrumentation Program continues its mission to provide innovative and capable instrumentation for the Gemini telescopes in support of frontline science programs. This article provides a status update on Gemini instrumentation being developed in the US, with progress since the September 2005 *NOAO/NSO Newsletter*.

NICI

The Near Infrared Coronagraphic Imager (NICI) will provide a 1- to 5-micron dual-beam coronagraphic imaging capability on the Gemini South telescope. Mauna Kea Infrared (MKIR) in Hilo is building NICI, under the leadership of Doug Toomey.

The NICI project is in its final assembly and testing phase. The most important NICI developments over the past three months relate to its adaptive optics (AO) system. A deformable mirror, fabricated by CILAS, was delivered to MKIR in late October. In addition, MKIR integrated the AO system's lenslet array with the AO electronics. The NICI AO interface software is complete and in testing. MKIR can now proceed with the remaining integration and testing of NICI's complete AO system.

As of the end of September, MKIR reports that 98 percent of the work to NICI final acceptance by Gemini has been completed.

FLAMINGOS-2

FLAMINGOS-2 is a near-infrared multi-object spectrograph and imager for the Gemini South telescope. FLAMINGOS-2 will cover a 6.1-arcminute-diameter field at the standard Gemini *f*/16 focus in imaging mode, and will provide multi-object spectra over a 6.1×2-arcminute field. It will also provide a multi-object spectroscopic capability for Gemini South's multi-conjugate adaptive optics system. The University of Florida is building FLAMINGOS-2, under the leadership of Principal Investigator Steve Eikenberry.

The FLAMINGOS-2 Team is continuing with the integration and testing phase of the project. Warm mechanism testing was successfully completed, with all mechanisms meeting specifications. Preliminary cryogenic testing also showed the mechanisms meeting specification at operating temperature. Florida completed acceptance testing of the FLAMINGOS-2 On-Instrument Wavefront Sensor (OIWFS), which was designed and built by the Herzberg Institute of Astrophysics (HIA). The OIWFS is being shipped from HIA to the University of Florida during the first week of November.

The FLAMINGOS-2 camera dewar optical bench, with Florida engineer Jeff Julian working. The dewar wiring is visible.

As of mid-October, Florida reports that 84 percent of the work to FLAMINGOS-2 final acceptance by Gemini has been completed. FLAMINGOS-2 pre-ship acceptance and shipment to Gemini South is anticipated around the middle of semester 2006A.