Recent Spectroscopic Highlights from Gemini

Verne V. Smith

The Gemini telescopes offer US astronomers access to queue observing on 8-meter class facilities with a powerful suite of instruments and full-sky coverage. Among these instruments are a capable set of optical, near-infrared, and mid-infrared spectrographs deployed at both Mauna Kea and Cerro Pachón.

At Gemini North, the spectroscopic opportunities include those in the optical with GMOS, having R=670–4400, multi-object capability, as well as an IFU mode. In the near-infrared (from ~1–5 microns) there is NIRI (R=500–1600) or NIFS (~1–2.5 microns with R=5000). Both spectrographs are capable of accepting the adaptive optics-corrected beam from Altair in either natural or laser guide-star modes. In the mid-infrared, from 8–26 microns, Gemini offers Michelle with R=100–30,000. In addition, the very high spectral resolution mid-infrared echelle TEXES (with R=100,000) has been offered twice (in 2006B and 2007B) as a visitor instrument and may be offered in future semesters. It is worth noting that the capability provided by TEXES on Gemini fulfills one of the scientific goals laid out in the Aspen project.

At Gemini South, the available spectrographs include another GMOS, with capabilities very similar to the one in the North, as well as the 1- to 5-micron capable spectrograph GNIRS (R=1700, 6000, 18,000), which also has an IFU mode. In the near-infrared, there is T-ReCS for R~100 or 1000 spectroscopy from 8–26 microns.

Potential users should check the Gemini instrument Web site at *www.gemini.edu/sciops/instruments/instrumentIndex.html* for the latest news about instrument capabilities. The following two articles highlight recent scientific results based upon spectroscopy from the Gemini telescopes.

A Direct Distance to M33

Alceste Bonanos (Carnegie Institution of Washington)

The first direct distance to a detached eclipsing binary in M33 was recently determined by the DIRECT Project (Bonanos et al. 2006 ApJ, 652, 313), using data obtained in part at Gemini. The goal of the DIRECT project is to obtain accurate distances to two important galaxies in the cosmological distance ladder, M31 and M33. The long-term plan is to replace the current anchor galaxy of the extragalactic distance scale, the Large Magellanic Cloud, with galaxies more similar to those used by the Hubble Space Telescope Key Project (Freedman et al. 2001, *ApJ*, 553, 47).

The DIRECT Project has involved three phases: the initial survey of M31 and M33 to search for bright and detached eclipsing binaries (~200 nights with the F. L. Whipple Observatory 1.2-meter telescope and the MDM 1.3-meter telescope at Kitt Peak during 1996–1999), the follow-up of the best candidates to obtain precise light curves (27 nights with the Kitt Peak National Observatory 2.1-meter telescope in 1999 and 2001), and finally spectroscopic follow-up of the brightest system (V=19.5 mag) for 4 nights with the Keck II 10-meter telescope and 19 hours of queue time with the Gemini North 8-meter telescope. In this targeted system, absorption lines from both stars are clearly resolved in the spectra, making it a double-lined spectroscopic binary.

Careful modeling with non-local thermodynamic equilibrium model spectra yielded effective temperatures $Teff_1$ = 37000 ± 1500K and $Teff_2$ = 35600 ± 1500K. The primary star is defined as the hotter star eclipsed at phase zero. We measured radial velocities from the spectra and, using the photometric and radial-velocity curves, derived

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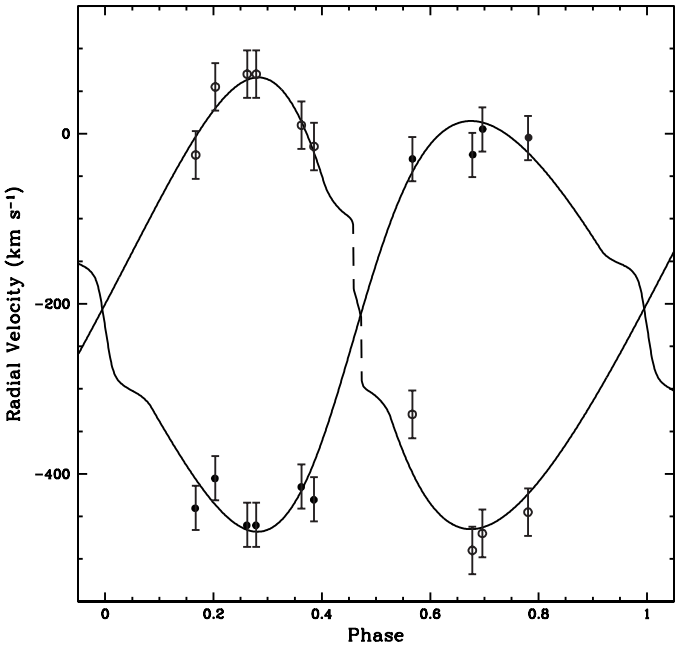

Radial velocities for the detached eclipsing binary in M33 measured by two-dimensional cross correlation with synthetic spectra. The model fit is from the Wilson-Devinney program. Error bars correspond to the rms of the fit: 26.0 km/s for the primary (filled circles) and 28.0 km/s for the secondary (open circles). The four measurements at quadrature were taken thanks to the queue-observing capability of Gemini.

A Direct Distance to M33 continued

the parameters of the component stars. The radial velocity curve is presented in figure 1. The rms residuals are 26.0 kilometers per second (km/s) for the primary and 28.0 km/s for the secondary star. Note that ~4 hours of observations per epoch were required for radial velocity measurements, a large investment of 8- to 10-meter class telescope time. We find the components to be O7 type stars with masses: M_1 = 33.4 ± 3.5 M_{Sun}, M_2 = 30.0 ± 3.3 M_{Sun} and radii R_1 = 12.3 ± 0.4 R_{Sun}, R_2 = 8.8 ± 0.3 R_{Sun}.

Additional infrared photometry from Gemini helped constrain the extinction to the system and yielded a distance modulus of 24.92 ± 0.12 (964 ± 54 kpc), which is 0.3 mag longer than the Key Project distance to M33. This possibly indicates unaccounted sources of systematic error in the calibration of certain distance indicators and demonstrates the importance of accurately calibrating the distance scale and determining H_0, which are vital both for constraining the dark energy equation of state (Hu, W. 2005, in ASP Conf. Ser. 339, Observing Dark Energy, S. C. Wolff & T. R. Lauer [San Francisco: ASP], 215) and complementing the cosmic microwave background measurements from the Wilkinson Microwave Anisotropy Probe (WMAP; Spergel, D. N., et al. 2006, *ApJ*, submitted (astro-ph/0603449). NL

GNIRS Infrared Spectroscopy and the Origins of the Peculiar Hydrogen Deficient Stars

Verne V. Smith

The Gemini Near-Infrared Spectrograph (GNIRS) recently conducted fascinating observations of a normally rare isotope of oxygen, ^{18}O, in the atmospheres of two classes of unusual stars. The GNIRS spectra have provided the key clue in understanding the origins of these stars. The peculiar stars in question are the hydrogen-deficient carbon (HdC) stars and their variable cousins, the R Coronae Borealis (RCrB) stars. These particular stellar types are characterized by having almost no hydrogen, but quite large amounts of carbon.

Two scenarios have been suggested to account for these chemically unusual classes of H-poor yet C-rich stars. In the first, it is postulated that in the normal transition from a luminous, cool asymptotic giant branch (AGB) star to its later planetary nebula stage, a final pulse of triple-alpha helium burning occurs in a thin shell near the stellar surface, with the observable stellar atmosphere being polluted by the products of this burning. The combination of He-burning, to produce carbon, coupled to the mass loss of a hydrogen-rich envelope in the AGB-PN transition results in the C-rich and H-poor characteristics.

In the second formation scenario, a binary system consisting of a carbon-oxygen white dwarf (CO-WD) and a helium white dwarf (He-WD) merge through a combination of magnetic braking and gravitational radiation. Such a white dwarf binary system results from the evolution of two normal low- to intermediate-mass stars in a relatively close binary system. The merging sequence would release large amounts of energy, driving nuclear reactions that could produce oxygen-18.

Using GNIRS infrared spectra obtained with Gemini South, Geoffrey Clayton (Louisiana State University) and an international team of observational astronomers and nuclear astrophysicists detected significant enhancements of oxygen-18 in seven HdC and RCrB stars; the overabundances of oxygen-18 are enormous, being several hundred to a thousand times larger than in the Sun when compared to the usually more abundant oxygen-16 isotope. The spectra showing the detection

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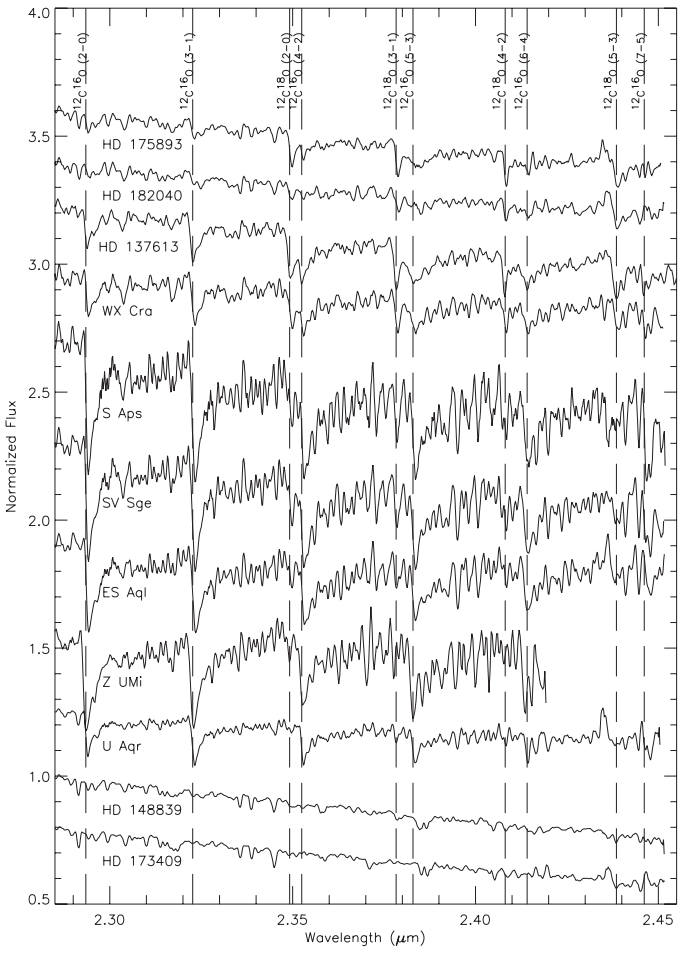

GNIRS spectra of HdC stars (top three and bottom two) and RCrB stars (the six in the middle) with molecular absorption from CO indicated. The bandheads due to both $^{12}C^{18}O$ and $^{12}C^{16}O$ are indicated.

GNIRS Infrared Spectroscopy continued

of oxygen-18, via molecular absorption from $^{12}C^{18}O$ is shown in figure 1. This absorption is detected due to the isotopic shift from absorption due to what is usually the much more abundant $^{12}C^{16}O$, which is also indicated in the figure. In modeling the two possible formation mechanisms, Clayton and collaborators conclude that the oxygen-18 can only survive in significant quantities as a result of the binary white dwarf merger picture. In the shell helium-burning pulse, the temperatures are so hot for such a length of time as to burn virtually all of the oxygen-18 to neon-22.

This work provides key input for attempts to understand the physics involved in white dwarf mergers. Such mergers in binaries with more massive components are believed to be one possible source of supernovae of type Ia (SNe Ia). Supernovae of this type provided the first evidence for an accelerating universe, so any data that pertain to white dwarf mergers is potentially significant in understanding the physics involved in these very important SNe Ia systems.

The Gemini-Subaru Time Exchange Program

Verne V. Smith

The NOAO Gemini Science Center (NGSC) would like to remind US astronomers about the Gemini-Subaru time-exchange program. This agreement exchanges service observing time at Subaru for queue observing time at Gemini. This program is currently in operation for semesters 2007A and 2007B.

The Subaru instruments currently available to the Gemini community are Subaru Prime Focus Camera (Suprime-Cam), which offers wide-field optical imaging, and the Multi-Object Infrared Camera and Spectrograph (MOIRCS) for near-infrared imaging and multi-object spectroscopy. In exchange, the Subaru community has access to both GMOS instruments (North and South) and NIFS, in queue mode only. Joint proposals for Gemini time between the Japanese community and Gemini partners are permitted and encouraged. See the Gemini Call for Proposals for more information on applying for time on Subaru through Gemini at *www.gemini.edu/sciops/ObsProcess/ObsProcIndex.html*.

This agreement is likely to be continued for semester 2008A, so keep an eye on both the Gemini Web site (*www.gemini.edu*) and the NGSC Web site (*www.noao.edu/usgp*) for current information about the Subaru exchange program. Semester 2008A proposals to NOAO will be due near the end of September 2007. US users interested in applying for Subaru time should keep this agreement in mind when planning their 2008A proposals. Questions about the Subaru exchange program can be directed to Verne Smith (*vsmith@noao.edu*).

Technical Reviews of US Gemini Observing Proposals

Dara Norman, Ken Hinkle & Dick Joyce

Everyone who submits an NOAO observing proposal knows that the proposal will be reviewed and ranked on the basis of scientific merit by a Time Allocation Committee (TAC). Each Principal Investigator (PI) then receives notification of the TAC decision and a summary of the discussion of the proposal. It is less well known that a complementary and equally important review of the technical aspects of the proposal occurs in parallel with the TAC process.

Each proposal is read prior to the TAC meeting by a member of the NOAO scientific staff, who assesses its technical feasibility based on information provided by the PI and then writes a summary report which is made available to the TAC. This is usually a matter of verifying that the telescope/instrument configuration and observing time requested in the proposal are consistent with achieving the scientific goals of the proposal. Most proposals have no technical problems. Many simple problems can be resolved after a discussion with the PI and TAC notification of any changes. In some cases, reviewers are also able to make suggestions to improve the efficiency of the proposal. The goal of this process is to ensure that PIs get the highest-quality data with which to achieve their scientific goals, and avoid the awarding of time to scientifically meritorious proposals which turn out to be impossible to carry out.

Almost all Gemini proposals are for queue-based observations. While these observations are carried out by Gemini staff, the technical reviews are done by the National Gemini Offices (NGOs). The NGO for the United States is the NOAO Gemini Science Center (NGSC). Each NGSC scientific staff member is responsible for reviewing proposals for at least one Gemini instrument; multiple reviewers are assigned to instruments with large numbers of proposals, such as GMOS or GNIRS.

Because the Gemini queue mode observations are ultimately carried out exactly as specified in the Phase II version of the proposal, and the fundamental parameters (targets, observing constraints, total requested time) are usually carried over from the Phase I proposal, the technical review of Gemini proposals is quite comprehensive, including a check of:

- The target list and compliance with any RA restrictions set by Gemini for the instrument
- The appropriate telescope/instrument combination for the proposed observations
- Instrument parameters (filters, slit widths, spectral resolution) which are both appropriate to the science and possible with the instrument
- Observing condition constraints appropriate to the proposed observations
- Observation times (using the Integration Time Calculator) required to achieve the desired signal-to-noise for the specified

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Technical Reviews of US Gemini Observing Proposals continued

target brightness under the observing conditions requested, including overheads for acquisition, readout, and telescope motions. The total time is checked against the overall time requested for the proposal
- Lunar phase requirements and (for bright-time proposals) lunar position with respect to the targets to identify any time constraints
- Proper transcription of proposals submitted using the Gemini Phase I Tool (PIT) into the NOAO form which is seen by the TAC

However, a technical review can be accurate only if sufficient information is provided to the reviewer, and so PIs should take care to provide all relevant details for evaluation. For example, PIs who use the Integration Time Calculator to determine exposure time should provide all input parameters in the Technical Section of the proposal. This level of detail allows the reviewer to easily understand how exposure times were determined and to identify any problems that might prevent the PI from reaching their stated goals.

While the technical review can be time consuming, we have found that identifying potential problems as early as possible in the proposal process facilitates our ability to work with the PI and the TAC to alleviate them. In this light, the best technical review is one that occurs prior to the submission of the proposal. We encourage PIs who are considering challenging scientific programs, or who may be uncertain whether a particular instrument is appropriate for their program, to consult with the NGSC instrument contact well in advance of the proposal deadline. This will not only result in a stronger proposal, but will also make the job of technical review during the TAC process that much easier. A list of NGSC staff contacts is available at *www.noao.edu/usgp/noaosupport.html*.

Phoenix Leaves Gemini South

The last night for the Phoenix spectrograph at Gemini South was 6 March 2007, concluding more than five years of use on Gemini. During this time, the instrument exhibited a high level of performance thanks to the attentive support of NOAO and Gemini staff.

High-resolution infrared spectra obtained with Phoenix on Gemini have produced a large number of scientific papers. At the time of this article, Phoenix has led to the second highest number of peer-reviewed papers from US community usage of Gemini (exceeded only by GMOS on Gemini North), with many more papers to come. Some of the scientific results include detailed studies of physical conditions and chemistry of gas and stars in obscured regions, such as the Galactic center or star-forming regions. Phoenix spectra have been used to determine the kinematical and physical structure in circumstellar gas, such as that found around Eta Carinae. High-resolution infrared spectra provided by Phoenix resulted in radial velocity measurements that were used to establish the first-ever direct measurements of brown-dwarf masses and radii.

Phoenix was scheduled to be moved to the SOAR 4.1-meter telescope and, if everything had proceeded as planned, to be available to the SOAR community in semester 2008A. However, as this article was going to press, an accident occurred with GNIRS that rendered it out-of-service for the 2007B semester. Because of this, Phoenix is now slated to remain at Gemini South for the 2007B semester (see the link to the related article at *www.gemini.edu*).

—Katia Cunha & Ken Hinkle

Altair and the Laser Guide Star System

Robert Blum

Altair, the facility adaptive optics system at the Gemini North telescope, has been in routine science use and continues to provide excellent images in Natural Guide Star (NGS) mode. In semester 2007A, basic commissioning and science verification of the Altair Laser Guide Star (LGS) system were completed.

The LGS may be used for targets with zenith distances up to 50 degrees (elevation > 40 degrees). Because the LGS system needs high throughput and stability when it is launched to the atmospheric sodium layer at 90 kilometers, good conditions are required (IQ=70, CC=50). The LGS will be used regularly throughout the semester, one to two weeks per month, depending on the science balance coming out of the International Time Allocation Committee.

The LGS system can be used to feed either the facility near-infrared imager NIRI (for imaging or long-slit spectroscopy) or the integral-field spectrometer NIFS (for IFU spectroscopy). It is expected that normal queue observing with Altair+LGS, as well as Altair+NGS, will continue in 2007B. Please see *www.gemini.edu/sciops/instruments/altair/altairIndex.html/* for details.

NGSC Instrumentation Program Update

Verne V. Smith & 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 gives a status update on Gemini instrumentation being developed in the US, with progress since the March 2007 *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.

NICI had its first commissioning run on the Gemini South telescope in late February. On its first night, NICI successfully closed the adaptive optics loop on the internal 85-element curvature-sensing AO system and produced acceptable Strehl ratios and FWHM performance. Although some software bugs, cryocooler issues, and other items will be addressed in a future commissioning run scheduled for June, Gemini instrumentation staff appear to be pleased overall with the instrument's performance to date.

As of the end of March, MKIR reports that 99 percent of the work toward NICI final acceptance by Gemini is complete.

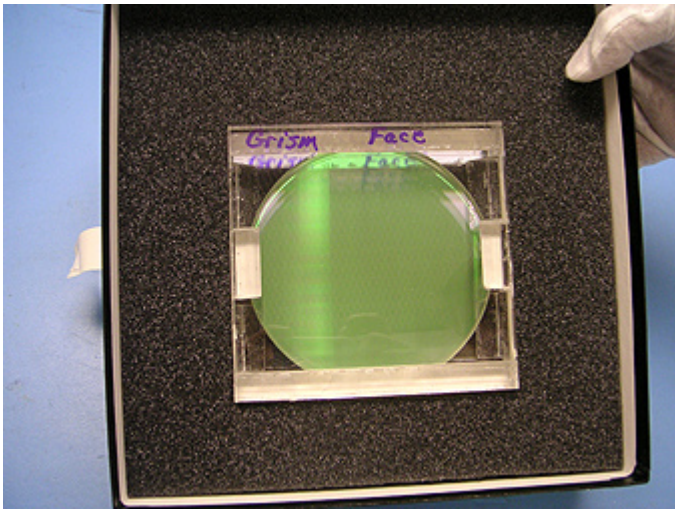
FLAMINGOS-2

FLAMINGOS-2 is a near-infrared multi-object spectrograph and imager for the Gemini South telescope. FLAMINGOS-2 will cover a 6.1-arcmin-diameter field at the standard Gemini f/16 focus in imaging mode, and will provide multi-object spectra over a 6.1 × 2-arcmin 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 NGSC held a Quarterly Review of the FLAMINGOS-2 instrument at Gainesville with the University of Florida Team on April 12. The instrument continues in the integration and testing phase of the project. The Team received the R~3000 grating (shown in the figure), and it passed a visual inspection. The matching prism is expected to be delivered in May, at which time both optical elements will be placed with an intervening air space in a single optical mount.

Instrument team efforts are focused on improving image quality, mechanical reliability, and reducing electronic noise. Previous image quality issues appear to have been addressed, and some problems with mechanisms have been diagnosed and fixed.

As of March, the University of Florida team reports that 95 percent of the work toward FLAMINGOS-2 final acceptance by Gemini has been completed.



The R~3000 transmission grating for Flamingos-2 shown in its protective case. A separate cross-dispersing prism has been ordered and will be mated in a cell with this grating to form the grism.