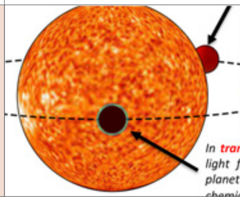
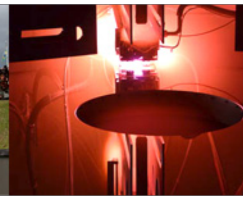
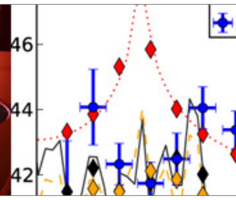
GeminiFocus

Publication of the Gemini Observatory | October 2013



GeminiFocus

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GeminiFocus October 2013

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On the Cover:
2013 Australian Imaging Contest selection of the nebula Gum 85. Otherwise known as the Nested Egg Nebula in Serpens, Gum 85 forms part of the Serpens OB2 association. The image combines two pointings of the Gemini Multi-Object Spectrograph at Gemini South. This image is one of two contest winners sponsored by the Australian Gemini Office; this one selected by amateurs, and the other, selected by students, is featured on page 29.

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Markus Kissler-Patig

Director's Message

Instruments at the fore… and more!

As 2013 progresses, we can already look back on an exciting year for instrumentation at Gemini. Indeed, after the Gemini Multi-conjugate adaptive optics System (GeMS) started first science in 2013A, FLAMINGOS-2 finished its commissioning and is now ready for science in 2013B, and finally the Gemini Planet Imager (GPI) has arrived on Cerro Pachón!

I am particularly thrilled by GPI's arrival at Gemini South. This unique and powerful world-class instrument will give our users the ability to image with unprecedented contrast not only exoplanets, but also circumstellar disks and Solar System objects. In the first half of this year, nearly a decade after we developed the first concept for this complex instrument, GPI was extensively tested at the University of California Santa Cruz where it was built. The instrument successfully passed its Acceptance Review in July and was shipped to Cerro Pachón in August.

The U.S. and Canadian consortium of over a dozen institutions (see: *www.planetimager.org*) unpacked and rebuilt GPI in record time, leaving it assembled on Cerro Pachón by the end of August. As this issue goes to e-press (early October), final tests are being conducted on the flexure rig before mounting the instrument on the telescope later in October (see GPI update starting on page 23 of this issue). Stay tuned for GPI's first and what promises to be spectacular images in November!

Meanwhile, the first GeMS/Gemini South Adaptive Optics Imager (GSAOI) paper has appeared — a study of young cluster stars led by Canada's Tim Davidge, and published from System Verification data, all of which has now become public. A summary of this result is featured as a science highlight in this issue on page 12. In 2013A, 11 of the 12 regular science programs using GEMS were executed, and more time has been allocated in 2013B (see GeMS update on page 22 of this issue).

After FLAMINGOS-2 (F2) recovered from last year's catastrophic failure, just as it was getting ready to go on sky, we concluded the re-commissioning of the imaging and long-slit modes in the last months. F2 is now on the telescope for its first regular science programs in 2013B. Work continues to resolve minor problems in the alignment of the On-Instrument Wave Front Sensor, but first images and spectra look very promising. A detailed update can be found on page 22 of this issue.

The Last Call for Proposals saw F2 jumping into the position of third most demanded instrument at the Observatory! Considering that GeMS/GSAOI is also very popular, and that GPI is about to take its first images, Gemini South will undoubtably become more oversubscribed than ever in the next few semesters.

New Modes of Operation Taking Shape

While making progress in instrumentation, we also saw some of the new operations modes now taking shape. The Gemini Board has agreed on guidelines for the Large and Long programs, to which ~20 percent of telescope time will be dedicated from 2014B onward (see details starting on page 16). Together with the National Optical Astronomy Observatory, Gemini is now finalizing the implementation details and is ramping up towards the first yearly Call for Letters of Intent in December; we anticipate a deadline in early February, followed by a Call for Proposals.

The agreement on Large and Long programs now allows us to work on the third regular mode for proposal applications: the "Fast Turnaround" proposals. This has been discussed with the Users' Committee for Gemini (UCG) in August, and Gemini has started working on its implementation with the Canadian Gemini Office. We expect to have a solid concept by the middle of next year. Other topics discussed at the UCG meeting are summarized in a report that appears in this issue on page 25.

On another front, Gemini staff and members of the National Gemini Offices met in August for the semesterly Operations Working Group meeting. Participants began looking into more efficient user support by specializing their activities and moving towards a smarter distribution of their work. A new focus will be on better post-observation user support.

Finally, the Observatory is nearing the end of its first year of the transition to a reduced budget. We have made good progress on cost-savings activities, and restructuring is advancing, but two more years of hard work remain to achieve sustainable operations under the new conditions. We, at Gemini, are particularly proud that despite this heavy constraint, we can continue to offer exciting new scientific opportunities to all of our users!

While 2013 has been challenging and extremely busy, 2014 promises to be no less exciting!

Markus Kissler-Patig is Gemini's Director. He can be reached at: mkissler@gemini.edu

Jacob Bean, Kevin Stevenson, Jean-Michel Desert, and Marcel Bergmann

Ground-based Transit Spectroscopy of an Exoplanet Atmosphere

Using the Gemini Multi-Object Spectrograph, researchers help characterize the atmosphere of exoplanet WASP-12b. The transit spectroscopy technique used — until recently only attempted with space telescopes — opens the door for future ground-based studies that will lead to a better understanding of exoplanet systems, and even our own Solar System.

The Importance of Exoplanet Atmospheres

Recent telescopic surveys have revealed an amazing diversity of planets orbiting other stars. This wide assortment of exoplanets offers both challenges and opportunities to astronomers studying them. The challenge is to understand these objects from the perspective of a complete theory of planetary system origin and evolution, which is one of the main goals of modern astrophysics. In a broader context, the opportunity is a chance to study classes of objects that may lead to a better understanding of how our own Solar System formed and evolved.

One key to understanding and exploiting the diversity of exoplanets is to study their atmospheres. Planetary atmospheres mediate the energy balance between incoming stellar irradiation and outgoing self-luminosity and re-radiation. Therefore, a planet's atmospheric properties control its size and appearance.

A planet's atmosphere also keeps a record of its origins and evolution. For example, the atmospheres of gas-giant planets make up a significant fraction of their total mass. Therefore, they must be intrinsically linked to the planet-formation process. Lower-mass planets with rocky, metallic, and/or icy compositions could also have primary atmospheres. These would have been either accreted from the primordial protoplanetary disk (as with giant planets), or appeared as secondary atmospheres created from outgassing or collisions with other bodies after the planets formed.

Over the last few years, our group has started exploring exoplanet atmospheres by making differential spectroscopic observations of exoplanets passing in front of their host suns (see details on this technique starting on page 9). These ground-based transit observations yield spectra (and thus clues to the composition of exoplanet atmospheres) with precisions that rival those taken with space telescopes.

Using GMOS to Probe WASP-12b: A Hot Exoplanet Prototype

One exoplanet that has long fascinated us is WASP-12b. This hot, Jupiter-sized planet orbits its Sun-like (G0) parent star every 26 hours. Recent work has suggested that this highly-irradiated exoplanet could have a carbon-to-oxygen ratio (C/O > 1) that is significantly higher than that of the Sun (0.54, Madhusudhan *et al.*, 2011). When a planetary atmosphere is so carbon-rich, different chemical pathways dominate and unexpected molecules, such as methane and metal hydrides, begin to emerge.

To better understand the atmospheric composition of WASP-12b (Stevenson *et al.*, 2013) we used the Gemini Multi-Object Spectrograph on the Gemini North telescope (GMOS-N) on Mauna Kea to perform the transit spectroscopy technique described starting on page 8.

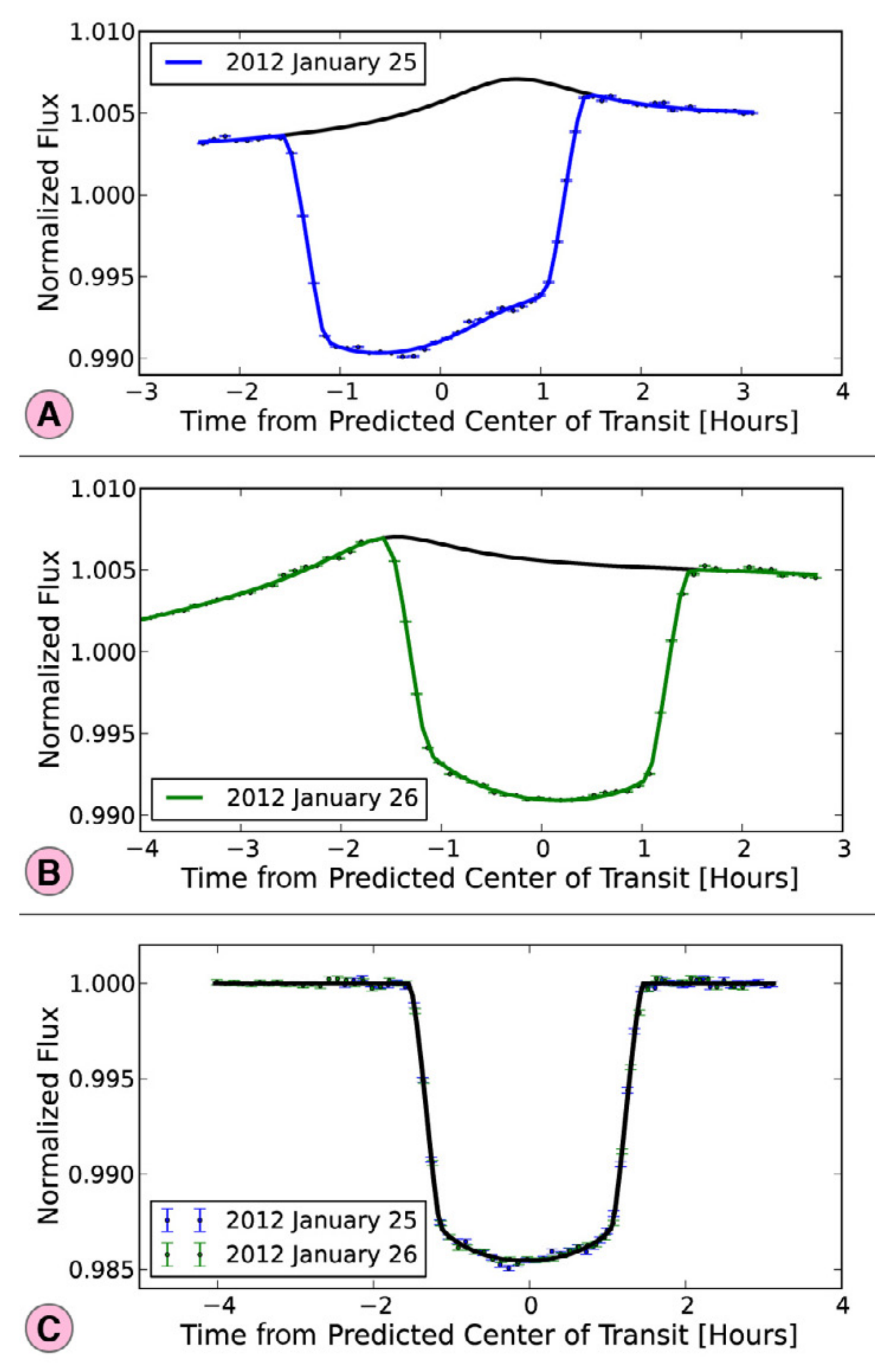

Figure 1.

"White" light curves for the hot Jupiter-type exoplanet WASP-12b Panel A: Transit time series, from January 25, 2012, after correcting for telluric effects using the simultaneously observed reference star (points). The data exhibit an unexpected instrument systematic that is modeled using an analytic function (black line). The combined transit and instrument model is shown as the blue line. Panel B: Same as panel A, but for the January 26th observation. Panel C: White light curves for both nights with the instrument systematic removed (points). The combined transit model is shown as the black line. The residuals have a root mean square of 180 parts per million.

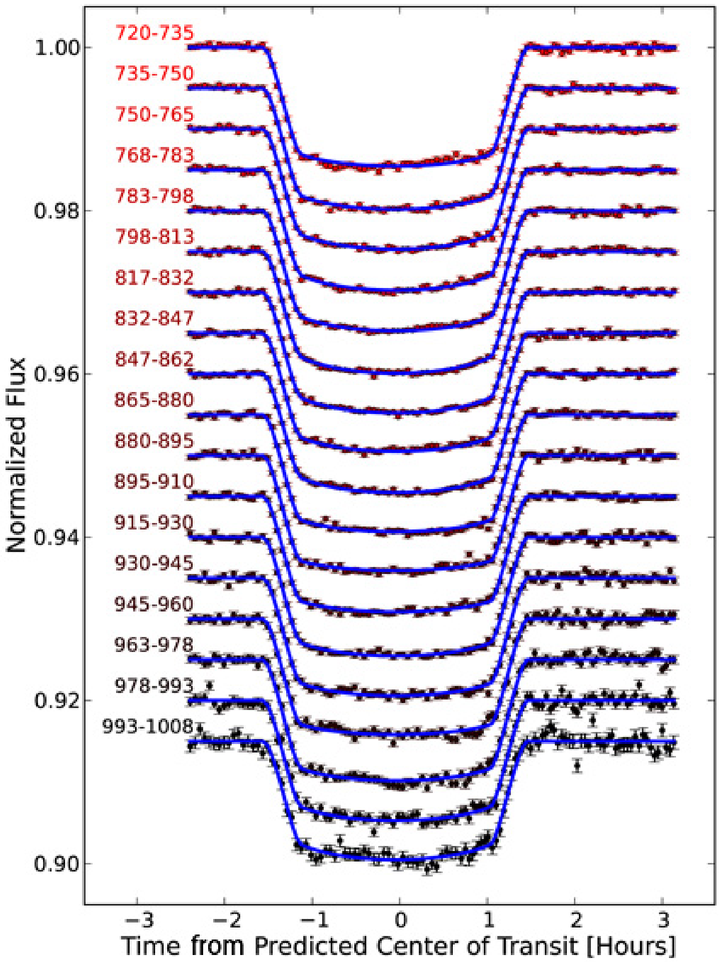

Figure 2.
Spectroscopic light curves of WASP-12b (points) and best-fit models (lines) for the January 25th observations. The numbers on the left side give the wavelength range of the channels in units of nanometers.

Because WASP-12b's orbital period is close to one day, we were able to observe two transits on two consecutive nights in classical mode. Our observations were gathered in the red optical (720 - 1008 nanometers [nm]) and took advantage of the new e2v deep depletion CCDs that had been installed in GMOS-N just a few months beforehand. The excellent red optical quantum efficiencies and cosmetics of these detectors were a big boon to our program.

The so-called "white" light curves for WASP-12b — made from the Gemini data by summing over all of the wavelengths — is shown in Figure 1. The data exhibit an unexpected instrument systematic. The effect is correlated with the rotation angle of the Cassegrain instrument support structure. (Note that this angle changes smoothly over the course of a transit observation as the structure rotates to keep the GMOS slit mask aligned on the stars.) The origin of this effect is unknown and is currently being investigated. However, we found that it can be modeled (black lines in the top two panels of Figure 1) and removed from the data.

In Figure 2, we show the corrected high-precision spectroscopic light curves that we obtained with GMOS-N by binning the data for the first night over 15-nm-wide spectral channels. The measured transit depths vary as a function of wavelength; this gives us the planet's transmission spectrum, which in turn, tells us about its atmospheric composition.

The transmission spectrum of WASP-12b along with three atmospheric models is shown in Figure 3. The GMOS-N data rule out the possibility of an atmosphere with only hydrogen and potassium. For an oxygen-rich atmosphere, the data can be explained by the presence of metal oxides. However, the presence of metal hydrides in a carbon-rich atmosphere can also explain the data.

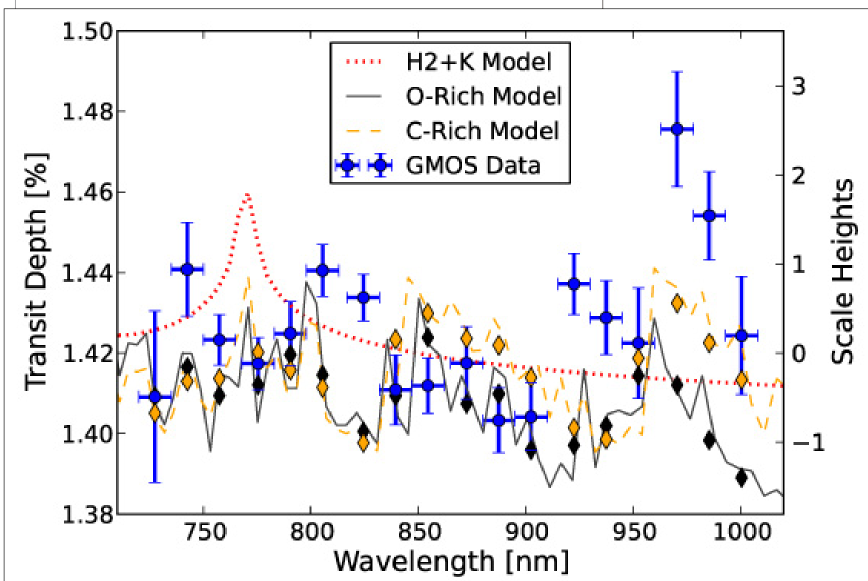

Figure 3.
Derived transmission spectrum of WASP-12b (blue circles with error bars) with the transit depth (left y-axis) and relative number of scale heights (right y-axis). The different lines represent different models for the planet's atmosphere, and the diamonds are the models binned over the data bandpasses. The red line is a model with only hydrogen and potassium. The feature in this model at 0.775 micron is due to the potassium resonance doublet. The black line is a model for an atmosphere that has solar elemental abundances (i.e. oxygen rich). The gold line is a model with a carbon-rich composition.

Looking Forward

In our study of WASP-12b, we achieved comparable precision to previous Hubble Space Telescope Wide Field Camera 3 measurements, thus proving that ground-based studies of exoplanetary atmospheres can be a complementary addition to space-based observations. We are currently conducting a National Optical Astronomy Observatory survey program (Principal Investigator (PI) Jean-Michel Desert) using GMOS to measure transmission spectra of a number of transiting planets and to investigate the nature and origins of these planets in a systematic way.

In addition, the recent commissioning of FLAMINGOS-2 (see update on page 21) opens up the possibility of applying the same differential spectroscopy technique in the near-infrared. We have some observations coming up in October 2013 (GS-2013B-Q-71, PI Kevin Stevenson) to test the capabilities of the instrument for this science. These test observations will be used to observe secondary eclipses of a different planet, WASP-18b, allowing us to to measure its thermal emission spectrum.

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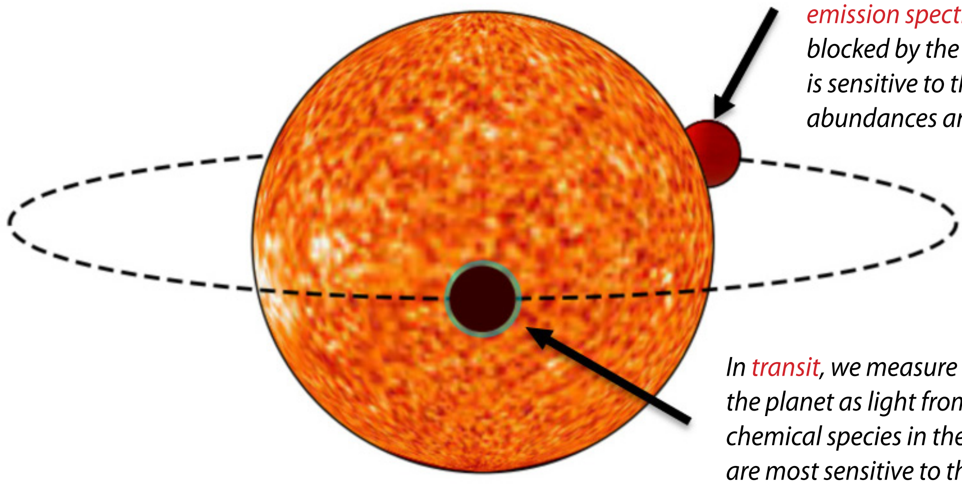
Exoplanet Transit Spectroscopy: A Primer

Conceptually, the simplest way to take a spectrum of an exoplanet is to spatially resolve the light from the planet from the light of its host star and to feed that light into a spectrograph. However, this is extremely challenging due to the large contrast and small angular separations between planets and stars.

As an alternative to the approach of direct imaging spectroscopy, transit spectroscopy involves resolving the light from exoplanets and their host stars temporally rather than spatially (*e.g.*, Charbonneau *et al.*, 2002). This is possible because a subset of known exoplanets are observed to eclipse (transit) their host stars due to a favorable geometric alignment of their orbital plane with our line of sight (Figure 4).

The atmospheres of transiting planets can be probed in transmission by examining the wavelength-dependency of the primary transit depth. This arises because the

Figure 4.



light from the host star is blocked at different altitudes in the planet's atmosphere due to the absorption by chemical species. Also, measurements when transiting planets pass behind their host stars can reveal their thermal emission and reflection spectra. Figure 4 illustrates the geometry of transit spectroscopy observations and discusses what information can be deduced from these observations.

Transit spectroscopy measurements have been used to probe the atmospheres of planets ranging from the hottest Jupiter-size to moderate-temperature, Neptune-size planets and even warm super-Earths. These measurements have been used to deduce the presence of sodium, water, methane, hazes, *etc.* in these planets' atmospheres, and also to constrain their thermal structure, dynamics, and evaporation.

However, there are still many outstanding questions about the fundamental nature of exoplanet atmospheres despite the many recent successful applications of the transit spectroscopy technique. Progress in this area requires observations of more targets and over a wider range of wavelengths than has been obtained so far.

Observing Exoplanet Atmospheres from the Ground

Just as the blurring effect of Earth's atmosphere hinders direct imaging of exoplanets, the scintillation component of atmospheric seeing limits the precision of ground-based transit observations. That's why most transit spectroscopy observations have been done with space telescopes like Hubble and Spitzer.

However, these telescopes have limitations. Both are relatively small, and so achieving the 1 part in 10,000 or better type of precision that is needed for this work can only be done for planets orbiting very bright host stars. Spitzer also no longer has spectroscopic capabilities, and Hubble's spectrographs have limited wavelength coverage.

The large ground-based telescopes of today offer the potential for complementary wavelength coverage, especially in the optical. They also have the reach to target interesting planets around fainter host stars. However, the limitations imposed by Earth's atmosphere first need to be overcome.

The brightness variations in ground-based time-series photometry are typically overcome by simultaneous observations of reference stars that are close to the target on the sky. On the assumption that the reference stars are not intrinsically variable, and that the effect of scintillation is a common mode across a small field-of-view, ground-based differential transit photometry can be obtained to precisions necessary to probe exoplanet atmospheres with the transit technique.

Spectroscopy is ultimately needed to resolve the lines and bands from chemical species in exoplanet atmospheres. We accomplish this by performing simultaneous time-series spectroscopy of the transiting planet host star and a few reference stars of similar brightness with multi-object slit spectrographs. A key aspect of this approach is the use of very-wide (12 arcsecond) custom slits, which is crucial for eliminating light loss at the slit due to variations in atmospheric seeing and guiding as a function of time.

The only downsides to this approach are a loss in spectral resolution over what could be obtained with a slit smaller than the seeing profile, and a higher background. These factors are not major limitations. We typically have to bin the data to a significantly lower resolution than is native in the data (to boost the signal-to-noise ratio) and the stars we observe are very bright relative to the background.

History of Ground-based Transit Spectroscopy

The first application of the multi-object transit spectroscopy technique was with the Focal Reducer and Spectrograph (FORS) instrument on the European Southern Observatory's Very Large Telescope (Bean *et al.,* 2010), and we have subsequently used the technique with MMIRS on Magellan (Bean *et al.,* 2011, and 2013) and now the Gemini Multi-object Spectrograph (GMOS) on Gemini (Stevenson *et al.,* 2013). Recently, another group has also had success using the technique on GMOS (Gibson *et al.,* 2013).

Nancy A. Levenson

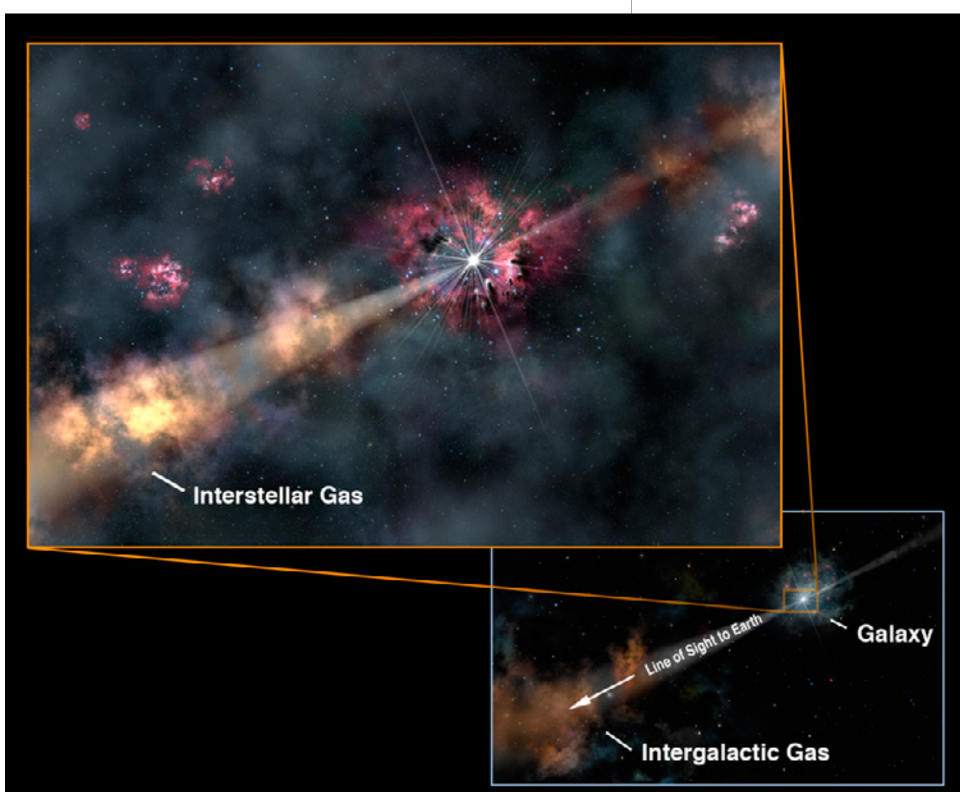
Science Highlights

From extremely fast-turnaround GRB observations to the first published science paper from GeMS/GSAOI data, science results from Gemini during the past quarter demonstrate remarkable new technical capabilities and our expanding scientific discovery-space.

Intergalactic and Interstellar Medium Studies with Gamma-Ray Bursts

The high-redshift gamma-ray burst denoted GRB 130606A rapidly demonstrated its utility as a probe of the intergalactic medium — both along the line-of-sight to Earth and through the interstellar medium of its host galaxy. On June 6th of this year, Ryan Chornock (Harvard University) and colleagues used the Gemini Multi-object Spectrograph at Gemini North to obtain sensitive observations of the GRB's afterglow within 13 hours of when NASA's Swift satellite first detected the burst. They used the data to measure reionization in the early universe and properties of the host galaxy (Figure 1).

Figure 1.
This artistic rendering illustrates how the light from GRB 130606A serves as a beacon through the interstellar gas of the host galaxy of the burst source. It also reveals the ionization state of the medium between galaxies along the line of sight.



At redshift $z = 5.91$, GRB 130606A remains one of just a handful of spectroscopically confirmed GRBs at $z \gtrsim 6$. Quasars have been used to probe the intergalactic medium (IGM) at this epoch, when the universe was only one billion years old. This work is the first to provide a similarly high-quality GRB spectrum for analysis.

An advantage of pursuing this work with GRBs is that there is no expected bias toward highly ionized areas, as may be the case with quasars. The net results along this single sightline are similar to those obtained based on quasar observations, showing an increase in the Lyman-α optical depth from $z = 4.9$ toward larger redshifts.

A particular feature is that the IGM appears nearly opaque in a region around $z = 5.77$, although measurable Lyman-β and Lyman-γ flux show that the IGM is still significantly ionized over this high-redshift interval. In addition, at the redshift of the host galaxy, Chornock *et al.* establish an upper limit on the neutral fraction of the IGM of 0.11.

A number of absorption lines were used to determine the host galaxy's redshift. Some of these lines are useful tracers of the galaxy's metallicity, with the expected result of low metallicity — about one-tenth of solar values. Assuming these lines are optically thin, it sets a lower limit; *e.g.*, [Si/H] $\gtrsim$ -1.7. The non-detection of some ionized sulfur lines sets an upper limit of [S/H] $\gtrsim$ - 0.5.

The complete results are published in *The Astrophysical Journal*, **774:** 26, 2013.

First Refereed GeMS Results: Young Stars Leave the Nest

The first refereed astronomy paper based on data using the Gemini Multi-conjugate adaptive optics System (GeMS) demonstrates the effective use of young, lower-mass stars to determine the age of a star cluster. In this case, the infrared sensitivity and resolution of GeMS, together with the Gemini South Adapative Optics Imager (GSAOI), enabled measurements of stars in the low-mass cluster Haffner 16 in the Milky Way.

In particular, photometry of faint, pre-main-sequence stars is now possible. These become essential for determining the cluster's age accurately because the higher-mass stars usually used are often absent in low-mass clusters. The GeMs/GSAOI data yield an age $\gtrsim$ 10 million years (Myr). In contrast, optical measurements results in an age about 2 Myr greater for this cluster.

Figure 2.
This image of Haffner 16 illustrates that the GeMS AO system can successfully sharpen data even under relatively poor imaging conditions. With the correction, the point sources appeared spread by less than 0.16 arcsecond (full-width at half-maximum, in the K_s band). This represents a significant improvement over the natural quality of the sky, which, on the night these data were obtained, was roughly 0.8 arcsecond — a value worse than average at Gemini South on Cerro Pachón.

One of the broader interests of lead author Tim Davidge (Dominion Astrophysical Observatory, Canada) is the origin of the field star population — stars that have "left the nest" of the clusters where they likely formed. Haffner 16 is an example of a cluster in the processes of dissolving, providing evidence of the transition of stars from a cluster to the field. In particular, the authors found that the sub-solar mass population is deficient in Haffner 16, which they suggest results from the cluster's dynamic evolution, during which it lost protostars of sub-solar masses.

Haffner 16 contains a large population of pre-main-sequence stars that are still accreting material, demonstrated by their line emission. This is unexpected given Haffner 16's age — usually the accretion phase ends after only a few Myr. This extended period of mass buildup may eventually result in somewhat overly massive stars for their position on the main sequence. To explain the observations, the authors suggest that the supernovae and strong stellar winds of massive stars that normally disrupt accretion are absent, allowing the process to continue unabated.

For astronomers interested in all subjects, these observations most importantly demonstrate the utility of the GeMS AO system even in the relatively poor seeing conditions under which these data were obtained. The delivered image quality here (Figure 2) provides full-width at half-maximum in the K_s band of < 0.16 arcsecond. This represents a significant improvement over the natural seeing, which, on the night these data were obtained, was roughly 0.8 arcsecond — a value worse than average at Gemini South on Cerro Pachón.

The paper appears in *The Publications of the Astronomical Society of the Pacific*. Davidge, T. J., *et al.*, F. Haffner 16: A Young Moving Group in the Making. eprint **arXiv:**1308.5432.

Limits on Quaoar's Atmosphere

The Kuiper Belt Object Quaoar (pronounced Kwa-whar), located well beyond the orbit of Pluto, can be studied through occultations as it passes along the line of sight through the crowed plane of the Milky Way. Occultations are an effective probe because astronomers know the speeds of Solar System bodies very precisely from their orbits, so the duration when starlight is blocked provides a direct measurement of the size of the occulting object. In addition, an occultation can uncover information about the nearby body's atmosphere, if it exists. A rocky body without an atmosphere will immediately extinguish the starlight, while one with an atmosphere will create a "fuzzy" event with a slow dimming and eventual blocking of the starlight.

Recent "near-misses" of Quaoar occultations provide some constraints on a possible atmosphere, as Wesley Fraser (National Research Council Herzberg, Canada) and collaborators rule out some pure N_2 and CO models. They find that a methane atmosphere is possible, with temperature and pressure values that prevented detectability in the latest observations.

The background stars are relatively faint, and rapid photometry is required, so the acquisition camera on Gemini, normally used to adjust the telescope pointing, became (unusually) the science instrument. Photometric measurements were recorded several times per second.

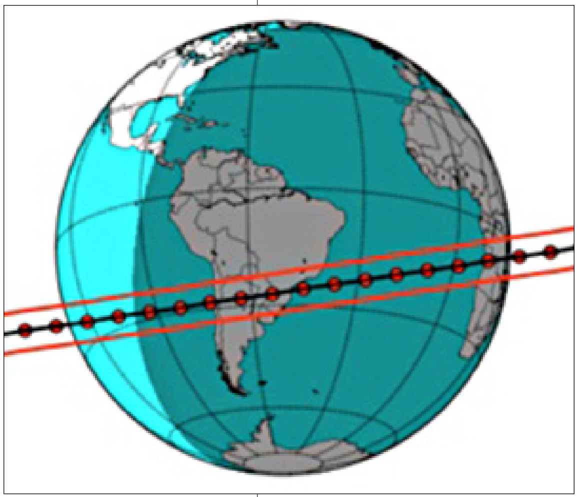


Figure 3.
Predicted track of Quaoar during an occultation attempt on August 5, 2013. This event was another "near-miss" at Gemini South.

One of the challenges of these observations is that the catalogued positions of many of the stars are not sufficiently precise to predict an occultation with certainty. The team uses observations from the Canada-France-Hawaii Telescope (CFHT) Legacy Survey to make the predictions of upcoming occultations, and then they only observe events that have the highest probability of being successful. Despite these efforts, to date no occultation event of the large (1000-kilometer-diameter) Quaoar has been observed. Nonetheless, as previously mentioned, full analysis of the observations obtained on July 13, 2013, at Gemini South set useful limits on the atmosphere.

References:

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Andy Adamson

Operations Corner

Operations at Gemini have been very productive over the last six months. In this wide-ranging review, we report on a significant improvement in the installation process for Gemini IRAF users, large amounts of engineering work done in mid-year, and instrumentation developments at both our northern and southern facilities.

The *UREKA* Unified Release

The process of installing all of the software our average user might need to have a workable IRAF/Python environment has always been difficult. The idea of *Ureka* (also known as the "unified release") is to bundle all of the required pieces and release them together in one easily-installed package. *Ureka* has the added bonus of not interfering with any existing installations.

A quote from the *Ureka* page sums up what it's about: "*Ureka* is a collection of useful astronomy software that is generally centered around Python and IRAF. The software provides everything you need to run the data reduction packages provided by The Space Telescope Science Institute and Gemini." Since its Beta release to the community in June, *Ureka* has been downloaded by hundreds of users, and feedback is being used to bring it to production release status. Even at Beta, however, it is for many users already fully functional and does not require administrative privileges to install. If you would like to try *Ureka* out, go here: http://ssb.stsci.edu/ureka/. Your feedback will be gratefully received as we improve it further.

Gemini South Shutdown

The Gemini South winter shutdown was completed successfully, with a wide variety of work carried out. One of the biggest jobs was a complete reworking of the summit data center, which included replacing old obsolete racks with new ones. To achieve this, we had to install the computer systems themselves in temporary racks while the old ones were swapped out. We also did maintenance and improvement work on the telescope infrastructure including the Acquisition & Guiding Unit (A&G) and the Cassegrain Rotator), as well as on GMOS-S itself, including significant work to improve reliability of the mask exchange unit.

Finally, we replaced the large chiller, which is used for the toughest cooling tasks in the building (including the air handling units in the dome itself). This task was a major undertaking. It required a choreographed exchange between the existing chillers and the new unit — one that enabled the new one to be run in a test mode so that stability could be achieved before we permanently switched the units. The new unit appears to work very well, and, because it is much more efficient, we expect to realize significant savings on electricity costs.

Gemini North Safety Platforms

Following in the footsteps of Gemini South, this summer, during necessary low wind conditions, engineering staff at Gemini North successfully installed its Shutter Service Platform (Figure 1). This structure is designed to provide a safe means to perform critical periodic maintenance on the enclosure shutter drive motors, encoders, gearboxes, and chains.

The installation work required careful coordination and collaboration of four outside contractors with the site team, plus necessary approvals and oversight of the Office of Mauna Kea Management.

Figure 2 shows the 150-foot telescoping crane required to pick up and place the platforms into position. For the crane to safely perform the lift, Gemini had to excavate and grade a level foundation pad and limit the operation to wind speeds less than 20 miles per hour; both items impacted the time and cost of the installation work.

Thanks to the dedicated efforts of all, Gemini now has a safe means to perform critical periodic maintenance on our important shutter drive systems.

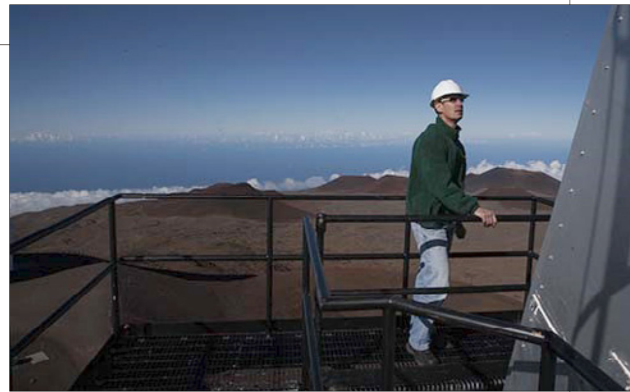


Figure 1. (above)
View from the newly installed Shutter Service Platform installed to facilitate safety and accessibility during Shutter motor servicing.

Figure 2. (below)
A 150-foot telescoping crane was needed to install the Shutter Service Platform.

DSSI Speckle Camera Visitor Instrument

Gemini's new visiting-instrument policy, developed jointly by the Observatory and the Science and Technology Advisory Committee (STAC), allows a quick process for bringing a visiting instrument to the telescope on a "once-off " basis. It also allows for the possibility of attracting a wider base of users within the Gemini partnership, who may be interested in the performance potential of these instruments (without going the whole way to facility class, which is a much larger, and likely prohibitive, undertaking). The policy, posted here: http://www.gemini.edu/sciops/instruments/visiting-instrument-policy, was put into action with the Differential Spectral Survey Instrument DSSI; a speckle camera). Elliott Horch, Steve Howell, Mark Everett, and David Ciardi made up the team of Principal Investigators (PIs).

Gemini offered DSSI as a visitor in the 13B Call for Proposals. On the basis of proposals received, the instrument was scheduled for eight nights on the telescope in July -- for convenience, before the formal start of 13B but using time from the later semester. Five science programs were scheduled, including the DSSI team's own.

These were executed in a "mini-queue" run by the visiting team in close consultation with the PIs.

This plan worked out quite well, with three of the five programs either completed or nearly completed, and two programs more than half completed; the shortfall was due to target position and filter availability, as well as observing conditions, including the loss of a complete night to the passage of Tropical Storm Flossie.

The science included measuring the diameters of nearby stars, Kepler exoplanet confirmations, and observations of Pluto and Charon — a wide range of exciting science observations for a niche capability. It is expected that the instrument will be offered again for 2014B; its capabilities and performance are summarized here: *http://www.gemini.edu/sciops/instruments/dssi-speckle-camera-north*.

Farewell to NICI, Welcome FLAMINGOS-2

For some time Gemini has been preparing various changes to Gemini South's instrument complement, and now those changes are upon us: The Gemini Planet Imager (GPI) is currently on site, being readied for the sky; the Gemini Multi-conjugate adaptive optics Spectrograph (GeMS) has already been scientifically productive, and we expect to accept it into operations before the end of the year; and, finally, FLAMINGOS-2 is back on the telescope and has attracted a lot of proposals for Semester 13B.

This flurry of new instrumentation at Gemini South means that something has to give, and with T-ReCS already removed from the complement, that something is the Near-infrared Camera and Imager (NICI). Strictly speaking, NICI remains a backup option in case of problems with GPI. If all goes well with GPI, however, observing time with NICI on Gemini South will have ended in early 2013B. Despite some hardware and computer problems in the last few weeks of operation, 70 percent of the 2013A NICI programs received more than 75 percent of their requested data.

FLAMINGOS-2 (F2) also continues to move toward operations, even ahead of a formal acceptance (see update on page 21). Recently the On-Instrument Wavefront Sensor (OIWFS) developed an alignment problem during commissioning observations. We opened the instrument for very quick maintenance. At the time of writing, the OIWFS is once again being closed and cooled down after its CCD detector was realigned to take account of an apparent shift in the optics barrel; we intend to make a permanent, long-term fix to the root problem.

In the short term, however, we aim to protect the 13B science programs as far as possible. For current information on F2 status see the F2 Status and Availability page at: *http://www.gemini.edu/sciops/instruments/flamingos2/status-and-availability*.

New: Large and Long Programs at Gemini

Gemini will be offering a new proposing mode, for Large and Long Programs (LPs), with first observations in Semester 2014B.

The participating partners — United States, Canada, Australia, and Argentina — are contributing up to 20 percent of their time to a common pool for these programs. As a guideline, LPs either require significantly more time than a partner typically approves for a single program, or are extend over two to six semesters, or both.

Large programs are expected to promote collaborations across the partnership's communities, have significant scientific impact, and, normally, provide a homogeneous data set potentially for more general use. PIs must be based in an institution of one of the participating partner countries, though there is no restriction on Co-Investigator affiliation.

With the LPs, Gemini will also introduce a new observing mode, "priority visiting observing." In this mode, the PI or team member comes to Gemini prepared to observe either their own program, if the conditions are sufficiently good, or execute approved queue programs if the conditions are too poor for the LP.

The LP will be charged only for time devoted to the program, and additional observations may be made by Gemini staff during the semester. With this mode and that of traditional "classical" observing, we encourage the benefits of being directly involved with the program team in observing, and their interaction with Gemini staff who also support the program.

LPs will be reviewed through a dedicated LP Time Allocation Committee, and the process will bring additional application and reporting requirements. Specifically, Letters of Intent will be required in advance, the proposal will include a management plan component in addition to the usual scientific justification, and approved programs will be reviewed annually. There may be additional partner-specific procedures or requirements, as well. Complete details will be available with the Announcement of Opportunity, which Gemini expects to release in early December 2013. Proposals will be due around the usual 2014B deadline at the end of March 2014. Instruments and observing modes that are fully commissioned at the time of the announcement of opportunity will be open for LPs; a specific list will be provided at that time.

Update on Gemini North Shutdown

As this issue goes to e-press, an extensive planned shutdown at Gemini North, which started on September12th, has ended and the telescope is back on the sky doing science. The primary objective of the shutdown, to recoat the 8-meter primary mirror; the mirror now has unprecedented success with unprecedented reflectivity (blue: 470 nm = 93.0 %; green: 530 nm = 95.0 %; red: 650 nm = 95.2 %; near-infrared 880 nm = 96.4 %; thermal infrared 3300 nm = 99.0 %). Also 100 % adhesion was adhesion achieved (see Figures 3-9). "We should get at least as long a life out of this coating as the last one, which

Figure 3.
The Gemini North 8.1-meter primary mirror is inspected inside of the coating chamber.

lasted almost six years!" said Senior Optical Technician Clayton Ah Hee.

While the overarching purpose of this shutdown was the coating of the primary mirror, we took the opportunity of the closed time to accomplish a lot of other tasks. Highlights of the work accomplished include:

- Repair of mirror cover;
- Repairs to the A&G unit; and
- Upgrades and repairs to instruments.

The entire summit team worked exceptionally hard to accomplish everything during this shutdown and deserve congratulations for their remarkable work.

Andy Adamson is Gemini's Associate Director of Operations and can be contacted at:
aadamson@gemini.edu

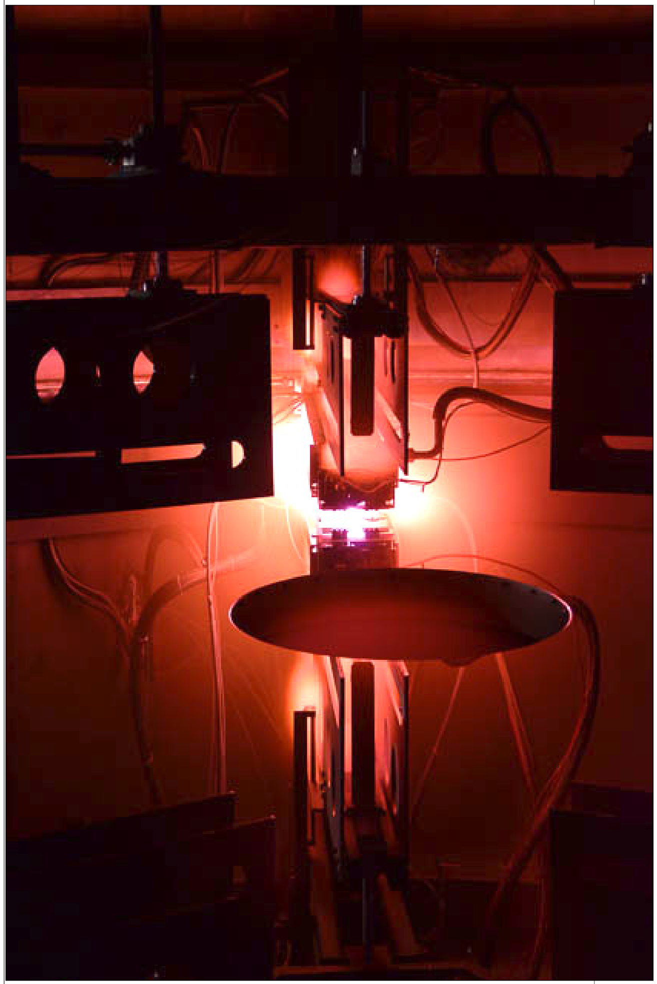


Figure 4. (left)
A view inside of the coating chamber while the magnetron that applies silver to the primary mirror is in operation.

Figure 5. (top right)
The Gemini primary mirror emerges from the coating chamber with a fresh coating of Silver.

Figure 6. (middle right)
Gemini mechanical engineer Marcel Tognetti inspects the primary mirror shortly after it was re-installed in the mirror cell.

Figure 7.
The 8.1-meter Gemini primary mirror being washed (after stripping of old coating) and prior to receiving a new protected silver coating.

Figure 8.
The Gemini primary mirror during cleaning and stripping procedures prior to recoating.

Figure 9.
A rare sight showing all of the Gemini North instruments on the observing floor while the mirror is being recoated.

Scot Kleinman, Bernadette Rodgers, Chad Trujillo

Instrument Development Report

Instrument Development at Gemini is firing on all cylinders, with forward-looking planning into the next decade and a suite of new instruments coming online at Gemini South. From the long-awaited FLAMINGOS-2, to operational improvements on the Gemini Multi-Object adaptive optics System, to the delivery of the Gemini Planet Imager, these new instruments represent the fruits of long, dedicated efforts by our user community and Gemini staff and three highly-anticipated and exciting capabilities for the Gemini South telescope.

During this past quarter, we saw many areas of progress on new instrumentation at Gemini. However, before going into those details, let's look at our longer-range planning, which is also presenting opportunities as well as frustrations.

Since the recent announcement (*http://www.gemini.edu/node/12064*) of the loss of one of the proposed subcontractors for the Gemini High-resolution Optical Spectrograph (GHOS), we have been working closely with the instrument team and our governing and advisory committees to develop the best path forward. As these plans finalize, we will make announcements on the Gemini web site.

Work on the Gemini Remote Access to CFHT ESPaDOnS Spectrograph (GRACES) is proceeding substantially on course. The big accomplishment this quarter is that the fiber cable vendor succeeded in producing, to our specifications, a full-length (270-meter) shielded fiber with connectors. More work, though, is needed before GRACES' final fiber cable (consisting of two shielded fibers in an armored cable) can be reliably developed, which we expect to be completed before the end of this year.

We also made a recent announcement (*http://www.gemini.edu/node/12066*) on the upcoming proposal process for Gemini's next instrument, temporarily named Gen4#3. As current projects finish and resources become available, we will make updated reports regarding our plans and schedule for this new instrument.

In the meantime, there is significant news on the three powerful new instruments at Gemini South. The following sections highlight each of these new tools for our user community, tools which will provide a solid foundation for Gemini's scientific potential for many years to come.

— Scot Kleinman

FLAMINGOS-2 (F2) On Sky, Doing Science

"Gemini Observatory's latest tool for astronomers, a second-generation infrared instrument called FLAMINGOS-2, has 'traveled a long road' to begin science observations for the Gemini scientific community." So begins the early August press release (*www.gemini.edu/node/12047*) showcasing several spectacular F2 on-sky commissioning images and giving an update on the commissioning progress. As this issue of *Gemini*Focus goes to press, we can report that science observations have begun!

The first preliminary science queue data were obtained July 19th, and regular queue observations began in late September. Fifteen queue programs were accepted for execution in 2013B, and Gemini staff have been working closely with the Principal Investigators to prepare their observations for execution. As the data begin to come in during this "shared risk" semester, the Observatory encourages PIs to take an early, and critical, look at them — your data — and provide feedback via your Gemini Contact Scientist.

Despite this exciting milestone, and characteristic of F2's "long road," challenges remain. The latest problem involves the instrument's On-Instrument Wavefront Sensor (OIWFS), used to optimize the delivered image quality to the camera. During the last on-sky checks on the night of August 24th, an alignment problem with the OIWFS became apparent.

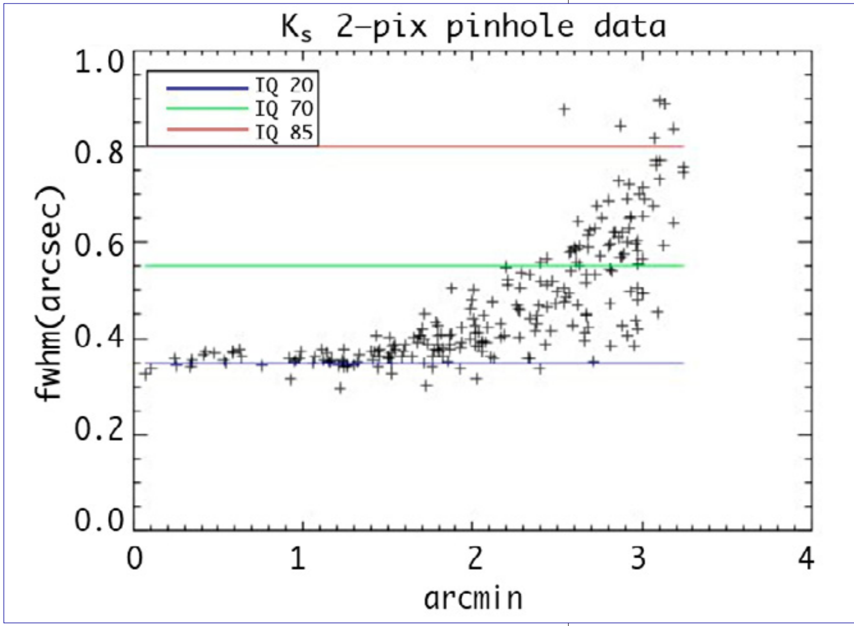


Figure 1.
This plot shows the radial profile for F2's full-width half-maximum (fwhm) for a K_s 2-pixel pinhole. We also show the limits for Image Quality (IQ) observing condition bins: 20%, 70%, and 85%.

An inspection quickly followed, and in the interest of getting F2 back into operations quickly, the mechanism was re-aligned as well as possible with minimum intrusion (*i.e.,* without moving optical components). This is justified given the backup option of using one of the telescope's Peripheral Wavefront Sensors (PWFS2).

Meanwhile, as a more detailed analysis of the cause and proper solution continues, the instrument returned to the telescope on September 9th. PIs with programs in the 2013B queue have been informed of the possibility of reverting to PWFS2, and the observations have been prepared for either option.

With either wavefront sensor, it is also the case that the achieved image quality does not currently meet the design specifications in the outer arcminute of the 6 arcminute field-of-view (see Figure 1). Interested readers can learn more about this on the instrument web pages *http://www.gemini.edu/sciops/instruments/flamingos2/imaging/camera-amp-imaging-properties*.

In parallel to the start of "shared-risk" science operations, Gemini will be conducting an internal "Operations Acceptance Review" for FLAMINGOS-2 before the end of the

2013B semester. The review will take a close look at the performance and operability of F2 in its present state with respect to successfully operating, maintaining, and supporting F2 as a facility-class Gemini instrument, and delivering the expected scientific return to the Gemini community. Feedback from users with early science data will be an important part of the review. The committee will also assess the remaining work going forward, including addressing the image quality and commissioning the powerful multi-object spectroscopy (MOS) mode.

FLAMINGOS-2 is offered to the community again in long-slit and imaging modes for the 2014A semester.

— *Bernadette Rodgers*

GeMS/GSAOI Moving Toward More Robust Operations

By the last quarter of 2013, we hope to have dramatically changed the way we operate the Gemini Multi-conjugate adaptive optics System (GeMS). GeMS has been producing science since late 2012 when the first System Verification (SV) observations occurred. This led to the writing of the first refereed journal article that includes GeMS data ("Haffner 16: A Young Moving Group in the Making," Davidge *et al.*, to appear in *The Publications of the Astronomical Society of the Pacific*, see Science Highlights on page 12 of this issue).

In 2013A, Gemini first offered GeMS to our user community for shared risk queue-based science. Now, in 2013B, the GeMS team is working to make it an operational queue instrument available to all Gemini users as part of normal operations. The major difficulty is that GeMS is an extremely complex instrument — in fact, GeMS has more wavefront sensors (12) than the total number of wavefront sensors the Observatory typically uses for all other science instruments combined at both sites (11). Adding to this complexity is the nightly logistical overhead of clearing targets with the U.S. Space Command (for laser propagation), which must be done several days before observations are made. In addition, aircraft spotters are necessary to ensure the safety of the many civilian aircraft flying above Cerro Pachón every night.

The second key element in this effort will be the upcoming GeMS operational Acceptance Review (AR) in November. The AR will clearly define the extra support personnel and tasks needed prior to each GeMS run to ensure the instrument is ready for science. This effort will include members of many groups across Gemini — Science Operations, Optical Systems, Electronics and Instrumentation, Systems Engineering, Software, Information Systems, and, of course, the Adaptive Optics group — and demand that they work in a coordinated manner.

In addition, the AR will stress that every successful night of GeMS operation requires careful communication between the telescope operator, observer, laser technician, adaptive optics group support, and laser spotters. The key to a successful transition to routine queue operations of GeMS is communication between all of these highly technically savvy individuals.

We also expect the AR to document key performance metrics and identify areas where improvements can be made in 2014 and beyond. As we transition to queue operations, the roles and communications defined in the AR will allow Gemini to navigate a clear path to state-of-the-art adaptive optics success.

During the Chilean winter in June and July, many hardware and software improvements were made to the GeMS system, including the Gemini South Adaptive Optics Imager (GSAOI, the science camera behind GeMS), the laser used to produce the artificial guide stars, and Canopus (the adaptive optics instrument itself). These improvements were made to increase the operability and performance of the system as it enters queue mode.

The most recent GeMS run, from September 12-16, was the first time the system was on-sky since the improvement work was completed in June and July. The major goal of the run was to return GeMS to a state of readiness for queue operations following the shutdown period. This was only partially accomplished, in part due to poor weather during the run (cirrus clouds prevented use of the laser, and poor seeing prevailed), and also because a number of technical issues were uncovered. Despite this, some useful progress was made, including: 1) a number of operational software improvements were successfully tested; 2) the beam transfer optics for the laser were calibrated; and 3) Canopus probes that acquire the natural guide stars were callibrated. In addition, the GeMS team has identified a number of items that will be tested in the next run beginning on September 23rd. Hopefully the weather will be much improved.

— *Chad Trujillo*

Gemini Planet Imager Arrives "Home:" A Travelogue

The Gemini Planet Imager (GPI), Gemini's next-generation instrument for characterizing new worlds, has finally arrived home at Gemini South after a long period of integration and testing at the University of California Santa Cruz. As Stephen Goodsell, who manages the project for Gemini said in a recent Gemini Webfeature, "Now, the fun begins as GPI arrives home and, before the end of this year, gets mounted on the back of the Gemini South telescope and collects light, from real planets!"

As the series of photos in this story shows, GPI is soon to enter the beginning of its scientific life as technicians prepare to mount it on the Gemini South telescope at the end of October. Between the release of this issue of *Gemini*Focus and when GPI is secured on Gemini South's Instrument Support Structure, GPI will be thoroughly tested on the flexure rig at the Gemini South instrument lab and readied for its first photons from space. On-sky testing will then commence leading to early science observations with the instrument during the first half of 2014. These first science observations are to be selected through an open call to the community during the 2014A semester Call for Proposals.

GPI departs for the almost 6000-mile (9700-km) trek from the labs at the University of California Santa Cruz, where the instrument spent the past 2.5 years, to Gemini South.

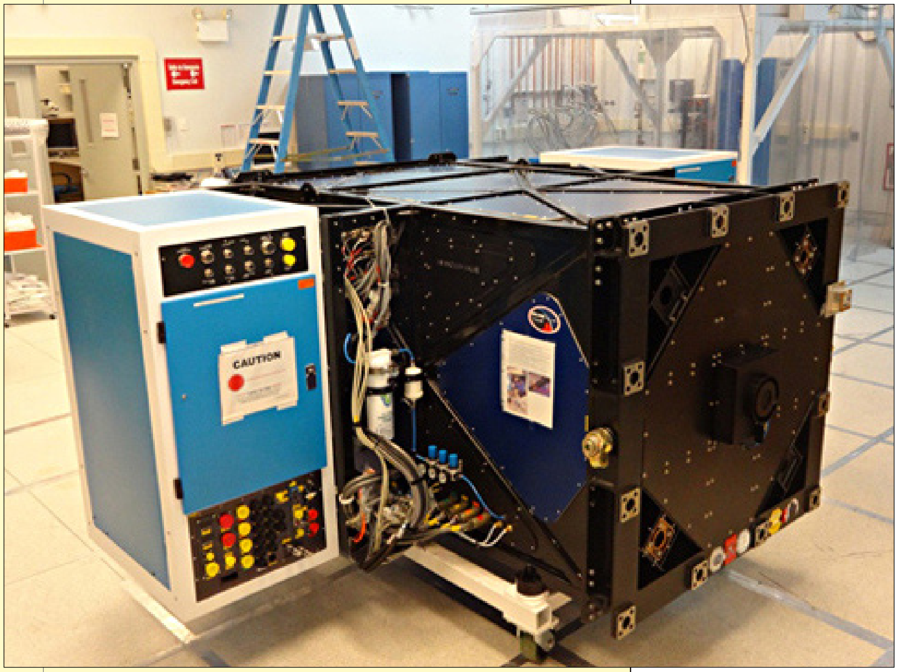
Testing is now well underway, and the team reports that GPI's computers are operational, software integration is complete, and mechanisms are tested and operational, including the deformable mirrors. All cryogenic systems are functioning, and, of special note, the Integral Field Spectrograph is under vacuum and cooled to its operational temperature of 70 K.

Congratulations to the entire GPI team, members of which appear in the last image below.

Scot Kleinman heads the Instrumentation Program at Gemini. He can be reached at: *kleinman@gemini.edu*

Bernadette Rodgers is Gemini South Head of Science Operations. She can be reached at: brodgers@gemini.edu

Chad Trujillo is the head of the adaptive optics group and located at Gemini North. He can be reached at ctrujillo@gemini.edu



Top:

Eighteen hours after leaving the Santiago, Chile, airport, the Gemini Planet Imager arrives atop Cerro Pachón.

Middle:

GPI fully assembled in the Gemini South instrument lab on Cerro Pachón, Chile.

Bottom:

Members of the GPI team celebrate the arrival and assembly of the instrument's systems at the Gemini South instrument lab.

Pauline Barmby

Progress Report from the Users' Committee for Gemini

Recently, the Users' Committee for Gemini met in Hilo, Hawai'i, and addressed numerous issues and other tactical matters that influence our community.

The Users' Committee for Gemini (UCG) represents Gemini users, giving them a voice at the Observatory and providing advice on "tactical" matters affecting them. Complementing this, the Science & Technology Advisory Committee (STAC) covers longer-term, strategic decisions.

On October 18-19, 2012, the UCG held its first face-to-face meeting in La Serena, Chile (see the December 2012 issue of *Gemini*Focus, page 43). It concentrated on assimilating results from a user's survey and formulating recommendations based on that feedback, our own experiences, and data gathered from the Observatory. The results of the meeting were summarized in a report (and Gemini response), available on the Gemini webpage (*www.gemini.edu/node/11953*). One key issue that surfaced during that meeting was that there needed to be better communication between Gemini's staff and its user community. In March 2013, the UCG also held a teleconference to discuss and comment on possible changes to operations proposed by Gemini.

We held the second face-to-face UCG meeting in Hilo, Hawai'i, August 25-27, 2013, which included representatives from all of the Gemini partners. It focused on the changes the Observatory underwent after the withdrawal of the UK, initiatives of the new Director, and pertinent issues brought forth by Gemini users, such as timing and ease of completion for Phase 2 preparation and observation overheads. The Committee, which has added several members to its original seven, visited the Gemini North telescope during nighttime operations to observe queue operations in action.

A Positive Direction

The UCG is pleased to see Observatory activities on a number of fronts that we believe will impact users in a positive way. These include the commissioning of the Gemini South Adaptive Optics Imager and FLAMINGOS-2 instruments, the release of the *Ureka* binary packaging installer for common astronomical software (*ssb.stsci.edu/ureka*), a new version of the mask-masking software GMMPS, forthcoming data-reduction cookbooks, an online forum, and better coordination of Phase 2 responsibilities among National Gemini Offices (NGOs).

We also recommended that the time available for Phase 2 preparation be lengthened by announcing the allocations at least a week earlier than normal — especially for Semester A, where the deadline often conflicts with academic duties for many users. We were happy to hear that the Observatory was already planning such a change. Eavesdropping on queue observations also appears to be off to a good start, and the first call for Large/Long programs will be released soon.

The Observatory is now taking steps to improve communication between Gemini and the NGOs, and will assist the UCG in its efforts to reach out to the Gemini user community. The UCG encourages Gemini users to provide comments and suggestions directly to the Observatory through the feedback forms *http://www.gemini.edu/sciops/data-and-results?q=node/10800*; it also intends to solicit users for feedback directly. Of course, users' comments and suggestions are welcome at any time and can be directed to any UCG member regardless of national affiliation. For current members and contact information, see: *http://www.gemini.edu/science/#ucg*

Pauline Barmby is an astronomer at Western University, Canada, and can be reached at:
pbarmby@uwo.ca

Members of the UCG visit the Gemini North telescope on Mauna Kea. The group stayed to watch evening operations and experienced the observing process first-hand.

Peter Michaud

Gemini Interns: A Glimpse to the Future

Gemini's intern program has never been more active. Especially this year at Gemini North, where, already in 2013, 14 students have participated in diverse projects in science, engineering, and operations.

A critical role for an observatory like Gemini is to inspire and help prepare the next generation of scientists, engineers, and others who want to play a part in our exploration of the universe. We achieve this in many ways — from reaching out to K-12 students, to providing in-depth experiences at the observatory that help prepare university students for successful careers in science.

Figure 1.
Interns Emily Berkson, Mikeala Leners and Andrew McNichols (left to right) are part of this year's "Intern Explosion" at Gemini North!

It is the latter approach that brings a diverse collection of students to both the Gemini South and North offices, every year. Intern programs like Research Experiences for Undergraduates, INSPIRE, and the Akamai Observatory, as well as programs like the one at the University of Victoria in British Columbia are representative of the opportunities available. Gemini Senior Scientist (and frequent intern mentor) Tom Geballe knows how important it is to have these "future scientists" involved in the "nitty-gritty" of our work. He notes that, "Their freshness and eagerness cannot help but inject excitement into our work and renew enthusiasm."

Already, 2013 has been a banner year for interns at Gemini. Specifically, at Gemini North, no fewer than 14 budding scientists have filled the rather "communal" intern's office in Hilo (see Figure 2) so far this year. Here, interns share ideas, life in Hawai'i, and even bicycles as they are challenged with projects and problems that are only found in a working observatory.

While both sites frequently host multiple interns, Gemini Human Resources Assistant Carolyn Medeiros commented on the "explosion" this year at Gemini North. "It's great to have so many interns here. But this year is exceptional, each intern brings so much energy and when it is multiplied by so many at once, it's been an intern explosion!"

Intern Emily Berkson (Inger Jørgensen, mentor), who recently completed her undergraduate studies in astronomy at the University of Arizona, shares her experiences at Gemini North in her blog, which she fills with compelling stories and images. Anyone visiting her page titled "Day Trip VII: Mauna Kea Observing Run" can get a feel for the beauty, exhilaration (and exhaustion) of an observing run at Gemini North — from a perspective that only a student on the mountain for the first time can capture.

Human Resources Assistant Carolyn Medeiros witnessed the "explosion" this year at Gemini North. "It's great to have so many interns here. But this year is exceptional, each intern brings so much energy, and when it is multiplied by so many at once, it's been an intern explosion!"

Emily touts that her time on Mauna Kea was the "peak" of her Hawai'i internship. "Standing atop Mauna Kea at night for the first time is definitely a surreal experience," she says. "The entire four-night stay is something most budding astronomers only dream of doing. I know I'll never forget it!" Readers can find Emily's collection of stories and images at: http://emilyberkson.com.

Jeremy Bullis, working with Mathew Rippa and Chas Cavedoni in the engineering department, was the first Gemini intern from the University of Oregon's program. He arrived through a grant from former Gemini scientist Scott Fisher. According to Cavedoni, "Jeremy quickly got up to speed on a new 24-channel acceleration monitoring kit, providing critical support and expertise in capturing, logging, and analyzing data." Cavedoni adds that Jeremy's support was so critical that they talked him into staying during the recent Gemini North shutdown so he could make more measurements.

While on the mountain, Jeremy recalls that he constantly had a smile on his face, "...like a kid in a candy store! "Like many interns, Jeremy said his time at Gemini was the "experience of a lifetime," adding that he cannot wait to return, "hopefully as an employee instead of an intern!"

The nature of internships is to provide opportunities for students that offer valuable work experience, but also challenge them to complete projects that are beyond the scope of what staff can ordinarily do. Gemini has gained much thanks to the efforts of interns over the years, and if this year's trend continues, lots of exciting times lie ahead for future interns at both Gemini sites.

Peter Michaud is the Public Information Outreach Manager of Gemini Observatory. He can be reached at: pmichaud@gemini.edu

Figure 2.
Interns Hulali Kaapana, Emily Berkson (talking to Data Processing Developer, Kristina Fedorenko), Erini Lambrides, and Erin O'Leary (left to right, back to front) exemplify intern camaraderie at Gemini North.

Two Images Released from Australian Contests

Australian Student Imaging Contest (2013) image of the nearby (8.4 Mpc) spiral galaxy, IC 5332, as well as a cluster of more distant galaxies. The color composite image is composed of images from 4 filters: g (blue), r (green), I (orange), and Hydrogen alpha (red). The field-of-view is 9.8 x 5.4 arcminutes and was made from two pointings using the Gemini Multi-object Spectrograph at Gemini South.

In a special "Live from Gemini" videoconference event in mid-September, students from St. Margaret's Anglican Girls celebrated not only winning the 2013 Student Imaging Contest, sponsored by the Australian Gemini Office, but also the release of the image they selected as a target for Gemini to observe — the galaxy field field including IC 5332 (below). The contest, now in its fifth year, gives Australian students an opportunity to select a target for Gemini to image based on a nation-wide essay contest. St. Magaret's student Isobelle Teljega suggested this year's winning target.

On October 4th (Australian time) Isobelle and her class shared this honor with Paul Fitzgerald, who won the Amateur Astronomer Imaging Contest, which was run in parallel with the student competition. His image of the nebula Gum 85 is featured on the cover of this issue (see detail on Table of Contents page 2).

The Gemini Observatory is operated by the Association of Universities for Research in Astronomy, Inc., under a cooperative agreement with the National Science Foundation on behalf of the Gemini Partnership.

United States

Canada

Australia

Argentina

Brazil

Chile

The Gemini North telescope structure with the mirror cell removed during the September 2013 shutdown. See details and more photos of this shutdown and recoating of the primary mirror starting on page 17.

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