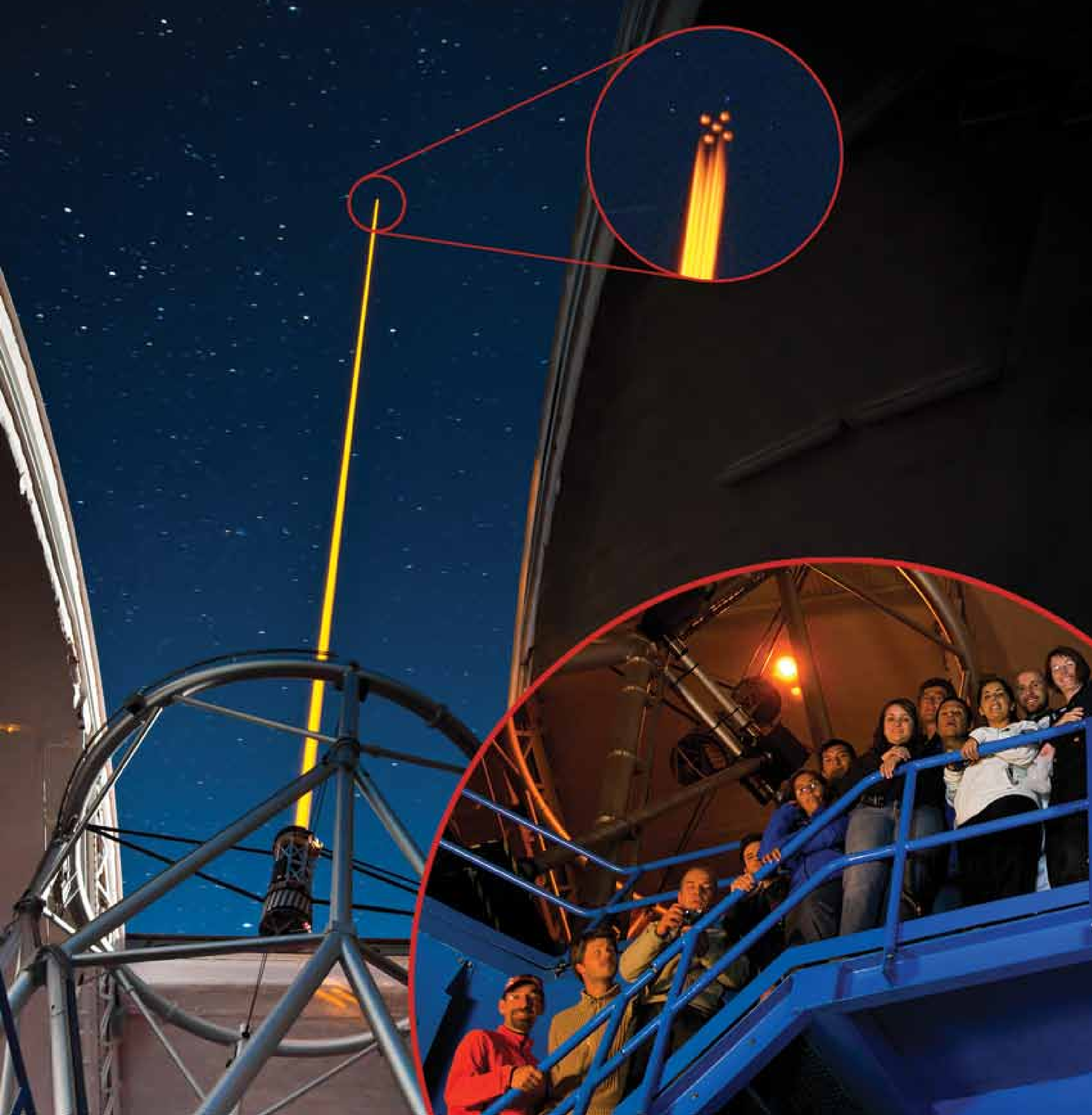
GeminiFocus

June 2011 Publication of the Gemini Observatory



*Gemini*Focus

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Mailing address:
670 N. A'ohoku Place, Hilo, Hawai'i 96720 USA
Phone: (808) 974-2500 Fax: (808) 974-2589

Online viewing: *www.gemini.edu/efocus*

To receive a printed copy of *Gemini*Focus, please send a request (with your mailing address) to: *xzhang@gemini.edu*. *Gemini*Focus is also available in electronic format at: *www.gemini.edu/geminifocus*

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Associate Editors: Stephen James O'Meara and Carolyn Collins Petersen

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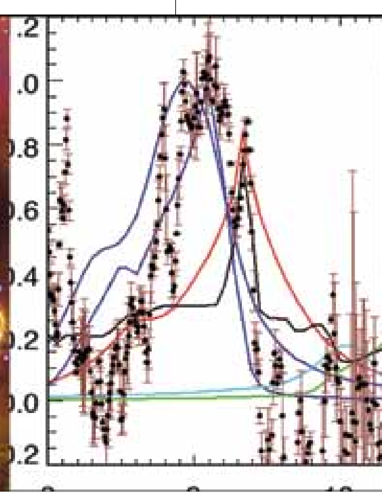
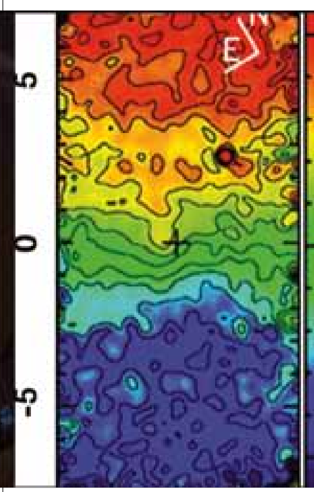
On the cover:
This image composite shows the new Gemini South laser guide star (LGS) system with a closeup of the 5-star LGS constellation as it appears in a small telescope. Below, the laser propagation team, from left to right, includes: François Rigaut, Benoit Neichel, Matthieu Bec, Andrew Serio, Camila Durán, Carlos Segura, Vanessa Montes, Maxime Boccas, Tomislav Vucina, Gelys Trancho, Vincent Fesquet and Celine D'Orgeville.

Gemini telescope and staff photo by Manuel Paredes; inset LGS image by Maxime Boccas.

Back cover:
Gemini North primary mirror reflecting the light of sunset off the interior of the dome. Gemini image by Joy Pollard.





by Doug Simons
Director, Gemini Observatory

Gemini's Move to Base Facility Nighttime Operations

Among the many options considered in response to the budget reductions we face at Gemini, operating the telescopes remotely from the base facilities quickly emerged as an important part of our transition plans. This approach represents significant savings by eliminating transportation and lodging costs for nighttime staff. It also improves safety by reducing the amount of long-distance mountain driving required. Both sites are subject to harsh conditions that can change quickly and require evacuations due to extreme weather from time to time. On Cerro Pachón, remote observing is already conducted by our neighbors at the Southern Astrophysical Research (SOAR), telescope and the new sodium laser at Gemini South has been monitored and operated from Gemini North as part of our distributed laser Adaptive Optics (AO) support model. The difficulty of working on Mauna Kea's approximately 4,200-meter (14,000-foot) elevation, in particular, is well known. We expect the benefits of moving to base facility operations in Hilo to be particularly advantageous to the Gemini North science operations staff, where they will enjoy a more oxygenated environment near sea level. A veteran of observing on Mauna Kea myself, I once spent a total of a month in "open-air" observing conditions conducting a brown dwarf survey using a 24-inch (60-cm) telescope that used to be where Gemini North now stands. After that experience, the prospect of operating a telescope and instruments from Hilo is a profound and welcome paradigm shift for me.

Interestingly, Gemini's move from summit to base facility operations is part of a larger progression that's occurring at many facilities. In most cases, reducing the cost of operating telescopes was an important driver in the decision to develop this new approach across astronomy. It is also doubtless enabled by modern technologies that permit a range of telemetry, diagnostics, and remote-control systems that even some 10-15 years ago was hard to achieve. I point this out because while this move at Gemini may seem novel, in reality, we're riding the same "wave" that many other facilities are generating. I suspect that in the not-too-distant future, the default mode of operating telescopes will be via remote operations, not on-site.

The accompanying photo shows Mauna Kea's summit area. Each observatory circled has adapted to a remote observing mode in one form or another. At the W.M. Keck Observatory, for example, they have perfected the technique of classically running programs from Australia, Waimea, and sites across California. Dedicated standardized observing stations are used by Keck to minimize support requirements, while helping to ensure reliable and effective communications and data transmission. Staff is still present on the summit at night to operate the telescopes, but observations are conducted mostly off-site.

A similar model is used at the NASA InfraRed Telescope Facility (IRTF), though virtual private network (VPN) connections and a simpler interface allow even greater flexibility for observers to connect worldwide. On the upper ridge of Mauna Kea, the United Kingdom InfraRed Telescope (UKIRT), UH 2.2-meter, and Canada-France-Hawai'i Telescope (CFHT), are all fully remote-controlled from Hilo, Honolulu, and Waimea.

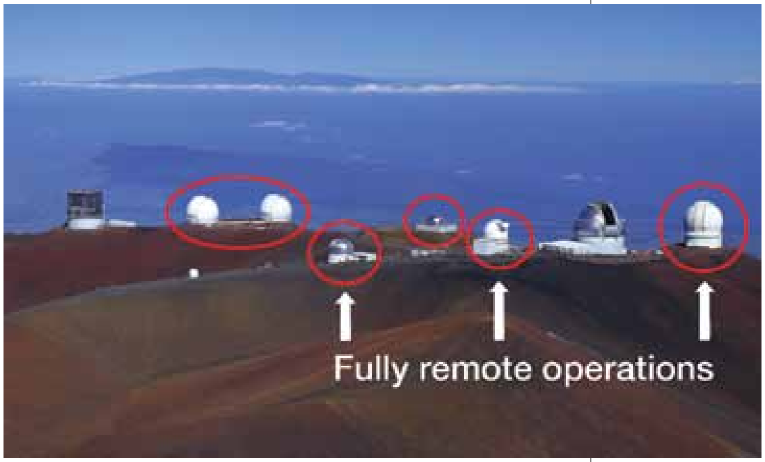
An obvious concern with the absence of staff on-site is telescope safety and the ability to address problems that occur without any human intervention. Mainly, this is addressed through the sophisticated use of monitoring systems that continuously transmit data — like oil pressure in hydraulic drive systems, coolant temperature, voltages on key electronic systems, *etc.* In addition, cameras and microphones are used to provide a network of "eyes" and "ears" for remote observers. Remotely operated power distribution systems are integrated into facilities to make it possible to power-cycle problematic control systems or shut off power-hungry electronics or compressors that do not need to be on during the day.

While all of this adds to the complexity of a facility, this type of automation actually tends to increase its reliability when compared to more conventional approaches. In particular, through data logging, this approach to operating a complex facility makes it easier to trap developing failures in key subsystems before they cascade into serious problems. All of this makes it possible to use predictive, not just preventive, maintenance, to reduce telescope downtime, cut costs, and improve efficiency. In addition, since we have well-established control rooms in La Serena and Hilo and broadband communications across all Gemini sites, and since the telescopes overall are still quite new and modern, much of the core infrastructure needed to enable this new mode is in place at Gemini already.

So, while pursuing this new operating mode carries risks, from a technical standpoint Gemini is already fairly well-poised to make this transition. As a final degree of safety in the entire system, and given the propensity of remote observing elsewhere, we will pursue the formation of joint telescope nighttime support teams that are able to respond to unforeseen issues that might arise at Gemini or our neighboring observatories. The intent is to share costs with other facilities while never leaving them fully unattended.

While we developed this project at Gemini, I deliberately constrained the move to base facility operations only (vs. operations beyond Chile and Hawai'i), to set a well-defined objective for the project. Given budget constraints and all of the other activities we're managing as part of our transition plans, this seemed like a logical and prudent milestone to define. Even though base facility nighttime operations will be the initial form of this new mode at Gemini, we intend to use this as a bridge to broader engagement and access of Gemini by our highly distributed community in the future. Clearly the trend in global communications is to increase bandwidth. This will make it easier for astronomers at either dedicated sites, beyond Chile and Hawai'i or their home institutions, to use easily accessible videocon and computer equipment, to conduct remote observations, and/or eavesdrop on queue observations to evaluate data being taken for their programs.

Figure 1.
Base facility operations, in one form or another, is now commonplace on Mauna Kea. The observatories circled below, including Keck, IRTF, UKIRT, UH 2.2-meter, and CFHT, all use remote observing of some form today. The three facilities (indicated by arrows) on the upper ridge of Mauna Kea neighboring Gemini are operated from Hilo, Honolulu, or Waimea.



Despite all of its benefits, Gemini's reliance upon queue observations has weakened the "organic" link that should exist between the observatory and members of our user community. I am keen to nurture this link through more direct interaction between the two. This link stands to enrich everyone involved. In this way, Gemini's base facility operations plans are really just a segue to much more innovative and modern approaches to conducting observations in the future — one that remains bright as we develop a sustainable and scientifically productive model to operate Gemini for years to come.

Doug Simons is Director of the Gemini Observatory. He can be reached at: dsimons@gemini.edu

by Glenn Orton

Jupiter: Battered from the Outside, Turmoil from Within

Jupiter is one of the most accessible objects to amateur observers. A new breed of amateur astronomers, armed with video cameras and advanced image-reduction freeware, have obtained stunning images that, only a decade or so ago, we might have thought were only possible from an adaptive-optics (AO)-stabilized or even a space-based observing platform. On July 19, 2009, one of these competent amateurs, Australian Anthony Wesley, noticed a new spot on the giant planet.

We know, of course, that the Jovian atmosphere has many features and different-colored storms which routinely come and go. But what made this new feature at about 55° south latitude unusual was its intensity — the spot was darker than anything naturally known to occur on Jupiter's clouds except for shadows from its four largest moons. However, these satellites were not in the right place at that time. So, as Wesley pointed out in an email to the wider amateur community and a few professionals he knew to be studying Jupiter, the new spot looked just like the dark visible "scars" left behind on the planet by various fragments of tidally disrupted Comet Shoemaker-Levy 9 (SL-9) after colliding with Jupiter's atmosphere in 1994.

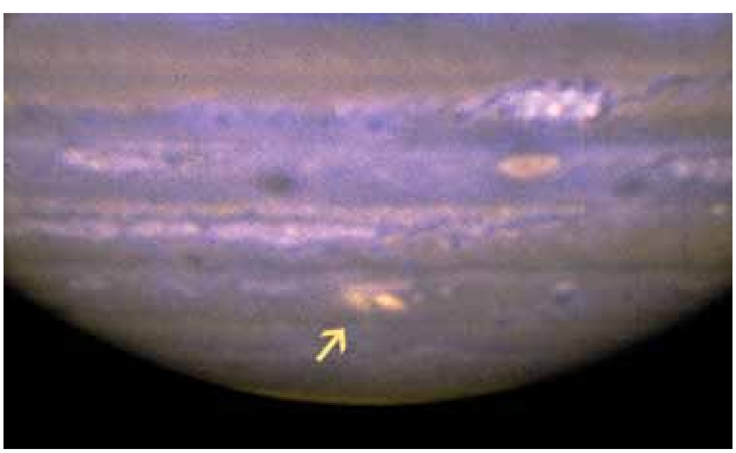


Figure 1. *This mid-infrared composite image was obtained using the Gemini North telescope on Mauna Kea, Hawai'i, July 22, 2009, at ~13:30 UT with the MICHELLE mid-infrared spectrograph/imager. The impact site is the bright yellow spot at the center bottom of Jupiter's disk (arrowed). The image was constructed from two images: one at 8.7 microns (blue) and one at 9.7 microns (yellow). The excellent quality of the Gemini images reveals that the morphology of this new impact bears a striking resemblance to that of the larger impact sites seen after Comet Shoemaker-Levy 9 crashed into Jupiter in 1994.*

Our team just happened to be scheduled to observe Jupiter from the 3-meter NASA InfraRed Telescope Facility (IRTF) on the following night and confirmed that this new feature had all the earmarks of the SL-9-type collision: high-altitude particles detected in the near infrared, elevated temperatures, and ammonia gas. But, it was the quick response by the Gemini North staff to our team's request (led by Imke de Pater, University of California, Berkeley) for Director's Discretionary Time to use MICHELLE, that allowed us to provide a mid-infrared map of the impact site within two days of the event.

The smaller size of the IRTF did not provide sufficient diffraction-limited resolution to differentiate between a central area, which corresponded to the impact itself, and a distinct region of ejected materials distributed in a partial "halo" northwest of the impact site (Figure 1). Five days after the impact, we made mid-infrared spectroscopic observations with the Thermal-Region Camera Spectrograph (T-ReCS) on Gemini South in both the 8- to 13-micron (μm) and 17-to 25-micron regions, which also distinguished between the impact site material and the ejecta. These results were extremely interesting and constituted the "smoking gun" that indicated this impactor might not have been a comet.

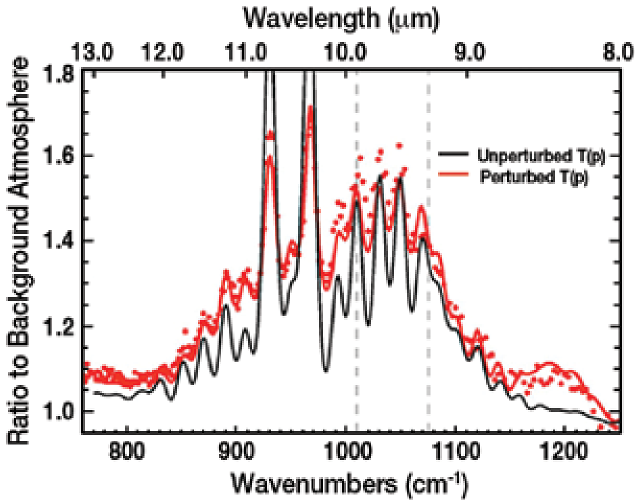


Figure 2.
Spectrum of the 2009 Jupiter impact site (red circles), showing the strong lines of ammonia gas between 9 and 11.5 microns. The red line illustrates the best fit of a model with both enhanced stratospheric ammonia and temperatures; the black line is a model with only enhanced stratospheric ammonia. This illustrates substantial heating of the atmosphere by the impact.

Just as with SL-9, we saw a large amount of ammonia gas, both in Jupiter's stratosphere at the impact site and in the ejecta. This verified that the impact shock wave had penetrated down to the ammonia condensation level near 600 millibars (mbar) of atmospheric pressure and the subsequent atmospheric rebound had transported ammonia up into Jupiter's warm, thermally "inverted" stratosphere, where it could easily be detected as an emission feature.

Analysis of the spectra, led by Leigh Fletcher (University of Oxford), concluded that a total of about 8 x 10^{14} grams (g) of tropospheric Jovian air was "upwelled" into the planet's stratosphere, depositing some 8 x 10^{12} g of ammonia over a 6° longitudinal range above the impact core. It was distributed over the 20-80 mbar region of the stratosphere with a peak abundance of about 1 part per million at the 45-mbar level. Only about one-tenth of this upwelled material was deposited over the ejecta region, consistent with the ejecta being primarily the remnants of ballistically-transported Jovian atmosphere.

We found a localized tropospheric temperature perturbation of 2.0 K at the 200-300 mbar level and a broader stratospheric heating of up to 3.5 K (Figure 2). Significantly different from the SL-9 impacts was the fact that no temperature perturbations were detected above the 1-mbar level of Jupiter's upper stratosphere. As was the case with the SL-9 impacts, we could not fit the spectra without particles, but, more intriguing, rather than the single spectral type implied by SL-9, we detected three distinct spectral signatures. These were distributed over a larger area than was the case for ammonia gas, and they were spatially more inhomogeneous, implying that the particulates were entrained with the rising hot plume that followed the impact. Or, they were created upon re-entry of the plume and quickly redistributed by Jupiter's prevailing winds. A broad 18.5-micron emission feature was not adequately reproduced by a mixture of simple mineral material and remains unidentified. A broad 10-micron feature is consistent with peaks expected from material rich in amorphous olivines but poor in pyroxenes, similar to astrophysical silicates, SL-9, or comets in general.

Finally, a narrow 9.1-micron feature appears most consistent with a mixture of amorphous and crystalline silicas. Figure 3 shows the residual absorption over the best model for stratospheric ammonia gas to fit the observed emission from the impact center, shown as black circles with brown error bars. In order to interpret the source of the absorption, the residual spectrum was compared with a ~ 100-element suite of solid and gaseous mid-infrared thermal emission profiles (solid curves) used to fit the material evolved from the 10.2 kilometers per second (km/s) Deep Impact Experiment, and a number of comets and dusty exoplanetary systems. Included in the suite were profiles due to various sulfates, amorphous and crystalline composition, and amorphous and crystalline silicas. NH_4SH, which might have been a rea-

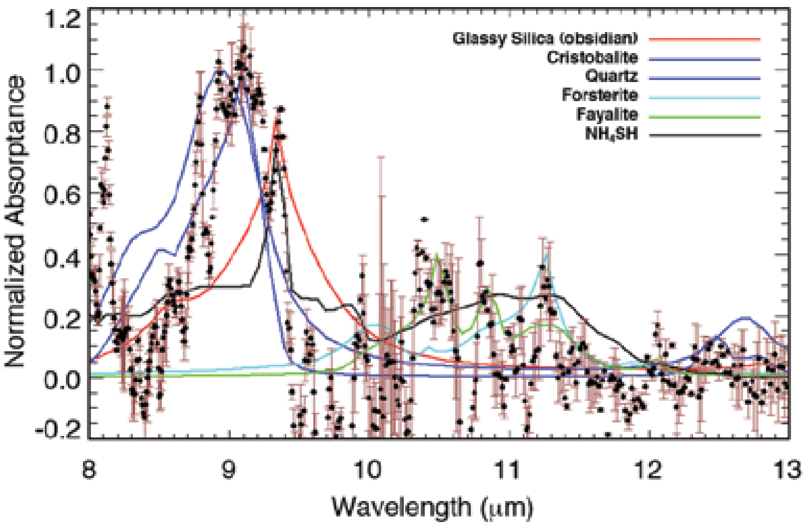


Figure 3. *Residual absorption over the best models for perturbations of stratospheric temperatures and gas at the impact site (black circles with brown error bars), together with candidate constituents (colored lines).*

sonable candidate from Jupiter's own cloud system, has an extremely large emission near 7 microns that was not detected by our 7.8- and 7.9-micron filtered images.

The presence of silica was particularly intriguing because its production requires high temperature and pressure conditions, and it is unlikely that it could have arisen from the collision of icy cometary material. The detection of silica in this mixture of Jovian atmospheric gases — processed bits from the impactor, and byproducts of high-energy chemical reactions — was significant. This is because abundant silica could only be produced in the impact itself, by a strong rocky body capable of penetrating very deeply into the Jovian atmosphere before exploding, but not by a much weaker comet nucleus. No silica was detected in the cometary SL-9 impacts, for example. Assuming that the 2009 impactor had a rock-like density of around 2.5 grams per cubic centimeter, we calculated a likely diameter for the impactor of 200 to 500 meters (m).

This interpretation is consistent with the following: 1) additional high-resolution spectroscopy made using the Very Large Telescope VLT Imager and Spectrometer (VISIR) instrument, which detected more hydrocarbon production over the impact site and less carbon monoxide than was the case for the SL-9 sites, consistent with markedly less oxygen delivery associated with water ice; and 2) less extended debris fields detected by the Hubble Space Telescope ultraviolet imaging than was the case for SL-9 (which also disappeared more rapidly, arguing for heavier or denser particles in the 2009 impact than for cometary ices).

On the other hand, Jupiter should have long ago removed all asteroids from its orbit. Either this impact was a statistical fluke, or the possibility exists that more rocky material exists in the objects that constitute the outer Asteroid Belt or in the Kuiper Belt Objects that are the primary source of impacting comets. There still remains a lot to sort out in the outer Solar System, both among the giant planets themselves and the myriad small bodies that reside there.

Another Impact: When it Rains…

On June 30, 2010, Anthony Wesley made yet another fortuitous discovery. Together with skilled amateur astronomer Christopher Go of the Philippines, they simultaneously observed a flash in Jupiter's atmosphere. Their approach to high-resolution imaging (using video photography and then selecting the best-resolved frames, re-registering and co-adding them) enabled the discovery. The flash was interpreted as a bolide, aka "fireball" — an object burning up in Jupiter's atmosphere.

Again, we immediately requested telescope time to examine the aftermath of this new impact. Among the telescopes involved were Gemini North, using the Near-infrared Imager and Spectrometer (NIRI),

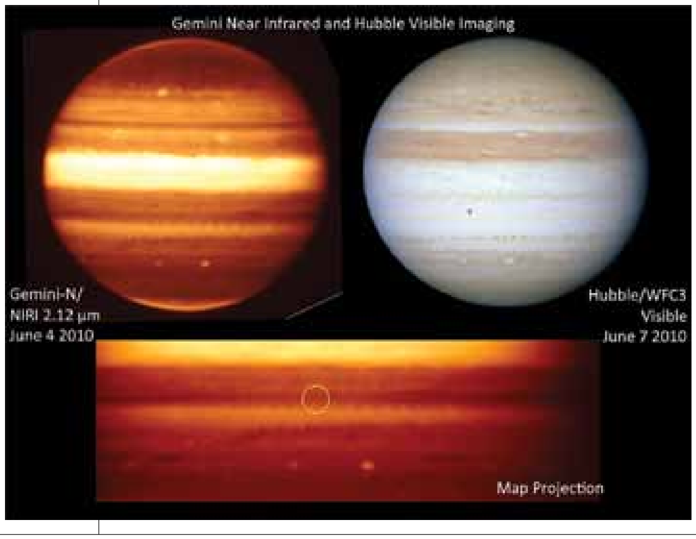


Figure 4. *Gemini near-infrared images of Jupiter (left/bottom) shortly after superbolide event obtained with NIRI on Gemini North, projected impact location indicated by circle in bottom image. Hubble Space Telescope image shown to right.*

and Gemini South, again using T-ReCS. NIRI was used to detect telltale signs of high-altitude particulate deposition at wavelengths where the sunlight reflected back from Jupiter's clouds is mostly absorbed by gaseous methane and molecular hydrogen (Figure 4). T-ReCS provided the ability to detect thermal perturbations and enhancements of ammonia gas, following the phenomenology of the SL-9 and the 2009 impacts (Figure 5). In both cases no atmospheric disturbance was detected (a finding which was also verified by VLT and Hubble Space Telescope data). From the analysis of the red- and blue-filtered bolide flash, led by Ricardo Hueso (University of the Basque Country, Spain), the bolide flash produced a radiant energy on the order of 0.9 – 4.0 x 10^{15} joules, corresponding to a body between 8-13 m in diameter, assuming a density of 2 g/cm^3.

The absence of any influence on Jupiter's atmosphere shows that an impacting object of this size will completely burn up in Jupiter's atmosphere. We would be well-advised to continue watching Jupiter for impacting objects of various sizes as a means to assess the inventory of objects in the outer Solar System that are too small to detect directly, as well as to test models for the influence of impacts on planetary atmospheres.

Turmoil from Within: Another Unexpected Event

At the same time the 2010 bolide was detected, we were witnessing a planetary-scale transformation of Jupiter's major cloud system — one that had been documented several times in the 20th century but had not taken place for nearly two decades. The southernmost of the pair of major dark bands on either side of Jupiter's equator had "disappeared," that is, its dark brown color had faded to match the light-colored regions on either side of it. This region, called the South Equatorial Belt (SEB), had last faded in 1991 and then revived to its typical dark brown color in 1993. We realized that the seeds of the fade were planted back in 2009, and we are now in the process of examining all of our 2009 impact data for additional information on the physical and chemical state of the SEB during that sequence. It appears to have taken place from the "bottom up." That is, the deep atmosphere is most affected initially, followed by progressively higher cloud layers in the atmosphere.

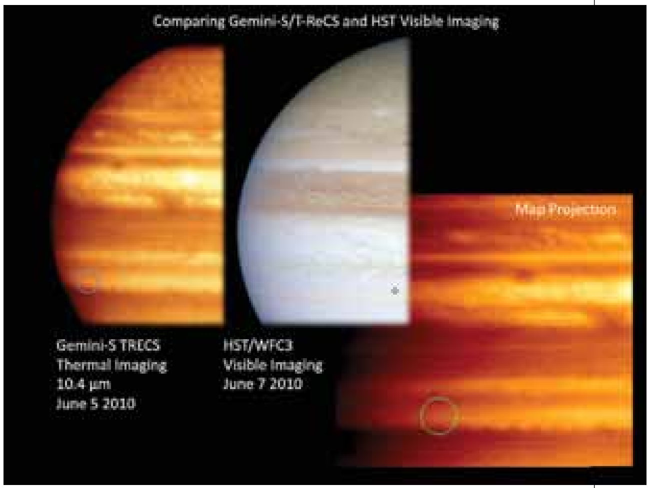


Figure 5.
Mid-infared image of Jupiter (left/right) obtained using T-ReCS on Gemini South shortly after the superbolide event. Projected impact site indicated by circle. Hubble Space Telescope image shown at center.

Although the fade is gradual, the revival is known as one of the most spectacular and energetic events that can be witnessed in Jupiter's atmosphere. This phase of the SEB "life cycle" could take place anywhere from three months to three years after the completion of a fade.

On November 7, 2010, imaging of Jupiter by dedicated amateur Christopher Go provided the first detection of a super-plume of upwelling material in the faded SEB that typically signals the beginning of a revival. (Bad winter weather in Australia prevented Anthony Wesley from also observing the phenomenon on that night.) Following a course that has been well-documented in the 20th century, but never before with such capable instrumentation, we noted that dark regions began appearing following the downstream motion of the plume.

Although probably suffering from "Jupiter fatigue" by this point, Gemini management provided us with more Director's Discretionary Time for NIRI at Gemini North for a combination of AO-guided and non-AO guided imaging at strategic wavelengths. Observations with NIRI's *M*-band filter, in particular, are sensitive to upwelling thermal radiance from a spectroscopic "window" in Jupiter's atmosphere. Brighter emissions diagnose a region clear of overlying clouds to greater (warmer) depths. At the same time, reflected sunlight at shorter wavelengths near 2 microns is strongly absorbed by methane (CH_4) and hydrogen (H_2).

Simultaneously, then, both sets of spectral data provide information on cloud depths, with bright

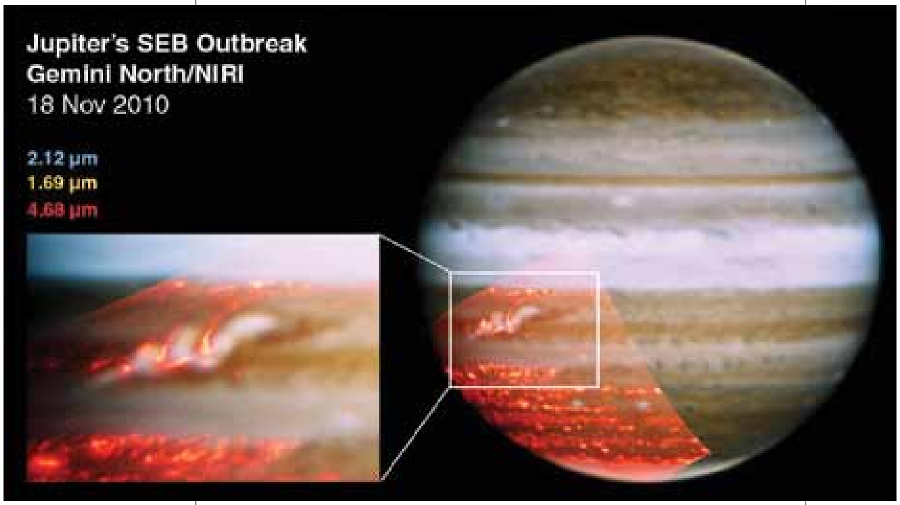


Figure 6. *Composite of three color images taken on November 18, 2010, using the Gemini North telescope in Hawai'i. The composite image shows a belt that had previously vanished in Jupiter's atmosphere and is now reappearing.*

2-micron reflectivity showing the altitudes to which the primary plume, and what were observed to be "daughter" plumes, lofted atmospheric particulates. These regions (Figure 6) were interleaved with regions of dark material, many of which had signatures of bright 5-micron radiance denoting cloud-free areas. Thus, they acted as tracers of vertical motions: high-velocity upwelling vertical winds are signified by clouds, and downwelling, desiccated (dryer) regions were recognized by high *M*-band radiance.

This work is ongoing, and we are currently (March 2011) watching much of the SEB breakout in dark regions. What is intriguing is that the breakouts are taking place in two major features that branch out from the primary upwelling site. The southern branch of dark material is denoted by bright *M*-band radiance, and the dark material is likely to be associated with Jupiter's deeper clouds. However, the dark material in the northern branch is not, and so it must be associated with purely chemical changes that are not associated with vertical depth.

When Jupiter emerges from solar conjunction in the early northern summer of 2011, we will once again examine the extent to which the SEB has "revived" its typical dark color and bright 5-micron appearance. Our plan is to track the changes associated with this revival. We note that recently other regions of Jupiter have also been undergoing large-scale changes. These include a similarly clear northern belt that underwent a comparable fade and quasi-revival from 2002 to 2007, and a major color change (reddening) of the second largest vortex in the Solar System (after Jupiter's Great Red Spot), becoming nearly the same unique red color. All of these phenomena have been placed in the category of a "global upheaval," an unusual—possibly coincidental—period of massive changes taking place in multiple regions of the planet. A possible underlying cause has not been identified.

Our pursuit of these phenomena also has a programmatic motivation for NASA: the Juno spacecraft is scheduled to launch in August of this year. It will reach Jupiter and begin a short period of very close-in orbits in August 2016. We intend to understand the rudiments of the planet's climatology by establishing its baseline behavior.

For more information:

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Glenn Orton, whose hobby is high-performance driving, is a senior research scientist at Jet Propulsion Laboratory, California Institute of Technology, a NASA field center. He can be reached at: Glenn.S.Orton@jpl.nasa.gov

by John Martin and Étienne Artigau

Peering into Eta Carinae's Past with NICI

From 1837 to 1858, Eta Carinae (η Car) produced the largest non-terminal stellar explosion ever observed, setting all-time records in a number of categories, including mass-loss rate, total mass lost, and luminosity. Its "Great Eruption" became the prototype for a class of objects now called "supernova imposters" that survive their eruptions and live to tell the tale as they tangle with undiagnosed physical instabilities at the top of the Hertzsprung-Russell diagram. As the closest and most accessible 100+ solar-mass star, η Car presents us with a very rare opportunity to observe the end stages of a super-massive star from close range.

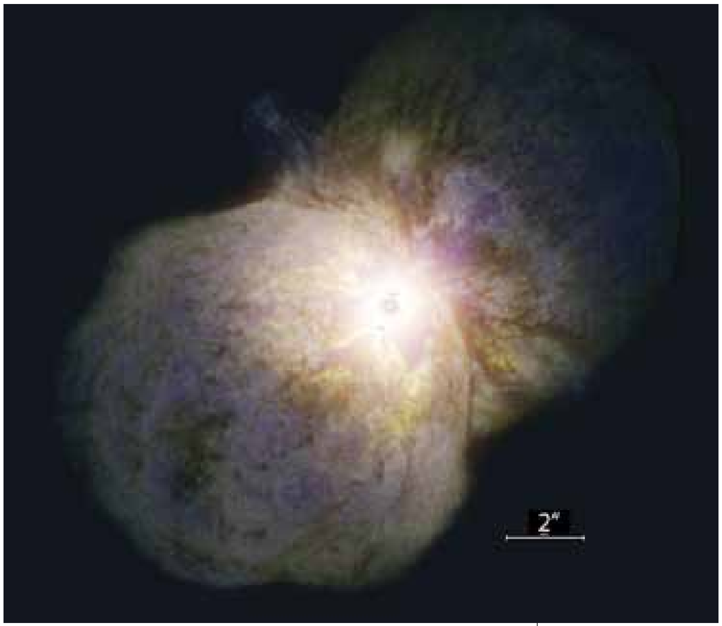


Figure 1.
The combined color composite image of η Carinae without continuum subtraction; Brγ (red), H_2 (green), and [Fe II] (blue). North is up and east is left in this Gemini, NICI image. Note the Little Homunculus is visible even in this image as a brighter region encircling the star.

Most stars evolve very little on human timescales. η Car is a clear exception to this rule. A quick glance at its light curve over the past 200 years shows that the star's brightness has changed dramatically on time-scales ranging from days to decades as it rushes headlong toward its ultimate fate. In the past, it has lulled astronomers into complacency only to change its character completely while we were looking the other way. Because we have not always watched η Car as carefully as we could, reconstructing its past relies critically on understanding the complex ejecta surrounding it. Rather than confirm long-held theories, new information about this object has often challenged established axioms. For example, the Homunculus Nebula, which is so familiar from Hubble Space Telescope (HST) images, caused us to reform many assumptions regarding the structure and symmetry of energetic stellar explosions.

More recent epochs of ejecta are shrouded from view inside the dusty Homunculus. Spectroscopic observations with the HST Space Telescope Imaging Spectrograph by Ishabashi (2003) reveal a structure nested inside the Homunculus known as the "Little Homunculus Nebula." Analysis of the kinematics

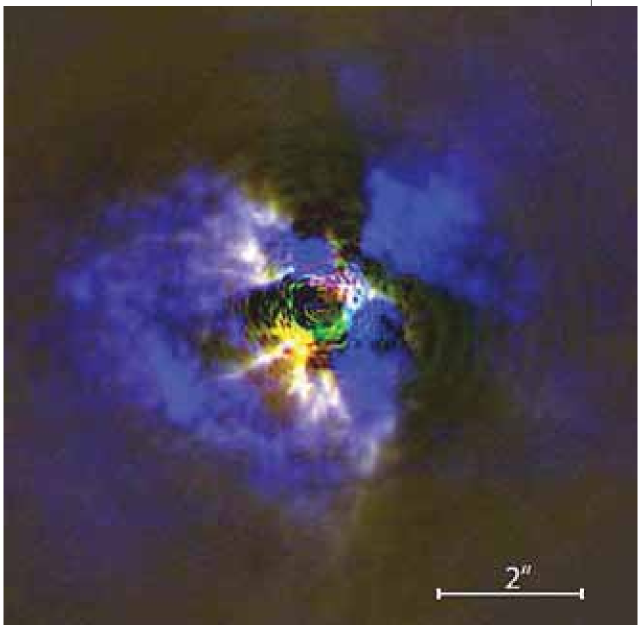


Figure 2. *The combined color composite line minus continuum image; Brγ (red), H_2 (green), and [Fe II] (blue). This figure shows the inner part of the Homunculus and region of the Butterfly. Note the very different distribution of the [Fe II] emission compared with Brγ and H_2. Brγ and H_2 have nearly identical distributions, therefore their combined image, which outlines the Butterfly, appears white or yellowish.*

from the spectral lines revealed this structure was probably produced during a secondary eruption in the 1890's that was mostly shrouded from view by the nascent Homunculus.

Chesneau *et al.* used the Very Large Telescope (VLT) NaCo *J*-, *H*-, and *K*-band imaging to obtain high-resolution views of the Homunculus Nebula between 2002 and 2006. These data revealed a new structure nested inside the Homunculus, the so-called "Butterfly Nebula" centered on the star, with wings that extended up to 2 arcseconds outward. This suggested that the Butterfly might represent a polar outflow separate from the Little Homunculus, while Smith (2006) proposed an equatorial disrupted torus. To determine the true nature and origin of the clumps and knots in the Butterfly, information on its geometry and orientation was needed.

NICI, the Near-Infrared Chronographic Imager on the Gemini South telescope, incorporates adaptive optics (AO) and other techniques to detect the faint infrared light from planets orbiting nearby stars. It is also ideally suited to image the layers of ejecta around η Car. Its relatively wide 17-arcsecond field-of-view is just large enough to include the entire Homunculus Nebula.

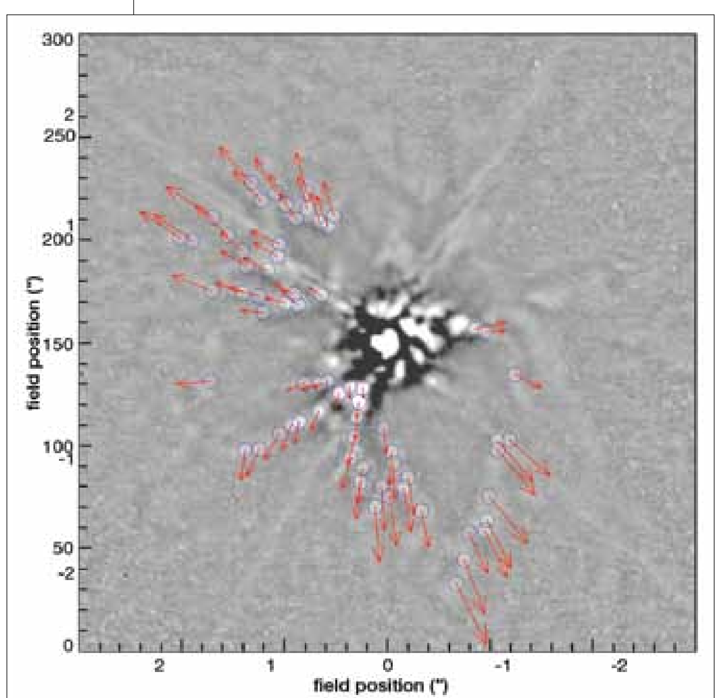
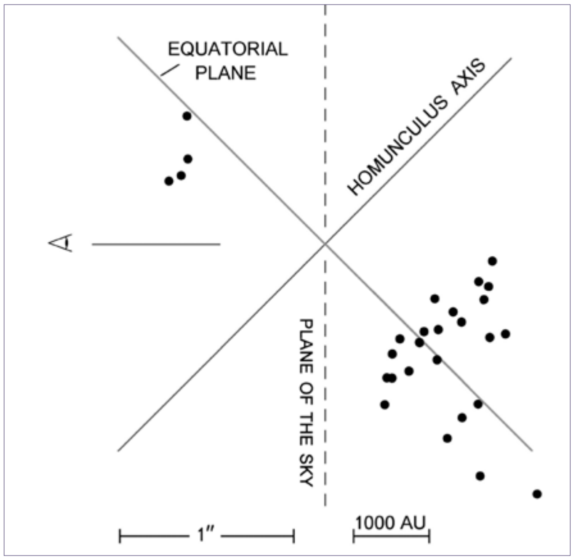


Figure 3. *A map of the proper motions measured for knots in the Butterfly plotted on the NICI K-band continuum image. The arrow lengths are proportional to the total motion in the plane of the sky.*

On an observing run in early 2009 to take spectra of η Car with GMOS, we learned about NICI's capabilities. Kris Davidson, Roberta Humphreys (both of the University of Minnesota), and co-author Martin submitted a Director's Discretionary proposal to use NICI to image η Car. Nothing like this had been attempted with this instrument, so it broke new ground for both us and the NICI instrument team. Co-author of this article Étienne Artigau also joined our effort as an expert familiar with reducing NICI data.

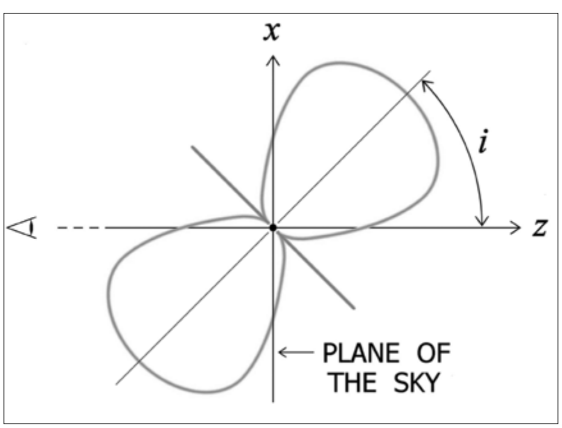
We selected three sets of on- and off-band filters that covered known H_2 and [Fe II] emission as well as Brγ and the *K*-band continuum to produce the corresponding continuum-subtracted emission-line images. Most of the Homunculus fit in the imaging field with the star placed behind a chronographic mask that excluded 95 percent of the light within 0.32 arcsecond of the star. A combination of AO and dithering produced images with effective resolutions of 0.056 and 0.060 arcsecond in the *H* and *K* bands, respectively.

The images are remarkable (Figures 1 and 2). A full description can be found in our paper in the June 2011 *Astronomical Journal*. The H_2, Brγ, and *K*-continuum images all revealed the Butterfly Nebula previously discovered in VLT NaCO images. However, [Fe II] emission revealed a com-



pletely different structure: a bipolar distribution embedded in the larger Homunculus, *i.e.* the "Little Homunculus." They provided unambiguous verification that it is indeed a smaller version of the larger Homunculus Nebula.

We compared our *K*-band images with earlier images taken using the VLT NaCO imager and measured the relative motions of identifiable knots or clumps of reflected emission (Figure 3). Combining those motions with Doppler velocities from spectra, we determined 3-D space velocities of material in the Butterfly. Different parts of this structure have different ejection dates from the star. Some appear to have originated in the Great Eruption of the 1840s, while others may have been ejected in the secondary eruption of the 1890s. Most of the material is projected away from us, behind the Little Homunculus and the southeast Homunculus lobe, distributed above and below the equatorial plane (Figures 4 and 5). The apparent butterfly shape is not a coherent structure or torus but a super-position of two epochs of ejecta 2,000 to 4,000 astronomical units from the star!



The NICI images thus penetrated the Homunculus. The clumps and filamentary features of the Butterfly are apparently part of η Car's famous ray-like equatorial skirt. The origin of this equatorial debris or spray is still not understood, but it is especially interesting that this ejecta was produced in two separate eruptions. We are planning to obtain a second sequence of NICI images on Gemini South. They will provide a three-year baseline to directly measure the expansion of the Little Homunculus and further refine our understanding of the Butterfly. We expect more surprises from η Car in the future, but this time we'll be sure to be watching.

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John Martin is an assistant professor of astronomy and physics at the University of Illinois at Springfield. He can be reached at: jmart5@uis.edu

Étienne Artigau is a research associate at the Université de Montréal. He can be reached at: artigau@astro.umontreal.ca

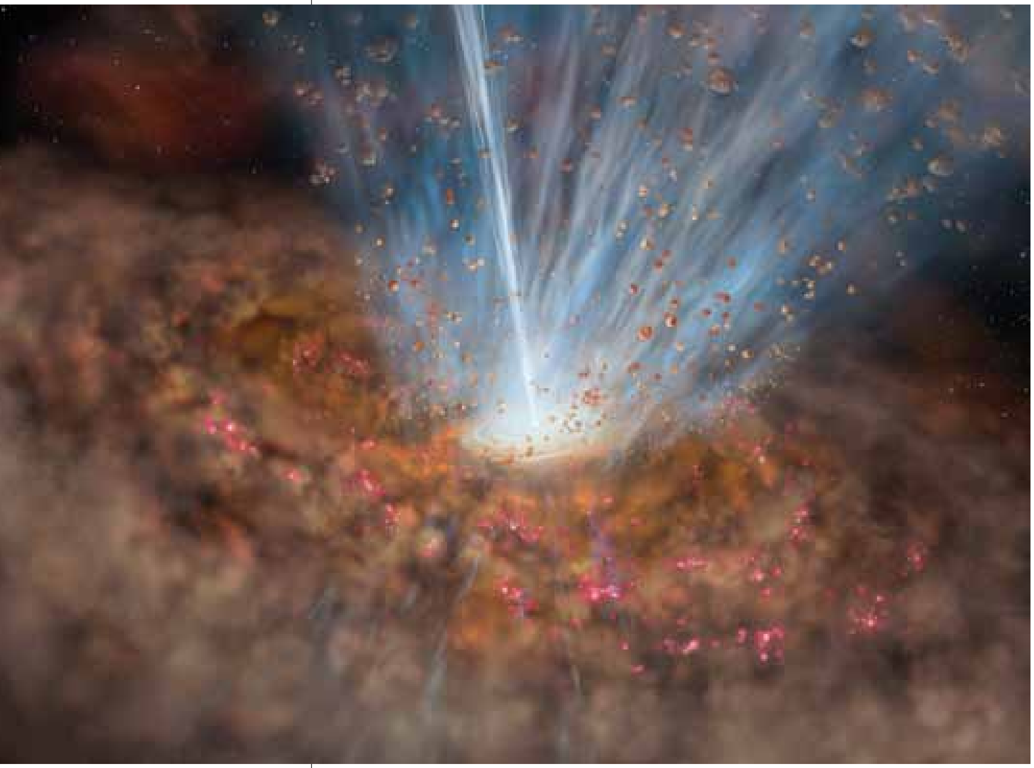
Figure 4.
A side view of the knots in the Butterfly identified in Figure 3. These are 3-D locations derived from position and radial velocity and projected onto a plane orthogonal to the plane of the sky and cutting along the axis of the Homunculus. Since this is a projected view rather than a cross-section, random samples of a circular or toroidal configuration would create a band connecting the upper left and lower right sets of points; the distribution plotted here does not show evidence for such a structure.

Figure 5.
The inclination angle i (40.7º) between our line of sight and the axis of the bipolar Homunculus, adapted from Davidson et al. *(2001). This agrees with the conventional definition of i for binary star orbits, if we substitute the Homunculus equatorial plane for the orbit plane. The total polar diameter of the Homunculus is roughly 40,000 AU, much larger than the area shown in Figure 4. Caveat: the axial symmetry is only an approximation.*

by David Rupke

The First Clear Evidence for QSO-Driven Feedback in a Galaxy Merger

Under the influence of gravity, galaxy interactions and mergers have powerful effects on galaxies of all shapes and sizes. There is a debate about the precise role that these physical processes play in galaxy evolution, but it is indisputable that they are significant players. In particular, they may be important not only in transforming galaxy structure, but also in the growth of supermassive black holes and in episodes of star formation (which are both linked back to structure through galaxy bulges).



An important component in theoretical models of galaxy mergers in recent years has been negative feedback from the supermassive black holes at the hearts of mergers. This negative feedback, in the form of radiation or mechanical energy, is important for two reasons.

First, feedback is a natural way to link the growth of supermassive black holes with the growth of galaxy bulges, leading to the well-established correlation between central black hole masses and bulge masses. The bulge grows through the formation of new stars in a merger, which funnels the gas necessary for star formation into the inner regions. The black hole also receives this merger-driven fuel and proceeds to accrete it. The resulting energy produced by the accretion process eventually expels the gas in the center of the galaxy. A bright, rapidly accreting black hole — a quasi-stellar object (QSO) — is uncovered. The removal of gas truncates the growth of the black hole itself and, if the feedback is on large-enough scales, cuts off the growth of new stars as well. This self-regulation mechanism ties the black hole to galaxy structure.

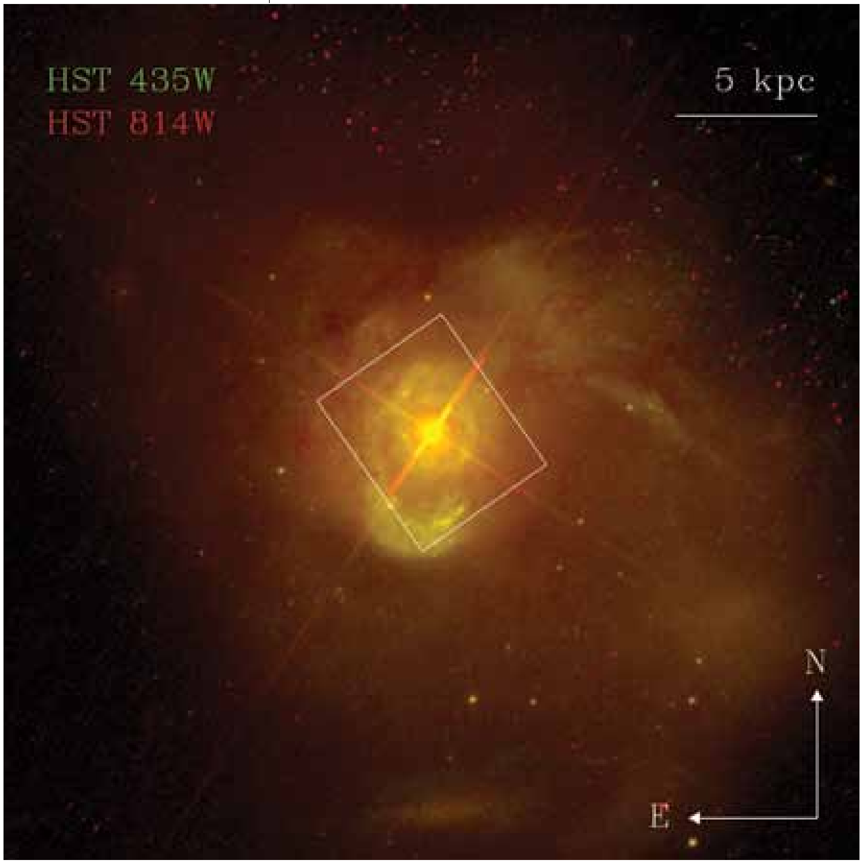


Figure 2.
A two-color Hubble Space Telescope image of Mrk 231, taken in the F435W and F814W filters with the Advanced Camera for Surveys. The white box around the central regions shows the footprint of the GMOS observations.

Figure 1.
(Opposite page) Artist's concept of the environment around the supermassive black hole at the center of Mrk 231. The broad outflow seen in the Gemini data is shown as the fan-shaped wedge at the top of the accretion disk around the black hole. This side-view is not what is seen from the Earth where we see it "looking down the throat" of the outflow. A similar outflow is probably present under the disk as well and is hinted at in this illustration. The total amount of material entrained in the broad flow is at least 400 times the mass of the Sun per year. Note that a more localized, narrower jet is shown. This jet was known prior to the Gemini discovery of the broader outflow featured here. Gemini Observatory/AURA Artwork by Lynette Cook

Second, feedback from merger-driven QSOs can rapidly transform star-forming galaxies (with blue optical colors) into red-and-dead elliptical galaxies, so-called because of their red optical colors and lack of ongoing star formation. Observations point to a strong duality in galaxy colors between blue and red galaxies, with a weakly populated intermediate region. This suggests that transformation between the two classes is relatively fast; *i.e.* most galaxies spend their time as red or blue. Energy from star formation and black holes can quickly remove gas from star-forming regions. Thus, feedback is an easy way to shut off star formation and change a blue galaxy into a red one.

Types of Outflows in QSOs

These attractive theoretical drivers have led to a re-examination of outflows of gas in QSOs. Such outflows, in various forms, have been intensively studied for years, but attention is now being focused on the global impact they have on their host galaxies. They can take varied forms. 1) Collimated, relativistic jets of matter, channeled by the magnetic fields around the black hole, start on small scales but can emerge from the host galaxy. However, the influence of such jets within the host may be confined to a small volume due to their narrow opening angles. 2) Broad-line winds subtend a much wider angle and take on velocities up to 10 percent of the speed of light. Most broad-line winds are confined to the inner parsecs around the black hole, so they may also have only a small impact on their hosts. And 3) in large-scale winds, the QSO power is efficiently converted into forms that can emerge on large scales by coupling to ambient gas in the host galaxy. These winds have smaller velocities than jets or broad-line winds, while having a much broader impact on their host.

Despite many years of data, observers have struggled to pinpoint clear cases of QSO-driven feedback removing large amounts of gas from the centers of mergers. Outflows driven by star formation are ubiquitous in major mergers (where the masses of the two merging galaxies are similar), and estimates of the masses of these outflows are high. But, no case of a massive, large-scale outflow obviously driven by a QSO exists in these systems. Such outflows can

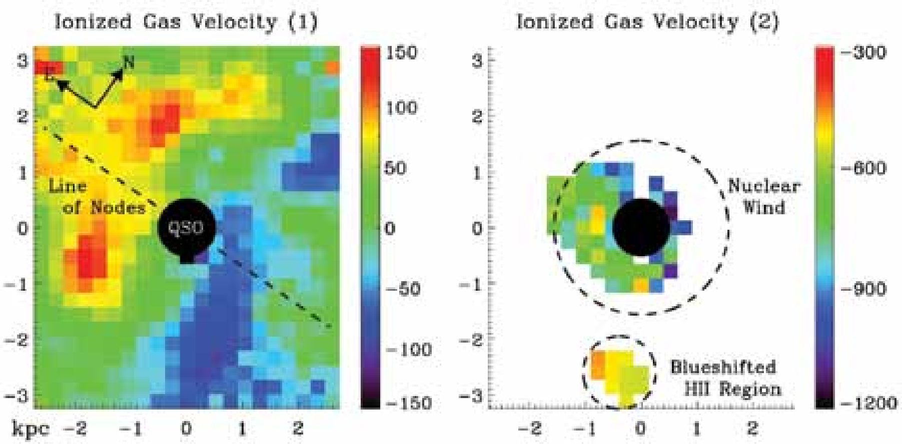


Figure 3.
Maps of the ionized gas velocities across the central regions of Mrk 231. A rotating gas disk is evident (left panel), as well as a high-velocity nuclear outflow (right panel).

be distinguished from starburst-driven winds by their higher velocities. Power from the QSO need not be invoked to explain low outflow velocities.

Integral Field Observations of Markarian 231

The nearest, and arguably the best, laboratory for studying QSO feedback in a major merger is the ultraluminous infrared galaxy Markarian 231 (Mrk 231, Figure 2). It hosts all three of the outflow types discussed above. However, the origin and mass of its large-scale wind were initially unclear. Long-slit spectra that we published in 2005 showed kiloparsec-scale winds moving faster than 1,000 kilometers per second (km/s). This is suggestive of a QSO power source. However, the observations were taken along the axis of the radio jet. That jet could explain the high velocities, but it would have less impact than a wind with a broad opening angle.

We observed Mrk 231 with the Gemini Multi-Object Spectrograph (GMOS) integral field unit on Gemini North in order to gain a better understanding of the structure and power source of its large-scale wind. We focused on tracers of both neutral gas (Na I absorption lines) and ionized gas (Hα and [N II] emission lines). Because the QSO is so much brighter than its host galaxy, we had to carefully subtract the nuclear point source from the host galaxy's light using spectral modeling. We then fit the profiles of the absorption and emission lines to determine their velocity structures.

A Large-Scale, High-Velocity Wind

The emission lines (Figure 3) reveal a rotating disk of gas around the QSO, which was known previously from molecular gas observations. This disk is forming stars at a rate of 170 solar masses per year. A second velocity component shows highly Doppler-shifted gas confined to the inner kiloparsec of the system. This gas has blueshifted velocities exceeding 1,000 km/s, but its origin and mass are uncertain. (It could be related to the well-known narrow-line region of active galactic nuclei.) Furthermore, blue-shifted emission lines can be outflowing or inflowing.

Fortunately, the neutral gas provides clear evidence for a QSO-driven outflow. Figure 4 shows that there is a large region of interstellar absorption surrounding the QSO, reaching 2-3 kiloparsecs in every direction (in the plane of the sky).

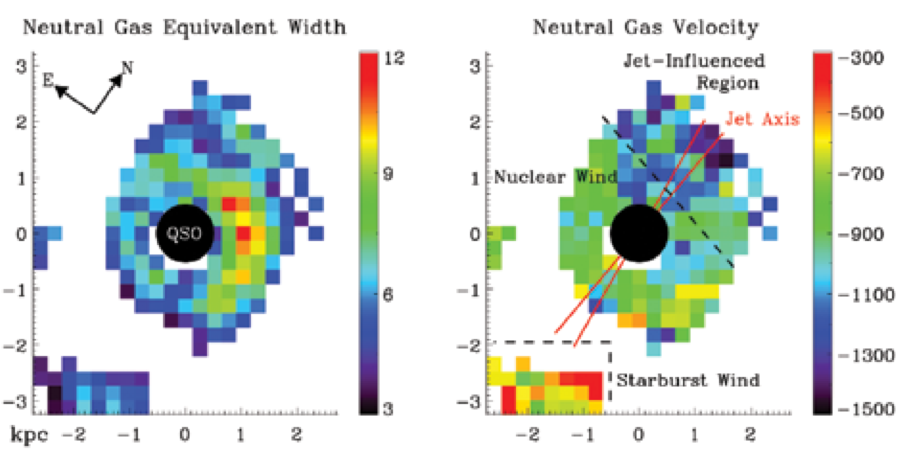


Figure 4.
Maps of the neutral gas equivalent widths and velocities in Mrk 231. Significant absorption (left panel) arises up to 2-3 kiloparsecs from the nucleus in every direction, as well as above a star-forming region to the south. The high velocities (right panel) around the nucleus point to a QSO-driven wind. The wind is further accelerated by the radio jet in the north.

Blue-shifted absorbing gas is unambiguously outflowing. The peak velocities of this outflow are high, averaging almost 1,000 km/s. Along the radio jet, the gas is accelerated to even higher velocities, reaching 1,400 km/s.

The high velocities of this outflow point to the QSO as its power source. The observed velocities are much higher than in any starburst-driven outflow in a major merger in the local universe. The morphology of the outflow also implicates a power source acting over large volumes, rather than the narrow impact of a radio jet.

Using simple models, we estimate that the outflow is carrying the equivalent of 400 solar masses per year of gas out of the galaxy's nucleus. Compared to the rate at which the galaxy is forming stars, this is significant. In other words, the outflow can deprive both the black hole and star-forming disk of the material needed to grow. The energy carried by the outflow is a tiny fraction (less than one percent) of the QSO's radiated energy, so the QSO can easily power the outflow.

The large-scale outflow has also been detected using single-aperture spectroscopy with the Herschel Space Observatory, which reveals similar gas velocities in the molecular phase. Recent molecular gas imaging also points to high velocities and significant outflow masses, though the outflow has only been marginally resolved in carbon monoxide (CO) lines.

Implications and Future Work

Is this the QSO feedback predicted by the models? The Mrk 231 outflow fits the criteria: a massive, energetic outflow emerging in all directions (in the plane of the sky) from the galaxy nucleus. The outflow is clearly powered by the QSO, and is transporting significant amounts of gas away from the regions of black hole activity and star formation. As the old saying goes, "If it looks like a duck, swims like a duck, and quacks like a duck, it must be a duck."

Thus, Mrk 231 is highly likely to host QSO-driven feedback.

However, this is only one galaxy. History suggests that drawing broad conclusions about a class of astronomical objects from a single data point is dangerous. With that caveat in mind, the current observations are a promising development, and should clearly motivate future searches for large-scale winds in QSOs.

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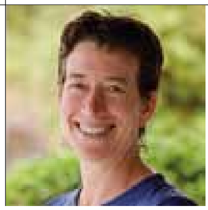
David Rupke is an assistant professor of physics at Rhodes College in Memphis, Tennessee. He can be reached at: drupke@gmail.com.

The work described here was done in collaboration with Sylvain Veilleux, Professor, University of Maryland.



by Nancy A. Levenson

Science Highlights

Measuring a Massive Black Hole

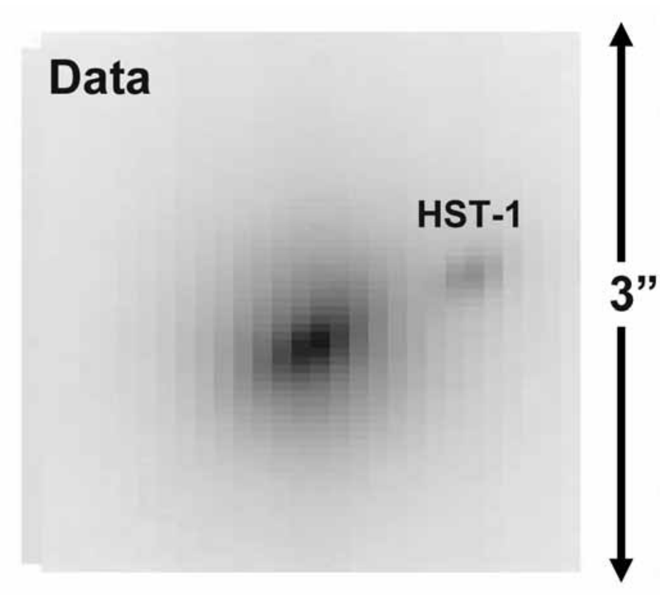
M87 is a nearby luminous galaxy that offers excellent opportunities to measure its physical properties accurately. An important property is the mass of the central black hole, since black hole growth is fundamental to galaxy formation and evolution in general. The conclusion from Karl Gebhardt (University of Texas) and collaborators, who used the Near-infrared Integral-Field Spectrograph (NIFS) on the Gemini North telescope to study the central region of the galaxy, is that M87 hosts the most massive directly-measured black hole, with a mass of 6.6 x 10^9 solar masses (*The Astrophysical Journal*, **729:** 119, 2011).

Measurements of black holes in massive galaxies remain crucial. The central black hole mass is correlated with a galaxy's stellar velocity dispersion. The result from M87 is somewhat discrepant, however, suggesting that the correlation is not well calibrated at the high-mass (and high-galaxy-luminosity) end.

Figure 1. *Artist's concept of the black hole at the heart of the galaxy M87. Clumpy gas swirls around the black hole in an accretion disk, feeding the central beast. The black area at center is the black hole itself, defined by the event horizon, beyond which nothing can escape. An energetic jet of material flowing away from the black hole appears in bright blue. Gemini Observatory/AURA illustration by Lynette Cook.*

While the mass of M87's black hole had been estimated previously, the improved sensitivity of these new observations yields a more robust result. The data were obtained with NIFS using laser guide star adaptive optics (AO). With these capabilities, scales of less than 10 parsecs (about 30 light-years) are resolved over the central three arcseconds of M87 (Figures 2 and 3). The black hole's region of influence is isolated on these small scales, reducing confusion of the mass contributions of stars and dark matter. Indeed, this black hole measurement is insensitive to assumptions about the galaxy's dark matter halo, although this component remains significant on larger scales.

Detailed stellar dynamical models are essential to determine black hole mass from the data. The team considered a variety of orbital shapes and



orientations that may result in the observed projected velocity dispersion (when combined with a possible black hole). The preferred stellar models show a relative lack of radial motion, which could be a consequence of a binary black hole or the destruction of stars on radial orbits, either by accretion onto the black hole or ejection from the central region.

M87 remains an important example of central supermassive black holes, and this type of work can be extended to other more distant massive galaxies in the future. Utilizing the good spatial resolution and sensitivity of NIFS with AO offers the possibility of reconciling the outstanding discrepancies in the correlations of galaxy properties in order to account for galaxy formation and evolution more completely.

Figure 2.
Near-infrared image of the center of M87 showing emission from the active galactic nucleus and its associated jet (including features such as the knot labeled HST-1), along with the stars. In this negative image, the brightest emission regions appear dark. The image is 3 arcseconds on a side, which corresponds to about 260 parsecs (about 850 light-years).

Galaxy Evolution in Groups

Galaxy groups are good places to study galaxy evolution. They do not have such extreme environments as galaxy clusters, where severe dynamical effects subject their members to strong interactions and gas stripping. In order to measure sufficient contrast with the field galaxies not in the group, however, observations of relatively high redshift groups (z~1) are essential.

Initial results from Michael Balogh (University of Waterloo, Canada) and collaborators studying high-redshift groups already point to differences between group galaxies and those located in the low-density field (Figure 4). They find that red galaxies of all masses appear in groups. This is in contrast to the comparison samples that appear to lack the low-mass (less than $10^{10.5}$ solar mass) examples. While some blue galaxies are group members, they are relatively rare compared with the field. In order to account for the relative absence of blue, high-mass members, the group environment could either have the effect of reducing the star-formation rate in total or prevent rejuvenation of star formation in a repeating cycle of galaxy evolution.

One interesting outcome is the discovery of a significant fraction (around 30 percent) of intermediate-color (green) galaxies in groups. Previous work had distinguished the “green valley” from blue and red populations, but an outstanding question had been whether this result was merely a consequence of dust (which would make intrinsically blue galaxies appear redder) as opposed to a genuinely different population. Here, the team suggests that these represent

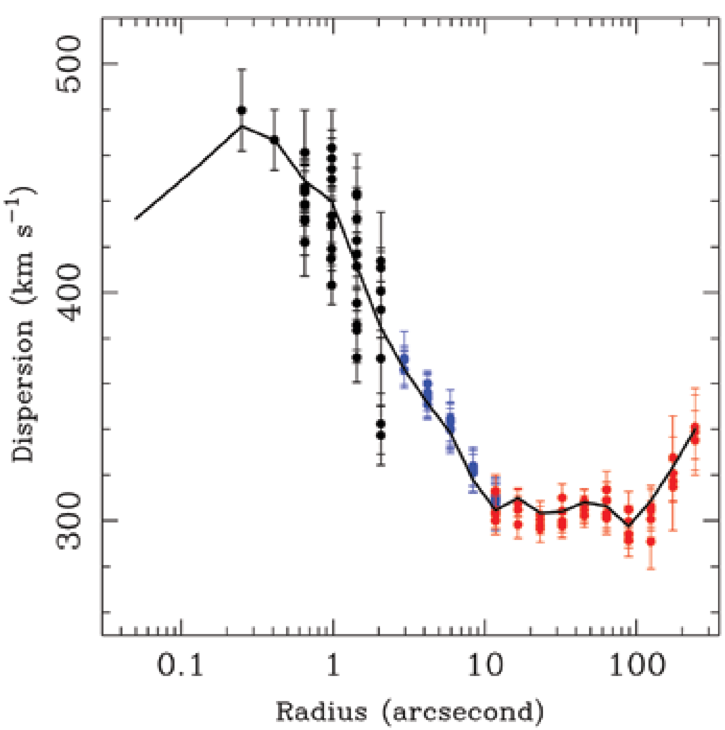


Figure 3.
The NIFS data (black points) show the velocity dispersion as a function of radius within the central arcsecond (around 90 parsecs (about 290 light-years)) of M87, where the black hole mass dominates. Other observations contribute to the larger-scale measurements.

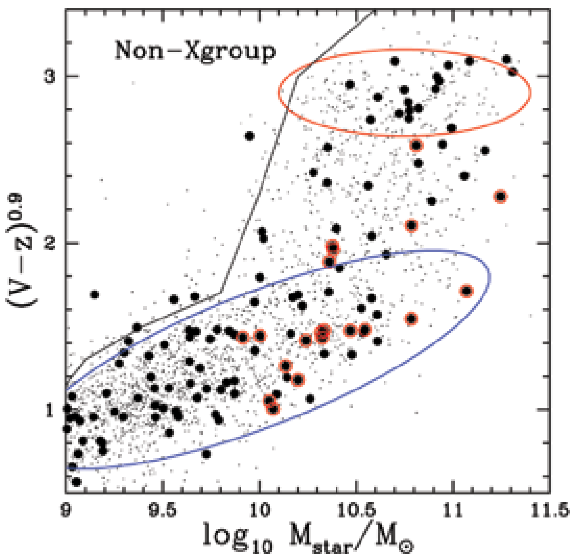


Figure 4. *The distributions of galaxy color and stellar mass are different for the field galaxies (left) compared with members of X-ray measured groups (right). The groups include red galaxies at all masses (in the upper red ellipse), have relatively few blue galaxies, especially at higher masses (in the lower blue ellipse), and include a significant population of intermediate "green" galaxies. The large black points all have secure spectroscopic redshifts and are the basis of this work. The smaller points indicate the underlying parent population from which this sample was selected.*

a transient population, as galaxies evolve from a blue star-forming stage to a red quiescent period. Hubble Space Telescope images also support the interpretation that these represent truly intermediate conditions, showing morphology between the well-structured disks that are characteristic of the blue cases and the generally elliptical appearance of the red ones.

In order for a galaxy to spend significant time in the green phase, simple stellar population synthesis model fitting implies that after an initial period of constant star formation, the timescale for subsequent decline of such activity is moderate (0.6 to 2 billion years).

The observations were obtained using the Gemini Multi-Object Spectrograph (GMOS) on Gemini South. The nod & shuffle mode was key for good sky subtraction and redshift measurements, yielding spectroscopic redshifts that are more than 80 percent complete for I < 24. The current work, published in *Monthly Notices of the Royal Astronomical Society* (**412:** 2303, 2011), presents the results from six groups. The team's complete sample includes 20 groups, all of which have been detected in X-rays, as well.

No Remnant Planetary System around Sirius B

Planetary systems form in the debris disks around stars, and excess infrared emission in stellar observations is a signature of these metal-rich environments. Dusty disks can persist to late stages of stellar evolution, and they are likely responsible for observations of "polluted" (metal-rich) atmospheres measured in some white dwarfs, being the source of enriched material the white dwarfs accrete.

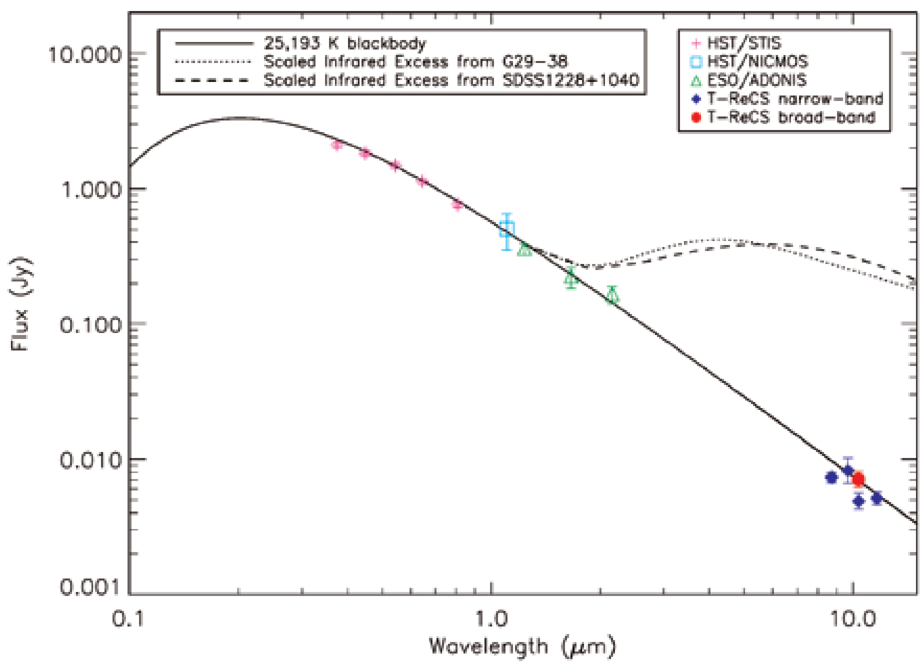
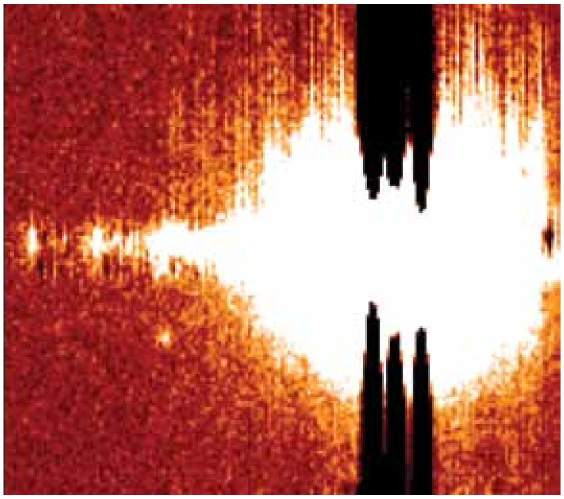


Figure 5. *Spectral energy distribution of Sirius B, including data from the Hubble Space Telescope, European Southern Observatory 3.6-meter telescope, and T-ReCS on Gemini South. The solid line, a 25,193 K blackbody, describes the data well. In contrast, the spectral energy distributions of white dwarfs showing excess infrared emission (broken lines) exceed the observed mid-infrared emission significantly.*



Previous observations had suggested that Sirius B, the nearest white dwarf to the Sun, shows an infrared excess. However, in a new paper (*Astrophysical Journal*, **730:** 53, 2011), Andrew Skemer and Laird Close (University of Arizona) conclude that Sirius B does not have a significant dusty disk, and thus, shows no sign of a remnant planetary system. This result cleverly uses a large number of archival observations made with the Thermal-Region Camera Spectrograph (T-ReCS) on Gemini South, which are available because its companion, Sirius A, is a mid-infrared photometric standard, so it is observed frequently (Figure 5).

Combining the observations, Skemer and Close obtained accurate photometry of Sirius B at several mid-infrared wavelengths. These measurements are all consistent with a T = 25,000 K blackbody, as Sirius B exhibits at optical and near-infrared wavelengths (Figure 6).

Resolving the Feeding and Feedback Mechanisms in M81

The nearby galaxy M81 offers an exceptional opportunity to measure the motion of stars and gas at high spatial resolution around its low luminosity active nucleus. At a distance of only 3.5 megaparsec (11.4 million light-years), one arcsecond corresponds to 17 parsecs (pc; 55 light-years). Observations made with the integral field unit of the Gemini Multi-Object Spectrograph (GMOS) on Gemini North provide sub-arcsecond resolution, revealing both inflowing gas that could feed the central engine and the outflowing material that may be a crucial part of the feedback mechanism between star formation and black hole growth in galaxies.

With these 3-D data, which provide a spectrum at each location in the central galaxy image, Allan Schnorr Müller (Universidade Federal do Rio Grande do Sul, Brazil) and colleagues use the characteristic absorption features to trace the stellar motion (Figure 7; *Monthly Notices of the Royal Astronomical Society*, 2011, in press). The net effect shows rotation, and the velocity dispersion leads to a bulge mass of 210 million solar masses. The correlation of bulge and central black hole masses then implies the mass of the black hole to be 55 million solar masses, which is similar to previous results.

The gas is evident in emission lines and shows strong non-circular motions. Several areas show strong blueshifts (of around 100 kilometers per second), suggesting that gas streams into the nucleus. The rate of ionized gas inflow is comparable to the accretion rate required to power the active nucleus.

Additional results come from principal component analysis (PCA) of the data. This technique identifies the key spectral features of the data, and "tomographic" images can be constructed to show the spatial distribution of these characteristics. Not surprisingly, the dominant component is associated with the nucleus and stellar bulge. Most interesting are the weaker components that seem to be associated with the gaseous disk and outflow. The

Figure 6.
T-ReCS 8.74-micron image of Sirius A and B. The individual observations are shifted to align on the calculated position of Sirius B, the fainter source in the lower left quadrant. The full image is 13 x 18 arcseconds, and Sirius B is separated by 6.75 arcseconds from Sirius A, and is about 20,000 times fainter.

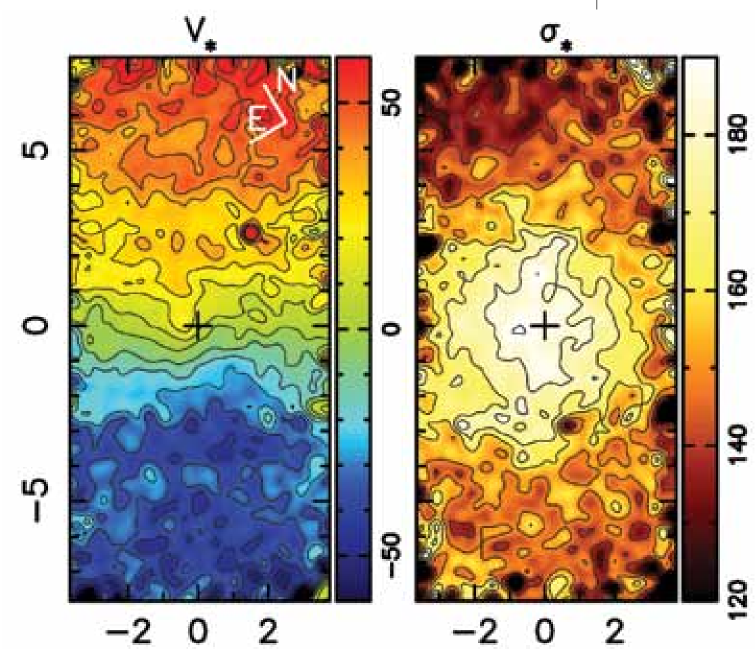


Figure 7.
Stellar velocity centroid (left) and velocity dispersion (right) around the nucleus of M81 (marked with +). The velocity field shows rotation, and the residual velocity dispersion allows determination of the stellar mass and central black hole mass. The image sizes are measured in arcseconds, and scale bars indicate the values, measured in kilometers per second.

Figure 8. *The stars showing detectable helium absorption (filled circles), which corresponds to increased helium abundance, also have increased light element abundances ([Na/Fe] and [Al/Fe]). Thus, enhanced helium is associated with a second generation of star formation in Omega Centauri.*

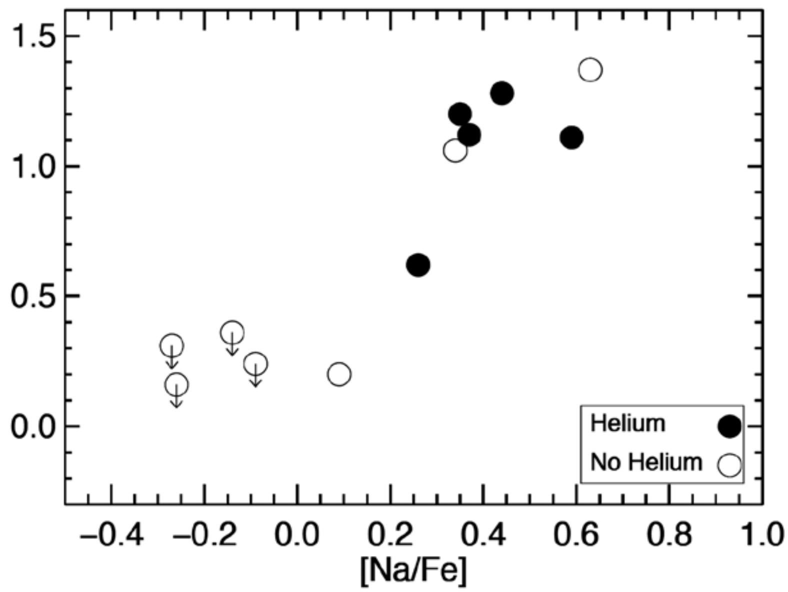
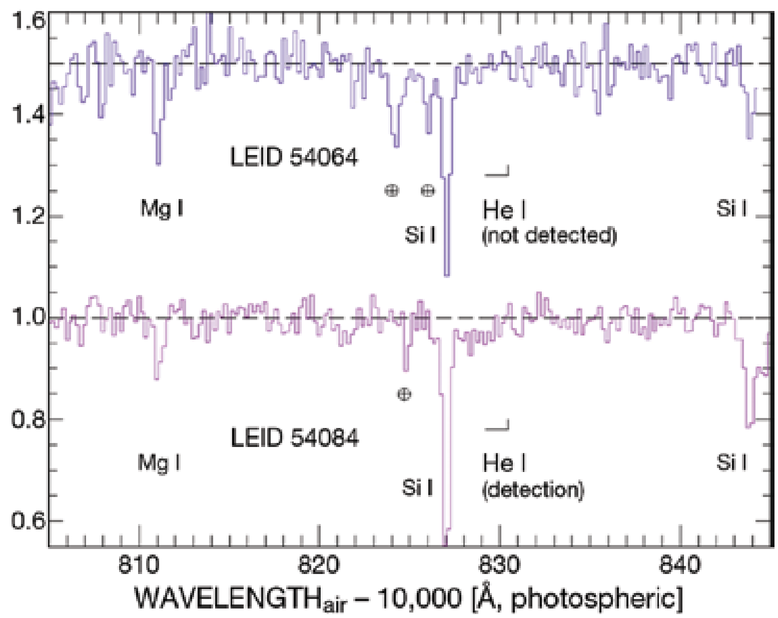


Figure 9. *Near-infrared spectra obtained with Phoenix show the He I 10,830 Å line detected in LEID 54084, but not detected in LEID 54064.*



apparent outflow is aligned with the observed radio jet of M81 and the axis of the presumed gaseous disk, which is located within 50 pc of the nucleus.

Multiple Stellar Populations and Helium Variations in Omega Centauri

The stars of any individual globular cluster were once interpreted as a single population, all having formed at the same time. Over the last decade, however, evidence for multiple stellar populations has emerged. Andrea Dupree (Harvard-Smithsonian Center for Astrophysics) led work that now shows direct evidence for helium abundance variations — a sign of multiple histories — in the bright globular cluster Omega Centauri.

The team further finds that helium abundance is correlated with overall metal abundance and especially with enhancement of light elements such as aluminum and sodium, which are produced by high-temperature hydrogen burning within stars (Figure 8). Helium enhancement is thus likely a consequence of second-generation stars formed from enriched material processed by an earlier generation of stars.

Dupree and collaborators Jay Strader (Harvard-Smithsonian Center for Astrophysics) and Graeme Smith (University of California Observatories/Lick Observatory) used the Phoenix high-resolution spectrograph on Gemini South to measure the near-infrared helium line at a wavelength of 10,830 Å (Figure 9). The strength of this transition is correlated with the helium abundance. In addition to the Gemini data, the team used optical observations with the MIKE spectrograph on the Magellan Clay telescope to determine the overall and light element abundances in this sample of 12 red giants within Omega Centauri. Specifically, the helium transition is not detected in the very metal-poor members, and it is present in most of the higher-metallicity examples. The complete results are published in *The Astrophysical Journal* (**728:** 155, 2011).

Nancy A. Levenson is Deputy Director and Head of Science at Gemini Observatory and can be reached at:
nlevenson@gemini.edu

by Céline d'Orgeville

Laser First Light at Gemini South

Figure 1.
Fish-eye image taken during the January 2011 first light propagation of the Gemini South LGS. Gemini image by M. Paredes.

During the night of January 21-22, 2011, the Gemini "paparazzi" on Cerro Pachón had their cameras ready to catch the very first laser photons leaving the dome of the Gemini South telescope. This happened at 4:38 a.m. local time (Figure 1). Adrenaline had been running high all night among the 12 scientists and engineers operating the complex machinery that would soon enable laser first light (Figure 2). But genuine wonder and a powerful sense of accomplishment seemed to overcome all who rushed outdoors to see the beam with their own eyes. Even though the laser beam looked just like its six-year old sibling at Gemini North, we knew differently. As the image in Figure 3 shows, Gemini South had successfully propagated the first sodium laser guide star constellation in history, looking just like the number "five" you see on the face of dice.

A Brief History of the Gemini South Laser

With the Gemini South laser shining for the first time over the Chilean skies, the Gemini Multi-Conjugate Adaptive Optics (MCAO) project begins the last chapter of its decade-long story. The tale began in 1999 when Gemini released the MCAO feasibility study. That same year, the observatory had (regular) first light at the Gemini North telescope in Hawai'i. The Conceptual and Preliminary Design Review chapters of the MCAO saga unfolded fairly quickly in 2000 and 2001, respectively. Gemini was to subcontract the design and fabrication of most subsystems, then play the part of system integrator for the Gemini Multi-Conjugate Adaptive Optics System (GeMS) during the project's final phase. The stage was set for procurement of the most critical subsystems, including but not limited to the MCAO optical bench (Canopus) and a 50-watt (W)-class laser system.

Figure 2. *GeMS commissioning team on telescope with laser propagated on dome. Gemini image by M. Paredes. See caption on page three for a list of individuals in this image.*

Unfortunately, at that time, no clear path existed to procure powerful, "ruggedized," 10- to 50-W-class sodium lasers for use with Laser Guide Star (LGS) Adaptive Optics (AO) systems in astronomy. The dye laser technologies used to pioneer these systems were either bulky, high-maintenance, or both; some of them even presented fire or chemical hazards. All of this led the AO community to turn its interest to more promising technologies, such as solid-state and fiber lasers. However, 10 years ago those technologies were not nearly mature enough to provide the kind of laser power and beam quality that the AO community required at the sodium D2 line wavelength (589 nanometers).

This sticky issue in the otherwise fairly well laid-out MCAO plot prompted the Association of Universities for Research in Astronomy (AURA) and Gemini to set out on a joint laser research and development (R&D) program with the W.M. Keck Observatory, the Center for Adaptive Optics, and the U.S. Air Force Research Laboratory. The goal was to develop key components for the state-of-the-art sodium lasers that both astronomical and military LGS AO infrastructures needed to enable next generation projects such as MCAO on 8- to 10-meter-class telescopes.

The first outcome of this multi-million-dollar sodium laser R&D program was to enable the design and fabrication of a first-generation, 10-W-class, diode-pumped, solid-state laser system for the Gemini North telescope. Developed and built by Lockheed Martin Coherent Technologies (LMCT), the Gemini North 14-W laser was part of the Laser Guide Star Facility (LGSF) that provides an artificial guide star to the Gemini North AO system (Altair). This laser saw first light on Mauna Kea in May 2005, and the Altair LGS mode of operation was commissioned in the months that followed.

A second-generation, 20-W-class laser, part of the same laser R&D program, was to be built on similar technology as the Gemini North laser and installed on the Keck I telescope. To leverage this effort, and take advantage of lessons learned with the Gemini North laser, a single AURA contract was placed in 2005 with LMCT to build not only the 20-W laser for Keck I, but also a 50-W version for Gemini South. The first of these two lasers, which actually performed better than anticipated at the 30- to 40-W level, was delivered to the W.M. Keck Observatory and installed on the Keck I telescope in Hawai'i in late 2009. The second laser was delivered to the Gemini South telescope in March 2010 after it demonstrated all critical performance specifications at the LMCT headquarters in Colorado, including output powers at the 50- to 60-W level.

One of the epic chapters of this laser story began just prior to delivery of the Gemini South laser to Chile. On February 27, 2010, the laser was awaiting

Figure 3. *First propagation of the Gemini South LGS constellation is shown in this 30-second exposure taken through a 500-millimeter f/5.6 Celestron telescope. Rayleigh plumes reveal the path of the laser light as it travels to the mesospheric sodium layer located about 90 kilometers above sea level. Gemini photo by M. Boccas.*

air shipment out of Miami when a deadly 8.8-magnitude earthquake shook southern Chile, damaging much of the airport and road infrastructures in and around Santiago. It is fortunate for Gemini that the laser had not reached Santiago as early as planned due to export license paperwork delays caused by a snowstorm that had paralyzed Washington, D.C., earlier that month! Who knows what would have happened to this equipment had it been sitting in a warehouse at the Santiago airport when this powerful earthquake hit?

The summit of Cerro Pachón was a flurry of activity in preparation for, and after the arrival of, the Gemini South laser. One of the most prominent activities involved a significantly large crew who, in July 2010, moved the laser with great care from the summit instrument laboratory to its final home — the Laser Service Enclosure (LSE). The LSE is a custom-built, class 10,000 clean room on the "-X" side of the Gemini South telescope elevation platform. Laser infrastructure-related projects, such as building the LSE and its dedicated support structure on the telescope, had been on-going for most of 2007-2010.

However, a significant effort was still foreseen in order to integrate the laser with the rest of the Gemini South LGSF and thus enable first light for the laser in January 2011. The most critical part of the work rested in the (gloved) hands of the Gemini laser specialist whose sole focus over the next few months would be to complete a meticulous and lengthy end-to-end re-alignment of the 50-W laser system (Figure 4). The goal of this effort was to bring the laser performance back to its pre-shipment level — with output powers in the 50- to 60-W range, a diffraction-limited beam with M^2 of 1.4 or better, reliable operation and high performance stability.

LGSF Anatomy 101

The Gemini South laser is at the heart of a larger system: the LGSF. Its sole purpose is to create a constellation of five artificial guide stars arranged at the corners and center of a 1-arcminute-per-side square, about 30 times smaller than the apparent diameter of the full Moon. The artificial stars are effectively created by propagating the laser through the atmosphere at the exact same orange wavelength at which sodium streetlights glow, except that in our system

Figure 4.
Gemini laser specialist Vincent Fesquet, wearing laser safety goggles and clean room clothes, aligning the Gemini South laser bench in the Laser Service Enclosure. Gemini photo by M. Paredes.

the "lamp" is a roughly 10-kilometer (km)-thick layer of sodium atoms located about 90 km above the ground. When sodium atoms excited by the laser light glow, they create the artificial guide stars that the MCAO bench (Canopus) and its real-time controller (the actual "brain" of the system) need to probe atmospheric turbulence. If this turbulence is left uncorrected it blurs astronomical images formed at the focus of the Gemini telescope. The larger the number of guide stars used to probe the atmosphere, the larger the corrected field-of-view available after Canopus works its magic.

If the laser is like the beating heart of the LGSF, then the Beam Transfer Optics (BTO) and Laser Launch Telescope (LLT) are akin to the veins and arteries delivering the precious orange laser photons to the sky. The role of central nervous system is filled by the Laser Interlock System (LIS). Its job is to make sure that laser propagation proceeds in safe conditions for personnel and hardware alike. The LIS receives inputs from all the GeMS subsystems (laser, BTO/LLT, Canopus), as well as from human spotters who are outside watching for planes (they are quite literally the "eyes" of the system!). The Laser Traffic Control System (LTCS) checks to make sure that we do not spoil science observations for our Cerro Pachón neighbor, the Southern Astrophysical Research (SOAR) telescope. In the future, the LIS will also process inputs received from the U.S. Laser Clearing House to enforce laser shuttering windows whenever sensitive satellites are at risk of crossing our laser beam path.

The Gemini South LGSF currently boasts five pairs of "eyes" (see article on laser spotters starting on page 34 of this issue). Although Cerro Pachón's summit elevation is less than Mauna Kea's, making the spotter's job somewhat less strenuous in Chile, the responsibility associated with the job is significantly greater due to the much higher number of planes transiting above Cerro Pachón all night long. The Gemini South spotters are aided in that job by the use of a radar-fed aircraft display and monitoring system called "VITRO" provided by the Dirección General de Aeronáutica Civil (DGAC) of Chile, the equivalent of the U.S. Federal Aviation Administration (FAA) overseeing Hawai'i.

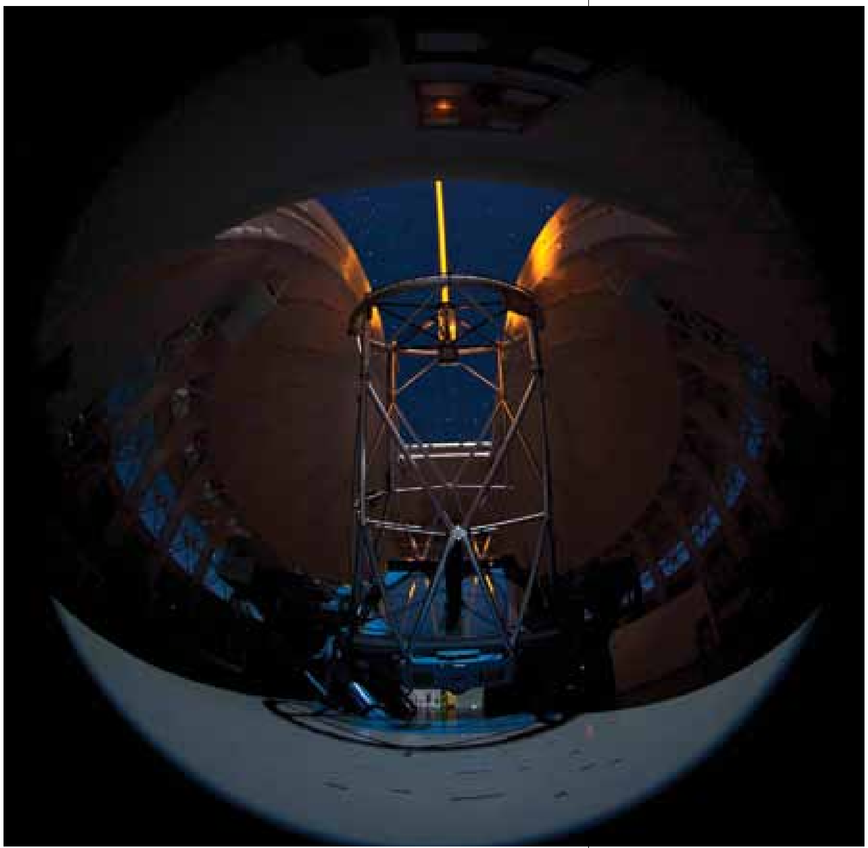


Figure 5.
Interior of Gemini South during laser propagation. Stars can be seen reflecting on the primary mirror.

GeMS Commissioning Highlights

Nighttime GeMS commissioning activities require many "hands" at the summit (the core GeMS commissioning team plus technical support staff) as well as a good many "ears" (on-call support staff) to ensure optimum use of precious telescope time. Since GeMS commissioning started in January 2011, as many as 23 people have worked on a given night at the Gemini South telescope. These include Gemini staff and a handful of visiting specialists who fulfill a number of functions: they 1) operate the Gemini South LGS facility, Canopus, and the Gemini South AO Imager (GSAOI); 2) provide technical support in all disciplines (optics, electronics, mechanics, and software); 3) receive laser and MCAO operations training; and 4) document events and activities with photographs and video for public relations.

The fact that heavy construction work started in February 2011 at the Cerro Pachón hotel and at nearby Cerro Peñon — to prepare the site for arrival of our new neighbors at the Large Synoptic Survey Telescope (LSST) — certainly did not make GeMS commissioning logistics any simpler. Getting everyone to the summit of Cerro Pachón and then lodging and feeding them, and transporting individuals back and forth between the summits of Cerro Pachón and Cerro Tololo (where most sleep during the daytime to avoid construction noise) are daunting tasks, requiring highly reactive and flexible support from Gemini and AURA-O administration staff.

As discussed above, laser first light was achieved on the second night of our first on-sky GeMS commissioning run (January 20-23, 2011). Commissioning has progressed at a fast pace since then, with one seven-night run per month (around the full Moon) planned until May (February 21-27, March 21-27, April 15-21, and May 16-22). The focus of the first two runs in January and February was mainly to commission the LGSF, and goals for the third run were split between LGSF and Canopus commissioning. At this point, most LGSF commissioning tasks have either been completed or are well under way. (See article on specific commissioning activities in this issue starting on page 29.)

Once the Gemini South laser was finally propagated on the sky (Figure 5) and the excitement created by this beautiful sight subsided, the next task consisted of imaging the LGS constellation with the 8-meter telescope acquisition camera (ACam). The Gemini South telescope was defocused from its normal set point at infinity to image the sodium layer at an altitude of roughly 90 km. Although we had to hunt for the LGS constellation (which initially lay just a little outside of the ACam field-of-view) we soon were able to align the laser beams on the Canopus laser hot spot on ACam.

After we had seen the laser propagating outside of the dome for the first time, a second jolt of adrenaline hit the team, as we could visualize the entire LGS constellation with its near-perfect, five-point arrangement on the sky. This was not just some neat orange laser light show, the sodium LGS were actually there for us to see (meaning that the laser wavelength was right on target), and we had created five of them for the first time in history!

It did not take very long before we had refocused the Gemini telescope to infinity and tried our luck imaging the laser light on the Canopus LGS wavefront sensors. Seeing the distinctive Rayleigh light pattern appear on the wavefront sensors provided the third and possibly most thrilling moment of excitement for the team — we had just seen first light on Canopus as well! (See article in this issue of *Gemini*Focus, pages 29-31.)

LGS Preliminary Results

Having demonstrated that we could create a five-point LGS constellation for GeMS and position it at will within the field-of-views of both ACam and Canopus, our team set out to characterize the LGSF performance in terms of LGS spot size and photon return. Initial results obtained in January were disappointing, providing exceedingly large spot sizes of 6 to 7 arcseconds and an alarmingly low photon return from the sodium layer. However, rapid progress was made during the February and March runs, when spot sizes were reduced to 3.7 and 1.7 arcseconds, respectively. Smaller spot sizes also boosted the photon counts detected by the 2.8 x 2.8 arcsecond square LGS wavefront sensor subapertures.

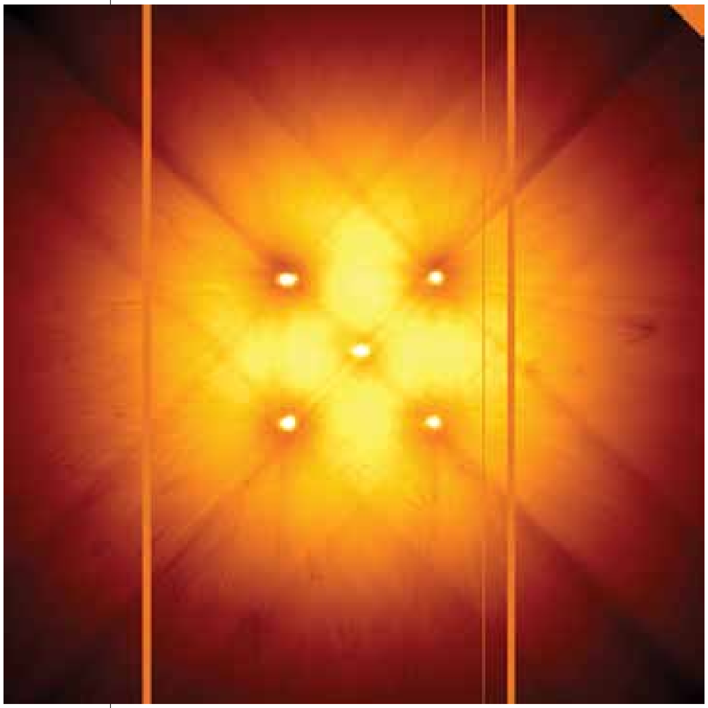


Figure 6.
Five-point LGS constellation imaged with GMOS. Image by E. Marin and C. Trujillo.

We have also checked that the Laser Launch Telescope (LLT) is providing fairly good image quality, with little to no evidence of local seeing affecting the projected laser beam. Smaller spot sizes (closer to the expected Gemini North values of 1.3 arcseconds) should be achievable in the near future, once the laser beam quality has been further improved at the output of the Gemini South laser system.

During our latest run in March, photon return from the sodium layer was characterized in greater detail when we used a series of LGS constellation images obtained with the Gemini Multi-Object Spectrograph (GMOS). Figure 6 presents a typical image of the LGS constellation as captured by the GMOS detector, with a noticeable grid pattern created throughout the image by shadows of the telescope's spider vanes around each LGS. Results were quite encouraging in spite of the Beam Transfer Optics throughput which was measured at a disappointingly low value of about 50 percent. Assuming the LLT has a 90 percent throughput, this yields a ratio of about 1 to 0.5 x 0.9 / 5 = 0.09 between 589 nanometer power measured at the output of the laser system and projected power per laser beam on the sky. Using about 50 W of 589-namometer laser light at the output of the laser system, this corresponds to about 4.5 W per laser beam projected to the sky (50 W x 0.09). Even at that level, the resulting laser guide stars were actually saturating the GMOS detector at its lowest exposure time of one second.

To avoid saturation, while tracking a standard star from 70° down to 60° elevation, we took a series of images at laser output powers in the 20-to 30-W range. We also propagated the laser at a fixed elevation/azimuth of 60°/270° and separately varied the laser power and wavelength to study their impact on the sodium photon return. Data reduction and analysis were performed almost on the fly to derive the apparent V magnitude of the LGS constellation. During this experiment, we found that the highest photon return was obtained when the laser system produced about 40 W of output power near what appeared to be the optimum laser wavelength on that night (March 24, 2011). Because the laser wavelength was not locked, the actual laser wavelength in this configuration remains uncertain.

The laser guide star V magnitude averaged over the five-point LGS constellation was V = 9.0 when the Gemini South laser system produced 40 W of output power. This result can be compared to the photon return measured at Gemini North during the Altair LGS mode commissioning in May 2005. The apparent V magnitude of the Gemini North LGS was V = 9.8 with 6 W of laser power projected to the sky on May 28, 2005. This is 0.8 magnitude fainter (about a factor of 2 in flux) than the current Gemini South peak performance of V = 9.0 for each LGS in the Gemini South constellation — each of which was receiving 6 / (40 x 0.09) = 1.6 times less laser power than the Gemini North LGS. Thus, overall, we are getting a factor of about three more photon return from the sodium layer per watt of projected laser power with the Gemini South laser in late March 2011 (medium sodium season in the Southern Hemisphere) than with the Gemini North laser in late May 2005 (low sodium season in the Northern Hemisphere).

Note that both the Gemini North and South laser polarization states were still poorly controlled in the early commissioning stages. Although actual projected polarization states during these tests were most likely elliptical, we believe that the Gemini South polarization in March 2011 was closer to circular, while the Gemini North polarization in May 2005 was closer to linear (this was before the Gemini North polarization was optimized on-sky and produced a photon return increase of about 30 percent). We are planning to repeat photon return measurement and wavelength optimization tests later this year after the BTO throughput has been improved and experimental parameters, such as on-sky laser power and wavelength are better controlled.

A Bright Future

The Gemini South laser first light on January 22, 2011, has left its mark on everyone who has been involved with the laser and AO programs at Gemini over the past decade. Its impact is felt not only within Gemini but also outside of the observatory, as attested by the many congratulatory emails received soon after the event from colleagues and friends all over the world. Gemini South laser public outreach pictures, especially that of the five-star pattern shown in Figure 3, were published multiple times on-line and in blogs, magazines, and newspapers, to alert the astronomy community that a small, laser-guided revolution was taking place in Chile.

This long-awaited milestone not only stood as the climax of a decade-long laser development program but also marked the official start of GeMS on-sky commissioning activities slated to continue throughout 2011. As of March 31, 2011, initial concerns about the Gemini South LGS spot size and photon return have been largely alleviated by encouraging results obtained during our third GeMS commissioning run. There is little doubt by now that GeMS has a bright future ahead!

Céline d'Orgeville is a senior laser engineer at Gemini South. She can be reached at: cdorgeville@gemini.edu

by Benoit Neichel and François Rigaut

GeMS Commissioning Progress

At the annual Gemini Planning Retreat in Santiago, Chile, in early October 2010, the decision was made to move Canopus, the Gemini South adaptive optics (AO) system, to the telescope as early as November 2010 and start on-sky commissioning as soon as possible in 2011. Since then, it has been an almost constant race to meet timelines.

Motivated by the seasonal weather conditions at Cerro Pachón, and the need for clear nights to propagate the laser for efficient commissioning, the aggressive plan began immediately as the mechanical group prepared Canopus for the move. In one short month, they prepared a detailed procedure to ensure a safe trip from Gemini's Southern Base Facility (SBF) to the telescope. Transportation began on November 16th, under the supervision of Mike Sheehan, who came from Gemini North to lend his expertise to this delicate operation.

Figure 1.
Canopus arrives at Gemini South on Cerro Pachón on November 17, 2010.

A few days prior to the 16th, the team removed all of the critical optical and electrical components from the bench and prepared them for separate transport. Two days of packing were necessary to carefully seal Canopus in its transportation box which required a few protective layers of plastic and wood to minimize any contamination by dust from the road. A special truck and vibration-damped cart were also used to minimize the strong vibrations caused by transport over rough roads.

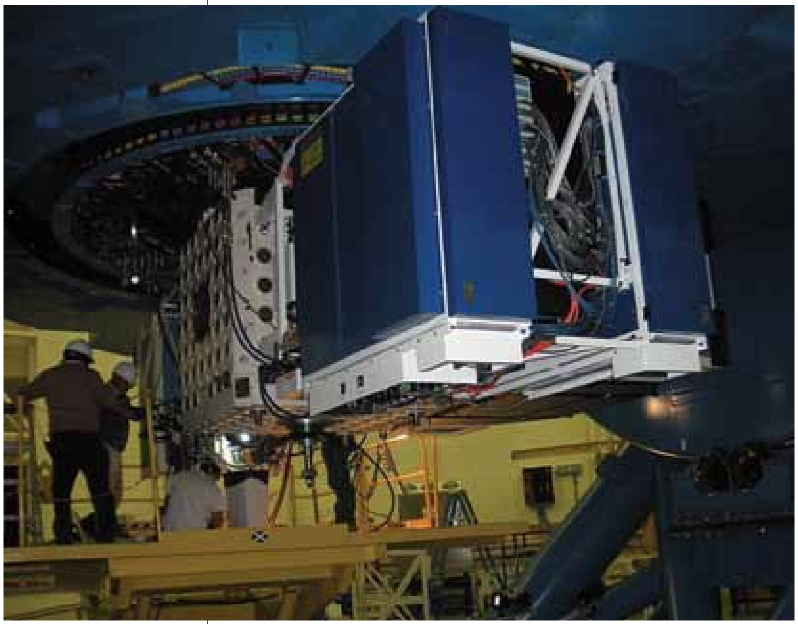


Figure 2. *January 10, 2011. Canopus is installed on the AO port of the Gemini South telescope.*

Late at night on the second day of packing, Canopus was finally installed and attached to the special transportation truck. A few hours later, the vehicle departed from the SBF, driving in the middle of the night (to avoid any traffic issues) at a mean speed of about 30 kilometers per hour. The truck stopped at the control gate around 3:00 in the morning and then resumed again at around 10:00 a.m. — finally arriving at the summit by noon (Figure 1). The mountain road portion of the journey reminded us of the 1953 French film by H.G. Clouzot, "*The Wages of Fear.*"

Once Canopus was installed in the Cerro Pachón instrument lab, the team immediately started to unpack, and to bring the system back to an operational state. A few days later, the DM0 (Canopus' Deformable Mirror - conjugated to the ground layer) arrived from CILAS, where it had spent almost seven months for repairs. The deformable mirror was re-installed on the bench, and by December 9th, we had closed the loops on Canopus again, confirming that everything was working well after the transport process.

We began working immediately to answer an extremely puzzling question: "How do we get all of the wavefront sensors and the Gemini South Adaptive Optics Imager (GSAOI) to achieve their optimal focus at the same time?"

This was not an issue when we were working in the lab, because we did not have the constraint of the science path focus, so we waited to tackle this problem at the end of the process. To solve the issue we basically had to move almost all of the Canopus optics and re-align them properly, one by one. A metric demonstrating the magnitude of this work is found in the number of entries on the Canopus blog for this topic (there were no less than 12). This may be a record number of entries for a given topic.

Electronic and mechanical engineers worked in parallel each day to resolve the cooling issues and solve the many system failures that occurred, mainly due to the Cerro Pachón's dry environment. The team spent long days and nights working in the instrument lab to finish everything. Finally, on January 7th, the team packed Canopus for the trip to its final destination: installation on the telescope.

On Monday, January 10th, a team of many engineers and technicians, led by Mike Sheehan, installed Canopus on the telescope's AO port (Figure 2). The procedure went by the book and was essentially finished in under six hours without any major issues. We quickly confirmed that everything was working correctly, and that the LGS wavefront sensors (WFS) CCD noise was not higher than when it was tested in the lab (about 3.1 electrons).

On the other hand, vibration proved to be significant. We measured 15 milli-arcseconds (mas), compared to less than 3 mas under regular conditions in the lab. Fortunately, this noise turned out to be mostly induced by the GSAOI cryocoolers, running at maximum to cool down GSAOI after it had been installed the day after Canopus. The vibrations subsided somewhat after a few days, down to the current level of 7 mas. While that level is not ideal, we can live with it during the first part of commissioning. An effort has been initiated at Gemini to mitigate vibration issues, from which we will eventually benefit. The mitigation could be a mechanical solution (better insulation of GSAOI and other cryocoolers) or take other forms (such as using some kind of smart control law, perhaps Kalman, to filter the vibrations at the level of the GSAOI focal plane).

After installation, and during the first weeks on the telescope, we dealt with various cooling issues. Canopus dissipates about 3 kilowatts of energy, and special cooling circuits had to be designed to handle such a high load. Air bubbles regularly appeared in the cooling systems and that reduced the cooling capacity. Eventually this problem was solved by careful and repetitive glycol purges.

The GeMS team started to work quickly on the Canopus/GSAOI integration, first focusing on image quality. This meant solving the NCPA (non-common path aberrations) problem in a 3-D fashion, which, as far as we know, had never been done before. The goal is to optimize the point-spread function (PSF) over the whole GSAOI field-of-view, by tweaking the three Canopus deformable mirror (DM) shapes at rest (or the average shape when correcting turbulence). In response to this new problem, we have developed new techniques, including a novel phase diversity tomographic approach. Some optical re-alignments were also necessary to optimize the focus and reduce astigmatism in order to deliver the best image quality to GSAOI.

Nighttime commissioning started on January 20, 2011. Five runs were planned (one is still pending as this article goes to press) throughout the first semester of 2011: one each month during and around the full Moon, starting in January. The first two runs were dedicated to the commissioning of the Laser Guide Star Facility (including the laser itself, the Beam Transfer Optics (BTO), the Laser Launch Telescope (LLT), and the various safety systems: the Laser Interlock System (LIS), the Laser Traffic Control System (LTCS), the aircraft location feed from the Dirección General de Aeronáutica Civil (DGAC, VITRO), and others. This is all described in more detail in Céline d'Orgeville's article starting on page 23 of this issue.

By the beginning of the third run, on March 21^{st}, the LGSF was running fairly smoothly, all the procedures were in place, and the laser was delivering 55 watts (30 watts on-sky) with an LGS spot size on the sky of 1.7 arcseconds. This is not yet ideal for Canopus, but can be worked with. We are confident that it will improve.

Even though the GeMS high-order loop (*i.e.* using the laser) was closed successfully as early as February 25^{th}, the real work on Canopus commissioning started during the third run, on March 24^{th}. In the last four nights of this run, we made very significant progress; in fact, we are ahead of schedule (as this issue goes to press). The main loops were closed (high-order loop with the five-point LGS constellation, Figure 3), together with the tip-tilt loop (using only one natural guide star for now), and almost all the offloads are now operational (offloads to the telescope M1, M2, and the BTO fast steering array to stabilize the LGS spots in the LGS WFSs). The next run will be filled with more functional work (a few more offloads and loops to commission) and more performance optimization.

Eventually, on June 1, 2011, Canopus will enter a five-month shutdown to fix various issues, such as optical re-alignment, upgrade of the LGS WFSs, and various other hardware upgrades. Commissioning will resume later this year during the Southern Hemisphere spring. At that time, we will hopefully be in a position to deliver the specified performance in terms of compensation capability and sky coverage.

Benoit Neichel is an adaptive optics fellow at Gemini South. He can be reached at: bneichel@gemini.edu

François Rigaut is a senior scientist at Gemini South. He can be reached at: frigaut@gemini.edu

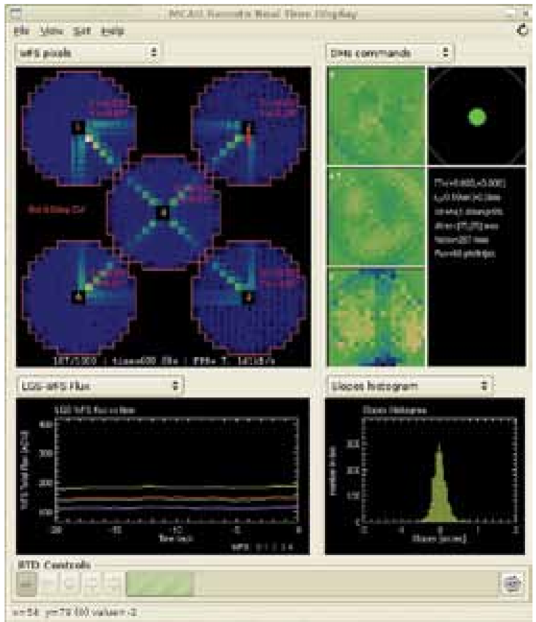


Figure 3.
Snapshot of the real time display of Myst (the "MCAO Yorick Smart Tool") while the GeMS high-order loop was closed. The five blue circles in the top-left panel are the five wavefront sensors (WFS) looking at the five laser beams. The stripes seen on the WFS are due to the Rayleigh scattering (also called the "fratricide effect") and are typical of multi-laser systems. The three blue-green circles in the top right panel represent the shape of the three deformable mirrors. The green spot on the top right shows the position of the tip-tilt mirror.

A Stellar Nursery in the Lagoon Nebula

The southern cliff of the Lagoon Nebula (Messier 8), as imaged using the Gemini Multi-Object Spectrograph on the Gemini South telescope on Cerro Pachón (Chile). The picture — a composite of individual images obtained with two narrow-band optical filters sensitive to hydrogen (red) and ionized sulfur (green) emission, and far red light, beyond the range of the human eye (blue) — reveals in dramatic detail a glorious cloudscape of dust and gas surrounding a nursery of intermediate- and low-mass stars. Most of the newborn stars are imbedded in the tips of thick dusty clouds, which have the appearance of bright rimmed pillars. As these "baby stars" grow, they eject large amounts of fast-moving gas which plow into the surrounding nebula, producing bright shocks known as Herbig-Haro objects. This image shows a dozen of these objects spanning sizes from a few thousand astronomical units (about a trillion kilometers) to 1.4 parsecs (4.6 light-years), i.e. a little larger than the distance from the Sun to the nearest star Proxima Centauri. Argentine astronomers Julia I. Arias and Rodolfo H. Barbá are studying this portion of the Lagoon Nebula to explore the evolutionary relationship between the newborn stars and Herbig-Haro objects. For more details and to download this image see the image release at: *www.gemini.edu/node/11631*

Image and text by Julia I. Arias and Rodolfo H. Barbá
Departamento de Física, Universidad de La Serena (Chile), and ICATE-CONICET (Argentina).

by Stephen James O'Meara

Gemini's Spotters: Guardians of the Light

Figure 1.
Gemini South spotter Carlos Segura on the summit of Cerro Pachón, demonstrating how a hoop is used is used to determine the safe distance of aircraft from the propagated laser.

The Adaptive Optics (AO) and Laser Guide Star (LGS) systems are key elements in Gemini's instrument program. Gemini North uses a single 14-watt beam and Gemini South has the revolutionary, 50-watt laser (it forms a "constellation" of five 10-watt beams). When projected on the night sky, these beams create artificial guide stars that help astronomers remove aberrations to starlight caused by Earth's atmosphere. This cutting-edge technology allows Gemini's twin 8-meter telescopes to produce the sharpest images possible from the ground of celestial objects at near-infrared wavelengths. However, these systems would be powerless without the people who work for Gemini's Aircraft Spotter Program.

The Federal Aviation Administration (FAA) and Space Command in the United States, and the Dirección General de Aeronáutica Civil (DGAC, the Chilean version of the FAA) restricts outdoor laser projection because of possible danger to or distraction of aircraft crew. Consequently, before any LGS system propagates a beam, Gemini has to ensure that no aircraft or satellites pass near it. Currently, that very important position is filled by Gemini's aircraft spotters, who, together with the Science Operations Specialist (SOS, formerly System Support Associates, SSAs), are trained to follow a script which concludes with the permission to propagate being given by a spotter. As Callie McNew, an aircraft spotter and satellite monitor at Gemini North makes clear, "If there are no spotters outside, there can be no use of the laser."

Figure 2. *Gemini South spotters (from left to right) Carlos Segura, Rodrigo Balladares, Eric Petit, and Camila Durán. Segura holds the spotter button used to shutter the laser system.*

Guardians of the Light

"Spotters are vital, in the sense they are absolutely necessary if we want to propagate," said François Rigaut, Adaptive Optics Senior Scientist at Gemini. Rigaut also admires the spotters' commitment to a physically demanding job. "Looking continuously at the sky to identify flashing lights for hours in a row takes some serious dedication."

Spotters are required to work at summit altitudes, sometimes in the wind and cold, for three to five consecutive nights, from sunset to sunrise. To prepare for their overnight summit vigils, spotters acclimatize to altitude the night prior to their first shift, and try to get plenty of sleep during the day. "I think one has to prepare mentally to do your best," says Gemini South spotter Rodrigo Balladares, who likes to ready himself first at home by reviewing and studying his work agenda. "Our duty is to [guard] the laser. So, every plane that goes by presents a challenge, one that demands we be aware, so we don't make any mistakes."

Gemini South coworker Patricio Véliz agrees. "We have to be wide awake, because as hours go by, and it gets cold, sometimes you get sleepy. For me, coffee is the best solution," he said, noting that his adrenaline surges when controllers propagate the laser.

Callie McNew admits to a different solution. "I like to sing out loud and dance around when I am outside at the summit by myself," she said. The serenity of her work location also helps. "It is so beautiful and quiet outside at night by yourself, especially when the Moon is reflecting off all of the silently rotating domes and the clouds all below me."

At least two aircraft spotters must be on station when laser propagation is planned: one outside, one inside. The outside spotter logs the time, elevation, and general heading (or known destination of) all aircraft in the sky. If an aircraft approaches within 25º of the beam, the spotter must notify telescope personnel and press a button that shutters the laser system. The laser system must also be shuttered if thick clouds drift within 25º of its beam, because scattering of laser light could prevent an approaching aircraft from being detected by the spotters.

Meanwhile, the inside spotter at Gemini North keeps track of times that the FAA and Space Command Laser Clearing House has requested Gemini not use the laser (see "A Team Effort" sidebar on page 36). He or she also monitors Gemini's all-sky camera (ASCAM) for aircraft detection alerts and notifies the outside spotter for confirmation. Similarly, at Gemini South, the inside spotter monitors Sistema de Visualización de Tránsito Aéreo Oceánico (VITRO) — an air-traffic visualization system which receives a feed from the DGAC and pinpoints the location of air traffic in the area around the observatory. The inside and outside spotters on station then rotate their positions and responsibilities every hour or two.

Finding Balance … and Opportunity

Despite what she describes as the brutal cold and wind she sometimes experiences at night on Mauna Kea, Callie McNew has found a way to compensate. When not at work — either as a Gemini spotter, a telescope operator at the University of Hawai‘i 2.2-meter telescope, or as a student pursuing a master's in Educational Technology through the University of Hawai‘i at Manoa — Callie enjoys basking in the Sun. “I love to swim in the ocean and spend time with my boyfriend, Tony Matulonis, who also works at Gemini. Although we both mostly work at night, we are actually Sun worshippers and could spend all day at the beach!”

The cold doesn't bother Patricio Véliz either. He moved from his home in Ovalle to nearby La Serena, Chile, in 2000 not only to look for new horizons and a more promising future, but also “to leave bad memories and little opportunities behind.” Before Véliz arrived at Gemini South, he worked as an electromechanical technician, a technician supervisor for Aguas del Valle (a water company), and also as a supervisor in public schools. Gemini afforded him the new opportunities he sought.

A Team Effort

“I am proud of our dedicated team of spotters,” praised Senior Optical/Laser Engineer Richard Oram. “They do a tough job and have an outstanding and consistent record of achievement.” Nevertheless, Oram points out that the spotters' job is actually a part of a much larger team effort.

“The successful and safe operation of the Laser Guide Star (LGS) is only possible due the consistent team effort from all the professionals involved,” he explained. “To prepare for the monthly laser run involves input from wide-ranging resources across Gemini, including the Administration and Facilities Group to book logistics (cars/rooms), Queue Coordinator to generate the approved target list, Engineering Administration to publish notifications and communicate with the Laser Clearing House (LCH), Aircraft Spotter Team to protect airspace and space assets, Laser Operation Team to prepare and run the laser, Systems Engineering to coordinate activities, Science Operations Support and Observer and Instrument Scientists to prepare and operate the AO systems and instruments.”

Before astronomers use an LGS system, Gemini has to abide by FAA/DGAC and U.S. Space Command LCH regulations to ensure that no aircraft or satellites pass near any propagated beam and that Gemini's operation of the laser complies with other international legal obligations.

In Hawai‘i, Gemini also calls the Honolulu Control Facility of the FAA prior to, and upon termination of, any laser use. Gemini North also sends the target list to U.S. Army Range Operations Pohakuloa Training Center (PTA) for clearances, because they have numerous flight paths around Mauna Kea's summit area. Laser operations are terminated immediately upon the request of Air Traffic Control or Military Flight Operations.

Although the possibility seems remote, the U.S. Space Command is also concerned that ground-based lasers may cause damage to sensors onboard surveillance spacecraft in low-Earth orbit. Therefore, the coordinates of each celestial target must be approved prior to an observation.

The Gemini Engineering Administration Specialist sends these target lists to U.S. Space Command for approval via email no earlier than four business days, and not later than three business days, prior to the first day of a laser run. If approval has not been received eight hours prior to laser propagation, a follow-up call to Space Command is required by the Engineering Administrative Specialist. No target may be observed which has not been approved by Space Command, and the laser may not be pointed more than 2 arcminutes from an approved target position.

"Honestly," he confessed, "I had never heard of such a position [as an aircraft spotter] before. I did apply, however, because Gemini Observatory was behind the ad, and this meant a great opportunity in my life to belong to such a prestigious enterprise. I have never before considered myself a sky watcher. Now, I have discovered something absolutely majestic. I like the fact that everyday I can learn something new and interact with people from different parts of the world."

Carlos Segura, who was born and raised in Coquimbo, Chile, worked for many years as a salesperson in telecommunications and as a security guard before joining the spotter crew at Gemini South. He was always fond of the stars and curious about what else is "out there." Now, Gemini has given him a chance to be a part of that search. "The fact that we are all contributing to science by helping at a telescope is spectacular," Segura said proudly.

AO Lifelines

The scientific potential afforded by Gemini's LGS/AO systems cannot be understated. In 2012, the new five-beam laser system at Gemini South (see article on page 23 of this issue) is expected to begin providing remarkably sharp images that should help astronomers unlock the mysteries of objects and processes ranging from the birth and evolution of stars to the dynamics of distant galaxies. Gemini's spotters will continue to play a stellar role in helping them to achieve success until ASCAM officially enters service to monitor the night sky and shutter the laser for air traffic over the mountains' summits. (For additional details on ASCAM, see *Gemini*Focus, December 2007, page 42, and December 2008, page 59.)

ASCAM is still awaiting a "green light" from the FAA. François Rigaut, who developed ASCAM's software, believes in the all-sky camera's promise and efficiency as an automated, early detection system of aircraft. "ASCAM never tires[…] and is actually, most of the time, more sensitive than spotters (but not always)," he said.

To make a robust detection system that works in both clear and cloudy skies, ASCAM is being developed in parallel with a system at the W.M. Keck Observatory on Mauna Kea that determines aircraft positions by monitoring their transponder signals. The hope is that the combined use of these sensors, as a fully automated aircraft detection system that works under all conditions, will be approved by the FAA. Until then, the spotters will remain an essential part of Gemini's success in AO science.

"We are key pieces to a great machine," said Patricio Véliz. "Maybe we are small pieces, but we do have a special role."

Callie McNew concurs. "Aside from the exhilaration of simply being at the summit in the middle of the night by myself surrounded by stars and above the clouds," she said, "I love the professionalism of the people I work with and the opportunity to be involved in the pursuit of obtaining astronomical data at one of finest telescopes in the world."

"Every day is a great day," added Rodrigo Balladares. "As a team we support each other." For instance, Senior Optical/Laser Engineer Richard Oram said, "We have had numerous instances of mild, high-altitude sickness over the years, resulting in a spotter being taken down to sea level and/or emergency room during the night. The spotters who are trained as first aid responders can be relied upon to handle these situations and look after their coworkers."

Indeed, what Balladares says he enjoys the most is belonging to a great working group of people and to a great observatory which has allowed him to grow professionally.

Balladares, who keeps himself busy playing soccer and swimming, says he's proud to be a Gemini Spotter because arriving at this position wasn't easy for him. "Everything I am today is thanks to my uncle and aunt (my parents) who raised me since I was little," he said. "I have worked since I was 12, always giving my best to become a good professional, and I will continue making myself proud."

Stephen James O'Meara is an author, columnist/contributing editor of Astronomy *magazine, and an associate editor of* Gemini*Focus. He can be reached at: someara@interpac.net*

by Eric Tollestrup

Gemini's Instrumentation: an Update, and a Look to the Future

Gemini Observatory has several instrumentation projects in the final stages of development that will bring exciting new capabilities to the Observatory in the next year. In addition to the very exciting news of first light with the Gemini Multi-Conjugate Adaptive Optics System (GeMS, see article starting on page 29 of this issue), the Gemini Planet Imager, and FLAMINGOS-2 projects are also progressing and should be producing their own exciting results in the short term.

GPI

The Gemini Planet Imager (see the December 2010 issue of *Gemini*Focus for an in-depth review) has entered a critical stage this year. It is currently undergoing the integration and test phase (I&T), which is taking place at the University of California, Santa Cruz (UCSC). Nearly all the subsystems passed acceptance testing by the end of last year. Since then, two of the three major subsystems, the opto-mechanical super-structure (OMSS, Hertzberg Institute of Astrophysics (HIA)) and the calibration unit (CAL unit; NASA-JPL) have been shipped to UCSC (Figure 1). The third major subsystem, the integral-field spectrograph (IFS; University of California, Los Angeles), is scheduled (as this issue goes to press) for

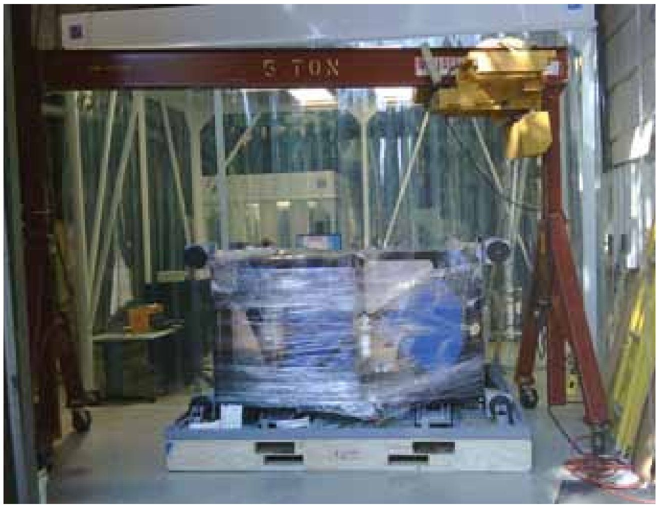


Figure 1. *The OMSS, still encased in shrink-wrap, after arrival at UCSC. The clean room facilities can be seen in the background.*

Figure 2.
A view from the GPI web camera. The two blue boxes, one on either side of the OMSS (the black enclosure between them), contain the electronics. The OMSS is partially uncovered, allowing the two GPI team members access to the optical bench.

its subsystem acceptance review in May. In addition, the adaptive optics subsystem (Lawrence Livermore National Laboratory) and coronagraph subsystem (American Museum of Natural History) have also been shipped out for integration into the OMSS, CAL, and IFS.

These days, without software, astronomical hardware is nothing more than metal, glass, and silicon. Therefore, significant effort is underway to ensure that the instrument and telescope control software and the data pipeline package is keeping pace with the hardware tasks. The initial data reduction pipeline software package underwent acceptance testing at the University of Montréal in late March. Meanwhile, the Gemini Instrument Application Programming Interface, the new software interface between the observatory and instrument controls system, continues towards completion later this year. With this new "front end," both the observatory and future instrument teams will find it much easier to connect and control extremely complex instruments like GPI to the equally complex Gemini telescopes.

The UCSC laboratory is buzzing with activities as the subsystems are methodically integrated. To help connect a very dispersed GPI/Gemini team spread over much of the Western Hemisphere (from the United States and Canada all the way to Chile), members can view current activities in the GPI clean room at UCSC with an internet accessible web camera (Figure 2). With a simple visual reminder like this, it is no wonder that team excitement grows weekly as GPI gets closer and closer to being ready for the "main event"—obtaining direct images and spectroscopy of warm, giant extrasolar planets in the Sun's neighborhood. GPI should be ready for shipping to Chile by the end of this year, and then to Cerro Pachón for commissioning and first light in early 2012!

GMOS-N Upgrade

As described by Katherine Roth in the June 2010 issue of *Gemini*Focus (pages 95-97). GMOS-N is being upgraded with red-sensitive CCDs from Hamamatsu Photonics and a new set of control electronics from Astronomical Research Cameras, Inc. The I&T of the CCDs and controller into GMOS-N is being done by HIA, part of the original build team for the two GMOS instruments. Unfortunately, progress has been slowed due to controller problems and a failed detector. The detector problem was the result of a defective detector flex cable, which had a microscopic solder bridge that shorted a critical voltage on the CCD (Figure 3). This short caused excessive currents to burn out the output amplifier circuitry and damage other parts of the CCD.

Since our new CCDs (the so-called "SC-type") are discontinued Hamamatsu products, finding a replacement CCD has been difficult. One solution could have been to buy the newer, current product line CCDs that replace the SC-type CCDs. However, these newer CCDs, the "HSC-type" are significantly different in both physical dimensions and performance. The physical difference would have required modifying the existing focal plane, something we did not want to do. The performance differences would have made photometric imaging, in particular, more difficult due to the significantly different characteristics between the three CCDs that make up the GMOS-N focal plane assembly. Another option would have been to have a custom run to build a new SC-type CCD. While possible, it was also a very time-consuming option. Therefore, we chose the third option, which was to use the existing HSC product line to build a semi-custom CCD that has the same physical dimensions and nearly the same performance characteristics of the discontinued SC-type CCD. The exception is that this "SC/HSC" hybrid would have a HSC-type anti-reflection coating that is more blue sensitive than the older SC-type CCDs (while retaining the red sensitivity; Figure 4). This third option allowed for a fast delivery time and plug-in replacement. While the performance is nearly the same, the fact is, for many projects, the increased blue sensitivity will be a real advantage.

Provided the new CCD passes acceptance testing, the new and improved GMOS-N should be undergoing commissioning in October, 2011. Following commissioning, there will be a short science verification run, and then it will go back for what should be another very successful decade of popular usage by observers.

FLAMINGOS-2

As reported in the June 2010 issue of *Gemini*Focus (pages 90-92), FLAMINGOS-2 experienced a variety of problems during on-telescope acceptance testing that required the instrument to be returned to La Serena for additional evaluation and work. The most serious problem was the failure of the HAWAII-2 science detector. Since the instrument's detectors are a discontinued product, Teledyne Imaging Sensors had to fabricate the final batch of detectors from the residual parts still remaining in their inventory. The first batch was made early last year and partially tested in March 2010. Since then, a second batch of detector assemblies have been made. These final HAWAII-2 detector arrays are currently being tested at Teledyne, and Gemini Observatory has the option to purchase the best one or two devices. Meanwhile, Gemini has been working with the University of Florida to fix the problems that were identified last year. Barring any further delays, FLAMINGOS-2 will be ready for re-testing and commissioning in July 2011.

Fourth-Generation Instrumentation

As the last generation of instrumentation development winds down, and as some of our current instruments are getting older, we are looking ahead and planning for the future. One critical capability missing from Gemini is high-resolution optical spectroscopy. To address this issue, the observatory has been pursuing a couple of options. The user community has been asked to submit papers describing the science case for high-resolution optical spectroscopy and the related instrument requirements. The response was enthusiastic, with 21 white papers covering a very broad range of projects. The Gemini Science Committee (GSC) reviewed these submissions last October and recommended that the observatory pursue two options: 1) a Gemini fiber feed to the Canada-France-Hawai'i Telescope (CFHT) ESPaDOnS high-resolution echelle spectrograph, and 2) a Gemini spectrograph with a resolving power in the range of 20,000 to 60,000 and a wavelength coverage of 370 nanometers (nm) to 1,000 nm (dual beam) or 400 nm to 700 nm (single beam). Feasibility studies have been underway for both these options and we plan to release a Request for Proposal to build the Gemini spectrograph as this issue goes to press.

On a longer time scale, the observatory will be seek-

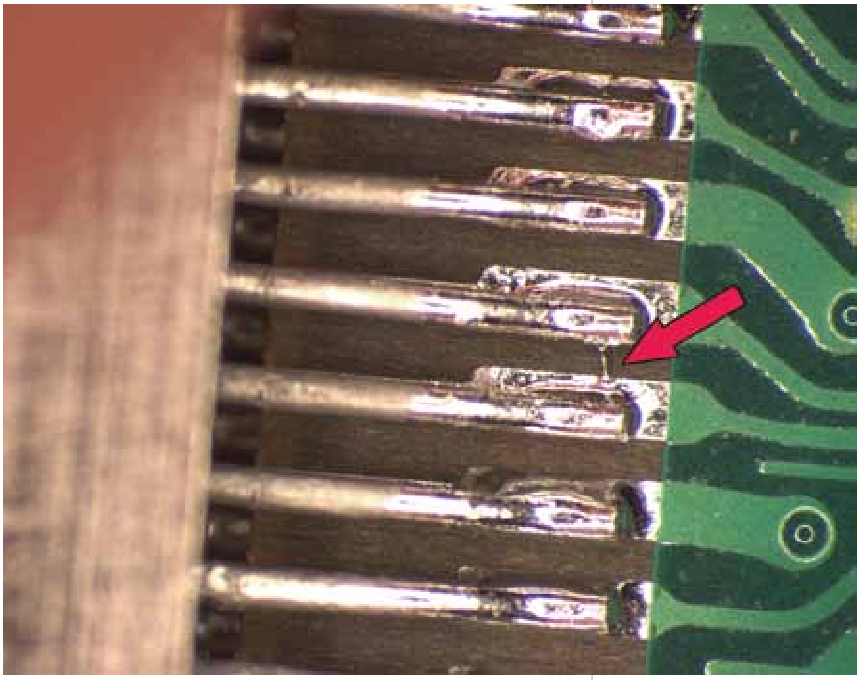


Figure 3. *A close-up image of the CCD flex cable showing the solder bridge that caused the CCD to fail.*

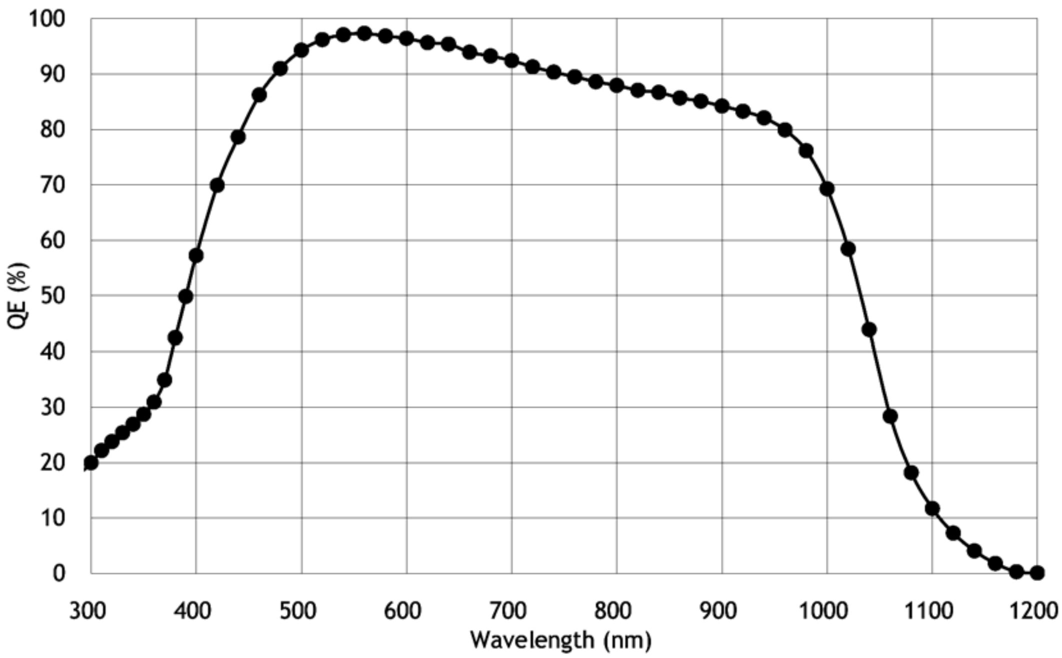


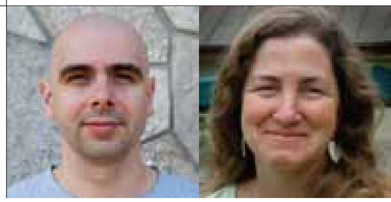
Figure 4.
The "HSC-type" anti-reflection coating for the replacement CCD has high quantum efficiency from 400 to 1,000 nm. Note the excellent blue and red sensitivity.

ing input from the community to help develop, prioritize, and plan the future instrumentation suite for Gemini. Currently, and continuing into the future, the observatory has started the process of receiving input from all the Gemini stakeholders, such as the national funding agencies, Gemini Board, and most of all the Gemini users. The goals are to build a closer partnership with the community, align the instrumentation program with the needs of the community, and make it sustainable within the resources available from the partner countries.

So, if you want to contribute to the successful future of Gemini instrumentation, be a part of the process: attend the upcoming Gemini meetings (look for future Gemini Users Meetings, Town Halls at professional society meetings, local and regional Gemini "Forums," *etc.*), contribute a white paper, visit us when you are in Hawai'i or Chile, or just drop us an email or call.

With all this activity, and more, it is no wonder that the next few years will be exciting not only for the Gemini Observatory, but also for our community, as exciting new capabilities come on line and new astrophysical frontiers are explored.

Eric Tollestrup is Associate Director of Development for Gemini Observatory. He can be reached at: etollest@gemini.edu



by Peter Pessev and Bernadette Rodgers

Gemini's Green Queue and Other Green News

Gemini takes its commitment to environmental stewardship seriously; the December 2009 *Gemini*Focus reported on the Gemini green initiative (pages 62-66). That article highlighted various steps the Observatory has taken to reduce our carbon emissions and environmental impact as an organization, and we're proud of our results. In 2009, we reduced our carbon footprint from travel by 23 percent, and an additional 7 percent in 2010, compared to the 2008 level. In this article, we turn to sustainability topics facing the broader astronomical community — and a big one is air travel.

Astronomers Fly—a Lot!

When one of the authors (Pessev) began his astronomical career as an undergrad, a professor told him, "You'd better enjoy travel if you want to be an astronomer." Fifteen years and hundreds of thousands of kilometers later, the wisdom of this advice is clear. Astronomers travel to international conferences to pres-

Figure 1.
The mode of transport used by astronomers traveling with Captain James Cook left no carbon footprint behind. "The Bark, Earl of Pembroke, later Endeavour, leaving Whitby Harbour in 1768" *painted by Thomas Luny,* ca. *1790.*
Image used courtesy of the National Library of Australia

ent and discuss scientific results. We also travel for committee and other meetings to conduct the "business" of astronomy. And, more than anything else, astronomers travel great distances to collect the invaluable photons on which our trade relies.

The best observational sites have always been remote ones. Our search for the best locations from which to study the universe and the constant need to escape from light pollution have brought us to really isolated places: the Chilean desert, Hawaiian mountaintops, even the South Pole.

Although "service" observing has been around for a long time, the majority of ground-based observing is still done by visiting astronomers traveling to (usually) far-away telescopes for a few brief nights of observations. Ever since Gemini pioneered the queue observing model, this modern mode of operations has been widely discussed in the astronomical community. Many different opinions based on individual preferences and experiences have been raised, and the pros and cons have been hotly debated. However, there is a relatively overlooked aspect of queue operations: its positive environmental impact.

When Captain James Cook took a team of astronomers to Tahiti to study the 1769 transit of Venus, they traveled by sailing ship (Figure 1), emitting little or no carbon pollution.

The modern astronomer travels by jet airplane of course, considerably more convenient, but with average CO_2 emissions per person/per kilometer comparable to driving the same distance alone in a car (Ryan, 2007). Marshall *et al.* (2009), estimate that as much as 80 percent of the professional carbon footprint of an average astronomer comes from air travel.

The queue observing system is an efficient way to operate a large ground-based observing facility. It also enables astronomers to help save a bit of the environment with every program observed. To illustrate this point, we analyzed a year of queue operations (semesters 2009A and 2009B) at both Gemini telescopes to see how much travel would have resulted from 100 percent classical observations.

We used a count of Principal Investigators (PIs) who would have traveled between their home institutions and the observing sites, based on the time allocated to each program in the queue. To be conservative, we estimated that programs awarded less than 30 hours of time would be handled by a single observer. For larger programs, we assumed two astronomers would be involved. The distances between major airports in the corresponding home countries of the PIs and those in Santiago and Honolulu (for Gemini South and North, respectively), were used when calculating the roundtrip mileage. Programs from the host institutions of both telescopes and Gemini staff were not included in the travel balance.

This travel information is compiled in Table 1. The bottom line shows that by running a queue observation system in 2009, Gemini prevented the release of at least 1,500 tons of greenhouse gases into Earth's atmosphere. This is comparable to driving a 40 miles per gallon (17 km/liter) vehicle over 8 million km or about 200 times around the Earth (assuming an equatorial highway existed!)

Professional Awareness — and Action — on the Rise

Although astronomers are generally well aware of the fragile equilibrium of Earth's ecosystem, and many consider themselves environmentally conscious, often our focus and our actions toward sustainability are largely restricted to personal rather than professional behavior. However, both awareness and activity within the astronomy profession are on the rise.

In 2009, Phil Marshall and more than 20 co-authors submitted a State of the Profession white paper to the 2010 U.S. Decadal Survey asking—and bravely attempting to answer—the question: "What is professional astronomy's carbon footprint?" Although preliminary, this landmark work deduced that the average astronomer is not low impact, and, in fact, is comparable to a "typical high-flying business person" in terms of professional carbon emissions per person (Marshall, 2009).

In January 2010, one of the authors (Rodgers) joined five other astronomers from five different U.S. institutions to organize a "splinter" meeting at the Washington, D.C., American Astronomical Society (AAS) meeting titled "Energy, Astronomy and the Environment." At that meeting, jointly sponsored by Gemini and the Space Telescope Science Institute, a standing-room-only crowd heard climate activist Joe Romm give a now all-too-familiar account of how a future with global climate change could look. We also heard from several astronomers, including Gemini Director Doug Simons, about a variety of related green activities within our profession, including social outreach, education, and energy conservation in professional facilities.

Then, in May 2010, the AAS Council approved a new Committee on Sustainability, with eight members including three current AAS councilors. Its charge is "to review and recommend plans relating to energy conservation within the AAS." Its initial focus is in three areas: 1) training and encouraging astronomers to be effective advocates for sustainability; 2) reducing the carbon footprint of large professional meetings; and 3) exploring avenues to reduce professional travel. At the January 2011 AAS meeting in Seattle, this newly-formed committee hosted another splinter session on "Green Astronomy" featuring keynote speaker Dean Sandra Archibald (University of Washington (UW)), co-author of UW's Climate Action Plan.

The Committee will also host a special session at the Boston AAS meeting in May 2011, entitled "Sustainability and Astronomy: 'Green' Professional Action and Public Outreach" (Tuesday, May 24th, 4:30-6:00 p.m.), featuring a panel of astronomers, climate scientists, and policy experts. It promises to be a lively discussion!

Information on all of these activities can be found online at:
http://low-energy-astro.physics.ucsb.edu/index.php/Main_Page

	Gemini North		Gemini South			
PIs Origin	# PIs	Average Distance (km)*	# PIs	Average Distance (km)	Total (km)	Total CO_2 Emissions (Tons)/Passenger
United States	56	12,100	59	17,088	1,685,792	460.90
United Kingdom	48	23,266	41	23,363	207,4651	567.22
Canada	28	16,090	25	17,700	893,020	244.16
Argentina	11	24,328	5	2,446	279,838	76.51
Brazil	10	26,355	9	5,986	317,424	86.79
Australia	12	17,731	10	22,526	438,032	119.76
Total:					5,688,684 km	1,555.34 tons of CO_2**

* Round-trip distances for international travel. Local travel from major airports to each telescope site adds ~5 percent.

** 0.440 kilogram of CO_2 per passenger per mile — assuming the average occupancy for the U.S. carriers (John C. Ryan, *Over Our Heads: A Local Look at Global Climate*, Seattle: Sightline, 1997, p. 43).

Table 1. *Estimated total CO_2 emissions based on a conservative estimate of PI travel, assuming semester 2009 A and B queue programs executed in visitor observing mode.*

So, when you are writing your next proposal and are considering its impact on our planet, consider submitting it to an observatory that runs queue observations. The number of telescopes offering this mode of operations is increasing. By doing this, you'll obtain high-quality data under the most appropriate weather conditions. And, you will be able to help preserve our "pale blue dot," which is still (as far as we know) unique in the universe.

References and more information:

Ryan, John C., *Over Our Heads: A Local Look at Global Climate* (Seattle: Sightline, 1997), p.43

Marshall, *et al.*, 2009: *http://www8.nationalacademies.org/astro2010/DetailFileDisplay.aspx?id=449*

Low-energy-astro wiki: *http://low-energy-astro.physics ucsb.edu/index.php/Main_Page*

webfeature: *http://www.gemini.edu/node/11441*

Peter Pessev is a Gemini science fellow at Gemini South. He can be reached at: ppessev@gemini.edu

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

by Peter Michaud, Janice Harvey, and Antonieta Garcia

Sharing Gemini's Wonders: Looking In… and Out

Sharing the wonders revealed by Gemini Observatory takes many forms. These range from traditional press releases and web features (which can reach nearly anyone, anywhere) to educational outreach programs that impact students, teachers, parents, and the public throughout our local host communities in both Hawai'i and Chile.

It's not unreasonable to boast that most people find what happens at an astronomical facility like Gemini intrinsically interesting — as anyone who has ever mentioned that they work at an observatory at a dinner party can attest! Looking more broadly than last night's dinner party, however, sharing the work and discoveries of Gemini is one of the most important legacies we can possibly leave for humanity.

Admittedly, this article presents a narrowly-focused snapshot into what the world has seen from Gemini during the first half of 2011 by looking at two innovative initiatives that use very different approaches to share what Gemini does.

Figure 1.

Images below extracted from the Gemini podcast documenting the coating of the Gemini South primary mirror in late 2010.

A Peek Inside: Behind the Scenes

With our public announcements focusing on some of the most fascinating topics in astronomy — such as supermassive black holes, record-breaking distant gamma-ray bursts, and colliding galaxies — it's easy to overlook the people at Gemini who work behind the scenes to bring the science alive. That's why Gemini

South's outreach staff has spearheaded the GeminiCast program. It focuses on the people of Gemini and what they do to make our observatory work. It also provides astronomy podcasts in Spanish (with English subtitles) to the world, and reveals the compelling stories of the people, events, and activities that allow Gemini to bring our universe into focus.

A number of subjects are now available in the GeminiCast series, including a five-minute introduction to Gemini, a time-lapse movie of the Gemini South Laser Guide Star (LGS) delivery, and a view of the *in-situ* washing of the primary mirror. However, probably the most intensive GeminiCast yet is the documentation of the recent coating of the Gemini South primary mirror (in late 2010). To accomplish this, Gemini South Public Information and Outreach staff member Manuel Paredes and Joy Pollard from Gemini North captured every aspect of the mirror-coating process with time-lapse photography, video, and still images (Figure 1). "We were everywhere," said Paredes. "It really made me appreciate everything that goes into coating the mirror; just keeping up with all of the activity was exhausting!"

In addition to providing the world with an insider's view of what happens at Gemini, the video and images are important to document events, train future staff, and identify and correct procedural and safety protocols. According to Brian Walls, who managed the mirror-coating process, "This time-lapse movie is a unique way to capture the entire coating process and supplements our existing procedures perfectly. Simply by watching the video, any new engineering staff or technicians can come up to speed quickly the next time we coat the primary mirror at either site."

Currently under production is the story of the Gemini Multi-Conjugate Adaptive Optics System (GeMS). Already this undertaking has produced some of the most stunning images of a LGS system in operation. (For examples of these, see the figures in the Gemini South LGS articles on pages 23 and 36 of this issue.)

Figure 2.

Gemini Science Operations Specialist Bernie Walp shares his passion for astronomy with a classroom at Hilo's Waiakea Elementary School.

Future GeminiCasts are planned, including one that will take viewers through a night of observations at Gemini to witness what astronomers and support staff do every night to accomplish their goals. In addition, staff profiles and interviews will be available to share the options available to students considering careers in science, technology, engineering, and other observatory operations.

To access the current selection of GeminiCast videos, visit the following URL:
www.gemini.edu/gallery/v/Special-Images/podcasts/

Other videos are also available at:
www.gemini.edu/gallery/v/Special-Images/Video/

Figure 3.

Over 70 local Hawai'i island teachers participated in the Journey Through the Universe teacher workshop.

Reaching Out: Journey Through the Universe

Another way Gemini shares what we do is by reaching out to educators and becoming immersed with local students and the public in our host communities. Take, for instance, what happened during Gemini North's seventh annual Journey Through the Universe (JTtU) program.

Between February 10-18, 2011, Gemini scientists, engineers, and support staff once again left the comfort of their offices to visit local (highly-energized) classrooms in, and around, Hilo. The visits, part of "Journey Week 2011," reached over 6,500 students at 19 schools in the Hilo/Waiakea/Laupahoehoe School Complex. Fifty-one participating (58 in total) astronomy educators — including representatives from many Mauna Kea observatories, other national observatories, and NASA — visited more than 310 classrooms over a one-week period.

Assisting them were 38 "Ambassadors" from the local business and civic communities, who took time from their busy schedules to make sure that the visiting classroom presenters were properly introduced and had everything they needed. Hilo's local business community, in particular, also continued their ongoing support of Gemini's nationally recognized JTtU program by providing much needed and appreciated support for items like classroom materials, T-shirts, and food. Other events included family science nights and teacher workshops (Figures 2 and 3) and a "thank you" celebration hosted by the Hawai'i Island Chamber of Commerce and the Japanese Chamber of Commerce; this latter event brought together over 170 community and business members to the Hilo Yacht Club for an evening of recognition (and good food!).

Figure 4.

Students, their teachers and school administrators participate in a solar system walk during Hawaii's Journey Through the Universe week.

Hawai'i's state superintendent of education Kathryn Matayoshi even flew over from 'Oahu to spend a morning at a local Hilo high school (her alma mater) during Journey Week and said it was "inspiring." She also shared how impressed she was by "…the broad community engagement supporting the hands-on and engaging activities, showing students and the community the real research that is happening at the telescopes, exploring the field of astronomy, and more." Matayoshi continued, "It's a model that is being copied in other parts of the nation — and it started in Hilo. We hope to expand that model, and this kind of approach is already being incorporated into plans for expanded STEM programs."

According to local area superintendent Valerie Takata, visiting the classrooms this year was "like magic." She said a key component for a successful JTtU program is to have a diversity of classroom presenters and presentations. "Over the past years of JTtU," Takata said, "our astronomy educators have become familiar with the Hawai'i state science standards, and they now have discussions with the teachers in advance of their classroom visits to better understand what is most appropriate for their students as they strive to inspire our youth." Teachers responded overwhelmingly in post-visit evaluations to the exceptional quality of classroom presentations and expressed the desire for "their" astronomy educators to continue visiting throughout the remainder of the school year.

Of course the question is, "Are we making a difference?" To answer that, consider Kellon Bello, who showed up this year to help with the JTtU program. Kellon has participated in Journey as a student for the past six years. Now, thanks in part to his Journey experience, he has enrolled in the undergraduate astronomy program at the University of Hawai'i in Hilo. Although Kellon is only a single example, he demonstrates that the future of our planet rests in our ability to train the next generation of students for careers in science, technology, engineering, and mathematics (STEM disciplines). In Figure 5, Kellon can be seen leading a classroom demonstration on how the Gemini mirror is cleaned with carbon dioxide snow.

Jeff Goldstein, founder of the National JTtU program, is scheduled to conduct our keynote address and lead our workshops for the principals, teachers, and community leaders (Ambassadors) at various events through the week during next year's JTtU 2012, already slated for March 1-9. Regardless of where you are reading this article, consider a trip to Hawai'i during the 2012 JTtU program and sign up to become an astronomy educator for a few days. Or simply use JTtU as an inspiration to go visit a classroom in your community. Every effort you make to share your work will impact students in ways you cannot anticipate and will possibly change a life.

More details on the JTtU program can be found at: www.gemini.edu/journey

Note: in July 2011, a pilot version of JTtU, called *Viaje al Universo Chile*, will be implemented at Gemini South. This program will focus on existing local neighborhood associations for families during winter break at local schools. The program will be combined with the annual AstroDay Chile event. More details can be found at: http://www.gemini.edu/node/11609

Janice Harvey is the Community Outreach and Education Programs Leader at Gemini North. She can be reached at: jharvey@gemini.edu

Ma. Antonieta García is Gemini South's Outreach and Media Specialist. She can be reached at: agarcia@gemini.edu

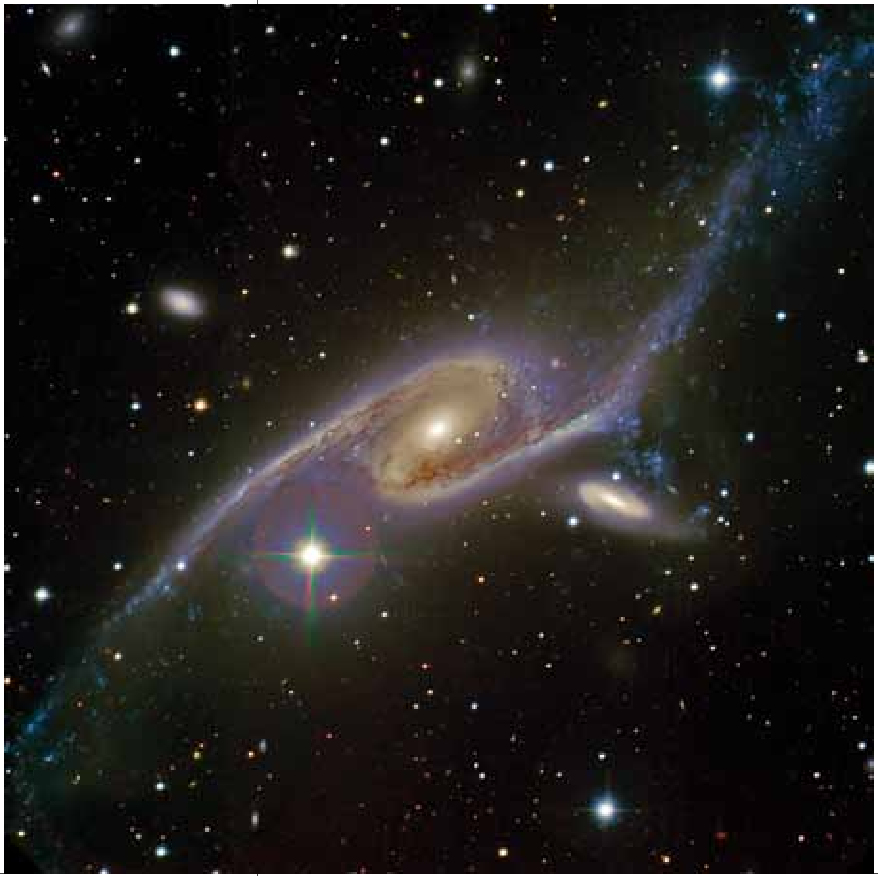
Peter Michaud is the Public Information Outreach Manager of Gemini Observatory. He can be reached at: pmichaud@gemini.edu

Figure 5.
JTtU student alumnus and current University of Hawai'i at Hilo astronomy student Kellon Bello demonstrating carbon dioxide mirror cleaning during a JTtU classroom event.

by Christopher Onken

Australia's 2010 Gemini School Astronomy Contest

Could high school students shed any light on the mysteries of the universe with an hour of precious time on Gemini? To find out, the Australian Gemini Office (AusGO) decided to sponsor its second Gemini School Astronomy Contest to let the students suggest their own cosmic exploration ideas. The result is the amazing image seen here (Figure 1), showing an extragalactic wrestling match between NGC 6872 and IC 4970.



The 2010 contest drew entries from across Australia. To have their chosen object imaged with Gemini, finalists had to get past a diverse panel of volunteer judges (comprised of professional astronomers, journalists, and artists), who were looking for the best justification on both scientific and artistic grounds. The panel decided that the Astronomy Club at Sydney Girls High School (SGHS) had the most impressive submission. In their competition-winning essay, the students pointed to the scientific concepts that could be explored with images of the NGC 6872-IC 4970 interacting galaxy system: the different populations of stars in the galaxies, the formation of new stars when galaxies collide, and the evolving nature of the universe. As the club's proposal pointed out, "It will be more than just a pretty picture."

Once the SGHS Astronomy Club had been selected as the contest winner on May 20, 2010, work began to collect the image data using the Multi-Object Spectrograph (GMOS) camera on Gemini South. Travis Rector (University of Alaska, Anchorage) planned the details of the observations, selecting filters to bring out the beautiful features of the colliding galaxies when the image was obtained later in 2010.

On March 22, 2011, the new Gemini image of NGC 6872 and IC 4970 was revealed to the SGHS Astronomy Club at their school in Sydney (Figure 2). During the grand unveiling, the room was filled with the sounds of "oohs" and "aahs" as the students also received a framed copy of their image. In addition, Ángel López-Sánchez (Australian Astronomical Observatory/Macquarie University) provided the larger context by explaining the various features in the image and — using computer simulations and animations — illustrated the important influence of collisions on galaxy structure and evolution.

Joining the SGHS students in the spotlight were the two runners-up: Benjamin Graham from Whitefriars College (a high school in Melbourne, Victoria) and Kieran Cerato from the Forest Lake College Astronomy Club (a high school in the Australian state of Queensland). All three earned their classes "Live from Gemini" events (see http://www.gemini.edu/lfg). This program features a video link between the students and the Gemini control room for an interactive introduction to the observatory by members of Gemini's Public Information and Outreach (PIO) Office. Each of the classes came prepared with probing questions about black holes, galaxies, and exoplanets, which were deftly answered by the PIO staff. In some cases, astronomers from nearby institutions joined in the conversation to speak about their research, much to the delight of the students. "The students had a great time and learned a lot. I know I did," said Ian Lightbody, the supervising teacher from Forest Lake College.

During the presentation, the students learned that when galaxies grapple with each other, gravity tugs at their structures, catapulting spiral arms out to enormous distances. In NGC 6872, the arms have been stretched out to span hundreds of thousands of light-years — reaching many times farther than the spiral arms of our own Milky Way Galaxy. Over hundreds of millions of years, the arms will fall back toward the central part of the galaxy, and the companion galaxy will eventually merge into NGC 6872. The coalescence of galaxies often leads to a burst of new star formation. Already, the blue light of recently created clusters of stars punctuates the outer reaches of the elongated arms. Dark fingers of dust and gas along the arms soak up the visible light. That dust and gas is the raw material out of which future generations of stars can be born. The Gemini image acquired for the Astronomy Club shows the early phase of this collision process in exquisite detail.

Figure 2. *Students receiving the picture on behalf of the whole SGHS Astronomy Club. L-R: Julia Picone-Murray, Katerina Papadakis, Jeff Stanger (the teacher who led the Astronomy Club in 2010), Isabel Colman (Club president), Christopher Onken (Deputy Australian Gemini Scientist), Angel Lopez-Sanchez (an astronomer with the Australian Astronomical Observatory), Vivian Yean, and Juliet Schilling.*
Photo credit: Australian Gemini Office

A new contest is underway for Australian students in 2011, and we look forward to more exciting ideas from the youth of Australia. AusGO uses these contests to foster the curiosity of students, and to raise the profile of the Gemini Observatory within the community at large.

Learn more about the upcoming 2011 contest at: http://ausgo.aao.gov.au/contest/

Christopher Onken is the Deputy Australian Gemini Scientist and is a postdoctoral researcher at the Australian National University. He can be reached at: onken@mso.anu.edu.au

Figure 1 (opposite).

Gemini GMOS image of NGC 6872 and IC 4970 proposed by a student team from the Sydney Girls High School Astronomy Club. The image was also selected as an Astronomy Picture of the Day for April 3, 2011, see: http://apod.nasa.gov/apod/ap110403.html

Image credit: Sydney Girls High School Astronomy Club, Travis Rector (University of Alaska Anchorage), Ángel López-Sánchez (Australian Astronomical Observatory/ Macquarie University), and the Australian Gemini Office.

by Carolyn Collins Petersen

Mercedes Gomez:
Gemini's Citizen of the Galaxy

Mercedes Gomez enjoying the hills near her home in Córdoba, Argentina.

When Mercedes Gomez of the Argentina National Gemini Office was growing up, she knew exactly what she wanted to be: an astronaut. And, like any budding space explorer, she did her research about her career choice, starting at the top. "I wrote to NASA asking for information about how to become an astronaut when I was 10 years old," she said.

Mercedes was so sure that her future lay in the stars that she began thinking of herself as a citizen of space. "I remember one Christmas when I was around nine years old, I sent Christmas cards to my friends, specifying the addresses not only with the number, the street, the city and zip, and the country, but adding planet Earth, Solar System, Milky Way, Local Group, and so on," she said. "It happened that one of these letters came back from the mail and that's how my mom found out about this weird thing I was doing. My explanation was that in the future I would have friends in all the universe and that my address would have to have all those specifications in order to get to them."

Those childhood dreams were the beginning of a life-long interest in astronomy for this would-be Citizen of the Galaxy. They ultimately led her to study the births of stars from Argentina during her undergraduate and graduate years, and at Harvard University in Cambridge, Massachusetts.

Mercedes, or "Merce" as she is known to her friends and colleagues at the Observatorio Astronómico de Córdoba in Argentina, focuses her research on young stars and star-forming regions in the Milky Way Galaxy. "It's something that has always interested me," she said. "How were the Sun and Earth born?"

Some of the targets she and her colleagues have studied are relatively nearby, such as FU Orionis stars in the Orion star-forming region some 1,500 light-years away. FU Orionis is a variable pre-main-sequence star, and its rhythmic changes in brightness are the hallmarks of an entire class of such young stars. Astronomers are interested in what causes their pulsations in brightness. In a recent paper, Merce and her Ph.D. student, Emanuel Sainz, report on spectroscopic infrared observations of protoplanetary disks around FU Orionis stars. In particular, she says, they are interested in the mineralogy — that is, the mineral composition — of dust grains in these disks.

With Emanuel, Merce and her colleagues observed a group of FU Orionis stars using the mid-infrared spectrographs MICHELLE at Gemini North and T-ReCS at Gemini South. "The idea is that dust particles grow in size to form planets as the parent star evolves to what we call the main sequence (when the star arrives at its adult life)," she said. "Our expectation was to find evidence of grain evolution — for example, that typical dust grains such as those made of silicates were bigger in these disks than the ones you find in the interstellar medium."

Mercedes Gomez takes great delight in mentoring and shepherding her astronomy students.

The experiment turned out to have mixed results: while a few objects showed evidence of this dust-grain evolution, others did not. The reason for this apparent difference is not clear. All the stars the team studied have similar ages and properties. Merce explained that Emanuel is expanding the sample of objects to observe and wants to find an empirical correlation that could provide clues to explain this difference in grain size. "For example," she said, "he is investigating whether the environment or the cloud in which the stars form somehow accelerate to prevent grain evolution."

Merce's interest in young stellar systems stems back to her graduate student days at the Harvard-Smithsonian Center for Astrophysics (CfA) in the 1990s. There, she met and worked with astronomers Lee Hartmann, Scott Kenyon, as well as Barbara Whitney, who was a post-doc there at the time. Whitney, who is currently a researcher with the Space Science Institute, described how Mercedes and the CfA team began working together. "It started when Scott and I made models of young stellar objects that required bipolar cavities to produce the necessary optical and near-infrared flux due to scattering," she said. "I figured if there are cavities, there must have been outflows. So, Mercedes and I decided to try to observe optical outflows from them using the 48-inch telescope and CCD camera at Mt. Hopkins Observatory in Arizona."

Such cavities would have been formed by the action of outflows from young stellar objects. But a study of them would be large, requiring a wide field-of-view, according to Whitney. "People thought this was crazy because these embedded objects are not visible at optical wavelengths," she pointed out. "But, the large field-of-view from this setup allowed us to see shocked visible [S II] emission emerging from the outskirts of these objects. We found outflows in two-thirds of the objects we searched. This was a very fun discovery and led to several more observing runs and papers with Mercedes."

Barbara and Merce spent a number of nights observing together. "We had lots of fun observing at

Mt. Hopkins, where we were on our own, driving on dirt roads in old 4-wheel drive trucks and preparing our meals," Barbara said. "The only problem was that instruments seemed to break whenever Mercedes was around. The telescope operators used to joke around about it when they found out Mercedes was coming up the mountain." But, as Barbara explained, the real issues were more a combination of operator error and coincidence. "We worked 18-hour days because of all the calibrations required," continued Barbara. "My job on these observation runs was to provide useful oversight — kind of like Dr. Watson was useful to Sherlock Holmes."

Merce recalls her days at CfA with great fondness, saying she was incredibly grateful to be working there with some of the luminaries of astronomy and astrophysics. "CfA was a wonderful place to be. So many things going on, [such as] the colloquium talks, as well as the possibility to meet and talk with so many well-known scientists. I enjoyed my time there very much," she reminisced. "I did also enjoy Boston, although it was very hard for me to get used to the winters and snow at the beginning. I did complain a lot about the cold weather, but I did also enjoy the fall and the amazing colors of the trees."

Growing up in Córdoba, Argentina, where the weather was much milder than Boston's, Merce was part of a typical, extended "standard" Argentinean family. Her family lived with Spanish and Italian grandparents, two brothers, and more than 20 cousins. She recalls always being interested in math, physics, and astronomy. She studied astronomy at the school of Mathematics, Astronomy and Physics (FaMAF) at the University of Córdoba. "After the 'Licenciatura,' or master's degree, in astronomy, I got the Ph.D. in Astronomy," she said. That led to her sojourn at CfA and eventually a career in studying hot young stars and outflow regions. Merce is hopeful that more astronomers will come from her family. She has a niece and four nephews and says of them, "I hope to get an astronomer from among them, but right now they are only interested in soccer."

These days, Merce is helping the next generation of young astronomers in Argentina, both as a professor of astronomy and as a mentor to graduate and undergraduate students. "This takes a lot of my time," she said. "I also work with students who have to do a research project to get their master's degrees and also with Ph.D. students who are working on their thesis projects." One of her undergraduate students graduated in March 2011, and, as of this writing, another is expected to in May. Much of her time had been taken up with helping them to get their research projects finished and written, she said.

In addition to her teaching and research duties, Merce is Gemini's Argentina National Office contact, where she assists the country's Gemini users in getting time on the telescopes. "We assist users with phase I and II preparations, and also make connections between the local community and this international observatory," she said, noting that she and her colleagues help new users with everything, from asking for observing time to helping with all the tasks that need to be done to ready an observation for implementation.

Despite the busy life that she leads, Merce takes time to enjoy music. "To be honest, I enjoy all kinds of music, in the right moment," she said. "I like traditional Argentinean music and folklore. Argentina and Uruguay are well-known because of tango, which I also like. However, tango is more representative of the La Plata river region. The Argentinean folklore speaks about the history and customs of the other regions of the country, closer to my reality."

On weekends, she likes to get outdoors when she can. Merce doesn't claim to be much of a sports fan, but instead prefers to walk and appreciate nature. "Near the city where I live there are a few lakes, hills, and rivers," she said. "I enjoy spending my weekends there. I take long walks and sometimes spend all day outside. The night sky is beautiful and I can not help the emotion I feel every time I see it."

Gemini*Focus associate editor Carolyn Collins Petersen is a science writer, producer, and vice-present of Loch Ness Productions. She can be reached at:*
carolyn@lochnessproductions.com

The setting sun, seen through the Gemini South vent gate. Photo taken on September 22, 2010 by Gemini astronomer Michael Hoenig.

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GEMINI OBSERVATORY

Northern Operations Center
670 N. A'ohoku Place, Hilo, Hawai'i 96720 USA
Phone: (808) 974-2500 Fax: (808) 974-2589

Southern Operations Center
c/o AURA, Casilla 603 La Serena, Chile
Phone 56-51-205-600 Fax: 56-51-205-650