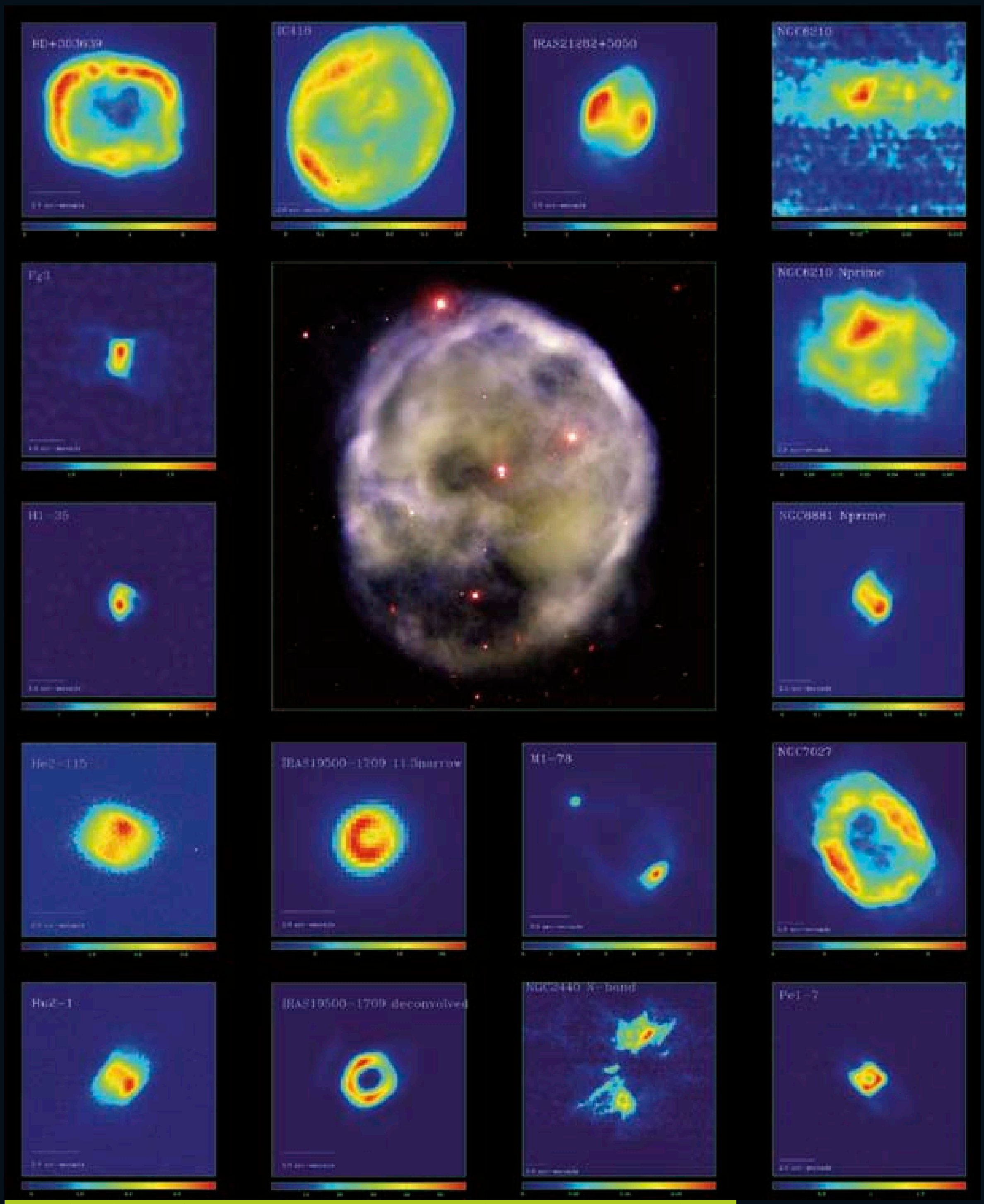
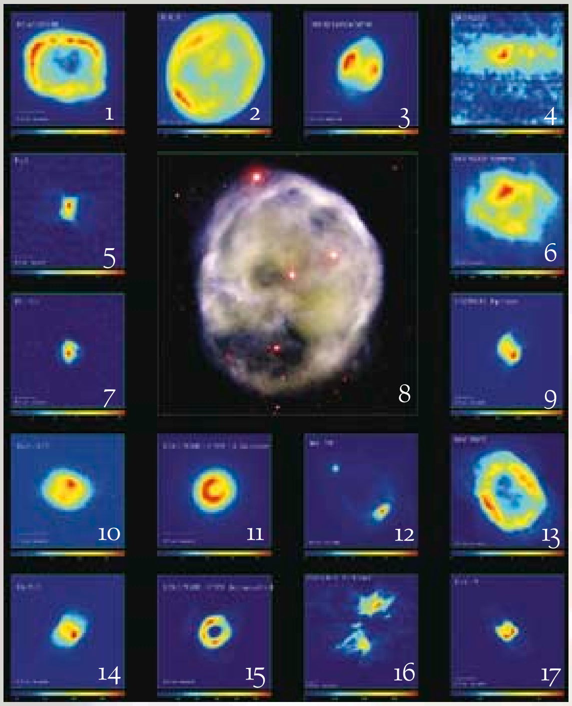
GeminiFocus

Newsletter of the Gemini Observatory

June2006



Gemini mid-infrared planetary nebulae images, K. Volk, optical inset NGC 246, GMOS-South, T. Rector University of Alaska, Anchorage



Key:

#1: BD+30°3639 (MICHELLE)

#2: IC418 (T-ReCS)

#3: IRAS21282+5050 (MICHELLE)

#4: NGC 6210 (MICHELLE - dust 11.7 microns)

#5: Fg3 (MICHELLE)

#6: NGC 6210 - (MICHELLE - Nebular Lines, N' filter)

#7: H1-35 (T-ReCS)

#8: NGC 246 (GMOS-South)

#9: NGC 6881 (MICHELLE - N' filter)

#10: He2-113 (MICHELLE)

#11: IRAS19500-1709 (T-ReCS - Raw, 11.3 microns/narrow band)

#12: M1-78 (MICHELLE)

#13: NGC 7027 (MICHELLE)

#14: Hu2-1 (MICHELLE)

#15: IRAS19500-1709 (T-ReCS - Deconvolved, narrow band)

#16: NGC 2440 (T-ReCS - N-band)

#17: Pe1-7 (T-ReCS)

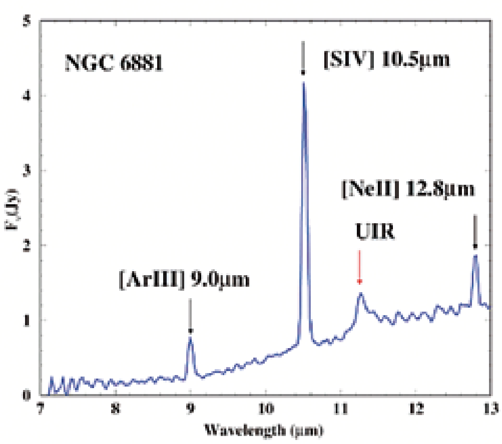
Planetary nebulae are favorite targets for imaging both by amateur and professional astronomers. Optical images such as that of NGC 246 show the nebular emission lines from the ionized gas produced by the hot central star, which illuminates its former atmosphere as the gas expands out into space.

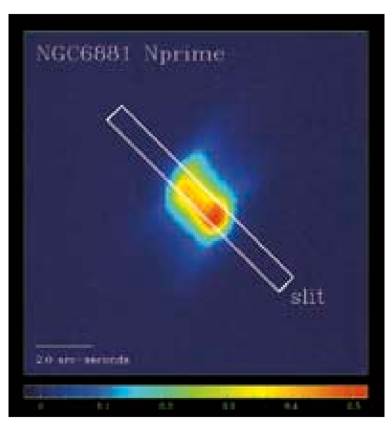
A somewhat different view of these objects is obtained in the mid-infrared where, in addition to nebular emission lines similar to the optical ones, there is often strong thermal dust emission from small solid grains in and around the ionized region. These dust grains are some of the main sources of heavy elements in the interstellar medium. Pre-solar grains of this type have been identified in meteors in our solar system. There are a number of interesting questions concerning the physics of dust particles that can be addressed by observations in the mid-infrared.

Cover Illustration: this montage of false-color images shows dust emission from a number of smaller planetary nebulae imaged by T-ReCS and MICHELLE (Gemini South and North, respectively). These images (except number eight which is an optical image obtained with GMOS-South) were obtained as part of an on-going project to study the dust grain properties (size, composition, total dust mass, and temperature) in different nebulae in order to understand what effect the grains have on the nebulae and the interstellar medium.

–Kevin Volk

Figure 1. MICHELLE spectrum of NGC 6881 with image of slit location used to obtain data.





GeminiFocus

Newsletter of the Gemini Observatory

In This Issue:

NGC 7424 / S. Ryder, AAO and T. Rector, University of Alaska Anchorage

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by Doug Simons,
and Jean-René Roy

A New Era of Operations at Gemini Observatory

With the full implementation of the multi-instrument queue observing system at Gemini North and South, we now have a unique, extremely versatile and incredibly powerful astronomical observing system available for our community. Every night we routinely use any or all of our optical, near-infrared (with or without adaptive optics at Gemini North) and mid-infrared instruments to best match observing programs with sky conditions. All instruments are active 24/7, fully calibrated and ready to be used throughout the night. Switching from one instrument to the other can be done within minutes, and instruments are normally re-configured as we slew to a new target in accord with our philosophy of "use every second wisely" at Gemini Observatory. Not too surprisingly, since we seldom physically swap out instruments on the back of the telescope, our instrument suite has proven to be quite reliable in this model of operations.

The implementation of this versatile observing system has been achieved with the skillful efforts of all the support groups at the Gemini Observatory working in a very close partnership with each other. The enthusiastic support of the Gemini staff for the multi-instrument queue approach has been truly amazing and has contributed to the successful early implementation of this capability and its effectiveness. The staff members at the National Gemini Offices have also been most supportive as we, at long last, leave telescope commissioning behind us and enter an era of steady-state operations.

Despite this remarkable progress, the current queue planning system is quite "manual" in nature, requires a rather intensive planning effort by our science staff, and would benefit greatly from more automation. Gemini's high-level software group, interacting closely with our science team, is working to improve the queue planning process by implementing a new "intelligent" queue planning tool that should cut the effort of our science staff in half. Queue planning feeds critically into the open-shutter efficiency achieved each night at Gemini. Analysis shows that running several instruments during the same night has a negligible impact on our open-shutter efficiency. With our science staff fully trained to run all instruments, we soon expect to push our current shutter-open efficiencies even higher (see articles in this issue and in the December 2005 issue of *GeminiFocus*). More importantly, beyond just achieving high open-shutter efficiencies, the true advantage of using a multi-instrument queue is that we are able to maximize the quality of our scientific product by matching programs to ever changing atmospheric conditions. This is especially critical for observations in the thermal infrared, which require dry conditions, or programs that require good seeing and/or adaptive optics.

Our very aggressive mirror cleaning program is also paying dividends. Beyond the weekly CO_2

snow cleaning or the protected silver coating on the telescopes' mirrors, we recently developed an in-situ mirror-washing technique for both of our primary mirrors. This procedure can bring mirror reflectivities back to within about one to two percent of the fresh-coated values, depending on wavelength. Importantly, our in-situ washing operation can be done in one day, and does not result in any time lost at night. Using our mirror cleaning regimen, we are now projecting a lifetime of about 2.5 years for the protected silver coatings on Gemini's primary mirrors. The longevity of our protected silver coatings minimizes the down-time needed for recoating and, compared to our early estimates of recoating frequency, leads to an increase in the time the telescopes are available for science time by about two to three percent per year. Taken together, our mirror-cleaning procedures leave us with nearly optimal reflectivity and emissivity at all times.

We are continuously working to improve the image quality that the telescopes deliver to the focal plane of our instruments. Intensive re-work of our peripheral wavefront sensors and related elements has contributed to the robustness of our A&G systems and to an improvement in the average image quality at both sites. Depending on the season (*e.g.*, winter *vs.* summer) the image quality measured through the science instruments varies between 0.5 and 0.7 arcseconds, normalized to zenith and at 550 nanometers (see image quality article in this issue starting on page 43).

Finally and most importantly, the growth of refereed papers based on Gemini data is healthy and competitive. We now have more than 250 papers published or in press, and currently a new paper based upon Gemini data appears about every three days. It has been very encouraging to see a robust growth in the number of papers published in the highly competitive journals like *Nature* and *Science*. Taken together, this impressive array of capabilities has led to the transformation of Gemini. With first light occurring at both telescopes about six and five years ago, Gemini is a young and vibrant observatory, poised to play not just an important, but also a historic role in humanity's quest for a deeper understanding of the realm in which we all live.

Update on the Aspen Instrumentation Program

Considerable progress was made in the Aspen development program since the previous GeminiFocus *article (see article about this program starting on page seven of the December, 2005 issue). Most of the recent effort within Gemini has gone into contracting a large number of teams to perform various tasks. Specifically, the Gemini Planet Imager (GPI) team, led by Lawrence Livermore National Laboratory, is now under contract to carry out the detailed design and construction of this remarkable instrument, which is designed to directly image self-luminous Jovian-class extrasolar planets lurking within ~ 0.2 - 1.5 arcseconds of young nearby stars. In parallel, teams led by the Astronomy Technology Centre and Cornell are engaged in competitive conceptual design studies for the Precision Radial Velocity Spectrograph (PRVS). These studies will be completed in September, 2006 and feed into a decision about building this next-generation radial velocity survey machine by the end of this year. The University of Hawai'i is now under contract to lead an aggressive site-testing program to measure the ground layer turbulence above the upper ridge on Mauna Kea over a one-year period. These data will feed critically into a future decision about developing a Ground Layer Adaptive Optics (GLAO) system for Gemini North.*

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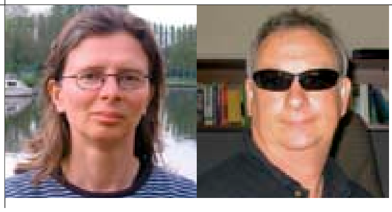

by Rachel Johnson
and Dennis Crabtree

The Role of the National Gemini Offices

During the course of a typical night at Gemini, observations can be executed using several different instruments for astronomers from a number of partner countries. Gemini users may think that carrying out their observation requests is the main work of the observatory, but in reality, observing runs are just the visible pinnacle of a large mountain of preparation. A big part of this mountain is user support, particularly important for queue-scheduled telescopes such as Gemini, where the majority of the user community never visits the telescope.

What is an NGO?

The Gemini community consists of astronomers with diverse scientific interests and a range of observational experience, and spans countries in more than 12 time zones. The Gemini partners and the observatory gave a lot of thought as to how best to support such a broad user base. They adopted a solution, unique among large telescopes, where astronomers in the Gemini partner countries are an integral part of the support system.

Each partner created and funded a National Gemini Office (NGO) to manage their Gemini responsibilities. The majority of NGO staff members are professional astronomers, and there are also a small number of administrative positions. The NGOs have primary responsibility for user support and represent Gemini to their user community.

As shown in Table 1, the size, organization and funding of each NGO varies from country to country, with partner share and with country size.

Placing the user support in the partner countries creates an easily accessible nucleus of expertise, helps to build ties between the partners and Gemini, and creates a sense of telescope ownership in the community. This "distributed approach" also allows for a flexible response to the specific needs of each partner in areas such as time allocation committee (TAC) support and public outreach. The NGOs are hosted in university departments, or in national observatories with strong research groups. This allows the staff members to personally interact with real users and provides jobs that allow astronomers to get involved with observatory work without having to move to an observatory site. Such a model also creates challenges, notably in maintaining strong communication links between the observatory and the NGOs.

NGO support responsibilities

The main responsibility of the NGOs is user support, and each office is required to provide detailed support and advice for users of all the Gemini instruments. For the smaller NGOs, supporting all the instruments is quite a challenge, and so those offices are exploring ways to pool their expertise and resources.

U.S.	
Number of Staff = 14	**Gemini Support FTE = 6.64**
Funded as part of NOAO. Staff members are distributed between Tucson and La Serena	
U.K.	
Number of Staff = 4	**Gemini Support FTE = 2.8**
Funded by the Particle Physics and Astronomy Research Council. Staff are based at Oxford University.	
Canada	
Number of Staff = 4	**Gemini Support FTE = 2.0**
Funded as part of the National Research Council of Canada's Herzberg Institute of Astrophysics. Staff are based at the Dominion Astrophysical Observatory, Victoria	
Australia	
Number of Staff = 11	**Gemini Support FTE = 1.6**
Funded by the Australian Research Council. The Gemini Project Scientist is currently based at the ANU, Canberra, with other staff throughout Australia.	
Argentina	
Number of Staff = 2	**Gemini Support FTE = 1.0**
Funded by Argentinean Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET)	
Brazil	
Number of Staff = 6	**Gemini Support FTE = 1.35**
Funded by the Brazilian Federal Government. Staff are based at the Laboratório Nacional de Astrofisica, Itajubá.	
Chile	
Number of Staff = 3	**Gemini Support FTE = 1.6**
The Chilean Gemini Office is funded directly by CONICYT and it is located in the CONICYT premises in Santiago.	
University of Hawai'i	
Number of Staff = 1	**Gemini Support FTE = 0.15**
Funded by the University of Hawai'i. Staff are based in the IfA, Honolulu.	

Table 1. Total number of staff, number of full time equivalent staff (FTE), funding source and location of each National Gemini Office. The staff numbers include astronomers and administrative staff. The Gemini Support FTE is lower than the Number of Staff because staff members have time for personal research, and in some cases, other support duties, in addition to Gemini support.

General user queries arrive throughout the year, mostly via the web-based Gemini HelpDesk system (although many still arrive by phone or E-mail). The HelpDesk system requires users to choose the correct category for their query, which is then automatically sent to the person in their NGO with the relevant expertise. The NGOs provide the first level of support (Tier 1) for all HelpDesk queries, and many are answered at this level. The HelpDesk has two further tiers of support for more complicated queries. Tier 2 support is provided both by the NGOs and by the observatory, depending on the query category. The NGOs provide Tier 2 support for instruments that were built in their countries. The ultimate responsibility for Tier 3 HelpDesk support lies with the observatory.

Much of the user support work is related to the Gemini proposal process. The areas of responsibility in the process of turning a Gemini proposal into Gemini data are described broadly below (though there is some overlap in observatory and NGO responsibilities).

In general, the observatory maintains and improves the performance of the instruments and telescopes, takes observations and calibrations, and provides the necessary software for observations and data reduction. The NGOs are primarily responsible for user support before and after the observations are taken.

The NGO proposal and observation related support tasks are on a six-month cycle (illustrated in Figure

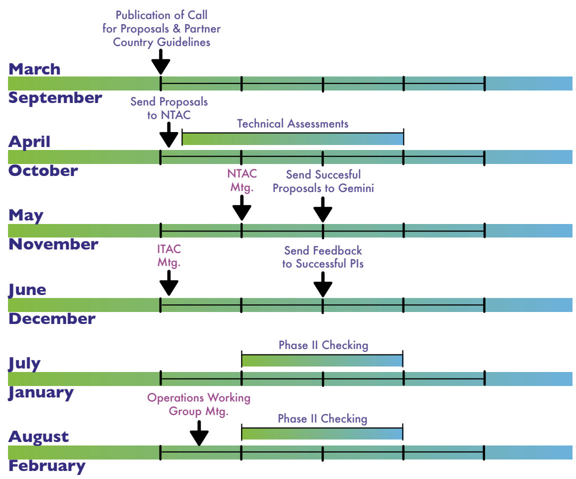

Figure 1. The NGO tasks dealing with proposal processing and observation definition are on a six-month cycle. The dates indicated for each task in the illustration are only approximate, as they can vary by a few days from semester to semester. As well as the tasks indicated here, the NGOs answer general user support and data reduction queries throughout the year.

1), starting with publicity for the Gemini Call For Proposals and publication of the individual partner country guidelines, and including checks that the software and computer systems in each country are ready to receive proposals. Once the last-minute queries have been answered and all the proposals submitted, they are packaged by the NGOs for the National Time Allocation Committee (NTAC) members.

In the three weeks immediately after the proposal deadline, the NGO staff members assess the proposals for technical content, contact the PIs to sort out any known problems and make the technical assessments available to the NTAC members. Some NGO members may be NTAC members but the NGOs do not provide additional scientific assessment beyond the TAC process. The successful proposals are packaged by the NGOs and sent to Gemini before the International TAC meeting (ITAC), where the final list of successful proposals is identified.

In the next step (Phase II), the NGOs work with the successful PIs to define their observations using the observing tool (OT) software. This is the same software used at the telescope to take the observations, and all aspects of the observation (instrument set-up, exposure times, dithers, guide stars, etc.) have to be correctly defined. To maintain good observing efficiency, Gemini needs observations requiring a wide range of observing conditions to be ready for immediate execution, especially early in the semester.

There are two deadlines around the beginning of each semester when PIs need to submit their observation definitions. PIs with objects that are not observable until late in the semester sometimes wonder why they have to define their observations so early. The deadlines allow NGO staff members to make sure they are available during the Phase II checking process.

After the deadline, the observation definitions go to NGO staff members for checking and iteration with the PIs. Once the observations are corrected they are sent to the observatory for a final check and placement in the queue. The deadline for the NGOs to send correct observation definitions to the observatory is about two weeks after the PI submission deadline. This stage of the support process can be especially time-consuming because less-experienced Gemini users usually require several iterations with the NGO before their Phase II programs are "telescope ready."

After the observations, when users have received their data, the NGOs are the first "port of call" for data reduction help. Several of the NGOs have also provided support for instrument commissioning and operations. For example, the U.S. NGO is currently responsible for running Phoenix, the NOAO high-resolution near-infrared spectrograph at Gemini South, and for supporting its observations.

Maintaining Communications

A crucial component of the distributed support model is communication, both between the users and the NGOs and between the NGOs and the observatory.

The NGO staff members meet with Gemini users in their communities throughout the year, both to gather feedback from the users and to update them with news from the observatory. The national astronomy meetings of the partner countries provide good opportunities for interaction, and for outreach activities such as presenting Gemini talks and posters, staffing Gemini booths, and running town hall meetings. NGO staff members also give talks at university astronomy departments, and several NGOs have organized community workshops to focus on particular areas (*e.g.* data reduction, mid-infrared capabilities, and Phase II training). Many of the NGOs have set up user committees that provide invaluable sources of feedback. The Canadian, U.S. and UK NGOs publish regular Gemini articles in (respectively) the Canadian Astronomical Society/Société Canadienne d'Astronomie (CASCA), *NOAO Newsletter*, and the Particle Physics and Astronomy Research Council (PPARC) *Frontiers* magazine. The NGOs also have web sites where they publicize Gemini news and issues of particular interest to their communities.

Discussion of user feedback is an important component of the twice-yearly Operations Working Group meetings between NGO leads and observatory staff. Participants focus on the various issues that affect Gemini users, including such products and discussion points as software for observation preparation and data reduction, web page content, and observational strategy. This group also has regular teleconferences organized by the NGOs.

It is important for NGO staff to remain up to date with existing instrument capabilities and observing procedures. The best way to achieve this is to visit the telescopes to run the observing queue and to interact with Gemini Observatory staff. Most of the NGOs have sent staff members to the telescopes, and some visit every semester. Training during these

Assessing the NGOs and the Proposal Process

By Doug Simons and Jean-René Roy

Later this year the Observatory will launch a series of reviews of the National Gemini Offices (NGOs) in an effort to streamline interfaces to Gemini, efficiently couple resources between the Observatory and our NGOs, and make sure that the distributed science support systems on which our community critically relies are consistent with the scientific mission of the Observatory. One of the key components of the overall Gemini distributed model is the observing proposal process and assessment. This process is under the purview of national institutions; the NGOs work with and support each of these national processes.

The quality of the science that Gemini delivers depends in large part on the programs that are recommended to the Gemini Director by the national time allocation committees (TACs) and the international TAC (ITAC). This is a process that Gemini Observatory has very little control over. The current TAC process is comprised of nine separate review systems (six partner countries, two host institutions and the Gemini Staff TAC). This complicated and fragmented structure requires sophisticated logistics to successfully coordinate and to avoid errors. We naturally remain concerned about such a complex and distributed TAC process when it is ultimately the Observatory's responsibility to ensure that the depth and breadth of the scientific product that emerges from Gemini is world-class.

A careful examination of the Gemini TAC/ITAC process, as part of a broader review of the NGOs, should help make certain that our collective methods are robust, yield proposals well-tuned to the performance strengths of the Observatory, and reflect the broad scientific interests of our community. It is important that our TAC process is not an impediment to large projects, which may be the case as the average time requested in 2006B varies from four hours for the smallest partner to 18 hours for the largest one.

Bibliometric studies show clearly that the highest impact papers result from programs conducted by moderate (10 or more) to large teams (20 or more). These teams are generally associated with large observing programs, or at least programs conducted over several semesters and, given Gemini's international composition, require consideration by multiple TACs. Historically at Gemini we have had very few large programs. Some notable exceptions are the Gemini/HST Galaxy Clusters program by Jørgensen et al. (~ 400 hours), the Gemini Deep Deep Survey by Glazebrook, Abraham, Crampton et al. (145 hours), the Gemini Deep Planet Survey by Doyon et al. (about 150 hours). Interestingly, the success of the Director's Discretionary (DD) Time allocations (i.e., non TAC allocations) is symptomatic of the problem we may, as a community, be suffering from. DD time represents about 5-7% of the time scheduled on the telescope, but has resulted in about 30% of the papers published, several of which having very high impact.

There is a striking contrast between the fully integrated observing system and engineering/administrative support of the "one observatory/two-telescope" system we have in place, and the current highly-fragmented NTAC/ITAC system. We will work closely with the National Gemini Offices and the funding agencies throughout this review process to make sure that our distributed resources all work together as efficiently as possible and yield a scientific product worthy of our community's research ambitions and the remarkable telescopes at Gemini Observatory.

Figure 2. NGO and Gemini Observatory staff members at the November 2005 meeting in Tucson.

visits is provided by the observatory instrument scientists via video or phone tutorials. NGO staff have also participated in several of the Science Verification opportunities available to test new instruments, which allows the NGOs to provide feedback to instrument scientists.

Every year and a half, the NGOs organize a meeting for a large group of NGO and observatory staff members. There are talks about instruments and software, as well as ample opportunities for the exchange of ideas between staff at all levels, and discussion of improvements in user support activities. The most recent meeting in Tucson, Arizona, in November 2005 (Figure 2) was attended by 40 NGO staff members representing all of the partner countries.

NGO outreach activities

The NGOs also play an important role in publicizing Gemini to a wider audience. They do this by giving talks to amateur astronomy groups and the public, working with press officers and journalists, and distributing Gemini publicity materials. The Canadian office has even provided an opportunity for amateurs and students to use Gemini, by organizing three competitions for observing time. Two were reserved for schools and the third was limited to amateur astronomy groups. The GMOS image of the Trifid Nebula requested by Ingrid Braul (a seventh-grader from Vancouver, British Columbia, Canada), was a result of this program and has been used by Gemini in many publications.

Each Gemini partner interacts with Gemini through the Public Information and Outreach Liaison Group which meets annually. The representative(s) from some countries can be part of their NGO while for other countries their representative is from a distinct group.

Finally...

Making astronomers in the partner countries an integral part of the Gemini organization was an innovative strategy. It is not without challenges, but does give us many unique advantages. The NGOs are a vital part of Gemini and will remain so for years to come.

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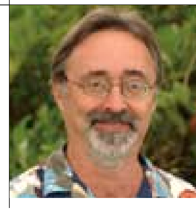
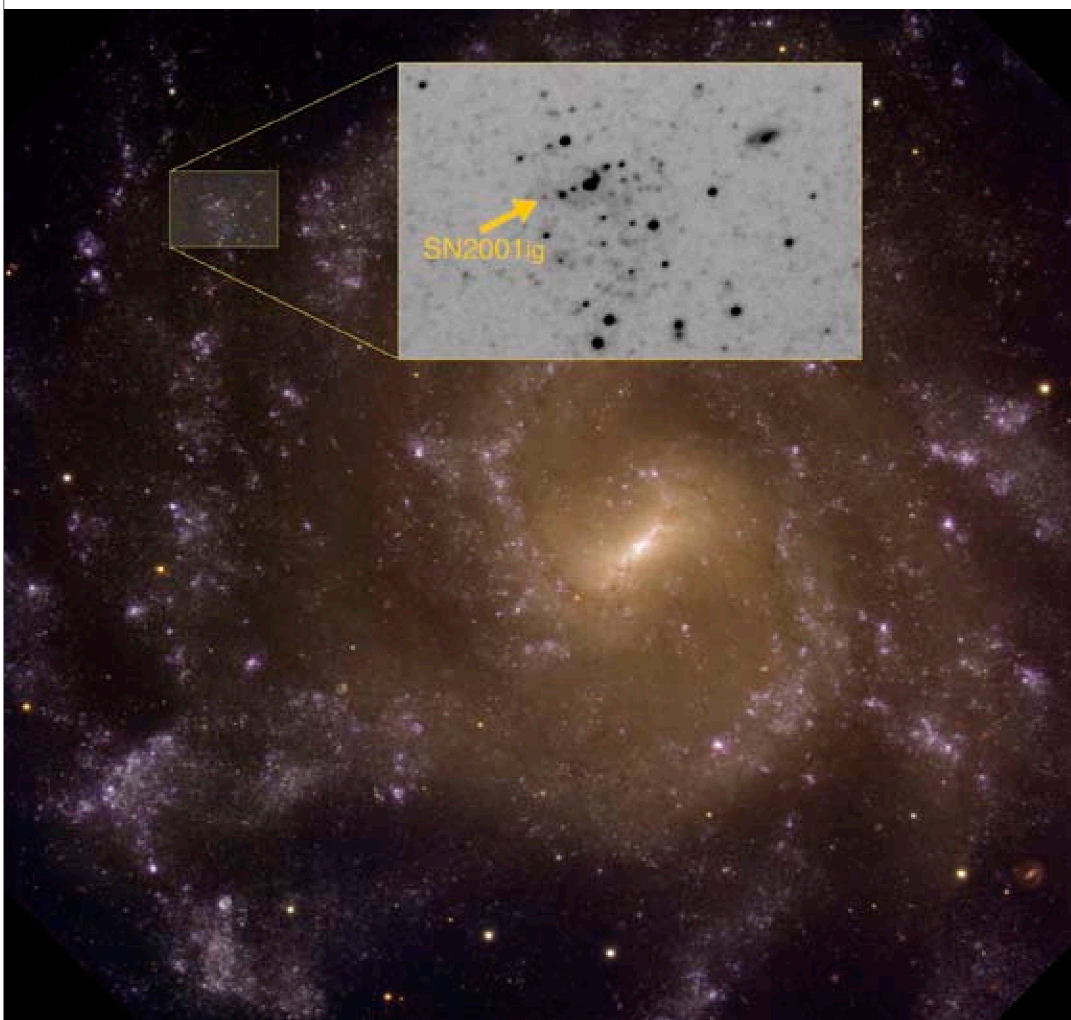



by Jean-René Roy
and Scott Fisher

Recent Science Highlights



NGC 7424 / S. Ryder, AAO and T. Rector, University of Alaska Anchorage (background)

Remnant Binary Companion to Type IIb Supernova 2001ig in NGC 7424

Deep imaging of the barred spiral galaxy NGC 7424 (Figure 1) obtained with GMOS at Gemini South about 1,000 days after the explosion of the Type IIb supernova SN 2001ig reveals a point source at the location of the explosion. An Australian team led by Stuart D. Ryder of the Anglo-Australian Observatory (AAO) has investigated the object and surmises that it is the remnant massive binary companion (Figure 2). The object has a g´ magnitude of 24.14 and the color of a B-type star. A careful analysis shows that the shape and colors of the object are consistent with it being a stellar object, and not a nebula. SN 2001ig is the second Type IIb supernovae shown to have a massive binary companion to the progenitor. The other was SN 1993J.

Figure 1.
NGC 7424 which was host to Supernova 2001ig as indicated in the inset (r‘-band) image at top. All images are from the Gemini South Multi-object Spectrograph.

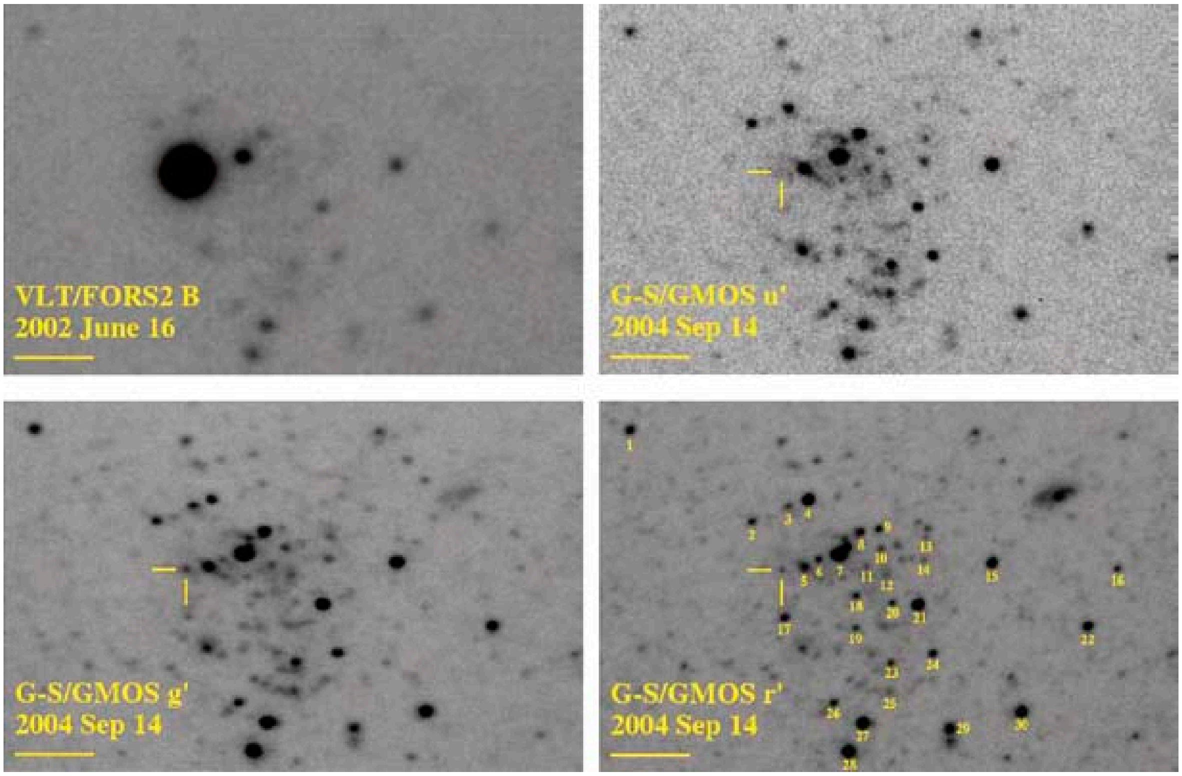


Figure 2. Images of the region immediately surrounding the location of SN 2001ig in NGC 7424. The upper left image was obtained with VLT FORS-2 near the time of the maximum brightness of the supernova under poor sky conditions. The line in the lower left of each panel is five arcseconds long.

Previous imaging constrained the progenitor of SN 2001ig as a Wolf-Rayet star with a luminosity of about 30,000 times that of the Sun and a mass between 10 and 18 solar masses. Type IIb supernova explosions are rare, underlying the importance of the this object's discovery. The production of a Type IIb supernova appears to require the mass transfer in a binary system to produce the stripping necessary to account for the Type IIb phenomenon. Future investigations of the remnant of SN 2001ig will help to reconstruct the circumstances surrounding the very end phase of massive stars, and throw light on the possible role of interaction as a final trigger.

The Ice Surfaces of Giant Kuiper Belt Objects

Kuiper Belt Objects (KBOs) are known to have very diverse surfaces in terms of global visible colors. Fortunately, signatures of the most primitive solar system volatiles can be seen in the infrared region of the spectrum. Although many attempts have been made to detect ices on KBOs in the near infrared, very few have been successful to date. The best known are the methane ice surfaces of 2003 UB313, FY9 and Sedna. Some others have signs of water ice, with Quaoar being the only KBO to show signs of crystalline water ice.

A Gemini and U.S. team led by Chad Trujillo (Gemini Observatory) used NIRI on Gemini North and NIRC on Keck to observe the object known as 2003EL61 and get spectra of it. It is the only known ternary or higher system in the Kuiper belt (excepting Pluto, now known to have Charon and two tiny moons). 2003 EL61 is also the most rapid large (greater than 100 kilometers) rotator in the solar system. Trujillo et al. have found great amounts of crystalline water on 2003 EL61 (Figure 3).

Although some additional blue material provides even better fits to the observation, pure crystalline

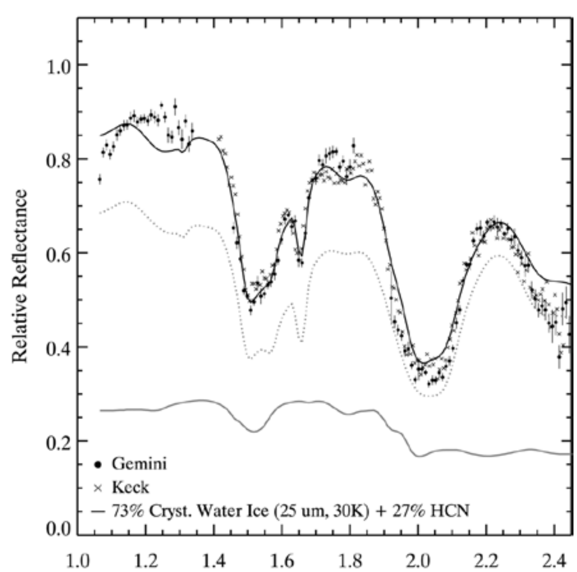


Figure 3. Composite spectrum of 2003 EL61 showing that a pure water ice model fits the major features of the spectrum.

water is the major component, just as it is for Charon and Quaoar. The surface is unlikely to be covered by significant amounts of dark material, such as carbon black. Crystalline water ice may have been prevalent in the solar system due to heating events in the early solar nebula. Such ice could have been incorporated into bodies at low temperatures (below 100 K) if the deposition flux of water molecules was low. However crystalline water ice is unstable on solar system timescales. Over long periods, cosmic rays and solar flux are expected to rearrange crystalline water ice to amorphous in the outer solar system.

Fundamental Plane at Redshift 0.8 to 0.9 Supports the "Downsizing" Scenario of Galaxy Formation and Evolution

Inger Jørgensen has led a team of Gemini and British astronomers in the study of the Fundamental Plane (FP) for two distant galaxy clusters: RXJ0152.7-1357 at z = 0.83 and RXJ1226.9+3332 at z = 0.89. GMOS-N was used in the multi-object mode to obtain high signal-to-noise spectra of dozens of galaxies in the two clusters.

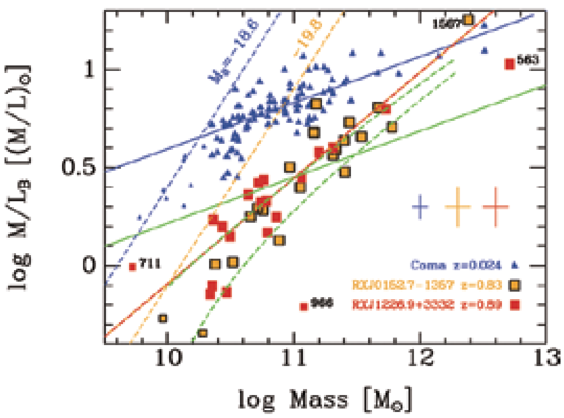


Figure 4. Plot of the axis log M/L_B vs log Mass $[M_{sun}]$ for the distant clusters RXJ0152.7-1357 (orange), RXJ1226.9+3332 (red) and of the nearby cluster Coma Cluster (blue).

The FP for elliptical (type E) and lenticular (type SO) galaxies relates key macroscopic properties of these objects, such as the effective radius, the mean surface brightness and the velocity dispersion. A simple way to see the FP is as a relation between the galaxy masses and their mass-to-light (M/L) ratios. The FP is well known in the local universe and previous studies have explored its evolution between redshift z = 0.2 and 1.0.

Using the large Coma Cluster sample of galaxies as the low-redshift reference sample, the team showed that the FP for the high-redshift clusters is shifted and rotated with respect to that of the Coma Cluster. Such a shift is expected for a mass-independent epoch of formation of the galaxies. The rotation is not expected. The FP is significantly steeper for the high-redshift clusters. This is interpreted as a mass dependence of the star formation history, e.g. lower-mass galaxies have formed more recently than the more massive ones. The z = 0.8 to 0.9 Fundamental Plane shows significant recent star formation in low-mass galaxies, consistent with the now popular "downsizing" scenario, where big galaxies formed first and the smaller ones came together more slowly and over more extended periods of time, depending on their masses.

This work is part of a key Gemini project on the study of the evolution of galaxy clusters between now and half the age of the universe (z ~ 1.0).

The Remarkable Mid-infrared Jet of Massive Young Stellar Object G35.20-0.74

Jim de Buizer (Gemini Observatory) used T-ReCS on Gemini South to image the young massive stellar object G35.20-0.74 located about two kiloparsecs (6,500 light-years) away in the constellation Serpens. He found a well-defined bipolar jet associated with this relatively isolated young massive star, clear evidence of a single massive star undergoing accretion. This is important because it is not yet clear whether massive stars are formed by merger of small stars or by accretion of infalling matter. Confirmed jets from a massive star are very rare. The T-ReCS observation shows the jet in the mid-infrared continuum conclusively for the first time. This source represents a young stellar object that is dominated by mid-infrared emission not directly associated with a circumstellar disk or envelope.

There are interesting consequences to this finding. Many investigations are performed at low resolution, looking for infrared excesses assumed to be tracing only the disk properties of the disk properties of the sources. Such an approach may miss any jets emanating from the young massive stellar objects. It is also interesting to note that methanol masers

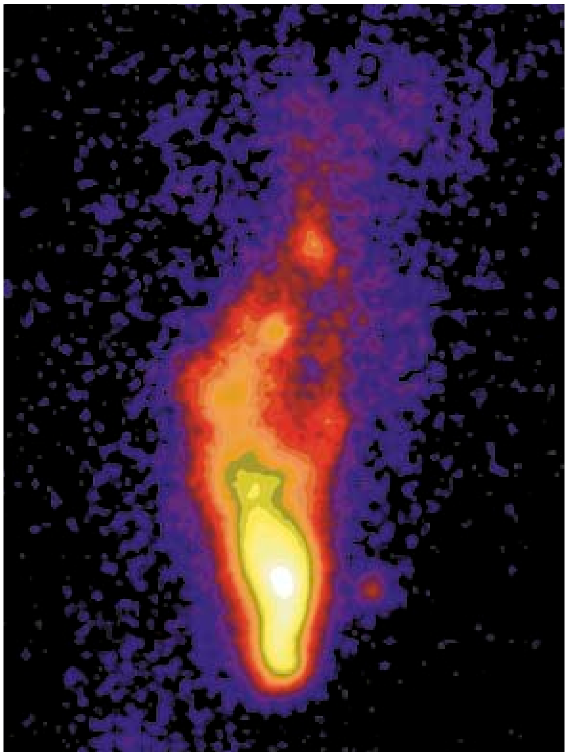


Figure 5. Mid-infrared jet (false color) from the young massive stellar object G35.20-0.74 observed with T-ReCS on Gemini South.

observed in G35.20-0.74 are closely associated with the mid-infrared outflow cavity itself.

MICHELLE Studies Formation of Massive Stars in Orion and Taurus

A team of astronomers led by University of New South Wales researcher Steve Longmore recently used MICHELLE (the mid-infrared imager/spectrograph) on Gemini North to study the earliest stages of massive star formation by observing a small sample of hot molecular cores that are associated with methanol masers.

The team found that each of the sites, which are located in an active star formation region in an area of the sky bounded by the constellations of Orion and Taurus, contains a mixture of large regions of extended emission as well as multiple point sources. Initial analysis of the MICHELLE imaging shows that the unresolved sources are extremely red in color (F18.5/F7.9 › 3) implying that they are likely highly embedded (A_v › 40 magnitude) young stellar objects. The maser emission is found to be closest to the brightest mid-infrared point source in each field. This is not completely unexpected since these sources are luminous enough to evaporate methanol ice from nearby dust grains and they produce a sufficient number of infrared photons to pump the masing transition. Mass and luminosity estimates for the embedded sources range from 3 to 22 solar masses and 50 to 40,000 times the luminosity of the Sun, placing them squarely into the high-mass star regime.

Massive stars play a fundamental role in the chemical and physical evolution of galaxies, and thus they are generally intensely studied. However, the large distances to the nearest sites of massive star formation coupled with their clustered mode of formation makes it difficult to study individual protostars. This new MICHELLE data reinforces the idea that young high-mass stars are gregarious in nature as multiple sources were found in each of the observed fields. As shown in Figure 6, the sources are easily resolved with MICHELLE as their separations are on the order of one arcsecond. This separation corresponds to projected physical distances of 1,500 to 6,000 AU at the targets. There is no way to determine if the sources are physically bound using the imaging data described here. However, the authors calculate that for a bound system with the most favorable (edge-on)

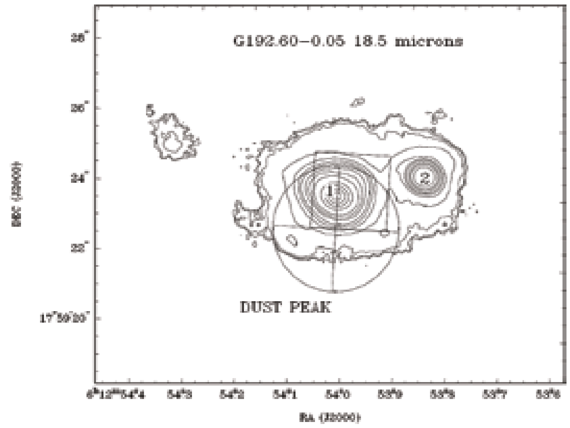


Figure 6. A portion of the MICHELLE field associated with G192.60-0.05 at 18.5 microns. The two brightest point-sources are surrounded with a region of extended emission several arcseconds in extent. The peak of the millimeter dust emission (from previous work) is shown as an ellipse, the location of the methanol maser sites are shown as plus symbols and radio continuum sources are shown as boxes. In the case of G192.60-0.05 there is very good coincidence between the multi-wavelength observations.

orientation, the radial velocities of the sources would be on the order of 2 kilometers/second (about 1.2 miles/second). Although this level of velocity shift is too low to detect, even for the echelle mode of MICHELLE, it is close to what can be obtained with an instrument like TEXES on Gemini.

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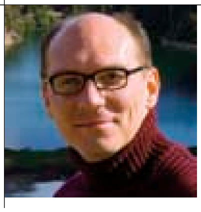

by Scott Fisher

Comets Hiding in the Main Asteroid Belt

Comets and the Solar System

Comets are among the most recognizable objects in the sky. Due to the classic chevron shape and ephemeral nature of these celestial objects, humans have observed comets with awe, and sometimes with fear, for the entirety of written history. Far from being harbingers of doom (as they were once portrayed), we now know that comets are icy bodies that become active as they approach the Sun. The main source of this activity is due to sublimation of the ices that hold a comet's nucleus together. This process causes jets and outbursts that form the ion and dust tails we see streaming away from comets as they pass near the Sun.

There are two broad classifications of comets based on where they originate in the solar system. The first are the so-called "short-period" or Jupiter-family comets (JFCs for short). These are believed to have formed in the Kuiper Belt just beyond Neptune (between 30 and 50 astronomical units (AU) from the Sun). The second are the "long-period" (or Halley Family) comets. These are thought to originate in the much more distant Oort Cloud, which lies about 3,000 – 50,000 AU from the Sun. Even though the vast majority of the comets we observe today come from these two reservoirs, astronomers have long suspected that other populations of solar system objects may also be rich in water ice (which dominates the ice component of most comets).

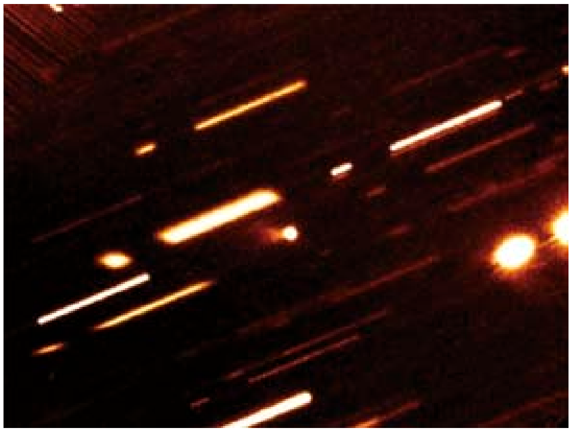

Figure 1. Gemini North (GMOS) image of Asteroid 118401. This new comet is centered in the frame. The tail of the comet is clearly seen as the v-shaped fan of emission extended from the object to the left. To make this observation, the telescope tracked the comet in non-sidereal mode as it moved across the sky. This caused the stars in the field of view to "smear out" into the long trails visible in the image. The brightness of the comet in this frame is: $m_r = 19.16 \pm 0.05$.

Astronomers seeking to explain the origin of our planet's oceans have often invoked the bombardment of the infant Earth by ice-rich objects such as comets as a plausible source of the water. To prove this theory, it's important to identify the populations of comets that could supply the amount of material needed to form all of the bodies of water on Earth.

In support of this endeavor, recent observations made with the Gemini Multi-Object Spectrograph at Gemini North helped Henry Hsieh and David Jewitt of the University of Hawai'i Institute for Astronomy uncover a new class of comet that orbits in the main asteroid belt. Hsieh and Jewitt were motivated to perform a survey of about 300 small (a few kilometers in size) asteroids after the object 133P/Elst-Pizarro was observed to exhibit a dust coma similar to that of a classical comet during its perihelion passages of 1996 and 2002. During this survey, two more objects—P/2005 U1 Read and asteroid 118401—were found to be active with comet-like morphologies. Together, these three objects form a new class of comets that have stable orbits completely within the main asteroid belt: the Main-Belt Comets (MBCs). Imaging with Gemini (as well as 1- to 2-meter telescopes in Chile and Taiwan) leaves no doubt that these objects are physically cometary in nature (Figure 1), but dynamically they are bona fide asteroids with orbits unlike any other known comet.

The discovery of the MBCs is scientifically interesting on several levels. Geothermal and spectroscopic evidence for hydrated minerals on main-belt asteroids is best explained if the objects were once bathed in liquid water. However, two-thirds of the asteroids near the new MBCs have no evidence for such minerals. This could imply that the water on these objects is trapped in sub-surface ice and is only released in a collision. Even more intriguing is the fact that the main asteroid belt has long been theorized as a source of the water on the proto-Earth as it collided with bodies on high-eccentricity orbits during the era of heavy bombardment (during the first 500 million years of the formation of the solar system).

Hsieh and Jewitt state that the MBCs are probably not interlopers from either the Kuiper Belt or the Oort Cloud. It is more likely that they are intrinsically icy bodies that formed and have stayed in the main belt for their entire lifetime (about 4.5 billion years, the age of the solar system). The two researchers theorize that the currently active bodies were recently "activated" by some sort of trigger, since there is no way they could sustain their current levels of activity for more than a few thousand years without exhausting all of their volatile materials. The most obvious trigger would be a collision with another body. Such a collision would need to be large enough to penetrate through the surface layer of the MBC to expose deeply buried ice to the heat of the Sun. The Deep Impact mission is a good human-made example of this kind of collision. The result of this mission was a large plume of gas (which contained copious amounts of water vapor) and dust released by the spacecraft's impact on the Jupiter-family comet 9P/Temple 1.

While we do not yet have any firm conclusions about whether or not the MBCs are definitely the source of the water on Earth, it is clear that these objects are extremely good, and perhaps the best candidates, to do the job. The discovery of this new class of object shows that there is still much to learn about our own solar system and it accentuates the power of large telescopes like Gemini to push back the envelope of our current knowledge, even about something as fundamental as the origin of the Earth's lakes and oceans.

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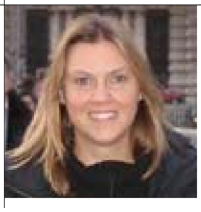

by Isobel Hook
and the SNLS Collaboration

The Supernova Legacy Survey

Gemini Observatory, the Canada-France-Hawaii Telescope (CFHT), the W.M. Keck Observatory, the Very Large Telescope (VLT) and other observatories have been working together since 2003 on a major observing program called the Supernova Legacy Survey (SNLS). The goal of this ambitious project is to determine the nature of a mysterious form of energy in the universe called "Dark Energy."

The project follows up on a startling 1998 discovery made by two teams of astronomers working independently of each other. They were making measurements of distant Type Ia supernovae and found that the expansion of the universe is accelerating, contrary to the deceleration that would be expected from the pull of gravity.[1, 2] The results implied that there is some form of energy dominating the dynamics of the universe, which is pushing the universe apart. Today we still do not know what this energy is, and so its name reflects our ignorance of its nature.

How do supernova explosions help us understand dark matter? Type Ia supernovae (SNe Ia) are believed to be thermonuclear explosions of white dwarf stars which have accreted matter from their stellar companions to the point where they can no longer support themselves. These outbursts appear to us as new point-like optical sources lasting only a few weeks. SNe Ia have two important properties that allow them to be used for cosmological tests. First, they are bright (sometimes outshining a whole galaxy), so can be observed at cosmological distances. Second, their uniform peak brightness allows them to be used as "standard candles." Because their intrinsic brightness is known, their apparent brightness on the sky provides a measure

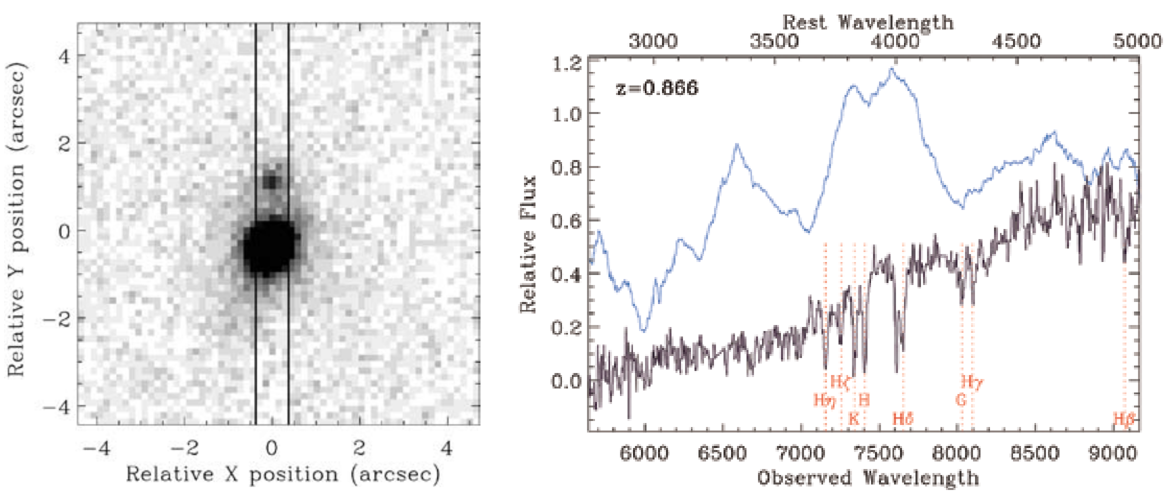

Figure 1. Example GMOS data for one of our supernovae at z = 0.87 (i' = 24th magnitude). **Left**: 9 × 9 arcsecond section of the GMOS acquisition image showing the host galaxy (below) and the supernova above. The approximate position of the spectroscopic slit is shown: spectra of the supernova and its host are obtained simultaneously. **Right**: extracted GMOS spectrum of the host galaxy (lower, in black) showing narrow absorption features that are used to measure the redshift. Above (in blue) is the smoothed spectrum of the supernova showing the characteristic broad features of Type Ia SNe.

of their distance. Thus, by measuring the distance and also the redshift, which corresponds to how much the universe has expanded during the light-travel time between us and the supernova, for a set of SNe Ia we can measure the expansion history of the universe. Cosmological models containing differing amounts of dark energy predict different expansion histories, so supernova measurements can be used to determine the quantity and, more importantly, the nature of dark energy in the universe.

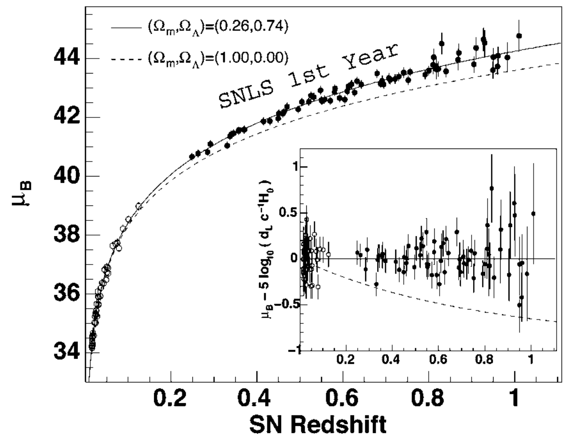

Figure 2.
Hubble diagram from the first full year of SNLS data (71 high-redshift SNe) and nearby SNe Ia from the literature, with various cosmologies superimposed. The inset shows the residuals from the best-fitting cosmological model. See Astier et al., (2006), for details.

Observations of SNe Ia, the power spectrum of the cosmic microwave background[3] (CMB), the detection of the Baryon Acoustic Peak (a type of "standard ruler" measurement which is complementary to the "standard candle" supernova measurements) in the galaxy correlation function[4], and other measurements, now yield a consistent picture of the universe in which the energy budget is made up of about 30% matter and the remainder in the form of dark energy. Although combinations of complementary measurements can lead to a separate confirmation of the universe's acceleration, the Type Ia supernovae provide the most direct evidence for dark energy.

What is Dark Energy?

Perhaps the simplest explanation for dark energy is that it corresponds to the "cosmological constant." Also known as Λ, this term was introduced by Einstein in order to balance the effect of gravity, because he (wrongly) believed that the universe is static. In fact the "pushing" effect of the cosmological constant turns out to be very well matched to what we need to explain the observed acceleration of the universe.

However, there are problems with this explanation. First, the measured size of the cosmological constant is very hard to explain by existing quantum field theories. Second, there is the "coincidence problem." Why is it that the energy density of dark energy is so similar (to within a factor of about two) to that of matter now, when the evolution of each of these energy densities over cosmic time is dramatically different?

These problems have led theorists to propose other, fundamentally different, forms of dark energy, such as slowly varying scalar fields (similar mathematically to the field that drove inflation). The difference between these types of models and the cosmological constant can be addressed by measuring the dark energy's average equation-of-state parameter, "**w**" (which indicates pressure/density), where **w** = -1 corresponds to a cosmological constant. Most scalar-field models predict **w** > -0.8. However, previous measurements of this parameter were consistent with a very wide range of dark energy theories. [5, 6, 7]

The importance of improving measurements to the point where **w** = -1 could be excluded has led to the ambitious Supernova Legacy Survey described here. The primary goal of SNLS is to derive a constraint on **w** by building an order of magnitude larger sample (more than 500) of SNe Ia in the redshift range **z** = 0.3 - 0.9 where **w** is best measured. With this sample, we aim to answer the key question: is dark energy something other than Einstein's Λ?

An Unprecedented SN Ia Dataset to Measure Dark Energy

Carrying out such an ambitious program requires a very large amount of observing time and subsequent data analysis. The SNLS is carried out by a large international collaboration of Canadian, French, UK and other European astronomers.

The basis of the survey is wide-field imaging data obtained using the MegaCam instrument, as part of the CFHT Legacy Survey. Four one-square-degree fields are imaged repeatedly in four filters (g´,r´,i´,z´). These "rolling search" images are used to find new supernovae and also to monitor supernovae discovered in previous images. The

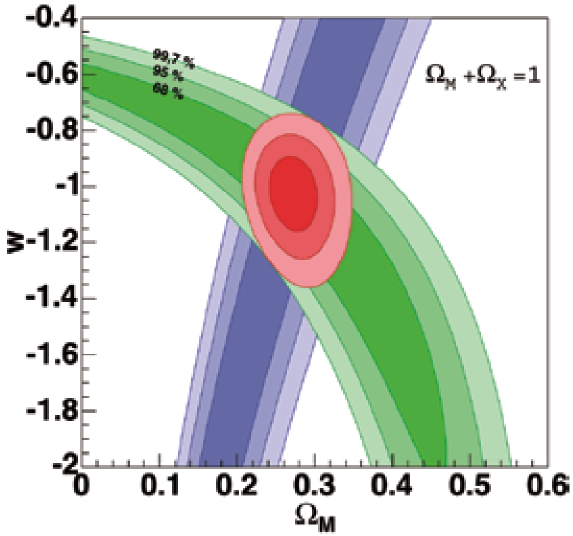

Figure 3. Constraints on Ω_M and w, assuming a flat cosmology. The green contours show the 1, 2 and 3σ confidence levels from the SNLS first-year data. The blue contours show the constraints from the SDSS Baryon Acoustic Oscillation measurements alone (Eisenstein et al., 2005), and the joint confidence contours are shown in red. To date the constraints are consistent with dark energy being in the form of the cosmological constant (w = -1). See Astier et al., (2006) for details.

frequent sampling and multi-color data allow us to obtain an accurate measurement of the peak brightness and color of the supernova (which allows us to measure the extinction).

Gemini's Role

The CFHT images produce (on average) about 40 supernova candidates per month. However, before they can be used for cosmology, two vital pieces of information are needed: the redshift and measurement of the type of supernova (only those of Type Ia can be used for this purpose). Both of these are determined from the optical spectra.

The queue observing mode used at Gemini North and South has proved to be particularly well-suited to this program. It allows spectra to be obtained with the Gemini Multi-Object Spectrograph (GMOS) when the conditions are optimal (dark time with good seeing) and while the supernovae are still bright enough (within a few days of maximum light). We coordinate the Gemini observations with spectroscopy from other observatories, in particular VLT and Keck. The Nod & Shuffle mode on GMOS makes Gemini the best for observing the faintest, most distant supernovae in our sample. Typical Gemini targets have i´ = 23-24.2 (magnitudes), and GMOS integration times of between one and two hours per object are needed. Indeed, observing the faintest targets with GMOS makes the most efficient use of the observing time, given the relatively long acquisition times (which will be improved once blind offsetting is implemented).

To date, about 120 supernova candidates have been observed at Gemini (see Figure 1 for a sample). The results of the first year of spectroscopy were published in 2005.[8] We use a novel method for selecting the targets[9], based on real-time measurements of their brightness and colors in the g´,r´,i´,z´ bands. This technique allows us to predict candidate redshift and phase, as well as the probability that the candidate is a SN Ia, after only two or three epochs of CFHT data. This lets us trigger Gemini queue follow-up time when a supernova candidate is at maximum light, while efficiently rejecting active galactic nuclei (AGN), variable stars and Type II supernovae from our follow-up program.

Cosmology Results from SNLS… So Far

Our first-year results were published in January, 2006.[10] The analysis was based on 71 distant supernovae, which represents the largest homogeneous SNe Ia sample for cosmological measurements. As shown in Figures 2 and 3, the results continue to support the current consensus that the universe is made up of approximately 30% matter, with the rest being in dark energy. When combined with complementary constraints from Baryon Acoustic Oscillation (BAO) measurements from the Sloan Digital Sky Survey[4], the results are consistent with the value corresponding to the cosmological constant (**w** = -1): we measure **w** = -1.023 +/- 0.090 (stat) +/- 0.054 (systematic) for a flat cosmology with constant equation of state. The recent analysis of the third year Wilkinson Microwave Anisotropy Probe (WMAP) CMB data further highlights the power of SNe Ia data in determining cosmological parameters.[3] Indeed, the tightest constraints on **w** are obtained when the WMAP data are combined with our first-year SNLS results. Again, these combined constraints are consistent with a cosmological constant. To date, and despite more accurate measurements, we do not see any evidence for more exotic forms of dark energy (such as a slowly varying scalar field).

However, to reach the full precision of the SNLS survey (which will allow us to measure w to a statistical precision of +/- 0.05 and distinguish between **w** › -0.8 and **w** = -1 at more than 3σ) will require the final five-year SNLS dataset.

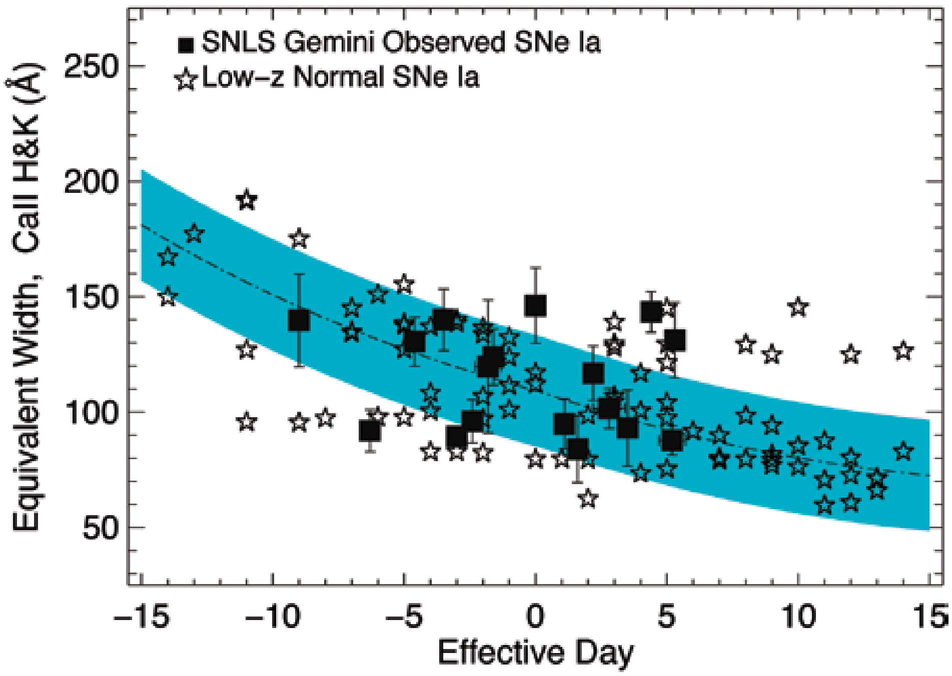

Figure 4. A comparison of equivalent-width measurements of the absorption feature attributed to Ca II, H and K in local, normal Type Ia supernovae, and the same measurement on high-redshift SNLS spectra from Gemini. The dashed line is the mean trend of the nearby objects, and the blue contour is the 1σ dispersion about this trend. Spectroscopic comparisons such as this provide a test for possible evolution of SNe Ia. No significant statistical difference is seen between the two populations (*J. Bronder, Ph.D. thesis*).

Parallel SNLS Science

Although the main goal of SNLS is measurement of **w**, the vast amount of high-quality data allows a wealth of related statistical studies on supernova properties, their environments and rates, as the following examples illustrate.

Tests for Evolution

A fundamental assumption of the supernova method for estimating cosmological parameters is that Type Ia supernovae at low and high redshift are similar. We already know that there is a range of SNe Ia properties at low redshift, and that these can be calibrated using techniques such as the lightcurve-width *vs.* peak brightness relation. It is crucial to determine that the range of SNe Ia properties and behaviors is similar over the range of redshifts being studied.

SNLS allows several such tests. First, a similar width-brightness relation has been seen in the high-redshift photometric data.[10] Second, the GMOS spectral data allow an independent test for evolution by comparing quantitative measurements of spectral features. An example of such a comparison is shown in Figure 4.[11] So far, no significant differences have been seen in the spectra between the high- and low-redshift populations. We have also tested the uniformity of the light-curve shape and find spectacular uniformity across the redshift range of SNLS[12], and also see that the rise-time of SNLS supernovae is consistent with that of supernovae at low redshifts. As the SNLS sample grows these tests will gain statistical strength.

Supernova Rates

Recently measurements of the SNe Ia rate at $z = 0.47$ based on 73 SNLS SNe have been made.[13] Intriguingly, we find that after normalizing for host mass, the SNe Ia rate in active star-forming galaxies is about a factor of ten higher than in quiescent galaxies such as E/SOs.[14] This result has profound implications for our understanding of progenitors and explosion mechanisms of these supernovae.

Future Prospects

SNLS is likely to remain the definitive SNe Ia dataset for the next decade. The full five-year data set is required in order to measure **w** to a precision of +/- 0.05 or better, distinguishing between **w** › -0.8 and **w** = - 1 at more than 3σ. Gemini is expected to continue its crucial role in completing the survey (all the published and upcoming SNLS papers described here make use of supernova redshifts and spectral classifications obtained with Gemini). As the observatory develops to include observing capabilities such as CCDs with higher red sensitivity, blind offsetting and MOS mask-making from external images, our observations will become more efficient and simultaneous observations of other objects in our supernova fields will become possible.

Because the multi-color SNLS data allows superior control of systematic effects (such as reddening), it may be possible to take the cosmological analysis one step further and place constraints on the variation in **w** with time (by comparing redshift measurements of **w** at **z** = 0.5 and **z** = 0.9, for example), an important discriminator between the cosmological constant and other dark energy models.

As Figure 3 shows, accurate measurement of **w** requires combination of data from more than one method. The Baryon Acoustic Oscillation (BAO) technique (based on galaxy redshift surveys) provides ideal complementarity in the $\mathbf{w}$-Ω_M plane to the SNe Ia method. CMB measurements, such as those provided by WMAP and, in the future, with the Planck mission, also provide powerful constraints on **w** when taken in combination with supernova measurements, as demonstrated by the recent three-year WMAP data analysis mentioned above.[3] The fact that three different techniques for measuring cosmological parameters agree is reassuring. Indeed, they are essential in order to have confidence in the result. The Gemini Wide-Field Multi-Object Spectrograph (GWFMOS) is being proposed by the Gemini and Subaru communities to carry out the next generation BAO measurement. When combined with supernova results such as SNLS, this is expected to provide a measurement of the time derivative of **w**, a crucial test of dark energy models.

Acknowledgements

The SNLS is made possible by the contributions of many individuals. The queue planners, observers and system support associates at Gemini have been extremely helpful, in particular by making the data available very rapidly after they were taken (especially important in the days before distribution through the Gemini Science Archive). We also gratefully acknowledge the assistance of the CFHT Queued Service Observing Team. The Canadian collaboration members acknowledge support from the National Sciences and Engineering Council of Canada (NSERC) and the Canadian Institute for Advanced Research (CIAR); French collaboration members from the National Council for Scientific Research/National Institute of Nuclear Physics and Particle Physics (CNRS/IN2P3), Institut National des Sciences de l'Univers du CNRS (CNRS/INSU), PNC and CEA (Comissariat à l'Energie Atomique); and UK collaborations members from the Particle Physics and Astronomy Research Council (PPARC). This work was supported in part by the Director, Office of Science, Office of High Energy and Nuclear Physics, of the US Department of Energy. The France-Berkeley Fund provided additional collaboration support. We are also grateful for the continued strong support of the national Gemini TACs for this program.

For more information, including a full list of SNLS collaborators visit the SLNS website at:
http://cfht.hawaii.edu/SNLS/

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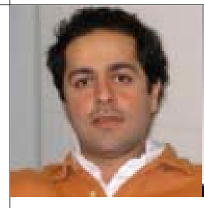

by Kambiz Fathi and Thaisa Storchi Bergmann

Gemini Maps Gas Streaming Toward Black Hole in NGC 1097

A new Gemini study of the barred spiral galaxy NGC 1097 has provided the first measurements of the motions of gas over a two-dimensional field from outer parts of the galaxy's nuclear region down to within ten parsecs from the galaxy's central supermassive black hole.

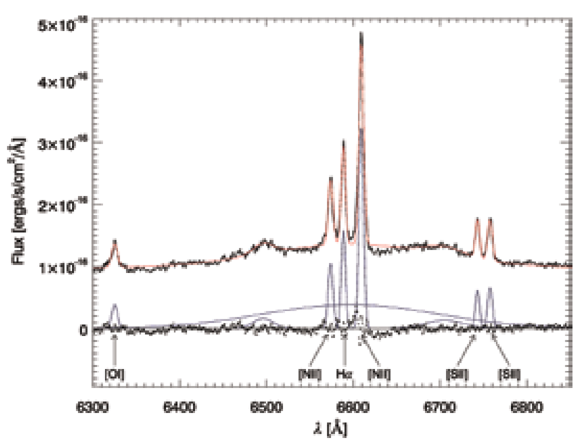

Figure 1. A sample spectrum showing the nuclear broad Hα component, as well as the narrow emission lines. Overplotted is the entire set of single Gaussians with the individual Gaussians plotted at the zero level, together with the residuals (dots) from the fit of the Gaussians plus a fixed continuum level. The three "unmarked" Gaussians are a fit simply to remove nuisance structure due to the double-peaked broad Hα emission-line and should not be interpreted as an accurate model of the broad line region.

Our international team used the Integral Field Unit (IFU) on the Gemini Multi-Object Spectrograph (GMOS) to make observations in conjunction with high-resolution images obtained with the Advanced Camera for Surveys of the Hubble Space Telescope. We mapped the gas velocity field and structure within the central kiloparsec (about 3,300 light-years) of NGC 1097 (which is a type SBb LINER/Seyfert 1 galaxy) in unprecedented detail. There is clear evidence of radial streaming motions associated with nuclear spiral structures observable within a radius of a few hundred parsecs down to within about ten parsecs (33 light-years) of the unresolved nucleus (less than 3.5 parsecs (11.4 light-years) in diameter). These motions have been interpreted as evidence of a large-scale "fuel chain" that transports gas from the outer regions of the galaxy nuclear region directly into the nuclear starburst and supermassive black hole.

Galaxy Evolution: From Large Scale Dynamics to Feeding the Nucleus

Current galaxy evolution theories postulate two main processes to account for how galaxies change over time: strong interactions between galaxies and/or internal evolution due to gravitational perturbations. The evolution often results in morphological distortions (changes in a galaxy's overall shape) or other kinds of transformations. In the absence of an interacting companion, the signatures of these evolutionary changes include the emergence of spiral arms, the creation of bars, as well as formation and feeding of an active nucleus.

Due to concentrations of mass towards the central gravitational potential well in galaxies, galactic nuclear regions are suitable environments for the formation of supermassive black holes (between a million and a billion solar masses). We now believe that there are supermassive black holes at the centers of most galaxies, or at least the ones with significant bulge components. Recent research shows that the mass of the supermassive black hole is proportional to that of the bulge. This relation implies a possible relation between the large-scale properties of galaxies and the nuclear properties such as the mass of the supermassive black hole. Gas infall into such a supermassive black hole gives rise to energy output from the nucleus of the galaxy (which is known as an active galaxy). As long as gas is being fed to the black hole, the galaxy remains active. However, once the inflow of gas has ceased, the galaxy activity slows or stops. In this context, measuring the speed at which gas is falling from the outer parts of a galaxy towards the center, as well as the rate of the gas infall, allows us to calculate supermassive black hole's growth rate and the lifetime of the active phase.

One of the long-standing problems in the study of nuclear activity in galaxies has been to understand the process by which gas is transferred from galactic scales (large regions of space) to nuclear scales (smaller areas within the galaxy). This process requires a huge loss of angular momentum. Some pioneering research seems to suggest that the gas is transferred to the nuclear region by large-scale bars, but observational studies have not found an excess of bars among active galaxies when compared with control samples. Recent morphological studies have found an excess of nuclear dusty spiral structures in active galaxies instead, while recent theoretical works have shown that such nuclear spirals could be channels by which gas is transferred to the nucleus. But until the present date there were no kinematical studies to provide observational evidence that gas was indeed flowing along these small-scale spiral arms towards the active nucleus.

An integral field spectroscope takes light from many different parts of the instrument field simultaneously and disperses the light from each region into a spectrum that allows the measurement of the properties of the emitting structures. This technique allows astronomers to obtain in 30 minutes, and with better precision, data that would have taken four nights a decade ago. Modeling the galaxy's spectra revealed the dynamic shifts in the gas and showed the spiral arms pulling gas from regions about a thousand light-years away from the center to the nucleus at 50 kilometers (31 miles) per second. Previous imaging done with the European Southern Observatory Very Large Telescope showed the structure inside the central kiloparsec region of NGC 1097. The Gemini data complement this work with a velocity map of the gas in this region. It is the first time anyone has been able to follow gas this close to the supermassive black hole in the center of another galaxy. Our team's effort strengthens the theories that have never been observationally confirmed at this level, namely that nuclear spirals can be the channels through which gas can reach and feed the nuclear supermassive black hole. We have been able to demonstrate that it is possible to measure streaming velocities down to the scales of the nuclear spirals.

This work was presented at the January 2006 meeting of the American Astronomical Society in Washington, D.C., and as part of the annual black hole briefing for journalists at the conference. The invited independent reviewer, Dr. Kimberly Weaver of NASA's Goddard Space Flight Center summarized the result as "a major step forward in our understanding of how fuel can be funneled to a supermassive black hole."

The observations supporting this work were originally proposed as part of the Brazilian

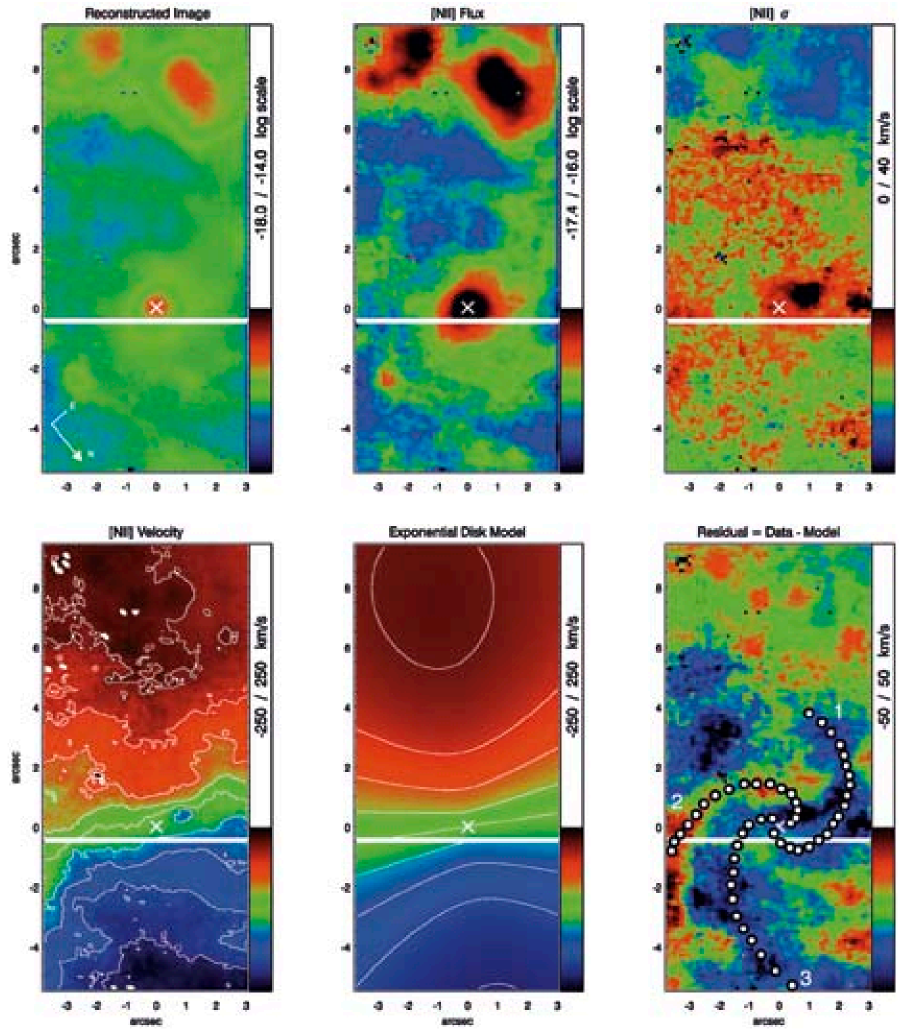

Figure 2. GMOS-IFU data results: reconstructed image was made by collapsing the 6300-6850Å wavelength range (top left); [NII]λ 6583 flux distribution (top middle); together with the kinematic maps derived from the [NII]λ 6583 emission line, as well as the best-fitting exponential disk velocity field model and residuals. Note that these residuals delineate spiral arms, outlined on the residual map, with the numbers indicating the arms observed in our HST image. In the bottom panels, red color indicates redshift and blue color, blueshift. All panels share the same orientation.

allocation of observing time on Gemini. Other team members include Rogemar Riffel (Instituto de Fisica, UFRGS, Brazil), Claudia Winge (Gemini Observatory, Chile), David Axon and Andrew Robinson (RIT), Alessandro Capetti (INAF, Turin), and Alessandro Marconi (INAF, Florence). The paper with the results of this study appeared in the April 10, 2006 issue of the *Astrophysical Journal Letters*.

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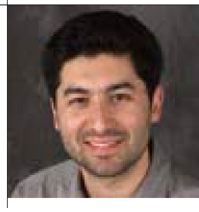

by Keivan G. Stassun

Phoenix Measures a Brown-Dwarf Binary

Observations of a newly discovered brown-dwarf eclipsing binary using the high-resolution near-infrared Phoenix spectrograph on Gemini South provide the first direct, accurate measurements of the fundamental physical properties of two young brown dwarfs. These measurements have important implications for theories about how such objects form and evolve.

Brown dwarfs are "failed stars" that span the divide between stars and planets. They serve as a critical link between theories of star and planet formation. Yet, even the most fundamental physical properties of brown dwarfs—their masses and radii—have so far eluded direct measurement. Prior to our observations, the mass of only one brown dwarf had been measured with sufficient accuracy to demonstrate that the object was, indeed, a brown-dwarf.[1] In no case had a brown dwarf's radius been measured directly.

We have discovered the object 2M0535-05 to be a brown-dwarf eclipsing binary—the first of its kind—in the young (about a million years old) Orion Nebula Cluster. This discovery was made as part of an ongoing long-term program to identify and study new eclipsing binaries in nearby star-forming regions by repeatedly imaging thousands of young stars and searching for those that exhibit periodic diminutions of flux. The I-band (0.8-micron) light curve (Figure 1) clearly shows the eclipsing nature of the system and provides a precise measure of the orbital period (about 9.8 days).

Phoenix/Gemini Observations

In order to measure the masses of the 2M0535-05 components, we required accurate radial-velocity measurements of the system from time-series observations of its double-lined spectrum. Given the extreme faintness of the pair in visible light (at about 22nd magnitude) and the need for high resolving power (R ~ 30,000), we sought high-resolution spectroscopy in the near-infrared, a capability provided to the U.S. community only through Phoenix on Gemini South. The Gemini Time Allocation Committee generously awarded 40 hours of Scientific Band 1 queue time for this

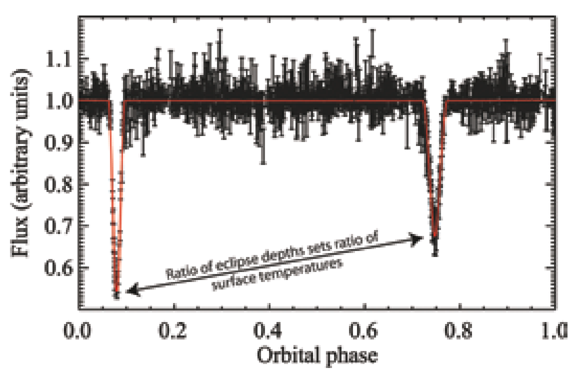

Figure 1. A light curve of 2M0535-05 at 0.8 microns, folded on a period of 9.78 days and phased relative to periastron passage. A model fit incorporating the orbital and physical parameters of the binary system is shown (solid red curve). Surprisingly, in this system, the deeper eclipse corresponds to the eclipse of the lower-mass component, implying that it is hotter than the higher-mass component.

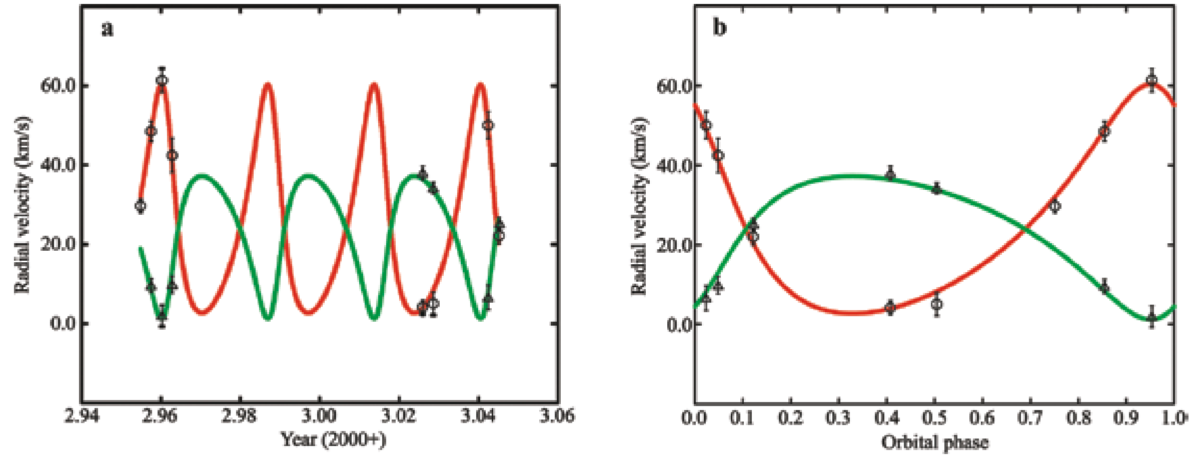

Figure 2.
Left. Radial velocity measurements and an orbit solution for the system, derived from near-infrared spectra obtained with the Phoenix spectrograph (resolving power 30,000) at the 8-meter Gemini South telescope. **Right.** The orbital phase is measured relative to periastron passage. Measurements of the primary brown dwarf are represented as triangles, the secondary as circles. The orbit solution is shown in (a) and (b) as solid curves, green for the primary brown dwarf, red for the secondary.

program. The queue observing capability was ideally suited to this program because it permitted this binary system to be observed only during excellent sky conditions and yielding observations that nicely sampled all phases of the 9.8-day orbit.

Adopting an instrumental setup employed by Tsevi Mazeh et al., in 1999, for the study of low-mass spectroscopic binaries[2], we obtained eight separate observations of 2M0535-05 at 1.555 microns. Cross-correlation analysis of the individual spectra against a template star gave us the radial velocities of the two components at eight distinct orbital phases (Figure 2). We found that a type M6.5 template produced the strongest cross-correlation for both components. This told us that both brown dwarfs in the 2M0535-05 system have spectral types of approximately M6.5 (Figure 3).

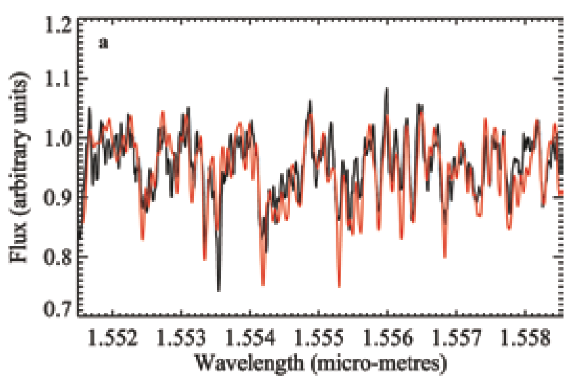

Figure 3.
The spectrum at 1.555 microns of the primary brown dwarf, obtained by averaging the eight individual Phoenix spectra after shifting them to the velocity of the primary, is shown (black). For comparison, the spectrum of an old M6.5 dwarf is also shown (red). On the basis of this very good spectral match, we adopt a spectral type of M6.5 ± 0.5 for the primary brown dwarf of 2M0535-05.

Physical Properties of 2M0535-05

We simultaneously fit the light-curve (Figure 1) and radial-velocity (Figure 2) measurements to obtain the orbital and physical parameters of the system. The “primary” (M_1), which is the more massive of the pair at 0.0541 ± 0.0046 solar masses, is four standard deviations below the 0.072 solar-mass threshold for a star. The lower-mass “secondary” (M_2) comes in at 0.0340 ± 0.0027 solar-mass threshold, and is even further below the threshold. This proves that both components are brown dwarfs.

In addition, we directly and accurately measured the radii of the brown dwarfs from the observed eclipse durations and orbital velocities. The radius of the primary is 0.669 ± 0.034 solar radii, while the secondary is 0.511 ± 0.026 solar radii. This represents the first direct measurements of brown-dwarf radii. Such large radii, more akin to low-mass stars in size, are generally consistent with theoretical predictions of young brown dwarfs in the earliest stages of gravitational contraction.

From the relative depths of the eclipses, we also obtain the ratio of the brown dwarfs’ effective temperatures. Adopting an M6.5 spectral type for the primary (2650 K) yields both temperatures separately, from which we can calculate the luminosities of both objects. We derive a distance to the pair of 435 ± 55 parsecs (1,239 - 1,600 light-years) from the 2MASS magnitudes. This distance, and the observed center-of-mass velocity, are both consistent with membership in the Orion Nebula Cluster (which is about a million years old).[3]

Good and Bad News for Theoretical Models of Brown Dwarfs

Theoretical brown-dwarf evolutionary models predict that very young brown dwarfs still in the early stages of gravitational contraction should be significantly larger and warmer than their more

A Primer on Brown Dwarfs and Eclipsing Binaries

Mass is arguably the single most fundamental property of a brown dwarf, because it determines all other physical characteristics and governs how such a star evolves with time. To truly understand a brown dwarf requires knowledge of its mass. Unfortunately, the masses of brown dwarfs are extremely difficult to measure directly. Instead, young star and brown dwarf masses are usually inferred indirectly from secondary traits, typically on the basis of a theoretical mass-luminosity relationship. Importantly, the theoretical mass-luminosity relationship has not been empirically tested for young brown dwarfs.

This is primarily because of the paucity of actual mass measurements for brown dwarfs, although accurate luminosity measurements are also hampered by uncertain distance measurements. Moreover, because a brown dwarf's luminosity evolves with time, the mass-luminosity relationship is itself time-dependent (as seen at left and below left); translating luminosity to mass requires that an age for the brown dwarf also be known. Consequently, virtually all current determinations of brown dwarf masses depend explicitly on uncertain distances and ages and implicitly (through theoretical mass-luminosity relationships) upon the very theoretical models that these measurements are needed to test.

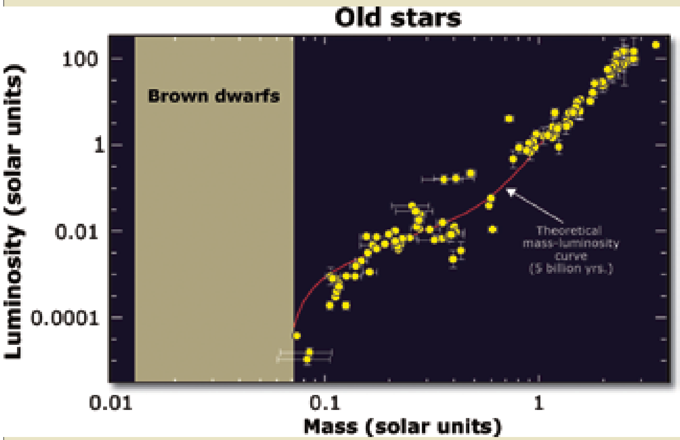

Figure 1. Plot of the mass versus the luminosity (the "mass-luminosity relationship") of a large number of stars illustrates that stars of the same mass tend to have the same luminosity at the same general age. Shown here is the mass-luminosity relationship for old stars. The curve is the theoretically predicted relationship for stars that are about five billion years old.

Eclipsing binary star systems—two stars that eclipse one another as they orbit their common center of mass–have long been used as ideal laboratories for directly measuring stellar masses as well as radii, temperatures, and luminosities. Thus they are the astrophysical "Rosetta Stones" that link all other stellar properties to mass. Ultimately, eclipsing binaries give astronomers the ability to infer the masses of the vast majority of stars from measurements of more accessible, secondary properties such as temperature and luminosity. The power of eclipsing binaries lies in our ability to measure directly their masses, radii, and ratio of effective temperatures with only the most basic theoretical assumptions, and without knowing their distance. Externally determining a temperature for just one of the stars then yields both luminosities through the Stefan-Boltzmann law. Finally, considering the two stars' properties together permits study of the binary as twins at birth with differing evolutionary histories because of their different masses.

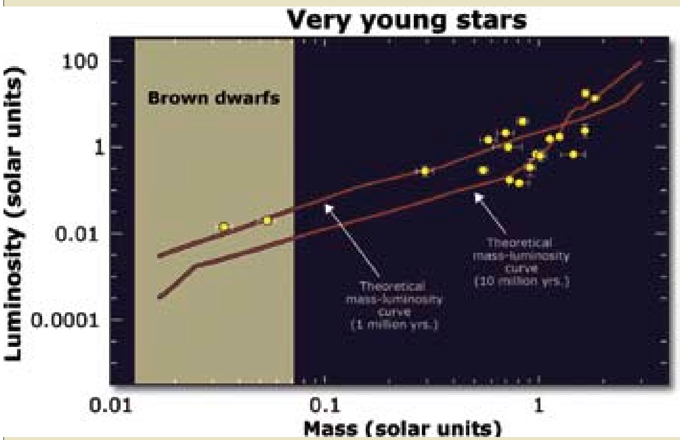

Figure 2. The mass-luminosity relationship for very young stars. The two objects plotted in the "brown dwarf" area of the plot are the two young brown dwarfs in 2M0535-05.

True to their status as "Rosetta Stones," eclipsing binaries are not only precious; they are exceedingly rare. Hence, while numerous brown dwarfs have now been found to be binary, the system that we report on here represents the first discovery of a brown dwarf eclipsing binary, allowing the first-ever direct measurements of both the masses and the radii of two brown dwarfs.

evolved counterparts.[4,5,6] This is, in fact, what we see in the 2M0535-05 system. At an age of about a million years, the brown dwarfs in 2M0535-05 are about 500% larger, and nearly 1500 K warmer, than older brown dwarfs, which are predicted to be about 0.1 solar radii and have surface temperatures of about 1000 K at an age of one billion years. The recently measured radius (R = 0.12 solar radii) of the old and low-mass (M = 0.09 solar mass) star in OGLE-TR-122 confirms that objects with near-brown-dwarf masses do indeed have planet-like radii when they are old.[7] Together, these observations verify the basic theoretical prediction that brown dwarfs begin their lives in a "star-like" state—large and warm—and evolve to a more planet-like state as they contract under gravity.

However, we find a surprising result regarding the ratio of the brown dwarfs' effective temperatures. The relative depths of the eclipses (Figure 1) yield the ratio of surface fluxes at 0.8 microns, from which we determine the ratio of their surface temperatures to be $T_2 / T_1 = 1.054 \pm 0.006$. Remarkably, the lower-mass secondary has an effective temperature that is slightly—but significantly—warmer than the primary. This follows directly from the fact that the deeper eclipse occurs when the secondary is eclipsed, which implies that it has the higher surface flux.

This finding is puzzling, because all theoretical models predict that a brown dwarf of a given mass will be warmer at all times than a lower-mass brown dwarf of the same age. Thus, perhaps the brown dwarfs in 2M0535-05 are not the same age. It's possible they did not form together as a binary pair, but rather formed separately and were later married in a dynamical interaction. Indeed, recent theoretical work and detailed numerical simulations suggest that dynamical interactions may be integral to the formation of brown dwarfs, but this hypothesis remains under debate.[8,9] Alternatively, the theoretical model ages may simply be in error. Indeed, the model ages of low-mass stars and brown dwarfs have never been independently calibrated. Instead, the models currently adopt arbitrary starting points for their calculations. 2M0535-05 may thus provide an empirical calibration of the initial conditions for newly formed brown dwarfs. Its characteristics may also indicate the need for additional physical ingredients in the models. For example, the presence of strong magnetic fields on one or both brown dwarfs could be affecting energy transport, thereby altering their physical structure. Additional work will be needed to ascertain whether these ideas are plausible. In any event, the reversal of temperature with mass in 2M0535-05 is an unexpected result that demands explanation. More generally, the discovery of 2M0535-05 represents the first direct, accurate measurement of the fundamental physical properties of young brown dwarfs. Detailed analyses of this unique system promise to yield meaningful tests of the predictions of theoretical models for young brown dwarfs, and to provide rare empirical insight into the nature and origins of these "failed stars."

This article is excerpted in part from an article that appears in the March 16, 2006 issue of *Nature*, with co-authors Robert Mathieu and Jeff Valenti.

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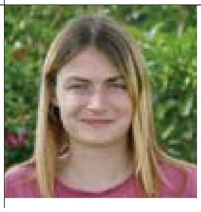


by Rachel Mason

Gemini's Look at Active Galaxy NGC 1068

During commissioning of the spectroscopic modes of MICHELLE, the mid-infrared imager and spectrometer, on Gemini North, our team (including Tom Geballe, Chris Packham, Nancy Levenson, Moshe Elitzur, R. Scott Fisher and Eric Perlman) seized the opportunity to examine the mid-infrared emission from everybody's favorite Seyfert 2 galaxy, NGC 1068. This active galaxy is located about 14.4 megaparsecs away (about 47 million light-years), making it one of nearest and best-studied example of an active galactic nucleus (AGN, see sidebar page 47). Radiation from the center of this galaxy illuminates two "cone-shaped" zones of gas and dust like a searchlight.

After taking an acquisition image at 11.6 microns, we aligned MICHELLE's 0.38 arcsecond-wide slit (well-matched to the image quality routinely delivered by Gemini in the N-band atmospheric window) along the ionization cones of the galaxy, and extracted R~200 spectra in 0.38-arcsecond steps outward from the nucleus. The results are shown in Figures 1 and 2. In the acquisition image, with only a 4-second exposure, we see a large amount of emission extended over several arcseconds (a few hundred parsecs) out from the bright nucleus. At the nucleus itself, we observe an unresolved source with a radius of less than 15 parsecs (about 50 light-years). Because of the small size and high surface brightness of this central source, which are both predicted by some current torus models and observed in a handful of other nearby Seyfert galaxies, we identify it (the central point source) as the dusty torus thought to surround and obscure the central engine of this AGN. We interpret the extended emission, which is well-aligned with the ionized gas thought to be collimated by the torus, as AGN-heated dust in the ionization cones of NGC 1068.

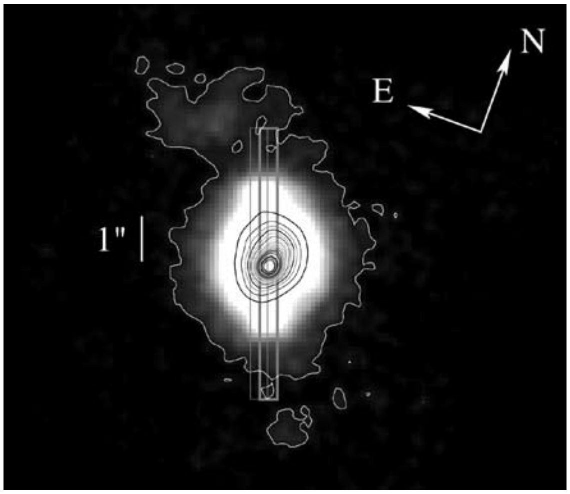


Figure 1. An 11.6 micron image of the nucleus of NGC 1068, taken to position MICHELLE's 0.38 arcsecond slit over the nucleus and ionization cones of this galaxy. Spectra were taken on two different nights, and the slightly different position of the slit each night is shown.

Photometry of the central source and extended emission is revealing. A comparison of measurements in various apertures shows that the compact central source contributes less than 30% of the flux measured in an aperture of 1.2 arcseconds

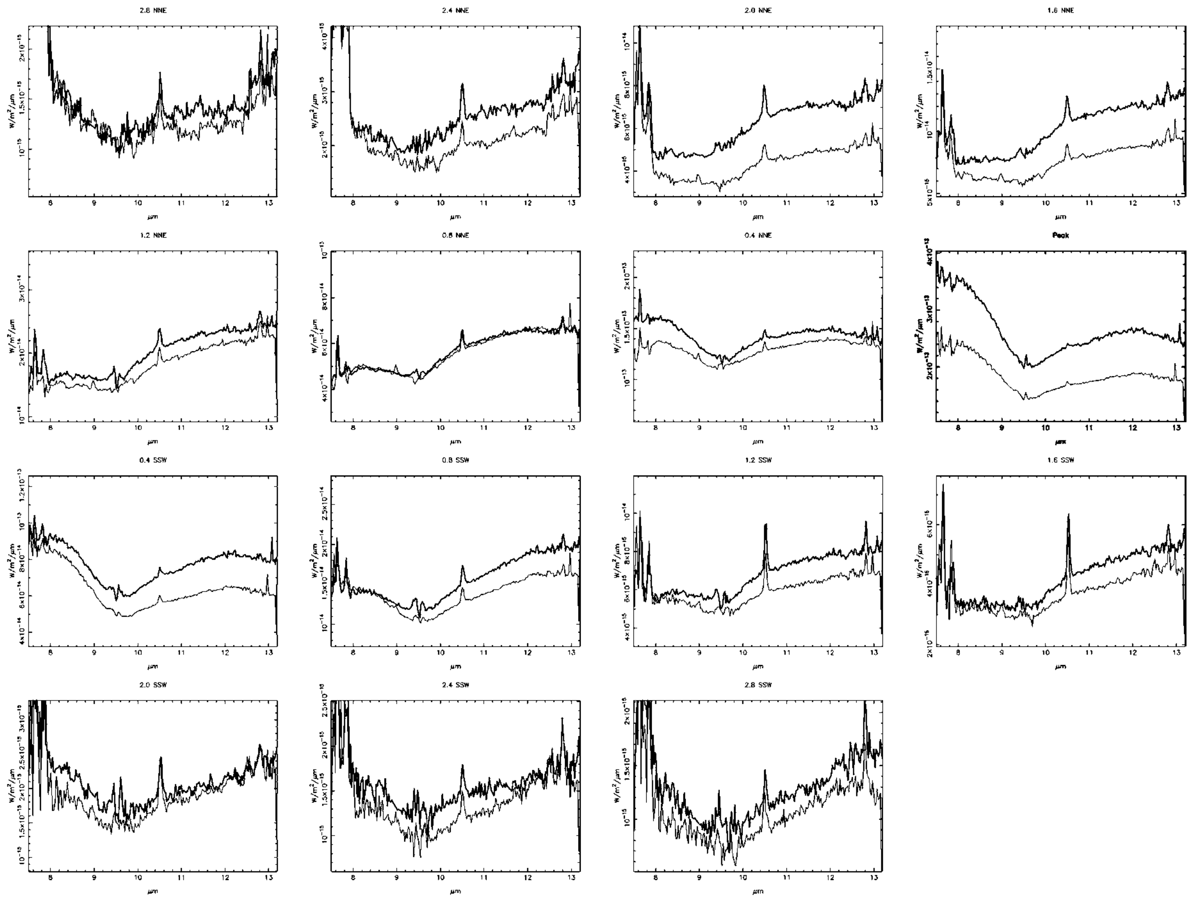


Figure 2. N-band spectra extracted over the central 6.4 x 0.38 arcseconds of NGC 1068. Note the variations in the profile and depth of the broad 10-micron silicate absorption feature, the continuum slope and the unresolved emission lines on very small scales.

in diameter. The torus certainly does not dominate the mid-infrared emission on scales of anything greater than a few tens of parsecs. If NGC 1068 turns out to be typical of AGNs in general, then these results suggest that anyone attempting to fit torus models to the infrared spectral energy distributions of more distant galaxies must take great care to account for dust heated by the central engine, but that is not part of the torus itself.

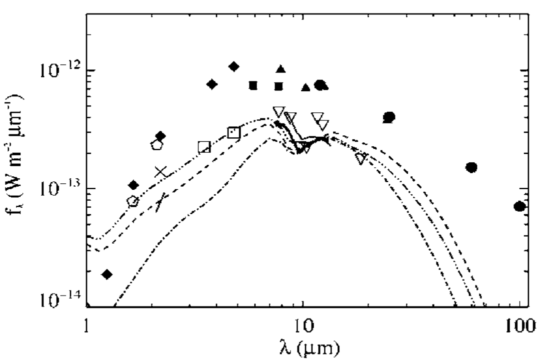


Figure 3. Fits of clumpy torus models to the nuclear (0.38 x 0.38 arcseconds) spectrum of NGC 1068. Note the difference between measurements taken in small and large apertures (open and filled, respectively); good spatial resolution is essential if the emission from the torus itself is to be isolated.

NGC 1068's extended mid-infrared emission had previously been seen in images taken at the W.M. Keck and Subaru observatories, as well as the Very Large Telescope in Chile. However, we use the MICHELLE data to argue that the high surface brightness of the central compact source compared with the surrounding regions means that emission from the torus must dominate images and spectra of the central 0.4 arcseconds or so of this galaxy. This means that, even though recent VLT interferometer data show that the torus in NGC 1068 is only a few parsecs across at mid-infrared wavelengths (a factor of about ten below our spatial resolution), data taken near the diffraction limit of an 8-meter telescope can provide a good approximation of the properties of the torus alone. With this in mind, we can examine the spectra of the nucleus and extended emission. Perhaps the most striking feature of the data is the considerable variation between spectra taken less than one arcsecond apart, in the profile and depth of the 9.7-micron silicate absorption feature, the slope of the continuum, and the emission line fluxes. On the whole, the silicate absorption decreases in strength with distance from the nucleus. However, at points just to the south-southwest, it remains at a depth comparable to that at the nucleus itself.

The Active Galaxy Zoo and the Mid-Infrared

Active galactic nuclei (AGNs) are regions of galaxies that emit copious amounts of energy from very energetic x-rays to long-wavelength radio waves. In addition, they usually contain large amounts of hot, fast-moving gas swirling in a disk around the central region. Studying the properties of gas and dust in such environments allows astronomers to understand the nature and evolution of the massive black holes at the centers of active galaxies.

Even a casual glance at the astronomy literature reveals a bewildering variety of AGN, with a nomenclature to match. They range from types 1 and 2 Seyfert galaxies to broad absorption-line quasars and blazars, taking in broad- and narrow-line radio galaxies and low-ionization nuclear emission-line region galaxies along the way. In fact, it has recently been estimated that there are as many as 60 different classes of AGN. This variety calls for some sort of model to help astronomers understand their formation, evolution, and activity.

Astronomers can breathe a sigh of relief that we have the so-called "unified model" of AGNs to bring some order to the zoo of active galaxies. In its most basic form, this model proposes that the accreting supermassive black hole that is the powerhouse of an AGN is surrounded by a doughnut-shaped "torus" of dust and gas which obscures the nucleus from certain angles, but leaves it exposed from others. The detection of broad emission lines in polarized light scattered from the hidden nuclei of several Type 2 galaxies demonstrates the basic validity of the unified model. However, plenty of questions remain as to the nature of the obscuring material (its origin, geometry, composition, extent) and the extent to which this simple model can really explain the differences between the many flavors of AGNs.

If one takes a large amount of dusty material and places it close to an accreting supermassive black hole, this material will emit copious amounts of radiation in the infrared, and in particular, at mid-infrared wavelengths. This means that observations in the mid-infrared are particularly well-suited to probing the detailed nature of the material obscuring the massive hearts of these objects. The advent of the Spitzer Space Telescope, with its superb sensitivity in the mid-infrared domain, has allowed us to begin probing the global infrared properties of the AGN population out to high redshifts (great distances). At the other end of the distance scale, the excellent spatial resolution afforded by ground-based mid-infrared instruments on large telescopes, especially infrared-optimized facilities like Gemini, means that we can now inspect key nearby AGNs in microscopic detail.

Similarly, we find that the emission lines of [Ar III/Mg VII] (8.99 microns), [S IV] (10.51 microns), and [Ne II] (12.81 microns) are strong at the nucleus, but actually reach their peak 0.4 arcseconds to the north-northeast. Clearly, the active nucleus of NGC 1068 is every bit as complex in the mid-infrared as in optical or ultraviolet wavelengths.

That we observe a moderately deep silicate absorption feature at the nucleus of NGC 1068 is in agreement with the basic predictions of the unified model (in this Seyfert 2 galaxy we should be seeing the nucleus through a large column of cool dust in an edge-on torus). To gain more insight into the dust distribution, we compare the MICHELLE spectrum of the central 0.4 *x* 0.4 arcseconds of the galaxy with current clumpy torus models developed at the University of Kentucky. Such models represent a step forward over older, homogeneous torus models which required an uncomfortable degree of fine-tuning to reproduce observed spectral energy distributions and had difficulty accounting for the properties of the silicate feature seen in the various AGN types. These particular models are characterized by a certain number of clouds along the line of sight, each with the same optical depth (τ), a near-Gaussian angular distribution of clouds and a radial distribution declining as a power law. The heating of each clump by both the central engine and the emission of all the other clouds is taken into account when calculating the emergent spectrum.

By fitting the models to only the MICHELLE nuclear spectrum, and then extrapolating to longer and shorter wavelengths, we obtain good fits to all the infrared data taken with resolution of less than an arcsecond. The model fits require an optical depth of 60 or greater per cloud and at least five clouds along the line of sight. Perhaps most interesting is the prediction that the torus is compact, with most of the clouds lying within a few parsecs of the nucleus. This is in good agreement with the VLT interferometer data and high spatial-resolution infrared imaging of a few other Seyfert nuclei, and is a departure from the predictions of many previous models.

Here again, spatial resolution turns out to be crucial: the larger-aperture points have fluxes well in excess of both the small-aperture data and our model fits. This has long been known to affect long-wavelength data from facilities such as the Infrared Space Observatory and Infrared Astronomical Satellite (ISO and IRAS), each with their beams spanning many arcseconds or even arcminutes on the sky, but Figure 3 shows that the difference persists at wavelengths as short as three microns and in apertures that would traditionally have been considered quite modest.

These results are a clear illustration of how high spatial resolution ground-based, mid-infrared imaging and spectroscopy of nearby active nuclei such as NGC 1068 represent a valuable opportunity to sharpen our understanding of these systems. They also help to put into context the sensitive Spitzer observations of AGNs that populate the universe out to great distances. The proximity and brightness of NGC 1068 made it an ideal test case, but we look forward to performing similar observations on numerous other AGNs to establish how representative NGC 1068 is of active galaxies as a whole, and how the properties of other objects fit (or don't fit) with the unified model of active galactic nuclei.

These data were published in Mason et al., 2006, *ApJ*, **640**, 612. Together with results reported by Rhee et al., (2006) in *ApJ*, **640**, 625, this is the first N-band spectroscopy of an active galactic nucleus that is spatially resolved on sub-arcsecond scales.

Rachel Mason is a Science Fellow at Gemini Observatory (Hilo, Hawai'i), she can be contacted at rmason@gemini.edu

MICHELLE Mid-infrared Polarimetry: A Unique Capability at Gemini

A unique new observing opportunity recently arrived at Gemini North with the commissioning of the mid-infrared imaging polarimetry (M-POL) mode of MICHELLE. Now the only mid-infrared polarimeter on any 8- to 10-meter-class telescope, M-POL offers the community at large imaging polarimetry in the 10- and 20-micron regime with < 0.5 arcsecond resolution, coupled with the sensitivity of an 8-meter telescope.

In general, radiation from astronomical sources shows some degree of polarization. While the amount of polarized flux may be a small percentage of the total, it normally contains a wealth of information about the physical state and geometry of the intervening material. Indeed, polarimetric techniques are well established and often used in research across the spectrum from the optical to the radio.

MICHELLE uses the combination of a wire grid and half-wave plate (at ambient temperature) to obtain the data needed to derive the Stokes parameters for an observation. Polarimetric data is obtained by MICHELLE using the normal "chop-nod" technique of mid-infrared observing, however, we are using MICHELLE in a novel way in this mode. To deal with the overwhelming and rapidly changing background we observe eight individual wave plate positions within each 40-second nod in an "ABBA" fashion. While the synchronization of the interactions between the instrument, the chopping secondary, and the telescope control system are non-trivial we are confident that the Gemini commissioning team has built upon the prior work of the team that built the instrument and the team that used it during its tenure at United Kingdom Infrared Telescope.

Early results from M-POL are extremely encouraging. From highly embedded protostars to highly obscured AGN nuclei, if you have an object to observe that contains dust, a plasma, or a strong magnetic field, MICHELLE imaging polarimetry is a new capability that you should be interested in for your own research. For more information please contact Kevin Volk. Scott Fisher, or Rachel Mason at Gemini North.

– Scott Fisher

by Michael Pierce

Globular Clusters as Star Formation and Kinematic Tracers

The study of galaxy formation continues to be one of the main thrusts in astronomy. However, many global uncertainties cloud our understanding of the details, raising questions in particular about the early chemical history, the role of minor star formation, and galaxy merger histories. Even more uncertain, for elliptical galaxies especially, is quantifying the dark matter content at large radii. These uncertainties are all important issues, particularly those that deal with the existence of dark matter halos. We hope to clarify them by studying galaxies and their associated star clusters. Complex mixes of stellar populations in the central regions of galaxies make disentangling different star formation epochs and chemical enrichment histories a difficult problem. Low stellar surface brightness in the outer regions makes obtaining velocity measurements prohibitively time-consuming.

Our team uses the spectra of globular clusters (GCs) to probe both the star-formation histories and gravitational potentials of elliptical galaxies.

Globular clusters are suited to this purpose for several reasons. First, they are single stellar populations, which means that their stars are characterized by a single formation age and metallicity. Second, they are found around all galaxy types. Third, their high surface brightnesses makes them possible to observe to large distances.

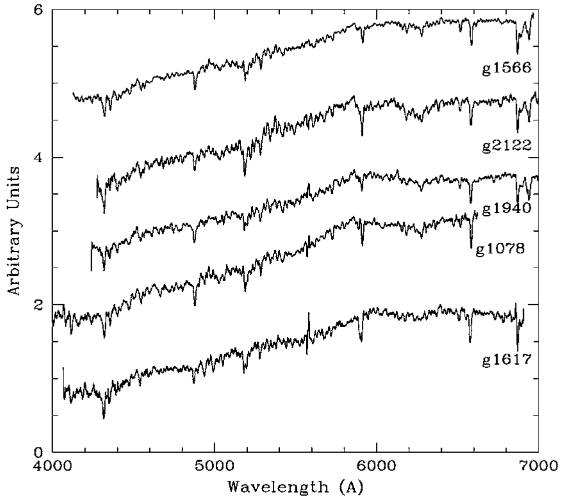


Figure 1. Normalized globular cluster spectra that have been offset by one unit. These spectra have not been de-redshifted. These sample spectra show the wavelength range that the majority of our spectra cover and display the range of S/N and metallicity present.

Continued on page 36

Gemini South captured this stunning view of a massive gas cloud surrounding a cluster of stars in the N44 superbubble complex in the Large Magellanic Cloud. The tempest is dominated by a vast cavern measuring about 325 by 250 light-years across, and accompanied by multiple smaller bubbles around it. Our view into this vast bubble could be like looking through an elongated tube, giving the object its monstrous mouth-like appearance.

Astronomers describe the N44 cloud as a giant laboratory where they can study the effects of massive star evolution and supernova explosions in great detail. While they do not agree on exactly how it has formed over the past 10 million years, it's likely that the explosive death of at least one of the cluster's most massive stars played a key role in blowing this cosmic bubble.

This image is one of the most detailed views ever obtained of this relatively large region in the Large Magellanic Cloud (LMC), a satellite galaxy to the Milky Way. The LMC is located some 150,000 light-years away and visible from the Southern Hemisphere. The colors reveal the compression of material and the presence of gases (primarily excited hydrogen gas and lesser amounts of oxygen and "shocked" sulfur) in the cloud.

Many questions remain about the exact sequence of events that formed the cloud. The speed of gases in the cloud highlights inconsistencies in the size of the bubble and the expected velocities of winds from the central cluster of massive stars. The data used to produce this Gemini Legacy image have been released to the astronomical community for further research and follow-up analysis. Data can be found in the Gemini Science Archive by querying "NGC 1929."

Gemini Explores an

N44 Superbubble Complex, T. Rector, University of Alaska Anchorage

Interstellar Cavern

Figure 2. Plots of radial velocity dispersion and M/L ratio using GC and stellar data (from Gebhardt et al., 2000, and Statler and Smecker-Hane 1999). The upper panel shows the velocity dispersion of the GCs. Blue open squares and hashing include the four GCs that that may be associated with NGC 3384, and the red hashing and filled squares when they are excluded. The squares show the binned data and the hashed areas show the range of values using the Lowess estimator (with 1% errors). The PN data points from Romanowsky et al., (2003) (circles) and the expected isotropic profile with constant M/L (thick line) are also shown. In the lower panel, the blue line (1% hatching) shows that when the four ambiguous GCs are included the M/L ratio rises slowly. The red line (with 1% hatching) shows that the M/L ratio rises strongly in the outer regions when the four ambiguous GCs are excluded. The horizontal line in the bottom panel is M/L = 6.

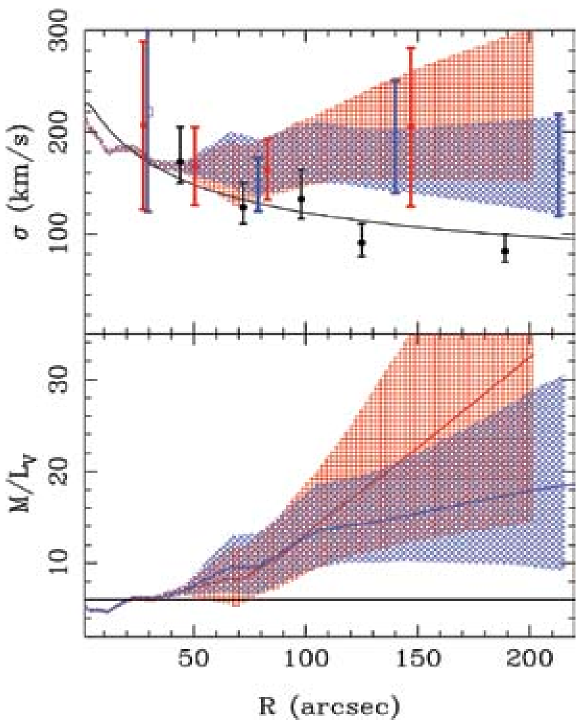
Fourth, they probe the gravitational potential out to large radii (more than five times the effective radius (R_e) of an elliptical galaxy).

The focus of this article is NGC 3379, a moderate-size, magnitude -21.06 (absolute) elliptical galaxy in the nearby Leo group. It lies about 35.2 million light-years away and shows no indications of recent star formation, merger activity, or interaction. We have obtained spectra of 22 GCs associated with this galaxy, using the Gemini Multi-Object Spectrograph (GMOS) on Gemini North. The magnitudes of the majority of observed GCs are in the range of g = 21.4 - 23.7. Ten hours of on-source integration yielded a signal-to-noise ratio of about 20 - 60, which is sufficient to measure stellar population parameters as well as recession velocities for individual GCs.

We have measured Lick indices for our 22 GCs. Then using a chi^2 minimization method to fit the indices to a single stellar population model we measure ages, metallicities and alpha-element abundance ratios for our 22 GCs. In our sample we find all of the GCs to be consistent with old-age stellar populations (older than ten billion years). A trend between [Fe/H] (the ratio of iron to hydrogen) and alpha-element abundance is also found. We find that the alpha-element abundance decreases with increasing [Fe/H]. However, this result is dependent on the low metallicity points for which alpha element abundances are poorly constrained and difficult to model.

In 2003, Romanowsky and colleagues, using planetary nebulae (PN, which are aging stars similar to our Sun) as tracers, reported in *Science* that three elliptical galaxies—NGC 821, NGC 3379, and NGC 4494—appeared to have little, if any, dark matter in their haloes. “This unexpected result,” they wrote, “conflicts with findings in other galaxy types and poses a challenge to current galaxy formation theories.”

Enlarging our kinematic sample with 14 GC velocities from the Very Large Telescope by Puzia and colleagues, we measured the velocity dispersion of the GC system with projected radius. Most significantly, the projected velocity dispersion of the GC system was found to be constant with



radius beyond one R_e, indicating the presence of dark matter at large radii in its halo. This contrasts with the results of Romanowsky’s team, which found that the line-of-sight velocities in the outer parts of all of these galaxies (NGC 821, NGC 3379, and NGC 4494) show a clear decline in dispersion with the radius.

We find that the PN dispersions are smaller than the GC dispersions with a greater than 97% confidence beyond an effective radius (55 arcseconds). Since the PN dispersions are consistent with mass following light, the GC dispersions suggest a need for a dark halo.

Why the discrepancy between PN and GC velocity dispersion profiles? In 2005, Dekel and colleagues presented results (in *Nature*) from merger models that suggest that the orbital properties vary for stellar populations of different ages. Globular clusters that trace the old stellar population tend to be on isotropic orbits, whereas a younger population (about three billion years) as traced by PN, can have more radial orbits. If the models for the PN velocites did not contain enough radial anisotropy, then they may provide a biased estimate of the dark halo content.

Another suggestion which has previously been made is that NGC 3379 is a face-on type SO (lenticular) galaxy. If a significant fraction of the PN belong to the disk, this would suppress the line-of-sight velocity dispersion of the PN relative to that of the GCs that lie in a more spherical halo.

There are also several recent independent observations that imply a dark-matter halo. Bergond and collaborators have presented an independent set of GC data, obtained with FLAMES (a multi-object, intermediate and high-resolution spectrograph) used at the Very Large Telescope, which shows velocity dispersion consistent with ours. Similarly, Samurovic and Danziger have used Chandra x-ray data to analyze the hot gas halo around NGC 3379 and predict the stellar velocity dispersion with projected radius. Their results are entirely consistent with ours. Schneider, in 1989, presented the kinematics of the HI gas ring around the Leo triplet of NGC 3379, 3384 and 3389 which indicates a mass-to-light ratio of 27, which is consistent with a dark matter halo. Thus, we are confident that NGC 3379 has a dark matter halo and that the interpretation of PN kinematics is more complicated than previously assumed. In the future large samples of GC velocities will allow us to test orbital properties, azimuthal distributions, rotation axes and velocity dispersions of the red and blue color sub-populations and potentially a young sub-population if a significant one is found.

The team conducting this research also includes: Duncan Forbes and Rob Proctor also of Swinburne University of Technology, Mike Beasley of Univeristy of California at Santa Cruz and Karl Gebhardt of the University of Texas, Terry Bridges and David Hanes from Queens University, Favio Faifer and Juan Carlos Forte, Facultad de Cs. Astronomicas y Geofisicas, UNLP and CONICET, Ray Sharples at Durham and Steve Zepf at Michigan State University.

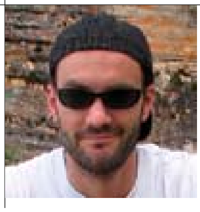
References:

Romanowsky et al., *Science* 19 September 2003: Vol. 301. no. 5640, pp. 1696 - 1698

Dekel et al., *Nature*, 2005: Vol. 437, no. 7059, pp. 707-710

Pierce et al., *MNRAS*, 366, 1253

Michael Pierce is currently a Ph.D. candidate at the Centre for Astrophysics and Supercomputing, Swinburne University of Technology Melbourne, Australia.



by Nathan Smith

Phoenix Gives a New View of Eta Carinae

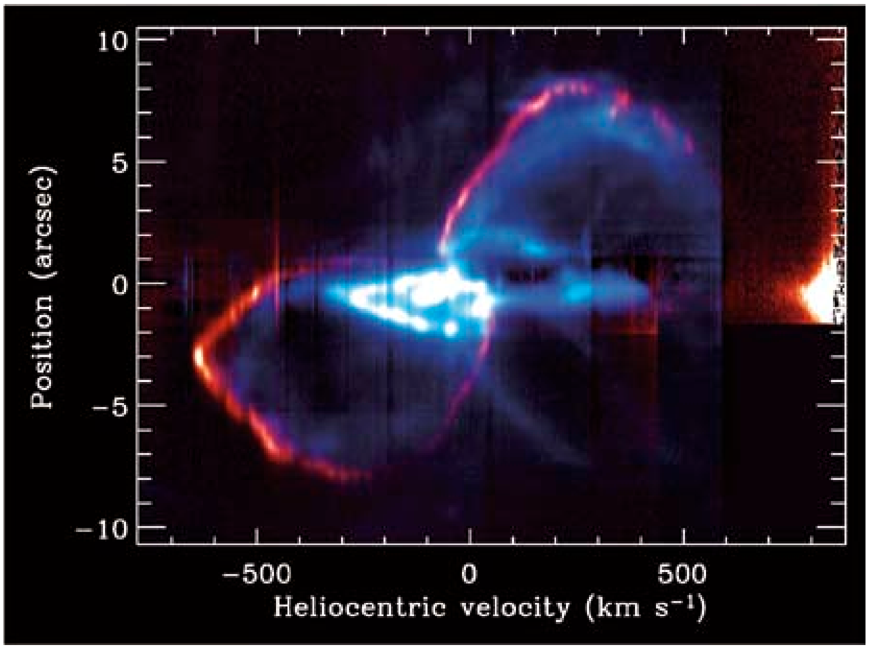


Figure 1. An example of the long-slit spectra obtained with Phoenix on the Gemini South telescope. The vertical axis is the spatial position along a slit, aligned with the polar axis of the nebula (rotated about 50 degrees clockwise from vertical in the image in Figure 2). The horizontal axis is the Doppler-shifted velocity, which translates directly to a cross section of the 3-D shape along our line of sight. In this representation, red is emission from molecular hydrogen at 2.122 microns, and blue is emission from singly-ionized iron at 1.644 microns.

New spectra obtained with the high-resolution infrared Phoenix spectrograph on Gemini South provide striking insight to the structure of the so-called "Homunculus" nebula around the massive southern hemisphere star Eta Carinae. In addition, they help produce the first definitive three-dimensional picture of the nebula's geometry.

This bipolar nebula (Figures 1 and 2) was ejected by the massive star at its heart in the mid-nineteenth century. During that outburst, Eta Carinae was briefly the second-brightest star in the night sky, despite its distance of 2.3 kiloparsecs (about 7,500 light-years). The star faded after 15 - 20 years, but today its luminosity is re-radiated in the thermal infrared by dust formed in the nebula. This makes Eta Carinae the brightest 10-micron object in the sky outside the solar system. The outburst ejected a huge amount of mass—more than ten times that of our Sun—and almost 10^{50} ergs of kinetic energy, as inferred from observations in 2003 of emission from its dust. (That is about a billion times more energy than our Sun gives off in a year). The cause of the event and the mechanism that launched such a huge amount of mass off the star (while allowing the star to survive) remains unknown, but the structure of the fossil nebula it created holds important clues.

The new Phoenix spectra in Figure 1 reveal that the Homunculus is composed of an intricate double shell structure, with a thin outer shell seen in emission from molecular hydrogen at a wavelength of 2.122 microns (red), and a thicker inner shell seen in [Fe II] emission at 1.644 microns (blue). These observations improve significantly upon our previous studies of the nebular structure using the Space Telescope Imaging Spectrograph (STIS) on the Hubble Space Telescope. While the spatial resolution of the Gemini observations (about 0.4 arcseconds) was not quite as good as with HST/STIS, the most significant advantage of Phoenix is its ability to obtain long-slit spectra at very high velocity resolution. An additional advantage in the unique case of Eta Carinae is that Phoenix on Gemini South provides these capabilities at near-infrared wavelengths, where the dusty nebula is more transparent than at visual wavelengths. The infrared capability of Phoenix also allows access to unique tracers of the nebular structure, such as lines of molecular hydrogen, which cannot be studied at visual wavelengths. The main scientific results of this study are discussed in more detail in a paper that will appear in the June 20, 2006 edition of the *Astrophysical Journal*.

Knowing the three-dimensional shape of a nebula just for its own sake is not necessarily a scientific goal that inspires one to do somersaults. However, since we know from measurements of the expanding nebula that all of the material was ejected at about the same time and is of the same age, (a Hubble flow), the three-dimensional shape conveys very important physical information because it bears the imprint of the geometry of the initial explosion. For example, the observed three-dimensional shape provides a direct measure of ejection velocity as a function of latitude on the star during the outburst. That, in turn, gives us important clues to the role of rapid rotation in shaping the ejected material. Perhaps even more interesting is that the detailed shape and structure reveal the actual distribution of mass and kinetic energy as a function of latitude on the star.

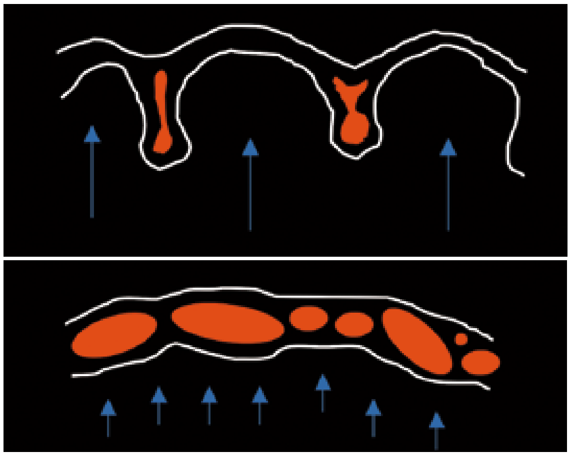
This is likely the first time such information has been measured quantitatively for a bipolar nebula. The reason this can be done with the new Gemini/Phoenix data is because the near-infrared molecular hydrogen emission is a tracer of the thin and cool outer shell of the Homunculus, where 90% of the ejected mass resides. From a detailed analysis of the H_2 emission, one finds that about three quarters of the total mass and more than 90% of the kinetic energy were released at latitudes between 45 degrees and the polar axis. In other words, Phoenix data show that the nineteenth-century event was an intrinsically bipolar explosion that shot most of the ejected material out along the poles.

This sort of interpretation involving an intrinsically bipolar explosion is radically different from prevailing views of mechanisms that shape bipolar nebulae, and that apply mainly to some planetary nebulae. In that picture, a fast wind plows into a surrounding equatorial torus or low-latitude density enhancement. The mass loading from the surrounding swept-up equatorial material slows the expansion at low latitudes, pinching the waist and forming a bipolar nebula. The resulting nebula would actually have extra mass at low latitudes, proportional to the difference in radius. However, at least in the case of the Homunculus, this mechanism can be ruled out by the new Phoenix spectra, because we see more mass concentrated at the poles instead. With a strong mass deficit at low latitudes around Eta Carinae, there's nothing that would have pinched the waist via an external mechanism. Thus, the explosion geometry must have originated in the star itself.

Figure 2. HST/WFPC2 image of Eta Carinae made from a composite of many visual-wavelength filters. *Image credit: Nathan Smith (University of Colorado) and NASA.*

This interpretation is particularly interesting because of its potential application to models of supernovae and gamma-ray bursters (GRBs). Some supernova explosions are considered to be bipolar, based on polarimetric observations, and GRBs are thought to

Figure 3. In a nebula where a thin shell is pushed from underneath by a faster stellar wind, we might expect instabilities to develop, giving rise to strong corrugations in the walls of the nebula (top). Instead, the walls of Eta Carinae's nebula look more like clumps in a thin and coherent shell wall (bottom). This probably means that the nebula is not shaped by the stellar wind that fills the inside of the hollow nebula (i.e. it is not being "inflated").



be driven by bipolar jets. A few young supernova remnants like Cassiopeia A also show bipolar expansion patterns. For a dramatic illustration of an intrinsically bipolar supernova explosion, look at some of the spectacular images of the expanding ejecta of SN1987A obtained recently with the Advanced Camera for Surveys on HST.

In addition to the overall geometry of the Homunculus, the Phoenix spectra also advance our understanding of the detailed structure of this nebula, with corresponding clues to the nature of the nineteenth-century eruption. For the first time we have a clear picture of just how thin the outer walls of the bipolar lobes really are. As noted above, 90% of the total mass is in this thin outer shell of molecular hydrogen. Its very small width puts limits on the duration of the main mass-loss phase to about five years or less. With a total mass of more than ten solar masses released in that short amount of time, the instantaneous mass-loss rate must have been enormous—perhaps as high as several solar masses per year. That is far beyond the limit of what can be driven by a normal stellar wind, and may suggest instead that the outburst was actually a hydrodynamic explosion (where the materials from the explosion interact in a turbulent flow outward from the progenitor star). There are other independent clues that point in this direction as well.

Finally, the outer molecular hydrogen shell is not only remarkably thin—it is also remarkably smooth. It does not exhibit the intricate loops and corrugations that we have come to expect from wind-blown bubbles. Such structures usually grow from instabilities (called Rayleigh-Taylor instabilities) when a lighter and faster fluid is trying to accelerate into a denser fluid (Figure 3). Instead, the molecular hydrogen walls of the Homunculus seen in the Phoenix spectra show clumps embedded within a more uniform thin shell. The lack of such Rayleigh-Taylor instabilities probably means that the post-eruption stellar wind that fills the interior of the nebula is not very effective at accelerating the massive outer shell, and therefore has little effect on its shape.

In other words, the outer shell of the Homunculus is like a bunch of bricks flying through space—another testament to the powerful explosion that created the nebula. Based on the total mass in the nebula and the apparent thickness revealed in the Phoenix spectra, the density in this outer molecular hydrogen shell is probably about ten million hydrogen atoms per cubic centimeter. Coincidentally, that's just about what it needs to be in order for the material to self-shield itself from the pounding ultraviolet radiation from the central star, allowing molecular hydrogen to survive in the first place.

The Phoenix spectra also reveal new details about the inner shells seen in [Fe II] emission (blue in Figure 1). The intensity and apparent structure of the inner [Fe II] emission is time variable, responding to changes in illumination during Eta Carinae's 5.5-year spectroscopic cycle. Continued analysis of the changes in this inner [Fe II] emission should provide geometric constraints on the orientation of the orbit of the suspected binary system at the heart of Eta Carinae through its next periastron passage in 2008/2009.

For more information on Eta Carinae, the Homunculus, and the system's outburst, see these papers:

Davidson et al., 2001, *AJ*, **121**, 1569
Frank et al., 1995, *ApJ*, **441**, L77
Morse et al., 2001, *ApJ*, **548**, L207
Smith and Gehrz, 1998, *AJ*, **116**, 1823
Smith, 2002, *MNRAS*, **337**, 1252
Smith et al., 2003, *AJ*, **125**, 1458
Smith, 2005, *MNRAS*, **357**, 1330

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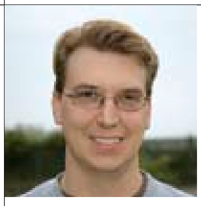


by Jim de Buizer

Mid-Infrared Astronomy in Full-Swing at Gemini

Gemini Observatory has worked since its inception to become a unique facility offering northern and southern sky coverage with telescopes fully optimized for mid-infrared (7- to 25-micron) observing. MICHELLE, the Gemini North mid-infrared imager and spectrometer, was first on the scene, initially operating only in a purely imaging mode for the scientific community in semester 2003B. During that same time, commissioning also began for T-ReCS (the Thermal-Region Camera and Spectrograph) at Gemini South. Since 2003B, Gemini staff members have made tremendous progress in enhancing and improving the mid-infrared performance of our telescopes and instruments. Now, more than ever, Gemini is poised to make great strides in understanding our mid-infrared universe.

Gemini Mid-Infrared Capabilities are Better than Ever

Among the improvements and enhancements, the 2006A semester marks the commissioning of the imaging polarimetry mode of MICHELLE. Our mid-infrared instruments are now fully operational for the upcoming 2006B semester and performing better than ever. Concerted efforts since 2003 have focused on improving mid-infrared image quality, increasing delivered sensitivity, and reducing instrument noise. Our instruments are now more reliable and productive, with shortened acquisition times and increased observing efficiencies. (See "Operational Efficiency at Gemini in 2005" starting on page 59 of this issue).

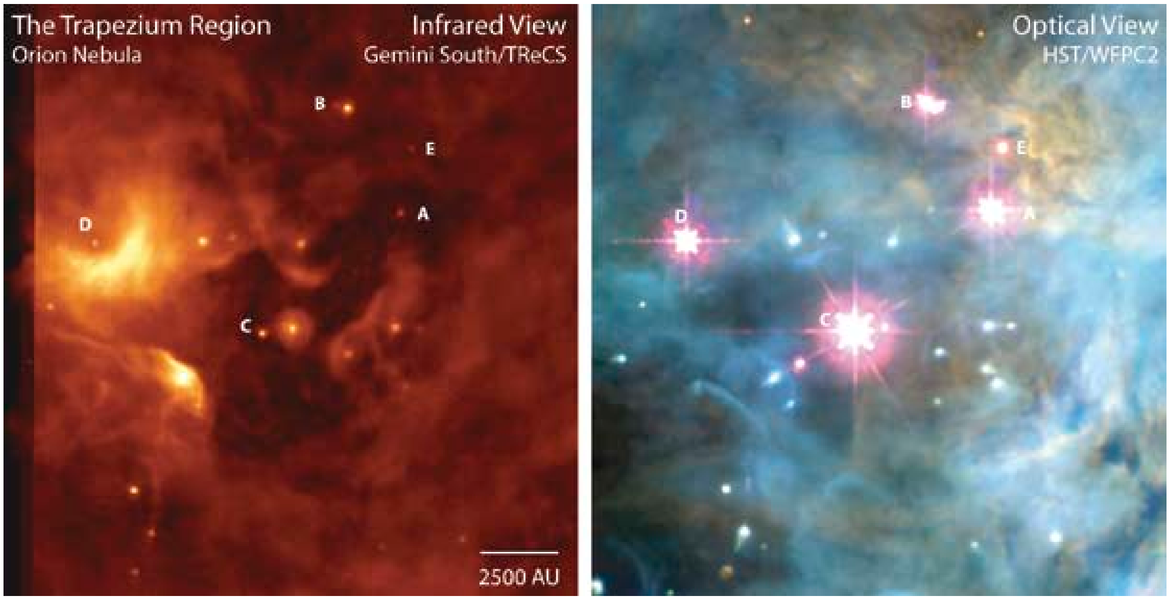


Figure 1. Gemini South Mid-Infrared T-ReCS image of the Trapezium region of the Orion Nebula (left) and the optical Hubble Space Telescope WFPC2 image of the same field (right). Dust structures can be seen in unprecedented spatial detail in this T-ReCS image obtained at Gemini South. The brightest Trapezium stars are labeled in both images. Images are courtesy of Nathan Smith (U. Colorado) and are from an Astronomical Journal article by Smith et al. (2005), *AJ*, **130**, 1763.

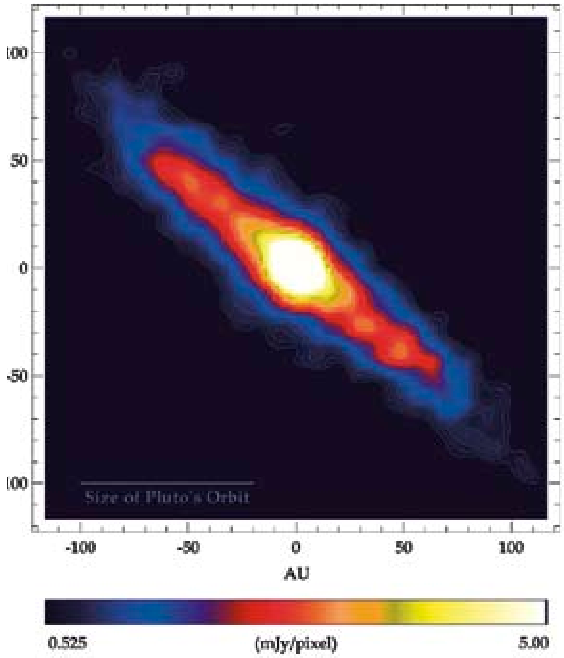


Figure 2. The "archetype" disk surrounding the star Beta Pictoris as images by T-ReCS on Gemini South in the mid-infrared. Roughly the size of our solar system, it is likely that there are planets forming in the inner part of this disk.

Within the last year Gemini has finally achieved true queue observing, with any instrument available at any time during the night. This is especially important for mid-infrared observations, which require more stringent observing conditions that can be highly variable. This means more efficient use of low water vapor and cloudless conditions throughout the entire semester, which translates to higher completion rates for mid-infrared observing programs. This, combined with the arrival of a water vapor monitor at Gemini South and improved weather forecasting and real-time weather feedback, means that PIs will be getting more data with even better matching to the observing conditions requested.

Furthermore, the staff at Gemini has developed a technique that provides the unique ability to acquire sources with extremely accurate mid-infrared absolute astrometry (less than about 0.3 arcseconds). This is extremely valuable for those who wish to observe sources not visible in the optical, and compare the spatial relationships between morphologies in the mid-infrared to other wavelengths. And finally, both Gemini North and South telescope's primary and secondary mirrors are now silver-coated, bringing the observatory's total emissivity in the mid-infrared regime down to values lower than any other 8-meter telescope in the world. This translates to more sensitive system performance for both MICHELLE and T-ReCS.

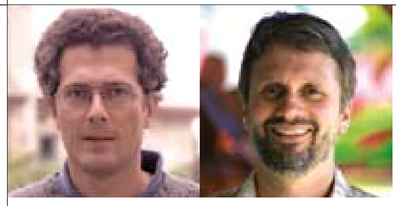
Ground-Based Mid-Infrared Observing in the Spitzer Era

While MICHELLE and T-ReCS are extremely sensitive ground-based mid-infrared instruments, no ground-based mid-infrared instrument can match the sensitivity of the Spitzer Space Telescope (Spitzer). However, where both Gemini instruments excel is in their ability to deliver high spatial resolution imaging and spectral observations. Gemini's mid-infrared facility instruments can routinely achieve six-times better spatial resolution at eight microns than Spitzer.

With slit widths that are up to 18 times narrower than on Spitzer, spectroscopy with MICHELLE and T-ReCS can be performed on individual sources with no contamination, even in highly crowded areas. Extended sources can be mapped spectrally with higher spatial detail (see Figure 2). Furthermore, while Spitzer has similar spectral resolution to the T-ReCS and MICHELLE low-resolution modes (R~100), the Gemini instruments can achieve much higher spatial resolutions in the 8- to 13-micron spectral window than Spitzer, especially using the R~30,000 echelle mode of MICHELLE.

With such different capabilities, the mid-infrared instruments of Gemini Observatory complement well those of Spitzer. MICHELLE and T-ReCS present excellent opportunities not only for exciting projects in their own right, but also for high spatial and spectral resolution follow-up observations of Spitzer projects.

Jim de Buizer is a Science Fellow at Gemini Observatory (La Serena, Chile), he can be reached at: jdebuizer@gemini.edu



by Maxime Boccas
and Peter Michaud

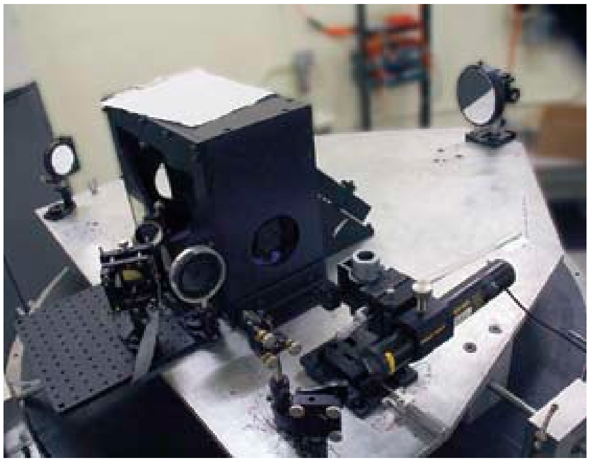
Image Quality Refinements and Monitoring

As standing members on the list of the "Top 10" biggest telescopes in the world, each of the Gemini primary mirrors has a surface area of about 50 square meters. With such large areas to control, the challenge of maintaining the shape (or figure) of the mirrors, as well as the alignment of the entire optical system, requires enormous quantities of technology, ingenuity, and effort.

A recent paper by Gemini's Optics Group summarizes the ongoing campaign of Gemini's Engineering staff to refine the optical performance of both telescopes to take full advantage of nights when atmospheric conditions allow the telescopes to operate at or near the diffraction limit. (See "Performance and Upgrades of Active Optics on Gemini Telescopes" by Maxime Boccas and Tomislav Vucina, *Proceedings of SPIE*, 6273, May 2006).

A main challenge of producing excellent image quality (IQ) stems from the fact that the Gemini primary mirrors are "meniscus mirrors." This type of mirror is relatively thin (~ 20 cm) for its width (~ 800 cm), which allows it to "slump" against its supports as the telescope tracks targets across the sky. Naturally, any deformation of the surface induces aberrations into the optical shape of the mirror, and therefore into any data obtained by the telescope. To mitigate these aberrations, Gemini (like all 8- to 10-meter-class telescopes) uses active optics (aO) to continuously maintain and optimize the optical surface and alignment of the elements in the massive seven-story-high optical system.

Given the "active" nature of the aO system, many of the engineering and optimization tests of the system components require real (on-sky) data, taken when atmospheric conditions are at their absolute best (to assess the performance of the system). Because these sky conditions are both rare and much coveted by PIs around the partnership, the testing procedures must be done with great efficiency as to minimize the impact on the science productivity of both telescopes.



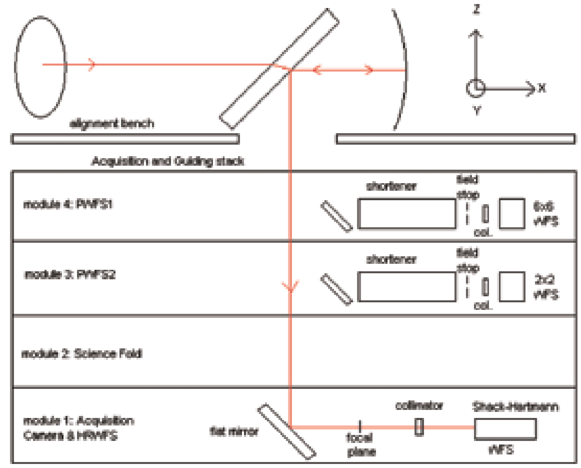


Figure 1. The alignment bench mounted on the A&G assembly (left). Side (schematic) view of the alignment bench (right).

Technologies and Techniques

Without overstating the obvious, active control of the Gemini optical system is a detailed and complex task. This is partly due to the many interrelated elements that must work in concert to achieve the excellent IQ needed to exploit the exceptional sky conditions available at both Gemini sites. At the heart of these systems are several wavefront sensors (WFS, see box at right) that measure the distortions present in the incoming light stream (the wavefront) and provide feedback to both the secondary mirror as well as low-order corrections to the primary mirror.

All of the WFS in the Gemini telescopes are "Shack-Hartmann" type sensors. These work by producing a collimated beam of light that falls upon an array of microlenses, (a 2 x 2 WFS means that a 2 x 2 array of lenses (four total) are used), that focuses multiple spots, one for each lenslet onto a detector. This is equivalent to dividing the light from the primary mirror into many small areas and analyzing the deformation of the incoming wavefront in each of these areas separately. Then a three-dimensional map of the complete wavefront is calculated and decomposed in a sum of known independent aberrations. Once this total is known, it can be corrected by applying a carefully calibrated pattern of forces to the primary mirror through the 120 pneumatic pistons, (or actuators), that make up its support. As discussed below these corrections are applied to the mirror approximately once every 30 seconds.

Key Gemini Wavefront Sensors:

- *Peripheral Wavefront Sensors (PWFS1: 6 x 6 and PWFS2: 2 x 2): located above the telescope focal plane and used in real time off-axis for tip-tilt and focus (TTF) and aO correction*
- *High Resolution 20 x 20 Wavefront Sensor (HRWFS): located in the acquisition camera assembly, and used on-axis for calibrations*
- *On-Instrument 2 x 2 Wavefront Sensors (OIWFS): located in some Gemini instruments, confocal with the science detector and used in real time on- or off-axis for TTF and aO correction*

In practice, the observing team at the telescope uses the PWFS1 for the initial tuning of the primary mirror figure at the beginning of the night. "Tuning" is the process of observing a standard star while the aO system calculates and then applies corrections to the primary mirror iteratively, to minimize any residual aberrations present in the image. We use PWFS1 to tune (or HRWFS in some cases) since they provide corrections for the many flavors of aberration present in any large optical system. (Note: at Gemini North, the procedure has been modified to use the WFS on the ALTAIR adaptive optics system to allow earlier tuning and more rapid nighttime deployment on the sky).

During science observations, either PWFS2 or an OIWFS (in the case of GMOS) is used to provide both fast (~ 200 Hz) guiding corrections to the secondary mirror and low-order aO corrections to the primary mirror to keep any optical distortions at a low level. Concurrently, astigmatism, coma,

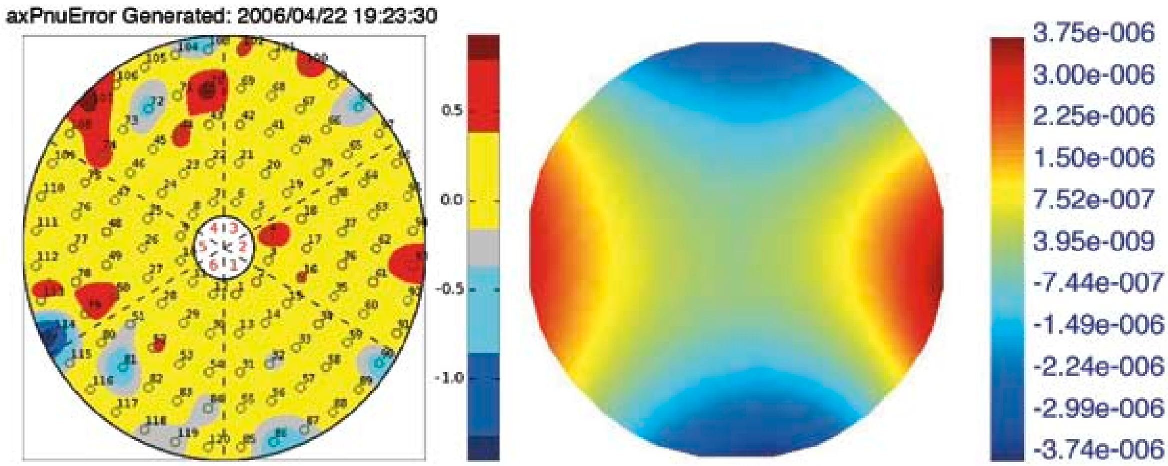


Figure 2.
Left: snapshot of the M1 pneumatic actuator errors
Right: M1 reconstructed surface figure

trefoil and other higher order Zernike modes are corrected by lookup tables (LUT) that take into account the changing forces on the mirror due to elevation of the telescope. LUT corrections are performed at intervals that are synchronized with the aO demands issued by the currently active WFS. These corrections are made every 30 to 60 seconds, depending on the natural seeing. In general, corrections are made less frequently in worse seeing conditions.

Refining the PWFS System

In 2003, an effort was begun to improve alignment and internal calibration of the PWFS1 system at Gemini North by the implementation of a dedicated alignment bench used while the acquisition and guiding (A&G) system is off the telescope. The alignment bench contains a set of optics that simulate the f/16 beam of the telescope. In this way it is equivalent to a “perfect” artificial star that provides the engineering team with calibration data under very stable and controlled conditions. For example, there is no turbulence present when using the alignment bench as opposed to observing a real star through the atmosphere. When the bench is in use, the incoming wavefront of the artificial star is monitored by a reference WFS in the bottom module of the A&G (see Figure 1). The refinement of the system involves tweaking the optical elements of the bench until a perfect wavefront is observed by the reference WFS. At this point we can accurately determine and calibrate for the internal aberrations of the PWFS optics and correct them using software. These changes are then implemented into the hardware and software and the system is returned to science use.

Immediately upon its arrival, the alignment bench allowed the correction of a serious misalignment of the lenslet array within PWFS1. This misalignment caused the wavefront sensor to incorrectly sample the pupil of the primary mirror in some areas of its patrol field. An upgrade to the bench in 2005 allowed for full alignment and calibration of the peripheral wavefront sensors at both sites between the end of 2005 and mid-2006. The most important result of these efforts was to reduce the residual astigmatism errors in the PWFS2 sensors by a factor of three during most nighttime operations. The resulting impact on image quality was immediate and quite dramatic. Because of the better intrinsic performance of the PWFS2 sensors, the delivered image quality (DIQ) of T-ReCS was markedly improved after the re-work. These instruments operate in the mid-infrared ($\lambda > 5$ microns) where the performance of the telescope is primarily limited by diffraction. However, operating at close to the diffraction limit has the unfortunate consequence of amplifying any remaining aberrations. Because of this, the mid-infrared science in the queue tends to push the telescope’s performance to the extreme.

Long-Term IQ Monitoring Systems

The Gemini Engineering Archive (GEA) is a comprehensive data-gathering program that constantly logs a wide assortment of parameters

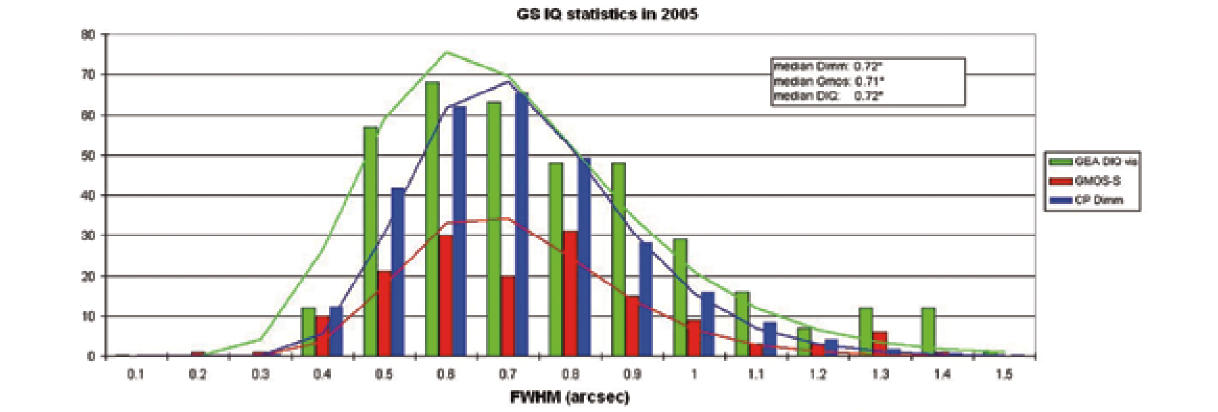


Figure 3. Comparison of image quality at GS in 2005: GMOS, DIMM, GEA DIQ (all FWHM are corrected to zenith and 500 nm)

from all of the telescope subsystems. From the most elemental quantities, such as the nighttime temperature and the elevation of the telescope to minutiae such as the voltage in the motor that turns the science fold, the GEA knows all! This data is then accessible though a web interface that allows the user to either perform basic plotting of the data in GEA itself, or to download the data for more rigorous reduction and analysis at a later time. Keeping a careful log of the feedback from the myriad of sub-systems is critical as it allows us to see trends in the overall performance of the telescope. This has been particularly useful in detecting drifts in system datum points and in the troubleshooting of IQ issues. Examples of data that are monitored in GEA with relevance to IQ include:

Primary Mirror Control System (PCS): This is the core of the image quality control system. The PCS is the name given to the actuator system that keeps the shape of the primary mirror in tune. A movie based upon image maps of pneumatic actuator errors (Figure 2, left) is produced at the end of each night to allow easy detection of problems. This data can also be transformed into a theoretical surface figure map (Figure 2, right) to gain knowledge on short- and long-term problems and drifts.

Zernike Modes Measured by Wavefront Sensors: Long-term monitoring of Zernike terms (both during initial mirror tuning and ongoing observations) allows for the identification of trends that will impact values used in the LUT. Correlating these parameters with environmental conditions (like wind speed, temperature, etc.) will allow further refinement of variables of closed loop feedback systems.

Wavefront Sensor Seeing Estimates: Algorithms are implemented in both the PWFS2 and OIWFS to estimate the seeing based upon a DIMM-like calculation. DIMM stands for Differential Image Motion Measurement, a standard technique used by seeing monitors that derives an approximate full-width-half-maximum (FWHM) for a point-source by recording the separation of the spot pattern on the WFS unit in use.

There is an ongoing program to better integrate the real-time seeing data into normal science operations. For example, real-time seeing estimates could be used by future queue-planning tools

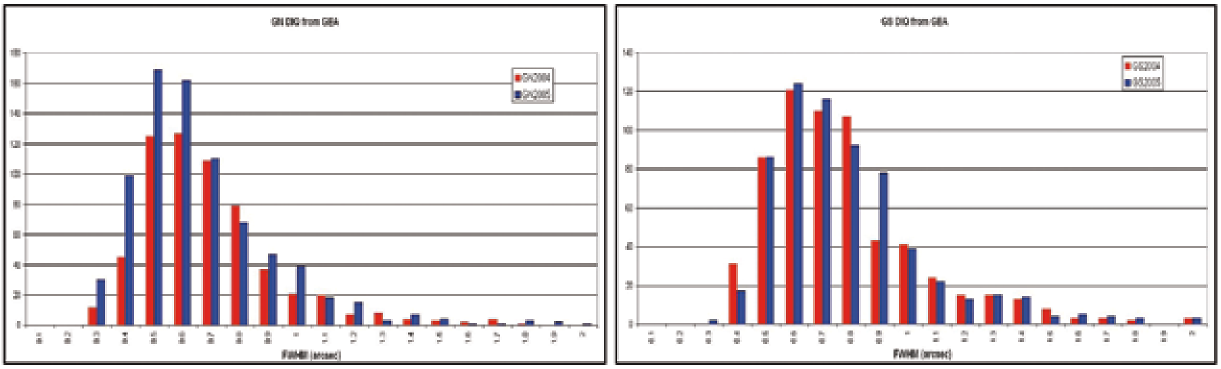


Figure 4. DIQ at both telescopes during 2004 and 2005

to help choose which programs are available for immediate execution. This program is one facet of a much larger campaign to understand differences in the broad seeing trends at each site.

Another part of the campaign is almost complete with the successful installation of a DIMM seeing monitor mounted on the roof of the support building at Gemini North. It has been producing data since April 2006. The equivalent monitor at Gemini South has supplied seeing data since March 2004. These provide another way we can compare Gemini's DIQ to the requirements originally set for the telescopes. All of the seeing data are automatically archived in the GEA.

Delivered Image Quality

As mentioned above, the multi-instrument queue model requires a strong emphasis on real-time DIQ monitoring in order to match observations to the current sky conditions as well as the performance of the telescope. In the Gemini queue image quality demands are binned into three "bands," as indicated in Table 1. This table also shows relative demand by users averaged over both telescopes. Unfortunately, the vast majority of our remaining image quality problems become evident under the absolute best seeing conditions. This occurs because, under these conditions, the telescope point-spread function (PSF) is not blurred or dominated by the natural seeing disk. We typically see IQ problems in most 20-percentile and some 70-percentile programs. We estimate that they affect 5 - 10% of the science usage at Gemini, but the time lost is biased heavily toward the mid-infrared instruments where static aberrations immediately degrade the PSF.

A rough determination of whether or not we are meeting the DIQ requirements of the telescopes can be realized from the seeing data at Gemini South from 2005 (Figure 3). The first thing to note is that the consistency between the three sets of seeing data is excellent. The fact that the data from GEA, which represents the IQ delivered by the science instruments, are the same as those measured by the external DIMM, strongly suggests that the telescope is performing at the limit of the natural conditions a large portion of the time.

Another requirement on DIQ, this one for the near-infrared, which states, "the telescope contribution in spot diameters should not exceed 50% of enclosed energy at 0.10 arcseconds and 50% of enclosed energy at 0.25 arcseconds (at zenith, across a one arcminute field of view)." Because this requirement is more difficult to precisely and effectively monitor it requires measurements and statistics of high-order wavefront errors. Since almost all of the near-infrared observations are guided using a 2 *x* 2 Shack-Hartmann WFS we have a very limited detailed knowledge of the wavefront. We do know that the 2.2-micron image quality requirement is equal to having a 285-nanometer wavefront error (rms). When compared to a sample of PWFS2 wavefront error data obtained over a period of several months we see that at Gemini South the error is below that threshold 75% of the time. It should be noted that this is a preliminary result since it does not include both astigmatic modes nor does it filter out times when the astigmatism is converging (e.g., when slewing to a new field).

There are many other datasets related to IQ in GEA. Perhaps the most recognizable is the DIQ reported by the night observers in the observing log. This value is where "the rubber meets the road," since it is the most direct measurement of how the overall telescope/instrument combination is performing. Corrections for wavelength and airmass are made to the data so they can be directly compared. Figure 4 shows this data from both sites between 2004 - 2005. An average of 1.75 entries per night were made by the observers during this time. An obvious source of bias in this type of analysis is if the observer systematically selects the best results of the night. Nevertheless, we have demonstrated statistically that this is a good indication of performance.

	Band 1 = 20%-ile	Band 2 = 70%-ile	Band 3 = 85%-ile	Any band = 100%-ile
V-band	0.45"	0.80"	1.20"	1.90"
K-band	0.35"	0.55"	0.80"	1.40"
demand	3%	39%	13%	45%

Table 1. Gemini queue image quality demands grouped by observing bands (as of early 2005).

Some interesting trends can be seen when the IQ data is considered as an ensemble. Data obtained primarily at Gemini South over a period of 18 months shows these interesting results:

- The DIQ generally improves as the night progresses, in particular during the second half of the night;

- DIQ is nearly constant for various typical integration times, which rules out significant guiding error. We do see periods of varying correction, particularly in astigmatism, but the DIQ is good enough to rule out any significant guiding error;

- The point-spread function of the system shows a higher spread in ellipticity values at the smallest FWHM indicating that image quality is dominated by astigmatism (elongated images) in good seeing;

- The performance of the adaptive optics system ALTAIR is also strongly correlated with natural seeing. The DIQ drops by 25% when the seeing degrades from 0.5 to 1.0 arcseconds.

The Future

Our understanding of both the capability of the telescope system and the limitations of working under real-world conditions has increased greatly over the last year. This is largely due to the fact that the engineering team now has access to new logging tools like the GEA. They have also gained much experience during the overhaul of the wavefront sensors, and this valuable experience is now paying off during routine science operations. Continued gathering of real-time data from the systems is the critical feedback needed to understand the complex relationships between the telescope systems that result in the telescope's delivered image quality.

Another area of work is the field astigmatism seen by the WFS, which is calibrated by a theoretical model that can be affected by telescope misalignments between the primary and secondary mirrors. We will either implement a procedure to check this alignment or develop new models allowing some misalignment. The last major upgrade scheduled (maybe through 2007) is the thermal control of the primary mirror (through radiation plates cooling the back surface) in order to avoid mirror seeing that can be a large source of error in certain conditions (low wind for example).

Although adaptive optics (AO) will have a growing use at both telescopes in the next few years (Multi-Conjugate AO should become operational at the end of 2007 at Gemini South), active optics will remain the core system to deliver good images for all the non-AO instruments.

To address the remaining image quality anomalies that impact some infrared observations the team is continuing to study the residual errors seen under the best natural seeing conditions. This is the most coveted of time for a large number of science observations, but it is critical to obtain appropriate engineering data under exquisite conditions to continue improving image quality at all wavelengths.

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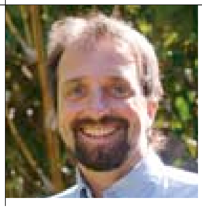
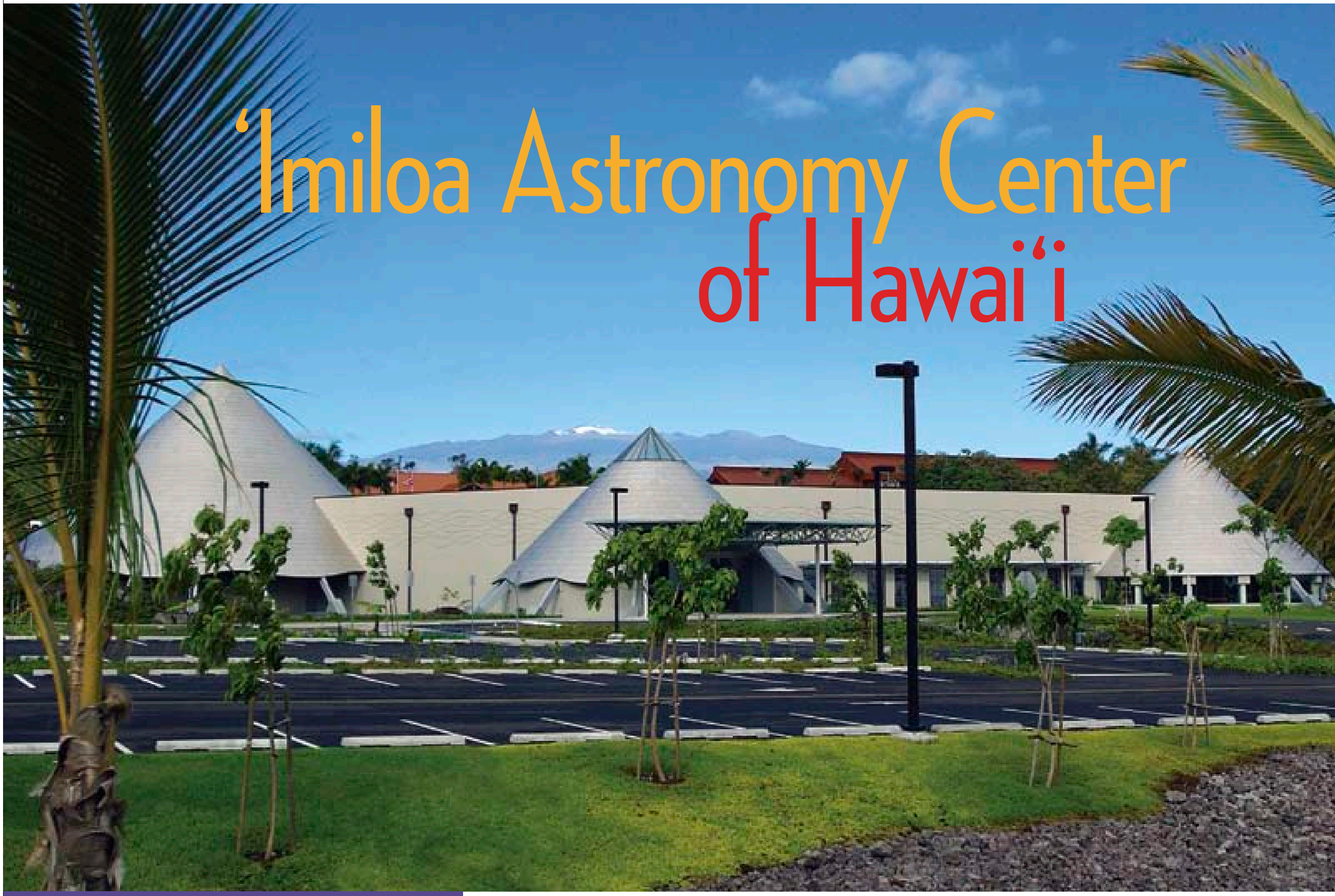


by Stephen James O'Meara



'Imiloa Astronomy Center of Hawai'i / K. Pu'uohau-Pummill

'Imiloa Astronomy Center of Hawai'i

"The proper and immediate object of science is the acquirement, or communication, of truth." So observed Samuel Coleridge (1772-1834) in his 1811 book *Definitions of Poetry*. Today these words live on in the new 3,700-square-meter (40,000-square-foot) 'Imiloa Astronomy Center of Hawai'i. 'Imiloa, the Hawaiian word for explorer or seeker of profound truth, is more than an education center. The $28 million (U.S.) facility promises to be a gathering place where native Hawaiians, astronomers and the public can share discoveries about science and the way early island inhabitants interpreted and studied the sky, ocean and land.

In essence, 'Imiloa will put Coleridge's words to the test. No one knows that better than the center's executive director, Peter B. Giles. "The future must harmonize culture and science in a powerful way," he said not long after the center opened, "because both feed the mind and the heart, and that's what we're trying to do."

'Imiloa is a place of beginnings and origins. It gives people a place to connect with one another in new and stimulating ways. Knowledge of Hawaiian language and culture and the elements of astronomy and technology are at the heart of the

Figure 1.
The new 'Imiloa Astronomy Center of Hawai'i is a $28 million (U.S.), 3,700-square-meter, (40,000-square-foot), exhibition and planetarium complex located in Hilo.

Figure 2.
On February 20, 2006, a blessing ceremony and dedication at the ‘Imiloa Astronomy Center brought together astronomers and native Hawaiians—reflecting ‘Imiloa's purpose. Three days later, the center officially opened its doors to the public.
Photo: Kirk Pu‘uohau-Pummill

center. "'Imiloa could rightfully be envisioned as a fulcrum on which you could put the lever of the outreach activities of the observatories," Giles said, "to move the world one step closer to grasping the significance of astronomy, and not lose sight of the fact that the Hawaiians were here first."

Figure 3.
An 8-meter, (26-foot)-diameter Italian tile mosaic, based on artwork by Hawai‘i Island artist Clayton Young, titled "Voyage of the Navigator," adorns the floor of ‘Imiloa's main Lobby. Foreground, left to right: Polynesian navigator Nainoa Thompson; UH Institute for Astronomy Astronomer Paul Coleman; Director of UH College of Hawaiian Language Kalena Silva; UH Hawaiian Language Professor Larry Kimura; and UH President David McClain.
Photo: Kirk Pu‘uohau-Pummill

Reflections

Everything about ‘Imiloa speaks of humanity's connection with Earth and sky. Situated on 9.1 acres directly across from Gemini's Hilo Base Facility on the University of Hawai‘i-Hilo Science and Technology Park, ‘Imiloa is fashioned after the land. The building's striking architecture includes three titanium-clad domes representing the three tallest volcanoes on the island: Mauna Kea, Mauna Loa, and Hualalai, respectively. The building's architect, Melvyn Choy of Durrant-Media Five Ltd., described the design as emphasizing the connection between earth and sky. "The use of titanium adds space-age luster that propels our thoughts toward future discoveries," he said.

Inside, the center's object of focus is the nearly 4,300-meter-high, (14,000-foot) summit of Mauna Kea—the nexus of Hawai‘i's past and modern astronomical research. Like the brave Pacific navigators who steered their canoes by the stars, today's astronomers voyage among the stars. We use world-class telescopes like Gemini as our high-tech canoes to probe the cosmos. In the words of U. S. Senator Daniel Inouye, who was instrumental in securing the center's funding (largely from NASA), "'Imiloa will show how the exploration done by Native Hawaiians of the past lives on at Mauna Kea."

The center uses a common thread of exploration to weave together the seemingly diverse yet fundamentally similar aspects of traditional Hawaiian culture and astronomy. More than 100 interactive exhibits, multimedia theaters, and a state-of-the-art planetarium are designed to take visitors on a journey through culture, space, and time.

The Voyage Begins

As visitors leave the lobby, they pass through a stylized koa forest on their way to the starlit summit area of Mauna Kea. One of the center's many volunteers, Don Romero, described it as "the easiest walk to the summit you'll ever have." Along the way visitors pass over an adze pit accompanied by the sound of someone actually walking on those flakes of rock, which are seen through a glass floor. They will also see the vivid green hue of Lake Wai'au, where natives would leave a newborn child's umbilical cord (piko) to acknowledge the connection to one's origins.

The origins connection is strengthened in the Kumulipo Theater. This multimedia experience presents the Hawaiian chant that chronicles the birth of life. Just as astronomers today have shown that the universe emerged as a chaotic mix from the darkness, so too did ancestral Hawaiians understand that all life emerged from *Po*, meaning the featureless dark. In a way, the Kumulipo chant symbolizes the mission of 'Imiloa: that from darkness (ignorance) will grow light (a new mental order and enlightenment). "The Kumulipo Theater gives you an insight that you might not have brought with you from New York City or from Los Angeles," said Peter Giles. "Is that important to the modern word? I would argue, yes!"

Figure 4. 'Imiloa houses more than 100 interactive exhibits, each presented in Hawaiian and English. In the Voyaging Exhibit, a one-fifth scale model of a voyaging canoe symbolizes the ongoing journey to preserve Hawaiian culture. Personal quotes from today's explorers and communicators are printed on stylized sails. *Photo: Kirk Pu'uohau-Pummill*

The Voyage Continues

The centerpiece of the center's Voyaging Exhibit area is a one-fifth scale model of a canoe, a symbol of the ongoing journey of contemporary Hawaiians to preserve their language, history, and culture. All the exhibits at the center are presented in Hawaiian and English, and quotes from today's explorers and communicators are also printed on stylized sails.

The Hawaiian voyaging experience is balanced by numerous exhibits that showcase the exploration of space by astronomers on Mauna Kea. Outlines on the room's carpet compare the sizes of the different telescope mirrors on the mountain, while hands-on exhibits allow visitors to test out the astronomers' tools and instruments. One of the more popular interactive displays is the Gemini "Virtual Observatory." It uses the former Gemini North control console to feature the Gemini Virtual Tour, live views of the Mauna Kea summit area, sample control screens, and astronomical images.

Figure 5. From the origins of the universe as told through Hawaiian chant, to the origins of the universe as explained by astronomers, visitors to 'Imiloa can explore the multidimensional answers to the question: "Where do we come from?" *Photo: Kirk Pu'uohau-Pummill*

Beneath the center's largest titanium dome is 'Imiloa's world-class planetarium. It features a 120-seat theater and a Digistar-3® system from Evans & Sutherland (E&S). Later this year the planetarium will receive a revolutionary new laser video projector developed by E&S. It will produce 16 million pixels of video resolution across the dome. The theater's sound system provides a 6-channel, 5.1 surround-sound experience to create a completely immersive planetarium presentation.

'Imiloa also features an experimental and unique computer simulation theater. Presented by the National Astronomical Observatory of Japan (NAOJ), the "4D2U—Voyage Through Space" is a four-dimensional simulation (the normal three dimensions plus time) based on real astronomical data from researchers at the National Astronomical Observatory of Japan, which operates the Subaru Telescope on Mauna Kea. The seven-minute program takes the viewer from present-day Hilo back in time to the origins of the universe some 13 billion years ago. NAOJ director Norio Kaifu said he wanted people to experience the "mesmerizing beauty of the universe, as revealed by modern astronomy, without sacrificing scientific accuracy."

The Future Awaits

'Imiloa is well-poised to make great contributions to science outreach, according to director Giles. "The thing that will distinguish 'Imiloa from other astronomical centers," he said, "is the extent to which we can keep Mauna Kea alive here at the base of the mountain. It's not enough just to show what's in the sky. Our specialty here has to be interpretation and communication. To me it's a no brainer. This is very powerful stuff."

Big Island benefactor Earl Bakken summed up the purpose of 'Imiloa this way: "What we want to do is get the young people dreaming about the future, and the 'Imiloa center will certainly be a key in making that happen," he said.

To learn more about 'Imiloa visit: www.imiloahawaii.org

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Gemini: Welcoming Our New Neighbor

Gemini Observatory is participating in the development of the 'Imiloa Astronomy Center of Hawaii from the beginning at different levels, from supplying content advisors to loaning its unused summit console for use in a Gemini-developed Virtual Observatory exhibit.

Figure 6. From the beginning, Gemini Observatory helped with the development of 'Imiloa Astronomy Center of Hawai'i, including the contribution of a console to house the Gemini Virtual tour. *Photo: Kirk Pu'uohau-Pummill*

"'Imiloa is really important to us at Gemini," said Public Information and Outreach Manager, Peter Michaud, who co-directed 'Imiloa's inaugural planetarium show, **Mauna Kea: Between Earth and Sky.** *"Besides being a neighbor across the street, it is a wonderful place for us to leverage our local outreach and education programming. So we're working to partner with them in as many ways as we can. It's an incredible resource for all of us."*

Gemini acting director Jean-René Roy is extremely passionate about Gemini's role in supporting 'Imiloa. He sees the new center as an organization that can help astronomers relate to the public. "It's going to help to remove the stigma that we have of being here just for our own interests, not caring about the local population, not sharing, being those people who just come and get their data and run away," he said.

Gemini has already helped 'Imiloa on various fronts technically. The loan of its unused summit console is one example. "We were supposed to have a $300,000 observatory simulator in that spot," said 'Imiloa executive director Peter Giles, "But that project was cut. Now, thanks to Gemini, we have a real artifact that's more precise than a fabricated exhibit. And it came to us for nothing. This is an incredible example of how the observatories and 'Imiloa can work together for the common interest. What a thrill!"

The planetarium is also coming in for visual support from Gemini. "We're now working on a 180° fisheye lens time-lapse video system that will image the night sky for an entire night," Michaud said. "Once we create a video of that, we'll put it in the planetarium at 'Imiloa. We'll also make the video available to other planetaria. So we're really getting ahead of the curve to provide resources not just to 'Imiloa but to planetarium facilities throughout the entire Gemini partnership."

Figure 7. 'Imiloa's 12,000 square-foot exhibit hall features exhibits that weave astronomy and Hawaiian culture into a compelling story of human exploration. *Photo: Kirk Pu'uohau-Pummill*

'Imiloa is also causing Gemini to reconsider what it's doing in the areas of public outreach and education. For instance, Roy believes that Gemini needs to work even more closely with 'Imiloa, so that there can be a more efficient partnership. "We need to look at the type of resources we have," Roy says, "and to look at what we've been doing in the past."

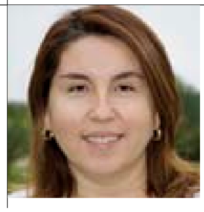
For instance, there may be things that Gemini has been doing that can now be done in partnership with 'Imiloa. On the other hand, Roy says, "If we see something that doesn't work at 'Imiloa, we should suggest paths for improvements and find out how we can help. It's easy to criticize, especially a new thing like this, but it's like a new baby, we need to help it."

Figure 8. The primary astronomy exhibit gallery at 'Imiloa. The observatory dome in background is home to the Gemini Virtual Tour which runs on the console formerly used on Mauna Kea (see Figure 6). *Photo: Kirk Pu'uohau-Pummill*

A new collaborative outreach effort is already looming on the horizon. Recently, Roy has decided to offer one hour of director discretionary telescope time to local high school students, something that Subaru is planning to do as well. "Each semester we plan to offer some time to high-school students," Roy says, "and we're doing a pilot project right now for that. In the future I see 'Imiloa as being the organization that could be in the intermediary position between the schools and the great observatories, like Gemini and Subaru. 'Imiloa would probably play a lead role in selecting the proposals with us. So that's a concrete activity."

There's another level of meaning that has more political, philosophical, and practical overtones. "Thanks to the great vision of Senator Inouye," Roy said, "'Imiloa will try to link what astronomers from other countries are doing with the people here on the island." He is equally excited that 'Imiloa is connecting astronomy to navigation. Throughout history those two things have been linked together. Now Roy hopes they will reconnect in the future, when humans set sail for other planets and stars. The ongoing research on Mauna Kea, Roy believes, is "preparing the groundwork for future incredible travel."

Figure 9. Hawai'i Senator, Daniel Inouye (center) and University of Hawai'i-Hilo, Chancellor, Rose Tseng (left), along with astronomy personnel watch the *4D2U* Theater program. *Photo: Kirk Pu'uohau-Pummill*



by Antonieta Garcia

Expanding Gemini's Educational Outreach in Chile

Figure 1. Evening observation programs for the public offer views of the night skies at the CADIAS facility outside of La Serena, Chile. *Photo: Milton Urzúa*

Teachers and students from the region of Coquimbo, along with those in the community of Altovalsol in La Serena, are taking a closer look at the sky. While they are located only 15 minutes away from downtown La Serena, in the past their access to astronomy education has not always been the same as local students.

Fortunately for these students, CADIAS (the Centro de Apoyo a la Didáctica de la Astronomia, or Center for the Support of Astronomy) has opened the doors to its 2,500-square-meter (26,900-square-foot) facility to the educational community, bringing support for astronomy teaching to people in the area. "It is not easy when it comes to coordinating the needs and requirements of the teachers along with the constant demands from our students," said Oriale Castellón, a Rivadavia teacher who uses the facility. "These young people seem wiser every day when it comes to exploring and researching in our skies."

CADIAS, sponsored by the Universidad de La Serena, and currently operated by a group of teachers and students, is situated in an old

Figure 2. Primary exhibit space at CADIAS with a visiting school group in mid-May 2006. *Photo: Milton Urzúa*

country-style house that was formerly the village school. The building has undergone a $140-million-peso (about $268,000 U.S.) renovation, a process done entirely by the City Hall of La Serena and given to the Universidad de La Serena through a legal agreement over a 10-year period.

The center features diverse rooms that include exhibits, auditoriums, a small theater, a specific room for one of the portable planetariums that Gemini Observatory operates, a library (which will soon have full Internet connectivity) sponsored by the Dirección de Bibliotecas Archivos y Museos (DIBAM), in addition to observation platforms where four telescopes provided by CTIO are used on clear evenings (see Figure 1).

Since this building re-opened to the public in August 2005, (having formerly been a center for UFO enthusiasts), CADIAS has been visited by more than 8,200 people. Its current renovations and additions will be completed in 2006, along with a variety of new initiatives.

According to the Director of CADIAS, David Orellana Astorga, "This place represents a dream. It will mean that teachers can work in improved or new methodologies in learning for their students," he said. "Now, not only can we train educators in the teaching of astronomy, but also we can support them with the necessary data that we have always dreamed of sharing with them."

For Raúl Saldívar Auger, the Mayor of La Serena, this new project has crystallized an alliance that encourages new municipal educational policies. "They are integrating the largest number of students to study astronomy," he said. "We have a tremendous patrimony in our good and dark skies. It is unique in the world and especially great for this science."

Gemini Observatory has participated actively in the development of this new educational center through our close relationship with the educational programs that are operated in conjunction with the RedLaser group that belong to the Universidad de La Serena. Gemini is also partnering in the development of exhibits (like the Gemini Virtual Tour), printed image panels and the development of a room devoted to innovative and engaging experiences for visitors.

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by Colin Aspin

One Million And Counting

In recent weeks the Gemini Science Archive (GSA) has passed three significant milestones and attained new levels of use unforeseen in the early days of its development. In this article, we have decided to reflect on the origins of the GSA, its current status in service to the Gemini community, and our plans for its future expansion into the world of the Virtual Observatory (VO).

The first release of the GSA for public use, version 1.0, was in September 2004. At that time we expected its main function to be as a complex data repository, albeit one in which considerable "metadata" was stored along with the observation data. (Metadata is typically information that is itself not of direct scientific importance, but aids in the characterization of the science data. A good example would be data describing weather conditions during an observation run.) We have come a long way in the 18 months since opening public access to the GSA and now view it as a dynamic, crucial, and integral part of Gemini operations, with a future closely linked to observatory-wide dataflow and the international Virtual Observatory development.

A major direction shift in our vision of the GSA occurred with the public release (in May 2005) of what we term PIETD. This acronym stands for "Principal Investigator Electronic Transfer and Distribution." With this service, we took the first step in moving the GSA from the old model of a

Figure 1.
A processed calibration form using the query function on the Gemini Science Archive.

directly interact with both observatory operations and users in close to real time. With the latest release of the GSA (version 1.35) in January 2006, we are closer to realizing this vision. The new version includes several different types of data products, such as processed calibrations, and such new features as "Processed Calibration" and "Observing Log" query pages. In addition, with the successful implementation of the "DataManager" software at both telescopes, we now stream raw data from the instruments to the GSA.

The average "ingestion" time for such data is about 30 minutes. This includes on-line ingestion validation and verification, electronic transfer (via a Virtual Private Network link from the Hawai'i and Chile to the Canadian Astronomy Data Centre (CADC) in Victoria, BC, Canada), ingestion into the GSA, and the appearance of the dataset in results pages created through user queries. Of course, all Gemini Queue and Classical data is proprietary for 18 months (the proprietary period is three months for science verification data) but Principal Investigators can download their data using the "Access your PI Data" link via password-protected access. Already several users have downloaded their data within minutes of it appearing in the GSA science tables and fed back useful information on the results obtained to the Gemini the next day!

So, what is the next step for the GSA? The observatory-wide Dataflow Project is driving GSA development in many areas. Our plan is to expand the flow of data into the GSA to include all available processed science products and ancillary metadata files. With the implementation of proposed data quality assessment and control tools, together with modifications and enhancements to the OLDP (On-Line Data Processing system), we hope to be able to quickly provide processed data products to the GSA and (in the near future) to the Canadian Virtual Observatory, our adopted portal to the VO. Our hope is that, within the next few years, to provide processed data products to Principal Investigators via the VO including, for example, source catalogs, so that recipients of Gemini data can work immediately on the scientific content of their data.

Now, back to the milestones. As we mentioned above, the GSA achieved three significant milestones earlier this year. We are confident that these are the first of many more to come. Yet they serve to mark the rapid growth in content, usage, and usefulness of the GSA, to the Gemini

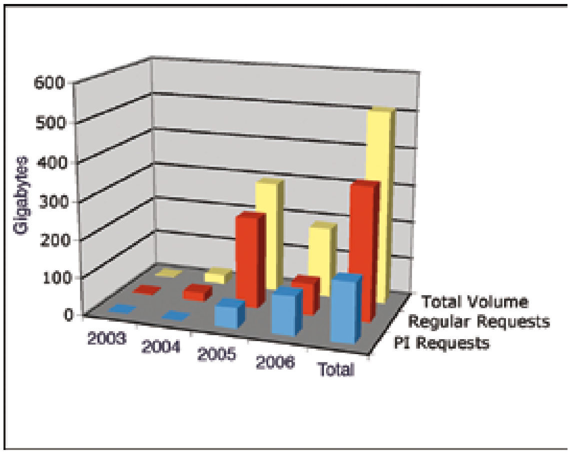

Figure 2. Increasing use of the GSA as indicated by downloaded data.

community and astronomers worldwide, as well as the rapidly evolving sophistication of GSA operations at CADC.

The first milestone was, as the title of this article suggests, the one millionth file ingested into the GSA. This number truly represents the maturing of the Gemini telescopes and the dedication of so many staff members to the goal of the efficient collection of astronomical data. These one million files are our "complete collection," yet include close to 200,000 individual science datasets, together with extensive calibration data and metadata files. As of April 1, 2006, the GSA science collection has more than 112,000 public datasets, with more being released every day.

The second milestone is related to the first although expresses a somewhat different message. The content of the GSA has recently exceeded three terabytes in size. Again, this is the complete collection of data stored in the GSA, yet it represents a growth trend unforeseen in the early days of the design of the GSA. The GSA is now the third-largest collection hosted by CADC (behind CFHT and HST) and will likely continue to grow at an accelerating rate as more and varied data products are made available.

The final milestone we note here is the 300th registered user of the GSA. The number of users has been growing rapidly, particularly after the release of PIETD. However, retrieval statistics show that PI requests are still a factor of two smaller than those of general non-PI users. Already the totals in the first three months of 2006 have matched the total number of retrievals in the whole of 2005! To conclude, the future of the GSA is very bright and we look forward to reporting on the next stages of GSA development soon.

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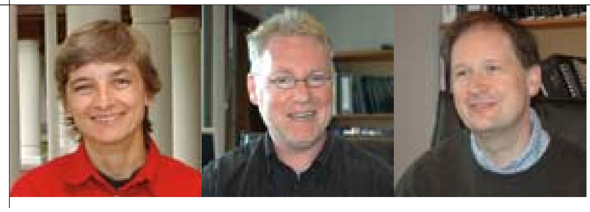

by Inger Jørgensen,
Michael West and
Phil Puxley

Operational Efficiency at Gemini in 2005

With the Gemini North and Gemini South telescopes reaching more mature science operations status, and with multi-instrument queue execution in place at both sites it is a good time to review semester 2005A and 2005B at Gemini from a science operations point of view. The highlights in terms of science operations, instrument commissioning and selected engineering tasks are summarized in Table 1. Figure 1 shows the mix of data taken on a single multi-instrument queue night.

Both sites 2005A
Electronic observing log for all facility instruments
Rapid Target-of-Opportunity mode implemented
Gemini North 2005A
Multi-instrument queue for the entire semester
All staff cross-trained for multi-instrument queue by the end of 2005A
All nights planned by a queue coordinator
Laser guide star commissioning started
Engineering tasks mixed with science queue from June 1, 2005
Altair technical problems early in semester hampered completion rates of band 2 NIRI/Altair programs
Gemini South 2005A
Started multi-instrument queue scheduling
bHROS commissioning completed
Primary mirror washed
Very poor weather late in semester (see Figure 3)
Gemini North 2005B
Multi-instrument queue for the entire semester
Tight queue planning leading to high completion rates in band 1 & 2
All nights planned by a queue coordinator
NIFS commissioning in queue - completed on schedule
NIFS System Verification in queue - completed in Jan-Feb 2006
Michelle imaging polarimetry commissioned in queue
Telescope engineering tasks to improve image quality done in queue
Continued commissioning of laser guide star system
Gemini South 2005B
Strong effort to cross-train all staff for multi-instrument queue
All nights planned by a queue coordinator
bHROS Demo Science completed for 2 out of 3 programs
GNIRS lens replaced and GNIRS re-commissioned
Poor weather continued during first part of semester (see Figure 3)

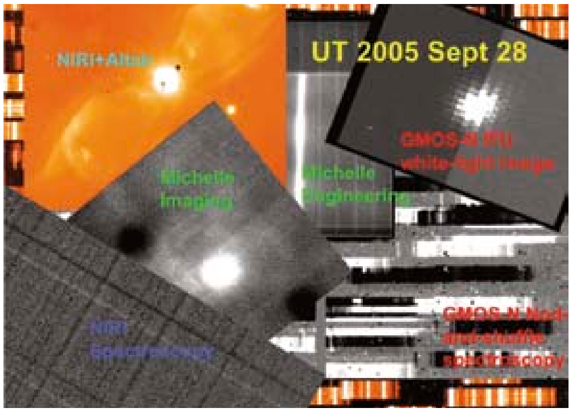

Table 2 shows proposals statistics for semesters 2005A and 2005B. The oversubscription was 2.6 to 3.1 at both telescopes, when weighted by the partner shares. The U.S. and UK dominate the oversubscription. At Gemini North, GMOS-N (Gemini Multi-Object Spectrograph) continues to be the most popular instrument, attracting about half of all proposals for time on Gemini North. At Gemini South GMOS-S attracts a similar fraction of all proposals, while the Gemini Near-Infrared

	2005A				2005B			
	# proposals	GN oversub	GS oversub	Total oversub	# proposals	GN oversub	GS oversub	Total oversub
US	219	5.2	4.4	4.8	170	3.4	3.6	3.5
UK	82	3.6	1.8	2.7	80	2.4	3.5	2.8
Canada	50	3.2	1.4	2.4	47	2.7	1.1	1.9
Australia	22	1.2	2.0	1.6	31	1.6	3.4	2.8
Chile	12		1.8	1.8	11		1.2	1.2
Argentina	8	1.4	1.1	1.3	12	1.1	1.3	1.2
Brazil	22	1.3	1.9	1.6	18	1.3	1.3	1.3
Gemini Staff	41	3.5	2.6	3.0	32	1.6	2.4	2.0
Univ. Hawaii	12	1.2		1.2	14	1.3		1.3
Total	468				415			

Figure 1.
Collage showing the mix of data taken on the night of September 27-28, 2005 at Gemini North, during which all available facility instruments were used.

Table 1.
Left: Summary of science operations, instrument commissioning and selected engineering tasks executed during semesters 2005 A and B.

Table 2.
Right: Proposal statistics for semesters 2005 A and B.

Table 3. Scheduled science nights at the Gemini telescopes for semesters 2005 A and B.

Site-Semester	Queue [nights]	Classical [nights]	Total science [nights]	Total science [%]
GN-2005A	142	19	161	89%
GN-2005B	135	12	147	80%
GS-2005A	116	48	164	91%
GS-2005B	119	43	162	88%

Spectrometer (GNIRS) attracted about 29% of the proposals in 2005B.

The number of scheduled science nights at both telescopes was higher than originally planned. This was due to the delay of various instrument commissioning tasks. Table 3 summarizes the number of scheduled nights in queue and classical mode. The higher fraction of classical nights at Gemini South is primarily due to Phoenix (the NOAO infrared high-resolution spectrograph) being scheduled only in classical mode.

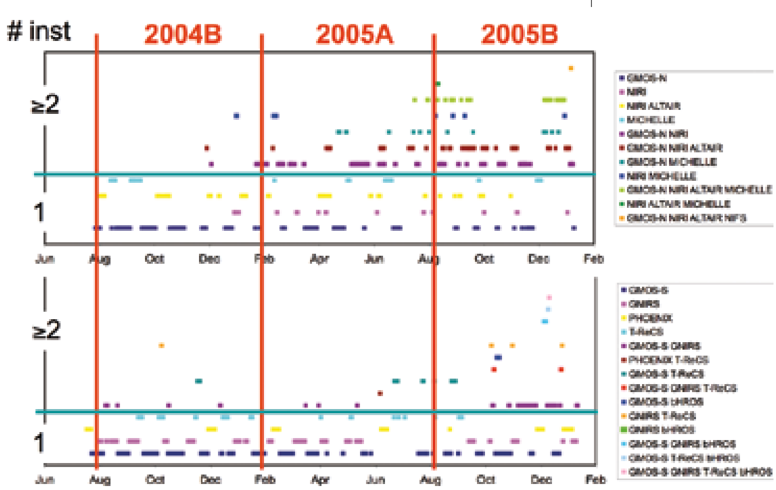

Figure 2. The development of multi-instrument usage at Gemini North (top panel) and Gemini South (bottom panel). The multi-instrument queue mode was started at Gemini North in 2005A. In 2005B multi-instrument nights were 77% and 55% at Gemini North and South, respectively, as a percentage of useful queue nights.

In order to make the best use of available telescope time, both telescopes now operate every queue night with all of the facility instruments currently mounted on the telescopes available for use in the science queue. Figure 2 shows the development of this multi-instrument operational mode. At Gemini North, the multi-instrument mode began in early 2005A, with MICHELLE (the mid-infrared imager/spectrometer) added to the available instrument suite in May 2005. At Gemini South, the weather loss (Figure 3) delayed staff cross-training and full implementation of the multi-instrument mode. Whether multiple instruments are in fact used on a given night is a function of the observing conditions and the current content of the queue. During 2005B, 77% of the useful queue science nights used multiple instruments at Gemini North, while this was the case at Gemini South for 55% of the usable queue science nights.

We have begun scheduling instrument commissioning and system verification, as well as telescope engineering mixed with the science queue, in order to make the best use of observing conditions. At Gemini North in 2005B, near-infrared integral field spectrograph (NIFS) commissioning and system verification were done fully within the queue. The commissioning of the laser guide star system is done in blocks due to the large engineering staff required. However, all laser guide star commissioning nights have a science queue backup plan when conditions are not usable with the laser guide star system.

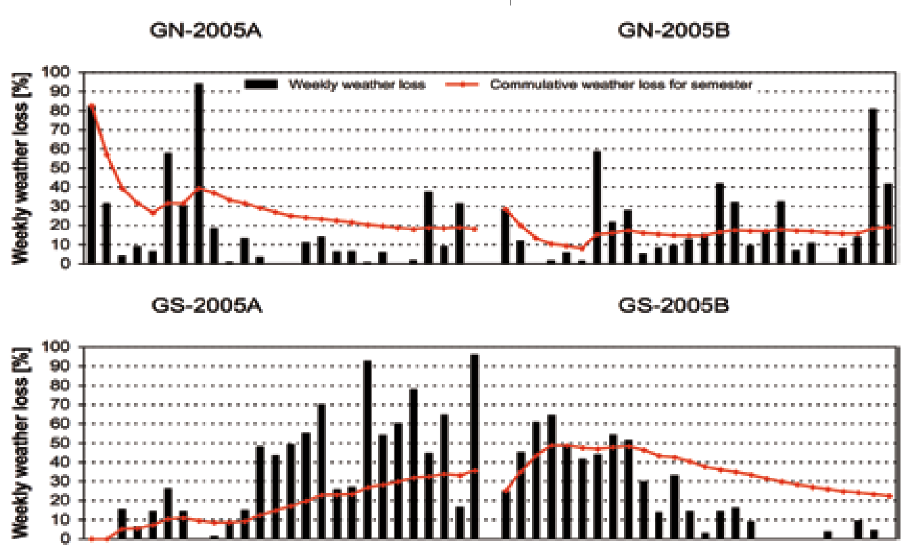

Figure 3. Weekly weather loss at Gemini North (top) and Gemini South (bottom) for 2005A and 2005B. The very non-uniform distribution of the weather loss at Gemini South has had a significant impact on the queue program completion rates.

	GN-2005B: Number of Queue Programs						
Band	done (100%)	>75%	50%-75%	10%-50%	<10%	Not started, or pre-imaging only	out of
1	13	13	0	0	0	0	13
2	22	22	0	0	0	0	22
3	17	18	3	3	16	16	40

	GN-2005B: Fraction of Queue Programs					Fraction of started programs	
Band	done (100%)	>75%	50%-75%	10%-50%	<10%	done (100%)	>75%
1	100%	100%	0%	0%	0%	100%	100%
2	100%	100%	0%	0%	0%	100%	100%
3	43%	45%	8%	8%	40%	71%	75%

	GS-2005B: Number of Queue Programs						
Band	done (100%)	>75%	50%-75%	10%-50%	<10%	Not started, or pre-imaging only	out of
1	6	6	2	1	0	0	9
2	12	12	2	1	2	2	17
3	12	13	3	5	13	8	34

	GS-2005B: Fraction of Queue Programs					Fraction of started programs	
Band	done (100%)	>75%	50%-75%	10%-50%	<10%	done (100%)	>75%
1	67%	67%	22%	11%	0%	67%	67%
2	71%	71%	12%	6%	12%	80%	80%
3	35%	38%	9%	15%	38%	46%	50%

Table 4. Completion rates for queue programs in semester 2005B.

Careful planning is required when running the telescopes in multi-instrument mode and when commissioning and engineering tasks are mixed with the science queue. The nightly plans at both sites are prepared by a "queue coordinator," who is a member of the science staff. Four to five staff members at each site share this responsibility. Queue coordination was put in place at Gemini North at the start of 2005A, while Gemini South followed in 2005B.

During 2005, Gemini put forward goals for queue completion rates to be reached by the end of semester 2006A, (weather permitting). The goals, which apply to all facility instruments at both telescopes, were presented in the *GeminiFocus* December 2005 issue. The queue coordination, as well as the multi-instrument nights, has resulted in a very positive effect in the realization of our completion rate goals. The completion rate goals exclude target-of-opportunity programs, and programs (for bands 2 and 3) for which only

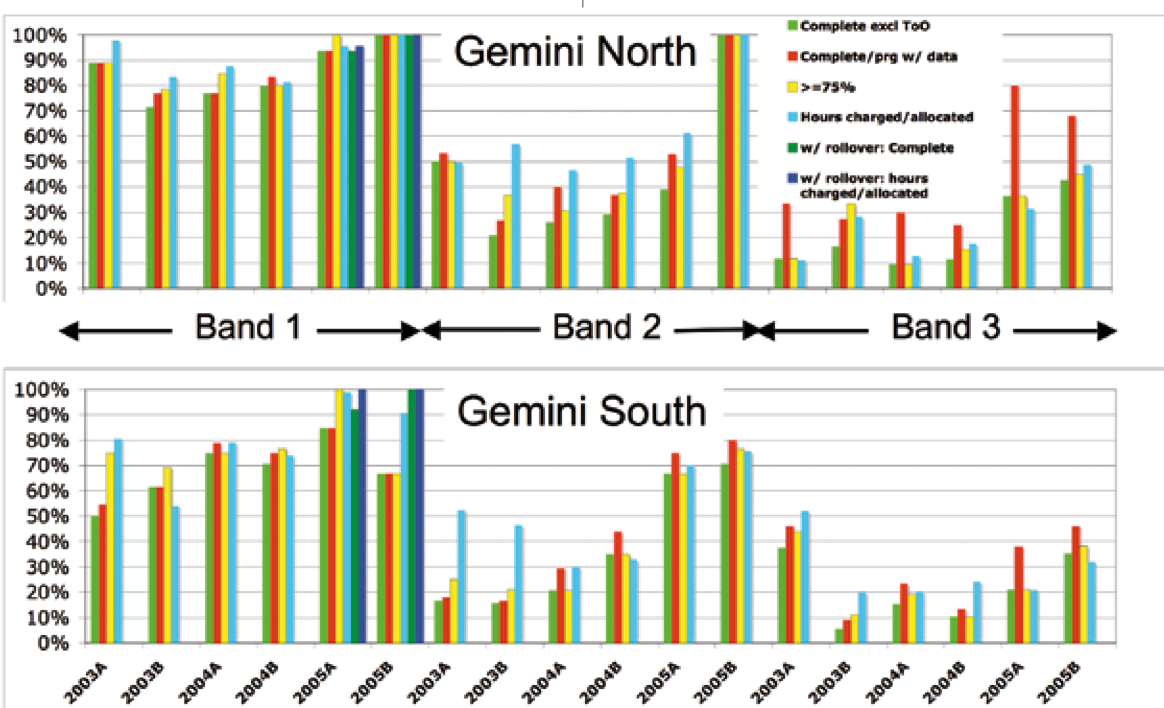

Figure 4. Queue completion rates at Gemini North and South since semester 2003A. Also shown is the projected completion rates for band 1 programs for semester 2005A and B if rollover status programs are completed. Rollover status was started for selected band 1 programs in 2004A. At the same time the relative allocations in band 1 and 2 were reduced. The current size is about 25% of the allocated queue time in band 1 programs, 25% in band 2, and the remainder in band 3.

GMOS pre-imaging has been obtained. Following is the current status relative to these goals:

- **Band 1:** 90% or more of the queue programs are completed, in the sense that 100% of their requested data have been acquired or all their allocated time has been used. **Status:** this goal was met at Gemini North in 2005B. With rollover status the goal is reachable for Gemini South 2005B programs.

- **Band 2:** 75% or more of the queue programs are completed. **Status:** this goal was met at Gemini North in 2005B.

- **Band 2:** 80% of started queue programs should have at least 75% of the requested data obtained. This excludes programs for which the only data obtained was GMOS pre-imaging. **Status:** this goal was met at both Gemini North and Gemini South in 2005B.

- **Band 3:** 80% of started queue programs should have at least 75% of the requested data obtained. This excludes programs for which the only data obtained was GMOS pre-imaging. **Status:** this goal was met at Gemini North in 2005A. In 2005B at Gemini North 75% of started band 3 programs got at least 75% of the requested data.

Table 4 summarizes the completion rates at both sites for semester 2005B. In Figure 4, the completion rates are summarized for all semesters starting with 2003A. Since 2004A, the Time Allocation Committees (TACs) have had the option of recommending rollover status for band 1 programs. At the same time the sizes of the queue bands were revised. Currently the amount of time contained in each queue band is 25%, 25%, 50% for band 1, 2, and 3, respectively. The total amount of time overfills the available queue time slightly. Further, weather loss reduces the actual time available during a given semester.

Figure 3 shows the weekly weather loss at the two sites for both semesters. The total weather loss for 2005A was 18% and 36% for Gemini North and Gemini South, respectively, while for 2005B both sites had about 20% weather loss. The majority of the weather loss at Gemini South occurred in the period from mid-April to the end of September 2005, while the weather loss at Gemini North was quite evenly distributed throughout the semesters. The weather loss distribution, and higher average in 2005A at Gemini South, had a significant effect on the completion rates at Gemini South, and is undoubtedly the major factor in the lower completion rates in band 1 and 2 at Gemini South in 2005A and 2005B when compared to those of Gemini North.

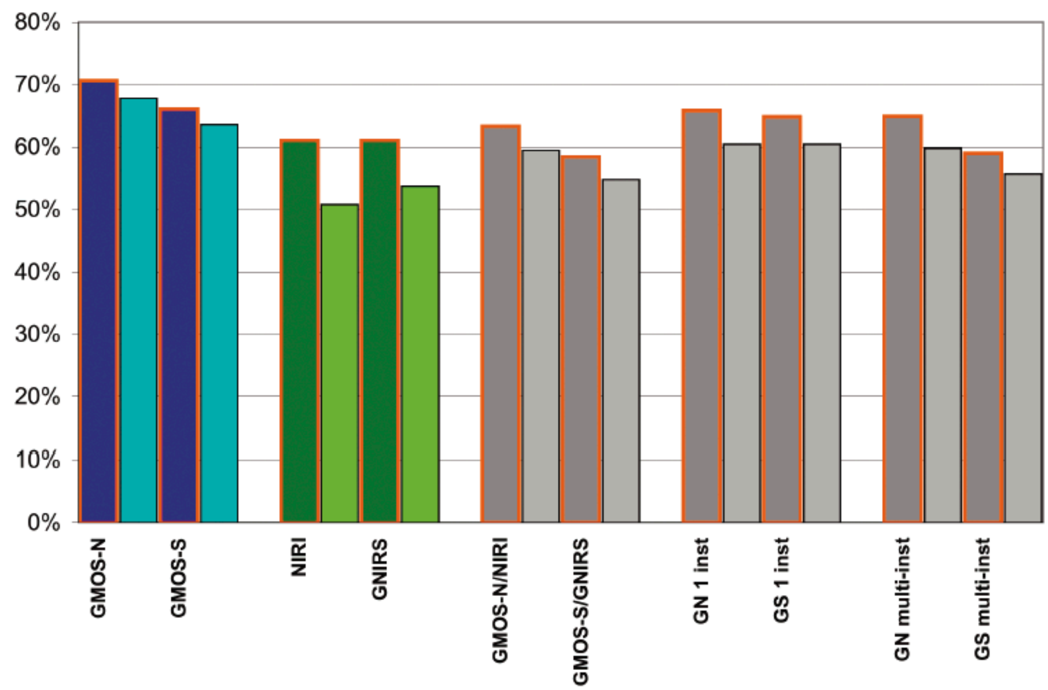

Figure 5. Open-shutter efficiency for Gemini's facility instruments. GMOS-N and NIRI are on Gemini North, GMOS-S and GNIRS are on Gemini South. The first bar for each instrument or combination of instruments shows the open-shutter efficiency in stable, good observing conditions, while the second bar shows the open-shutter efficiency in less stable conditions. "GN 1 inst" and "GS 1 inst" show the average for all nights during which only one instrument was used. "GN multi-inst" and "GS multi-inst" shows the average for the multi-instrument nights. The data show similar open-shutter efficiencies for near-infrared instrumentation at Gemini North and South, while GMOS-N has open-shutter efficiency about 4% higher than GMOS-S. Multi-instrument nights at Gemini North are as efficient as single-instrument nights, while at Gemini South multi-instrument nights are about 5% less efficient than single instrument nights.

We have assessed the open-shutter efficiency for all Gemini facility instruments. Figure 5 summarizes the results from data based on science queue nights between August 2004 until mid-February 2006. These data allow us to compare the open-shutter efficiency for similar operations at Gemini North and Gemini South, and also assess the effect of operating in multi-instrument mode. For all instruments, the average open-shutter efficiency is 60-70%, with GMOS-N having the highest average open-shutter efficiency. On nights when only GMOS-S was used at Gemini South this efficiency was about 4% lower than for GMOS-N, a small but significant difference. The difference may be due to GMOS-N being a more mature instrument than GMOS-S (GMOS-N entered science operations during semester 2001B, while GMOS-S followed in 2003B). However, it is also possible that the difference is due to the consistent use of queue planning for GMOS-N nights, in which case we would expect the difference to disappear over the next few semesters. The open-shutter efficiency for near-infrared instrumentation is similar at Gemini North and Gemini South.

When we average all of the nights during which only a single instrument was used, the average open-shutter efficiency in good, stable observing conditions is 65% at both telescopes. At Gemini North, the average open-shutter efficiency on multi-instrument nights is the same (65%) as the average of the single instrument nights. At Gemini South, the open-shutter efficiency is about 5% lower on the multi-instrument nights than the average on single instrument nights. We are currently assessing whether this is due to truly lower efficiency at Gemini South or if it might be the result of a higher use of the near-infrared instrumentation now at Gemini South, compared to those nights that go into average derived for the single instrument nights.

We continue to monitor the efficiency of the operations at both telescopes. In particular, we are focusing on why the open-shutter time of multi-instrument nights is different at the two sites, as well as identifying bottlenecks in the science queue operations. We are also evaluating how to improve the queue planning at both sites.

In summary, the implementation of the multi-instrument queue has brought Gemini to the model of operations that was originally envisioned: a true queue operation where the instruments and various science queue programs complement each other to make the best possible use of the available observing conditions. It is also clear that the multi-instrument queue operations have increased completion rates for high-ranked queue programs at both telescopes.

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by Carolyn Collins Petersen

Tracy Beck: Reaching for the Stars

When Gemini Science Fellow and young-star astronomer Tracy Beck was in fifth grade in Los Angeles, she and her best friend were working on a science project unrelated to astronomy. They decided to take a break and go outside. It was nighttime and when she looked up, Tracy saw the Pleiades star cluster directly overhead. As she recalled, it was a life-changing moment. "I remember getting very dizzy and thinking "Whoa! Those stars are FAR, FAR away!!" she said. "It was a profound moment for a ten-year-old. I was hooked from then on, and told myself that I wanted to study them."

The path from L.A. to studying young stars at Gemini Observatory has been challenging for Tracy, who considers herself a miracle of modern medical technology. She was born with a rare metabolic disorder called phenylketonuria (PKU), a condition that was once a sentence of mental retardation in nearly everyone who had it. She began treatment shortly after birth, which allowed her to pursue a normal life by following a medically prescribed diet and taking special supplements. "This can often be extremely inconvenient, especially for a job where travel is often required" she said, "But I have never strayed because the consequences are very dramatic."

Remarkably, Tracy is the first person in the world with PKU to ever receive a Ph.D. That fact, plus holding down her busy job at Gemini, has earned her a bit of recognition in the PKU world. Her friend and collaborator Lisa Prato, an assistant astronomer at Lowell Observatory in Flagstaff, Arizona, calls Tracy's achievements despite PKU, "pretty darned cool. She has the required fortitude to push the crazy observer schedules and extreme working conditions while not being able to eat what everyone else eats—and sometimes feeling not so great, but having to keep working anyway," she said.

Tracy has been at Gemini for five years, studying the formation and evolution of very young stars and young star multiples. There are many systems that were historically thought of as "prototypes" of youthful stars, but a closer investigation has shown that some are strange. "One such object that I have spent way too much time trying to understand is the young multiple T Tau, itself," she said. "It defined a whole class of young stars, but this system is really bizarre. It's a young triple star system, but the embedded and obscured "companion" is likely the most massive star in the system. This is remarkable, considering that the optical source is one of the brightest and most luminous T Tauri stars in the sky."

Tracy's research on T Tauri and similar objects known as "Infrared Luminous Companion Systems" seeks to define this strange class of young stars and determine what their formation and dynamical evolution says about the formation process of young multiple stars.

Tracy continues to apply for time at both Gemini and the NASA Infrared Telescope Facility (IRTF, where she did her Ph.D. thesis work). This means that she usually has several projects cooking on the burner at one time. At Gemini, she has been using the Multi-Object Spectrograph (GMOS), the near-infrared spectrometer (GNIRS) and near-infrared integral-field spectrograph (NIFS) instruments to investigate outflows in young stellar objects. "I also very much enjoy working on projects to study the evolution of water in the star-formation process using 2-4 micron infrared spectroscopy," she said. "I am investigating the properties of water-ice absorption in the spectra—from very embedded protostars to more evolved, but obscured "weak-lined" T Tauris."

Tracy's work at Gemini also includes leading the instrument commissioning for the near-infrared field spectrograph (NIFS). As her time at Gemini comes to an end (her appointment is up in July 2007), Tracy notes that her observational experience, as well as her work on instrument commissioning and dealing with PI proposals, have been very important. "Along with my (upcoming) experience coordinating queue observations, I think that Gemini has prepared me well for work at any other observatory" she said. "I love Mauna Kea, and Hawai'i is a fantastic place to do astronomy. Regardless of my next job, I'll be ready for it!"

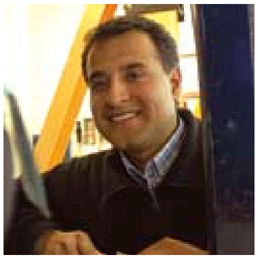
As one might imagine, with such a busy schedule, free time is an experience that sometimes eludes Tracy. Yet, she does manage to get away. "I absolutely love swimming and catching some rays at the gorgeous Hawaiian beaches," she said.

Tracy has also taken up scuba diving, and spends time exploring other aspects of life on the Big Island. "She's very friendly and outgoing, yet, a very sensibly balanced person," said Lisa Prato. "She gets into her science, but takes time to play with her cats and to go to the beach! As a grad student, she was always getting people together to have dinner or hang out. "

Tracy also likes to cook, and with her need to control her diet, she says some of her culinary inventions can be different. "I'm fairly inventive in the kitchen and often "make up" weird recipes to share with other people (particularly people with PKU)" she said.

Tracy lives in Hilo with her cats Niko and Paka. She enjoys music, watching movies, beading, and creating candles. "With all the baking and candle making I do during the holiday season, every Christmas my household looks simultaneously like an exploded cookie and a melted candle," she said. "But it smells really nice."

Gemini South's Technical Giant



Sir Isaac Newton once wrote that "If I have seen further, it is by standing on the shoulders of giants." While astronomers using Gemini South may be standing on Newton's shoulders as they do their work, their ability to see farther and fainter rests largely in the supportive hands of staffers like Senior Electronics Technician Alejandro "Al" Gutierrez. This seven-year veteran of Gemini operations has handled everything from routine operations and instrument verifications to troubleshooting surprise issues that pop up at the most inopportune times.

One of his most memorable experiences came when Andrew, Duke of York came for a tour of Gemini South in November 2002. All was in readiness for the visiting royalty. "Everything had been triple-checked," said Alejandro, recalling the day. "The Duke was five minutes away from the door and at that very minute, we experienced an electrical outage. Everybody ran every direction and luckily we solved the problem very quickly."

Performing a variety of tasks on a tight schedule is part of Alejandro's daily duties at Gemini South, even when he isn't getting ready for visiting dignitaries like the Duke of York or the President of Chile. Running an 8-meter telescope and keeping it in perfect working order takes constant attention to every system. Alejandro spends his days supervising a crew of technicians to keep the telescope in 100 percent operating order. This includes testing of instruments and procedures. "We do many daily verifications and tests, such as moving the telescope, the cassegrain rotator, the acquisition and guiding system, the dome, and shutters," he said. "We simulate targeting a false star, doing something similar to what a systems support associate would do at night, but using different programs and real objects."

What prepares someone to work in such a technical position at a major observatory? For Alejandro, it was experience with another aspect of exploration: mining. Before coming to Gemini, he worked as an instrument specialist for the El Indio mining company near La Serena. He was mainly responsible for maintaining the equipment control systems in the silver, gold, and copper mines. About seven years ago Alejandro answered an ad in the local newspaper for a technical position at what was then known as the Gemini Telescope Project. He began working on the mountain in October 1997, perfecting the state-of-the-art systems that would allow astronomers to explore the universe.

Alejandro's work has also brought him to Gemini North, where he served in systems support for a time before Gemini South opened. "It was definitely a positive and interesting experience," he said. One Hawai'i visit taught him a lesson about bringing gifts for friends. It's a story he tells with a laugh. "When I arrived at the Hilo airport, all the passengers were waiting for their suitcases," he recounted. "Mine didn't come. Eventually, I found a lady struggling to lift this heavy suitcase. When she spotted me, she asked, 'Is this yours?' You should have seen the relief on her face when I said, 'Yes.' She had been trying to lift it for 15 minutes. The moral of the story? Don't ever pack all the stuff your friends and coworkers ask you to bring!"

Rolando Rogers, Gemini South Electronics and Instrumentation Group Leader describes Alejandro as a hard-working asset to the Gemini South technical group. "Alejandro is one of the best technicians (if not the best) we have at Gemini South," he said. Like so many others at Gemini South, Rogers depends heavily on Alejandro and his team to keep things running smoothly. It helps that Alejandro gets along famously with everyone, according to Rogers. "He has a very good sense of humor and he is really good at jokes," he said. "We also tease him because sometimes he is so enthusiastic that he talks too fast."

Alejandro gives credit for the smooth operations at Gemini to everyone he works with. "What I enjoy the most is our excellent working relationship among all the employees, from janitor to the director of the observatory," he said. "Most of my working mates are very humble, which is a very important factor in any workplace." He describes the most fulfilling part of his job is the opportunity to take a leadership role, to supervise a good crew of technicians. "We work very hard to minimize lost time due to telescope failures. This makes us feel that we are doing a very good job."

Because he works at Gemini, one of the most common questions Alejandro faces from his friends is whether or not he knows a lot about astronomy. "They think I have a deep knowledge of astronomy, " he said, adding that he usually ends up talking more about the equipment.

Alejandro is married, and he and his wife Gloria have four children. He spends his spare time riding his bicycle, going out with his children, and playing soccer. Ever the technician, he putters around home, often inventing new projects to work on. His current goal is to improve his English language skills.

Carolyn Collins Petersen is a astronomy/science writer based in Massachusetts. She also serves as a contract writer/editor for GeminiFocus.

Science Retreat in La Serena

Members of the astronomical community in the La Serena area gathered together for a science retreat on April 21, 2006. Hosted by Gemini Observatory and Gemini South Head of Science Michael West, the event was attended by about 50 astronomers from area institutions, including Malcolm Smith, Director of AURA Observatories in Chile, Alistair Walker, Director of Cerro Tololo Inter-American Observatory (CTIO), Steve Heathcote, Director of the Southern Astrophysical Research (SOAR) telescope, and Mark Phillips, Director of the Magellan Observatory. It was the first time that scientists from the region of Coquimbo had the opportunity to share a day of activities together.

The program provided time for presentations and a few minutes for questions at the end of each talk, plus plenty of opportunity for discussions during coffee breaks and lunch. The event concluded with a cocktail party at the Centro de Convenciones at the La Serena Club Resort. "It was simply a way of learning what we're all working on, and hopefully stimulating some new collaborations and sharing of knowledge," said Michael West.

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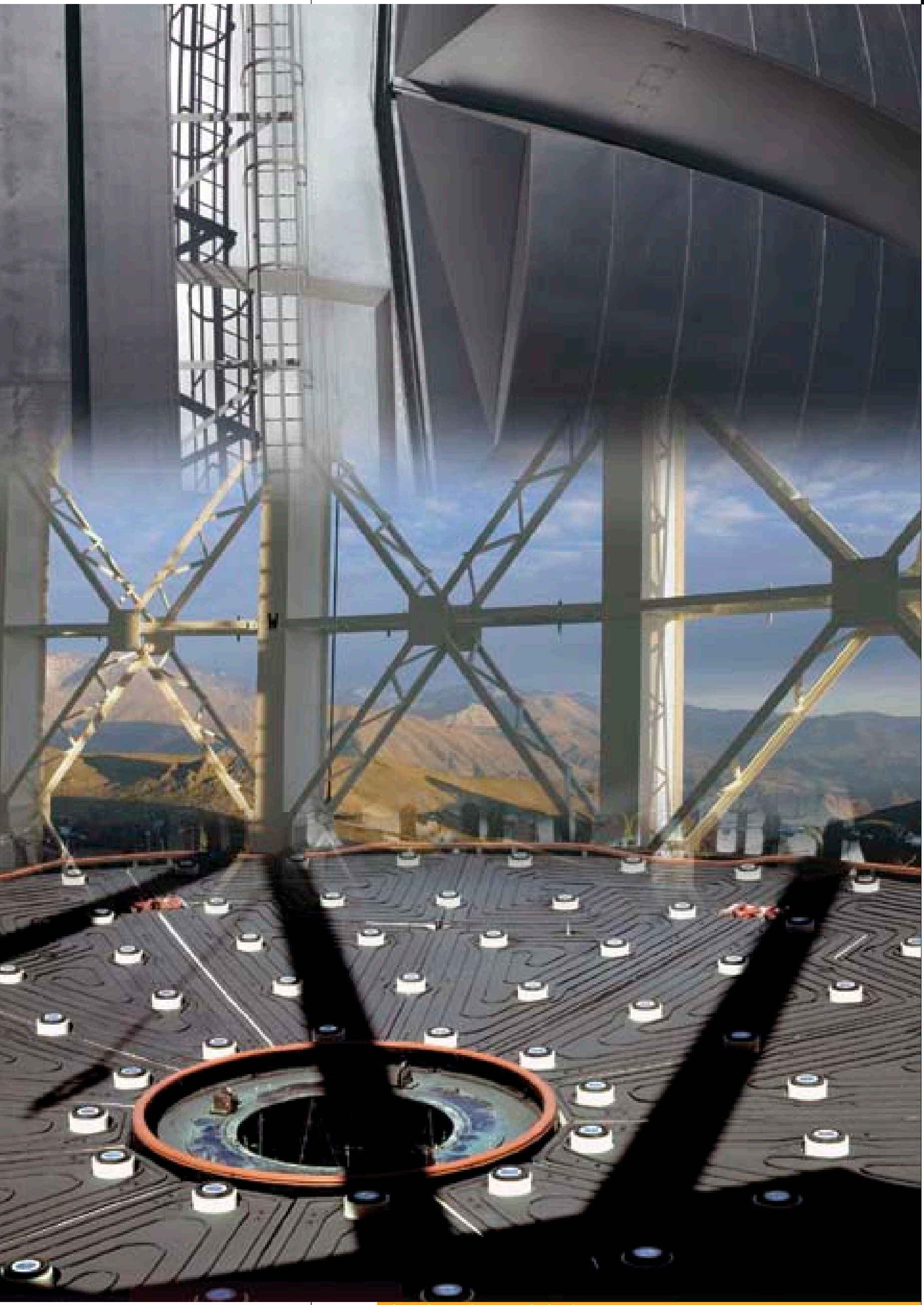
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