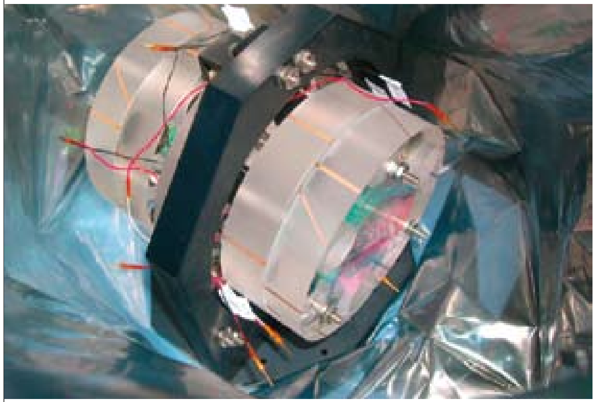
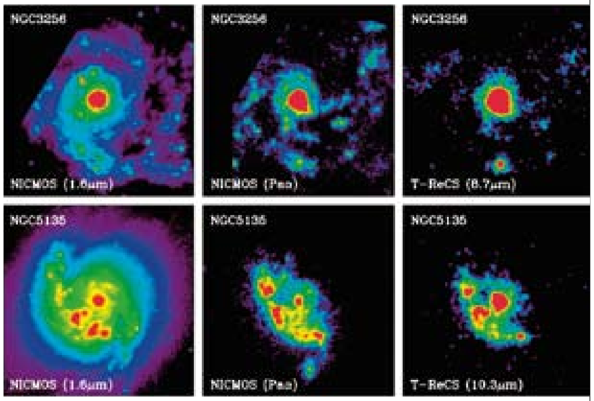
GeminiFocus

June2007 Newsletter of the Gemini Observatory

In This Issue:





On The Cover: Gemini laser guide star adaptive optics image of the "bullets" region of the Orion Nebula in the near infrared. For more details see the center section of this issue, page 29.

Comet McNaught captured by Marie-Claire Hainaut

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by Doug Simons
Director, Gemini Observatory

Planning Gemini's Future

Sustainability–this is a word I find myself asking about a lot around Gemini Observatory lately. This is particularly true as I think about the future, with an awareness of the past accomplishments that have made Gemini the world's premier ground-based infrared observatory.

Designing, integrating, and commissioning the Gemini twins required an enormous investment of some unusual resources. This investment cannot be easily measured in units like dollars spent, tons of steel consumed, meters of glass cast, or hours of labor expended. Too often, the "cost" of Gemini is characterized in such impersonal units, mainly by those who did not directly participate in, yet alone witness, the fabrication of these machines. In the same sense, the scientific value of Gemini is too often gauged by the number of papers published based on Gemini data—a rather convenient but narrow metric, and one that falls well short of the true impact a facility like Gemini will have on society. The pressure to craft two of the world's largest telescopes on a fixed budget and within hard schedule constraints was enormous, and the success of Gemini's staff in achieving these goals required tremendous dedication, personal sacrifice, and a willingness to donate—well beyond the constraints of a 40-hour work week—the time and energy needed to create Gemini Observatory. Though we unquestionably succeeded in building marvelous telescopes, we were also left with a staff that, in many respects, retains a construction project mindset. It is a little like a team dedicated to building a spacecraft: after the excitement of launch transitioning that same construction project team into an operations team capable of running a mission for decades is non-trivial. What was required to build Gemini under hard cost and schedule pressures is not the same mindset that is needed to sustain Gemini for decades to come. We need to learn how to run an operations marathon now that the construction sprint is over, and therein lies one of the principal goals I have set for my tenure as Director.

Today Gemini is functionally composed of engineering, scientific, administrative, and development divisions. Taken together, these contain all of the skills and resources needed to not only maintain a successful science operations era now, but will ensure a compelling scientific role for Gemini in astronomy for decades to come. Focusing all of these groups to function as a team working toward a common objective is one of the greatest challenges before the observatory. Though Gemini is comprised of two telescopes, they are separated by seven time zones with staff scattered across eight different locations in Hawai'i, the continental U.S., and Chile. The Gemini team is modest in size by most standards, with about 160 people. Many on the staff have never even seen some of their co-workers due to the sheer geographic diversity of the observatory. This inevitably contributes to communications challenges, despite a significant investment in sophisticated information-exchange technologies including videoconferencing systems, advanced phone and e-mail systems, and broadband data links between all sites. During the frenetic construction of Gemini, a simple widely understood goal drove a sense of unity and common purpose: achieving first light at specific dates for both Gemini North and South. Today, Gemini's staff understands the general direction we must take, but we still need well-defined signposts to gauge progress and plot a course toward the horizon with confidence. Providing a common sense of purpose across a highly distributed organization is also a key component of my vision for Gemini.

Achieving these goals is all part of a cultural evolution that will take years to complete, but is a perfectly natural transition for a young observatory to make. Though there are many facets to the change now underway at Gemini—some subtle, others obvious—one of the most far-reaching internal shift underway now is a new observatory planning process. Ultimately, this process is intended to focus the incredible array of staff expertise onto well-defined tasks. Developing such a plan was the thrust of a three-day planning retreat attended by around 20 members of Gemini's management team in February, 2007. This planning session was both bottom-up and top-down, to ensure that: 1) the wisdom and experience of Gemini's staff was tapped, 2) strategic goals were factored into near- and long-term plans, 3) external "customer reps" had input to the process, 4) resources (both FTE's and cash) needed to execute the final plan were available, and 5) everyone on the staff has visibility into the process used to generate the plan and into progress being made in executing that plan. Not surprisingly, as the science, engineering, administrative, and development teams within Gemini first met as separate groups to formulate their plans for 2007, then met together to discuss everyone's proposed tasks during the Planning Retreat, a number of tensions emerged. They centered around the need to fix what needs repairing, the support of steady-state operations, and the push to build new systems to maintain our competitive edge. In total, about 350 separate tasks were put on the table during the retreat and rank-ordered from high to low priority. That amounts to about one task per day and some of the tasks included such major projects as work on Multi-Conjugate Adaptive Optics (MCAO), the commissioning of FLAMINGOS-2, coating the primary mirror at Gemini North, and so on. In the end, when the resources needed to complete proposed tasks were evaluated to create a credible plan, the bulk of them that had been proposed going into our planning retreat were deferred to a 2008+ timeframe. Such is the reality of having an extremely ambitious, yet finite staff.

Figure 1. *A natural tension emerged during Gemini's planning process between the need to develop new capabilities (like instruments, AO systems, etc.), support on-going operations on a 24/7 basis, and maintain facilities that include some components that are over a decade old.*

It is safe to say that Gemini's first annual operations planning retreat was a learning experience for everyone involved. It generated a plan that will be managed dynamically during 2007 to ensure success, while also retaining the flexibility needed to respond to changing circumstances. While the 2007 plan consists of about 600 separate tasks and sub-tasks, the overall plan is actually comprised of multitudes of projects that will be pursued over the next five or so years. Tasks that did not make the 2007 "cut" in February will be programmed into a longer-range plan ultimately pinned to Gemini's strategic interests and overall observatory mission. This continuum of planning processes, with near-, mid-, and long-term components, should help Gemini's diverse work force remain focused, while keeping our collective "throttle" at a level that lets us meet planned milestones without burning out.

It is through this type of careful and deliberate planning that we will find a realistic pace and define a set of achievable goals that provide a common sense of direction across a highly distributed team. *Sustainability*—this essential property of an organization does not happen by accident. An organization must plan to have it and at Gemini, we do.

by Joseph Jensen

New Instrumentation for the Gemini Telescopes

To produce forefront science and continue to compete in the global marketplace of astronomy, Gemini Observatory must constantly update its instrument suite. A new generation of instruments is now nearing completion. The Near-Infrared Coronagraphic Imager (NICI) was recently delivered to Gemini South, and the near-infrared multi-object spectrograph FLAMINGOS-2 should arrive at Cerro Pachón later this year. Gemini staff members are integrating the Multi-Conjugate Adaptive Optics (MCAO) system in Chile now, and the Gemini South Adaptive Optics Imager (GSAOI) is already there, waiting to sample the exquisite images MCAO will deliver. At Gemini North, the visiting mid-infrared echelle spectrograph TEXES will join the Gemini collection again for a few weeks in semester 2007B as a guest instrument. The new instruments, along with the existing collection of facility instruments, will propel Gemini towards the lofty science goals outlined in Aspen, Colorado nearly four years ago.

Gemini is now beginning construction of the next generation of instrumentation that will help answer profound questions about the universe and our place in it. Many of these questions relate directly to the formation of planets, their physical characteristics, and their prevalence. Others address the most fundamental questions about the nature of the matter (baryonic and dark) and dark energy that make up the universe. Two of the new Aspen instruments–the Gemini Planet Imager, (GPI), and the Precision Radial Velocity Spectrometer, (PRVS)–have been designed explicitly to find and study extrasolar planets. The Wide-field Fiber Multi-Object Spectrometer (WFMOS) will provide a revolutionary new capability to study the formation and evolution of the Milky Way Galaxy and millions of others like it, reaching back to the earliest times of galaxy formation. WFMOS will also shed light on the mysterious dark energy that is responsible for the accelerating expansion of the universe, counteracting the force of gravity on the largest scales. Finally, the Ground-Layer Adaptive Optics (GLAO) capability being explored for Gemini North will improve our vision across a large enough field of view to explore the first luminous objects in the universe, along with practically everything else as well.

The Aspen instruments build on pathfinding projects being started now using existing Gemini instruments like the Near-InfraRed Imager (NIRI) and Near-Infrared Coronagraphic Imager (NICI). The promise of the new Aspen instrument projects will only be fully realized if they are built in a timely fashion and are allocated large amounts of telescope time for appropriate surveys, with well-supported teams to conduct them.

The Gemini telescopes are unique among the family of large 8- to 10-meter-class telescopes because they are optimized for maximum performance at infrared wavelengths. They were designed and built to: 1) deliver the finest image quality allowed by the excellent site conditions, 2) deliver diffraction-limited images, and 3) have the greatest thermal infrared sensitivities achievable from the ground. Adaptive optics (AO) is a key technology installed on both telescopes to achieve this goal (see the December 2006 special AO issue of *GeminiFocus*). Gemini is also unique in that the two telescopes provide astronomers with complete sky coverage, an important advantage in the field of exoplanet research. Gemini's search for extrasolar planets using imaging techniques has been ongoing since late 2000. During the same period, astronomers using Gemini have worked at the forefront of research at the highest redshifts. Several teams have used the Gemini telescopes to search for the first luminous objects that reionized the hydrogen throughout the early universe. Other astronomers using Gemini have observed fleeting supernovae and gamma-ray bursts to better understand these violent explosions early in cosmic history, and how the universe has changed since then. This is transformational science that is uniquely enabled by the cutting-edge tools (sensitive detectors, AO and laser guide stars) now available at Gemini.

With the discovery of more than two hundred planets around other stars, we now stand on the brink of a new understanding of the universe and our place in it. After centuries of debate, speculation, and many false starts and erroneous claims, a growing population of extrasolar planets has finally been conclusively identified in the last decade. In addition to these exciting and fundamental discoveries, we have obtained a few glimpses into the intermediate stages that link the births of stars to the formation of planetary systems. We are now poised for the transition from discovery of these systems to their characterization. At Gemini we have telescopes and instrumentation optimized for exoplanet detection, and a fully integrated program to strategically explore a range of planetary masses and semi-major axes around nearby stars. Figure 1 illustrates the projects and related instruments discussed in the next sections.

The Gemini Near-Infrared Coronagraphic Imager (NICI)

Gemini's latest addition to its instrument arsenal is the Near-Infrared Coronagraphic Imager (NICI) at Gemini South. NICI is the first Gemini instrument designed specifically to search for and analyze the properties of planets orbiting other stars, and one of the first in the world optimized to image the light from the planets directly. With its own custom AO system, dual imaging cameras, and specialized coronagraph, NICI is designed to be a significantly more capable planet-finder than existing instruments. Each camera has its own detector and set of filters, so two wavelengths can be sampled at the same time. Giant planets that contain methane will appear dark in some narrowband infrared filters and brighter in others. The contrast between the two simultaneous images will help astronomers to distinguish methane-rich giant planets from background stars and residual diffracted starlight.

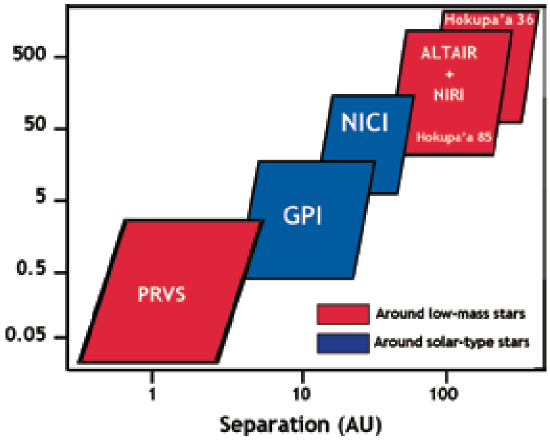

Figure 1.
Some of the new instruments planned for Gemini are key components of strategic development within the observatory. These will enable astronomers to systematically probe lower-mass regimes in the quest to find extrasolar planets.

NICI passed acceptance testing in Hilo in October 2006, and was shipped to Cerro Pachón at the beginning of 2007. The Gemini and Mauna Kea Infrared (MKIR) team, under the leadership of Doug Toomey, Mark Chun, Tom Hayward, and Manuel Lazo, assembled NICI and tested it in the lab at Gemini South. NICI was installed on the telescope in mid-February, and saw first light on the night of February 20, 2007. The very successful first commissioning run results are shown in the box on page 13.

Figure 2.
NICI installed on the Gemini South telescope, getting ready for its first commissioning night on the sky.

The NICI team is actively working through a number of issues to prepare it for regular science operations, and for the NICI planet search campaign in particular (for more information see page 63 of the special December 2006 AO issue of *GeminiFocus*). Perhaps the most important issue with NICI that must be corrected has to do with the deformable mirror (DM) in the NICI AO system. The current DM lacks the stroke needed to achieve the desired Strehl ratios because of a relatively large minimum radius of curvature, low resonant frequencies, and two damaged actuators. We plan to fix the two actuators prior to the next NICI commissioning run. We are also exploring the possibility of acquiring a new DM with a smaller minimum radius of curvature and higher resonant frequencies than the existing DM. Testing of the existing and new DMs will be conducted in June and July of this year, hopefully leading to better performance in poorer-than-average seeing conditions. If NICI's AO system can be made to work in a wider range of natural seeing conditions the survey observations will be much easier to integrate into Gemini's multi-instrument queue observing system.

Once NICI's AO performance is fine-tuned with a better DM, and other minor problems solved, the planet search observing procedures and software will be tested. Some test data will be taken on targets that are known from past planet searches to have faint background objects near them. These observations will demonstrate the ability to subtract the point-spread function and distinguish real targets from speckles. Methane-rich brown dwarfs will also be imaged to demonstrate the ability to distinguish such objects using the two narrow-band filters. Giant planets should have methane in their atmospheres, making them easier to find with NICI's dual imaging channels (for more information see page 66 of the December 2006 issue of *GeminiFocus*). The test data will be released with the call for proposals when NICI is offered for regular observing for the first time. When the test observations have shown that all is ready, both with the instrument and software, the NICI planet search campaign will begin.

NICI is the most specialized of Gemini's instruments thus far, and meeting its science goals requires a large survey of nearby stars conducted over several years. This will hopefully find a few needles in a very large haystack. In 2005, Gemini awarded approximately 500 hours to a team led by Michael Liu, Laird Close, and Mark Chun to conduct the NICI planet search survey. The experience acquired with ALTAIR and other exoplanet research projects will be crucial to the success of the NICI campaign.

The 500-hour NICI planet survey will search for massive planets (like Jupiter) around young, nearby stars. With a census of young planets, the NICI campaign team will address three important questions:

- What is the distribution of masses and separations of planets in the outer regions of other planetary systems?

- How does the mass of the parent star affect the chances of planetary formation?

- What are the properties and compositions of the young extrasolar giant planets?

Most planets that have been discovered around other stars are detected only indirectly via their gravitational influence on their parent stars (the radial velocity technique). NICI will find a very different class of planets than the radial velocity searches do. This is because it will preferentially find the giant planets orbiting farther out in regions of their planetary systems comparable to those occupied by the giant planets in our own solar system. Unlike the radial velocity instruments, NICI will be able to detect the infrared light from the planets directly, revealing much about their masses, compositions, and temperatures.

NICI is unique among Gemini instruments in that it was funded by a NASA grant as part of the agency's mission to explore extrasolar planets. This independent funding made it possible to design a specialized AO instrument that might not have otherwise been built because of tight funding within the Gemini partnership. NICI is a pioneering instrument that is blazing a trail for the future Gemini Planet Imager (GPI).

FLAMINGOS-2

While their basketball and football teams have been attracting national attention, our colleagues at the University of Florida at Gainesville have been working feverishly to complete FLAMINGOS-2 and get it ready for delivery later this year. FLAMINGOS-2 will provide wide-field imaging and multi-object spectroscopy across a field of view six arcminutes in diameter. When used with MCAO, FLAMINGOS-2 will provide an AO-corrected multi-object spectroscopic capability across more than an arcminute (more details may be found in the December 2006 issue of *GeminiFocus*, page 69). In the past few months, the team has integrated all of the optics, electronics, mechanisms, and detectors in FLAMINGOS-2 in their lab in Gainesville. All the optics are now installed, including the low-resolution grisms. The high resolution (R=3000) grating was received in February 2007, after years of effort by the University of Florida team working closely with the vendor. It will be integrated with its prism and installed in the instrument shortly. Having all the optics installed, aligned, and tested cold is an important milestone in the integration and testing of FLAMINGOS-2.

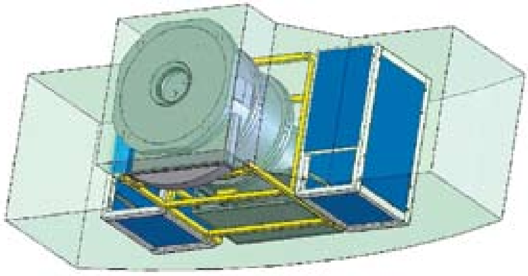

Figure 3. *A schematic of FLAMINGOS-2 shows the dewars and electronics enclosures inside the instrument space envelope.*

During the recent cold tests, the mechanisms were also tested and a number of minor problems were fixed. All the mechanisms are now working reliably.

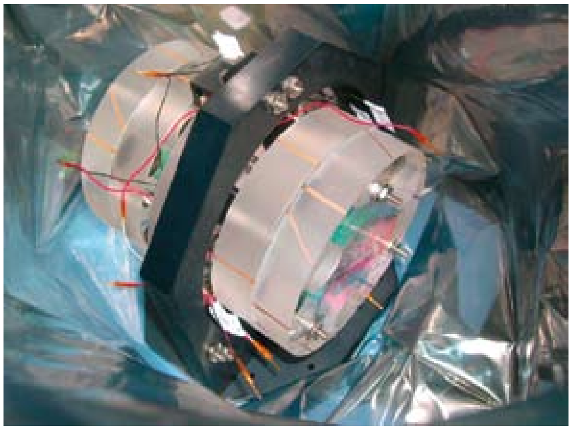

Figure 4. *The dual etalons of the tunable narrow-band filter are currently being integrated and tested in Canada.*

One of the key science questions that FLAMINGOS-2 will address is how the first luminous objects formed and how they ionized the neutral hydrogen in the universe less than a billion years after the Big Bang. At redshifts greater than z = 6 the Lyman-alpha emission from hydrogen is shifted into the near-infrared J and H bands (1.1 and 1.6 microns, respectively). To find these objects, special narrow-band filters are being procured for FLAMINGOS-2. In one experiment, very narrow filters are being designed to take advantage of the dark gaps between bright atmospheric OH emission lines. In another experiment, a team led by Roberto Abraham at the University of Toronto is building a special tunable filter composed of two Fabry-Perot etalons in series. The etalons have been built and are now being tested in Canada (Figure 4). They will be installed in the FLAMINGOS-2 mask foredewar for dedicated observing campaigns.

The Gemini Planet Imager (GPI)

The Gemini Planet Imager (GPI), currently being designed and built by a collaboration led by Bruce Macintosh at Lawrence Livermore National Laboratory, follows directly in the tradition of NICI, both scientifically and technologically. A large consortium of institutions in the U.S. (Lawrence Livermore, the University of California at Los Angeles, the University of California at Santa Cruz and Berkeley, the American Museum of Natural History and the Jet Propulsion Laboratory) and Canada (the Herzberg Institute of Astrophysics and the Université de Montréal) is involved in what is one of the most ambitious instruments ever built for a ground-based telescope. GPI is described in more detail in the December 2006 issue of *GeminiFocus*, starting on page 73.

Like NICI, GPI is a specialized coronagraph designed to see planets around young, nearby stars. However, GPI has a couple of new tricks up its sleeve to improve on NICI's performance. GPI is a coronagraphic instrument with its own sophisticated on-board AO system and apodized masks. GPI will have a much higher order AO system to achieve higher Strehl ratios than possible with NICI or ALTAIR. GPI will also have an advanced interferometer incorporated into the AO system to further reduce wavefront errors. Finally, GPI will have a unique low-resolution (R = 45) integral field spectrograph to help identify planets and characterize their atmospheres (Figure 5).

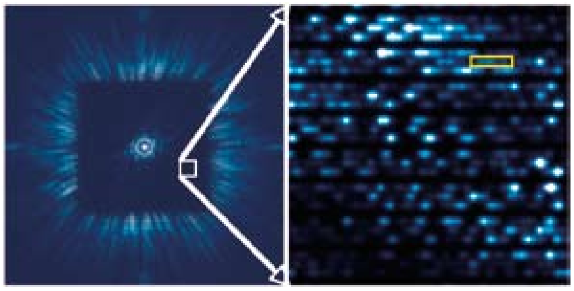

Figure 5. *Simulated GPI data (left) shows the dark square hole created by the calibration wavefront sensor. The expanded image on the right shows the individual spectra created by the integral field spectrometer for each point in the field of view.*

GPI represents the natural progression of high resolution and coronagraphic imaging that has been developed through Gemini's instrument program, consistent with the intrinsic strengths of the Gemini telescopes. This progression started with Hokupa'a and ALTAIR at Gemini North, continues with the deployment of NICI at Gemini South, and ultimately will be defined by the capabilities of GPI. The NICI instrument will be an important pathfinder to test observing schemes, quantify in real terms the coronagraphic performance on Gemini, and experiment with different apodization techniques, all of which can be fed into the GPI design, reduction pipeline, and science program.

GPI is the first of the Aspen instruments to advance beyond the conceptual design phase. After completing a conceptual design study, the GPI team won the competition to build what was then known as the "Extreme AO Coronagraph." The project was started in June 2006, and the team quickly came up to speed, making several key design decisions. The GPI team is now (as of this writing) in the final stages of preparation for their preliminary design review, to be held in Santa Cruz, California in May. If all goes according to schedule, GPI will be completed and ready for testing on the telescope toward the end of 2010. The campaign to survey hundreds of southern stars to find young giant planets will begin shortly thereafter. The science goals of the survey are being developed along with the instrument, and the design decisions made thus far are tightly coupled to the requirements of the science case.

The Precision Radial Velocity Spectrometer (PRVS)

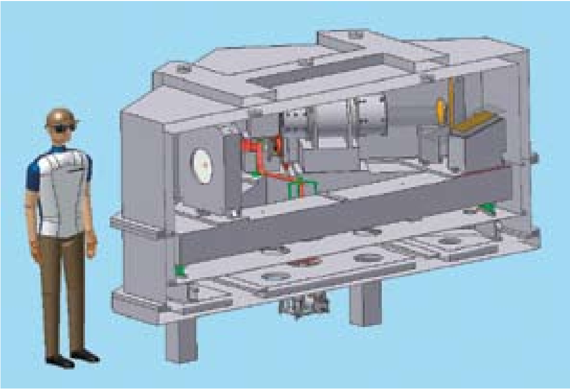

Figure 6. *The UK ATC conceptual design of the PRVS spectrograph shows it mounted on a vibration isolation bench and located inside a vacuum jacket and radiation shield. The spectrograph will be located in the pier lab and fed with a fiber running up through the ceiling to the telescope's cassegrain focus*

Last year, Gemini Observatory commissioned two conceptual design studies for a Precision Radial Velocity Spectrograph (PRVS). PRVS is the offspring of the High-Resolution Near-Infrared Spectrograph (HRNIRS), a multi-purpose instrument that went through the Conceptual Design phase following Aspen, but was not built due to limited funding. One of the Aspen science goals that motivated HRNIRS was to detect planets down to a few earth-masses around low-mass stars by measuring the radial velocity reflex motions of stars. By making PRVS a bench-mounted fiber-fed spectrograph sensitive from 1 to 1.6 microns, high stability can be achieved. PRVS will open up the radial velocity planet search to low-mass M-dwarf stars, which are very numerous in the solar neighborhood and brightest at near-infrared wavelengths. Planets in the "habitable zones" of M-dwarf stars have short-period orbits, and the low-mass stars will wobble more due to the influence of such planets. PRVS will find lower-mass planets around the most common stars in our galaxy, and therefore answer important questions about how common terrestrial-class planets may be in the universe. The parameter space probed by PRVS is highly complementary to that sampled by optical radial velocity searches and the imaging surveys described above. PRVS therefore represents an essential part of Gemini's overall strategy to answer the fundamental questions posed at the Aspen meeting. PRVS can also provide a sample of terrestrial-mass planets for follow-up imaging by the James Webb Space Telescope (JWST).

The PRVS conceptual design studies were completed in October 2006 and the team lead by the United Kingdom Astronomy Technology Centre (UK ATC) was chosen to build PRVS. The team includes the University of Hawai'i Institute for Astronomy, Pennsylvania State University, and the University of Hertfordshire. The Gemini Board will meet in May 2007 to decide whether or not to proceed with the design and construction of PRVS.

The Wide-field Fiber Multi-Object Spectrometer (WFMOS)

The scientifically highest-ranked instrument to emerge from the Aspen process was WFMOS. It would permit about 4,500 spectra to be taken simultaneously across approximately a 1.5-degree field of view. This multiplex gain makes WFMOS a truly transformational instrument, enabling exciting science projects that were nearly unfathomable with the current generation of instruments.

During the WFMOS Feasibility Study two years ago, Gemini and Subaru Observatory (of the National Astronomical Observatory of Japan) agreed to explore the possibility of a collaboration on WFMOS. The Japanese would share the cost of building WFMOS and it would be installed on the Subaru telescope, a more appropriate platform than Gemini for such a massive, wide-field prime focus instrument. In exchange for observing time on Subaru, Japanese astronomers would have access to observing time on Gemini.

The agreement is still in the early phases of development. Subaru's new wide field imager, HyperSuprime, is now being designed, and it would be developed in parallel with WFMOS. They would share a common wide-field corrector, and the science goals of the two instruments, to measure the acceleration of the expansion of the universe, are highly complementary.

In October 2005, the Gemini Board agreed to begin competitive conceptual design studies for WFMOS. In May 2006, while contract negotiations were still in progress with two teams, the Gemini Board decided to suspend the studies until adequate funding could be secured. A few months later, in September, the funding for the design studies was committed, and Gemini began the challenging process of re-engaging the two teams, a process that is still underway. Gemini is exploring possible organizational models that will be needed to coordinate WFMOS construction across a number of institutions around the world and to include Subaru in the overall management of the project. An instrument as expensive and complex as WFMOS will demand new ways of working together within the Gemini partnership and around the world.

Ground Layer Adaptive Optics (GLAO)

The final Aspen capability that is being considered will improve telescope image quality and performance for almost all instruments. GLAO is a specialized AO system using five laser beacons and an adaptive secondary mirror to correct the turbulence very near the ground on Mauna Kea (see the December 2006 issue of *GeminiFocus*, page 77 for more information). Since the targeted turbulence is close to the telescope pupil, the corrected field of view on the sky is quite large. GLAO will be able to feed an instrument with a field of view of several arcminutes across, providing images with 0.2 to 0.3 arcsecond resolution (FWHM) across the field. The effect of improving image quality is to reduce integration times, making the telescope more efficient and productive. Some science projects that would otherwise require prohibitively long exposures, such as deep imaging of very faint, distant galaxies, will become possible with GLAO. As an additional benefit, the Strehl ratio and system emissivity in the mid-infrared will be significantly improved using the adaptive secondary mirror.

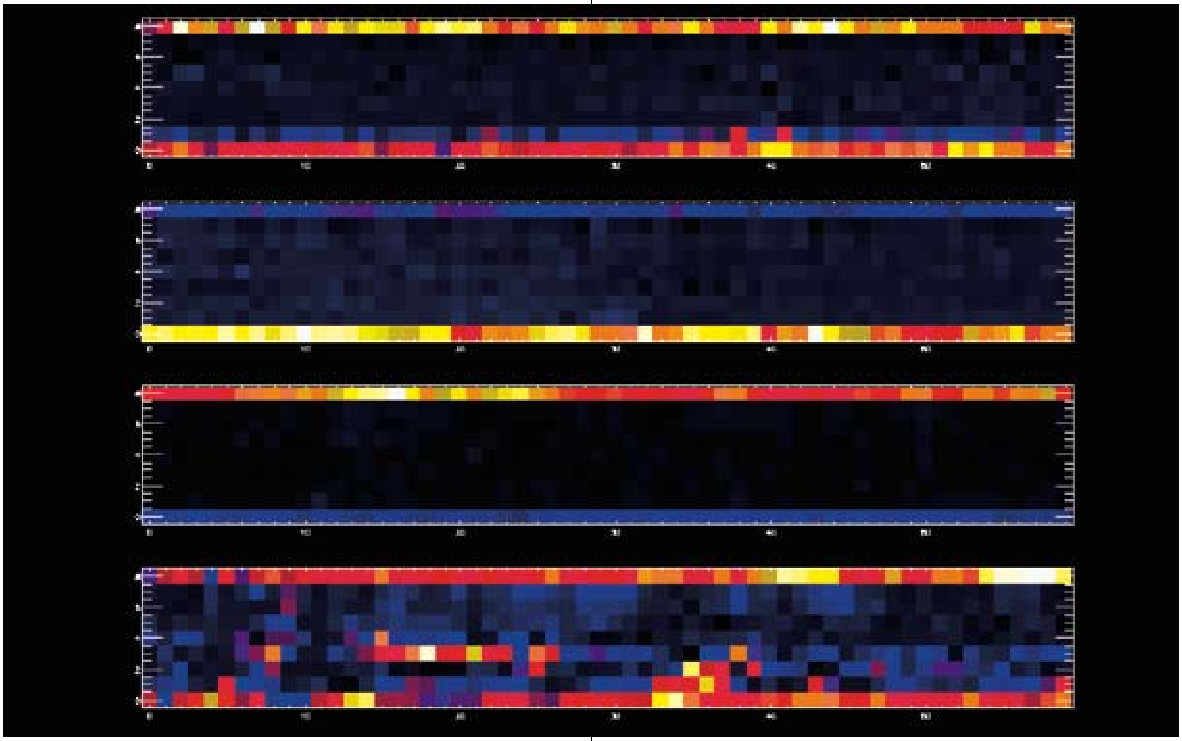

Figure 7. *A sample of turbulence data from the MKSM project illustrating four different types of turbulence profiles. In each box, time progresses along the x-axis. Height above the ground is represented on the vertical axis (the uppermost row represents all of the turbulence above roughly 500-1,000 meters). The brighter colors indicate stronger turbulence. There is often a strong layer of turbulence in the lowest 100 meters.*

After the Aspen meeting identified the potential of GLAO, a feasibility study was performed by our colleagues at the Hertzberg Institute for Astrophysics (in Victoria, British Columbia), Durham University (in the United Kingdom), and the University of Arizona, (in the U.S.). It showed that GLAO would indeed be very effective at improving observing efficiency, almost like having a third Gemini telescope when GLAO is in use. The baseline GLAO system calls for an adaptive secondary mirror, a laser guide star constellation comparable to the MCAO system at Gemini South, and new wavefront sensors in a new acquisition and guidance system (which are already scheduled for replacement in a couple of years). No new instruments have yet been proposed to take full advantage GLAO, but the conceptual design was made to be compatible with the existing suite of instruments.

The feasibility study results were based on atmospheric data from Cerro Pachón. Since the ground layer turbulence on Mauna Kea may not be as significant as at Gemini South, the next step in the GLAO development is to make a detailed measurement of the ground layer turbulence on Mauna Kea. The Mauna Kea Site Monitoring (MKSM) project is now under way, under the direction of Mark Chun at the University of Hawai'i. The MKSM project runs two specialized instruments on a small telescope, temporarily installed on the roof of the University of Hawaii's 88-inch Observatory building. They are collecting data for approximately 1,000 hours spread throughout the year to sample a variety of weather conditions during all seasons (see Figure 7, previous page).

When the project is complete, the MKSM data will be fed into the numerical models constructed during the feasibility study. The model results will indicate the efficiency gain likely to be achieved with a GLAO system for a variety of conditions. The results will be used to decide whether or not to conduct a conceptual design study for GLAO in 2008.

Summary

With the existing and future instruments that are being designed, constructed, and commissioned now, astronomers using the Gemini telescopes will be able to detect new and different types of planets than have been found to date. Through dedicated surveys, these will help determine the abundance of planetary systems like our own. We will find the first galaxies to form after the Big Bang and chart the expansion history of the universe. Astronomers will examine the relationships between millions of stars in the Milky Way by reading their compositions and motions. Through international cooperation in constructing these new instruments (which are designed and built by institutions in our partner countries), and by conducting dedicated surveys, the Gemini partnership will contribute fundamentally to our understanding of planetary systems, the formation and evolution of galaxies, and the nature and composition of the universe.

Joseph Jensen is the Head of Instrumentation for the Gemini Observatory and can be reached at: jjensen@gemini.edu

A Successful NICI Commissioning Run

By Joe Jensen with Mark Chun

The Gemini Near-Infrared Coronagraph (NICI) is a dual-channel imager with its own on-board adaptive optics (AO) system, specifically designed to search for faint planets in the bright glare of a nearby star. NICI is quite a complex instrument, and it has taken a great deal of work to get it assembled and tested. In February 2007, NICI passed the milestone of first light, and all the careful design work and testing paid off. On the second night of the run (the first night that the seeing was decent, 0.7 to 0.9 arcsecond FWHM), the AO loops were closed on a star for the first time. NICI's performance was very good from the first second the team pushed the button. With minimal tuning and testing, the AO system delivered Strehl ratios better than 20% in H (1.6 microns). The point-spread function was very clean, and the residual speckle patterns in the two imaging cameras were similar. While there are still performance issues with the deformable mirror that need to be resolved, this achievement shows that NICI is well on its way to meeting its performance goals and will soon be searching for planets.

The first commissioning run with NICI was still very much a hands-on operation, with many tasks done manually. In the coming months, software will be finished and tested to automate many of the steps. Data reduction software will also be tested by the NICI campaign team. The deformable mirror (DM) will be repaired and a new one tested. We plan to have NICI back on the telescope for the next round of tests in June 2007.

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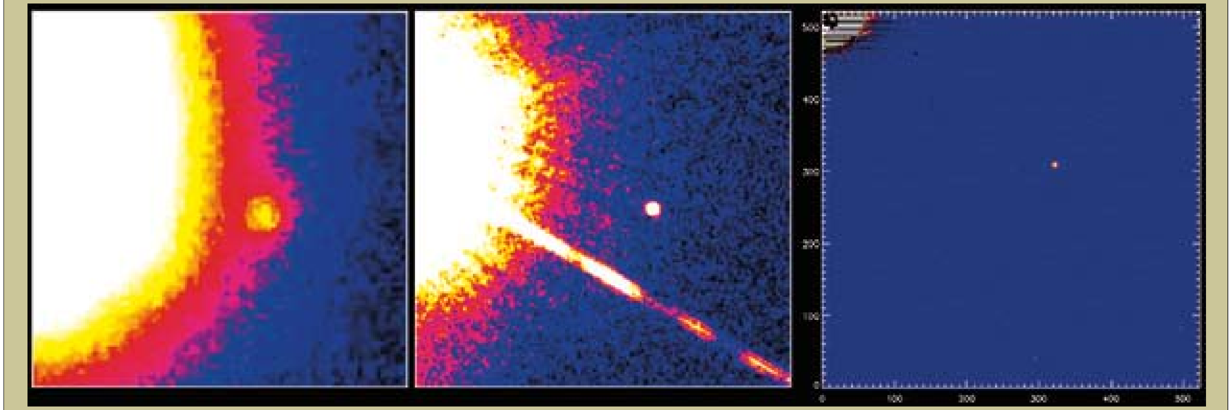

Figure 1. *Palomar Observatory discovery image (left) of the brown dwarf star Gliese 229B is paired with a Hubble Space Telescope view (center). A five-minute NICI exposure (right) of a ~10 x 10 arcsecond field shows the brown dwarf (its bright companion star is blocked by the coronagraph). The two channels have been differenced. GL 229b is about eight arcseconds from the star and this image shows how well NICI performs, even within an arcsecond of the star.*

by Heidi B. Hammel

New Views of Neptune

In the atmosphere of Neptune, methane is the most abundant constituent after molecular hydrogen and helium. Its photolysis (decomposition under the influence of light) near the microbar pressure level produces a variety of hydrocarbons, including ethane. Together, methane and ethane emission dominate the planet's spectrum from 7 to 13 microns.

Neptune's mid-infrared ethane emission strength has increased markedly over the past two decades, which has been interpreted as resulting from a steady rise in stratospheric temperature. The planet's reflectivity at visible wavelengths has also steadily increased over the same time period, reaching its brightest level in nearly 30 years of photometric monitoring in 2003.

Physical correlation between these two long-term changes could indicate increased hydrocarbon creation at upper altitudes, with implications for the dynamical and transport properties of the upper troposphere and lower stratosphere. The planet has exhibited significant atmospheric activity throughout this time at both visible and near-infrared wavelengths. Such activity is attributed to variability of methane-condensate cloud brightnesses and distributions.

To determine if a link exists between the variation seen at mid-infrared wavelengths and the deeper clouds observed in the visible and near infrared, we used the Gemini and Keck telescopes to obtain nearly simultaneous mid-infrared and near-infrared imaging in July 2005. Given that the disk of the planet subtends 2.3 arcseconds in the sky, large telescopes are needed to provide high enough spatial resolution to study distant Neptune.

Neptune in the Mid-Infrared

With the Gemini North telescope, we observed Neptune (Figure 1) using the MICHELLE mid-infrared instrument. We imaged Neptune with Gemini at 11.7 microns on July 4, 2005. We repeated images on July 5 at 11.7 microns, and also obtained images at 7.7 microns. Our 7.7-micron images sense primarily methane emission arising from a broad vertical region peaking near ~0.02 millibars, whereas our 11.7-micron images sense predominantly ethane emission arising around the 0.2 millibar pressure level, slightly deeper in the atmosphere. The measured effective resolution in our Gemini images was ~0.4 arcsecond, a value close to the 11.7-micron diffraction limit of 0.36 arcsecond. At the distance of Neptune this corresponds to ~8,500 kilometers, a factor of six smaller than the 49,500-kilometer diameter of the planet.

With the W. M. Keck 2 telescope, we imaged Neptune on July 5 using the facility Near-Infrared Camera (NIRC2) coupled to the adaptive optics system. We used the H-band filter (1.6 microns) which senses sunlight scattered from clouds at or above the 1-bar level of the atmosphere. This is even deeper in the atmosphere than the Gemini images. In high angular resolution mode, each NIRC2 pixel subtends 0.00994 arcsecond, which translates to 212 kilometers, given Neptune's distance from Earth in July 2005. We measured a full-width at half maximum of 0.042 arcsecond for a stellar point source on July 5, corresponding to an effective resolution of ~895 kilometers.

We measured disk-integrated flux densities for Neptune of 4.39 ± 0.08 and 2.10 ± 0.04 Jy/sr (a measure of power per unit area of sky) at 11.7 and 7.7 microns, respectively; these values are consistent with observations at similar wavelengths made in 2004 using a different instrument on the NASA Infrared Telescope Facility. From our images, we derived disk-averaged brightness temperatures of 93 and 123 K at these wavelengths, respectively, consistent with Spitzer Space Telescope observations to within our ability to correct for telluric methane at 7.7 microns. (Telluric methane refers to the presence of methane in Earth's atmosphere.)

Images of Stratospheric Organization

The nearly simultaneous mid- and near-infrared images from July 5 2005, (Figures 1B-1D) demonstrate that the stratospheric regions probed by mid-infrared ethane and methane emission are not spatially correlated with tropospheric clouds. This is perhaps not surprising; nevertheless, the images demonstrate this conclusively for the first time.

In the mid infrared, both the ethane (Figure 1B) and methane (Figure 1C) emissions are dominated by a bright region near the southern pole. In contrast, the clouds seen in the Keck H-band images (Figure 1D) are concentrated in the mid-latitude regions in both hemispheres. The ethane emission also exhibits strong limb brightening at all latitudes. This phenomenon arises from a vertical distribution of ethane that peaks high in the stratosphere, consistent with photochemical models. Ethane limb brightening is 25% greater at northern mid-latitudes than at the equator, a phenomenon that is likely due to enhanced stratospheric abundances or temperatures there. The organized zonal banded structure on Neptune in the H-band images continues to high southern latitudes, culminating in a bright spot (enhanced in Figure 1E) located at the southern pole (to within our spatial resolution).

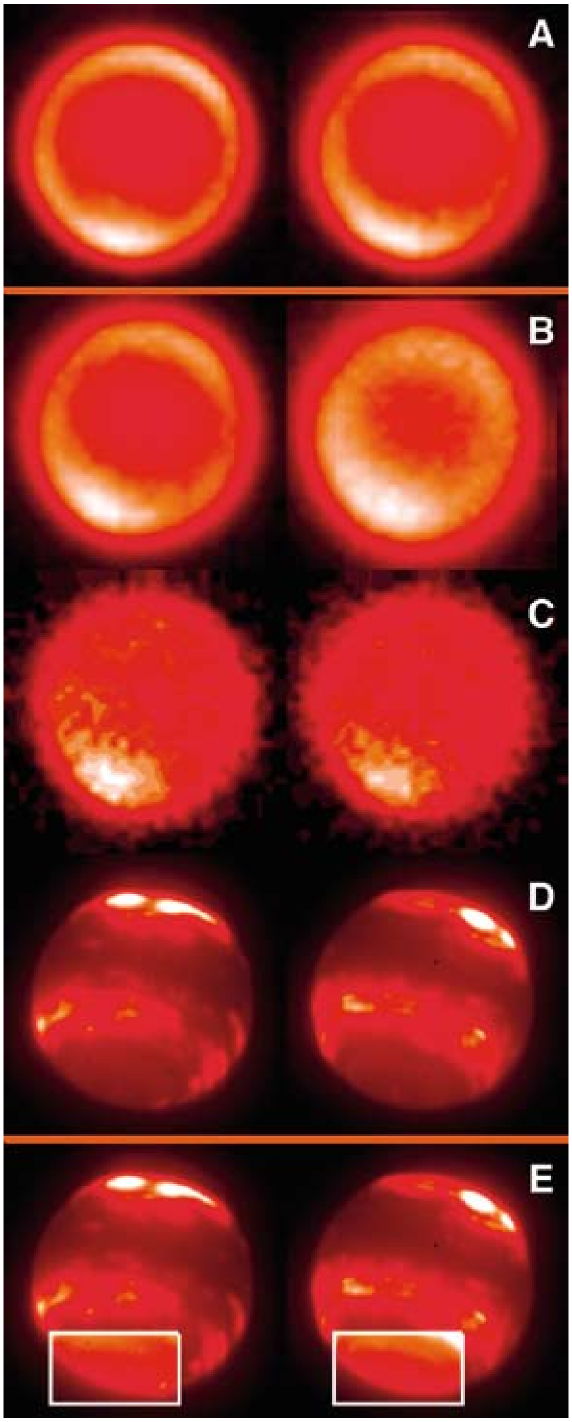

Figure 1.
Neptune images at mid- and near-infrared wavelengths in July 2005. (A) Mid-infrared images from MICHELLE at 11.7 microns from July 4 show stratospheric ethane emission is tightly confined to the polar region; global limb brightening is also seen. (B) Mid-infrared MICHELLE images on July 5 at the same wavelength show a similar pattern of ethane emission. (C) In mid-infrared MICHELLE images at 7.7 microns from July 5, methane emission is also confined to the polar region, although less limb brightening is seen. (D) Near-infrared images from Keck/NIRC2 at 1.6 microns on July 5 reveal tropospheric clouds predominantly at mid latitudes in both hemispheres. (E) The south polar regions of the images in panel D are enhanced by a factor of 2.6 to show that the zonal circulation pattern continues right to the pole.

A Common Atmospheric Structure

Neptune's ethane- and methane-bright south polar structure is strikingly similar to the south polar region of Saturn (Figure 2, next page), which showed a highly concentrated bright pole at a similar wavelength, 8.0 microns. Due to limited spatial resolution on distant Neptune, we cannot yet determine if the emission at its pole is as tightly confined as that seen on Saturn.

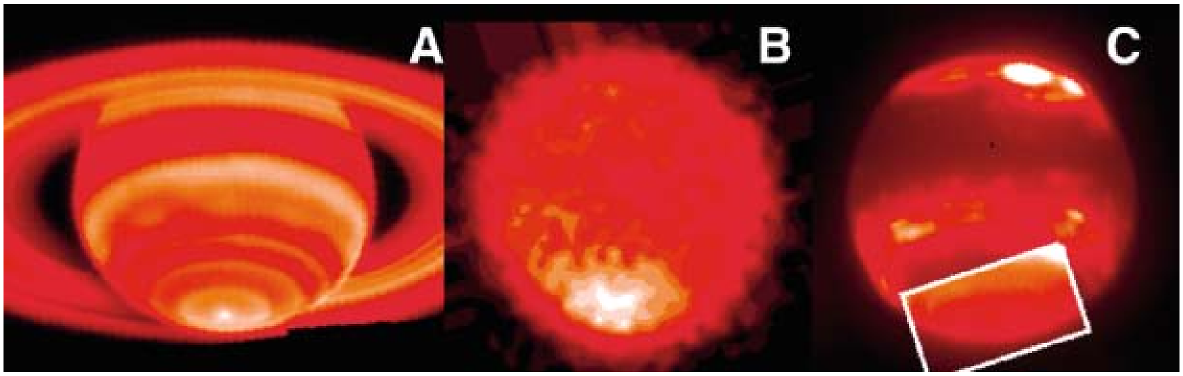

Figure 2. *Neptune compared with Saturn. (A) Saturn at 8.0 microns shows strong methane emission from its southern pole. (B) Neptune at 7.7 microns (from Figure 1C) also shows methane emission from the south polar region. (C) Neptune at 1.6 microns (from Figure 1E) shows this planet's zonal circulation is as tightly confined in the polar region as that of Saturn.*

Neptune's warm stratosphere causes the infrared ethane emission, and enhancements in the emission are most easily interpreted as small temperature increases. We thus infer that the brighter pole is warmer than other latitudes, probably by about 4-5 Kelvins. In 1991, Bézard and colleagues detected latitudinal temperature variations of acetylene emission at 13.7 microns in Voyager 2 IRIS spectra.

Neptune's warm south polar region may arise from the same strong seasonal insolation to which Saturn is subjected (the obliquities, or axial tilts, of Neptune and Saturn are 30° and 27°, respectively). When Neptune reached southern solstice in 2005, the southern hemisphere received maximum sunlight and was most fully visible to observers on Earth. Some portion of the increasing ethane emission over the past twenty years may arise from increased visibility of this south-polar bright spot, as well as increased temperatures or even increased ethane concentration (all previously published mid-infrared observations from Earth have been disk-integrated).

The warm summer poles of Saturn and Neptune suggest this is a typical phenomenon in the stratospheres of giant planets with moderate to high inclinations and strong gaseous or particulate absorption of sunlight. However, the long Neptunian orbital period (165 terrestrial years) confounds a direct quantitative seasonal comparison with Saturn (orbital period 29.5 years) at present.

Surprises Still Lurking in the Data

In addition to the long-term trend of increasing temperature, mid-infrared spectroscopy indicates short-term variability of ethane emission, suggesting a secondary component of variation, either due to longitudinal inhomogeneities or to true time variability. This additional component is supported by our mid-infrared images, which exhibit subtle longitudinal structure close to the south pole (Figure 3). On Saturn and Jupiter, some zonal oscillations of mid-infrared temperature are associated with atmospheric wave patterns. Keck images of Uranus have also revealed wave patterns. Future observations of Neptune with better spatial and temporal sampling may reveal whether or not this structure on the planet arises from similar wave patterns.

We also obtained spatially-resolved low-resolution spectroscopy with MICHELLE on Gemini, and are in the process of analyzing these data. We expect they will shed light on why Neptune's ethane emission does not track more precisely the emission morphology of its parent molecule methane. Likewise, the puzzle of the long-term brightening of Neptune is not yet resolved.

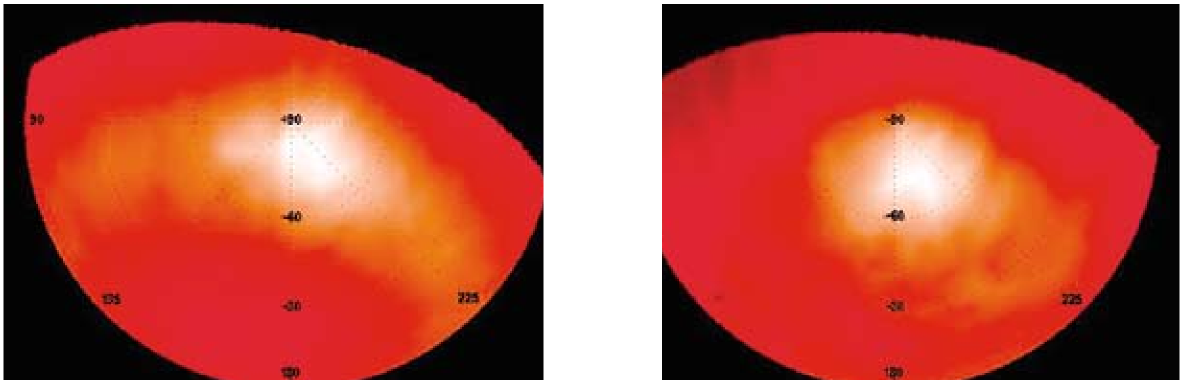

Figure 3. *Polar projections of Neptune mid-infrared images taken July 5, 2005. These maps show ethane emission at 11.7 microns (left) and methane emission at 7.7 microns (right). The effects of limb brightening have not been removed. In addition to the general enhancement of emission near the south pole, we detect an additional localized enhancement of radiance slightly offset from the polar position, equivalent to about 1 Kelvin in brightness temperature. The regions of enhancement are generally coincident for both wavelengths. No similar enhancements are found at other longitudes sampled by our observations.*

Even if a seasonal model can explain the increasing mid-infrared emission, such explanations are, at present, inadequate to explain the visible-wavelength long-term brightening.

These resolved Gemini images of Neptune's thermal characteristics reveal that a comprehensive understanding of this planet's radiative and dynamical processes will require observations and models ranging across the stratosphere down into the troposphere. Gemini and its superb instrumentation will play a key role in deciphering the secrets of this remote giant world.

The paper with the results of this work has been submitted to *Astronomical Journal*. For more information, please see:

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by Thomas R. Geballe & Geoffrey C. Clayton

^{18}O and the Origin of Two Types of Rare Carbon Stars

Sometimes the path to an important scientific discovery has a totally unexpected beginning. In our case the beginning was an e-mail on November 10, 2004, from one of us (GCC) to the other (TRG). It asked for assistance in identifying some absorption features in an unpublished infrared spectrum obtained a few years earlier at Steward Observatory in Arizona, of a hydrogen-deficient carbon (HdC) star, one of a class of stars so obscure that only five members are known. The identification of these features and subsequent follow-up observational studies at Gemini South, together with theoretical modeling by our collaborators, Martin Asplund, Falk Herwig, and Chris Fryer, appear to be spurring a leap in understanding the origins of these five stars. In addition, it also helps us understand a somewhat more populous, much more famous, and apparently closely related class of star that the two of us had been studying together for several years, the R Coronae Borealis (RCB) stars.

The infrared spectrum in question was of HD 137613, a cool HdC star. Carbon stars are so named because they contain more carbon than oxygen. Each of the five stars in this class has a large overabundance of carbon and almost no hydrogen. The infrared spectrum of HD 137613, like that of most cool stars, showed strong overtone bands of the most common isotopic species of carbon monoxide, $^{12}C^{16}O$. But it also showed a second set of equally strong absorption bands offset in wavelength from those of $^{12}C^{16}O$. In many evolved stars the bands of the next most abundant isotopic species of carbon monoxide, $^{13}C^{16}O$, are also present at somewhat lower strength. However, the wavelengths of the second set of bands in HD 137613 did not match those of $^{13}C^{16}O$. In fact, no $^{13}C^{16}O$ was apparent.

It took only ten minutes for TRG to locate some computer printouts from three decades earlier and identify the second set of bands as those of an extremely rare species of CO: $^{12}C^{18}O$. The usual abundance of ^{18}O (measured on Earth, on the Sun, and in the interstellar medium) is 1/500 that of ^{16}O. However, in HD 137613 the equal strengths of the bands of $^{12}C^{16}O$ and $^{12}C^{18}O$, which we later confirmed using the United Kingdom Infrared Telescope (see Figure 1), clearly demonstrated that the abundance ratio [$^{16}O/^{18}O$] was about unity, not 500. Such a low value of the ratio had never been seen before in any astronomical object. Because the bands of $^{12}C^{16}O$ were of typical strength for the atmosphere of a cool star, the measured ratio implied a huge enhancement of ^{18}O in the star rather than a nearly total depletion of ^{16}O.

All stars initially have more oxygen than carbon. In addition, it is well understood that carbon stars are in the late stages of their evolution–when carbon and other products of thermonuclear burning inside the star either are transported to the outer layers or are exposed by the star losing its outer layers. The enormously enhanced ^{18}O we found in HD 137613 clearly had to be a consequence of thermonuclear burning. But precisely which thermonuclear reactions were producing the ^{18}O and by what type of surface enrichment mechanism or stellar event were we being allowed to see it?

HdC stars appear to be closely related to another type of carbon star—the R Coronae Borealis (RCB) stars. Roughly fifty RCB stars are known. They also are lacking in hydrogen and have other elemental abundances similar to those of the HdC stars. However, unlike an HdC star, an RCB star varies enormously in brightness. In an interval of a few days it can fade optically by as much as eight magnitudes. Recovery to its normal brightness takes anywhere from several weeks to several months. The intervals between these episodes are unpredictable, but typically range between a few months and a few years. Because of the dramatic changes in brightness, the RCB stars are popular targets for amateur astronomers. Due to amateur observations, detailed and ongoing light curves exist for most RCB stars. The cause of the rapid fading and slow recovery is known to be the rapid condensation of light-blocking dust grains in the outer atmosphere of the star followed by the dispersal of the dust into space in a wind driven by radiation pressure from the star. On the other hand, HdC stars do not have winds and thus their brightnesses do not vary.

Two different evolutionary models have been suggested for the origin of RCB stars. Both theories invoke white dwarfs, the ultra-dense cores of previously normal stars with initial masses roughly the same as the Sun. In one model, proposed by Icko Iben and collaborators, an RCB star is formed when a single star on the verge of becoming a white dwarf undergoes a final flash of thermonuclear burning near its surface. This blows the dwarf up to supergiant size and cools off its outer atmosphere to the normal stellar temperatures that are found for RCB stars. In the other theory, proposed by Ronald F. Webbink, an RCB star is formed when two white dwarfs, one helium-rich and one carbon and oxygen-rich, merge. Webbink suggested that as the merger occurs, the helium-rich white dwarf (He-WD) is disrupted, with part of it accreting onto the more massive carbon- and oxygen-rich white dwarf (C/O-WD) and undergoing thermonuclear "burning." The remainder forms an extended atmosphere around the object. Webbink proposed that this structure, a star with a He-burning outer shell in the center of a ~100 solar radius hydrogen-deficient envelope, is an RCB star.

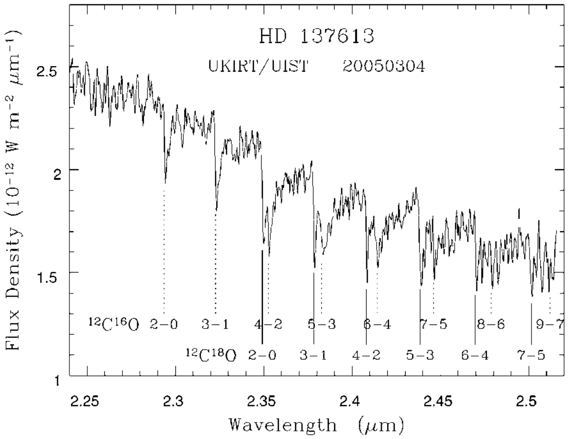

Figure 1.
The 2.24-2.52 micron spectrum of HD 137613, the first HdC star found to have enhanced ^{18}O, obtained at the United Kingdom Infrared Telescope (UKIRT) in March 2005. Eight bands of ^{12}C^{16}O and six bands of ^{12}C^{18}O are seen; the locations of the band heads are marked.

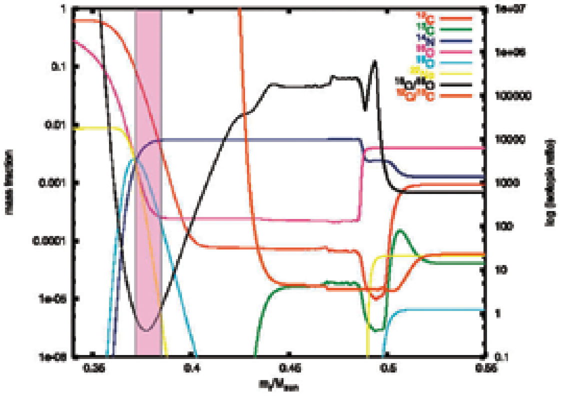

Figure 2.
Model abundances of key carbon, nitrogen, oxygen, and neon isotopes, and isotopic ratios of carbon and oxygen in a portion of the interior of a two solar mass star with initial solar abundances, soon after the end of He-core burning (from Clayton et al. (2005)). The red-shaded portion indicates the region where ^{16}O/^{18}O < 1. Temperatures outside of that region (to the right) are too cool for ^{18}O to be created by α-particle capture onto ^{14}N; inside ^{18}O is converted by α-capture to ^{22}Ne. Models of single star evolution apparently do not explain the extreme ^{18}O enhancements at the surfaces of so many stars, but the diagram illustrates the key thermonuclear reactions in the production and destruction of ^{18}O.

The bible for describing HdC stars is a 1967 paper by Brian Warner. There, he speculates that HdC stars can result from the evolution of single stars of roughly solar mass beyond the red giant stage. Amazingly, in that forty-year old paper, Warner predicted that ^{18}O would be abundant in the atmospheres of these stars. He suggested that the high abundance would result from the capture of alpha particles by nitrogen nuclei, ^{14}N(α,γ)^{18}O, a nuclear reaction that is expected to occur deep inside the star, followed by the uncovering of this material via mass loss episodes as the star evolves into the central star of a planetary nebula and eventually a white dwarf.

Warner also suggested that ^{18}O be searched for in the very manner by which we found it: via the infrared bands of CO, which had barely been observed in any stars at that time. Our discovery initially appeared to us to be a beautiful confirmation of his prediction. However, discussions with our colleagues who were knowledgeable about nuclear reaction rates, made it clear

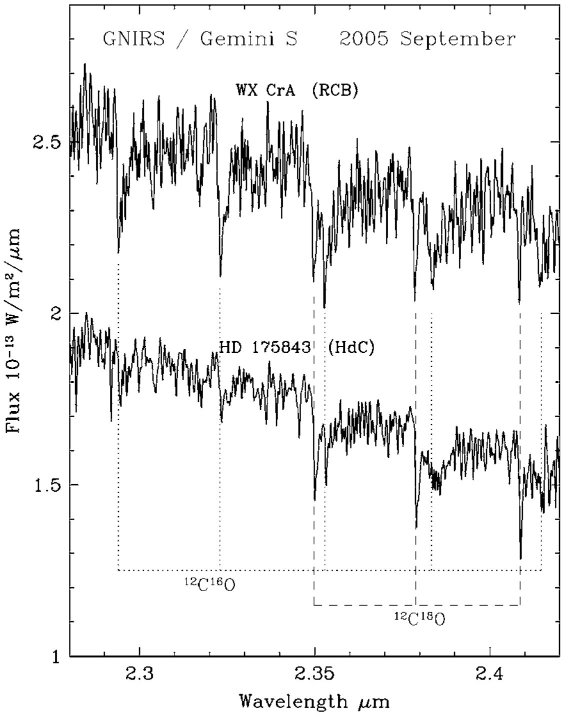

Figure 3.
Spectra of two of the eight cool RCB and HdC stars obtained by GNIRS at Gemini South showing the most extreme cases of ^{18}O enhancement found to date in each class of stars. The locations of the bands are shown by vertical lines and have the same identifications as in Figure 1. In the RCB star, WX CrA, the abundance of ^{18}O is nearly as high as that of ^{16}O. In the HdC star, HD 175843, the bands of $^{12}C^{18}O$ are 2-3 times stronger than those of $^{12}C^{16}O$, and model spectra suggest that ^{18}O actually has about five times the abundance of ^{16}O.

that the situation was more complex. It is now known that almost the same conditions that produce ^{18}O via the above reaction also destroy it via the reaction $^{18}O(\alpha,\gamma)^{22}Ne$. Thus, the interior of an intermediate-mass star would not be filled with ^{18}O; instead, as shown in Figure 2, it would contain only a very thin shell containing a large abundance of ^{18}O, where ^{14}N had been converted to ^{18}O, but the ^{18}O had not yet been converted to ^{22}Ne.

If HD 137613 were the result of the evolution of a single star, apparently the only viable explanation for its high abundance of ^{18}O would be the loss of the outer half of the star precisely down to the thin ^{18}O-enhanced shell and no further. This seemed unlikely, but perhaps HD 137613 was a unique object, a fluke. To test this idea, we requested and received time at Gemini South in semester 2006B to use the Gemini Near Infrared Spectrograph (GNIRS) to observe the CO bands in the other four HdC stars, all of which could be observed from Gemini South. We also asked and were granted time to observe five RCB stars accessible from the southern hemisphere in 2005B that are cool enough to have CO in their atmospheres.

The observations were performed by Gemini staff in late September 2005 as part of the normal queue process. The data reduction was complete by the end of the year and the results were truly astounding. Two additional HdC stars, HD 175893 and HD 182040, showed bands of $^{12}C^{18}O$ that are as strong as, or stronger, than those of $^{12}C^{16}O$. (The other two HdC stars were too hot to have CO, and thus no conclusion could be drawn about the abundances of ^{18}O in them.) And equally remarkably, all five cool RCB stars also contained unusually strong bands of $^{12}C^{18}O$. In short, every HdC and RCB star cool enough to have CO showed enormously enhanced abundances of ^{18}O, by factors of 100-1000 over the normal abundance relative to ^{16}O. Moreover, none of the stars showed any evidence for either $^{13}C^{16}O$ or $^{13}C^{18}O$, just as had been found for HD 137613.

The complete set of spectra is being published by Clayton, et al. in *The Astrophysical Journal* this year. Figure 3 shows the GNIRS spectrum of the most extreme example of each type of star. In the RCB star WX CrA, the bands of $^{12}C^{18}O$ are nearly as strong as those of $^{12}C^{16}O$ and our model spectra by Martin Asplund (of the Anglo-Australian Observatory) suggest that the abundances of ^{18}O and ^{16}O are equal. In HD 175843, where the CO bands are weaker than those in WX CrA because the star is hotter, the bands of $^{12}C^{18}O$ are much stronger than those of $^{12}C^{16}O$. Comparisons with Asplund's model spectra suggest that here the abundance of ^{18}O is five times greater than ^{16}O. Indeed, in each of the three HdC stars ^{18}O is more abundant than ^{16}O. Although the overall uncertainties are a factor of two for each star, there is a clear pattern that ^{18}O is more extremely enhanced in HdC stars than in RCB stars.

Thus, the Gemini observations demonstrate that an extreme excess of ^{18}O is a common and perhaps universal feature of HdC and RCB stars. As nitrogen is abundant in these stars, the α-capture reaction on ^{14}N is the most likely source of the enhanced ^{18}O. However, the possibility that the observed ^{18}O is produced deep within a star, and that for each such star, mass loss proceeds nearly precisely to the ^{18}O-enhanced layers and not deeper, is very far-fetched. Some other mechanism must produce these high surface abundances of ^{18}O. And, whatever the cause of these uniquely low values of $[^{16}O/^{18}O]$, the strong implication is that these two classes of carbon-rich and hydrogen-poor stars have followed similar evolutionary paths.

Only a very few examples of final He-shell flashes of objects on the white dwarf track have been documented. The rapidity with which those few objects have passed through the regime where their temperatures and luminosities are similar to RCB stars suggests that final flashes cannot account for even the small number of RCB stars known. Moreover, in the few cases where isotopic ratios of carbon and oxygen have been measured in final flash objects, the high abundances of ^{18}O and low abundances of ^{13}C in RCB and HdC stars are not found. Also, on a theoretical level, final flashes are not expected to result in overproduction of ^{18}O. Thus, final flash events do not appear to be the creators of RCB and HdC stars.

Therefore, we and our colleagues, especially Falk Herwig and Chris Fryer (both at the Los Alamos Astrophysics Laboratory), have been examining the alternative white dwarf merger scenario as a means of producing greatly enhanced ^{18}O. Fryer's and Herwig's approach has been two-pronged: first to determine the temperatures and densities encountered during the merger, and in particular in the helium-rich material accreting onto the C/O-WD; and second, to model the nucleosynthesis (the creation of new atomic nuclei from pre-existing particles) that occurs in that material. Needless to say, both the merger and its thermonuclear consequences are highly complex, and our initial approach to each has been simple by necessity. The results indicate that a typical merger takes only a few days and results in temperatures of $1\text{-}2 \times 10^8$ K at the base of the accreting material (temperatures at which He-burning to ^{12}C readily occurs). This range also encompasses the temperatures at which ^{14}N is transformed to ^{18}O and also where ^{13}C is destroyed. If the higher temperatures in this range are reached and persist for too long, however, all of the ^{14}N and ^{18}O are destroyed.

However, we expect that the period of thermonuclear burning cannot be very long since it is the result of a rapid merger. After the merger is completed, temperatures will decrease and thermonuclear reactions on the surface of the white dwarf will end. Many details and questions remain to be resolved, but our strong impression is that the white dwarf merger provides a suitable environment for significant production of ^{18}O and can account for many other isotopic and elemental peculiarities of these stars.

Thus the discovery of abundant ^{18}O in HdC and RCB stars may have unlocked the secret to the origins of these bizarre classes of objects. It is clear that more detailed simulations and modeling are justified. There are many unanswered questions, perhaps most notably: why do HdC stars have lower values of [$^{16}O/^{18}O$] than RCB stars? Future observations could produce more accurate determinations of [$^{16}O/^{18}O$] in the stars that we observed, probe the remaining cool RCB stars whose CO spectra have not been measured, and test for other isotopic anomalies predicted by the white dwarf merger hypothesis.

For more information see:

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by Margaret Moerchen

Tightening the (Asteroid) Belt Around Zeta Leporis

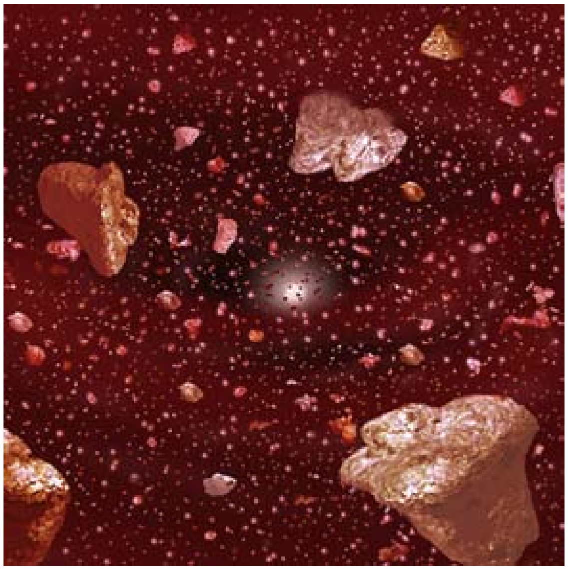

Figure 1.
Artist's conception of a rich asteroid belt that sustains dust production through the ongoing collisions of larger bodies. Gemini artwork by Jon Lomberg.

While most people are content to sweep dust under the rug, astronomers investigating planet formation are taking a closer look at it. By peering at the dust surrounding the star Zeta Leporis with T-ReCS at Gemini South, we have found strong evidence that this dust may be generated in an exosolar asteroid belt much like the one in our own solar system.

While all stars initially possess a primordial dust disk as a byproduct of collapse from a molecular cloud, most of this material is blown out by the newly formed star within the first few million years of its life. Therefore, if large amounts of dust are observed around stars older than this, the dust must have a more recent source of replenishment. Before the primordial material escapes, there may be time for planetary bodies to form, and it is from these objects—from collisions of rocky bodies and the evaporation of comets passing near the star—that dust is regenerated.

Once the reprocessed dust is released into the so-called debris disk, its presence is involuntarily battled by its host star. The smallest particles, less than a micron in diameter, are pushed out of the system by radiation pressure almost immediately. Larger particles are consumed by the star after spiraling in under the effect of Poynting-Robertson drag, a process that occurs over a slightly longer timescale, perhaps hundreds or thousands of years. As these dust particles travel inward, they are likely to experience further collisions that break them up into ever-smaller particles that are then blown out

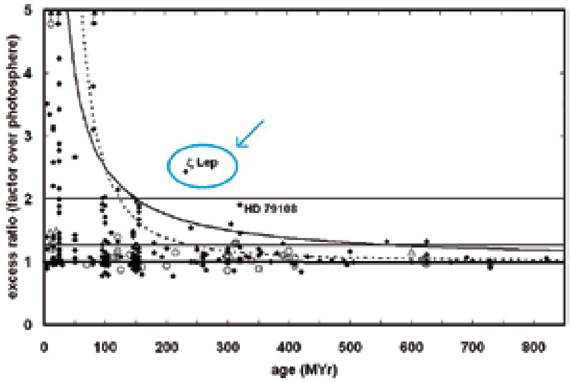

Figure 2. *In this plot of infrared excess against age for a sample of A-type main-sequence stars (from Rieke et al. 2005), note Zeta Leporis's high infrared excess among stars of similar age.*

in a process known as a collisional cascade. If we detect substantial amounts of dust around a star, then we can likely infer that the dust production processes are either essentially ongoing or very recent.

Debris disks are not rare. To date, there are over a hundred candidates derived from photometric measurements. However, only about a dozen have ever been spatially resolved at any wavelength. The advent of large ground-based telescopes such as Gemini has provided an excellent opportunity to pursue unresolved candidate sources in an effort to probe the disk structure and investigate the physical processes occurring within them. The observations of the archetypal disk around the star Beta Pictoris, which suggest the recent occurrence of a cataclysmic collision, provide a superb example of this capability. More recently, we have uncovered what may be a new archetype in the disk around the star Zeta Leporis.

This system stands out as an interesting source for two reasons. First, it was imaged at mid-infrared wavelengths at the W. M. Keck Observatory by Christine Chen and Michael Jura in 2001. However, variable weather conditions only allowed the disk radius to be limited to nine astronomical units or less. (An astronomical unit is the average distance between the Sun and Earth). Second, the 230 million-year-old star has an unusually high infrared excess among stars of similar age (Figure 2). Since most dust particles absorb ultraviolet starlight and re-radiate it at longer wavelengths, the amount of excess infrared emission is a fair gauge of the amount of dust around the star. While the precise era of peak collisional activity in circumstellar disks is still being investigated, several studies have indicated an apparent falloff in maximum infrared excess with age. This could well be attributable to a general settling of orbits in the disk that, in turn, results in fewer collisions among planetesimals and a more depleted dust disk. For sources such as Zeta Leporis that exhibit infrared excesses much larger than the expected "maximum" excess therefore implies some sort of stochastic, or transient, activity, as was indeed recently suggested with Spitzer data on this source.

Our team at the University of Florida, including Charles Telesco, Chris Packham, and Tom Kehoe, obtained mid-infrared images of Zeta Leporis with T-ReCS in queue mode in February 2005. The data are part of a broader ongoing research program focused on the search for resolved circumstellar debris disks. With the 18.3-micron images, we found that the bulk of the dust orbiting this A-type main-sequence star lies at a radius of 3 AU, roughly the same distance as the Asteroid Belt in our own solar system. By observing a point-like reference star before and after Zeta Leporis, we were able to compare their brightness profiles (Figure 3) to assess the characteristic distance for the dust. In a *Science News* article on this result, Charles Beichman of NASA's Jet Propulsion Laboratory in Pasadena, California said, "the high angular resolution measurement of the Zeta Leporis disk is a very exciting result. We now have direct evidence for structures around other stars that are directly analogous to the asteroid belt in our solar system."

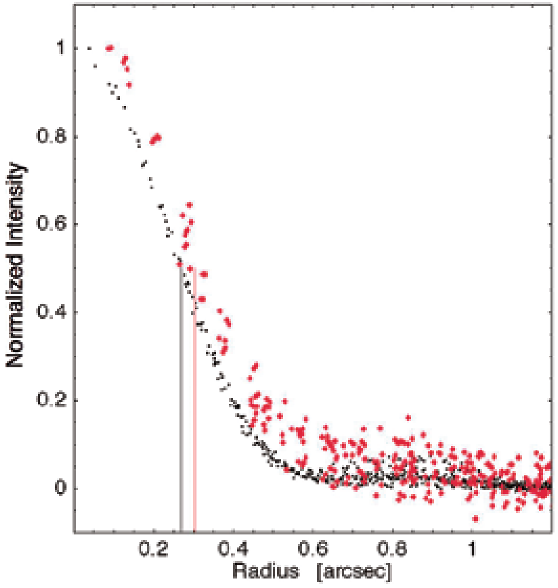

Figure 3. *Azimuthally averaged radial plots of Zeta Leporis (red) and a nearby point-spread-function (PSF) star (black). The colored lines denote the widths of the sources at 50% their peak brightness.*

Additionally, simple modeling (in which the shape of the point source was convolved with a variety of disk annuli) suggests that most of the dust inhabits a region between two and four AU, but that some dust also extends out at least as far as eight AU. This replenished dust population could have been generated by one of two extreme cases, or likely, some combination of events: 1) steady-state grinding collisions within a reservoir of asteroid-like planetesimals, or 2) a single catastrophic collision of two larger bodies, perhaps comparable to the collision that created Earth's moon. We cannot distinguish between these two scenarios with the present data.

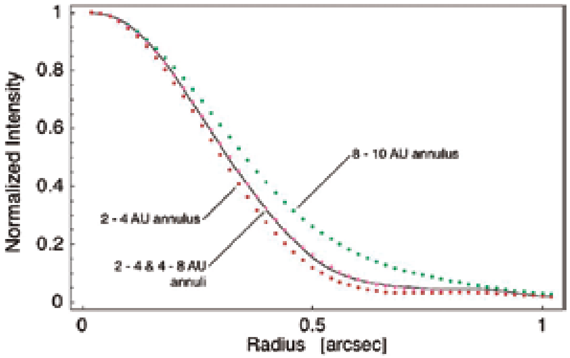

Figure 4.
Results showing that a two-component model best fits the emission detected near Zeta Leporis. A single 2 - 4 AU annulus does not provide the correct FWHM while a lone 8-10 AU ring exhibits too much extended emission.

The Zeta Leporis result is remarkable not only for the fact that it adds a new source to the collection of spatially resolved debris disks, but in particular for its comparatively restricted extent. Of the previously resolved sources (such as Beta Pictoris, HR 4796A, Vega, and others), none have disk diameters of less than about 100 AU. In comparison to our own solar system, these could be considered young Kuiper Belt analogs. Until now, this scale of structure stood as the sole archetype. We must now consider that among the many as-yet unresolved debris disk candidates, several of which have infrared excesses that suggest the presence of warm dust within only a few astronomical units of the parent star, there may be many other asteroid belt-sized disks that are not currently resolvable due to their distance (Zeta Leporis is only 21.5 parsecs or 51.5 light-years away).

The measurement of this novel scale of circumstellar disk is only possible due to the combination of benefits gained by imaging at mid-infrared wavelengths with large telescopes such as Gemini. At the relatively long wavelengths of the mid-infrared, most stars do not shine brightly at all, however, the thermal emission from the nearby dust peaks near these wavelengths, yielding inherent high-contrast imaging. At optical and even near-infrared wavelengths, the central star dominates over the emission from the dust and a coronagraph must be employed if the fainter dust component is to be observed. The disadvantage of this technique is that, for even the closest stars, the coronagraph will block at least the region which corresponds to the Kuiper Belt in our own solar system, clearly an area of interest for studying any planet formation.

With mid-infrared imaging, we take advantage both of this ability to probe areas of the dust disk close to the central star, as well as the nearly diffraction-limited resolution (typically < 0.5 arcsecond) afforded by an 8-meter telescope that allows examination of fine structures within the disk. These structures may result from a wide range of processes that are still not well understood–from secular perturbations by giant planets to ongoing or stochastic collisions of planets and planetesimals.

By examining dusty signatures of disk evolution, we have a unique and highly informative approach for studying the early stages in the formation of planetary systems. The resolution of the Zeta Leporis debris disk clearly demonstrates this capability. Presently, there exist only four mid-infrared instruments at 8-meter-class facilities around the world that can execute such state-of-the-art observations, and the two (T-ReCS and MICHELLE) residing at the infrared-optimized Gemini Observatory thus afford the best sensitivity among them. We look forward to continuing our program of investigating young solar system analogs as part of the greater effort to understand our own planetary system.

This result appears in the February 1, 2007 issue of *Astrophysical Journal Letters* (vol. 655, L109) and was featured in the January 8, 2007 issue of *Science News*.

For more information see:

Chen, C., & Jura, M., 2001, *ApJ*, **560**, L171
Rieke, G., et al. 2005, *ApJ*, **620**, 1010.

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By John Lacy

Flows and Jets in H II Regions Observed with TEXES

Newly formed massive stars can have much more dramatic effects on their surroundings than stars like the Sun do. Stars with masses greater than twenty times the Sun's, known as O-type stars, are hot enough to emit ultraviolet radiation that ionizes surrounding gas, forming prominent H II regions (heated hydrogen gas clouds). The best-known example of a H II region is the Orion Nebula, M42, where gas ionized by the Trapezium stars glows brightly enough to be visible to the naked eye. These bright stars must have formed inside of the Orion Molecular Cloud a few million years ago. They ionized and heated the gas around them, which then expanded and broke out of the cloud because of the high pressure of the hot gas. When the H II region was still inside the cloud, it would have been a compact or ultracompact H II region, with high enough density to be very bright at radio and infrared wavelengths, although hidden in the visible. After the H II region broke out of the cloud, it became visible. However, the gas continued to expand as it continued to expand as it flowed away from the cloud, causing its surface to gradually decrease as a result.

That is the standard story of the formation and evolution of the ionized gas around a newly formed massive star. But there are problems with that story, the best-known of which is referred to as "the lifetime problem." We think we know how rapidly an H II region should expand, and thus how long it should take it to break out of the molecular cloud in which it formed. We also think that we know the rate at which O-type stars are being born in the Milky Way. From the ratio of those two numbers we can calculate how many H II regions should still be embedded in their molecular clouds and therefore be dense enough to be seen as compact H II regions. However, many more compact H II regions have been found than would be expected from this calculation. Is some effect preventing compact H II regions from expanding and breaking out of their molecular clouds?

Several solutions have been suggested for the compact H II region lifetime problem. One of them was supported by observations made with Texas Echelon-cross-Echelle Spectrograph (TEXES) on the NASA InfraRed Telescope Facility (IRTF). TEXES can observe the infrared fine-structure lines of several ions, which are forbidden transitions like the [N II] and [O III] visible lines which make excellent tracers of ionized gas motions and distribution. On the IRTF, TEXES observed motions at about four km/sec spectral and one-arcsecond spatial resolutions. From mapping of the [Ne II] (12.8 microns) line, we found that the gas motions in the compact H II regions we observed generally do not have patterns indicating expansion. Instead, the gas typically flows along the surface of a shell.

If gas motions in compact H II regions are not dominated by expansion, their lifetimes could be greater than expected. Astronomers have put together a standard scenario for this model of H II region evolution, but it too has problems. The story involves an O star moving rapidly through a molecular cloud, with the interaction between the stellar wind and the cloud resulting in a bow shock that concentrates the ionized gas in a paraboloidal layer moving with the star. However, for that model to explain the observed velocities, the O star would have to be moving as fast as the expansion of an H II region around a stationary star. Under these circumstances the star would then leave the molecular cloud in the short timeframe that the original models predicted for the break out of an H II region.

Observations with TEXES on Gemini North point to a variation on the bow-shock model that avoids the problem of the O star moving out of its molecular cloud. During the July 2006 demonstration science run, an object called W51 IRS 2 was mapped in [Ne II] and [S IV] (10.5 microns) with 0.4 arcsecond and four km/sec resolution. W51 is a giant H II region in the Sagittarius spiral arm of the Milky Way. IRS 2 is a cluster of compact and ultracompact H II regions within W51 which is ionized by a young OB star cluster on the near side of a molecular cloud. This is very much like the Orion Nebula, although it is several times more luminous.

By mapping in a spectral line with sufficient resolution to measure Doppler shifts due to gas motions TEXES produces a data cube with two dimensions of spatial information and one of velocity. The [S IV] data cube, displayed as a sequence of narrow band images, can be obtained from the Gemini web site. Before reading on we encourage readers to look at the movie at: http://gemini.edu/index.php?option=content&task=view&id=225

The movie runs from V_{LSR} = +85 to -82 km/sec, (in 0.94 km/sec steps). It is dominated by two features. Going from +80 to +20 km/sec, the emission starts near the center of the image and seems to explode outward with decreasing redshift. The emission is then relatively faint until a ridge of blueshifted emission appears at -30 to -70 km/sec.

Several cuts through the data cube are shown as position-velocity diagrams in Figure 1, and images in three broad velocity ranges are shown in Figure 2. But look at the movie. It's a lot more interesting.

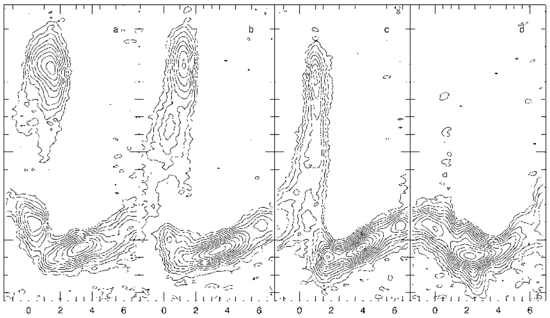

Figure 1. *Position-velocity diagrams of the [S IV] emission from W51 IRS 2. The contours show how the line emission is distributed in position (horizontal axis) and Doppler shift (vertical axis). The molecular cloud is at +57 km/sec. Movies of the full data cube are at the url referenced in the text in the left column on this page.*

We interpret the "exploding" red-shifted gas as a flow along the surface of the molecular cloud (which is at +57 km/sec) behind the OB cluster. The star cluster has excavated a bowl-shaped cavity in the front side of the cloud. Ultraviolet photons from the stars are ionizing the gas on the cloud surface, while stellar winds prevent the ionized gas from flowing away from the surface. Instead, the gas flows along the surface, from the center of the bowl toward its edges, and turning toward us,

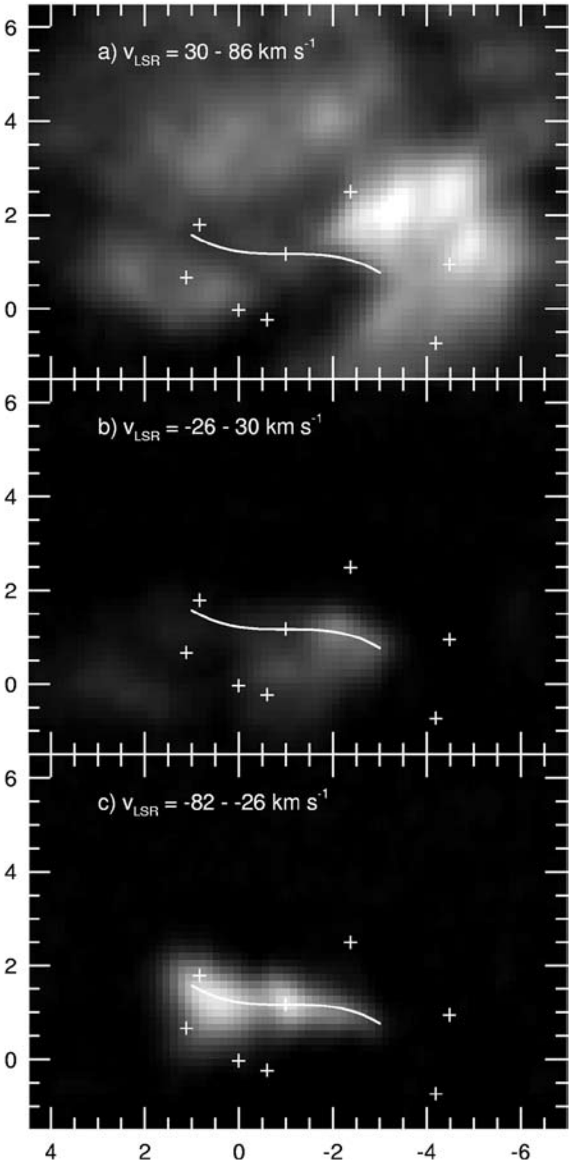

Figure 2. *Images of [S IV] emission from W51 IRS 2 in three velocity intervals. a) shows gas on the surface of the molecular cloud, b) shows gas in the jet that has punched through the cloud surface, and c) shows gas which forms a bridge between the cloud surface and the jet.*

resulting in the observed Doppler shift pattern. This is just like the flow pattern in the bow-shock model of a compact H II region, except that as we observed, the head rather than the tail is at the molecular cloud velocity. In addition, the density and brightness of the gas is as large as in a compact H II region, even though the ionizing stars have already broken out of the cloud where they formed. W51 IRS 2 is showing us that there is a way to make a compact H II region that can survive much longer than the time it takes for ionized gas to break out of a molecular cloud. The trick is to ionize the surface of a cloud, while keeping the ionized gas compressed against the surface with the ram pressure of the winds from the O stars.

The blue-shifted gas appears to be telling us about a different way in which massive stars can interact with their environment. This gas is moving at about 110 km/sec toward us, relative to the molecular cloud. Since it has ionic line ratios similar to the gas on the surface of the cloud and it is right in the middle of the ionizing star cluster, the blue-shifted gas must also be getting ionized by starlight from the cluster. Apparently a jet of some sort has emerged from the molecular cloud, reaching into the OB star cluster. One piece of evidence that the jet has punched through the H II region on the surface of the molecular cloud can be seen in Figure 1. In the position-velocity diagrams emission can be seen which connects that from the cloud-surface gas, which is at +80 to +20 km/sec Doppler shift, to the jet, which is at -30 to -70 km/sec. This emission is centered just south of the jet, indicating that the jet interacted with the cloud surface south of its current position, and is moving toward the north as well as coming toward us. The mechanism for interaction between the jet and the surface H II region is not known, but the appearance in position-velocity space of the emission bridging between these two features suggests that the surface H II region might have some sort of elastic properties that allow it to be carried along behind the jet.

The model of a jet emerging from a molecular cloud fits nicely with observations of H_2O masers moving away from a point 1.5 arcseconds south of and probably behind the blue-shifted [S IV] streamer. Similar ionized jets are seen where Herbig-Haro flows emerge from the Orion Molecular Cloud into the Orion Nebula, but these jets from low-mass stars are much less massive and luminous than the one in W51. The jet in W51 was most likely emitted by a newly forming massive star. It has generally been thought that outflows from massive stars are less well-collimated than those from low-mass stars, but in this case a well-collimated precessing jet, or perhaps a fan-like jet, seems to be required. Perhaps rapidly precessing jets have in the past been mistaken for poorly collimated jets.

The ionized gas in W51 IRS 2 had previously been imaged at near-infrared and radio wavelengths. In fact, the blueshifted gas had been seen in Very Large Array (VLA) recombination line images, although it was not known whether it was simply an unrelated source along the line of sight to IRS 2. The much better sensitivity and spatial resolution of TEXES on Gemini compared to that of VLA recombination line interferometry was needed to see the interaction of the blue-shifted and cloud surface ionized gas, allowing us to see the structure of this region.

For more information see:

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Bally, J. and Reipurth, B. 2001, *ApJ*, **549**, 299.
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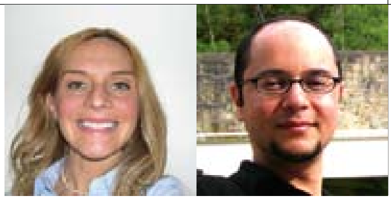


By Alicia Soderberg & Edo Berger

Recent Progress in Gamma-ray Bursts

The launch of the Swift satellite in November 2004 heralded a new era in the study of gamma-ray bursts (GRBs) and their use as powerful probes of the high-redshift universe. Already known to possess bright optical and near-infrared "afterglows," gamma-ray bursts can now be pinpointed on the sky faster and more accurately than ever before, allowing us to address fundamental questions about the nature of these powerful explosions.

We also use them as lighthouses for the study of the chemical and star-formation evolution of high-redshift galaxies and the intergalactic medium. Of primary importance in the context of understanding where these events originate is the nature of the progenitors of both the long-duration gamma-ray bursts (longer than two seconds), which appear to be related to the death of massive stars, and the mysterious short-duration bursts for which no afterglows had been found previously. Thanks to their rapid response capability (see article by Katherine Roth stating on page 35 of this issue), the Gemini telescopes have played a central role in addressing these questions.

Long-duration Gamma-ray Bursts and their Connection to Supernovae

Long-duration bursts have been revealed over the last decade to be a rare variety of Type Ibc supernovae (SNe Ibc). While all classes of core-collapse supernovae result from the death of massive stars and share a common energy scale, only gamma-ray bursts are capable of producing highly relativistic jets (that is, jets moving material away from the site of the explosion at close to the speed of light). The essential physical process that causes some progenitors—isolated Wolf-Rayet stars or close binary helium stars—to produce a gamma-ray burst and not just a supernova remains one of the most important outstanding questions.

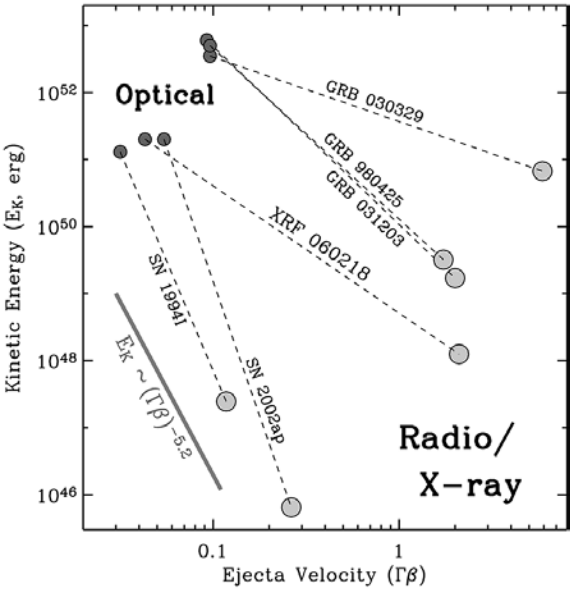


Figure 1.
The outflow kinetic energy, E_K, of cosmic explosions may be probed through optical, radio and x-ray observations and is compared for ordinary SNe Ibc and GRBs/XRFs. Optical data (small dark circles) trace the slowest ejecta to which the bulk of the kinetic energy is coupled while radio and x-ray data (large light circles) trace the fastest ejecta in the explosion. XRF 060218 is an intermediate example that lies between ordinary SNe and GRBs with respect to energy coupled to mildly-relativistic material.

On February 18, 2006, the Swift satellite detected one of the nearest bursts discovered to date at a redshift of just 0.033, or a distance of about 466 million light-years. Less than three days later, we used the Gemini North telescope to reveal a supernova in association with the burst, demonstrating that the explosion represents the death of a massive star. The spectrum, however, indicated that the supernova had properties that placed it somewhere between those of previous GRB-SNe and ordinary Type Ibc supernovae found in the local universe.

Article continued on page 32

The Delicate Trails of Star Birth

Gemini's Laser Vision Reveals Striking New Details in Orion Nebula

Using the recently commissioned Gemini North Laser Guide Star (LGS) system, a stunning image of the "Bullets" region of the Orion Nebula was obtained on the night of March 6, 2007. The adaptive optics (AO) near-infrared image appears on the cover of this issue (and as part of the poster on the next two pages).

The Orion bullets were first seen in a visible-light image in 1983. By 1992, infrared images led astronomers to conclude that these were clumps of gas ejected from deep within the nebula following a violent event connected with the recent formation of a cluster of massive stars. The bullets are speeding outward from the cloud at up to 400 kilometers (250 miles) per second, more than a thousand times faster than the speed of sound. The typical size of the bullet tips is about ten times the size of Pluto's orbit around the Sun and they are estimated to be less than a thousand years old. The wakes are about a fifth of a light-year long.

Clouds of iron atoms at each bullet's tip glow brightly (colored blue) as they are shock-heated by friction to around 5000°C (10,000°F). Molecular hydrogen, which makes up the bulk of the bullets and the surrounding gas cloud, is destroyed at the tips by violent collisions between the high-speed bullets and molecules in the cloud. On the trailing edges of the bullets, however, the hydrogen is not destroyed, but instead heated to about 2000°C (4000°F). As the bullets plow through the clouds they leave behind distinctive tubular wakes (colored orange) that shine like bullet tracers due to the heated molecular hydrogen gas.

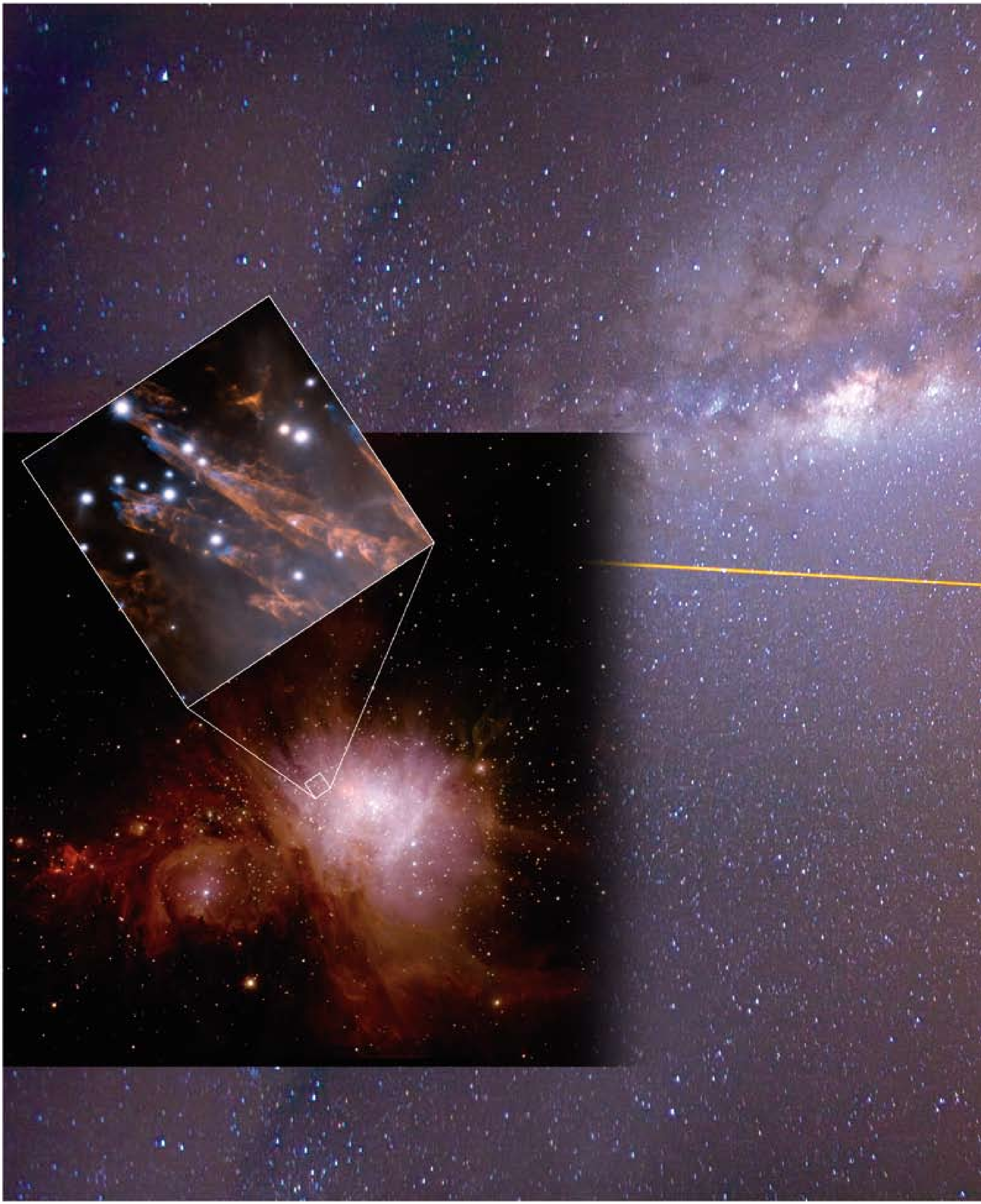
"What I find stunning about the new image is the detail it shows, which was blurred out in any previous studies, revealing the structure of the bullets and their trailing wakes as they run into the surrounding molecular cloud," said Michael Burton of the University of New South Wales who, along with the late David Allen (Anglo-Australian Observatory), was the first to suggest the origin of these spectacular bullets 15 years ago. "This level of precision will allow the evolution of the system to be followed over the next few years, for small changes in the structures are expected from year to year as the bullets continue their outward motion."

The new high-resolution image was made possible by adaptive optics technology at Gemini. With a laser guide star as a reference and a rapidly deformable mirror for real-time correction, most atmospheric distortions that blur a near-infrared image can be compensated for. The system deploys a yellow/orange solid-state sodium laser that produces the artificial guide star by exciting sodium gas about 90 kilometers (56 miles) up in our atmosphere and causing it to glow. This "artificial star" becomes a reference for the adaptive optics system, which uses it to determine how the atmosphere distorts the incoming near-infrared starlight.

The data used for this image are available to astronomers through the Gemini Data Archive: http://www1.cadc-ccda.hia-iha.nrc-cnrc.gc.ca/gsa/ The color image can be downloaded at: www.gemini.edu/bullets

Laser guide star technology has recently been advanced by the Gemini Observatory with the development of a solid-state sum-frequency laser for this purpose in a joint venture with the U.S. National Science Foundation and the U.S. Air Force. This laser was built under contract by Coherent Technologies (now Lockheed Martin/Coherent Technologies). ALTAIR, the Gemini North adaptive optics system, was designed and built by the Herzberg Institute of Astrophysics in Victoria, Canada.

The poster on the reverse side shows Gemini North on Mauna Kea during commissioning of the laser guide star system. The image was obtained from the Canada-France-Hawai'i Telescope's catwalk and the exposure is about 50 seconds. The inset image shows a blow up of the Orion "Bullets" described on this page with a wide field view of Orion Nebula field obtained using the ISPI near infrared camera at the Blanco 4-meter telescope at the Cerro Tololo Inter-American Observatory in Chile. The Gemini near-infrared image of the bullets was obtained with the ALTAIR adaptive optics system and Gemini's Near-Infrared Imager (NIRI). The image shows the Orion "bullets" as blue features and represents the light emitted by hot iron (Fe) gas. The light from the wakes, shown in orange, is from excited hydrogen gas. The images were taken at f/14 through the Fe II, H_2 1-0 and K-band filters and then combined into one color composite image. The field of view of the Gemini AO image is about 50 arcseconds across and structure on a 0.1 arcsecond (2 pixel) scale is visible.



Laser Vision Reveals Striking New Details in Orion Nebula

GEMINI
OBSERVATORY

Continued from page 28

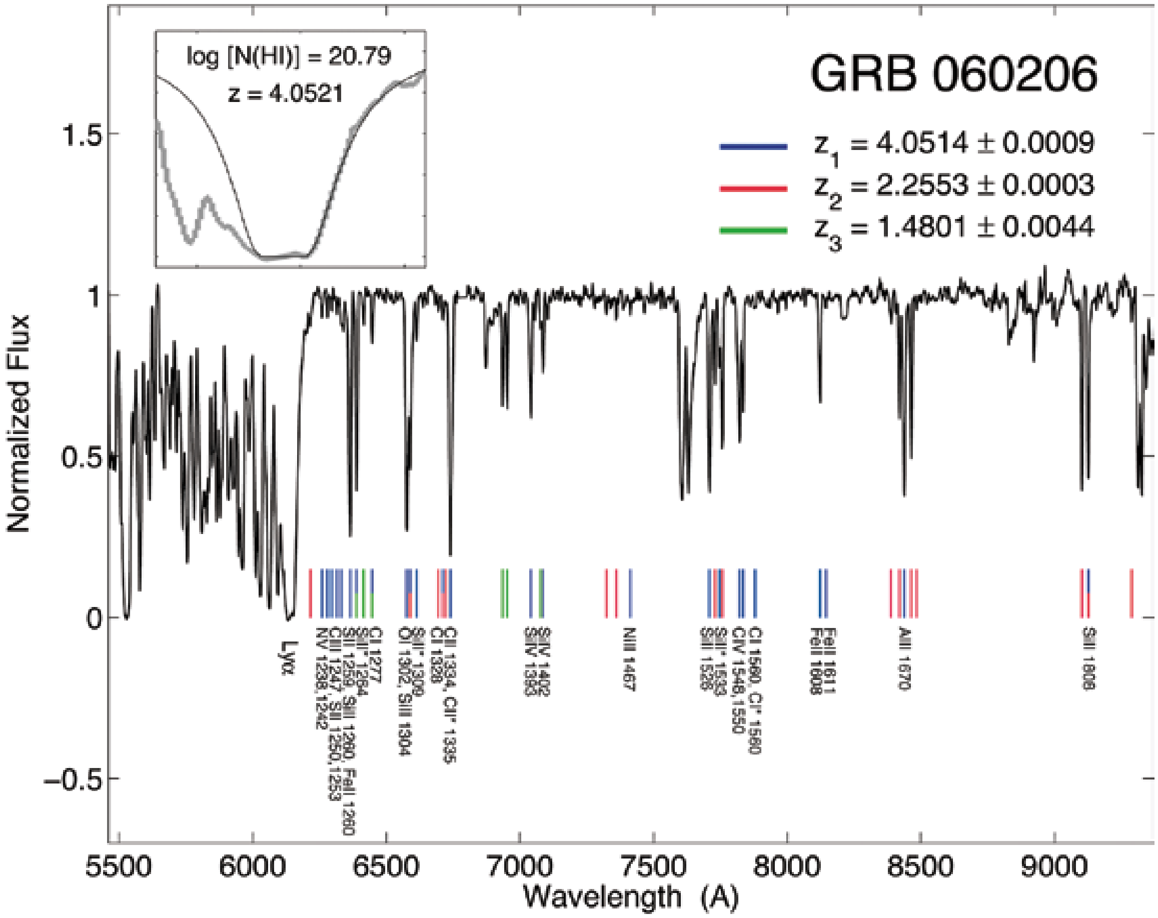


Figure 2. *Absorption spectrum of GRB 060206 obtained with GMOS on the Gemini North telescope 11 hours after the burst. The inset shows the damped lyman-alpha feature with a column density of log[N(HI)]=20.8 at z=4.0514. The gas metallicity inferred from the large number of metal absorption features redward of lyman-alpha is ~ 0.1 solar metallicity.*

In a paper that appeared in the journal *Nature*, we furthermore showed (from radio and x-ray observations) that this type of burst is a hundred times less energetic but ten times more common than cosmological gamma-ray bursts (which lie at greater distances and look-back times). At the same time, the explosion is distinguished from ordinary Type Ibc supernovae by the presence of a mildly-relativistic outflow (a high-speed jet, for example). Thus, this new explosion is intermediate between typical gamma-ray bursts and supernovae and hints at an overall continuum (Figure 1) that includes a range of GRB-supernova properties.

Gamma-ray Bursts as Probes of the High-redshift Universe

Thanks to their extreme brightness, their locations within star-forming regions, and simple spectral shapes, the afterglows of bursts provide powerful tools for tracing the interstellar medium in star-forming galaxies, as well as the intergalactic medium (IGM). With rapid position determinations now available from Swift, we have been using the Gemini telescopes to obtain absorption spectra of burst afterglows ranging in redshift from about z = 1 to z = 5 (Figure 2), corresponding to when the universe was only 15 - 50% of its present age.

The spectra of gamma-ray bursts are nearly always marked by a damped Lyman-alpha absorber (DLA) within the host galaxy of the burst, with neutral hydrogen column densities that exceed those observed in quasar spectra by at least an order of magnitude. These DLA systems (clouds of neutral hydrogen gas) also exhibit significant enrichment, with typical metallicities of about 0.1-1 solar for gas in the vicinity of the burst. In addition, we have found evidence in some cases for high-velocity, high-ionization absorbers that are likely the result of mass loss from the progenitor star during the Wolf-Rayet stage prior to the gamma-ray burst explosion. Additional detections of such systems will provide insight into the properties of individual high-mass stars at z ~ 2-5.

In a similar fashion, gamma-ray bursts provide a powerful probe of cosmic re-ionization—an epoch in the early universe when the first stars were beginning to shine. This is primarily thanks to their brightness and the lack

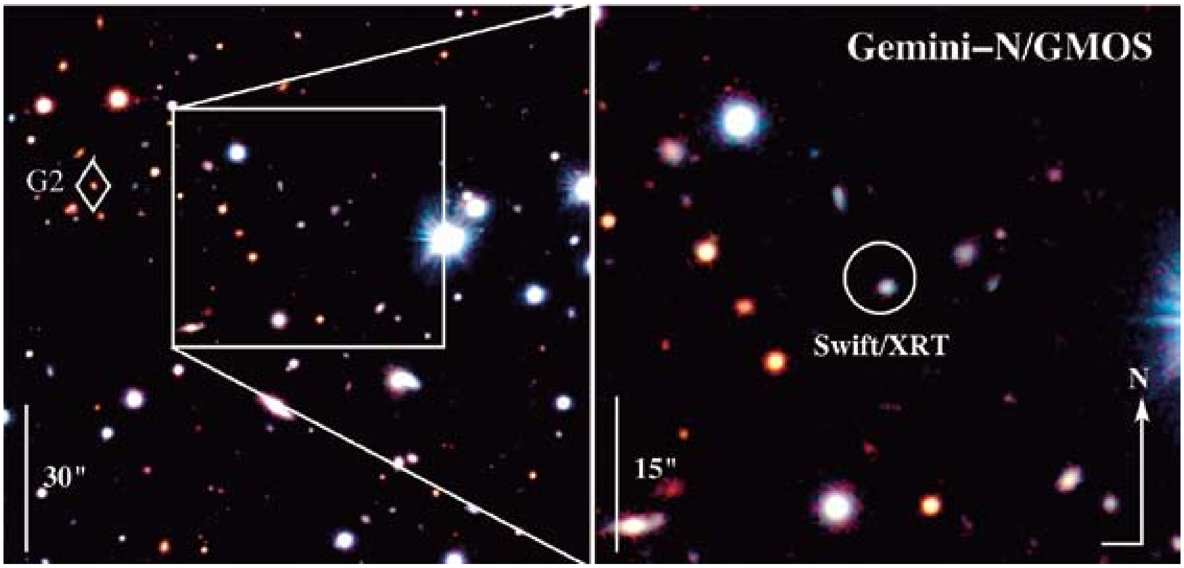


Figure 3. *Color composite image of the field of short-hard GRB 051221a as observed with Gemini North/GMOS on Dec. 27, 2005 UT. The host galaxy is the only source detected inside the XRT error circle and it's blue color is expected for a star-forming galaxy.*

of a large-scale proximity effect that plagues the use of quasars for accurate measurements of the intergalactic medium neutral fraction (the ratio of neutral hydrogen to ionized gas). Already we have discovered one burst at a redshift of 6.3 (when the universe was about 900 million years old), in the realm of the highest-redshift quasars and galaxies. Our current gamma-ray burst program at Gemini is indeed focused on rapid near-infrared imaging of burst afterglows in order to increase the number of high redshift gamma-ray bursts and hopefully in the near future detect the first objects at $z > 7$.

The Nature and Progenitors of Short Gamma-ray Bursts

The discovery in 2005 of the first afterglows from short gamma-ray bursts has triggered a long-promised revolution in our understanding of these events. In rapid succession, we have been able to localize short gamma-ray bursts to elliptical galaxies, galaxy clusters, and regions with no on-going star formation in late-type galaxies and we have been able to show that they are not accompanied by supernovae. These observations rule out origins in the deaths of massive stars. Instead, short gamma-ray bursts appear consistent with theoretical expectations for the coalescence of compact-object binaries such as the merger of two neutron stars, or a neutron star and a black hole.

The best-studied short gamma-ray burst to date, GRB 051221a, has provided the first glimpse into the energy scale and presence of jets in these short bursts. Using the Gemini North telescope, our team discovered the optical afterglow for this burst and established the redshift to be $z = 0.546$ (about ten billion light-years away), more distant than any previously known short gamma-ray burst (Figure 3). Our detailed modeling of the optical, radio, and x-ray afterglow observations revealed that the outflow was collimated in a jet with an opening angle of about 10 degrees, and that the explosion energy was a factor of ten larger than those of previous short gamma-ray bursts, but nearly two orders of magnitude lower than for long bursts.

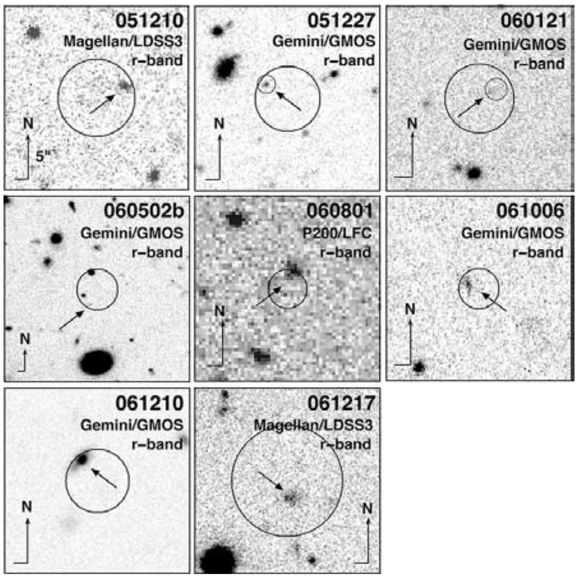


Figure 4. *Images from Gemini and other facilities of several faint short-hard GRB hosts that reside at higher redshifts ($z \sim 0.5-1.2$) than previously expected. The large circles mark the x-ray positions of the afterglows (<5-arcsecond radius). Arrows mark the positions of the hosts. The higher redshifts lead to a wide range in energy release for short GRBs and to a typical progenitor age of about four billion years.*

Building on this progress, we have recently demonstrated the existence of high-redshift short gamma-ray bursts with greater energy release than previously suspected, placing at least half of all of these short events in the neighborhood of the long gamma-ray bursts (Figure 4). One of the crucial implications of this work (carried out primarily with the Gemini telescopes, with additional contributions from Magellan and Keck) is that the typical age of short gamma-ray burst progenitors is 4 billion years, but with a large spread, providing constraint for models of compact object mergers. Continued studies of the energetics and environments of short gamma-ray bursts will shed light on their progenitor systems, and in turn, on the possibility of their detection as gravitational wave sources.

A. M. Soderberg and E. Berger are part of a large collaboration that uses the Gemini telescopes to study both long- and short-duration GRBs. Other team members are D. B. Fox, P. A. Price, B. P. Schmidt, A. Cucchiara, S. B. Cenko, S. R. Kulkarni, D. A. Frail, B. E. Penprase, A. Rau, E. Ofek, S. J. Bell, P. B. Cameron, L. L. Cowie, M. A. Dopita, I. Hook, B. A. Peterson, Ph. Podsiadlowski, K. C. Roth, R. E. Rutledge, S. S. Shepard, A. Songaila, A. Gal-Yam, and E. Nakar.

For further information see:

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By Katherine Roth

Rapid Target of Opportunity Mode at Gemini

The Target of Opportunity (ToO) mode at Gemini Observatory enables observations of astronomical phenomena whose exact timing and/or location cannot be predicted, but which can be anticipated to occur at some time in the near future. Historically, ToO observations have been initiated at telescopes though various channels, such as phone calls requesting favors of classical observers, or official requests for Director's Discretionary (DD) time made to observatory directors. Generally, the turnaround intervals (from detection of the interesting event to acquisition of the scientific data) for ToOs requested through these manual channels have varied from about an hour to several days. Gemini Observatory supports requests for DD observations, but also offers two formal ToO modes (Rapid and Standard) which are requested when an investigator submits a proposal during the Phase I process.

The Rapid ToO mode is intended to allow observations to commence as soon as possible after an investigator decides that an astronomical event meeting the program criteria has occurred. The goal is for a Rapid ToO spectroscopic observation to commence within 15 minutes of the trigger being received at Gemini, with significantly shorter response times for imaging since no acquisition is required.

The effort to support Rapid ToOs at Gemini Observatory began early in 2004, with the full implementation becoming available within the Phase II Observing Tool in February 2005. The Gemini North telescope began operating a multi-instrument queue mode beginning early in 2005, with Gemini South following suit soon afterward. Each Gemini telescope is therefore available for Rapid ToO observations with any instrument currently mounted on the telescope on any science night that is scheduled for queue observing. The only nights that are not available for Rapid ToO observing are the classical nights and those nights scheduled for observatory engineering or instrument commissioning. For example, in the current semester (2007A) at Gemini North, we expect to have approximately 149 nights available for potential Rapid ToO observing, excluding only the 20 scheduled classical nights, the nine nights scheduled for telescope maintenance and engineering in late March, and three nights which were required for the final commissioning of the laser guide star system with ALTAIR, NIRI and NIFS.

The Rapid ToO mode at Gemini Observatory was designed specifically to provide support for follow-up observations of Gamma Ray Bursts (GRBs) detected by the Swift satellite which was launched in November 2004.

However, Gemini does not have a policy of automatically observing GRBs. The Rapid ToO observations of these events made are all initiated by investigators in the community who have been awarded time through the regular TAC process. These individual investigators each have their own arrangements to receive notices of Swift GRB detections, through channels such as the GRB Coordinate Network Circulars. Once an investigator receives notice of a GRB detection, that person then decides whether or not they wish to observe that GRB with Gemini. Currently there are approved GRB Rapid ToO programs active at both observatory sites.

There are two methods by which an investigator can activate a rapid ToO trigger for their program. The older method is more manual, requiring interactive access to the Gemini Observatory Phase II Observing Tool in order to activate the trigger. The investigator simply updates the coordinates for the GRB target and guide star in the program template that has previously been defined, sets the observation status of the edited template to "ready," and stores the program back into the Gemini Observatory database. At the moment the program is stored, the Observing Tool recognizes that a Rapid ToO trigger has been activated and immediately alerts the observer on duty by popping up an alert window on their monitor. In fact, this alert window appears on the screen of any computer at Gemini on which an active Observing Tool is connected to the observing database. In practice, this means that most of the science staff of the observatory knows when each ToO is triggered.

As soon as a Rapid ToO trigger has been received by the Observing Tool, the queue observer is expected to immediately interrupt whatever observation is currently underway. The goal is for the System Support Associate to be slewing the telescope to the GRB target position within two minutes after the pop-up window appears, leaving only enough time to stop and read out whatever exposure was being acquired at the time the trigger was received. Typically, the ToO observations can commence as soon as the telescope has slewed to the position of the GRB target and the guide star has been acquired. Because of the ease with which the Gemini telescopes can switch between instruments this holds true even if the previous queue observation was not using the same science instrument as the ToO observation. For imaging, this translates into data collection within five to ten minutes of the Rapid ToO trigger being activated by the program investigator. Spectroscopic triggers require a bit more time to commence since the target must be acquired and placed in the slit of the requested instrument. Spectroscopic triggers of bright GRBs may also utilize the Integral Field Unit available with either GMOS instrument; in this case the acquisition step may be skipped if the GRB coordinates are known to within about an arcsecond.

Recent modifications to the Observing Tool and Observing Database now allow investigators to trigger Rapid ToO observations more automatically, without requiring an investigator to manually access the Observing Tool in order to activate a ToO. Users of this mode employ various software channels to automatically receive GRB notices and select those candidates for which immediate follow-up observations are desired. This software then forwards to Gemini, through the appropriate web socket, a URL string containing target, guide star, and template observation information. Once this data is received by the observing database, a Rapid ToO trigger is automatically activated and observations commence following the same procedures as for manually triggered Rapid ToOs. This new capability, available since 2006, even further reduces the time between the actual detection of the GRB event by the Swift satellite and the receipt of the ToO trigger by the Gemini observer.

Gemini remains dedicated to providing the quickest possible turnaround times to investigators wishing to follow up GRBs, or any other astronomical event that requires immediate response. Owing to our trained multi-instrument queue mode observing staff, the high fraction of queue nights that are all available for Rapid ToO trigger activation, the rapid switching between science instruments, and our Rapid ToO support through the Observing Tool, both Gemini telescopes are well positioned to provide consistent and immediate availability for GRB follow-up observing for many years to come.

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By Jean-René Roy & Scott Fisher

Recent Science Highlights

Dust and Gas Mingle in the Disk of the Herbig Ae star AB Aurigae

Circumstellar disks around young stars contain copious amounts of both gas and dust, so astronomers think that they are likely the sites of planet formation. Recently two teams used different Gemini instruments to study the disk around the Herbig Ae star AB Aurigae.

A team led by Naibi Mariñas (University of Florida) resolved the disk using MICHELLE on Gemini North. The imaging data showed that the disk has a FWHM of approximately 20 astronomical units (AU), with fainter emission detected out to 200-300 AU (Figure 1). Modeling of the thermal emission implies that there are two distinct grain populations in the disk. Large particles with diameters of ~1 micron dominate the inner 100 AU of the disk, while smaller grains account for the bulk of emission at larger distances from the star. The results are consistent with a model of a nearly face-on, flared disk with an illuminated inner rim.

A complementary study led by Martin Bitner (University of Texas) used the high resolution spectrograph TEXES on Gemini North to make the first definite detection of molecular hydrogen gas in the AB Aurigae disk. Using TEXES unique high-spectral resolution modes (R › 80,000) the team detected emission in the S(1), S(2), and S(4) lines (Figure 2). Based on the 8.5 km/sec FWHM of the S(2) line, Bitner places the location of the H_2 emission near 18 AU from the star. This provides an intriguing synergy with the Mariñas result mentioned above, and it implies that the gas and dust in the AB Aurigae disk mingle freely near the central star. The TEXES data also provides a tight constraint on the temperature and mass of the emitting gas. The team calculates $T = 670 \pm 40$ K and a mass of $M = 0.52$ +- 0.15 $M_\oplus$ for the H_2 in the near vicinity of the star.

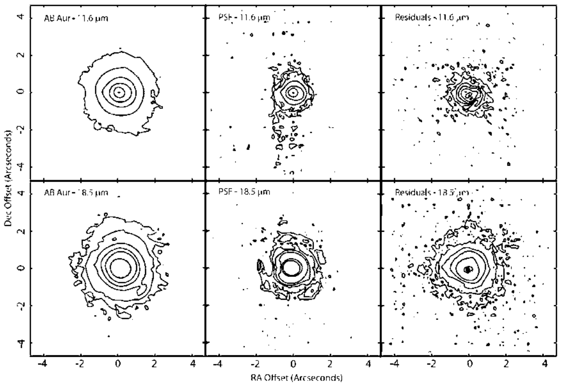

Figure 1. *Images of AB Aurigae and a nearby point-spread-function (PSF) star at 11.6 and 18.2 microns. The residual emission is seen by subtracting a scaled PSF star from the target data. Emission is detected out to ~ 2 arcseconds at 18.2 microns, which corresponds to ~300 AU at the distance of AB Aurigae.*

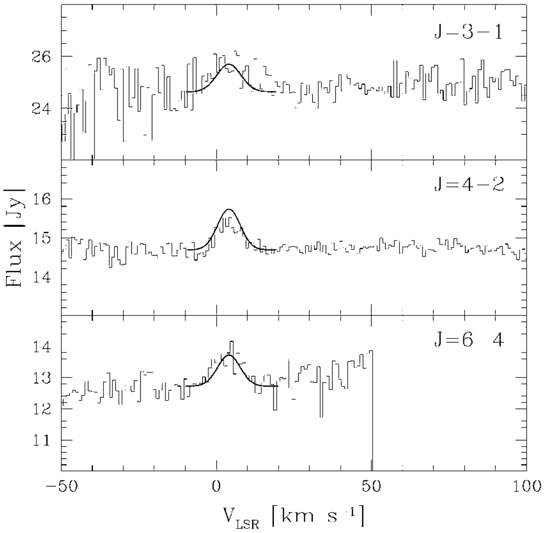

Figure 2. *Detection of three pure rotational H_2 lines in the AB Aurigae disk. The best-fit model with T = 670 K and H_2 mass = 0.52 $M_\oplus$ is overplotted on each line.*

Strength of C IV Absorption Lines Point to Very Early Heavy Element Enrichment in the Universe

Robert A. Simcoe of the MIT-Kavli Center for Astrophysics and Space Research has found new evidence indicating intensive enrichment of the intergalactic gas occurring less than a billion years after the Big Bang. Simcoe has found a relatively high level of carbon IV in the spectrum of two very distant quasars. Looking at the behavior of the abundance of carbon ions along the line of sight to distant quasars as a function of distance is like drilling deeper into the early universe.

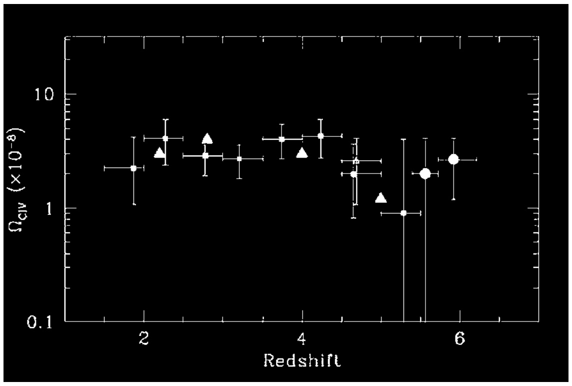

Figure 3.
Evolution of the C IV ion abundance as a function of redshift, expressed as the C IV contribution to the closing density of the universe. The new GNIRS points form Simcoe are shown as round dots.

What is surprising in these new measurements is that we do not see a downturn in the integrated C IV abundance as we observe ever closer to the Big Bang. Instead, the new observations show that the level of C IV remains surprisingly constant as far back as redshift z ~ 6. In fact, the trend of constant mass density of C IV atoms observed at z ~ 2-5 appears to continue to z ~ 6, the highest redshifts at which the C IV abundance has now been measured (Figure 3).

Simcoe conducted infrared spectroscopic observations of the C IV spectral regions in the high redshift QSOs SDSS1306+0356 (z_{em} = 6.002) and SDSS1030+0524 (z_{em} = 6.272) using the Gemini Near InfraRed Spectrograph (GNIRS) at Gemini South. An infrared spectrograph is required to observe the intergalactic C IV absorption line at z › 5 because, at these extreme distances, the lines are redshifted from the optical into the infrared spectral domain.

The apparent constant "floor" of C IV throughout most of the history of the universe is surprising. Computer simulations predict that the mass density of C IV should start to turn down at z ~ 6, in contrast to what Simcoe observes. The galaxies that formed at z ~ 6-10 may have been among the very first to produce the heavy elements found in the intergalactic medium at lower redshift. The evidence from C IV measurements at z ~ 6 indicate that they did so extremely vigorously and efficiently.

Massive Galaxy Cluster Revealed in GDDS Images

Galaxy clusters that existed when the universe was less than half its current age are rare. Finding them is difficult, but crucial to our understanding of the growth of large-scale structure and to help probe the underlying existence of dark matter and dark energy.

Deep HST and Spitzer images of a massive, passively evolving, galaxy identified in the Gemini Deep Deep Survey (GDDS) have led to the detection of a very compact cluster of massive red galaxies around the galaxy GDDS-12-5869, at a redshift of z = 1.51 (corresponding to about ten billion light-years away). Ultra-deep spectroscopy with Gemini coupled with deep multi-band photometry provided a firm redshift for this group of galaxies which at this redshift is well beyond the reach of most spectroscopic studies.

HST imaging with the infrared-sensitive NICMOS camera reveals a large number of faint galaxies in the vicinity of the central galaxies clustering around GDDS-12-5869 (Figure 4). It is plausible that several of the central galaxies will merge in less than a billion years, such that by redshift z = 0.5 this group will look like a typical bright galaxy cluster.

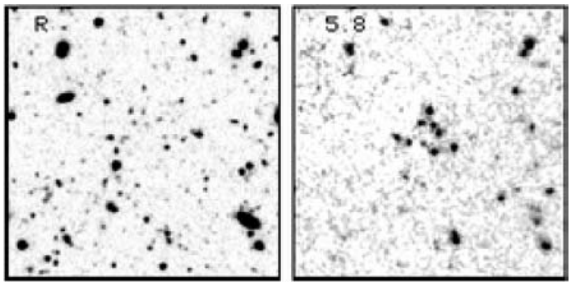

Figure 4.
R-band (left) and IRAC channel 3 (right) images of a 2 × 2 arcsecond area around GDDS-12-5869. The concentration of red galaxies is most evident in IRAC channel 3 (5.8 microns) as the foreground of galaxies at z ‹ 1 drop out.

Surprising Featherweight Celestial Pair Characterized by GNIRS

Étienne Artigau, of the Gemini Observatory, and a team that includes astronomers from the Université de Montréal and the Canada-France-Hawai'i Telescope, have serendipitously discovered a record-breaking pair of low-mass stars with an extreme orbital separation. The petite

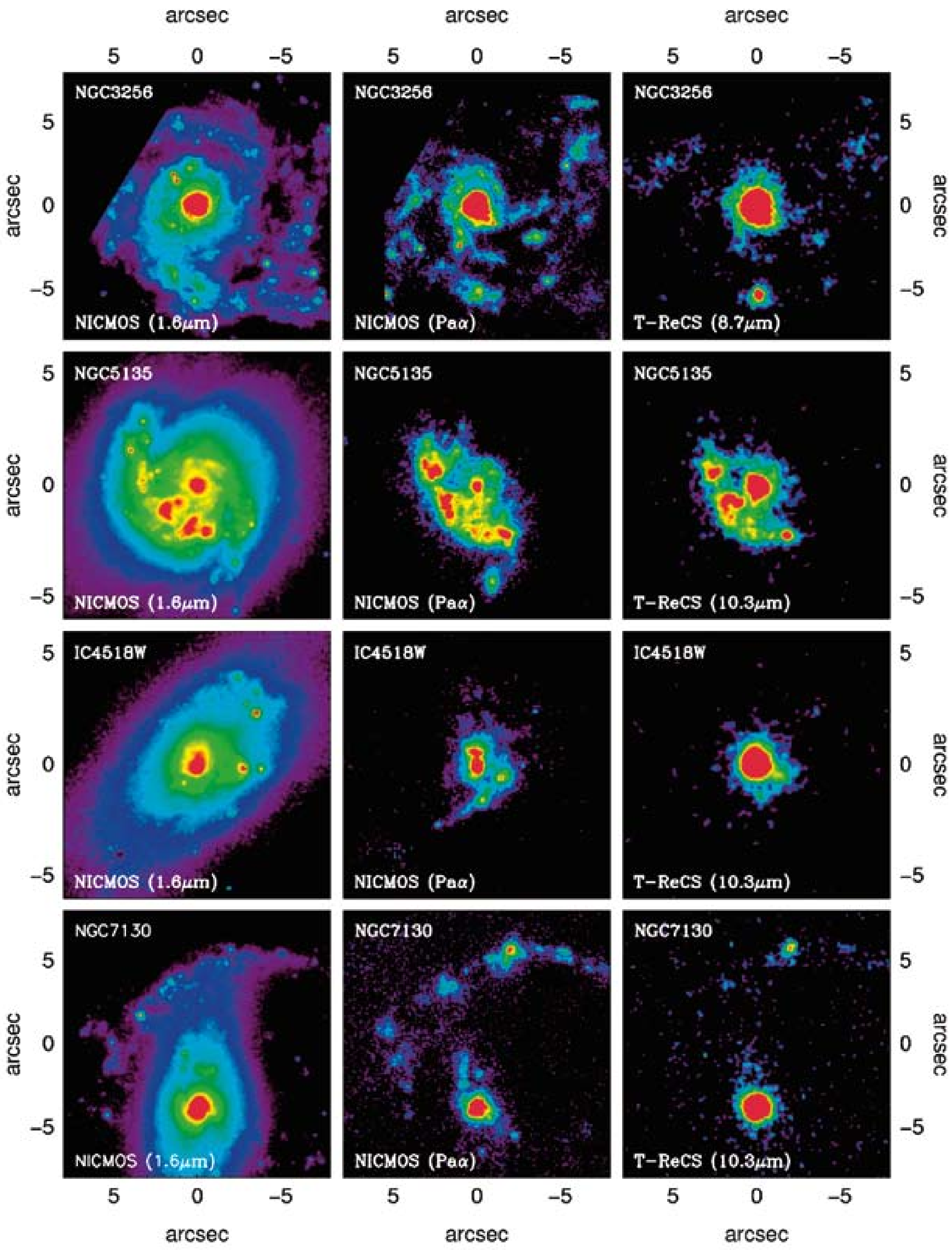

Figure 5.
Left panels: Near-infrared continuum images from HST/NICMOS. Middle panels: Paschen-alpha images from HST/NICMOS. Right panels: T-ReCS 10.5-micron images. All images have the same field of view. North is up and east is left for all panels.

objects, each of which has a mass less than 100 times that of Jupiter, are separated by more than 5,000 astronomical units (the average distance between Earth and the Sun), a value that breaks the previous record by a factor of three and leaves the duration of their future together uncertain. The celestial duo is tethered by a weak gravitational link that results in an orbital dance so slow that it takes about 500,000 years to complete a single revolution.

The characterization of the system was made using GNIRS on the Gemini South telescope in conjunction with earlier discovery and confirmation observations made at the Cerro Tololo Inter-American Observatory 1.5-meter telescope operated by the Small and Moderate

Aperture Research Telescope System (SMARTS). In addition, the studies relied on archival data from the 2-Micron All-Sky Survey (2MASS) and the Digitized Sky Survey (DSS).

The discovery came as a surprise because the only other known binaries that have similar or greater separations are significantly more massive systems. Since mass determines how strongly objects pull on each other, the more massive stars in the known systems have strong gravitational attractions. On the other hand, the stars in the newly discovered system have extremely low masses.

The data revealed that both stars are likely to be red dwarfs (M dwarfs) with temperatures around 2200 K and a probable age of about a billion years. Interestingly, the pair is seen juxtaposed against a group of stars called the Tucana/Horologium (TH) association. This presents the tantalizing possibility that the binary is part of the group. If true, then the stars would be significantly younger than the one-billion-year estimate and could be categorized as even less-massive brown dwarfs. However, if they are not members of the TH association, these stars would indeed be more-massive red dwarfs and could stay embraced for perhaps a billion years or more.

Resolving the Hearts of Luminous Infrared Galaxies

To investigate the morphology of nearby Luminous InfraRed Galaxies (LIRGs) in the mid-infrared, an international team of researchers led by Almudena Alonso-Herrero (Departamento de Astrofisica Molecular e Infrarroja, DAMIR, Instituto de Estructura de la Materia (IEM), CSIC, Spain), observed a sample of four objects using T-ReCS on Gemini South. While small, the sample is significant since the observed galaxies are nearby LIRGs that are analogous to others seen at redshift z = 1. The distant galaxies are known to be major contributors to the obscured star formation rate (SFR) at that epoch.

The T-ReCS images uncovered an intriguing correlation between the mid- and near-infrared emission in the nuclear regions of these energetic galaxies. They reveal that, at high spatial resolution, the morphology of the mid-infrared emission (created primarily by thermal emission from warm dust) is strikingly similar to the Paschen-alpha emission of ionized gas seen in near-infrared observations. As seen in Figure 5 (previous page), both the mid- and near-infrared emissions from the LIRGs generally consist of bright nuclear emission, multiple circumnuclear and/or extranuclear H II regions, and diffuse emission. This is in contrast to the smoother and more extended stellar emission which is traced by the near-infrared continuum images.

These new data lead to the conclusion that calibration of the SFR for distant galaxies should be based on the integrated mid-infrared flux, not that of the H II regions alone. This study also illustrates the need for high spatial resolution imaging, since it is often necessary to separate emission components to arrive at a more precise understanding of the underlying physical processes.

Mid-Infrared Polarimetry Uncovers an AGN Torus-Host Galaxy Connection

A team led by Chris Packham of the University of Florida used the recently commissioned polarimetry observing mode of MICHELLE to reveal a long sought-after connection between a host galaxy and its active galactic nucleus (AGN) torus in the archetypal Seyfert galaxy NGC 1068. The team chose NGC 1068 as a target for several reasons: 1) It is a relatively nearby galaxy which exploits the high-spatial resolution of MICHELLE on Gemini (one arcsecond = 72 parsecs); 2) it is a bright target with a high surface brightness in the mid-infrared; and 3) it can be used as a standard for comparison as it was previously observed with 3- to 4-meter-class telescopes.

Using the first polarimetry data obtained with MICHELLE, the team found that the degree of polarization and the position angle of the polarization vectors are consistent

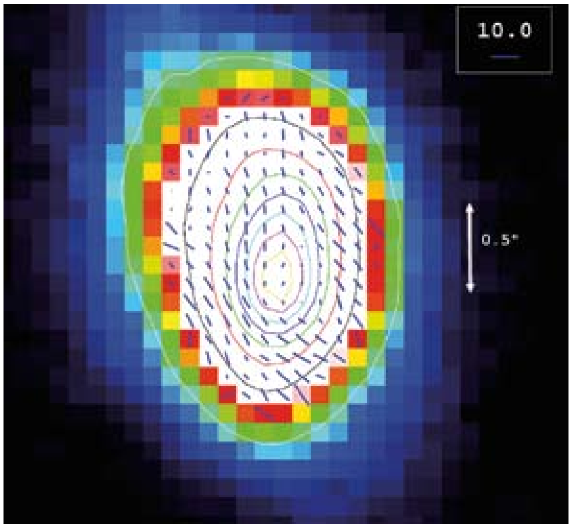

Figure 6.
Total flux image of the nuclear region of NGC 1068 (color) with polarization vectors overlaid. The length of each vector is proportional to the degree of polarization and the angle shows the position angle of polarization. Each pixel is 0.1 arcsecond; the 10% polarization scale bar is shown in the upper right. North is up, east is left in this image.

with three dominant polarizing mechanisms. North of the nucleus there is a region where dust grains are aligned within the narrow-line region of the Seyfert ionization cone. South, east, and west of the nucleus are regions where dust is being channeled toward the engine powering the central AGN (and presumably onto the central torus). And lastly, there is a central minimum of polarization consistent with a compact torus with a diameter no larger than about 22 parsecs (about 72 light-years). These observations provide continuity between the geometrically thick nuclear torus and the larger nuclear environment of the host galaxy.

Figure 6 shows the total flux image (color-scale and contours) with the polarization vectors overlaid. Integrating the degree of polarization and position angle within this region gives a total degree of polarization of ~2.5% at a position angle of about 27 degrees, values that are consistent with previous observations. However, it is the high-spatial resolution of the data that is most exciting as it allowed the team to see the three distinct regions of polarization. Perhaps most intriguing of these is the central minimum of polarization which likely reveals the true position of the central torus and limits its size to about 22 parsecs. This size limit is about a factor of five smaller than previously published values.

Are Short Gamma-ray Bursts Playing Tricks?

Analysis of nine recent short gamma ray bursts (GRBs) observed with the Gemini and Magellan observatories, along with the Hubble Space Telescope, reveals that the progenitors of these GRBs may reside in faint host galaxies at redshifts as great as $z = 1.1$ (about 8.5 billion light-years away), (Figure 7). The host galaxies (fainter than $R \sim 23$ magnitude) of these short GRBs can be as much as 100 times fainter than those of previously known short GRBs (brighter than a magnitude of $R \sim 22$). The hosts are starkly different from the first few short GRB hosts observed, which were brighter and closer (at $z < 0.5$, about five billion light-years away), (Figure 8).

Although initial observations suggested that short GRBs occur at significantly lower redshifts than long GRBs (for which $z \sim 3$ (about 13 billion light-years away), the recent observations by a team led by Edo Berger (Observatories of the Carnegie Institution of Washington), establishes for the first time that about a third or more of all short GRBs originate at high redshift (at greater distances and earlier in the history of the universe). Additionally, the new observations show that some bursts produce between 10^{50}-10^{53} ergs, a value that is at least two orders of magnitude larger than for the low-redshift short bursts. The behavior of low-redshift GRBs has been used to argue for long progenitor lifetimes, that is, host and constituents of age greater than four billion years, and against a substantial population of short GRBs at high redshift.

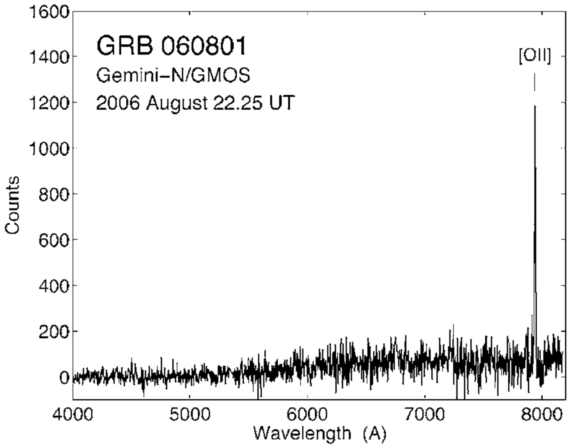

Figure 7. *GMOS-North spectrum of the highest redshift short GRB known.*

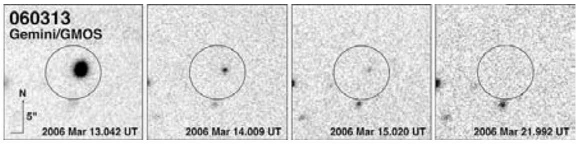

Figure 8. *No host galaxy is visible at the afterglow position (March 21) as monitored by GMOS-North in the r-band over several days.*

The new observations show that short GRBs are not necessarily associated with progenitors that are several billion years old and that their ages may be shorter than previously thought. Furthermore, the existence of a population of short GRBs at high redshifts implies that the energy release of some events can be larger than previously suspected.

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by Dennis Crabtree, Paul Hirst,
Kathleen Labrie & Kim Gillies

Gemini's Dataflow Project

Figure 1. *Dataflow Working Group during presentations in Hilo in October 2006.*

Previous generations of telescopes focused on reliably producing quality raw data for their observers. The observers would typically take the data home on magnetic tape, reduce it (or have graduate students reduce it), analyze it, and produce a publication. They may even have written their own software to do the data reduction. The availability of data reduction packages such as IRAF, or tool boxes such as IDL, reduced the burden of data reduction, but the observer still needed to reduce the data. The Space Telescope Science Institute (STScI) advanced this process for data from the Hubble Space Telescope (HST) by producing reduced data for their users utilizing automated reduction pipelines. Not only did STScI deliver reduced data to people, they also made the processing software available so investigators could tweak the reduction or use more current calibration files to improve the quality of the data reduction.

Numerous other observatories, including many ground-based facilities, now make reduced data available to their science community. While in some cases the processing may not be intended to be science-quality, or may be limited to a subset of instruments or observing modes, it is entirely possible that we could create a system to automatically reduce Gemini data in such a way as to reduce the effort needed by our users (or their graduate students) to extract science results from their data.

The availability of pipeline-reduced data from HST and other telescopes has whetted researchers' appetites for automatically reduced data. Science that once took months of toil now may be only a few mouse clicks away.

In addition, the advent of automatic pipeline data reduction continues to expand the frontiers of how astronomy research is done. In the early days, an observer or principal investigator (PI) was the only person who would make use of their data. Then came the era of the raw data archives, where the raw data from all observations became public after a certain amount of time and thus available to anyone in the community to seek out and use. The problem became that one could find some potentially interesting data in an archive and spend months reducing it, only to find that your source or spectral line of interest wasn't actually detected. The current era is one where reduced data archives can let you see at a glance whether the data are interesting to you. This however, creates a further problem: there's so much public data out there, how do astronomers find data that matches what they're interested in? It's not practical to go to and search through the archive site for every telescope that might possibly have data that interests you. Enter the "Virtual Observatories," which exist to provide a single point of access to the reduced data archives of all the telescopes that have made their observational data products available.

The Gemini Dataflow Project

The context and initiative for the Gemini Dataflow Project stems from a declaration made by the Gemini Board during its September 2004 Oxford retreat:

"The Board reiterates its support of enhanced data reduction pipeline processing and delivery of processed data to the user. Further, the Board considers it an appropriate goal to set for each instrument that data will be processed to the degree that all impediments to further reduction and analysis have been removed before data are provided to the user. The Board recognizes that this goal requires the definition of a processing procedure that is specific to each instrument, both those existing and in-progress, and urges the GSC to take this consideration up as soon as is possible. The Board also charges the Observatory to plan for and to cost data reduction capability that will provide sufficiently processed data to the user and to the Gemini Science Archive."

The Gemini Observatory aspires to create a system whereby all Gemini science data is provided to the scientific community in such a manner and form as to enable scientific exploitation of the data in as simple and expedient a manner as possible. Generally, this means that (to the extent possible) the data are processed to a degree that accurately represents the properties of the target being observed and are free of instrumental signatures.

The Dataflow Project involves Gemini staff from both the Science and Engineering groups, with some other effort likely to be contracted out. One of us (PH) was hired in September 2006 as Project Scientist for the Dataflow Project. The Project Manager will come from the Engineering group.

In order to receive advice from experts within the Gemini community, we established the Gemini Data Reduction Working Group (DRWG). The members of the DRWG include:

- Tom Matheson (Chair) – NOAO/NGSC
- Mark Swinbank (Durham University)
- Dave Harker, (UC San Diego)
- Tim Davidge (HIA/CGO Canada)
- John Rayner, (UH/IfA)
- Martino Romaniello (ESO)

The expertise of the DRWG spans the very diverse suite of Gemini instrumentation, including optical multi-object spectroscopy, near-infrared instruments, mid-infrared capabilities, integral-field instrumentation, and adaptive optics.

The DRWG met in Hilo on October 11-12, 2006, and received several presentations from Gemini staff members. They included results of an internal review of dataflow and data products within Gemini, a summary of the efforts of the data reduction group, the progress in the work to migrate Gemini's data reduction software from IRAF to PyRAF and the ESO perspective on quality assessment and pipeline data reduction.

The DRWG members also shared their perspectives on the challenges that Gemini faces in this project and some of the lessons they have learned in dealing with particular types of data. The committee members then met in closed session and quickly focused in on their key recommendations:

- the first priority is a complete suite of reduction tools with clear instruction on their use;

- Gemini Instrument Scientists and skilled users should work together to develop tools/set goals for the pipeline;

- the pipeline should also provide data quality assessment for the observatory;

- removal of the instrumental signature is the core requirement of the pipeline.

Data Reduction Tools

The committee felt strongly that current and past PIs need a full set of data reduction tools now, so

Figure 2.
The Gemini Data Reduction Working Group in its entirety (with additional staff participants) during a break in the October 2006 meeting in Hilo.

providing a complete suite of such software for the various instruments and modes should be Gemini's first priority.

The committee recognized that the development of a successful data reduction pipeline will rely on the creation of tools that perform the basic data reduction steps. The current Gemini IRAF package is fairly complete for a subset of instrument modes, but tools for many modes plus those for the new instruments will need to be developed. Current tools will have to be modified to work with a reduction pipeline and new tasks designed with this requirement in mind.

The development of reduction tools (and modification of current tools) involves the transition of Gemini data reduction software from IRAF to PyRAF. PyRAF is a command language for running IRAF tasks that is based on the Python scripting language. It gives users the ability to run IRAF tasks in an environment that has all the power and flexibility of Python. PyRAF allows for much more robust scripting including error handling and other features. Before support for IRAF is dropped in favor of PyRAF, however, we will work to ensure that PyRAF and the Gemini PyRAF software are as simple as possible to install and use. The PyRAF interface has been written such that an IRAF user will have little problem adapting to PyRAF.

The transition work is well underway, with a significant portion of the current Gemini package now compatible with both IRAF and PyRAF. New development projects are being designed to make the most of the new capabilities that PyRAF will offer.

PyRAF is supported by STScI and Gemini currently has a contract with the institute for joint development of PyRAF tailored to Gemini's needs.

Data Reduction Pipeline

Data reduction pipelines can not only produce processed data for PIs and archive users, but can also be used at the telescope to provide feedback to the user about data quality. Pipelines will allow for improved assessment of data quality and automated monitoring of instrument health. The same software and reduction tools will be used for the data quality assurance pipeline as for the science quality pipeline.

The goal of the science-quality pipelines will be to process data in an automatic way so that it is as close to the final science result as possible. In practice, this will vary depending on the instrument and mode, as well as on practical considerations. This does not mean limiting the goal from the outset. The extent to which data will be processed automatically will be learned during the development of the reduction tools and pipeline. It will no doubt evolve in the future as pipeline development progresses. There are mandatory tasks, however, that are the minimum requirements for the pipeline. Data quality is a top priority and we do not intend to process data beyond the point where we lose confidence in the quality of the processed data. The DRWG recommended that the minimum processing requirements for all modes of each instrument should be the highest priority at the outset.

There is a significant caveat with the data reduction pipelines: a common practice among observatories with automatic data reduction pipelines is to not guarantee the science quality of the output. This means that there is still some onus on the PIs or authors to check their data, rather than blindly take it at face value. While the Gemini pipelines will aspire to produce publication-quality output, there will be no guarantee.

Who's Who in the Dataflow Project

Paul Hirst *Project Scientist*				Kim Gillies *Dataflow engineering lead*
Claudia Winge *Deputy Project Scientist*	Kathleen Labrie *Data Reduction Software Lead* James Turner *Data Reduction Software Scientist* *Data Process Developers:* Jen Holt Craig Allen New Position 1 New Position 2	(Paul Hirst) *GSA scientist*	*Data Analysis Specialists:* Jorge Garcia Yus Matthew Dillman Andre Wong Sergio Fernandez-Acosta Pablo Candia Anil Dosaj (arrives May)	High Level Software Development Group

The dataflow project is a joint venture between the science and engineering groups at Gemini. The main people involved are shown in the table on previous page.

A Look Ahead and New People

We are in the early stages of the Dataflow Project and are still developing the project plan and team. Besides the hiring of Paul Hirst as Project Scientist in September 2006, we have hired James Turner as an Assistant Scientist for Dataflow (based at Gemini South) and we are in the process of hiring two Data Process Developers to work with the two already on staff. In addition, Anil Dosaj will fill the Data Analysis Specialist position at Gemini North in May 2007.

The Dataflow Project will follow a normal project development process, with the next major milestones being completion of the observatory transition to PyRAF and a project Conceptual Design Review. Both are scheduled to take place later this year.

Part of the Dataflow Project includes further development of the Gemini Science Archive (GSA). Work is underway to enhance the GSA's handling of reduced data products and to prepare to incorporate the Science Quality Pipeline into the GSA infrastructure. In addition, the GSA is being prepared to publish public reduced data products to the Virtual Observatory.

Pipeline processing at Gemini will open up new possibilities for science operations and the manner in which we operate. Imagine, for example, a scenario where Gemini receives a trigger on a GRB Target of Opportunity (see article in this issue starting on page 35). Within 20 minutes, Gemini slews to the object and acquires a quick spectrum of the target. The data is processed by the Quality Assurance Pipeline and the system sends an e-mail or text message to the PI with information about the redshift. The PI, who might be sitting in a pub, reads the e-mail on a cell phone or PDA and triggers a suitable followup observation.

Efficient data handling, effective quality assessment tools, data reduction software, the pipeline processing of scientific data, and the availability of processed data through the virtual observatory are all important aspects of Gemini's science operations. The dataflow project will provide each of these over the next few years.

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A Glimpse of the Virtual Gemini Observatory

The Gemini Science Archive is hosted by the Canadian Astrophysics Data Centre (CADC), which hosts archives of several other major observatories, including HST and JCMT. The CADC is also heavily involved in the Canadian Virtual Observatory (CVO) efforts and has published the small amount of reduced data in the GSA to the CVO. This data is almost all GMOS pre-imaging data, which is reduced and uploaded to the GSA by the Gemini Data Analyst Specialists in order to assist PIs with the rapid production of MOS mask designs.

Using the Octet tool running inside a regular Java-enabled browser, it is simple and easy to search for objects that have been observed by several facilities with data published to the system. For example, one can cross-match the JCMT SCUBA catalogue with the data from GMOS to find all objects for which it would be simple to calculate the submillimeter-to-optical-flux ratio.

by Peter Michaud and François Rigaut

The Science of Seeing: An International Symposium in Hawai'i

Figure 1. *Participants in the Symposium on Seeing held on the Big Island in March 2007.*

A milestone was reached on March 20-22, 2007, when close to a hundred atmospheric scientists, instrumentalists, astronomers, meteorologists and others interested in the intersection of astronomy and our atmosphere came together on the Big Island of Hawai'i. Gathering these two "upward-looking" disciplines in the *Symposium on Seeing* was viewed by many participants as a long-overdue development. The presentations and informal discussions on topics ranging from how to monitor atmospheric seeing to the forecasting models used to predict seeing over astronomical observatories will undoubtedly lead to many new collaborations that will significantly advance both sciences.

The symposium was sponsored in part by the Gemini and W.M. Keck observatories and organized by the Mauna Kea Weather Center (MKWC) led by Steve Businger, (and who was greatly assisted by Research Meteorologist Tiziana Cherubini in facilitating this meeting). The U.S. National Science Foundation provided the core funding through the Divisions of Astronomical and Atmospheric Sciences.

"Over the past 20 years, astronomers have realized the importance of understanding how the turbulent characteristics of the Earth's atmosphere affect the quality of their observations. The atmospheric scientists are poised to help them," said Craig Foltz, Program Director of the Division of Astronomical Sciences at the National Science Foundation, who participated in the meeting held at the Keauhou Beach Resort just south of Kona, Hawai'i. "The enthusiastic confluence of the two groups seen at this meeting gives us hope that we are on the verge of realizing immense gains in telescope performance by measuring, predicting, and correcting for the blurring effects of the atmosphere. It is an exciting time to be an astronomer."

Over the course of the three-day meeting, nearly 50 oral presentations and more than 20 posters shared research on topics ranging from the instruments used to monitor and measure atmospheric turbulence to how this information can be applied in practical forecasts for astronomical observations. "It is very exciting as a meteorologist to witness the growing ability of the observatories to use forecast atmospheric conditions to adjust their observing strategies and maximize the science that can be achieved," said Steve Businger, who spearheaded the initiative for this symposium.

With the advent of more and more observatories adopting the queue scheduling mode of operations (like Gemini), the advantage of understanding and forecasting astronomical seeing has a profound impact on operational efficiencies. Furthermore, with advanced adaptive optics (AO) systems such as multi-conjugate AO combined with laser guide stars (LGSs), the need to understand and characterize the four-dimensional aspects of atmospheric turbulence has become critically important to the design and implementation of core observatory instrumentation.

The meeting was organized into five primary sessions:

1) instrumentation and observations to quantify the magnitude and distribution of atmospheric optical turbulence;
2) adaptive optics, interferometry and other approaches to mitigate atmospheric optical turbulence;
3) approaches for modeling atmospheric optical turbulence;
4) applications of optical turbulence observations and custom forecasting in telescope astronomy; and
5) open discussion.

Each session had many highlights and prompted good discussions. As in any symposium of this sort, the meeting went well beyond the constraints of formal presentations. The following attempts to capture some of the meeting's high-level impact.

Measuring and Monitoring Astronomical Seeing

The sheer magnitude and variety of techniques for detecting and quantifying astronomical seeing was clearly a theme that emerged from the meeting. From the usual DIMM (Differential Image Motion Monitor) and SCIDAR (SCIntillation Detection And Ranging) to MASS (Multi-Aperture Scintillation Sensor) instruments and even a lunar limb scintillation detector, the field of seeing instrumentation is exploding and developing rapidly. Throughout these discussions, a consensus was building regarding what was being measured and how these data are calibrated throughout this relatively new field of study.

Results on new techniques like SLODAR (Slope Detection and Ranging) or LOLAS (LOw LAyer Scidar) were also reported. These are used to characterize the low-altitude turbulence in the frame of Ground Layer AO studies (one such study is currently ongoing on Mauna Kea). Additionally, new concepts were presented, such as an instrument using the lunar limb to measure the C_n^2 profile, or the FADE instrument, used to measure the atmospheric time constant.

The subjects of accuracy, precision and calibration of all these monitoring instruments was also central to the discussions. Teams from Canarias (Spain), Chile (Paranal, CTIO), Mexico (San Pedro Martyr), and the Thirty Meter Telescope (TMT) group based in Pasadena presented extensive cross-comparison studies.

The Missing Link Between Astronomy and Meteorology

Meteorologists with the Mauna Kea Weather Center had a clearly central role and reported on atmospheric parameters forecasting, citing tools such as the Mesoscale atmospheric circulation model version 5 (MM5) which is run on Subaru's supercomputer. As an example, MKWC issues a daily five-day forecast of many parameters relevant to astronomical observations. These include cloud cover, fog/precipitation, temperature, wind speed and direction, and even seeing and the C_n^2 profile. Similar modeling and studies are done for Haleakala on Maui. These semi-local models (e.g. for the overall summit of a mountain) use meteorological data obtained from meteorological balloon launches or satellite data as input. Steven Businger, from the MKWC, reported on COSMIC, a space-based GPS system that can provide key data to derive local C_n^2 profiles and allow remote characterization of random sites worldwide.

Obviously every astronomical site is unique, and the influences that create astronomical seeing variations are as diverse as the sites themselves. The need for understanding these differences for existing and planned sites was stressed from many points of view, ranging from the standardization of site surveys for the TMT, to how variations occur from one site to another, even on the same mountain. Several speakers reported on "meso-scale models." These are basically meteorological models similar to MM5 or Meso-Nh, but run on a much finer grid that allows the determination of how the turbulence is affected by orographic conditions such as the summit of a mountain.

The Rubber Hits the Road: Modeling and Forecasting for Astronomy

The ultimate goal of the work presented in this meeting is to come to a better understanding of the atmospheric turbulence that impacts astronomical seeing and use it to improve forecasts. In turn, this facilitates better planning and execution of astronomical observations.

Atmospheric turbulence, and seeing in particular, are of prime importance to today's telescopes. It is also an essential input into the design of the AO systems that will mitigate the seeing's effect. Such systems, like the soon-to-come Multi-Conjugate AO and Ground Layer AO (MCAO and GLAO), were discussed. System design and preliminary results were reported by teams from the European Southern Observatory (ESO), Gemini Observatory and the Multi-Mirror Telescope.

For those interested in obtaining more information, the symposium program and a copy of the presentations are available at:
http://mkwc.ifa.hawaii.edu/symposium/program/

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By Michael Sheehan

Earthquake Recovery & Workshop

Just after 7:00 a.m. on October 15, 2006, a strong earthquake occurred about ten miles northwest of Kailua-Kona, Hawai'i. It registered at magnitude 6.7, and caused power and communications outages as well as a significant amount of damage to structures in the Kona and Waimea areas.

At Mauna Kea, Gemini Astronomer Tom Geballe and System Support Associate Simon Chan had shut the telescope down and had just arrived at Hale Pohaku when the earthquake occurred. They called Gemini North Site Manager Steve Hardash to update him and report that power was out at Hale Pohaku. Geballe and Chan then returned to the summit to switch to generator power, restore UPS power and check for proper operation of the instrument cooling systems. They also did a quick inspection of the site facilities for gross damage. None was found.

Later that day, a more detailed inspection by Steve Hardash and Senior Instrumentation Engineer John White revealed that the telescope had shifted on its azimuth and elevation bearings, even though the telescope's hydrostatic bearing system was off, the bearings were dry and the brakes were engaged. The evidence for this was a bent overspeed tachometer wheel connected to the telescope mount that rides over the outside radius of the track. A further description of this motion was provided by azimuth and elevation encoder data logged and archived during the event. Approximately +/- 12 millimeters of tangential telescope to track relative motion was measured for both axes. The enclosure bogies also showed signs of large motion, with significant marks where the lateral guide rollers had scraped the side of the bogie track. The telescope floor was littered with small pieces of insulation below the dome crane, indicating that the crane trolley also experienced large motion.

By the end of the day, Hawaiian Electric Power Company (HELCO) had restored power, the telescope cooling water systems were running normally, computer systems were up, and communications were operational. In Chile and Hilo our observatory managers began preparing a recovery plan.

Gemini Earthquake Recovery

The return to normal science operations at Gemini consisted of a thorough set of detailed inspections and tests for all telescope and summit facility systems. Major work in the first week consisted of realigning the telescope hydrostatic bearings, realignment of the azimuth tape encoder scanners, repair of an azimuth wrap limit switch, and repair of dome pintle screws and lateral guide rollers. By day six, we felt ready for on-sky tests. Unfortunately, the secondary mirror system (M2) would not initialize consistently or properly. Changes in telescope elevation angle would cause the mirror to lose position. After several days of troubleshooting the M2 mirror system on the telescope, it was apparent that no more could be done until the unit was off the telescope and in the lab. There, close inspection revealed that one of the three Zerodur® rods, supporting the M2 position sensors had broken. In consultation with the rod manufacturer and the contractor that supplied the mechanism, we decided to bond the rod back together with an appropriate adhesive. Once repaired, the mechanism was checked in the lab for solid performance while initializing and chopping, and then re-installed on the telescope. Successful engineering checks were completed during our first night back on the sky. In all, Gemini North lost 26 nights as a result of the earthquake. Our staff was kept informed by daily coordination meetings, and our user community was kept up to date in a timely manner with a web-based regular report of activities, issues and progress.

Figure 1.
The Zerodur® rod broken as a result of the earthquake.

Mauna Kea Observatories Earthquake Workshop

On March 23, 2007, representatives from all of the Mauna Kea Observatories (MKO) met in Kona for what was called the MKO Earthquake Workshop, to review the events that occurred during and after this earthquake. The workshop was also attended by members of other telescope groups with projects in various stages of design and development. The entire day was devoted to sharing technical, managerial and historical information related to the experiences the observatories had while dealing with and recovering from this event. Each of the observatory representatives had the opportunity to present their own versions of response, recovery and lessons learned.

Engineers from Gemini made presentations on the following topics: 1) the seismic design process and how it was applied to the Gemini telescope design; 2) the initial response to the earthquake; 3) the methodical inspections, tests and performance verification for all systems; 4) detailed descriptions about our telescope bearing systems realignment; 5) the M2 Mirror sensor rod repair; and 6) overall lessons learned.

Representatives from Canada-France-Hawai'i Telescope (CFHT) and the W.M. Keck Observatory began by describing the aftermath in Waimea, where their headquarters buildings suffered extensive damage. The measured ground motion in Waimea was four times more severe than at the summit. At Mauna Kea, the immediate threat was lack of electrical power. With the earthquake occurring on a Sunday morning, few people were at the summit and day crew engineers and technicians were generally off for the day. By noon however, all observatories were up and running to some extent on their own generator backup power and inspection for damage was ongoing. In general, the larger telescopes on the ridges experienced more damage than the smaller telescopes and those in the valley.

CFHT had a broken window in the visitor gallery. The enclosure shifted laterally and damaged some lateral guides. The telescope also shifted, with large excursions on dry bearings–evident by marks on the bearing tracks.

The Keck telescopes and enclosures had similar issues. Enclosure lateral guides saw high loads and became misaligned. The telescope lateral guides also saw high loads and several experienced permanent deformation. The large telescope loads also caused problems with one azimuth track and telescope encoding systems. Damage to the grout under the Keck I azimuth track was extensive and repairs were only recently completed.

At Subaru, the central bearing on the telescope azimuth axis was damaged, with a shift in the position of the bearing structure and damage to its supporting grout layer. Their infrared secondary mirror also sustained damage to its supporting hardware. (The mirror was not on the telescope at the time).

The other telescopes experienced limited damage and were able to recover rather quickly. There were problems at the University of Hawaii 88-inch telescope with its shutter bearings and enclosure encoders. It also had a broken water pipe in the ceiling that caused damage, and there was a crack found in one of the main concrete structural beams that supports the second floor level. It was thought to be an old shrinkage crack and not caused by the stress of the earthquake. The Submillimeter Array experienced chiller leaks on some of its antennas, but was generally free of damage. This was due to the fact that the antennas are designed to be moved to different array pad locations from time to time and the loads due to the moving process are far higher than those experienced during the earthquake. Damage at United Kingdom Infrared Telescope (UKIRT) and the James Clerk Maxwell Telescope (JCMT) was minimal. At UKIRT, the telescope has a mechanical fuse—a shear pin that breaks under moderate seismic load. The entire telescope then floats on bearings during the event and does not see the high loads experienced by restrained structures.

Nasmyth instruments at Keck and Subaru saw a particularly high degree of damage. This included some broken and bent parts, but the main issue was misalignment. The speculation was that these instruments, in contrast to those mounted at the Cassegrain foci, were not designed to handle the high earthquake loads since they reside on the gravity stable Nasmyth platforms.

Throughout the day, common themes emerged. These included the initial limitation of stable back-up electrical power, poor communications with HELCO and prospects of a return to grid power, challenged communications in general between management and staff, and adequate emergency preparedness and safety procedures. The workshop concluded with roundtable discussions about common areas of interest. As lessons learned, each recovery plan that was presented included some description about the lack of emergency preparedness in general and preparations for seismic events in particular. Much of this planning is common to all MKO facilities and it was generally agreed that a certain level of common planning would benefit all. The need for a stronger communication link with HELCO was also stressed, although it was pointed out that the Mauna Kea Support Services Oversight Committee, comprised of members from all of the Mauna Kea Observatories, has been pushing for this for more than a year.

Conclusions

It is apparent that the Mauna Kea summit facilities need to make improvements in emergency preparedness before the next severe seismic event. Safety plans need to be updated to handle issues such as emergency egress and post-event ingress for inspection and damage assessment. At Gemini, we plan to confer with outside experts in seismic safety and risk mitigation to determine areas of the summit and sea level facilities that may need to be strengthened. In particular, the safety restraint system for the primary mirror will be reviewed. Participants to the workshop unanimously agreed that there is a critical need to have a robust and efficient communication system (and back-up) in place to ensure strategic communications between the telescopes, the base facilities, and the families of observatory staff members.

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by Carolyn Collins Petersen

Chad Trujillo: Trailblazing in the Outer Solar System

When it comes to finding dwarf planets and smaller worlds out beyond the orbit of Neptune, Gemini Observatory has a real trailblazer in assistant astronomer Chad Trujillo. He's an engaging individual with a great sense of humor and one of a triumvirate of astronomers busily exploring the outer solar system in search of the smallest planetary prey. Chad is co-discoverer of the dwarf planet Eris (aka "the Tenth Planet") and through his work on sophisticated computer programs, he has studied trans-Neptunian objects as they trace their orbits out beyond the planet Neptune. Along with planetary science colleagues Michael Brown of Caltech and David Rabinowitz of Yale University, Chad also discovered Quaoar, Sedna, and Orcus. According to Rabinowitz, Chad's work has been invaluable in out solar system exploration. "Chad wrote the software that detected some of our most intriguing discoveries, including Sedna," he said, "And, he has made spectral measurements with Gemini that reveal the composition of the dwarf planets. It was his early effort that led to the discovery of the first dwarf planet, Quaoar."

His colleagues and co-workers describe Chad as a great guy, highly professional and intelligent, yet one who can be outrageously funny at times. David Rabinowitz described Chad's role in the naming of some of their joint planetary discoveries as an example of Chad's humor. "Regarding the discovery of 2004 DW (later named Orcus) , which is a dwarf planet with a pluto-like orbit," said David. "Chad suggested that we refer to it as "Pluto's lost twin because people like 'lost-sibling-gets-found' stories." I think it was also his idea to initially nickname the larger-than-Pluto object "Xena" after the Lucy Lawless character, which was a stroke of genius."

Gemini has been Chad's research home on this planet for more than three years. He came to the observatory from California Institute of Technology, where he did his post-doctoral work. He graduated from the University of Hawaii's (UH) Institute for Astronomy with a PhD in 2000. At UH, Chad studied under David Jewitt and met long-time friend and classmate Scott Sheppard, now an astronomer with the Carnegie Institution of Washington. The two are now working together on a project that takes advantage of Chad's programming and skills for finding tiny, distant worlds. According to Scott, they've been quite successful. "Recently, Chad and I have been collaborating on discovering Neptune Trojan asteroids," he said. "We made a bet on how many Neptune Trojans we discovered during an observing run. Chad won and I now owe him $100, which he reminds me about every time we talk."

In 2006, Chad and Scott Sheppard found three new Trojan asteroids while using the Gemini North telescope. The discovery quadrupled the number of known Neptune Trojans, according to Sheppard, and largely due to Chad's inventive work. "Chad is a pretty remarkable person," said Scott. "He is highly intelligent and loves astronomy. His program for finding moving objects was one of the first if its kind and is still one of the few in existence. His programs have found several very interesting solar system objects including the Neptune Trojans and Dwarf Planet-type objects. He is very dedicated to doing things the right way. If something doesn't seem right he will work on it until it is right."

Chad and his co-discoverers are part of an explosion of research interest in the outer solar system, fostered largely by the availability of large infrared-sensitive telescopes like Gemini, coupled with good data analysis. He noted that when he first got started, there were only 30 known Kuiper Belt Objects (KBOs). "We were in the discovery business; not really the characterization business," he said. "We found 86 KBOs with the Canada-France-Hawaii telescope using the MOSAIC 12K camera. We had a parallel project with Jane Luu at Kitt Peak to help us find the biggest objects. That's what got me interested in finding something bigger than Pluto out there."

That interest dovetailed with research that another planet searcher, Mike Brown of Caltech, was doing. Chad met Mike at a Division of Planetary science meeting in 1999 and described the work he was doing at Kitt Peak. "Mike told us he wanted to do similar work using the Samuel Oschin telescope on Palomar Mountain in California," Chad said. "We had some mutual interest."

Now that Chad has major discoveries under his belt, his work is taking him to the surfaces of the worlds he discovers. "Coming to Gemini seems an obvious step, a place where I can find out what's on their surfaces," he said. "Most of the information you can get from these icy, white things can be seen in the near-infrared spectra we're doing. That's my current research interest. At Gemini half our time is research, half our time is support. I support the adaptive optics system ALTAIR and we're trying to get the laser guide star adaptive optics working well."

Chad's interest in the sky was inspired by childhood visits to his grandfather's house in Pagosa Springs, Colorado. "We'd go there for the summers and I remember the stars being pretty spectacular," Chad said. "I was also inspired by watching the TV series *Cosmos*, with Carl Sagan. I didn't understand it all, but it spurred me on to get interested in astronomy."

That inspiration also flows through his interest in doing outreach work whenever time permits. As a postdoctoral fellow, he worked with both graduate and undergraduate students on various telescopes, and since then has lectured at UH Hilo and hosted a summer intern for the Deep Impact mission. Chad has given talks at Sonoma State University in California, the University of Colorado at Boulder, the University of Hawai'i, as well as at Oak Park River Forest High school (which he attended), and at the Saturday Academy for Space Science at Chicago State University. In 2002 he wrote an article about the Kuiper Belt for the World Book Encyclopedia, and shared his work on Kuiper Belt science with *Sky & Telescope* magazine.

In 2005, *Science Spectrum* magazine selected its yearly roster of top minorities in science. Chad was among these luminaries as an honor he is pleased with, yet remains humble about. His trailblazer status allows him to connect with students of all ages, and answer a variety of questions about his work. "They ask interesting things, like, is it difficult? They want to know if THEY can do what I do. I'm also surprised at how interested people are in what I do. Kids are excited about the subject, especially if it's presented in a good manner. When I went back to my high school, the kids could see that I went to their high school and that I do this stuff. I hope it helps them realize that they can do the same thing."

One of Chad's most memorable outreach experiences was with the *Make-A-Wish Foundation*. "A girl had a wish to come to meet me," he said. "She wanted to come to Hawai'i and see the telescopes. It was organized by the University of Hawai'i and her family. We met on the mountain at the visitor's center and we talked for a long time. It was a fun thing to do."

Outside of his work at Gemini, Chad spends much of his time with his new son Evan and wife Tara, who works as a sign language interpreter. They are interested in what he terms "outdoors kind of stuff: photography, hiking, canoeing, and surfing."

"We did lava trips before the baby," he said. "We're starting up our backpacking again now that Evan is a little older. Sometimes I like to go snorkeling and watch the turtles and reef life, too." Both Chad and Tara are also avid long-board surfers, and he is active with the Kamehameha Canoe club, where they both spend time paddling canoes. "We both paddle the traditional six-person outrigger canoes," he said. "You're part of a team, you learn a lot about teamwork on the water."

Chad and his family enjoy Hawai'i and plan to stay as long as they can. In the future, Chad is looking forward to more outer solar system research, possibly looking for larger worlds out there that just haven't been spotted. "There could certainly be Mars-sized bodies out there if you put them far enough away," he said. "The next generation of survey telescopes will revolutionize Kuiper Belt research. For my own particular work there are going to be a lot of new objects to study."

Characterizing those objects will be a forefront issue, one that Chad is well-suited to pursue. With his continuing work at Gemini, he and his colleagues will be blazing trails across the outer solar system and shedding light on these never-before-seen dark, cold bodies.

Sofía Páez: Support Staff Superstar

Ask Sofía Páez what she likes best about her job with the summit day crew at Gemini South on Cerro Pachón and she doesn't even have to think about it. She'll tell you immediately that she loves it all and she is really fond of the team she works with. Ask her co-workers what they think about Sofia, and they tell you a lot of really good things about her, starting with her smiles, her personality, and her incredible efficiency on the job.

Sofía is administrative assistant to Diego Maltes, the site manager for Gemini South. On any given day, her duties keep her busy in support of the day crew at the summit. Whether it's setting up video conferences, sending out meeting reminders, taking phone calls, coordinating shipping and receiving, supporting the safety department, or working with her supervisor, Sofía is right in the thick of things, making sure that summit operations go as smoothly as possible. She describes her job as fun. "I really enjoy working here," she said. "I work very closely withal the summit's technicians and engineers, but most closely with Diego."

Not everything in Sofía's job is routine. She works constantly to find new ways to carry out familiar tasks, like creating a new database to track work done by contractors, or devising a new web page to track purchase orders. Even her daily "commute" to work is something she finds new and exciting. "My office is on the summit and I come up every day with the rest of the crew" she said. "When it snows we have to come up by truck. Last winter was my first one at the summit and it was the first time I had ever seen snow here. I used to work for a mining company in the Cordillera de Los Andes and we had lots of snow there, but the view there was not even close to the beauty of what I see on my ride up the mountain here!

From the first day she came on the job about a year ago, Sofía has been a tremendous asset to the Gemini South team. While she doesn't directly supervise anybody, Sofía works closely with everyone involved in summit operations. "It is a very good work environment here at the summit," she said. "Normally everybody is in a good mood. We are a very close team and there are not many differences between us, even though some are engineers and technicians and others are not. We all have our duties and we cooperate with each other really well. I feel very comfortable here."

One team member, optics engineer Tomislav Vucina, commented that Sofía treats everyone well, no matter what their status and that her work is always first-rate. "Her efficiency is amazing, fast and very productive," he said. "I sometimes wonder if it is difficult for her to work on the summit with only men, but Sofia's personality helps us all keep good relationships. Her adaptation to the summit day crew was very fast and I think that maybe her previous experience with remote jobs was the key."

Sofía grew up in La Serena, Chile and moved to Brazil when she was 17 so her father could complete his graduate degrees. She attended the Universidade Federal de Vicosa and received a degree in Letters with a minor in bilingual languages (English and Portuguese). She has traveled in Europe, and says that her favorite places were Neuschwanstein Castle in Bavaria (Germany) and the Italian city of Venice.

Before she came to Gemini Sofía worked as a commercial assistant to the general manager of an import-export company. "I loved to work in business,“ she said. "But, the major problem was that I was working 14 and even 16 hours a day. I never had time for my family or for myself."

She saw an advertisement for an administrative assistant at Gemini South appeared in the paper and she jumped at the chance to apply. "I went through ten different interviews," said Sofía. "Finally, I was chosen for the position. It was like the answer to a prayer and one of the happiest days of my life."

Working at Gemini has given more family time back to Sofía, even though her job does require her to be up early each day. Sofía and her husband have a daughter, Larissa, who is 14. They also share their home with three cats and a dog. "My family is very happy with my job," she said." Finally I have time enough to have a life with them!"

One of Sofía's favorite things to do on her days off is to wake up late, since she has to be up at 5:30 a.m. each work day. She finds time for a variety of home projects and leisure time activities. "I love reading and doing big puzzles," she said. "Some of my puzzles have two or three thousand pieces. But actually, what I love most is to be with my husband, so you can pick any activities—gardening, playing with the kitten, seeing movies, walking on the beach—and if I am with him that's my favorite one to do!"

Sofía describes herself as a simple person both at work and in her daily life at home. "I try to help the others in everything I can and also I am very open to receiving some help when I need it," she said. "I like to make new friends and love to travel. I never leave a friend in trouble and sometimes I am more concerned about them than about my own problems."

That generosity is one of the many things that people notice about Sofía right away. "The thing I most like about Sofía is her honesty and generosity," said Evelyn Cortes, Gemini South's Human Resources representative. "She is always willing to help you in whatever you need. She is also a good listener and always has good advice. She's a person you always can trust, and she's creative. Every time I go to Pachón, I learn something new from her!"

Sofía considers working at Gemini one of the most rewarding things she's ever done and is very proud of her position on the summit team. "I think that the feeling of belonging to a team is the most amazing thing that ever happened to me at Gemini," she said.

Sofía was very pleased when her parents and brothers came to visit the observatory. "At the end of the tour, my mother gave me a big hug and said she was very proud of me and of my job," said Sofia, who says she doesn't know much about astronomy, but regularly reads the Gemini web site, particularly when the observatory is in the news. "My friends ask me a lot about the telescope and about some astronomy issues, and I tell them all I know. Sometimes it's hard for some of them to understand that we do not look at the stars as Galileo did, but that we use sophisticated instruments and programs to "see" the sky."

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by María Antonieta García

AstroDayChile

Figure 1. *Gemini staff members, Jorge Garcia (front) and Pablo Candia (back) answer questions from visitors at the "Ask the Astronomer" booth.*

This year's successful AstroDay Chile took place on a sunny Chilean Sunday in the middle of summer. On this day, February 17, 2007, La Serena was a busy and energetic place, bustling with an estimated 7,000 people who visited the Mall Plaza La Serena, where the day's events took place.

There was Gemini Observatory, right in the middle of everything, on one of the most visited aisles of the mall, right next to a local library. Observatory scientists and outreach staff welcomed visitors to five kiosks devoted to showing the public how a state-of-the-art observatory operates during the day and night.

People were so interested and excited about visiting AstroDay Chile that they were visiting kiosks even before they were open. Mall Plaza La Serena welcomed the event with open arms. According to Mauricio Mendoza, Deputy Manager of the mall, AstroDay Chile was a rare gift to the people of La Serena. "We were given a unique opportunity to bring astronomy a step closer to our clients and learn through their expert opinions about the universe and its mysteries," he said. "We consider it a great chance for the thousand different visitors who were here during the event".

Planning for Gemini South's participation began with a few e-mails asking for volunteers so that the observatory could have science and technical staff members available at the "Ask the Astronomer" kiosk all day. Luckily, the team spirit took over and everybody had a great time answering questions and talking with the visitors who stopped by the exhibits.

Along with the "Ask the Astronomer" booth, (Figure 1) the Gemini display included a "Cerro Pachón Corner," where site manager Diego Maltes spent the day, along with volunteers from the summit, responding to people's questions about their work. Every hour there was a simulated "mirror cleaning" session. Optical technician Claudio Araya dressed up in a clean-room suit and surprised people by spraying dry ice over a small sample of the mirror (Figure 2, next page). "I am impressed and overwhelmed by the great support that Cerro Pachón employees gave to this event," said Diego. "I don't think any of us knew how many visitors we were to have that day, and I found this effort to be tremendously important. We honestly look forward to doing it again next year."

Figure 2. *Claudio Araya prepares to demonstrate the carbon dioxide mirror cleaning process used at Gemini.*

Gemini's Virtual Tour computer module also played a starring role in the event. There, people really got a chance to interact with the technological aspects of a telescope. "It was great to see how people of all ages decided to play with the Virtual Tour," said public information office intern Andres Rojas, who also spent the day answering questions at the kiosk, "especially taking into an account that we were standing a few steps away from a very popular arcade."

One of the best parts of AstroDay Chile was participation of other astronomical centers invited to attend by Gemini Observatory. Collowara Observatory from the city of Andacollo ran a very successful booth with information about their programs. The Office for the Protection of the Skies of Northern Chile (OPCC) had a booth, where director Pedro Sanhueza explained the correct lighting procedures to a very interested crowd of all ages. In addition, members of the Centro de Apoyo a la Didáctica de la Astronomía (CADIAS), an astronomy teaching support center in Altovalsol, brought their telescopes and talked about their observation programs to interested attendees.

The highlight of the day was the moment when "VIP Tour" winners were announced. Carla Parra, a student at the Universidad Santo Tomas and one of the winners of a tour of Gemini South summed up what AstroDay Chile meant to her. "I love astronomy, I had a wonderful time at the display, specially at the StarLab where I learned about our skies," she said. "And now I am going to the telescope with my brother. What else could you ask for?"

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AstroDay Hawai'i 2007

While AstroDay Chile is a new initiative in 2007, on the Big Island of Hawai'i, the annual event has been ongoing since 2002. It is reasonable to say that the success of AstroDay in Hawai'i is one of the reasons the idea was implemented by Gemini's Public Information and Outreach staff in Chile.

In Hawai'i, the program is directed by Gary Fujihara, who serves as the Outreach Officer at the Hilo office of the University of Hawaii's Institute for Astronomy. In the six years since its inception, the Hilo event has drawn ever larger crowds at the community's largest shopping center, the Prince Kuhio Plaza.

Figure 3. *An estimated 15,000 people attended the most recent AstroDay in Hawai'i held on April 21, 2007. This image shows families making pinhole planetarium constellation viewers with the entrance to a room devoted to the StarLab planetarium at right.*

The Hawai'i version engages a broad range of organizations, including all of the observatories on Mauna Kea, many local education groups, teachers and students and even features a robotics competition for future engineers and scientists. Each year a local teacher is selected for the AstroDay Excellence in Teaching Award for exceptional science teaching.

Gemini participates in AstroDay in Hawai'i in a major way. With support by our observatory's staff at all levels, we feature a variety of hands-on activities, give-aways and continuous programs in the portable StarLab planetarium.

AstroDay has helped to bring the spirit of scientific exploration to our host communities in both hemispheres.

Journey2007

Highlights from this year's "Journey through the Universe" week, held from January 19-26, 2007. Led by Gemini's Public Education and Outreach Office, thousands of Hilo-area students, teachers and the public participated in programs that shared our researchers, staff and guest speakers in classroom presentations, teacher workshops and public lectures. For more details see: www.gemini.edu/journey

GeminiFocus

Gemini North LGS photo by K. Pu'uohau-Pummill

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