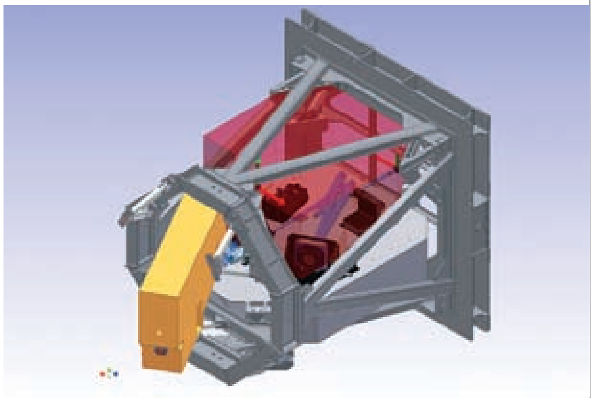
GeminiFocus

June2008 Newsletter of the Gemini Observatory

In This Issue:



On the Cover: NGC 2770, home to Supernova 2008D (see story starting on page 7 of this issue, and image above showing location of supernova). Image was obtained with the Gemini Multi-Object Spectrograph (GMOS) on Gemini North.

Gemini South at moonset, April 2008

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GeminiFocus

by Doug Simons
Director, Gemini Observatory

Director's Message

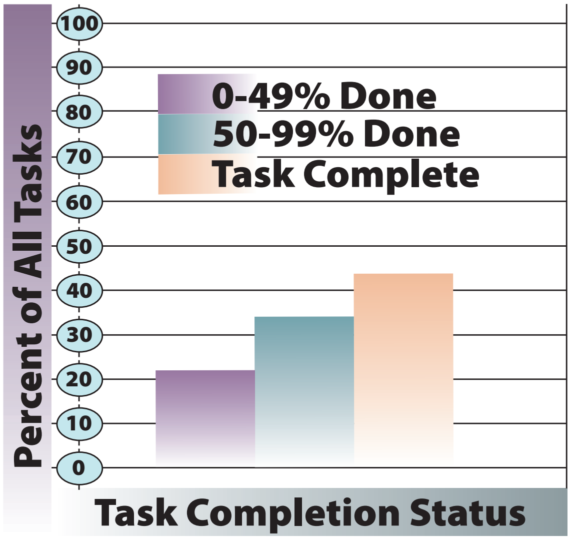

Figure 1.
The year-end task completion statistics across the entire observatory are shown. Roughly half of the projects planned early in 2007 were completed by the end of the year.

Many organizations (Gemini Observatory included) have extremely dedicated and hard-working staff members striving to achieve a worthwhile goal. While laudable, that is not enough to prevent disappointment and confusion between a provider (like Gemini) and its "customers" (the astronomers that use Gemini), unless clear objectives are defined and mutually understood. The "MO" at Gemini has historically been to try to get as much done as possible, as quickly as possible. While we have achieved an incredible amount under that operating philosophy, failing to communicate to the community what we can and cannot realistically commit to provide contributes to burn-out on the part of Gemini's staff and disappointment among members of our user community. For this and related reasons, we have embarked upon a sweeping change at Gemini centered on detailed planning of what we can actually achieve with the resources we have available. We are effectively turning the tide from a best-effort operation dedicated to trying to please as many people as possible to a committed operation that will only take on a certain amount of work, saying what we will do, and then doing what we said. This type of organizational cultural change is incredibly challenging, but I am convinced it will reap many benefits in the future, once complete.

An important part of this cultural change involves incorporating meaningful accountability at many

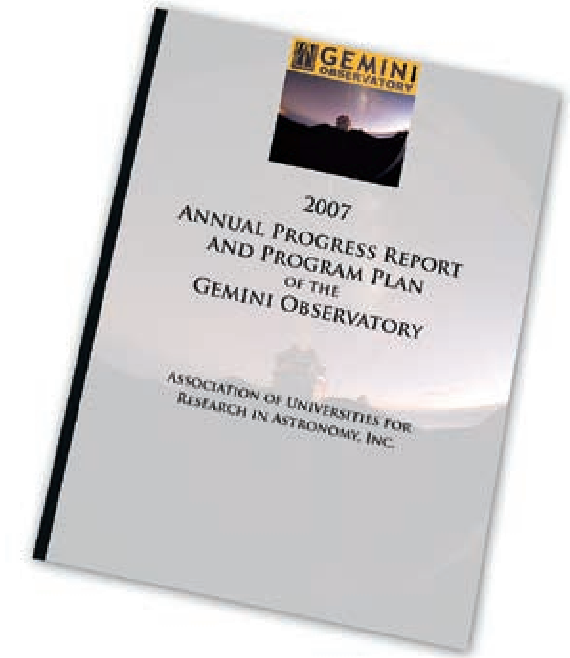

Figure 2.
The 2007 Gemini Observatory Annual Progress Report and Program Plan.

levels into our plans and actions. As an international organization Gemini Observatory must account to many entities but ultimately we are accountable to our community for providing a world-class research platform and to the taxpayers who make a publicly funded observatory like Gemini possible. These stakeholders need and deserve to understand our performance, as measured through a variety of metrics.

Part of the process of building accountability into our culture therefore involves informing our stakeholders of our performance on many fronts. Toward that end we have recently posted on our Website, for the first time, our Annual Progress Report (2007) and our 2008 Program Plan summary (see Figure 2). Historically this report has been submitted to the National Science Foundation per our Cooperative Agreement and, though it has theoretically been a public document, it has never really been made easily accessible to the community until now.

Consistent with our goal of increased transparency, Gemini's Annual Progress Report for 2007 was overhauled and linked directly with our 2007 observatory Program Plan by inserting top-level performance statistics which show what we completed and failed to complete compared to our plan. Since the reporting period used in this report is the U.S. federal fiscal year, and our observatory Program Plan is pinned to the calendar year, we have also provided the 2007 year-end task completion statistics and an over-all performance plot in Figure 1. In summary, across all of the tasks programmed into Gemini's 2007 observatory Program Plan, a little under half were completed, and about 75% were either completed or mostly completed. For our first attempt at this process I was pleased with the result but also recognize that we have much room for improvement. As Director, I take ultimate responsibility for our performance last year, which was a "mixed bag" in the end. During 2007 we identified a number of areas where better planning and, just as importantly, plan execution will improve these statistics in 2008 and beyond.

The 2008 observatory Program Plan was generated through an exhaustive analysis of potential liens on our resources (cash, labor, time, etc.) and is predicated upon an overall goal of maximizing Gemini's scientific product. In September 2007, roughly two dozen members of our management team met in Santiago to discuss and formulate this plan after a couple of months of intense preparation across all divisions. Representatives from the Gemini Science Committee and Board were also present during this planning retreat. The end result was a stark reminder of a "brutal reality" we must all appreciate. In Santiago, with a vast number of pending projects (beyond daily operations) displayed before our managers and no way to find the resources required to do anything close to all of them, the core problem became clear to me. It has been right in front of us for years but never have we quantified it so convincingly as we did during our Santiago planning retreat. Simply put, Gemini's staff was not sized to do much more than sustain operations. We do not have a large stand-alone development team and our science staff is stretched too thin to make our very successful queue-based model work, with the "contingency" too often occurring in the form of staff research time. We have just enough engineering resources to cover our needs, but the multi-conjugate adaptive optics (MCAO) program substantially consumes what little margin is available. The arrival of a new instrument that needs to be incorporated and commissioned into our observatory environment represents a significant perturbation in our resources. While staring from the back of the conference room during our 2007 planning retreat at the projection of this complex planning spreadsheet, I was reminded of a comment from a sage former observatory director. Fred Chaffee (former Director of the W.M. Keck Observatory and Chair of the AOC-G) expressed to me earlier words

Figure 3.
Gemini System Support Associate Erich Wenderoth operates the Gemini South telescope on the night of April 13, 2008. While nightly operations at both telescopes are ongoing, planning for the short- and long-term future at Gemini has also become an ongoing process now that Gemini has entered a "mature" phase of operations.

to the effect "...the first time we held such a planning exercise at Keck we concluded we had just enough manpower to turn on the lights in the morning." It was at that moment that I knew exactly what Fred meant.

I encourage the community to have a look at our 2008 plan and, at the end of the year, check to see how well we performed in completing the tasks defined therein. Until then, I want to point out that we have made some tough choices in developing this plan. Repairing the Gemini Near-Infrared Spectrograph (GNIRS) was flagged as "mission-critical" in 2008 and will be pursued. Likewise, increasing the reliability of the Gemini North laser adaptive optics system was included in the 2008 Program Plan. Other enormously important projects will not be pursued though. For example, we are only committing to deploy all of the hardware needed for MCAO on Gemini South in 2008, not to actually start commissioning this key facility. Beginning work on building new acquisition and guidance units to replace our aging systems and commissioning a new secondary mirror at Gemini North were deferred until 2009. While we commit to developing a detailed plan in 2008 to upgrade one GMOS with high-performance red CCDs, we have not committed to actually making that upgrade, pending resolution of a variety of cost and resource issues. And, while our science team has committed to supporting commissioning of the Near-Infrared Coronagraphic Imager (NICI) and campaign science in 2008, dozens of other proposed tasks within the science division have been deferred to no sooner than 2009. This includes developing additional reduction scripts for instruments, addressing MICHELLE spectroscopy issues, and improving our image-quality-monitoring program.

Laying out all of this information for the community to see is an admittedly unusual (and some may assert) naïve move on Gemini's part, with ever more pressure on astronomy budgets and the political realities of competing for scarce funding in the future. Nonetheless, I decided to do it because meeting our community's expectations means communicating more clearly than ever what we plan to do. In addition, the integrity we achieve as an observatory and trust we seek from our community must be earned, and the starting point in that process is a candid assessment of our current position on the path forward. I understand my staff (or "hanai family") at Gemini extremely well, and it is because I have such deep faith in our ability to grow and improve as a team that I know in a few years time we will look back at our first observatory plan in 2007, chuckle about our performance, and take great pride in how far we've come.

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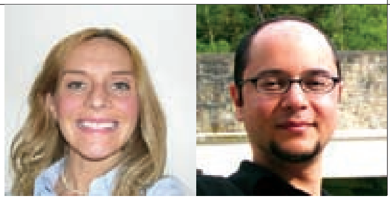


by Alicia Soderberg & Edo Berger

Supernova Birth Seen in Real Time

Figure 1. *Composite (4-band) optical image of the host galaxy NGC 2770 obtained with Gemini North (GMOS) on March 6-7th 2008. SN 2008D is indicated at center of blow-up box.*

The most massive stars in the universe end their short lives in spectacular explosions called supernovae. These events mark the births of neutron stars and black holes, and play a central role in the processes of star formation and galaxy evolution through the injection of heavy elements and mechanical energy into the interstellar medium. Indeed, much of the material from which the solar system and life on Earth were forged was processed and dispersed by supernovae and their progenitor stars.

The basic picture of a supernova explosion involves the collapse of the iron core at the end of a massive star's life. The collapsing core reaches nuclear densities within tens of milliseconds, and then rebounds. This generates a shock wave that eventually tears the star apart. The details of the mechanism, however, remain highly uncertain and even the most sophisticated numerical simulations fail to generate a clear explosion.

The explosion also leads to the synthesis of new elements. Of particular importance is nickel-56 (^{56}Ni). Its radioactive decay gives rise to the bright optical emission of supernovae. This optical light becomes progressively brighter, reaching a peak level about two weeks after the explosion. Since supernovae are invariably discovered through their optical emission, they are generally found many days after the actual explosion. It is predicted that the explosion should be marked by bright x-ray and ultraviolet emissions, but these signatures have never been observed. As a result, no supernova has been seen at the time of its explosion. Therefore, we lack an understanding of the first minutes, hours, and days in the evolution of a supernova.

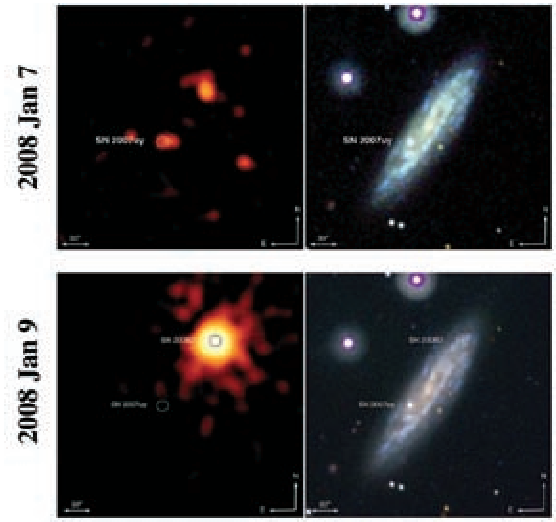


Figure 2.
Discovery images of SN 2008D from the Swift satellite showing x-ray images (left) and ultraviolet images (right) on January 7th and 9th. The supernova appears in the top right corner of the January 9th images. Also marked is an earlier supernova (SN 2007uy), whose monitoring led to the discovery of the x-ray outburst.

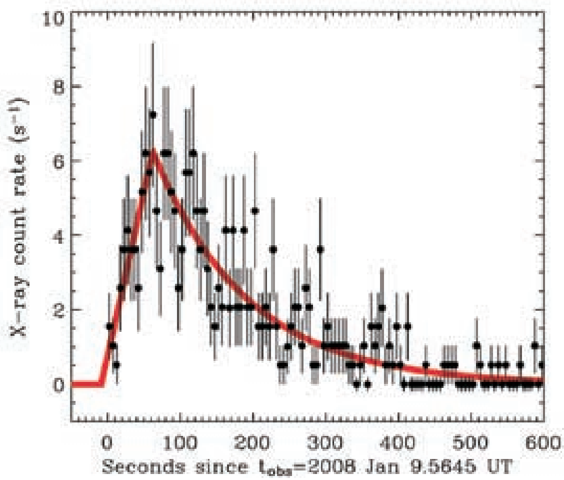


Figure 3.
X-ray light curve of the x-ray outburst marking the birth of SN 2008D.

This changed dramatically on January 9th, 2008. During x-ray observations of the nearby galaxy NGC 2770 with NASA's Swift satellite, we discovered an extremely bright transient that was not visible in observations taken on January 7th. The x-ray and ultraviolet images of the field from the two observations are shown in Figure 2. The x-ray emission quickly rose to a peak luminosity of about 10^{44} ergs/second and then faded away after about 1,000 seconds (Figure 3). No ultraviolet emission was detected during the x-ray outburst, but bright emission was detected about two hours later and lasted for several days (Figure 5).

Following the detection of the x-ray transient we initiated spectroscopic observations of the optical counterpart using the Gemini Multi-Object Spectrograph (GMOS) on the Gemini North telescope. Our first spectrum was obtained 1.7 days after the transient discovery and revealed a relatively smooth continuum, with an overall shape that is reminiscent of a supernova (a dip at about 530 nanometers (nm) and a decline in flux beyond 700 nm). Additional spectra obtained on subsequent nights conclusively showed the emergence of supernova features, and in particular the existence of helium lines. No hydrogen lines are detected, marking the event as a helium-rich type Ib/c supernova, which was designated SN 2008D. The series of GMOS spectra is shown in Figure 4. Our first spectrum was obtained on a timescale similar to the earliest observations of SN 1987A. The combination of early discovery and dense monitoring with Gemini provided one of the most detailed set of spectra for any supernova to date.

The discovery of SN 2008D indicates that the x-ray transient is the long-awaited shock break-out emission. Essentially, this x-ray emission marks the emergence of the supernova shock wave from the progenitor star. Thus, it marks the exact explosion time of the star! The details of the x-ray light curve and spectrum indicate that the star was surrounded by a dense wind that prolonged the duration of the x-ray transient and up-scattered the thermal photons according to a power-law spectrum. The impact of the stellar wind has not been considered in theoretical models previously, but it clearly plays an important role for the Wolf-Rayet progenitors of type Ib/c supernovae. The x-ray data also allowed us to measure the speed of the shock as it emerged from the star at about 70% of the speed of light.

The early ultraviolet emission also supports the shock break-out scenario. We expect in this case that the shock will expand and cool, shifting the resulting radiation into the ultraviolet and then optical bands. This is exactly what we see in the light curves, which display two components. At early time we detect an ultraviolet-dominated component that peaked about one day after the x-ray outburst and then faded away. It was subsequently overtaken by a redder component that peaked about 20 days after the outburst. This component is the traditional one seen in supernovae (due to the radioactive decay of ^{56}Ni).

The ultraviolet shock emission and the optical ^{56}Ni emission provide independent measures of the energy of the explosion and the mass of ejected material. We find consistent results from both components. Namely, the explosion energy is 3×10^{51} ergs and the mass of the ejecta is 3.5 solar masses. The velocity at which the material travels is about 10,000 kilometers per second. From the ultraviolet emission we can also estimate the

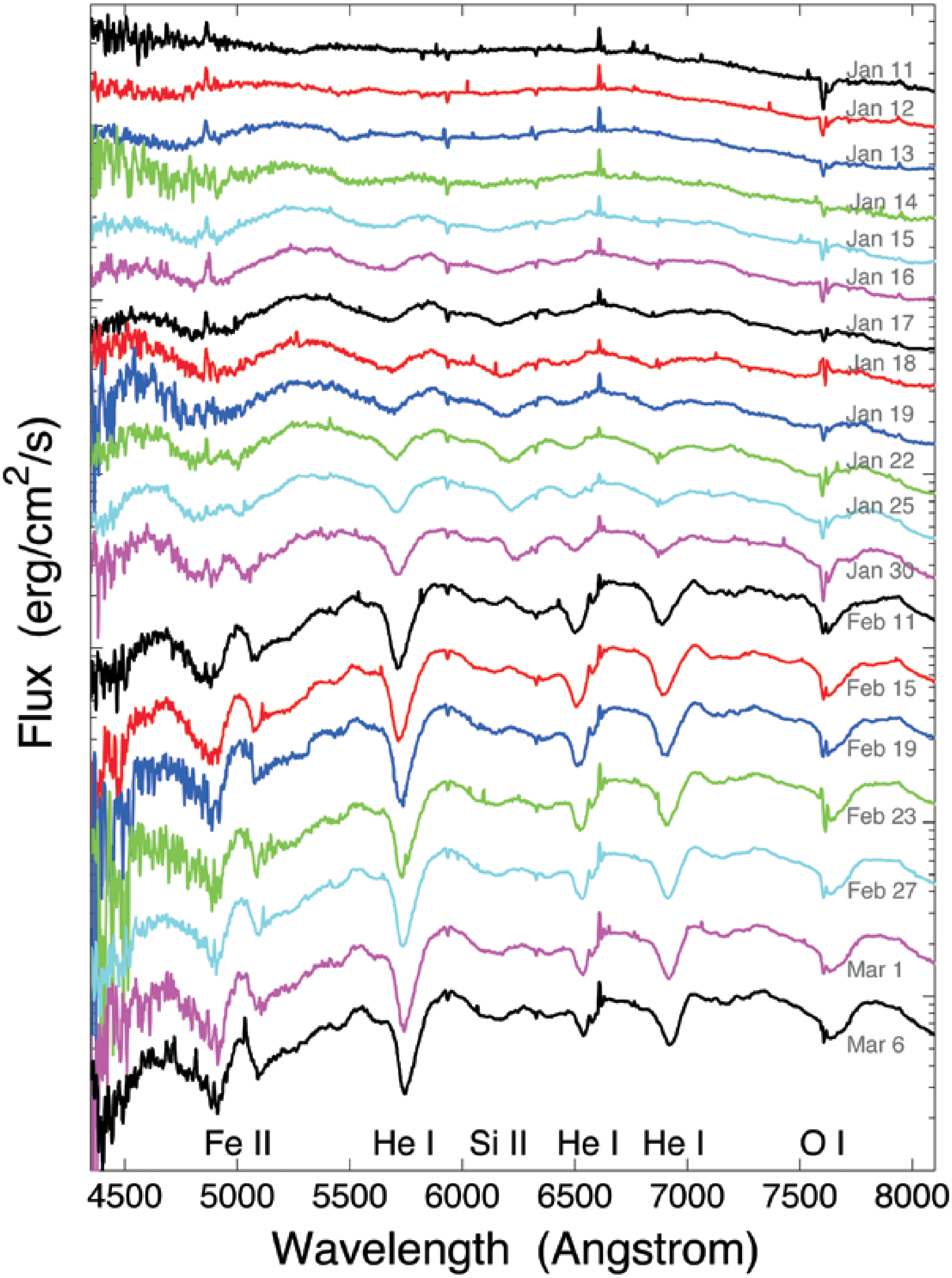
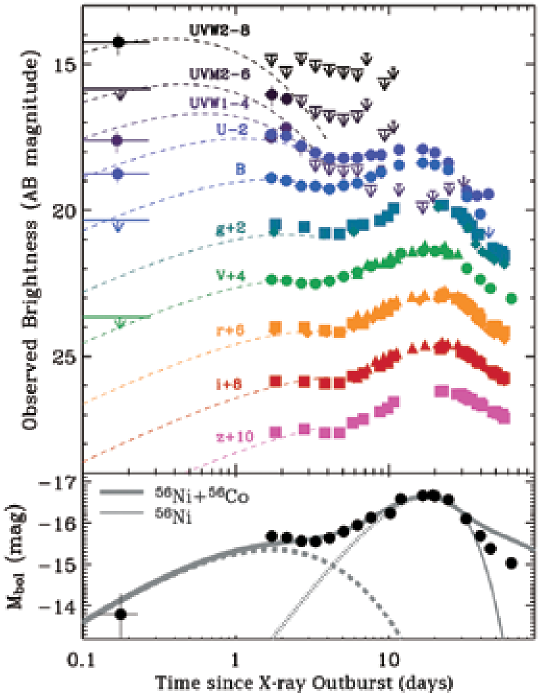


Figure 4. *GMOS spectra of the x-ray outburst source. The top spectrum (taken 1.7 days after discovery) shows that the transient is associated with a supernova. Subsequent development of supernova features is clearly visible in very broad and shallow absorption at early time, to narrow and deep features at late time. Various species giving rise to the absorption are shown (bottom). Strong helium lines and a lack of hydrogen lines indicate that this is a type Ib/c supernova. We infer an explosion velocity of about 10,000 kilometers/second.*

size of the exploding star, which we find to be about 10^{11} centimeters, about the same as the radius of the Sun.

In addition to the optical and ultraviolet observations, we observed SN 2008D in the radio band using the Very Large Array (VLA), and obtained additional x-ray observations with the Swift and Chandra observatories. The radio and late x-ray observations allow us to trace the fastest material ejected during the explosion. Indeed, we find material moving at velocities of 100,000 kilometers per second, about 30% of the speed of light. This material, however, accounts for only 0.1% of the total explosion energy.

Figure 5.
Ultraviolet and optical light curves of SN 2008D, exhibiting two components associated with the shock break-out (peak at about one day in the ultraviolet) and the ^{56}Ni decay (peak at about 20 days in the optical). The dashed line is a simple shock break-out model. The bottom panel shows the bolometric light curve with models that fit the two supernova components. The thick line includes 100% contribution from the radioactive decay of cobalt 56. The true light curve includes a smaller contribution from cobalt. The two components are determined from the same explosion parameters and are therefore self-consistent.



The detection of the x-ray break-out emission from SN 2008D allows us to investigate the expected rate of similar events. Using Swift's sensitivity we find that such events can be detected out to about 200 megaparsecs. Within this volume we find that our single detection is consistent at the 10-50% confidence level with the hypothesis that all core-collapse supernovae (and in particular Ib/c supernovae) produce such outbursts.

This leads to the exciting conclusion that all core-collapse supernovae can be detected at the time of explosion using a wide-field x-ray instrument. We expect the next-generation x-ray satellites to detect hundreds of supernovae per year at their exact times of explosion, thereby revolutionizing the study of supernovae. The explosion time-stamp available from the x-rays will enable future detailed studies such as the one we carried out for SN 2008D with Gemini, Swift, the VLA, and multiple other facilities. Most importantly, however, this will enable numerous detections of neutrinos and gravitational waves, which may ultimately hold the key to unraveling the mystery of the supernova explosion mechanism.

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by Eva Noyola

Intermediate-Mass Black Hole in Omega Centauri

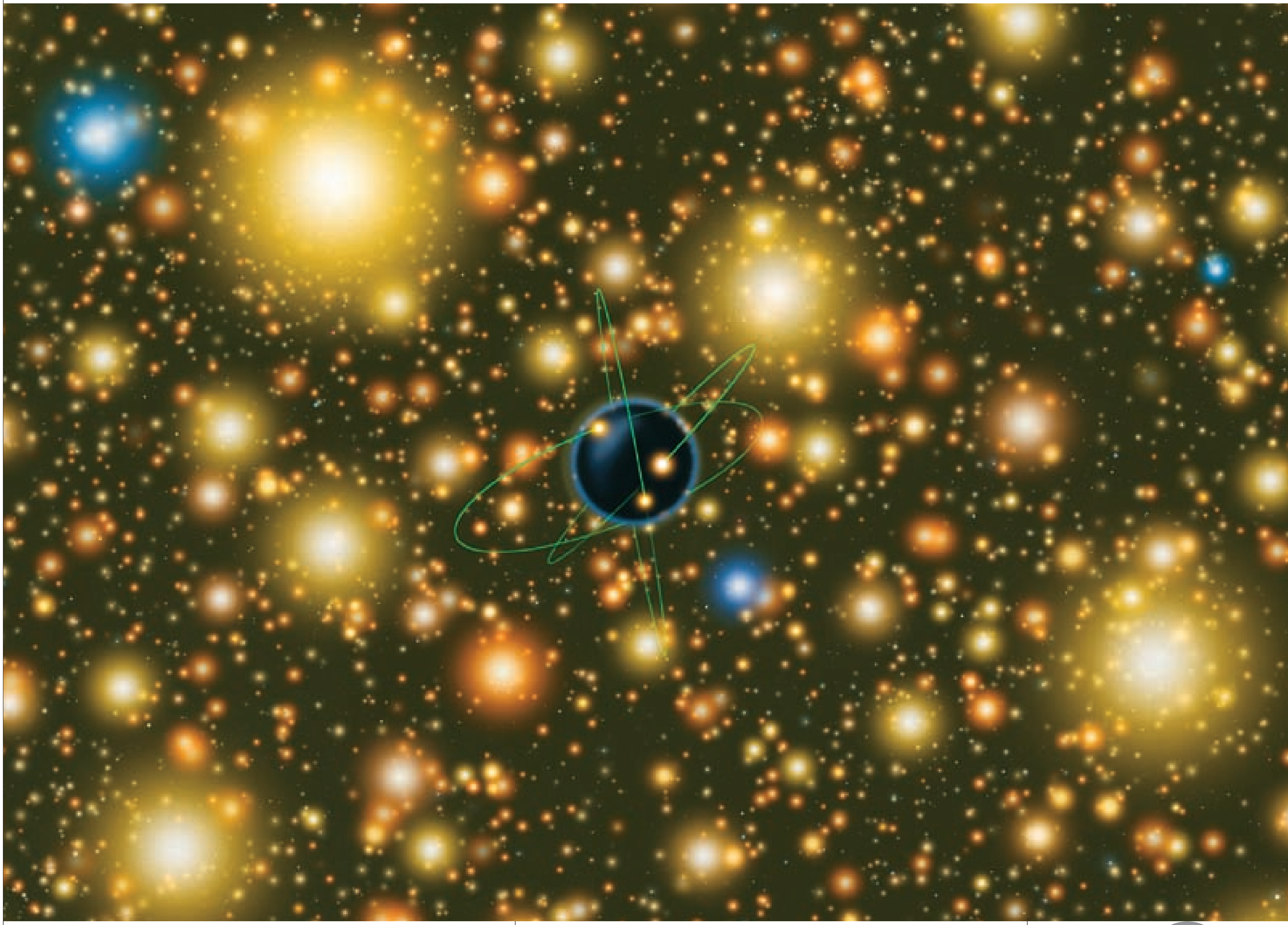

Figure 1.
(previous page) Artist's conception of the environment around an intermediate-mass black hole at the center of Omega Centauri. The relative size of the black hole has been extremely exaggerated for illustrative purposes and hypothetical orbital paths of fast-moving stars are shown. Illustration by Lynette Cook for Gemini Observatory.

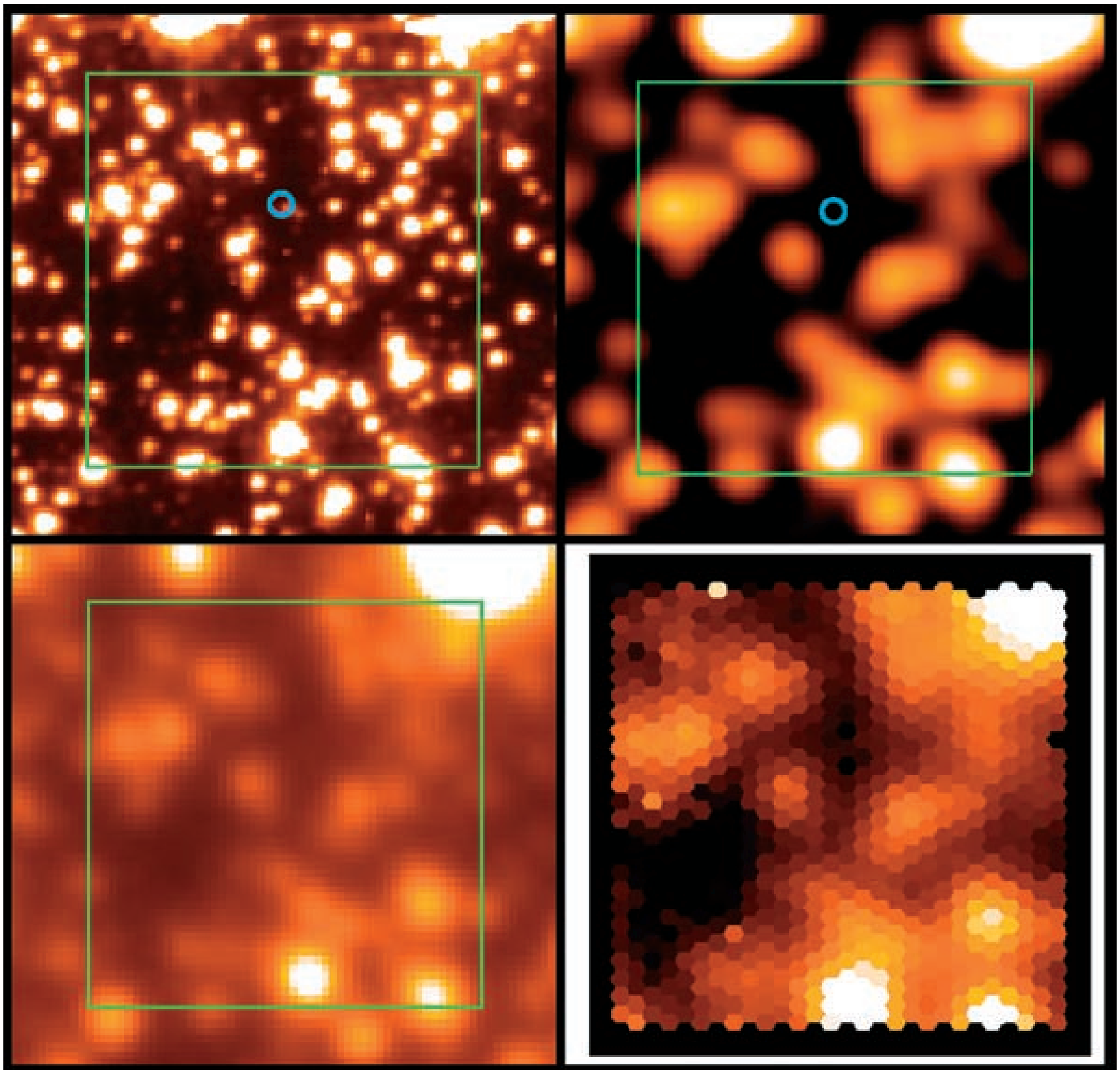

Figure 2.
The central 5 × 5 arcseconds of Omega Centauri. Top left: the ACS HST image with blue filter. Top right: a blurred ACS image to match ground-based resolution. Bottom left: the GMOS acquisition image in red filter. Bottom right: a reconstructed image from the spectral frame. The blue circles (top) mark the center of the cluster.

There are two types of black holes whose existence has been established: stellar-mass black holes (10-100 solar masses) produced from the deaths of heavy stars, and supermassive ones (with 1 million to 1 billion solar masses) that reside at the centers of most galaxies. There are no physical reasons that would prevent black holes from existing with masses between those two types, but so far such intermediate-mass black holes have been difficult to detect.

For the case of supermassive black holes, there is a known relationship between the size of a central black hole, and the size of its host galaxy (for elliptical galaxies) or of the galactic bulge (for spiral galaxies) in which they reside. So far, the smallest ones detected in small galaxies have about 1 million solar masses. If one could find a "minuscule" galaxy that would be a good place to look for an intermediate-size black hole.

Globular clusters host anywhere from ten thousand to a million stars, which are all considered to be old and born in a single burst of star formation. Omega Centauri is the largest globular cluster associated with the Milky Way Galaxy and contains 2.5 million solar masses. In recent years, peculiarities have been found in the stellar populations in Omega Centauri which indicate that its stars might not have all been born in a single burst. This would indicate that Omega Centauri is not a genuine globular cluster, but instead might be the remnant nucleus of a former dwarf galaxy that fell into the Milky Way and had some of its stars stripped away. The possible progenitor galaxy whose nucleus turned into Omega Centauri might be exactly the type of minuscule galaxy that could host an intermediate-mass black hole.

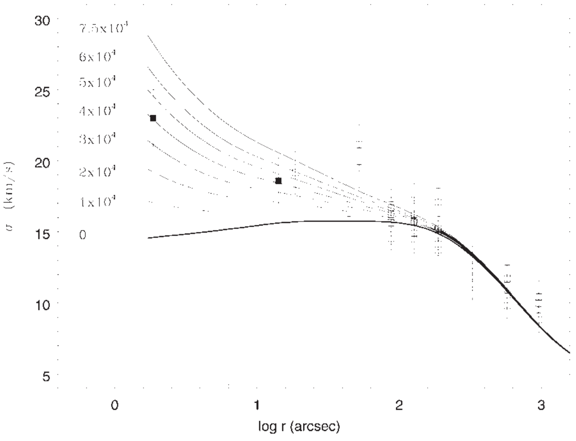

Figure 3.
The measured velocity dispersions of the stars in the center of Omega Centauri. The filled squares are GMOS measurements; open squares are from previous measurements. Lines are models with different central black hole masses. The model with a 40,000 solar-mass black hole fits the data best.

We collected imaging and spectroscopic data with the aim of testing this hypothesis. First, we looked for high-quality images of the central part of Omega Centauri where a black hole should reside. We collected an archival image taken with the Hubble Space Telescope's Advanced Camera for Surveys; from this we measured the radial density profile for the central parts of the cluster. We then combined this information with an earlier profile measured from the ground. The result of these measurements was surprising. We expected a flat central density profile because that is the expected state for a star cluster with the size of Omega Centauri. Instead, we found that the central profile rises slowly but clearly towards the center. This type of behavior had been recently observed in numerical simulations for star clusters containing central black holes. Thus we had a first good indication for the existence of an intermediate-mass black hole.

In order to investigate the kinematics, we asked for time at Gemini. Our goal was to measure the velocity of stars in the central region of the cluster. The Gemini Multi-Object Spectrograph on Gemini South was perfect for our purposes since it is capable of measuring spectra simultaneously for about 700 adjacent regions in a given field of view. This meant that we could get the velocity information of 700 mini-regions that cover our area of interest (Figure 2) in a single observation. Another advantage of this type of instrument is that we can decide which regions of the cluster in which to measure velocities and exclude very bright stars that would have otherwise dominated the velocity measurements.

We pointed the telescope at the very center of the cluster, and also at a region 14 arcseconds off center. The velocity signature of the black hole was expected to show in the central pointing, but not in regions farther away. Our results show that there is a considerable rise in velocity between the measurement of 18 kilometers/second made away from the center (the off-pointing measurement) and the velocity observed at the center, which was 23 kilometers/second.

We combined this information with velocities obtained by other authors and were able to estimate the mass of a black hole using all of the velocity measurements and a very straightforward method. From the high-quality image we could estimate reasonably well how much mass is present in the central region due to stars. Given the mass, we could calculate what the expected velocity of the stars would be and then compare that with the measured velocities. Since our measured velocity was higher than the prediction, for having just stars at the center, it meant that there is more mass present from something that does not contribute any light. This detailed comparison told us that there are 40,000 solar masses of non-luminous matter at the center of Omega Centauri (Figure 3).

It is tempting to claim that we have found our intermediate-mass black hole, but first we have to rule out other possibilities. One way to explain the data is that the orbits of stars are not really random, but instead are biased towards having many radially elongated orbits. This would produce the same velocity signature but would not require extra mass at the center. We estimate how many orbits of this type would be necessary to reproduce the observed velocity and find that a large percentage of stars would be required to be in this state. This type of configuration is known to be very unstable in a dense stellar field like the one in Omega Centauri and we do not know of any mechanism that could have created those types of orbits in such large numbers.

Another possible alternative to explain an excess of central mass is that it is in the form of a large number of heavy, dark remnant stars (such as stellar-mass black holes, neutron stars or white dwarfs) that are not necessarily completely dark, but rather are extremely faint. If this was the case, they'd have to be concentrated in a small region at the center of the cluster in a very dense configuration. The process that normally drives heavy stars to the center of star clusters is called core collapse, and we know that, given Omega Centauri's characteristics, there has not been enough time for this process to happen. However, even if we assume that the process could have happened anyway, the very dense

Figure 4. *Omega Centauri as imaged by the Hubble Space Telescope in June 2002 and released as a color composite image in April 2008. Credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA) Acknowledgment: A. Cool (San Francisco State University) and J. Anderson (STScI).*

configuration that is necessary to explain the data is also known to be unstable and it is therefore not expected to remain that way for very long. In short, creating so many radial orbits, or driving so many dark remnants to the center of the cluster and keeping them there, seems to be extremely unlikely.

This leads us to the conclusion that a central black hole of 40,000 solar masses is the simplest explanation for our measurements. There is only one other globular cluster with a similar size black hole detected in its center; it is a very massive cluster which is also a suspected stripped galaxy nucleus and is associated with the neighboring Andromeda Galaxy. What we need to do now is try to figure out if these intermediate-mass black holes are very rare and only exist in stripped galactic nuclei or if they also exist in genuine globular clusters. If large-enough numbers of these intermediate-mass black holes are found, they could be the needed (and so far unidentified) black hole seeds necessary to grow supermassive black holes at the centers of galaxies.

This work was done in collaboration with Karl Gebhardt (University of Texas, Austin) and Marcel Bergmann (Gemini Observatory). This result appeared in *ApJ*, Volume 676, Issue 2, pp. 1008-1015

For more information see:
H. Baumgardt, *et al.*, 2005, *ApJ*, **620**, 238
K. Gebhardt, *et al.*, 2005, *ApJ*, **634**, 1093
E. Noyola, *et al.*, 2008, *ApJ*, accepted
S. C. Trager, *et al.*, 1995, *AJ*, **109**, 218
G. van de Ven, *et al.*, 2006, *A&A*, **445**, 513

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by Joseph Rhee

Collisions of Planetary Embryos in the Pleiades

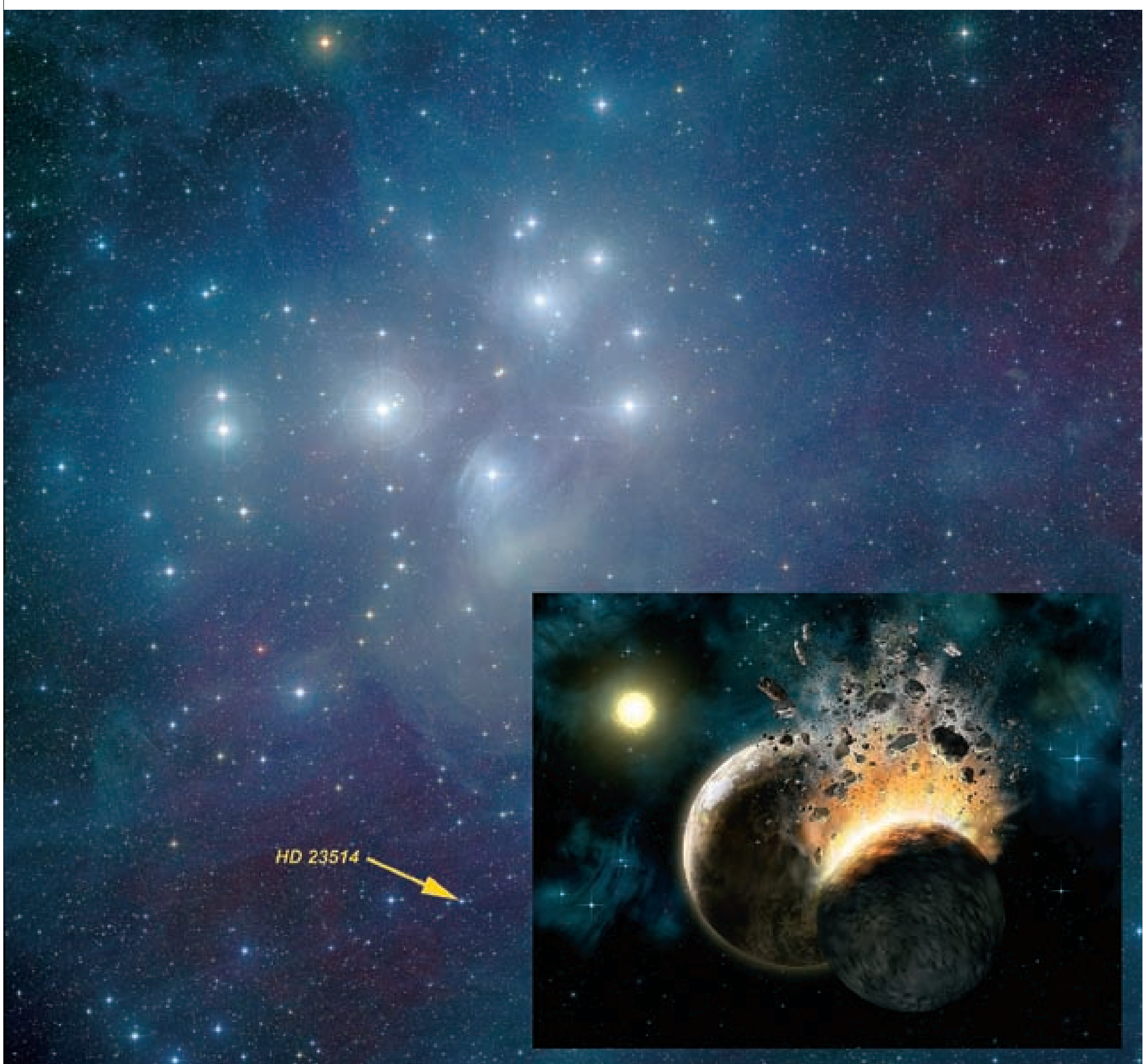

Figure 1. *Color composite image of the Pleiades star cluster and surrounding region produced by Inseok Song of the Spitzer Science Center. The yellow arrow indicates the location of HD 23514. Inset artwork (lower right) is an artist's rendering of what the environment around HD 23514 might look like as two Earth-sized bodies collide. Artwork inset illustration by Lynette Cook for Gemini Observatory.*

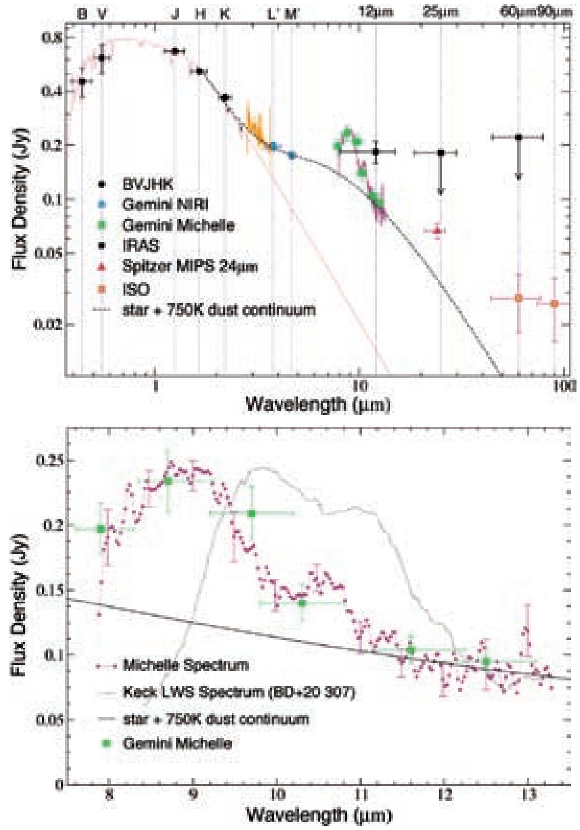

Figure 2.
(top) Spectral energy distribution of the dusty 100-million-year-old solar-type star HD 23514 in the Pleiades star cluster. The unusual infrared excess is most noticeable in the thermal infrared region. (bottom) There is also a strong silicate feature around 9 microns.

Collisions between asteroids, complemented by material released from comets, produce a dust cloud in the inner region (about 3.5 astronomical units [AU]) of the solar system. The terrestrial planets in our system orbit inside this so-called "zodiacal" cloud. Cratering statistics indicate that when the solar system was about 600 million years old, the impact rate of bodies in the region of the terrestrial planets was sometimes as much as a thousand times higher than it is now. Thus, the dust production rate in the young zodiacal cloud should have been orders of magnitude larger than the current value.

These zodiacal cloud bodies are warm (more than 150K). Collisions between such objects orbiting around youthful Sun-like stars are manifested in strong excess emissions at mid-infrared wavelengths. These signatures would point toward the formation of planets in the terrestrial zone. Several hundred main-sequence stars are known to have orbiting dust clouds; however, this dust, which is located in regions analogous to our solar system's Kuiper-belt region, is cold. Despite many searches, only a few main-sequence stars have shown warm dust analogous to the zodiacal dust near Earth.

The first known evidence for such warm dust appeared in a region near the youthful (roughly 400 million-year-old) *A3*-type star, Zeta Leporis. Shortly after that discovery was reported, a much more extreme example of this warm-dust phenomenon was identified near another star by Inseok Song of the Spitzer Science Center (and a former staff astronomer at Gemini Observatory), and our team (including Ben Zuckerman at UCLA). The star BD+20 30, is a Sun-like star with a volume of hot dust about a million times more than what the Sun's current zodiacal cloud holds. Since then, a few more stars with warm dust have been identified through recent Spitzer Space Telescope observations.

While working as a research postdoc at Gemini North headquarters late December 2005, I (along with Inseok Song) began to search for excess emission in the mid-infrared around the main-sequence stars using Spitzer archive data. Spitzer multi-band imaging photometer (MIPS) 24-micron images have a fairly large field of view (5 × 5 arcminutes); which means that, in addition to a target object, many field stars appear in most MIPS images. During a pilot program to test the feasibility for a possible project, we discovered HD 23514 (located in the Pleiades star cluster) to be a warm dusty star in the Spitzer Legacy Program FEPS (Formation and Evolution of Planetary Systems) field of HII 1182. The star's large mid-infrared excess (Figure 2) was previously discovered by IRAS only in its 12-micron band but has gone uncommented upon in the published literature. In 2001, there was a marginal detection of dust excess emission from HD 23514 at 60 and 90 microns with a pointed observation using the Infrared Space Observatory (ISO). However, the importance of the IRAS 12-micron band was not commented on and the team used only ISO data, which led to an incorrect conclusion about the dust properties of this star (the temperature of the dust was about 70 K, and the ratio of the luminosity of the star to its parent star was about 3×10^{-4}).

Gemini Observatory has played a pivotal role in investigating this warm and dusty Sun-like star. We carried out follow-up imaging observations of HD 23514 using the Near-InfraRed Imager (NIRI) and Mid-Infrared Imager/Spectrometer (MICHELLE) at the Gemini North telescope. The observatory recognized the importance of this discovery and acted swiftly to grant us Director's Discretionary time to follow up on HD 23514. NIRI and MICHELLE images of HD 23514 at 3.8- to 11.7-micron bands showed an unresolved single source detection in the vicinity of HD 23514 (field of view of 32 × 24 arcseconds), thus verifying that the dust emission shown in Figure 2 originates from HD 23514. Flux measurements at those wavelengths confirmed excess emission well above the stellar photosphere. Further investigation using MICHELLE spectroscopy at 8-13 microns revealed the presence of small particles of warm dust through a prominent emission feature.

Excess emission peaking at mid-infrared wavelengths indicates that dust must be warm and close to the central star. The temperature, as well as the amount of dust and its distance from the central star, is constrained by creating a Spectral Energy Distribution (SED) provided that dust exists as an optically thin ring. We produced an SED of HD 23514 (Figure 2) by fitting observed measurements at optical and infrared bands with the NextGen stellar photosphere model and a single temperature blackbody of T = 750 K. Large blackbody grains in thermal equilibrium at 750 K would be located within about 0.25 AU from HD 23514 while small grains that radiate more inefficiently at about 1 AU.

A standard method for characterizing the amount of dust orbiting a star is through the quantity τ ($\tau \sim L_{IR}/L_*$, fractional infrared luminosity) where L_{IR} is the excess luminosity above the stellar photosphere emitted at infrared wavelengths and L_* is the bolometric luminosity of the star. We obtained $\tau \sim 2 \times 10^{-2}$ by dividing the infrared excess between 2.3 and 90 microns by the stellar bolometric luminosity. This is about a hundred thousand times greater than that of the Sun's current zodiacal cloud (with $\tau \sim 10^{-7}$). Such a large amount of dust around a star that is only a few million years old is extraordinary, especially considering that a typical Vega-like star with infrared excess at a similar age or other stars with warm dust (such as Zeta Leporis and HD 68930) shows a τ two orders of magnitude smaller. HD 23514 thus joins BD+20 307 ($\tau \sim 4 \times 10^{-2}$) as the two Sun-like main sequence stars with by far the largest known fractional infrared luminosities.

The age of BD+20 307 is about 400 million years based on the recent x-ray observation, as well as stellar kinematic measurements. As a member of the Pleiades (HII 1132), the age of HD 23514 is about 100 million years. There can be little doubt of its cluster membership because HD 23514 is located in the heart of Pleiades cluster (see Figure 1) and shares common proper motion and radial velocity with other Pleiades members.

Initially, when there was only one known main sequence star with very large τ ($> 10^{-2}$), the BD+20 307 phenomenon might have been regarded as a "miracle," so that a statistical analysis of the occurrence rate would have been of questionable value. Now, however, with HD 23514 the frequency of occurrence of such extraordinarily dusty stars can be treated statistically more reliably.

By comparing the number of adolescent-age (70-700 million-year-old) solar-type stars at which the Infrared Astronomical Satellite (IRAS) could have detected the "very dusty" phenomenon, with the number of such stars that were actually found by IRAS to be very dusty, that is these two (HD 23514 and BD+20 307), we estimate that about one star in a thousand is very dusty. Thus, the lifetime of the very-dusty phenomenon at a typical solar-like star is a few hundred thousand years. But, the lifetime of the observed micron-size particles is orders of magnitude shorter. So, how can we supply such a large amount of dust for a few hundred thousand years? While Zeta Leporis and the other handful of stars with warm dust may be understandable as a result of the passage of a super comet or created by the many collisions of asteroid-size bodies, generation of the extreme amount of warm dust indicated that HD 23514 and BD+20 307 may require collisions of actual planet-size objects.

To interpret our observations, we have considered a model of colliding planetary embryos during the late stages of the formation of planets in the terrestrial planet zone by Craig Agnor and Erik Asphaug. Based on their models and those they attribute to earlier researchers, we have drawn the following conclusion: the process of terrestrial planet formation involves the formation of a minimum of many hundreds of planetary embryos of dimensions up to 1,000 kilometers. These collide and they either coalesce or oftentimes the smaller embryo fragments into smaller objects along with the ejection of "copious debris." While the mass spectrum of the fragments is not well constrained, no large monoliths survive following disruption of such large solid bodies. Rather a typical large fragment size might be about 100 meters. Collisions of planetary embryos continue for as long as a few hundred million years, about the ages of HD 23514 and BD+20 307.

For these assumed ages and an occurrence rate of one in a thousand stars, we use a lifetime of 250,000 years for the HD 23514/BD+20 307 phenomenon at a typical adolescent-age solar-type star. Small particles now in orbit around these two stars will be lost in a much shorter time span and must be replenished many times over. One possible loss mechanism is a collisional cascade that breaks particles down in size until, when their radii become as small as a few tenths of a micron, they become subject to radiation pressure blowout.

Assuming that collisions are sufficiently frequent to establish an approximately equilibrium size distribution, we derive the collision time: ~ $a^{1/2}$. Thus, the smallest particles collide the fastest; for HD 23514 this is about 50 years at 1 AU. Larger objects take longer to collide destructively. Then, they will be broken down into smaller fragments such that, after a collision of two roughly equal-mass objects, the largest leftover fragment has a radius about half that of a collider. In the Agnor/Asphaug picture outlined above, the largest initial fragments of a collision of planetary embryos might have a ~ 100 meters. Thus, if the lifetime of a = 1 mm particles is ~ 50 years, then the lifetime of 100-meter fragments will be ~ 500,000 years. In addition to the collision, the stellar wind drag calculation results in a similar lifetime. Thus, catastrophic disruption of a large planetary embryo (see mass estimate below) can supply material for a time equal to the 250,000-year event lifetime indicated by our observations.

To determine how rapidly mass is lost due to either stellar wind drag or collisions, we estimated the minimum dust mass needed to intercept 2% of the light emitted by HD23514 to be ~ 1.8×10^{22} grams, with a corresponding mass-loss rate, 2×10^{13} grams/second. For BD+20 307, τ is twice as large, resulting in 4×10^{13} grams/second. In 250,000 years, the total mass lost per star will be about 2×10^{26} grams, or twice the mass of Earth's Moon. Or, for the above assumed average density, an object with radius of about 3,000 kilometers. Of course, this mass need not all be produced in one single catastrophic collision, but instead might be a consequence of multiple collisions of smaller planetary embryos spaced over hundreds of millions of years.

Our data are consistent with these model predictions, provided that such catastrophic events followed by a subsequent collisional cascade converts a mass on the order of the mass of Earth's Moon to tiny dust particles during the early lifetime of many (perhaps most) stars. Infrared data for stars such as HD 23514 and BD+20 307 are consistent with (and may well validate) the standard picture of violent formation of terrestrial-like planets in the early years of planetary systems.

This result appeared in the March 1, 2008 issue of *Astrophysical Journal*, **675**, 777.

For more information see:

C. Chen and M. Jura, 2001, *ApJL.*, **560**, 171

C. Spangler, *et al.*, 2001, *ApJ.*, **555**, 932

I. Song, *et al.*, 2005, *Nature*, **436**, 363

E. Asphaug, *et al.*, 2006, *Nature*, **439**, 155

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by Andrea Prestwich

Taking the Measure of a Black Hole

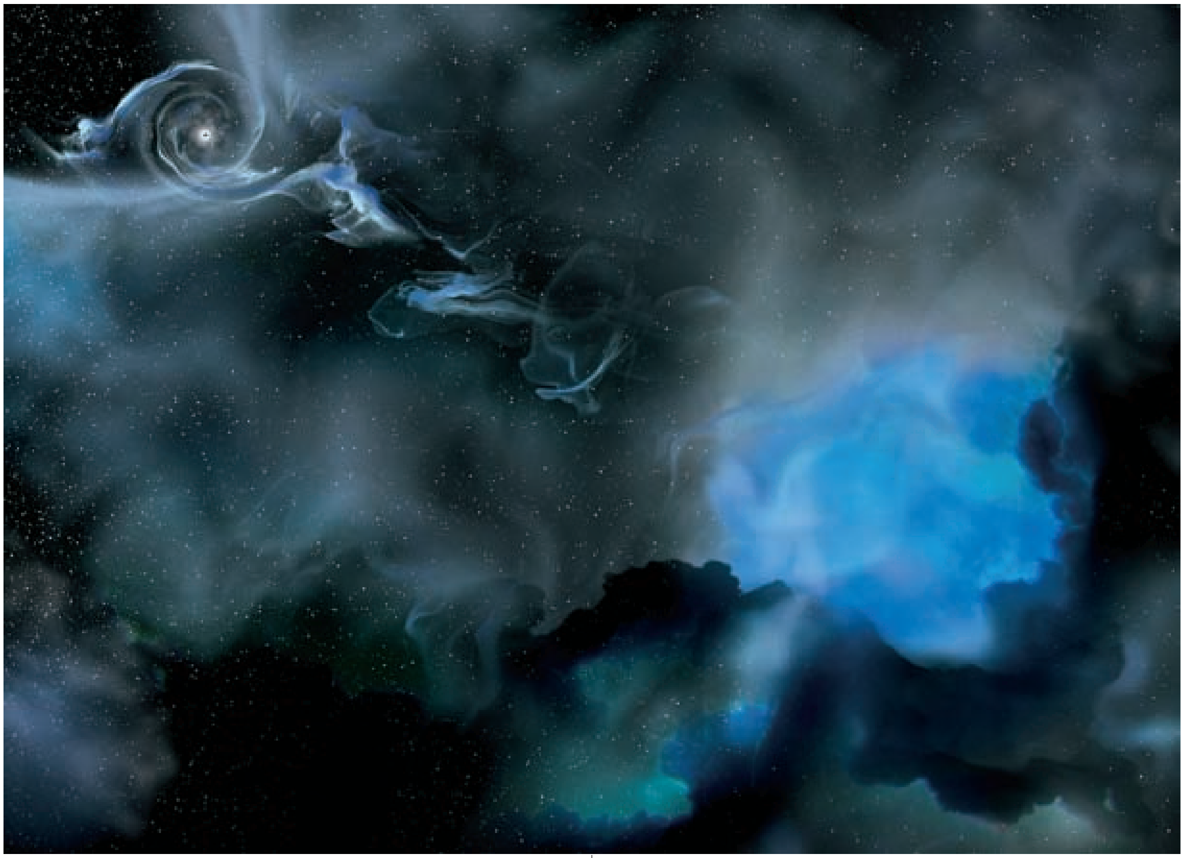

Figure 1. *In an artist's portrayal of IC 10 X-1, the black hole lies at the upper left and its companion star is on the right. The two objects orbit around a common center of gravity once every 34.4 hours. Such stars are highly evolved and destined to explode as supernovae. Credit: Aurore Simonnet/Sonoma State University/ NASA.*

There are about 300 million stellar black holes in the Milky Way Galaxy. How do you measure their masses? Black holes are black of course, meaning that we have no way to measure their characteristics using emitted or reflected light. We must fall back on indirect methods of measurement by estimating their masses. This can be done by determining their gravitational effects on the material around them.

The best (and only) way to measure the mass of a stellar-size black hole (formed by the gravitational collapse of a massive star), is when it is part of a binary system with a "normal" star. We record the orbital period and radial velocity of the normal star and then use Kepler's Laws to obtain a mass for the

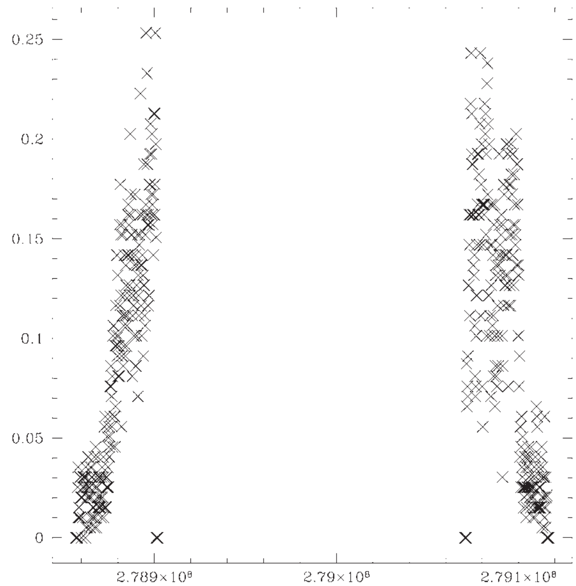

Figure 2.
Light curves of IC 10 X-1 during two Chandra observations. The x-axis is time and y-axis counts the number of x-ray photons incident in the detectors. The flux increases dramatically in the first observation and in the second one it declines. This is highly suggestive of an eclipsing binary where the x-ray source passes behind the donor (normal) star. However, we can not deduce the period from this data alone.

system. In principle, this is simple. The fact that only 20 of the estimated 300 million black holes in our galaxy have dynamically determined masses illustrates how difficult it is to do in practice! These 20 black holes are subject to intense scrutiny because they offer opportunities to test stellar-evolution models and general relativity.

In this article I will focus on two newly discovered black hole binaries, M33 X-7 and IC 10 X-1. They are the first extragalactic black hole binaries to have dynamically measured masses. The normal stars in these binaries are faint: it is only possible to obtain spectra with new generation large telescopes such as Gemini. M33 X-7 and IC 10 X-1 are important primarily because they contain the most massive stellar black holes known, weighing in at 15.6 solar masses (M_{Sun}) and greater than 23 M_{Sun}, respectively. Masses this high challenge current theoretical models of stellar evolution and shed light on an enigmatic class of x-ray sources known as Ultra-Luminous X-ray Sources (ULX).

As the "X" in their names implies, both M33 X-7 and IC 10 X-1 were first identified as bright x-ray sources. Like other known black hole binaries, these objects radiate x-rays when material from the normal (or donor) star is transferred onto the black hole. The material is heated and emits copious amounts of x-rays as it spirals into the gravitational potential well. The x-ray luminosity scales as the black hole mass gets larger, with heavier black holes being brighter x-ray sources.

IC 10 X-1 is the brightest x-ray source in the starburst galaxy IC 10 (which is part of the Local Group of galaxies that also contains the Milky Way). It attracted a lot of interest for two reasons when it was discovered 10 years ago. First, its x-ray luminosity was high enough to suggest that the accretor must be a black hole; it would be very unusual for a neutron star x-ray binary to have a luminosity of 10^{38} ergs/second. Second, the x-ray source was apparently coincident with a luminous Wolf-Rayet star (called [MAC92] 17-A), making it one of the first extragalactic x-ray sources to have a plausible optical counterpart. We confirmed these two findings in the fall of 2007 when we used the Chandra X-ray Observatory to obtain two deep x-ray images of IC 10 separated by two days. The x-ray light curve of X-1 increased dramatically in the first observation, and decreased in the second observation (see Figure 2).

These observations suggested that the x-ray source was being eclipsed by the Wolf-Rayet star. However, because the two Chandra observations

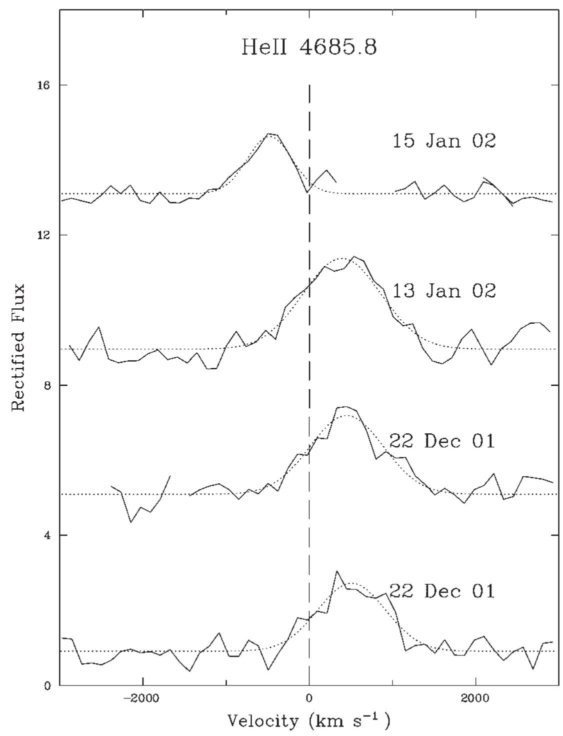

Figure 3.
Four Gemini spectra of the Wolf-Rayet counterpart to IC 10 X-1. The dotted line shows zero velocity of the HeII 4686 line. There is clearly a velocity shift in the centroid of the HeII line between the observation taken on January 15, 2002 and the other epochs.

were separated by two days we could not determine the period. This ambiguity was neatly resolved by the X-Ray Telescope (XRT) on board the Swift Gamma Ray Burst Satellite. When not chasing gamma-ray bursts, the Swift XRT is able to target other interesting x-ray sources. It was able to monitor IC 10 X-1 for a total of 10 days, getting an x-ray data point once per orbit. The data helped us confirm the hypothesis of an eclipse and we determined an orbital period of 34 hours.

The discovery of an eclipse was very exciting and suggested that we were seeing the X-1 binary almost edge-on. But, we could not determine the mass of the black hole without the radial velocity of the Wolf-Rayet donor star. So, we examined archival Gemini spectra of [MAC92] 17-A and found that the HeII 4686 Å line did indeed show a velocity shift (Figure 3) of 740 kilometers/second. Taken at face value, this radial velocity implies a mass for the black hole between 24 to 30 solar masses. The range of allowed masses is due to uncertainty in the mass of the donor star. We were taken aback ("gob-smacked" to use a British colloquial expression) by this value. It implied that IC 10 X-1 was the most massive known stellar black hole, and was somewhat heavier than could be explained by models of stellar evolution. In fact, the result was so startling that we wondered whether the HeII line shift was "real" and if it was real whether it was due to orbital motion. Our results were confirmed in a recent paper by Jeffrey Silverman and Alexei Filippenko. They obtained Keck spectra of [MAC92] 17-A over a one-month period, confirming that the He lines tracked the orbital period.

The mass of the black hole in IC 10 X-1 has a firm lower limit. However, the binary parameters (in particular, Wolf-Rayet mass and radius, orbital inclination, duration of the eclipse) are not well determined. This is in contrast to the binary M33 X-7, where these parameters are known very precisely. In a recent paper published in *Nature*, Jerome Orosz and his collaborators were able to build up a beautifully detailed and consistent picture of this binary. The donor is a 70 solar-mass O-type star with an effective temperature of 35,000 K, corresponding to a spectral type of *O7III*. This monster is orbited by a much smaller and lighter black hole with a 3.45-day period. The mass of the black hole is $15.65 \pm 1.45\ M_{Sun}$, and the "radius" is about the size of an asteroid! The whole system would fit within the orbit of Mercury.

A tremendous amount of detailed observational and theoretical work was required to obtain this result. Multiple Chandra observations were analyzed to accurately determine the length of the eclipse. Gemini was used to obtain the radial velocity curve and ellipsoidal light variations of the O-type star. The star's spectrum was modeled to get the spectral type, mass and radius (which also required a precise knowledge of the distance). All these parameters were fed into a light-curve synthesis code to find the optimal model of the binary system.

What is the "big picture" science? Both of these systems challenge current models of high-mass star evolution. In the case of M33 X-7, it is very hard to explain the combination of masses and small separation of the O star and black hole. According to current models of black hole formation, the star that collapsed to form the black hole must have been extremely massive with a radius much larger than the current distance between the binary pair.

In order to form the close binary we observe today, the two stars must have spiraled together to the point where their outer atmospheres merged during what is known as the "common envelope phase." Stellar evolution models predict that to get the common envelope phase, the black hole progenitor had to be 1.2 times more massive than the present-day secondary (the Wolf-Rayet partner star). This gives us a mass for the black hole progenitor of 100-120 M_{Sun}. The problem is that stars this massive should lose material via strong winds at a rate that would leave a core of about 17 M_{Sun}. Therefore, in order to make a massive black hole, the progenitor must have retained much of its original mass before going into the common envelope phase, making the mass-loss rate close to a factor of 10 smaller than predicted.

There are no detailed models of IC 10 X-1 because the binary parameters are not well determined. However, stellar evolution theory suggests an upper limit of about 20 M_{Sun} for ANY stellar black hole, regardless of the mass of the progenitor, because of the extreme mass-loss rates for high mass stars. Both IC 10 X-1 and M33 X-7 point toward dramatically lower mass-loss rates for massive stars.

The discovery of high-mass stellar black holes also has implications for understanding ultra-luminous x-ray sources. The brightest x-ray sources in the Milky Way Galaxy and nearby spiral galaxies have luminosities less than 10^{38} ergs/sec. This is generally interpreted as a few percent of the Eddington limit for a black hole of about 10 M_{Sun}. The Eddington limit is the maximum theoretical x-ray luminosity of a black hole (or any compact object). As the accretion rate increases, the x-ray luminosity gets larger, but so does photon pressure. At the Eddington limit, photon pressure is large enough to blow away infalling material and accretion stops. X-ray binaries are known to radiate at super-Eddington luminosities, but only for short periods. The accretion is highly unstable. Stellar evolution models predict that the most massive stellar black holes are about 10 M_{Sun}. The argument is that if most stellar black holes radiate at a few percent Eddington, we would expect the maximum luminosity of galactic x-ray sources to be 10^{38} ergs/second, with some radiating at higher rates for short periods. This is indeed what is observed.

However, some star-forming galaxies have spectacularly bright x-ray sources, in the range 10^{39}-10^{40} ergs/second. The luminosities are so extreme that a new class of black hole (intermediate-mass black holes, IMBH, see article by Eva Noyola starting on page 11 of this issue of *GeminiFocus*) was invoked to explain them. The IMBH candidates have masses in the range 100-1000 M_{Sun}, intermediate between stellar black holes and the supermassive black holes found in the nuclei of galaxies.

The rationale is that an IMBH can radiate at a few percent of the Eddington luminosity, producing the required high luminosities without requiring such high accretion rates. Other models for ultra-luminous x-ray sources postulate regular stellar mass black holes which radiate anisotropically. In such a case, the x-rays are collimated by an accretion disk around the black hole. Sources that are pointed at us appear to have extremely high luminosities because we assume the x-rays are emitted over 4π steradians (in other words, from the entire "surface" of the emitting area around the black hole).

Both models have their supporters and detractors and the controversy is likely to continue for some years. However, it seems likely that M33 X-7 and IC 10 X-1 will feature in the debate. Neither of these systems has an x-ray luminosity which approaches those of ultra-luminous x-ray sources. However, our x-ray analysis suggests that neither system is accreting at the Eddington limit. This is especially true for IC 10 X-1, which we suspect is in a low accretion state. If for some reason the accretion rate in IC 10 X-1 were to increase, the corresponding increase in the x-ray luminosity could turn IC 10 X-1 into a modest ultra-luminous x-ray source without any need to invoke beaming. Exotic beasts may be needed to create the most extreme ultra-luminous x-ray sources, but the population as a whole may be explained by black holes such as IC 10 X-1.

Perhaps one of the greatest rewards of this line of research is the chance to use high precision measurements from state-of-the-art facilities such as Gemini, SWIFT and Chandra to solve simple classical equations such as Kepler's Laws. We hope that astronomers will continue to use these observatories to push the limits on black hole masses even further!

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by Damien Gratadour & Jean-René Roy

Arp 299 Through the LGS AO Looking-Glass

Figure 1.
Composite Altair-LGS NIRI (H and K bands) and HST WFPC2 (V and I bands) of Arp 299. The field of view is almost 50 arcseconds across.

In current models of galaxy formation, galaxies are created through downsizing and/or by hierarchical merging. In the latter scenario, galaxy interactions modify the galaxy mass distribution function and trigger bursts of star formation during these spectacular events. Because of this, the study of interacting galaxies provides useful hints about the merging process and its impact on the content and morphologies of galaxies in the local universe.

When galaxies collide, part of their gas is ejected out of the system along tidal tails that can stretch many thousands of light-years. However, most of the rest of the gas remains trapped within the system where it is rapidly redistributed. While falling to the gravitational center(s), the atomic hydrogen is first transformed into molecular gas. This gas is then available as fuel that is often consumed by intense bursts of star formation that occur during a galactic

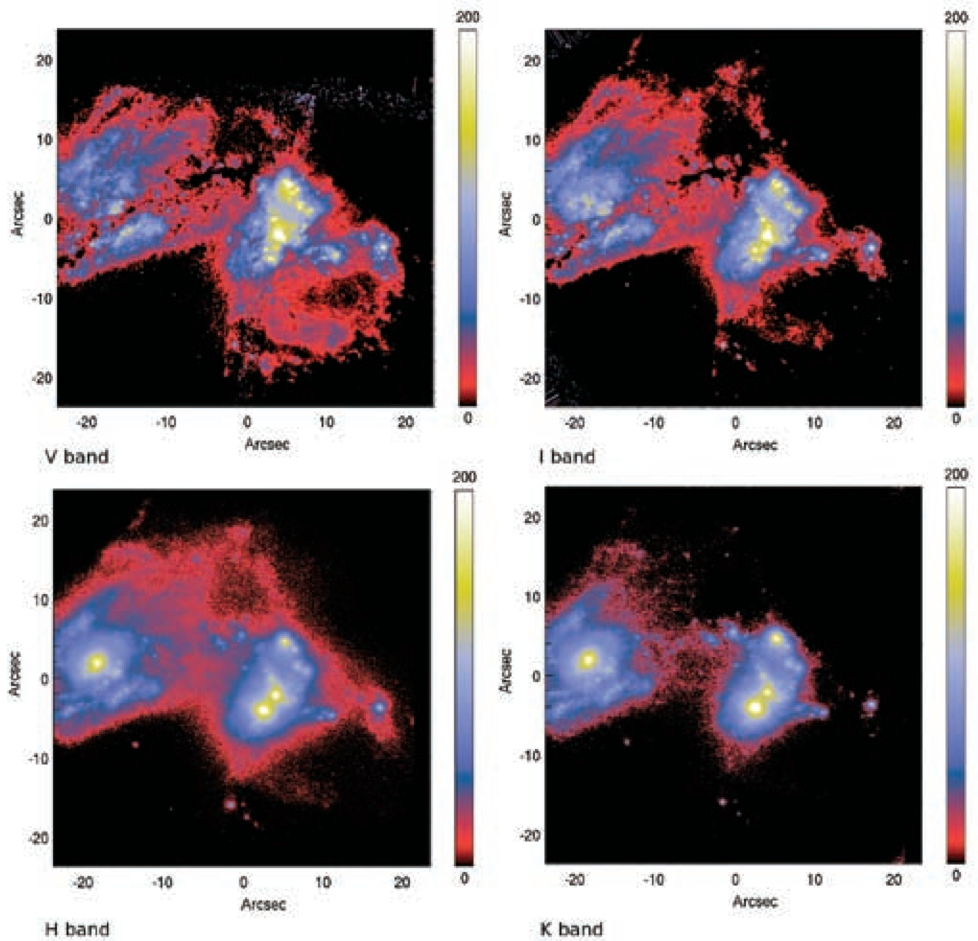

Figure 2.
Images of Arp 299 in the V and I bands from HST/WFPC2 (top two panels), and in H and K bands from Altair-LGS/NIRI (bottom two panels).

merger. The remaining molecular gas and interstellar dust that does not form stars is eventually captured around the core(s) to form a thick obscuring screen where an active galactic nucleus (AGN) may be buried.

The study of star formation in merging systems in the local universe is of particular use in the understanding of galactic evolution. High-contrast and high-angular-resolution imaging in the near-infrared provide powerful tools to analyze objects like star-forming regions that were triggered by merging. These objects are often enshrouded by dust, making them difficult to observe at optical wavelengths. The high spatial resolution, provided by adaptive optics (AO) systems, on telescopes such as Gemini, allows observers to separate the contribution of star forming regions from intrinsic nuclear emission in systems as far away as 100 million light-years. Such observations can be complemented with Hubble Space Telescope (HST) observations in the ultraviolet (UV) and optical wavelength ranges.

Digging Into the Arp 299 Supernova Factory

At a distance of 42 megaparsecs (Mpc), Arp 299 is one of the nearest and most studied merging galaxy systems. It consists of at least three main components: the eastern component IC 694 (Arp 299 A) and the western components within NGC 3690 (Arp 299 B and C). The interaction is at a stage where the two galaxies are in contact (with a nuclear separation of 3.5 kiloparsecs (kpc)). Approximately 60% of the total luminosity of this object comes from the A nucleus (IC 694). Arp 299 is often referred to as a supernova factory since its supernova rate (as measured in radio wavelengths) is up to six times greater than those found in typical starburst galaxies like M82 and about fifty times larger than in our own galaxy. Star formation is occurring there at a spectacular rate (about a hundred solar masses per year) with several tens of star formation sites clearly identifiable in visible wavelengths and many more in the infrared, as we will show.

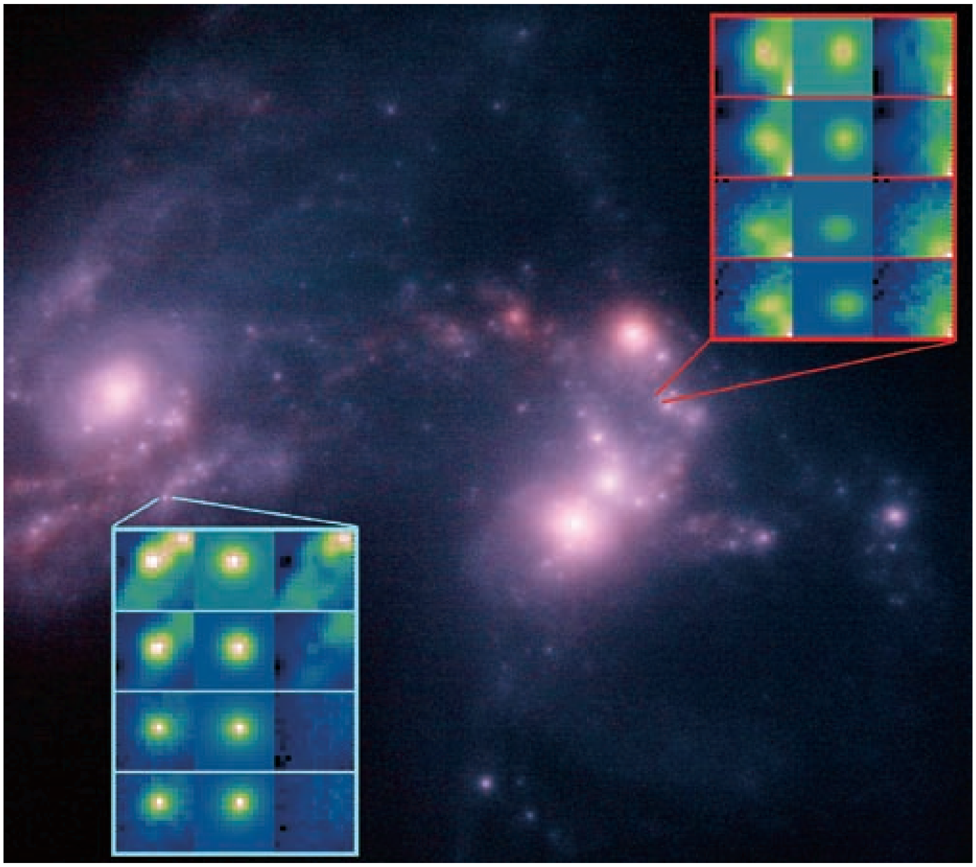

Figure 3. *False-color composite of the near-IR images of Arp 299 obtained with Altair-LGS/NIRI. Insets show the results of the PSF fitting process on two different clusters: A5 and C6.*

Star formation in both nuclei is taking place in a very dense medium: a mix of extremely dense gas and dust inherited from the prograde-retrograde encounter of the two gas-rich parent galaxy disks. While at least one previous interaction took place 700 million years ago, the system is now beginning another crossing. At this stage, the gas is mostly driven into the nuclei to form stars and feed putative AGNs, and not thrown out into tidal tails. Widespread episodes of star formation began six to eight million years ago and correspond to the beginning of the current interaction event. Visible light cannot penetrate this dense region so observations at longer wavelengths are necessary to explore the star forming sites at greater depth.

We observed Arp 299 during the nights of April 30 and May 1, 2007 with Altair-LGS/NIRI in the H and K bands. The f/14 mode was employed in order to get the widest field possible while keeping a reasonable (Nyquist) sampling of the point-spread function (PSF). The western nucleus was used as a guide source for tip/tilt correction while the laser itself was placed at the center of the field to get as homogeneous a correction as possible. The Strehl ratio (a metric for the AO compensation quality) ranged from 15 to 17% in the K band and 10 to 15% in the H band. Strehl was quite uniform across the field thanks to the use of the laser guide star that reduced the anisoplanatic effect that normally degrades the off-axis image quality in classical AO systems.

Our observations of Arp 299 are the deepest H- and K-band images of this object with a resolution of 0.1 arcsecond or better. They supersede previous data obtained with the Near-infrared Camera and Multi-object Spectrograph (NICMOS) on HST. The reduced data (shown in Figure 1) reveal a large amount of detail. The quality achieved with the LGS AO system allowed several new stellar clusters to be detected for the first time. Moreover, the f/14 mode (with a field of view of almost 50 arcseconds) provides a high-resolution snapshot of the whole system which is especially important for the study of the central bridge that links the two main components of the system.

Using a Near-Infrared Super Goggle

Images at various UV and visible wavelengths obtained with the Wide-Field and Planetary Camera 2 (WFPC2) on HST are available from the HST archive (Figure 2). They have a spatial resolution similar to that achieved with Gemini (~0.1 arcsecond). We selected two bands in the visible (V and I) to complement our near-infrared data. The remarkable depth of the near-infrared observations allows us to probe the various point-like sources of emission from star-forming regions, as well as the more diffuse emission from warm gas and dust. Superposition of the Gemini data onto HST optical imaging worked well. While the morphology of source A appears dramatically different in the V and K bands, common features allowed us to precisely register the visible and near-infrared data. This provided color maps with unprecedented resolution. While the high-resolution infrared color map [H-K] traces warm (500-1000 K) dust emission and stellar content, the visible-IR [I-H] color map brings a wealth of information regarding intrinsic absorption and the stellar content.

There is patchy extinction across the system, with very red regions (caused by high extinction) especially noticeable around nuclei A and B. The neighborhood of nucleus C appears very blue, betraying several less-obscured giant HII regions. We used the color map to estimate the extinction at appropriate locations across the merger. This information is of prime importance for establishing the stellar content and to reconstruct the star-formation history of the system. The measured color excesses of nuclei A and B reveal an extinction as high as A_V= 15 to 20. The surrounding reddish regions have significant extinctions of A_V= 5 to 10. Such high extinction rates imply that many clusters are not detected at visible wavelengths because they are hidden by optically thick material. With lower extinction in the near-infrared, numerous clusters are seen at H and K without a clear counterpart at V and even at I. Moreover, the number of clusters detected in our new Altair-LGS images is two to three times larger than found in HST near-infrared imaging. This demonstrates the unique capabilities provided by Altair-LGS in the near-infrared and the complementarities of this mode with UV- and visible-light-sensitive instruments onboard HST.

Finally, the most dramatic feature revealed by our multi-wavelength analysis is a wide reddish "lane" crossing the whole system from the southern part of the eastern component (nucleus A) to the northern part of the western component (source C); see Figure 1. This dust "highway" is the bridge between the two merging units whose emission is dominated by molecular gas emission. We plan to map this dusty lane with Altair-LGS using narrow-band H_2 filters to get clues on its nature and on the state of the gas. Many bright sources are detected in the near-infrared along the dust "highway".

Reconstructing Star Formation in Arp 299

To parameterize star-forming activity, we compared the photometry of each star-forming region in the four available bands to evolutionary synthesis models. We then derived the ages of the clusters and the extinctions. This type of analysis is known to suffer from the degeneracy between parameters such as metallicity and extinction, particularly for extinction. It is reasonable to assume a solar metallicity for the sort of galaxies involved in the Arp 299 merger. A more precise analysis will allow us to disentangle this degeneracy better.

Photometry was performed by fitting the point-like sources with either a Gaussian function (for HST data) or a Moffat function for Altair-LGS data. The latter is a modified Lorentzian function and is a good approximation of a PSF affected by residual turbulence. It is well adapted to AO PSF fitting. Both functions are assumed to lie on a complex background (the underlying galaxy starlight and/or dust background). In order to remove this background, we added a two-dimensional second-order polynomial to the fitting function. This method appears to give reliable results (see the panels of Figure 3 where the first column is the cluster images in the various bands, the second column the fits, and the third the residuals). We detect about 105 point-like sources over the whole system that we interpret as super stellar clusters. This is more than twice as many clusters as detected in previous studies with NICMOS. While most of these clusters have a counterpart in the I band, only 75% of them can be clearly detected at V for a preliminary diagnostic of age and extinction.

Using the measurements in the four bands, we can compute 3 different color indices for all star clusters identified: [V-I], [I-H] and [H-K]. The combination of these 3 color indices can then be compared to theoretical models of stellar synthesis such as those of Bruzual and Charlot, which are widely used in the community. Insets in Figure 3 show the results of the PSF fitting process on two clusters (one rather bright lying on a regular background: A5 and one rather faint lying on a disturbed background: C6) demonstrating the quality of the photometric measurements available from these data. These two clusters represent the two main classes of clusters in our sample; A5 is rather young (with an estimated age of about 7.5 million years) while C6 is an older cluster (with an estimated age of about 120 million years). Both clusters suffer very high extinction, with estimated A_V of 11 and 17 magnitudes respectively. Analysis of the 105 star clusters detected in our Altair-LGS images is ongoing. Preliminary results indicate three main classes of stellar populations: a very young one (about 7 million years old) that corresponds to the current interaction stage; an older class (about 15 to 19 million years old) and a rather old one (about 120 to 130 million years old) which may correspond to the previous interaction stage.

It is our intention with this preliminary release of Altair-LGS AO imaging to demonstrate the unique capability provided by this facility for the study of this and similar objects.

Technical Note: A Note on Extended Reference Tip/Tilt Guide Sources

Observations of faint and/or distant galaxies at the diffraction limit with Gemini North are now possible with the laser guide star (LGS) mode of Altair. In good conditions (seeing $<$ 1.2 arcseconds), and provided the presence of a bright-enough guide star ($M_R < 18$) in the neighborhood of the science object (in a 25 arcsecond radius), this system allows us to routinely reach 0.1 arcsecond or better resolution in the near-infrared. However, LGS systems suffer from some limitations and one of them is the determination of focus. As the LGS is located at a finite altitude, this configuration introduces defocus in the images if the effect is not tracked. Altair uses a slow focus sensor (SFS) to measure the focus on a real star and apply

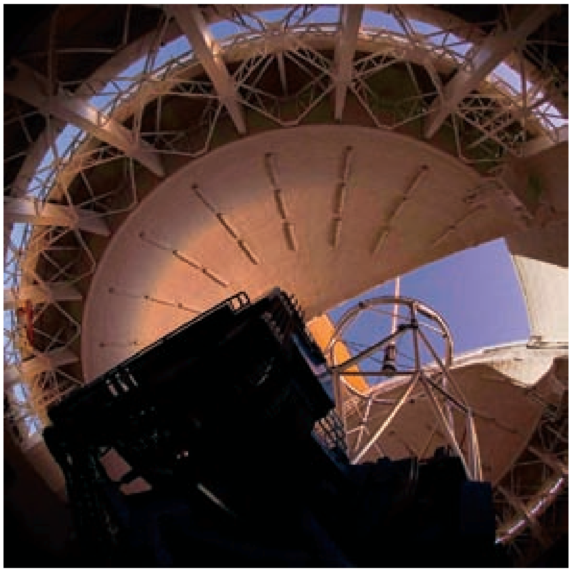

Figure 4. *Laser propagation at Gemini North.*

a correction. However, this sensor does not work properly on extended faint sources like a galaxy nucleus. In such cases, a model of focus versus the LGS evolution is used to maintain the true sky images in focus with Altair. Additional focus adjustments made (every 30 minutes or so) on a nearby star are mandatory to ensure an acceptable final result in terms of resolution. This limitation must be taken into account by investigators who want to observe objects with Altair-LGS using extended and faint guide sources. The mandatory focus readjustments on the nearby star is an opportunity to acquire data on a photometric standard (maximize the telescope time efficiency) and check image quality. This focus check is not necessary for stellar shape tip-tilt objects.

For more information see:

G. Bruzual & S. Charlot, 2003, *MNRAS*, **344**, 1000-1028

A. Herrero, *et al.* 2000, *ApJ*, **532**, 845.

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by Étienne Artigau & Philippe Delorme

To Coldly Go Where No Brown Dwarf Has Gone Before

The search for substellar objects had a frustrating beginning. More than 20 years passed between the theoretical groundwork that predicted the existence of brown dwarfs and the discovery of the first unambiguous substellar object in 1995: Gl229b. Despite this slow start, about 650 L and T dwarfs have now been identified, mostly thanks to the 2-Micron All Sky Survey (2MASS), the Sloan Digital Sky Survey (SDSS) and the Deep Near-Infrared Survey of the Southern Sky (DENIS).

Objects known as L dwarfs, with temperatures ranging from 2200 down to 1400 K, are characterized by the weakening of metal-oxide signatures, typical of the warmer M dwarfs, in the far red part of the spectra.

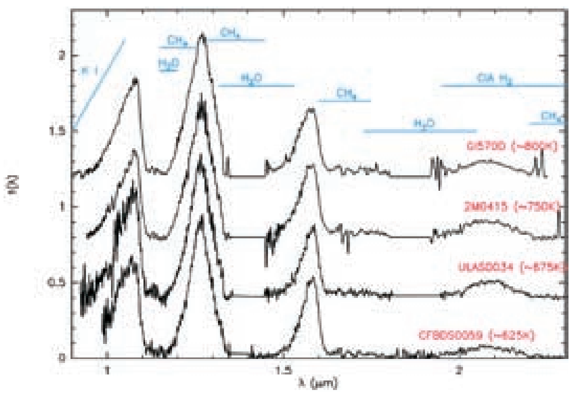

Figure 1. *Spectral sequence with the coolest T dwarfs and the two ammonia-bearing brown dwarfs.*

Those signatures vanish as the oxides condense into grains. In colder T dwarfs, the grains have settled below the photosphere and the opacity now mostly comes from molecular species such as water vapor, carbon monoxide, molecular hydrogen, and methane—the hallmarks of this spectral class. Indeed, these features are more reminiscent of planetary atmospheres than anything seen in stellar objects.

As the L and T sequence unraveled, an obvious question remained to be answered: what would a brown dwarf look like at a significantly cooler temperature? This question is still relevant since in more than a decade of surveys only a handful of objects colder than Gl229b have been found. On another front, deep surveys of star-forming regions have uncovered very light brown dwarfs and planetary-mass objects that will eventually cool down to room temperature within a few billion years. This leaves little doubt that objects much colder than Gl229b exist in the solar neighborhood. As the appearance of methane defined the T dwarf class, modelers predicted that colder objects would show ammonia signatures in the H band. These objects would fill the only temperature gap left in the observed stellar and substellar atmospheres, covering a continuum of physical conditions from the hottest stars at 100,000 K to the giant planets of the solar system at only 100 K. Furthermore, many of the recently discovered extrasolar planets fall within this temperature range. Finding such objects unencumbered by the glare of a parent star would greatly help refine untested extrasolar planet models.

As the appearance of ammonia is likely to produce large changes in the near-infrared spectral energy distribution (SED) of brown dwarfs, a spectral class has even been reserved for what are coming to be known as "Y dwarfs." Digging in the Gemini observing database, I found no fewer than 21 programs between 2004B and 2008A mentioning Y dwarfs in their titles or scientific justifications—not bad for objects that had yet to be discovered.

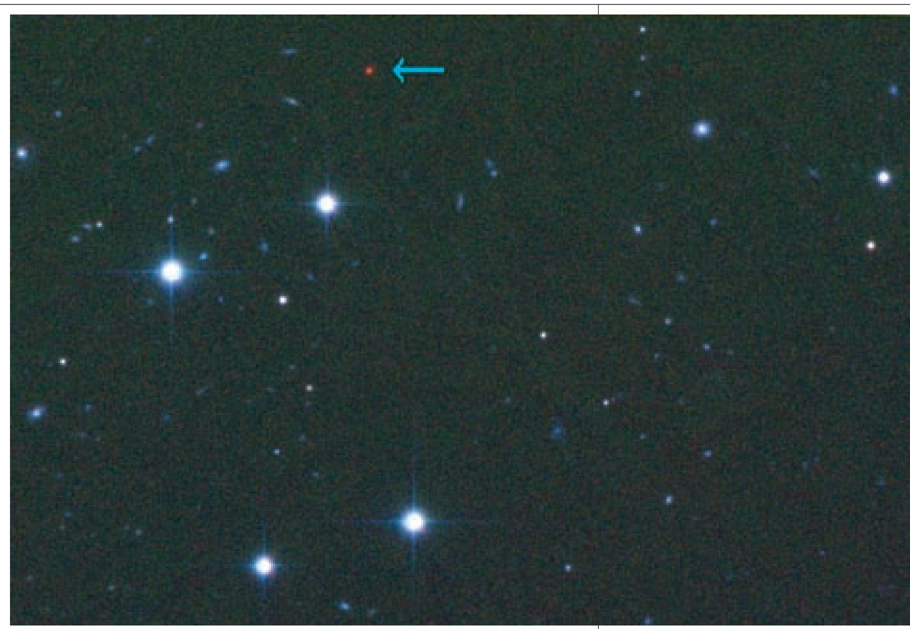

Figure 2. *Composite i/z/J-band image of CFBDS0059. The brown dwarf is by far the reddest object in the field.*

CFBDS0059

To identify brown dwarfs cooler than 750 K, our team used the Canada-France-Hawai'i Telescope Legacy Survey (CFHTLS), an ambitious multi-color imaging survey undertaken with the CFHT wide-field camera MegaCam. This data, complemented with principal investigator observations, allows us to image about a thousand square degrees in i and z bands. Cool brown dwarfs were identified through their very red i-z colors (Figure 2). The only other known astronomical sources this red are z = 6 quasars. Since brown dwarfs outnumber quasars by an order of magnitude, quasars constitute only a minor contaminant in our sample—and finding a z = 6 quasar is certainly an interesting discovery in itself! The major false positive sources proved to be artifacts and supernovae that had to be weeded out through

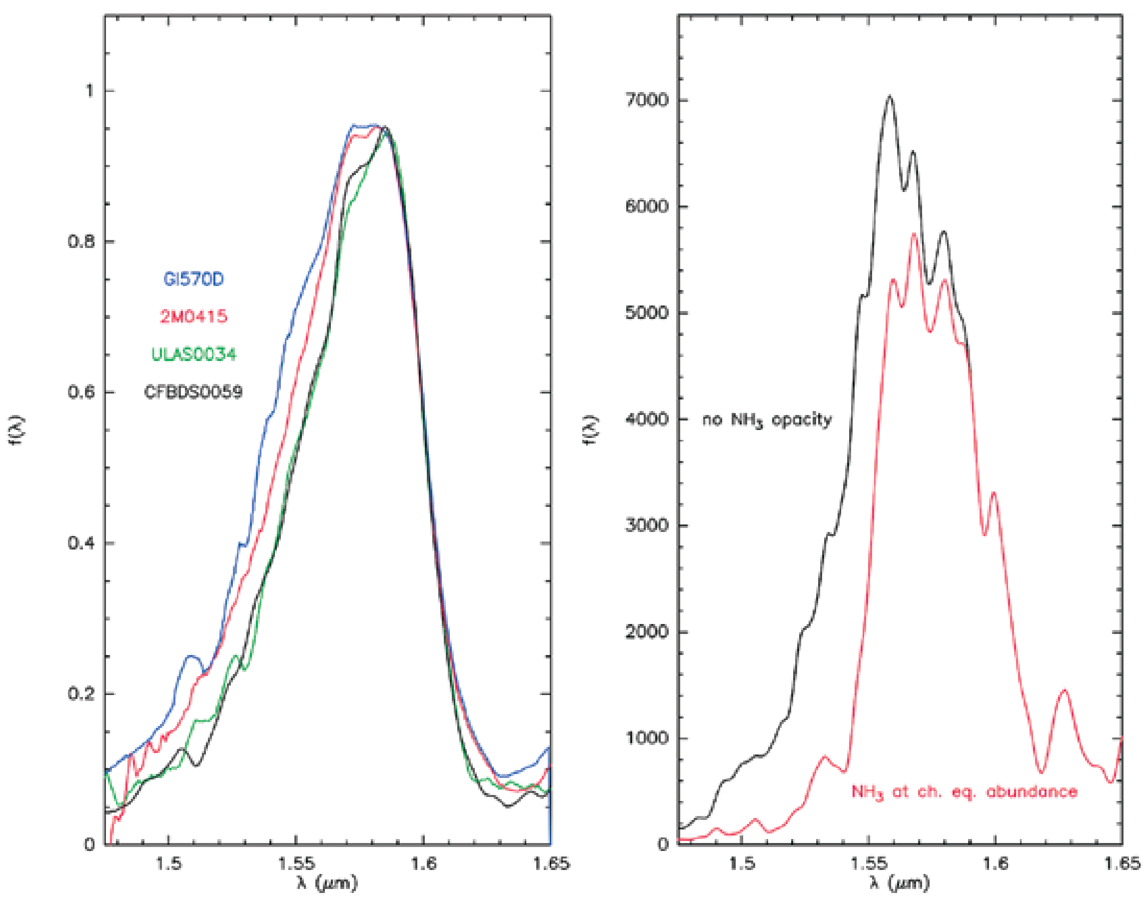

Figure 3. *Left panel: H-band spectra of CFBDS0059 and ULAS0034 compared to two of the coolest brown dwarfs previously known (2M0415: T8, Gl570D: T7.5). Right panel: Synthetic spectra for a T= 600 K brown dwarf with and without near-infrared NH3 opacity; the NH3 abundance is at its chemical equilibrium value. These models have been developed by Saumon et al. (2000).*

targeted J-band imaging at various 2- to 4-meter-class telescopes. Near-infrared spectroscopic follow-up of the most promising candidates was done with Gemini Near-infrared Spectrograph (GNIRS) and, since 2007A, with the Near-Infrared Imager and Spectrometer (NIRI).

Spectroscopic follow-ups confirmed about two dozen T dwarfs from the 370 square degrees that have been analyzed to date. One object, CDBDS0059 (found as part of the Canada-France Brown Dwarf Survey), was immediately seen to have a remarkably narrow *H*-band continuum, a telltale sign of very cool temperatures. The first spectroscopic follow-up of CDBDS 0059 was done only in the H band, but its very cold nature prompted *J*- and *K*-band spectroscopic observations from Gemini North using NIRI. This, combined with more-accurate photometry at the *i, z, Y, J, H* and *K* bands, unraveled the peculiar SED of this object. A comparison of CDBDS0059 spectra with the coldest known brown dwarf at the time, ULAS0034, show that CFBDS0059 is mildly colder (by about 50 K) and somewhat more massive than ULAS0034 (Figure 3).

Evolutionary models point toward an age of 1 to 5 billion years and a mass between 15 and 30 times that of Jupiter. At 620 K (about 350° C) CFBDS0059 has a temperature within the realm of our daily experiences. While early T dwarfs at 1200 K have temperatures more akin to that of molten lava, CFBDS0059 is cooler than the surface of Venus and has a temperature similar to that of the tip of a lit cigarette or hot oven.

As the spectral analysis continued, our interest focused on a discontinuity in the spectra of both CFBDS0059 and ULAS0034 around 1.565 microns, reminiscent of a molecular-band head. The nature of this spectroscopic feature was identified when both spectra were compared with that of Gl570D, a well-studied T7.5 dwarf. The contribution of this new source of opacity was singled out by taking the ratio of the spectra of CFBDS0059 and Gl570D. The H-band transmission curve of the new absorber neatly matched laboratory spectra of ammonia. Contrary to the first methane-bearing brown dwarf, whose spectra show clear and deep methane bands, these first ammonia-bearing dwarfs needed a careful analysis to sort out the never-before-seen absorption band in the near-infrared. This means that even if CFBDS0059 and ULAS0034 are remembered as the first Y dwarfs, their final classification will clearly depend on future discoveries and how this new molecular species modifies the SED of even colder objects.

As the follow-ups of the CFBDS objects are nearing their end, our team is planning a new survey to uncover even colder objects with temperatures down to about 500 K. We will use the near-infrared wide-field camera WIRCAM at CFHT to obtain J-band imaging of *z*-band CFHTLS fields and identify objects that are undetected in i-band and have eluded our first search. The limiting magnitude of this survey will ensure that all targets will be bright enough for spectroscopic characterization at Gemini and, in particular, with GNIRS (which will be recommissioned at Gemini North in 2009). GNIRS cross-dispersed mode has been one of the most efficient means of follow-up and characterization of field and open cluster brown dwarfs. Its broad wavelength coverage (1.0 - 2.5 microns) covers various metallicity and surface gravity indicators within a single observation.

One could wonder what lies beyond CFBDS0059 and its siblings going down the temperature scale. The current best guess from models of ever-colder objects is that steam, which is an important source of opacity in both L and T dwarfs, will ultimately be depleted as it condenses into water droplets to form clouds not unlike those that spoil astronomers' observing nights!

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by Jean-René Roy & R. Scott Fisher

Recent Science Highlights

Cyclotron Radiation from Interacting Dwarf Star Pair

The binary star SDSS J121209.31+013627.7, more commonly known as SDSS 1212, is possibly the first interacting binary where a substellar companion has been directly detected. The detection was made with the Gemini Near-Infrared Spectrograph (GNIRS) on Gemini South. The system was initially suspected to be a detached, non-interacting pair containing a cool (10,000 K) magnetic white dwarf plus a brown dwarf companion. However, the new data favor the interpretation that the pair consists of a magnetic cataclysmic variable (called a "polar" because of its highly polarized light emitted by the mass-transferred material falling in via a strong magnetic field) and a substellar donor in a quiescent (non-eruptive) state.

The research team was led by Jay Farihi (Gemini Observatory/University of Leicester) and included Matt Burleigh (University of Leicester) and Don Hoard (Spitzer Science Center). The team obtained spectroscopic data at 1-2.5 microns with GNIRS in its cross-dispersed mode. Due to the intrinsic faintness of this system and the fact that the light showed changes on approximately 90-minute timescales GNIRS was the only instrument available that could provide the team with high signal-to-noise data in reasonable integration times.

The team's most successful model of the system includes a white dwarf, a brown dwarf, and a cyclotron radiation component representing the infalling material from the substellar donor. The material that is accreting is caught in the 7 megagauss magnetic field of the white dwarf (Figure 2). The data, particularly the middle region of the spectrum (the H band), are consistent with the first direct detection of a substellar object in such a system. The substellar donor may be of spectral type T, a class that represents methane-bearing brown dwarfs. None had ever been detected associated with any type of white dwarf, including non-interacting systems.

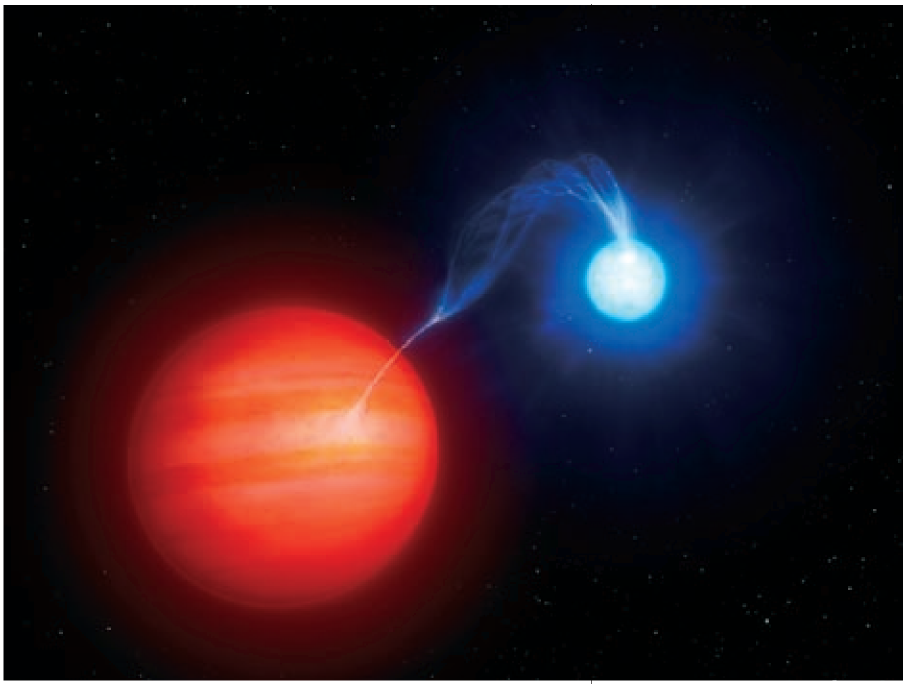
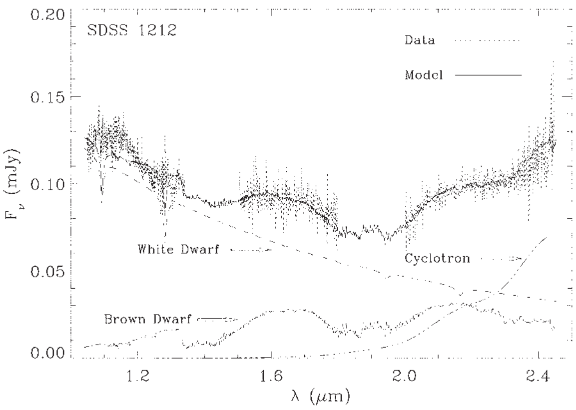


Figure 1. *Artist's view of material ejected by a brown dwarf captured by the strong gravitational field of a white dwarf. Falling particles are accelerated in the 7 megagauss magnetic field of the white dwarf generating cyclotron radiation. Credit: Gemini Observatory/ University of Leicester (UK)/ Mark A. Garlick*

However, the donor star in this system was not likely "born" as a substellar object nor has it cooled to near T-dwarf temperatures (about 1300 K and below) over billions of years. Rather, it evolved and lost internal energy via mass transfer onto the white dwarf, becoming smaller and colder as it was whittled down to its current size of about 60 Jupiter masses. This donor could end

Figure 2. *GNIRS near-infrared spectrum (dotted line) fit with contributions from a 10,000 K white dwarf, a brown dwarf of 60 Jupiter masses; and cyclotron emission.*

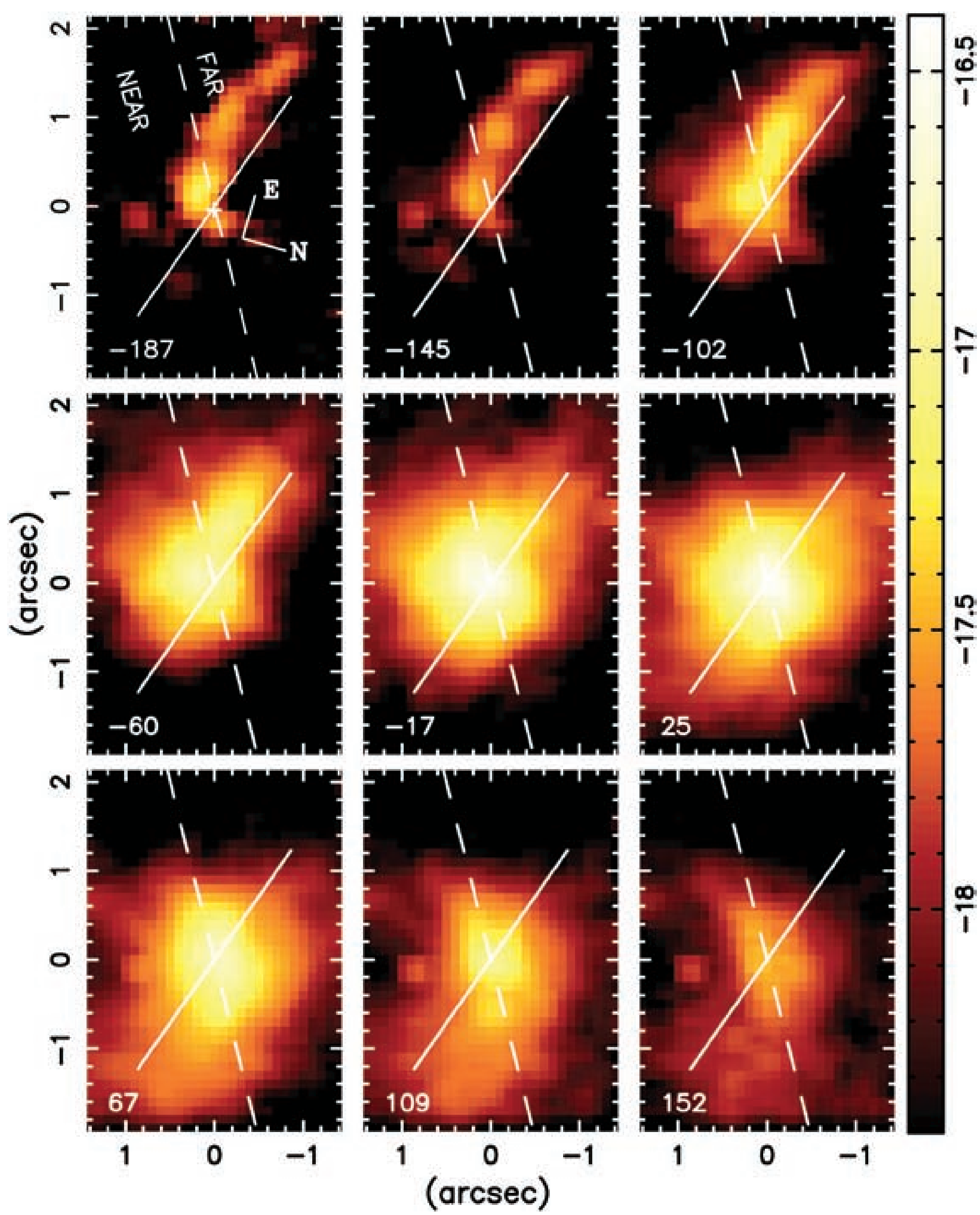


up as a planetary-mass object before the mass transfer turns off, or it may become entirely cannibalized by the white dwarf. The fates of these cataclysmic variables are somewhat uncertain.

More Evidence of Gas Inflows Toward Galaxy Nucleus

In 2006, central gas inflows toward the centers of galaxies were revealed in optical observations for the first time (see *GeminiFocus*, June 2006, p. 22). Now, new infrared observations of gas flows streaming toward the Seyfert

Figure 3. *Tomography of the inflow of gas toward the central region of NGC 4051. The numbers in the boxes indicate velocities in kilometers/second with respect to galaxy reference system.*



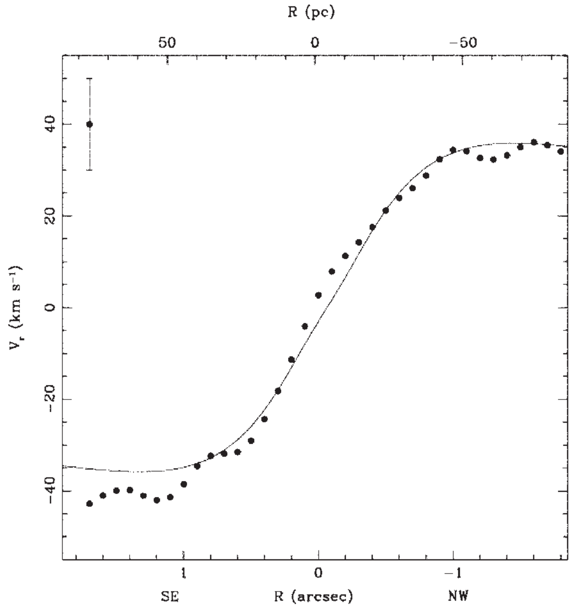


Figure 4. *The central part of a rotation curve derived from kinematics of the stars in NGC 4051.*

nucleus of the active galaxy NGC 4051 provide stronger evidence for this phenomenon. An international team used the Near-Infrared Field Spectrometer (NIFS) integral field unit on Gemini North, in conjunction with the Altair adaptive optics system to observe this nearby (12.7 megaparsecs) Seyfert galaxy. NIFS was essential for these observations as it allowed the observation of regions near the nucleus of the galaxy that suffer from high extinction.

Accurate subtraction of the stellar velocity field from the gaseous velocity field permitted the team to isolate non-circular motions of the hot H_2 gas flowing near the nucleus. Two nuclear spiral arms—one blueshifted on the far side of the galaxy and the other redshifted in the near side—are interpreted as inflows toward the nucleus (Figure 3). However, the mass inflow rate of dM/dt ~ 4×10^{-5} M_{Sun} per year is 100 times smaller than the accretion rate necessary to power the active nucleus. These observations may be detecting only the "hot skin" of the total gas flow, which is otherwise dominated by cold molecular gas. The hot H_2 is heated by x-rays from the AGN shocks produced by the radio jet.

The NIFS observations show the turnover of the stellar rotation curve to be at only ~ 55 parsecs from the nucleus (Figure 4). The curve suggests that the stellar motions are dominated by a highly concentrated mass, implying a central black hole of about one million solar masses.

Eruptive V1647 Orionis is Taking a Nap

A "new" star appeared in the constellation Orion in late 2003 when the young pre-main sequence star V1647 Orionis went into outburst and produced a reflection nebula called "McNeil's Nebula" (named for its discoverer, Jay McNeil). During the outburst, the star and nebula remained bright for approximately 18 months before fading rapidly over a six-month period. By early 2006, the star and its environment were very similar to their pre-burst stage. A team led by Colin Aspin (Institute for Astronomy (IfA)/University of Hawai'i), Tracy Beck (Space Telescope Science Institute [STScI]) and Bo Reipurth (IfA/University of Hawai'i) spearheaded the monitoring campaign of this event.

The 2003 eruption of V1647 Orionis was associated with a mass dumping of the inner regions of a heated circumstellar disk onto the young stellar photosphere.

Figure 5. *Gemini/GMOS-N color images of V1647 and McNeil's Nebula in eruptive and quiescent phases.*

The spectacular flaring in brightness of the object was caused by a significant increase in accretion luminosity and the clearing of surrounding dust by an energetic wind that made the star visible. These eruptions are thought to be repetitive and indicative of periods when a significant fraction of the final star's mass is accreted.

The Gemini observing campaign has revealed some interesting results, particularly for the quiescent period that started in February 2006. These include:

a) McNeil's Nebula is faintly visible in Gemini Multi-Object Spectrograph (GMOS-N) images (Figure 5) indicating that the nebular material is still weakly illuminated by the star V1647 Orionis. At the time of acquisition of the GMOS-N imaging and spectroscopic data, V1647 Orionis had a r' magnitude of 23.3;

b) Near-Infrared Imager and Spectrometer (NIRI) spectra revealed (for the first time in this type of object) the presence of molecular overtone absorption from carbon monoxide (CO) and other key diagnostic atoms like sodium (Na) and calcium (Ca) (possibly betraying the photosphere of the star);

c) Mid-infrared observations with MICHELLE on Gemini show evidence of silicate dust evolution over the outburst-to-quiescence period;

d) V1647 Orionis has a mass of about 0.8 solar mass and its age is about half a million years or less. The star is in its pre-main-sequence phase and is about five times more luminous than the Sun.

Aspin studied a previous outburst of the star that occurred in 1966. It's possible that V1647 Orionis "wakes up" every 37 years, but then quickly (after one or two years) tires and takes another long nap!

The Birthplace of Supernova 2007gr in NGC 1058

Supernova forensics—searching for the progenitors of recently exploded supernovae—is a new area of research enabled by the high spatial resolution imaging of the Hubble Space Telescope and large ground-based telescopes equipped with adaptive optics. Luminous red supergiant progenitors of the hydrogen-rich type II-P supernovae have now been identified with initial mass above 8 M_{Sun}. Astronomer R. Mark Crockett of Queen's University Belfast and his collaborators explored the pre-explosion site of SN 2007gr in the galaxy NGC 1058 (which lies about 10.6 megaparsecs away) from images obtained by HST Wide-field and Planetary Camera 2 (WFPC2) on July 3, 2001. Ground-based adaptive optics images were taken on August 19, 2007 with Gemini North Altair/NIRI in the K band, a few days after the supernova's August 15th explosion. The position was measured in the Gemini image and transformed to the coordinate system of the WFPC2 F814W pre-explosion frame yielding a pixel position on the HST detector (Figure 6).

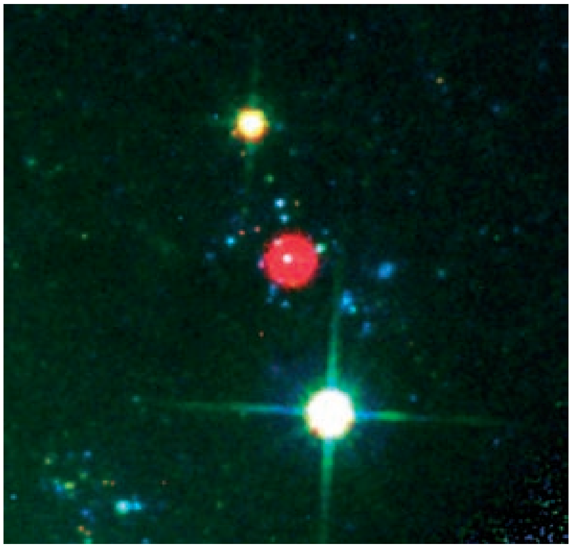


Figure 6. *A composite image of the SN 2007gr field in NGC 1058. The Gemini Altair image of the supernova (red) is superposed on the pre-explosion image obtained with HST/WFPC2.*

SN 2007gr occurred in a large, extended star-forming region where there are several bright sources. The supernova site is very close to, but not coincident with, an object that is bright in both the F450W and F814W images. The very closest object would correspond to M_B = -8.99, consistent with a single star with 30-40 M_{Sun} when adjusted for extinction and color corrections. The authors made a careful analysis of the various possibilities, including the existence of a coeval cluster between 7 and 20-30 million years old that could have hosted the supernova, with the individual star non-detectable in pre-explosion frames. No definite candidate object was found.

The work illustrates the kind of challenges facing the chasers of supernova progenitors. In the meantime, astronomers will wait for the supernova to fade and study it again using the refurbished HST in combination with additional adaptive-optics observations. These new observations would narrow down the age estimate of the cluster to less than 2 million years, and allow a better constraint on the probable mass of the progenitor of SN 2007gr.

A Second Look at RY Tauri Reveals New Jet

Canadian amateur astronomers Gilbert St-Onge and Pierre Bastien (Université de Montréal) took a deeper look at the Gemini legacy image of RY Tauri obtained in February 2005 (see Figure 7) as part of an outreach effort to have amateur astronomers propose observing targets for the Gemini telescope. RY Tauri is a classical T Tauri star located in the Taurus dark cloud about 134 parsecs away. The authors report the discovery of a new stellar jet. Their H-alpha image shows the jet extending out to at least 31 arcseconds, with a counterjet extending to at least 3.5 arcminutes in the opposite direction. Comparison with HST images obtained in August 1998 indicates a probable tangential motion of the brightest clumps in the jet of about 165 kilometers/second and a dynamical age of about 10 years. This new jet is a good candidate for further studies to map its motion and understand jet production mechanisms in young stars.

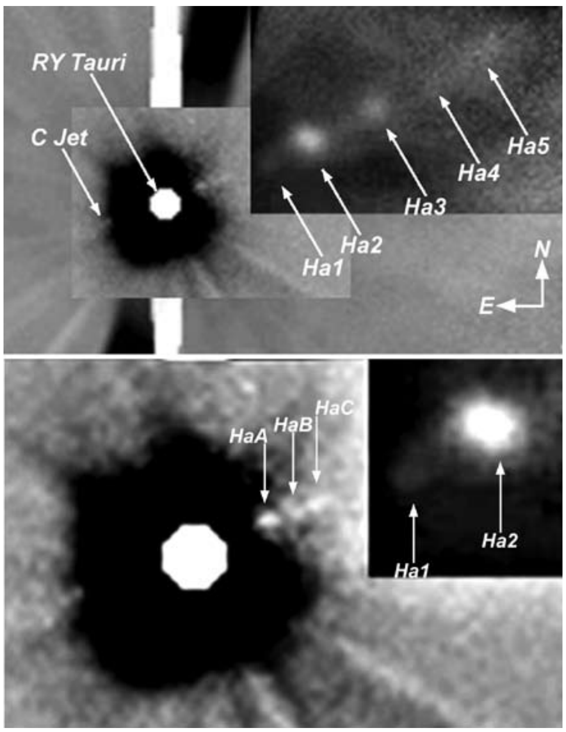


Figure 7.
The RY Tauri jet as seen in a Gemini GMOS-N image. Short exposures are shown, with superimposed long exposures to show the fainter knots.

Seeing Double (Nuclei) in NGC 3256

Resolved mid-infrared spectroscopy by T-ReCS has helped clarify issues surrounding the amount of obscuration present towards the double nucleus of NGC 3256. Its close distance (~ 39 Mpc) and high luminosity ($L_{bol} \sim L_{IR} \sim 6 \times 10^{11} L_{Sun}$) have made NGC 3256 one of the best studied luminous infrared galaxies (LIRGs). The high infrared luminosity is the result of a merger of two massive galaxies whose nuclei have a projected separation of only ~ 1 kiloparsec (kpc), which indicates that this merger is in an advanced state. Interestingly, NGC 3256 is also among the most x-ray luminous galaxies for which there is no clear evidence for an active galactic nucleus (AGN).

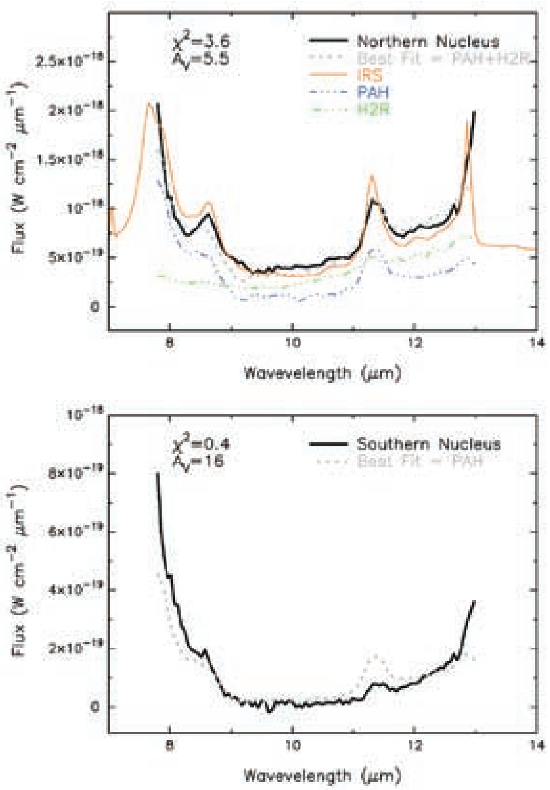
Scientific understanding of LIRGs has increased steadily through studies using pace-based infrared telescopes like the Infrared Astronomical Satellite (IRAS), the Infrared Space Observatory (ISO), and recently the Spitzer Space Telescope. However, high spatial resolution is still not available from these platforms. This limitation can be overcome with complementary observations made from 8- to 10-meter-class ground-based telescopes like Gemini. This is a particularly powerful technique for a target like NGC 3256, where regions of interest may only be an arcsecond (or less) removed from each other.

Imaging with TIMMI2 on the European Southern Observatory 3.6-meter and deep Gemini imaging by Alonso-Herrero (in 2006) show that the northern nucleus dominates in the mid-infrared where it is about a factor of five brighter than its southern counterpart. The T-ReCS spectra of the two nuclei are shown in Figure 8.

Determining the strength of the continuum for the sources was problematic given the strength of their polycyclic aromatic hydrocarbon (PAH) features and the relatively narrow spectral coverage of the data. Instead, the authors assigned fixed values of A_V = 5.5 magnitude and 16 magnitude to the northern and southern nuclei respectively. Both spectra are bounded by a strong 7.7-micron PAH feature at short wavelengths and the 12.8-micron [Ne II] line on the long wavelength end of the spectrum. These PAH features are also prominent at 8.7 and 11.3 microns in the northern spectrum. Modeling of the spectra shows that only 55% of the integrated flux of the northern nucleus comes from the PAH features, the other 45% is accounted for by a warm dust component that provides continuum emission. No significant continuum component is required for the southern nucleus. As shown in Figure 8, with appropriate scaling (to account for slit widths, etc.), there is good agreement between the Spitzer and Gemini data for the northern nucleus.

This research provides strong evidence that the environments near the two nuclei are different, even

Figure 8.
Mid-infrared spectra of the NGC 3256 nuclei. T-ReCS spectra (black lines) show evidence for PAH emission at 7.7, 8.7, and 11.3 microns. The [NeII] line at 12.8 microns bounds the spectra at long wavelengths. The components of a spectral model are shown in the top panel with a scaled Spitzer spectrum overlaid.



at this late stage of a galactic merger. The differences in the infrared characteristics of the nuclei can not be accounted for by different levels of obscuration alone. In fact, the northern nucleus requires a completely additional dust population to account for the spectral (and SED) differences. This suggests that local star-forming conditions can vary significantly within the environment of a single system.

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by Tom Hayward

NICI Update

The Near-Infrared Coronagraphic Imager (NICI) continues to advance toward the start of its planet-hunting campaign and queue science operations with a series of improvements and commissioning runs at Gemini South during 2007 and early 2008.

The most significant improvement has been the installation of a new deformable mirror (DM) built at the University of Hawai'i (UH). As described on page 7 of the June 2007 issue of *GeminiFocus*, the initial DM had an undesirably small stroke and two damaged actuators, which limited its performance. The UH DM with a maximum curvature of 10 meters radius, was installed in the NICI adaptive optics (AO) bench in April 2007. During its first commissioning run in July, with all 85 actuators functional, the new DM delivered a Strehl ratio of about 30% at a wavelength of 1.6 microns in 0.7-arcsecond seeing.

Following the July 2007 run, we implemented several upgrades to NICI:

• one thermal enclosure was rebuilt to provide adequate cooling for the array controller electronics and computers;

• some of the optical mechanisms were serviced to improve their reliability;

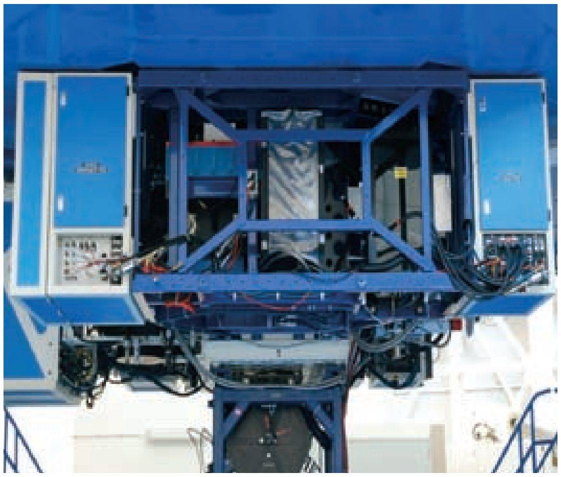


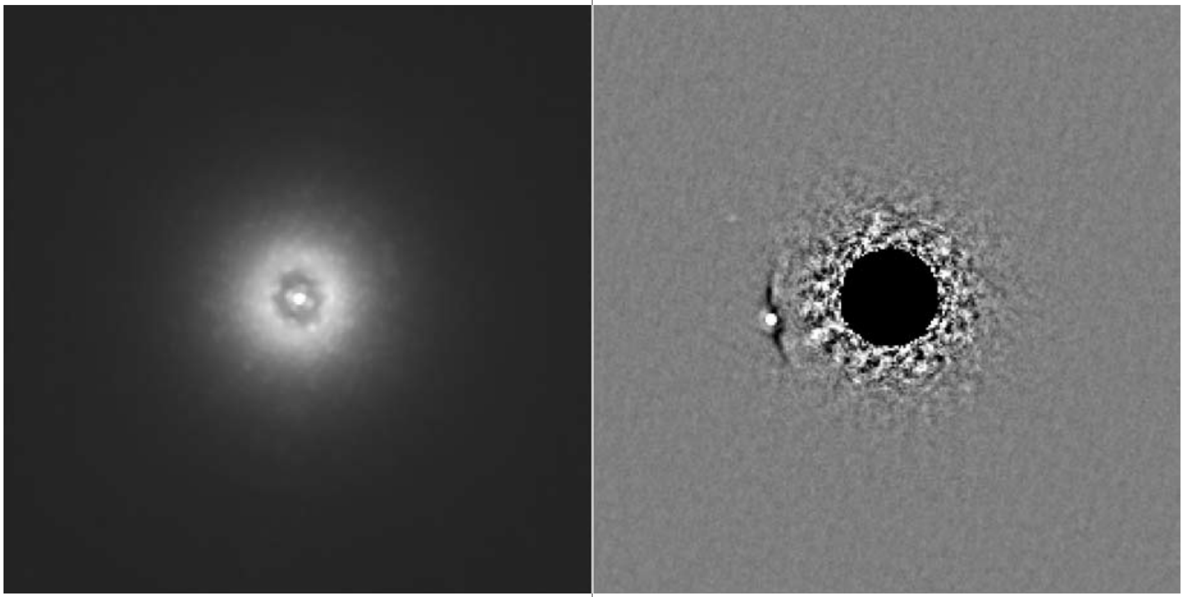
Figure 1.
NICI mounted on the ISS side port of Gemini South, February 2008.

• worn displacers in the cold heads were replaced;

• efforts were made by Mauna Kea Infrared, the University of Hawai'i, and Gemini's optical engineering staff to refine the AO system's optical alignment and optimize its wavefront correction algorithms.

A major effort is also underway to integrate NICI into Gemini's high-level software system, which includes the instrument sequencer and NICI-specific capabilities in the Gemini Observing Tool (OT), Sequence Executor (SeqExec), the telescope control console, and data handling system.

Figure 2.
Images of HD 129642 in the 1.6-micron methane 4% filter with the AO loop closed. The image at left is a coaddition of 76 images; the peak of the star is visible through the semi-transparent coronagraph mask. The image at right was processed to remove the central star, revealing a faint background star. In 0.6 arcsecond seeing the delivered Strehl ratio is 0.35 to 0.40 at 1.6 microns.



All these features were tested during two commissioning runs in January and February 2008. For the first time, NICI was mounted on the side port of the instrument support structure (ISS, Figure 1), its nominal position for general operations, and run completely under high-level software control. After calibrating the transformations required to control the AO system steering mirror, formerly long and laborious target acquisitions became a simple, semi-automatic process requiring only a few minutes. Operating in the familiar Gemini mode using the OT/SeqExec greatly simplified the construction and execution of long sequences containing science, background, and flat-field observations. Figure 2 shows images of the star HD 129642 and a nearby background star, made by combining 76 individual integrations taken over a 2-hour period, in which the Strehl ratio is 0.38 at a wavelength of 1.6 microns.

In the next few months we plan to improve NICI's performance in two basic ways. The first is to refine the alignment and tuning of the AO system to deliver higher Strehl ratios. The second is to reduce read noise and improve the reliability of the array electronics. The instrument builder, Mauna Kea Infrared, together with subcontractors at UH, are currently assembling a test system on which improvements will be implemented and tested before modifying the actual instrument. We expect to be starting campaign science around the beginning of semester 2008B.

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by Joseph Jensen & Scot Kleinman

GNIRS Update

The accident that befell the Gemini Near-Infrared Spectrometer (GNIRS) in April 2007 has resulted in the absence of this exquisite instrument for the past year. (See page 43 in the December 2007 issue of *GeminiFocus* for more background information). Once restored, GNIRS will be recommissioned for use on Gemini North. The decision to move the instrument from Chile to Hawai'i was partly a response to logistical considerations—primarily the arrival of new instruments at Gemini South. It was also made because of the considerable benefits to the Gemini community of having a world-class 1- to 5-micron spectrograph on Mauna Kea, with its cold and dry conditions. These, together with the better image quality on Mauna Kea and the low emissivity of Gemini North, should make GNIRS the most powerful spectrometer of its type, especially in the 3- to 5-micron region.

The GNIRS instrument is already in Hawai'i. Before it arrived in October 2007, considerable discussion took place and decisions were made about how the repair should proceed. The most important issues were:

- the kind of replacement detector array to be installed;
- whether repairs should be made to all observing modes; and
- were other simple but significant improvements possible.

A working group consisting of Joe Jensen, Scot Kleinman, Bernadette Rodgers, Henry Lee, Tom Geballe (from Gemini), and Jay Elias and Dick Joyce (of National Optical Astronomy Observatory (NOAO)) who had built the instrument, undertook an investigation to determine if there were good scientific reasons to replace the damaged Aladdin-3 array with the newer HAWAII-2RG 5-micron detector. The HAWAII array has pixels that are two-thirds the dimension of the Aladdin array, and there are four times as many of them (twice as many along a spectral row). The working group concluded that the need to redesign and then construct some items in the optical train (for example, the slit wheel) and the detector mount and electronics would lead to both significantly

Figure 1.
Top image: the contaminated entrance window from inside the dewar. The screw heads and inner baffle also show signs of the discoloring contamination seen more clearly in the bottom image of the GNIRS interior. Small areas of the contamination have been cleaned off for illustration.

Figure 2.
One of the many lenses on GNIRS shows surface contamination and coating damage.

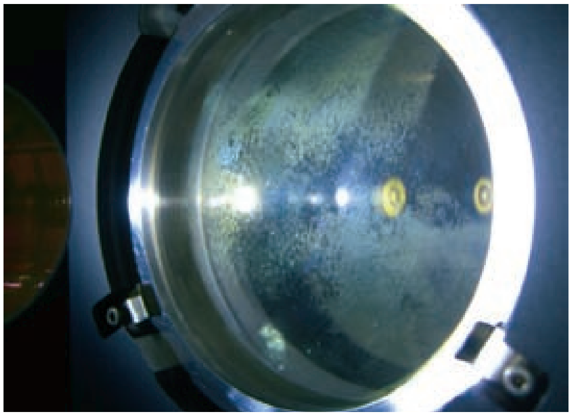
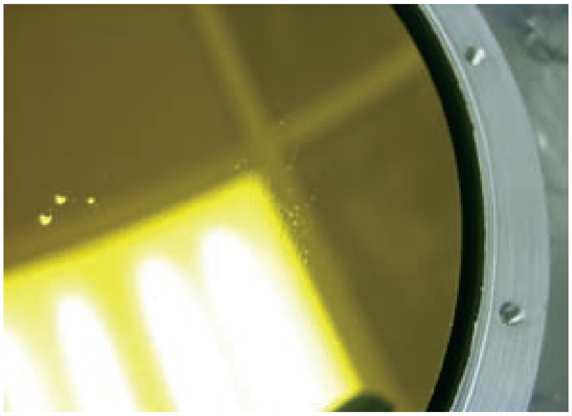


Figure 3.
Coating damage visible as pits and wrinkles on a GNIRS mirror.



longer down time and higher expense. Although the HAWAII-2RG would produce somewhat better science than an Aladdin-3 (primarily by providing better spatial and spectral sampling and increased wavelength coverage in some scientific modes) it would not enable new science, or significantly reduce exposure times, or produce higher spectral resolution. Furthermore, the existing optics in GNIRS would not allow us to take advantage of the finer spatial sampling nor most of the possible wavelength coverage gains of the HAWAII-2RG detector without a significant redesign. Thus, the working group concluded that the Aladdin-3 was the better choice for GNIRS.

GNIRS has now been disassembled in the instrument lab in Hilo. The primary damage to GNIRS was to the G10 fiberglass supports, the optics, the Delrin™ plastic spacers, and the infrared detectors. The metal pieces, motors, and wiring are all intact and mostly undamaged.

Supports and Detectors

We are now working to fix or replace the damaged parts. The G10 fiberglass supports have already been replaced. The resin in the original supports broke down, and a yellowish deposit is now coating parts of the vacuum jacket (the coldest part of the instrument during the overheating event). The fiberglass was structurally compromised, and the replacements had to be installed before GNIRS could be shipped to Hilo for further repairs.

The Aladdin-3 InSb science detector was destroyed when its indium layer melted. Similarly, the HAWAII-1 array in the on-instrument wavefront sensor (OIWFS) is presumed dead. We have ordered the replacement Aladdin-3 array from Raytheon Vision Systems and expect delivery and expect delivery soon. The array will be further tested and characterized at NOAO prior to installation in GNIRS. In the meantime, a multiplexer and engineering-grade array are available for testing the repaired GNIRS before installing the new science-grade detector.

The HAWAII-1 HgCdTe detector in the OIWFS must also be replaced. The University of Hawai'i (UH) Institute for Astronomy is providing a new array and repairing the OIWFS. UH built the three wavefront sensors for NIRI, GNIRS, and NIFS. The HAWAII-1 array need not be science-grade, since only a small subset of pixels in one quadrant are used to track image motion. UH will test existing engineering-grade arrays they have on hand and choose an appropriate one to repair the GNIRS OIWFS.

Optics

Most of the optical elements have been removed and examined. A subset of the lenses and mirrors were sent to NOAO for further expert assessment. What we found was discouraging. Many of the optics, even those that were protected from direct contamination, were damaged. Some of the lenses had chips. The damage is outside the clear aperture, but the chips will have to be stoned out, and the surfaces repolished and coated. Many of the lens coatings were thermally damaged, and they appear hazy and discolored. Contamination on some lenses is especially sticky, even with fairly aggressive cleaning with solvents. It is likely that most of the lenses will require repolishing and recoating by the original vendors.

The mirrors weren't spared either. One of the fused silica mirrors shattered, and the gold coatings on the diamond-turned collimator mirrors were damaged. The replicated epoxy diffraction gratings were destroyed, and

Figure 4.
The restored filter wheel and a sample damaged filter from GNIRS.

new gratings will have to be produced. Some mirror samples were sent to Optical Data Associates in Tucson, Arizona, for further testing. Their report showed that the contamination on the mirrors did not have significant absorption features in the near-infrared, meaning that any optics with intact coatings may be usable.

After examining all the optics, we decided that the best approach was to send everything back to the original vendors for further testing and repair. This will take some time and money, but should get us the optics we need to repair GNIRS in a timely fashion. The flat mirrors will be replaced, and the diamond turned mirrors recut or replaced as necessary. We are also investigating some rework on the collimator to remove some original defects. This should result in better image quality, especially when used with the Altair adaptive optics system. Also, while the other optics are being repaired, we will send away the cross-dispersion prisms for repolishing. We expect that improving the prisms will result in improved spatial resolution when using GNIRS with Altair.

Like the other optics, the thermal damage to the optical coatings in the integral field unit (IFU) was significant. Because of the way it is constructed, it is probably not feasible to disassemble or repair. The IFU would most likely have to be rebuilt from scratch, and that would significantly exceed our repair budget. Although the GNIRS IFU is most likely a complete loss, we may attempt to fix it at a later time.

Although the GNIRS IFU is a complete loss, we have not lost the majority of its capabilities. Gemini has recently commissioned the Near-Infrared Integral Field Spectrograph (NIFS), an IFU instrument with similar capabilities. NIFS has excellent spatial sampling and is designed to be used with the Altair adaptive optics system. The field of view is almost identical to the defunct GNIRS IFU, with better sampling. NIFS has spectral resolution of ~ 5000, similar to the resolution delivered by the GNIRS IFU. The one area where NIFS falls short in comparison to GNIRS is in the 2.5- to 5-micron regime. NIFS uses a HAWAII-2RG detector that cuts off at 2.5 microns, while GNIRS is sensitive to 5 microns. The longer-wavelength mode of the GNIRS IFU was not commonly used, however, so we expect that this loss of capability will have minimal impact on the science delivered by GNIRS.

The installed science filters were damaged beyond repair, but will be replaced with existing spares and new procurements as necessary.

After the optics are cleaned, repolished and recoated, they will be installed and aligned. While the optics and detectors have taken most of our attention, a number of other tasks require significant effort to get GNIRS back in working order. The motors have all apparently survived, but some of the cables will need to be fixed. The solder on some connectors melted. A great deal of cleaning is needed to remove the yellow resin residue from the inside of the dewar and to take away the melted plastic from many parts. New Delrin™ lens and filter spacers are needed as well. Once all the pieces are cleaned and the optics reinstalled, we will align the optics using a warm multiplexer, test the vacuum and cooling systems, and eventually test the entire system with an engineering or science grade detector.

We expect that GNIRS will be ready for recommissioning on the Gemini North telescope starting in semester 2009A.

The GNIRS repair effort is being lead by Gemini Senior Instrument Engineer, John White. The authors thank John for his contributions both to this article and to getting GNIRS back into service.

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Scot Kleinman is the Instrument Program Scientist at Gemini and can be reached at: skleinman@gemini.edu

by Stephen Eikenberry

FLAMINGOS-2 Update

Figure 1.
The fully integrated FLAMINGOS-2 instrument undergoing final testing at the University of Florida.

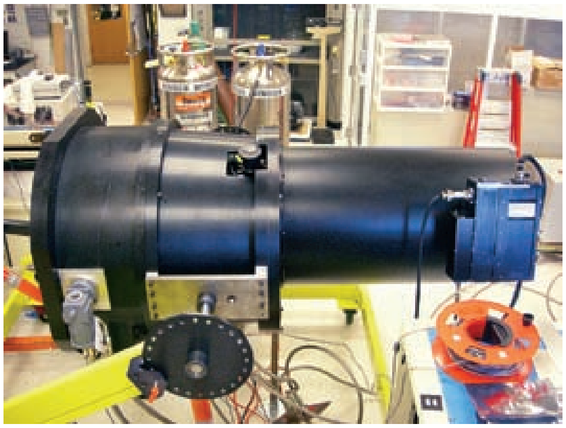
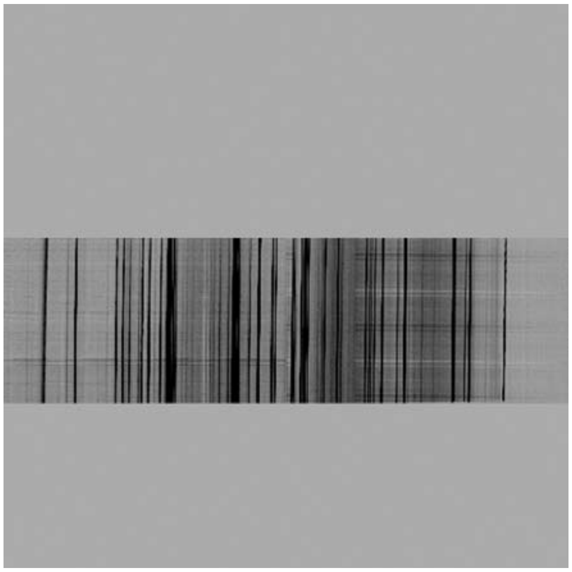


Figure 2.
JH spectrogram of a laboratory krypton arc lamp taken with FLAMINGOS-2 in 2007. The spectrogram used a 4-pixel test slit covering ~1/3 of the field length, and spans the wavelength range of approximately 1.0-1.8 microns. The slight tilt of the spectral lines is due to the (correctable) initial coarse alignment of the grism dispersion axis with the slit mechanism.

FLAMINGOS-2 will provide near-infrared wide-field imaging and multi-object spectroscopy on Gemini South after its delivery later this year. With a 6.2-arcminute imaging field diameter and spectroscopic multiplexing capability of up to 80 or more sources simultaneously over broad bandpasses, FLAMINGOS-2 will be a powerful scientific asset for the Gemini community. It will also work with the MCAO system to provide multi-object spectroscopy at high angular resolution (with 90-miliarcsecond pixels). Currently, FLAMINGOS-2 is fully integrated and undergoing final testing and performance verification in the University of Florida lab in Gainesville, prior to acceptance testing.

A key highlight of the lab tests so far is that we expect FLAMINGOS-2 to provide exceptional sensitivity for both imaging and spectroscopic observations. The throughput requirements for FLAMINGOS-2 are 50% in imaging mode and 30% in spectroscopic mode (excluding the detector and telescope). Measurements for all optical components as delivered by the vendors give actual throughputs of more than 60% in J-band imaging, and greater than 75% in H- and K-band imaging, providing sensitivity gains



of ~ 0.1 magnitude to more than 0.2 magnitude over the initial requirements for FLAMINGOS-2. Likewise, the spectroscopic throughputs reach greater than 45% in J+H (R ~ 1300) spectroscopy, greater than 55% in H+K (R ~ 1300) spectroscopy, and >40% in high-resolution J, H, or K (R ~ 3300) spectroscopy. The excellent throughput alone provides large (~ 20-40%) signal-to-noise gains—or, factors of ~ 1.3 to ~ 1.8 reductions in observing time—over the baseline requirements initially envisioned for FLAMINGOS-2.

Other factors also contribute to the exceptional sensitivity we expect for FLAMINGOS-2. We have demonstrated full-system read noise with the HAWAII-2 detector of ~ 10 electrons RMS, indicating very little added noise to the intrinsic read noise of the detector array itself. In addition, we have achieved low instrumental background and dark current, as well as excellent image quality across the entire field of view (we expect less than 10% degradation in image quality even under seeing conditions of less than 0.5-arcsecond FWHM). Another recent highlight is that FLAMINGOS-2 completed flexure testing, fully meeting all requirements for this important performance hurdle, ensuring that the excellent image quality will be maintained in the Gemini Cassegrain environment.

Work is continuing at the University of Florida at an intense pace to get FLAMINGOS-2 ready for acceptance testing and onto the telescope. The primary effort remaining is final performance verification of the on-instrument wavefront sensor, the focal plane mask mechanism, the (now fully loaded) cryogenic grism wheel, and the high-level instrument sequencer control software. We expect to be ready for on-site acceptance testing by August of this year; shipment to Gemini South and installation on the telescope for final acceptance would follow shortly thereafter.

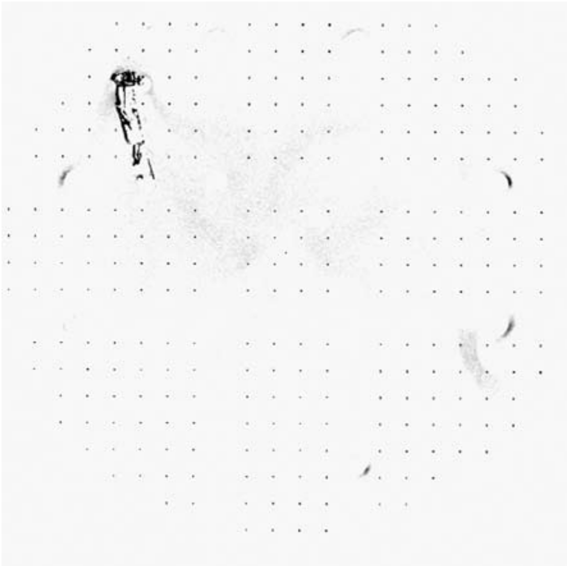


Figure 3. *Image of a test pinhole mask taken with FLAMINGOS-2 in 2008. The pinholes produce a regular grid, interrupted by a frame pattern used to support the test mask and keep it flat across the entire field for testing. The apparent defect in the upper left is actually a piece of aluminum tape used to orient the various coordinate transformations in the optical system. The faint "arc" images seen at various places are light leaks around the screws used to hold the test mask to its frame.*

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by Maxime Boccas & François Rigaut

MCAO System Status

Figure 1.
The Gemini South MCAO laser service enclosure is prepared on Cerro Pachón in Chile.

The Gemini Multi-Conjugate Adaptive Optics (MCAO) system which is in its final phase of completion at Gemini South will use five laser guide stars and three natural guide stars to correct for limited sky coverage, restricted field of view and the cone effect that affect the performances of "classical" adaptive optics systems. (A full description of the Gemini MCAO system can be found in *GeminiFocus*, December 2006, pp. 48-53.) Since our last update in fall 2007, progress has been made on several fronts for the MCAO project. In November 2007,

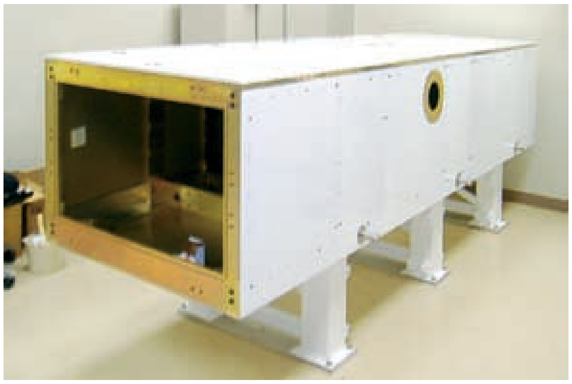

Figure 2.
Laser bench enclosure and support during integration at LMCT (Colorado).

Lockheed Martin Coherent Technologies (LMCT) succeeded in producing the required 50 watts of 589 nanometer laser light with the beam quality and stability specified. This was the last major technical hurdle for the project and clears the way for MCAO to perform up to expectations. Recently, LMCT completed the fabrication of the laser bench enclosure (see Figure 2). The next developments are: full characterization of the laser performance on the test bench, final bench testing (strength, vibrations), final integration of the optical components on the deliverable bench, environmental testing, and factory acceptance. We currently expect the laser to be delivered to Chile in early September 2008.

Another area of significant progress is with the laser service enclosure (LSE) and the supporting structure, both designed and made by the Gemini staff (Figure 1). The LSE is being built at Cerro Pachón and is about 60% complete. The design of the support structure (comprising 10 tons of mass added to the telescope mount) is complete and was reviewed by a structural engineering firm. Fabrication of the truss elements in local shops in Chile should start in May 2008.

The beam transfer optics (BTO) system has also made significant progress. All of the active optics mechanical assemblies are built and the electronics subsystems are complete. End-to-end computer control tests have begun in the Cerro Pachón instrumentation lab prior to integration on the telescope. We have also sent the first natural starlight through the laser launch telescope to characterize image quality of the up-link propagation. One last pending sub-system, the laser bench stabilization system (required to cancel the jitter of the beam injected into the BTO), is in final design and requirement phase and might be subcontracted out if we can not free the necessary internal resources.

CANOPUS, the adaptive optics bench, has seen slower progress due to involvement of staff in telescope operation and maintenance. There are ongoing efforts to fix or improve some mechanical systems (in particular, the thermal management), electronics systems (the servo motors for the moving elements), and the optical systems (for final acceptance of the laser guide star wavefront sensors both in temperature and flexure). Several summer students who worked with us for two months contributed significantly to development of the software for the diagnostic WFS, the slow focus sensor, the motor drivers and the APD TT sensor light protection.

The all-sky camera (ASCAM) is currently working reliably on Cerro Pachón and awaits the integration of a second CCD before being sent to Gemini North. We are still on the learning curve using the new Project Insight planning tool and improving the resource allocation between telescope operations and projects, but phases 1 and 2 of the project (up to installation of all hardware on the telescope) are committed milestones for 2008. We currently plan to be on the sky for the laser first light early in 2009 and thereafter start the technical and science commissioning for completion before the end of 2009.

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François Rigaut is the Adaptive Optics Senior Scientist at Gemini Observatory and can be reached at: frigaut@gemini.edu

by Joseph Jensen

Aspen Instrument Update

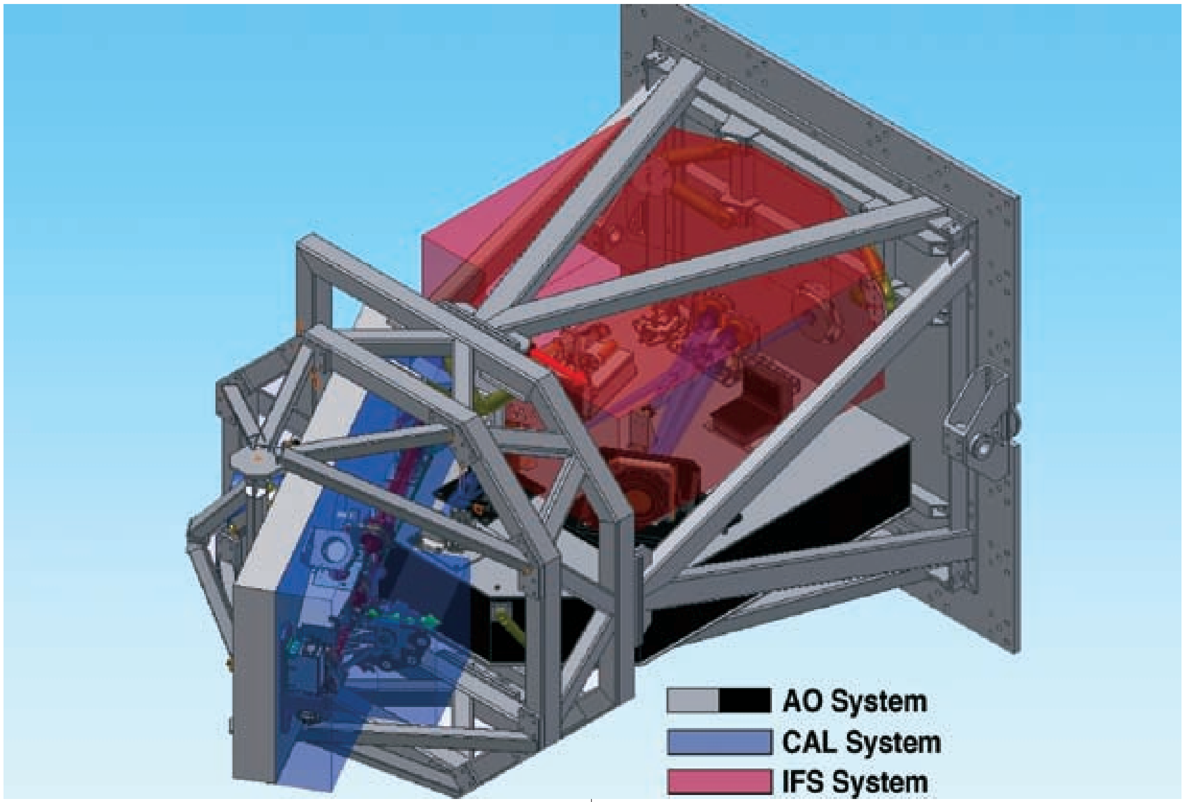

Figure 1. *A schematic showing the arrangement of the various GPI subsystems, including the AO bench, coronagraph, calibration interferometer, and integral field spectrograph in their mechanical frame.*

Significant progress in the Aspen instrumentation program has been realized since the last update in *GeminiFocus* (December 2005, pages 7-15). Scot Kleinman, Steve Varlese, and Arturo Núñez have joined the Gemini instrument development group and now help with the science, engineering, management, and software development on various Aspen and other instrument projects. The following summaries highlight progress on key Aspen instruments.

GPI

The first major component of the Aspen instrumentation program is the Gemini Planet Imager (GPI). The GPI team, led by Bruce Macintosh at Lawrence Livermore National Laboratory (LLNL), is now advancing rapidly towards completing the design phase. The critical design review (CDR) for GPI is scheduled for May 2008. To prepare for CDR, the science team (led by James Graham (Berkeley)) has developed several proposed planet-finding surveys for GPI. These "design reference missions" help the team make complex design decisions as they arise.

Gemini is working with the project manager Dave Palmer (LLNL) and the systems engineer Les Saddlemyer (HIA) to better define how GPI will work within the Gemini environment. Gemini has two new employees helping with GPI full-time: Steve Varlese, who has extensive experience with project management and systems engineering, and Arturo Núñez, a software engineer. Both started working for Gemini on the GPI project in January 2008. We are happy to have them on board as we prepare for the important CDR milestone.

The rest of the GPI team, including UCLA (integral field spectrograph), the Jet Propulsion Laboratory (calibration interferometer), the American Museum of Natural History (coronagraph), the Herzberg Institute of Astrophysics (mechanical structure and software), University of California-Santa Cruz (deformable mirror, assembly and testing), and Université de Montréal (data processing software) are working as an effective and united team to complete the detailed design. Their recent efforts will help ensure that this precision optical instrument performs to specification for many years, even in the dusty, vibrating, and changing environment on the telescope.

WFMOS

The second Aspen instrument out of the gate is the Wide-field Fiber Multi-Object Spectrometer (WFMOS). It will revolutionize our understanding of the history of the Milky Way Galaxy and the evolution of the universe by measuring thousands of spectra simultaneously across a field of view 1.5 degrees in diameter. Gemini is planning this ambitious instrument in collaboration with our Japanese colleagues at the Subaru Observatory, and WFMOS will be installed on the Subaru telescope where it will share a common corrector and infrastructure with the HyperSuprime Camera.

Two years ago uncertainty in the availability of funding for WFMOS led to a three-month pause in the conceptual design studies, which were just getting started at the time. Now, nearly two years later, we have finally succeeded in restarting conceptual design studies conducted by two competing teams. One team is led by Sam Barden of the Anglo-Australian Observatory (AAO). Richard Ellis (Caltech) heads a second team headquartered at JPL. Both teams include international members from across the Gemini partnership and Japan. Competition is an essential element of the conceptual design studies because it encourages creative thinking about the technical aspects of such a revolutionary instrument, and it maintains pressure on the teams to be as realistic as possible with their cost estimates and performance requirements. The conceptual design studies are scheduled to be completed and a team selected early next year.

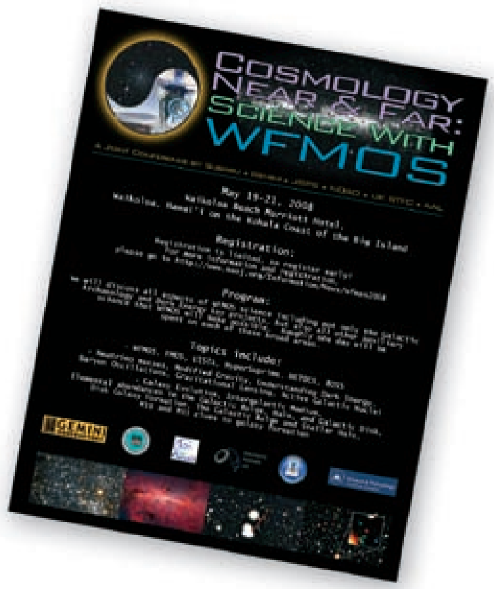

Figure 2. *Meeting flyer for the WFMOS science conference.*

As mentioned above, Gemini is teaming up with Subaru to build WFMOS. Very early in the planning process, while the feasibility of WFMOS was being studied, we realized that the Subaru telescope on Mauna Kea would be a much better platform for a massive prime-focus, wide-field optical instrument than Gemini. The Japanese are major players in the scientific areas that WFMOS will address. Subaru and Gemini will share the costs of building the instrument and observing time on all three telescopes (the two Gemini telescopes and Subaru). Japanese astronomers will have access to unique Gemini instrumentation and the southern hemisphere, while Gemini astronomers will be able to use WFMOS on Subaru to address fundamental questions of interest to everyone. It is truly a win-win situation as the Gemini and Subaru telescopes will be used for the observations for which they were designed and optimized. Neither observatory could build such an ambitious and expensive instrument alone.

Another new Gemini staff member, Scot Kleinman, is overseeing the WFMOS conceptual design studies. Scot is an astronomer who most recently worked at Subaru. Previously he worked with the Sloan Digital Sky Survey project, so he is familiar with both large-scale spectroscopic surveys and working with the Japanese at Subaru. We are pleased to have Scot on our team.

To encourage greater appreciation for the ground-breaking science enabled by WFMOS, Gemini and Subaru have organized and sponsored a science workshop with additional support from the Japan Society for the Promotion of Science (JSPS), the UK Science and Technology Facilities Council (STFC), the US National Optical Astronomy Observatory (NOAO), and Astronomy Australia Ltd. (AAL). Proceedings of the conference can be found at: http://www.naoj.org/Information/News/wfmos2008/. This meeting (which was held on May 19-21, 2008, as this issue goes to press) will bring together astronomers from around the world to meet each other, establish collaborations, and plan for the revolutionary science discoveries WFMOS will enable.

GLAO

We continue to explore the possibility of building a Ground-Layer Adaptive Optics (GLAO) system for Gemini North. Currently, a team led by Mark Chun at the University of Hawai'i Institute for Astronomy is continuing to collect data on the turbulence in the lowest layers of the atmosphere over Mauna Kea. So far, the data indicate that a significant turbulent ground layer exists more than half of the time. Correcting for this layer with a wide-field adaptive optics system would allow Gemini to deliver 20-percentile image quality 80% of the time in the near-infrared, and possibly even improve seeing in the optical as well. To better quantify the gains that could be realized with GLAO, Gemini is working with the team that conducted the original GLAO feasibility study to update the numerical models originally run more than two years ago with the new ground layer measurements collected by the UH team. We expect that the results of this investigation will be used to justify a conceptual design study for GLAO, possibly starting in 2009 once the WFMOS conceptual design studies are complete.

PRVS

In March 2008, the Gemini Board of Directors decided not to proceed with construction of the Precision Radial Velocity Spectrometer (PRVS) in the light of budgetary constraints, hence PRVS will not be built for use on Gemini. The Board regretted cancelling the PRVS project, but felt it was important to focus on the highest priority elements in the Aspen instrumentation program given the financial uncertainties in the Gemini partner countries.

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by Michael Sheehan

Earthquake Readiness Workshop

Following the October 2006 earthquake that shut down many of the Mauna Kea observatories for weeks, some actions were taken in order to mitigate the risks associated with future earthquakes. First, a workshop was held in Hawai'i in March 2007 to get the perspective of all Mauna Kea observatories on how their facilities reacted to the recent earthquake and what could be done to improve performance and response in future events. Of this group, Gemini is unique in that we have a telescope facility in Chile as well. As such, a similar workshop was planned for Chile in early December 2007 where all astronomical observatories in Chile were invited to participate, (see Table 1).

The program for the Earthquake Readiness Workshop in Chile was a much-expanded version of the meeting held in Hawai'i. Two primary areas of focus were defined early in the preparation phase; structural design considerations and safety.

The first day focused on the science and engineering aspects of earthquake risk mitigation and the second day was devoted to health and safety issues. The morning sessions consisted of a series of presentations by experts in various fields. Small working group sessions convened during the afternoons with each covering a specific area of concern. A summary of each of the working group meetings was given by the session leaders at the end of each day, followed by general discussions.

Two powerful keynote talks opened the workshop and set the stage for the sessions over the next two days. Sergio Barrientos, the Scientific Director of the Seismological Services Department for the Universidad de Chile gave a talk entitled "New Considerations About Chile's Seismic Hazard." An overview of seismic activity throughout Chile was presented along with a description of the mechanisms by which ground motion is created from seismic events. Several maps depicted the distribution of earthquakes throughout Chile, along with magnitude and historical time periods. A significant observation was that major earthquakes tend to occur at a recurrence interval of about 80 years. The second introductory

Association of Canadian Universities for Research in Astronomy (ACURA)
Atacama Large Millimeter Array (ALMA)
AURA Observatory Support Services (AOSS)
Canada-France-Hawaii Telescope (CFHT)
Cerro Tololo Inter-American Observatory (CTIO)
Empire Dynamic Structures, Ltd.
European Southern Observatory (ESO)
Gemini Observatory
Geotecnica Consultores
Large Synoptic Survey Telescope (LSST)
Herzberg Institute for Astrophysics
Las Campanas Observatory (LCO)
La Silla Observatory
M3 Engineering and Technology Corporation
National Optical Astronomy Observatory (NOAO)
National System for Civil Defense (ONEMI)
Southern Observatory for Astronomical Research (SOAR) Telescope
Thirty Meter Telescope (TMT)
Universidad de Chile
USGS Hawaiian Volcano Observatory
Very Large Telescope Project (VLT)

Table 1. *Participant organizations in the two-day Earthquake Readiness Workshop in Chile.*

Figure 1.
Participants at the Earthquake Readiness Workshop in Chile take time out for a group photo.

talk, "Earthquake-Hawai'i October, 2006," was given by Derrick Salmon, the Director of Engineering for the Canada-France-Hawaii Telescope. Here, an overview of the impact of the Hawai'i earthquake on all Mauna Kea summit-area and sea-level facilities was presented. Many of the Mauna Kea telescopes sustained damage and/or misalignments to varying degrees resulting in weeks of down time. Facilities in Waimea sustained significant damage as well. Many technical, logistical and personal lessons learned from this experience were shared. In particular, "communication is everything" was a common thread. The same staff members who we count on to get the telescope back together have their own sets of issues to deal with at home. Plans to open and maintain communication with all personnel need to be in place in advance of the earthquake. Technical aspects of bringing telescope systems back on line also need to be well-planned in advance.

Next up was a technical presentation on seismic sensors and networks written by Paul Okubo, a geophysicist from the Hawai'i Volcano Observatory, and Sergio Barrientos. This is a relatively new area of work, using sensor networks deployed in areas known for a high probability of significant earthquakes. These sensors would measure ground motion and trigger warnings to remote areas. Such a system in and around Mauna Kea and Cerro Pachòn could possibly provide an advance warning of around 10 seconds prior to the arrival of significant ground motion at the summit. This time could be used in many ways, from triggering a graceful shutdown of sensitive systems to sounding warning alarms for personnel in the facilities.

Another technical talk finished off the morning of day 1: "Seismic Design Considerations" which was given in two parts. First, I gave a general overview of seismic design considerations for telescopes, instruments, observatory buildings and equipment. Design methodologies for various types of new structures and considerations for retrofit of existing structures were also presented. Mike Gedig from Empire Dynamic Structures, Ltd. then gave an overview of the progress on the seismic design of the planned Thirty Meter Telescope.

After lunch, we divided into three large working session groups that spent the next 90 minutes in detailed discussions about seismic design considerations for new structures, seismic retrofit of existing structures, and seismic sensors and networks. Each working group session was led by a team of experts, but the bulk of the discussion came from the observatory personnel in the general audience. These sessions provided an opportunity for the various groups to share their knowledge and experience and make detailed notes for future reference.

The second day was devoted to safety issues. It began with a presentation by Mario Perez Rojas, the Regional Director for Civil Defense and Emergencies entitled "National System for Civil Defense, Reduce the

Vulnerability of People and Properties." He described official processes for planning prior to natural disasters as well as post-disaster communications and actions. Emergency plans are in place for earthquakes as well as other catastrophic events. The levels of response in these plans depend on the magnitude of the event. Assessment is immediate and follow-up occurs several times a day until the emergency is declared over.

Representatives from AURA, ESO, and ALMA then gave short presentations about the design and operation of their facilities with regard to seismic considerations. Sergio Franco spoke about the AURA facilities and emergency plans and processes in place for earthquakes and other disasters. Processes and procedures for dealing with earthquakes have matured over the years to a very detailed level. Roberto Tamai gave an overview of the ESO facilities at Paranal and measures taken to deal with seismic risks. These measures began early in the design phase, with active and passive systems built into the telescope, enclosure and facilities systems to react in an appropriate way to ground motion. High levels of monitored ground motion trigger restraint systems. Inspection and recovery procedures are also in place at the Paranal facilities.

Eduardo Donoso described the status of the ALMA project and then went into a detailed discussion on the seismic design philosophy and requirements for the facilities. ALMA chose to adopt a more stringent set of seismic design elements than required by code in order to minimize or eliminate the risk of damage in a seismic event. Massive foundations, robust structures and anchorage to rock are typical features of ALMA facilities design. The up-front costs of such an approach are far less than the cost of potential repairs at such a remote location.

Two final talks focused specifically on safety plans and considerations for major emergencies. Mario Gonzalez spoke about AURA's plans and procedures and Michael Boecker outlined the plans and procedures in place within ESO for the Paranal and La Silla facilities. These include extensive documentation along with training, practice and drills, trained emergency teams, fixed lines of communication and an organizational structure with defined roles and responsibilities.

The afternoon working group sessions on day two were focused on three specific time periods related to earthquake activity and what we can do to ensure the safety and well-being of people and facilities at those times. The first period considered was the time prior to a future earthquake. The second was the time period during a major earthquake, and third was the time immediately after an earthquake. These working group sessions produced lengthy discussions on planning, training, and practicing. Facility inspections to identify areas that are at risk of damage or collapse and methods of providing restraint were discussed. Coordination with external agencies such as Civil Defense, medical facilities, fire brigades and others was reviewed. The sessions also identified safe areas within the facilities that people can get to quickly as well as instructions for personnel on appropriate actions to take when they experience an earthquake. Immediately following an earthquake, pre-defined actions should begin as directed by a fixed and well-planned responsibility and authority structure.

All documentation including presentations and working group session notes are available on a dedicated website: http://www.gemini.edu/earthquake/

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by Stephen J. O'Meara, Janice Harvey
& Maria Antonieta García

Engaging Our Host Communities

One important lesson that astronomers have learned since Galileo first turned his telescope to the sky nearly 400 years ago is to never underestimate the power of public opinion. A misinformed or ill-educated public can slow scientific progress, sway legislation, or even impact how science is taught to our children in the classroom.

A well-informed public can be one of astronomy's most powerful allies. In this world of rapidly evolving technologies and instruments that span the electromagnetic spectrum, astronomers need to reach out to the public now more than ever. We must effectively communicate the exciting breakthroughs in our research and share these findings so they can enrich everyone's lives now and in the future.

That's why two of Gemini's flagship local outreach programs—*Journey through the Universe* in Hawai'i and *AstroDay Chile*—engaged thousands of students, teachers, parents and the public in a host of educational activities earlier this year. The programs not only presented Gemini's work in public outreach, but brought dozens of other astronomical institutions together in both of our host communities to share the excitement of astronomical research.

Journey through the Universe 2008

It takes a community to educate a child, and a network of communities to reach a generation. That's the basic philosophy behind *Journey through the Universe* (*JttU*), a space-education program originally established by the National Center for Earth and Space Science. For the past four years Gemini has supported this philosophy, and during the week starting February 1, 2008 the fourth annual *JttU* brought the universe to Hawaii's students, teachers and the public. During this week, the program opened a window on the universe to more than 8,000 students in 21 schools on the Big Island of Hawai'i.

Beyond visiting 340 classrooms, our educators and scientists from all of the Mauna Kea observatories shared their knowledge of the cosmos at public lectures, teacher and astronomer workshops, family science nights, and events for community and government leaders.

This year's *JttU* week strove to effectively embrace the community, and as it has in past years, Gemini's Public Information and Outreach (PIO) office led the coordination of the event. To accomplish this, Gemini's PIO staff worked hand in hand with all of the Mauna Kea observatories, the Hawai'i State Department of Education, 'Imiloa Astronomy Education Center, the University of Hawai'i at Hilo, and the Institute for Astronomy. Fourteen local corporate/business sponsors and numerous ambassadors (individuals who assisted our astronomy educators in the classroom) rounded out the community engagement. Inmates at the local Kulani Prison even hand crafted lei to thank us for teaching their children. These lei were used at a special *JttU* celebration sponsored by the Hawai'i Island Chamber of Commerce.

Journey to the Classroom

Joining the almost 50 educators and researchers from the Mauna Kea observatories, Gemini staff members Doug Simons, Scott Fisher, Tom Geballe, Kathy Roth, Scot Kleinman, Kevin Volk, Anil Dosaj, Koa Rice, Peter Michaud, and Janice Harvey all shared in the excitement by visiting classrooms throughout this year's *JttU* events.

Gemini Director Doug Simons visited Waiakea High School. In an engaging talk he described how astronomers use light to understand the nature of distant objects in the universe. To help convey that message, Doug showed off a photometer that he built in college to demonstrate that light exists in the form of discrete photons by coupling the photometer to a speaker. In this way students could literally listen to individual photons rain on the desktop before them.

Valerie Takata, Complex Area Superintendent of the Hilo/Laupahoehoe/Waiakea school district, commented on the engagement of observatory staff in the program. "One of the most valuable assets of our partnership with Gemini," she said, "is having a pool of expert researchers, technicians, and other career-resource people who are willing to work with our students, teachers, parents, and the community at large. These ambassadors of science are teaching us literally how to reach for the stars—especially by strengthening our science curriculum and integrating other content areas into learning. Thanks to Gemini, we've discovered the power of learning in a synergistic system. Learning is a process; learning is hands-on; and it is fun!"

Figure 1.
Here NASA engineer and JttU *educator Kevin M. Caruso uses a leaf blower to inflate this young astronaut, Jaeda Victorino's, low-budget flight suit as fellow Waiakea Elementary School classmates look on.*

The children were not the only ones who benefited from the program's educators. More than a hundred Hawai'i teachers attended the Master Teacher and Teacher workshops held at the 'Imiloa Astronomy Education Center in Hilo, led by astronomy education expert Dr. Tim Slater of the University of Arizona. 'Imiloa is an educational resource for students, teachers, scientists and the larger community. According to center director Peter Giles, *JttU* is a perfect fit. "In these hands-on workshops, the teachers learned how to better promote astronomy

Figure 2.
More than a hundred Hawai'i-based teachers attended the JttU teacher workshops held at the 'Imiloa Astronomy Education Center in Hilo.

education in the classroom, so to create a stable of prospective researchers in the future," said Giles.

State and National Recognition

At a December 2007 Department of Education Appreciation Luncheon for Business and Community Partners in Honolulu, Karen Knudsen of the State Board of Education and Valerie Takata presented Gemini Observatory with a community engagement award, primarily for the *JttU* program. As Takata told a *Hawai'i Tribune Herald* reporter, "Public education needs the community to help fulfill its mission to our students," she said. "And programs like this inspire our students to aim for the sky."

This year the *JttU* team also received special state proclamations from Mayor Harry Kim of the Big Island and Hawai'i Governor Linda Lingle. In addition, the team was presented with a State Senate resolution at a thank-you celebration held by the Hawai'i Island Chamber of Commerce. Big Island State Senator Lorraine Inouye flew in that evening from Honolulu to personally read the resolution.

"What an incredible team!" said Dr. Jeff Goldstein, founder of the national *Journey through the Universe* program, pointing out that the Big Island's event is the flagship *JttU* site. "Gemini Observatory has impacted thousands of lives, inspiring big dreams in young minds. A vision starts with a champion who arouses a coalition of the willing. Anyone who witnessed the remarkable program held on the Big Island in 2008 knows that that vision has now been realized. Gemini's scientists and engineers live on the frontier. They have become heroes to the next generation."

Figure 3.
JttU also benefited from widespread professional, political, and community support. Seen here (from left to right) are some local dignitaries participating: Ron Koehler (Mauna Kea Support Services director), Hawai'i Senator Lorraine Inouye, Gemini North director Doug Simons, Janice Harvey (Administrator Gemini North Education, Outreach and Media), and Inge Heyer (Science Outreach Specialist for the Joint Astronomy Centre).

Into the Future

Looking forward to 2009 (and the *International Year of Astronomy*), the Gemini-based *JttU* team plans to increase the number of teachers trained, add more classroom visits, and hold an additional *Family Science Night* at the 'Imiloa Astronomy Education Center.

Figure 4.
JttU teacher workshop where educators enjoy a safe, homemade sun-viewing device that can be used to teach children about our closest star.

Figure 5. *Classroom visits play a major role in the JttU program. In this photo, Sophie Milam, one of our local ambassadors, interacts with students at Nawahiokalani'opu'u, a Hawaiian language immersion school in Kea'au.*

Doug Simons also thinks that Gemini can help *JttU* widen its vision. "In my 1,000,000+ miles of travels with Gemini around the globe," Simons explained, "I have never heard of anything that matches the *JttU* program in its scope. Yet it remains something of a secret on the mainland and beyond. Given the impact we are making in Hawai'i, our little secret will surely be noticed far beyond the shores of the Big Island in the near future."

With that goal in mind, Gemini is now looking at the possibility of combining *JttU* with the Astronomical Society of the Pacific's *Project ASTRO*, a national program that provides opportunities for professional and amateur astronomers to contribute to science education in their local communities. Together, the two groups hope to inspire more students and create a model for Gemini's international partnership.

AstroDay Chile

Astronomy Day is a grassroots movement born in California in 1973. Its ongoing mission is to bring astronomy to the people. Rather than asking members of the public to travel great distances to enjoy the stars or meet astronomers, *Astronomy Day* participants set up displays at local public hotspots such as shopping malls and museums. The initiative has been one of the most far-reaching and highly successful outreach activities in astronomy and it continues to grow. *AstroDay Chile* is one of the newest annual events of this exciting, 35-year-old tradition.

Figure 6. *A star attraction at* AstroDay Chile *2008 was the portable* StarLab *planetarium. Several extra programs had to be added to accommodate the demand.*

Al Calor de las Brasas (Warmed by the Embers)

The idea for *AstroDay Chile* was born during a staff barbecue with the Gemini Board in 2006 at the Gemini South Base Facility. According to Gemini's Pete McEvoy, "A bunch of us were just 'talking shop' and ended up discussing new ways to promote Gemini in Chile. Among the ideas was one for an AstroDay event in Chile like the one held in Hawai'i. Looking back, after all that's been done, we can say that it was a very productive barbecue!"

Figure 7.
During AstroDay Chile 2008, held at the Mall Plaza La Serena on February 23, Gemini astronomers Rodrigo Carrasco (sitting at table pointing) and James Turner answered questions at the "Ask-a-Scientist" booth.

Prior to the debut of *AstroDay Chile* on February 7, 2007 no such large-scale astronomy event had ever been held in the La Serena region. With the participation of NOAO and other Chilean observatories, Gemini based the event on the successful *AstroDay Hawai'i* events held at the Prince Kuhio Plaza in Hilo every year since 2002. The Gemini South team decided to celebrate its first *AstroDay Chile* at the Mall Plaza La Serena, and it was a phenomenal success (see *GeminiFocus*, June 2007, page 57 for more details). More than 7,000 people attended, which surpassed everyone's expectations.

One Step Beyond

Needless to say, there were high expectations for this year's *AstroDay Chile*. The objective was to make it the most important showcase for astronomy outreach in Chile. To achieve that goal, professional and amateur observatories and astronomical institutions throughout Chile were invited to join in the celebration. Nearly all responded, as indicated in Table 1.

One lesson learned in 2007 was that the public enjoys interactive exhibits and engaging with observatory staff. This year there were 14 visitor kiosks, up from four in 2007, and they included interactive hands-on displays, educational tools (like Gemini's virtual tour), ROMAC I (a remote-controlled replica of the Spirit explorer), and the very popular "Ask-a-Scientist" booth.

Gemini astronomers James Turner and Rodrigo Carrasco volunteered to answer the public's questions about astronomy in the "Ask-a-Scientist" booth. Turner was impressed by the public's reaction to the event. "The people were fascinated to learn more about the exceptional scientific discoveries that their local region provides for the world," he said.

Table 1.
Participants in the AstroDay Chile 2008 event organized by the Gemini Public Information and Outreach office. The event took place on February 23, 2008 at the Mall Plaza La Serena.

AstroDay Chile 2008 Participants:
European Southern Observatory
Atacama Large Millimeter Array Project
University of Concepción
Universidad de la Frontera from Temuco (and its affiliated astronomy group C.A.O.S.)
Amateur observatories of Collowara and Cerro Mayu
National Optical Astronomy Observatory/Cerro Tololo Inter-American Observatory
Centro de Apoyo a la Didáctica de la Astronomía
Office for the Protection of the Skies of Northern Chile (OPCC)

Carrasco was also amazed by the experience, and by people's interest in what Gemini astronomers and staff do during the night. "I love interacting with the public and responding to their questions," he said. "For example, one 14-year-old student asked about how a black hole forms and what is the most important source of energy. I was very surprised to hear that from such a young person."

Carrasco also commented on how *AstroDay Chile* helps bring astronomers back into the real world. "We need to explain in a simple way what we are doing and help the public to understand how important astronomy is not only in the context of a pure science but also on a day-to-day basis," he said. "We also need to educate the public about how to preserve the environment around us and keep our sky clear of light pollution."

Although the several thousand people who attended this year's event live in light-polluted areas in and around La Serena, *AstroDay Chile* events were able to show the beauty of the Chilean night sky in the portable StarLab planetarium. According to Dalma Valenzuela, former Gemini StarTeacher and now a StarLab educator for Gemini, attendance at the shows was beyond expectations. "We had to respond to demand and hold three extra shows."

Felipe Pinochet Brito, manager of Mall Plaza La Serena was thrilled with the event. "Obviously, our region has the most privileged skies for astronomy. We need to help people become aware of its importance. Please count on us every year to support this event."

The Importance of Astronomy Education in Chile

In one day the *AstroDay Chile* event brought astronomy (as done in Chile) into thousands of households. Aside from the local communities where Gemini South and other observatories are located, many Chileans still have the misconception that astronomy is a science designed to benefit foreign countries—not theirs! A key educational goal of *AstroDay Chile* is to show that not only is the science exciting but astronomy provides jobs. These jobs are not only for astronomers, but for any Chilean trained in a wide variety of fields from electronics to business management.

Finally, Gemini was able to offer a lot of materials such as Virtual Tour CDs, images and contact information. Thanks to the public's interest in these materials and a generous amount of media coverage, the number of calls and e-mails to our offices has increased dramatically. There is no doubt that *AstroDay Chile* has given many Chileans a better understanding of astronomical research and how observatories like Gemini positively impact society, locally, nationally and internationally.

Figure 8. *Gemini South's outreach program focuses on sharing knowledge and results with the public. Children and parents from La Villa and nearby locations in the Elqui Valley hosted a StarLab and stargazing event.*

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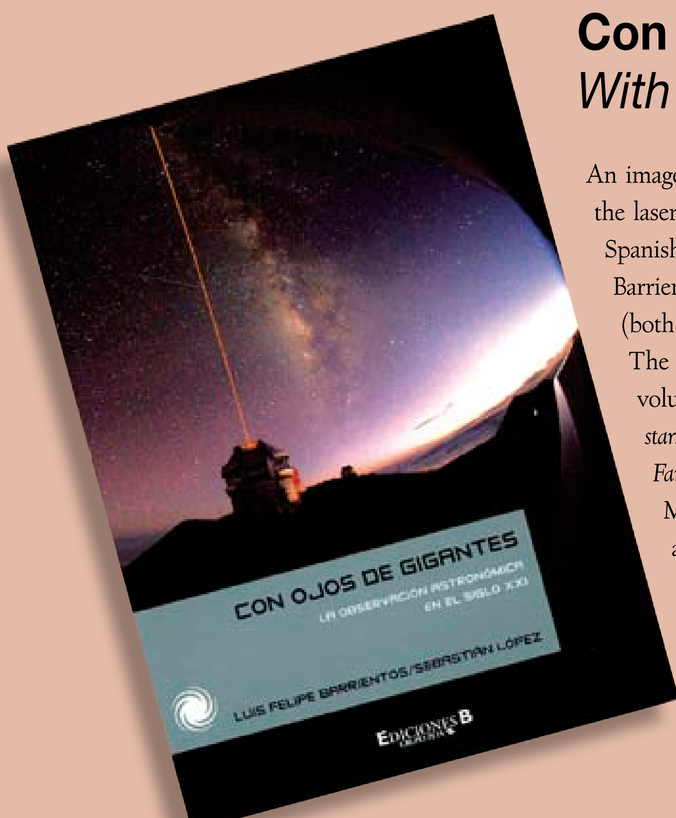
Con Ojos de Gigantes
With Giant Eyes



An image of Gemini North during propagation of the laser guide star has been featured on a new Spanish language astronomy book by Luis Felipe Barrientos Parra and Sebastián López Morales (both authors are at the Universidad de Chile). The book (shown here) is one of a four-volume series that includes: *Children from the stars* (*Hijos de las Estrellas*) by Ma. Teresa Ruiz, *Far Away Worlds* (*Mundos Lejanos*) by Dante Minniti and *Supernovas* by Mario Hamuy and José Maza.

by Peter Michaud

Gemini's Compass

Polly Roth

Consider this challenge: using only one word, try describing a person who leaves a promising career with a private company in part because of a corporate culture and attitude that expected, and even required, the use of frivolous perks such as always flying first class. Or, who quits a management-track position because her extra effort was being used to unfairly increase work quotas for others.

For most people who know Gemini's Polly Roth, Associate Director of Administration, the solution to this challenge is easy. It's the word *integrity*.

It is a testimony to Polly's character that she made those difficult career and moral decisions based on a never-veering compass of personal and professional integrity. It is also a plus for Gemini Observatory that she has navigated Gemini's Accounting Department for more than 10 years, her longest affiliation with any institution. Her long-time friend Manulani ("Manu") Meyer said Polly didn't compromise. "She could do accounting at Gemini and feel good about it because it was non-invasive and it explored education and science in meaningful ways," she said. "She wouldn't say that, but that's what I remember!"

According to Jim Kennedy, who retired in 2007 from the post Polly currently holds, Polly is a consummate professional. "She is of very high integrity and passionately dedicated to doing a good job and uncompromisingly honest," he said. When Jim told a high-ranking university official about his replacement he introduced her with the comment, "If you ever trusted me you can trust her even more."

Polly Roth:
Gemini's Associate Director of Administration

When Gemini's Polly Roth (pronounced "Rote") was promoted to her current position in 2007, her position was renamed to Associate Director of Administration–a job which includes a wide swath of Gemini's core operational units. These include: Information Systems, Accounting, Payroll, Budgeting, Purchasing, Contracts, Administrative Assistance, Human Resources, Buildings and Grounds, Facilities, Infrastructure Support, Shipping and Receiving and the Vehicle Fleet.

According to Jim Kennedy, Gemini's former Associate Director of Operations, "My former position was originally created to take care of all the operational business that nobody else wanted to manage."

Polly has earned her title and responsibility, starting with her first job as an Accountant at Gemini about a decade ago. Her current position is widely recognized as one of the most critical at the observatory. As Gemini's Director Doug Simons points out: "Polly is always quick to remind our managers who are focused on science and engineering a simple truth that underlines the importance of her group to Gemini – imagine what kind of problems we'd face if paychecks weren't cut every other Friday..."

(Opposite page) Polly Roth takes an early morning walk with Kiko and Ida.

Photo by K. Pu'uohau-Pummill

Of course, the word "integrity" can mean different things to different people. To Polly's close friend Val Kalei Kanuha, who has known her since college, Polly's main virtue is a given. "Of course Polly has integrity," she points out, adding that Polly's integrity manifests itself in many different ways. "She's loyal to friends, work and has a genuine interest in people and in the process she'll always–and I mean always–make you laugh."

While the concept of integrity seems to be a common denominator when describing Polly, it doesn't begin to capture what it is like to be in her company. "Polly has charisma, and I don't mean the Hollywood type," said Kanuha, "she has the type where you know she is fully engaged when she is talking to you and she is an amazing story teller."

Relating to people, putting them at ease, and most notably, her keen sense of humor and a knack for understatement, are just a few of the things that stand out when you are lucky enough to encounter Polly. According to Tamara Brown, who has worked under Polly at Gemini for almost ten years, Polly describes herself as a good little "chatter." "If she is in the room there is not going to be a moment of silence," said Tamara. "If people start feeling uncomfortable or the conversation lulls, she jumps right in. She always has some little story to tell, and no matter what she's talking about, she can make it funny."

Even describing the combination of working as an accountant at a cemetery in Minneapolis (a situation ripe for jokes), Polly's words let that story take on a life of its own. " I needed a change," she said. "That is how I ended up working for the cemetery. It was a non-profit cemetery—very, very large, 250 acres, nine miles of roads and one of the buildings was even on the National Historic Register as the most perfect example of Byzantine architecture west of the Mississippi! It was just gorgeous. We had a crematory there and I really loved the job. It was one of my favorites because I was not only in charge of accounting but I was a budding cemeterian. I was learning the whole cemetery business. I would do everything from helping people to select markers, scatter ashes, and look up family histories. Also, cemetery accounting is very interesting because if you think about it, what are their assets? What's their inventory? That's where I was working before I moved to Hawai'i."

Obviously, the path that led Polly to Gemini has not always followed the most direct trail through the woods. She grew up in the midwestern United States the youngest of three daughters of a Lutheran minister. According to Manu Meyer he was beloved and had the most amazing sense of humor. "Polly's mom gave the sense of, 'Let's sit down and talk story and enjoy each other's company,'" she said.

These qualities from both parents were deeply instilled during Polly's formative years, as well as an obvious pride at being brought up in the Midwest. According to Meyer, the statement, "My father has a barn," is one that Polly uses frequently. When asked what it means Polly explained, "It means we can help you. 'My father has a barn,' means we're hard working, coffee drinking; we can handle it, we're sincere, we're from the Midwest!"

Polly's positive attitudes served her well, especially during her exploratory years at the University of Wisconsin at Madison, "Polly seemed to have a different major every week! She's an explorer," said Kanuha, who was fortunate enough to be on the dorm floor where Polly served as a Resident Assistant. "Everyone wanted to be on Polly's floor. She always had something fun going on. I remember once, after she declared Nutritional Science as her major she had us all help with an experiment to only eat, I think it was six bananas and four glasses of milk each day for ten days to see how diet effects your mood. We just did it, nobody knew if it was nutritionally sound or not but we all volunteered without questioning because it was Polly who asked."

Polly started out as a music composition major. "Despite the fact that I probably had eight years of piano lessons, I couldn't play worth a damn!" she said. "I mean, we're not talking about being picky about the artistic part of it. I can barely pick out a melody. Although I was good at composition, I knew I had to get out, there was no room for me!"

Polly eventually earned her Bachelor's degree in Nutritional Science and her career path led to the corporate world. There, she discovered that she could not morph herself to work in that environment while maintaining her integrity. Those experiences were followed by a career-gap filler where she did all sorts of things. "I did small construction repairs like fence building or remodeling somebody's house. I just made it up, I just did it!" she recounted. "I'd say, 'well, I've never done this before, but I'll cap the job at this much plus the cost of materials,' and that's how I learned. I would do it until they were satisfied. I really didn't have to do much rework because I'd do it until I was satisfied."

Eventually, Polly found her way into the non-profit world, where she landed in a comfortable and satisfying niche. Her first non-profit job was in accounting for a domestic abuse center where she had helped to raise funds. "I had achieved my goal," she said. "As I was edging my way out the door, their accountant quit! I said, 'I'm sure I can do what [the accountant] did...' Four years later, I walked out of the door again, having gone to school at night to earn my accounting degree. They never did [hire an accountant] while I was there."

Although Polly admits that working in the field of domestic abuse finally took an emotional toll on her, to this day she has an active concern about the issue. As Polly's partner, Ronda Faye Ashby, recalls, "She'll see a couple having an argument that is escalating and getting physical and she'll just jump into it and try to defuse the situation," she said. "That takes courage. Most people wouldn't do that!"

Following Polly's work in domestic violence and then cemetery accounting, she came to Hawai'i in 1988 to be with her friend Manu Meyer and worked at Mauna Kea Support Services and then as a Senior Accountant at the W.M. Keck Observatory. After five years, the couple found themselves back on the mainland U.S., this time so Manu could pursue her Doctorate in Philosophy of Education at Harvard.

Manu remembers how easily Polly was able to find work, "Whenever she touched down, she got a job within a week. I said, 'Come on, I thought we were going to cruise around a bit!'"

True to form, Polly quickly found a job as the Director of a $10 million-per-year employment and career training center in Cambridge, Massachusetts. "That is actually the job I am proudest of," she said. "It was a difficult time and the agency was in danger of going under due to some changes in the way it was funded. We ended up getting a grant to open a one-stop career center. That was just very satisfying."

While at Harvard, Polly helped Manu with her writing skills. "I didn't really know how to write," said Manu. "I mean not at all. Writing English is hard, just face it. If you grew up over here [in Hawai'i] it's even harder." According to Manu, editing with Polly will change you forever. "She sat me down and said 'Manu, I know you know what this means here, but for me it's like a miracle occurs to get from here to there. You have to sloooow it down.' It was the best advice I've ever received and to this day I credit Polly as the genesis for my ability to write. No one ever told me with that amount of clarity and compassion that I didn't know what the heck I was doing. And then I thanked her!"

Like her integrity and humor, Polly's compassion for people and their dignity is legendary. Almost everyone who knows Polly has a story about her speaking to someone regarding something they did that was wrong or simply foolish. These stories always seem to end with a statement like: "I can't believe how good I felt about being told that I did something really stupid!"

Since coming to Gemini, Polly has been a trusted compass. As Jim Kennedy points out, her value to Gemini goes far beyond accounting, "She's no shrinking violet," he said. "If she sees something that is not going right she steps right in and addresses it."

Polly enjoys the challenges of her position at Gemini, as well as her life in Hilo. She and Ronda Faye live near the ocean along with a golden retriever named Ida and a mixed-breed called Kiko; she loves to walk with them within sight and sound of the waves.

Their lifestyle is in contrast to the whirlwind of activity that Polly's job at Gemini entails. Although she confesses that her mind never shuts down, she is always striving to find a balance in her work and downtime. Ronda Faye commented, "When I first met Polly, she's like, 'Oh yeah, I don't need more than a few hours of sleep a night,'" she said. "She's just now getting to the point where she says 'Ok, I guess I do need eight hours sleep now!'"

Polly also does have some guilty pleasures. "People don't know this, but Polly is a closet chocolatier!" said Ronda Faye. "She has gotten really good at it. There's an art to making chocolate, it takes patience, like her wood carving."

Polly hopes to eventually spend more time on other activities that she loves such as wood carving and spending more time with her family. But for now, she looks back on everything she's done so far and says, "I think I've had an interesting life. At least I've been interested in it, pretty much all of the time!"

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by David Tytell

The Workhorse's Caretaker

Rodrigo Carrasco

Whenever telescopes make news, the scientists earn the credit. Journalists never speak of the hundreds of people who work tirelessly to make observations possible. One of the lead characters in the "behind-the-scenes cast" at Gemini Observatory is Rodrigo Carrasco. From his office in La Serena, Chile, Rodrigo serves as an instrument scientist for the Gemini Multi-Object Spectrograph (GMOS) at Gemini South (there is a GMOS twin at Gemini North). More than half of the observatory's observations happen with GMOS, the only visible light instruments at Gemini, and Rodrigo serves as a caretaker. At the same time, he continues his research into the properties of massive galaxies, a topic that has fascinated him since his university days.

It takes a special type of leader to mind an instrument as important as GMOS — someone who is not afraid of challenges, who doesn't balk at the prospect of hard work, and who can handle the responsibility of having people depend on them. Rodrigo has exemplified each of those traits since an early age. He was born in Chile in 1965, but moved to Argentina at age 10. There, he spent an active childhood reading, studying science, and playing sports. He took part in pickup soccer games with neighborhood kids, and swam competitively for several years. However, his first love was field hockey. In the sports world, his personality came through in his position on the field. The student who was never afraid of responsibility adopted the post the team relied upon most — goalie. Rodrigo donned the pads and protected the net for five seasons, participating in several championship tournaments in Argentina.

"In my last year we played in the national tournament against the other provinces," said Rodrigo. "We finished in third place — which was very good because the team from Buenos Aires later finished second in the [field hockey] World Cup."

Rodrigo attended undergraduate university in Buenos Aires, focusing on physics and astrophysics. With some friends he formed an astrophysics club and published journals filled with student-written articles for anyone with an interest in astronomy to read. Topics included planets, stars, galaxies, and the evolution of the universe.

Yet, Rodrigo's college years in Argentina were short lived. In 1987, two years into his undergraduate career, he hit a roadblock. A nationwide teacher strike meant a semester without classes. Stopping school wasn't an option, so he seized the opportunity to study in Russia. But that opportunity came with a price. It meant pressing "reset" on his education. When Rodrigo left South America for Moscow, he also left behind every college credit he had ever earned. Year one in Russia was "language boot camp." His second "freshman" year began more than three full years after his first, and he came away from the experience fluent in one of his now four languages.

(Opposite page) Rodrigo and his wife Elenir enjoy time with their two sons Daniel and Joaquin.

Photo by M. Paredes

Rodrigo Carrasco demonstrates his enthusiasm for the work he does with GMOS as one of his duties as a Gemini staff scientist. The Gemini South cluster of instruments at the Cassegrain focus (GMOS in front) are shown.

Eventually, Rodrigo settled in St. Petersburg where he studied astronomy but specialized in astrometry—the science of the positions and motions of celestial objects. It's a topic he feels passionate about, since it is all about providing accurate, understandable information to others. "Astrometry is the foundation," he said. "All of astronomy relies on astrometry and catalogues."

One of his undergraduate projects involved calibrating cameras that were built for a later-canceled Russian spacecraft mission. The mission was to do accurate astrometry and photometry for more than 100,000 stars, and was analogous to the very successful Hipparcos mission flown by the European Space Agency. Instead, the CCD instruments were moved to a small telescope outside of St. Petersburg where Rodrigo used them to model more accurate coordinates for stars.

In 1993, Rodrigo finished his undergraduate thesis and graduated. He moved back to South America for his graduate degrees, first landing back in Chile. Much to his dismay, the study of astrometry was nearly extinct below the equator. He was forced to change career paths, and eventually earned his Master's degree in physics studying the characteristics of galaxies. He then moved to Brazil in 1996 to work on his Ph.D. in São Paolo.

"My thesis was about dwarf galaxies in groups of galaxies, and the detection of these fuzzy, low-surface-brightness objects," said Rodrigo. "It's a very interesting problem because you expect to see a lot of dwarf galaxies. But that is not the case. You have less dwarf galaxies than expected from theory, which is still a mystery today."

"And I tried but I couldn't see the galaxies that they said I should have seen. The problem is that these galaxies are very fuzzy and the sky background imposes a limitation. Today we know that there is probably a problem with theory and not with observation. In general people find many less small galaxies than they should see by theory."

Upon graduation, the newly minted Dr. Rodrigo Carrasco returned to Chile and joined the Gemini South team in 2001. Shortly after that, he helped commission GMOS on Gemini North, and later used that experience to bring GMOS online at Gemini South. In both cases, it was his astrometry work back in Russia, along with his vast research experience at various telescopes, that helped him to make GMOS the powerhouse instrument it is today.

After years of globe-hopping, Rodrigo has settled down and become a family man. These days he lives outside of La Serena with his wife, Elenir, and two boys Daniel (age 8) and Joaquin (age 5). When he isn't playing with the kids, he checks on GMOS-South remotely and protects it as if it were one of his two sons. Whenever something is amiss, whether it is general maintenance of the instrument, or an emergency fix for some big problem, Rodrigo is there. The instrument never leaves the telescope without Rodrigo watching like a hawk.

"This is an observatory, it's a science factory. We are running a science machine," he said. "You have to spend a lot of time trying to get the best science that you can get from the telescope. Minor problems have to be fixed so we can eliminate the loss of time during the night."

Yet Rodrigo hasn't abandoned his scientific career. "One of the things I learned from my former advisor is that you have to apply every semester for telescope time to have projects and observations and something to do in the future," he said.

Rodrigo estimates he spends about 15% of his time working on research projects, collaborating with colleagues in English, Spanish, Portuguese, or Russian. He has still managed to publish three papers a year for the past three years. Oftentimes, his research involves GMOS, but he is also branching out toward the infrared, particularly in studies of compact galaxy groups, fossil galaxy groups, and weak gravitational lensing by galaxy clusters. For example, one of his ongoing projects is to study the properties of massive galaxies in the distant universe. "In the last year I applied for projects that were only looking in the infrared, because I am trying to move to the higher redshift universe," said Rodrigo.

Rodrigo's work doesn't stop at science research or guiding GMOS through its paces. For someone who once helped create a journal to help others understand astronomy, it's no shock that some of his favorite projects also involve outreach. Oftentimes he helps provide the Gemini Legacy Imaging program with visible-light images from the southern hemisphere. He beams with pride as he retells one of his favorite stories: "When we commissioned GMOS South in 2003, we performed some imaging to show people how the instrument was working. We decided to observe one of the compact groups observed by the Hubble Space Telescope's Heritage Program, Hickson 87. It was amazing to see and compare the GMOS image with the HST image. The two images side by side looked amazingly similar."

"I was so proud of the instrument and the telescope, but especially, I was so proud of the people behind the instrument. We demonstrated that when conditions allow, you can have fantastic image quality and fantastic results," he said.

Gemini South GMOS image off the Hickson Compact Group (HCG) 87 located about 400 million light years away in the direction of the constellation Capricornus. This image was obtained as part of the ongoing Gemini Legacy Imaging program for which Rodrigo provides technical assistance.

And the caretaker's pride and enthusiasm shows no sign of waning. "I believe that the two GMOS instruments will continue to be the workhorses of Gemini," said Rodrigo. "And I hope they will continue to be on the telescopes. It's certainly our workhorse here in the south."

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When Gemini South Science Fellow Étienne Artigau learned that the world's largest hummingbird (the Giant Hummingbird, *Patagona gigas*) lived around La Serena, he put it on his "most wanted" list. When one started frequenting a patch of flowers near his office window Artigau took action. "I brought my photographic gear and would run outside as soon as I heard its high-pitched voice," he said. The strategy paid off and he got this shot. Image obtained on Christmas Day 2007 with a Nikon D100 digital camera using a 300mm lens at f/4 and a 1.4X teleconverter.

Étienne Artigau is an avid birdwatcher and photographer, and his website oiseaux.hobby-site.com features his bird images.

Photo by E. Artigau

A complex of nearly a hundred pre-western contact shrines populate the Mauna Kea summit plateau. These shrines resemble those found on the older, uninhabited islands in the Hawai'i island chain and some found in Tahiti. Unfortunately there is no reference to these pohaku (stones) from traditional sources that might explain their purpose or function. The general interpretation is that these are associated with the work of adze makers, and tied to Ku in his form as the god of the adze makers. The photograph was taken with a Nikon F4 using a 24-mm lens at an ISO of 200.

Kirk Pu'uohau-Pummill is a Computer Graphics Specialist at Gemini Observatory.

GeminiFocus

Photo by Derrick Salmon (CFHT) after one of the frequent snowstorms on Mauna Kea during this past (Northern Hemisphere) winter. Photo obtained on February 10, 2008.

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