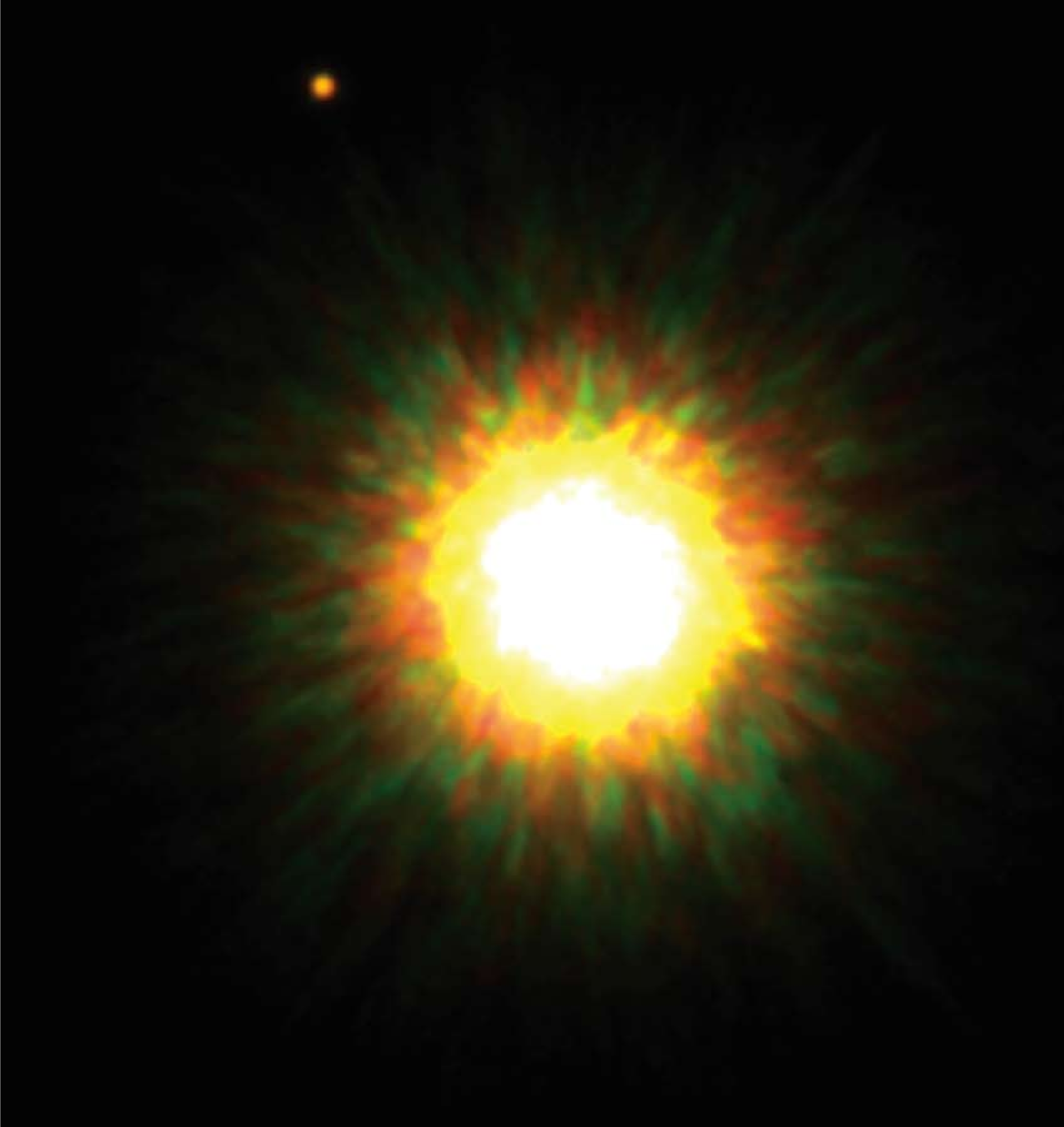
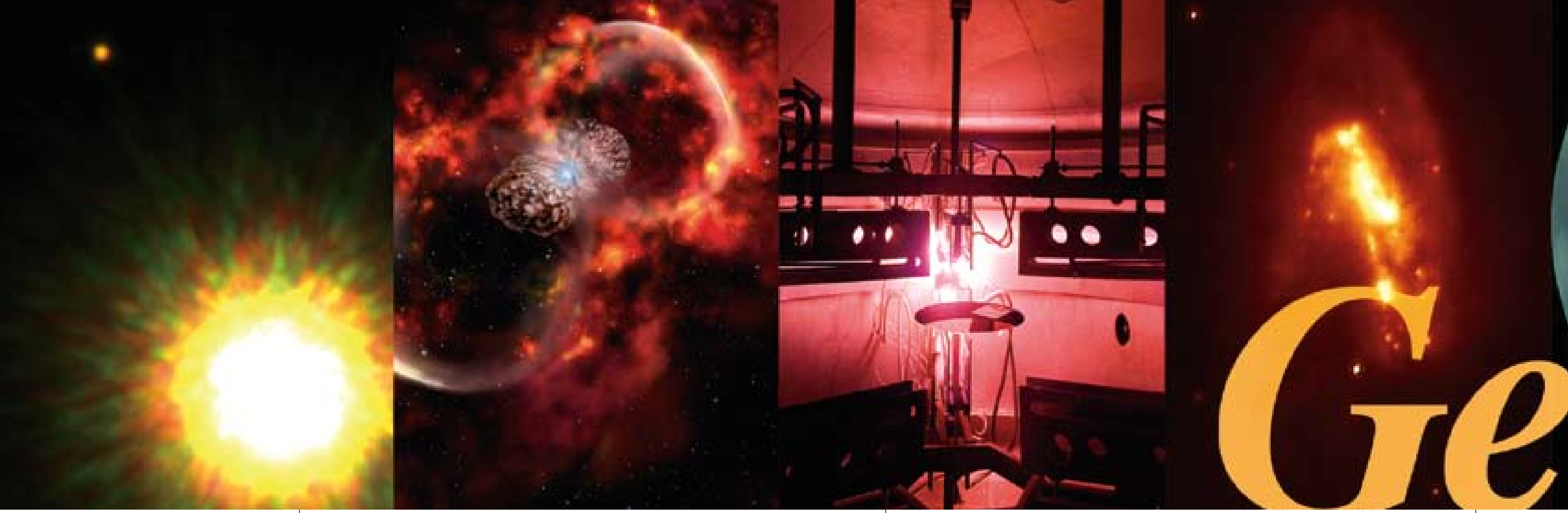
GeminiFocus

December2008 Newsletter of the Gemini Observatory





On the cover: Gemini adaptive optics image of 1RXS J160929.1-210524 and its likely ~8 Jupiter-mass companion. See article starting on page 31.

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by Doug Simons
Director, Gemini Observatory

Mapping Gemini's Future

The next five years will bring a range of challenges and opportunities to Gemini Observatory that will be unique in our relatively brief history. In that time, we will transition not only into a new funding cycle but, more importantly, a new International Agreement which may include new partners, or at least a redistribution of shares among the current partners. Furthermore, with the completion of Multi-Conjugate Adaptive Optics (MCAO) at Gemini South, we will transition from one of many adaptive optics (AO)-capable observatories to a truly AO-optimized facility, unmatched well into the next decade. With the arrival of FLAMINGOS-2 at Gemini South and redeployment of the Gemini Near-Infrared Spectrograph (GNIRS) at Gemini North, we will finally be able to offer our community world-class near-infrared spectroscopic capabilities at both sites. Finally, with the development of next-generation instrumentation like the Gemini Planet Imager (GPI) and hopefully the Wide-Field Multi-Object Spectrograph (WFMOS), breakthrough research opportunities will be possible for our community well into the next decade. Ensuring that all of these complex milestones (with a range of technical, financial, and political implications) are met, requires that we plan ahead well into our future to proactively manage these complex and interlinked activities.

While Gemini's new observatory-wide planning system is focused on near-term (1-5 year) activity (see my Director's Message in the June 2008 issue of *GeminiFocus*) we have recently launched a new initiative to develop our Long-range Plan. It is intended to answer the question: "What should the state of Gemini Observatory be in 2020?" We chose 2020 because, on that timescale, the nature of astronomy (and Gemini's role in it) will be revolutionized by such technological marvels as (at least) one extremely large telescope (ELT), the James Webb Space Telescope (JWST), and advanced survey facilities such as the Large Synoptic Survey Telescope (LSST) and the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS).

For centuries, astronomy has been a technology-driven endeavor, and the nature and extent of our discovery horizon will expand with these impressive new machines. Like many of today's 4-meter-class telescopes Gemini, and other 8- to 10-meter-class telescopes, will slowly transform into support facilities for even more advanced observing platforms in the future. But slipstreaming Gemini into that new mold, whatever it may be, requires considerable forethought, community engagement, resource alignment, and above all, planning.

To support a viable long-range planning process, Gemini, our funding agencies, and communities need to work together to achieve not just a "blue sky" vision that captures our collective imagination, but one that is also viable given realistic projections of resource availability. Failing to ground our vision with a realistic assessment of what is achievable will lead to mismatched expectations and disappointment in the end. That is why I have engaged the observatory at this early stage in the long-range planning process to look into the future and identify key needs and trends that will shape and leverage whatever scientific missions our community and governing board define. Some of the more obvious elements that will impact Gemini include the skyrocketing cost of energy, which impacts us not only through higher electricity bills but through our travel expenses. For example, Gemini's engineering staff was deliberately sized to be sub-critical in the sense that we do not keep a full complement of engineering resources at both sites all of the time–finding it more cost-effective to shuttle staff between sites as required. Perhaps the most visible example of this practice is with our mirror coating system. During the recent Gemini North mirror coating process we had about ten members of the Gemini South engineering team in Hawai'i for several weeks to assist with that complex process (see article in this issue starting on page 64). That operational model is now being challenged due to much higher international airfares and we will have to be more innovative in our approach to supporting both sites within the constraints of our existing budget. Another result of rising energy costs is that Gemini will develop an energy policy next year. In fact, we expect by 2020 that such policies will be as commonplace as procurement, retirement, and travel policies for businesses and non-profit organizations alike. In the future, energy will simply be too precious a resource to use without a more deliberate approach to managing it.

Arguably the most complex and strategically important component of our Long-range Plan will be the science mission definition for Gemini in 2020. It might also be termed the "post-Aspen" era. A wide range of inputs must be considered, including the national strategic plans already defined or about to be defined (e.g., the U.S. Decadal Survey), assessments of technologies available in the future, and a comprehensive instrument deployment plan that includes not only new instruments but a process and plan for decommissioning old ones. Key milestones in the formulation of our scientific strategic plan include the upcoming joint Subaru/Gemini Kyoto science conference in 2009 (see page 82) and a likely international Gemini science workshop in 2010. In these gatherings, the voices of our diverse community will be heard as we identify common threads and weave a coherent mission.

Figure 1.
The first step in the formulation of Gemini's new Energy Policy is through the new "Green Blog" on Gemini's internal web site. Staff are encouraged to use this blog to suggest energy-saving changes at our various facilities. The response to this blog has been overwhelmingly positive.

All of this long-range planning activity will culminate with the submission of Gemini's next funding proposal, which will contain a justification for future funding for Gemini's operations and development programs. The collective vision of our community, funding agencies, and the observatory will be captured in that funding proposal, which will define the resources, technologies, and timescale needed to make that vision a reality. Although it's admittedly complex, I personally find this process to be fascinating as we tap the creativity of so many contributors to Gemini's future.

Underlying all of this is a core philosophy that transcends the countless "details" alluded to above. Defining our future and then taking the needed steps to live into that future isn't just a business or planning strategy. It's an essential component of the life experience. Gemini is very much a reflection of its diverse and resourceful community and its strengths and weaknesses are inextricably linked to those of the people that operate, fund, and use it. There are few experiences in life more rewarding than defining an exciting vision and then watching it crystallize over time through the actions of a vibrant team. That is the experience I was privileged to have as part of the original Gemini 8-meter Telescopes Project team and it is that same experience I intend to share in the future with our new team, the stewards of Gemini Observatory.

by Cássio Barbosa & Robert Blum

a New Era for Massive Young Stars

with Gemini Laser Guide Star Adaptive Optics

Massive stars, though rare, have a strong impact on the universe we see. Such stars are responsible for many interesting and important processes. They alter their surroundings through the action of high-energy radiation and intense stellar winds, and they can trigger star formation in regions far from their own sites. When massive stars die in supernovae events, they pollute the nearby interstellar medium with heavy elements. Winds from massive stars, particularly in rich clusters, can blow large bubbles in the interstellar medium and, in the most extreme cases, blow material into the intergalactic medium. Much of what we see in the high-z universe is dominated by star-forming knots powered by massive stars.

The mechanisms that govern the formation of stars more massive than 10 M_{Sun} are still shrouded in nebulae, and dusty controversy. Because of the intense nebular and hot dust emission around the young massive objects, it is difficult to probe the stellar photospheres and their immediate surroundings. Understanding the details of the mechanism of massive star formation, or even obtaining a direct estimate of the spectral types of massive young stars, is a difficult task.

Massive star formation has been a matter of heated debate over the last three decades. The chief problem is accounting for the radiation pressure from the nascent star which should otherwise stop the accretion flow once the protostar reaches a limit of 10 M_{Sun}. Several models that overcome the problem of radiation pressure have been proposed to explain the formation of stars more massive than 10 solar masses. The first is the classic accretion disk model for low-mass stars, scaled up for more massive young stellar objects. It allows for the accretion of matter to continue along the flattened disk surrounding the star while the intense radiation can escape along the poles. A second model has massive stars forming through the collisions of lower-mass stars. For now, the debate continues.

The difficulty of observing sites of massive star formation–exacerbated by distance, as well as by crowding and obscuration by dust–make the confirmation of both theories a challenging observational task. However, the

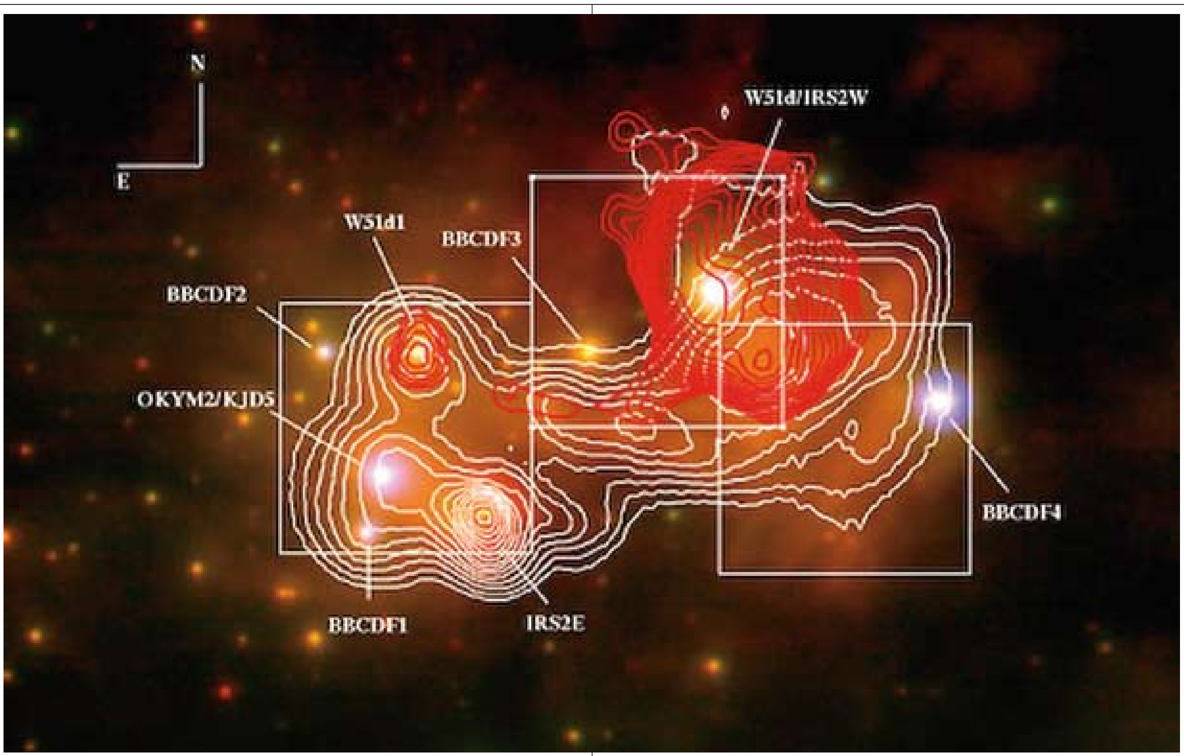

Figure 1. *Composite color image of W51 IRS2 showing the objects studied in this work. Each square represents a 3 × 3 arcsecond NIFS field of view.*

development of new technologies and new facilities is changing the picture for this exciting field of research. New instruments on large-aperture telescopes equipped with adaptive optics are providing crucial tools to better attack this problem. The Near-Infrared Integral Field Spectrograph (NIFS) has recently been deployed at Gemini North behind the facility adaptive optics module, Altair, and its powerful new laser guide star (LGS). Gemini is in good company. The W.M. Keck Observatory and the European Southern Observatory (ESO) Very Large Telescope (VLT) have similar capabilities. We used the Gemini system to make some of the highest angular-resolution spectroscopic observations to date in the massive star-forming complex IRS2 in the giant HII region W51.

This region is an immense stellar nursery where massive stars are forming at such a prodigious rate that it may represent a local example of a starburst event. As such, it provides a rich laboratory for studying the birth and early evolution of massive stars. Within this laboratory is the smaller HII region IRS2, for instance harbors three ultracompact HII regions, possibly a dozen young *OB-type* stars, and the enigmatic young stellar object IRS2E. Figure 1 is a color composite image based on VLT public data taken of IRS2. Images obtained through K, H, and J using the NACO adaptive optics camera corresponds to RGB channels respectively. The three squares indicate the NIFS field of view of the regions observed. White curves correspond to emission at 12 microns (from our T-ReCS data) and red curves represent radio emission (from Wood and Churchwell's catalog of ultracompact HII regions) observed at the Very Large Array (VLA).

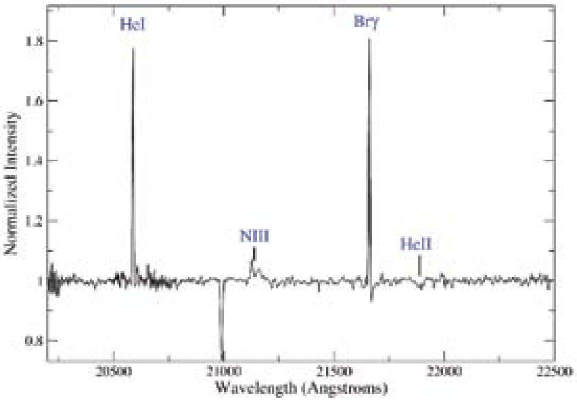

Figure 2. *K-band spectrum of the ionizing source of the ultracompact HII region W51d. NIII (emission), HeII (absorption) and the absence of CIV favor the classification of an O3 star. HeI and Br gamma are nebular emission. The deep absorption profile is an artifact of the sky subtraction process. The spectrum was smoothed by a factor of three.*

IRS2, with all these massive stars in different stages of early evolution, makes an ideal target for NIFS and to test the capabilities of the Gemini North adaptive optics system, Altair. Since young massive stellar objects are always found embedded in bright circumstellar emission nebulae, high spatial resolution images can, in principle, allow us to separate compact circumstellar emissions from those of the star itself. And it did! Achieving resolutions as high as 0.1 arcsecond through the use of a LGS system to correct the atmospheric distortions on the images, we were able to obtain

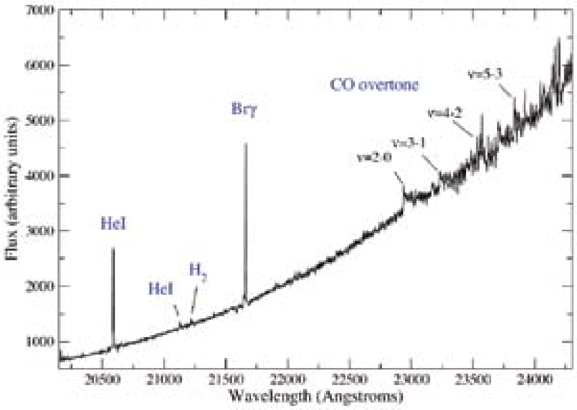

Figure 3.
K-band spectrum of the enigmatic source IRS2E. No photospheric lines are detected, but the CO bandhead is seen at the end of the band. Note the steep slope toward longer wavelengths.

spectra of the objects within IRS2 with much reduced contamination of the surrounding emission region, and it made all the difference.

Figure 2 shows the K-band spectrum of the near-infrared counterpart of the ultracompact HII region W51d. This spectrum was extracted through a 0.2 arcsecond circular aperture, which minimized the contamination of nebular emission. With this, the photospheric features of an O3 star emerged, and we were able to identify one of the most massive stars ever in such an early stage of its evolution.

Figure 3 shows the K-band spectrum of the enigmatic IRS2E. This object is undetected at wavelengths shorter than 1.6 microns. Actually, it is barely seen even in the H band. But, it becomes the brightest source in the IRS2 region at wavelengths greater than 2 microns. Moreover, it is not detected at radio wavelengths, making it a massive young stellar object candidate in a stage of evolution younger than an ultracompact HII region. Based on our unpublished mid-infrared data taken at the Gemini South observatory with T-ReCS we estimated an upper limit for its spectral type as O6. The NIFS spectrum shows the CO bandhead in emission, which is a typical signature of a circumstellar disk. We may be witnessing a ~ 40 solar mass star still in the process of assembling.

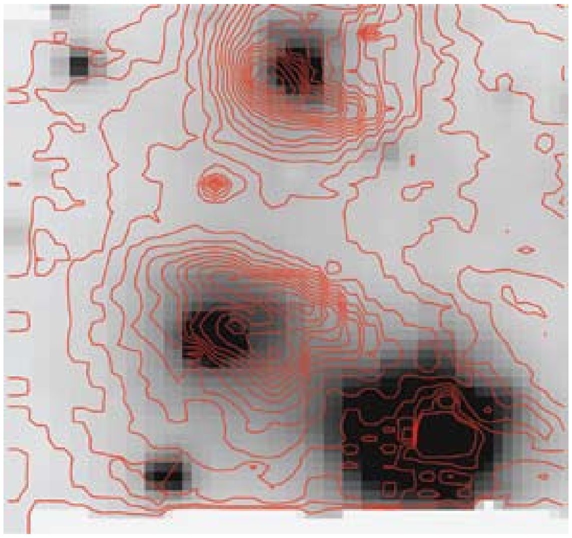

Figure 4.
[FeIII] (22184 A) line map. The red contour lines denote [FeIII] emission plotted over an image representing the nearby continuum emission. This field corresponds to the left box in Figure 1.

And, the good news is not over yet; NIFS is an integral field unit spectrograph, and the datacubes are still being analyzed. Our first results on deriving extended line maps of IRS2 show that the bulk of [FeIII] emission does not come from IRS2E, as previous published spectra indicate. As can be seen in Figure 4, the [FeIII] emission comes from the ultracompact HII region W51d1.

This project is part of an ongoing study of the environments of massive young stellar objects and is the third Gemini paper on this subject.

For further information see:
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by Anil Seth

Probing the Formation of Nuclear Star Clusters

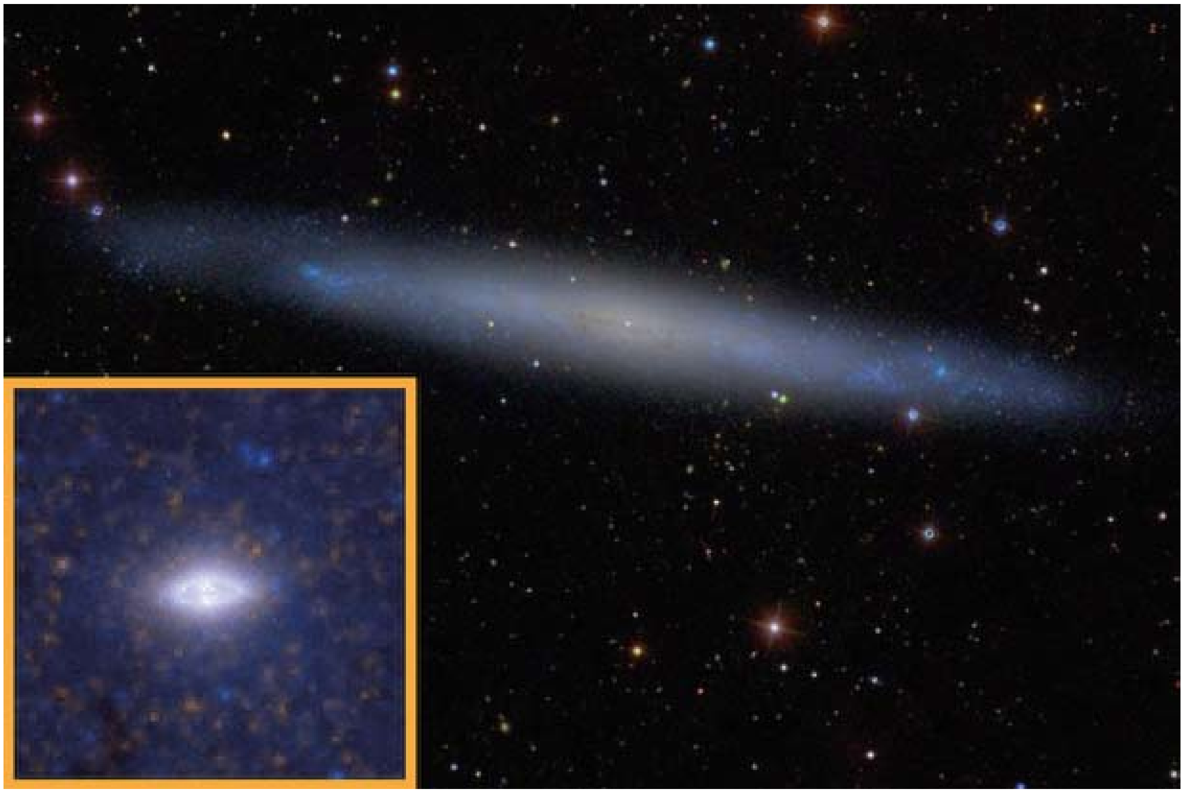
with Gemini Laser Guide Star Adaptive Optics

In the center of our Milky Way Galaxy there are two very massive objects: a black hole with a mass a few million times that of the Sun, and surrounding the black hole, an even more massive collection of stars called a nuclear star cluster. Other galaxies also have nuclear star clusters like the one in the Milky Way's heart, and they are among the densest stellar systems in the universe. Typically, they contain many millions of stars within the central few parsecs of a galaxy.

Despite being very bright, nuclear star clusters are so compact that, due to the blurring effects of Earth's atmosphere, ground-based observations of such regions in nearby galaxies often fail to distinguish the clusters from the surrounding galaxy light. Higher-resolution observations are therefore needed to find and study these clusters. Over the last decade, the Hubble Space Telescope (HST) has surveyed hundreds of nearby spiral and elliptical galaxies and found that a majority of galaxies have nuclear star clusters with masses ranging from 100,000 to 100 million solar masses. (This is true specifically for spiral and elliptical galaxies with masses less than or equal to the Milky Way's. The most massive galaxies do not appear to have such clusters at their hearts.) Nuclear star clusters are resolved by HST and are distinct from the underlying light profile of the galaxy.

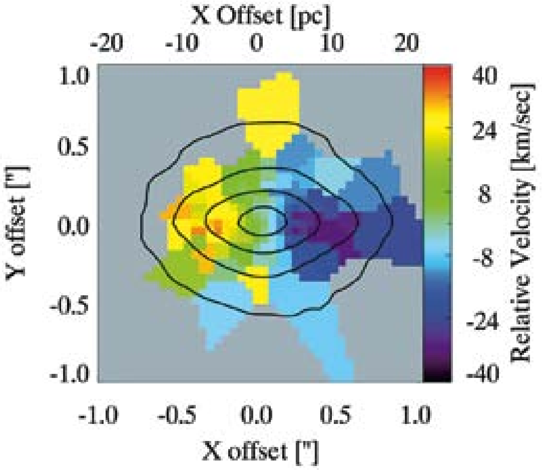
The large number of such clusters revealed by HST has led to a further discovery: the mass of nuclear star clusters is proportional to the total stellar mass of their host galaxies. In other words, it appears that a fixed fraction (~ 0.2%) of all the stars in a galaxy reside in the nuclear star cluster. This relationship is similar to the well-documented relationship between the masses of central black holes and their host galaxies. The implication of these relationships is that the central few parsecs of a galaxy are tightly linked to the formation and evolution of the entire galaxy. One way to better understand this link is to examine the formation history of the central objects. Nuclear star clusters provide a unique opportunity for studying this history because, unlike black holes, they are built from stars whose light can tell us when and how they formed.

Figure 1.
(Main image) A Sloan Digital Sky Survey image of the nearby edge-on galaxy NGC 4244. The nuclear star cluster is visible at the center. (inset) A Hubble Space Telescope image of the flattened nuclear star cluster in NGC 4244. The image shows the central 5 × 5 arcseconds of the galaxy.



Nuclear star cluster formation may occur as a result of several different mechanisms. These clusters were first proposed to have formed from globular clusters moved to the galaxy center by encounters with stars and dark matter in a process called dynamical friction. Alternatively, gas from the galaxy may have moved toward the center and then either: (1) formed stars directly in the nucleus of the galaxy; or (2) formed star clusters near the center of the galaxy, which then migrated inward.

Figure 2.
The line-of-sight velocity map of the NGC 4244 nuclear star cluster derived from NIFS data. Contours show the shape of the cluster in the integrated K-band light created from the NIFS data. The color gradient across the cluster indicates that it is rotating.



Not Just Balls of Stars

Most star clusters are simple systems: balls of stars that all have the same age. However, optical spectra of nuclear star clusters in spiral galaxies reveal that they have complicated histories. Specifically, most nuclear star clusters appear to contain both young (< 100 million years) and old (> 1 billion years) stars and thus must have a prolonged formation history. The morphology of the clusters also appears to be complicated. Using HST imaging of nuclear star clusters in edge-on spiral galaxies, we have found that many such clusters are elongated in the plane of the galaxy. Furthermore, color maps indicate that the younger, bluer star populations in the clusters appear to have a flat disky structure while the older, redder stars are distributed in a rounder, more spheroidal component.

Both HST imaging and ground-based spectroscopy have provided important information on nuclear star clusters, but both methods have their limitations. HST imaging has high-enough resolution to resolve the structure of the clusters, but provides little or no information on their stellar populations and kinematics. On the other hand, ground-based optical spectroscopy can be used to examine the stellar populations and kinematics of nuclear star clusters, but cannot resolve structures within the clusters. Fortunately, the recent advent of adaptive optics on ground-based telescopes enables high-resolution, near-infrared spectroscopy that can resolve the kinematics and stellar populations of nearby nuclear star clusters. Gemini's Altair laser guide star system can be used to correct distortions caused by Earth's atmosphere, yielding resolution as good as 0.1 arcsecond; equivalent to the resolution of HST. This facility can be used with the Near-Infrared Integral Field Spectrograph (NIFS) to obtain thousands of spectra across a small field of view.

We have used NIFS and Altair LGS on Gemini to observe a nuclear star cluster in the nearby galaxy NGC 4244, shown in Figure 1. This galaxy is only 4.3 million parsecs (14 million light-years) away from us and is the nearest edge-on spiral galaxy to the Milky Way. NGC 4244 has a prominent nuclear star cluster that shows the flattening and composite morphology discussed above and is visible in the close-up HST image (inset in Figure 1).

A Rotating Nuclear Star Cluster in NGC 4244

Using the strong CO absorption features at 2.3 microns in the K band, we were able to derive the kinematics within the NGC 4244 nuclear star cluster. This includes the line-of-sight velocity and the velocity dispersion of the stars. The line-of-sight velocity map is shown in Figure 2. To obtain better measurements in the outer parts of the cluster, we binned together spectra from multiple spatial pixels; these can be seen as geometric shapes with identical color in the figure. Figure 2 shows the cluster is strongly rotating, with a maximum rotation of around 30 km/sec at a distance of around 10 parsecs (0.5 arcseconds; ~ 32 light-years) from the center along the major axis of the cluster (the x-axis in figures 1 and 2). The direction of rotation and elongation of the nuclear star cluster are similar to that of the galaxy. This important result strongly suggests that at least the stars in the disk component of the cluster formed by accretion of gas or by accumulation of stars from the disk of the galaxy.

There also appears to be rotation above and below the midplane of the nuclear star cluster (Figure 3, top panel). Careful analysis of the data suggests that this actually results from rotation of the older stars that lie in a more spheroidal distribution above and below the midplane. We base this conclusion on three pieces of evidence shown in the lower three panels of Figure 3: (1) the color of the stars above and below the plane are redder than the color of the stars in the midplane based on HST imaging; (2) stellar population changes moving off the midplane are also seen in changing CO line-strengths in the NIFS data; (3) a morphological decomposition of the integrated K-band light from the NIFS data suggests that only a small fraction of the light above and below the plane comes from the midplane. The rotation of the older spheroidal component would not be expected if the nucleus formed from globular clusters. This result provides strong evidence that most of the nuclear star cluster mass was built up by accretion from the galaxy disk.

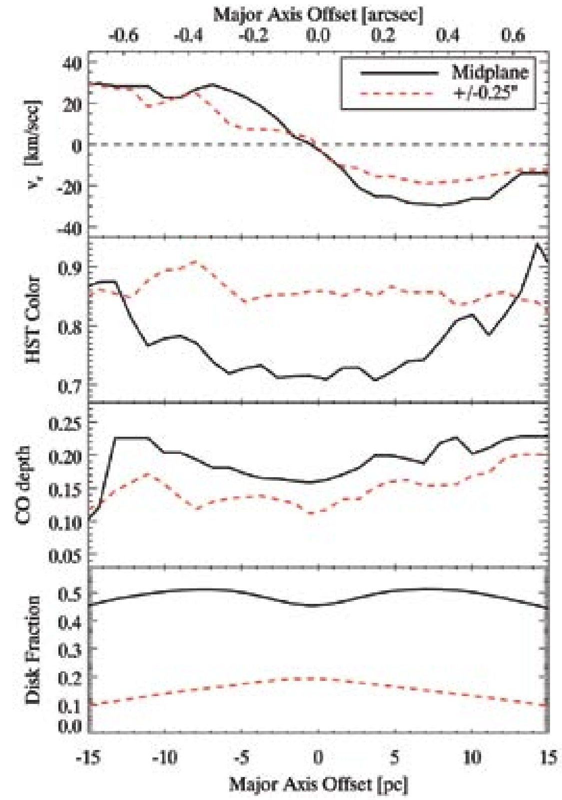


Figure 3.
Comparison of rotation and stellar populations in the midplane and above and below the midplane. The individual panels show the: NIFS line-of-sight velocity profile; color derived from HST imaging; depth of the 2.3-micron CO absorption line; and the fraction of light originating from the disk component.

We can also use the nuclear star cluster's rotation to determine its mass. Assuming that the rotation represents a Keplerian disk, the mass of the cluster within ~ 10 parsecs is about 2 million solar masses. A more sophisticated mass model that incorporates the measured velocities and dispersions will allow us to obtain both an accurate mass measurement of the cluster and estimate the mass of any black hole at the center of the nuclear star cluster.

Future Horizons

Our NIFS observations using Gemini show that the nuclear star cluster in NGC 4244 was predominantly formed by accretion of stars and/or gas from the disk of the galaxy. However, different formation mechanisms could dominate in different galaxies. For instance, a recent article by Bellazzini and collaborators argues that the nucleus of the Sagittarius dwarf spheroidal galaxy, which is currently merging with the Milky Way Galaxy, was formed primarily from the sinking of a globular star cluster to its center, with only small amounts of mass accreted from the galaxy. Therefore, we are extending our study to include nearby spiral and elliptical galaxies across a range of masses. The high-quality data provided by NIFS will help us understand the process of nuclear star cluster formation more generally and address open questions on the relation between nuclear star clusters, black holes, and their host galaxies.

This work was done in collaboration with Bob Blum, Nate Bastian, Nelson Caldwell, Victor Debattista and Thomas Puzia. It is published in the November 10th, 2008 issue of the *Astrophysical Journal*.

For further information see:

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by Linda Watson

Probing a Quasar Host Galaxy

with Gemini Laser Guide Star Adaptive Optics

Soon after the discovery of quasars in the early 1960s, astronomers noticed that faint fuzz often surrounded these mysteriously luminous objects. However, it was not until the early 1980s, with the help of CCD spectroscopy, that the fuzz was convincingly proven to be a galaxy. Verifying the connection between quasars and their host galaxies required a couple of decades and significant technological advances because, at quasar distances, the point-like quasar outshines the comparatively faint and extended host galaxy.

Of course it is not enough to know that galaxies and quasars coexist. We are now striving to understand how the accreting black hole that powers each quasar affects its host galaxy. One of the main results from this pursuit has been the discovery that black hole properties are correlated with galaxy properties. Arguably, the tightest of these correlations is the M_{BH}-σ relation, which relates the mass of the central black hole (M_{BH}) to the stellar velocity dispersion of the host-galaxy spheroid (σ). This relation was initially discovered for quiescent galaxies but was soon extended to include active galaxies known as Seyferts, which are the lower-luminosity analogs of quasars (quasars have an active nucleus with luminosity greater than about 10^{44} ergs/sec). The M_{BH}-σ relation is surprising because the stars in the spheroid are outside the gravitational sphere of influence of the black hole and therefore should know nothing about its mass. And yet, the tight relation implies that black holes and their host galaxies not only know about one another, but their growth is actually synchronized. Theories have been suggested to explain this correlation but none have yet shown sufficient predictive power to be well accepted.

To help us understand the M_{BH}-σ relation, we can compare active versus quiescent galaxies and look for offsets in the relation that could help constrain the physical mechanism that links the host galaxy and the black hole. We are focusing our efforts on measuring the stellar velocity dispersions for the hosts of high-luminosity quasars, these are particularly interesting as their black holes are typically the most massive and are growing the fastest.

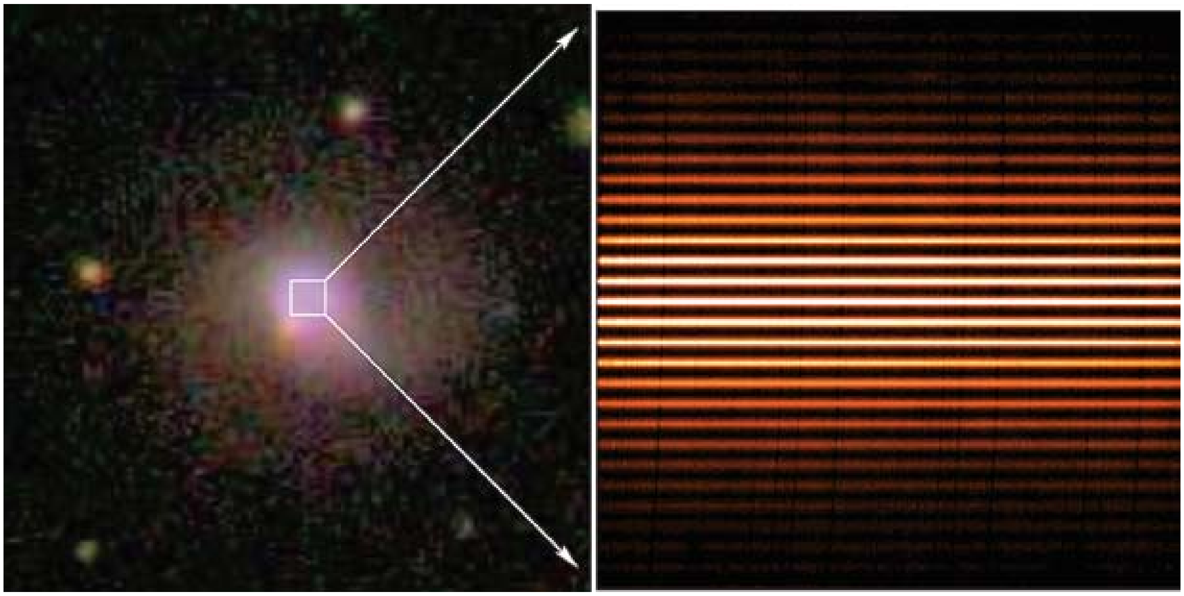

Figure 1.
Left: image of PG1426+015 from the Sloan Digital Sky Survey. The box represents the 3 × 3 arcsecond field of view of NIFS. Right: Dispersed light from within the NIFS field-of-view.

The fact that quasars outshine their host galaxies presents a significant challenge for measurements of precise host-galaxy velocity dispersions because a quasar's light dilutes stellar absorption features. The effect of this challenge was evident in work by Dasyra and collaborators, which used long-slit spectra from the Very Large Telescope (VLT) to measure stellar velocity dispersions for the hosts of high-luminosity quasars. This work demonstrated that CO bandhead absorption features in the H band (1.5 - 1.8 microns (μm)) could be used to constrain the stellar velocity dispersion. However, the observations were still of faint hosts with significant quasar contamination. As a result, some of the host spectra were rather noisy and therefore the derived velocity dispersions had large uncertainties. We targeted the object with the most uncertain velocity dispersion, PG1426+015, which has a measured black hole mass of 1×10^9 M_{Sun} and a quasar luminosity of 5×10^{45} ergs/sec.

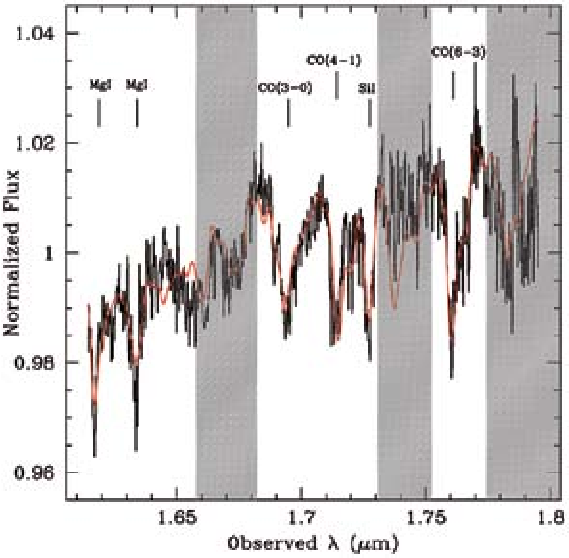

Figure 2.
Observed-frame host-galaxy spectrum of PG1426+015. The red curve shows the spectrum of a M5 Ia velocity template, broadened to fit the host-galaxy absorption features. The gray bands show regions excluded from our fit.

To overcome the challenges of velocity dispersion measurements of the hosts of luminous quasars, we require a combination of state-of-the-art instrumentation available at Gemini North: the recently installed Near-Infrared Integral Field Spectrometer (NIFS) and the Altair Laser Guide Star (LGS) adaptive optics (AO) system. NIFS's 3 × 3 arcsecond field of view allowed us to gather more host-galaxy light from near the galaxy's center than is possible with a normal single-slit spectrograph (see Figure 1). The superb image quality offered by LGS AO was a further aid because it confined the quasar light to the central few pixels of the image. We could then remove this quasar contribution from the spectrum without losing much host-galaxy light.

Figure 2 shows the observed-frame host-galaxy spectrum of PG1426+015 obtained with NIFS and Altair. The stellar absorption features we used to determine the stellar velocity dispersion are marked and include Mg I (1.488 μm), Mg I (1.503 μm), CO(3-0) (1.558 μm), CO(4-1) (1.578 μm), Si I (1.589 μm), and CO(6-3) (1.619 μm). The solid line shows the spectrum of an M5 Ia velocity template star with absorption features that have been broadened by the line-of-sight velocity distribution that best matches the host-galaxy features. Using a variety of templates, we determined that the best-fit stellar velocity dispersion for the host galaxy is 217 ± 15 km/sec.

The signal-to-noise ratio (SNR) of the NIFS spectrum is larger than the SNR of the long-slit VLT spectrum even though the VLT spectrum was obtained with a longer exposure. In addition, the velocity dispersion we derived is four times more precise than the value

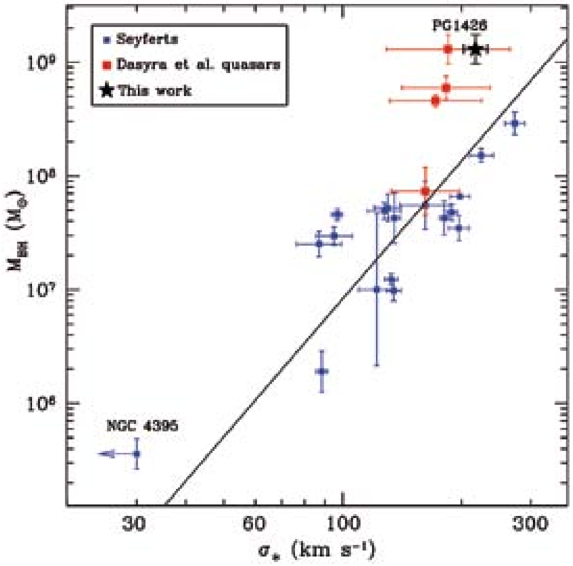

Figure 3. *The M_{BH}-σ relation with points designating active galaxies. Blue squares represent Seyfert galaxies, red squares represent quasars studied by Dasyra and collaborators using long-slit VLT spectra, and the star represents the position of PG1426+015 using our new velocity dispersion. The line shows the fit to the quiescent galaxy M_{BH}-σ relation.*

determined from the VLT spectrum. The high SNR and precise velocity dispersion are evidence of the combined advantages of NIFS and the Altair LGS AO system for stellar velocity dispersion studies of the hosts of luminous quasars.

In Figure 3, we use our measurement of the stellar velocity dispersion and the black hole mass determined in a previous study to place PG1426+015 on the M_{BH}-σ relation. All the points represent active galaxies: the blue squares are Seyfert galaxies, the red squares represent quasars studied in the Dasyra team's work using long-slit VLT spectra, and the star represents the position of PG1426+015 using our new velocity dispersion value. For comparison, the red square to the immediate left of the star indicates the position of PG1426+015 in the Dasyra analysis. The solid line denotes a fit to the quiescent galaxy M_{BH}-σ relation.

Although PG1426+015 is now closer to the M_{BH}-σ relation, it is also now more significantly discrepant with the relation because our measurement has a smaller error bar. From the few active galaxy data points that we have at the high-mass end of the relation, there is a suggestion that these objects lie above the trend. It is certainly possible that more data will show that we have simply been victims of small number statistics. Alternatively, underestimated velocity dispersions or selection biases could spuriously drive quasars above the M_{BH}-σ relation. Another, and perhaps the most important, possibility is that the black hole masses of high-luminosity quasars may be overestimated. All the points in Figure 3 have black hole masses estimated by reverberation mapping. This technique provides the radius of the broad-line region (BLR), which is a region of rapidly moving gas that is typically at sub-parsec distances from the black hole. By combining this radius with a measure of the BLR gas velocity derived from emission line widths, one can estimate the black hole mass. But this mass is uncertain due to the unknown geometry of the BLR. We currently simply include a constant scale factor in mass calculations that on average accounts for the geometry. The scale factor has been calculated for the lower-luminosity Seyfert population, but it could vary with luminosity. The degeneracy between true offsets from the M_{BH}-σ relation and scale factor differences between populations complicates the interpretation of our results.

Determining if one of these possibilities is correct could help us advance our understanding of galaxy formation, black hole growth, and quasar physics. But if we can rule out each of the above possibilities, and high-mass quasars do in fact lie above the M_{BH}-σ relation, we can begin to consider the crucial question of how this observation can constrain current models of the co-evolution of black holes and their host galaxies. To accomplish these goals, we will require a larger sample of high-mass quasars with measured black hole masses and precise stellar velocity dispersions. And as we have found in this work, the NIFS IFU and Altair LGS AO system are very well suited for obtaining these precise velocity dispersions for luminous quasars.

For further information see:
"First Stellar Velocity Dispersion Measurement of a Luminous Quasar Host with Gemini North Laser Guide Star Adaptive Optics," published in *ApJ*, Volume 682, Issue 1, pp. L21-L24. More information is also available in a paper by Dasyra, K. M., *et al.*, 2007, *ApJ*, 657, 102.

http://adsabs.harvard.edu/abs/2008ApJ...682L..21W
http://adsabs.harvard.edu/abs/2007ApJ...657..102D

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by Stuart Ryder & Seppo Mattila

Finds Supernovae Lurking in Luminous Infrared Galaxies

with Gemini Laser Guide Star Adaptive Optics

The rate at which massive stars exhaust their nuclear fuel, undergo core collapse, and then end their lives in colossal supernova explosions, has a huge influence on the evolution of their host galaxies. Supernovae drive the enrichment of gas by releasing the products of nuclear burning in their core out to the interstellar medium, which then triggers the next round of star formation. In dwarf galaxies undergoing a burst of star formation, supernovae may even expel some of this gas out of the galaxy entirely as a superwind. Stellar evolution theory, combined with recent identifications of actual supernova progenitor stars, indicates that only stars more massive than ~ 8 M_{Sun} will end their lives as core-collapse supernovae. Assuming that the ratio of such massive stars to less-massive stars (the so-called Initial Mass Function) is the same everywhere in the universe, then the observed supernova rate provides a measure of the star formation rate. This can potentially be employed across a vast range in redshift.

Despite the efforts of dedicated amateur supernova hunters such as Australian Bob Evans, and robotic searches such as the Lick Observatory's Katzman Automatic Imaging Telescope, the only thing we know for certain is that the current rate of supernova discoveries is less than the actual rate of supernova events. But just how many supernovae are we missing? To give an idea, let's examine the types of galaxies where supernovae ought to be occurring at the highest rates, namely those undergoing a starburst episode in which massive-star supernova progenitors are being born at the highest rates. The class of starburst galaxies known as Luminous Infrared Galaxies (LIRGs) whose total infrared luminosity exceeds 10^{11} solar luminosities, and their more extreme cousins the Ultra-Luminous Infrared Galaxies (ULIRGs) that emit more than 10^{12} solar luminosities at infrared wavelengths, ought to be the ideal hunting grounds for supernovae. Yet, barely a handful of the more than 4,500 catalogued supernova discoveries were found in LIRGs and ULIRGs.

Why is this? There are two main reasons. First, LIRGs and ULIRGs are incredibly dusty. Indeed, it is the action of the dust–which absorbs nearly all the optical radiation emitted by the young stars, and re-radiates it at longer wavelengths–that gives rise to their prodigious infrared luminosities. Secondly, both this dust and

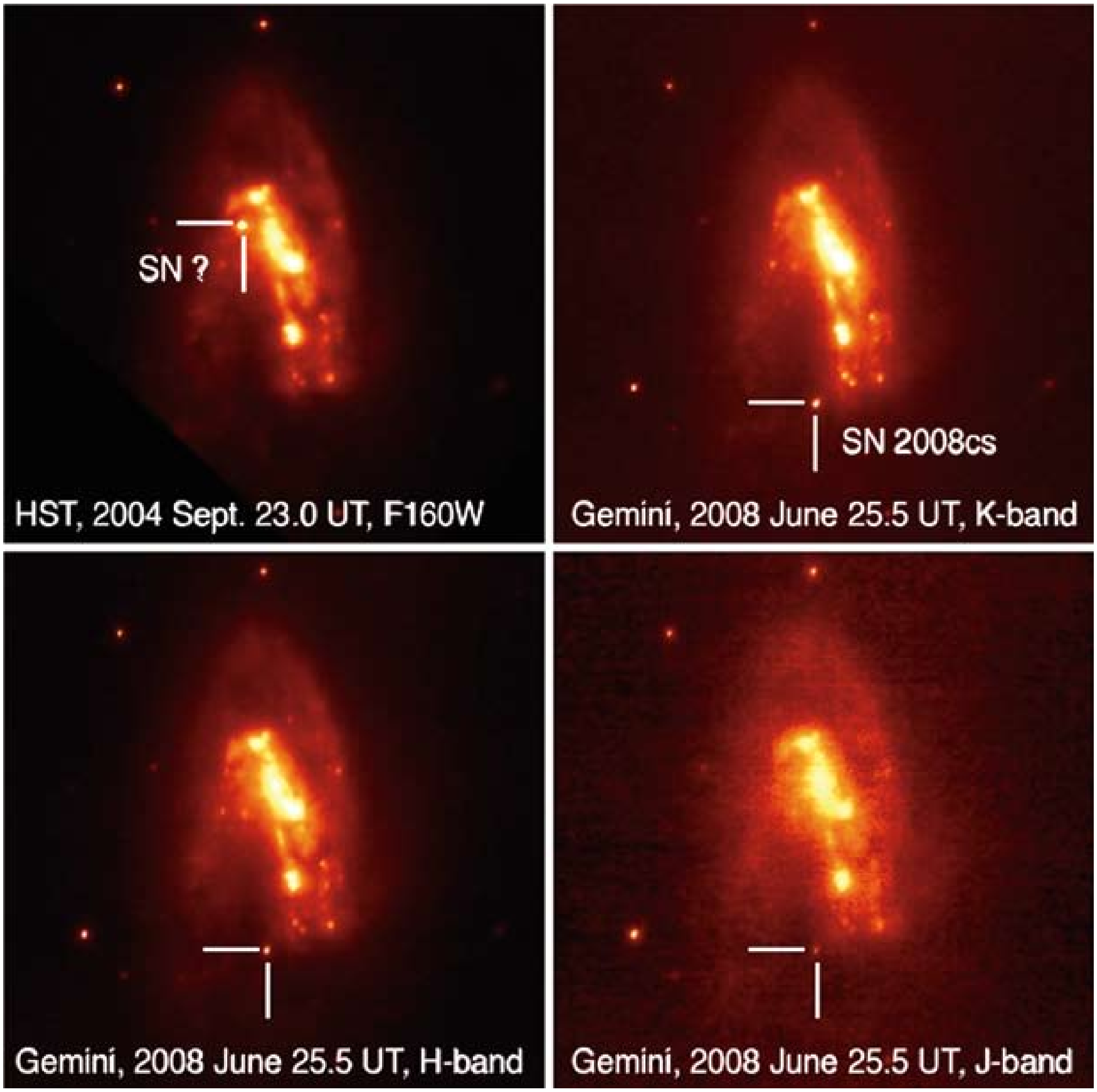

Figure 1.
Pre- and post-discovery images of SN 2008cs in the LIRG IRAS 17138-1017. The image at top left was obtained with NICMOS onboard the HST in September 2004, while the rest were obtained with Altair+NIRI on Gemini North in June 2008.

the tendency of stars to form in clusters result in LIRGs and ULIRGs appearing extremely clumpy. As most of the LIRGs are at least 50 megaparsecs (Mpc) away spotting a new point source against such a complex background in natural seeing conditions is extremely challenging. The availability of adaptive optics systems like Altair on Gemini North, which can deliver image quality of 0.1 arcsecond at near-infrared wavelengths, enables us to overcome both of these handicaps at one stroke.

Back in September 2004, we used the NAOS-CONICA adaptive optics system on the European Southern Observatory's (ESO) Very Large Telescope to discover a supernova in the LIRG IRAS 18293-3413 that had not been present in images from May 2004. Unfortunately, it took another two years before SN 2004ip was officially recognized as such by the IAU's Central Bureau for Astronomical Telegrams (CBAT), and subsequently vindicated with our discovery of a radio counterpart using the Very Large Array (VLA). SN 2004ip was the first supernova ever discovered using a natural guide star adaptive optics system. Encouraged by this success, and wanting to extend our supernova search to LIRGs that don't happen to have a bright-enough natural guide star within reach, we have initiated a program to use Altair's laser guide star mode to image a set of nine LIRGs at intervals of three to six months over four observing semesters. Our simulations have indicated that this is the optimum interval to detect supernovae. Any longer than this and we risk allowing a supernova to rise to maximum and decline again without ever being caught, while more frequent observations

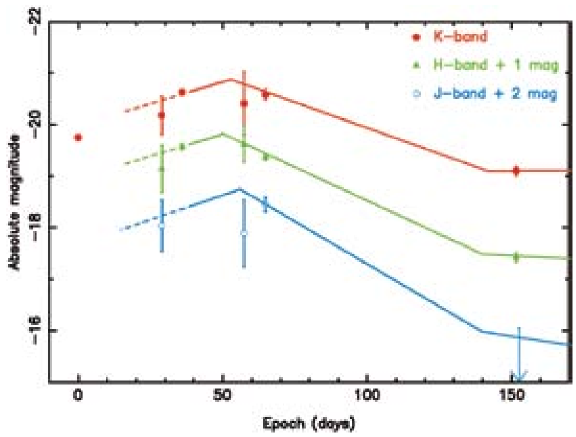

Figure 2. *Multi-color light curves for SN 2008cs, fitted to data from NIRI (both with and without Altair) and the Nortic Optical Telescope. These indicate that SN 2008cs is of the "slowly declining" type, and reached its maximum brightness some 50 days after discovery.*

would restrict the sample of galaxies we can monitor in the available allocation, and would actually lower our chances of a discovery.

Remarkably, with just our third target observation we hit pay dirt. Normally we rely on careful matching and subtraction of an earlier reference image of the same LIRG in order to reveal any new supernova candidate. The LIRG IRAS 17138-1017 had previously been observed with the NICMOS infrared camera on board the Hubble Space Telescope in September 2004. A simple visual comparison of our reduced Altair/NIRI image from 2008 April 21.6 UT with this image revealed in fact not just one new supernova candidate in the 2008 image, but also one "historical" candidate from 2004 which is no longer visible. Subsequent target-of-opportunity Altair + NIRI re-observations of the new southeastern source in IRAS 17138-1017 in May, June, and September 2008, (Figure 1), together with a Director's Time allocation for NIRI (without adaptive optics) in May 2008 and some service observations from the Nordic Optical Telescope (NOT) in June 2008, have enabled us to compile the multi-color light curves in Figure 2. Once again, VLA detection of a radio counterpart on 2008 May 19.4 UT put the core-collapse supernova nature of this object beyond doubt, and CBAT soon conferred on it the designation SN 2008cs.

Previous work has shown that the near-infrared light curves of core-collapse supernovae fall into two classes: the so-called "ordinary," and the "slowly declining" events which are almost 1.5 magnitudes brighter at maximum. The near-infrared light curves in Figure 2 indicate that SN 2008cs is of the latter type, and that it was discovered some seven weeks prior to reaching its maximum brightness. The inferred extinction towards SN 2008cs is a whopping 17.2 - 18.8 magnitudes in the V-band! It is little wonder that so few supernovae have so far been found in LIRGs by optical searches. Regrettably, the absence of any independent confirmation images or a radio counterpart precludes the CBAT from conferring an official supernova designation on the northeastern object from 2004. Nevertheless, SN 2008cs marks the first of what we anticipate will be a significant number of highly-obscured and previously uncounted supernovae to be discovered with the aid of laser guide star adaptive optics.

A paper on the discovery of SN 2008cs has been accepted for publication as an *Astrophysical Journal* Letter (astro-ph/0810.2885) with our collaborators from Finland (E. Kankare, J. Kotilainen), Spain (M. A. Pérez-Torres, A. Alberdi, C. Romero-Canizales, T. Díaz-Santos, A. Alonso-Herrero, L. Colina), South Africa (P. Väisänen), and Cyprus (A. Efstathiou).

For further information see:

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http://adsabs.harvard.edu/abs/2007ApJ...671L..21P

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by Tom Geballe & Markus Hartung

Does It Rain Methane on Titan?

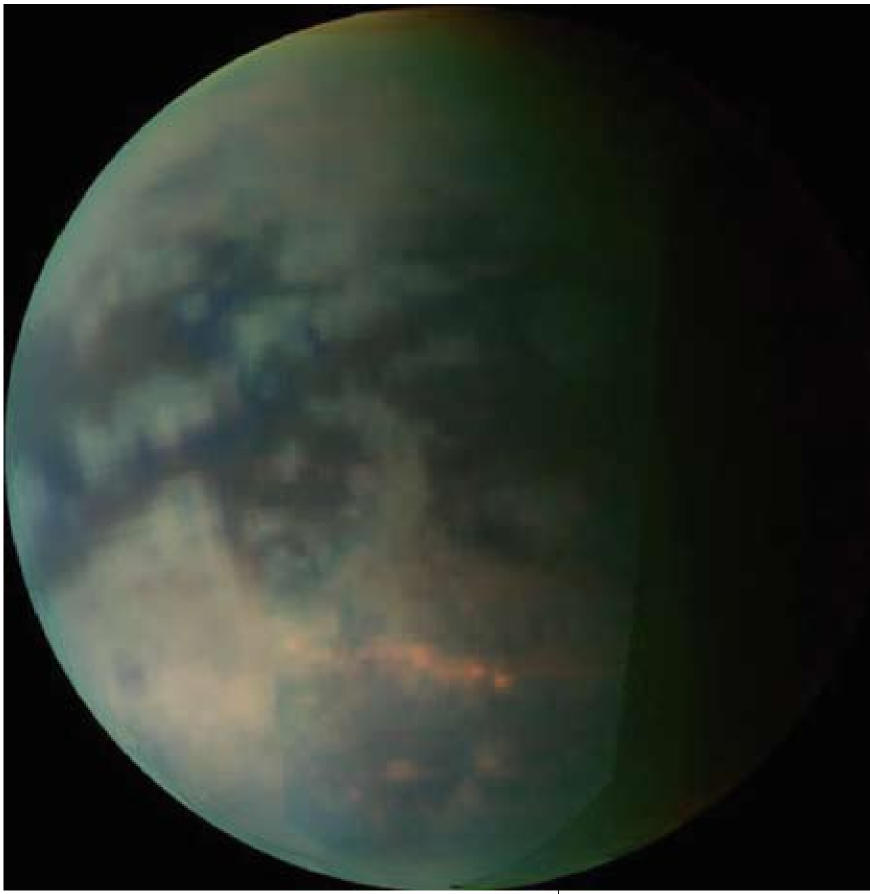

Figure 1. *Titan as seen by the Visual and Infrared Mapping Spectrometer on board the Cassini spacecraft as it performed a flyby on July 22, 2006.*

Saturn's moon Titan is the second-largest moon in the solar system and has long fascinated astronomers because it is the only moon with a thick atmosphere. Adding to the fascination, Titan's very cold atmosphere (94 K or -179°C near the surface) has a number of interesting similarities to Earth's. For example, its complex temperature profile (temperature vs. altitude) has the same overall structure as Earth's, and the atmospheric pressures at the surfaces of both worlds are nearly the same. Also, like the Earth's atmosphere, nitrogen gas (N_2) is the dominant chemical species, except that on Titan, it is much more dominant, making up about 97% of the gas particles (compared to Earth's approximately 78%).

After nitrogen, methane (CH_4) is by far the most abundant molecule in Titan's atmosphere. Because methane is rapidly destroyed by solar ultraviolet radiation at the top of Titan's atmosphere, there must be a source on the surface or within Titan that releases it into the atmosphere; otherwise it would have disappeared long ago. Toby Owen, a professor at the University of Hawai'i, has commented that Earth may have begun with an atmosphere similar to Titan's, but because of the planet's proximity to the Sun, it has oceans of water. In addition, the more active chemistry of Earth's warm environment ultimately led to the origin of life. In Titan's atmosphere, we find only a frozen echo of Earth: nitrogen, methane, and a small group of organic molecules. Location is the underlying reason, according to Owen, that "we are investigating Titan instead of Titanians investigating us."

Despite the cold environment, which one might suspect would lead to a sluggish atmosphere, Titan does have weather. This has become abundantly clear from ground-based infrared monitoring in the last decade. In visual images of Titan obtained from Earth or from spacecraft instruments, few details are apparent because high-altitude haze completely blocks our view of the low-altitude atmosphere. Infrared imaging, however, is able to view much farther down into the atmosphere, and at some wavelengths, allows us to see all the way to the ground. Those images reveal that clouds are present, although not what they are made of.

It has often been said that methane could play the same role in Titan's atmosphere as water does in ours. At low altitudes, the temperatures and pressures in Titan's atmosphere are close to those in which methane can condense into liquid and solid forms. During the last several decades, there has been considerable speculation among astronomers as to whether or not Titan contains seas of liquid methane and whether or not methane actually rains onto the surface.

The marvelous close-up images of Titan provided by the Cassini spacecraft, which is still operating, and by its Huygens probe, which parachuted to the surface of Titan in January 2005, have revealed that seas are not present. However, they show river channels and what appear to be hundreds of small lakes. This suggests that liquid hydrocarbons do exist on parts of the surface or have existed there in the past. Recently liquid ethane has been reported as being in one such lake, near the south pole of Titan, suggesting that other hydrocarbons, especially the much more plentiful methane, are also in liquid form there. Meanwhile ground-based monitoring of Titan at Gemini and other large telescopes has revealed shifting cloud patterns and the occasional formation of thick and highly localized clouds. Thus, conditions seem ripe for precipitation.

The two of us are each a member of a different team of astronomers that has recently been investigating the question of methane precipitation. The two teams reached quite different conclusions. Although we find ourselves on opposite sides of a controversy in terms of being associated with papers having opposing viewpoints, we continue to be on good speaking terms and to perhaps even enjoy the argument, and we want to write about it together. The story we relate below is not atypical in describing how scientists advance toward understanding and underlines the complexity of present day astronomical instrumentation, data reduction, and interpretation.

The advent of integral field spectrographs only a few years ago has provided astronomers with a powerful tool to gather spectral information over an extended field of view in a glance. The three-dimensional datasets (two spatial dimensions and wavelength) produced by these devices contain huge amounts of information and require large investments of computing time, analysis, and mental energy to understand. Slicing the field of view into small parts for spectral decomposition and then reconstructing images in certain wavelengths intervals is one of the most revealing ways to examine the data. However, these reduced images can be susceptible to instrumental and data-reduction pipeline artifacts. This susceptibility, common to all integral field spectrographs, means that care is required during data reduction and thorough verification of the results is mandatory.

In 2007, a group of astronomers led by Máté Ádámkovics of the University of California at Berkeley reported direct detections of methane drizzle over a large equatorial region of Titan known as Xanadu. The detections were based on observations of Titan made in 2005 at the Very Large Telescope (VLT), where one of us (MH) was then a staff member, and in 2006 at the Keck Observatory on Mauna Kea. Both datasets were taken with adaptive optics supported integral field spectrographs, SINFONI at the VLT, and OSIRIS at Keck. The observed data cubes were fitted by radiative transfer models of Titan's atmosphere, taking into account the complex absorption behavior of methane over the complete wavelength range. To visualize small spectral variations, the team extracted images from the fitted data cubes in two wavelengths ranges, 2.027-2.037 microns and 2.060-2.070 microns, in which Titan's atmosphere is semitransparent, but in the latter of which liquid methane absorbs more strongly. Their comparison technique involved scaling one of the images until its average intensity matched that of the other image, then subtracting one image from the other and examining the residuals in the subtracted image. In the subtracted images from each telescope, the Berkeley team found evidence for a decreased signal at 2.060-2.070 microns in the region largely corresponding to Xanadu. In both cases that region had recently been exposed to sunlight. The team attributed this decreased signal to absorption by small methane droplets. The near identical locations where the extra absorption occurred in 2005 and 2006 led them to suggest that they had detected morning drizzle and that it might be a daily phenomenon.

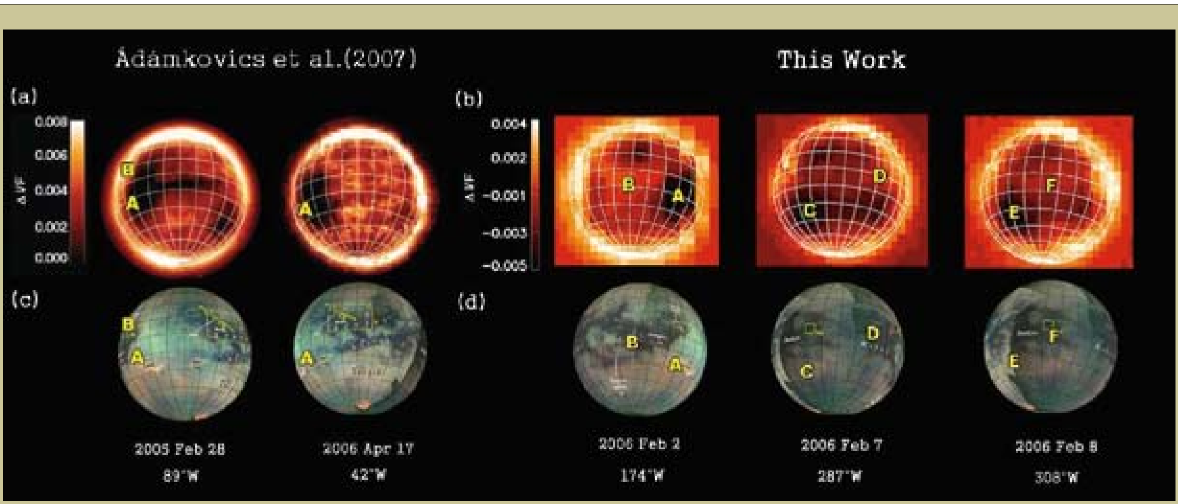

Figure 2. *Subtracted ground-based images of Titan (first row, (a) and (b)) compared with corresponding Cassini/VIMS images (second row, (c) and (d)). The dark region (A) shown in (a), which largely corresponds to Xanadu and nearby bright areas in the VIMS images, was first suggested to be an area of morning drizzling (Ádámkovics et al., 2007. However, the same dark region is also identified in the Gemini image (b) (labeled "This Work" in the figure), from Kim* et al. *(2007) but in the late afternoon. The bright region (B) in the subtracted images (b) is seen as a relatively dark region, Shangri-La, in the VIMS images (d). No distinctive dark regions in the subtracted images other than those that are anti-correlations with the VIMS surface features are found and thus widespread methane drizzle cannot be confirmed.*

Independently, a second team of astronomers (including Professor Sang Joon Kim of Kyunghee University in Korea, Dr. Laurence Trafton of the University of Texas, and the other of us (TG)), interested in studying other aspects of the atmosphere of Titan, had used Gemini North's Integral Field Spectrometer (NIFS) and the adaptive optics system Altair to acquire the necessary data. On three nights in 2006, that team had obtained a detailed set of infrared spectral images covering all of Titan. This set included the wavelength ranges observed by the first team. Although the second team had presented some aspects of their data at astronomy meetings in 2007, it was still far from being ready to write a full-blown research paper. However, the report that the Berkeley team had detected methane rain sent Kim, Trafton, and Geballe scrambling to examine their data for the same phenomenon.

Using the comparison technique described by the Berkeley team, Kim's group also found regions of apparent extra absorption at 2.060-2.070 microns at some locations on Titan, including the same region, Xanadu, where it was seen by the Berkeley team. However, at the time of their observations, it was not morning but afternoon on Xanadu. Further investigation showed that, in their datasets, the apparent extra absorption always occurred at locations where the surface of Titan is bright (*i.e.*, more highly reflective of incident sunlight) and that regions of apparent excess emission tended to correlate with regions on Titan where the surface is darker.

This sort of anti-correlation suggested that the comparison technique might be flawed. Kim's team made a detailed study of the technique and found that it is easy to produce difference images with spurious bright and dark regions. In their work, recently published in *Astrophysical Journal Letters*, they conclude that none of their datasets contained evidence for widespread methane drizzle and that drizzle is not a morning phenomenon. This does not mean that drizzle does not occur, but rather that remote detection of it, in particular via this technique, is much more difficult than first thought.

In their paper, Kim *et al.* point out that clouds, localized haze, and differences in Titan's surface geography complicate the remote detection of methane rain. Methane dew drops on the surface of Titan could also be confused with drops in the atmosphere. Thus, although monitoring Titanian rainfall from Earth is attractive, considerable additional observations and analytical work are needed to investigate the conditions under which the signature of methane drizzle can be extracted unambiguously from images of Titan.

The debate continues. The teams now agree that image differencing alone is not a "waterproof" indicator of methane rain. The Berkeley team is undertaking sophisticated analysis of its data. The combination of ground-based observations with data obtained by the Visual and Infrared Mapping Spectrometer (VIMS) on the Cassini spacecraft at viewing angles impossible from Earth will help to remove ambiguities arising when only ground-based observations are used. In addition, the Huygens probe took images and sampled the methane humidity as it descended towards the surface of Titan near Xanadu in early 2005. This could reveal whether droplets were present in the atmosphere at that time and place.

As the story goes on, we expect that, just as people will continue to talk about the weather on Earth, scientists will continue to talk and argue about rain on Titan.

For further information see:
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S. Kim, M. Trafton, and T. Geballe, 2008, *AJ*, **679**, L53

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http://adsabs.harvard.edu/abs/2008ApJ...679L..53K

For the press release regarding the lake on Titan see: *http://www.nasa.gov/mission_pages/cassini/media/cassini-20080730.html*

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by David Champion

The Unusual Companion of Pulsar J1903+0327

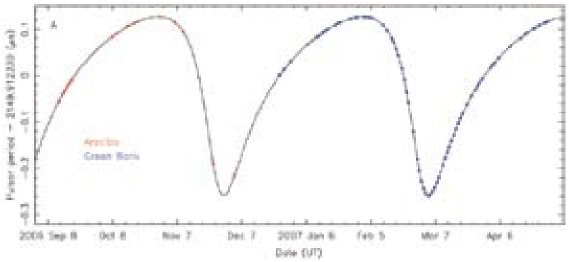
Pulsars are usually solitary objects. The supernova explosions in which they are born disrupt the vast majority of systems, leaving behind a rapidly rotating neutron star. In situations where a binary system survives, the remaining companion star can later "recycle" the pulsar which extends its observable lifetime by a factor of a thousand or more. These recycled systems are of particular interest because they allow for tests of general relativity and they place limits on the gravitational wave background. They may also provide a method to detect gravitational waves and could be used to produce a terrestrial time standard more accurate than atomic clocks over long timescales.

The population of recycled pulsars in the disk of our galaxy is thought to have two main formation mechanisms, each resulting in different final systems. Most pulsars with spin periods of tens of milliseconds (ms) have neutron-star companions in eccentric orbits. In contrast, pulsars with spin periods less than about 10 ms (millisecond pulsars) have white-dwarf companions in highly circular orbits (eccentricities, $e < 0.001$).

Pulsar J1903+0327 was the first millisecond pulsar to be discovered through the PALFA survey at Arecibo. Its short period and large estimated distance make it the most distant example found in the disk of the Milky Way. It also confirmed the sensitivity of the PALFA survey to millisecond pulsars deep within our galaxy.

With a spin period of 2.15 milliseconds, PSR J1903+0327 is the fifth-fastest pulsar in the galactic disk, so we fully expected that it would have a white dwarf companion in a highly circular orbit. However, follow-up observations at Arecibo and Green Bank showed that the rotational period is slowly changing due to orbital motion (Figure 1). To our surprise, we discovered that the orbit of the object is clearly eccentric ($e = 0.44$). This poses a problem for the widely accepted recycling theory.

Figure 1. *The apparent pulsar rotational period plotted against time over 2.5 orbits.*



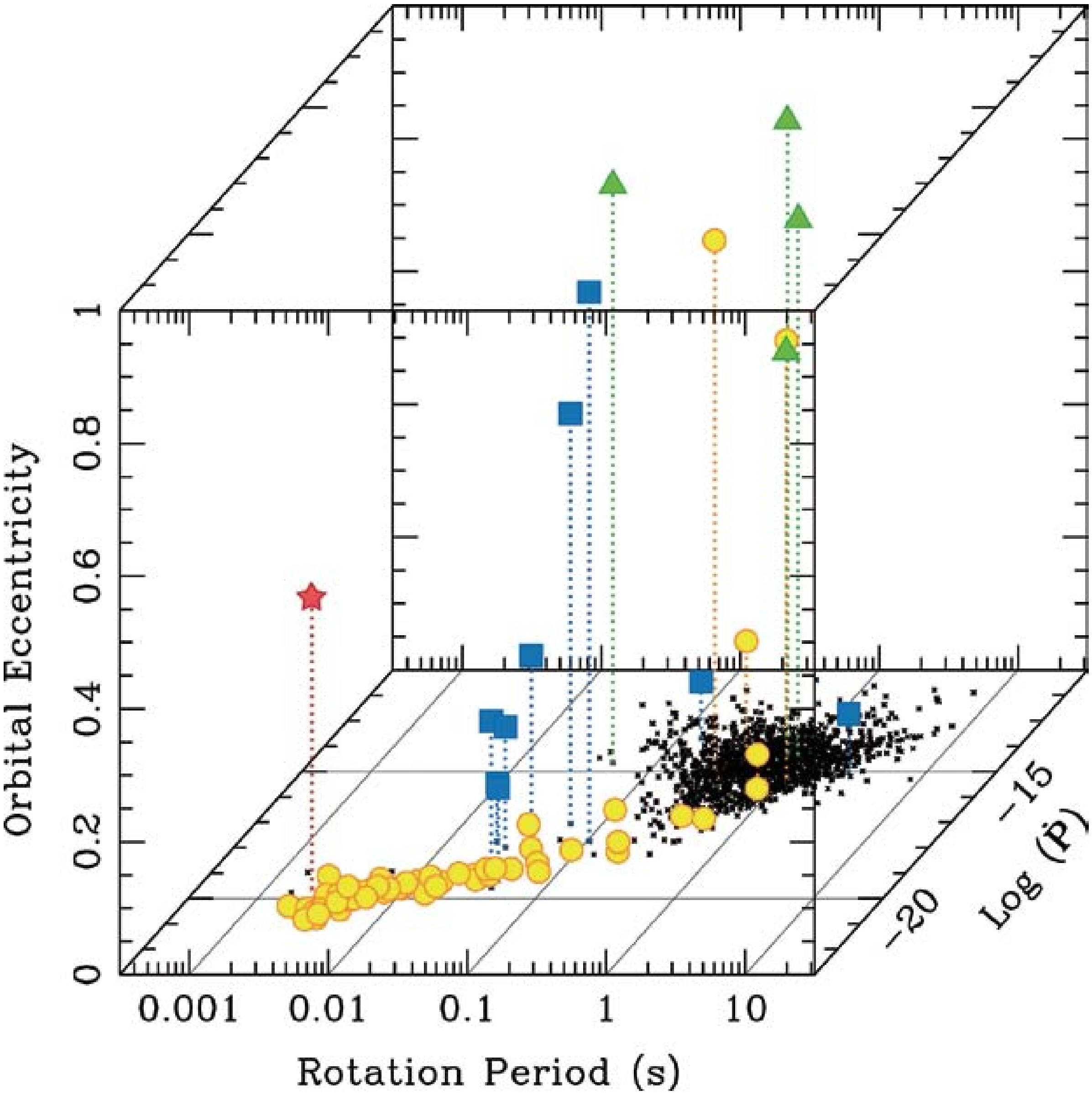
Pulsar Recycling

The combination of rapid spin rates and circular orbits is considered vital evidence that millisecond pulsars achieve their short periods via accretion of mass and angular momentum from binary companion stars.

The recycling of a normal pulsar can be split into two broad scenarios. In the first one, the initial binary contains a high-mass (› 8 M_{Sun}) star and one low-mass star (~ 1 M_{Sun}). The high-mass star evolves, undergoes a supernova explosion, and becomes a pulsar. The low-mass star evolves more slowly, eventually swelling to become a red giant. As the star over-fills its Roche lobe, matter streams off the red giant onto the pulsar. This spins it up through transfer of angular momentum. At the same time, tidal forces make the orbit of the companion extremely circular. This leaves a highly recycled pulsar (*i.e.*, a millisecond pulsar) in a circular orbit with a white dwarf companion.

In the second scenario, both members of the initial binary are high-mass (› 8 M_{Sun}) stars. The most massive of the pair evolves more quickly and becomes a pulsar via a supernova explosion. The companion star evolves to become a red giant. However, the mass difference

Figure 2. *Rotation periods, period derivatives, and orbital eccentricities of pulsars in the galactic disk. Colored symbols show the binary pulsars, projected upward from the bottom. Square blue points are double neutron star systems, triangular green points have main sequence companions, circular yellow points have white dwarf companions, and the red star is PSR J1903+0327.*



between the two stars makes accretion unstable so most of the mass is transferred via the stellar wind, which makes a slight contribution to the spin-up of the pulsar. The companion star then undergoes its own supernova explosion to become a neutron star, which induces eccentricity into the orbit. This leaves a mildly recycled pulsar (with a period of a few tens of milliseconds) in an eccentric orbit around a neutron star: a double neutron star system.

PSR J1903+0327 does not fit into either of these categories. Its short period rules out the double neutron star scenario, and its high eccentricity rules out the white dwarf possibility (Figure 2).

A Search for the Companion

Continued timing measurements refined the orbital parameters and allowed limits to be placed on the mass of the companion. These limits were consistent with a neutron star, white dwarf, or a main-sequence star. Given the possibility of a neutron-star companion, we searched the data for radio pulsations from the companion. No pulsations were seen, but the neutron star may not be pulsing or the pulses may be unfavorably beamed (with respect to our line of sight).

Given the distance to the system and its low galactic latitude, we could not expect to detect a white dwarf but we should be able to see a main-sequence companion using an optical/infrared telescope. There was no reason to expect such a companion; after all a main sequence star could not have recycled the pulsar via accretion. But, given the unusual nature of the system and the small amount of telescope time required, we decided it was worth a look.

We used the Gemini North telescope to image the position of the pulsar in the infrared J, H, and K_S bands. To our astonishment, we found a single star within the 0.13 arcsecond 1-sigma frame-tie error circle at the position of the pulsar (Figure 3). It has magnitudes J=19.22(9), H=18.41(10), and K_S=18.03(9). Given the density of stars in this field, we estimate the probability of finding a star in the error circle by chance is only 2.6%. Using main-sequence star models and estimating the reddening with red clump stars at the inferred distance of the pulsar, we find that a ~ 1 M_{Sun} star of age of ten billion years best fits these magnitudes.

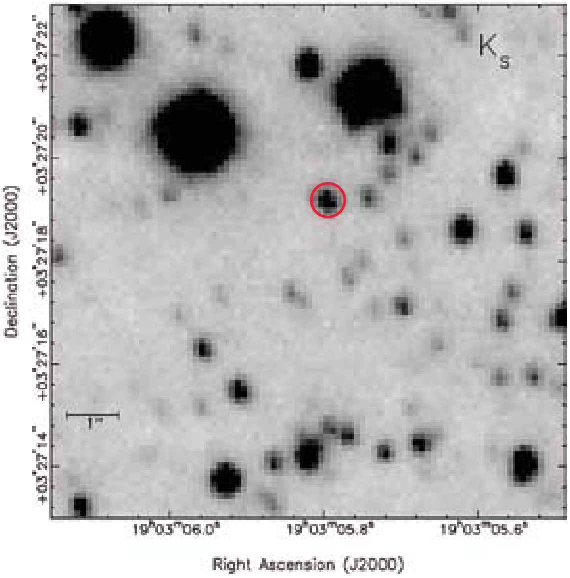


Figure 3. *A KS-band image of the PSR J1903+0327 field taken during excellent conditions using the Gemini North telescope. The red circle shows the 2-sigma error circle, with radius 0.32 arcsecond. The star within the error circle is the possible main-sequence companion to the pulsar.*

System Masses

Continued timing measurements in radio wavelengths provided another surprise. We noticed a delay in the pulses from the pulsar when it was at inferior conjunction. This is a phenomenon known as the Shapiro delay and it occurs when the pulses are delayed by passing through the gravitational well of the companion. Measurement of this delay allows the mass of the companion and the inclination of the orbit to be determined via general relativity. Since we know the total system mass from the advance of periastron we can also calculate the mass of the pulsar.

The mass of the companion was ~ 1 M_{Sun}, the inclination of the orbit was ~ 78° giving the pulsar an unusually high mass of ~ 1.75 M_{Sun}. This is similar to the inferred masses of several globular cluster pulsars and the x-ray system Vela-X1, but it is much higher than the mass range of 1.25-1.45 M_{Sun} seen in other pulsar systems.

Formation Mechanisms

So what is the origin of this unique system with a short spin period, large orbital eccentricity, and possible main-sequence companion?

While this system is unprecedented in the galactic disk, it would not seem out of place in a globular cluster. Unusual systems, including eccentric millisecond pulsar binaries, have been observed in various globulars. In these cluster systems the densities of the cores are so

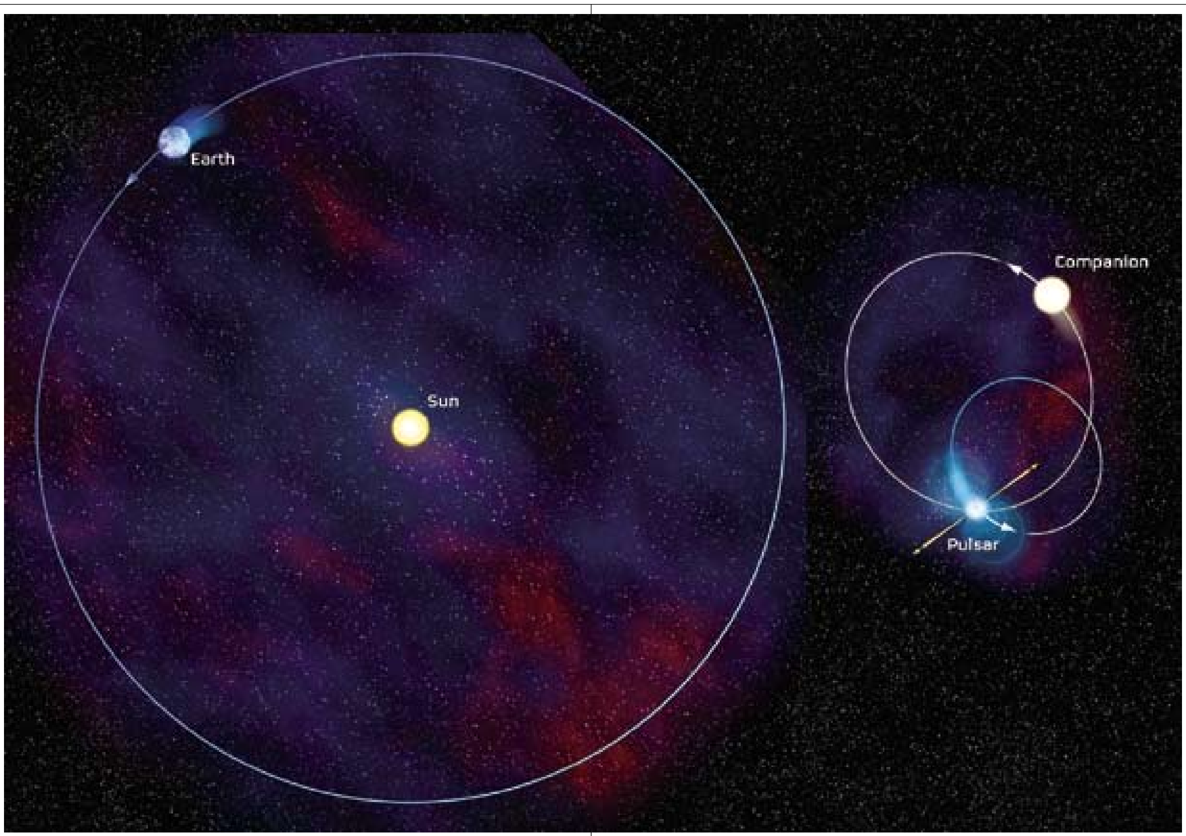


Figure 4. *This diagram shows a comparison of the sizes and strangely elliptical shapes of the orbits of the pulsar J1903+0327 and its possible Sun-like companion star with the Earth's orbit around the Sun for comparison. The sizes of the stars have been exaggerated. Credit: Bill Saxton, NRAO/AUI/NSF*

high that interactions between systems and the swapping of binary companions are commonplace (in contrast to the galactic disk).

There is no known globular cluster at the position of PSR J1903+0327 nor is there evidence for a previously unknown cluster in the 2MASS catalog, the GLIMPSE survey, or our own Gemini observations. An intriguing possibility is that PSR J1903+0327 was formed in the core of a globular cluster and was then ejected from the cluster, possibly in the same interaction that induced the orbital eccentricity we observe today. Alternatively, the cluster could have been disrupted during orbital passages through the galactic disk and bulge. Rough estimates suggest a 1 to 10% chance that PSR J1903+0327 originated in a globular cluster.

An alternative scenario has PSR J1903+0327 recycled as part of a compact inner binary in a hierarchical triple, in a configuration that was recently suggested for a different system named: 4U 2129+47. If the "triple system" scenario is true then PSR J1903+0327 and its companion evolved to become a millisecond pulsar as expected, albeit in a way that its evolution was largely unaffected by the third body. The pulsar then ablated away its white dwarf companion and was left in a 95-day eccentric orbit around the main sequence star we now observe.

Further observations of PSR J1903+0327 will allow us to decide between these (or other) formation scenarios. A measurement of a large projected space velocity via long-term timing or Very Long Baseline Interferometry astrometry, might reflect a cluster origin given the high velocities of most globulars. Spectroscopic observations of the main-sequence star will reveal its spectral type and metallicity, both possible indicators for or against a globular cluster origin, and will show whether it exhibits the 95-day orbital motion of the pulsar.

This research is based on D.J. Champion, *et al.*, 2008, *Science*, **320**, 1309 and presented on behalf of the PALFA collaboration.

http://adsabs.harvard.edu/abs/2008Sci...320.1309C

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By Tanio Díaz-Santos, Almudena Alonso-Herrero
& Christopher Packham

Resolving the Hearts of Luminous Infrared Galaxies

Since the launch of the Infrared Astronomical Satellite (IRAS) and the Infrared Space Observatory (ISO) satellites, and more recently with the Spitzer Space Telescope, one of the main lines of investigation in the field of infrared galaxy research has been the calculation of the star-formation rate of star-forming galaxies using monochromatic mid-infrared luminosities. But, why do this using mid-infrared measurements and not classical star-formation rate indicators like H-alpha or the ultraviolet continuum? It is now known that the star-forming rate density at high redshift ($z > 1$) is dominated by galaxies classified as luminous or ultra-luminous infrared galaxies ((U)LIRGs). Because of their high dust content, these galaxies emit the bulk of their energy between 5 and 1,000 microns. This occurs since the ultraviolet/optical light generated by the intense processes of star formation taking place in these galaxies is almost totally absorbed by the dust and then re-emitted in the infrared. Thus, a measurement of the luminosity at these wavelengths (the mid-infrared) is a measure of the "obscured" star formation, which cannot be traced using classical ultraviolet/optical star-formation rate estimators. However, high-z examples of infrared-bright galaxies are too distant and therefore too faint to be observed with ground-based telescopes in the mid-infrared. To circumvent this issue a detailed study of their local analogues is crucial for understanding the obscured star formation processes at high-z.

The 8-micron monochromatic luminosity (accessible on Earth through the N-band atmospheric transmission window) might be one of the most interesting star-formation rate indicators. One reason is that at $z \sim 2$ the rest-frame 8-micron emission from an infrared bright galaxy is redshifted to 24 microns; so we can study local LIRGs at 8 microns and then relate our findings to high-redshift galaxies detected in deep Spitzer surveys at 24 microns. However, a number of caveats must be taken into account before we can directly relate the 8-micron luminosity and the star-formation rate of an HII region (which is a region where all the hydrogen is in ionized state) or an entire galaxy. For example, we know that the emission at 8 microns is produced by both the thermal continuum from

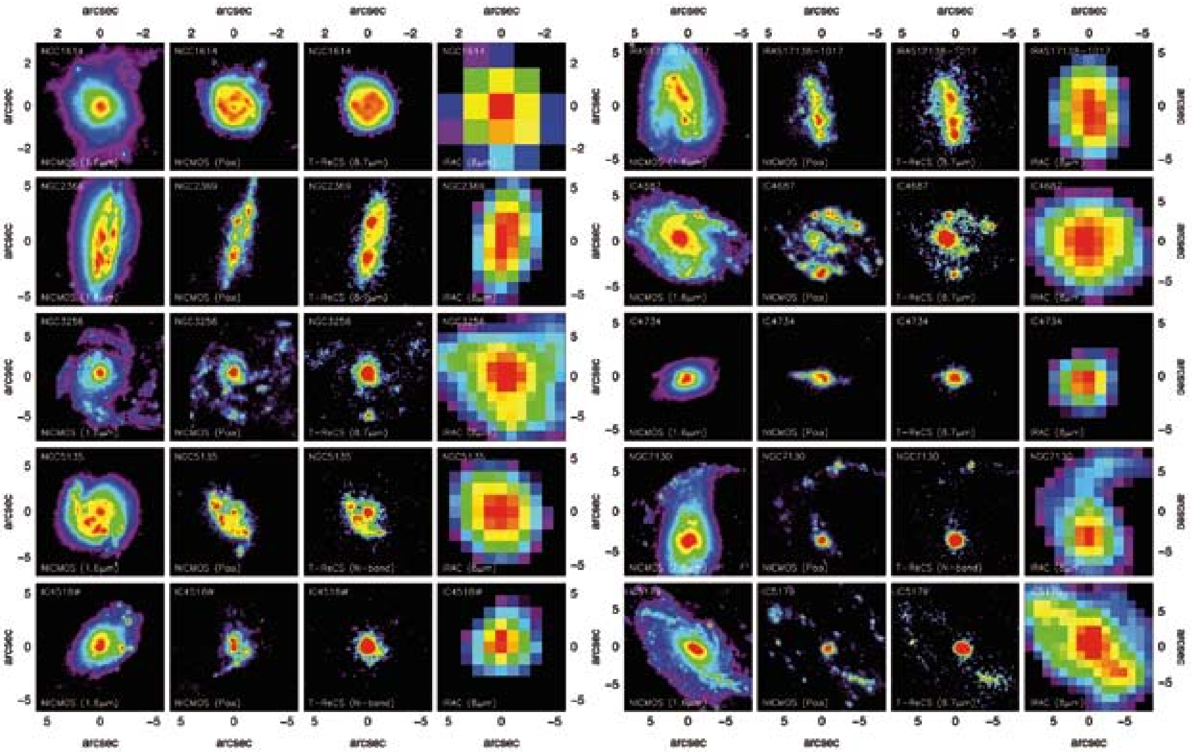

Figure 1.
HST NICMOS 1.6-micron continuum (left) and continuum-subtracted Pa-alpha line (middle-left) images, together with Gemini T-ReCS 8.7-micron or N-band (middle-right) and Spitzer IRAC 8-micron (right) images. The field of view is optimized to show the extent of the mid-infrared emission. North is up, east to the left.

hot dust (heated by the stars) as well as by polycyclic aromatic hydrocarbon (PAH) features. PAHs are molecules made of carbon and hydrogen atoms, and are commonly observed in the mid-infrared spectra of local and high-z star-forming galaxies. However, while the dust continuum emission is found to be more peaked towards the center of HII regions, the PAH emission arises from areas of photo-dissociation located in the rims of the star-forming regions. In addition, PAH emission can also be stimulated by the galaxy field radiation and therefore not directly associated with young ionizing stellar populations. This explains why the 8-micron emission appears to be more extended and diffuse than the H-alpha or Pa-alpha emission (Figure 1). In fact, some researchers have found that the individual HII regions and the integrated emission of LIRGs show a different behaviour in the L(8-micron) vs. L(Pa-alpha) relation (where the Pa-alpha emission line is a direct tracer of the star-formation rate). Therefore, choosing an adequate aperture size for measuring the emission of individual star-forming regions is crucial, as is the spatial resolution of the data.

We have studied the 8-micron emission of a sample of low-z LIRGs at sub-arcsecond scales using Thermal-Region Camera and Spectrograph (T-ReCS) on Gemini South. The superb spatial resolution afforded by this telescope-instrument combination has allowed us to probe individual HII regions on scales of a few hundreds of parsecs (pc), almost an order of magnitude improvement with respect to the spatial resolution afforded by Spitzer (see Figure 1). We have explored the effects of the age and extinction of the individual star-forming regions on the 8-micron vs. Pa-alpha relation and how they may contribute to the observed scatter of the relation. We also have compared our results with those found for high-metallicity HII knots in star-forming galaxies from the Spitzer Infrared Nearby Galaxies Survey (SINGS) sample.

In the work discussed here we present T-ReCS (8.6-micron or 10.3-micron) imaging observations of a sample of ten low-z (d < 76 megaparsecs (Mpc)), high (solar or slightly higher) metallicity LIRGs, as well as HST NICMOS continuum and Pa-alpha images. The main goal is to study in detail the L(8-micron) vs. L(Pa-alpha) relationship for HII regions in LIRGs on scales of a few hundred parsecs. We measured the luminosity at the different wavelengths using 3 apertures with radii of r = 75 pc, r = 150 pc and r = 300 pc. The first aperture was chosen to take advantage of the high angular resolution afforded by Gemini T-ReCS and HST NICMOS images. The larger apertures are useful to compare our results with those found for HII regions in the high-metallicity SINGS galaxies observed with Spitzer at 8 microns.

We find that although the overall Pa-alpha (tracing the youngest ionizing stellar populations) morphologies

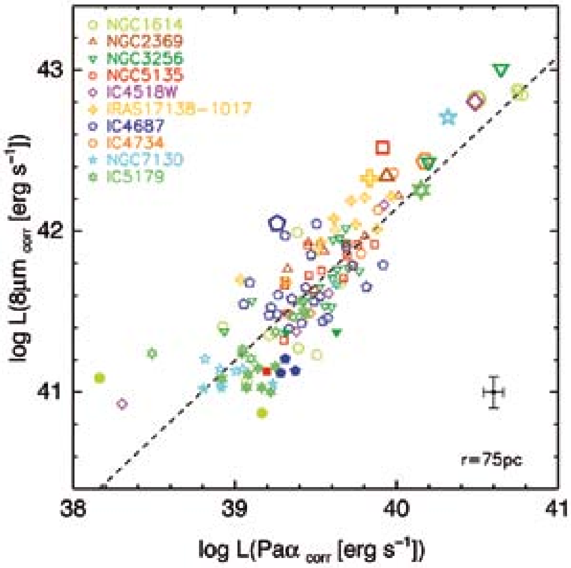

Figure 2.
The 8-micron vs. Pa-alpha relation of the LIRG HII regions (small open and filled symbols are for › 3 arcseconds and 2-3 arcseconds measurements, respectively) and nuclei (big open symbols) measured using the r = 75 parsec aperture. The dashed line is our least-squares fit to all the LIRG HII regions.

of LIRGs are similar to those in the mid-infrared (see Figure 1), there are some differences on the smallest (~ 100 pc) scales. On one hand, on scales of r = 300 pc (approximately the physical sizes probed by the Spitzer observations at 8 microns at the distances of the SINGS galaxies), the LIRG HII regions extend the L(8-micron) *vs.* L(Pa-alpha) relation found for the SINGS HII knots to higher luminosities by about two orders of magnitude. On the other hand, when studied on smaller scales (r = 75 pc), the relation holds for the LIRG HII regions, although with a slightly shallower slope and a greater scatter around the fit (see Figure 2). Taking into account that our sample has a nearly constant metallicity, we have found that the scatter of this relation may be explained in terms of the ages of the ionizing population and different PAH contributions.

There is a tendency for the youngest HII regions in our sample to show low L(8 micron)/L(Pa-alpha) ratios. Considering instantaneous star formation and assuming that L(8 micron) is proportional to L(IR), which for LIRGs is approximately equal to the L(bol), we naturally reproduce the observed L(8 micron)/L(Pa-alpha) ratios as a function of the age of the star-forming regions. In particular, the factor of ten change in this ratio can be accounted for by stellar populations with ages ranging from ~ 4 to 7.5 million years (Figure 3). The residual dispersion around the model prediction is likely to be caused by the different contribution from galaxy to galaxy of the 8.6 micron PAH feature (in our case) to the 8-micron emission (and in general, to the infrared luminosity), as observationally found by other works.

The work detailed above highlights the complimentary nature of space- and ground-based mid-infrared observations. By performing follow-up observations of these galaxies, the work has allowed us to place the ground-breaking Spitzer observations in context, through discriminating between the various emission mechanisms noted above. It is sometimes suggested that mid-infrared observing is the domain of space-based observatories, where the complications induced by the high thermal background are eliminated. This is typically true where high sensitivity is key (*e.g.* objects fainter than ~ 1 milliJansky (mJy)). However, where high spatial- or spectral- resolution proves to be important, the diffraction-limited observations afforded by the 8-meter class of telescopes are often crucial to reveal the underlying physics.

Compared to the entire suite of Gemini instruments, it is interesting to note that while MICHELLE and T-ReCS current receive only ~ 15% of the proposals, they are the instruments that need the fewest number of observing hours per paper. This demonstrates the rich discovery space offered by the mid-infrared. It also points to the idea that the thermal optimization of the Gemini telescopes combined with the capabilities of the mid-infrared instruments gives us a powerful combination that can be used to advance modern astronomy. As Gemini users, we also note that the shift to queue observing has improved both the quality and volume of our data. This is presumably due to very specific conditions that mid-infrared observations typically require.

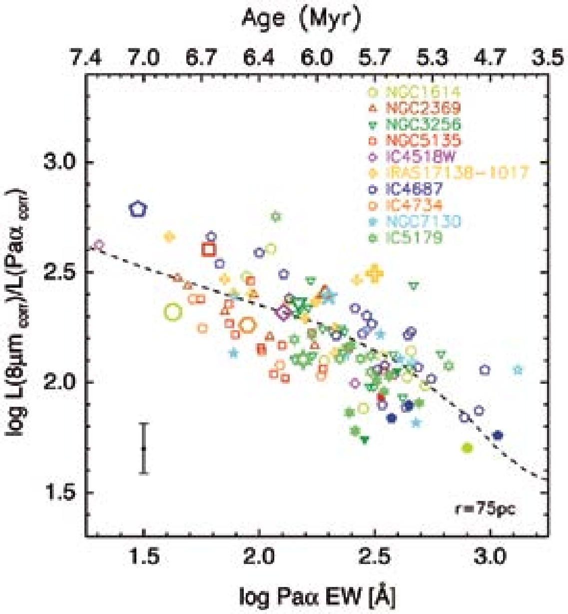

Figure 3.
The 8 micron / Pa-alpha luminosity ratio of the HII regions as a function of their age. Symbols are as in Figure 2. The general evolution seen for the data points if fully accounted by the starburst models (dashed line).

As we move toward the era of the James Webb Space Telescope (JWST) and the 30-meter class of telescopes, it is interesting to speculate about the direction in which mid-infrared ground-based astronomy will develop. At the recent Giant Segmented Mirror Telescope Conference in Chicago, key discussions differentiated between the strengths of ground-based mid-infrared astronomy and that which will be offered by the JWST. High, stable spatial resolution, high spectral resolution, and "novel" observing modes (such as nulling interferometry and polarimetry) were highlighted as strengths of ground-based mid-infrared astronomy.

These strengths are already available with today's instrumentation, current optimization and developments of the mid-infrared systems are aimed to ensure they reach their full potential on Gemini. Through the deployment of dual-beam guiding, ground layer adaptive optics and an adaptive optics secondary, all of which are planned for Gemini over the coming years, the synergy between the Spitzer legacy and follow-up observations will become ever stronger. Such work is also crucial preparatory work for the JWST, and to span the time gap between the space-based observatories. Gemini, through its thermal optimization and highly sensitive mid-infrared instruments, is well placed to serve the community in this respect.

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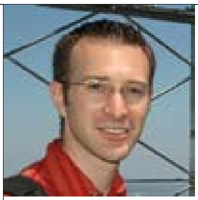

By David Lafrenière

Gemini Images Possible Exoplanet

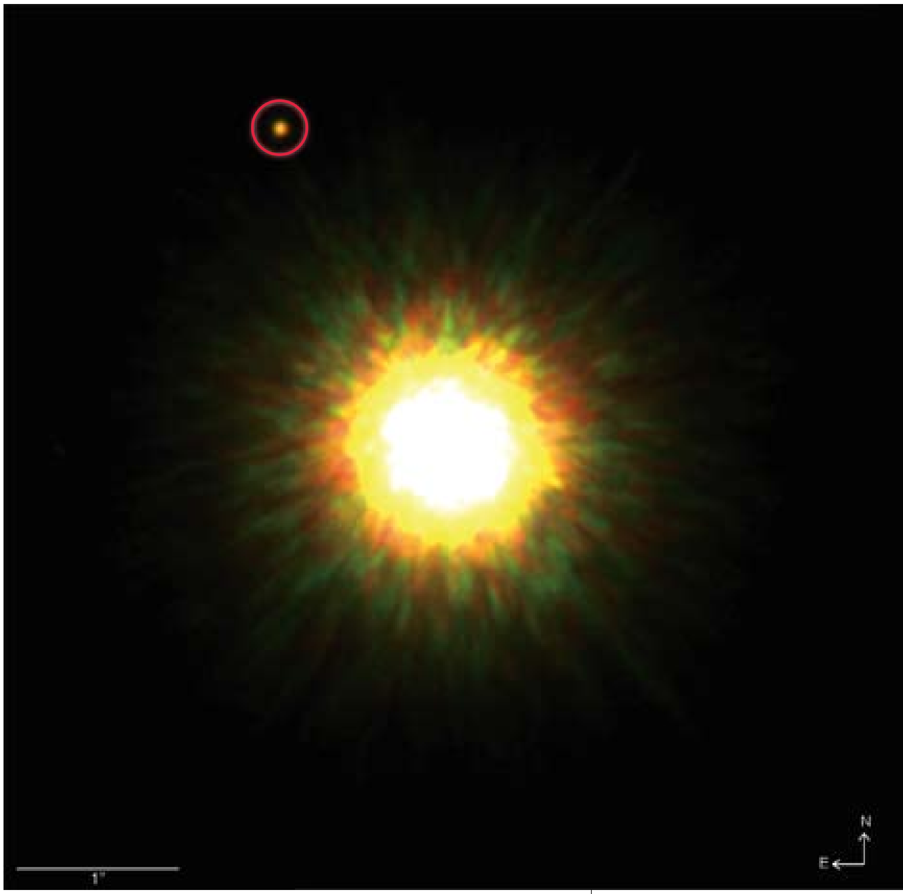

Figure 1. *Gemini adaptive optics image of 1RXS J160929.1-210524 and its likely ~8 Jupiter-mass companion (within red circle).*

For more than ten years, astronomers have been trying to capture the first image of an exoplanet, without success. This dry spell might have finally reached an end with what may be the first-ever picture of a planet orbiting another sun-like star. The composite near-infrared image, shown on the front cover of this issue of *GeminiFocus* was obtained at the Gemini North telescope using the Altair adaptive optics system and shows the star 1RXS J160929.1-210524 at the center with a candidate companion in the upper left corner. The star lies roughly 500 light years from Earth in the Upper Scorpius association, a group of a few hundred stars thought to have formed in a burst only 5 million years ago. Apart from its much younger age, this star is very similar to the Sun. The near-infrared colors and spectrum of the candidate companion indicate a temperature of 1800 K and clearly show that the object is still contracting under its own gravity, and thus that it is very young. This is consistent with the age of the primary star. The fact that the proposed planet has not yet had time to cool off explains its much higher temperature compared to Jupiter (160 K). The mass of the candidate companion is about eight Jupiter masses. This is low enough to qualify it as a planet according to the definition of the Working Group on Extrasolar Planets of the International Astronomical Union. Additionally, the luminosity of the object, when compared to theoretical models, indicates that it lies at roughly the same distance from Earth as the primary star.

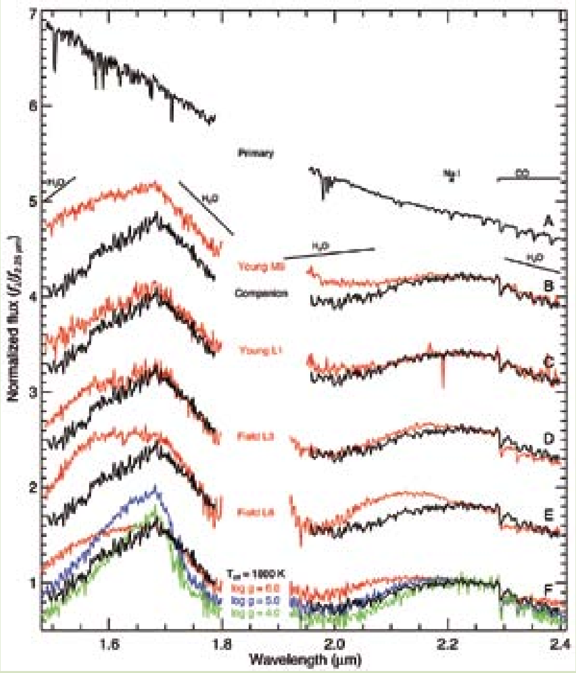

Figure 2. *Near-infrared spectra of 1RXS J160929.1-210524 and its candidate companion. The primary's spectrum (row A) is as expected for a temperature of about 4000 K (spectral type K7). The candidate companion's spectrum (black curves repeated in rows B - F) is compared with the spectra of two young brown dwarfs (red curves on rows B - C; spectral types M9 and L1) and two older, cooler brown dwarfs (red curves on rows D - E; L3 and L6). The "triangular" shape of the left part of the companion's spectrum is in much better agreement with the two young brown dwarfs, indicating the candidate companion has low gravity; in turn, this implies it has not yet fully contracted and thus is still young. The companion spectrum and those of all comparison objects have been normalized to be the same on the right-hand side. The fact that, compared to the young brown dwarfs, the candidate companion is slightly fainter in the left-hand part* indicates that it is cooler, *more like the field L3 brown dwarf. The comparison with models (row F) confirms that the companion has low gravity, and thus is young.*

While all of this offers compelling evidence that the two objects form a star-planet pair bound by gravity, it does not constitute a proof. Indeed it is possible, albeit unlikely, that the candidate companion is a young planetary-mass object traveling independently through space, and that it appears close to the star on the sky only because of a chance projection effect. Over the next year or two, the two objects will be observed repeatedly and their relative positions measured precisely to determine whether or not they are indeed traveling through space together.

If the gravitational link between the candidate companion and the star is confirmed, their angular separation of 2.2 arcseconds would indicate an orbital separation of roughly 330 times the Earth-Sun distance. The existence of a giant planet so far from its parent star would pose a serious challenge to models of star and planet formation. Such a planet could not have formed at this orbital separation through the same mechanism believed to have formed Jupiter: the gradual growth of a solid planetary core within the circumstellar disk, followed by rapid accretion of large amounts of gas. Indeed, at hundreds of astronomical units from the star, the density of solid material in the disk is so low that any planetary "seed" would not be able to grow enough before the disk vanishes. However, such a planet could still have formed by this mechanism at a smaller distance from the star, where time is not an issue. It then could have migrated out to a larger orbit through interaction with other planets or with the residual disk. Another possibility is that the planet formed directly at its current location but through a different mechanism, maybe by the direct collapse and fragmentation of a molecular cloud core, as for binary stars, or by the rapid gravitational collapse of the circumstellar disk.

The direct imaging search for exoplanets, their ensuing characterization, and the study of the planet formation process all bear the promise of spectacular developments in the years to come, in particular with the venue of the Gemini Planet Imager. The discovery reported here is only a taste of more exciting things to come!

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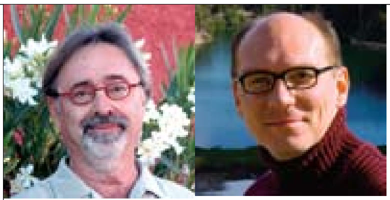


By Jean-René Roy & R. Scott Fisher

Recent Science Highlights

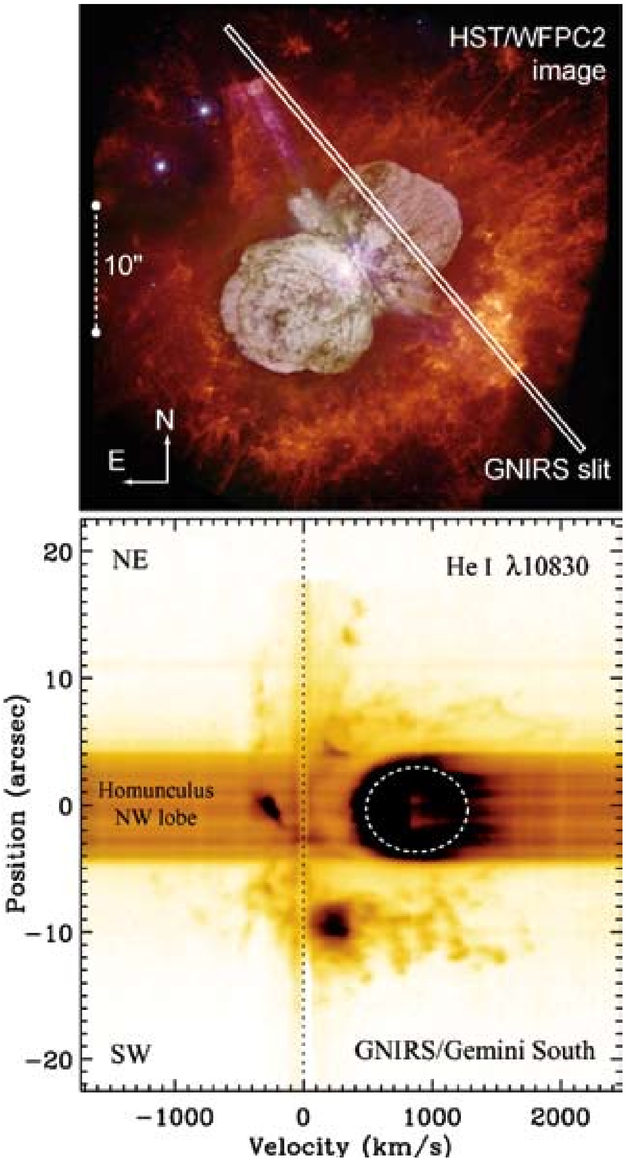


Figure 1.
Top: HST image of Eta Carinae with GNIRS spectroscopic slit aperture indicated. Bottom: Position-velocity plot used to determine velocities of gas in the nebula.

Astronomers have been puzzling over the engine that powered the historical 1843 outburst of the luminous blue variable star Eta Carinae since it happened. Now, recent observations made using the Gemini South and Blanco telescopes in Chile have added a startling clue. New data reveal faint but extremely fast-moving material indicative of a powerful shock wave produced by the 1843 event. This suggests that the driving mechanism was an explosion rather than a steady stellar wind. The research, led by Nathan Smith of the University of California, Berkeley, shows that the famous nebulosity around Eta Carinae contains extremely fast-moving filaments of material that had not been seen before, and are not explained by current theories.

Gemini spectroscopy, obtained using the Gemini Near-Infrared Spectrometer (GNIRS) instrument, helped confirm the high speed and geometry of this material and shows that the 1843 outburst released even more energy than previously estimated. In particular, the measured high velocities of the ejecta

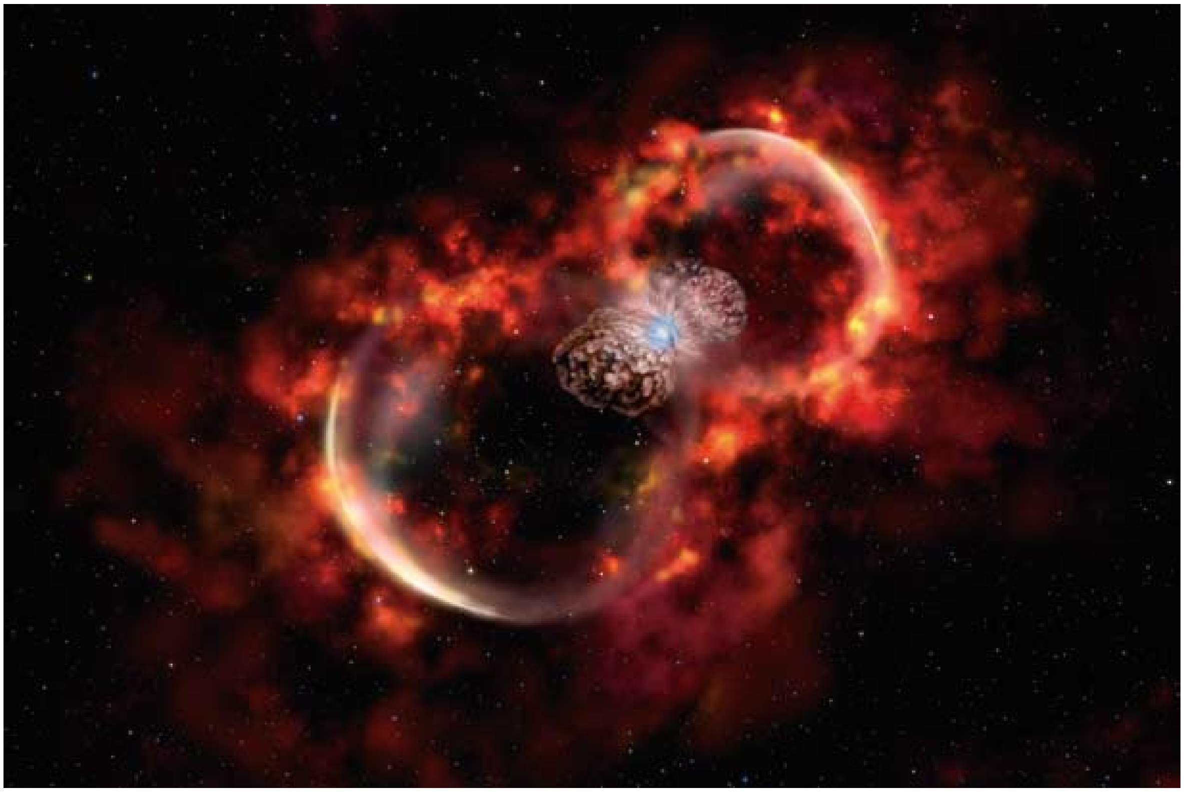


Figure 2. *An artist's conception of the expanding blast wave from Eta Carinae's 1843 eruption. The inner two-lobed "Homunculus" nebula, plus a fast shock wave propagating ahead of the Homunculus, are clearly seen in this drawing. As the shock wave from the eruption collides with material in the vicinity of the star, it causes that material to glow (represented by the red/orange nebulosity in the figure). An animation of this process is available at: http://www.gemini.edu/node/11120) Gemini artwork by Lynette Cook.*

require that the event generated a shock wave analogous to a supernova-type event, but with less energy. The new observations revealed far-flung material moving at a rate more than three times faster than the fastest material seen previously (up to 3,500-6,000 km/sec). This work has implications for similar events observed around stars in other galaxies where the resulting outbursts have not quite matched the energy of a supernova, and currently lack any theoretical explanation.

Bloated Galaxies at Redshift z ~ 1.5

Ph.D. student Ivana Damjanov (University of Toronto) led a large international team in a near-infrared imaging study (using the Near-Infrared Camera and Multi-Object Spectrometer on Hubble Space Telescope (HST/NICMOS)) of early-type galaxies observed as part of the Gemini Deep Deep Survey (GDDS). Her team demonstrated that these large galaxies were exceptionally dense and compact about nine billion years ago. The effective radii of the GDDS galaxies appear then smaller (by a factor of two to three) than those of present-day cluster elliptical and early-type field galaxies (Figure 3). Some, called "red nuggets," are as massive as modern large ellipticals, but are only a tenth of the size.

This strange population is puzzling since there is no equivalent of these compact "red nuggets" in today's universe. Somehow, the galaxies puffed up with time. The size evolution occurs primarily in the $1.1 < z < 1.5$ redshift interval, or over a time of only 1.6 billion years. This timescale is incredibly short for any swelling mechanism known.

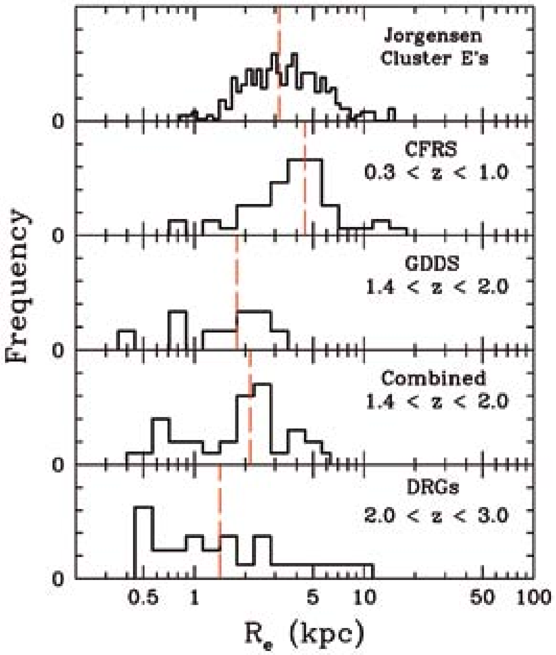


Figure 3. *The distribution of effective radii (in kiloparsecs) for early-type galaxies in several redshift bins from z ~ 3 to the present. The different panels refer to different studies covering different redshift windows.*

Equal-mass galaxy mergers that input energy into the stellar systems could increase their equilibrium sizes. Another mechanism might be adiabatic expansion

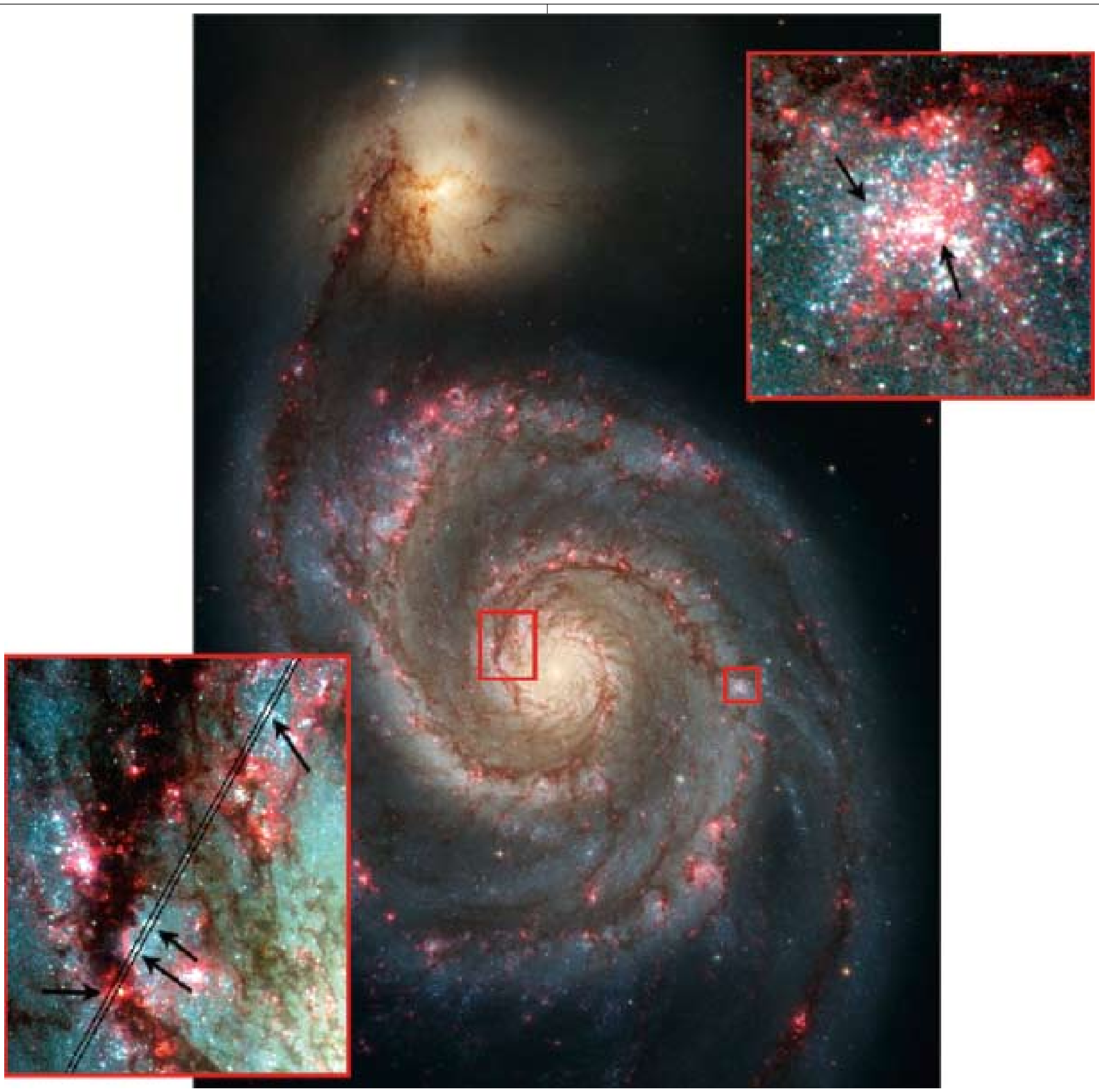


Figure 4. *HST mosaic image of M51 with two regions containing the studied open clusters. The bottom left panel shows GMOS slit crossing four clusters.*

driven by stellar mass loss—driven, for example, by stellar winds from sites of active star formation. As mass is lost the gravitational potential becomes shallower, so the system expands in order to relax into a new stable equilibrium. However, none of these mechanisms appears able to transform the distant compact galaxies into something looking like their counterparts in the local universe. This leaves the origin and fate of these "red nuggets" unresolved.

Expanding Stellar Cluster Cores

If finding the bloating of early-type galaxies in the young universe was a surprise (as reported in the "red nuggets" highlight above), by comparison, the expansion of young star clusters is a phenomenon that has been known for some time. Nate Bastian (University of Cambridge) and his international team have used Gemini North spectroscopy with Gemini Multi-Object Spectrograph (GMOS) and Hubble Space Telescope (HST) imaging to observe six young clusters in the nearby spiral galaxy M51 (Figure 4). They find quantitative evidence for a rapid expansion of the cluster cores during the first 20

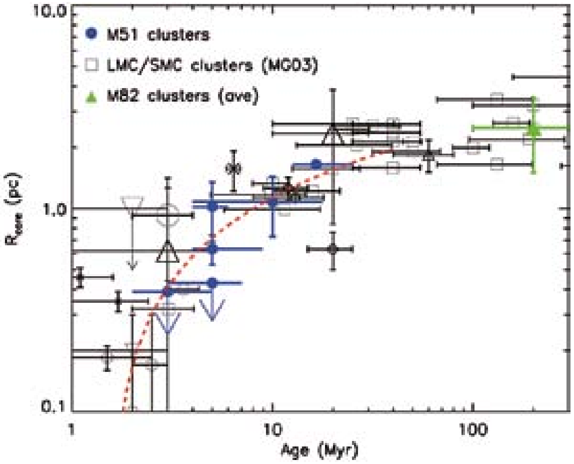


Figure 5. *Relation between the derived core radius and age for the six clusters in M51 (filled blue circles). Older clusters are larger than the younger ones.*

million years of their evolution (Figure 5). The sizes of the clusters were measured from the HST images and their ages derived from the GMOS optical spectra using standard age indicators. Core radii of the clusters are ‹ 0.4 to 1.6 parsecs (1.3 to 5.2 light-years) and their ages ~ 3 to 25 million years.

Apart from mass segregation (with massive stars falling to the center while low-mass stars move to the periphery), the likely mechanism for this cluster swelling is adiabatic expansion. The clusters expand in response to the loss of the residual gas, the exact amount of which depends on the star formation efficiency. Depending on the strength of various processes, the cluster may remain bound or become a loose aggregate that will slowly blend into the background field population. The growth in cluster size appears to begin at 2-3 million years of age, when the onset of major gas expulsion starts.

Molecular Hydrogen Emission from Protoplanetary Disks

We know about many young stars with protoplanetary disks from their strong mid-infrared emission, which is due to circumstellar dust heated by the central star. Although the gas component of such disks represents a hundred times more mass than the dust, it is much more difficult to detect and measure this gas because of its physical state. Molecular hydrogen (H_2) is the most abundant gaseous constituent of protoplanetary disks and is the most likely species to be detected in the infrared.

Martin A. Bitner (Space Telescope Science Institute) and a team of U.S. astronomers have reported the results of a survey for pure rotational molecular hydrogen emission from the circumstellar environments of several young stellar objects. The observations were conducted on Gemini North (and also NASA's Infrared Telescope Facility (IRTF) and Keck's Near-infrared Spectrograph (NIRSPEC)) using the Texas Echelon Cross Echelle Spectrograph (TEXES) as a "guest" instrument. H_2 emission was detected from six of 29 sources observed: AB Aur, DoAr 21, Elias 29, GSS 30IRS 1, GV Tau N and HL Tau (Figure 6).

In all cases, the detected emission lines are narrow and centered at the stellar velocity. The narrow range of line widths (FWHM of 7 to 15 km/sec) suggest that the mechanism for exciting the emission may be the same in each case. In some cases, there is evidence for surrounding material in an envelope in addition to a circumstellar disk. It is possible that gas in the envelope is shocked by an outflow from the star.

Assuming Keplerian rotation in a disk, the narrow line widths imply that emission arises at a range of disk radii extending from 10-50 astronomical units (i.e. the equivalent of Saturn's orbit to well beyond Pluto's orbit on the scale of our solar system). X-ray/ultraviolet irradiation of the disk surface layer and accretion shocks resulting from matter infall onto the disk are plausible mechanisms that could be providing additional heating at large distances in the disk.

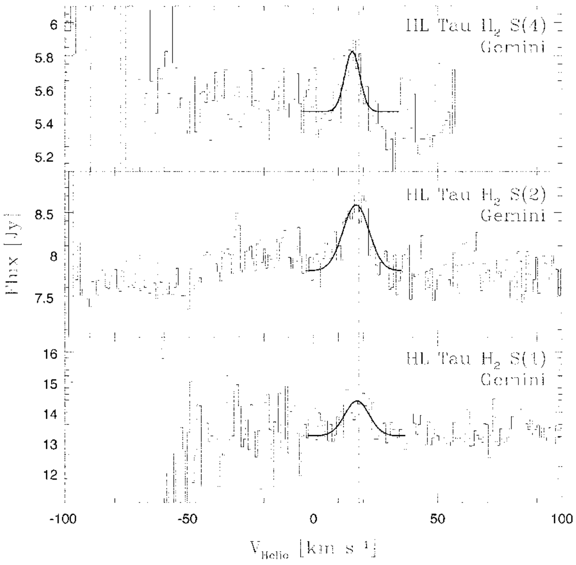


Figure 6.
Spectrum of H_2 rotational lines of HL Tau in the mid-infrared obtained with TEXES on Gemini North. A single-temperature local thermodynamic equilibrium (LTE) model comprised of ~ 1 Earth mass equivalent of gas at $T = 465$ K fits the observations. Full width of the H_2 lines is ~ 10 km/sec.

Supernova 2006jc: Infrared Echoes from New and Old Circumstellar Dust

SN 2006jc (Type IB) was discovered on October 9, 2006, in the nearby spiral galaxy UGC 4904. Precursor activity had taken place in 2004, leading to the interpretation that the supernova originated in a binary system with an eruptive luminous blue variable (LBV) and a companion Wolf-Rayet star. The LBV is thought to be the progenitor object that gave rise to SN 2006jc. The supernova was observed and followed with the Gemini North telescope (using the Near-Infrared Imager (NIRI)), the UK Infrared Telescope (UKIRT) (Figure 7), and the Spitzer Space Telescope between days 86 and 493 post-explosion. The observations were done by an international team led by Seppa Mattila (Queen's University, Belfast, and University of Turku).

The post-explosion infrared excess is best explained by

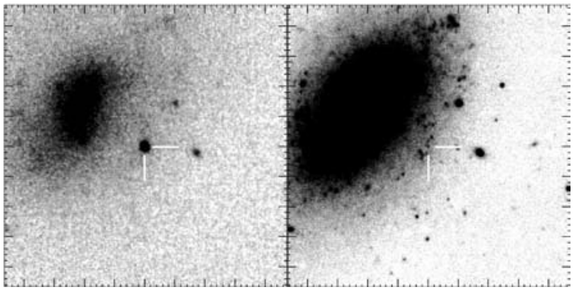


Figure 7. *The 47 × 47 square arcsecond field of SN 2006jc at 2.2 microns (the supernova is marked with ticks). Image at left is from UKIRT (combined images from April 26, and May 10, 2007). Image on right is from NIRI on Gemini (from January 27, 2008).*

the interaction of the supernova shock wave with a cool, dense shell generated by earlier eruptive events of the progenitor star. The authors show that the emission is due to a combination of infrared echoes from the circumstellar material, and the bulk of the emission is from an echo from the newly condensed dust. The dust formed in the cool dense shell produced by the interaction of ejecta with another dense shell of circumstellar material previously ejected during the LBV outburst. This latest eruptive event was observed two years prior to the supernova explosion. The new observations present the first evidence ever for dust condensation in a cool dense shell formed behind the ejecta's outward shock (Figure 8). At later epochs, a substantial and growing contribution to the infrared flux arises from an infrared echo by pre-existing dust in the progenitor wind.

Once again, there is no direct evidence that the explosion of a supernova produces anything other than a very modest amount of dust.

Young Asteroid Families Newly Classified by GMOS

Optical spectroscopy from the Gemini telescopes has revealed a relatively uncommon type of asteroid in the main belt. The discovery was made by a joint Brazilian and U.S. project, led by Thais Mothé-Diniz of the Observatório Nacional in Rio de Janeiro and David Nesvorný of the Southwest Research Institute (Boulder, Colorado). The team used Gemini Multi-Object Spectrograph (GMOS North and South) to obtain optical spectra of asteroids with estimated ages of ‹ 1 million years, which they then compared to laboratory spectra of meteorites that have fallen to Earth. They found that spectra of asteroids in the newly discovered Datura family have a deep absorption feature near 0.8 microns, which classifies them as "Q-type" asteroids. This spectral feature is produced by silicate material, in particular olivine and pyroxene. Most interestingly, the spectra of these objects are well-matched to the most common type of meteorite found on Earth called an ordinary chondrite (OC).

This is an important result since we do not know (with a few exceptions) the location of the parent bodies that form the meteorites we find on Earth. Since we think that many of the objects we find here come from the main asteroid belt, the lack of any asteroids that have a spectrum similar to OCs has been a long-standing and fundamental problem in planetary science. One theory as to why it has been difficult to find such parent bodies is that the process of "space weathering" changes the shape and depth of spectral features of asteroids over relatively short timescales.

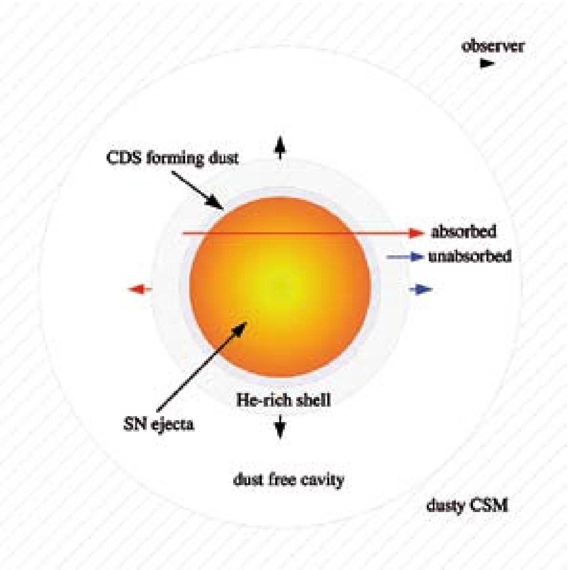


Figure 8. *A schematic illustrating the geometry of the newly formed and pre-existing dust around SN 2006jc.*

To get around this difficulty, Mothé-Diniz and Nesvorný used numerical methods to determine where they might be most likely to find some of the youngest asteroids in the main-belt. They then took GMOS spectra of these objects, under the hypothesis that the surface of the youngest asteroids will likely not be "weathered" and will therefore show the unaltered shape of an object's spectrum.

The spectra of the Datura family members (Figure 9) are particularly exciting. Probably formed by the breakup of a larger body, these objects are between 400,000-450,000 years old. This makes them some of the youngest asteroids in the main belt. It is also notable that the sensitivity of the GMOS instruments made it possible to obtain high signal-to-noise spectra of these objects in

Figure 9.
GMOS spectra of the asteroid targets. All of the spectra are normalized to unity at 0.55 microns. Particularly important is the presence of the absorption feature that start to appear at approximately 0.8 microns.

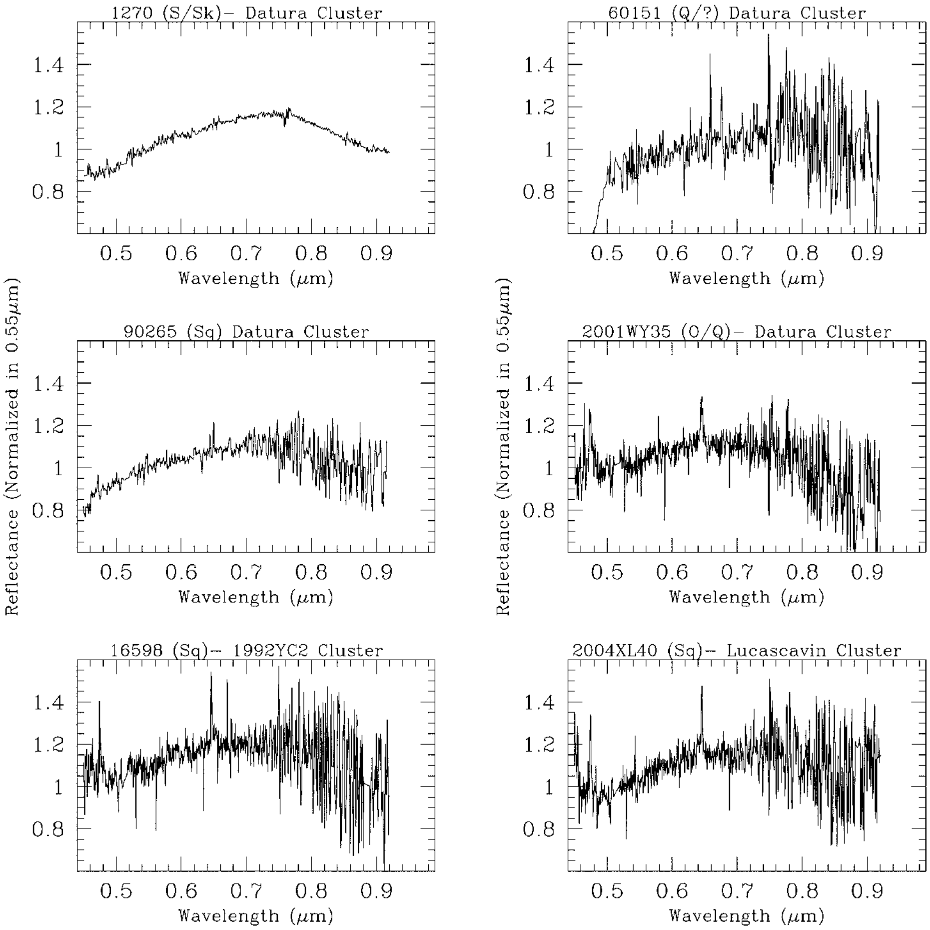
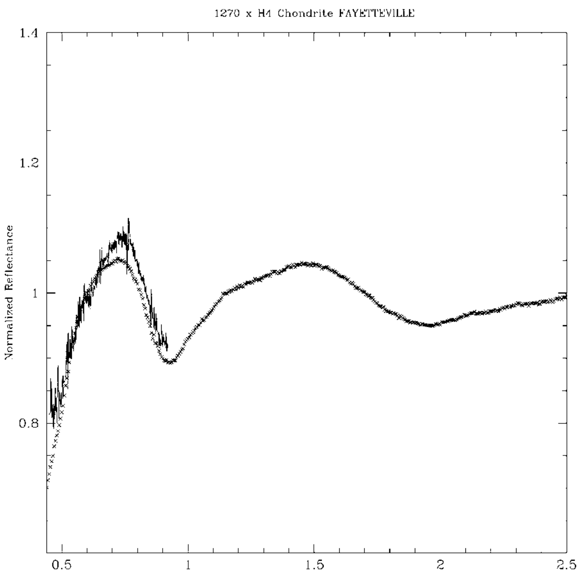


Figure 10.
GMOS spectrum (black line) plotted with the laboratory spectrum of an ordinary chondrite (OC) meteorite named "Fayetteville." The close match between the spectra implies that the Datura family of asteroids is young since "space weathering" has not had enough time to diminish the strength of the absorption feature.



about one hour per target, even though the targets were only a few kilometers in diameter.

As seen in Figure 10, the spectrum of (1270) Datura is a good match to that of an OC found on Earth (named Fayetteville, after the place near where it was found). The fact that the spectrum shows a deep and well-defined absorption feature near 0.8 microns is what allowed the team to classify this target as type Q (or perhaps type Sk, a classification similar to Q). This result will likely have a broad impact on the study of OCs and young asteroid families, since there is now a strong connection between the objects we find here on Earth and those we observe in the main part of the asteroid belt. The authors note that more observations, especially in the near-infrared, would strengthen this result.

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By Dennis Crabtree

Scientific Productivity & Impact of Large Telescopes

The most important output of a modern observatory is the collection of papers based on its data that are published in refereed journals. These papers represent the facility's contribution to knowledge and the return on the capital investment for the construction of their telescopes and instruments. Increasingly, bibliometric measures—the number of publications and the number of citations—are used to measure the quantity and quality of the output of modern observatories.

Citation counts must be used very carefully as they are only one indicator of impact, and an imperfect one. However, they are the best quantitative measure currently available for studying the impact of papers published in refereed journals.

In this article I investigate and compare the productivity and impact of several large ground-based optical/infrared telescopes as well as Hubble Space Telescope (HST), using complete publication lists that cover a significant time period. The ground-based telescopes included in this study include Canada-France-Hawaii Telescope (CFHT), Gemini, Keck, Magellan, Subaru, UK Infrared Telescope (UKIRT) and the Very Large Telescope (VLT). As I will show, Gemini's productivity and impact is very comparable to other 8- to 10-meter-class telescopes.

Data

The raw data for this study are lists of papers in refereed journals compiled by each observatory. Observatories generally maintain a list of papers on the Web that they consider as being based on data from their telescope(s) and these were typically the source of the data used. I relied on each observatory to provide an accurate list

Table 1.
Distribution, by observatory, of the papers included in this study through 2006.

Observatory	Year of First Paper	Total Number of Papers
CFHT	1980	1434
Gemini	2000	292
HST	1991	5250
Keck	1994	1683
Subaru	2000	338
UKIRT	1992	986
VLT	1999	1685

of its publications. The papers analyzed here include those published though the end of 2006. The citation counts are as of January, 2008. The first publication year for each observatory and the total number of papers included for the period through 2006 are indicated in Table 1.

When, as is often the case, a paper is counted by more than one observatory, I give each observatory full credit for the paper. Division of the credit (citations) between different telescopes is subjective and with more than 10,000 papers in this sample, a careful reading of every paper is not feasible.

A paper accumulates citations as it ages. The accumulating citation counts for papers makes it very difficult to compare papers published in different years. A paper with 40 citations after one year is likely having more impact than a paper with 40 citations after 12 years, even though they have the same number of citations at the moment.

In order to account for this age effect in the raw citation counts, I determine a paper's impact factor (hereafter called impact). A paper's impact is determined by dividing the number of citations to the paper by the median number of citations to all *Astronomical Journal* (*AJ*) papers published in the same year. This approach treats the median *AJ* paper as a standard measuring stick (which grows with time as citation counts increase) against which to measure all papers.

Observatory Productivity

The number of papers per telescope for the observatories included in this study for the period 1992-2006 is shown in Figure 1. Note that the number for HST is divided by five for display purposes. One can see how the number of papers for a telescope ramps up after it first begins producing papers. For example, the number of Keck papers continues to increase until it plateaus between 2000 and 2002. It is interesting to compare the rate at which new telescopes produce refereed papers as they ramp up their operations. As can be seen in Figure 1 from the newer facilities, telescope productivity ramps up quickly with age.

Figure 1.
Number of publications per telescope per year for several observatories.

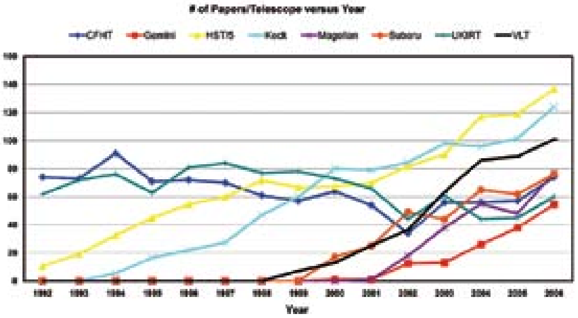

Figure 2.
Number of papers per-telescope per-year as a function of observatory age as measured by the time from the first significant paper output.

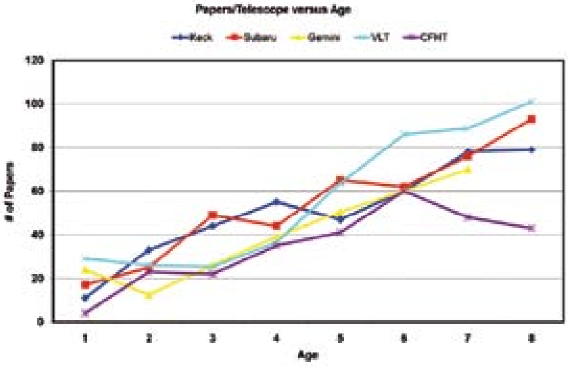

Figure 2 shows the number of papers per telescope, for CFHT, Gemini, Keck, Subaru, and the VLT, as a function of the number of years (age) after their first significant number of papers. In the case of multi-telescope observatories I have estimated the age at which the second (or third and fourth) telescopes began producing papers. To first order, all these observatories, including Gemini, have increased their productivity at the same rate.

Figure 3.
Average number of authors per paper for observatory papers included in this study (square) and for several years of ApJ (diamonds). Note the rapid linear increase in the average number of authors per paper.

Figure 3 shows the average number of authors per paper for two datasets. The first dataset consists of the observatories included in this study. Note the remarkable linear increase in the number of authors from 1980 to 2006. While in 1980 there were on average 2.5 authors per paper, by 2006 that number had increased to almost seven.

To compare this trend with the general literature and to extend it back in time, I determined the average number of authors per paper for those published in *Astrophysical Journal* (*ApJ*) over several years. This is shown in Figure 3 as the dataset indicated as *ApJ*. It shows that the trend of increasing number of authors is indicated in the general literature, and that in 1950 the average *ApJ* article had 1.5 authors. The average number of authors on *ApJ* papers is less than that of observatory papers (for the same year) because a lot of theory papers are still done by individuals or small teams.

This rapid increase in the average number of authors per paper indicates a move towards more research being undertaken by scientific teams as opposed to individuals or small groups. This increase in team size is likely related to the larger datasets produced by modern instruments and the fact that many papers are based on multi-wavelength data that require a range of expertise for reduction and analysis.

Observatory Impact

Increasingly the impact of published research is being recognized as a more important metric than productivity. How important or valuable is the contribution of a research paper if it is never or infrequently cited?

The number of citations to a paper is usually considered a good quantitative measure of a paper's impact. While not a perfect measure, it is the best quantitative metric available for measuring impact. Impact is not to be confused with the quality of the research. Rather, impact is a measure of the relevance of the paper to other research and researchers in the field. Of course, the number of citations is influenced by other factors such as the area of research and the culture of each particular sub-field. However, since we are studying large aggregates of papers and not comparing individual authors, the effect of these factors should average out.

Before investigating the impact of the observatories in this study, let's look at how the impact of papers correlates with the length of the paper and the number of authors (team size).

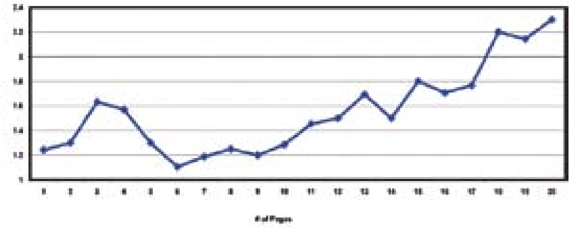

Figure 4.
Median impact of a paper as a function of the length of the paper. This includes all of the papers from all of the observatories included in this study.

Figure 4 shows the median impact of papers as a function of the length of the paper. The median is used rather than the mean as the distribution of impact is not a normal distribution and has a long tail towards very high-impact papers. The "Letters Effect" is clearly visible as the median impact shows a local maximum for articles of 3-4 pages—the usual maximum for a Letter in various journals.

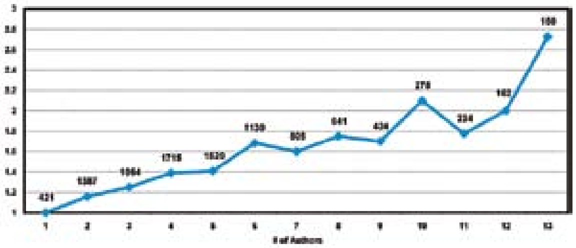

Figure 5.
Median impact of all the papers in this study as a function of the number of authors. The number above each point is the number of papers included with that number of authors.

Another interesting correlation to investigate is the one between impact and the number of authors. Figure 5 shows the median impact of all the papers in this study as a function of the number of authors (team size). It is clear from Figure 5 that the impact of research papers is a strong function of the size of the team. Larger teams produce papers that are of relevance to a larger number of researchers (and research teams) than papers produced by smaller groups. Papers with a larger number of authors are almost always based on larger datasets and are more likely to include data from more than one facility (including ones not included in this study). Recall that the impact has been adjusted for self-citations so this is not simply the effect of team members citing team papers and hence increasing the impact.

How do the various observatories compare in the impact of their publications? Figure 6 shows the median impact of observatory papers for the period 2002 - 2006. Again, the median is used rather than the mean to lessen the impact of a small number of very high impact papers.

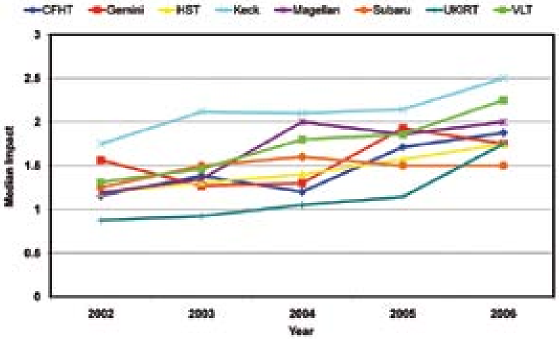

Figure 6. *Median impact of observatory papers as a function of year.*

First, note that Keck has the largest median impact for all years. It is clearly producing papers that are of the most relevance to the broad astronomical community. In 2006, the median Keck paper had twice the number of citations as the median *AJ* paper of 2006.

Interestingly, while producing about five times as many papers as a ground-based telescope, the median impact of an HST paper is lower than that of Keck or VLT. Of course HST's total impact, i.e., the sum of the individual impacts of each paper, is significantly higher than the other telescopes because of its large productivity. Gemini's median impact was high for 2005 papers but appears to have slipped a bit in 2006.

It appears that it is tricky (and risky) to quantify an observatory's impact by a single number such as mean or median impact per paper. An approach that captures the range of impact of observatory publications (including the very high-impact papers) would give a more complete picture of observatory performance.

I calculated the fraction of the total impact of each observatory's papers in six bins of impact. I labeled them from Very Low to Extreme. Papers with an impact factor less than one are considered to be of very low impact while those with impact factors above eleven are considered to be of extreme impact. The other bins include papers with impact factors between the two. The Impact Distribution Function (IDF) is a plot of the fraction of papers in each of the six impact bins.

In general, an observatory is performing better if it has a smaller percentage of lower-impact papers and a larger percentage of higher-impact papers. This would show up as a flatter IDF. As can be seen in Figure 7, Keck's IDF is characteristically different from the IDFs of the other observatories. Keck has the lowest percentage of very low impact papers and the highest fraction of papers with moderate to extreme impact. HST's IDF is very similar to the other ground-based telescopes included. HST produces a large fraction of very low and low impact papers as do the other telescopes. Gemini's IDF is very similar to the VLT's but has a significantly higher fraction of extreme impact papers.

A novel approach to quantify the statistical dispersion in the impact distribution of papers from an observatory is to use the Gini coefficient (see http://en.wikipedia.org/

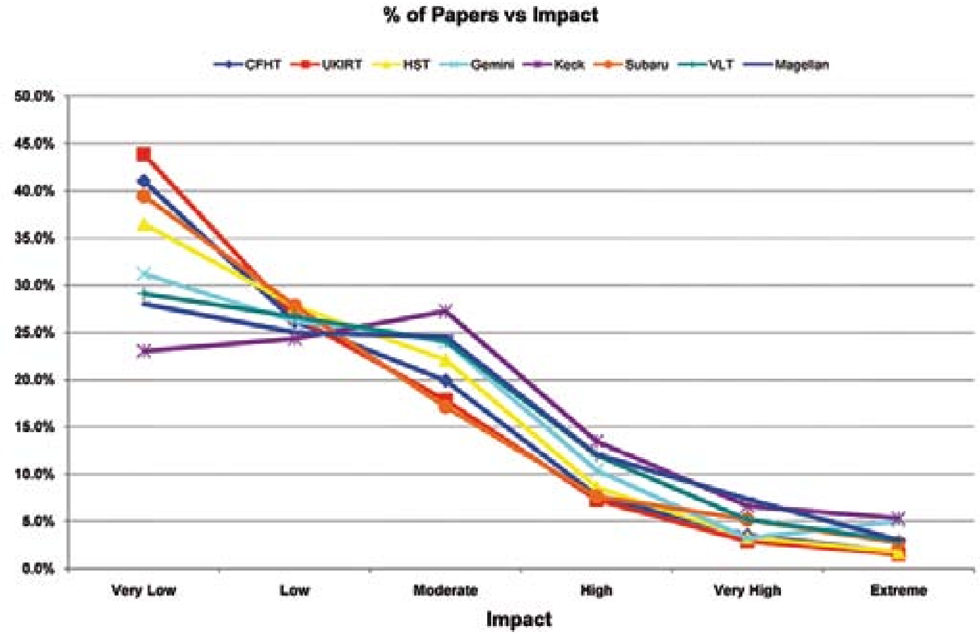

Figure 7. *Impact Distribution Function (IDF) for the indicated observatories. Generally an observatory with a flatter IDF is performing better.*

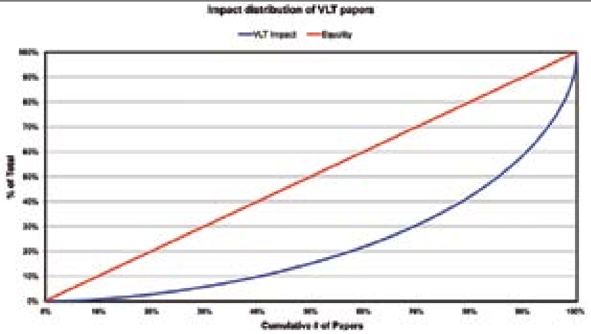

Figure 8. *Distribution of impact of individual papers for the VLT. The dotted line indicates the actual distribution while the solid line indicates what the distribution would look like if each paper had exactly the same impact.*

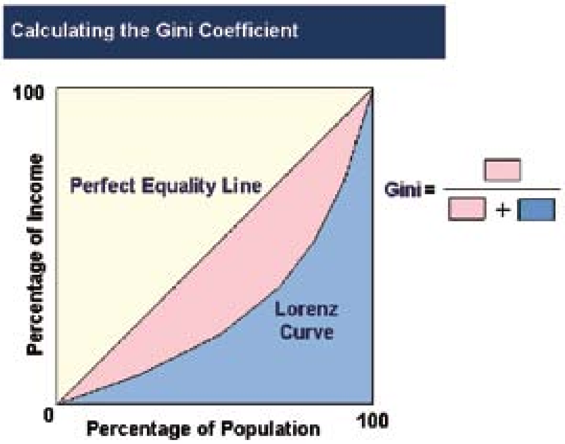

Figure 9. *Graphical display of how the Gini coefficient is calculated. In applying this to impact, 'Population' is replaced by 'Papers' and 'Income' is replaced by 'Impact.'*

wiki/Gini_coefficient). The Gini coefficient is usually applied in economics to quantify the inequality of income or wealth distribution. It is defined as a ratio with values between 0 and 1; a low Gini coefficient indicates more equal income or wealth distribution, while a high Gini coefficient indicates more unequal distribution. A zero corresponds to perfect equality (everyone having exactly the same income) and 1 corresponds to perfect inequality (where one person has all the income, while everyone else has zero income).

In using the Gini coefficient, a zero would indicate that all papers have the same impact factor. It says nothing about the absolute level of impact, only how equal its distribution is amongst all the papers. The Gini coefficient for countries ranges from around 0.25 to above 0.6 for the countries with the most unequal income distribution. More developed countries generally have lower Gini coefficients. For example the Gini coefficient for the U.S. has risen from around 0.39 in the late 1960s to 0.47 in 2006.

The Lorenz curve for the impact of VLT publications is shown in Figure 9 along with the line indicating perfectly equal distribution of impact. The Lorenz curve for VLT papers shows that the lower 50% of papers, in terms of impact, produce less than 15 percent of the total impact of VLT papers. The top 20% of papers produces approximately 80% of the total impact. The Gini coefficient for the VLT impact distribution is 0.54, which indicates a very unequal distribution of impact.
The Gini coefficients for most of the telescopes in this study are shown in Figure 10. All observatories exhibit Gini coefficients of between 0.5 and 0.6. The distribution of impact of observatory publications is far from equal, with approximately 80% of the impact being produced by the top 20% of published papers.

Another approach to studying the distribution of the impact of observatory publications is to aggregate impact by first author, *i.e.*, sum the impact of all papers for a given author. One can then investigate how the impact of an observatory's papers is distributed among first authors. Figure 11 shows the Gini coefficients for the distribution of impact of observatory papers by first author.

Impact across authors is most evenly distributed for Subaru while the distribution is most unequal for Keck authors. All of the observatory Gini coefficients are quite high, indicating a very unequal distribution of impact across authors with the majority of the impact concentrated in a relatively small number of authors.

Conclusions

Our investigation of the productivity and impact of a number of optical/infrared telescopes shows that a new telescope's productivity ramps up quickly once publications start appearing, with all telescopes demonstrating a very similar rate of increase. A plateau in productivity is reached seven to eight years after the initial publications. A telescope's productivity can be rejuvenated by new instrumentation or, as is the case for HST, having a large number of papers based on archival data. HST is a paper-generating-machine,

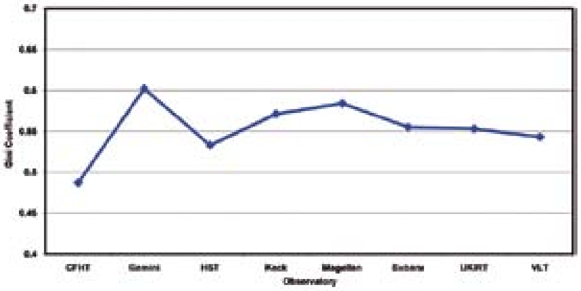

Figure 10. *The Gini coefficient for impact distribution of papers for each observatory.*

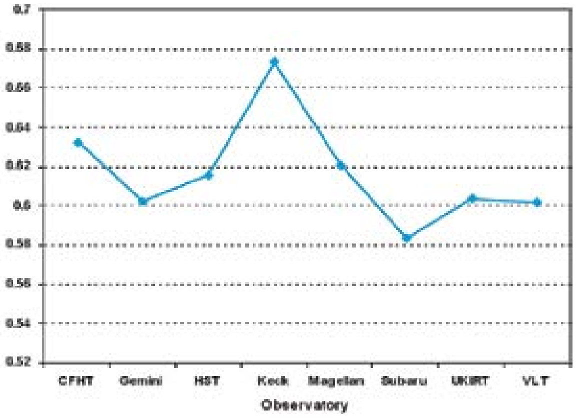

Figure 11. *The Gini coefficient for the distribution of impact by first author for various observatories.*

producing approximately five times as many papers as a ground-based telescope.

One interesting result of this work, that is unrelated to observatory productivity, is the increasing size of the teams publishing papers based on observatory data. The average number of authors on a paper is now close to seven which is more than double the number from 25 years ago. This trend of the increasing importance of teams in observational astronomy shows no signs of changing. The immense datasets generated by large panoramic detectors, and the increasing use of multi-wavelength datasets, require more expertise and a larger number of team members to work effectively with the data.

The Impact Distribution Function (IDF) is a good approach for quantifying the impact of an observatory. The IDF provides a measure of the number of low performance papers as well as the number of high performance papers, unlike a single number metric such as median or mean impact. The IDF for Keck papers shows that Keck produces a significantly smaller fraction of very low impact papers, while producing relatively more papers with higher impact. The IDF for HST shows that it produces a significant fraction of very low impact papers and a relatively small fraction of high impact papers.

The distribution of impact across an observatory's papers, as indicated by the Gini coefficient, is very unequal with approximately 20% of the papers producing 80% of the impact. This same analysis applied to the distribution of impact across authors also shows that impact is distributed very unevenly across authors. It shows that a relatively small number of authors produce the majority of the impact from observatory publications.

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By Rachel Mason

Science Operations Web Page Progress

With the majority of Gemini observations taken in queue mode, our observatory Website plays many roles traditionally filled by face-to-face interactions between the user community and observatory staff. Perhaps to a larger extent than with many other observatories, our Web pages really are the "face" of Gemini. A good set of pages is essential if our users are to write technically sound proposals, optimize their Phase II setups, reduce their data with a minimum of difficulty, and generally make the most of Gemini's capabilities.

With this in mind, a group from both Gemini sites and the UK and Canadian National Gemini Offices (NGOs) has been overhauling the Science Operations Web pages (that is, all pages formerly underneath http://www.gemini.edu/sciops; instruments, schedules, helpdesk, data, etc.). In the course of this project we aim to update, correct or remove out-of-date, inconsistent, inaccurate or duplicated information, as well as to improve the organization of the site to ensure that users can quickly find the information they are looking for. The new pages use a menu system to keep important links from being buried in paragraphs of text. To ensure proper version control, the pages are organized using the Drupal open-source content management system.

Because of its size and complexity, the "Instruments" section of the site was the first to receive the group's attention. In reorganizing the instrument pages, we sought to bear in mind the path taken by a Principal Investigator from initial idea to final publication, the kind of instrument information that would be needed at each stage, and where a "typical" user might look for that information. The Near-Infrared Imager and Spectrometer (NIRI) pages illustrate this design (Figure 1). After a brief introduction, a "Status and Availability" page links to news items and announcements relevant to the instrument. This is followed by sections for each of the instrument's modes, (imaging, spectroscopy, etc.), containing information about relevant instrument components and strategies for getting the best performance from the instrument in that particular observing mode. Sensitivity and overheads are detailed under the next heading. A "Guiding Options" area presents instrument-specific guidance about peripheral wave front sensors and adaptive optics options, while links to calibration information and resources are given under the "Calibration" heading. Instructions for setting up observations in the Observing Tool are presented next, followed by links to data reduction tools and information, general reference documents, and, where relevant, a link to resources common to near- or mid-infrared instruments in general.

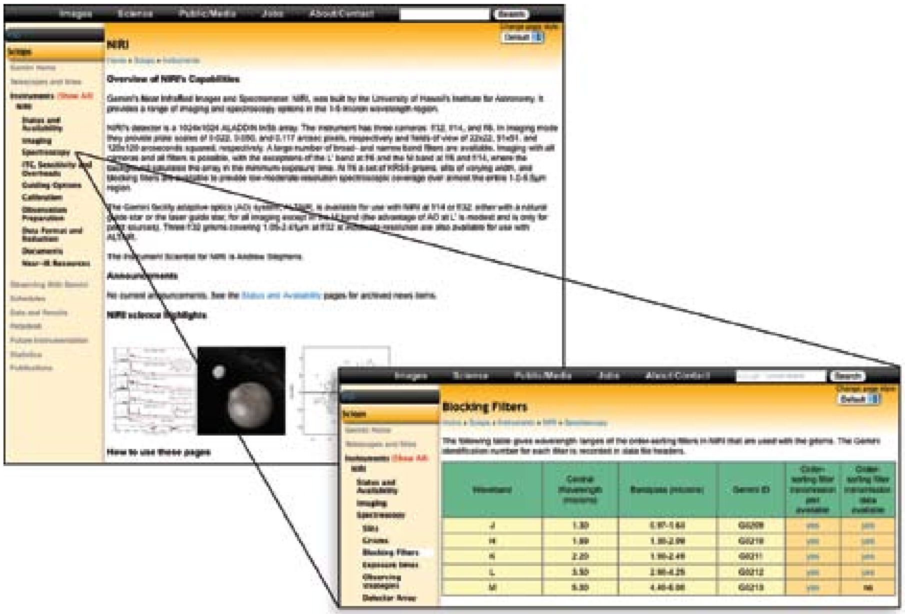

Figure 1.
The web pages for Gemini's Near-Infrared Imager and Spectrometer (NIRI) illustrate the layout common to all instruments. Instrument components and attributes (e.g., the spectroscopic blocking filters shown here) are grouped by observing mode, while separate sections exist for instrument status, sensitivity, calibration, etc. The menu system is intended to improve ease of navigation around the site.

As the content of each of the ~ 600 instrument pages was moved into the Drupal database, it was read by a member of the Web working group and edited for accuracy and clarity wherever necessary. Outdated information was updated or removed, in consultation with the relevant instrument scientists. Gemini and NGO staff members always had access to the pages, and, at the end of the migration, were asked to use the new pages as their "default" instrument pages for several weeks, to allow us to uncover and fix as many bugs, mistakes and generally undesirable features as possible. In December 2007, at the end of this period of testing, the full set of instrument pages was integrated with the existing Website and released.

Of course, the instrument pages only represent about 30% of the "iceberg," and in the last few months the same treatment has been received by the "Telescope, Site and Weather," "Adaptive Optics," "Data and Results," "Observing with Gemini," "Phase I Tool" and "Helpdesk" sections. Some sections (particularly the Telescope pages) have undergone major changes, while others have simply been subjected to basic checks for inaccurate and out-of-date content. In the coming months, we will be working on the Observing Tool information (a major task requiring reorganization of a vast collection of pages), the Schedules pages, and a revised home page with an improved selection of science operations links. At that point, all of the Science Operations pages will have been checked, updated, and transferred to the new content management system and released.

Behind the scenes, a great deal of effort has gone into areas such as automating repetitive tasks, locking dormant files in the old system, and automated checking for broken links. We are currently working to address issues to do with Website mirroring (so that our partners can host independent copies of the site), ease of use and stability for authors and editors of pages, and the general appearance and user-friendliness of the site. To keep the site in optimal condition every page will have someone responsible for its upkeep. We are also aiming for a more streamlined system of editorial control.

We have put a great deal of effort into improving the science operations web pages but with upwards of 1,000 pages in the system (and counting) there are bound to be things that we've missed. We want these pages to be as useful as possible to all our users, so we encourage users to get in touch with us and report inaccuracies, inconsistencies, or other points in need of attention. We'll do our best to address these concerns.

The Gemini science operations Web working group consists of: Rachel Mason, Tom Geballe, Aprajita Verma, James Turner, Bernadette Rodgers, and John Blakeslee, with technical support from Jason Kalawe, John Perkins, and Jared Eckersley.

Rachel Mason is a Gemini Science Fellow and located at Gemini North. She can be reached at: rmason@gemini.edu

By Marie-Claire Hainaut & Dolores Coulson

The System Support Associate Model at Gemini Observatory

At Gemini Observatory, the traditional position of telescope operator has been discarded in favor of a more diverse and flexible position: the System Support Associate (SSA). From the very beginning, the Gemini operational model was designed to involve SSAs in observatory projects well beyond the strict operation of the telescope systems. Here, we will comment on the motivation behind the model and describe how the schedule allows SSAs to assume different roles within Gemini, and how flexible time allows them to participate in a wide range of projects. This increases their motivation, deepens their knowledge, and strengthens communication between groups, and allows management to allocate resources to projects that would otherwise lack personnel. We give examples of such projects and comment on the difficulties inherent in the model.

Figure 1. *Pictured here are two of the Gemini North SSAs, Matt Dillman (right) and Tony Matulonis (left). Matt is operating the telescope while Tony is mentoring him during a laser run on Mauna Kea.*

The SSA Model at Gemini

Gemini needs skilled and proactive people to take on the SSA responsibilities. They must be able to face the challenges brought by the operation of complex systems, current and future, such as the Gemini North adaptive optics system Altair, Multi-Conjugate Adaptive Optics (MCAO), multiple laser guide stars or the integration of increasingly sophisticated instruments. Efficient and successful data acquisition with such complex systems requires the SSA to be not only skillful and knowledgeable but also highly committed. People with this profile are ambitious and eager to learn. In Gemini's operation model, SSAs have the opportunity to acquire experience by collaborating in observatory projects, and actively contributing to Gemini progress beyond supporting telescope operations. They are also encouraged to develop their skills either through in-house or external training.

The traditional "telescope operator" schedule requires three operators to provide night coverage on one telescope. This does not allow for sick leave and vacations without burdening the other operators. It also does not allow for additional training or other activities. Although there are variants of this model allowing for more contingencies, the main purpose at most observatories is to cover night operations.

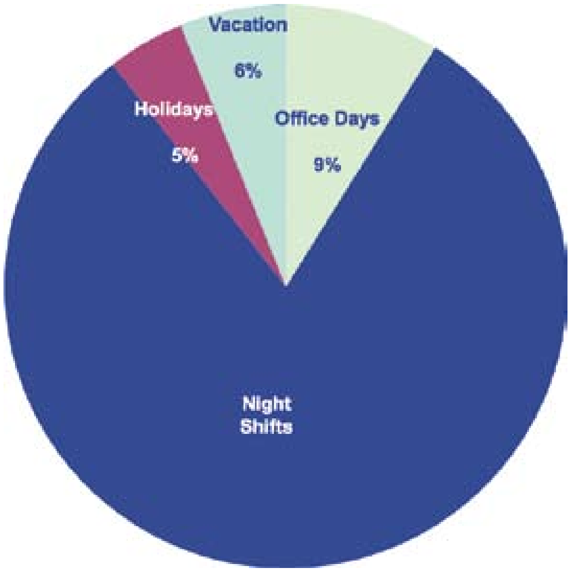

Figure 2.
Time distribution for the traditional telescope operator schedule.

Unlike the "traditional operator schedule," Gemini's model is designed to enable participation by SSAs in observatory activities beyond their operational duties. The Gemini SSA schedule is a simple rotation of a day shift followed by a night shift and recovery period. This is then followed by office time which is free of operational duties (flexible time). This simple rotation has a powerful variant: the large rotation schedule, which allows one SSA to drop off the regular rotation for one period (four to five weeks). While the SSA is off rotation he or she is free to focus on projects while duties are re-distributed evenly among the group. The flexibility of the large rotation scheme benefits both SSA and Gemini management; it is used only when needed.

Diversity of SSA Duties

Following is a brief description of the various roles assumed by the SSAs in the Gemini model:

Night Shift: Responsible for telescope operation with all its subsystems; to obtain the highest quality data for scientists and engineers. The SSA is not responsible for the data taking but is encouraged to learn how to execute observations in order to provide maximal support for the observer. The SSA is also the duty officer and responsible for people and equipment safety during nighttime operations.

Day Shift: Available to assist science and engineering staff as needed, with highest priority given to the completion of the previous night's work (missing or failed calibrations), followed by preparations for next night's observing (troubleshooting faults from previous night, follow-up on existing problems, routine checks and instruments monitoring and calibrations).

Flexible Office Time: ~ 25% of the time is available to the SSA to focus on specific projects. Flexible time may involve different types of work according to observatory needs and to the SSA's skills. Flexible time assignments range from participating in new instrument commissioning to in-house training, meetings, and workshops or seminars which are relevant to assignments, collaborations with engineering staff (e.g. building and testing of software tools) and with science staff (data reduction, outreach), but are not limited to these examples. Each SSA is systematically assigned to an instrument and a telescope subsystem, which they learn in depth, and for which they must maintain documentation and keep the group informed about new developments. The following descriptions elaborate on the use of SSA flexible time.

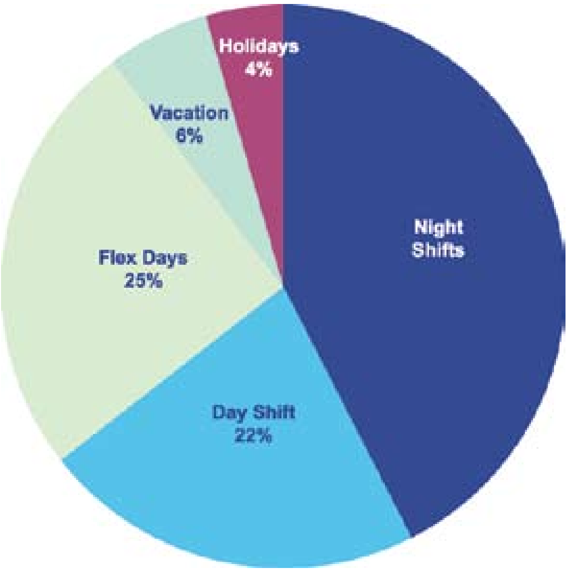

Figure 3.
Time distribution for the Gemini schedule. It is equivalent for the simple rotation and large rotation schedules.

The Time Allocation Committee (TAC) and International Time Allocation Committee (ITAC) technical secretary work is the responsibility of one SSA with another SSA trained as a backup. The TAC/ITAC work includes

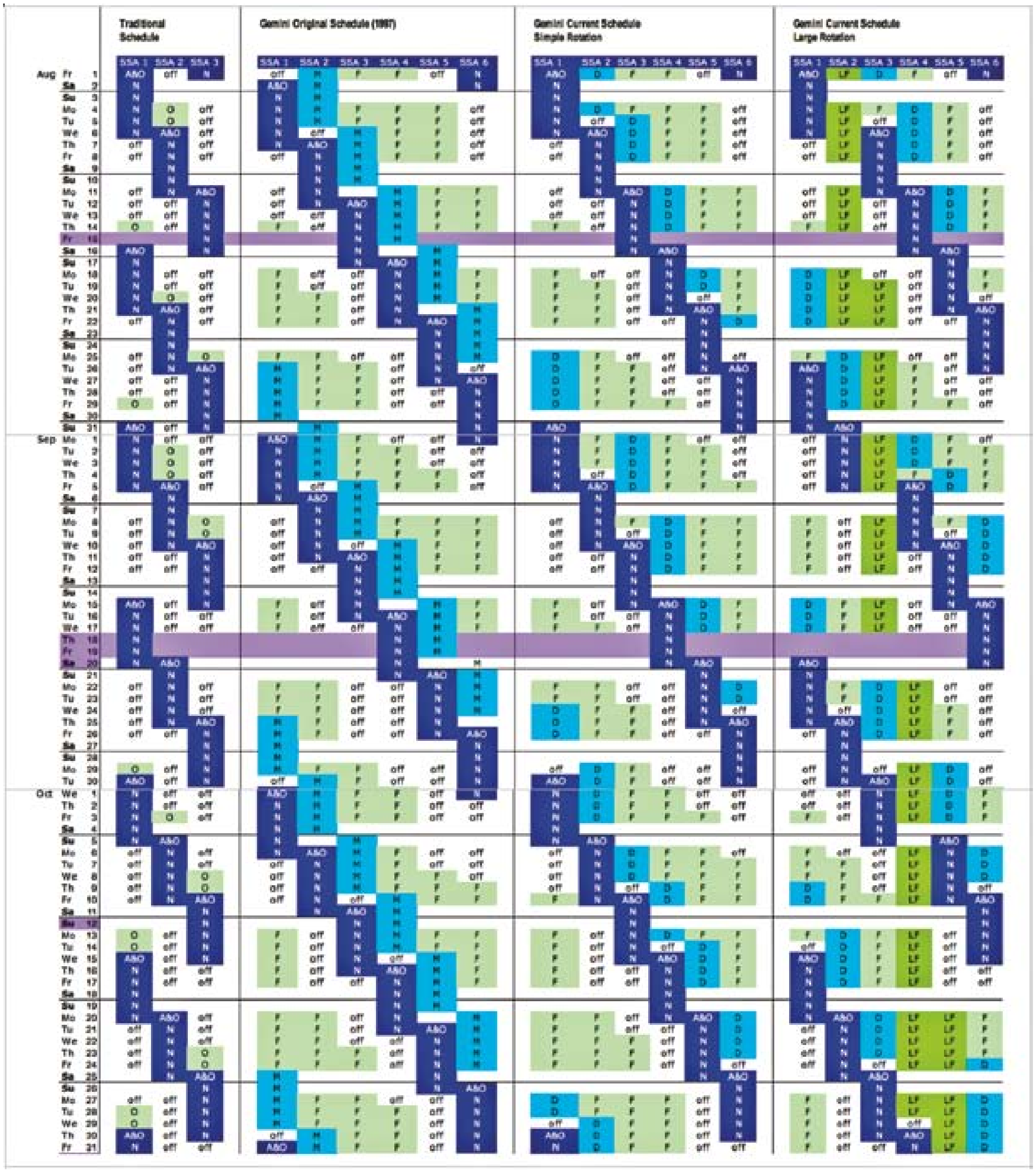

Figure 4. *Example of the implementation over three months of the four types of schedules described in the SPIE document. The codes used are the following: N (night shift); A&O (acclimatization and overlap); off (off-duty); O (office work); M (morning shift); D (day shift); F (flexible time); LF ("Large rotation" Flexible time).*

programming scripts facilitating the proposals evaluation and ranking. It requires the SSA to be off of their duties for roughly six weeks twice during a year.

One SSA is regularly assigned to the commissioning of a new instrument from its early stages. The SSA builds up in-depth knowledge of the instrument and its history, how to use it at all levels, and how to troubleshoot it. This type of experience is extremely valuable during on-sky commissioning and early use, and for training other SSAs. The SSA must also ensure the instrument is well integrated into the telescope controls, and is operating safety and efficiency.

Career Advancement

In the past seven years, we have employed approximately 16 SSAs, four of whom have used skills gained at Gemini to advance their careers within Gemini in the following areas:

- One SSA received training in Remedy programming to develop the Remedy Helpdesk which consists of: (1) the fault reporting system; (2) the external helpdesk; and, (3) the internal helpdesk as a ticket tracking system. Dedicated flexible time was used to work for the Information System group, and the SSA eventually became a full-time member of that group as the current Linux administrator;

- Two SSAs have taken full-time positions within the engineering group thanks to their deep understanding of operations and their knowledge of the subsystems. Their knowledge led to the swift integration of a new instrument onto the telescope;

- One SSA who showed particular expertise in data analysis was transferred to the data analysis group and has advanced to the lead data analyst.

Among the SSAs still working in the SSA group:

- One used the training he received in mySQL to build a prototype instrument monitoring database and an environmental monitoring display;

- Several SSAs have been able to attend the summer Adaptive Optics (AO) school at the University of Santa Cruz. One has had several additional optics and AO courses and is now the lead SSA for the Altair Natural and Laser Guide Star systems;

- Another SSA worked with the instrument scientists to build the Gemini integration time calculators;

- Other SSAs have used flexible time to build a web-based interface for the night log system, a weather alarm monitor, IRAF routines specific to instrument checks, and engineering scripts to monitor a variety of systems.

The list of useful SSA contributions is long and these examples clearly illustrate the model's benefits. However, the model also has inherent difficulties and challenges. It requires good organization and high flexibility to allow flexible time assignments to be productive. It requires time and dedication to define those assignments. It is absolutely necessary to have excellent communication between groups and commitment to collaboration. The model is a perfect fit for an SSA showing initiative and creativity–it can be more demanding for an SSA needing more guidance. All of this is challenging, but to overcome these difficulties will only make Gemini stronger and more productive.

Conclusion

The Gemini operational model is a key factor in attracting new people to work for the observatory. It has proven its worth through the achievements of individual SSAs, their diverse contributions to Gemini, and their commitment and dedication to succeed in all projects. Having a schedule in which flexible time allows involvement at different levels contributes to the creation and maintenance of a high-performance, motivated team. It encourages and requires excellent communications with other groups, and is a demanding model that needs commitment from management and cooperation between the various groups within Gemini.

The model also demands careful planning and follow-up to offer SSAs ongoing challenges. The very detailed planning process recently implemented at Gemini is making SSA assignments easier, and ensures the effort invested is compatible with the overall observatory priorities. It is critical to reinforce this model as we face the upcoming challenges (new extremely complex instruments). It is also very important that everyone assumes their roles in making the model work—both the ambitious SSAs in showing initiative and the managers in encouraging them. Gemini will continue to provide the SSAs continued opportunities to develop their skill sets by providing new challenges. For more information on the Gemini SSA model, see Proc. SPIE 7016 (2008).

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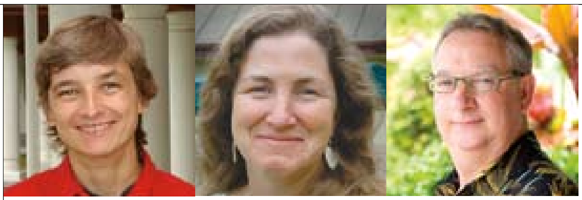


By Inger Jørgensen, Bernadette Rodgers
& Dennis Crabtree

Gemini's Multi-instrument Queue Operations

Gemini has operated primarily in multi-instrument queue mode at both sites since mid-2005. In this mode, all mounted facility instruments are available during the night for execution of observations from the queue. A typical night involves observations for five to eight different programs in the queue, often using all the instruments mounted on the telescope. Two or more instruments are used 75-80% of all nights. Driven by user demand, more than 90% of the telescope time on Gemini is scheduled as queue time. We encourage visits from students as well as users with programs in the queue. Such visits have proven very useful both for the visitors and for Gemini in terms of feedback from our users. Weather and queue schedule permitting, we will attempt to execute the visitor's queue program during the visit.

In the time since the start of multi-instrument queue observing at Gemini North in early 2005, our operations have matured on several levels. In this article we review the changes since 2005, as well as the metrics for the efficiency on the sky, which include delivered science nights, completion rates for queue programs, acquisition times, and open shutter efficiency. The last part of the article focuses on some unique possibilities in the queue and the current laser guide star operations at Gemini North.

Table 1 (next page) lists selected milestones for Gemini science operations from 2006-2008. The science staff is now fully cross-trained to operate all instruments on the sky. Software has been improved such that all facility instruments are operated with consistent interfaces and acquisition procedures across all instruments and modes. The queue management and planning of the individual nights have also matured significantly, from the use of prototype software literally pieced together by the science staff to a fully integrated Queue Planning Tool interfaced with the Gemini Observing Database.

Queue Coordination

A high fraction of science nights are required to operate efficiently in queue mode. On average since 2005A, 88% of all nights were scheduled as science nights. Some time is lost to weather and technical problems. On average, 24% is

Table 1.
(left) Science Operations milestones 2006-2008

2006
NIFS enters queue operations at Gemini North
Telescope time accounting integrated into the Observing Tool
Queue Planning Tool integrated with the Observing Tool
Acquisitions for facility instruments integrated into one acquisition script
Both sites fully staffed with Data Analysts
Commissioning of Laser Guide star AO in queue at Gemini North
Oct 15, 2006: Magnitude 6.7 earth quake hits the Big Island, Gemini North off sky for one month for repairs
TEXES on Gemini North for 10-night run in October, after the earthquake recovery
Poor weather programs in the queue to make otherwise useless conditions scientifically productive
2007
Laser Guide Star AO enters queue operations at Gemini North
MICHELLE off-sky from mid-September due to detector cooling problems
GNIRS off-line from mid-April due to accidental warm-up
Special Call-for-proposals for Gemini South to fill the 400 hours of available time otherwise used by GNIRS. Oversubscription more than factor of five.
Phoenix integrated into the multi-instrument queue
NICI commissioning started at Gemini South
Queue coordinator groups restructured to have core-QCs with focus on queue management and long-term planning
TEXES on Gemini North for 13 night run in October
2008
MICHELLE back on the sky at Gemini North
NIFS demand doubled since 2007B, primarily NIFS+Laser Guide Star AO
Gemini North primary mirror coated in July
NICI commissioning on-going at Gemini South
Exceptionally large demand for GMOS-S in dark time

Table 2.
(right) Definition of observing condition bins

Bin	Observing Conditions	Description
1	IQ ≤ 70% CC = 50% BG ≤ 50%	Good seeing, photometric, dark
2	IQ ≤ 70% CC = 50% BG › 50%	Good seeing, photometric, grey/bright
3	IQ ≤ 70% CC ≥ 70%	Good seeing, not photometric
4	IQ = 85% CC = 50%	Poor seeing, photometric
5	IQ = 85% CC ≥ 70%	Poor seeing, not photometric
6	IQ = Any	Bad seeing

Planning for the queue nights involves optimizing the use of telescope time such that the majority of the time on the sky is spent executing observations for the higher-ranked science programs (Band 1 and 2 rankings) with the aim of reaching very high completion rates for these programs. The queue planning also involves selecting lower-ranked programs (Band 3) wisely, such that started programs have a reasonable probability of being completed or are close to completion and therefore producing science. Band 3 programs often make use of poorer observing conditions than required for those in Band 1 and 2, enabling productive use of these non-optimal observing conditions. Put another way, a Band 3 program that can use poor seeing and non-photometric conditions has a much higher probability of getting executed than one that requires better-than-average conditions.

Program Completion Rates

Figure 2 shows the completion rates for programs in the three ranking bands. Semesters 2003A-2004B occurred lost to weather, with fairly large variations from semester to semester. The large fraction of engineering time in GN-2006B was spent on repairs after the magnitude 6.7 earthquake that hit the Big Island on October 15, 2006. Figure 1 shows the semester-by-semester distribution of how telescope time was spent.

Figure 1.
(Right) Semester-by-semester distribution of how the telescope time was spent.

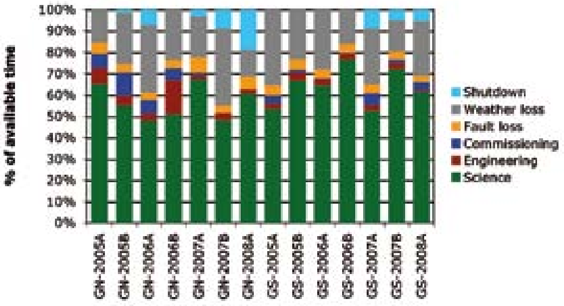
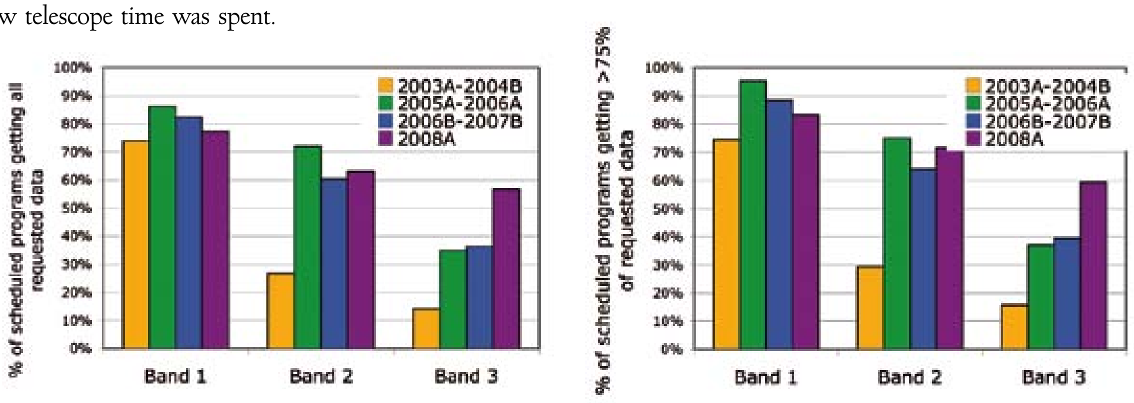


Figure 2.
Completion rates of queue programs. Left: % of programs completed by band. Right: % of programs with at least 75% of requested data.



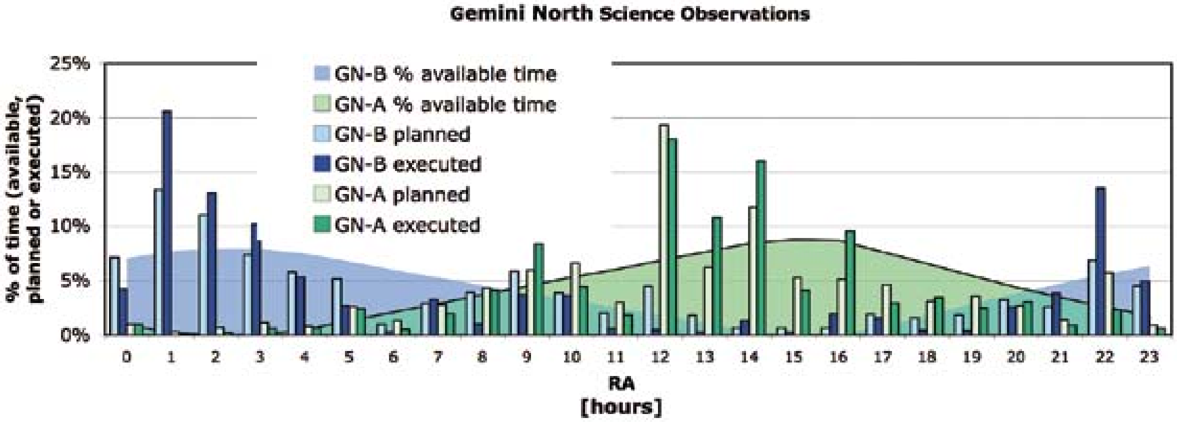
before multi-instrument queue operations began. Further, only the Gemini Multi-Object Spectrograph (GMOS-N) had queue planning during this period. With full queue coordination and multi-instrument queue nights, the completion rates in all bands have improved, especially in Band 2. However, the productivity in Band 3 has also improved in the sense that the emphasis is now on completing or obtaining scientifically useful datasets (as defined by the principal investigator) for all Band 3 programs that are started.

Since 2004A rollover status has been granted to selected Band 1 programs, as recommended by the national TACs. In 2007B and 2008A on average 60% of all Band 1 programs were given rollover status. A program with rollover status remains active in the queue for up to three semesters. Thus, the final completion rates for 2007B and 2008A Band 1 programs are expected to be higher than reflected in Figure 2 (previous page). If all programs with rollover status are completed then completion rates of 88%-100% will be reached for 2007B and 2008A for both Gemini telescopes. Attaining similarly high completion rates in Band 2 has proved very challenging, especially after the band sizes were adjusted in 2007A to have 60% of the time in Bands 1 and 2 instead of 50%, as was the case for 2005B-2006B.

Table 3.
Statistics on acquisition times

Gemini 2008A Statistics		
		Acq. time [min.]
Preset: Telescope slew + guide star acq. same as imaging acquisition w/o AO		6.0
Instrument mode	# obs.	Acq. time [min.]
GMOS-N / GMOS-S Longslit	218/398	9.4 / 8.9
GMOS-N / GMOS-S MOS	60 / 59	12.3 / 9.9
GMOS-N / GMOS-S IFU	30 / 30	12.9 / 10.5
NIRI / GNIRS (5B+6A) Longslit	195/465	7.0 / 9.8
GNIRS IFU (5B+6A)	24	13.4
NIFS (IFU) + Altair	83	5.0
NIRI+Altair NGS imaging	188	4.3
Michelle (5B+6A) / T-ReCS	103/28	6.5 / 14.3
Gemini 2008A LGS modes including preset		
Instrument mode	# obs.	Acq. time [min.]
NIFS (IFU) + Altair LGS	20	25.1
NIRI+Altair LGS imaging	25	19.4

One of the challenges of running an efficiently operated queue-scheduled observatory is the ability to fill the queue with programs such that all useful observing conditions can be used productively and (at the same time) schedule programs consistent with the recommendations from



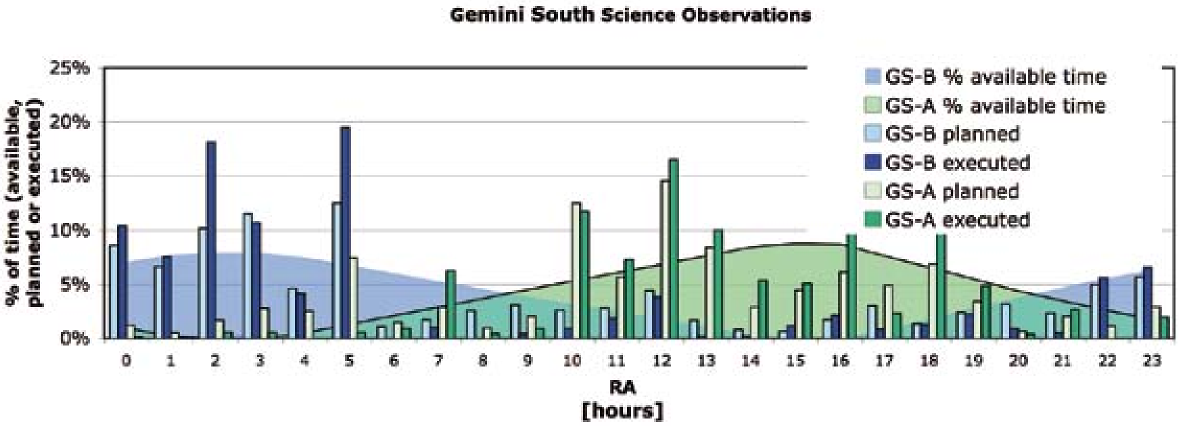


Figure 3.
RA distributions for science observations 2006B-2008A. 2008B also included in the distributions for planned observations.

the Time Allocation Committee (TAC) process. Broadly speaking, there are two areas of concern in filling the queue: (1) the distribution of observations in right ascension (RA), and (2) the distribution of observations among the observing conditions. While there is ongoing work to improve how the queue is filled, past semesters show the historical high-demand RA ranges and also give empirical information on what realistically can be executed in the queue in terms of observing conditions.

Figure 4. *Distributions of science observations in observing condition bins. See text for details.*

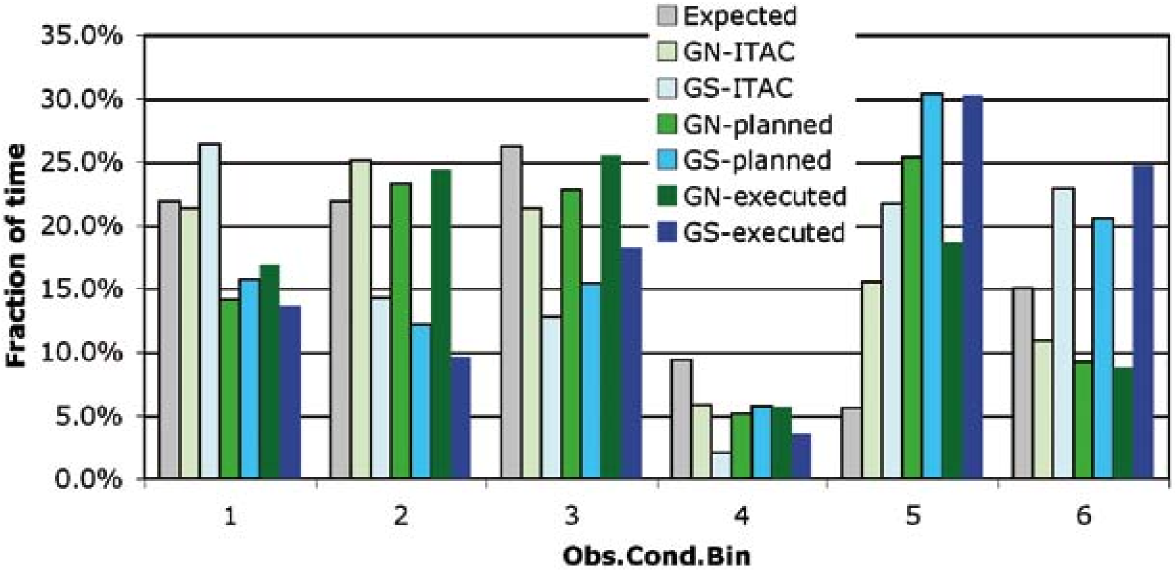


Figure 3 (previous page) shows the RA distributions for both sites for semesters 2006B-2008A. Semester 2008B is also included in the figure but only in the planned time. For each distribution—available, planned or executed—the figure shows the percentage of time in each RA bin. At Gemini North, historical high-demand ranges are 12-14 hours RA, which include the North Galactic Pole, and 1-2 hours RA, which include fields in M31 and M33. At Gemini South, high-demand ranges are around 1 hour RA (The Small Magellanic Cloud), 5h (The Large Magellanic Cloud), and 12 hours RA. The latter includes galactic and extragalactic targets in the Centaurus region as well as galaxies in the Virgo cluster. There are also RA ranges in very low demand, e.g. RA=6 hours at both sites. The RA distribution of the executed observations is different from the RA distribution of the planned observations, as it depends on the band ranking of the observations, as well as the observing conditions throughout the semesters. Percent executed can exceed the percent planned at some RAs, as the percent executed is the fraction of the executed observations, which is less than the planned.

Figure 5. *Acquisition statistics: Comparison of statistics for 2005B+2006A and 2008A showing the improvement gained by the integration of acquisitions into one common script.*

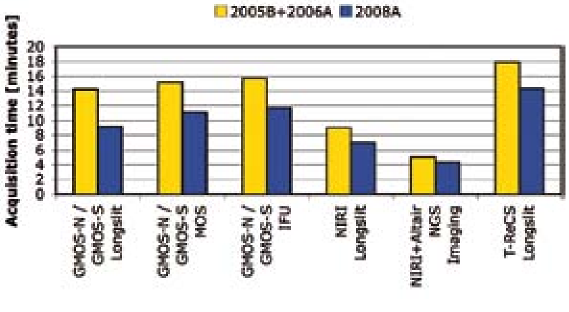


Figure 4 shows how the science observations are distributed among six broad observing condition bins. The bins go from good seeing and photometric in dark time (bin 1), through poor seeing and non-photometric, to bad seeing (bin 6). See Table 2 (page 52) for details. Figure 4 also shows the expected distribution of time, under the assumption that thick cloud cover (2 magnitudes or more of extinction) is not useful for science. The distribution labeled "ITAC" refers to the approved queue programs. Some program PIs later relax their conditions, while others ask for approval to use better conditions than originally planned. The distribution labeled "planned" contains all science observations planned in the Observing Database. This distribution shows less time in the first two observing condition bins, reflecting changes by the PI to poorer conditions during the phase II definition process. The distribution labeled "executed" contains all observations executed during the semesters. However, it is the distribution of requested conditions rather than the actual conditions that gets recorded for this metric. It is common that Band 1 and 2 programs get executed in better-than-requested conditions to improve the chances of completion. Work is ongoing on evaluating the distribution of the actual observing conditions for both telescope sites.

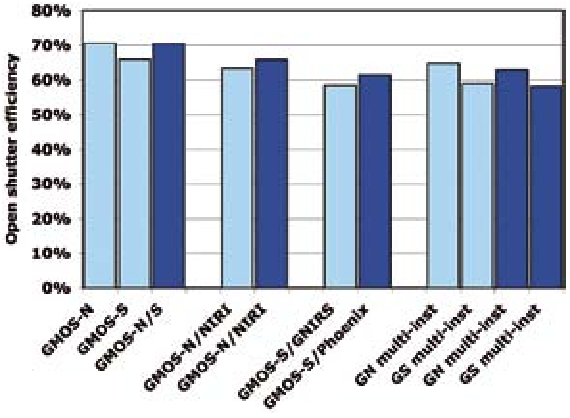


Figure 6.
Open shutter efficiency for 2004-2005 (light blue) and 2008A (dark blue).

Acquisition Times

In 2006B, all facility instruments except T-ReCS were integrated into the common acquisition procedures and user interface. This has resulted in a significant positive effect on the acquisition times for all spectroscopic modes. On average, the acquisition times for these modes are 2-5 minutes shorter in 2008A than they were in 2005B+2006A. Figure 5 compares the statistics from 2005B+2006A with 2008A. Not all modes can be compared due to either small number statistics (MICHELLE) or the non-availability of data for one of the periods (Gemini Near-infrared Spectrometer (GNIRS) and Near-Infrared Integral Field Spectrometer (NIFS)). The average of the acquisition times for all spectroscopic acquisitions was 11.9 minutes in 2005B+2006A and 9.2 minutes in 2008A, excluding laser guide star modes. Table 3 (page 53) shows the average acquisition times derived from the 2008A data. While a few minutes per acquisition may seem like a small improvement, it adds up over the course of a semester. The difference between the acquisition times in 2005B and 2006A and those for 2008A is equivalent to three nights per site per semester of saved acquisition time.

Open Shutter Efficiency

Gemini also tracks the open-shutter efficiency. The open shutter efficiency is defined as the sum of the exposure times of all science and calibration observations divided by the available time, less any time lost to weather or technical problems. In Figure 6, the open shutter efficiency for 2004-2005 is compared to the efficiency in 2008A. In 2004-2005, Gemini was still operating on many nights with only one instrument active. However, this has changed significantly and only GMOS-N and GMOS-S are used as a single instrument on enough nights to make a comparison with the similar 2004-2005 data. The other comparisons are between identical or similar instrument combinations. GMOS-N and GMOS-S now operate at the same high open-shutter efficiency, 70.5%. GMOS, combined with the primary near-infrared instrument at the two sites, has also improved by a few percent. GMOS-N and the Near-Infrared Imager and Spectrometer (NIRI) used together operate at 66% efficiency, while GMOS-S and Phoenix operate at 61% efficiency. The average efficiency of all multi-instrument nights has decreased a small amount and is now 58-59%. However, it is important to keep in mind that this efficiency is also a function of the demand for the various instruments. Since 2004-2005 Gemini North has seen NIFS come into operation and the demand for GMOS-N decrease slightly. At Gemini South, the visitor instrument Phoenix is currently used in queue and is slightly less efficient than fully integrated facility instruments.

The Queue in the Era of Laser Guide Star Science

The laser guide star (LGS) AO system at Gemini North entered full science operations in January 2007. Figure 7 shows the Gemini North laser in operation. The LGS is quite complicated for both the System Support Associate (see SSA article starting on page 47) and the observer to operate. Work is ongoing to streamline the system from a user's point of view and to improve the technical reliability of all components. The demand in the queue has been for about 200 hours of LGS programs per semester. Its use requires a cloudless sky and the seeing needs to be better than 0.8 arcsecond in the optical. To ensure comparable completion rates for LGS queue programs as for non-LGS queue programs, Gemini schedules three to four times as many LGS nights as the queue contains. When observing conditions do not allow use of the LGS, non-LGS queue programs are executed instead. All 2006B and 2007A Band 1 LGS programs have been completed, while all 2007B and 2008A Band 1 LGS programs can be completed within their roll-over time period. Band 2 LGS programs from 2006B to 2007B have not done as well. This is now improving; for 2008A eight out of ten LGS programs in Band 2 got at least 85% of the requested data. Five programs were completed.

Summary

Gemini's design—which allows for fast instrument switches as we slew the telescope—together with the

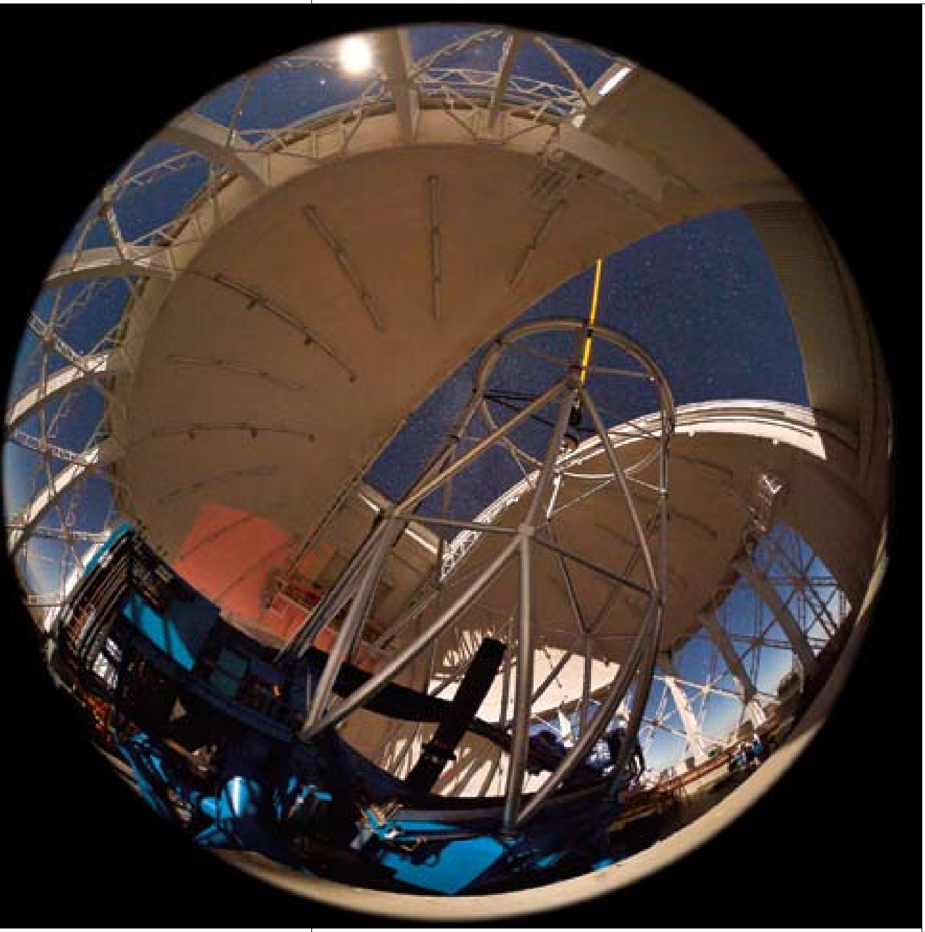


Figure 7.
Gemini North during laser guide star propagation on September 27, 2007.

fully cross-trained science staff operating all instruments in a homogeneous software environment are the key components that make it possible to run an efficient multi-instrument queue. With additional instruments coming online at both sites over the next few semesters, it is going to be a challenge to maintain the high completion rates for all instruments, given that some will be on the telescope for only a limited amount of time. We continue to look for ways to improve our efficiency on the sky as well as optimizing our science productivity by delivering scientifically useful datasets to our users. Future improvements will include more efficient queue planning and also better overview and therefore management of the content of the queue at both sites.

More information on the science operations statistics can be found on the Gemini web site at:
http://www.gemini.edu/sciops/statistics

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by François Rigaut

MCAO Update

Overview

The Gemini Multi-Conjugate Adaptive Optics System (GeMS) has been advancing on several fronts. The integration and testing of Canopus (the AO bench) is proceeding at the southern base facility instrumentation lab in Chile. The BTO (Beam Transfer Optics) integration and testing are also well underway, having recently passed a successful end-to-end test. The laser work is proceeding at Lockheed Martin Coherent Technologies (LMCT) with the help of Vincent Fresquet, now on site since May (for training). Unfortunately, the laser delivery date has been delayed once more (to May 2009). The Laser Launch Telescope (LLT) is commissioned, and the Gemini South Adaptive Optics Imager (GSAOI), the MCAO Infrared Imager, will see its last set of acceptance tests in November, 2008.

Documentation Effort

GeMS is a complicated beast. To track efforts, results and changes, we put together a set of efficient documentation tools. On top of the SiteScape collaboration software package, where the final version of documents are/will be kept, we now have a Wiki (twiki) and a blog (using Movable Type). Both are actively used and we often count several entries a day. These have turned out to be very convenient tools, with easy and efficient search options, notification, and organization features (visible at: http://myst.cl.gemini.edu/twiki/bin/view/MCAO/WebHome from within the GS firewall). The Wiki is mostly used for documentation, while the blog is used for news, results of calibrations, and other material.

MYST

The last six months have also seen significant progress on the Canopus software, which provides high-level control of the MCAO core. Called MYST (for MCAO Yorick Smart Tools), it is based on a combination of Python (general scripting, GUI, epics control), Yorick (mathematical and physical engine, leveraging AO simulation tools developed in house for the past six years) and the gtk/glade (GUI and GUI builder) interface. Its main functions are as follows:

- Report of MCAO status;

- Graphic display of wave-front sensor (WFS) pixels, slopes, deformable mirror (DM) errors, commands, etc.;

- Higher-level diagnostics as r_0, projection on Zernike modes, etc. It will also act as a high-level diagnostics tool to detect configuration mistakes (including status of the many look-up tables, etc.). Several modes are available (lab, telescope, calibration, night time);

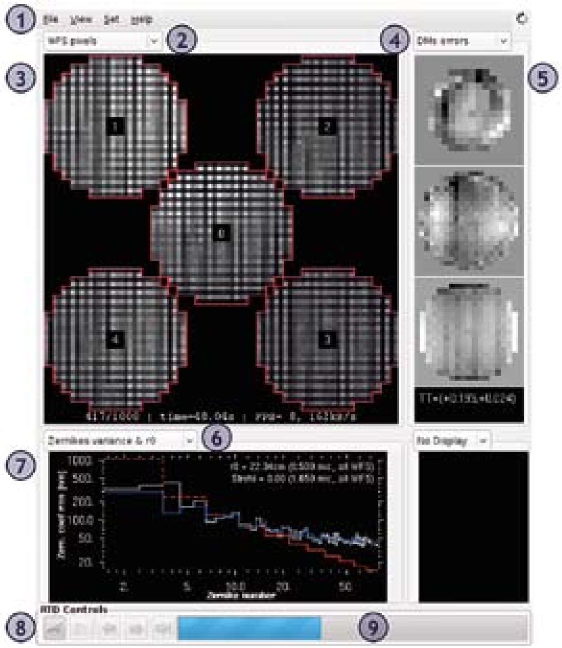

Figure 1.
A screen from the Canopus software MYST provides a real-time display of the MCAO parameters.

- Control of the real-time computer (RTC) main functions: close loops, adjust gains, enable offload, enable disturbance, etc.;

- Centralized/coordinated control of the high level functions of the various MCAO subsystems (Canopus, BTO, LLT), except laser and telescope;

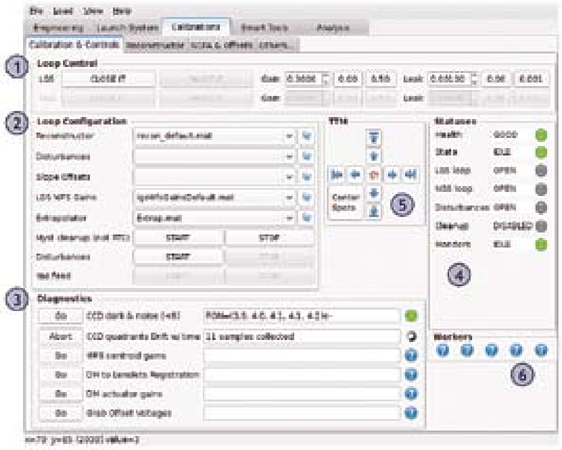

Figure 2.
Interface for the control of the real-time computer (RTC) main functions.

- Generation of initialization files: reconstructors, slope offsets, NCPA tomographic reconstruction from DWFS or GSAOI input.

This tool will facilitate the engineering and science commissioning tasks enormously, as well as the final operations. It should insure better reliability and a more efficient operation of this very complex instrument.

General Progress

There have been a number of notable milestones and results accomplished with Canopus over the past six months.

- We obtained more than 99% (without turbulence) static Strehl ratio over several locations in the Canopus output focal plane. This proves that we understand the non-common path aberrations and are able to compensate with high accuracy for them. We are currently working on tomography of these static aberrations to compensate all locations simultaneously. The diagnostics WFS has been installed, is fully functional, and was used for these measurements.

- Vibrations are very low in the current configuration (about 1.5 milliarcseconds root-mean-square). We will work to maintain a low level of vibration on the telescope.

- The laser guide star (LGS) wavefront sensor acceptance tests are almost complete. We still need to finish the rest of the flexure tests and the cold tests. Surprisingly, the air conditioning/cooling has proven a challenge in the lab.

- The entire cooling system has been redesigned and went through an internal conceptual design review (CDR) in September. This turned out to be a challenging task, as the Canopus deformable mirror power supplies dissipate a lot more heat than anticipated—two to three times more than typical Gemini instruments.

- Work on the integration and testing of the natural guide star (NGS) wavefront sensor is progressing, and we should soon have remote motion control.

On another front, an effort to rework the error budget has started. Many things have changed from the initial design era, and we need to fold these modifications, as build specifications, into this new error budget.

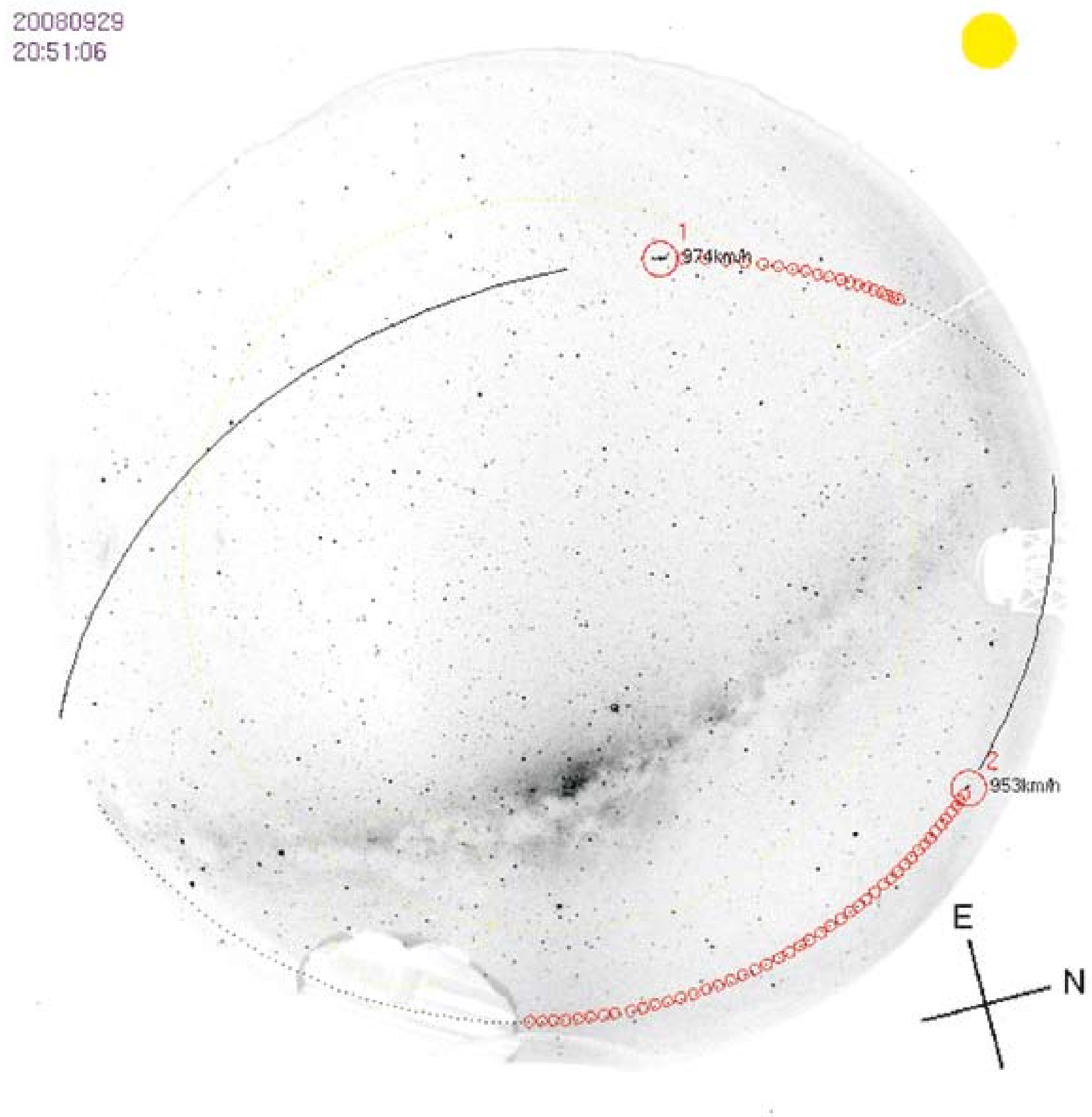

Figure 3. *Screen capture of an ASCAM image showing typical real-sky events.*

ASCAM

On a different (but related) front, work has also been proceeding on the all-sky camera (ASCAM). A second camera has been installed, and the software upgraded to use both of them. The upgrade provides more robust detections; in particular, as they are oriented at 90 degrees from each other, this means the "dead zone" from Moon blooming/scattering is considerably reduced. If they are used in interleaved mode, it provides a faster frame rate (2.5 seconds between exposures), which means earlier aircraft detection. This new ASCAM version has been tested very successfully at Cerro Pachón for the past few weeks and will soon be tested at Palomar Observatory in California.

Staffing

In August, we said a fond goodbye to Damien Gratadour, who could not refuse a permanent position as Assistant Professor at the University of Paris. We wish him all the best. We have been lucky enough to find a replacement for Damien in Benoit Neichel, who is finishing his Ph.D. thesis at ONERA, the French Aerospace Laboratory and Observatoire de Paris. Benoit is an adaptive optics specialist and will start working at Gemini in January 2009. He will be fully dedicated to MCAO.

Watch future issues of *GeminiFocus* for updates, exciting times lie ahead!

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

by Joseph Jensen

Progress with New Gemini Instruments

New instrument development plays a key role in Gemini's mission to reveal the secrets of the cosmos by providing our astronomical community with the tools it needs to answer fundamental questions in astronomy and astrophysics. New instrumentation invariably allows astronomers to ask—and answer—important new questions about the nature of the universe.

Two new Gemini instruments are now being delivered and commissioned, and one is being repaired and re-commissioned. The Near-Infrared Coronagraphic Imager (NICI) is now being commissioned on the Gemini South telescope in Chile. It will soon begin a large survey to discover extrasolar planets using its specialized coronagraph, dual imaging cameras, and on-board adaptive optics (AO) system. The FLAMINGOS-2 near-IR multi-object spectrograph is nearing completion at the University of Florida and is scheduled to be delivered to Gemini South by the end of 2008. With a 6-arcminute-wide imaging field of view and spectroscopic multiplexing capability of up to ~80, FLAMINGOS-2 will help Gemini astronomers study the first galaxies that formed in the universe and the formation of stars and planets in the Milky Way. Finally, the Gemini Near-Infrared Spectrograph (GNIRS) will be returned to service at Gemini North in 2009, where it will be used with the Altair Adaptive Optics (AO) system for the first time.

NICI

NICI is a near-infrared coronagraphic imager built by Mauna Kea Infrared (MKIR). It has been undergoing an extensive period of commissioning, instrument performance characterization and optimization, all of which is expected to be completed by the start of 2009A. Recent commissioning runs have demonstrated that NICI can achieve the high contrast sensitivity needed to detect young planets around nearby stars.

NICI has a specialized dual-channel camera with a dedicated Lyot coronagraph and an 85-element curvature adaptive optics system optimized to directly detect massive self-luminous extrasolar planets around nearby stars. NICI spectrally differences two images taken simultaneously at two slightly different wavelengths bracketing the strong near-infrared methane features found in substellar (planet-mass) objects. The NICI design philosophy tightly integrates the three major subsystems (AO system, coronagraph, and dual-channel camera) to minimize non-common path aberrations so that planets will not be confused with diffracted speckles produced by the optics in the instrument itself. Both cameras are equipped with 1024 × 1024 ALADDIN InSb (indium antimonide) arrays sensitive from 1 to 5 microns. The imaging plate scale is 0.018 arcsecond per pixel, providing a field of view 18 arcseconds across. A variety of broad- and narrow-band filters are available, including various narrow band filters sampling the methane absorption band at 1.6 microns.

NICI will be the first Gemini instrument to be used in "campaign" mode. A dedicated program has been awarded up to 50 nights over three years to look for extrasolar planets. Campaign observations are planned to start before the end of 2008. NICI is also being offered for non-exoplanet AO imaging and coronagraphy starting in 2009A. While the instrument characterization has not been completed yet, the measured performance for some observing modes exceeds specifications. At present, NICI is being offered for 1- to 2.5-micron coronagraphic imaging on targets closer than 1 parsec (pc), or more distant than 200 pc with guide stars brighter than V = 11 magnitude. This restriction is to allow non-exoplanet research on a shared-risk basis during 2009A; full open access will be offered in 2009B once NICI has been fully characterized and the planet search campaign has begun.

When the Gemini Board of Directors authorized an allocation of up to 50 nights to the NICI Planet Search team led by Michael Liu and Mark Chun (University of Hawai'i), and Laird Close (University of Arizona), they required that the Gemini Science Committee (GSC) provide technical oversight of the campaign on an annual basis. They also required that the GSC assess NICI performance prior to starting the campaign. The GSC has organized the Planet Finding Science Working Group and charged it to review NICI performance prior to beginning the NICI Campaign. The working group and the GSC met in September and October to review NICI performance and provide feedback to Gemini and the campaign team.

The GSC defined two basic criteria to establish NICI's performance. The first is that NICI must be capable of achieving the science goals set out in the campaign proposal submitted by Liu's team. The campaign proposal was based on certain performance estimates and assumptions defined by Gemini as part of the campaign Request for Proposals (RFP) more than two years ago. To go forward with the campaign, Gemini must first establish that NICI performs at least as well as anticipated in the RFP. Secondly, NICI must perform at least as well as NIRI + Altair, Gemini's comparable AO imager without an optimized coronagraph. The best measurements to date using NIRI and Altair were made by the Gemini Deep Planet Search (GDPS) team under the leadership of David Lafrenière and René Doyon (and described in volume 670 of the *Astrophysical Journal*, page 1367) as well as an article on page 31 of this issue of *GeminiFocus.*

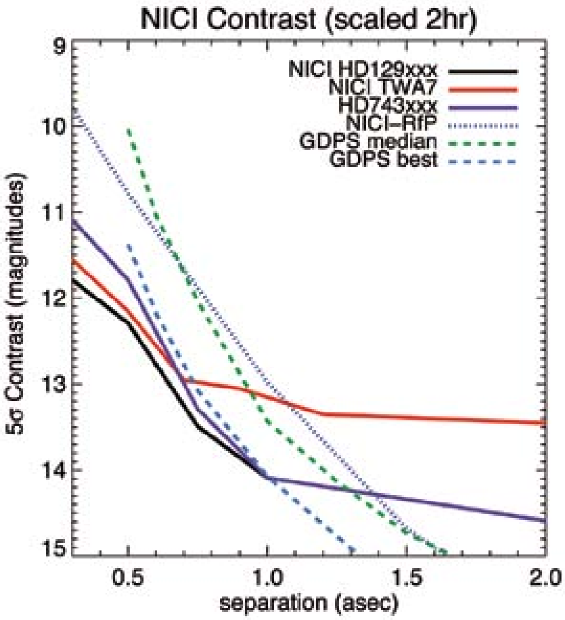

Figure 1.
The NICI contrast curves derived with the campaign pipeline reduction software. These contrast curves show the achieved contrasts compared to the original RFP expectations scaled to a two-hour exposure. For reference, two contrast curves from NIRI are also shown scaled to the same integration time. (Figure adapted from M. Chun et. al. 2008, Proc. SPIE and using data from D. Lafrenière et. al., 2007. The preliminary NICI contrast curve was derived from commissioning data by Zahed Wahhaj, Mike Liu, and the NICI Campaign Team.)

During commissioning, the NICI instrument team found that Strehl ratios at 1.6 microns were typically 35% to 40% during median or better seeing, matching expectations for guide stars brighter than V = 13 magnitude as a function of natural seeing and guide star brightness. The delivered contrast ratio as a function of radius from the guide star exceeds the RFP predictions by a significant margin inside a radius of ~ 1 arcsecond, and are at least as good or better than the best NIRI observations at small radii (Figure 1). The coronagraph is working as designed, and the unique dual-camera speckle-suppression system adopted for NICI will yield the best contrast ratios of any current instrument when observing within an arcsecond of the primary star. When the array controller reprogramming is complete, NICI's performance advantage will be extended to larger radii.

There is still a fair amount of work required to fully prepare for the start of the NICI campaign and other science observations. The most important task to complete is the optimization of the dual detector controllers. For the last few months Gemini, MKIR, and University of Hawai'i staff members have worked to reprogram the controller firmware to improve reliability, remove interference patterns and dropped rows, and to decrease read noise. At the time this article was written, the array controller work was in progress, in preparation for testing in October 2008.

A second important area of improvement is the high-level Gemini software. A great deal of progress has been made during the last year, but more testing is required to ensure that sufficiently automated and robust observing sequences can be executed efficiently. The high-level software is critical for NICI campaign observations to be conducted during regular queue operations by Gemini staff members who are not expert in NICI operations. NICI campaign observations will begin as soon as NICI detector controller and software issues are resolved, hopefully before this issue of *GeminiFocus* reaches your hands.

FLAMINGOS-2

One of the most exciting new instruments to be built for any observatory is the FLAMINGOS-2 near-infrared multi-object spectrograph. It will image a field of view 6 arcminutes across and take up to 80 spectra at a time. FLAMINGOS-2 will be the first of its kind in the southern hemisphere, allowing Gemini observers to address a wide variety of science questions. It also promises to be one of Gemini's most popular instruments, so we are working hard to get it installed and commissioned on Cerro Pachón as soon as possible. It will also take advantage of the new multi-conjugate AO system being built for Gemini South once that system comes on line later in 2009.

Since the last report (*GeminiFocus* June 2008, p. 42), a number of important milestones have been passed. The most important was the beginning of Acceptance Testing last August. A large team of Gemini scientists and engineers converged on Gainesville to "look under the hood and kick the tires." The University of Florida team provided extensive support and opportunities to train the Gemini staff members. About half the tests were completed successfully, particularly the software tests and mechanical interface measurements. The team demonstrated the warming and cooling of the multi-object mask dewar and performed a full mask exchange cycle. The documents were reviewed and safety procedures discussed. Unfortunately, the camera cryocooler failed the day before the tests were scheduled to begin, so we were unable to complete the camera mechanism tests or measure detector performance. These tests have been successfully run before, so we expect FLAMINGOS-2 to pass them easily when Acceptance Testing is completed.

Figure 2. *Gemini scientists and engineers, standing, left to right: Manuel Lazo, Ramon Galvez and Percy Gomez examine the FLAMINGOS-2 wavefront sensor during acceptance testing in Gainesville last August.*

A number of punch-list items were identified by the Gemini visitors, and the Florida team is now working energetically to tie up all the loose ends. At the present time they are working to complete some optical baffling work, get the cables and services into their final configuration, and finish the documentation in preparation for a final pre-ship acceptance test in November. We are confident that when FLAMINGOS-2 is delivered to Gemini South, hopefully before the end of 2008, it will pass final acceptance tests and be ready to start commissioning early in 2009.

GNIRS

During the last few months, Gemini engineers have made good progress getting GNIRS components repaired, cleaned and tested in preparation for reassembly and re-commissioning on Gemini North. As reported in earlier issues of *GeminiFocus* (December 2007, p. 43, June 2008, p. 39), GNIRS overheated due to a temperature controller failure in 2007. Gemini is now carefully repairing the extensive damage. Since GNIRS was one of the most productive and popular instruments at Gemini South prior to the accident, we are confident that its restoration is worth the time and effort.

Two potential replacement Aladdin-3 science detectors have been produced by Raytheon Vision Systems, and we are awaiting test data to determine which will be installed in GNIRS. A replacement HAWAII-1 array for the on-instrument wavefront sensor has been provided by the University of Hawai'i, and the detector and mount are now ready for testing. The rest of the work needed to get the on-instrument wavefront sensor back up and running is nearly complete.

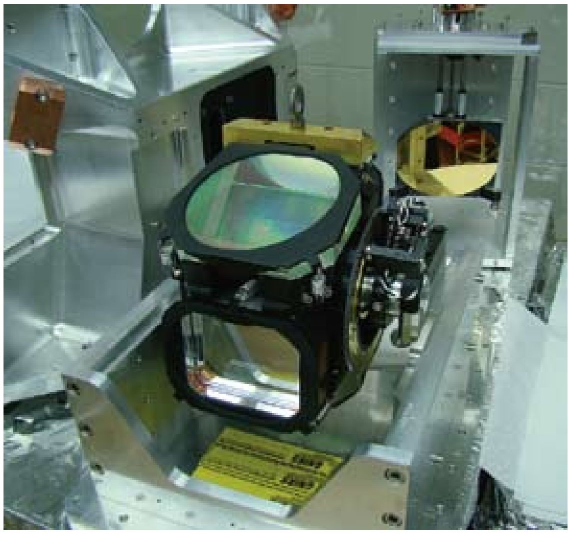

Figure 3.
GNIRS cross-dispersing prism reinstalled in the turret mechanism.

Several of the new and refurbished optics have now been received from various vendors. We have the re-polished prisms and the new flat mirrors, which have now been reinstalled in their housings (see Figure 3). The new diamond-turned mirrors are expected in October 2008. Unfortunately, two of the damaged lenses cracked during the recoating process following repair of edge chips, and will have to be replaced. We expect that two new lenses will take until the end of the year to procure. The other optics procurements are proceeding as planned.

Back in Hilo, Gemini engineers continue to clean and repair the mechanisms. The dewar shell and shields have been cleaned, reassembled, and are undergoing vacuum testing with the refurbished vacuum and cryocooler systems. The mechanism control software and computers are assembled and ready for further testing. As soon as the rest of the optics arrive, they will be tested, installed, and realigned. We expect to have the detectors by then, ready for full system integration and testing early next year. In spite of delays with the detector and optics vendors, we still expect to be re-commissioning GNIRS on Gemini North in semester 2009A, and offer it for science in 2009B. GNIRS will once again become one of the most popular and productive instruments at Gemini, particularly when it is commissioned with the Altair adaptive optics system. In the meantime, Gemini engineers are working hard to bring this important instrument back to life.

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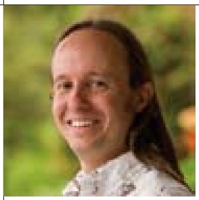

by Brian Walls

Gemini North Shutdown & Primary Mirror Recoating

Figure 1. *Magnetron three applying the very thin protective coating of silicon on top of the silver coated primary mirror.*

In July 2008, the Gemini engineering group conducted a major shutdown to work on key telescope systems and recoat the Gemini North primary mirror (M1). The process only took 20 days, but it was the culmination of more than 11,000 hours of preparation work, making it the third-largest project that the Gemini engineering group would execute during the year. The number of staff members involved was considerable: at one point during the shutdown we had a total of 38 technicians, engineers, and support staff working on the summit, including 13 members of the engineering and safety group from Gemini South in Chile.

It had been four years since the last coating of the Gemini North primary mirror. At the time, it was only expected that our coating would last two years, but careful maintenance and regular cleanings extended the coating's lifetime for two more years. As our previous coating has shown, we are well on our way to developing a silver-coating process that maintains the same high quality as that of fresh silver for a long period of time. Although the reflectivity of the previous coating had deteriorated by only 5% at 470 nanometers (nm), the less-than-optimal adhesion left Gemini North unable to perform the *in-situ* washes critical to removing leftover dust particles after the weekly CO_2 cleanings.

Since the last M1 coating, we have scrutinized our process and procedures in an effort to minimize all identified safety hazards. As a result of these reviews, nearly 20 projects were added to the preparatory work and finished before we shut down for silver coating. We added procedures for extractions of people from enclosed spaces, such as our coating chamber, and designed extensions for the mirror lifter, to allow us to work underneath the mirror instead of risking the hazard of a suspended load. The procedure for removing the mirror cell was updated and a permanent high-pressure hydraulic line was installed to support this work. All employees who were involved in the M1 stripping process went through a three-day Hazardous Waste Operations and Emergency Response training course. We also created projects to improve airflow and remove harmful vapors produced during the stripping process. All of these projects created a much safer working environment.

All of the preparatory work, including safety projects, came to a close on July 14, 2008, when the Gemini North telescope was shut down. The initial phase went very smoothly, including the extraction of the mirror, its transportation to

Figure 2. *Preparations for work on the Gemini North telescope during the 2008 shutdown.*

the first floor, and stripping. However, we did run into problems with the magnetron that deposits the silicon adhesion layer. This required us to open the chamber, find the problem, and fix the magnetron. In the end, the failure was traced to a short in a single faulty insulator. The rest of the coating process went off without a hitch. After reinstallation of the newly coated primary mirror, we were able to go back on the sky for engineering on the first of August, and science observation resumed two nights later (August 3rd).

The mirror's current reflectivity is as good or better than the previous coating (see Table 1). Scotch® tape pull tests show that the adhesion of this coating is superior to the previous one. This may allow us to perform in-situ washing of the mirror that will extend the coating's lifetime. Cosmetics are very good, with no union visible between the magnetron passes. Pinhole performance is similar to the previous coating (~ 6 per 10 cm^2) and is a result of the MK non-clean room environment (as expected). Pinholes are caused when dust falls on the mirror after the stripping process. It is not removed by the final CO2 cleaning as the mirror is inserted into the coating chamber. The total thickness of the coating is only ~ 1350 Ångstroms, which can be smaller than the dust that is sitting on the surface of the mirror. This leaves us with an uncoated "pinhole" on the mirror. Emissivity measurements were unavailable at the time of writing, but will be made once MICHELLE has been installed on the telescope in October. A newly coated secondary mirror (M2-3), scheduled and installed in mid-October, will bring the emissivity down even more.

While the unique four-layer silver coating gets most of the spotlight, the engineering group took the opportunity to work on many other areas of the Mauna Kea facility and with its instrumentation. Running a queue-based observatory means that we don't let our instruments rest for any extended period of time. It is very difficult to do invasive and complicated work when the instruments, and the acquisition and guiding system must be ready to go each and every night. We used this time to do maintenance on the mirror cell and support structure, as well as the mirror covers. Thermal stability of our laser system was also a maintenance priority, and we have seen much improvement in its performance during nighttime operations since the shutdown. Major work was performed on the installation of a new uninterruptible power system that will allow us to be better protected during the power outages that sometimes result from winter storms.

	470 nm	530 nm	650 nm	880 nm	2200 nm
Nov. 2004	93.3%	95.0%	94.7%	96.4%	98.1%
July 2008 (before coating)	87.97%	90.65%	91.68%	94.12%	N/A
Current (after coating)	93.94%	96.1%	96.1%	96.73%	98.78%

Table 1. *Reflectivity of the Gemini North primary mirror (M1) at various wavelengths before and after the 2008 coating.*

In late 2007 Gemini Observatory selected Project Insight (Metafuse Inc.) as our web-based project management software solution. The software package has played a key role in every aspect of this project and has significantly improved our efficiency during both the planning and execution of the shutdown. It allowed us to plan and track the more than 11,000 hours of preparatory work associated with such a large shutdown. The software also allowed us to provide weekly status reports to the Director and the Board, as well as other interested groups within the organization. During the shutdown, the software was used to create daily plans of the work to be performed and provide a centralized location for the engineers to report on finished tasks.

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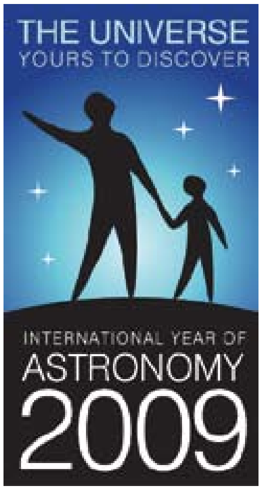
by Peter Michaud



Celebrating the International Year of Astronomy and More...

As the final touches go into this issue of *GeminiFocus*, the Gemini Public Information and Outreach (PIO) Office is polishing up our plans for 2009. Proclaimed as the International Year of Astronomy (IYA), 2009 will be an exciting year for education and outreach programming at astronomical observatories around the world. At Gemini we have plans to participate in IYA with events and programs that support the year-long celebration's motto, "The Universe, Yours to Discover."

In addition to our IYA activities, 2009 is going to be an extremely active year for Gemini PIO. In response to this, the Gemini PIO webpages have been updated and improved to highlight all of the ongoing and new IYA initiatives, allowing us to provide timely information as it becomes available.

The new PIO Web pages are part of a major initiative to redesign the entire Gemini public website with a new aesthetic and feel (see article on the new science pages starting on page 45 of this issue). Plans are in place to assess areas where further improvements are necessary and where new approaches and interactive Web-based media are appropriate for implementation.

You are invited to visit the newly improved Gemini Web pages at www.gemini.edu and link to the Education and Outreach home page for the latest information on Gemini's PIO programming. It is sure to be an exciting year as Gemini celebrates the IYA, and we hope you will help us make it an eventful year of discovery!

Canada and Australia Embark on Student Imaging Programs for IYA

Following in the tradition of the popular student/amateur imaging programs sponsored by the Canadian Gemini Office in 2002 and 2005, both Canada and Australia have initiated similar programs for 2009 to help celebrate the International Year of Astronomy.

In Canada, the program is limited to students in grades 9-12 and the deadline for target entries will expire at about the time readers receive this issue of GeminiFocus *(the deadline is December 15th, 2008). In Australia, the program is slated to solicit entries from high school students in early 2009 for selection and for observations to be made during the second half of 2009.*

Both programs are providing about one hour from each country's national time allocation available for imaging of a compelling astronomical object. As this issue goes to press, the Australian Gemini Office is awaiting approval from the Time Allocation Committee (TAC) for this project. In the past, Canadian participants have targeted both the Trifid Nebula (see Figure 1) and the young star forming region around RY Tau.

All Gemini partner countries are welcome to consider similar programs in their countries, and the Gemini PIO office will support your program with image production and media relations resources.

Figure 1.
Image of the Trifid Nebula, proposed by Ingrid Braul of Southlands Elementary School in Vancouver, BC as part of the Canadian Gemini imaging contest held in 2002.

For more information see the following websites:

Canada: www.nrc-cnrc.gc.ca/hia/cgo/contest08_e.html
Australia: www.ausgo.aao.gov.au (will be linked by early 2009)

A Cultural Resource for Chilean Students

For the past six months, a special project of the Gemini South PIO office has resulted in a new Spanish-language publication for local Chilean students, teachers and families. It is called "Cuadernillo Astronómico" *and is written for children ages 7 to 14. The magazine-format publication, (the cover is shown in Figure 2), provides readers with easy to use information and activities that share what indigenous Chilean ancestors saw when they looked at the sky, long before the arrival of big observatories like Gemini.*

The production involved intensive research into the Rapa Nui, Mapuche, Aymara, and Diaguitas cultures, and how they were linked to the sky. The result highlights the contrast between modern and traditional sky-watching, while emphasizing the never-ending human spirit of exploration.

Figure 2.
Cover of Cuadernillo Astronómico, *an astronomical cultural resource in Spanish for Chilean students.*

Two additional editions are planned; One will cover basic and naked-eye astronomy from Chile's Region IV, and the third edition will focus on some of the exciting research being done by Chile's big telescopes.

by Sarah Blanchard

Moving In:
Gemini's Hilo Base Facility Expansion

Above: a view showing the new Hilo Base Facility (HBF) expansion from the Lana'i. Opposite, right: the HBF expansion with a sample of landscaping that includes many traditional native Hawaiian plants.

Gemini North reached a key milestone on September 5, 2008, with a ceremonial blessing for the new Hilo Base Facility Extension (HBF-X). It was finished just 19 months after its March 2007 groundbreaking.

Twice the Space

With the completion of the $7.5 million, 13,500-square-foot extension, HBF has nearly doubled its office floor space. HBF-X provides comfortable new offices for more than 60 staff members, many of whom spent the last year or more in doubled-up quarters in the original building. A number of Hilo-based Engineering group members are now housed on the first floor of the new extension, with the Science and Instrumentation groups located on the second floor. Gemini Director Doug Simons also occupies a new office on the second floor.

The expansion also contains additional office space for visiting staff, three new conference rooms, two new kitchen facilities, a new science reading room, an elevator, and a shower room that was added at the request of employees who ride bikes, work out, or jog at lunchtime.

The main conference room is a major feature of the new extension. It measures 32 x 32 feet, with a custom-created U-shaped table that seats 18, but can also be folded and moved aside to reconfigure the room for much larger audiences. Two smaller conference rooms and a second-floor reading room provide lots of additional space for meetings and work groups.

Photos by K. Puʻuohau-Pummill

Gemini Outreach and Cultural Specialist Koa Rice performs a traditional Hawaiian blessing for the HBF expansion on October 17, 2008.

Meeting the Need for Growth

Jim Kennedy, Gemini North's former Associate Director for Operations, came back from "retirement" to head up the construction as chief consultant. He explained that the need for additional office space at HBF was a direct result of the changing model for allocating telescope use. "The original vision was that Gemini would be doing 50 percent classical observing and 50 percent queue observing," Kennedy said. "So we thought at first that we could run both telescopes with a total staff of 96 people. But around 2002, we saw that the queue system was working very well, and nearly all of our proposals were for the queue system."

The queue system stipulates terms and conditions for each proposed project, so projects are assigned by astronomical and environmental conditions, not simply by calendar date. This is a highly effective and efficient system for scheduling telescope time, but the queue system also requires more Gemini-employed staff. "Now we know how many people it takes to run the 'scopes under the queue system," Kennedy explained. "But, the day we moved into the HBF offices in August 1998, we were already more than full, and almost immediately we had to start work on finding more space."

In 2000, HBF was remodeled to create more offices and work stations. Then two temporary buildings were added, and after that Hale Melemele, temporary office space about a mile away from the base facility building, was leased to house financial services, human resources, and safety staff.

"There's another factor that has affected our staffing needs," Kennedy added. "We've launched several large-instrument development projects that weren't in the original business model. Projects like Gemini's Laser-Guide-Star [LGS] Multi-Conjugate Adaptive Optics [MCAO] system require more highly specialized personnel. So we've hired more people there, as well."

Left: construction of the HBF expansion as seen in April of 2008.

Managing the Details

HBF Mechanical Technician Joseph Leblanc served as the on-site project coordinator and liaison with Taisei Construction. "Overall, the project has gone really well," Leblanc said. "We had some schedule delays due to some permitting issues and the weather—of course, it's Hilo!—but everyone's hard work and good coordination kept the delays to a minimum."

One "permitting" issue arose because of a new Hawai'i County code provision that required the creation of a "rescue room," a special room that will facilitate the rescue of anyone on the second floor in case of an emergency that might make the elevator and staircases unsafe to use. The rescue room was built with a higher fire-rating than for other parts of the building, and it's equipped with an easy-to-use intercom system that will help rescue workers locate and communicate with anyone who would be unable to evacuate from the second floor in the event of fire or a similar emergency.

Other forward-looking elements were also included. HBF-X extension is built to a high standard of seismic design, and the plumbing fixtures are all low-flow to conserve water. The heating-ventilation-air conditioning (HVAC) system is not only energy efficient, but it also features thermostatic controls in almost every room so employees can control the environmental settings in their individual offices. The Administration and Facilities Group (AFG), led in Hilo by Steve Zodrow, coordinated the actual move of personnel and office equipment, and also helped bring in new, ergonomically designed office furniture. Removals planning took place over several months, with some 77 staff changing offices during the move-in process.

Bringing the 'Ohana Together

As Gemini Director Doug Simons noted, "The new extension to Gemini's Hilo Base Facility marks a profound turning point in the evolution of our observatory. Since 1997, when the original Gemini project team members dispersed from Tucson to our sites in Hawai'i and Chile, our staff has steadily become more scattered. Today we have people under eight different roofs in Hawai'i, Chile, and Tucson. Providing such a highly distributed staff with a sense of unity and common vision is a serious challenge."

"For the first time in a decade, with the completion of the HBF-X, this trend is being reversed. In November 2008, we will close our satellite office across town in Hilo and bring the administrative staff 'home' to the newly expanded and renovated Hilo Base Facility." Simons added, "This long-awaited change will doubtless enhance internal communications and promote a real sense of 'ohana (family) within our Hawai'i-based staff."

Sarah Blanchard is the Administration and Facilities Group Team Leader at Gemini North. She can be reached at: sblanchard@gemini.edu by Lauren Gravitz

An Intensity Beyond the Visible

Sandy Leggett

Sandy Leggett has much in common with her brown dwarf subjects—those sub-stellar bodies that shine with a subtle intensity that's obvious only when you peer beyond the visible. A tenured astronomer at Gemini North, Sandy is soft-spoken, polite, and considerate. But, beneath her quiet exterior is an intense woman who helped uncover some of the coolest brown dwarfs ever found.

(Opposite page) Sandy relaxes with Jake, one of her three cats.

Working with the Sloan Digital Sky Survey, Sandy played an integral role in the advance of brown dwarf studies. These cool, sub-stellar bodies are tricky to detect and can only be seen with infrared-sensitive instruments. As astronomers get more data for these objects, they have created two new major substellar classes—*L* dwarfs in 1997, and *T* dwarfs in 1999—the first new categories in nearly a century. Sandy was part of that process, but, as she is quick to point out, she is standing on the shoulders of giants—the women who played a substantial role in developing the *O, B, A, F, G, K,* and *M* stellar classification system at Harvard University early in the 20th century. Referred to as the "computers," they analyzed hundreds of thousands of photographic plates of stellar spectra (see *Nature* **455**, 4 Sept. 2008, pg. 36-37). "For a hundred years, there was no major change to the *O, B, A, F, G, K, M* system," Sandy said. "Then, just in the space of a decade, we had two letters to stick on the end—*L* and *T*."

Sandy's work centered around the new class of *T* dwarfs. She and two other astronomers—Gillian Knapp and Tom Geballe—spent an evening observing and analyzing the data in real time for the Sloan survey. "In one night at the telescope, we found the full range of *T* dwarfs," she commented. "To think, after such a long time we were re-doing the classification scheme." Being able to build on the work of women who preceded her by a century, she says, was a highlight, and she's


Photo by M. Paredes

continuing to seek out ever-cooler objects. "We're trying to find something different again, which we think should look very similar to planets, for the next letter of the alphabet."

Moving through academic circles often dominated by men was not difficult for Sandy, although it wasn't always easy fitting in—sometimes quite literally. While doing research for her Ph.D. at Tenerife Observatory in the Canary Islands, the five-foot, four-inch, (1.63 meter) astronomer was the youngest and smallest of the researchers. "I would get the job of climbing up to the secondary mirror to measure its reflectivity," she recalled. "It was probably 20 feet (6 meters) high—I would be there hanging on with one hand and holding the reflectometer with the other onto the mirror's surface. I'm proud of the experiment we did; it was quite difficult."

At her next observatory, Sandy discovered she was probably the first observer there who was less than six feet (1.8 meters) tall. "We used to observe alone on the 70-inch (1.8-meter), and we had to do the first acquisition on the sky with an eyepiece," she said. "And to get to the eyepiece, I had to pull out the ladder and then put two or three telephone books on top in order to reach the eyepiece and set it up."

Sandy published her work under her initials rather than her full name, frequently leading people to do a double-take and exclaim, "Oh, you're S.K. Leggett!"

Sandy at about age 11 in Barbados displays her early affection for cats.

"When I was younger, I would kind of enjoy surprising them," Sandy said, explaining that using her initials wasn't her attempt to pass as a man. Rather, the practice stemmed from a family custom of referring to themselves and each other in letters by their initials.

Sandy was born on the Caribbean island of Trinidad and moved with her parents to Barbados when she was two. At age 12 she went to boarding school in Britain, but returned to the Caribbean every winter and spring. In Barbados Sandy described herself as a "really boring, goody-goody, academic girl. I loved to read and hardly did anything outside."

She remained on the British Isles after high school, entering Oxford University as a physics major. A born puzzle-solver (her husband teases that she'd do math problems for fun if she could), she loved math in high school, but an advisor suggested that higher-level mathematics might be too abstract. In retrospect, she notes, that instinct appeared to have been spot on. "The definition of a real number would not have appealed to me. I just love bringing up my plotting package and comparing my colleagues' models to my data, deriving a radius for an object that's 100 light years away."

It was at Oxford, as part of her bachelor's degree, that Sandy discovered astronomy. "My recollection was that I only took astronomy because it got me out of doing something else," she said. But, she liked it so much that she took on a summer project with the Oxford Observatory, measuring the strength of the absorption features of iron gas. "Looking back, I'm not too sure why that got me hooked, because we were cooped up in the basement with this furnace of hot gas," she said, noting that when the observatory asked her to come back and earn her Ph.D. in astrophysics, she said yes.

Sandy first set foot on Mauna Kea in 1985, shortly after completing her Ph.D. research calibrating Vega in the infrared. It was like coming home. "Ever since that time, I would step off the plane and when the tropical air hit me it just felt so good. It would take me back to my Caribbean childhood... the flowers, that warm humid air," she said.

In 1992, Sandy moved to the Big Island for good. She stuck to her research in the infrared, first at the University of Hawai'i at Hilo, then at NASA's Infrared Telescope Facility, then the United Kingdom Infrared Telescope (UKIRT). In 2006, she accepted her current position as astronomer at Gemini North.

These days, Sandy spends less time observing and more time at sea level behind a computer, going up on the mountain only every few months. Now, rather than just solve her own puzzles, she's involved in almost all of the research that goes on with the telescope. She's there for the beginning stages of assessing the top research proposals and helps astronomers use the software to set up their programs. In addition, she works in slotting observations into each night's queue, and assists her fellow astronomers in making sense of them. Sandy takes everyone else's data as seriously as she takes her own. "I enjoy both my own research, which is close to my heart, but also the satisfaction of observatory life, when we can acquire and send off some really good data to a PI—making sure everything comes together to get data to the investigator," she said.

Hers is an immense job, and one that involves working cohesively with a wide range of groups. "Things don't always work as they should," Sandy commented. "When the data don't come together in some way, I feel the pain of the investigator," she says.

"Sandy is as thorough about her science as anyone I know, and she cares deeply about it," said collaborator Tom Geballe, who has been working with her since the Sloan Survey contacted them in 1999 about a potentially exciting find. Over two consecutive nights at the UKIRT telescope, the two worked together to confirm the second *T*-class brown dwarf ever found. "That led to one of the most fruitful scientific collaborations in my career," said Tom, who is now a senior astronomer at Gemini North.

Tom noted that Sandy has a drive to fill in all of the details and derive as much as she possibly can from her data. That thoroughness and drive means that she often takes the coordinator's role. "Even when she's not first author on a paper, she keeps gentle pressure on everyone to get their parts done, and she just does it in the nicest way," Tom said.

Attention to detail follows Sandy home. Her zest for planning and pleasure in checking things off her to-do list has triggered endless construction projects on the house and six acres of jungle that she shares with her husband, three dogs, and three cats. The bookworm who rarely ventured outdoors as a child is now often outdoors, pruning, weeding, and driving around on her riding mower. She can spend hours among the palms and fruit trees as well as her orchids and African tulip trees. She loves ginger and heliconia–and, in a nod to her roots, a special flower called Barbados Pride. Here, in her small slice of Hawaiian jungle, Sandy can leave behind precision and give in to organized chaos. "I love the whole greenery and lushness of it, with the odd splash of color," she said. "In one part of our driveway, the color schemes have gone all haywire—orange, maroon, and red... and my iris blue all mixed together. It's all kind of a mistake, but in another way it's quite nice."

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Gemini Electronics Engineer & History Buff

Rolando Rogers

(Opposite page) *Rolando enjoys a moment bicycling with his son Rolandito.*

Beneath the quiet, professional exterior that Rolando Rogers projects as manager of Gemini's electronics and instrumentation group is a man with a fascinating life story who is looking forward to specializing in his work with light detectors over the next few years. Yet, even as his daily tasks are aimed at keeping both Gemini telescopes working well, his personal interests are aimed very much at his family and his passion for exploring the past.

Perhaps influenced by his father, a Navy officer, or by his mother, who was a history teacher, Rolando is a Chilean history buff. Given his childhood disdain for the subject, this current interest surprises even him. "I didn't like it in school," he said, "but five years ago I began buying history books. I find it amusing to set myself in the time of the characters, and I've specialized in 19th century events, especially in the War of the Pacific (1879 - 1884), the Revolution of 1891 and the War of Independence."

Rolando's interest in history recently took a fascinating turn when he found the book "*Crónica de Guerra*" (Chronicles of War) at the Santiago airport when he was on his way to Hawai'i. As it turns out, Rolando has a personal connection to the book. It was written by a relative: Arturo Olid Araya, who, at the age of 13, fought on board the ship Covadonga during the War of the Pacific in the Punta Gruesa naval combat (May 21 1879). It's fitting that even though Olid Araya is buried at the Plaza Sotomayor of Valparaiso, his work lives on in Rolando's fascination with that period of Chilean history.

Photo by M. Paredes

His interest in historical periods stops at about 1950. This is because, as Rolando points out, it's difficult to block oneself out of the history one has lived through and experienced.

Rolando Rogers Tardel (his full name) was born in Villa Alemana, in the 5th Region of Chile. He is the third of three children and jokes that he lived a sort of "gypsy family" life, since they constantly followed their father around the world on his postings as a Navy officer.

When Rolando was seven years old, the family moved to Concepción, Chile. It was a tough transition for several reasons. "Arriving in a new city, without friends, was difficult," he recalled. "But, without a doubt, the hardest thing was that not long after arriving, I was faced with the earthquake of Concepción and the earthquake of Valdivia, the greatest ever recorded in modern history." The second of these catastrophes occurred on May 22, 1960 in Valdivia, Chile. It caused a huge tsunami that washed up in Hilo, Hawai'i, about 15 hours later.

The family moved to New Jersey when Rolando was 11 years old so that his father could pick up specialized training in electronics engineering—something difficult to do at that time in Chile. There, young "Rolo" learned to speak English and had experiences that were different from what other young Chileans of his age were having back home. He helped his older brother Alejandro deliver newspapers and jokes that he waited a whole year to proudly take on the title of "Paper Delivery Boy." Alejandro, who now works as a diplomat in Switzerland, points out that his younger brother learned a lot from that job. "It was without a doubt an activity that enabled Rolando to value work and learn how to make a living," he said.

Rolando saw the experience in more practical terms. "I earned a lot of money—it was $15 a week in the year 1964," he said, adding that his father offered to help them save more money. For every dollar they earned, he would put another one in from his pocket.

After two years had gone by, and realizing that the savings account was getting substantial, their father decided that the boys could spend some of the money (under his supervision). This is how Rolando got his first telescope. It enabled him to take a couple of pictures of the Moon and planets. "Maybe other things could be observed as well, but that was enough for us at that age and we were very proud of achieving these pictures," he recalled.

Eventually, the family moved back to Chile, and young Rolando began thinking about studying medicine. His class at the "Padres Franceses" school in Viña del Mar was fortunate enough to witness an open heart surgery performed by the renowned Dr. Jorge Kaplan (the surgeon who performed the first heart transplant in Chile in 1968). Rolando remembers it well. "Fortunately, I was able to stand it," he said. "I even helped several of my classmates who fainted, but I realized that such an area was not my cup of tea." Not long after that, he followed in his father's footsteps and enrolled in Universidad Federico Santa María and studied to become an electronics engineer.

Rolando graduated from the University at age 24, and his professional career took him around the world, allowing him contribute in the most diverse professional areas. He began his career at Cerro Tololo in 1979, but then moved to northern Chile to work in Chiquicamata in the copper mining area. "It was a hard job, since I was at a concentrate smelter," he recalled. "Besides being out on the field all day with a mask and helmet, I very much missed working in a company where there are good work relations."

Possibly because of his experiences in the mining industry, Rolando quickly returned to work at Cerro Tololo. That lasted until 1991, when he set off to work in South Africa at a synthetic fuel company. He left just a year later due to the uncertain political climate in South Africa. "At that time, Frederik de Klerk, the last white president of that country, governed," said Rolando. "They had recently liberated Nelson Mandela and the situation looked unpredictable."

Rolando also had another, more compelling reason to come back to Chile. Before leaving for South Africa, he had met Gemini South Administrative Assistant Lucía Medina (at that time CTIO Administrative Assistant), whom he later married. While he was gone they wrote to each other, and eventually she gave him some good news. "She notified me that they needed a person in Tololo," he said. "That was what made me decide to apply and come back."

Rolando and Lucía have a beautiful family consisting of her eldest son Diego, 24, who studies graphic design, and

Rolandito, now 11 years old. According to Rolando, his son was a great surprise in more ways than one. "When Lucía was five months pregnant, I knew that I had to travel to the United States, and we wished to know the baby's sex," recalled Rolando. The ultrasound and the doctor confirmed that it would be a girl, news that sent Rolando off on a shopping expedition. "That was reason enough for me to buy all the dresses and skirts I could find at the exclusive shops of Rodeo Drive," he said. "It wasn't until the birth, when the midwife said, 'What a beautiful boy!' that both Lucía and I realized that we would not be using the pink crib, or the stroller, and least of all the little skirts," said Rolando, recalling that it was a shock for all of them.

Today, Rolandito is his father's weekend partner in bike rides and trips to soccer games held by Club Deportes Coquimbo Unido (their favorite team). But Rolando also helps his son with his school subjects, as needed. "If he does well, they don't tell me anything," points out Rolando, adding that if Rolandito's grades aren't good, then Lucía holds them both responsible until the grades come back up.

At Gemini South, Rolando is known for his quiet expertise and dedication to his work. But his interest in sports (like his passion for history) breaks that calm demeanor, something that his friends tease him about. Pedro Ojeda, current Senior Electronic Technician of Gemini South, recalled some of Rolando's experiences. "In spite of being a calm man, Rolando freaks out in tennis, above all when things don't work out for him," said Pedro. "He was always a winning card in tennis for the Inter Observatory-Olympics. Since he easily gets annoyed, his opponents try to take advantage of his passion and use that to win over him."

One critical tournament took place on Lucia's birthday. "We were anxiously awaiting his arrival because his presence on our team in this tournament was a sure medal for us," remembered Ojeda. "However, he couldn't be away from Lucia's birthday celebration, and we lost the medal!"

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Rough sea along the Hilo coast. A long exposure on a fine-grained transparency film transformed the surging breaks, ebbs and flows into a surreal, primal seascape.

Chris Carter. Nikon F5, Fuji Velvia, neutral density filter.

Three small potteries from El Molle Culture period (130 BC-600 AD) discovered in mid-20th century along with other archaeological material inside burials in La Turquía, a small village adjoining Hurtado, 7km southeast of Cerro Pachón. El Molle culture ceramics, the oldest found in the Coquimbo region valleys, show the cultural enrichment from the Amazon as well as from the Andes regions

Tres pequeñas cerámicas perteneciendo a la cultura de El Molle (130 AC-600 DC) y descubiertas a mediados del siglo XX con otro material arqueológico en cementerios ubicados en La Turquía, pequeño villorio contiguo a Hurtado, 7 km al sureste del Cerro Pachón. La cerámica de la cultura de El Molle, la más antigua encontrada en los valles de la región de Coquimbo, demuestran un enriquecimiento cultural resultando de aportes tanto amazónicos como andinos.

Hélène Allard. Nikon D70S, AF-S Nikkor 18-70mm

Pottery dimensions: 9 cm (height), 10 cm (diameter)
From the Museum of Archaeology de La Serena

by Masashi Chiba, Timothy Beers,
Kouji Ohta & Jean-René Roy

KYOTO
京都 2009
THE JOINT SUBARU-GEMINI SCIENCE CONFERENCE

The Subaru and Gemini observatories are pleased to host a jointly sponsored science meeting, to be held at Kyoto University, Kyoto Japan, May 18-21, 2009. An estimated 250 participants, approximately half coming from each community, will meet to present research being conducted at the two observatories and highlight ongoing and future collaborations. The joint Subaru-Gemini Science Conference is not for a specific project, such as WFMOS, but such topics are expected to be discussed.

The Gemini Observatory and Subaru Telescope have several ongoing research activities across the facilities, including an exchange of observing time on our three 8-meter telescopes. Thus, there are already multiple synergies being exploited, and we think it is an appropriate time to come together as communities, to share our science results and discuss how to best explore the expansion of such collaborations in both the near- and long-term futures.

The two primary goals of the conference are to promote a mutual understanding of both communities and to highlight the international nature of modern astronomy. Other goals are to:

- Better understand the current Subaru and Gemini instruments and science programs;
- Better understand the future instrument development plans for both observatories, including, but not limited to, WFMOS;
- Foster scientific collaborations;
- Define key areas of "niche science" for both observatories;
- Initiate scientific collaboration for, and with respect to, the International Year of Astronomy in 2009.

The Co-chairs of the Scientific Organizing Committee, Masashi Chiba and Timothy Beers, have defined the scope of the joint science conference as follows:

In the past decade, 8-meter-class telescopes such as Subaru and Gemini have played a fundamental role in modern observational astronomy. The scientific achievements from these telescopes are enormous and broad, helping astronomers worldwide to establish a fundamental understanding of the cosmos. In the era of the next-generation of extremely large telescopes, Subaru and Gemini will maintain or increase their importance and be crucial to deepening our views of astronomy, for example, through ambitious extensive survey programs, much as 4-meter-class and smaller telescopes do in the present day. We hope this meeting will build on or help initiate collaborations across the telescope communities, thereby maximizing the scientific capabilities of the communities.

This is a joint Subaru/Gemini science conference, co-sponsored and organized by the Subaru and Gemini observatories. This international conference will focus on scientific results from the wide variety of projects undertaken by the Subaru and Gemini telescopes. It is an excellent opportunity for astronomers to present and discuss their exciting results and ongoing progress from the instrumental, observational and theoretical perspectives. The principal aim of the conference is to bring together astronomers from both the Subaru and Gemini communities, to recognize and understand scientific results that both have achieved, with particular emphasis on mutual communications, collaborations, and synergies between these communities which could further generate the next set of discoveries. This opportunity will help cultivate new astronomical frontiers, with fruitful and long-term collaboration of the present and future users of the Subaru and Gemini telescopes.

The Scientific and Local Organizing Committees have been appointed. The SOC is led by co-chairs Masashi Chiba (Tohoku University) and Timothy C. Beers (Michigan State University). The LOC is chaired by Kouji Ohta (Kyoto University).

In addition to the joint science meeting, a Gemini Users Meeting will be held on May 22 at the same venue. The Gemini Science Committee will be leading the organization of the Gemini Users Meeting.

Further announcements regarding the details of registration, travel, and accommodations will be made in the near future. For more information, please contact any of the authors of this article. The Local Organizing Committee is preparing a conference web site where general information and instructions for registration will be available. Announcements will be made on the conference web site.

Scientific Organizing Committee (SOC)

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Motohide Tamura (NAOJ)
Kazuhiro Shimasaku (University of Tokyo)
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GeminiFocus


Canis Major over Gemini South by Moonlight.

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