GeminiFocus

Newsletter of the Gemini Observatory

June2005

Gemini Legacy Image / NGC 6946 / T. Rector, University of Alaska Anchorage

Gemini Legacy Image / HGC 92 / T. Rector, University of Alaska Anchorage

Gemini Legacy Image / NGC 1532/31 / T. Rector, University of Alaska Anchorage

GeminiFocus
Newsletter of the Gemini Observatory

A Look Inside

If you are a regular reader of the Gemini Observatory Newsletter this issue is probably a bit of a surprise. In an effort to better serve our user community the Newsletter has become ***Gemini*Focus** – with a new name, look and approach that are a radical departure from the past. We hope you will find the full-color design created by Gemini Graphic Artist Kirk Pu'uohau-Pummill much cleaner and easier to read. The editorial content has also changed significantly, with greater emphasis on science content and feature articles that are more appropriate to our role as a fully operational observatory.

The future of the Gemini Observatory is unfolding and ***Gemini*Focus** reflects our evolution.

GMOS-N / I. Braul, Southlands Elementary, Vancouver, Canada

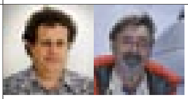
Managing Editor | Peter Michaud

Science Editor | Jean-René Roy

Associate Editor | Carolyn Collins Petersen

Associate Science Editor | Rachel Johnson

Designer | Kirk Pu'uohau-Pummill



by Matt Mountain &
Jean-René Roy

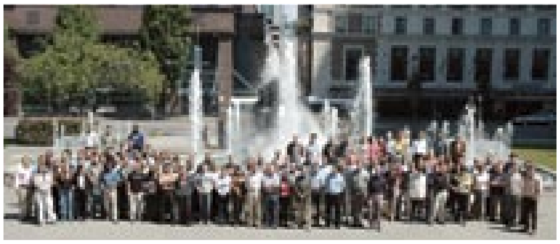
Gemini Observatory: the Next Decade

At a retreat in Oxford, UK in September 2004, the Gemini Board concluded a three-year, intensive and rigorous examination of the Observatory's future. The Board, representing the scientists and agencies of the Gemini partnership, issued the following statement:

We see the Observatory establishing a leadership role in a global effort to define, address, and solve compelling scientific questions. The answers to these questions will have a fundamental impact on our view of the Universe and our place in it. Gemini, by exploiting its unique strengths and capabilities, will be a keystone in that global effort. Among our strengths are the breadth of the partnership, the diversity and depth of our communities and staffs, our connections with other institutions sharing common scientific aspirations, and the energy and vision of our Observatory.

The Board also specified a number of changes in observatory operations while endorsing the Gemini community's scientific roadmap for the partnership, encapsulated in the Aspen Report, *"Scientific Horizons at the Gemini Observatory: Exploring a Universe of Matter, Energy and Life"* available at www.gemini.edu/nlurls.

As we approach 2006 and conclude the last year of our current operating plan, a new and vigorous program for 2006-2010 and beyond has been established. It is important to understand how we, and our communities, arrived at this pivotal point. The process was initiated in November 2002 when the Gemini Board established a Strategic Planning Group with the purpose of creating a vision for Gemini's future. Figure on fold-out highlights the key events and results that followed.



Astronomers from across the Partnership at the Gemini Science Conference, June 2004

It is not just the activities described on the fold-out (often called the "Aspen Process") that are changing the way Gemini will operate. As a result of this continuous consultation and review process, the Gemini Board (as reported in the previous Gemini Newsletter, December 2004, issue 29) has asked the observatory to initiate a number of key changes in the way we operate for 2006 and beyond:

- It's clear from the increased proposal pressure through our National Time Allocation Committees that the original plan of offering 50% queue and 50% classical has not given the community or the observatory enough flexibility in optimizing the scientific output of the two Gemini telescopes. We are now working to support both telescopes for 100% of nights, giving our communities opportunities to experiment in new and innovative ways with the observing process. These include “real-time” queue observing through “remote eavesdropping,” arbitrary-length classical or semi-classical “assisted” runs, and fully supported Target of Opportunity observations for research in areas such as supernovae and gamma ray bursters.

- As instruments and their data sets become more complex, our users are looking for more complete data sets with the telescope and instrument signatures removed (as is now the “norm” for facilities such as HST, Chandra, Spitzer and the VLT). Thorough and automated reduction of complex data sets immediately useable for research has now become a practical, and as it turns out, desirable goal for us to better enable the scientific aspirations of our user community.
- Gemini operates a unique user support model with local, national support expertise resident in each country in “National Gemini Offices” (NGOs). To make this network more effective, Gemini and its partner NGOs are working together to produce a more seamless, coordinated and accountable user support “system of systems.”
- The resources required to stay competitive in every aspect of optical/infrared ground-based 8- to 10-meter-class astronomy is today a considerable challenge for any one major observatory. However, if collectively we can give our respective communities access to a “system” of 8- to 10-meter telescopes through a greater degree of coordination and collaboration this will allow our collective communities to maintain access to a broader range of the competitive capabilities in the coming decade. The first tentative steps in this “experiment” are now being taken by the Gemini, W.M. Keck and Subaru Observatories as described on page 40 of this Newsletter.

Representatives of the Gemini Community at the Aspen Workshop, June 2003

The impact of the Aspen Process and the transformation of our operating model and partner national offices has been a three-year effort involving all Gemini partners. In particular, the Gemini Board and observatory have assembled input from its Science Committee, Science Working Groups, the National Science Advisory Committees, our AURA Oversight Committee, the Aspen and Gemini Science Workshops, the Visiting Committee, and Mid-Term Management Review Committee; collectively representing a broad and continuous consultation with our communities. By working together, we have constructed a step-by-step consensus on where Gemini and its users should head in the next decade. Due to this unprecedented collaboration between the observatory, its community and agencies, we now have an exciting scientific future ahead of us!

Committees and reports that have contributed to the Gemini vision for the next decade:

Menbership	Relevent Reports /Resolutions
Gemini Board	• Preliminary Report of the Strategic Planning Group, May 2003 • Message from the Chair of the Gemini Board, December 2004
Gemini Science Committee	• Resolutions of the GSC
Operations Science Working Group	
Adaptive Optics Science Working Group	
Wide Field Optical Spectroscopy Science Working Group	
National Gemini Offices	
AURA Oversight Committee for Gemini	
Gemini Visiting Committee & Mid-Term Management Review	• Report of the Gemini Visiting Committee and Midterm Management Review Committee • Response of the Gemini Board
Aspen Workshop	Scientific Horizons of the Gemini Observatory
Vancouver Gemini Science Conference	Program

All of these documents can be accessed at: www.gemini.edu/nlurls.

Gaining a Consensus from Across the Gemini Partnership

May 2005 - Gemini Board endorses an Aspen package that would allow the realization of most of the Aspen science objectives over the next six to eight years.

March 2005 - Multi-institutional teams from across the Gemini partnership present a comprehensive proposal for instruments and capabilities that would execute core Aspen science objectives.

October 2004 - Gemini Board holds a retreat to "seek to agree on a shared vision of Gemini's evolution and for provision of necessary resources within agreed limits." **Result:** November 2004 Gemini Board establishes guidelines for 2006-2010 and begins work with funding agencies to identify resources that will realize the Aspen aspirations.

June 2004 - Over 100 astronomers from all Gemini partners assemble in Vancouver, BC for a three-day science conference. **Result:** Almost 100 papers on Gemini results presented and a consensus emerges that the observatory should move to a higher fraction of queue-based observing.

May 2004 - Observatory selects six partnership-wide teams to prepare Aspen design and feasibility studies.

March 2004 - Combined NSF Visiting Committee/Mid-Term Management Review undertake a thorough examination of Gemini operations and development plans. **Result:** Recommendation to NSF and Gemini Board to invite AURA to propose an Operating Plan for 2006-2010 that would enable science capabilities identified in the Aspen process.

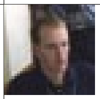
December 2003 - Observatory issues several Announcements of Opportunity to the community for Aspen instruments and capabilities.

June 2003 - **November 2003** - Gemini Science Committee works with the chairs of the Aspen panels to refine key capabilities required to address the Aspen questions. **Result:** Gemini Board releases Aspen Road Map: *Scientific Horizons at the Gemini Observatory: Exploring a Universe of Matter, Energy and Life*, (Table on previous page for URL access).

June 2003 - Gemini and partner countries hold "Aspen Workshop." **Result:** 93 astronomers participate in a two-day workshop in Aspen, Colorado. Top-level science questions on the universe of matter, energy and life are identified that Gemini could answer in unique ways.

May 2003 - Strategic Planning Group requests that the Observatory work closely with partner communities to develop Key Questions. **Result:** Several mini-workshops initiated throughout the partner countries that involve hundreds of astronomers.

November 2002 - Strategic Planning Group established by Board.



by Joe Jensen

Gemini Campaign Science

Astronomers (above) from around the globe converged in Aspen to think of ways to answer the most important questions in astronomy.

In June 2003, representatives of the Gemini partners met in Aspen, Colorado to discuss the future direction of the observatory. The participants in the Aspen meeting articulated science goals that included answering the deepest and most exciting questions we can currently pose about the nature of the universe and the characteristics that allow life to exist. The workshop participants didn't stop after posing those questions, but imagined the kinds of observations and types of instruments that could be used on the Gemini telescopes to furnish the answers.

The concepts for future Gemini instruments developed in Aspen were brought to the Gemini Science Committee (GSC) for further refinement and prioritization. The GSC endorsed the Aspen science goals, and suggested that a small number of instruments addressing the majority of the Aspen science questions be built. One of the recommended instruments is the Extreme Adaptive Optics Coronagraph (ExAOC), which would probe very close to bright stars in search of planets in orbits similar to those in our own solar system. The second instrument recommended by the GSC is the High-Resolution Near-Infrared Spectrograph (HRNIRS) designed for precision radial velocity studies to search for terrestrial planets around low-mass stars. HRNIRS would also have a second multi-conjugate adaptive optics (MCAO)-fed multi-object mode for high spectral and spatial resolution studies of multiple objects in star forming regions. These two instruments would directly address questions about how stars and planets form, and how common the conditions for life might be in the universe. The third instrument recommended by the GSC was the Wide-Field Multi-Object Spectrograph (WFMOS), which would measure 4,500 spectra simultaneously over a 1.5-degree field of view. This revolutionary new capability would allow Gemini astronomers to attack questions about the nature of dark energy and dark matter, as well as the origin and eventual fate of the universe. WFMOS would also survey millions of stars in our galaxy, helping to sort out the structure and formation history of the Milky Way. The GSC recommended that the observatory proceed with these three instrument concepts by funding conceptual design studies for HRNIRS and ExAOC, and a feasibility study for WFMOS. In addition to these top-ranked instrument concepts, the committee also recommended exploring the feasibility of the Ground Layer Adaptive Optics (GLAO) system on Gemini, which would make it possible to study the first galaxies in the universe and the epoch of reionization. GLAO would make many observations more efficient by improving delivered image quality much of the time.

The Gemini Board expressed its support for the Aspen science goals and will fund construction of as many Aspen instruments as possible. The Board's commitment on the part of the international Gemini partnership was expressed as follows:

We see the Observatory establishing a leadership role in a global effort to define, address, and solve compelling scientific questions. The answers to these questions will have a fundamental impact on our view of the Universe and our place in it.

The Board re-affirms its endorsement of the scientific goals of the Aspen program, as expressions of the aspirations of the entire Gemini community. The Board renews its pledge to actively pursue efforts to find the resources to enable the Gemini community to address these scientific issues in a highly competitive environment.

Along with this statement of the Board's resolve came a charge to the observatory, which is to;

remain an agile, responsive, innovative organization maximizing its use of the strengths of the partnership;

initiate and continually strengthen partnerships with other institutions in the pursuit of scientific aspirations we hold in common with the global community; and

explore new modes of astronomical observation and to lead in the evolution of necessary cultural, managerial, and institutional changes.

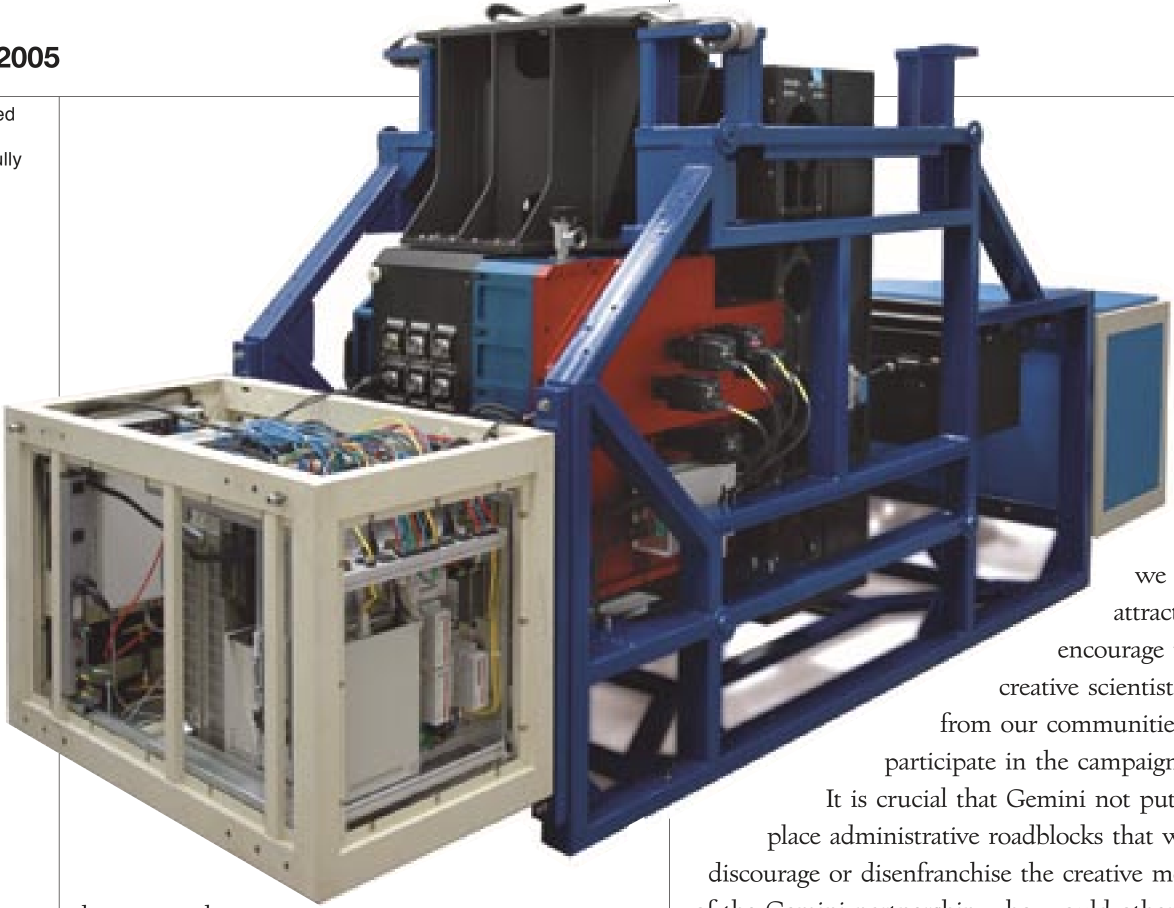
The last sentence is important. The Gemini Observatory has begun the process of defining what cultural, managerial and institutional changes will be necessary to meet the Aspen science goals.

The rest of this article describes a first attempt to construct a new way to select science teams, allocate observing time, and distribute data in support of large campaigns. The ideas described below have been presented to the Operations Working Group and GSC. As of this writing, the partners are providing feedback on these ideas. In May 2005, the Board will be asked to approve a preliminary strategy for use with the almost-complete near-infrared coronagraphic imager (NICI) based on the ideas presented here.

Campaign Science

The proposed Aspen instruments are much more specialized than the previous generation of general-purpose instrumentation. They are optimized to address particular science questions. The science questions demand both specialized equipment and large allocations of time to conduct extremely targeted surveys. The ExAOC planet search will target as many young nearby stars as possible to build up a large enough sample of planets to understand how such worlds form. This survey will take approximately 200 nights over a period of about three years. The HRNIRS planet search will take a similar number of nights, with repeat observations spread over several years. The WFMOS instrument has two large observing programs: the dark energy survey which will take 200 nights to complete, and the galactic archaeology survey of the Milky Way which could take more than 300 nights. These are truly staggering allocations of observing time, orders of magnitude larger than the typical Gemini proposal of 10 to 12 hours. It is therefore crucial that the Gemini partnership plan carefully and early to ensure success.

Construction of the near-infrared coronagraphic imager (NICI) is nearly done, with scheduled delivery to Gemini South later this year. NICI fills an important gap in our planned planet imaging surveys between current Altair adaptive optics studies, which are limited by the time-varying structure of the point-spread function (PSF), and ExAOC, which will open up a dark hole in the PSF that extends inward to within 0.1 to 0.2 arcseconds from the primary star. NICI fits between these two in both performance and in the size of the survey needed. For NICI to succeed at discovering planets, it will have to observe a



The near-infrared coronagraphic imager (NICI) fully assembled.

large enough number of stars, and it should do it before ExAOC (or a competing instrument at VLT) replaces it in three to five years. A NICI survey is likely to take about 50 nights a year for the next few years, since a sample of at least 100 stars must be observed, some of them two or more times. NICI therefore offers the perfect test bed for a new Gemini strategy for planning and executing a well-defined scientific campaign.

The Top-Level Principles

Before we embark on the Board-mandated mission of creating the new procedures to manage large Aspen campaigns, it is worth reflecting on the strengths of the way things are done now. The following principles were presented to the Operations Working Group in February of this year, where they were endorsed.

First, any new system of allocating observing time must make it possible to achieve the Aspen science goals. If we fail in this aspect of the program, the large amount of money and effort expended will have been wasted.

Second, we must attract and encourage the creative scientists from our communities to participate in the campaigns. It is crucial that Gemini not put in place administrative roadblocks that would discourage or disenfranchise the creative members of the Gemini partnership who would otherwise take the initiative to achieve the Aspen goals.

Third, access to Gemini observing time and data must be awarded on a competitive basis. The observing time must go to the best science, as recognized by a group of objective peers.

Fourth, there must be balanced and inclusive partner participation. The Board has expressed a “super-national” perspective by endorsing the Aspen science goals, and this attitude of collaboration must be preserved as the teams are formed and the time allocated. No partner will be excluded from participation, nor should any partner avoid responsibility for providing a share of the resources needed to make the Aspen science goals possible.

Fifth, the Aspen campaign teams must be open to all members of the Gemini community. Just as the responsibility for providing resources for the campaigns are shared among the partners, the benefits must also be shared. Campaign science data should be shared with astronomers from all of the partners.

Finally, Gemini must maintain access to the Aspen instruments for other science. We do not know what exciting new observations will be proposed in the coming years. We must maintain access to Gemini for those whose science is not directly related to the large campaigns. The observatory is a versatile resource that must continue to meet the needs of the entire Gemini community.

Allocating Time to Large Science Campaign Teams

Setting aside the hundreds of nights necessary to achieve the Aspen goals requires a new strategy. If we naively relied on the current time allocation process for the campaigns, each team would be faced with the multiple jeopardy of nine national time allocation committees (TACs) twice a year for several years. While this would preserve competition and partner share balance, it would be unmanageable for several concurrent campaigns, and might well result in failure if the TAC allocates insufficient time for a particular survey. It would also discourage potential principal investigators and suppress creativity.

It is important that the Director allocate the campaign time before the regular International TAC time to guarantee that the Aspen science goals are met. The Director will decide how much time is needed for a given campaign after consulting with the outside experts that serve on the different Science Working Groups and the GSC. The Board will then approve the proposed allocation.

Getting the most out of the huge data sets that will inevitably result from hundreds of nights of observing will require a great deal of effort and organization. Given the very targeted nature of the Aspen science goals, specialized international teams must be formed. Following the principles above, the Gemini Director will issue an Announcement of Opportunity for a Board-approved campaign science program. Teams will organize freely and submit proposals to Gemini. Proposals will identify resources the team can provide (scientific expertise, additional observing time or data sets, students and postdoctoral researchers, software, facilities, etc.). An independent committee of experts, perhaps incorporating international TAC members, will assess the proposals. Given that Gemini has not been funded to support large international teams, additional support will have to be found in the Gemini partner countries. Teams will have to find resources to support students and postdoctoral researchers, hold team meetings, build data processing pipelines, release data packages, and provide management oversight.

One area of concern is how to include astronomers who weren't part of the selected team. Some way to add a limited number of additional people with useful expertise and resources is being explored. It is important that teams be appropriately sized and managed to maximize their scientific productivity. The rules and conditions for adding people will be stated in the Announcement of Opportunity, and may be different for the various campaigns.

Data Distribution and Proprietary Time

The policies regarding data distribution should be defined to ensure that the Aspen science goals can be met, and that the teams and communities receive the benefits of that success in return for their hard work and financial support. In the case of the planet searches, which require follow-up or multi-epoch observations, this implies that the entire survey should be proprietary to the science team until the planets have been identified and confirmed. It is important that the team's efforts not serve only to confirm someone else's discovery. On the other hand, the WFMOS data sets could profitably be released during the survey so that other projects could go forward.

It is also important that the Aspen survey data sets be available to the rest of the community (and world) to allow other avenues of research. Such programs will increase the benefit of the survey to the Gemini community. It is therefore important that the data be released in a way that will maximize its usefulness and impact. The data should be distributed using the Gemini Science Archive, made available in discrete, well-calibrated and documented data sets. The data must be easy to use and understand. It is also expected that the Aspen data sets will be consistent with and a part of the Virtual Observatory.

Maintaining Time for PI Science

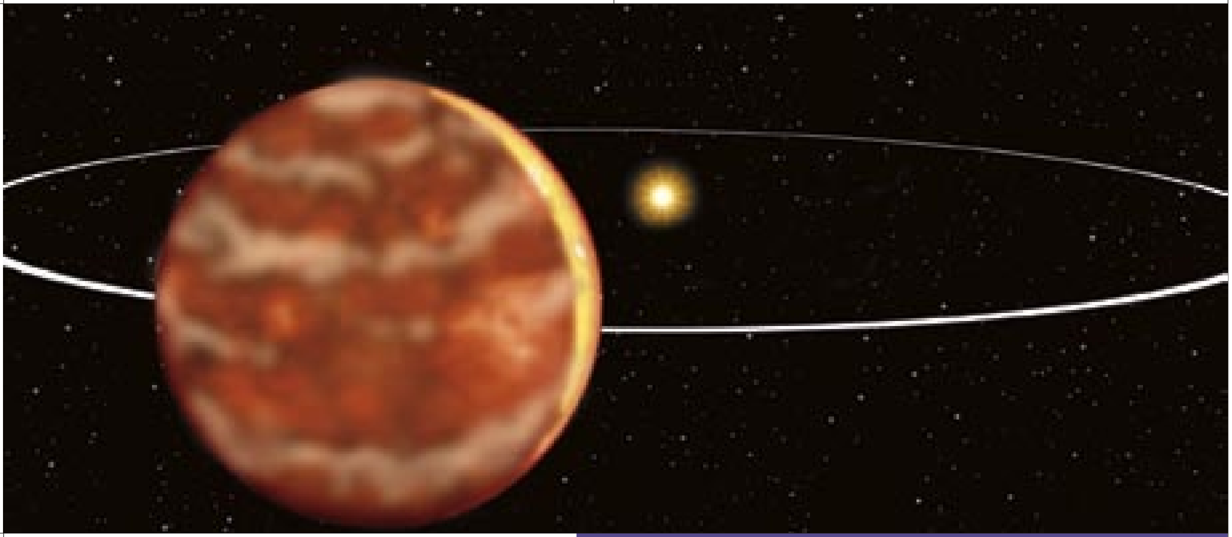
How do we make sure that time is made available for traditional principal investigator (PI)-led science when the Aspen campaigns are in progress? First, the Director will announce ahead of time the number of nights allocated to a given program over a set number of years. The number of nights will be based on the recommendation of the GSC and the Science Working Group for a particular instrument, and will be approved by the Board. The Director will balance the needs of the Aspen campaigns with the need for PI science time. The Board will provide their input in balancing the competing needs of the campaigns and the communities' access to observing time. Since the campaign size is defined before the original announcement, the approximate fraction of time available for PI science will be made public well in advance of the start of a survey.

Testing the Waters: The NICI Planet Search

The NICI planet survey will be used to develop and test procedures to be used for the Aspen campaigns. NICI will be commissioned and available for science observations by semester 2006A, and we need to start the campaign as soon as possible to take advantage of the window of opportunity that will close with the arrival of ExAOC and other similar competing instruments three to five years later. To start a NICI survey in 2006A, we need to organize a science team in late 2005. We plan to make a proposal solicitation announcement to the Gemini community by June. The team will be selected at the same time as the regular 2006A proposals. During NICI commissioning and its science verification observations, the science team will be involved so that observing techniques and data processing software can be tested.

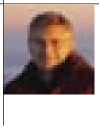
We are proposing a very tight schedule for a start to the NICI campaign. It is important, however, to use as many of the ideas developed for the Aspen program as possible so that problems can be solved and details refined. With a successful NICI program under way, we will be prepared to start organizing the Aspen science teams as soon as instrument construction begins.

The Gemini community is embarking on a mission of discovery to better understand the universe and the conditions that make life possible. Meeting the lofty aspirations of astronomers as expressed in Aspen will require expensive and complex instruments. It will also require a new way of thinking about how we go about doing science at Gemini. We look forward to developing a campaign strategy for NICI that will prepare the way for the exciting Aspen science campaigns to follow.

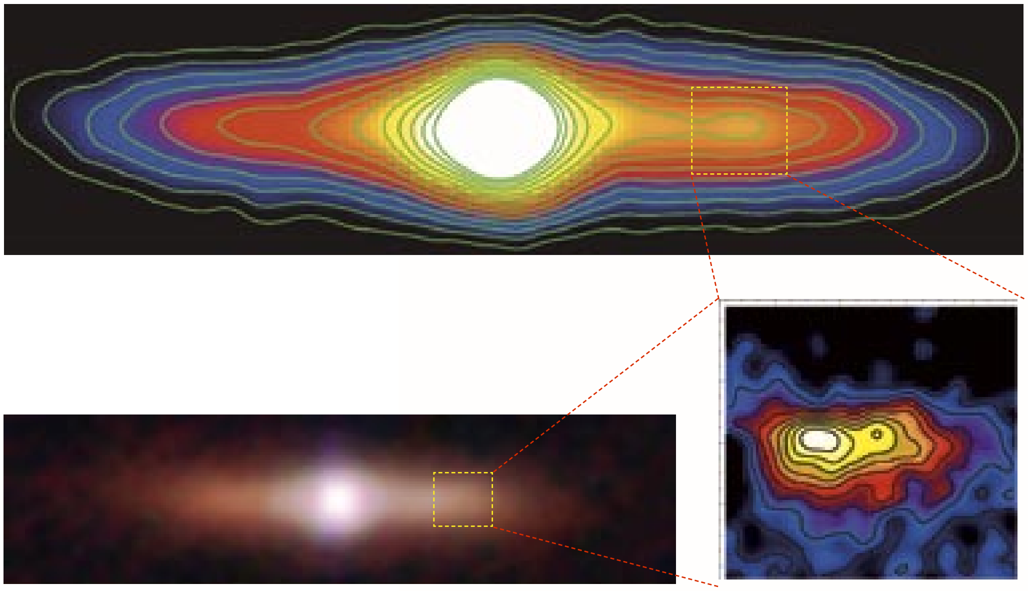


A companion object about 65 times the mass of Jupiter orbits the star 15 Sagittae in this artist's illustration. This brown dwarf is more massive than a planet and glows from its own internal heat source, but is too small to produce energy by nuclear fusion like a star.

Gemini artwork by Jon Lomberg



by Charles Telesco



Top: Image of β Pic disk at 18.3 microns (SW to right). Lower right: Detail of emission in SW wing at 18.3 microns. This tightly confined 'excess' emission is likely the result of a recent collision between two large planetesimals. Lower left: Color composite of disk using all images shown on page 13.

Exploring the Inner Disk of β Pictoris with T-ReCS

The debris disk around the main sequence star Beta Pictoris (β Pic) has remained near the center of our quest to understand the early evolution of planetary systems since its discovery by IRAS in 1984 and initial optical follow-up imaging from the ground shortly thereafter. Scattered-light or thermal-infrared (IR) images of β Pic are shown at virtually every conference or workshop on this topic to illustrate our modest but growing knowledge about these fascinating objects. The irony of this attention is that β Pic is actually an extreme example of a debris disk, with a mid-to-far IR excess second only to HR 4796A (another star- and dust-disk combination that lies about 230 light-years away in the constellation Libra) and a uniquely large diameter of at least 3,000 astronomical units (AU). As noted in other contexts though, pathological behavior can reveal the clearest, purest manifestation of basic phenomena, and in that sense β Pic is proving invaluable. In addition, its disk appears nearly edge-on, which substantially increases the surface brightness. At nearly 63 light-years (19.3 parsecs) it is realtively nearby, with the visible disk subtending nearly 155 arcseconds. Thus, both scientifically and practically, β Pic is a compelling target. Like the Orion Nebula or the Galactic Center, β Pic is invariably one of the first objects to be observed when a new astronomical instrument is commissioned in the southern hemisphere. This was the case shortly after the thermal infrared instrument T-ReCS became available on Gemini South in semester 2003B.

Extensive optical imaging of the scattered starlight from β Pic has shown that the disk beyond about 100 AU from the star appears asymmetric in a variety of ways. Most dramatically, the northeast wing of the disk is unambiguously brighter, longer, and thinner than the southwest wing, and there is an S-shaped warp of the entire disk. In addition, Hubble Space Telescope images showed that there is a structural discontinuity near 100 AU, such that the disk within this boundary (the "central disk") appears tilted by several degrees relative to the larger-scale disk. Probing the emission from the dust particles in the central disk at thermal-IR wavelengths within 10-20 AU of the star has shown that there is a central lower-density region (the central "hole") within 50 AU of the star, and, in marked contrast to the outer disk, the southwest is brighter and longer than the northeast wing in the 10- to 20-micron wavelength region. Several studies have shown that some of these properties may result from perturbations associated with planets on inclined orbits.

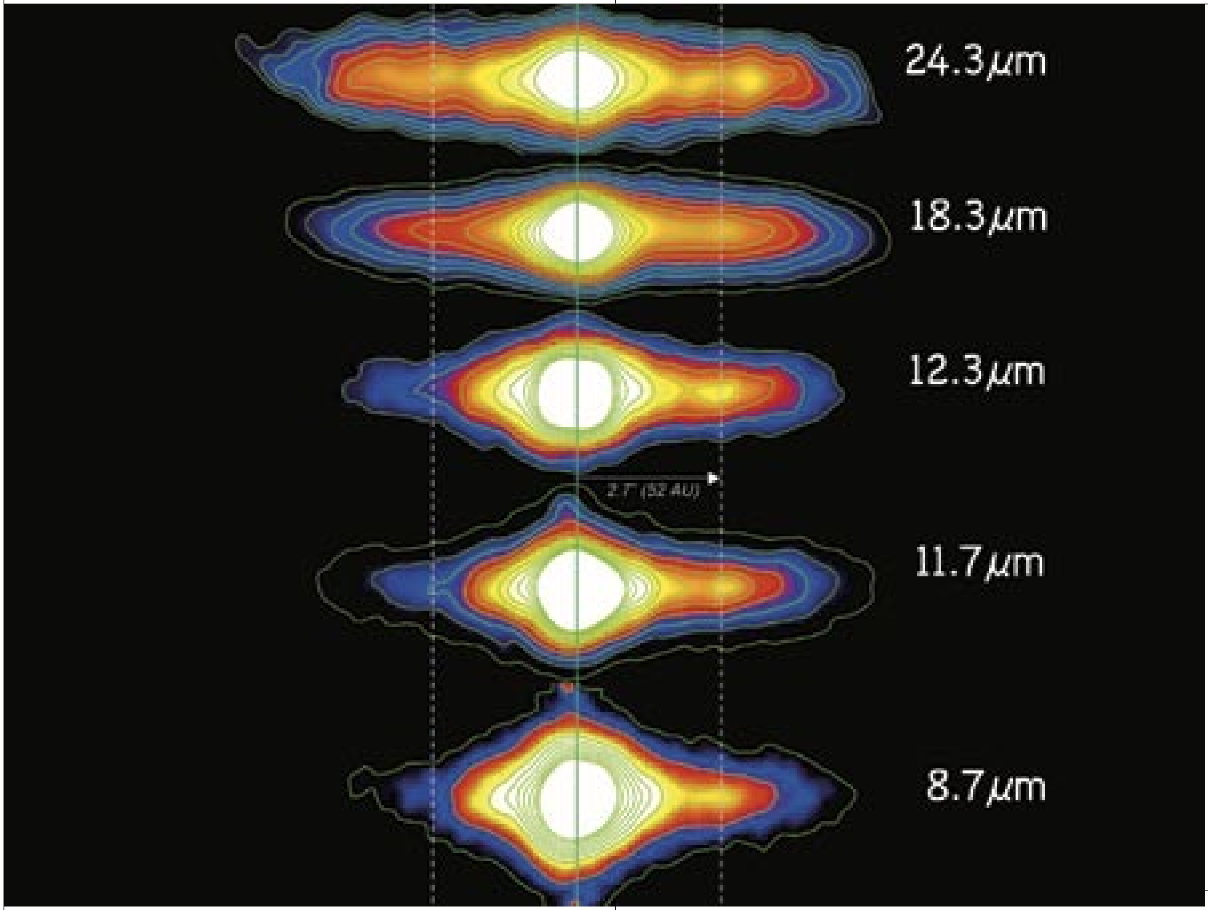
In December 2003 and January 2004, our team used T-ReCS to image β Pic's central disk in five passbands spanning the 8- to 25-microns region at close to the diffraction limit (5 AU at 10 microns) of the Gemini South 8-meter telescope. These results, presented in the January 13, 2005 issue of *Nature*, held several surprises. Our images confirmed the previously observed mid-IR brightness asymmetry, but they also showed clearly that the magnitude of the asymmetry depends strongly on wavelength. At 8.7 microns the southwest wing is nearly twice as bright as the northwest wing, whereas at 25 microns the asymmetry is negligible. This finding implies that the infrared-emitting dust particles in the southwest wing are different in some way from those in the northeast.

One simple interpretation of this finding is that, on average, the southwest wing particles are hotter and therefore smaller than those in the northeast wing. We estimate that the "characteristic" particle temperature at a projected distance of 52 AU in the southwest wing is 190 K, compared to only 140 K at 52 AU in the northeast, both of which are hotter than the blackbody temperature of 70 K at that distance from the star. For some grain materials, the corresponding typical particle sizes would be 0.1-0.2 micron in the southwest and 1 micron in the northeast. Thus, it appears that the southwest wing of the central disk is brighter than the northeast because there is this "extra" population of smaller dust particles.

A big clue to the origin of those grains is the shape of the infrared-emitting region in the southwest. The emission is dominated by a bright clump centered at about 52 AU in projection from the star. The clump appears to be spatially resolved along both the major and minor axes of the disk, having an intrinsic scale size of about 15-20 AU. If our estimates are correct, the dust particles that we see in this clump are small enough that stellar radiation pressure should remove them from the system on an orbital time scale of several hundred years. However, to appear so spatially confined they must be either continuously generated or produced in a single event within the last 50-100 years. Continuous generation of particles through the grinding collisions of planetesimals that are resonantly trapped and confined by a planet is one possible source of the clump, or we may be witnessing the recent dramatic release of particle fragments associated with a catastrophic collision of two planetesimals in the central disk.

These scenarios and plausible alternatives must still be explored in detail for β Pic, but it is interesting to speculate a bit more before all the hard facts are in. The collisional hypothesis has special appeal, because with an age of 10-20 million years, β Pic is quite young, and we know that planetesimal collisions were fundamental to the planet-building process in our solar system during its first few hundred million years. Indeed, it is thought that the Moon formed in just such a collision. The dust particles that we actually detect in the bright clump in β Pic would constitute a sphere about 100 kilometers in diameter. Larger fragments probably containing most of the mass of the original planetesimal would also be produced, but they would be cooler and undetectable in the mid-IR, so 100 kilometers is a strong minimum size. A collisional breakup that resulted in fragment velocities of a few kilometers per second could account for the minor-axis clump size, and radiation pressure acting on the dust for 50 years may have elongated the distribution along the major axis, as observed. A host of implications present themselves for observational testing of this or any other explanation for the structure of β Pic's central disk. Spectroscopy and imaging photometry of the disk will eventually reveal its secrets.

For more information, see our paper, "Mid-infrared Images of β Pictoris and the Possible Role of Planetesimal Collisions in the Central Disk," *Nature*, Vol. 433, 13 January 2005, pp. 133-136



Gemini mid-infrared images of Beta Pictoris as obtained with T-ReCS on Gemini South. Differences in the shape and strength of dust emissions within the disk can be seen as the observed wavelength changes. Note: The clump where the suspected collision occurred is to the right of the central white core at a distance of about 52 AU.

by Bob Blum

Searching for Accretion Signatures in Massive Stars

The NOAO Phoenix spectrometer on Gemini South (above)

How do massive stars form? Simple expectations based on the observed masses and lifetimes of massive stars dictate that the time scale for formation must be much shorter than for low-mass stars, and that the average mass accretion rates must be high, about 10^{-4} M_{Sun} per year. Detailed calculations suggest the formation time scale for massive stars is approximately 100,000 years. In contrast to their low-mass stellar siblings, which are more numerous and whose formation proceeds by distinct and identifiable phases over longer timescales, high-mass stars are rare. They form rapidly and are obscured by overlying envelopes of gas and dust. It is also unavoidable that during the formation of a high-mass star, a massive core will form first and begin evolving (converting hydrogen to helium) while the larger protostar is still accreting material. Despite the difficulty of discerning the massive cores as they form, progress is being made on both theoretical and observational fronts. New, large-aperture ground-based telescopes like Gemini are providing capabilities which allow us to look much farther away for these rare massive stars as they form and evolve in their birth environments. Adaptive optics, mid-infrared imaging, and infrared spectroscopy are all beginning to play a role in the quest to understand how massive stars begin their young lives and end up as optically identifiable O- and B-type stars through the process of shedding the natal cocoon through strong stellar winds and ultraviolet radiation.

Presently unique among the 8- and 10-meter class telescopes, Gemini provides a high-resolution near-infrared spectroscopic capability through the NOAO Phoenix spectrometer (above). Phoenix provides spectral resolutions of 50,000 to 75,000 through 0.34- to 0.17-arcsecond slits at wavelengths from 1 to 5 microns. My colleagues, Peter Conti (University of Colorado), Augusto Damineli, Elysandra Figuerêdo, Cássio Barbosa (University of São Paulo), and I have been working on a program to study massive star birth in giant galactic HII

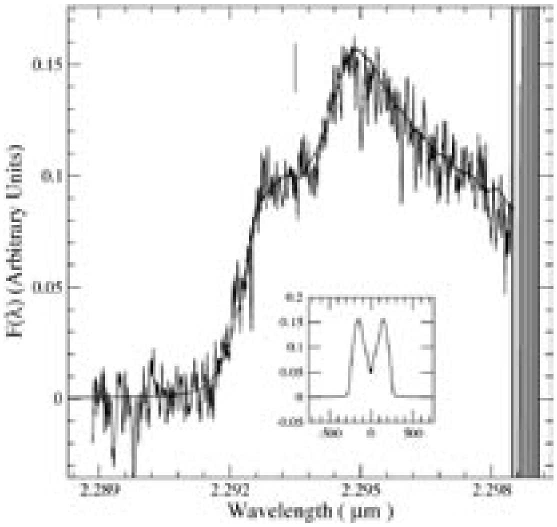
(GHII) regions such as NGC 3576 in Carina. The combination of Gemini sensitivity and Phoenix spectral resolution has allowed us to observe a set of objects toward several GHII regions and search for kinematic clues to the circumstellar geometry of newly forming massive stars.

Clearly, investigations of the earliest phases of massive star formation have centered around longer wavelengths that penetrate the large column depth of material surrounding massive protostars. However, currently achievable angular resolutions and sensitivities restrict study to a relatively few nearby sources. The Atacama Large Millimeter Array (ALMA) telescope under construction in Northern Chile will rectify this situation, complementing studies at shorter wavelengths made possible by telescopes such as Gemini. In the meantime, we can take advantage of the fact that newly formed massive stars (or massive young stellar objects (MYSOs)), while at the tail end of the stellar birth process, can be used to search for evidence of remnant accretion disks. Our ongoing survey of galactic giant HII regions in the near infrared (described in a paper published by Blum, Damineli and Conti in 2001) combined with the work of Hanson and Howarth (detailed in a 1997 paper), has led to the discovery of a sample of MYSOs with potential disk signatures.

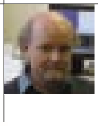
We observed each of the candidate MYSOs in ionized hydrogen wavelengths (Br-γ at 2.17 microns) and in the carbon monoxide (CO) 2-0 first overtone bandhead (2.3 microns). Both features were observed in each of the candidates at low spectral resolution. The CO bandhead has been particularly useful in studying the circumstellar geometry of lower mass YSOs since it is sensitive to the warm and dense gas lying close to the object (at small radii). Remarkably, the CO molecules survive even under the influence of the harsh radiation field provided by more massive central objects. In our initial report on four MYSOs, we successfully modeled the CO emission profile with Keplerian disks. An example of the CO emission and best fit rotating disk model is shown at right. Each of the objects was also observed in the 2.17 micron Br γ line. These lines are consistent with a disk or torus model, but in one case (source 48 in NGC 3576), the combined kinematics from the two grating settings suggest the CO itself may be coming from a physically narrow region farther away from the central star and not from a rotating disk. If true, this indicates that several CO emission mechanisms may be at play in the circumstellar environments of MYSOs. The kinematics for this source suggest a model in agreement with the results of Gemini/OSCIR imaging of the region done by Barbosa and colleagues and published in the November 2003 issue of *The Astronomical Journal*.

Our Gemini South/Phoenix observations clearly show strong evidence for an accretion process in massive stars. An independent investigation in 2004 by Bik and Thi comes to similar conclusions. All these objects are massive late O- or early B-type stars. They are found in clusters which harbor more massive stars, but the more massive objects do not show accretion signatures. They may form differently, or be more efficient in dissipating their disks through the action of their strong ultraviolet radiation and stellar winds.

Our GHII survey is continuing. We recently migrated our low-resolution spectroscopic observations to Gemini North, using NIRI and its grism capability in order to search for accretion signatures in more distant star-forming clusters. For the first time, our team has identified a source with a composite mid O-type ($M\sim/>50\ M_{sun}$) and CO emission spectrum. We are planning Phoenix/Gemini South observations of this source to see if it contains the tell-tale signature of rotational kinematics in its CO profile. Stay tuned!



The CO 2-0 first overtone rotational-vibrational bandhead for source 268 in M17. The blue-shifted shoulder of the profile and redshifted peak are characteristic of Keplerian disks. The smooth curve is a model for the emission profile arising from such a disk. The short vertical line marks the vacuum rest wavelength of the bandhead (2.2935 microns), and the inset shows the emission-line profile for a single line in the bandhead (v=2-0, J=51-50). The x-axis of the inset is in km/s and is one Phoenix grating setting in extent.



by Mike Barlow

Mid-infrared Dust Emission from Massive-Star Supernovae

Supernovae occupy a pivotal position in astrophysics. This is due to their importance as standard candles and cosmological probes, but also stems from the prime role they play in determining the overall energetics, mass recycling rate and heavy-element enrichment of galaxies. Astronomers have long suspected that supernovae may be important sources of recyclable materials in galaxies. In particular, massive-star supernovae may produce observable dust signatures over short time scales, and so are good targets for infrared imaging and spectroscopy.

We used the Michelle infrared imager on Gemini North to focus on the environment around the Type II supernova SN 2002hh, located in the nearby face-on galaxy NGC 6946 (which lies about 20 million light-years away). Our observations were obtained as part of a dual-pronged approach to understanding the contributions of supernovae to the interstellar environment.

The Survey for Evolution of Emission from Dust in Supernovae (SEEDS) collaboration, composed of astronomers from North America and Europe, obtained Spitzer Space Telescope time to search for mid-infrared dust emission from nearby supernovae hundreds of days after their outbursts, using the Infrared Array Camera (IRAC) and Multi-band Imaging Photometer for Spitzer (MIPS) instruments. In addition, we have accessed Spitzer Infrared Nearby Galaxy Survey (SINGS) Legacy data on a number of nearby galaxies that have been obtained with the same instruments, in order to search for mid-infrared emission from recent supernovae within these galaxies.

One of the earliest SINGS observations revealed strong dust emission from the vicinity of the Type II supernova SN 2002hh. Figure 1 shows the IRAC 8-micron image of the region around SN 2002hh obtained on June 10, 2004. The region is complex and, given the angular resolution of Spitzer at this wavelength (2.4 arcseconds), crowded-field deconvolution had to be used to fit the data. Five sources were identified, of which the brightest (Star 2) is a foreground 2MASS source (from the Two Micron All-Sky Survey) in our galaxy, and the next brightest (Star 1, with an 8-micron flux of 17 milli-Janskys) is located at the position of SN 2002hh. Sources 4 and 5 were suspected to be an extended HII region located in a spiral arm of NGC 6946, with a projected separation of 3 arcseconds (90 parsecs) from SN 2002hh.

It was clearly desirable to obtain mid-infrared observations at higher angular resolution in order to confirm the identity of Source 1 with the supernova. We received Director's Discretionary Time to use the Michelle mid-infrared imager/spectrometer on Gemini North to image the region around SN 2002hh at 11.2 microns and 18.5 microns. Figure 2 shows the region around SN 2002hh in the 11.2-micron Michelle image. With its ten times higher angular resolution, Michelle completely resolves SN 2002hh from its neighbors. Measurements relative to the 2MASS source (Star 2) confirm that strong mid-infrared emission originates from the position of the supernova. In addition, the Michelle data confirm that Star 4/5 is an extended source.

The mid-infrared spectral energy distribution (SED) of SN 2002hh matches a source that radiates like a 290 K blackbody with a radius of 0.1 light-year or, alternatively, like a 225 K source with an inverse-wavelength emissivity and a radius of 0.5 light-year. It would require 25 years for supernova ejecta expanding at 6,000 kilometers per second to reach the latter radius, so we conclude that the dust must have originated from an earlier mass-loss phase of the supernova progenitor.

From early-phase near-infrared spectroscopy, Peter Meikle and collaborators have estimated a visual extinction towards SN 2002hh of six magnitudes. One magnitude of that extinction can be attributed to foreground extinction by our own galaxy.

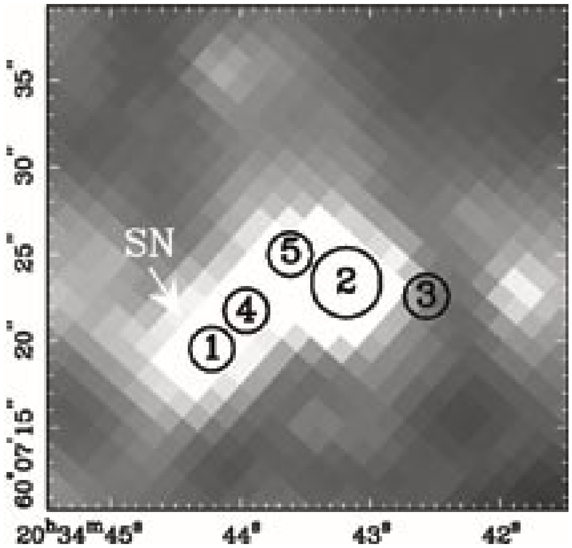


Figure 1. A SINGS IRAC 8.0-micron image of a 30" x 29" region around SN 2002hh (pixel size: 1.1 arcseconds), obtained on June 10, 2004. Five sources were fitted, with the supernova marked as Star 1 and a bright foreground field star (2MASS 20344320 +6007234) marked as Star 2.

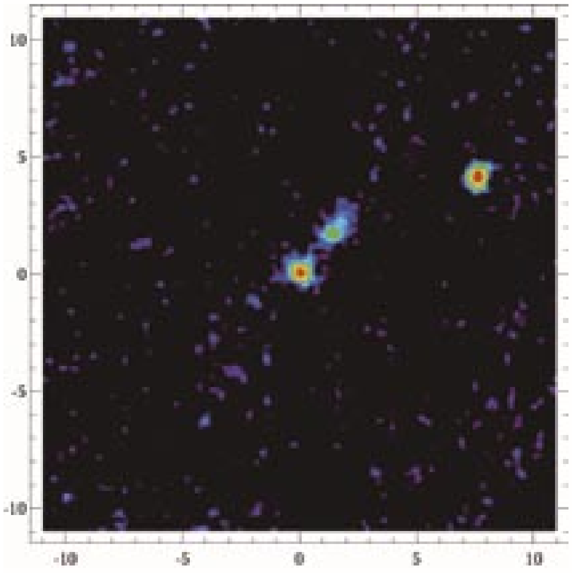


Figure 2. The Gemini North Michelle 11.2 micron image of a 21.8" x 21.8" region centered on SN 2002hh (pixel size 0.099"), obtained on Sept. 26, 2004. Offsets in arcseconds from the position of the supernova are marked on the axes. A 3-pixel (0.3") FWHM Gaussian filter was applied to the cleaned image. Both the supernova and Star 2 are easily detected in this image, while Star 4/5 is confirmed as an extended source.

Our radiative transfer modelling used a range of dust species and indicates that the observed mid-infrared SED can be fit by a dust shell of between 0.10 and 0.15 solar masses with a visual optical depth of between 3 and 4. This corresponds to a total gas+dust mass in the shell of at least ten solar masses. This is similar to those estimated for the dust shells around the self-obscured M supergiant NML Cygni and the luminous blue variable AG Carinae, suggesting that the precursor of SN 2002hh may have been similar to one of these objects.

Our observations do not rule out the possibility that significant quantities of new dust may have formed in the ejecta of SN 2002hh itself, merely that the observed infrared emission is dominated by dust located much farther out than the supernova ejecta. The relative numbers of self-obscured supernovae are unknown. For many galaxies supernovae with similar or even greater self-obscuration than the relatively nearby SN 2002hh could easily escape detection by optical supernova searches. This suggests that near-infrared-based searches may be required in order to determine the ratio of dusty to non-dusty supernovae as well as the contribution made by dusty outbursts to the overall dust enrichment rate of galaxies. Gemini Michelle time has been allocated in Semesters 2005A and 2005B for further mid-infrared follow-up studies of extragalactic supernovae for which Spitzer Space Telescope observing time has been allocated. The example of SN 2002hh demonstrates the benefits of such a dual approach.

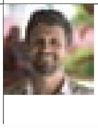
Supernovae as Cosmic Dust Suppliers

The violent explosions of massive stars as supernovae could well be major, or even dominant sources of dust particles in the universe. This idea is indirectly supported by the fact that many of the earliest-formed galaxies known are extremely dusty and luminous in the infrared. The evidence for this comes from the efficient detection of their redshifted dust emission at submillimeter wavelengths by the Submillimeter Common-User Bolometric Array (SCUBA) and other instruments. It seems that only massive stars can produce the observed dust over the short timescales implied, either during dusty mass-losing phases prior to the explosion, or else within the expanding and cooling ejecta from the supernova.

Supporting evidence for dust formation by at least some supernovae comes from precise studies of the ratios of chemical isotopes that make up the grain inclusions found in meteorites. Many of these inclusions exhibit isotopic distributions that differ significantly from those found in the Sun and Earth and have consequently been labeled as "presolar" grains, or "stardust." Some of these grains have isotopic distributions characteristic of the r-process that operates inside supernovae and is responsible for the synthesis of heavier elements during such an event. The first direct observational evidence for the formation of dust by supernovae came from studies of SN 1987A in the Large Magellanic Cloud. Mid-infrared emission from warm dust grains that had formed in the ejecta from this supernova was evident from about 500-600 days after the outburst. The same dust produced about 0.6 magnitudes of optical extinction at this time, as deduced from red-blue asymmetries that developed in the profiles of optical emission lines. The red-shifted emission from the far side of the ejecta suffered more extinction than the blue-shifted emission from the near side.

Models confirm that newly formed dust in supernovae ejecta should become detectable at mid-infrared wavelengths within 1-2 years of outburst. They also prove that the mid-infrared is particularly suitable to trace the onset of dust formation in supernovae and to determine the amount of dust formed. Supernova 1987A was an unusually close one and mid-infrared studies of other extragalactic supernovae have not been possible until recently. With the advent of ground-based 8-meter telescopes equipped with sensitive mid-infrared instruments, such as Michelle and TReCS, and the launch of the Spitzer Space Telescope, sufficient sensitivity has become available to embark on searches for mid-infrared emission from supernovae in nearby galaxies.

The SEEDS collaboration's work on SN 2002hh included astronomers from University College London; the Space Telescope Science Institute; the Gemini Observatory, Louisiana State University; the University of California at Berkeley; the University of Hertfordshire; the University of Arizona; the Kapteyn Astronomical Institute; and the University of Manchester.



by Peter Michaud

Digital Star Trails above Gemini South

Gemini Legacy Imaging

More Than Just Pretty Pictures

The Gemini telescopes are exquisite scientific instruments capable of producing some of the most detailed views of the cosmos ever obtained from the surface of our planet. This capability is already providing extremely high-quality scientific data (spectra and images) that will be reflected in the legacy of scientific papers published over the next 20 years and beyond.

As demonstrated by the Hubble Space Telescope Heritage project, there is another legacy that is possible for an astronomical observatory. It is one that presents stunning images showing our universe as only a large telescope can do. This legacy is important because it conveys the scientific potential and success of an observatory like Gemini to the members of the public. Ultimately taxpayers fund our research and sharing our "visions" is a critical element of our work.

To address this crucial aspect of our mission, Gemini has begun a campaign called Gemini Legacy Imaging. The primary driver for this ongoing program is to produce unique and aesthetically pleasing images from the Gemini telescopes that will appeal to the public and illustrate our capabilities to a broad audience (that also includes scientists).

The development of this project has been under way since the Gemini telescopes completed commissioning, but the formal adoption of the

This image of NGC 2467 is a recent addition to the Gemini Legacy image collection. It provides an incredibly detailed view of a star formation region that lies about 17,000 light-years away in the constellation Puppis. This image was produced using the Gemini Multi-Object Spectrograph at Gemini South on December 5th, 2004.

Making observations to produce striking astronomical images like this one is a very different process than acquiring data for science. To combine the best interests of science and public outreach, a concerted effort is being made to acquire all public image release data with the same specifications as any research data set. This will allow future scientific use of imaging placed on the Gemini Science Archive soon after the release of a public relations image (usually within two months of data acquisition).

Gemini Legacy Image / NGC 2467 / T. Rector, University of Alaska Anchorage program as a part of the observatory's operations is more recent. Philosophical commitment from the highest level of the observatory administration and oversight was necessary to make this program work. Part of that commitment is in the form of time to do the required observations. A nominal observing block of two hours per telescope per semester has been committed as part of the Director's Discretionary allocation. Additional time can be made available for special projects, especially those considered targets of opportunity or those with additional scientific interest.

Within these constraints, an extensive database of potential targets has been selected for imaging (primarily with the GMOS instruments). Each one has been run through the Phase II observing process, evaluated for appropriateness, and then grouped into a "primary" and "secondary" band for prioritization. Each semester a selection of primary-band targets will be activated over a range of hour angles so that they will be available at each telescope throughout a given night. This will allow flexible and timely insertion into observing windows for minimal impact on nightly schedules. We anticipate that this arrangement will allow for extremely efficient use of observing time since these relatively short programs (most are less than 60 minutes total) can be inserted into the queue with minimal impact. Seeing requirements for all Legacy imaging has been set to ~0.5 arcseconds to assure optimal image quality and accurately demonstrate Gemini's capabilities.

NEW – Make Your Own Gemini Screen Saver

The latest version of the Gemini Virtual Tour (available mid-2005) includes a interactive screen-saver maker for MacIntosh® or Windows®, that allows you to select only the images you want and customize them for your display. This is only available as part of the Gemini Virtual Tour CD-ROM which can be requested at: geminivt@gemini.edu

In all instances, data obtained for Gemini Legacy Imaging will be made public on the Gemini Science Archive within two months of in-house data reduction. All data will be fully calibrated and whenever possible, photometric conditions will be used (although they are not a requirement for Legacy imaging). Already several data sets have been made available on the Gemini Science Archive and links have been added to the Gemini Image Gallery for downloading the data.

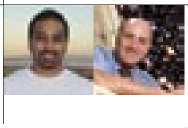
While aesthetic considerations are the primary drivers of this initiative, a process has also been developed to allow targets with scientific potential to be proposed. This allows for consideration of targets that might otherwise be ignored, especially if there is a strong scientific basis for obtaining imaging data and it is likely to result in a striking image or significant illustration of Gemini's abilities. Examples include adaptive optics imaging, Integral Field Unit data-cube animations, infrared imaging, and time-dependent targets of opportunity.

The Gemini Legacy Imaging project has already produced a number of stunning images that are available on the Gemini Image Gallery. If you haven't looked lately, take a look at the Image Gallery and download the new screensaver or posters to help share the Gemini legacy.

The Gemini Image Gallery

In an effort to make our images easily accessible to anyone, the Gemini Image Gallery (www.gemini.edu/images) has grown significantly over the past six months to include a multitude of new resources. These include:

- Full-resolution Gemini Legacy Images
- Electronic resolution image for displays and digital wallpaper
- Large print-ready PDF posters
- Broadcast-quality video
- Multiple screen resolution MacIntosh®/ Windows® Gemini Screen Savers



Gemini Tackles Key Problems in Stellar Evolution

by Jason Kalirai & Harvey Richer

CFH12K Image / NGC 2099 / Canada-France-Hawai‘i Telescope

Figure 1. This image of the rich open star cluster NGC 2099 (above) was obtained with the CFH12K mosaic camera on the Canada-France-Hawaii Telescope on Mauna Kea.

One of the key obstacles that astronomers face in developing a complete understanding of stellar evolution stems from our poor knowledge of the initial-final mass relationship. This correlation links the mass of a set of stellar remnants—the so-called white dwarfs—to the mass of their progenitors (at a point in time when they were burning hydrogen as main-sequence stars).

Recently, our team has begun to place strong constraints on this fundamental relationship. By combining data from three telescopes on Mauna Kea in Hawai‘i—Gemini North, Keck, and the Canada-France-Hawai‘i Telescope (CFHT)—we are now able to accurately determine how much material intermediate-mass stars will lose throughout their evolution. In a two-phase program, we first imaged a large sample of open star clusters using wide-field imagers on a 4-meter class telescope. In the second phase, these observations were used to feed the candidate objects to 8- and 10-meter telescopes for spectroscopic follow-up. The results of the current study are described in our paper "The Initial-Final Mass Relationship: Spectroscopy of White Dwarfs In NGC 2099 (M37)" co-written with D. Reitzel, B. Hansen, R.M. Rich, G.G. Fahlman, B. Gibson, and T. von Hippel, and published in the January 10, 2005 issue of *The Astrophysical Journal Letters*.

The CFHT Open Star Cluster Survey, which was the basis for phase one of our project, is a deep, wide-field imaging survey of rich, open star clusters in the Milky Way galaxy. These clusters typically contain several thousand stars and range in age from a few million up to several billion years old. The survey data came entirely from the 3.6-meter CFHT telescope, equipped with the CFH12K wide-field image mosaic camera. (Current observations are taken with the new MegaCam 340 megapixel wide-field camera.) Figure 1 presents an image of the rich star cluster NGC 2099 (M37) as taken with the CFH12K camera. These imaging data make it possible to determine key properties for each of the clusters, such as their ages and distances. At the same time, the depth of the survey allows us to probe to very faint stellar brightnesses and identify the now-dead remnants of once-massive hydrogen-burning stars in the cluster. These white dwarf stars represent the key ingredient in understanding the initial-final mass relationship.

In the second phase of our study, we used both the 8-meter Gemini and 10-meter Keck telescopes to obtain spectroscopic observations of potential white dwarf stars identified in the CFHT survey. New instruments on these telescopes, such as the Gemini Multi-object Spectrograph (GMOS) on Gemini North and the Low-Resolution Imaging Spectrograph (LRIS) on Keck allow us to obtain high quality spectra of dozens of white dwarfs in each cluster simultaneously. The synergy between these instruments, their parent large-aperture telescopes, and the CFHT imaging observations provides for an unprecedented study of the initial-final mass relation.

Spectral features of 16 white dwarfs observed using this approach in the rich open star cluster NGC 2099 are shown in Figure 2. Rather than showing the full spectrum, each panel presents the hydrogen Balmer absorption lines for each white dwarf. Hβ is shown at the bottom of each panel, with subsequent higher order lines on top. In the case of hydrogen atmosphere white dwarfs, these are the only features present in their spectra (a consequence of the large gravity in these stars which causes other elements to "sink"). By fitting the morphology of each of these absorption lines to theoretical model white dwarf spectra of known pressures, temperatures, and masses (shown in red on Figure 2) it is possible to derive these parameters for each star. For this, we used the white dwarf models, and spectral fitting routines devised by Dr. P. Bergeron at the Université de Montréal.

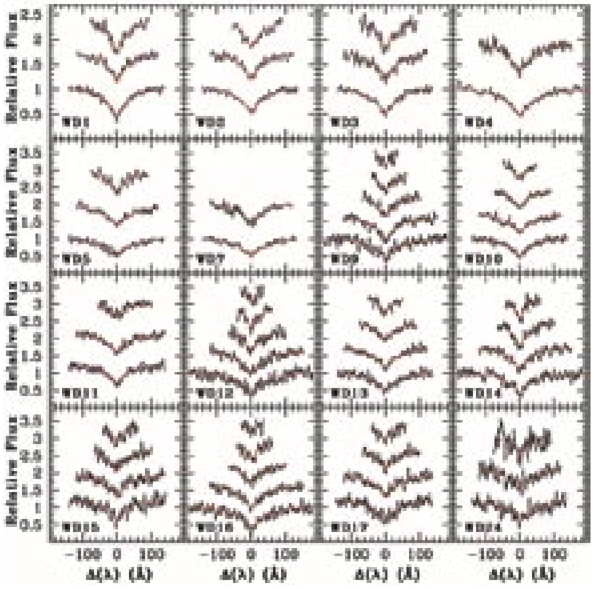


Figure 2. Spectral line profiles of the hydrogen-Balmer (Hβ) lines of 16 white dwarfs in the open star cluster NGC 2099 with model fits in red. Each panel shows the Balmer lines for one star, with Hβ at the bottom and higher order lines at the top. All spectra were acquired with Gemini/GMOS and Keck/LRIS. The models and spectral fitting routines were provided by Dr. P. Bergeron at the Université de Montréal.

Our results indicate that the mean mass of the white dwarfs in NGC 2099 is ~0.8 solar masses, making them about 0.2 solar masses more massive than typical white dwarfs in the disk of our galaxy. This result is related to the age of the cluster NGC 2099. Comparison of stellar evolutionary models (from F. D'Antona and P. Ventura at the Osservatorio Astronomico di Roma) with the CFHT photometry for brighter cluster stars indicates that the age of NGC 2099 is 650 million years. At this age, only those hydrogen-burning stars with masses more than 2.5 solar masses have had enough time to evolve into white dwarfs (since more massive stars evolve faster).

To quantify the initial-final mass relationship for these stars, we first determine the white dwarf cooling age for each star ($T_{cooling}$). This age represents the time that each white dwarf has spent traversing from the tip of the asymptotic giant branch (AGB) down to its present white dwarf luminosity. This age is easily determined from the white dwarf cooling models once the mass of the white dwarf is known. Next, we calculate the lifetime of the progenitor main-sequence star that produced the white dwarf (T_{MS}). This is simply the difference between the cluster age ($T_{cluster}$) and the white dwarf cooling age ($T_{cooling}$), which can be expressed as:

$$T_{MS} = T_{cluster} - T_{cooling}$$

Using models of main-sequence stars, the mass of the white dwarf's progenitor star can be determined from the progenitor lifetime. We now have final masses for all white dwarfs, and initial masses for the stars that produced them.

In Figure 3 (top) we present this calculation in the form of an initial-final mass relationship. First, this study of NGC 2099 white dwarfs (filled circles) has almost doubled the number of data points on the relationship from all previous studies combined (shown as triangles). We also find a very tight correspondence between main-sequence stars with an initial mass between 2.8 and 3.4 solar masses and resulting white dwarf masses between 0.7 to 0.9 solar masses (Figure 3, bottom). The results clearly indicate that intermediate-mass stars will lose 70 to 75% of their mass through stellar evolution.

With the success of this pilot study, we are confident that these techniques can be extended to other open star clusters of different ages. In Figure 4, we present the color-magnitude diagrams (CMDs) of NGC 2099 and five other rich open star clusters (all observed with CFHT). Possible white dwarf candidates in these clusters are shown as darker points in the faint blue end of the CMD. Given the different ages of these clusters, future studies will constrain a different range of progenitor masses than the present work. Therefore a complete mapping of the initial- to final-mass relation will soon be possible. For this, we have already begun a Gemini South program to look at the young cluster, NGC 2323.

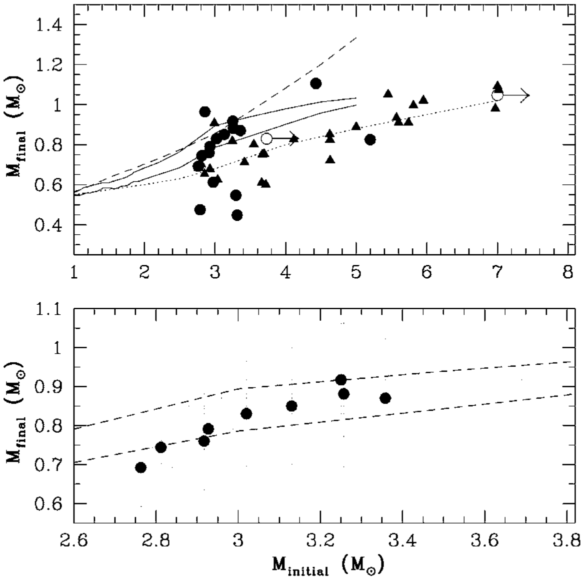


Figure 3.
The initial-final mass relationship is shown for stars in this work (filled circles) and all previous constraints (triangles). Also shown are several semi-empirical and theoretical relations discussed in Kalirai et al. (2005).

(Bottom) A closer look at the white dwarfs that form the tight sequence with initial masses between 2.8 and 3.4 solar masses (all of which have lost 70-75% of their mass through stellar evolution).

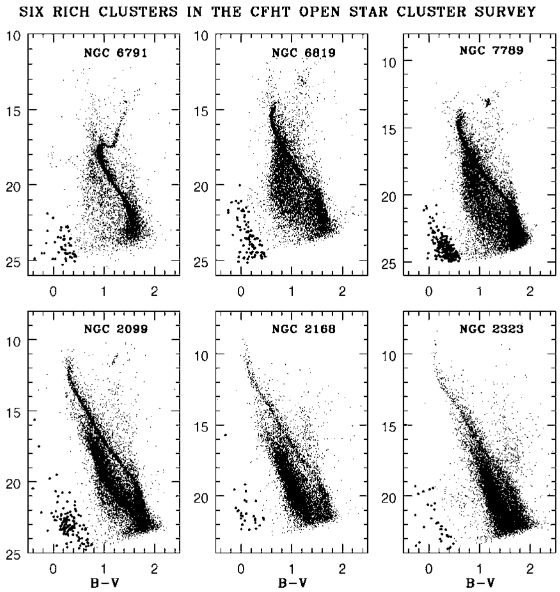


Figure 4.
The color-magnitude diagrams (CMDs) of six rich open star clusters in the CFHT Open Star Cluster Survey are shown. The ages of the clusters vary over a large range: 8 billion years (NGC 6791), 2.5 billion years (NGC 6819), 1.7 billion years (NGC 7789), 650 million years (NGC 2099), 180 million years (NGC 2168), and 130 million years (NGC 2323). White dwarf candidates in each cluster are shown as darker points in the faint-blue end of each CMD.

White Dwarfs: Nature's Stellar Diamonds

Observations of stellar evolution and the resulting theory about how stars are born, live, and die give strong evidence that all stars expel a large fraction of their mass throughout their lifetimes. The most intensive phase of this mass loss takes place late in a star's lifetime. When it nears the end of its life, a star's central region contains less fuel for hydrogen burning. This core region contracts until the temperature gets high enough to start the nuclear fusion of helium. The structure of the star changes dramatically as hydrogen in the shell surrounding the core also begins burning. Depending on the star's initial mass on the main sequence (where a star spends most of its hydrogen-burning lifetime), it then enters an unstable period where variations in its temperature, radius and luminosity occur. This can result in more structural changes in the star as it gently blows off its outer layers.

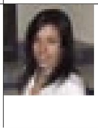
For stars more than about seven times the mass of the Sun, the ultimate effect of these instabilities is a spectacular supernova explosion. Stars less than seven solar masses enter a short phase (a few thousand years in duration) that includes successive episodes of mass loss. Eventually all that's left is a stripped stellar core of carbon and oxygen mixed with a dense, compressed gas of electrons that determine the structure of the remnant. This end product of stellar evolution is called a white dwarf.

Planetary Nebula BD+303639 / Gemini Observatory + University of Hawai'i

The properties of these stellar corpses are fascinating because of the curious nature of the highly compressed, highly conductive electron gas. In astrophysical terms, they form what is called a "degenerate gas" that cannot be compressed any further. It actually behaves like a solid. This incompressible quality of white dwarfs has led some to call them "the largest diamonds in the universe."

The white dwarf phase of a star can last for billions of years, and during this time the object does not generate energy by thermonuclear reactions. The energy that radiates is sustained simply by cooling, just as a hot piece of iron metal emits radiation as it cools.

White dwarfs have an average diameter of about 10,000 kilometers, roughly the size of the Earth. However, a white dwarf's mass is about half that of the Sun, which makes its density about a million times that of most common solid elements found on Earth.



by Stephanie Juneau

Did The Most Massive Galaxies Form First?

A Gemini-based study has led to the discovery of a population of red and massive galaxies in the "redshift desert," a zone in the universe that lies between a redshift of 1.3 and 2 and looks back at an era when the cosmos was between a quarter and half of its present age. This finding stems from observations done as part of the Gemini Deep Deep Survey (GDDS), an ultra-deep redshift survey looking out to a limiting magnitude of 20.6 in the K band and to 24.5 in the I band, targeting galaxies in this relatively unexplored region of the universe. The region in question was designated the "redshift desert" since massive galaxies in that redshift range lack strong spectral features at visible wavelengths. As a result, it proved extremely difficult to obtain spectroscopic redshifts until very recently. The survey seeks to construct the largest mass-limited sample of galaxies in this zone. In particular, the GDDS team aimed to discover galaxies with stellar masses similar to that of the Milky Way, which lie up to 9.9 billion light-years away (corresponding to a redshift of $z = 1.8$). This very challenging task is described in a series of papers stemming from the GDDS survey and available on the GDDS website (URL on page 29).

The spectra for the study were obtained using the Gemini Multi-object Spectrograph (GMOS). The team implemented the Nod-and-Shuffle observing technique that allows excellent sky light subtraction (to 0.1% accuracy) and deep exposures (with an integration time of 30 hours). This is a key element in obtaining high-quality spectra of faint galaxies. The main result from the GDDS is the discovery of a very significant population of red and massive galaxies at $1.3 < z < 2$, whose integrated light is dominated by evolved stars. Along with complementary studies from independent teams (most notable the VLT K20 survey), this was a major contribution to establish the abundance of massive galaxies at $z > 1$.

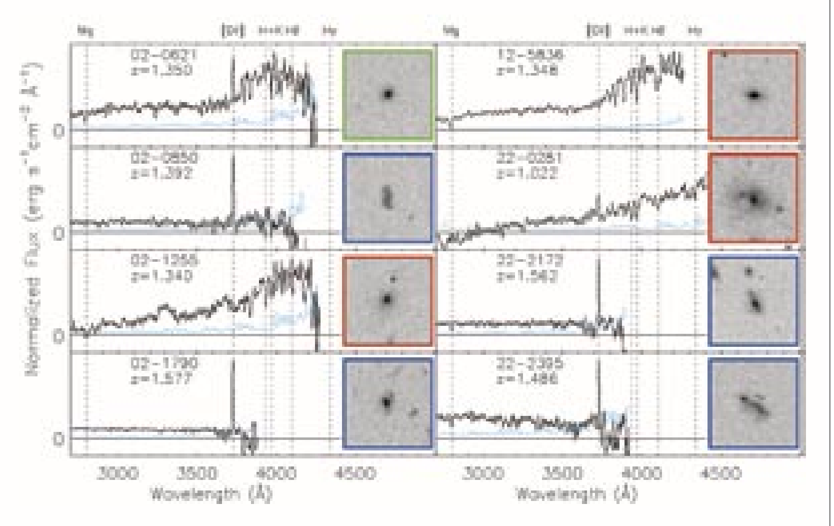


Figure 1. Example spectra showing a range of star formation activity in the GDDS galaxies. The images were obtained with the Advanced Camera for Surveys on the Hubble Space Telescope and show the morphology. The color of the image frame is keyed to the spectral classification: early-type in red, late-type in blue and intermediate-type (i.e. with both an evolved stellar population and ongoing star formation) in green. The sample shown here illustrates the "mixed bag" of galaxies observed by the GDDS.

Massive galaxy abundance declines at $z > 1$ but the rate of decline is slower than the simple models predict. The population remains significant at $z = 2$. One question that arises is whether star formation is more efficient in high-mass galaxies. Recent findings demonstrate that the evolution of the rate at which galaxies form their stars changes according to their total stellar mass. This new piece of evidence was obtained by measuring the star formation rates for a sample of 207 galaxies from the GDDS. The classical "Madau-Lilly" diagram quantifies the overall star-formation rate of the universe over time. Combining this information with the total stellar mass of galaxies is a new and promising approach in understanding how galaxies assemble the bulk of their stellar content.

One technique successfully used by the team to infer the total mass of stars in galaxies is to measure the red light (K band), which traces approximate stellar populations. Two strategies were combined to calculate the rate of star formation. First, the amount of star formation was estimated from the light emitted in the ultraviolet (UV) region of the spectrum. In normal galaxies, the signal at these wavelengths is predominantly generated by the newborn stars. Another commonly used indicator of star formation activity is the oxygen spectral line at wavelength 3727 Ångstroms. The energetic UV photons emitted by young OB stars ionize the oxygen present in the surrounding molecular clouds. Upon recombination, oxygen atoms emit photons at 3727 Ångstroms, which creates a strong emission feature in the spectrum. Some example spectra of galaxies with a range of star formation activity are shown in Figure 1. For the GDDS galaxies, both star formation rate tracers were combined.

Due to the stochastic nature of star formation events, the rate in individual galaxies can vary drastically, from hundreds of solar masses per year for a galaxy hosting giant bursts to essentially zero for passively evolving stellar populations. However, general trends can be revealed by averaging sub-samples of galaxies.

The star formation history is assessed by computing the density of star formation rates at different epochs over cosmic history. With its approximate mass selection, the GDDS allowed us to do this as a function of stellar mass. Figure 2 shows the comparison of our values of star formation rate densities with a compilation of results from 33 studies carried out between 1996 and 2004 (summarized by Hopkins in 2004). The key result is the clear dependence of the star formation history on the galactic stellar mass: high-mass galaxies go through the peak of their star formation activity at higher redshift. In a previous study by Heavens and colleagues, and based on nearby galaxies, it was suggested that such a dependency with galaxy present-day stellar mass exists. There, the star formation history was reconstructed from the analysis of the fossil traces of accumulated stellar populations. Here the equivalent relationship between formation history and stellar mass is tested directly at the epoch of observations.

The ratio of the total mass locked in stars to the star formation rate (SFR) gives a timescale. This characteristic growth timescale ($T_{SFR} = M^* / SFR$)

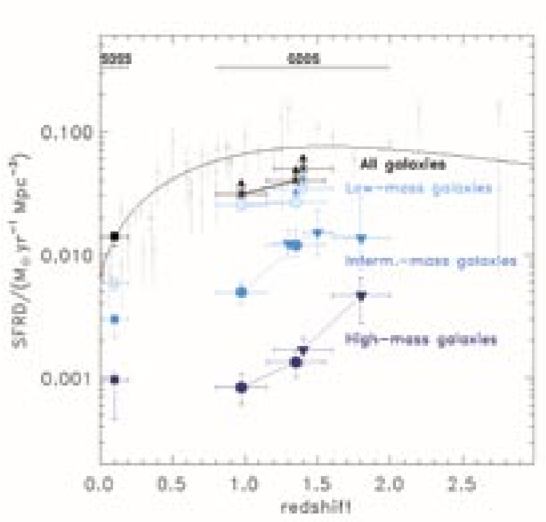


Figure 2.
This figure shows redshift-evolution of the star formation rate density (SFRD). The gray points show the compilation by Hopkins (2004). The sample of GDDS galaxies is split according to their stellar mass: low- ($10^9 – 10^{10.2}$ M_s), intermediate- ($10^{10.2} – 10^{10.8}$ M_s) and high- ($10^{10.8} – 10^{11.5}$ M_s) masses. The two indicators of star formation rates used are the [OII] 3727 emission-line (circles) and the rest-frame UV continuum at 2000 Ångstroms (triangles). SFRD data from the SLOAN Digital Sky Survey as reported by Brinchman (modified with our dust correction model and initial-mass function) are split into the same mass bins and shown as low-redshift counterparts (squares).

corresponds to the time required for a galaxy to assemble its mass, assuming that it forms stars at a steady rate. A simple interpretation of the mode of star formation emerges from the comparison of T_{SFR} with the Hubble time $T_{H(z)}$, the age of the universe at a given redshift *z* (or epoch). Figure 3 illustrates this concept. If the values are equal, a galaxy has enough time ahead to produce all of its stars. At a given redshift, $T_{SFR} > T_H$ suggests that the galaxies are in a declining or quiescent star formation mode. Conversely, $T_{SFR} < T_H$ indicates they are going through a burst phase.

Figures 2 and 3 demonstrate that the most massive galaxies formed most of their stars in the first three billion years of cosmic history. Intermediate-mass objects continued to form their dominant stellar mass for an additional two billion years, while the lowest-mass systems have been forming over the whole of cosmic time. This view of galaxy formation clearly supports "downsizing" in the star-formation rate (a mechanism proposed by Cowie in 1997), where the most massive galaxies form first and galaxy formation proceeds from larger to smaller mass scales.

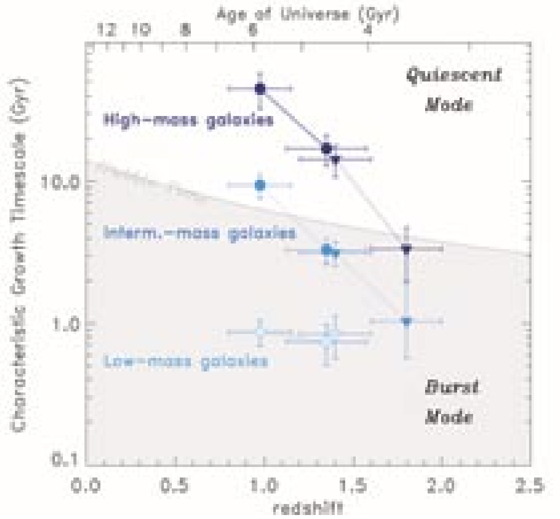
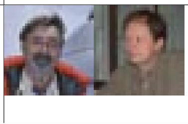


Figure 3.
The sample of galaxies is split according to their stellar mass: low- ($10^9 – 10^{10.2}$ M_s), intermediate- ($10^{10.2} – 10^{10.8}$ M_s) and high- ($10^{10.8} – 10^{11.5}$ M_s) masses. For every subsample, the ratio of the total stellar mass density to the star formation rate density gives the characteristic growth timescale. This timescale allows us to understand the mode of star formation when it is compared to the Hubble time (gray line).

These findings were rather surprising with respect to the early predictions of the hierarchical galaxy formation model. According to that model, massive galaxies form from an assembly of smaller units. The most massive objects therefore form last. However, the GDDS study of the most massive and quiescent galaxies back to an era only three billion years after the Big Bang point toward early formation for a significant fraction of present-day massive elliptical galaxies.

These findings could be reconciled with more modern versions of the hierarchical model if one posits a faster early star formation rate in more massive halos. Debate has ensued in the theoretical community as to the mechanism involved. This is another example where pushing the limits of the observable tightens the constraints that the models must satisfy and adds a piece to the puzzle. For more details, see the original paper at http://www.journals.uchicago.edu/ApJ/journal/issues/ApJL/v619n2/18987/brief/18987.abstract.html.

GDDS data and publications are available at www.ociw.edu/lcirs/gdds.html.



by Jean-René Roy
& Phil Puxley

Recent Science Highlights

Ultraluminous X-ray Source in the Spiral Galaxy M101

Ultra-luminous X-ray sources (ULX) with luminosities greater than 10^{39} ergs/second are suspected to be associated with intermediate-mass black holes of 100 solar masses or more. During the period of July 5-11, 2004 the source ULX-1 in the spiral galaxy M101 (which lies at a distance of about 5 megaparsecs, or 16 million light-years) was observed by Chandra to be in a brief period of "high state."

A team led by K. D. Kuntz of the University of Maryland used GMOS-North on Gemini to target a faint source seen in images taken by Hubble Space Telescope's Advanced Camera for Surveys. The team obtained a spectrum on July 22 of the V_{mag} ~23.7 faint optical source co-located with the X-ray source. The GMOS data show spatially unresolved He II 4686 emission that is associated with very high excitation. The line is consistent with an expansion velocity of ~600 kilometers per second. The fact that it appears as a point source indicates that this high excitation optical emission is not of nebular origin but is coming from a compact object. The team hypothesizes that ULX-1 is a high-mass X-ray binary, where the stellar wind of a B supergiant star accretes into a black hole companion.

Ultra-massive Black Hole at the Center of Centaurus A

The Gemini Near-Infrared Spectrograph (GNIRS) has unlocked new possibilities for the study of central black holes in dusty galaxies. Julia D. Silge of the University of Texas and her collaborators have used GNIRS to derive the central stellar kinematics from the signatures found in CO (carbon monoxide) bandheads at 2.3 microns in the galaxy NGC 5128 (Centaurus A). Located at a distance of about 3.4 megaparsecs (11 million light-years), this galaxy is an important object for our understanding of central black holes, galaxy mergers, active galactic nuclei, and the relationships among these components of galaxy evolution. NGC 5128 contains large amounts of dust which hamper optical spectroscopy, especially in the central regions that are critical for accurately measuring black hole mass.

Exploring orbit-based models to match the GNIRS spectra (Figure 1), the authors favor a solution with an edge-on model, and derive a black hole mass of 240 million solar masses. This is five to ten times higher than that predicted by the correlation between black hole mass and velocity dispersion. The GNIRS result is important because it confirms the earlier derivation by Marconi and colleagues in 2001 of a very high-mass black hole based on the kinematics of the gas. The motion of the gas could be due to other mechanisms, like ejection, instead

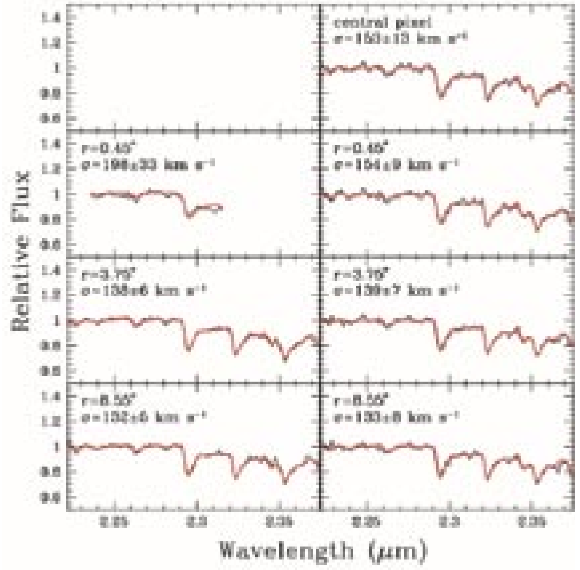


Figure 1. Rest-frame spectra of seven example spatial bins (jagged black line) and for the template model stellar spectrum (red line) at different distances from the center of Centaurus A. Three CO bandheads are clearly seen as deep absorption features around 2.3 to 2.35 microns.

of being orbital. Stars are much more robust tracers of orbital movement. The deviation of Centaurus A from the correlation suggests that its black hole assembled first, before the main host galaxy component formed.

Counter-rotating Structures in Galaxies

Several Gemini observing programs are aimed at understanding the structure and kinematics of nearby galaxies, and establishing the role and effects of past mergers on galaxy morphology. One GMOS-North study using long-slit spectroscopy by Peter Yoachim and Julianne J. Dalcanton of the University of Washington explored the rotation curves at and above the midplanes of the edge-on galaxies FGC 227 and FGC 1415. The team used the calcium triplet spectral lines around 850-860 nanometers to separate thin and thick disk stellar kinematics. In FGC 1415, the above-the-plane rotational speed of the stars is 30 to 40% less than at the mid-plane. In FGC 227, not only is the above-the-plane motion less than 25% of the mid-plane velocity, but it is also counter-rotating (Figures 2 & 3). The presence of a counter-rotating thick disk in FGC 227 rules out models of thick disks forming from monolithic collapse, or by heating of thin disks, and suggests direct accretion from infalling satellites.

In a parallel study of the low luminosity elliptical galaxy NGC 770 using the integral field unit on GMOS-North, M. Geha and collaborators used internal stellar kinematics to find a counter-rotating core. The authors propose that NGC 770 accreted a small gas-rich dwarf galaxy during a very minor merging event. If this scenario is correct, it represents one of the few known examples of merging between two dwarf-sized galaxies.

The Presence of Steam Betrays a Low-mass Brown Dwarf

Kevin Luhman (Harvard-Smithsonian Center for Astrophysics (CfA)), Dawn Peterson (University of Rochester) and S. T. Megeath (also from CfA) used the newly commissioned GNIRS on Gemini South to determine the nature of the low-mass object OTS 44. The observations of the faint infrared object confirmed that it is a very low mass, newborn brown dwarf, and the lowest-mass one found to date in the Chamaeleon I cloud complex. This is a nearby star-forming region located about 170 parsecs (about 550 light-years) away from us toward the southern hemisphere constellation Chamaeleon.

Astronomers have found many types of objects in orbit around stars or as free-floating objects. These range from other full-sized stars like the Sun (some in binary star systems) to Jupiter-sized planets (never directly imaged but inferred from radial-velocity spectroscopy).

From the strength of the water vapor (steam) absorption band found in the spectra at around 1.5 and 2 microns, and in comparison to other low-

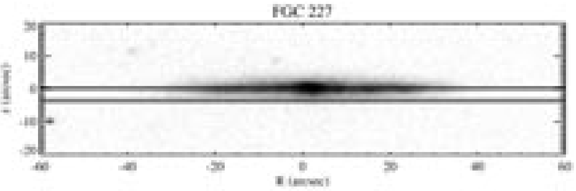


Figure 2. R-band image of the flat galaxy FGC 227. Solid lines represent the location of the slit for the mid and off-plane GMOS long-slit observations.

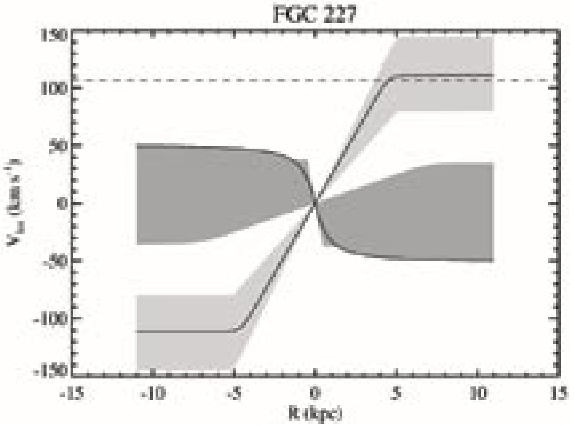


Figure 3. The rotation curve of the mid-plane (light shade and larger amplitude) and off-plane (dark shade and smaller amplitude) rotation curve; shaded areas show the full range of the fits for FGC 227.

mass stellar objects, the team determined OTS 44 to be of very late spectral type M9.5 (Figure 4). They estimate its effective temperature at 2300 K. Using the flux in the H band and the object's distance, Luhman and his team derived a bolometric luminosity of almost 800 times less than our Sun. Models of low-mass stars were used to infer the mass of OT 44 at about 1.5% the mass of the Sun and about 15 times the mass of Jupiter. Unlike older brown dwarfs (which have smaller sizes), this young object is relatively large with a radius of about one-quarter that of the Sun or 2.5 times that of Jupiter.

First Measurement of Hyperfine Splitting Constant in an Astrophysical Object

A joint Chile-United Kingdom team led by Simon Casassus has used the NOAO-built Phoenix near-infrared spectrometer at Gemini South to obtain high-resolution (R~75,000) spectroscopy of the [Al VI] 3.66-micron line region in the planetary nebula NGC 6302 (the Bug Nebula). By modeling the multi-component line structure, the authors have been able to derive values for the electric quadrupole constant in the [Al VI] transition and measure a reliable isotopic ratio for aluminum. This is the first measurement of such a constant in an atomic transition in any astrophysical object (figures on opposite page).

Most observed spectral lines arise from electronic transitions between well-separated energy levels. However some transitions take place between very finely separated energy levels. A good example would be the hyperfine structure (HFS) lines due to interaction between the internal magnetic field produced by the motion of the electrons of an atom and the spin magnetic moment of its nucleus. This effect is well understood in terms of quantum mechanics. While hyperfine transitions are common in the radio range (the best known is the 21-centimeter line of neutral hydrogen), at shorter wavelengths atomic HFS has seldom been resolved in emission lines because the velocity separation between hyperfine components is proportional to wavelength. This tends to broaden the lines and ignoring the effect can result in errors of ~50% in the inferred photosphere elemental abundances.

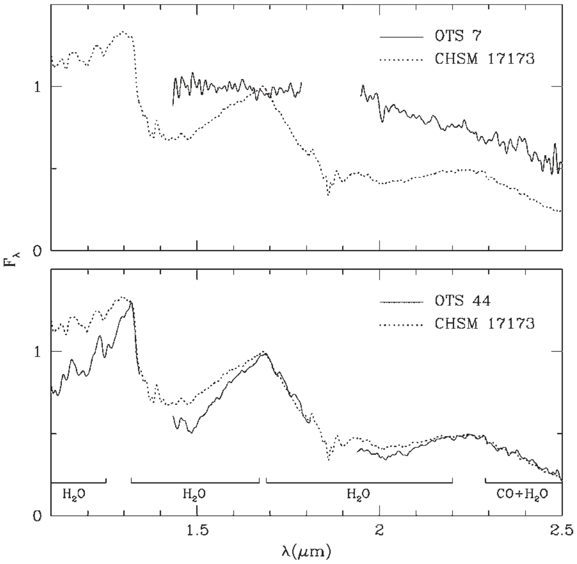


Figure 4.
Spectra of OTS 7 and OTS 44 are shown with CHSM 17173 for comparison. Regions of spectral water lines are indicated at bottom.

Of astrophysical interest is the isotopic ratio of aluminum (Al-26/Al-27). Al-27 is the stable isotope, while Al-26 is radioactive with a half-life of 720,000 years, and is a signpost of recent nucleosynthesis. Because the ratio is poorly established, the origin of Al-26 is currently assigned to a range of astrophysical processes ranging from nova detonations to cosmic-ray collisions in molecular clouds.

NGC 6302 is the highest excitation planetary nebula known. Its spectrum can be reproduced by ionization-bounded photoionization models with a 250,000 K central star. The photoionized coronal lines in NGC 6302 are astonishingly narrow, explained by a small expansion velocity. This and its rich spectrum make NGC 6302 an ideal object for the study and use of hyperfine structure as a diagnostic tool.

The derived isotopic ratio of Al-26/Al-27 is less than 1/33 in NGC 6302. This is the most stringent upper limit on the relative Al-26 abundance in any astrophysical object to date. Although the measurement is not constraining enough to quantify the Al-26 production in Asymptotic Giant Branch stars, that are the progenitors of planetary nebulae like NGC 6302, the technique has been established. Tighter constraints require deeper spectroscopy of this planetary nebula, and extension of the analysis to other targets of low or moderate expansion velocity.

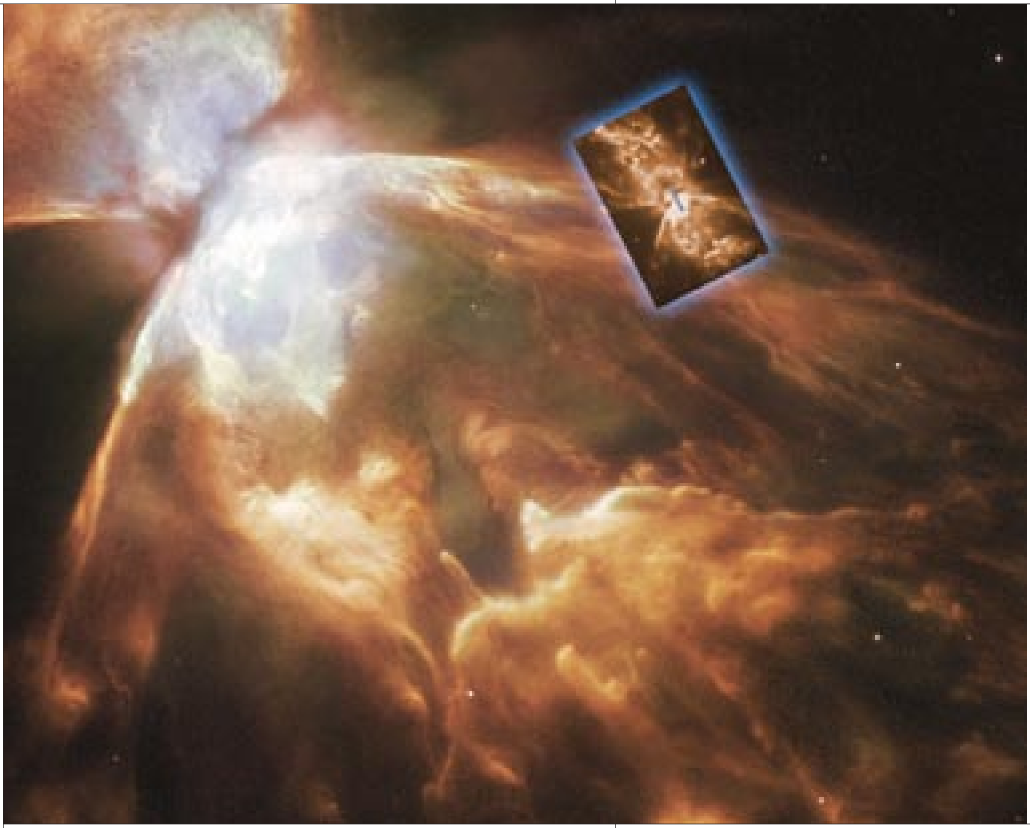


Figure 5.
A Hubble Space Telescope image of NGC 6302 with an inset showing the Gemini South acquisition R-band image (upper right) and the approximate location of the Phoenix spectrograph slit (small blue bar in inset).

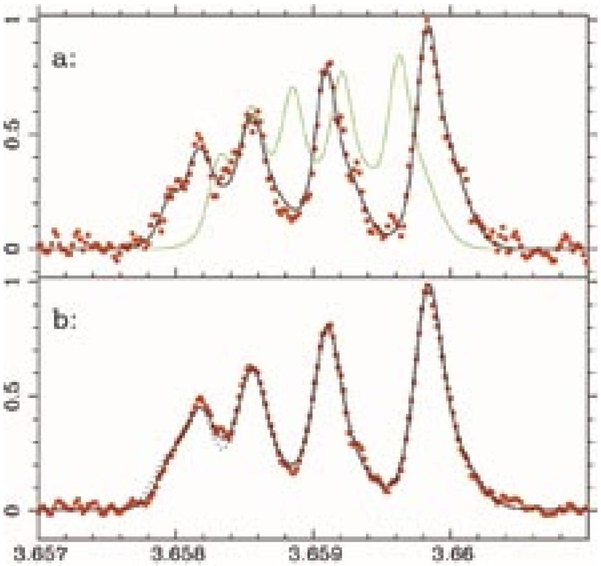
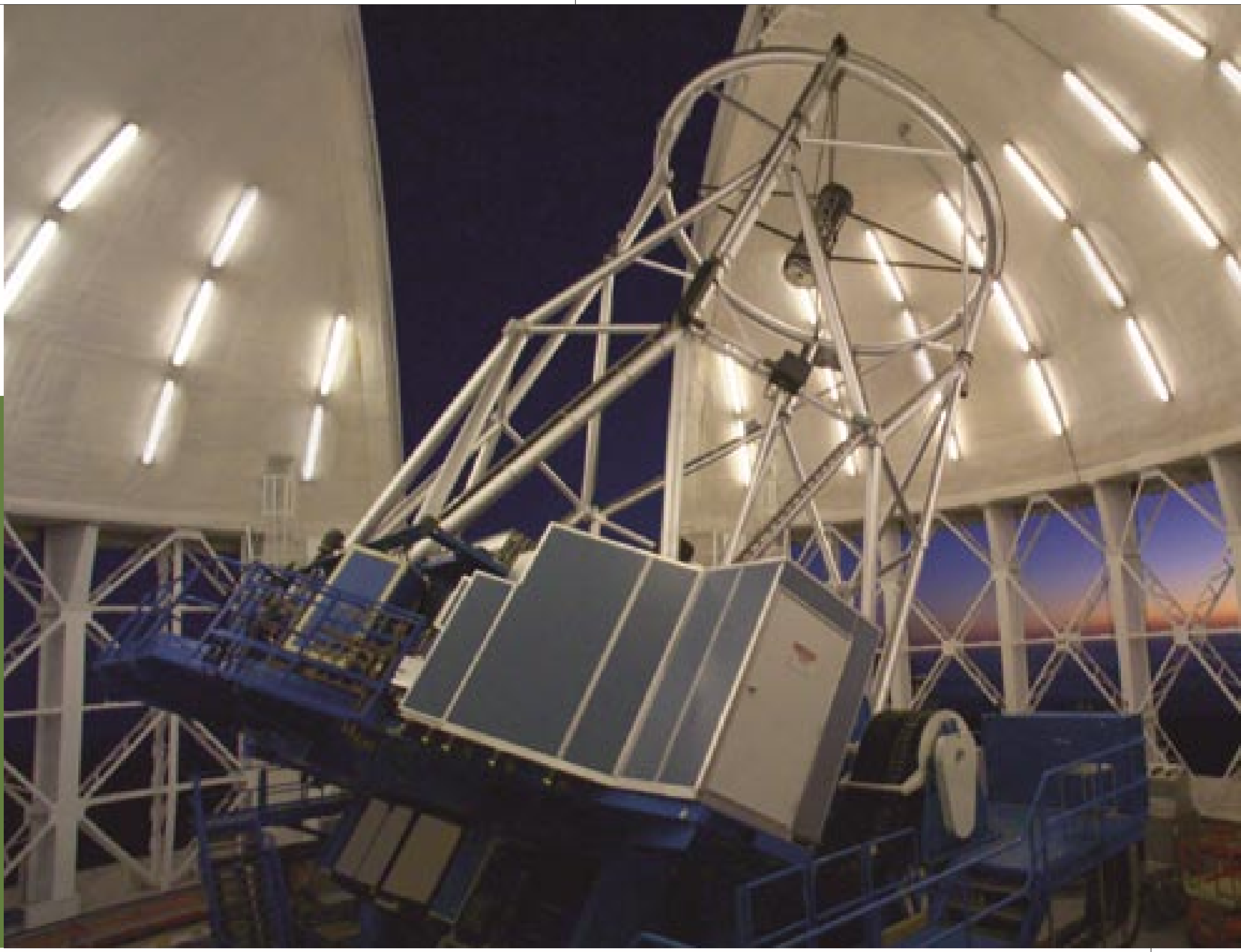


Figure 6.
(a) Resulting observed Phoenix spectrum (red points) of July 30, 2003, and model line profile of [Al VI]: in grey, model profile of Al-26 had it been present at an isotope ratio of 1. In (b), co-added spectrum (red points). Light dotted-line does not include electric-quadrupole hyperfine splitting. The inclusion of the electric quadrupole hyperfine terms improves the fit (solid grey line).



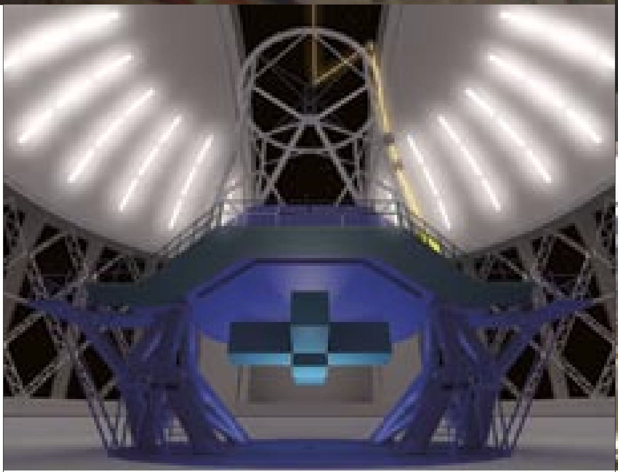
Gemini North / Laser Assembly on Mauna Kea

Laser Guide Star Update

This year represents a milestone for Gemini Observatory's adaptive optics (AO) program as the laser guide star (LGS) system comes online at Gemini North. The laser's "first light" propagation occurred on May 1-2, 2005. This is a big step toward the complete integration of the LGS system with the telescope, paving the way to LGS AO and multi-conjugate adaptive optics (MCAO) science.

The laser was built by Coherent Technologies, Incorporated, of Louisville, Colorado. The 13-watt solid-state diode laser fits into a relatively compact space on the side of the telescope. The system has an extremely modular design, which Gemini Senior Electronics Technician Kenny Grace praises for its ease of service. "Even during installation, we could replace modules very easily," he said. "This is cutting-edge technology." The LGS system also includes a sophisticated system of beam transfer optics, a laser launch telescope and a control system. On the first light test, the laser was operated at about 7 watts, significantly less than its maximum power. The delivered brightness of the laser guide star was measured to be of magnitude 9.3 and its size ~1.5 arcseconds.

First light proved the systems to be sound. More commissioning work is planned in the coming months, with science commissioning with Altair/NIRI imaging and spectroscopy and Altair/NIFS spectroscopy undertaken in the last quarter of 2005.



The new Gemini solid-state laser resides inside a 2.4- by 1.8-meter (8- by 6-foot) class 10,000 clean room on the side of the telescope (large blue box with white door in panoramic image above). The beam travels through transfer optics to a "launch telescope" mounted behind the secondary mirror assembly. The operation of the laser is illustrated in a new animation available on the Gemini Image Gallery (a frame from the animation is reproduced in the image above on this page).

Also shown above is a long duration (one-minute) image of the laser propagating on the sky during its second night of on-sky operations on May 2-3, 2005. Below this image, laser technicians and Gemini staff don safety glasses to test the laser in the lab at the Hilo Base Facility. – *Jean-René Roy*

Gemini Scientist Receives Prestigious Young Researcher Award

Gemini Observatory is proud to announce that Inseok Song, assistant astronomer at Gemini North has won the prestigious 2005 Outstanding Young Researcher Award (OYRA) given by the Association of Korean Physicists of America. The honor, bestowed during the American Physical Society's spring 2005 meeting in Los Angeles, includes a $1,000 cash award. It recognizes and promotes excellence in research by outstanding young ethnic Korean physicists in North America who are working at research-doctorate institutions, and industrial and government laboratories.

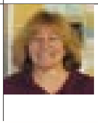
Dr. Song was nominated particularly for his work in the search for Jupiter-like planets and the formation and evolution of planetary systems. In making the award, the OYRA committee also cited his contributions to the systematic search for extrasolar planets using the Hubble Space Telescope. He is a Principal Investigator on a large HST program titled "Coronagraphic Imaging Search for Giant Gas Planets around Young Nearby Stars." Currently, eight Ph.Ds from three different countries are involved in this program. From observed data, Dr. Song and his team have found a handful of very promising candidate planets.

In addition to his HST planet search program, Dr. Song and his team are working with French astronomers using the 8-meter telescope at the European Southern Observatory in Chile. For the first time in history, they successfully imaged a bound extra solar planet orbiting a celestial object other than our Sun (known as planet 2M1207b). Major mass media, including BBC and CNN, reported this discovery and in-depth description of this system has been published as an article in *Astronomy and Astrophysics* (2004, volume 425, page 29).

Dr. Song is also studying sites of ongoing planet formation using both Gemini and Keck telescopes. He recently found a young solar system analog believed to harbor a planet at 1 AU (the distance between the Sun and Earth). The system has about 10,000 times more asteroidal material than our own system currently has, and it seems to be undergoing a period of very frequent collisions among planetesimals.

Frequent collisions in this star system are remarkably similar to the lunar creation event in our own Earth-Moon history. This discovery will be published soon in a major refereed journal.

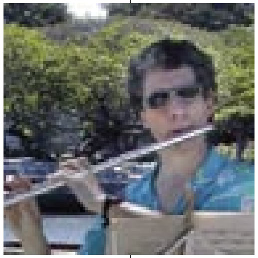
Dr. Song currently manages four research grants totalling a half-million dollars and has brought two post-doctoral researchers on board at Gemini. The Observatory is very proud of his achievements, and looks forward to many more exciting science results from Dr. Song's research group.



by Carolyn Collins Petersen

Tom Geballe: A Passion for Stars, Hoops, & Music

Pursuing the story of the universe requires individuals with an uncommon passion for solving the mysteries of the stars and understanding the instruments used to observe them. Gemini North Senior Astronomer Tom Geballe is one of those people who finds maximum enjoyment in whatever he does. His commitment and enthusiasm extend to everything in life, whether it's performing on flute as an accomplished musician, playing a fast-paced game of basketball, or coaxing the best performance out of a telescope to produce stunning spectra from a distant celestial object. "There is much beauty in astronomy," he said. "However, I think the most sublime beauty is in the spectra of planets, comets, stars, interstellar clouds, and galaxies. Spectroscopy reveals the most important secrets of the universe."



Tom's research interests include brown dwarfs, those elusive low-mass objects in the stellar cellar that bridge the gap between Jupiter-like objects and the coolest stars. I am a member of a team obtaining spectra and photometry of brown dwarfs in order to understand their properties, including the distribution of dust in their atmospheres and the effect of convection on their chemical abundances," he said. "There are about as many brown dwarfs as there are stars, but we can only do spectroscopic analysis on a handful of them—the brightest and the closest. Gemini and its instruments give us a chance to greatly expand our understanding of them."

At the other end of stellar existence, Tom is also fascinated by certain geriatric stars like Sakurai's Object, U Equulei, HD 137613, and V838 Monocerotis. "They have unique infrared spectra and apparently are behaving badly in their old age," he said. "These objects are a lot of fun to observe because they are so strange."

Between studying brown dwarfs and searching out misbehaving old stars, Tom peers deep into interstellar space to learn more about the clouds of gas and dust that exist there. "I and my colleagues are still trying to find the reason for the remarkably high abundance in diffuse clouds of the molecular ion H_3^+, which plays a fundamental role in the chemistry of interstellar clouds. “ he said. “The answer to this puzzle is sure to teach us something important about the physical processes occurring in these clouds.”

Tom is a long-time resident of Hilo with more than a quarter-century of experience observing on Mauna Kea. He worked at the United Kingdom Infrared Telescope (UKIRT) for 17 years, and spent eight of those years as its director before coming to Gemini Observatory in 1998. This experience gives him unique insight into the mountain, its difficulties, and what it can deliver under good conditions. According to Gemini North Deputy Director Jean-René Roy, Tom is the world’s foremost expert on thermal infrared spectroscopy and a valuable asset to Gemini North. “Tom’s knowledge is hugely broad and deep,” said Roy. “Show him an IR spectrum, he will likely tell you straight away what type of object it is, what problem there may be and how to solve it.”

Away from work, Tom’s lifelong love of basketball takes him to the nearest county gym every Friday night, and he shares his passion for music with wife Carole, who like Tom, is a flutist. They have two grown children, Anneke and Matthew, both doing their graduate work on the mainland U.S. Tom comes from a large family of musical and scientific performers. His father, the late Ronald Geballe, was a professor of physics at the University of Washington and played piano, his mother Marjorie used to be a singer, and his uncle, Theodore Geballe, is an emeritus professor of physics at Stanford. Tom studied flute for ten years, dabbles on guitar, and has performed with ensembles in Hawai’i, Seattle and Europe. He has served for 15 years as president of the Hawai’i Concert Society, an all-volunteer group that presents music and dance events by professional artists. “That musicians as famous as the Tokyo String Quartet and the Los Angeles Guitar Quartet, and dance groups as well known as Pilobolus Dance Theater and Smuin Ballet want to come to Hilo and will make themselves affordable to us is a wonderful gift for our community,” he said.

Introducing 4012 Geballe

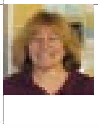
One of the rarer astronomical honors anyone can receive is to have an asteroid named after them. When asteroid 4012 was named for astronomer-musician Tom Geballe, he joined an even more select cross-section of asteroid honorees who happen to be musicians and composers. That group includes such luminaries as Antonio Vivaldi, the Beatles, Enya, Frank Zappa, Jan Sibelius, and another well-known astronomer-musican, William Herschel. What does 4012 Geballe look like? There are few images of it, but from light curve measurements and other observations, 4012 Geballe is now known to be an 11.2-kilometer (7-mile) diameter piece of rock orbiting at about 2.2 A.U. from the Sun. It’s a member of the Flora family of asteroids, whose orbits are influenced by Jupiter’s gravitational tugs. 4012 Geballe (also known as 1978 VK) has a V-band magnitude of 13.4, and was first spotted in 1934.

In 2004 Tom Geballe was honored by having asteroid 4012 named after him. The IAU citation recognized his outstanding expertise in infrared spectroscopy, stated:

T. R. Geballe is responsible for pioneering the first infrared spectral classification system for substellar objects. Discoveries include H_3^+ *in the giant planets and interstellar medium, non-LTE emission from Saturn VI (Titan), and countless IR observations of circumstellar and interstellar molecular sources.*

It’s a fitting salute to an astronomer who has written or co-authored nearly 300 science papers, and is described by friends and co-workers as enthusiastic about his work and his art, a man who gets more energy from juggling multiple projects, and thoroughly enjoys everything he does. One look at his record of accomplishments makes it clear that the honor is well-deserved.

“Tom is one of the most stunning examples of a scientist combining commitment, passion and easy-going manners,” said Jean-René Roy about his accomplishments. “He is always there to help. He is cool, patient, and joyful. It is just wonderful to have him on a team and to work with him.”



by Carolyn Collins Petersen

Helena Vincke: A Can-Do Person at Gemini South

The busy and complex environment of a modern-day observatory requires staffers to be flexible and clever, not just up on the mountain, but also in administration at the base facility. Gemini South Administrative Assistant Helena Vincke is one of those people that everyone calls on with a challenging problem to solve. This friendly, engaging Belgian transplant greets co-workers with a big smile and her "I can" attitude is one of the first things her colleagues mention. "Helena will never tell you that your problem is not related to her department," said Antonieta Garcia, Gemini South's Public Information and Outreach Assistant. "Even if it's not part of her job, she'll find a friendly way to help solve your issue."

A self-described "computer freak," Helena taught herself how to set up web pages, design PDF forms, and under the tutelage of Peter McEvoy, learned how to use Excel and other programs. "Her contribution at Gemini South is just fantastic," said McEvoy. "She knows how things work and she has a sincere dedication to helping people out. There's rarely a hiccup in the services she organizes."

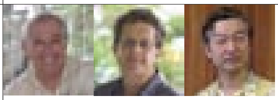
"My hobbies used to be reading, swimming, cooking, and aerobics. Then they were replaced by a lot of work and computer and administrative courses," she said. Helena devotes much of her spare time to her 9-year-old son Nando.

Helena speaks English, Flemish, French, German, and Spanish fluently. She is especially proud of her son's growing language abilities since they emigrated from Belgium. "He speaks perfect Spanish," she said.

After migrating from Belgium in 1999, Helena joined Gemini Observatory during construction of the southern telescope facility. She served as the site manager's administrative assistant, and immediately fell in love with the work. "It was fun because I had to walk around with two radios and a hard hat and there were about 50 men working and I was the only woman," she said. "At first the men who interviewed me wondered if I would be able to handle it. But because I'm 1.76 meters (5 feet 9 inches) tall, I think I made quite an impression."

After two years of traveling up and down the mountain, Helena joined the staff at Gemini's La Serena base offices. "I was surprised at the workload here in La Serena," she said. "With the move to the new building, having to coordinate the logistics, my purchasing experience came in handy. I think I was a good asset for our group knowing more about how things were organized on the mountain."

Helena's common sense, and what friend and Gemini colleague Marie-Claire Hainaut calls her "grounded nature," are a big part of Helena's valuable contribution to Gemini South's team-based atmosphere. "No matter how big the obstacles, she always finds the strength to look ahead and make the most out of every opportunity," said Marie-Claire. "She is a truly honest and sincere person, a great coworker and a wonderful friend!"



by Frederic Chaffee,
Matt Mountain &
Hiroshi Karoji

Mauna Kea observatories by Richard Wainscoat / IfA

New Capabilities, Cooperation atop Mauna Kea

Four of the world's nine largest operational telescopes—the two Keck 10-meter telescopes, and the Gemini 8.1-meter and Subaru 8.2-meter telescopes—reside atop Mauna Kea, making the entire astronomy complex there the most powerful in the world. We have recently taken steps to assure that this entire "system" of premier telescopes is used to maximum advantage by the world's best astronomers.

Often viewed by non-astronomers as locked in fierce competition with each other, the reality of inter-observatory relationships is much different. Each serves a different community of astronomers. Keck observers come largely from the institutions who fund the observatory—the University of California, Caltech and NASA.

Subaru serves the astronomers of Japan and Gemini those of the seven countries—the U.S., the UK, Canada, Australia, Brazil, Argentina and Chile—who make up the Gemini partnership.

In addition, all three provide observing time to astronomers from the University of Hawai'i.

With such a huge constituency of worldwide astronomers to serve, the demand for time on these large Mauna Kea telescopes exceeds the supply by a factor of from three to five. Many requests by the world's best astronomers for observing time at Keck, Gemini and Subaru must be turned down because time is simply not available.

All of the major Mauna Kea telescopes have a suite of basic instruments, which record the light from celestial sources for analysis by astronomers. The majority of instruments at any modern observatory are of two basic types—imagers and spectrographs. Imagers take "pictures" of the universe—the magnificent pictures from the Hubble telescope are familiar to people all over the world; even more spectacular images are beginning to be produced by the Mauna Kea "giants."

Spectrographs spread out the light from celestial sources into their component colors—providing the equivalent of a "fingerprint" or the "DNA signature" of the celestial objects. It is through the study of spectra that astronomers learn most about the nature of amazing constituents—planets, stars, galaxies, black holes, pulsars, gamma-ray bursters, and the like–of the Universe.

In their determination to provide the best possible facilities for the world's astronomers Keck, Gemini and Subaru have collaborated informally for many years. Their Directors meet regularly to discuss common problems and concerns. Technical groups at each observatory meet regularly to exchange ideas and share technical insights. Experts from each observatory regularly serve on review and advisory committees for the other two. Equipment is often shared among observatories. We live in and observe the same universe.

Recent advances in astronomical instrumentation have spawned an even closer relationship. In recent months, Gemini has begun commissioning a new instrument called Michelle—an acronym meaning "mid-infrared echelle" spectrograph. It offers a unique capability available at none of the other large Mauna Kea telescopes. For example, astronomers can explore the dust in proto-planetary disks to find evidence of hidden planets or probe the dust produced by the very first stars in distant galaxies.

Keck itself has recently commissioned a unique new capability for one of its "workhorse" instruments—the High Resolution Echelle Spectrograph (HIRES). The new capability, many years in development, will greatly increase HIRES' sensitivity to light of all colors, but especially to ultraviolet light to which it has hitherto been all but "blind." In the past, HIRES has been the world leader in discovering planets around other stars—in the last eight years some 70 new Jupiter-sized planets have been discovered by Keck's "planet-hunter" team.

However, planets smaller than Jupiter have so far eluded detection by HIRES. This newly-inaugurated capability should allow Neptune-sized planets—one-third the mass of Jupiter–around other stars to be detected for the first time.

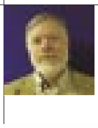
Recognizing that their respective observatories have developed unique capabilities that both of their user communities could exploit to produce new and exciting discoveries, the Directors of Keck and Gemini recently reached a formal agreement whereby Gemini astronomers will be given access to HIRES on Keck and Keck astronomers to Michelle on Gemini. This is the first formal time-exchange agreement between two Mauna Kea observatories.

In parallel development, Subaru and Keck recently arranged to exchange time when it was realized that a program already assigned time at Keck could better be done using Subaru's "Suprime-Cam," and that Keck has a unique and powerful spectrograph—DEIMOS—for which no equivalent is available to Subaru astronomers. Thus a deal was struck whereby Keck scientists will carry out their research with Suprime-Cam at Subaru.

These first steps toward time exchange among Mauna Kea's large observatories promise a new era of even closer collaboration, an era when we jointly seek to maximize the creative potential of all Mauna Kea astronomers, telescopes and instruments to produce evermore exciting discoveries about our rich and infinitely varied Universe.

Drs. Frederic H. Chafee, Matt Mountain and Hiroshi Karoji are the Directors of the Keck, Gemini and Subaru Observatories, respectively.

Reprinted from West Hawaii Today, *September 29, 2004*



by Larry Ramsey

Gemini's Directorship Transition

With the recent announcement that Gemini Director Matt Mountain will likely fill the position of Director at the Space Telescope Science Institute (pending NASA approval), a process has been initiated to assure the seamless transition of the Gemini directorship. As chair of the AURA Oversight Committee for Gemini (AOC-G), I will be managing the search process for the new director. I anticipate a smooth transition given the excellent state of the observatory and the strong management team that has been established under Matt's leadership. Jean-René Roy will be the Acting Director of the Gemini Observatory during the transition period.

A search plan has been developed and approved by the AOC-G. It includes the formation of a *Director Search Committee*, which is now underway. This search committee will both accept and solicit applications and will develop a report that should include a ranked list of director candidates. After receiving the search committee report, the AOC-G will forward their recommendation through the AURA president to the AURA board. The final step in the selection process will be a recommendation to the Gemini Board for approval of a new director during the latter half of 2005.

It is the objective of this plan to minimize the impact on ongoing operations and keep Gemini at the forefront of optical/infrared astronomical research. On behalf of the AOC-G, I would like to thank Matt and his team for all they have done to ease this transition and make the next phase at Gemini a success.

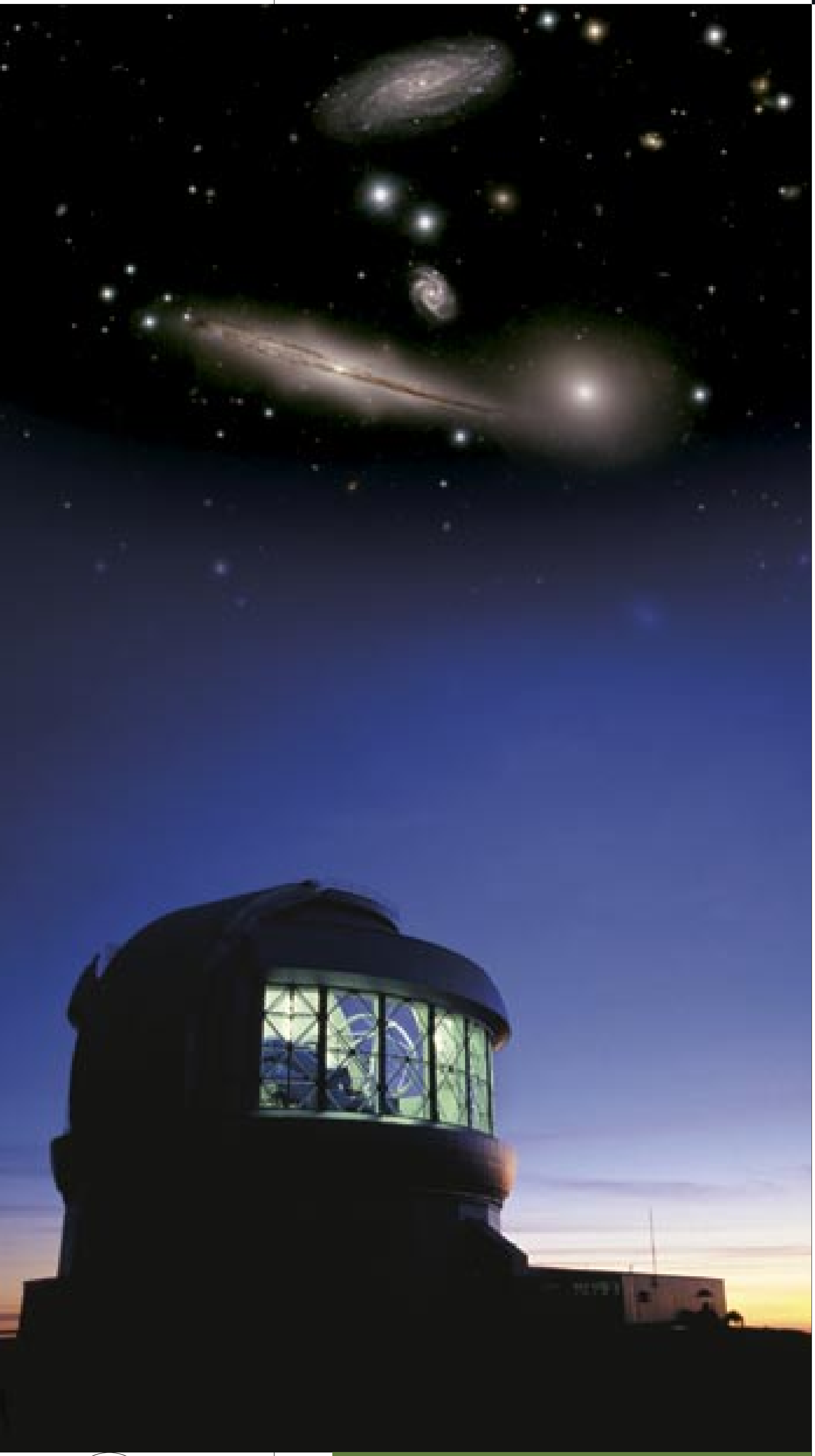
Recent Gemini Outreach Activities

StarTeacher, Tom Chun conducting physics lab via video conferencing from Chile.

AstroDay 2005 in Hilo / by Gary Fujihara / IfA-Hilo

Students from Kamehameha Schools participate in Gemini video-conference physics lab

Journey Through the Universe 2005 / NASA scientist talks to Waiakea High School physics class



Gemini South at Sunset / K. Pu'uohau-Pummill / HCG 87-GMOS-S

GeminiFocus
Newsletter of the Gemini Observatory

Gemini Observatory
Northern Operations Center
670 N. A'ohoku Place Hilo, Hawai'i 96720 USA
Phone: (808) 974-2500 Fax: (808) 935-9235

Gemini Observatory
Southern Operations Center
c/o AURA, Casilla 603 La Serina, Chile
Phone: 011-5651-205-600 Fax: 011-5651-205-650

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Gemini Observatory is an international partnership managed by the Association of Universities for Research in Astronomy under a cooperative agreement with the National Science Foundation.