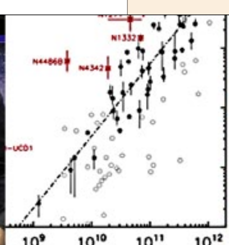
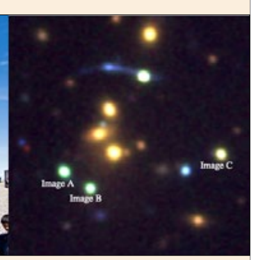
GeminiFocus

Publication of the Gemini Observatory | January 2016

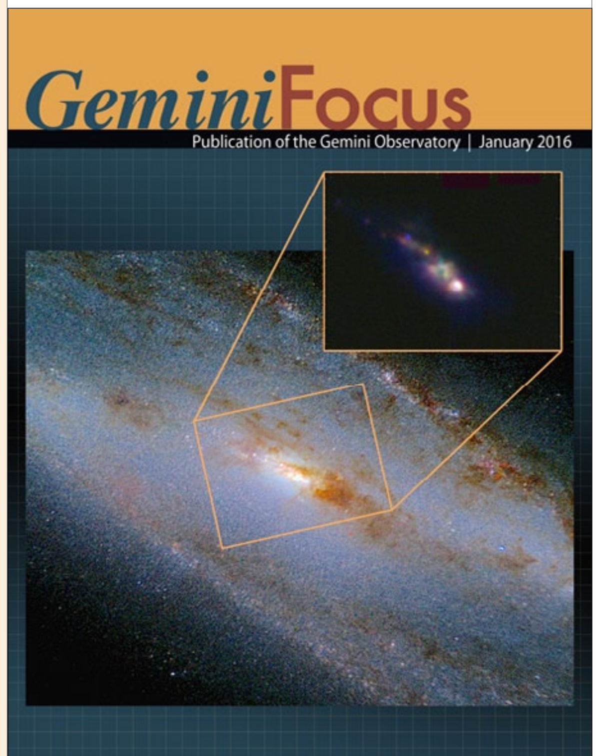
Gemini*Focus*





ON THE COVER:

A recent Flamingos-2 image of NGC 253's core region (as discussed in the Science Highlights section, starting on page 7). The inset shows the stellar supercluster identified as the galaxy's nucleus.



Gemini*Focus January 2016*

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Markus Kissler-Patig

Director's Message

The Culmination of Another Successful Year at Gemini.

After three years of effort, we proudly announce that Gemini Observatory has accomplished its transition to a leaner and more agile facility, operating now on a ~25% reduced budget compared to 2012. Achieving that goal was no easy task. It required questioning every one of our activities, redefining our core mission, and reducing our staff by almost a quarter; ultimately we relied on the ideas and joint efforts of everyone in the Observatory.

In the process of the 2016 budget preparation, we managed to fit all our current activities within the reduced budget, which our Finance Committee and Board of Directors have already approved. Huge kudos to all the Gemini staff for their contributions to three years of massive changes!

So Where Are We Now, and What's Next?

The Gemini Observatory's governance has provided us with ***guidelines for 2016-2021***, which includes this key statement: "Gemini will strive to be the best observatory in the world for the execution of flexible, innovative, and efficient science programs." I believe that we already are, and will continue to be so well into the future. Here are at least six reasons why.

First, we are unique in offering our users multiple ways of requesting telescope time for programs (regular, Long and Large, and Fast Turnaround). Second, Gemini's twin 8-meter telescopes are now equipped with four state-of-the-art facility-class instruments, several of which utilize adaptive optics. Third, Gemini has the only 8- to 10-meter-class telescope offering multi-conjugate adaptive optics. Fourth, we are the only 8- to 10-meter-class observatory to so openly welcome visitor instruments; so much so that our user community has built up a "waiting list" for them. Fifth, Gemini North is the first 8- to 10-meter-class telescope to fully operate remotely at night. And sixth, Gemini is the first major observatory to archive its data in the commercial Cloud. Now for the clincher: we achieved all of this while operating with a fault downtime of less than 4%.

Gemini is magnificently set up to enable the great science of the Gemini community in the next years. But we do not want to stop there. That is why the Gemini Board has recently kicked off a ***Strategic Vision Committee*** to explore what exciting role Gemini can play beyond 2020 — such as interacting closely with new observatories, in particular those planned on Maunakea in Hawai'i and the Cerro Tololo/Pachón complex in Chile. Stay tuned, as we ask both our stakeholders and users to contribute ideas to this vision exercise during 2016.

Even More Positive News

We are also making good progress on our two next facility-class instruments. GHOST, our next high-resolution spectrograph, just passed the first part of its Critical Design Review, and is on track to be commissioned by the end of 2017/early 2018. As for the instrument after that (Gen4#3), its four feasibility studies have concluded and the reports are ***now public***. Prepare for the full Call for Proposals in 2016 Q2.

On the operations front, the biggest news is that base facility operations began at Gemini North in November and nighttime staff is no longer needed at the summit during observations. This is one step on the path to our final goal: offering our users operations from your favorite sofa, anywhere in the world.

We also now offer monthly Fast Turnaround (FT) proposals for time on the Gemini South telescope (in addition to Gemini North), and the program is picking up fast in popularity. Also, the first peer-reviewed paper from an FT proposal earlier this year is now published (see feature science article, page 3). And, if you have not tasted our new ***archive*** yet, it is fully functioning, and we welcome feedback (see the article in this issue starting on page 10).

Finally, we had another successful *Viaje al Universo*, our week-long flagship outreach program for local schools in Chile. Our staff contributed to many activities and were rewarded by hundreds of smiles in the faces of the attending children. See the smiles starting on page 20 of this issue.

Overall, I believe that Gemini is in great shape to face the coming years and beyond, when we hope to offer more exciting opportunities than ever. Right now, the future certainly looks exhilarating. Join us in "Exploring the Universe, Sharing its Wonders."

Markus Kissler-Patig is Gemini's Director. He can be reached at: mkissler@gemini.edu

Keren Sharon

Probing Time Delays in a Gravitationally Lensed Quasar

Fast Turnaround observations with the Gemini North telescope are used to measure the difference in the arrival time of photons coming from a distant quasar, as they travel on different paths from the quasar to us due to gravitational lensing. The Gemini observations also produced deep spectroscopic data with GMOS that allowed our research team to obtain redshifts for other lensed galaxies behind the cluster.

Imaging data from the Sloan Digital Sky Survey (SDSS) has uncovered many gravitational lenses including SDSS J2222+2745 — a galaxy cluster whose projected mass density is high enough to bend space-time, causing light traveling near it from a distant quasar to change its path. This phenomenon, which is a theoretical prediction of General Relativity, is called gravitational lensing.

Describing a Strong Gravitational Lens

When we observe massive objects, such as galaxy clusters, we often find that distant background galaxies appear distorted and stretched, and their apparent position in the sky is different than their actual positions.

The equations that describe gravitational lensing dictate by how much the light is deflected due to the gravitational potential of an intervening object. The more massive an astronomical object, the stronger its lensing potential, and the larger the deflection of light. In some cases, which we call Strong Lensing (SL), there is more than one solution to the lens-

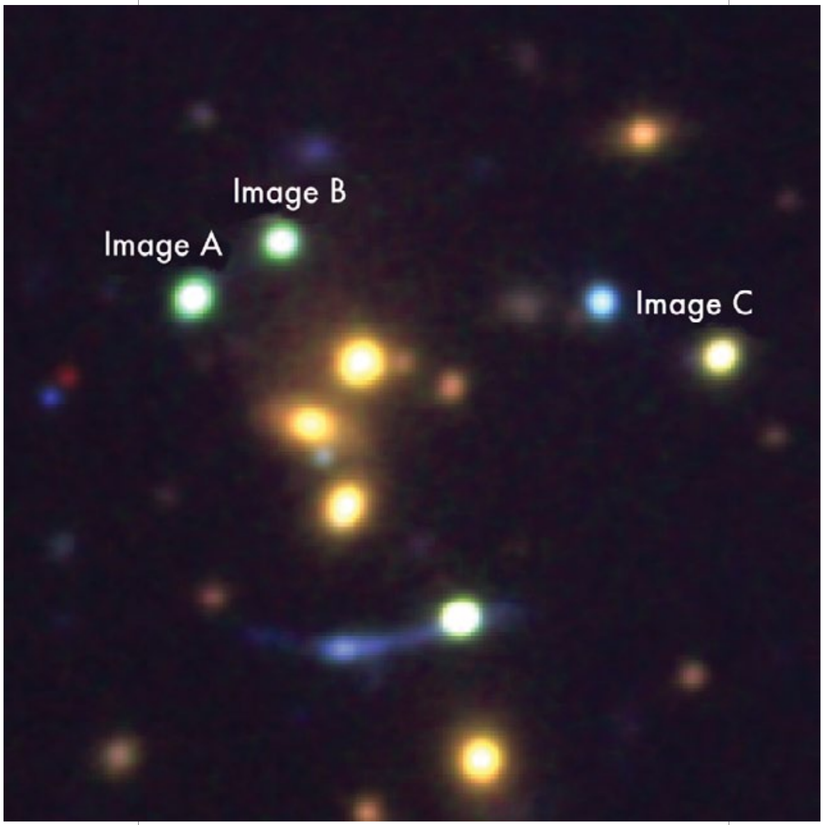


Figure 1.
A 30″ x 30″ field around the center of the galaxy cluster in the SDSS J2222+2745 lensing system. The composite color image combines Nordic Optical Telescope and Gemini North Fast Turnaround data. The slight color difference in the three images of the quasar (A, B, and C) results from the different optical filters used during the observations that were made at different times.

ing equation: light is allowed to travel from point A to point B on more than one path, resulting in multiple images of the same background source.

Such is the case of the SDSS J2222 + 2745 system — a galaxy cluster at $z = 0.5$, that strongly lenses a few background sources, including a quasar at $z = 2.82$ and a galaxy at $z = 2.3$ (Figure 1).

This lensing cluster was discovered by an international team of researchers, led by Michael Gladders from the University of Chicago, who mined data from the Sloan Digital Sky Survey to find strong lensing clusters that stretch and distort background galaxies into giant arcs. As part of this Sloan Giant Arcs Survey (SGAS), the team examined images of ~ 30,000 galaxy clusters, and systematically identified evidence of gravitational lensing in hundreds of galaxy clusters, many of which were discovered for the first time. Using follow-up imaging and spectroscopy with several telescopes, including Gemini North, Gladders' team was able to confirm these lensing clusters, and most importantly, measure the spectroscopic redshifts of the lensed background sources.

Of the hundreds of lensing clusters found in the SGAS, SDSS J2222 + 2745 is the only one that lenses a background quasar into at least six images of the same background source (Dahle *et al.*, 2013). This lensing configuration is so unique, that, in fact, this case is only the third one known of a quasar that is strongly lensed by a galaxy cluster. The other ones, SDSS J1004 + 4112 and SDSS J1029 + 2623, (Inada *et al.*, 2003; Inada *et al.*, 2006) split the light from a background quasar into five and three images, respectively.

Time-Stamping Light

Quasars are among the most luminous objects known in the Universe. They are powered by supermassive black holes accreting matter in an active galaxy's nucleus. What makes lensed quasars uniquely interesting is that their luminosity changes in time. A quasar's brightness can vary on time scales from days to months, owing to random physical changes in the accretion disk, and to the small region from which the light is emitted (the supermassive black hole). This variability allows us to put a time stamp on the arrival of light from a lensed source.

Whenever multiple lensed images of the same source are formed, each one is a snapshot of the source taken at a different cosmic time. This is because the light from each source has taken a different path from the quasar to us; and the time it takes light to arrive depends on the length of each path and the gravitational potential along this path.

In the case of SDSS J2222 + 2745, six photons leaving the quasar simultaneously at the speed of light encounter a massive galaxy cluster, whose gravity sends them on different paths to our telescope. The first may take a few billion years to arrive; the second may come a couple of years later, followed by the third a month or two later, and so on. If we can measure this time lag between the arrival of light to the different image positions, we can effectively measure the light-distance along these different paths and thus measure the geometry of the Universe.

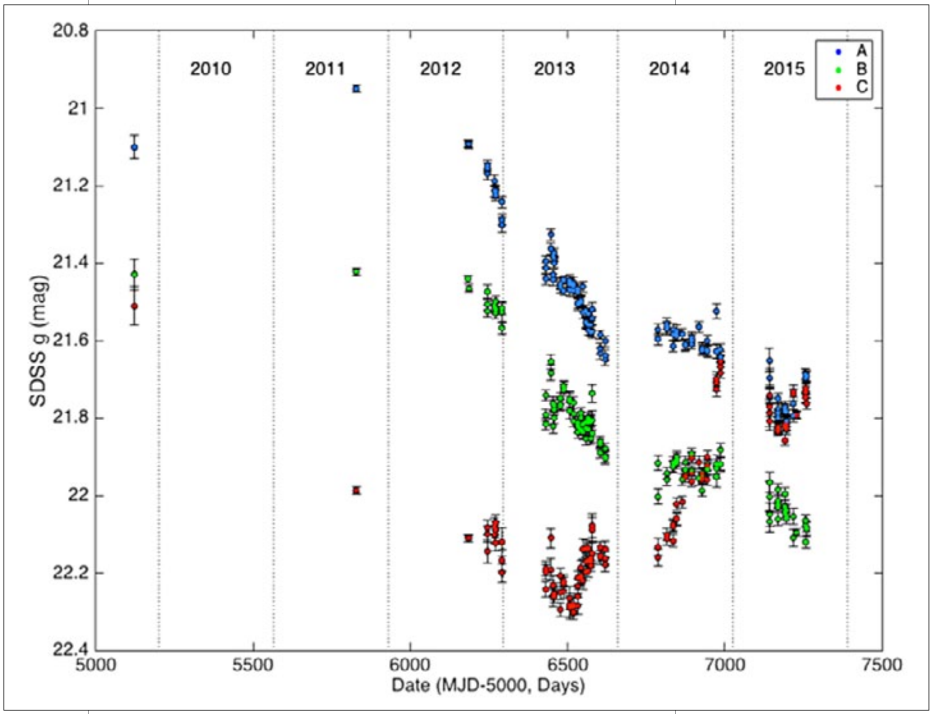


Figure 2.
Light curves of the quasar images A (blue symbols), B (green), and C (red). Figure reproduced from Dahle et al., *2015.*

Promptly after the discovery of SDSS J2222 + 2745 a follow-up campaign, led by Håkon Dahle from the University of Oslo, was initiated using the 2.5-meter Nordic Optical Telescope (NOT) at the Canary Islands. The team observed the field of SDSS J2222 + 2745 approximately every two weeks, resulting in over 40 observations in good conditions.

Dahle and his team used these observations to construct a light curve for the brighter three of the six images (Figure 2). They found that the quasar's brightness varies by as much as 0.8 magnitude (a factor of two increase or decrease in flux) over four years. Dahle then used computational techniques to cross-correlate the light curves of images A and B in order to identify similar patterns in the fluctuation of light. The team found that the time lag between image A and B is about 47.7 days, which means that if image A suddenly brightens, image B will do the same thing 47.7 days later.

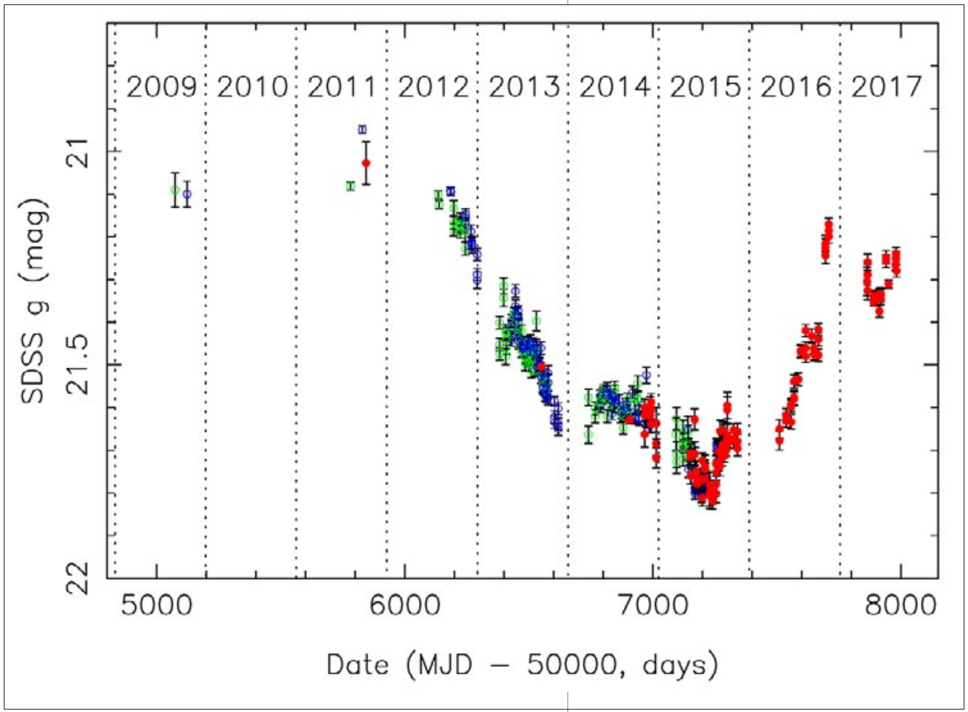
A robust measurement of the time lag of image C was harder to obtain. The team's lens model, computed by Keren Sharon (author of this article) predicted Image C to lead images A and B by a few months to years; thus to measure it required a longer monitoring period. However, recent observations, including imaging with NOT, and with the Gemini North telescope awarded through a Fast Turnaround proposal, helped pin down the elusive measurement of a time delay of image C. As predicted by the lens model, image C leads image A by about two years, at about 722 days.

What's Next?

Using spectroscopic observations with Gemini North (2015B; Principal Investigator Keren Sharon), we were able to determine the redshifts of lensed galaxies recently identified in our Hubble Space Telescope (HST) observations of this field. The new redshifts will inform a more accurate and precise lensing model of the cluster, which will improve our theoretical understanding of this system.

Having measured the lags between three of the six images of the quasar in SDSS J2222 + 2745, this lens system provides us with a rare tool: foresight. In particular, with a measurement of a negative time lag of image C, we now have a two-year warning for

Figure 3.
The combined light curve of image A (blue), B (green), and C (red), by shifting the data points of A and B by their respective time delay and magnification ratios: -47.7 days and -0.34 magnitude for B, and 722 days and 0.483 magnitude for C. The shifted light curve of C predicts the expected brightness of image A in 2016 and 2017. Figure reproduced from Dahle et al.*, 2015.*

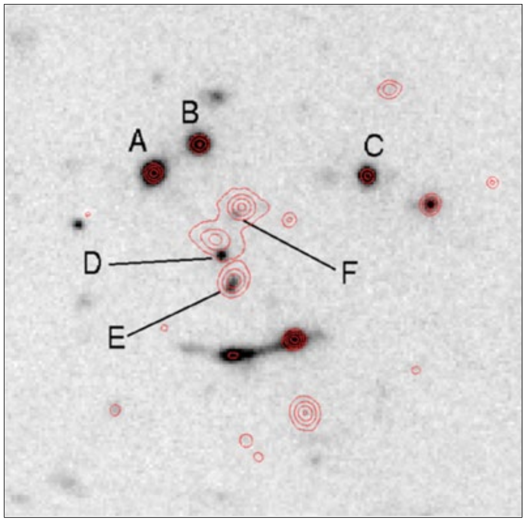


the behavior of images A and B (Figure 3). If C brightens significantly, as it did in 2014 and 2015, we know to expect the same magnitude of brightening in A and B about two years later, and plan future observations for that time.

Meanwhile, our team has embarked on a multi-wavelength monitoring campaign aimed at studying the physical conditions in the quasar's host galaxy. In this program, we will use Gemini and NOT in the optical, and the Swift space telescope in UV and X-ray, in a program awarded by the University of Michigan. We'll also use observations with the HST in Cycle 22 (PI: Keren Sharon) to compute a detailed lens model of the cluster, to further constrain the mass distribution of the foreground lens.

The Gemini monitoring will uniquely enable a measurement of the time delays of the three faint images of the quasar: D, E, and F (Figure 4). These images are much dimmer than A, B, and C, and their detection is further complicated by their position near the bright galaxies at the center of the cluster. These forthcoming measurements could shed light on the details of the distribution of the luminous mass and dark matter at the very core of the galaxy cluster, at a resolution that cannot be obtained by any other method.

Figure 4.
This figure, reproduced from Dahle et al.*, shows the field of SDSS J2222 + 2745 after the bright cluster galaxies were modeled and their light subtracted from the image .This procedure reveals the three fainter images (D, E, and F) of the quasar that are embedded in the light of these galaxies. The red contours show the light distribution in the original image.*



Keren Sharon is an astronomer and assistant professor at the University of Michigan astronomy department and can be reached at: kerens@umich.edu

Nancy A. Levenson

Science Highlights

Gemini observations identify a stellar supercluster at the heart of a nearby starburst galaxy, shed new light on quasars as reionization sources in the early Universe, and make a profound contribution to our understanding of galaxy formation.

Unshrouding the Buried Nucleus of a Nearby Starburst Galaxy

NGC 253 (Figure 1, and featured on the cover of this issue) is famous among astronomers as the nearest spiral galaxy hosting a nuclear starburst. The concentrated activity and associated dust, however, obscure the center. Guillermo Günthardt (National University of Cordoba, Argentina) and collaborators have now used Gemini infrared observations to identify the galaxy's nucleus. They conclude that the brightest near- and mid-infrared source (a stellar supercluster) marks the nucleus, rather than a radio source that astronomers had previously identified.

The team used new multi-wavelength near-infrared images and spectroscopy obtained with Flamingos-2 on

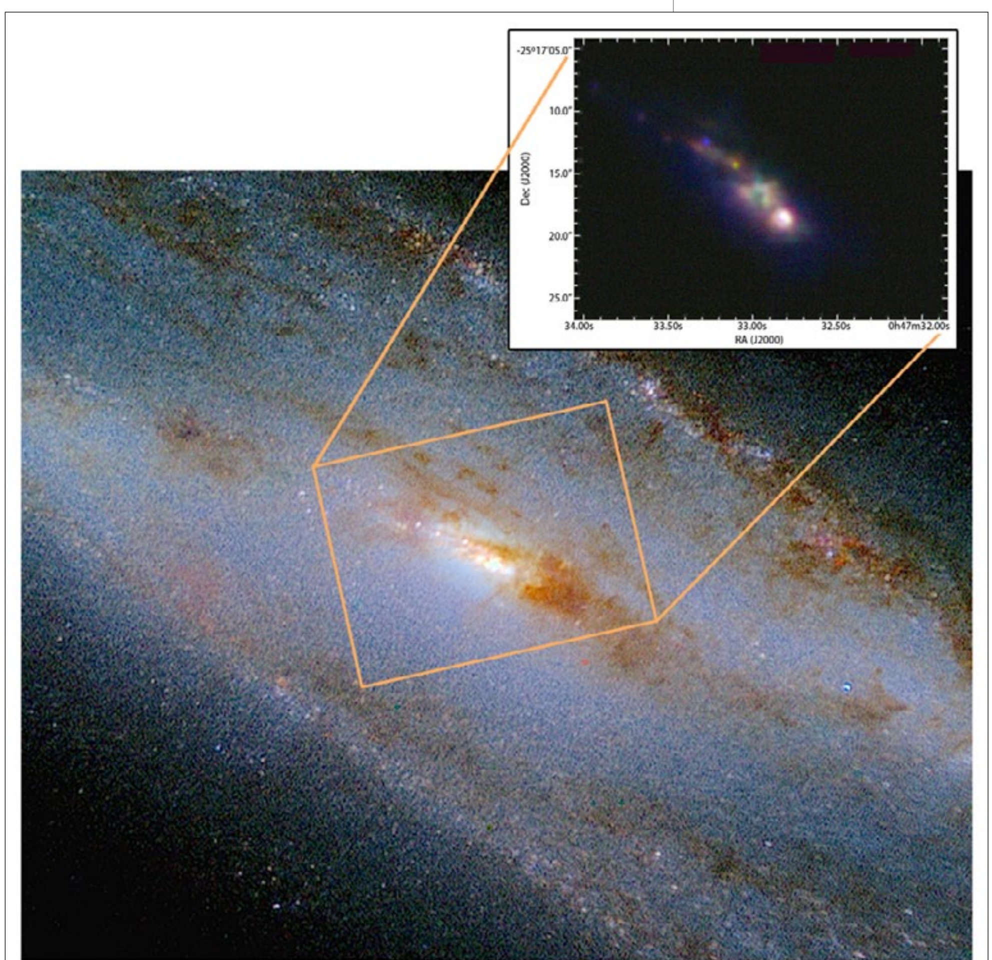


Figure 1.
Color composite image of the inner region of NGC 253, from Flamingos-2 images using the filters J (blue), H (green), and K_s (red). Large amounts of dust completely obscure this region in optical images.

(Inset) Color composite image of the starburst core region of NGC 253, from T-ReCS mid-infrared images using the filters Si-2 (blue), [NeII] (green), and Qa (red). The nucleus candidate IRC appears as the brightest object in this field in the infrared.

the Gemini South telescope, combined with archival multi-band mid-infrared images obtained using T-ReCS (Thermal-Region Camera Spectrograph) on Gemini South. The stellar supercluster, identified as the nucleus and kinematic center of molecular gas rotation, is almost coincident with the symmetry center of the galaxy's inner bar. This infrared core (IRC) is also the primary source of the starburst-driven outflow. Both the IRC and the nuclear disk are offset with respect to the galaxy's stellar bulge, which implies that the central gas reservoir and new star formation are decoupled from older galactic structure.

The complete results are published in [*The Astrophysical Journal*], and more information with detailed images is posted on the [*Gemini website*].

Discovery of a z ~ 6 Quasar: Rethinking Reioniation Sources in the Early Universe

Korea's first result as a limited Gemini partner, the discovery of a faint quasar at a redshift of $z \sim 6$, sheds new light on the sources of reionization energy about a billion years after the Big Bang.

Ionizing the neutral atoms of the intergalactic medium requires significant sources of energy, from either galaxies' stars or their accreting central black holes (as quasars). The new discovery, however, ultimately suggests that quasars do not contribute significantly.

In this work, the team began with the Infrared Medium-Deep Survey, based on data from Maunakea telescopes including the United Kingdom Infrared Telescope and the Canada-France-Hawai'i Telescope. Color selection revealed high-redshift quasar candidates, and observations of this newly-discovered quasar using the Gemini Multi-Object Spectrograph on Gemini South confirm its redshift and identity spectroscopically (Figure 2).

This single source and six additional candidates from the same survey are consistent with limited contributions to reionization from the faint end of the quasar luminosity function; thus, 90% or more of the ionizing flux must come from other sources.

This is the first Korean publication as part of the Gemini Partnership, and was led by Yongjung Kim (Seoul National University), Myungshin Im (Principal Investigator; Seoul National University), and colleagues. A translation of the Korean press release is posted on the Gemini *website*, and the full publication appears in *The Astrophysical Journal Letters*.

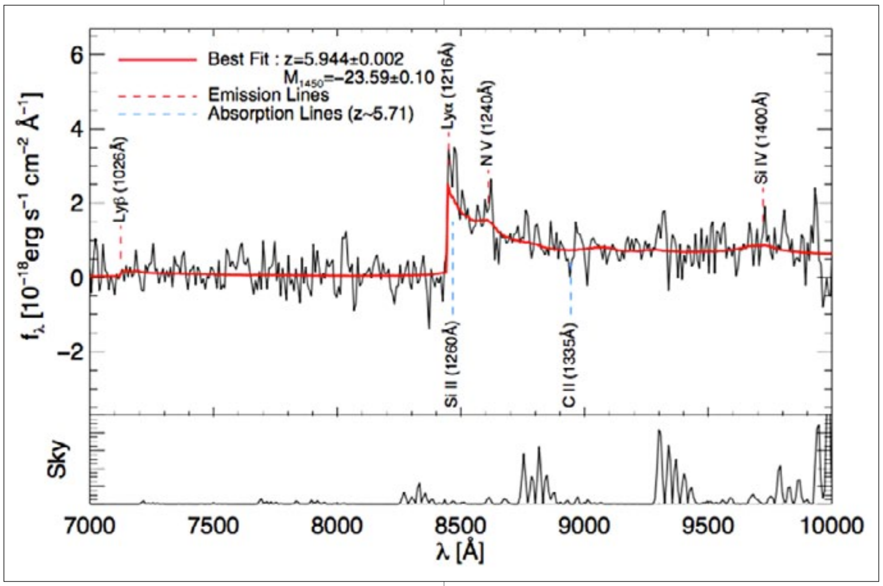


Figure 2.
This GMOS-S spectrum of the newly-discovered z~6 quasar confirms its identity and redshift.

A Massive Black Hole in a Possible Relic Galaxy

New results based on Gemini observations of the compact, early-type galaxy NGC 1277 yield a new, lower than previously determined, mass of its central supermassive black hole. The work also has more profound implications for galaxy formation, suggesting that massive black holes were formed before stars came into place.

Jonelle Walsh (Texas A&M University) and collaborators used the Near-infrared Integral Field Spectrometer (NIFS) and laser-assisted adaptive optics on the Gemini North telescope to obtain high-resolution observations within about 1,400 light years of NGC 1277's center. These provide both sensitive data within the black hole sphere of influence and simultaneously cover extended regions where stars are more important. The team used these data to determine a lower black hole mass — by a factor of about three (4.9 x 10^9 M_{Sun}) — compared with earlier findings; still the black hole at the heart of this galaxy remains one of the most massive ever measured.

This result puts NGC 1277 well above the standard relationship between black hole mass and galaxy luminosity, placing it close to the relationship between black hole mass and bulge stellar velocity dispersion (the "M-sigma relation"; Figure 3). These observations and previous work identify NGC 1277 as a relic galaxy — one that has suffered only passive evolution (the aging of stars) over time, rather than the mergers and transformations that result in giant elliptical galaxies in the nearby Universe. Such relics offer windows into the early Universe and galaxy formation.

Based on these results and similar examples, the authors suggest that black holes formed first, followed by star formation, to end up with galaxies that exhibit the usual relations. The complete paper will be published in *The Astrophysical Journal*, and a ***preprint*** is now available.

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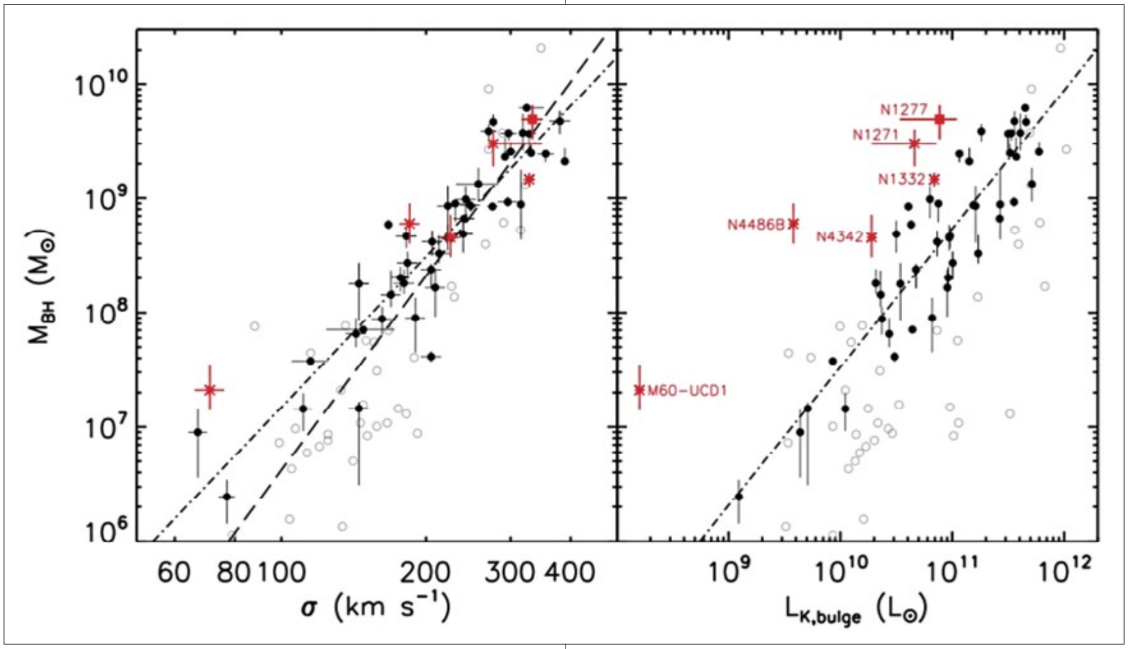


Figure 3.
NGC 1277 and other similar rotating, high-dispersion, early-type galaxies (red) are consistent with the M-sigma relation (left), but appear to be overluminous relative to their black hole mass (right).

Paul Hirst

The New Cloud-based Gemini Observatory Archive

The new Cloud-based Gemini Observatory Archive is now online and available to our user community and anyone wanting to retrieve Gemini data. The new archive has many powerful tools and features that are described here — take it for a test-drive!

The new Gemini Observatory Archive (GOA) provides a simple yet powerful way for the Gemini user community (especially those who wish to write scripts) to search for and download data. A key feature of the new Cloud-based archive is its ability to automatically find and match optimal calibration data for your search results. GOA's powerful web interface also allows bookmarking search results and provides an easy-to-use Application Programmer Interface (API).

As I write these words, I have one eye monitoring several windows in the corner of my computer screen, which shows that our new archive server is running quietly and smoothly. One window shows me that afternoon calibrations are being taken on Gemini North, and I see those data files transferring into the archive. More than a hundred users have already created accounts on the system and I see them accessing proprietary data for their projects; more users are accessing the server anonymously, either to just check out the system, or search for older data. The Gemini Observatory Archive can be accessed ***here***.

Data Management Dilemma

Shortly after I started working at Gemini in late 2006, I realized we had a problem with in-house data management: data were being manually copied between different disks and backup media in a somewhat ad hoc manner. In addition, a disk failure on an aged Sun workstation left us scrabbling to locate backup copies of some Near-infrared Integral Field Spectrometer engineering data that had been lost. The final straw came as an urgent phone call from the night crew who needed to free up disk space for incoming data, but they weren't 100% sure that the data they wanted to delete was safely on another disk or even in the archive.

"I have used the new Gemini Observatory Archive to retrieve data for our LP-3 and I found it very easy to use and fast so I don't anticipate any problems. I am grateful to the team at Gemini that has been working on it. "
— Catherine Huitson, PI of GN-2015B-LP-3

To solve all these problems, I initiated the FITS (Flexible Image Transport System) storage project and wrote a software package that would scan through the FITS files on a file system and record details of them in a database. A simple web interface presented concise summaries of the data files. Gemini also bought some modern LTO4 (high capacity and performance) tape drives, and wrote software to record (in the database) file details as it wrote them to tape.

With these changes, we'd never lose a single file again. We'd also be able to know with a few mouse clicks which files were safely on tape, and which tapes they were on. We wrote scripts that tied into the system to clear old data off disk (after first checking it was safely on multiple tapes) to ensure that disks didn't fill up.

Fast forwarding into the Transition Plan years, we realized that the FITS Storage System had evolved to the point where it would be possible, with a reasonable amount of effort, to expand it into a fully fledged archive system. As neither the Hilo nor La Serena base facilities have adequate internet connectivity for users to simultaneously download data from all over the world, they seemed unattractive as locations to host an archive server. However, when we researched the costs of Cloud computing services — such as Amazon Web Services and Google Cloud Platform — it became pleasantly apparent that substantial cost savings could be realized by moving to an in-house developed archive system hosted on a commercial Cloud platform.

We were given the go-ahead at the end of 2013, spent 2014 developing a prototype system; then, following approval by an external group of testers, worked through 2015 transforming the prototype into the fully developed GOA. The system is now deployed on Amazon Web Services, using an EC2 (Elastic Compute Cloud) virtual server and storing data on S3 (Simple Storage Solution) with backups on Amazon Glacier.

Cloud Computing

The decision to store data "in the Cloud" has raised more than a few eyebrows, but once we started researching this option, it quickly became obvious that this approach offers many advantages. As far as we know, we're the first major observatory hosting our archive on a commercial Cloud computing platform, though I'm sure more will follow.

Cloud computing prices, especially for data storage, have plummeted over the last few years; we're actually now paying about a quarter of what we estimated two years ago. One of the real strengths of the Cloud for us is Internet connectivity. As mentioned, our Internet connections from Hilo and La Serena aren't geared up for users simultaneously downloading data from all over the world, whereas that's exactly what Cloud systems are designed to support.

For a modest cost, we are able to buy into massive global computing and network infrastructure that also supports such Internet giants as Netflix and Dropbox. The GOA software itself is very flexible, and can run both on the Cloud or on a conventional Linux server. In fact, we run instances of the same software at both our summit sites to provide internal data management facilities.

"I've tried using the new archive for some PI data and I just wanted to let you know how impressed I am with how it works. The interface is easy to use and intuitive." — Tom Matheson, US NGO

Mixing this with Cloud computing gives us a huge range of scalability options; for example, if a new (or existing) Gemini partner country or institution found that their internet connection to the current archive server isn't so great, we could deploy an extra server, either within the Amazon Cloud at a data center located closer to them, or even potentially on a server located within an astronomical institution.

Keeping It Simple

In developing the GOA archive web interface, we wanted to keep things as simple, yet as powerful, as possible. There is only one search form for the archive; it provides a single and clear starting point for any archive search — whether it's a Principal Investigator (PI) looking for data from his or her own observing program or someone interested in searching for public data on an object. Searches by a variety of parameters (such as instrument, observing date, and observing modes) are provided, along with instrument-specific details and, of course, target names and sky positions.

GOA was by definition a lean project; the driver was cost savings, and this meant limited functionality. While we deliberately decided to make it a simpler system than the previous Gemini Science Archive, we would also maintain the functionality that had proved most beneficial over the years. The only example of lost functionality that users have commented on is that the archive no longer provides details of proposal abstracts in the database, and searching by PI name is not possible. We're keeping a list of ideas and feature requests to consider for future upgrades.

Bookmarkable Searches

Another particularly useful feature of GOA is its ability to bookmark searches. When you enter a field in the search form and click "search," your browser is directed to a URL that represents that search. This allows you to bookmark the page, copy and paste the URL from your browser, save the URL in your notes, email it to a Co-Investigator, or whatever you like. And if you visit that URL in the future, that search is preserved and will find all the data from that program; if any new data has been added since you saved the URL, you'll see the new results too.

Low Latency

Some time ago, we started "remote eavesdropping," whereby PIs could connect to the Gemini control room while their observations were being made. This allows users to interact with the queue observing team and provide feedback on the data as it comes in. With Base Facility Operations already happening at Gemini North, we might look to a future that also includes Remote Observations — GOA is already prepared for this, as we designed the new archive to make data available promptly. Data typically are available to download within a minute or so of completing a readout. At the moment, Gemini North data are slightly quicker (often as fast as 20 seconds) due to the better Internet connection to Maunakea. However, as the Large Synoptic Survey Telescope begins laying fiber optics to Cerro Pachón, we anticipate Gemini South data to fall into the same regime.

Paul Hirst is a staff scientist at Gemini Observatory and can be reached at: phirst@gemini.edu

Contributions by Gemini staff

News for Users

The final quarter of 2015 brings many changes and milestones at Gemini, from the successful implementation of Base Facility Operations at Gemini North, to final resolution of the GMOS-S Hamamatsu CCD readout issues. Also of note is the impact of a major earthquake at Gemini South, new optical coatings at both telescopes, and the anticipation of visitor instruments in 2016.

Figure 1 (top). *Image from the west-pointing cloudcam, showing a moonlit UKIRT and a nice meteor in the background. Cloudcams are used as part of the Base Facility Operations at Gemini North.*

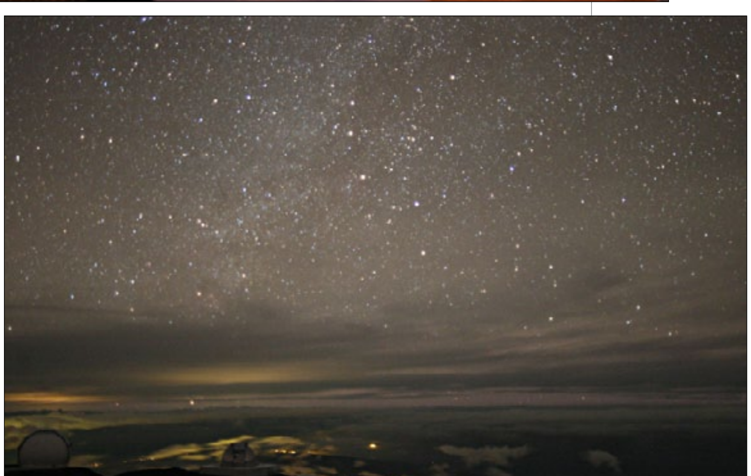


Figure 2 (bottom). *Not what you want to see! This image from the north-facing cloudcam, on a night in mid-November, shows the Keck and IRTF domes in the foreground, with approaching cirrus in the background.*

Operating Gemini North from the Base

Gemini North is now operating every night from the base facility on North A'ohoku Place in Hilo. We've been working for more than a year to make this possible, developing and implementing new monitoring and control capabilities; gradually we confined the night staff to the summit control room, to gain confidence that we hadn't missed anything before relocating to sea level.

Once we had cameras and microphones up and running on the observing floor, and a reliability upgrade to the mirror covers, we removed the need for night staff to be in the dome; we could now open or close the dome or telescope mirror covers remotely. As evaluating weather was the most challenging task for the night staff, we installed additional weather sensors

Figure 3.
Gemini staff operating Gemini North from Hilo.

outside the building to monitor sky conditions, precipitation, and summit-level fog (Figures 1 and 2). Software enhancements ensure that the dome will close automatically should the network link from Hilo go down while the dome is open, and we then encounter precipitation. In November, we started trial operations from the base (Figure 3), with the help of members of the day crew who stayed late in case of problems at startup. After a month of trials, which resulted in a lot of useful feedback, we were ready to "fly solo."

From here on, if you come observing at Gemini North (*e.g.*, for a Classical or Priority Visitor run), you can expect more air to breathe than you would have if observing at the summit.

We're now working on the plan to repeat this operation at Gemini South. In the interests of efficiency, we'll "copy and paste" as much as possible from what we did in the north. However, as this remains one of the single biggest projects ever undertaken at Gemini South, we don't expect to relocate to its base facility in La Serena until late in 2016. See the article on Base Facility Operations in the October 2015, and Year in Review issues of *Gemini*Focus.

GeMS Laser and the September Earthquake

The large earthquake that hit Cerro Pachón in September 2015 put the complex GeMS "sodium" laser totally out of alignment; the quake also caused us to lose the first of three GeMS runs scheduled in Semester 2015B.

The GeMS laser works by generating two infrared laser beams at different wavelengths, mixing and amplifying these in a nonlinear crystal, and producing a signal at the sum of the two input frequencies. The resulting beam is then directed into beam-transfer optics for launch onto the sky. There are many delicate, micron-scale adjustments in this system, and a magnitude 8.4 earthquake within 100 kilometers of the telescope site was more than sufficient to take the laser's alignment back to "square one."

To fix the laser, we essentially had to start from scratch. We adopted a systematic approach, implementing some enhancements that will make for much quicker recovery, especially should we suffer a recurrence (which we all, of course, hope we will not). By late November it became clear that we would lose the second GeMS run; now we're certain that we will not be operating GeMS in January either. We're now focusing on protecting the February run. Hopefully a final concerted push will get us back to 30 Watts of light at the sodium wavelength with the steady performance that had been achieved before the earthquake.

Mirror Coatings North and South

As reported in the previous issue of *Gemini*Focus, both Gemini telescopes were shut down for maintenance in September and October (North and South, respectively). Both shutdowns involved mirror coating — the secondary at Gemini North, and the

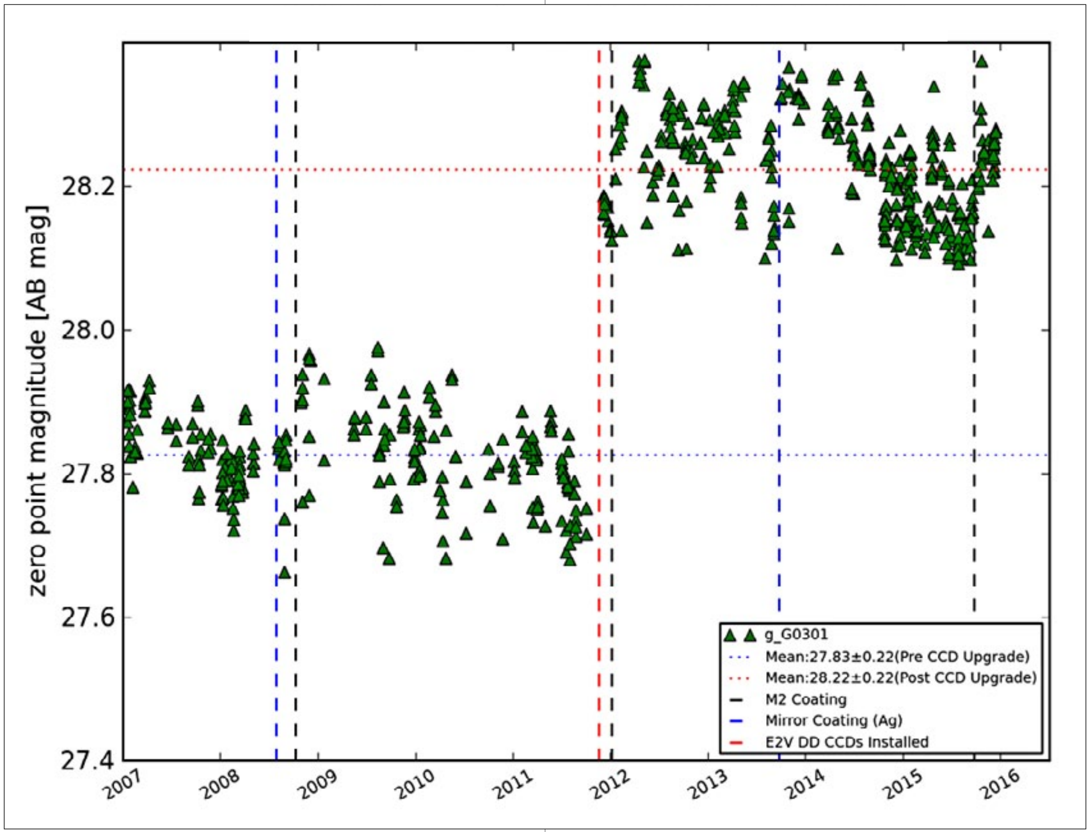


Figure 4.
GMOS-N g band zero point as a function of time. The various mirror coatings and CCD installations are marked with vertical dotted lines. Far right is the recent uptick due to the recoating of M2.

primary at Gemini South. The beneficial effect of a fresh coating on M2 is clearly seen in the GMOS-N zero points shown in Figure 4. In Chile, the coating of the Gemini South primary mirror was a team effort, with staff attending from both Gemini sites, Cerro-Tololo-Inter-American Observatory, and the Southern Astrophysical Research (SOAR) telescope. The results were excellent.

Also in the south, we continued to modify the cooling arrangements for the top-end control computer; the warmer ambient temperatures on Cerro Pachón have caused problems with condensation on the cooling lines in the past, causing us to lose telescope time due to high humidity. The modifications are designed to increase the flow rate to the top end, thus enabling the temperature of the cooling water to be reduced. Despite the loss of summit access for three days due to a spate of bad weather, we got back on sky on schedule — a considerable achievement reflecting the planning and effort that the whole team puts into these shutdowns.

GMOS-S CCDs Update

Since the previous *Gemini*Focus, we completed work on two major quality issues with the GMOS Hamamatsu CCDs at Gemini South and went back on sky. As previously reported, the "saturation effect," which produced banding artifacts on images with saturated pixels, was solved by a video board upgrade. Charge smearing effects, which we had also identified as an intermittent (and hard to reproduce) problem, were not convincingly identified; we could not pinpoint a particular cause in our investigation inside the detector cryostat, but the readout cable on the affected chip was replaced just in case. The smearing effect is now at a level so low that it will not affect any conceivable science observation. We have released an ***update*** to Gemini's Image Reduction and Analysis Facility (IRAF) which is capable of handling data from the new video boards and includes significant improvements to the GMOS data reduction examples.

Visiting Instruments

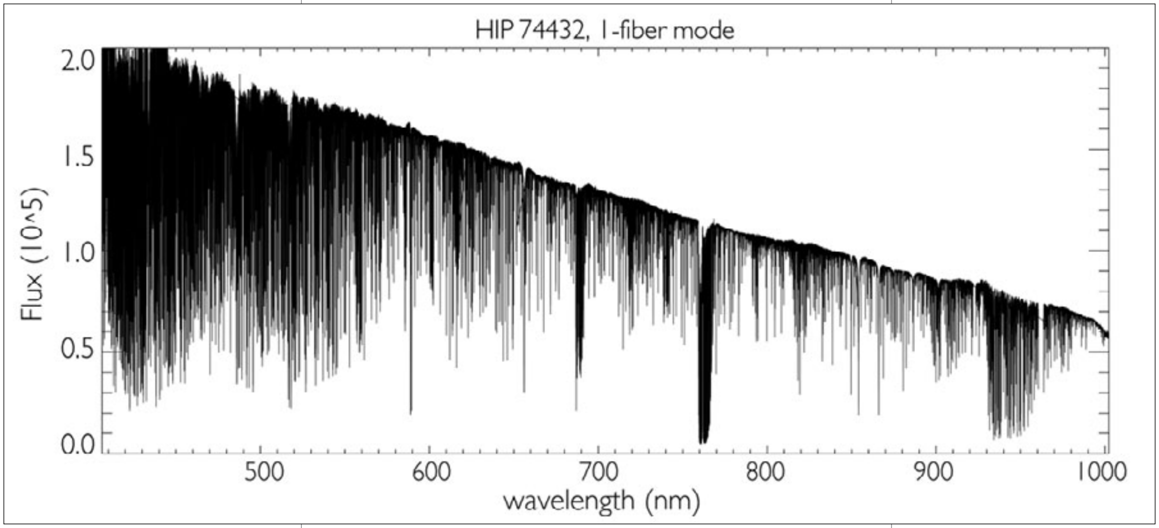
Gemini continues to welcome visiting instruments. After an absence of a few years, Phoenix (high-resolution near-infrared spectrograph) returns to Gemini South in 2016A. Also in the south, we will host a first run for the dual-band Differential Speckle Survey Instrument (DSSI). Watch the Call for Proposals pages for these opportunities.

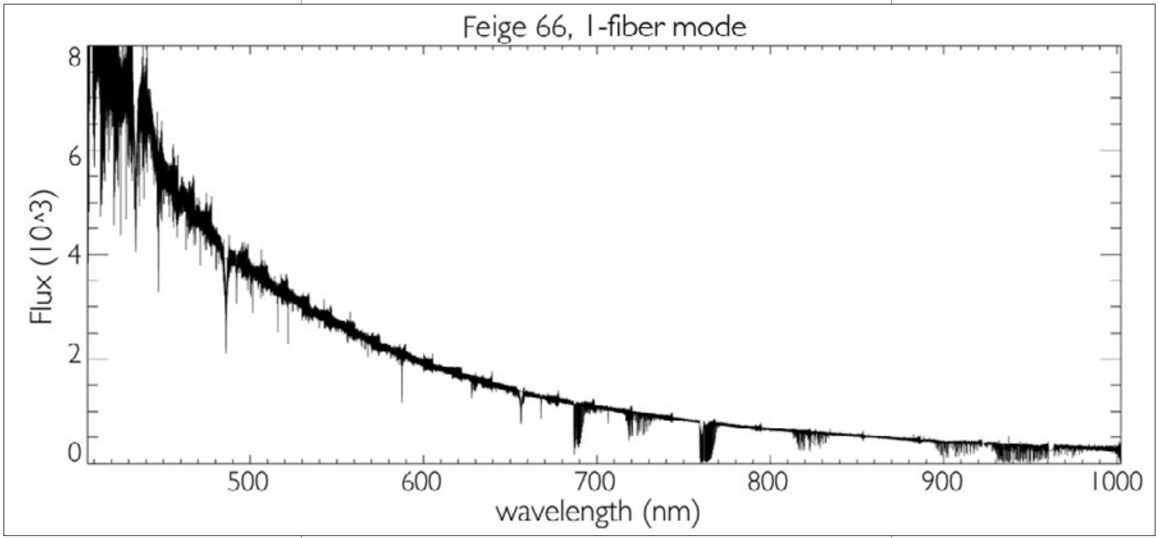
You may also have noticed that GRACES, our high-resolution spectroscopy capability realized by sharing CFHT's ESPaDOnS Spectrograph, is now listed with the other facility instruments on the web pages, where previously we listed it as a "visitor" instrument. In reality, GRACES is neither, but it has some of the properties of both. GRACES relies on a sharing agreement with CFHT, so we necessarily schedule it in a limited number of blocks per semester; we cannot fully integrate it into the queue as we do with facility instruments. In that respect, it is not dissimilar to instruments such as NIRI and NICI, which have relatively limited usage and are not always installed on the telescope.

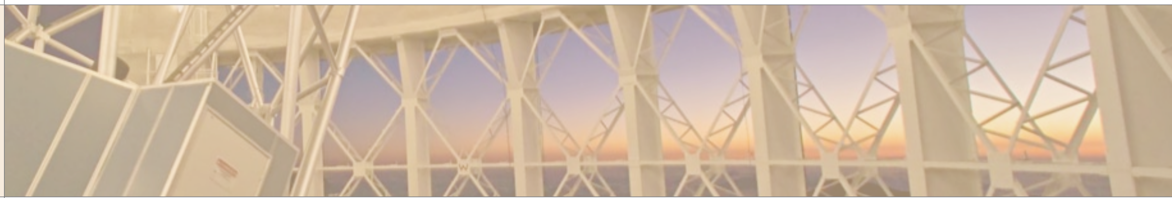
The project which developed GRACES was not tasked to deliver a facility instrument, but to give us a reasonably sensitive high-resolution spectroscopy capability; we would then monitor its performance and usage for about a year before deciding whether it should become better integrated into the Observatory's observing systems. We're now in that latter stage with GRACES, running the instrument for real and gauging demand and success (Figures 5 and 6).

If you want to see how GRACES performs on a range of targets, refer to the ***sample data*** taken in the run-up to the 2015B Semester. You can get preview images of the reduced spectra ***here***.

Figures 5-6.
(upper): HIP 74432, a solar-analog star observed with GRACES in 1-fibre (object-only) mode. (lower) For comparison, Feige 66, an O-type spectrophotometric standard star observed in the same mode. Both spectra have resolving power in excess of 65,000.







Contributions by Gemini staff

On the Horizon

AURA will announce its vendor selection for the New Gemini South laser in early 2016. Delivery of the upgraded Natural Guide Star New Generation Sensor is also expected in 2016. GHOST is undergoing Critical Design Review, the arrival of its engineering-grade CCDs are imminent, and the Gemini Board has decided to locate GHOST at Gemini South. Four outstanding studies on the Gen4#3 instrument have been completed; final reports are now available for reading. And Small Project proposals for existing instrument upgrades are now being evaluated.

Vendor Quotes Received for New Gemini South Laser

On October 2nd, the Association of Universities for Research in Astronomy issued a request for quotes (which were due in early December) for a new laser at Gemini South. The quotes are now in, and we intend to announce vendor selection in early 2016 — after approval by the National Science Foundation. The new laser will dramatically improve the reliability of the Gemini Multi-conjugate adaptive optics System (GeMS) at Gemini South. It should also allow us to reduce staff efforts in the daytime, prior to laser runs, and at nighttime, during laser runs.

Contract Signed for Natural Guide Star Sensor Upgrade

The Australian National University and the Association of Universities for Research in Astronomy have signed a contract for the Natural Guide Star New Generation Sensor (NGS^2) and begun its design and construction; we expect delivery in 2016. The NGS^2 upgrade will allow the Gemini Multi-conjugate adaptive optics System (GeMS) at Gemini South to utilize guide stars four times (1.5 magnitudes) fainter than the current system.

Figure 1 shows the percentage of sky coverage versus Galactic latitude after the NGS^2 upgrade (blue lines) compared to the current system (red lines) for 1, 2, and 3 guide stars

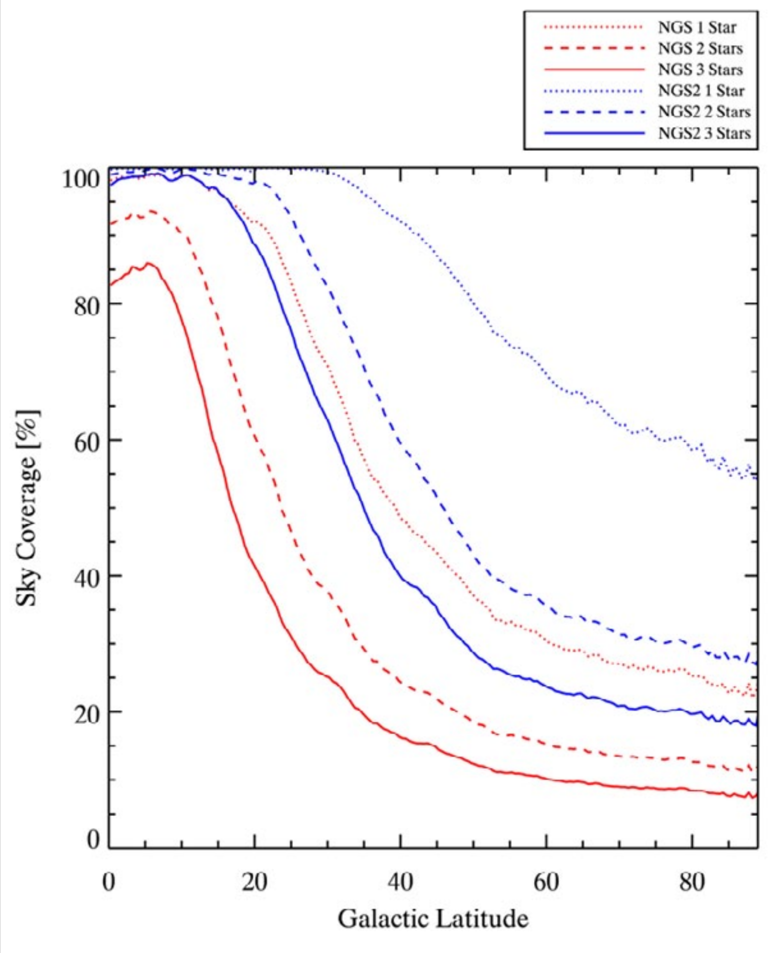


Figure 1. *Sky coverage vs. Galactic Latitude with NGS² on Gemini South.*

(dotted, dashed, and solid lines, respectively). On average, the upgrade will increase sky coverage by about 2.5 times at the Galactic poles and to about 80% in the single guide star case for targets within 50° of the Galactic plane.

GHOST News

During the first week of December, the Gemini High-resolution Optical Spectrograph (GHOST) team completed the first of a two-part project milestone: the Critical Design Review. The design team — led by the Australian Astronomical Observatory (AAO) and partnered with both Canada's National Resource Council-Herzberg (NRC-H) and the Australian National University — expect to complete the Critical Design Stage with the second part of this project milestone in early March 2016.

In order to reach this milestone, the GHOST project has continued to move forward in 2016, despite a couple of setbacks:

First, we lost NRC-H's project manager, a key player who moved on to another opportunity outside the organization. The existing NRC-H team has since absorbed his responsibilities, with some additional help from within their department.

Second, in mid-2015, the AAO experienced trouble securing an acceptable optical fiber from its vendors — until one of them finally delivered a usable fiber. With the fiber delivered, construction of the prototype fiber assembly is underway. We still believe that it is possible to manufacture a better fiber, so AAO is continuing to work with the vendor to optimize the product. While this prototype fiber assembly is not on the project's critical path, it remains a high-risk design item until completed and tested.

During the December 2015 Critical Design Review, an external committee and the Gemini GHOST internal team reviewed the spectrograph optics and system software and completed designs for the Cassegrain unit, fiber assembly, and slit-viewing assembly. Early in March 2016 a second review will cover the spectrograph's optomechanical design and electronics, as well as the thermal enclosure design and anything else that still needs addressing from the first review.

In other news, NRC-H expects the imminent arrival of GHOST's first engineering grade CCD detectors that were ordered in the first quarter of 2015. This CCD will be characterized and integrated in preparation for the arrival of the science grade detectors in third quarter 2016.

Adding to this progress, the Gemini Board has recently endorsed the decision to locate GHOST at Gemini South, where preparations have begun to receive the instrument. We expect delivery near the end of 2017. After testing and commissioning, we plan to have GHOST ready for use by semester 2018B.

Gemini Instrument Feasibility Studies

In April 2015 Gemini funded a number of independent and non-competitive Gemini Instrument Feasibility Studies (GIFS). We designed these studies to help Gemini understand the science, technical requirements, and costs associated with creating the next Gemini instrument (Gen4#3) — while complying with a set of top-level Science and Technology Advisory Committee guiding principles.

GIFS resulted in four outstanding studies for Gemini: ***GEONIS, GMOX, MOVIES, and OCTOCAM***. Each represents a different view of what is possible for Gemini's next instruments. However, the studies' outputs are not instrument design for build proposals; Gemini will use the GIFS studies to help inform the requirements that will go into the call for Gen4#3.

The community can now read the final reports and presentations from each ***team*** and provide comments and pose questions to: ***GIFSFeedback@gemini.edu***. Before completing the set of requirements for Gen4#3, Gemini will consider any comments received by December 22, 2016; we particularly welcome feedback on the science requirements, technical capability, and design aspects.

After January 22nd, Gemini will consider the community's input, along with recommendations from our advisory committees, to produce the Gen4#3 Request for Proposals (RfP). We are working towards a 2016 Q2 release of the RfP. Please visit the ***Gen4#3 home page*** for the latest information.

Instrument Upgrade — Small Projects Proposals

Gemini is committed to keeping our operational instrumentation competitive and to serving the needs of our user community. The Observatory also has a responsibility to provide major upgrades to the telescopes and their adaptive optics systems and associated instrumentation. To this end, in October we issued a request for the community to send us small-scale instrument upgrade proposals as part of our Instrument Upgrade Program.

With a total budget of $200,000, we were looking for compelling proposals requesting up to the whole budget, as well as those asking for minimal, or even no funding from Gemini. Each selected project will receive up to one night (10 hours) of observing time to be used for demonstrating the scientific potential of the upgraded instrument.

At the time of writing, we have received letters of intent and are excitedly anticipating receiving proposals by the December 17th deadline. We expect to quickly evaluate proposals and begin one or more instrument upgrade projects in 2016 Q1. For further announcements visit ***this site.***

Maria-Antonieta García

Viaje al Universo 2015: Learning, Fun, and Laughter!

The Gemini South flagship outreach program, Viaje al Universo *engaged and inspired thousands of students in late 2015.*

Figure 1.
In early December, Gemini hosted five students and one teacher from each of the participating Viaje *schools as special guests at the Gemini South telescope facility on Cerro Pachón.*

"Sharing what I do with local students is so energizing," says Gemini astronomer Erich Wenderoth as he reflects on time spent with students in classrooms in, and around, Gemini's host community, La Serena, Chile. Since 2006 Erich has participated in Gemini's annual *Viaje al Universo* (*Viaje*) program, sharing his passion for astronomy and science. "I look forward to the day that a young astronomer approaches me and reminds me of a talk I gave to the classroom," Wenderoth says, following his visit to San Nicolás school during the latest *Viaje* program in October.

Viaje al Universo is a week long program that brings astronomers, engineers, and science educators into local Chilean classrooms in order to share the excitement of scientific discovery with students and teachers. In addition to the classroom visits, a variety of other activities bring science down to Earth, such as StarLab portable planetarium shows, hands-on activities for the entire famiIily (see Figure 3), and a popular panel discussion that shares the job opportunities available at astronomical observatories.

Three members of Spain's stand-up/interactive comedy troupe, *"The Big Van: Scientists on Wheels"* added a healthy dose of humor to this year's mix (Figure 2). "It was an excellent week, and we discovered a lot of enthusiastic and creative people," says troupe member Irene Puerto, who, along with Alberto Vivó and Javier

Santaolalla, entertained and inspired nearly 4,000 students and teachers during their week in Chile. "Beautiful stages were waiting for us at the schools and two astronauts accompanied our performance in a fruit market and in front of a cathedral. It was definitely an unforgettable experience!" adds Vivó.

"Gemini is thrilled that we have many new partners in our effort this year," says Gemini Deputy Director Nancy Levenson at *Viaje's* opening ceremony. "It is indeed a sign that we are having an impact when our community steps up to participate actively in our work."

This year's *Viaje al Universo* program engaged students and teachers from six regional schools: San Nicolas, Trinity, St. Mary's, San Joaquin, Carlos Condell de la Haza, and Martin de Porres. Helping to advance their knowledge were staff from the following observatories and astronomy affiliates: the Association of Universities for Research in Astronomy, Gemini Observatory, Cerro Tololo Inter-American Observatory, Las Campanas Observatory, the Giant Magellan Telescope, the Office for the Protection of the Northern Sky of Chile, and the University of La Serena.

As a special treat, Gemini also hosted in early December five students and one teacher (from each of the schools that participated in the *Viaje* activities) as guests at the Gemini South telescope facility on Cerro Pachon (Figure 1). More surprises and special events are now being planned for Viaje 2016. We hope to see you there!

To learn more about *Viaje al Universe*, please visit: [***www.gemini.edu/viaje***](http://www.gemini.edu/viaje)

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agarcia@gemini.edu

Figure 2.
Students from Carlos Condell de La Haza Christ School (La Serena), and República de Israel (Coquimbo)) join the "Big Van: Scientists on Wheels" and Gemini staff after a presentation of fun scientific monologues.

Figure 3.
Learning phases of the Moon is much more attractive when you can eat the cookies, at least according to members of this Trinity School's family after their participation in Viaje al Universo *program.*

Figure 4.
Big Van's Javier Santalaolla (third from left), illustrates a proton collision by having San Joaquín School students interact in front of the entire high school audience.

Figure 5.
Although the Viaje program targets schools, a public event at La Serena's "Café ConCiencia" coffee shop attracted an engaged audience.

Figure 6.
Staff from the La Serena City Hall Department of Tourism participate in a special workshop lead by the Big Van members to help improve their skills at communicating science to the public.

by Richard McDermid

Peculiar Galaxy Collision Is a Winner!

The Australian Gemini Office has selected the winners of its most recent Gemini School Astronomy Contest.

Each year since 2009, teacher-sponsored Australian students in Years 5-12 (as well as their inter-school groups and clubs) have a chance to use an hour of observing time at the 8-meter Gemini South telescope in the Chilean Andes. All they need to do is select a celestial object visible from the Southern Hemisphere and write a winning explanation as to why it would be interesting to image.

A panel of astronomers, educators, and science journalists judge the mandatory teacher-sponsored entries on both the scientific interest of the target and the visual appeal of the resulting image. The best-ranked proposals will have their object imaged by Gemini South and its professionally processed picture presented to the school by astronomers who will discuss the image with them. The top three entries will also be able to participate in a "Live From Gemini" program, and more.

Figure 1.
The winning image of the most recent Australian Gemini Image Contest (Student Division), obtained with the Gemini South 8-meter telescope in Chile. It shows the peculiar galaxy NGC 7727 in Aquarius. It is a composite of g, r, i, and H-alpha filter images, with a total integration time of about one hour. Image credit: Ivanhoe Girls' Grammar School Astronomy Club, Samuel Carbone (Trinity College), Travis Rector (University of Alaska Anchorage), and the AAO.

Figure 2.
Richard McDermid (AAO/Macquerie University) with the Ivanhoe Girls' Grammar School Astronomy Club members.

The Winners

Two winners share the top prize in the most recent Australian Gemini Astronomy Contest: The Ivanhoe Girls' Grammar School Astronomy Club in Melbourne (Figure 2) celebrates the win with Samuel Carbone of Trinity College (Perth). Both winners proposed observing the peculiar galaxy NGC 7727 (Figure 1) in the constellation Aquarius. The judging panel was impressed by the science cases put forward by these two applications, and so awarded them as joint winners of the Student Division contest.

Once the panel of judges selected the winners, astronomers observed their selected target using one hour of time on the Gemini South telescope, taking multiple images in different colored filters. Travis Rector (University of Alaska Anchorage) then reduced and processed the image to create a stunning color portrait of this interesting and peculiar galaxy. NGC 7727 is in the late stages of a galaxy-galaxy collision, with irregular wisps of stars seen extending out from the central regions — a tell-tale sign that two moderately massive galaxies had a smash up that started around 1 billion years ago.

In addition to the winners having their object selected for observation on one of the world's largest telescopes, their schools received a visit from Richard McDermid from the Anglo-Australian Observatory/Macquarie University. McDermid awarded the top-rated students' schools with a framed print of the award-winning object taken with the Gemini South telescope (Figure 3); he also gave an astronomy presentation to the students at their respective schools, where celebrations took place. Samuel even made it into the local newspaper, which quoted him saying that the opportunity to have his selected target observed was "a huge honour."

Congratulations to our winners, and a big thank you to their respective sponsoring teachers — William Cooper (Trinity) and Paul Fitz-Gerald (Ivanhoe) — for supporting the students in their applications. And thanks to all of the students and teachers involved in applying for the contest last year. This year's event is already underway, but with a different approach to previous years. You can find out more about it by contacting contact Christopher Onken at:
geminicontest@mso.anu.edu.au

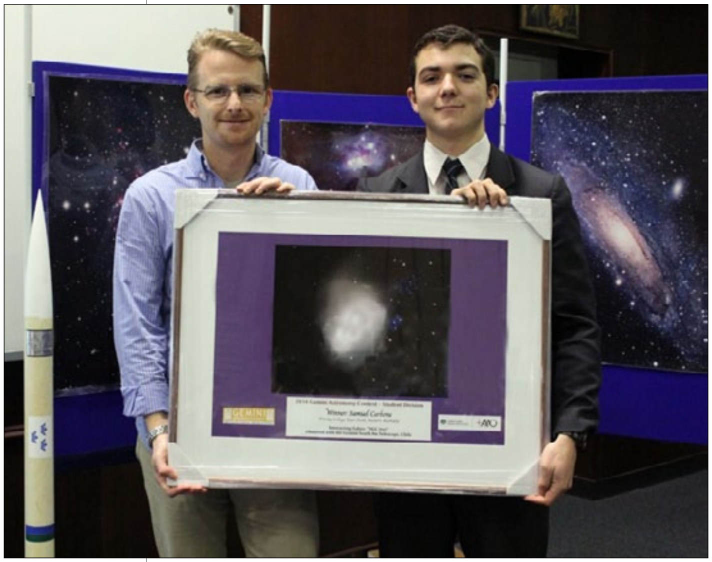

Figure 3.
McDermid presenting a prize photograph of NGC 7727 to Samuel Carbone of Trinity College, Perth.

Richard McDermid is an Assistant Scientist at Gemini North. He can be reached at:
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Gemini staff (Andy Stephens, Andreea Petric, and Adam Smith, front to back) during the recently initiated remote operations at the Gemini base facility in Hawai'i.

AURA

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