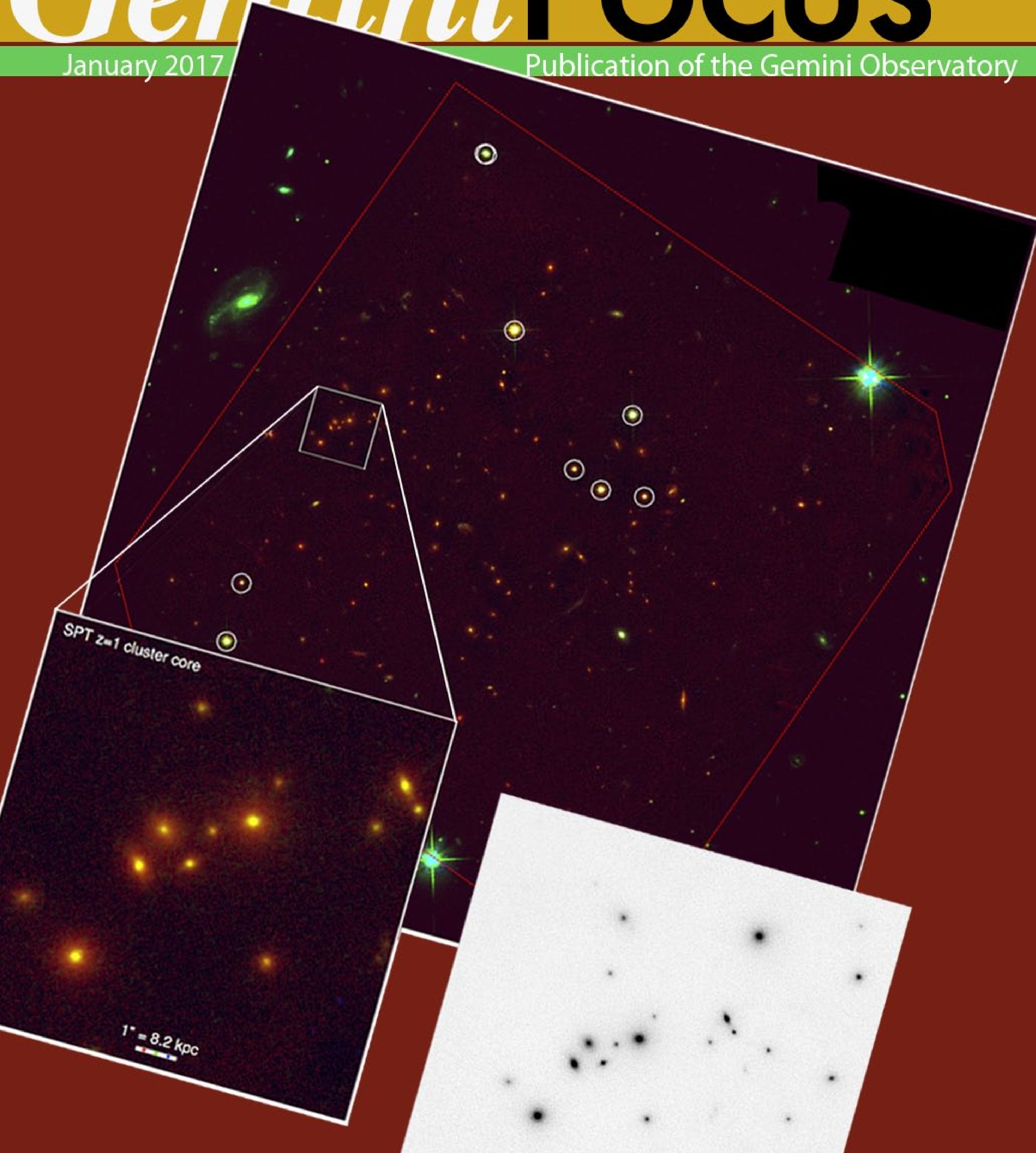
GeminiFocus

January 2017
Publication of the Gemini Observatory



ON THE COVER:

Color composite image of the galaxy cluster SPT-CL J0546-5345, comprised of Gemini GeMS/GSAOI and HST data. White inset at right bottom shows Gemini K_s image of the region. The article on this work begins on page 3.

Gemini*Focus* January 2017

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Director's Message

Gemini Brings 2016 to a Successful Close

Gemini is looking back at the rapid passing of a another successful year — the first full one after the transition to operating the Observatory on a 25% reduced budget, which translates to ~25% less staff. Of course a few things are moving forward more slowly, but, overall, the Observatory is as productive as ever and continues to operate smoothly. In fact, we have introduced several new and innovative ideas into our operations and instrumentation programs, as described in the following overview.

With December comes the end of the first full year of Base Facility Operations at Gemini North — that's a full year without nighttime staff at the telescope on Maunakea. Both our telescope operators and observers have been enjoying the increased oxygen in Hilo, and we have not seen any negative impact on our technical downtime. To the contrary, from the control room in Hilo the team operating the Differential Speckle Survey Instrument (DSSI) established a new record this past January for the number of targets (>130) observed in a single night!

The first night of Base Facility Operations at Gemini South began on November 14th, as described in this issue's *News for Users*. We still retain the option of observing from Cerro Pachón or Maunakea — especially in instances where a visitor instrument requires it — but we anticipate that summit observers will be rare in the future.

2016 was also the first full year of Fast Turnaround programs, which offer researchers in the Gemini community 10% of the time on both telescopes every month; participants typically obtain their data as quickly as six weeks after applying for time. Additionally, the Subaru community joined this Gemini program in May in exchange for time on the Subaru telescope. We continue to improve the Fast Turnaround schemes and will gradually offer all modes and all instruments in the regular Call for Proposals.

In 2016 we saw a surge of contacts from Principal Investigators offering potential visitor instruments. Consequently, we now have over 10 instruments in the queue to exploit Gemini's state-of-the-art telescope facilities. The Observatory continues to invite inquiries from all instrument teams that would like to bring their instruments to our telescopes. Over the past 12 months we have welcomed back some old friends — including DSSI, Texas Echelon Cross Echelle Spectrograph (TEXES), Phoenix, and Gemini Remote Access to CFHT ESPaDOnS Spectrograph (GRACES) — all offered in the regular Call for Proposals, as well as some newcomers (*e.g.*, the hyper-precision polarimeter POLISH 2, which visited in November). We also had groups projecting into the future, such as the Immersion GRating INfrared Spectrograph (IGRINS) team, from the University of Texas Austin, that obtained ~ 130 hours of observations for 2018A through the latest round of Large and Long programs; we are looking forward to supporting the IGRINS team and offering this great instrument to the rest of the Gemini community in about a year.

Internally, 2016 was an equally important year, as AURA was awarded a new six-year cooperative agreement to manage the Gemini Observatory — after a long recompetition process launched by the National Science Foundation at the end of 2014. We can now work closely with the Large Synoptic Survey Telescope project and with the National Optical Astronomy Observatory to streamline and coordinate our operations in Chile (and beyond).

Gemini's public education and outreach remained vibrant throughout the year, hosting its 12th and 6th editions of our flagship programs *Journey Through the Universe* in Hawai'i and *Viaje al Universo* in Chile, respectively. These programs paralleled Gemini's many other outreach activities, including the dissemination of numerous press releases that made front page news in national and international publications. And as has become custom over the past few years, Gemini made a strong presence at the recent Society of Women Engineers meeting (see article on page 20), joining forces with all the other AURA centers in a large booth to promote engineering positions at the observatories.

Yes, looking back, 2016 was a very successful, productive, and innovative year, and 2017 promises to be exciting as well — with both telescopes fully functional in remote operation mode, more visitor instruments in the queue, and progress being made in upgrades to our facility instruments (*e.g.*, the multi-object spectroscopy mode of FLAMINGOS-2). Also significant, we have procured a new laser for Gemini South (and are in the procurement process for Gemini North); Gemini is rapidly moving towards making laser adaptive optics a true part of our queue operations, rather than it being restricted to a block schedule. Stay tuned, because surely, in 2017, we will continue *Exploring the Universe, Sharing its Wonders!*

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

Sarah Sweet, Rodrigo Carrasco, and Fernanda Urrutia

Gemini South Explores the Growth of Massive Galaxy Clusters

*Using high-angular-resolution images obtained at Gemini South, we have measured, for the first time, the stellar mass–size relation for 49 galaxies in a cluster environment at redshift z ~ 1. Our data suggest that the most likely relationship between stellar mass and size has a constant slope over time. This finding leads us to conclude that the probable evolutionary course for the most massive spheroid-like galaxies since z ~ 1 is either from minor mergers (*i.e.,* when a galaxy grows via accretion of small satellite galaxies), or adiabatic processes (such as outflows from active galactic nuclei), or a combination of both.*

The Evolution of Massive Galaxies Over Cosmic Time

During the past 20 years astronomers have developed a picture for the evolution of the size and structure of galaxies — from the formation of the first galaxies in the early Universe, to what we see today. One of the most important discoveries in the last decade is that the most massive spheroid-like galaxies (*i.e.*, galaxies with masses $> 10^{11}$ M_{Sun}) in the distant Universe ($z > 1$) are much smaller in physical size than those with the same stellar mass in the local Universe; the effective radii of these massive galaxies at $z \sim 1$-4 are observed to be, on average, a factor of 2-6 times more compact when compared with local systems with the same stellar mass. At $z = 0$, massive compact galaxies are very rare; only a few have been found to date. Presumably, the most massive high-redshift galaxies must evolve significantly in size to become present-day passive elliptical galaxies.

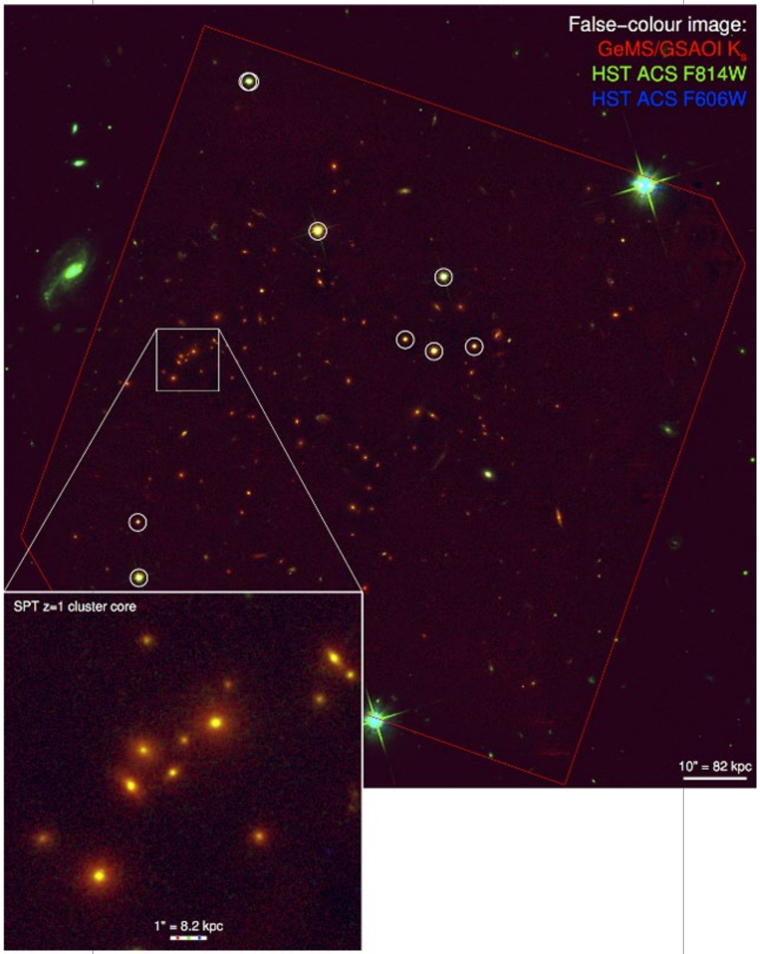

Figure 1.
False-color image of SPT-CL J0546–5345 at z = 1.067. Gemini GeMS/GSAOI K_s (this work) = red, HST ACS F814W = green, HST ACS F606W = blue. The red polygon shows the approximate sky coverage of the GSAOI pointings. PSF stars are indicated by white circles. The star near the top of the image with two circles is a binary star. The inset at lower left is a zoom-in of the cluster core. The scale bars in the inset and full image show the angular and physical projected distances at the cluster redshift. The red, green, and blue spots on the scale bar in the inset show the PSF FWHM for each band. North is up and east is left.

One important open question remains. It concerns how these galaxies grew in size and what main physical mechanism(s) are involved. Mergers of galaxies with similar stellar masses (major mergers), accretion of small satellite galaxies (minor mergers), and rapid mass loss caused by active galactic nuclei (AGN) or supernova winds (adiabatic expansion) could all contribute to the dramatic growth in the size of these galaxies. We can distinguish between these physical mechanisms by comparing the slope of the stellar mass–size relation of the massive high-redshift galaxies with the local sample.

Accurate determination of the stellar mass–size relation depends most strongly on the resolution of the images, the rest-frame wavelength of the observations, and the number of galaxies observed. Superb resolution is required to accurately measure the effective radius for the most compact galaxies at $z > 1$. We need rest-frame observations at wavelengths longer than the 400 nanometer spectral break to restrict the observations to galaxies dominated by the light of the underlying old stellar population. The accuracy of the stellar mass–size relation is also improved as the number of galaxies observed increases. Previous high-angular-resolution images obtained from the ground are limited by the small effective field-of-view of the instruments used for the observations. Given the large field-of-view provided by the Gemini Multi-conjugate adaptive optics System, combined with the Gemini South Adaptive Optics Imager (GeMS/GSAOI), we avoid this problem by simultaneously observing several galaxies in a single field.

A High-angular-resolution View of Cluster Galaxies at z ~ 1

We used GeMS/GSAOI, the world's most advanced adaptive optics system, to image galaxies in the cluster SPT-CL J0546-5345 at redshift $z = 1.067$. This cluster, detected as part of the 2,500 square degree South Pole Telescope Sunyaev-Zel'dovich survey (Brodwin, Mark, *et al.*, *ApJ*, **721:** 90, 2011), is a massive cluster with a virial mass of 10^{15} M_{Sun} and several compact massive spheroid-like galaxies at its center. We imaged the galaxies using the K_s filter at 2.2 microns. The final combined image presents a variation of the Point Spread Function (PSF) Full-Width Half-Maximum (FWHM) between 80-130 milliarcseconds (mas) within the GSAOI 85" x 85" field-of-view (Figure 1) — translating to a physical size between 0.66-1.07 kiloparsecs (kpc) within a field-of-view of 697 kpc^2 (1" = 8.2 kpc at the cluster's rest frame). The PSF FWHM achieved with GeMS/GSAOI is, on average, a factor of 1.5 better than the angular resolution provided by the H_{160} filter of the Hubble Space Telescope (HST) Wide-Field Camera 3, which has a PSF FWHM of 180 mas, and is comparable to that of the HST Advanced Camera for Surveys' F814W (I-band) filter (Figure 2).

The Stellar Mass–Size Relation at z = 1

An accurate calculation of the stellar mass–size relation requires a robust determination of the stellar mass and physical size of the galaxies. We estimated the stellar mass for 49 of the SPT-CL J0546–5345 cluster member galaxies using public codes. We then fit publicly available stellar population synthesis models (used as tools for interpreting the integrated light of galaxies) to the derived photometry assuming a certain Initial Mass Function (which describes how mass is initially distributed within a stellar population).

We selected galaxies with ages older than 10 giga-years and younger than the age of the Universe (details can be found in the article accepted for publication; see end of article). We used the publicly available code GALFIT (Peng, C. Y., *et al.*, *AJ*, **139:** 2097, 2010) to measure the circularized effective radius, defined as $r_e = ab$, where a and b are the effective semimajor and semiminor axis, respectively, as a measurement of the physical size of the galaxies. The K_s-band stellar mass–size relation for the SPT-CL J0546-05345 cluster member galaxies at $z = 1$ and SDSS galaxies at $z = 0.1$ is shown in the top left panel of Figure 3. The stellar mass–size relation at $z = 1$ is offset from the local relation by ~ 0.21 dex, with a slope consistent with the slope seen for galaxies with same stellar masses in the local Universe.

The results, obtained here for the first time for galaxies in a cluster environment, are consistent with previous findings for field galaxies, indicating that the primary mechanism for galaxy growth in size since $z \sim 1$ in clusters is either minor mergers or adiabatic expansion due to AGN mass loss winds, or both. If major mergers were a dominant source of the evolution in the stellar mass–size relation, then the most massive galaxies would experience the most rapid growth; the slope of the stellar mass–size relation would then be steeper in the local Universe than at $z = 1$ — an effect we do not see in our results.

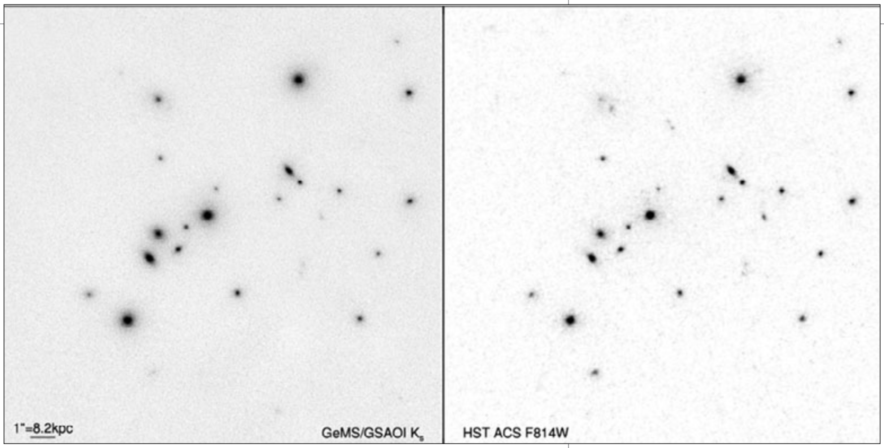

Figure 2.
The core of the SPT-CL J0546-5345 galaxy cluster at z = 1.067. Left: GeMS GSAOI K_s image. Right: HST ACS F814W image. The scale bar at the lower left shows the angular and physical projected distance at the cluster redshift. North is up and east is left.

Figure 3 also shows the stellar mass-size relation for the cluster SPT-CL J0546-5345 compared with other work in the literature. Our results emphasize the importance of high-resolution observations at the rest-frame wavelength of the cluster galaxies. Observations at shorter wavelengths — *i.e.,* at the B-band and U-band rest frame (top-right plot in Figure 3) — show a shallower slope and larger scatter in radius, due to ultraviolet-bright star-forming knots. In addition, the effect of resolution (bottom right plot in Figure 3) can lead to misinterpretation of the true physical mechanism involved in the extraordinary growth in size of the massive galaxies over time.

With this research we have demonstrated that wide-field, near-infrared adaptive optics observations, such as those we obtained with GeMS/GSAOI, are critical in order to characterize the galaxy population at high redshifts. GeMS is limited by the magnitudes of the natural guide stars (NGS) used to compensate for tip-tilt and plate-scale mode variation (currently R < 15.5 magnitude). High-redshift clusters are located in regions where

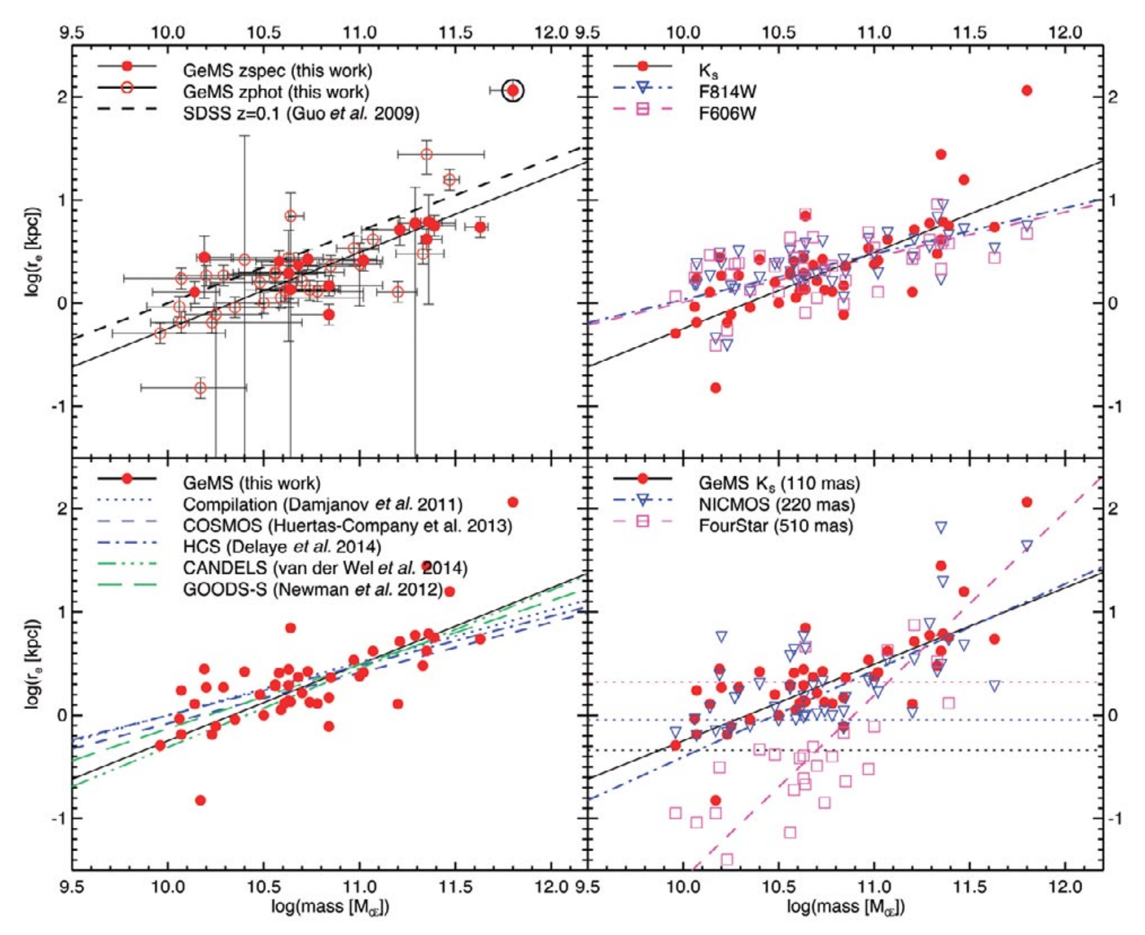

Figure 3.
Stellar mass-size relation for the cluster SPT-CL J0546-5345 compared with other work in the literature. Top left: K_s-band stellar mass-size relation at z = 1. The relation, defined by our cluster members, has a slope of $\beta = 0.74$, consistent with, but offset by, 0.21 dex from the z = 0 relation shown as the dashed line. Both relations trace the underlying stellar population. Top right: stellar mass-size relation for the SPT cluster measured in GeMS/GSAOI K_s (red filled circles and black solid line), HST ACS F814W (rest-frame B-band shown as blue down triangles and dot-dashed line), and F606W (rest-frame U-band as magenta squares and dashed line) bands. Bottom left: other z ~ 1 samples from the literature, measured in various rest-frame wavelengths. Rest-frame B-band measurements are shown in blue, and rest-frame V-band in green. Bottom right: the effect of resolution on the stellar mass-size relation. Filled red circles and solid line depict our GeMS/GSAOI K_s-band imaging (FWHM ~ 110 milliarcseconds). Blue down triangles and dot-dashed line show measurements from our imaging smoothed to the resolution of Gemini's Near-Infrared Camera and Multi-Object Spectrometer (220 milliarcseconds); magenta squares and dashed line are from smoothing to the resolution of the FourStar infrared camera (510 milliarcseconds) at the Magellan Baade 6.5-meter telescope at Las Campañas Observatory in Chile. The horizontal dotted lines indicate the physical size at z = 1, which corresponds to the resolution of each instrument.

bright stars are absent or have magnitudes fainter than the current limit. The new NGS system (NGS2) at Gemini South will extend the guide stars accessible to GeMS by 2-2.5 magnitudes deeper than the current system. This new capability will allow us to extend the observations to massive galaxy clusters beyond redshift $z \sim 1$ in order to determine the main cause of galaxy growth in size since cosmic high noon.

This work is accepted for publication in *Monthly Notices of the Royal Astronomical Society* and is availabe at ***this site***.

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Science Highlights

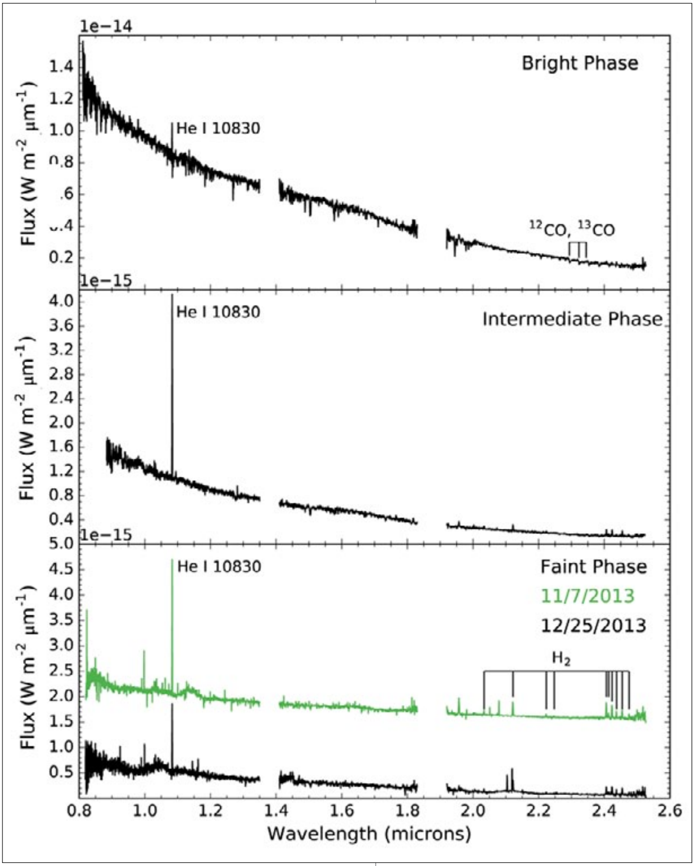
Recent near-infrared observations at the Gemini North telescope are used to characterize KH 15D — a binary T Tauri system and its circumbinary ring. Spectrographic data from Gemini North provides the strongest evidence yet that massive stars form in much the same way as do lower-mass stars. A team of astronomers use GeMS/GSAOI data at Gemini South to create the most accurate, and deepest, near-infrared color-magnitude diagram of globular cluster NGC 6624. And a joint program between Gemini North and the W.M. Keck Observatory on Maunakea completes the longest frequent, high-resolution imaging of Io's thermal emission, revealing patterns in the Jovian moon's volcanic activity over time and location.

Unscrambling a Complex Young Stellar System

Nicole Arulanantham of Wesleyan University (Middletown, Connecticut) and colleagues used the Gemini Near-InfraRed Spectrograph (GNIRS) on the Gemini North telescope to target the binary T Tauri system V582 Mon (KH 15D) — two K-type stars in a circumbinary ring that is inclined to the binary's orbit.

The team obtained data at three different orientations of the system's two young stars (Figure 1), allowing them to study several key aspects of this complicated system — including characterizing the photosphere and magnetosphere of the companion star (B), exploring a jet of material associated with a bipolar outflow, and probing the scattering properties of its circumbinary ring. The research uncovered an excess of near-infrared radiation that is possibly the signature of a self-luminous 10-Jupiter-mass planet. While this unresolved planet displays the expected excess in infrared radiation, as well as a 2-micron

Figure 1.
The top panel shows the spectrum of KH 15D during its "bright" phase, when the amount of direct starlight was greatest. The middle spectrum ("intermediate" phase) was taken when star B was just below the edge of the ring. Both spectra in the bottom panel were obtained during "faint" phases from two different cycles, when both stars were near periastron and the contribution from starlight was minimized. The spectrum from November has been offset by 1.5×10^{-15} W m^{-2} μm^{-1} for comparison to the data from December.



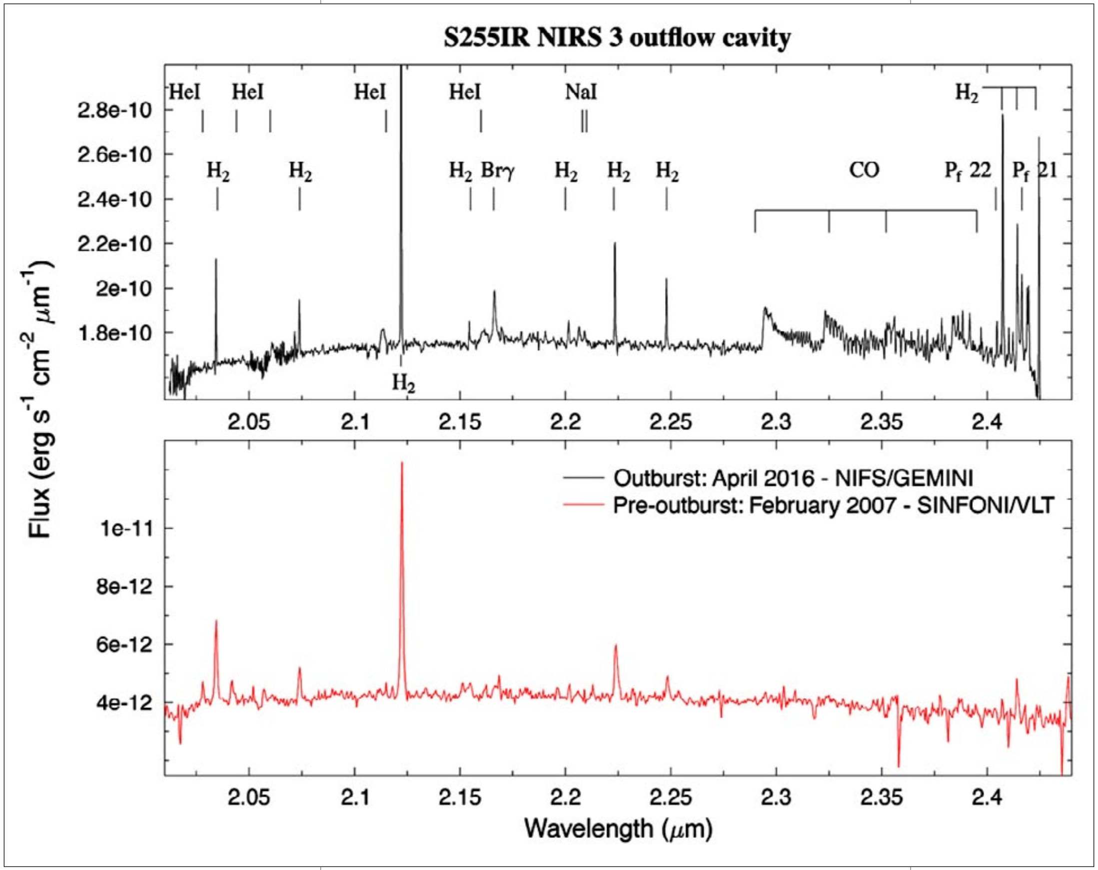
spectral feature that may be due to methane or ammonia, other anticipated signs of these two compounds went undetected in the observations. The team's spectroscopic observations also indicate that a mixture of water and methane ice grains lie within the circumbinary ring — close enough to the primary stars that the frozen methane must be shielded by dust from direct radiation.

Finally, in addition to determining that star B is an early K-type subgiant, the research revealed variable helium I emission in star B's magnetosphere due to ongoing mass accretion. The team's paper is accepted for publication in *The Astrophysical Journal* ***(view here)***.

High-mass Young Stellar Objects: Are all Stars Created Equal?

A team of astronomers using the Gemini Near-infrared Integral Field Spectrograph (NIFS) on Gemini North have found the strongest evidence yet that massive stars form in much the same way as do their lower-mass brethren.

Figure 2.
Gemini post outburst K-band NIFS spectrum (black at top) of the red-shifted outflow cavity of S255IR NIRS 3. The pre-outburst spectrum obtained with SINFONI/VLT is shown in red at bottom. The Gemini spectrum in the outburst phase shows a large number of emission lines typical of disk-mediated accretion outbursts.



In addition to the Gemini observations, the work includes data from NASA's SOFIA airborne observatory, Calar Alto Observatory, and the European Southern Observatory. The results show that when massive stars form, they consume chunks of their surrounding accretion disks, leading to episodic explosive outbursts — much like those known to occur during the formation of average mass stars like our Sun (only more intense). This finding may have a profound impact on the way some astronomers believe massive stars grow, namely by the fusion of less massive stars.

The international team of astronomers, led by Alessio Caratti o Garatti of the Dublin Institute for Advanced Studies in Ireland, published its work in the November 14th issue of the journal *Nature Physics* ***(available here)***. It was thought that an accretion disk could not survive around a higher mass star due to the star's strong radiation pressure, and thus it would not be a viable mechanism for producing the most massive stars, some of which can exceed 50-100 solar masses.

The developing star observed in this study, S255IR NIRS 3 (Figure 2), lies some 6,000 light years distant and has a mass estimated at about 20 solar masses. The Gemini observations reveal that the explosive outburst's source is a huge clump of gas, probably about twice the mass of Jupiter, accelerated to supersonic speeds and ingested by the forming star. The team estimates that the outburst began about 16 months ago and appears to still be active, albeit much weaker.

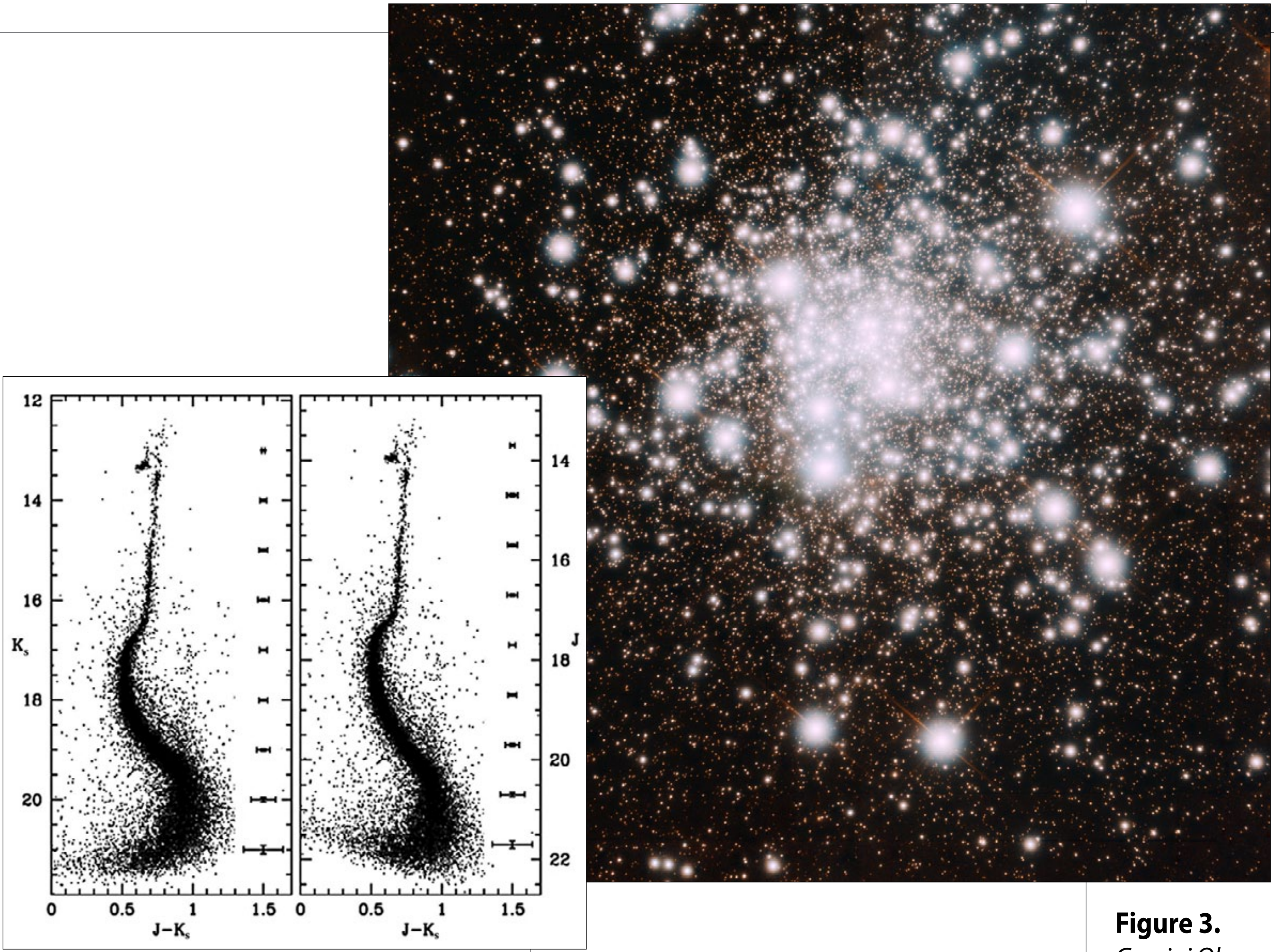


Figure 3.
Gemini Observatory GeMS image of globular cluster NGC 6624 revealing individual stars clear to its core. The inset shows the color-magnitude diagram with the main-sequence knee visible. The extreme sharpness of this adaptive optics image allows researchers to perform very precise photometry on individual stars — a task requiring exquisite imaging across the entire field, which would be a challenge for most adaptive optics systems. Composite color image by Travis Rector, University of Alaska Anchorage.

Image credit: Gemini Observatory/AURA

Cluster's Advanced Age is in Razor-sharp Focus

Researchers using the Gemini Multi-conjugate adaptive optics System (GeMS), combined with the Gemini South Adaptive Optics Imager (GSAOI), probed the depths of the highly compact globular cluster 6624 (Figure 3). These data reveal pinpoint star images with a uniformity across the crowded field, allowing the team to perform precise photometry deep into the cluster's crowded core.

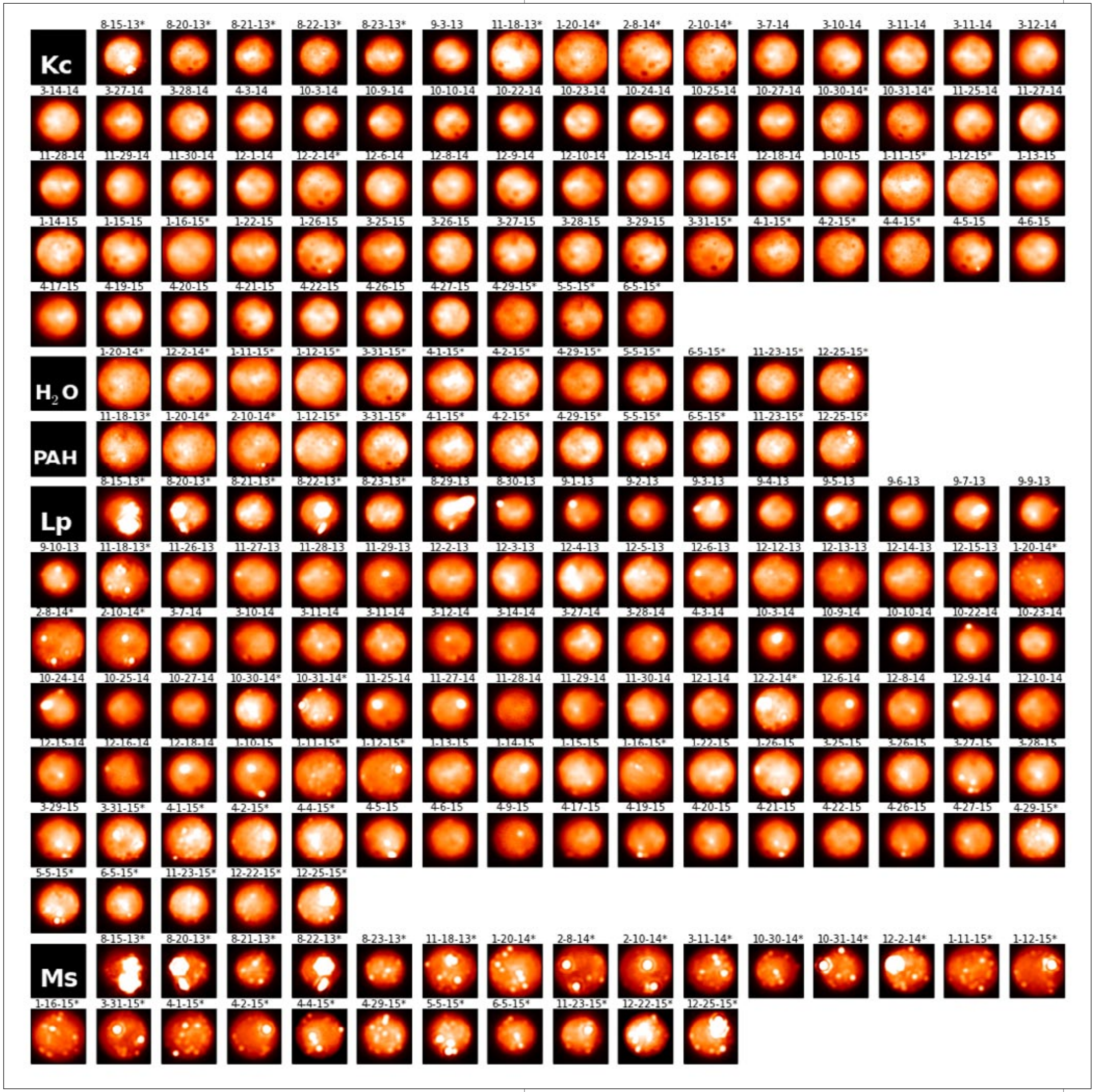
The team also detected a clear "main-sequence knee" (Figure 3, inset); this distinctive bend in the evolutionary track of low mass main-sequence stars is extremely difficult to detect without ultra-precise photometry. Indeed, this is the first time the feature has been identified in this globular cluster, and it allowed the team to determine the cluster's age with extremely high precision: about 11.5-12.5 billion years.

According to first author Sara Saracino of the University of Bologna, this is the most accurate, and deepest, near-infrared color-magnitude diagram ever produced of NGC 6624 and perhaps the best ever made for any bulge cluster. The results of this research are accepted for publication in *The Astrophysical Journal*, and a preprint is ***available here***.

Monitoring Io's Volcanoes with Adaptive Optics

The longest frequent, high-resolution imaging of Io's thermal emission is providing insights on the Jovian moon's volcanoes, thanks to a joint program between the Gemini North telescope (with the Near InfraRed Imager and spectrometer [+Altair adaptive optics instrument pairing) and the W.M. Keck Observatory. Gemini's queue scheduling provided the additional flexibility necessary to assure adequate coverage in the time domain.

Figure 4.
A sample of Io images obtained from the Gemini North telescope using NIRI with the Altair adaptive optics system for tracking volcanic activity over a 29 month period.
Image credit: Katherine de Kleer and Imke de Pater, UC Berkeley/ Gemini Observatory/ AURA/W.M. Keck Observatory



The observations spanned a period of 29 months and revealed patterns in the volcanic activity over time and location on the satellite (Figure 4), but also resulted in new questions.

According to University of California Berkeley (UCB) Graduate Student Katherine de Kleer, some of the eruptions appeared to progress across the surface over time, as if one eruption somehow triggered another 500 kilometers away. "While it stretches the imagination to devise a mechanism that could operate over distances of 500 kilometers, Io's volcanism is far more extreme than anything we have on Earth and continues to amaze and baffle us." De Kleer led the analysis of the data for this study with her advisor at UCB, Imke de Pater.

The results were presented at the American Astronomical Society's Division of Planetary Sciences and the European Planetary Sciences Congress in Pasadena, California, in October. De Kleer and de Pater presented the results jointly based on a pair of papers in the journal *Icarus*, which are available ***here*** and ***here***.

Gemini Legacy Image Release

Gemini staff contribution

Reflection Nebula GGD 27 Revealing the Chaotic and Messy Environment of a Stellar Nursery

This near-infrared image was obtained using FLAMINGOS-2, the infrared imager and spectrograph on the Gemini South telescope in Chile. It is a color composite made using four filters: Y (blue), J (cyan), H (green), and K_s (red). The total integration (exposure time) for all filters is just over one hour. The image is 4.6 x 3.5 arcminutes in size and is rotated 35 degrees clockwise from north up and east left. More information can be found ***here***.

Gemini staff contributions

News for Users

Base Facility Operations are underway at Gemini South. Interest continues to grow for visiting instruments. Gemini prepares to enter the era of followups on large, time-domain surveys. And adverse winter weather impacts Gemini North, while providing opportunities for Band 4/Poor Weather proposals.

Base Facility Operations Begin at Gemini South

Since late 2015, the Observatory has operated Gemini North at night from its Hilo Base Facility with no staff at the telescope facility on Maunakea. Gemini South has now followed suit; as of November the Base Facility Operations (BFO) project began full remote operations in La Serena, Chile. As promised in the January 2016 issue of *Gemini*Focus, in the interest of efficiency we copied much of the Gemini North project and pasted it into place at Gemini South, making this task as straightforward as possible. Along the way we made one or two locally-specific amendments and some minor improvements.

Figure 1.
Javier Fuentes (left) and Joy Chavez (right) operating Gemini South from the La Serena Base Facility on November 14, 2016.

Prior to November, we had already operated in "Base" mode with night staff at the summit of Cerro Pachón for more than two months — progressively confining them to the control room as we added more and more monitoring capabilities and remote control options to the summit systems. On November 14th we were ready as planned, and the nighttime staff carried out the first night of observing entirely from the La Serena Base Facility (Figure 1).

There are two instrument exceptions to BFO from La Serena: 1) the Gemini Multi-conjugate adaptive optics System/Gemini South Adaptive Optics Imager, for which we anticipate a new laser delivery in 2017 (and therefore we deferred the BFO safety interlock work until that new system is in place); and 2) the visiting instrument Phoenix, for which at least one subsystem required manual intervention (and therefore was run from the summit in December 2016).

Visiting Instruments

The increase in visiting instruments at Gemini continues. Both Phoenix (Figure 2) and the Differential Speckle Survey Instrument (DSSI) spent time on Gemini South in 2016A, and Phoenix returned to Chile in December. Phoenix suffered very badly from the dreadful weather in Chile in 2016A, but as this issue goes to press, the weather at Gemini South has improved. In 2017A both DSSI and Phoenix return to Gemini South, while the Texas Echelon Cross Echelle Spectrograph (TEXES) mid-infrared instrument visits Gemini North. We look forward to even more visiting instruments at Gemini in the near future. To learn more about our visitor instrument program, view Gemini's Visitor Instrument page ***here***.

Gemini Prepares for the Large Synoptic Survey Era

Gemini is and will likely be a key facility for following up interesting targets discovered in large, time-domain surveys. We are currently working hard to prepare Gemini for the era of massive synoptic surveys such as the Zwicky Transient Facility (ZTF) and the Large Synoptic Survey Telescope (LSST). New instrument development at Gemini, such as the Gemini High-resolution Optical SpecTrograph (and especially Gen 4#3), will provide the needed spectroscopic capabilities. We are also planning to improve the software and systems for handling a larger volume of Target-of-Opportunity triggers. In an effort to better align ourselves and coordinate with the rest of the community, we have been participating in planning exercises (such as the ***Maximizing Science in the Era of LSST*** workshop) and discussing the development of prototype Target and Observation Manager systems with

Figure 2.
The Phoenix near-infrared spectrometer during its run as a visitor instrument at Gemini South.

the National Optical Astronomy Observatory and the Las Cumbres Observatory. The community should also begin to think about other observing modes and strategies for using Gemini in the coming decade. Please contact Bryan Miller (*bmiller@gemini.edu*) for more information, especially if you are interested in participating in these efforts.

Making the Most of Poor Weather Nights

Clouds and poor seeing can frustrate any astronomer on a classical observing night. One of the main strengths of Gemini's queue observing is that your program is observed in the conditions it requires. While users of Gemini North and South may not need to worry much about bad weather nights, less-than-ideal conditions can occur when simply no targets exist in the regular queue programs to observe. Even if that happens, Gemini rises to the occasion and makes the most of the night by observing Band 4 or Poor Weather proposals (if available).

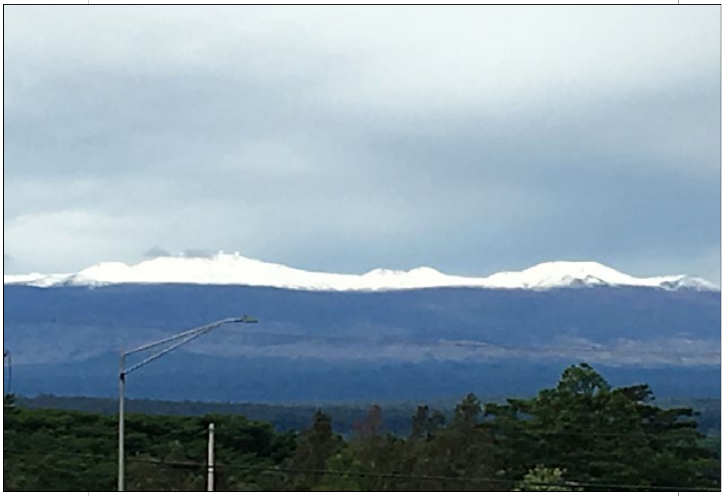
Band 4 programs can be submitted at any time during the semester and are most welcome during periods of bad weather (see the following News for Users item). If you have a science case with bright targets that can handle Cloud Cover = 70% and above (or any), any Image Quality, and any Water Vapor (with no restriction on Sky Background — or any Cloud Cover and Water Vapor (with no restriction on Image Quality and Sky Background) — then consider submitting a Band 4/Poor Weather program today. More details on the proposal submission process can be found at ***this link***.

Winter Blasts Maunakea

The tilt of our planet's axis has once again delivered an extended period of weather not conducive to astronomical observing on Maunakea. Starting in late November a series of fronts, troughs, and low-pressure systems have produced overcast skies, wind, and significant snow, (with drifting) at the Gemini North site (Figures 3 and 4). In the one month period from mid-November until mid-December,16 nights were entirely lost to weather, and an additional four were more than half lost. Overall, during this period we have only managed to obtain science for about one-third of the available time. As this issue goes to press the weather is improving!

Figure 3.
This image is a screenshot taken from the UH88 camera pointed at the Gemini North telescope, dated Monday, December 19, 2016.

Figure 4.
An image taken from Hilo on December 19, 2016, of a snowy Maunakea. Image credit: Joy Pollard



Gemini staff contributions

On the Horizon

A solution has been found to the problems with the Gemini Multi-conjugate adaptive optics System's Natural Guide Star Wavefront Sensor, and the remedy is well on its way. The Gemini South Laser Guide Star Facility is preparing for its Acceptance Testing in January 2017. Issues with the as-delivered hardware for the new Gemini Multi-Object Spectrograph (GMOS) CCDs for Gemini North have been corrected, and the CCDs should be installed on schedule in February 2017. And the Gemini High-resolution Optical SpecTrograph (GHOST) nears the midpoint of the GHOST project build phase.

GeMS' Next Generation Natural Guide Star Sensor: Making Progress

GeMS, the Multi-conjugate adaptive optics System deployed at Gemini-South, has been in use for several years now, producing spectacular results with its capability to deliver diffraction-limited image quality over a field more than 1 arcminute wide. To achieve this performance GeMS uses five laser guide stars for high-order wavefront sensing, and up to three natural guide stars (NGS) for tip-tilt and plate scale modes sensing. However, operation of GeMS is rather complex, principally due to technical issues. Recent technological developments have opened the possibility to improve the operational efficiency drastically (for instance, see page 17 of this issue to read about the new laser system being procured). Here we report on developments to enhance the selection and performance of natural guide star tip-tilt sensing.

A key problem encountered in GeMS operation revolves around the acquisition of natural guide stars. The existing Natural Guide Star Wavefront Sensor (NGS WFS) used for tip-tilt sensing suffers from low throughput, which severely reduces the number of stars that can be acquired, thereby diminishing the amount of sky coverage attainable by GeMS. Furthermore, the existing NGS WFS system uses three mechanical pickup probes, each of

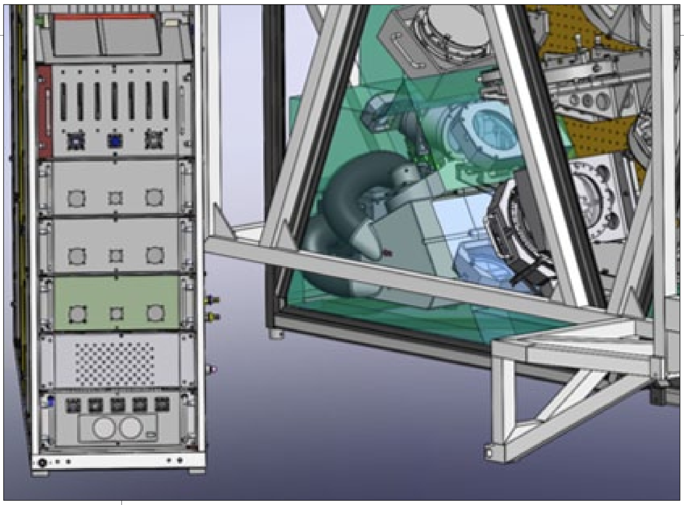


Figure 1.
Design drawing of the Natural Guide Star Next Generation Sensor (NGS2) unit (shown in green) occupying one corner of the Canopus AO optical bench.

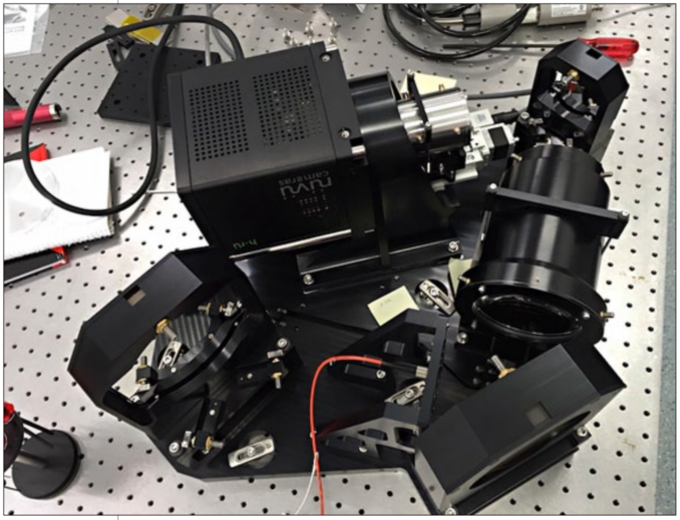


Figure 2.
The NGS2 unit, nearly fully integrated in the ANU laboratory. At the bottom of the image one can see two large fold mirrors that channel the light into the re-imaging optics. The large unit at the top left houses the electron multiplying CCD detector. Image credit: courtesy of the Australian National University

which can patrol the whole field. But these probes have only a very small field-of-view which, due to flexure and variable field distortions, sometimes makes it time consuming to acquire the stars.

Thanks to current state-of-the-art detector technology that has become available, these limitations can now be tackled. A key change is that rather than having three mechanical pickup probes patrolling the field to find and track the guide stars, the future system will use an electron multiplying charge-coupled device (CCD) detector that can image the whole field, allowing straightforward identification of guide stars.

Multiple regions of interest centered on the guide stars can also be configured and read out at very high speed — up to 800 hertz with very low read noise. This new sensor converts the existing delicate opto-mechanical arrangements of the guide probes to a system that will essentially be software configurable and more robust. Its higher efficiency is expected to improve the detection limit for natural guide stars by some 2.5 magnitudes, which will result in a dramatic improvement in sky coverage.

In 2014, we secured funding from the Australian Research Council for a proposal led by the Australian National University (ANU). This — together with additional funding from Gemini, the Australian Astronomical Observatory, and the Swinburne University of Technology — opened the possibility to design and build this Natural Guide Star Next Generation Sensor, or NGS2, in short.

We expect the new NGS2 subsystem will become an integral part of the Canopus adaptive optics system, replacing the existing NGS unit with the minimum necessary modifications. In a nutshell, NGS2 is composed of an optical system that re-images the focal plane onto a high-speed electron multiplying CCD detector. In full-frame readout, the guide stars can be easily identified. For tip-tilt sensing only, small areas around the stars are read out at high speed. A dedicated central processing unit will determine the centroids and pass the necessary information to the adaptive optics (AO) real-time control system.

The space constraint for the new NGS2 system, which needs to fit onto the existing AO optical bench, is very demanding; the alignment tolerances and system integration are challenging features, as well. Figure 1 shows the design drawing of how NGS2 will just fit into a corner of the AO optical bench. Furthermore, the detector generates heat that has to be actively removed, so as not to affect the rest of the AO system. And finally, one functionality of the existing system — the focus sensing of the natural guide stars — cannot be incorporated in the NGS2 design. Therefore, one of the existing peripheral wavefront sensors will take over that function.

Very good progress has been made to date in the detector upgrade. Essentially the opto-mechanical system and the detector system have been completed and are going through the final stages of integration and alignment at the ANU laboratories. Figure 2 shows a recent picture of the NGS2 system on the bench.

The system is in a very advanced stage of development and currently undergoing the final stages of alignment. Figure 2 also shows a recent picture of the built NGS2 module on the bench, ready for testing. Formal Acceptance Testing was successfully carried out in early December.

Still, much work remains to be done. In particular, a significant amount of software development is pending while resources are very tight. Also the integration of NGS2 into Canopus will be a delicate activity and require extensive testing, during which time it cannot be used for science. Hence planning of this activity must be done with care. We have great expectations for this new natural guide star system and expect that NGS2 can be delivered to the Observatory during the course of 2017. We intend to report on further progress in future issues of *Gemini*Focus.

— Rene Rutten

Gemini South Laser Guide Star Facility News

On October 5-6, the Gemini South Laser Guide Star Facility completed its Factory Acceptance Test (FAT) readiness review at Toptica AG Photonics in Munich, Germany (Figures 4 and 5). The actual FAT occurred between November 28–December 2 and was successful; all the requirements met the specifications established in the contract. Also, the Toptica team provided initial training to Gemini South scientists and engineers attending the FAT. The Toptica laser was shipped on December 2nd and arrived safely at Cerro Pachón on December 13th (Figure 3). We plan post-shipping Acceptance Testing (AT) in January 2017. During the post-shipping AT, we will verify the laser survived the shipping, maintaining all functionality at the specified performance. We plan to start installing the laser's subsystems at the telescope in May 2017, with commissioning on-sky in August 2017.

— Manuel Lazo

Figure 3.
Emmanuel Chirre (left) and Cristian Moreno stand guard over the new Toptica laser.

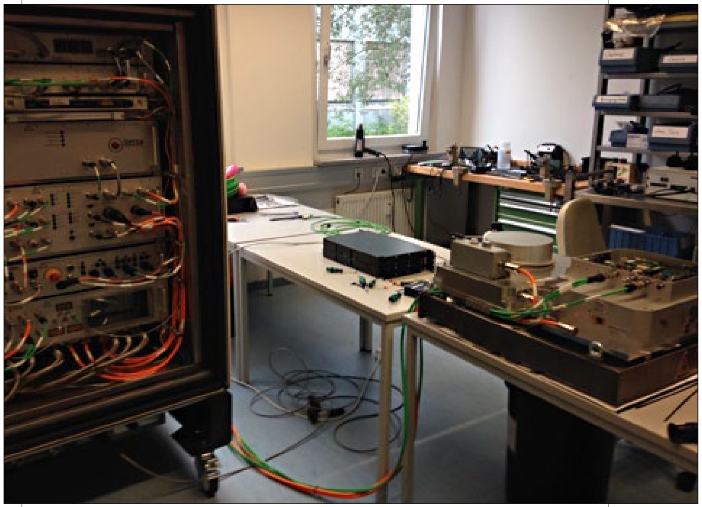


Figure 4.
The Gemini South laser system being integrated at Toptica. The Electronics Cabinet (at left) is connected to the laser head without the protective covers (at right) through the black fiber splice boxes (at center).

Figure 5.
The Gemini South laser cabinet just before connecting to the laser head during the FAT readiness review on October 5-6. Image credt: All three images by Manuel Lazo

Gemini Multi-Object Spectrograph CCDs

Through an exhaustive amount of troubleshooting, the Gemini Multi-Object Spectrograph (GMOS) upgrade team resolved the anomalies found in the as-delivered hardware for the GMOS-N CCD installation. We also called on Tim Hardy (detector engineer), who worked on the original set of GMOS-S Hamamatsu CCDs at the National Research Council of Canada-Herzberg, for additional support. As a result, we found and corrected some issues with the controller Digital Signal Processing code. We also developed a more efficient ground scheme for the Astronomical Research Camera controller to provide a more stable bias level and lower readout noise of about 4e-.

As we provide this report, the GMOS team continues to maintain schedule, having now completed the controller pre-installation Acceptance Testing in November (Figures 6 and 7). We also measured good read noise and all functioning amplifiers, and found no significant cosmetic concerns. The installation of the new CCDs into GMOS-N is scheduled to start by the first week of February 2017, with commissioning on-sky in mid March 2017.

— Luc Boucher

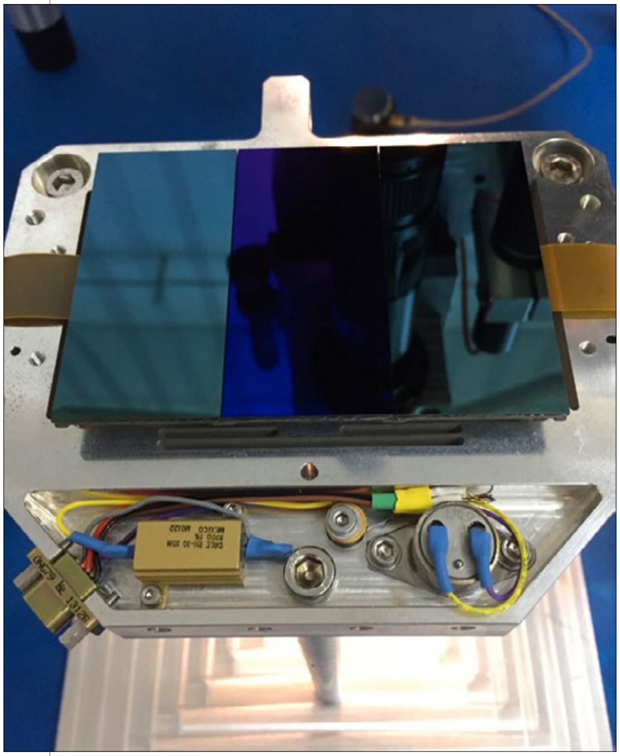


Figure 6. *The new Hamamatsu CCDs mounted and aligned in the Focal Plane Array and ready to be installed into the Test Cryostat to start pre-installation Acceptance Testing. Image credit: John White*

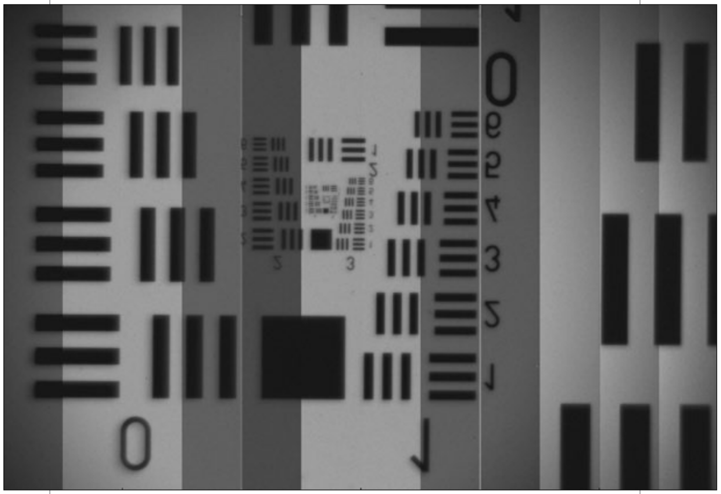


Figure 7. *The first light (raw) image of the new Hamamatsu CCDs; the 12 amplifiers see light, and show no evidence of cosmetic defects. Image credit: Luc Boucher*

Gemini High-resolution Optical SpecTrograph (GHOST)

As we near the midpoint of the GHOST project build phase, the build team continues to receive parts from its suppliers, and the assembly of the instrument and the development of the software progresses on schedule. The team recently completed some verifications on the telescope at Gemini South.

In November 2016, engineers from the Australian Astronomical Observatory (AAO) and Gemini successfully verified the alignment of the Instrument Support Structure (ISS) mounting surface relative to the telescope optical axis. This was important to check because any misalignment needed to be within tolerance to ensure that the GHOST system throughput is maintained. The GHOST Cassegrain unit is designed to be mounted directly on the ISS and both of its integral field units are designed to project the telescope pupil, which is coincident with the secondary mirror, onto the fiber core of the fibers which connect with the spectrograph in the pier lab. The fibers are protected by an outer conduit, constituting the optical cable assembly, running the length between the telescope and pier lab.

In October, other engineers from AAO and Gemini ran some tests using a mock optical cable assembly to demonstrate how this cable would move, and to identify any potential problem areas, such as snagging, as the telescope changes positions (Figure 8). These tests resulted in some minor design tweaks, and an overall confidence in the cable design. We expect the first delivery of GHOST subassemblies, Cassegrain unit, and cable assembly at Gemini South to occur in the fourth quarter of this year.

— David Henderson

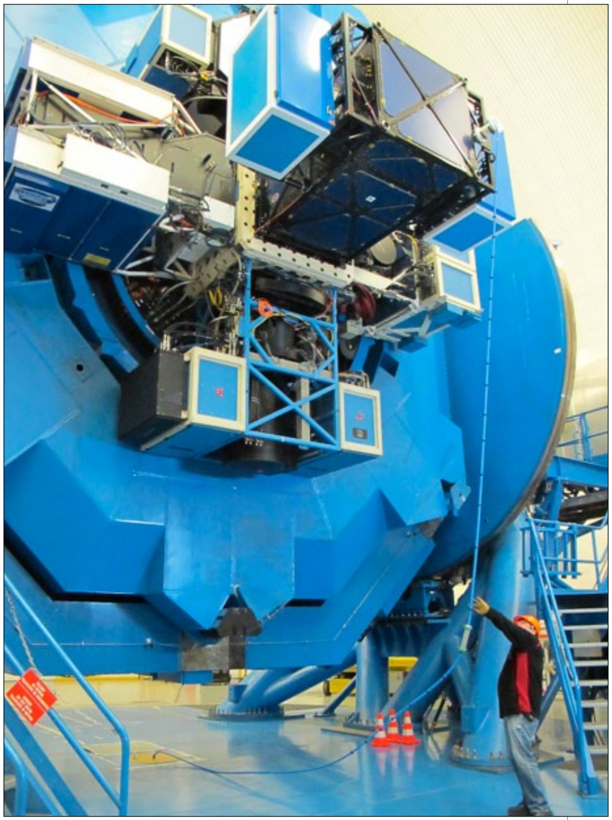


Figure 8.

AAO Engineer Vlad Churilov and the GHOST mock optical cable during testing in Chile.

Image credit: David Henderson

Highlights from the Society of Women Engineers Conference

In late October, 24 AURA employees, including eight staff from Gemini North and South, participated in the annual Society of Women Engineers (SWE) conference in Philadelphia, Pennsylvania (Figures 1 and 2). This gathering — the world's largest conference for female engineers — encourages women to achieve their full potential in careers as engineers and STEM leaders. Many participants engaged in workshops focusing on personal and professional development and attended a Career Fair. The Career Fair allowed Gemini and AURA staff to set up a booth where they could interact with attendees and increase awareness of the exciting engineering career opportunities available at astronomical observatories.

Figure 1 (right). *AURA and Gemini employees are in blue, engaging the engineers at the booth.*

Figure 2 (left). *Starting from the second to the left, Gemini North Software Operations Team Lead Angelic Ebbers, Maunakea Deputy Site Manager Chris Yamasaki, and Community Outreach/ Education Program Leader Janice Harvey interact with a SWE conference attendee (left).*

Manuel Paredes

Viaje al Universo 2016: Empowering Students with Science

Gemini South's premiere annual public outreach event extends its programming to expand impact on our local host community in Chile.

In late October 2016, Gemini South began its sixth annual *Viaje al Universo* in La Serena, Chile. As in previous years the annual event — which is one of the Observatory's core public outreach efforts — brought more than 20 scientists and professionals from different observatories into the classroom to motivate students into pursuing future careers in science, technology, engineering, and math (STEM).

Unlike any other *Viaje*, which generally lasts one week, Gemini South extended the 2016 event to offer more public talks, Starlab presentations, school lectures, family astro-events,

Figure 1.
People of all ages attend Viaje's opening talk by Gemini's Science Operations Specialist Erich Wenderoth. All images by Manuel Paredes

Figure 2.
Gemini South Senior Electronic Technician Pedro Ojeda explains the function and features of astronomical telescopes to students at the Colegio San Nicolás, in La Serena.

Figure 3.
Gemini South Public Information Office team member Dalma Valenzuela leads one of the Family Astro activities at the San Martin de Porres school, in Las Compañías, La Serena.

and tours to the Gemini South telescope and its La Serena Base Facility. The idea was to give students, teachers, and parents more time than ever to attend these special activities, which are designed to help develop a long-term interest in astronomy.

Gemini's Science Operations Specialist Erich Wenderoth kicked off *Viaje al Universo* 2016 with a public talk titled, "A Walk through the Universe," which took the audience from the Solar System and beyond — from nebulae and clusters in our own Galaxy to other galaxies that reached the edge of the observable Universe. A near-capacity audience of more than 120 people of all ages attended this event, held at the Intendencia, the government house of the Region de Coquimbo in La Serena. At the end of the lecture, Wenderoth voiced his opinion on the importance of a prolonged *Viaje* event: "Extending *Viaje al Universo* beyond the classic week of activities is a huge opportunity to reach a more diverse public interested in the development of science in Chile."

During the week of October 24-28, over 1,300 students were directly impacted with a variety of activities in different schools throughout La Serena. Over 30 classrooms

Figure 4.
Gemini Observatory, Cerro Tololo Inter-American Observatory, and Las Campañas Observatory professionals made up the Career Panel speakers. The feature continues as one of the most popular activities in the annual Viaje al Universo *programming.*

were visited by 21 professionals from many Chilean observatories, including 14 Gemini Staff.

These presentations covered a wide-range of topics from technical work (such as engineering and instrument design) to scientific research — including breakthroughs based on observations from Chile.

Fernanda Urrutia, an outreach astronomer at Gemini South who offered a presentation during *Viaje*, said, "I was delighted with the talk I offered about the Solar System at the public school San Martin de Porres, as I got very positive feedback from the 10-year-old students. I realized that they came away with an understanding of basic concepts that they didn't know before my presentation. That is something encouraging!"

The *Viaje* program ended with its popular Career Panel, featuring helpful insights on how students can pursue a career in astronomy or a related STEM field. Norma Isla, a professor at Christ School in La Serena, commented, "...the opportunity to share with top-level scientists is a huge boost for my students. In addition, the little ones had a lot of fun drawing constellations with stars sprinkled on cookies that they happily ate later!" For more information about *Viaje al Universo* activities please visit ***this site***.

Figure 5.
Information Systems Engineer Eduardo Toro chatting with students after the panel event about careers in astronomy.

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Maunakea after December 2016 snowfall.
Image credit: Joy Pollard, Gemini Observatory/AURA

AURA
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