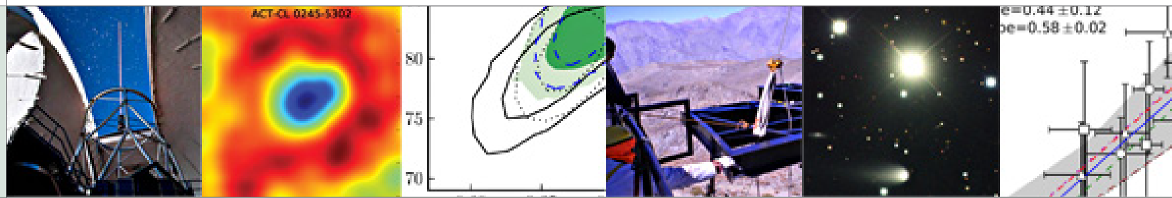
GeminiFocus

July 2013

Publication of the Gemini Observatory

GeMS

Embarks on the Universe



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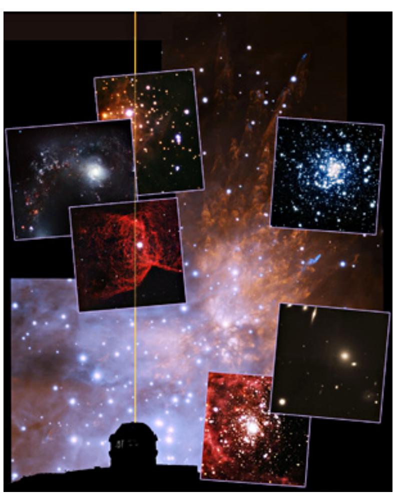
On the Cover:
The montage on this issue's cover highlights several of the spectacular images gathered as part of the System Verification of the Gemini Multi-conjugate adaptive optics System (GeMS). See the article starting on page 14 to learn more about this system and the cutting-edge science it is performing — right out of the starting gate!



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Markus Kissler-Patig

Director's Message

2013: A Year of Milestones, Change, and Accomplishments

We've seen quite a few changes at Gemini since the start of 2013. Now, halfway through the year, we're optimistic that many of our ambitious goals are nearing fruition.

So far, the absolute highlight is the spectacular scientific performance of the Gemini Multi-conjugate adaptive optics System (GeMS). This facility instrument is unique among any ground-based observatory, and it is ramping up strongly (as the cover article in this issue reveals). Twelve science programs have already been completed as part of the GeMS System Verification between January and April. Regular science observations are going strongly in 2013A, and GeMS, with its infrared camera, the Gemini South Adaptive Optics Imager (GSAOI), is fully booked for 2013B… and this is just the beginning. In the next few years, both the Gemini Multi-Object Spectrograph (GMOS) integral field unit and FLAMINGOS-2 are also expected to utilize light fed by GeMS. Three instruments will then profit from an image quality improved by a factor of two or better — a fantastic demonstration of how this critical technology will benefit the extremely large telescopes of the future.

A second highlight of 2013 is the (re)commissioning of FLAMINGOS-2 (F2). As this issue goes online, two runs remain (one in June, another in July) before F2 starts science operations in 2013B. F2 has recovered from its catastrophic lens breakage in 2012 and will be offered in imaging and long-slit modes this year. Despite its multi-object spectroscopy (MOS) mode, which is still pending commissioning, F2 jumped up to third place as Gemini's most in-demand instrument (behind the two evergreens: GMOS north and south). Commissioning of the MOS is foreseen in 2014A, making it available to Gemini's users in about a year.

The third challenge that Gemini faces this year is the arrival of the Gemini Planet Imager (GPI). GPI completed its acceptance testing at the University of California Santa Cruz in June and is awaiting acceptance review in July. We expect it to arrive at Gemini South in August for deployment on the telescope in the last quarter of this year. Gemini staff are working to solicit input from, and provide access to, the science community as soon as possible. Stay tuned for early data from this other unique facility!

Clearly, installing these three instruments on the Gemini South telescope in a single year is not only extremely challenging but very demanding on our resources. All those involved will work at their limit to make this possible. The scientific reward will be so huge, that the extra effort is well justified. Cross your fingers that no unexpected delays hit us in the next six months at Gemini South.

The Gemini North telescope is no less busy: the shutdown for the recoating of the primary mirror (occurring every 4-5 years) is scheduled for September, and two instruments will be visiting Gemini North during the second-half of this year. In July, the Differential Speckle Survey Instrument (Steve Howell, NASA-Ames Research Center, Principal Investigator) and in October the Texas Echelon Cross Echelle Spectrograph (John Lacy, University of Texas, PI) will both be available for limited runs. Gemini's strengthening visiting instrument program has found great resonance in the community!

Finally, our (numerous) advisory and oversight committees have met in April and May (see text on sidebar at right and figure on the next page for an overview of Gemini's oversight committees and governance). The full reports of these meetings are, as usual, public and appear on our web pages. Three resolutions are worth highlighting: Gemini will soon launch opportunities for its community to propose small (~$100,000) projects enhancing the scientific return of the Observatory. It will also propose leading upgrades (~$500,000) for existing instruments. The large/long observation programs are also being established, and we plan to synchronize them with (although distinct from) the National Optical Astronomy Observatory survey programs. Letters of intent will be solicited in early 2014. We are also working now on deploying, in 2014, the fast turnaround proposals, but more on these in future issues of *Gemini*Focus.

While 2013 will be challenging and extremely busy, 2014 promises to be no less exciting!

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

The Gemini Governance: Advisory and Oversight Bodies

Governance of Gemini Observatory is described in the International Agreement among the partner funding agencies. The needs and interests of each partner are represented through a number of different channels, described here, and in the figure shown on the next page.

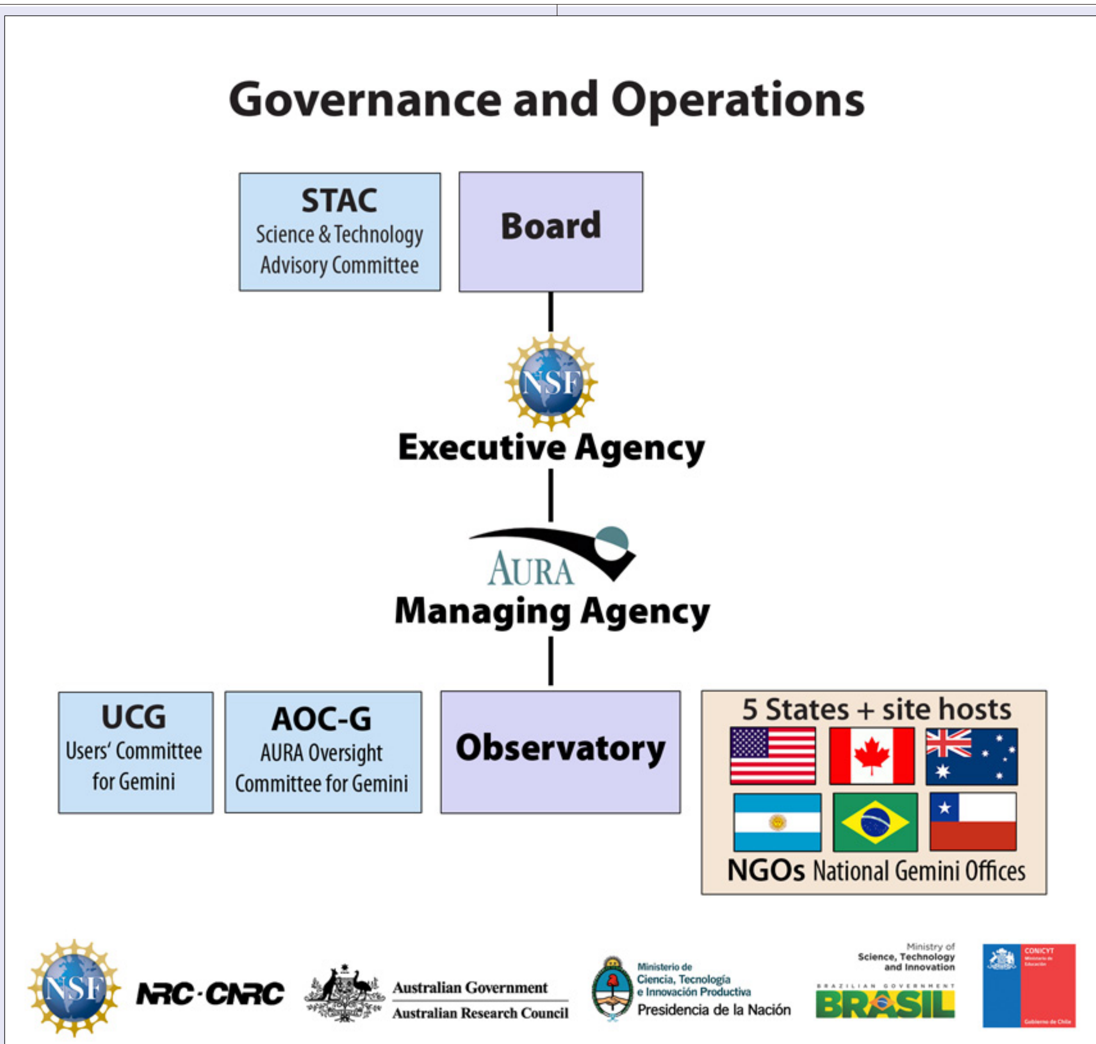
The Gemini Board serves as the supervisory and regulatory body, setting budgetary policy bounds and carrying out broad oversight functions. The Gemini Finance Committee acts as a subcommittee of the Board. It is comprised of financial authorities from the partner countries and advises the Gemini Board on financial plans and budget.

The Gemini Science and Technology Advisory Committee (STAC) advises the Gemini Board on policy matters of long-range scientific and technical importance, to enhance the long-term scientific productivity of the Observatory. This committee provides advice on scientific priorities for new instrumentation and other projects to maintain or improve the facility, and they keep the Board informed of the scientific priorities of the partner communities.

The Observatory and STAC work closely together to identify the long-range issues that require attention. The STAC is also charged to define an Instrument Science Team for each new instrument project to ensure a good connection between the desires of the Gemini user community and the delivered performance.

The U.S. National Science Foundation (NSF) executes the Gemini Program on behalf of the partners.

The Association of Universities for Research in Astronomy (AURA) is mandated by the NSF to operate and manage the Gemini Observatory.



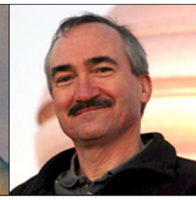
The Users' Committee for Gemini Observatory (UCG) provides feedback to the Observatory on all areas of its operations that affect current users. The committee members base their input on their own experiences and the information they solicit from the broader user community. Gemini uses this feedback to improve the service it provides to users.

The operational model for the Gemini Observatory delegates many functions to the partners. Each partner has a National Gemini Office (NGO) that provides the local interface between the national community and the Gemini Observatory to support their users.

Among the many responsibilities, each NGO supports the evaluation of proposals for, or site time through, a national time allocation committee, including providing for technical review and recommendation for time allocation to the international committee. The NGOs support users who have been allocated time during the Phase II Process and directly provide technical support of instruments and systems throughout the year. The NGOs also promote Gemini capabilities and use within their national communities.

An Operations Working Group, including the NGOs, advises the Gemini Director on the use and scheduling of the Gemini telescopes, and on matters related to the user support interface between the national communities and the Observatory. The group reviews science operations and makes suggestions for improvements, recommends content for each semester's call for proposals, and collaborates on science operations support among the NGOs.






Cristóbal Sifón, Felipe Menanteau, John P. Hughes, L. Felipe Barrientos, for the ACT collaboration

Dynamical Masses of Galaxy Clusters Discovered with the Sunyaev-Zel'dovich Effect

A large spectroscopic follow-up campaign of galaxy clusters, discovered via the Sunyaev-Zel'dovich Effect (SZE) by the Atacama Cosmology Telescope collaboration and largely carried out with the Gemini Multi-Object Spectrograph, has provided the first dynamical mass measurements for SZE-selected clusters.

Galaxy clusters are the most massive bound objects in the universe. Because of this, their number density is a sensitive function of the matter content of the universe. Clusters are composed of three main constituents: stars (both in galaxies and outside of them); ionized gas with typical temperatures of 10^6-10^7 Kelvin, known as the intracluster medium (ICM); and so-called "dark matter." (The presence of dark matter in clusters has been firmly established. The evidence dates back to the 1930s and the pioneering work of Fritz Zwicky at the California Institute of Technology, when he applied the Virial Theorem to galaxy velocities in the Coma cluster.) These three components have been exploited to discover and study clusters, most typically through X-ray and optical observations.

The power of galaxy clusters as cosmological probes depends largely on our ability to correctly infer their masses. However, we often estimate cluster masses from scaling relations that connect a given observable to mass itself. We usually obtain these relations through numerical simulations. Additionally, the mass function of galaxy clusters is a very steep one of both mass and redshift. Therefore, the few massive clusters at high redshift give the strongest weight to cosmological constraints.

A New Kind of Galaxy Cluster Sample

The Sunyaev-Zel'dovich Effect (SZE; Sunyaev and Zel'dovich, 1972) corresponds to the scattering of photons coming from the Cosmic Microwave Background (CMB) by the electrons in the ICM. This typically boosts the energy of individual photons, resulting in a distinct frequency dependence of the effect. Thus, the SZE is observed as a change in temperature in the direction of clusters with respect to the average CMB line-of-sight.

This effect is observed as a decrease in temperature relative to the undistorted CMB at frequencies below approximately 218 Gigahertz (GHz), peaking around 130 GHz, where it is of the order of a few hundreds of microkelvins (μK) for the most massive clusters. At approximately 218 GHz the net change in temperature is null, and the SZE is observed as a temperature increment at higher frequencies.

Importantly, since the SZE is a scattering process, the surface brightness of the SZE is strictly independent of the distance to the cluster. It is moreover, to first order, dependent only on the line-of-sight integral of the gas pressure through the ICM. Of course, more massive clusters tend to be hotter and have a denser ICM. This implies that they host ICM atmospheres with the highest pressures, making the SZE particularly sensitive to cluster mass. The bottom line is that the most massive clusters produce the strongest SZE signals.

The selection function for a sample of galaxy clusters detected with the SZE is essentially distance independent. Thus, an accurate calibration of the SZE brightness of clusters to their mass gives exciting prospects for the use of galaxy clusters as cosmological probes. This is especially true for two reasons: 1) Being almost independent of redshift, the SZE is best suited to detect the most massive galaxy clusters at high redshift (as mentioned before, it provides the strongest leverage to cosmological constraints); and 2) The SZE brightness is expected from numerical simulations to be cleanly related to the total mass of clusters, with an intrinsic scatter as low as 10 percent.

ACT Weighs In

The 6-meter Atacama Cosmology Telescope (ACT) in northern Chile was designed to scan the sky at millimeter wavelengths with a resolution approaching 1 arcminute. It is one of only two ground-based millimeter-band telescopes sensitive enough to conduct large area surveys (covering thousands of square degrees of sky) to study the CMB and other temperature fluctuations from astrophysical sources (*i.e.*, SZE clusters and distant galaxies).

The first results — based on a 450-square-degree survey of the southern sky at 148 GHz with a sensitivity of 36 μK — revealed 23 clusters in the redshift range $0.12 < z < 1.07$, of which 10 at $z > 0.28$ were newly discovered (Marriage *et al.*, 2011). The initial characterization of the sample, using optical imaging and archival X-ray data, confirmed that this was a sample of massive clusters spanning all redshifts, as expected from mass function predictions (Menanteau *et al.,* 2010).

However, a detailed analysis, including mass measurements and cosmological implications, had to wait for further observations. Figure 1 shows four sample clusters detected by ACT, showing the temperature decrements observed in 148 GHz (top) and the corresponding optical images (bottom), with the photometric redshift given in each image. Of these, the three highest redshift clusters were followed up with the Gemini Multi-Object Spectrograph (GMOS).

One of the highlights of this cluster survey was the discovery of ACT-CL J0102-4915, dubbed "El Gordo," which is at a redshift of 0.87 (Menanteau *et al.,* 2012). We character-

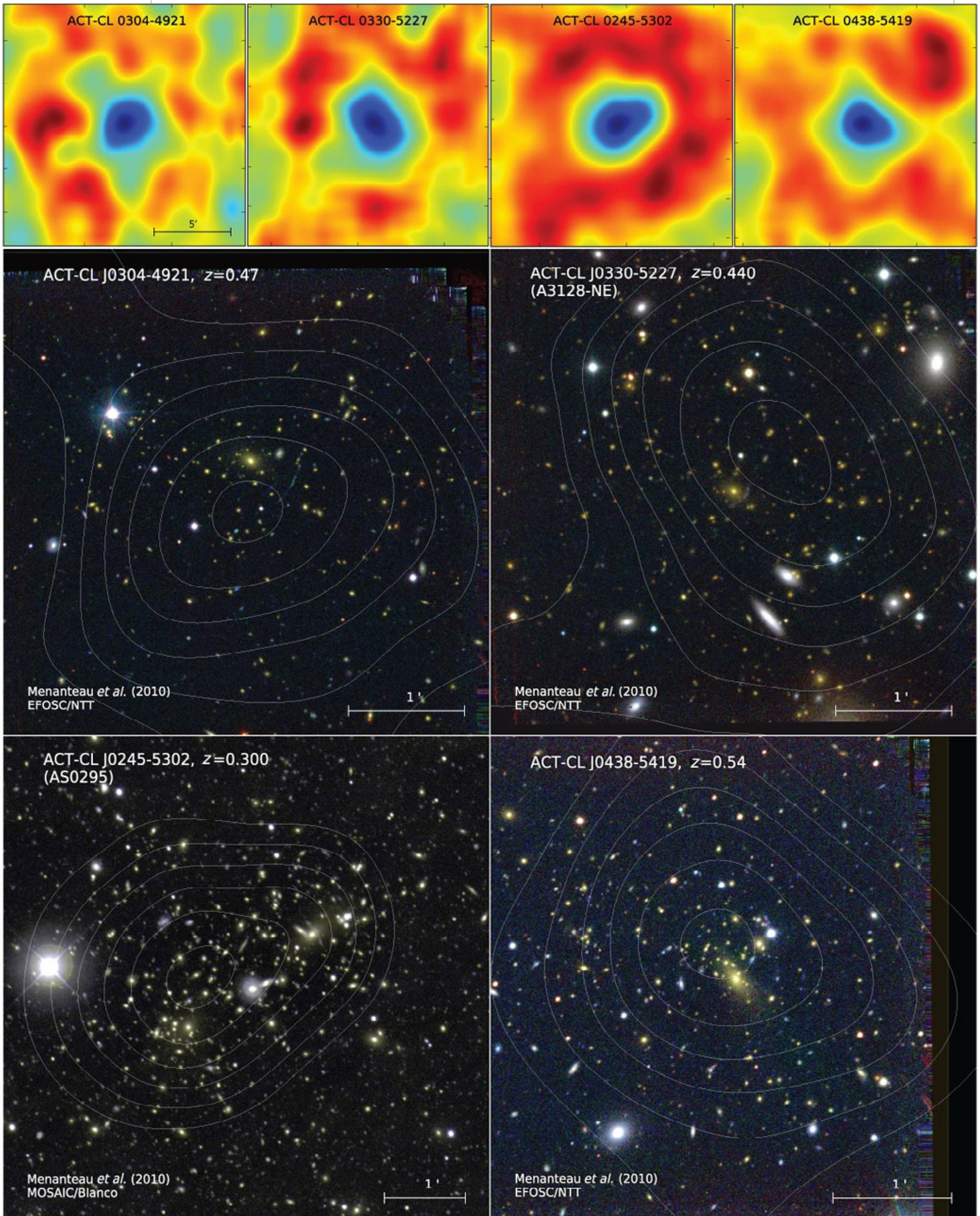


Figure 1. *Example clusters detected by ACT. The top shows the ACT clusters, displaying the temperature decrements observed in 148 GHz with blue the coldest and red the hottest. The middle and bottom panels show the optical images of the same clusters, with the ACT maps surrounding them. Three of these four clusters were followed up with Gemini.*

ized it as a system of two clusters in the process of merging roughly in the plane of the sky. It resembles the well-known Bullet Cluster. El Gordo is the hottest and most massive cluster known at redshifts above 0.6.

The Spectroscopic Follow-up

Given the potential of this cluster sample as a cosmological probe, we started a large spectroscopic follow-up campaign. We aimed to secure the redshifts of the clusters and determine their masses from velocity dispersions of member galaxies. These dynamical masses provide a proxy we can use to calibrate the SZE-mass scaling relation.

Over a total of seven nights at Gemini South in 2009-2010 (programs GS-2009B-Q-2 and GS-2010B-C-2, both joint Chile-U.S. programs), we observed some 1000 galaxies in the direction of 11 clusters in the high-redshift ACT sample. These data, obtained with GMOS in multi-object spectroscopy mode, were augmented with an additional five clusters observed with the Very Large Telescope during the same period (Sifón *et al.*, 2013).

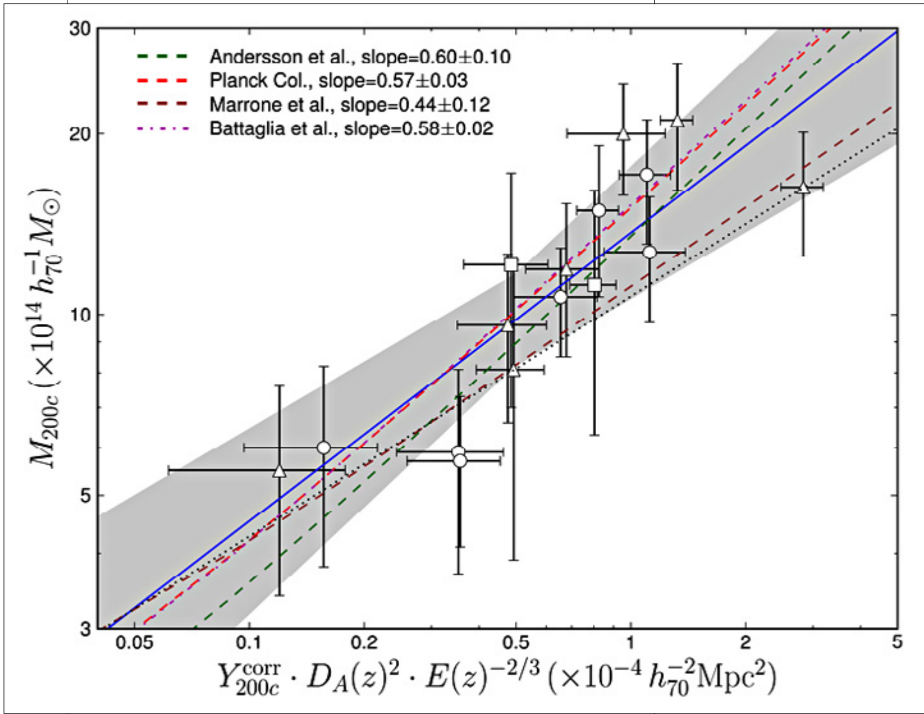
Our selection of target galaxies, based on color cuts and further visual inspection, resulted in a high success rate. The data allowed the robust identification of cluster members. With an average of 60 members per cluster, we could determine precise redshifts for all of the clusters and velocity dispersions with typical uncertainties of ~10 percent. We used a scaling relation calibrated with numerical simulations to infer the total masses of these 16 clusters. Typical uncertainties in the total masses of each cluster are ~30 percent.

We used these dynamical masses to obtain scaling relations between the SZE and total mass. We were able to show that these two quantities can be related with low intrinsic scatter, probably less than 20 percent. Figure 2 shows the best-fit scaling relation between dynamical mass and the total SZE, integrated within a virial radius r_{200} (the radius within which the average density is 200 times the critical density of the universe at the redshift of each cluster). The figure also shows several other determinations of this scaling from different mass proxies. Our results are consistent with results from X-ray observations, weak lensing measurements, and numerical simulations.

A Second Sample: More Gemini Data, Cosmological Constraints, and Prospects

ACT also performed a second survey over the equator, taking advantage of the rich archival dataset available, largely thanks to the deep optical observations of the Sloan Digital Sky Survey Stripe 82. In this second survey we detected 68 galaxy clusters up to $z = \sim 1.4$; of them 19 are new discoveries (Hasselfield *et al.*, 2013). Menanteau *et al.* (2013) have presented cluster properties from optical imaging and X-ray archival data, including spectroscopic redshifts from GMOS for many of them. We are undertaking a large follow-up program ex-

Figure 2.
Best-fit scaling relation between dynamical mass and total SZE, integrated within the virial radius (described in main text). Also shown are previous determinations of this scaling relation from different mass proxies.



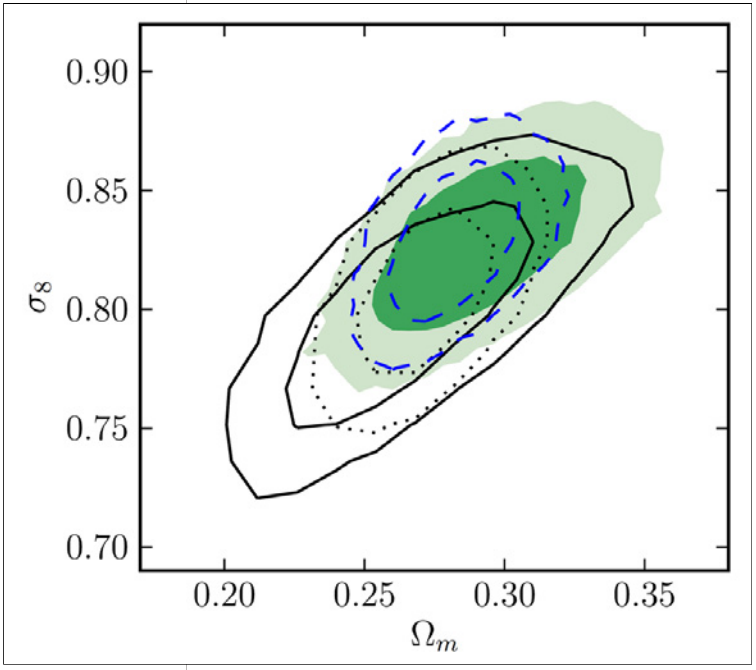
clusively with GMOS observations to obtain dynamical masses for a clean sub-sample of clusters (Sifón *et al.,* in preparation).

In Hasselfield *et al.* (2013), we have used this "equatorial sample" to obtain cosmological constraints from cluster number counts. As has been shown before, we find that the calibration of the SZE-mass relation is the critical missing ingredient that will allow us to fully understand the cosmological implications of this sample.

Figure 3 shows the constraining power of the ACT sample when the dynamical masses are included in the fit (Hasselfield *et al.,* 2013), specifically for the characteristic amplitude of matter fluctuations, σ_8, and the density of matter, Ω_m. The black contours show the best-fit parameters obtained from Seven-year Wilkinson Microwave Anisotropy Probe (WMAP-7) observations, and the green contours show the results when combining WMAP-7 with ACT clusters, including the dynamical masses of the southern sample. The blue dashed and black dotted contours show the results when combining information from WMAP, baryon acoustic oscillations and the Hubble constant from measurements of the distance ladder, with and without ACT cluster information, respectively.

Figure 3.

Constraints on cosmological parameters when dynamical masses from ACT are included. The black contours show the best-fit parameters obtained from WMAP-7 observations, and the green contours show the results when combining WMAP-7 with ACT clusters, including the dynamical masses of the southern sample. The blue dashed and black dotted contours show the results when combining information from WMAP, baryon acoustic oscillations and the Hubble constant from measurements of the distance ladder, with and without ACT cluster information, respectively.



The dynamical masses provide improvements on cosmological parameter constraints because they impose strong restrictions on the scaling relations. (In statistical terminology, they are "tight priors.") Our ongoing analysis of recent GMOS observations for the equatorial sample will provide a firmer basis for using galaxy clusters as precision probes of cosmology.

This work constituted the bulk of C. Sifón's MSc thesis at Pontificia Universidad Católica de Chile, which was completed in January 2012.

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References

Hasselfield, M., *et al.*, "The Atacama Cosmology Telescope: Sunyaev-Zel'dovich Selected Galaxy Clusters at 148 GHz from Three Seasons of Data," submitted to *Journal of Cosmology and Astroparticle Physics*, arXiv:1301.0816, 2013

Marriage, T. A., *et al.*, "The Atacama Cosmology Telescope: Sunyaev-Zel'dovich Selected Galaxy Clusters at 148 GHz in the 2008 Survey," *The Astrophysical Journal*, **737**: p. 61, 2011

Menanteau, F., *et al.*, "The Atacama Cosmology Telescope: Physical Properties and Purity of a Galaxy Cluster Sample Selected via the Sunyaev-Zel'dovich Effect," *The Astrophysical Journal*, **723**: p. 1523, 2010

Sifón, C., *et al.*, "The Atacama Cosmology Telescope: Dynamical Masses and Scaling Relations for a Sample of Massive Sunyaev-Zel'dovich Effect Selected Galaxy Clusters," accepted for publication in *The Astrophysical Journal*, arXiv:1201.0991, 2013

Nancy A. Levenson

Science Highlights

The second quarter of 2013 delivered a number of significant papers based on Gemini data. These include the three summarized here which feature supernovae progenitor stars, stellar disks, and major results from the NICI Planet-Finding Campaign. For an up-to-date list of scientific papers based on Gemini data, see: http://gemininewpublications.blogspot.com/

Mass, Metallicity, and History of Supernova Progenitors

What are the progenitors of various types of supernovae? Spectral signatures and lightcurve shapes characterize supernovae, and their range reveals the variety of progenitor stars that may produce these events. Differences in progenitor mass, metal abundance, or multiplicity are all possible origins of supernova diversity. In recent work, Hanindyo Kuncarayakti (University of Tokyo) and collaborators determine the properties of supernova progenitors through observations of the stellar population at the host sites.

This study concentrates on the local environments of Type Ib and Ic supernovae – those that do not show hydrogen in their spectra and likely result from the core collapse of massive stars, specifically, Wolf-Rayet stars. Strong stellar winds or mass loss to a companion could strip the outer hydrogen layers of a progenitor. Indeed, the team generally found the Type Ic supernovae in more metal-rich environments than the Type Ibs. Furthermore, both types have higher metallicity than Type II supernovae, which are also due to core collapse of massive stars but have retained their hydrogen shells. The higher metallicity would promote mass loss through stellar winds.

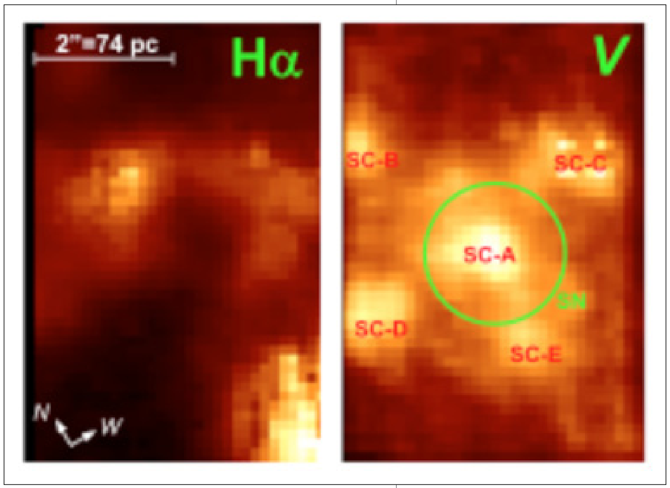

Figure 1.
Images of the SN 2007gr environment extracted from the integral field unit observations corresponding to Hα and V band. A green circle marks the supernova host star cluster, and other nearby star clusters (SB-C, etc.) are noted.

Another difference between the Types Ib and Ic is that the latter are generally younger, implying more massive stellar progenitors. Some of the progenitors of both types are less massive than about 25 times the Sun's mass and thus not massive enough to be stripped Wolf-Rayet stars. These authors instead suggest a history of mass loss through evolution in a binary system. Thus, binary environments appear to be important for some core-collapse supernovae.

For the study, the team used the integral field unit of the Gemini Multi-Object Spectrograph (GMOS) on Gemini North as part of Subaru exchange time, along with the SuperNova Integral Field Spectrograph at the University of Hawai'i 88-inch telescope, also on Mauna Kea. They targeted nearby galaxies, where 1 arcsecond typically corresponds to 230 light-years (70 parsecs), to distinguish the progenitor star clusters. The data show that other nearby clusters display a somewhat different history and metallicity from the supernova site (Figure 1). These results are published in *The Astrophysical Journal*, and in a separate paper (pending), the team applies identical techniques to the host environments of Type II supernovae.

Resolving a Stellar Disk at Earth-Sun Distance Scales

Planets in the disks around young stars may carve gaps or dynamically affect their environment. These so-called transitional and pre-transitional disks are therefore interesting as important stages in the development of planets. An international team led by Stefan Kraus (Harvard-Smithsonian Center for Astrophysics) used multiple telescopes, including Gemini South, to resolve the disk around V1247 Orionis on physical scales of astronomical units (AU; the average Earth-Sun distance), finding asymmetries and unambiguous evidence for a gap in the disk.

The observations included an uncommon use of Gemini's Thermal Region Camera Spectrograph (T-ReCS) for mid-infrared (MIR) imaging, using short exposures and interferometric analysis techniques, to determine the disk orientation and geometry. Considering longer-baseline MIR interferometry in addition, a compact disk is evident, extending over 0.2 AU. The inferred structure (Figure 2), based on the full set of observations, shows a hot inner disk, a cool outer disk, and optically thin carbon-rich dust in the gap between them. The emission in the gap region appears to be asymmetric, and the dependence on observed wavelength implies that this is due to density inhomogeneities, rather than the presence of a single body like a planet.

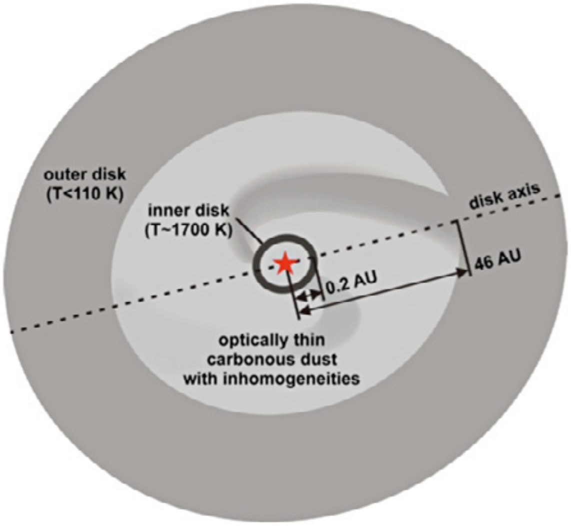

Figure 2. *Model of the environment of V1247 Orionis includes a hot optically thick inner disk, a cool optically thick outer disk, and optically thin dust in the gap between them.*

The persistence of the hot inner disk, with material located at the dust sublimation radius (corresponding to the hottest temperature where it can survive), rules out some proposed methods of clearing gaps in similar planetary disks, including photoevaporation, instabilities, and grain growth. Instead, the authors conclude that dynamical clearing of the gap, due to developing planetary or other companions, is the most likely origin. Other well-studied transitional and pre-transitional disks do not show evidence for such optically thin material close to the star, which suggests that V1247 Orionis may show us an earlier stage of development. The complete results are published in *The Astrophysical Journal*.

Gemini NICI Planet-Finding Campaign

Astronomers have evidence for hundreds of planets around stars beyond the Sun, but only a handful are observed in direct imaging. The planets are intrinsically faint, and detecting them near their bright host stars adds to the challenges. The Near-Infrared Coronagraphic Imager (NICI) at Gemini South is capable of imaging faint extrasolar planets, reaching greater sensitivity than previous ground- or space-based instruments. (NICI can detect an object one million times fainter than its bright host at a projected separation of 1 arcsecond; about one two thousandth of the Moon's apparent diameter.)

Michael Liu (University of Hawai'i) and a large international team from across the Gemini partnership and beyond used NICI for the Gemini NICI Planet-Finding Campaign, the largest, deepest systematic search for planets through direct imaging. The result is that fewer stars than previously expected show evidence for planets, which will require some updates to theories of planet formation and survival. While some low-mass (substellar) companion objects have been detected, the Campaign did not image any unknown planets.

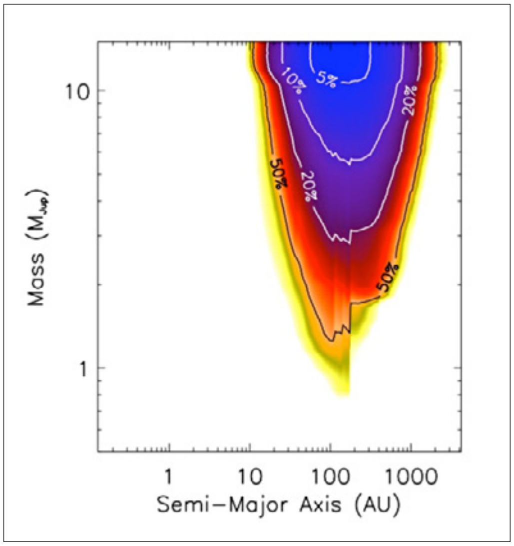

Figure 3.
Contours show the probability that a star of given mass has a giant planet at the given semi-major axis location.

The first comprehensive result from the Campaign considers young B and A stars, of about two times the mass of the Sun. Based on observations of 70 of them, Eric Nielsen, who led this effort, concluded that fewer than 10 percent of these stars have giant planets (with masses greater than 10 times that of Jupiter) at distances of about 40–650 astronomical units (AU; the average Earth-Sun distance) from their hosts, and fewer than 20 percent have planets with masses less than four times that of Jupiter. While the Campaign did image known extrasolar planets, the systematic analysis of the total program reveals that these systems are uncommon.

The search for planets is painstaking work. One source of confusion is the chance superposition of a distant star, which can mimic the appearance of a faint companion to the nearby host star of interest. Multiple observations of the candidate objects can distinguish these scenarios, and unfortunately, most of the time the less-interesting chance alignment is the conclusion. Another important detail of the work is to determine the ages of the stars. Because age has a strong effect on the appearance of planets and other low-mass companions — they are brighter and hotter when recently formed, and fade and cool over time — the inferred planet properties are sensitive to stellar age.

This is the first of three papers presenting the systematic results from the NICI Campaign. Separate papers, led by Beth Biller (Max Planck Institute for Astronomy) and Zahed Wahhaj (University of Hawai'i at Manoa), will analyze planet frequency around stars in young moving groups and systems with debris disks. Even more sensitive observations will come with the Gemini Planet Imager, to arrive at Gemini South later this year.

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Benoit Neichel and Rodrigo Carrasco

Gemini South's Revolutionary New Adaptive Optics System Embarks on the Universe

The first half of 2013 has been a busy one for the GeMS team, culminating with the success of GeMS System Verification (SV). This article features many of the stunning images obtained during the SV period by our users.

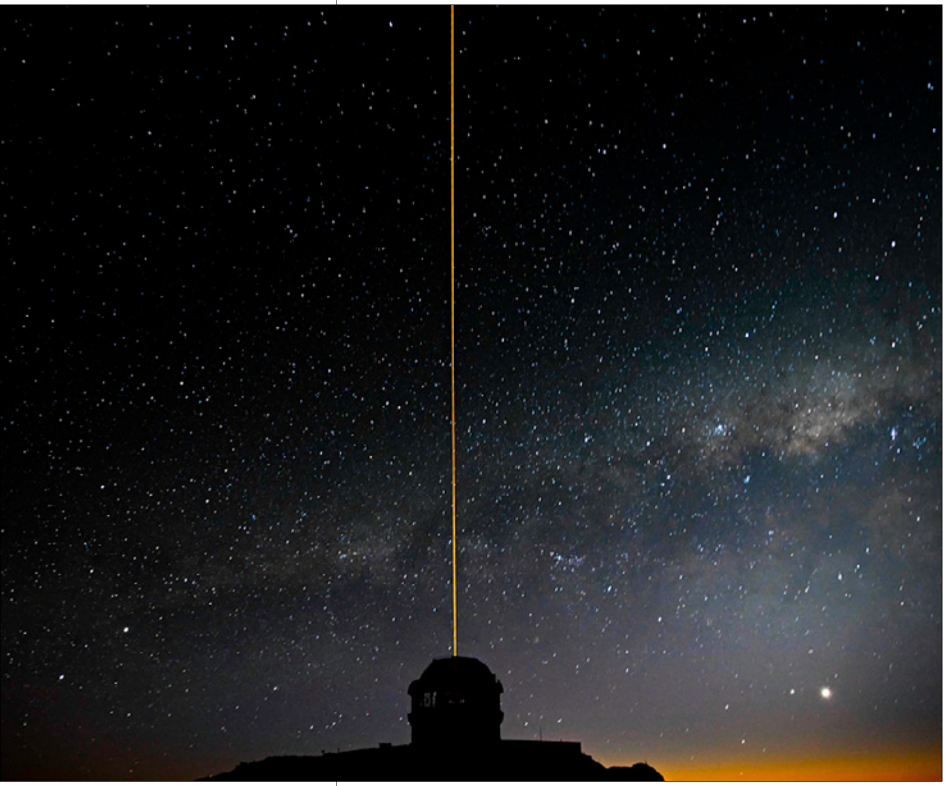

Figure 1.
The Gemini South GeMS laser propagates into the night sky during GeMS/GSAOI System Verification observations.

This last semester marked the beginning of science operations with the Gemini Multi-conjugate adaptive optics System (GeMS) and the Gemini South Adaptive Optics Imager (GSAOI). GeMS/GSAOI officially started its System Verification (SV) period in December 2012 after 1 1/2 years of commissioning. Since then, the system has delivered new and exciting science to Gemini's user community.

GeMS is based on a new adaptive optics (AO) concept, called Multi-Conjugate Adaptive Optics (MCAO). The technology behind MCAO involves the use of multiple laser guide stars (five in the GeMS system) and several deformable mirrors (three in all) to sample atmospheric distortions and cancel them out in real-time as imaging data are collected.

Using algorithms similar to those developed for medical tomographic imaging, the GeMS/MCAO system creates a three-dimensional snapshot of atmospheric turbulence between

~ 500 to 1000 times per second. The result is about a 20-fold increase in the area of the observed patch of sky compared to previous AO systems, while providing uniform corrections over the entire field from edge-to-edge.

GeMS is a facility instrument, and as such it can direct its light output to different science instruments installed at the Cassegrain focus of the Gemini South telescope. The main instrument used to date is GS-AOI, a wide-field camera designed to work at the diffraction limit of the 8-meter telescope in the near-infrared (NIR). In the next semesters, plans are to couple GeMS with FLAMINGOS-2 — the near-infrared imager and long-slit and Multi-Object Spectrograph, currently in commissioning at Gemini South (see update on page 19 of this issue)

Science Verification: A Long-awaited Milestone

In August 2012, the GeMS/GSAOI team released a call for System Verification (SV) targets, offering a total observing time of 60 hours for a wide range of science topics. The SV programs provide an end-to-end test of a new instrument or capability, from the proposal process to data delivery, prior to offering it to the community for general use. With GeMS/GSAOI, one main objective was to demonstrate the gain brought by MCAO on a large variety of science topics, including extended sources, crowded fields, and faint targets. We received great feedback, with 23 programs submitted for a total of 138 hours, from which 13 were selected for execution between November 2012 and January 2013.

The SV period did not start as expected: In early November, the power produced by the sodium laser fell to a level one-half of what it was a few weeks before, preventing the team from completing the remaining commissioning tasks. With the assistance of Zach Prezkuta (a laser engineer from Lockheed Martin Coherent Technologies), Gemini laser specialist Vincent Fesquet, worked non-stop for three weeks to recover the laser light to a nominal 50 watts (W) –– in time for a run in December (Figure 1). Atmospheric seeing and laser conditions were excellent during this period. The team overcame most of the delays accumulated during commissioning, and SV observations started before month's end.

Figure 2.
A three-pointing GeMS/GSAOI image of the Orion Nebula's Bullets field.

Orion Bullets: A Dramatic Demonstration

The team selected the Orion Bullets as their first SV target (Figure 2). These wake-like features in the Orion Nebula are clumps of gas violently ejected from an unknown event associated with the recent formation of a cluster of massive stars. The strong winds produced by this "explosion" expelled these bullets of gas at supersonic speeds, leaving behind the distinctive tubular and cone-shaped wakes

Figure 3.
The globular star cluster NGC 1851 as imaged with GeMS/GSAOI during System Verification

we now see; the wakes shine like tracers due to the bullets piercing and heating the molecular hydrogen gas in the Orion Nebula.

By comparing high-angular-resolution images of this region over several years (including observations at Gemini North with the Altair AO system obtained in 2006), the team, headed by John Bally and Adam Ginsburg (both of the University of Colorado), can actually measure a bullet's motion. By mapping the proper motions of each, they can build a complete 3D dynamical model of the region. A single-pointing version of this new image also made headlines at the January 2013 meeting of the *American Astronomical Society* (held in Long Beach, California) and was featured in a press conference at the meeting.

This remarkable image also illustrates the revolution brought by MCAO. The final mosaic, made by three GeMS/GSAOI pointings, covers a field-of-view measuring almost 4 x 3 arcminutes, resulting in one of the biggest AO-corrected images ever obtained. This is the main advantage of MCAO when compared to other AO systems: in one shot, the area of sky covered is 10- to 20-times larger than any previous AO system. This makes Gemini's 8-meter telescope 10- to 20-times more efficient, giving astronomers the option to expose deeper, or explore more effectively with a wider range of filters.

Globular Cluster NGC 1851: Going Fainter

Another critical SV target was NGC 1851, a globular cluster located about 40,000 light-years from our Sun (see Figure 3). Such a tightly packed city of starlight is a workhorse science case for MCAO; the AO corrections "deblend" multiple systems in crowded fields, allowing astronomers to access the cluster's fainter stars, which are crucial in studies of star formation in these different environments.

Moreover, by delivering a uniform performance over fields that encompass most globular star cluster sizes, MCAO greatly improves the photometric precision on these crowded fields. By studying the MCAO observations of NGC 1851, Alan McConnachie from the National Research Council's Herzberg Institute of Astrophysics and colleagues intend to precisely derive the different star populations that make up this cluster. By observing NGC 1851 over time, the team also expects to retrieve the cluster's orbit within our Galaxy. In that case, GeMS/GSAOI is also a perfect complement to the Hubble Space Telescope (HST): the image quality provided by the GeMS system in the NIR is very similar to that delivered by HST in visible light, which opens the possibility of combining these complementary data sets.

Galaxy Cluster Abell 780: Better Sky Coverage to Go Deep

The third SV target was Abell 780, a cluster of galaxies located at $z = \sim 0.05$ (see Figure 4). In extragalactic studies, only a few natural guide stars are available to provide AO corrections, which limits the areas of the sky available to study. With its five laser guide stars, GeMS increases the portion of the sky that can benefit from AO correction, and surpasses the previous generation of laser guide star AO systems. Put another way, only GeMS can provide this kind of uniform, sharp image quality in regions with few natural guide stars.

In this field, the team led by Rodrigo Carrasco from Gemini wants to explore not only the structure of potential massive compact galaxies in galaxy clusters but also the detailed properties of the massive galaxies with average sizes. Looking for "signatures" that could be related to ongoing merger activity (such as tidal tails, clumps of star formation, etc.), they would be able to decide between different competing evolutionary scenarios.

2013 and Beyond

The team continued their SV runs on 8 nights in January and 11 nights in February 2013. A total of 12 targets out of the 13 selected were observed, under different conditions, providing very useful information to the team on how to run and optimize this complex system. Also included in the SV observations, the researchers targeted planetary nebula NGC 2346, several star clusters (*e.g.* RCW 41 and R 136), NGC 4038 in the Antennae Galaxies (see Figure 5), a candidate supernova in a nearby Luminous Infra-Red Galaxy, a pulsar, a quasar, and gravitational lenses induced by a galaxy cluster. See many of these images in an image release issued concurrent with this issue of *Gemini*Focus. All these data are also now publicly available on the Gemini archive website at: *http://www.cadc-ccda.hia-iha.nrc-cnrc.gc.ca/gsa/sv/dataSVGSAOI_v1.html*

The team also used the 2013 SV period to stabilize and characterize the performance delivered by the system. They determined

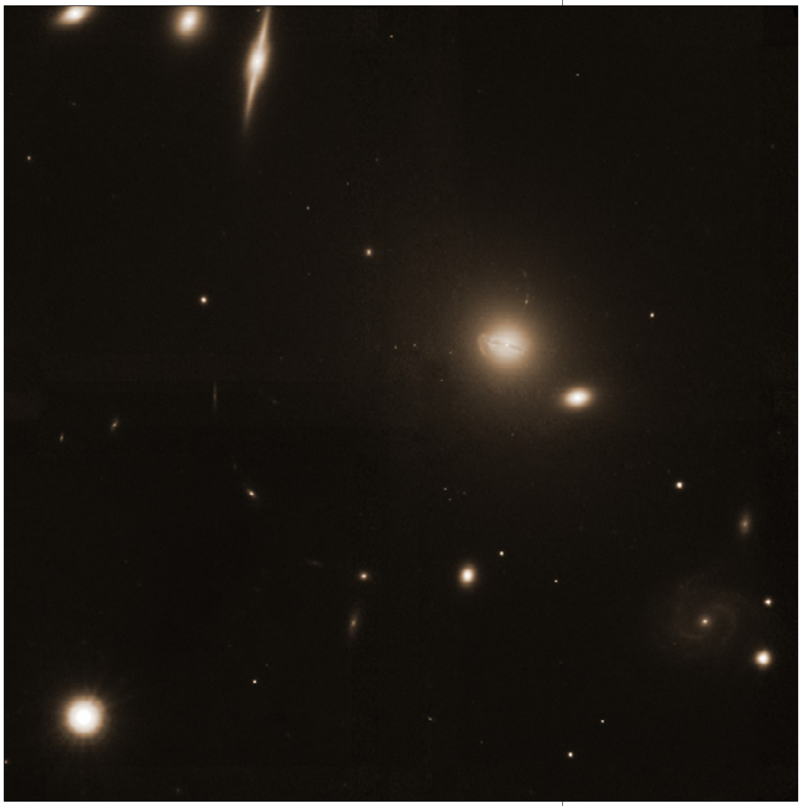

Figure 4.
Galaxy cluster Abell 780 in a single-band image obtained with GeMS/GSAOI during System Verification.

that 50 percent of the time, GeMS delivers an image quality of 95 milliarcseconds (mas) or better in K band and 75 mas or better in the H band. This is not yet at the original specification level but two primary, well-understood reasons explain this.

First, one of the three deformable mirrors in GeMS failed. These mirrors are optically conjugated at 0, 4.5, and 9 kilometers. However, since the system is currently running with only two deformable mirrors, at 0 and 9 km, corrections are not optimal. Second, while the laser itself is performing very reliably, the overall transmission of its projection system is under specification. Consequently, the AO corrections are applied at a lower-than-normal rate, so the performance suffers from the variations of the sodium layer concentration.

The SV team will address both items in the following semesters, first by recovering a three deformable mirror configuration, and then by optimizing the laser photon return. For this latter work, the Beam Transfer Optics, which is the set of mirrors

Figure 5.
NGC 4038, one of the Antennae Galaxies, imaged by GeMS/GSAOI during System Verification.

that allows shaping the laser constellation and propagating the beams on the sky, will be optimized with better coatings and a control of the light's polarization.

A third performance upgrade is also in the works for the next semester, and it concerns the Natural Guide Star wave-front sensor. Due to minor design and alignment issues, the current limiting magnitude achievable is around 15.5 in the visible. This dramatically reduces the number of targets obtainable outside of the Galactic plane. A completely new design, based on a recently developed low noise focal plane array, has been approved, and should be implemented in GeMS before the end of 2014. This fix is expected to boost the sensitivity of the system, allowing researchers to acquire stars as faint as 18.5 in visible light, hence increasing the portion of the sky accessible to GeMS.

On another front, there is also a large ongoing effort to smooth the "operation ability" of the GeMS system, and perform the transition into regular operations. The objective is to progressively reduce the amount of staff required to operate the system at night. This will be achieved by deploying more high-level software and diagnostic tools. The first semester of regular science operations was also intensively used for cross-training within the various teams supporting GeMS/GSAOI.

GeMS/GSAOI is now available through the regular Call for Proposals process. The 2013A semester, offered as "shared-risk," received 11 programs, for 80 hours allocated. At the time of this writing, eight were completed and two started. Semester 13B has been open for 150 available hours, which were recently allocated with 16 programs, and plans currently allow for this level of GeMS availability for the foreseeable semesters ahead. In the near-future, the goal will also be to diversify the science capabilities, by offering GeMS for FLAMINGOS-2 and possibly even the Gemini Multi-Object Spectrograph (observing at the red-end of the visible spectrum).

Impacting the Future of Astronomy...

After about 10 years of development, and almost 100 nights of commissioning, GeMS/GSAOI is now producing unique science! This accomplishment paves the way for future AO developments, and especially for the next generation of Extremely Large Telescopes, for which running multi-laser AO systems will be the baseline.

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Rodrigo Carrasco is an astronomer at Gemini South. He can be reached at: rcarrasco@@gemini.edu

Instrumentation Development Updates

With so much attention given to System Verification of GeMS during the past quarter (see article starting on page 14) other milestones deserve attention. Learn about the significant progress with FLAMINGOS-2, the Gemini Planet Imager, and GRACES, which illustrate the excitement ahead as our instruments provide the tools our users have requested and need.

FLAMINGOS-2

FLAMINGOS-2 (F2) moved another step closer to its final round of commissioning observations when it was moved from the Gemini South summit instrument lab onto port 5 of the Instrument Support Structure (ISS) on June 11, 2013. F2 is slated to begin obtaining data in "shared-risk" mode in August of this year. For the past month-and-a-half, F2 underwent work on the summit of Cerro Pachón to address repeatability problems with the multi-object spectroscopy wheel mechanism. This and other systems checked out successfully, leading to the installation of F2 on the telescope as seen in the accompanying image (Figure 1).

As this issue goes to press, we have nearly completed the late June commissioning run with success in testing imaging (see Figure 2) and low-resolution, long-slit spectroscopy. In addition, we plan to complete the fine-tuning of the F2 on-instrument

Figure 1:
Senior Mechanical Group Leader Gabriel Perez (left), and Optical Technician Claudio Araya (right) on the Instrument Platform Lift, installing F2.

wave-front sensor (OIWFS). In July, we will commission the relatively higher spectral resolution in F2 and complete any other pending commissioning tasks.

There are 16 observational programs accepted to use F2 in the 13B semester. These programs request a total of 180 hours or 17 percent of the total available time. We are only offering the imaging and the long-slit spectroscopy modes in this first semester. We plan to offer the multi-object spectroscopy (MOS) mode later, after it is commissioned in 2014.

— Percy Gomez,
Gemini F2 Commissioning Team

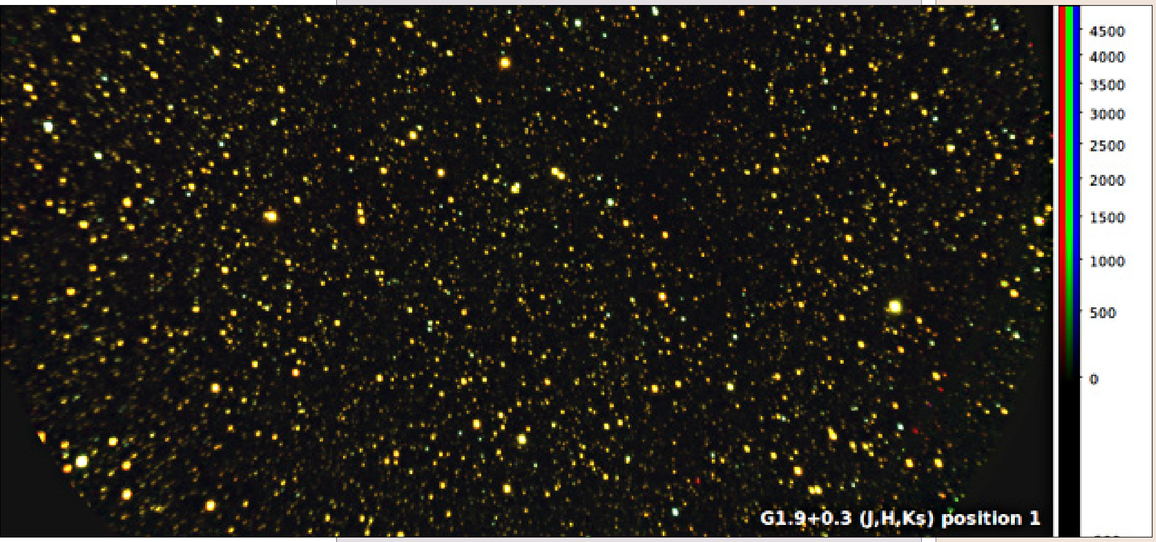


Figure 2: *Imaging data from the "crowded field" tests with F2. Despite relatively poor atmospheric seeing, the FWHM (resolution) is 0.75," which the commissioning team declared as a positive result.*

Gemini Planet Imager: the Final Stretch Before Commissioning

The Gemini Planet Imager (GPI) project — one of the most ambitious in the field of exoplanet research — was rebaselined on April 30, 2013. The project will host the instrument's pre-delivery acceptance review between July 8th and 19th, with a formal set of presentations scheduled for the 16th and 17th. Transportation to Chile is set for August, with expected unpacking on August 26th at Cerro Pachón.

GPI Integration and Testing is now complete at the University of California Santa Cruz. In total, 117 Functional and Performance requirements have been verified — 55 by tests and 62 by inspection and design. The team has completed all documentation requested for the pre-delivery acceptance review, some of which was circulated to key Gemini Reviewers in advance for early feedback. In total 10 members of Gemini will be at the University of California Santa Cruz during the review period to interact with the team that designed, built, and tested this spectacular instrument.

Over the last few months, GPI has been turned almost upside down and frozen down below 0˚ Centigrade. First, GPI was mounted on the flexure rig, then tilted and hung vertically, to simulate the effects of gravity on the instrument, which changes

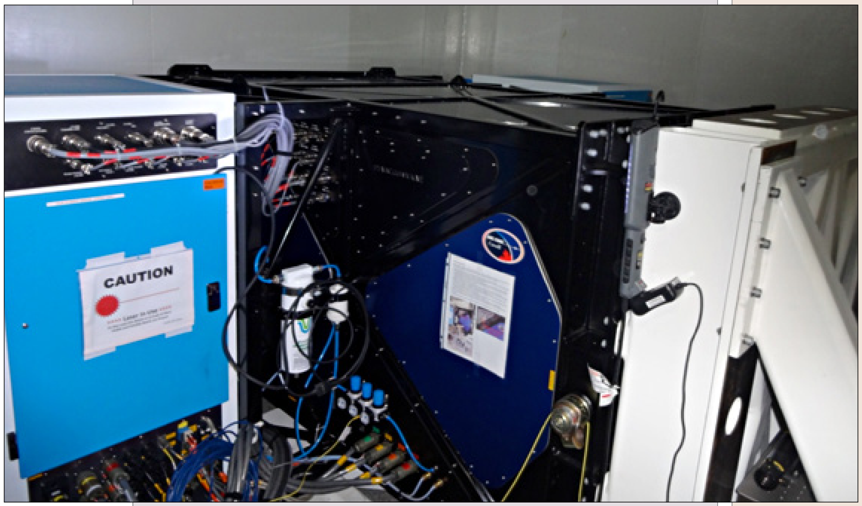


Figure 3: *GPI inside the cold room.*

when the telescope points to different parts of the sky. Next GPI went into a cold room (See Figures 3 and 4) and exposed it to the large range of temperatures that will occur at Gemini South.

While being tilted at varying angles and subjected to freezing temperatures, the team took GPI through a large set of tests and demonstrated to micrometer precision that it was able to maintain its extremely high contrast performance. As expected, GPI passed these rigorous exams with bravura.

Once GPI is unpacked, at Cerro Pachón, it will go through a subset of these rigorous tests to assure that shipping the instrument several thousand kilometers didn't cause any ill effects. Next, GPI will be mounted onto the telescope at the beginning of the fourth quarter of 2013. The instrument's much awaited first light will follow, which should reveal the instrument's amazing capabilities. Commissioning and Science Verification activities should then occupy GPI for the rest of the year.

— Stephen Goodsell and Fredrik Rantakyro

Figure 4:
Stephen Goodsell in front of the cold room at the University of California Santa Cruz.

GRACES Progress

The Gemini Remote Access to the Canada-France-Hawaii ESPaDOnS Spectrograph (GRACES) project is entering the latter stages of Phase I, the so-called "Experimental Phase," which should demonstrate that world-class, high-resolution spectroscopy can be achieved using Gemini North to feed ESPaDOnS.

GRACES is designed to have two resolutions: R=55,000 and 33,000, with a wavelength range of ~400 nanometers (nm) to ~1000 nm. It also has two observing modes: "Source+Sky" and "Source-only" (the latter is intended for bright sources). GRACES' most critical component, however, is the 270-meter-long, optical-fiber cable, which must achieve high performance — excellent focal-ratio degradation (RFD), internal transmission, and spectral range coverage — if it's to compete with other 8- to 10-meter-class, high-resolution spectrographs, such as the High Resolution Echelle Spectrometer at Keck Observatory or the Ultraviolet and Visual Echelle Spectrograph at the Very Large Telescope.

Currently the GRACES project is advancing on all fronts. The optical-fiber-cable vendor has overcome some earlier problems in processing the fiber ends and is consistently producing 2-meter-long test fiber cables with measured RFDs of about 5 percent. This is a milestone event toward achieving an RFD on the 270-meter-long science cable of ~20 percent (required) to ~10 percent (goal); the cable is partially fabricated and will be "connectorized," armored, tested, and delivered in July. We've received all of the optics (*e.g.*, lenses and slicer) and commercial hardware (*e.g.*, translation stages, adjusters, and mounts), and the custom

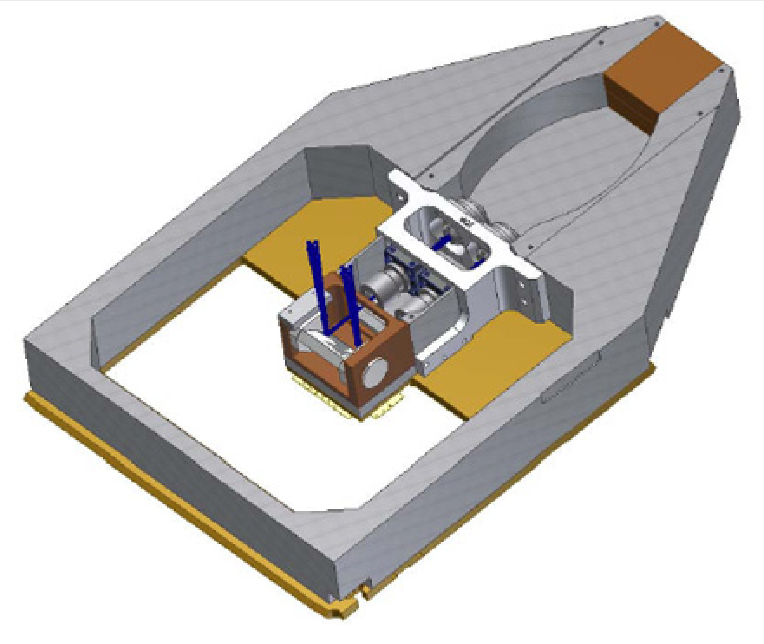
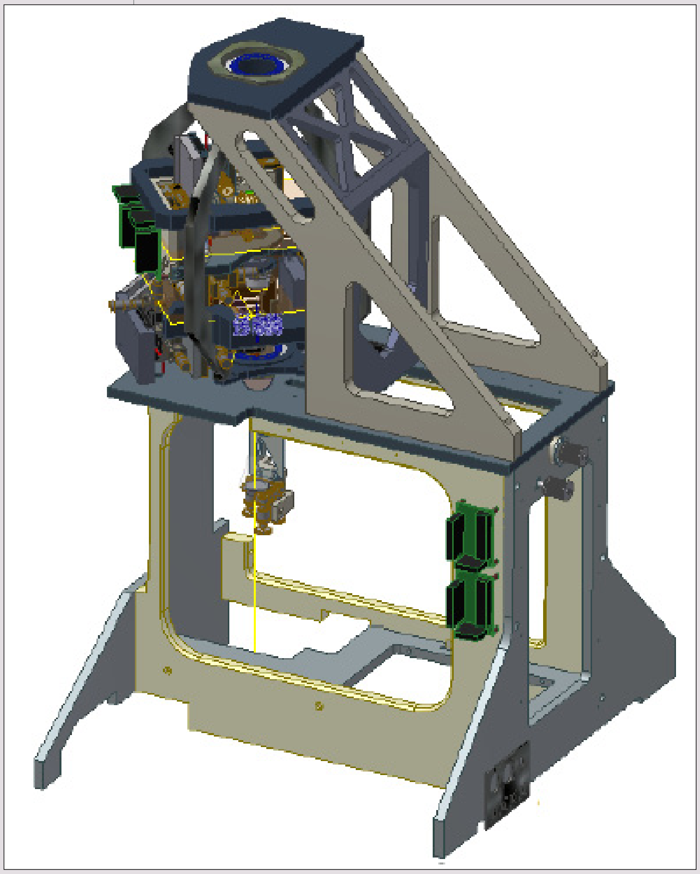


Figure 5:
Model rendering of the injector unit. The optics are housed in a GMOS-N filter cassette (large grey unit). The blue light rays in the center of the unit are the two input beams from Gemini (star and sky), which reflect off a mirror to the upper right where they are fed into two 270-meter-long fibers.

Figure 6:
Model rendering of the slicer bench. The ESPaDOnS optical beam passes though the large rectangular opening in the bottom half of the structure. The top structure houses the optical fiber inputs, the optics, adjustment stages, and the image slicer. The optical-fiber-cable attaches through the top of the assembly where it passes through the optics and slicer down to the fold mirror (grey and brown piece projecting down into the bottom half) to be inserted into ESPaDOnS.

hardware parts are being fabricated in the machine shop at the Dominion Astrophysical Observatory (formerly the Herzberg Institute for Astrophysics).

Figures 5 and 6 show computer-aided design model pictures of the injector unit (Gemini end) and the slicer unit (ESPaDOnS end). The injector unit uses a Gemini North Multi-Object Spectrograph (GMOS-N) filter cassette, which allows GMOS-N to act as an acquisition camera for GRACES. Permanently installed in ESPaDOnS, the slicer includes a deployable fold mirror that allows ESPaDOnS to be used with the CFHT or GRACES by simply moving the fold mirror in and out of the optical path of ESPaDOnS. Critically, this can be done without affecting the alignment or performance of either instrument. Finally, we've received the user interface and control software, and it is now undergoing acceptance testing by Gemini and CFHT staff.



Currently, GRACES is scheduled for on-sky commissioning in October or December of this year. Integration and Testing of the opto-mechanical systems at HIA is planned for July to September, after which it will be shipped to Mauna Kea for installation, daytime testing, and then commissioning. After that, GRACES will become available to Gemini's users in block observing mode (not queue mode).

Our Gemini users will play a critical role during the first year of operations, by helping to characterize and evaluate GRACES' performance. If it works well and there is a high enough user demand, GRACES could undergo a second phase of development to fully integrate it into the Gemini user environment (Phase I and II Observing Tools, for example) so that it becomes a valuable, standard capability for Gemini's future.

— Eric Tollestrup

Andy Adamson

Operations Corner

With GeMS/GSAOI science going along well in 13A, FLAMINGOS-2 currently in recommissioning, and both instruments now fully offered in the 13B call, this edition of Operations Corner looks at the upcoming semester with a brief review of the International Time Allocation Committee results, anticipating commissioning work at Gemini South, and visiting instruments making for an interesting time at Gemini North. Gemini South engineering operations have been very busy, and we describe two major pieces of work done on the telescope top end and on the enclosure. Finally we post a reminder about data checking, which has undergone a significant change in the north (and is undergoing the same change in the south).

Semester 2013B

The International Time Allocation Committee (ITAC) process has just been completed for Semester 2013B. Our thanks once again go out to all of the referees, assessors, and TAC representatives for their hard work. Highlights include the fact that both the Differential Speckle Survey Instrument (DSSI), a speckle camera, and the Texas Echelon cross Echelle Spectrograph (TEXES), a mid-infrared instrument, were awarded significant amounts of time on Gemini North, both to the instrument teams and to other investigators. DSSI will visit for close to a week in July, and TEXES will return to the telescope for 90 hours in November. The visitor instruments were oversubscribed by factors of two and three, respectively (DSSI and TEXES). In the south, GeMS/GSAOI proved popular, oversubscribing the available time by a factor of two. The two southern newcomers (FLAMINGOS-2 and GeMS/GSAOI) took a third of the time allocated, with FLAMINGOS-2 taking approximately the same fraction of the observing time as the Gemini Near-Infrared Spectrograph (GNIRS) at Gemini North.

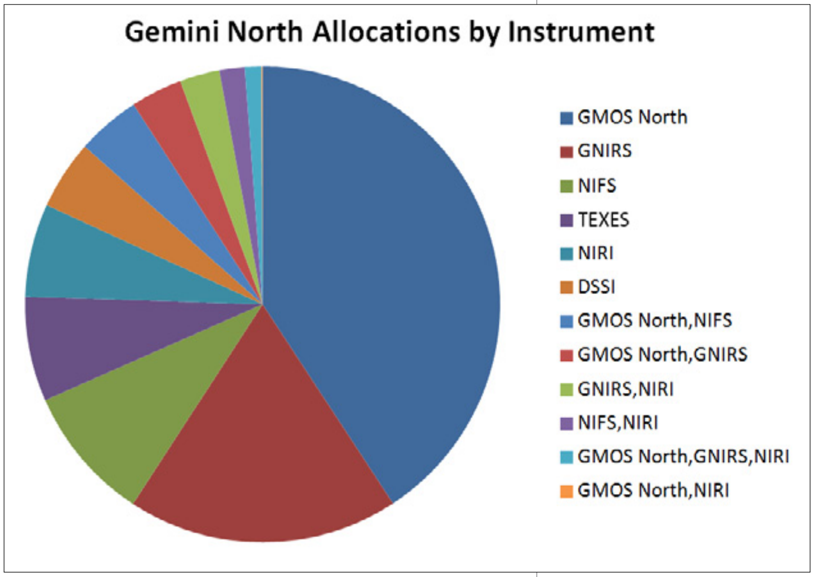


Figure 1. *Gemini North time allocations by instrument in Semester 2013B.*

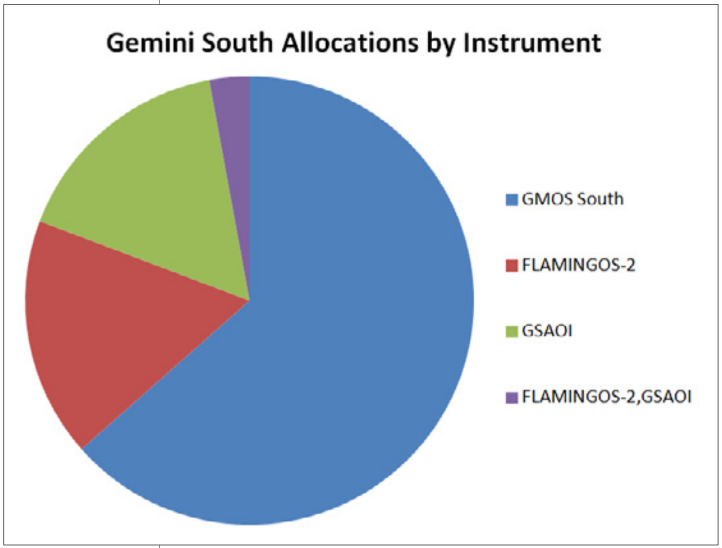


Figure 2: *Gemini South time allocations by instrument in Semester 2013B.*

A Busy Semester at Gemini South

Looking forward, Gemini South operations (assuming all goes well) should see one of the most event-filled semesters in recent memory. On the horizon is a maintenance shutdown at the start of the semester, the delivery of the Gemini Planet Imager (GPI) and its early commissioning, the delivery of the GMOS-S Hamamatsu CCDs, GeMS's continued transition into science operations, and the first full semester of FLAMINGOS-2 operations. While not all of these items are yet firm, as work continues in the lab on both GPI and the CCD package, the schedule is being set up to accommodate all of these activities.

Telescope and Dome Engineering

Replacing Top-end Position Sensors at Gemini South

Late last year it was determined that the light output from two of our top-end mirror position sensors (known as "micro-E"s) was failing, indicating that the sensors were nearing the end of their lifetime almost a year earlier than expected. The process of replacing these sensors is highly invasive, requiring the entire top-end unit to be removed (Figure 3) and thus requiring a shutdown of at least a week. What ensued is what you might expect. We took a detailed look at the likelihood of complete failure, which would leave us unable to guide, and of how detectable this would be in advance. We also weighed this against the disruption which would be caused by an unplanned shutdown, possibly in the middle of a GeMS or FLAMINGOS-2 commissioning or System Verification run. We worked it out such that the output could be monitored well enough to continue into semester 13A, but a number of possible shutdown points were identified in case deterioration accelerated or other opportunities emerged. In the end, a FLAMINGOS-2 delay produced an open schedule week in March, and it was decided that we had to go for it.

Work started in late March, but almost immediately we were hit with a failure of the main transformer which supplies electricity to the whole of Cerro Pachón. The rest of the period is not one which anyone would wish to ever repeat, but the engineering team did a fantastic job and both completed the micro-E replacement and kept nighttime operations going on generators – albeit with a couple of hiccups early on when the main Gemini diesel generator suffered a mechanical failure and required supplementing with a hired unit.

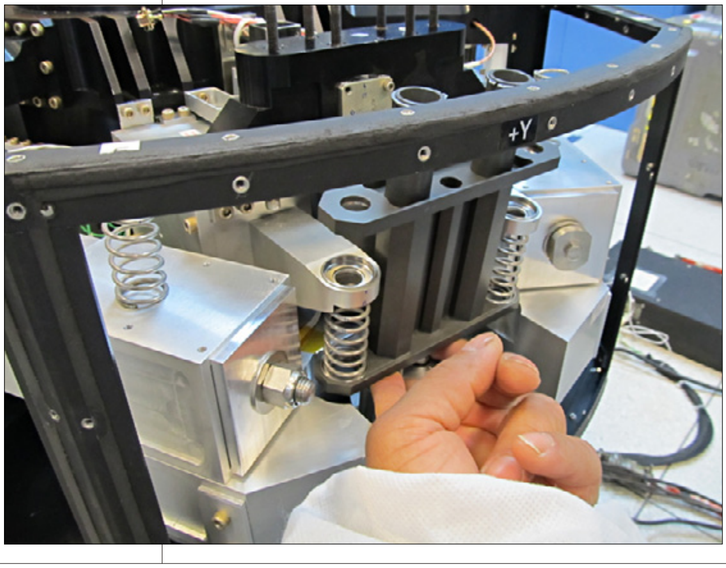


Figure 3: *Part of the Gemini South top-end system, in the lab during installation of the new micro-E sensors. The +Y sensor is installed behind the yellow plate on a black metal piece, just inside the upper ring next to the "+Y" label.*

Safety Improvements, North and South

A major safety milestone was passed at Gemini South (and in July will be passed at Gemini North), with the installation of platforms to enable access to the dome shutter drive motors. This will facilitate their removal and replacement in a much safer and secure manner than has been possible before (Figure 4).

Figure 4:
Photos, clockwise from top left:

Installing the base plate of the first platform.

Fleshing out the first platform.

Working on the completed platform.

The installed platforms, looking like they belong there even ahead of painting.

Changes in Data Checking

Gemini North users in semester 2013A will have noticed changes in the amount of data checking performed. This is driven by the reduction of Gemini's budget and the need for staff astronomers and Science Operation Specialists (SOSs) to use their efforts where it has the most impact. Similar changes will follow in the south also. At night, the observer takes responsibility for setting quality assurance flags to the best of his or her ability, using a variety of tools including data checking programs and the environmental sensors.

During the day all band 1 data will be checked as usual, as well as any programs where a check is deemed to be necessary by the Queue Coordinator (up to a limit of 30 percent of the night's data in total). Other programs, including band 4 and classical programs, are not checked, and may be left with their quality assessment state set to "UNDEFINED" if the nighttime observer was unable to review them in real-time.

This change represents a considerable cultural shift for Gemini staff; our dedication to our product is strong. However, the change is unquestionably necessary and has already produced effort savings in the north. We will gratefully accept help from Principal Investigators (PIs) in ensuring that we minimize any negative effects, and we appreciate the positive attitude received from 2013A PIs. Of course (and as always) if you, on inspecting your data, believe that it fails to meet the standard requested in your proposal, then you are more than welcome to contact the head of science operations at the site (north or south) and request a review. If we agree, we'll gladly take the affected data anew as long as the target is still accessible. The moral is, get in quickly and have a look at your data. Good advice at any time!

For much more detail, check out the data assessment web page at: *http://www.gemini.edu/sciops/data-and-results/quality-assessment*

And Finally...

... don't forget — the Phase II deadline is July 16th for Semester 13B!

Andy Adamson is Gemini's Associate Director of Operations and can be contacted at: aadamson@gemini.edu

Featured Press Release:

Comet ISON Hurtles Toward an Uncertain Destiny with the Sun

Images of Comet ISON between early February to May hint at coming changes as the comet speeds into the inner Solar System.

A new series of images from Gemini Observatory shows Comet C/2012 S1 (ISON) racing toward an uncomfortably close rendezvous with the Sun. In late November the comet could present a stunning sight in the twilight sky and remain easily visible, or even brilliant, into early December of this year.

The time-sequence images below, spanning early February through May 2013, show the comet's remarkable activity despite its current great distance from the Sun and Earth. The information gleaned from the series provides vital clues as to the comet's overall behavior and

potential. However, it's anyone's guess if the comet has the "right stuff" to survive its extremely close brush with the Sun at the end of November and become an early morning spectacle from Earth in early December 2013.

When Gemini obtained this time sequence, the comet ranged between roughly 455-360 million miles (730-580 million kilometers; or 4.9-3.9 astronomical units) from the Sun, or just inside the orbital distance of Jupiter. Each image in the series, taken with the Gemini Multi-Object Spectrograph at the Gemini North telescope on Mauna Kea, Hawai'i, shows the comet in the far red part of the optical spectrum, which emphasizes the comet's dusty material already escaping from what astronomers describe as a "dirty snowball." Note: The final image in the sequence, obtained in early May, consists of three images, including data from other parts of the optical spectrum, to produce a color composite image."

The images show the comet sporting a well-defined parabolic hood in the sunward direction that tapers into a short and stubby tail pointing away from the Sun. These features form when dust and gas escape from the comet's icy nucleus and surround that main body to form a relatively extensive atmosphere called a coma. Solar wind and radiation pressure push the coma's material away from the Sun to form the comet's tail, which we see here at a slight angle (thus its stubby appearance).

Discovered in September 2012 by two Russian amateur astronomers, Comet ISON is likely making its first passage into the inner Solar System from what is called the Oort Cloud, a region deep in the recesses of our Solar System, where comets and icy bodies dwell. Historically, comets making a first go-around the Sun exhibit strong activity as they near the inner Solar System, but they often fizzle as they get closer to the Sun.

Sizing up Comet ISON

Astronomer Karen Meech, at the University of Hawai'i's Institute for Astronomy (IfA) in Honolulu, is currently working on a preliminary analysis of the new Gemini data (as well as other observations from around the world) and notes that the comet's activity has been decreasing somewhat over the past month.

"Early analysis of our models shows that ISON's brightness through April can be reproduced by outgassing from either carbon monoxide or carbon dioxide. The current decrease may be because this comet is coming close to the Sun for the first time, and a "volatile frosting" of ice may be coming off revealing a less active layer beneath. It is just now getting close enough to the Sun where water will erupt from the nucleus revealing ISON's inner secrets," says Meech.

"Comets may not be completely uniform in their makeup and there may be outbursts of activity as fresh material is uncovered," adds IfA astronomer Jacqueline Keane. "Our team, as well as astronomers from around the world, will be anxiously observing the development of this comet into next year, especially if it gets torn asunder, and reveals its icy interior during its exceptionally close passage to the Sun in late November."

NASA's Swift satellite and the Hubble Space Telescope (HST) have also imaged Comet ISON recently in this region of space. Swift's ultraviolet observations determined that the comet's main body was spewing some 850 tons of dust per second at the beginning of the year, leading astronomers to estimate the comet's nucleus diameter is some 3-4 miles (5-6 kilometers). HST scientists concurred with that size estimate, adding that the comet's coma measures about 3100 miles (5000 km) across.

(Previous page)

Images of Comet ISON obtained using the Gemini Multi-Object Spectrograph at Gemini North on February 4, March 4, April 3, and May 4, 2013 (left to right, respectively; Comet ISON at center in all images).

Technical Specifications: The three images on left are through an r-band filter only, and the color composite on right includes g, i, and r bands. All are integrated for 2 x 45 seconds with the February 4 image integrated for 2 x 75 seconds (increasing the comet's apparent brightness). During the period of this sequence, the comet shined at about magnitude 15.5-16.5 in visible light. In these images north is up, east is left, and the field-of-view is about 2.5 arcminutes across, which corresponds to about 270,000-290,000 miles (435,000-470,000 kilometers) at the distance of the comet.

Color composite produced by Travis Rector, University of Alaska Anchorage.

Credit: Gemini Observatory/AURA

The comet gets brighter as the outgassing increases and pushes more dust from the surface of the comet. Scientists are using the comet's brightness, along with information about the size of the nucleus and measurements of the production of gas and dust, to understand the composition of the ices that control the activity. Most comets brighten significantly and develop a noticeable tail at about the distance of the asteroid belt (about 3 times the Earth-Sun distance — between the orbits of Mars and Jupiter) because this is when the warming rays of the Sun can convert the water ice inside the comet into a gas. This comet was bright and active outside the orbit of Jupiter — when it was twice as far from the Sun. This meant that some gas other than water was controlling the activity.

Meech concludes that Comet ISON "could still become spectacularly bright as it gets very close to the Sun," but she cautions, "I'd be remiss, if I didn't add that it's still too early to predict what's going to happen with ISON since comets are notoriously unpredictable."

A Close Encounter

On November 28, 2013, Comet ISON will make one of the closest passes ever recorded as the comet grazes the Sun, penetrating our star's million-degree outer atmosphere, called the corona, and moving to within 800,000 miles (1.3 million km) of the Sun's surface. Shortly before that critical passage, the comet may appear bright enough for expert observers using proper care to see it close to the Sun in daylight.

What happens after that no one knows for sure. But if Comet ISON survives that close encounter, the comet may appear in our morning sky before dawn in early December and become one of the greatest comets in the last 50 years or more. Even if the comet completely disintegrates, skywatchers shouldn't lose hope. When Comet C/2011 W3 (Lovejoy) plunged into the Sun's corona in December 2011, its nucleus totally disintegrated into tiny bits of ice and dust, yet it still put on a glorious show after that event.

The question remains, are we in for such a show? Stay tuned…

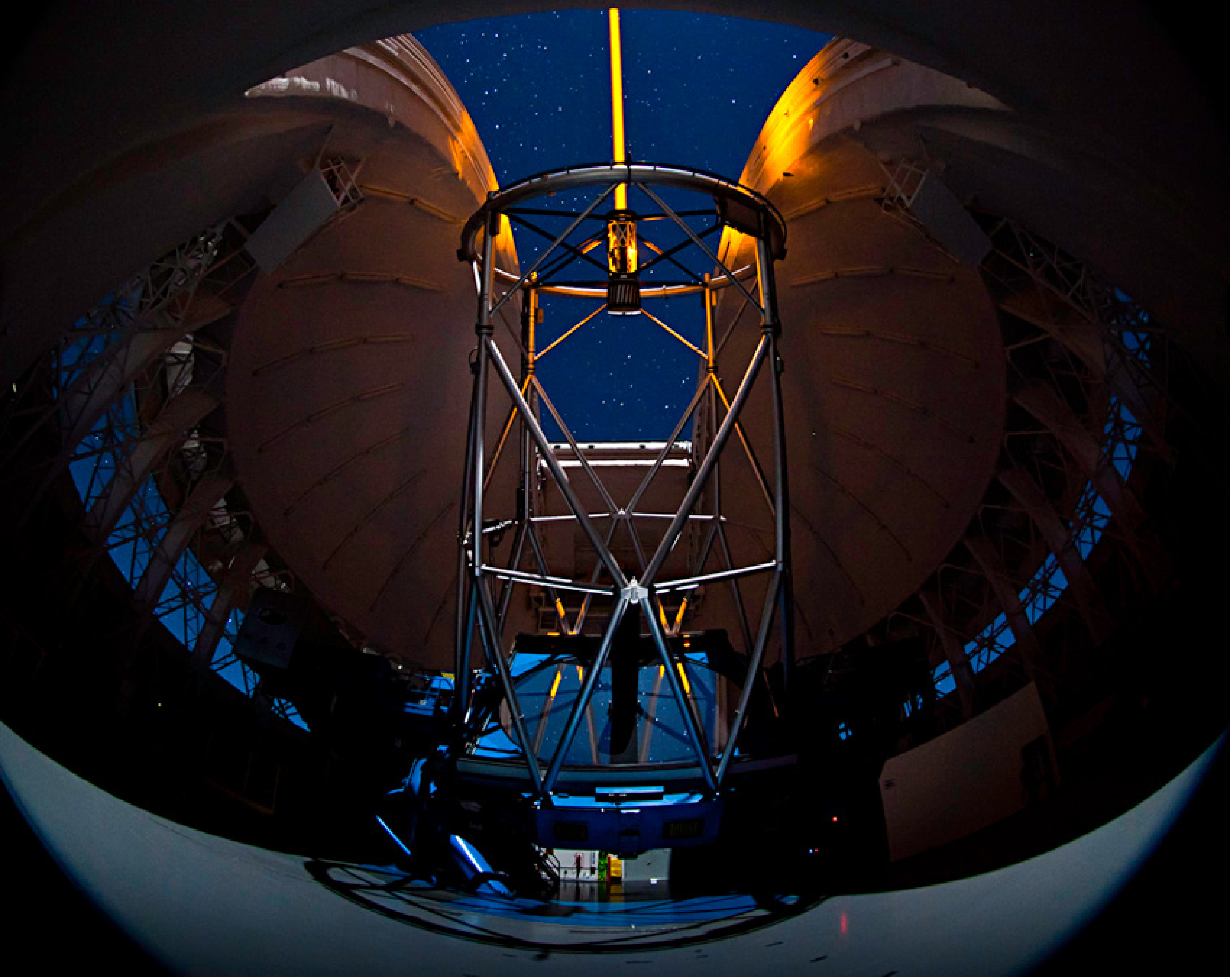
Comet ISON: The View from the North and South

Regardless of whether Comet ISON becomes the "Comet of the Century," as some speculate, it will likely be a nice naked-eye and/or binocular wonder from both the Northern and Southern Hemispheres in the weeks leading up to its close approach with the Sun.

By late October, the comet should be visible through binoculars as a fuzzy glow in the eastern sky before sunrise, in the far southeastern part of the constellation of Leo. By early November, the comet should be a much finer binocular object. It will steadily brighten as it drifts ever faster, night by night, through southern Virgo, passing close to the bright star Spica. It is during the last half of the month that observations will be most important, as the comet edges into Libra and the dawn, where it will brighten to naked-eye visibility and perhaps sport an obvious tail.

The comet reaches perihelion (the closest point in its orbit to the Sun) on November 28th, when it will also attain its maximum brightness, and perhaps be visible in the daytime. If Comet ISON survives perihelion, it will swing around the Sun and appear as both an early morning and early evening object from the Northern Hemisphere. The situation is less favorable from the Southern Hemisphere, as the comet will set before the Sun in the evening and rise with the Sun in the morning.

By December 10th, and given that everything goes well, Comet ISON may be a fine spectacle in the early morning sky as viewed from the Northern Hemisphere. Under dark skies, it may sport a long tail stretching straight up from the eastern horizon, from the constellations of Ophiuchus to Ursa Major. The comet will also be visible in the evening sky during this time but with its tail appearing angled and closer to the horizon.



Gemini South by moonlight while propagating the GeMS laser during System Verification (SV) observations. See the feature article starting on page 14 in this issue featuring GeMS SV images and milestones. Gemini Image by Manuel Paredes.

AURA

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