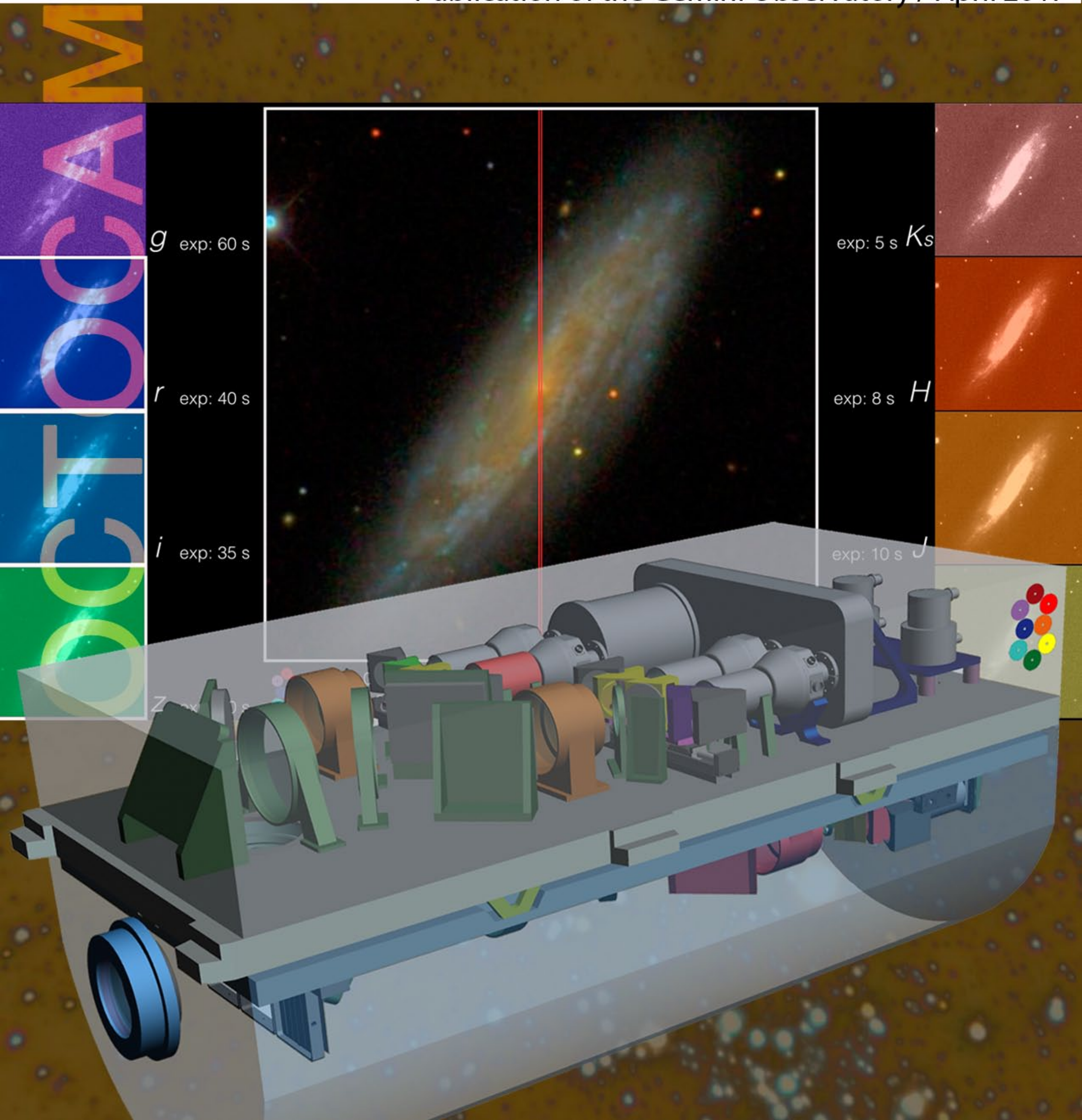
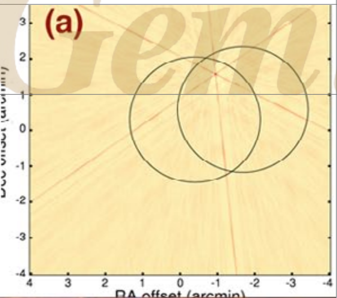
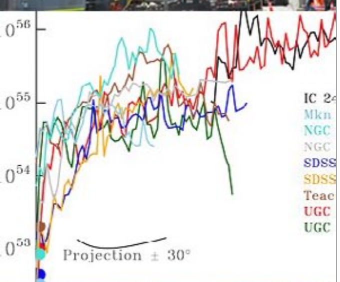
GeminiFocus

Publication of the Gemini Observatory / April 2017







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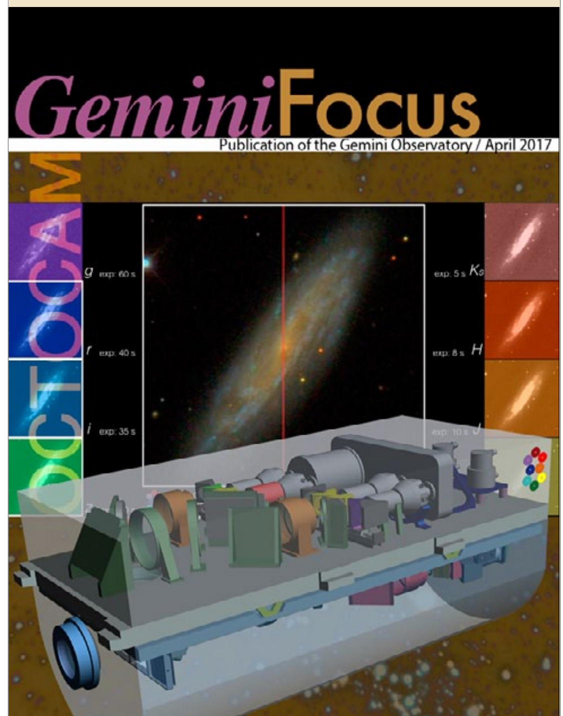

ON THE COVER:

A diagram of OCTOCAM — our next facility-class (Gen4#3) instrument shown against a background illustrating the wide spectral range of this 8-channel imager and spectrograph, which will enable Gemini to take advantage of Large Synoptic Survey Telescope follow-up opportunities. Learn more about OCTOCAM starting on page 15.

Gemini*Focus April 2017*

Gemini*Focus is a quarterly publication of the Gemini Observatory*

670 N. A'ohoku Place, Hilo, Hawai'i 96720, USA / Phone: (808) 974-2500 / Fax: (808) 974-2589
Online viewing address: www.gemini.edu/geminifocus

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Markus Kissler-Patig

Director's Message

Gemini's Future Beyond 2021: a consensus vision emerges with prospects for a new center for optical-infrared astronomy.

Over the last two years, the Gemini partners have been discussing the future of the Gemini Observatory. For the timeframe 2016–2021 (the length of the current International Agreement) the Gemini Board had given Operational Guidelines to the Observatory (***viewable here*** — issued in June 2015). For the decade beyond 2021, after consultation with the various stakeholders and the community (see editorial, October 2016 issue) the Gemini Board has now issued a Strategic Vision. The four recommendations to the Observatory are as follows:

1. Beyond 2021, Gemini should exploit its geographical location and agile operational model in order to be the premiere facility for the follow-up investigation of targets identified by the Large Synoptic Survey Telescope.
2. Beyond 2021, a significant fraction of the time on the telescopes should remain focused on Principal Investigator-driven science.
3. Beyond 2021, Gemini should be viewed as the premiere hosting facility for visitor instruments whose scope and ambition may be comparable to that of the 'facility-class' instruments.
4. Beyond 2021, direction of the two Gemini telescopes should be allowed to diverge.

The Observatory is now charged to develop, by the end of 2018, a Strategic Plan following these recommendations. The goal is to develop a path that will retain Gemini scientifically productive, relevant, exciting, and at the forefront of ground-based observational astronomy — in an era that will be dominated by other ground- and space-based facilities, including the Extremely Large Telescopes; a challenging task that we are happy to accept.

In parallel, over the last 18 months, the Association of Universities for Research in Astronomy (AURA) and National Science Foundation (NSF) have been in discussions about how to maximize the scientific return of NSF investment in optical-infrared night-time facilities in the era of the Large Synoptic Survey Telescope. From these discussions has emerged a consensus vision for a new National Center for Optical-infrared Astronomy (NCOA) that would combine operations of the current National Optical Astronomy Observatory (NOAO) and Gemini facilities with the future operations of the Large Synoptic Survey Telescope (LSST) system.

Such an evolution would present many advantages for Gemini and provide a host of opportunities for the Observatory to develop; opportunities that it would not have if it remained "stand-alone." The NCOA vision foresees a single, coherent scientific and service organization to exploit scientific synergies among several Optical and Infrared (OIR) facilities, including in the domain of instruments, data systems, and datasets.

By taking advantage of economies of scale, NCOA would eliminate operations redundancies and thereby maximize scientific return-on-investment. Furthermore, NCOA would be a natural nucleus for public-private and international partnerships to design, construct, and operate future facilities and capabilities.

Current NCOA planning fully recognizes that NCOA will participate in many activities as partners, not owner-operators. This recognition is especially important for LSST and Gemini, but is also relevant to the WIYN Observatory, Southern Astrophysical Research (SOAR) Telescope, Dark Energy Survey, *etc.*

As such, the NCOA concept fully respects that such partnerships have independent governance structures with strong programmatic and financial authority; *i.e.*, NCOA management will not have free will to determine strategic direction or program plans of such partnerships.

In turn, NCOA partners will benefit from the formation of NCOA by gaining access to a broader and deeper pool of scientific, technical, and administrative expertise at no additional total cost to the individual partnerships.

In more practical terms, NCOA has several key missions to fulfill, including the following: operating LSST as the flagship NSF-funded capability; operating Gemini Observatory as an international entity; developing and deploying OIR data science capabilities as a key strategic initiative; providing OIR System services and community engagement as a high priority activity; operating NOAO existing observatories and programs encompassed by Kitt Peak National Observatory (KPNO) and Cerro Tololo Inter-American Observatory (CTIO); and pursuing education, public outreach, and public engagement as a national focus for engaging the astronomical community with students and the general public in the discoveries of OIR astronomy.

Based on guidance provided by NSF, AURA is currently preparing operations, management, and implementations plans for NCOA. This process is being jointly led by the current directors of Gemini (Markus Kissler-Patig), LSST (Steven Kahn), and NOAO (David Silva) in partnership with the AURA Vice President for Programs (Dana Lehr). NSF has requested submission of these plans by June 30, 2017, after which NSF will begin a period of intensive review. Assuming the AURA plans are deemed acceptable, NCOA may come into existence as early as October 1, 2018.

Making NCOA a reality still requires significant effort and a lot of hard work from many people over the next few years. Yet, I believe that it offers a fantastic perspective for Gemini, allowing the Observatory to continue to flourish in a fruitful environment, exploit its strength serving the Gemini community, and continue on its mission: "Exploring the Universe, Sharing its Wonders."

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

Shriharsh P. Tendulkar, on behalf of the FRB 121102 collaboration

The Host Galaxy of the Repeating Fast Radio Burst FRB 121102

Fast radio bursts (FRBs) are a recent astronomical mystery consisting of short, yet extremely bright, pulsar-like bursts of radio waves that seem to traverse cosmological distances. Although they occur at a stunning rate of 1,000 per day in the entire sky, we know little about their origins, generation mechanisms, and, until recently, even their distances. Using the combined forces of the Karl G. Jansky Very Large Array in New Mexico and the Gemini North telescope in Hawai'i, we have localized and identified — for the first time — the host galaxy of an FRB. Surprisingly, the host galaxy is a low-metallicity, star-forming, dwarf galaxy ~1 billion parsecs distant, which hints at possible similarities of this FRB host to those of superluminous supernovae and long-duration gamma-ray bursts.

Almost exactly 10 years ago, Duncan Lorimer and his team at West Virginia University were searching archival data from the 64-meter Parkes telescope in New South Wales, Australia, for bright single pulses from Galactic radio pulsars. They discovered a short and brilliant burst (Figure 1; now known as the "Lorimer" burst) with a flux density or radio brightness of 30 Jansky (Jy)[1], bright enough to saturate the detectors at Parkes (Lorimer *et al.*, 2007). More oddly, unlike Galactic radio pulsars, the burst had a dispersion measure (DM; see the box, next page) far greater than the contribution of the Milky Way along that line of sight — 375 pc cm^{-3} compared to the Galactic contribution of 25 pc cm^{-3}.

[1] Jansky = 10^{-23} erg/cm^2/s/Hz.

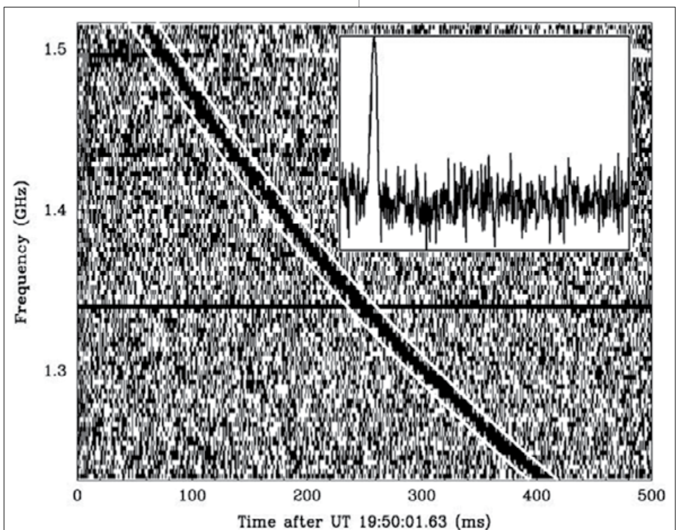


Figure 1.
The arrival of the Lorimer burst heralded a new era in radio astrophysics. The dynamic spectrum of the pulse is shown with frequency along the y-axis and arrival time along the x-axis. The grayscale depicts the 1-bit digitized intensity. Two thin white lines are drawn along the theoretical dispersion relation to guide the eye. The inset shows the total intensity profile as a function of time after correcting for dispersion. Figure adapted from Lorimer et al.*, 2007.*

Cold Plasma Dispersion

When electromagnetic waves pass through interstellar plasma, the inertia of electrons moving in response to the electric fields causes the lower frequency waves to propagate slower than the higher frequency waves. For non-relativistic, diffuse plasma, the pulse arrival time difference between two frequencies is given by

$$t_1 - t_2 = \frac{e^2}{2\pi m_e c} DM\ (v_1^{-2} - v_2^{-2}),$$

where the dispersion measure $DM = \int_s^o n_e dl$ is the integral of the electron density from the source to the observer, ν is the radio frequency and m_e, e and c are the mass and charge of an electron and the speed of light, respectively. The Milky Way interstellar medium (ISM) contribution to the DM along different lines of sight has been characterized using pulsar DM measurements, HI maps and Galactic models. Any excess in DM would have to be attributed to either excess electrons near the source or the intergalactic medium (IGM).

The simplest, yet unbelievable, explanation is that the source is extragalactic and the excess DM is contributed by the electrons in the intergalactic medium (IGM) — placing the source of the Lorimer burst at a redshift of $z \sim 0.3$, a distance of ~ 1 billion parsecs. The emitted power at the source would have been 10^{42} erg/s, about a billion times more luminous than the brightest radio pulsars ever observed in the Milky Way.

The Population of FRBs

Over the next decade, such radio bursts were detected at multiple radio telescopes — Parkes, Green Bank (West Virginia), Arecibo (Puerto Rico), and Molonglo (near Canberra, Australia) — and came to be known as Fast Radio Bursts (FRBs). To date, only 26 bursts have been reported in the literature, but considering the narrow fields-of-view of radio telescopes and the survey durations, the expected sky rate of FRBs is large — 10^3 per sky per day above a peak flux density of 1 Jy at an observing frequency of 1.4 GHz (Lawrence *et al.*, 2016).

Despite this prodigious rate, we have little knowledge about the sources that emit FRBs and the emission mechanisms that allow such luminous coherent bursts. Until this work, even the distance to any FRB was only estimated from the excess DM. Due to the paucity of observational constraints, there are more theoretical models of FRBs than the total number of observations (see box at lower left). In the future, FRBs are projected to serve as excellent cosmological probes of the electron and baryon distribution in the Universe.

Theoretical Models for FRBs

Due to the very short timescale (few milliseconds) and the bright, often polarized emission, it is almost necessary to invoke a compact magnetic field to produce an FRB, making some variety of neutron stars an obvious choice for FRB sources. However, the observed energy scales of FRBs are far higher than those of galactic radio pulsars. A plethora of models have been proposed including magnetar giant flares, Crab-like giant pulses from young extra-galactic pulsars, planets in pulsar magnetospheres, asteroids impacting neutron stars, neutron-star mergers and neutron stars collapsing into blackholes, black hole-neutron star mergers, magnetar pulse-wind interactions, flares from nearby stars, quark novae, and axion stars. For a more complete review, please see Katz, 2016.

The Repeater

FRB 121102 was discovered by the 300-meter Arecibo Observatory during a survey of the Galactic plane with a DM of 557 pc cm^{-3} (Spitler *et al.*, 2014). In follow up Arecibo observations conducted in 2015, eleven more bursts were found at the same location with the same DM (Spitler *et al.*, 2016), earning FRB 121102 the moniker "Repeater." None of the other FRBs, even after several follow up observations of various durations, have yet been observed to repeat.

It is not clear at this time whether the Repeater belongs to a separate population from the rest of the FRBs or whether all FRBs are a homogeneous population — but the much higher sensitivity of Arecibo compared to other radio telescopes allowed Arecibo to detect fainter bursts; ones that are likely to be more frequent than bright bursts and may have been missed by smaller telescopes such as Parkes.

The Repeater became the focus of our effort for the interferometric localization of FRBs. Radio interferometry is a technique to combine the signals from different radio telescopes to effectively achieve the resolving power of a radio telescope that is as large as the separation between the telescopes. Using the Very Large Array (VLA) and collecting interferometric data with a sampling time of 5 milliseconds (instead of a few tens of seconds), our team was able to search for repeated bursts.

Compared to the 10-arcminute localization of the single 300-m dish at Arecibo Observatory, the ~30 kilometer baseline of the VLA was able to localize nine bright bursts from the Repeater to a 100 milliarcsecond precision (Figure 2; Chatterjee *et al.*, 2017). Using the European Very Long Baseline Interferometry Network of radio telescopes spread across Europe, our team further localized the bursts to a precision of 4 milliarcseconds (Marcote *et al.*, 2017), allowing us to further constrain the environment of the FRB.

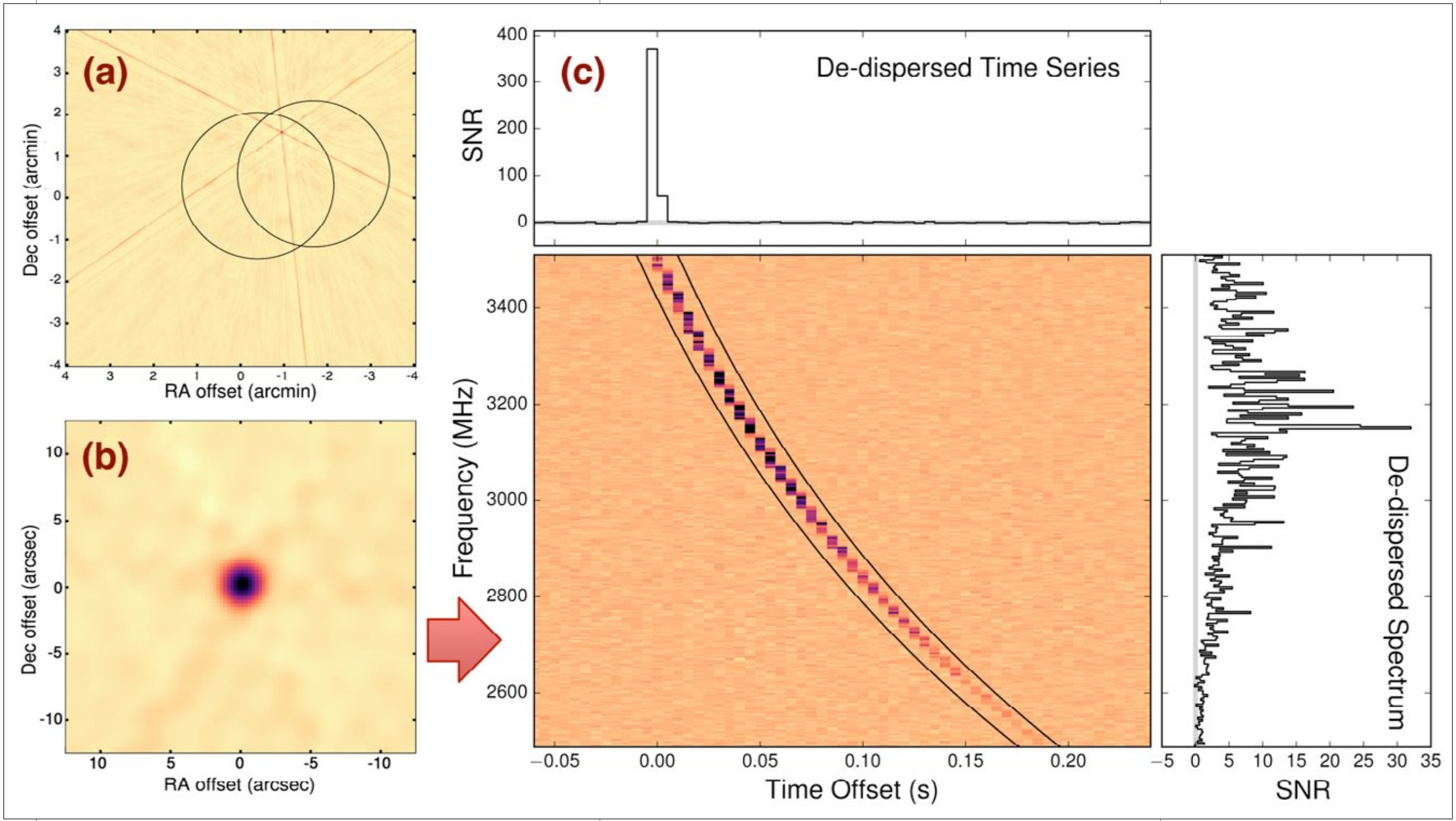
This was a watershed moment in the emerging field of FRBs. For the first time, the localization was sufficient to search for optical and infrared counterparts and perhaps identify where FRBs originate.

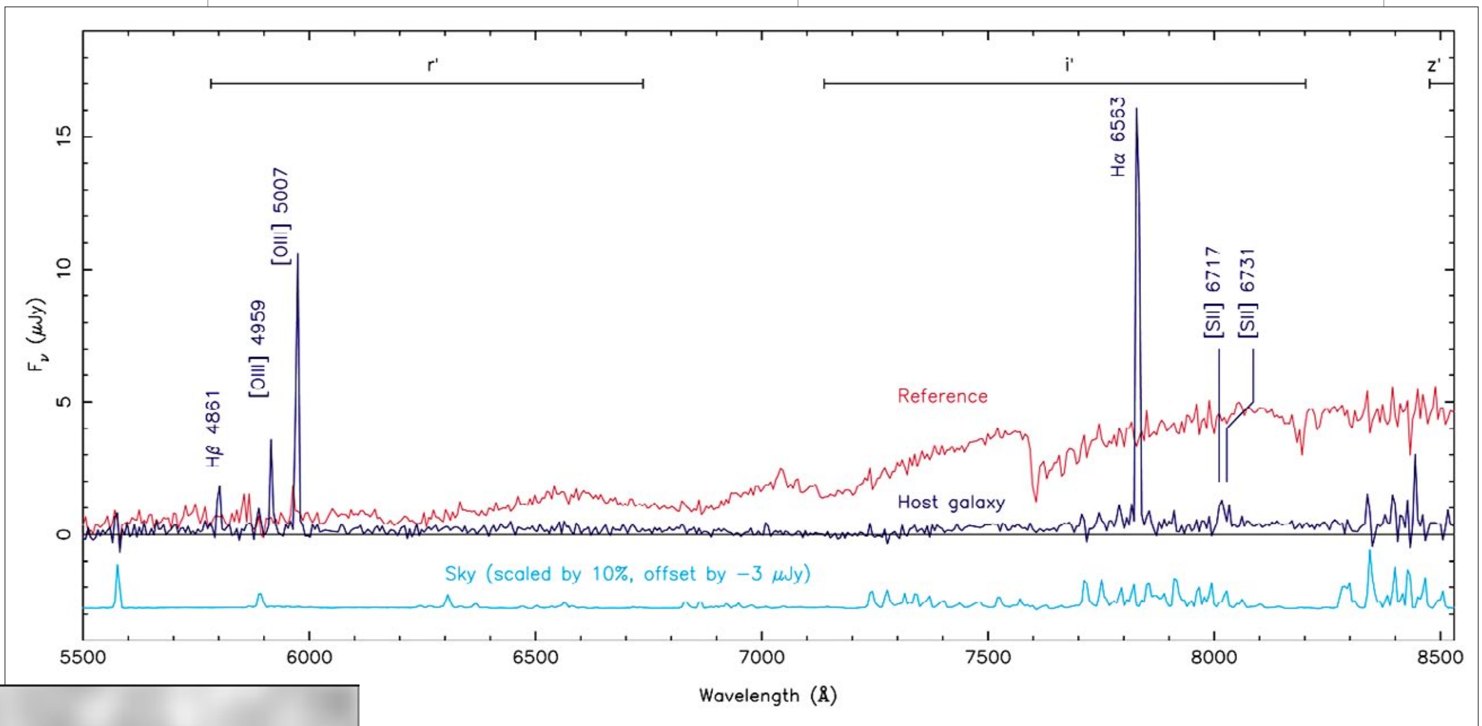
Optical Counterpart

Archival R-band images from the Keck Observatory showed a very faint ($R = 24.5$ magnitude) object detected at about 5-σ but it was not clear whether it was an extended source or a point-like object. We were granted nine hours of Gemini Director's Discretionary Time for further imaging and spectroscopy with the Gemini Multi-Object Spectrograph to characterize the counterpart and investigate whether the FRB was Galactic or extragalactic.

Gemini Observatory's flexible queue scheduled observations were critical to the success of this project. The faint target required dark

Figure 2.
The interferometric localization of the bursts from FRB 121102 using the VLA. Panel (a): radio image of the burst; the black circles are Arecibo beam sizes. Panel (b): zoom-in of the radio image; the position precision for each burst is less than one arcsecond. Panel (c): the de-dispersed time profile, spectrum, and dynamic spectrum of the burst. Figure adapted from Chatterjee et al.*, 2017.*





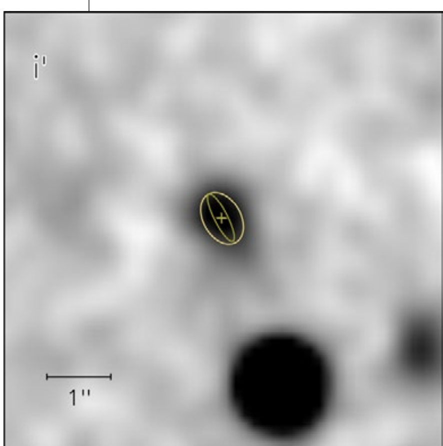


Figure 3.
Top panel: GMOS-N spectrum of the FRB host galaxy (dark blue line) shows prominent [OIII] and H-alpha emission lines. Other emission lines are also marked. The pink line shows a neighboring Galactic star.
Side panel: An i-band image of the host galaxy and the neighboring star. The galaxy is slightly extended compared to the seeing and is well fit with a Gaussian profile. Figures adapted from Tendulkar et al.*, 2017.*

observing time with very little cloud cover and excellent seeing (for the imaging). Unlike the nights lost to weather in classical observing, we obtained our data with the required sensitivity despite uncooperative weather over Maunakea.

Results

The Gemini-North imaging and spectroscopic observations revealed that FRB 121102 was hosted in a low-metallicity star-forming dwarf galaxy at a redshift of $z = 0.19273(8)$ — the first incontrovertible proof that FRB 121102 is at a cosmological distance (Figure 3; Tendulkar *et al.*, 2017). The redshift is consistent with the $z < 0.3$ redshift that was estimated from the excess DM for this FRB. If this holds for other FRBs, it implies that we have been observing FRBs from redshifts up to $z = 3$!

The most surprising aspect of this result is the location in a dwarf galaxy. The host galaxy, with an absolute magnitude $M_R > -16$ AB mag, has an estimated stellar mass of $M_* < 4 \times 10^7\ M_\odot$, almost three orders of magnitude lower than that of a typical L_* galaxy. The total star forming rate, 0.5 $M_\odot$ per year, is very large compared to the stellar mass of the host, yet it is very small compared to the 10–100 $M_\odot$ per year star formation rates of massive starburst galaxies. If FRBs were expected to originate from generic neutron stars, or indeed any typical stellar origin, we would have expected them to emanate from galaxies with the largest number of stars.

One of the special properties of dwarf galaxies at low redshift is that they retain a lower metallicity as compared to larger galaxies. The low metallicity plays a major role in explaining why hydrogen-deficient superluminous supernovae (SLSNe Type I) and long-duration gamma-ray bursts (LGRBs) preferentially occur in low-metallicity dwarf galaxies (*e.g.,* Modjaz *et al.*, 2008; Lunnan *et al.*, 2014; and future work).

In the magnetar model unifying SLSNe and LGRBs, the low metallicity allows for the formation of extremely high mass (60–100 $M_\odot$) stars with high angular momentum that undergo supernovae and leave a very rapidly spinning, hypermagnetized neutron star. It is conceivable that FRBs are emitted by some yet unknown mechanism from these magnetars (*e.g.,* Metzger *et al.*, 2017).

The Future of Fast Radio Bursts

The radio observations of FRBs give us almost no measure of distance, although, under some circumstances, we may expect to measure a lower bound on the redshift via neutral hydrogen absorption. They do, however, give us a limited view of the environment in which FRBs are born. Multiwavelength observations are essential for identifying and characterizing hosts and the environments of FRBs.

Future arcsecond-precision FRB localizations will tell whether the dwarf galaxy hosting FRB 121102 is typical of all FRBs, but it is certain that large optical observatories such as Gemini, Keck, and VLT will be crucial for the studies of this enigmatic class of transients.

With new FRB experiments such as the Canadian Hydrogen Intensity Mapping Experiment (CHIME; Kaspi *et al.*, 2017, in prep), and Swinburne University of Technology's digital backend upgrade for the Molonglo Observatory Synthesis Telescope (UTMOST; Bailes *et al.*, 2016), and Caltech's 10-element Deep Synoptic Array prototype (DSA-10; Ravi *et al.*, 2016) coming online in the near future, the rate of FRB detection will increase significantly — and along with it the challenge of identifying and characterizing the hosts of these bursts, in many cases with imprecise localizations.

The mystery of FRBs is an interdisciplinary challenge that can only be solved with the combined forces of sensitive radio and optical observatories to support a motley group of bewildered astronomers.

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Tom Geballe

Persistence Pays Off in the Study of Shock-heated Gas

A breakthrough has been made in a two-decade old mystery concerning the frequently observed shock-heated gas in dense star-forming clouds, thanks to sensitive new measurements using Gemini North and its infrared spectrographs NIFS and GNIRS.

Shock waves in dense interstellar clouds occur when the powerful winds generated by stars forming within the clouds ram into quiescent portions of the clouds. As a consequence of shock heating in a previously quiescent cloud, its most abundant molecule, molecular hydrogen (H_2), emits numerous strong spectral lines, especially in the 2.0-2.5-micron wavelength range, as the shocked gas cools. Measurements of the velocities and both the absolute and relative intensities of these lines reveal much information about the nature of the shock as well as the protostars responsible for them.

As reported in two recently published papers, Rosemary Pike (Academia Sinica, Taipei, Taiwan), Michael Burton (Armagh Observatory, Northern Ireland), Antonio Chrysostomou (Square Kilometer Array Office at Jodrell Bank, UK) and I have discovered lines of H_2 from much higher energy levels than previously observed, in two shocked clouds. We have tentatively linked these lines to H_2 that has recently reformed on dust particles following its destruction by the shock waves. If our interpretation is correct, our data are giving scientists a first look at the spectrum of newly formed H_2, the most abundant molecule in the Universe.

Shocking Shock Waves

In the late 1980s and early 1990s, Burton (first a graduate student at Edinburgh University and then a research fellow at NASA Ames), Chrysostomou (also a grad student at Edinburgh) and I (then employed at the United Kingdom Infrared Telescope; UKIRT), were part of a team led by Peter Brand at Edinburgh that was attempting to understand the physics of shock waves in star-forming molecular clouds. In a pure hydrodynamic shock, H_2 is dissociated into its constituent hydrogen atoms when collisions involving it and atoms or molecules in the wind from the protostar occur at speeds exceeding 20 kilometers per second (km/s).

During 1978-1981, however, when I was a Carnegie Fellow in Pasadena working with Gary Neugebauer of Caltech and his graduate student Daniel Nadeau, we had found that the H_2 lines in the Orion Molecular Cloud have velocity widths of over 100 km/s. Similar high velocity and high temperature H_2 was later found in other clouds as well. Molecule-molecule or atom-molecule collisions occurring at even a small fraction of that speed would have destroyed the H_2, and the emission lines from H_2 thus would not be observed.

Our finding helped to stimulate the development by theorists of magneto-hydrodynamic shock models in which the quiescent gas is accelerated and heated more slowly and the H_2 survives. Because these so-called continuous shocks, or C-shocks, are naturally created if the cloud contains a magnetic field, as is always the case, they appeared to be a natural explanation for the observations.

Brand, Burton, Chrysostomou, and I, along with a few other Brand grad students tested the C-shock models by measuring the relative intensities of numerous lines of shocked H_2. To our surprise, the relative intensities did not match the predictions for C-shocks. The highest excitation lines we could detect at the time (with upper energy levels as high as 25,000 K above the ground state) were far too strong; their strengths actually much more closely matched the predictions for pure hydrodynamic shocks than for C-shocks. Yet at the observed speeds, none of the H_2 could have survived a hydrodynamic shock. Unable to find a satisfactory resolution to this puzzle, we researchers eventually went our separate ways and moved on to other unrelated projects.

On the Sky Again … at Gemini

My move from UKIRT to Gemini and its set of powerful infrared spectrographs eventually led me to return to the problem, and I reassembled part of my old Edinburgh team (Burton and Chrysostomou) to do so. We chose as our target the Herbig-Haro object HH 7, a small patch of nebulosity associated with a newly born star well known for its strong H_2 line emission and its simple geometry in the sky, that of a classic bow shock. As our spectrograph, we selected Gemini's Near-Infrared Integral Field Spectrometer (NIFS), which was capable of dicing the bow shock into tiny regions that could be analyzed separately.

Gemini System Support Associate Rosemary Pike (now a PhD astronomer) reduced the complex NIFS spectral data on HH 7. In addition to the well-known high-excitation lines of H_2 that were the intended target of the program, the reduced data (see Figure 1) revealed a large number of very faint emission lines that were eventually identified as also due to H_2, but emitting from energy levels far above the highest ones previously observed (25,000 K). Some of these levels are 50,000 K above the ground state, very close to the dissociation energy of H_2.

Surprisingly, Burton successfully modeled all the line emission as arising from H_2 at just

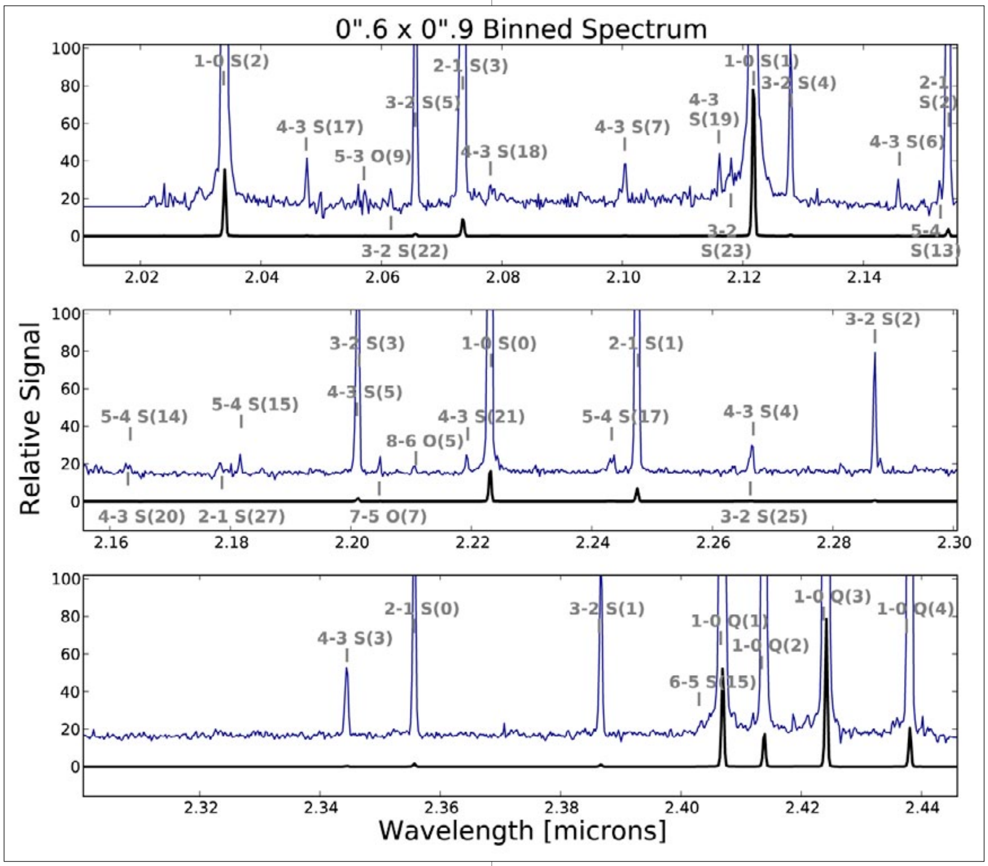


Figure 1. *Spectrum of a bright region near the apex of the HH 7 bowshock (as published in Pike et al., ApJ, **822:** 82, 2016). All lines are due to molecular hydrogen and are labeled according by their vibrational and rotational transitions. The blue trace is the same as the black trace, but is multiplied by a factor of 150 and offset vertically to show the weaker lines, which had not been detected previously in any astronomical object.*

two temperatures: 1,800 K and 5,000 K. Approximately 98.5% of the H_2 is at the lower temperature, which corresponds closely to the temperature expected for a C-shock. The higher temperature component, which is only 1.5% of the hot H_2, accounts for virtually all of the emission by the most highly excited H_2. The origin of the 5,000 K component is of intense interest. It seems most likely to be due to H_2 that has reformed on dust grains following destruction by the shock wave.

The formation of H_2 by the collision of two H atoms in the gas phase is an extremely unlikely process. However, hydrogen atoms will stick to a dust particle and can easily hop around on it, find each other, and make H_2. Their association produces a lot of energy, some of which ejects the newly formed H_2 molecule from the dust particle and some of which leaves the molecule in a highly excited state, from which it can emit spectral lines as it cools. Qualitatively this explains the observations, but many questions remain, especially regarding how well the relative line strengths match predictions of the "formation spectrum."

A Fundamental Question … and the Answer

A basic question about this discovery was whether the high temperature H_2 is unique to HH 7 or is found in other clouds that have been subjected to high velocity shocks. To begin to answer this question, Burton, Pike, and I observed the shocked H_2 in the location where it was initially discovered in 1976, and where it is brighter than anywhere else: the Orion Molecular Cloud (OMC-1). Using as a guide the exquisite images obtained by John Bally (University of Colorado) and collaborators with the multi-conjugate adaptive optics System at Gemini South, we positioned the long slit of the Gemini Near-Infrared Spectrograph (GNIRS) on Gemini

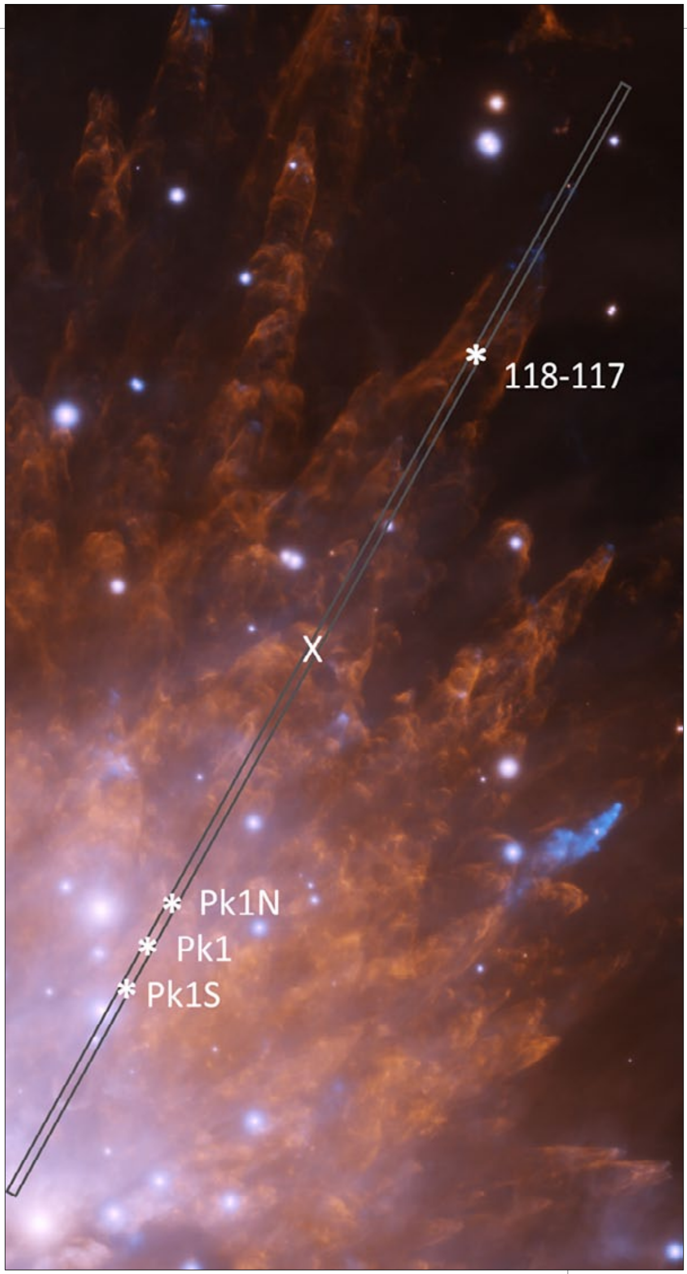


Figure 2.
Image of emisson from the 1-0 S(1) line of molecular hydrogen in a portion of the OMC-1 outflow in the H_2 1–0 S(1) line (from Bally et al., A&A, ***579:*** *A130, 2015) with the GNIRS slit superimposed. The 1.9-2.5-micron spectra (published in Geballe, Burton, & Pike,* ApJ, ***837:*** *83, 2017) at the four positions denoted by asterisks show some of the same weak, high-excitation lines previously seen in HH 7.*

North to traverse several regions of intense H_2 line emission in OMC-1, including one of the famous "bullets" or "fingers," as shown in Figure 2.

The results are unequivocal — the high temperature (5,000 K) component is present at all analyzed locations along the slit. It thus appears to be a common characteristic of shock-excited molecular gas. In OMC-1 the largest percentage of hot H_2 (still relatively small at only about 3.3%) is in the "bullet" (a dense and compact clump of gas piercing the ambient molecular cloud at about 120 km/sec). This is consistent with the hypothesis that the amount of dissociation increases with shock speed, and thus it lends support to the idea that the high temperature line emission is from recently reformed H_2.

Future detailed modeling and laboratory observations of the formation spectrum are badly needed to compare with the observations. Burton, Pike, and I have plans to obtain further observations of the high temperature H_2 at higher sensitivity and in both more extreme and less extreme environments.

Tom Geballe is an astronomer at the Gemini North Observatory. He can be reached at: tgeballe@gemini.edu.

Peter Michaud

Science Highlights

Gemini follow-up on fading active galactic nuclei (AGN) help confirm that they are dynamically different from radio-loud AGN. Gemini Multi-Object Spectrograph data assist astronomers in seeing for the first time clear signatures of rocky planet assembly via large asteroids in a dwarf binary system. And Gemini Planet Imager data reveal that exoplanet β Pictoris b appears to have an atmosphere similar to those found around low-surface-gravity brown dwarfs.

New Insights on Fading Active Galactic Nuclei in Collaboration with Galaxy Zoo

William C. Keel (University of Alabama) and collaborators use Hα narrowband filters on the Hubble Space Telescope (HST), in conjunction with the Gemini Multi-Object Spectrograph integral field unit (GMOS IFU) on the Gemini North telescope on Maunakea, to observe a set of fading active galactic nuclei (AGN). These AGN were first identified/classified as part of the Galaxy Zoo project — an online citizen science project in which the public help researchers deal with floods of incoming data aimed at classifying galaxies.

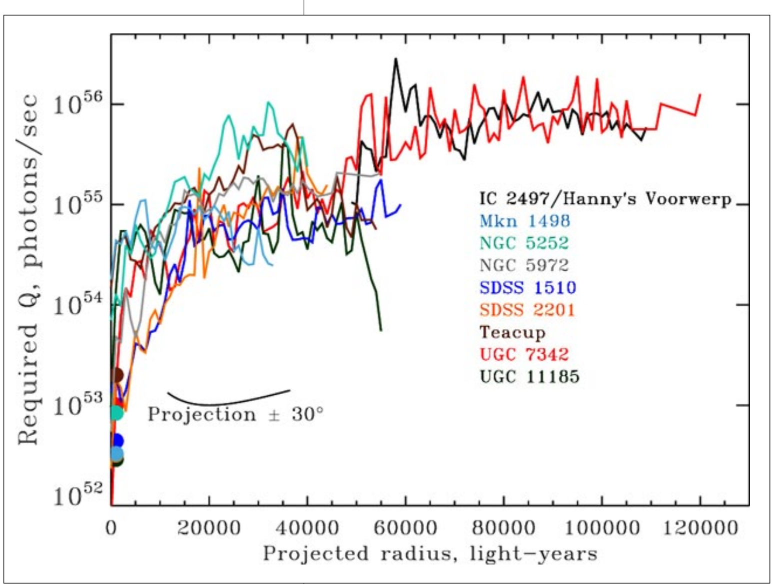


Figure 1. *Minimum ionizing luminosity of extended AGN-ionized clouds along the projected radius. These Hubble Space Telescope data show a luminosity drop in the last 20,000 years before our direct view of the nucleus, characteristic for all AGN of this study.*

This work focuses on nine AGN with ionized gas clouds extending more than 10 kiloparsecs from them. Because these clouds span galaxy scales (or even larger) they can implicitly tell us about the luminosity history of the AGN. Based on this research, the nine observed AGN appear to have experienced a significant reduction in luminosity within 20,000 years or less (Figure 1).

The research team also uses GMOS IFU spectra to measure line ratios in these regions — to probe their ionization mechanisms and look for kinematic evidence of outflows marked by large (often bipolar) velocity ranges or other phenomena.

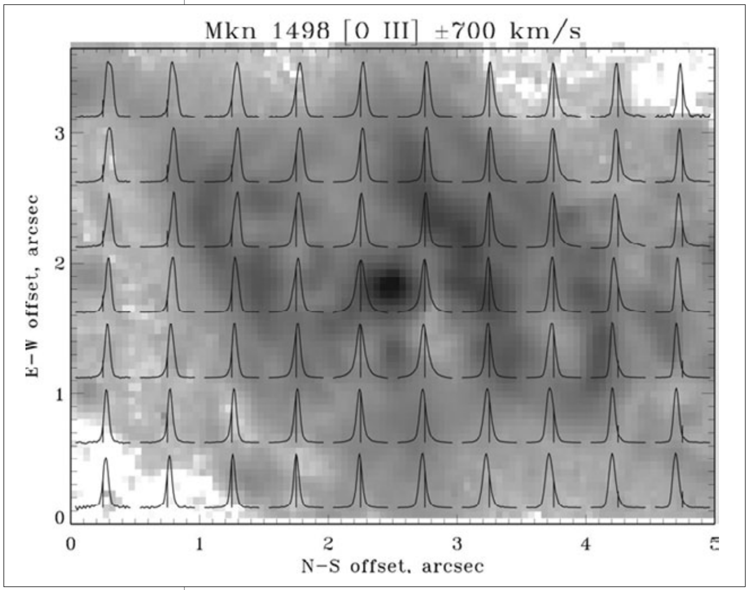


Figure 2.
[O III] emission-line profiles from the GMOS IFU spectra overlaid on the HST [O III] images for Mkn 1498, one of the galaxies studied in this work. This galaxy displays a ringlike emission feature dominated by rotation with a velocity range of ±175 km/sec, (the 700 km/sec referenced in the legend refers to the entire velocity range shown in each miniature line profile plot).

The team's results confirm what was hinted at by earlier, and less complete data (by the same team), that these fading AGN are structurally different from radio-loud AGN, which are dominated by outflows. Instead, these fading AGN are dominated by rotation and consist largely of externally illuminated tidal debris (Figure 2); the Gemini data show a shifting of the [O III] emission line due to the gas cloud's rotation.

This work appears in *The Astrophysical Journal*, and the paper can be found ***here***.

Also read this ***Galaxy Zoo blog*** posting describing this work.

Rocky Planets Assembling in a Dwarf Binary System

To date, almost all of the known planetary systems that include a white dwarf are single stars. Now, a team studying SDSS 1557 (a white dwarf and brown dwarf binary system) using the Gemini South telescope and the European Southern Observatory's Very Large Telescope, have made a surprising discovery that changes this old perception and opens a new window onto exoplanet formation.

Using GMOS spectra, Jay Farihi (University College London) and colleagues identified critical metal features in the system's spectrum as well as the higher Balmer lines. In contrast to the carbon-rich icy material commonly found in double star systems, the planetary material identified in the SDSS 1557 system has a high metal content, including silicon and magnesium. These elements were identified as the debris flowed from its orbit onto the surface of the white dwarf, polluting it temporarily with at least 10^{17} grams (or 1.1 trillion US tons) of matter, equating it to an asteroid at least 4 kilometers in size.

Farihi says: "Building rocky planets around two suns is a challenge because the gravity of both stars can push and pull tremendously, preventing bits of rock and dust from sticking together and growing into full-fledged planets. With the discovery of asteroid debris in the SDSS 1557 system, we see clear signatures of rocky planet assembly via large asteroids that formed, helping us understand how rocky exoplanets are made in double star systems."

The discovery came as a complete surprise, as the team assumed the dusty white dwarf was a single star, but co-investigator Steven Parsons (University of Valparaíso and University of Sheffield), an expert in binary systems, noticed the tell-tale signs of something unusual. "We know of thousands of binaries similar to SDSS 1557, but this is the first time we've seen asteroid debris and pollution," he says. "The brown dwarf was effectively hidden by the dust until we looked with the right instrument. But when we observed SDSS 1557 in detail, we recognized the brown dwarf's subtle gravitational pull on the white dwarf."

From the Gemini data the team estimated that the white dwarf has a surface temperature of 21,800 Kelvin (about 3.5 times hotter than the Sun) and a mass of ~0.4 solar masses; the brown dwarf companion has a mass of ~0.063 solar masses.

The research is published in the February 27th online issue of *Nature Astronomy*.

See the University College London ***press release here***.

β Pictoris b: an Exoplanet with the Atmosphere of a Brown Dwarf

A team of astronomers led by Jeffrey Chilcote (University of Toronto) uses the Gemini Planet Imager (GPI) at the Gemini South telescope in Chile to refine our understanding of the β Pictoris system. The system contains the ~ 13 Jupiter mass companion β Pictoris b, which is at the mass boundary sometimes used to distinguish between an exoplanet and a brown dwarf. Brown dwarfs are objects that are not massive enough for sustained nuclear reactions; and brown dwarfs less massive than 13 Jupiters cannot even start a nuclear reaction.

Based on the GPI data, combined with planetary evolution and atmospheric models, Chilcote suggests a "hot-start" planet formation scenario for β Pictoris b, which has a surface temperature of about 1,724 K. He adds, "This is consistent with the disk instability formation mechanism for wide-orbit giant exoplanets." However, the characteristics for the atmosphere of β Pictoris b found in this work best matches that of a low-surface-gravity (L2±1) brown dwarf, not a planet.

The team studied β Pictoris b during the verification and commissioning of the Gemini Planet Imager, and as part of an astrometric (position) monitoring program designed to constrain the orbit of the exoplanet (Figure 3). This work is also part of a Gemini Large and Long program.

"With GPI, the Gemini Observatory is at the forefront of exoplanet exploration," says Chilcote. He adds, "Direct imaging allows for the discovery of planets on solar-systems-scale orbits, provides new insight into the formation and characteristics of extrasolar systems, and enables direct spectroscopic observations of their atmospheres."

The full results are accepted for publication in *The Astrophysical Journal Letters*. A preprint is available ***here***.

Peter Michaud is the Public Information Outreach Manager of Gemini Observatory. He can be reached at: pmichaud@gemini.edu

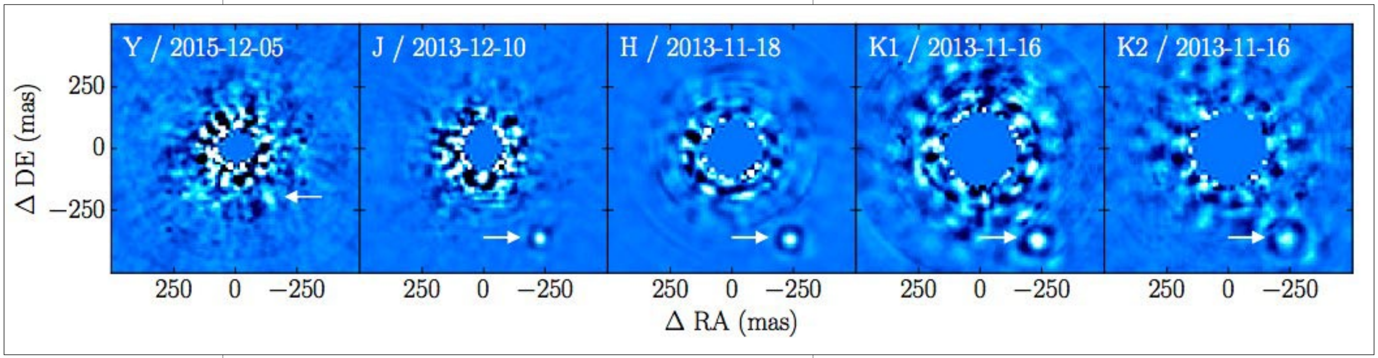


Figure 3. *Using advanced imaging techniques and the special capabilities of the Gemini Planet Imager (GPI), the light from β Pictoris has been suppressed in these images using GPI's Y, J, H, K1, and K2 filters. The arrow indicates the location of the exoplanet β Pictoris b in in all but the left image.*

Stephen Goodsell, on behalf of the OCTOCAM team

The Chosen One: OCTOCAM (Gen4#3)

With great pleasure we proudly announce our next facility-class instrument: OCTOCAM, a wide-band (visible/near-infrared) medium-resolution spectrograph and imager. This powerful facility will support a wide range of science and take advantage of the Large Synoptic Survey Telescope follow-up opportunities.

In May 2016 Gemini released a Request for Proposals for the next facility-class Gemini instrument (then known as Gen4#3). The Observatory received a total of four proposals by our August deadline. After a thorough selection process involving internal and external experts, we selected OCTOCAM, signing a contract to design, build, and commission the instrument with the Southwest Research Institute (SwRI) in San Antonio, Texas, in March 2017.

The OCTOCAM team began immediately thereafter to work on the Conceptual Design Stage, with Antonio de Ugarte Postigo (Instituto de Astrofísica de Andalucía, of the Consejo Superior de Investigaciones Científicas (IAA-CSIC)) as the Principal Investigator, Pete Roming (SwRI) as the Project Manager, Alexander van der Horst (George Washington University) as the Project Scientist and Christina Thöne (IAA-CSIC) as the Deputy Project Manager. A major member of the collaboration includes FRACTAL S.L.N.E. (a private technological company specialized in astronomical instrumentation). Together, we intend to commission OCTOCAM at Gemini South for general use before the 2023 planned start of Large Synoptic Survey Telescope (LSST) operations.

What is OCTOCAM?

OCTOCAM is an 8-channel imager and spectrograph that will simultaneously observe the *g*, *r*, *i*, *z*, *Y*, *J*, *H*, and K_s bands in a 3′ x 3′ field-of-view. It will obtain long slit (3′ long) spectroscopy with a resolution of R ~ 4,000, simultaneously covering the range between 0.37–2.35 microns.

The eight independent channels in OCTOCAM allow the user to adjust exposure times in each bandpass for increased efficiency and the best match to observing conditions. By using state of the art detectors — frame transfer in the optical and CMOS (complementary metal-oxide semiconductor) in the near-infrared (NIR) — OCTOCAM will have negligible readout times enabling high time-resolution observations. Table 1 provides a subset of the top-level requirements for OCTOCAM:

OCTOCAM Requirements	
Parameter	**Value**
Spectrographic	
Wavelength Range	0.37 to 2.3 µm
Simultaneous Coverage	Yes
Continuous Coverage	Yes, excluding atmospheric bands
Resolving Power (λ/Δλ)	≥3500 (@455 nm) and ≥4000 (@610, 745, 875, 1035, 1250, 1630, 2175 nm) assuming a slit width of 0.54”
Spatial Sampling	0.18 ±0.02” in all bands
Imaging	
Natural Seeing FOV	≥ 170” x 170”
Spatial Sampling	0.18 ± 0.02” in all bands
Performance	
Instrument Throughput (ADC through detector)	Average > 20% (@400) and >35% (@455, 610, 745, 875, 1035, 1250, 1630, 2175 nm) in imaging Average > 20% (@400) and >30% (@455, 610, 745, 875, 1035, 1250, 1630, 2175 nm) in spectroscopy
Photometric Time Resolution	≤ 50ms (for a 30 x 30 pixel window @50 kHz) in the *g*-, *r*-, i-, and z-band ≤ 50ms (@10 MHz) in the *Y*-, *J*-, *H*-, and K_s -band
Target Acquisition Time	Integration time + 10s (for automatic target acquisition and grism/slit setup)

centaurs in the Solar System (Figure 2), exoplanets, neutron stars, X-ray binaries, active galactic nuclei, supernovae, tidal disruption events, and gamma-ray bursts.

OCTOCAM's multi-wavelength spectroscopy (and the possibility for simultaneous multiband imaging) makes it the optimal machine for the efficient characterization of astronomical transients — similar to those expected to be discovered in the 2020s by LSST, which promises to play a leading role in advancing our understanding of these objects identified through their explosive variability. The availability of high time-resolution, coupled with Gemini's rapid response capability, will also allow researchers to use OCTOCAM to catch transient objects in their earliest phases and monitor their rapid evolution.

OCTOCAM Science Cases

A capable instrument for extremely broadband observations (both in imaging and long-slit spectroscopy), OCTOCAM will deliver groundbreaking scientific output over a very broad range of topics that cover fields as diverse as trans-Neptunian objects and

Spectral coverage from the optical to NIR, both in imaging and spectroscopy, is crucial for high-redshift sources in general, and high-redshift transients in particular. With

OCTOCAM researchers will be able to use gamma-ray bursts to explore the earliest star formation events in the Universe (Figure 1). It will also be ideal for following up and characterizing kilonova signatures of neutron star mergers, and likely counterparts of gravitational wave sources

OCTOCAM will allow effective broadband timing studies or reverberation mapping of X-ray binaries and active galactic nuclei (AGN) to constrain the physical size of the emission regions around their black holes, measure the mass of their black holes, and give new insights into accretion physics near the event horizon. For AGN, the wide wavelength coverage will allow observers to study these systems over a broad redshift range. OCTOCAM will also be able to make a significant impact in the studies of tidal disruption events (TDEs) — material being blown away from a black hole after it rips a star apart. Rapid broadband follow-up observations will also provide unparalleled probes of the regions close to the black hole, and ultimately allow measuring their mass and possibly their spin.

Simultaneous spectral coverage is also crucial for characterizing variable, but non-transient, objects. Such objects include asteroids where the rotation affects the colors derived if the observations are not obtained at the same time, and pre-main sequence stellar objects where star spots and accretion disks can heavily affect the derived colors. OCTOCAM's field-of-view will ensure suitable reference objects for any region observed. Having simultaneous imaging in all of OCTOCAM's eight bands enables users to determine the photometric redshift of high *z* objects, making the instrument efficient in rapidly identifying drop-out objects across the full field-of-view.

OCTOCAM has a strong and diverse science team led by Project Scientist Alexander van der Horst from George Washington University. Many other science cases were identified for OCTOCAM; for further details see our website ***here***.

OCTOCAM Instrument Design

Each of OCTOCAM's eight arms is an imaging spectrograph, based on the use of high-efficiency dichroics to split the light. The

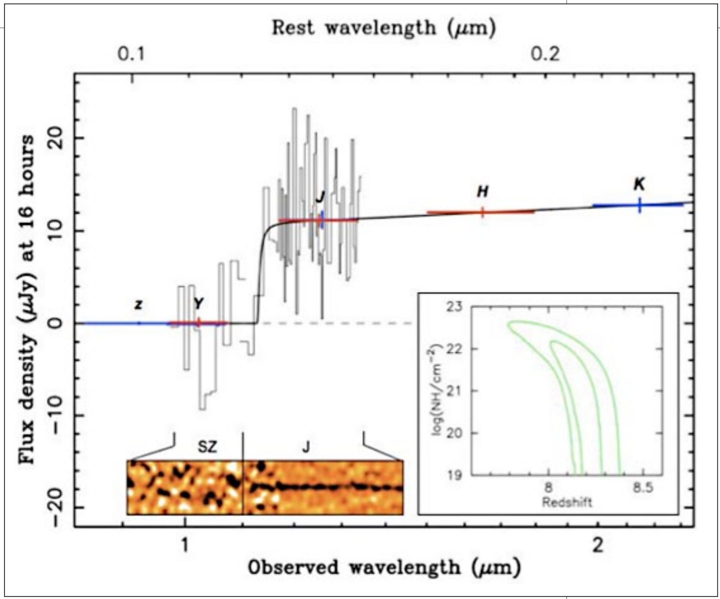


Figure 1.
Photometry and spectroscopy of the most distant spectroscopically confirmed GRB to date (Tanvir et al., Nature, ***461:*** *1254, 2009). The spectrum shows there is little dust in the host galaxy, consistent with a low metallicity. OCTOCAM will be an ideal tool for obtaining similar data sets very efficiently.*

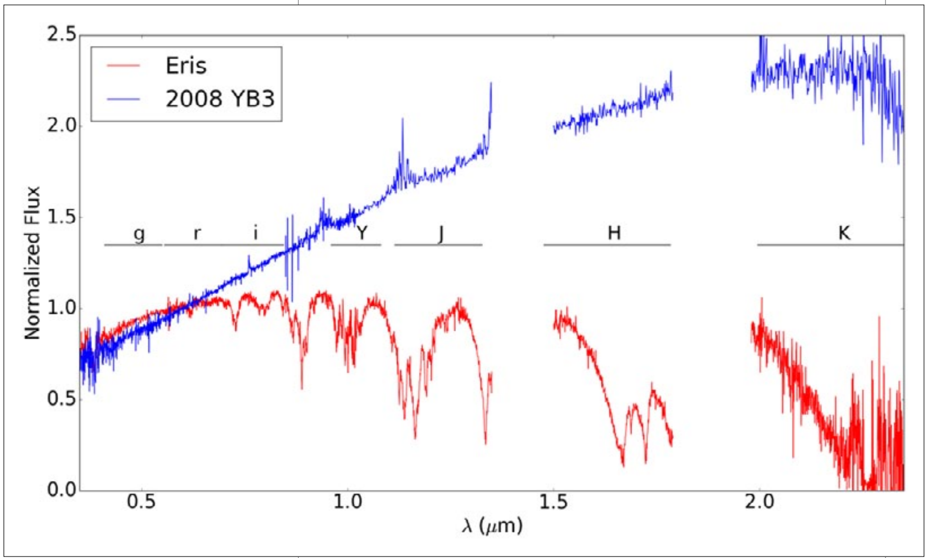


Figure 2.
Spectra of the Trans-Neptunian dwarf planet Eris with deep absorption features due to CH_4 ice (Alvarez-Candal et al., A&A, ***532:*** *A130, 2011), and the centaur 2008 YB3 with no apparent absorption features (Pinilla-Alonso* et al., A&A, ***550:*** *A13, 2013). Also shown are the approximate positions and width of some photometric filters of OCTOCAM.*

light arriving from the telescope first goes through an atmospheric dispersion corrector (ADC) that compensates for atmospheric chromatic aberrations. The light then enters the NIR cryogenic chamber, where it reaches the focal plane unit. After the focal plane, the light is divided by the first dichroic into NIR and Visible (VIS) light. The VIS light then leaves the cryogenic chamber through a second window to the VIS bench which is at approximately the same temperature as the telescope. From there, the light of both beams follow similar paths, where the light is collimated and subsequently split by additional dichroics. The collimated beam of each arm passes through either a filter or grism, depending on the observing mode, and is refocused by a camera onto the detector.

As the OCTOCAM block layout diagram shows (Figure 3), the design is highly symmetrical, with the VIS and NIR arms each sharing their own common optics among themselves. Symmetry helps to constrain the effect of the mechanical flexures occurring during motion at the Cassegrain mount. All wavelengths share a common optical path to the focal plane, where the focal plane carriage positions the slit. The single slit design will ensure that all the spectrographs are fed by light from the same sky aperture and provides better data calibration. The simultaneity of OCTOCAM's eight arms make it very fast to calibrate and extremely easy to operate.

The Gemini OCTOCAM project team consists of Stephen Goodsell (Program Manager), Morten Andersen (Project Scientist), Jeff Radwick (Project Systems Engineer), Cathy Blough (Project Specialist), and Rubén Díaz (Instrument Program Scientist). Both the external team and Gemini staff will work collaboratively to complete the Conceptual Design later this year. We look forward to sharing this instrument's adventures in the years to come.

Stay tuned, and see ***this webpage*** for the latest information.

Stephen Goodsell is the Gemini Instrument Program Manager and located at Durham University. He can be reached at: sgoodsell@gemini.edu

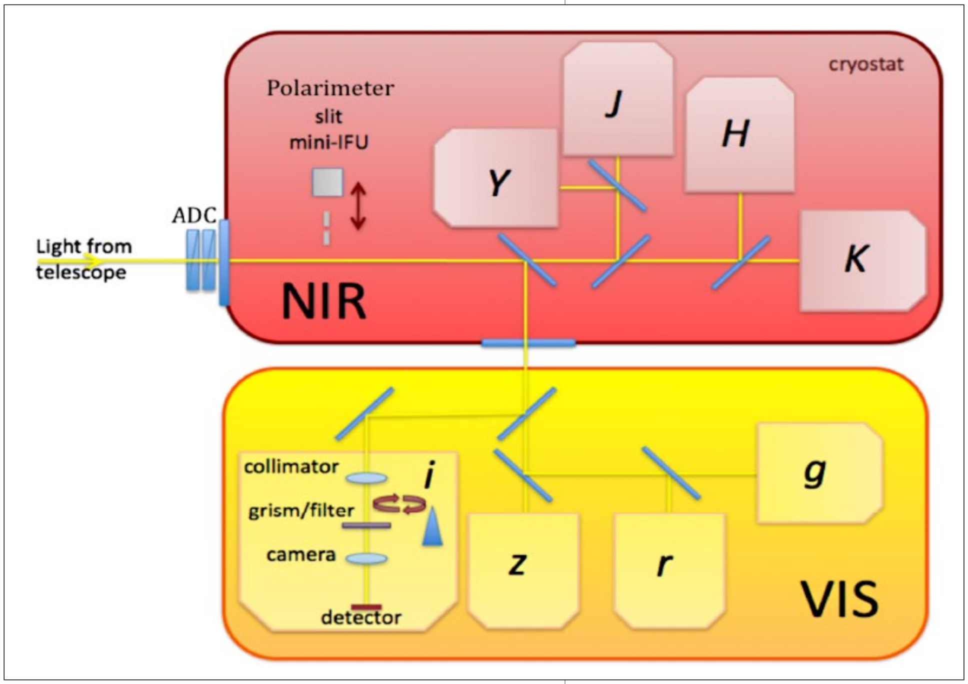


Figure 3.
Block layout diagram of OCTOCAM, showing its highly symmetrical design.

On the Horizon

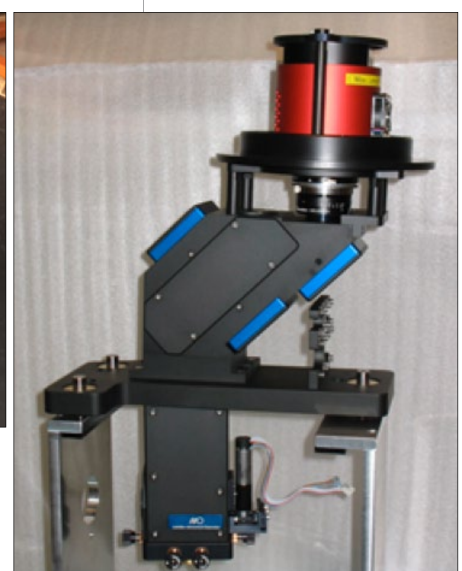
Various mechanical and optical assemblies and more are coming together for Gemini's high-resolution optical spectrograph GHOST. Multi-Object Spectroscopy with FLAMINGOS-2 has been commissioned, with the ability to change masks while the instrument is installed on the telescope. Gemini will also soon offer in shared risk mode two medium-band filters for splitting the K-band with FLAMINGOS-2.

Figure 1 (left). *GHOST integral field unit positioner frame.*

Figure 2 (top right). *GHOST Slit Viewer mechanical assembly.*

Figure 3 (bottom right). *GHOST IFU positioner mounted in its frame on the tilt table.*

Credits: All AAO



GHOST Taking Shape

Development of Gemini's high-resolution optical spectrograph GHOST — a joint effort by the Australian Astronomical Observatory, the National Research Council Canada-Herzberg, and the Australian National University — continues to progress. As of the end of 2016, most of the Cassegrain Unit's mechanical parts have been manufactured, received, test fitted (as shown in Figures 1–3), and partially disassembled for anodizing. The Cassegrain Unit's mechanical assembly is close to being completed. Most of its optics have also been received, and they have passed Acceptance Testing; optics integration will start at the end of March, followed by electronics integration.

The final mechanical elements for the Guide Camera assembly, Slit Viewer assembly, and Calibration Unit, have also been completed, and we are now ready to integrate their optical elements and electronics. The Guide Camera assembly and Calibration Unit are on target for Instrument Control Software integration in mid-May.

— David Henderson

FLAMINGOS-2 Capabilities

Multi-Object Spectroscopy Progress

The FLAMINGOS-2 (F-2) near-infrared (NIR) imager and spectrograph was designed with multi-object spectroscopy (MOS) in mind, but we could not commission this important feature until now. F-2 MOS is achieved by cutting aluminum plates ("masks") with the desired slitlets' width, length, and target positions in the 6 x 2 arcminutes field-of-view on the sky. The masks are located on the "MOS wheel," which locates each mask on the telescope's focal plane and has slots for nine different masks.

One critical capability for MOS observations is the ability to change masks while the instrument is installed on the telescope. By addressing this important function (as we did with this work) we minimize the impact on the instrument-telescope alignment and keep the camera cryogenic dewar cold, with the detector stabilized at its working temperature of 80 Kelvin (K). Because F-2 is sensitive to part of the thermal region of the NIR (up to 2.5 microns), the masks and the instrument's front section are inside a frontal cryogenic dewar. In order to exchange the MOS masks, the frontal dewar has to be thermally cycled between the ambient temperature and atmospheric pressure, and then back down to 100 K and high vacuum. The next step is to test the engineering procedures and install a batch of masks for science commissioning, planned for the week of March 27th. The next step is to test the engineering procedures and install a batch of masks for science commissioning, planned for the last week of April.

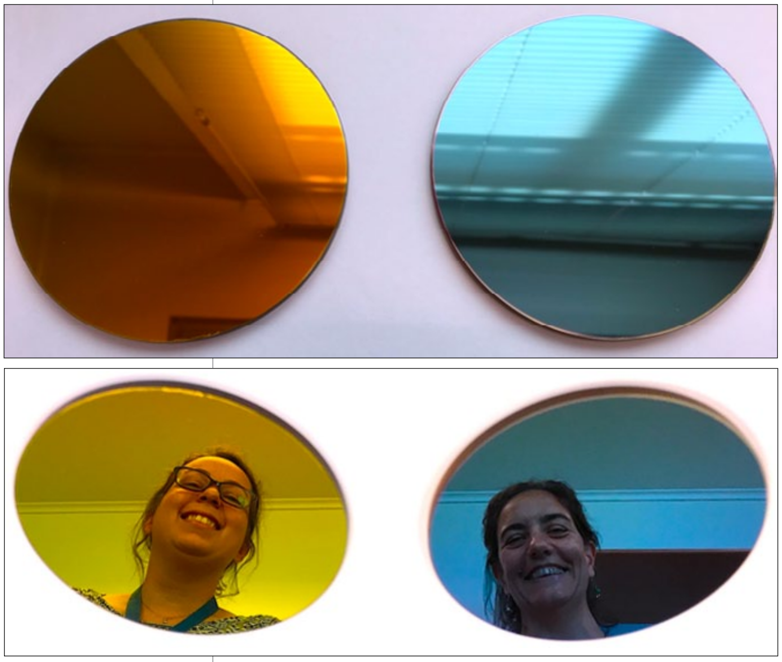


Figure 4. *The K-red filter on the left and the K-blue filter on the right. Images were obtained during the filters' physical inspection — with reflections of Gemini South Science Fellows Karleyne Silva and Veronica Firpo, left to right, respectively, in bottom frame.*

Update on K-band Filters for F-2 (K2F2)

In Semester 2017B, Gemini will offer in shared risk mode two medium-band filters for splitting the K-band (1.9–2.5 microns): a K-red filter (2.19–2.44 microns) and a K-blue filter (1.94–2.17 microns). We have received the filters from Texas A&M University as part of the K2F2 project — a Small Project for Instrument Upgrades awarded funds in 2016 (Figure 4). The filters will be installed during a scheduled instrument shutdown spanning April 6–18. On-sky acceptance tests will follow, with science commissioning slated for May.

— Rubén Díaz

Gemini staff contributions

News for Users

Gemini celebrates a major milestone with the recent handover of Base Facility Operations at both sites. Meanwhile the Hamamatsu CCDs in the Gemini Multi-Object Spectrograph at Gemini South (GMOS-S), which initially experienced a number of mysterious problems, have mostly been addressed during the past 20 months as described in this update. Also included are notes on construction progress at the Large Synoptic Survey Telescope (LSST) and Gemini's work to ensure integration into LSST's network of follow-up observations. The visiting Texas Echelon Cross Echelle Spectrograph (TEXES) recently completed a wide-ranging set of community science programs at Gemini North, and the new detectors for the Gemini-North Multi-Object Spectrograph (GMOS-N) are doing science!

Gemini Now Operates Remotely in Both Hemispheres!

On February 17, 2017, Gemini celebrated a final milestone with the official handover of Base Facility Operations (BFO) at Gemini South. It took a year to complete this important step and involved all departments from Gemini South. About a year ago, Gemini North reached the same milestone, so now both Gemini telescopes operate routinely from the base facilities in La Serena, Chile, and Hilo, Hawai'i.

The move has a profound impact on our nighttime operations, but so far with no losses in data acquisition or on-sky observing efficiencies. The move to BFO also significantly improves our environmental stewardship, mostly due to fewer trips up and down the mountains in both Chile and Hawai'i. For Gemini users, this

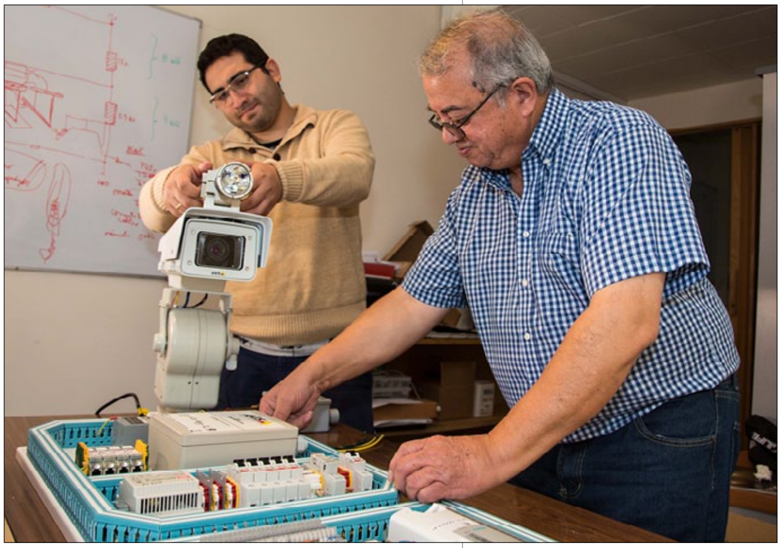


Figure 1.
Francisco Meza and Herman Díaz work on the Gemini South all-sky cloud cameras which are instrumental in BFO implementation. Credit: Manuel Paredes

change makes visiting Gemini easier, and we hope that more users will consider visiting Gemini North or South via our ***Priority Visitor*** mode, as well as for ***Classical*** observing programs. Principal Investigators should also remember that our ***Bring-One, Get-One*** program for early-career astronomers is ideally suited to BFO.

Watch for a look back at the first six months of BFO at both Gemini sites in the next (July) issue of *Gemini*Focus.

First 20 Months of Hamamatsu CCDs in GMOS-S

In June 2014 we installed new red-sensitive Hamamatsu CCDs in GMOS-S. The main scientific driver behind this important upgrade was the improved quantum efficiency at the longest accessible wavelengths, combined with reduced fringing. We achieved both of these improvements, and initially everything looked positive. Since then, however, a number of problems have developed, some of which still defy explanation. A brief summary of the problems' history, and an update on the current status of the detectors, follows.

An Unfortunate Turn

After successful commissioning of the new CCDs, a couple of unexpected technical problems appeared that negatively affected the CCDs' expected performance: severe smearing of charge ("bleeding") on CCD1; and a "banding" effect when binning, under which saturated pixels caused a depression with respect to the zero level across all the pixels from the same row within the affected amplifier. The bleeding problem was intermittent and made data on CCD1 essentially useless for all purposes; the banding issue was manageable, although it made data reduction very complicated.

As science operations were already underway, we had to make the best of the situation while trying to find a technical solution for the problems. Eventually we found the charge bleeding problem in the controller backplane, which we replaced during the telescope shutdown in August 2014. The fix brought the charge transfer efficiency (CTE) measurement back to ~ 0.999999 and therefore within specifications.

With the bleeding fixed, the "banding" issue remained, and by February 2015, we saw more serious complications when it coupled to a column of hot pixels that accumulated spurious charge on amplifier #5 (on CCD2). With longer exposure times and binning, the saturation of this column became worse, causing the background level in the section of the CCD on the same amplifier to deviate from the normal level by up to 25%. The best strategy was to avoid using the region of amplifier #5 as much as possible. An investigation of the historic trend of this effect showed that the problem had become progressively worse, particularly for long exposures and full frame binned readout.

After lengthy investigations we identified a solution for the banding problem by implementing new ARC47 Rev.E video boards — which still had to be modified in order to offer the same good readout noise performance as the previous boards. Satisfactory results were finally reached in May of 2015.

Mysterious Events

In May 2015, another problem cropped up, namely a CTE issue affecting CCD1 in Nod & Shuffle (N&S) data. CCD2 and CCD3 were not affected at all. Again we formed an *ad-hoc* tiger team to work on a remediation plan. Complicating matters, GMOS-S, our most highly-demanded instrument, was in near-continuous use. Then what no one expected happened: by the end of July 2015, the CCD1 CTE problem spontaneously disappeared, without any intervention, and N&S spectroscopy programs were resumed.

Although the detectors behaved well from September 2015 until June 2016, we were not out of the woods yet. Following a thermal cycling event of the cryostat in June 2016, a new vertical structure appeared in the bias of CCDs 2 and 3, as well as repetitive sharp horizontal lines. A few months later these structures became even stronger, now seriously affecting the science quality of the data; in particular, due to the increased noise over significant parts of the CCD array. Once again we looked for measures to minimize the effect and carried out many tests following advice from the chip manufacturer… but nothing seemed to improve the situation; it seemed desperate.

Then one day in February 2017 a fault on a compressor used for the cooling of GMOS-S caused the cryostat to warm up. We all feared the worst and were anxious to see the first bias frame come out of the instrument. To everyone's surprise, the bias looked normal, without any of the vertical banding or horizontal stripes!

A Happy Ending?

Well… yes and no. At this moment the detectors are performing well, and we are monitoring their behavior; but clearly something's not right as more than once serious problems have come and gone without any clear indication why. We need to take stock of the situation and determine the best way forward.

At the time of writing, similar detectors are being installed in GMOS-N with great care to avoid the problems we identified in GMOS-S; all tests carried out to date show no indication of problems with detector bias.

LSST: Gemini South´s Neighbor Comes Closer to Reality

New large telescope facilities always attract attention, and the Large Synoptic Survey Telescope (LSST), currently under construction on Cerro Pachón, is no exception. In December 2016, for instance, two eminent astronomers — Ewine van Dishoeck (Professor of Molecular Astrophysics at Leiden Observatory and President-elect of the International Astronomical Union), and European Southern Observatory Director Tim de Zeeuw — visited both LSST and Gemini South. The images in Figures 2, 3, and 4,

Figure 2.
Staff and visitors inspect the LSST pier and enclosure.

Figure 3.
View of the LSST telescope enclosure from where the LSST coating plant will be located.

Figure 4. *LSST´s neighbor, Gemini-South, shines in the distance. Credit: All LSST photos by René Rutten*

taken during their visit, give an impression of the rapid progress being made with the LSST construction; but if you want an up-to-date view of the site, please visit ***this link***.

Planning Continues for LSST Follow-up Observations

The flood of Large Synoptic Survey Telescope (LSST) transient follow-up observations is not expected to begin until 2021 or 2022. In preparation, the National Optical Astronomy Observatory (NOAO) is leading an effort to establish a network of follow-up facilities, and we are working with them to ensure that Gemini is not only well-integrated into this network but can perform the necessary observations. Continuing the momentum from last year's workshop, titled ***Maximizing Science in the Era of LSST***, several facilities — including Gemini, NOAO, Southern Astrophysical Research (SOAR) Telescope, and Las Cumbres Observatory — are defining a system for efficient follow-ups of LSST discoveries.

One major contribution from Gemini will be our new Gen4#3 instrument now in development (see article starting on page 15 of this issue). Called OCTOCAM this multichannel imager and spectrograph will perform the subsecond time-resolution observations critical to LSST follow-ups. Gemini will also participate in the development of Target and Observation Management software systems for rapid follow-up of LSST events.

We're also considering helping with the proposal processes, observing modes, and data reduction and analysis. The Gemini community is encouraged to provide input on how we should use Gemini to complement the LSST survey. Please send your ideas to Bryan Miller (*bmiller@gemini.edu*), and consider participating in the May 2017 workshop on ***Building the Infrastructure for Time-Domain Alert Science in the LSST Era***.

TEXES Returns to Gemini North

TEXES, the visiting high-resolution mid-infrared spectrograph, returned to Gemini North in March 2017. This run supported a wide-ranging set of community science programs, including the following: summer-solstice observations of Saturn's polar vortex; three programs studying Jupiter's atmosphere and aurora; studies of the chemistry of the gaps in protoplanetary disks around other stars; organics in hot star-forming cores; and the motions of gas in embedded super star clusters.

One of the science programs, carried out in collaboration with the TEXES team and Leigh Fletcher of the University of Leicester in the UK, involved mid-infrared (8-micron) observations to explore the meteorology and chemistry of Jupiter's dynamic weather layer. According to Fletcher, to truly understand the atmospheric phenomena at work in Jupiter, we must investigate three different domains: spatial, temporal, and spectral. Past investigations have allowed them to target one of these domains, but today they are able to explore all three by combining the Gemini Observatory, the TEXES spectrograph, and the worldwide campaign of Earth-based support for NASA's Juno mission.

The three-color map shown in Figure 5 reveals Jupiter's weather layer near 8.6 microns, where temperature, cloud opacity, and gaseous species (like deuterated methane and phosphine) govern Jupiter's spectrum. The researchers constructed the map from spectral scans over two nights (March 12–13, 2017), and it represents close to the highest spatial resolution ever achieved by the TEXES instrument. At mid-infrared wavelengths most of the seeing is due to image motion, which Gemini's rapid tip-tilt secondary mirror removes. The result is diffraction-limited images with 0.3 arcsecond resolution without the use of adaptive optics. This easily surpasses the spatial resolution afforded by past spacecraft flybys of Jupiter (Voyager and Cassini) in the mid-infrared wavelength range.

A high-resolution spectrum was measured for every pixel in this map. The essential information from the spectra is shown in the false color image: deep, warm temperatures at the cloud tops (red); cooler temperatures at higher altitudes near the tropopause (blue); and an intermediate altitude (green). The Equatorial Zone and the Great Red Spot at the bottom right are cold and dark at all three wavelengths. The turbulent wake seen to the west (left) of the Great Red Spot is darker (cooler) and distinct from the rest of Jupiter's South Equatorial Belt (SEB). An outbreak of dark, cold, and cloudy plumes can be seen in the SEB near 15˚ south, 270˚ west. Finally, the pattern of cold, cloudy plumes (dark) and warm, bright hotspots (white) can be seen encircling the planet near latitude 7˚ north, on the edge of Jupiter's North Equatorial Belt. These data will be used to determine the 3D temperature, aerosol, and gaseous structure to support Juno's close-in observations of the giant planet.

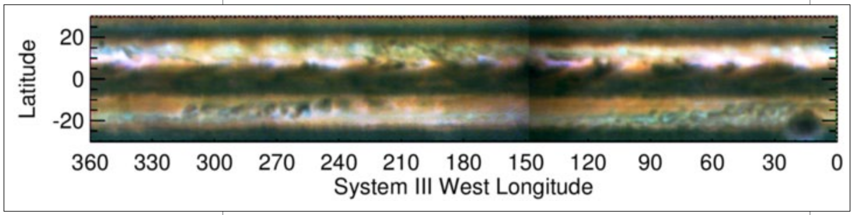


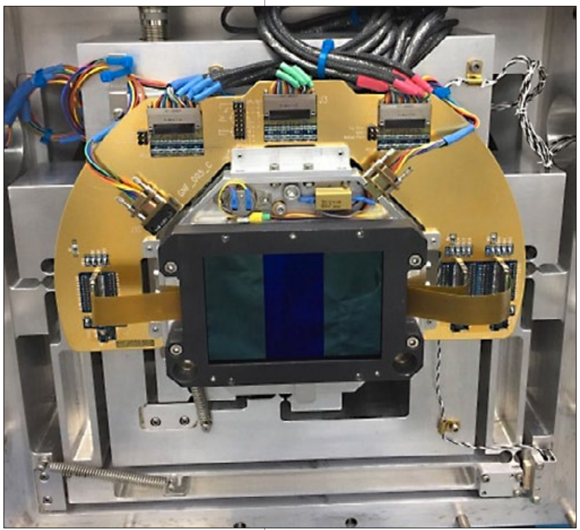
Figure 5.
Combination of three TEXES spectral scans, with red through blue, corresponding to increasing altitude above Jupiter's cloud tops. Note the cool wake to the left of the Great Red Spot seen at lower right (about 15˚ west longitude and -20˚ Latitude).
Credit: L. Fletcher, University of Leicester, UK

GMOS-N CCD Upgrade Update

The Gemini-North Multi-Object Spectrograph (GMOS-N) is currently being upgraded with a new detector array (Figure 6), consisting of three CCDs manufactured by Hamamatsu Photonics. During February, the commissioning team successfully installed and aligned the new array in the Gemini North lab. In early March, following the CCD installation, GMOS-N was mounted back on the telescope, where it passed the first light milestone during on-sky nighttime commissioning observations.

We expect the new Hamamatsu CCDs to show improved red sensitivity compared to the previous GMOS-N e2v deep depletion detectors. The new detectors are similar to those previously installed in GMOS-S. Further information and updates are available on the Gemini North ***night log summary pages***; watch for updates in our monthly ***e-newscast*** and on the ***instrument availability webpage***. The update of the data reduction package is ongoing, while the detector array is being characterized. We estimate that the full data reduction package will be available in a couple of months. First data with the new detector array have been obtained since March 26, 2017.

Figure 6.
The new GMOS-N detector array showing the three new CCDs, which consists of two different types of detectors: the two outer detectors (left and right) have an improved red and blue response compared to the middle detector.



Alison Peck, with contributions by Gemini interns

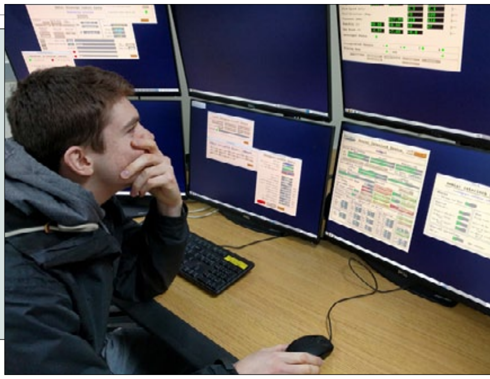
Internships

Preparing the Next Generation at Gemini

Gemini offers opportunities for upper-level undergraduates, recent grads, and early graduate students at both its Hilo, Hawai'i, and La Serena, Chile, locations. These positions can involve multifaceted projects in science, engineering, education and outreach, or software. Our internships not only offer participants first-hand experience in a real-world working environment, but allow them to perform in a professional capacity while establishing valuable relationships with workers in their fields of interest. The internships can vary in length depending on the project and funding source, but all range from 10 weeks to 6 months. The positions can take place at any time during the year, making these programs good "gap year" opportunities.

In the last several months, Gemini has hosted three interns at Gemini North and four at Gemini South. We asked the interns to tell us a bit about themselves and their exciting projects.

Tomás Ahumada recently graduated in astronomy from Pontificia Universidad Católica de Chile in Santiago. He has been working at Gemini South with Bryan Miller on a project using the high-performance, wide-field CCD Dark Energy Camera on the Blanco 4-meter telescope at Cerro Tololo Inter-American Observatory. He is doing photometry on images of the elliptical shell galaxy NGC 3923, a unique elliptical galaxy, whose halo stars are arranged in concentric layers. His goal is to search for unseen shells hidden within the structure of this intriguing system. He will also analyze the globular clusters found in the images, hoping to identify potential dwarf galaxy satellite candidates. Tomás' project is part of a six-month internship.



A recent graduate of New York's Stony Brook University, ***Tyler Cohen*** has spent four months at Gemini North analyzing Hubble Space Telescope images of the distant galaxy cluster XMM2215. He performed basic photometry on these images to derive colors for each galaxy in the field. These results were then used to select a sample of galaxies for further study as part of a larger program led by mentors Inger Jorgensen and Kristin Chiboucas. Tyler gave a presentation to Gemini staff on his results in February.

Sylvia Kowalski graduated from the University of Washington in 2016 and recently completed her six-month program as a Public Information and Outreach Intern in Hilo. Her work focused on creating events and curricula that bring the wonders of the Universe to groups not as frequently exposed to science topics. A few of the great events Sylvia organized during her internship include the *Astronomy on Tap* night at the Hilo Town Tavern (see article on page 31), free science nights at public libraries and schools across the island, and multimedia outreach through the Gemini blog.

Grace Lawrence came to us from Swinburne University of Technology in Melbourne, Australia, during the 2016 Southern Hemisphere summer break and interned with Morten Andersen at Gemini South. She used Gemini Multi-conjugate adaptive optics System near-infrared observations, in conjunction with Hubble Space Telescope data, to investigate the massive, young, and local Galactic cluster Westerlund 1. During her 10-week stay, Grace applied crowded field photometry techniques to resolve the low mass stellar population to the brown-dwarf limit; she also performed preliminary disk fraction measurements.

Daniel Muthukrishna received his Bachelor of Science in Physics and Engineering from the University of Queensland, Brisbane, Australia. He just completed a 10-week project at Gemini South, working with Veronica Firpo, to analyze the internal kinematics of giant HII region candidates in interacting galaxies. This program involved developing an open-source Python software package to model emission lines using multiple Gaussian components. The software automates the process so that all emission lines (in any number of spectral regions) can be modeled, and the corresponding luminosities, star-formation rates, and other region properties can be extracted.

Prabhani Rajakaruna earned her Master of Science in Physics at Central Michigan University, following her BS at the University of Peradeniya in Sri Lanka. She completed a four-month project at Gemini North, testing the data reduction pipeline and improving the data quality for the Observatory's new high-resolution optical spectrograph GRACES. This involved verifying the stability of the spectrograph focus with temperature and pressure, and identifying the optimal parameters for the calibration process. Prabhani has also written a script to gather the ideal calibrations for each GRACES observation in order to send the best data to the archive. In addition, she has thoroughly enjoyed the opportunity to observe with Gemini and see GRACES in action.

Piera A. Soto King earned her BS and MS at the Universidad de La Serena in Chile. She is working with Rodolfo Angeloni at Gemini South on spectroscopic confirmations of candidate symbiotic stars. Symbiotic stars are long-period interacting binaries composed of a hot compact star and an evolved giant star. For her six month project, Piera will reduce and analyze long-slit spectroscopic data of a carefully selected sample of symbiotic star candidates to fully characterize their nature. She is also working on a proposal to observe more candidates for this project with the Gemini Multi-Object Spectrograph at Gemini South.

Keep an eye out for more great work from these students as they move forward in their careers, and please do check the Gemini ***job opportunities link*** for internship opportunities at both Gemini North and South.

Alison Peck is an Instrument Program Scientist at Gemini North. She can be reached at: apeck@gemini.edu

Alexis Ann Acohido and Manuel Paredes

Exploring, Learning, and Fun: Gemini Outreach Events Span Both Hemispheres!

Gemini staff have been busy in both hemispheres leading local outreach events that foster public awareness in astronomy, support STEM content in classrooms, and inspire the next generation of explorers.

Journey Through the Universe 2017

From March 13-17, over 70 observatory professionals and informal STEM educators extended their reach to dozens of schools across the Big Island of Hawai'i, visiting over 8,000 students in the 13th year of the Journey Through the Universe (Journey) program. The Journey program extended beyond the main week of events with several outstanding outreach programs, including classroom visits for students in grades 2-12 (Hilo-Waiākea, Honoka'a, Pa'auilo, and Waimea) and StarLab Portable Planetarium shows for students in K–1 (Hilo-Waiākea).

Journey also featured workshops for teachers, including one for 40 teachers from the Ka'ū-Kea'au-Pāhoa Complex area. This important event — to support the integration of

Figure 1.

Devin Chu shares his career story at the Journey Through the Universe/Chamber of Commerce Educators' Reception at the Naniloa Hotel in Hilo.

Figure 2.

Gemini Public Information and Outreach Intern Sylvia Kowalski (left) takes directions from Gemini Associate Director of Development Scot Kleinman (right) and Keaukaha Elementary students as she pretends to be the Mars Curiosity Rover.

Next Generation Science Standards (NGSS) — sponsored a NASA Lunar and Meteorite Sample Certification Workshop led by NASA Solar System Exploration Research Virtual Institute's (SSERVI) Brian Day and Joseph Minafra. In addition, NASA's Brian Mitchell — the Education and Public Outreach manager for NASA's Discovery/New Frontiers/ Lunar Quest Program Office at the Marshall Space Flight Center in Huntsville, Alabama, — delivered an inspiring public talk titled, "Discovery, New Frontiers, and Solar System Exploration."

A highlight of this year's Journey program was the return of Hilo-raised student and astrophysics PhD candidate Devin Chu from University of California Los Angeles. An alumnus of the Journey program (and Hilo High School), Chu shared with students, teachers, and the community how the Journey program influenced and helped guide his dream of becoming an astronomer. During the week he also returned to his *alma mater* of Hilo Intermediate to model the effects of gravity on massive bodies using a "gravity well."

Figure 3.

NASA SSERVI's Jennifer Baer engages Kapiolani Elementary students in an activity on manipulating graphics using a tablet.

Figure 4.

Tomonori Usuda, Director of the Thirty Meter Telescope-Japan, has fun with Hilo Intermediate School students, showing them the ins and outs of the Subaru Telescope.

Figure 5.
Audience members ask Gemini Astronomer Alison Peck about black holes.

Astronomy on Tap

Gemini Public Information and Outreach intern Sylvia Kowalski along with Gemini astronomer Meg Schwamb put their heads together to organize the Big Island's inaugural *Astronomy on Tap* at the Hilo Town Tavern. *Astronomy on Tap* is a worldwide program that "combines the powers of space and spirits," according to Sylvia. Meg and her colleague Emily Rice started the *Astronomy on Tap* program in 2012, in New York City, and it has since expanded to more than 15 cities, including sites in the US, Canada, and Taiwan.

It was standing room only at the Hilo Town Tavern on February 23rd as four Gemini astronomers presented mini-talks interspersed with astronomy-themed drinks, trivia contests, and bar games! Talks from the program included:

- *Tales from the Outer Solar System* – Meg Schwamb
- *Asteroseismology: A Celestial Shake 'n Bake* – Atsuko Nitta
- *Star-Eating Monsters: Fact or Fiction?* – Alison Peck
- *Vanishing into the Darkness…* – André-Nicolas Chené

Figure 6 (top).
Gemini astronomer André-Nicolas Chené shares his passion for astronomy with a standing-room-only crowd at the Hilo Town Tavern.

Figure 7 (bottom).
Gemini Astronomer Meg Schwamb defends Pluto's dwarf planet status to a packed Tavern.

AstroDay Chile 2017

Gemini South's annual AstroDay Chile is one of the biggest outreach events at Gemini South, gathering representatives from both the most influential scientific observatories in the country and the largest amateur observatories of the Región de Coquimbo. More than 1,200 people participated in this year's AstroDay Chile, which was held (for the first time) at the Christ School in Las Compañías, La Serena, on Friday March 24th.

During the 2017 event, dozens of exhibitors shared the latest news about the science and technology related to astronomy in Chile. Thousands of people of all ages flooded the workshops and presentations prepared for the event, which included portable planetarium shows, scientific lectures, FamilyAstro workshops, 3D movies, video games, and more. The images here show some highlights of the diverse events.

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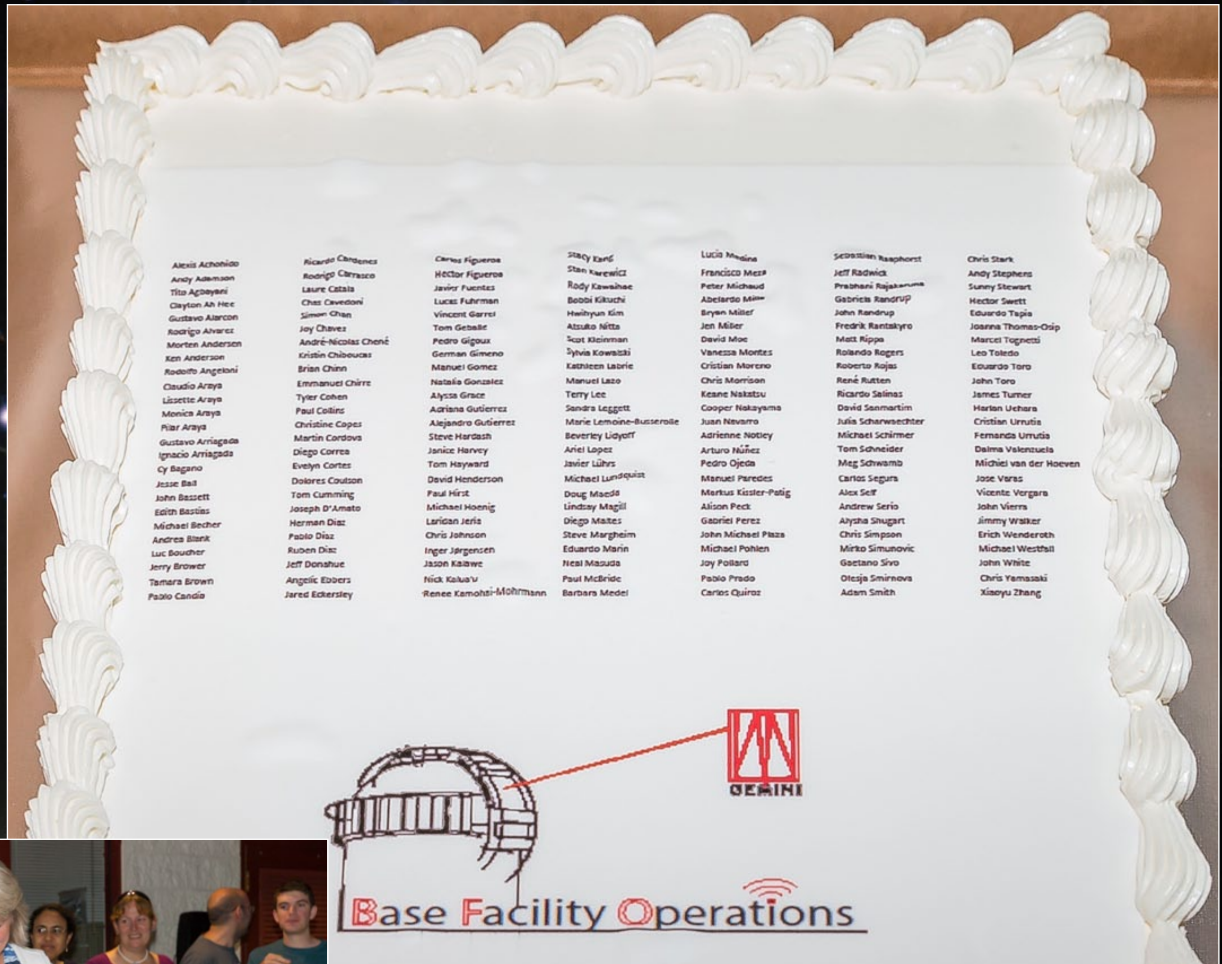
Figure 8 (top).
Gemini Administrative Specialist, Adriana Gutierrez, talking with the public about the technology used by the Gemini South telescope.

Figure 9 (middle).
Students get some hands-on experience in the spectroscopy workshop guided by Juan Seguel, EPO NOAO-S Coordinator from the Cerro Tololo Inter-American Observatory (not shown).

Figure 10 (bottom).
AstroDay Chile attendees waiting to observe Jupiter and its moons through a CTIO public outreach telescope.



Gemini staff celebrate the full implementation of Base Facility Operations (BFO) in early 2017. The image above shows a cake that includes the names of all staff who worked to make BFO a reality at both sites.

AURA

The Gemini Observatory is operated by the Association of Universities for Research in Astronomy, Inc., under a cooperative agreement with the National Science Foundation on behalf of the Gemini Partnership.

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