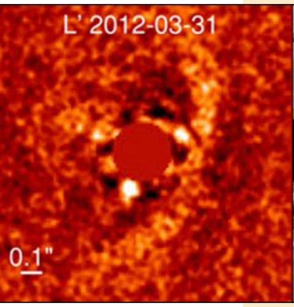
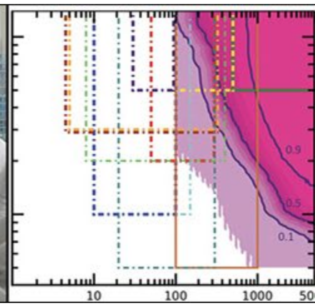
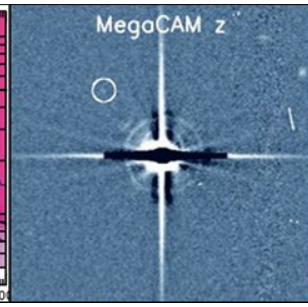
GeminiFocus

Publication of the Gemini Observatory / January 2019



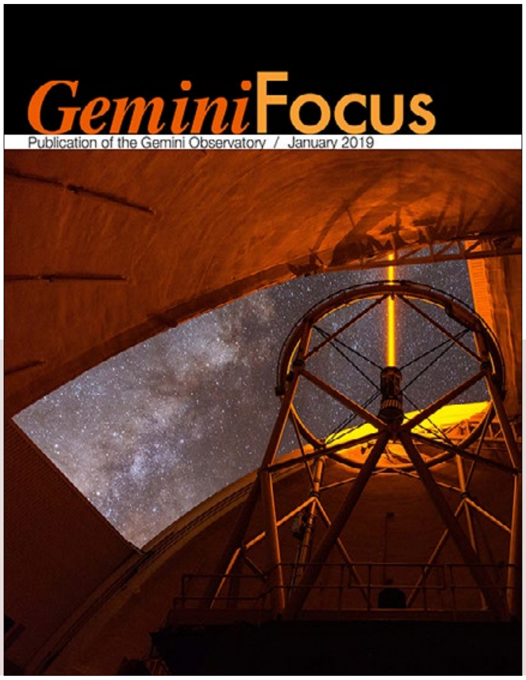




ON THE COVER:

On-sky commissioning of the new Gemini North TOPTICA laser guide star system on October 1, 2018.

Credit: Gemini Observatory/NSF/AURA image by Jason Chu



*Gemini*Focus January 2019

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Jennifer Lotz

Director's Message

Happy New Year!

With the start of 2019, we are very happy to welcome Korea as a full Gemini participant. We anticipate an exciting year ahead as new projects are underway to develop Gemini's adaptive optics and time-domain astronomy capabilities, commission the new visiting instruments MAROON-X and Zorro, and begin new Large and Long Programs to study the Universe in high resolution.

The Gemini Board and Science & Technology Advisory Committee (STAC) meetings were held at the La Serena Gemini South Base Facility in mid-November. The Board welcomed the full participation of the Republic of Korea, through the Korea Astronomy & Space Science Institute (KASI), in Gemini.

I'd also like to thank departing Board Chair Rene Walterbos and STAC Chair Laura Parker for their leadership, and departing Board members Greg Fahlman, George Jacoby, Maria Victoria Alonso, and Lucianne Walkowicz for their service to the Gemini community. To fill some of these departures, I'm pleased to welcome new Board Chair Todd Boroson and new STAC Chair Elliott Horch. Gemini also welcomes new STAC members Jane Charlton, Ryan Foley, Jae-Joon Lee, Damian Mast, Henri Plana, and Lisa Poyneer, and new Board members Guillermo Bosch, Marcos Perez Diaz, Narae Hwang, and Greg Rudnick. We look forward to a productive and exciting collaboration. We are also pleased to announce that all Gemini member participants declared their intention to remain in the Partnership and participate in the renegotiation of a new international Partnership agreement starting in 2021.

Much of the discussion at the STAC meeting centered around the plan to advance the adaptive optics facilities at Gemini Observatory by the mid-2020s. With the October announcement of new NSF funding called GEMMA (Gemini in the Era of Multi-Messenger Astronomy), plans are now underway to develop a state-of-the-art multi-conjugate adaptive optics (AO) facility instrument at Gemini North (GNAO) by 2024. In combination with the exquisite observing conditions on Maunakea, GNAO will yield high-resolution imaging and spectroscopic capabilities over a 2 arcminute field of view, allowing detailed studies of galactic stars and star-forming regions, high density stellar populations, and transient events in distant galaxies.

The GEMMA award also allows us to update the real-time controllers (RTC) — which analyze data from wavefront sensors and command the deformable mirrors that correct the image for the Gemini Multi-conjugate adaptive optics System. The same RTC design will be implemented into the GNAO system (benefitting both telescopes).

Complementing the GEMMA award, the STAC and Board endorsed a plan (targeted for completion by 2026) to develop an adaptive optics secondary mirror for Gemini North which will be fully compatible with the new MCAO and RTC systems and future Gemini North instruments. These developments allow us to push Gemini North AO on a path toward an even larger corrected field of view, higher correction performance, and greater wavelength coverage; it also gives us the future potential to provide Ground-Layer AO (GLAO) and Single-Conjugate AO (SCAO) for all instruments on the telescope.

Further Expansions and Results

Time-domain and multi-messenger astronomy are also exciting areas of development and on-going science programs for Gemini. We are looking forward to the next run at the Laser Interferometer Gravitational-wave Observatory (LIGO) during the first half of 2019. Recent upgrades to LIGO will make it sensitive to gravitational wave sources at greater distances and in larger numbers than previous observations. We are also preparing for rapid follow-up of electromagnetic counterparts with Gemini's bi-hemisphere access and flexible queue scheduling.

Thanks in part to the NSF's GEMMA award, we can now begin enhancing our software infrastructure for the start of Large Synoptic Survey Telescope's (LSST's) science operations in about 2022. These improvements will benefit all users through greater observing efficiency and improved data reduction tools. In order to prepare for the strong demand for time-domain follow-up observations, while maintaining non-Target of Opportunity (ToO) science productivity, we plan to develop the software necessary for an automated, dynamic queue system. This system will also coordinate with a wider network of follow-up facilities, and include an improved spectroscopic data reduction pipeline.

We continue making excellent progress on the Gemini facility instrument SCORPIO, an eight-channel optical/infrared imager and spectrograph with simultaneous coverage from 0.38-2.5 microns. SCORPIO will serve as a workhorse instrument at Gemini South for ToO and general observers alike by about 2022. For more information, please join me at the splinter session titled Science with SCORPIO on Gemini at the Winter 2019 meeting of the American Astronomical Society (AAS).

In the near term, Gemini's science programs are going "high-resolution" by pushing the extremes of spatial and spectral resolution, including two new Large and Long Programs: one, with Ian Crossfield (University of California Santa Cruz) as Principal Investigator (PI), plans to determine if the host stars of Transiting Exoplanet Survey Satellite (TESS) exoplanet systems are binaries or multi-component; the other, with Kim Venn (University of Victoria) as PI, intends to spectrally resolve the signature of ancient metal-poor stars in our Galaxy.

High spatial resolution speckle imaging with visiting instruments ʻAlopeke ("Fox" in Hawaiian) and the Differential Speckle Survey Instrument (DSSI) have studied the frequency of multiple star-systems in the exoplanet host systems found by Kepler 2 (K2) and TESS; In 2019, PI Steve Howell (NASA Ames) will replace DSSI with a new speckle imager, Zorro ("Fox" in Spanish). Additionally, recent results from Gemini Planet Imager (GPI), and plans for improving GPI's sensitivity and capabilities, will be discussed at the Gemini AAS Open House.

Meanwhile, Gemini's high-resolution spectroscopic capabilities are also expanding. The visiting instrument MAROON-X (PI Jacob Bean, University of Chicago) is on track for commissioning this year at Gemini North. MAROON-X will provide the US community with a state-of-the-art fiber-fed spectrograph with a resolving power of R = 80,000 at 0.5-0.9 microns, capable of ~ 1 meter/second exoplanet radial velocity measurements for late-type M dwarfs.

By the end of 2019, we also expect to begin commissioning at Gemini South on the new Gemini High-resolution Optical SpecTrograph (GHOST) — a facility instrument with high-throughput, high spectral resolution (R ~ 50-75,000) and continuous coverage between 0.36-0.95 microns. GHOST's world-class efficiency, resolution, wavelength coverage, and stability will enable a broad range of science by the Gemini community, including exoplanet characterization, radial velocity studies of TESS exoplanet transits, and high-resolution stellar population spectroscopic studies.

For more details on high-resolution spectroscopy at Gemini, please attend the AAS Winter 2019 meeting splinter session Resurgence of High-resolution Spectroscopy at Gemini.

We look forward to seeing many of you in Seattle, Washington, at the AAS Winter Meeting 2019 at our booth, Open House, and splinter sessions, and at the Korea Gemini User's Meeting in Daejeon in February.

May the new year bring clear skies, good seeing, and many new scientific discoveries.

*Jennifer Lotz is the Gemini Observatory Director. She can be reached at: **jlotz@gemini.edu***

Frédérique Baron, Étienne Artigau, and David Lafrenière

A Hunt for WEIRD Planets

The WEIRD (Wide-orbit Exoplanet search with InfraRed Direct imaging) survey was designed to search for Jupiter-like companions on very wide orbits around young stars in the solar neighborhood. Using observations from Gemini-S, CFHT, and Spitzer*, the survey should have enabled the discovery and direct imaging of five to eight such new planets, but none were to be seen. Our results constrain the occurrence of 1-13 M_{Jup} planetary-mass companions on orbits with a semi-major axis between 1,000 and 5,000 AU at less than 0.03, with a 95% confidence level.*

In the last two decades, the nearly 4,000 exoplanets discovered to date have come in all sizes and compositions, appearing quite different from the planets in our Solar System. Most of these planets were discovered using indirect methods, meaning that astronomers measure the effect that the planet has on its host star, while the planet itself is not seen; these indirect methods are only sensitive to planets at a few astronomical units (AU) from their star or closer. Relatively little is known for planets on wider orbits.

The Interest in Giant Planets on Wide Orbits

Direct imaging of exoplanets is extremely challenging. A star is so much brighter than a planet that, at very close angular separations, the emission from a planet can be easily drowned out by the light coming from its host star. Direct imaging is possible, however, with state-of-the-art high contrast imagers (such as the Gemini Planet Imager) that suppresses the starlight and enables the detection of companions as close as 10-20 AU. In 2004, the European Southern Observatory's Very Large Telescope Array made the first direct image of a planet four times more massive than Jupiter orbiting close to the nearby brown dwarf 2MASSW J1207334-393254. As a brown dwarf's light is far less intense than that of a true star — thus making a planet orbiting it easier to detect — this discovery paved the way for astronomers to search for similar giant planets but on very wide orbits around stars.

Giant planets on wide orbits are of interest for several reasons. They are so far away from their host that the star's light does not affect them. This means they can be imaged and studied directly (as if they were isolated objects) without the need for sophisticated imaging and data analysis techniques. In some cases, high-resolution spectra can also be acquired to learn more about them. And because the planet and its host star formed together, they share the same age and distance from Earth; thus, they are generally more interesting to study than isolated objects, for which age and distance is notably more difficult to obtain.

Of the 20 or so planets detected by direct imaging, about half belong to a class of giant planets whose orbits have a very large semi-major axis (greater than 100 AU); no such planet exists in our Solar System. We, therefore, began a WEIRD (Wide-orbit Exoplanet search with InfraRed Direct imaging) survey for the most extreme planetary systems.

The WEIRD Survey

Designed to search for Jupiter-like companions on very wide orbits (1,000 to 5,000 AU), the WEIRD survey focuses on the 177 stars younger than 120 million years that are known members of moving groups in the solar neighborhood, closer than 70 parsecs. Unlike stars, planets do not have core nuclear reactions allowing them to sustain their temperature. Thus, after their formation, they cool down with time. A young planet will therefore be brighter than the same planet at an older age, and easier to detect directly.

The data collection of deep seeing-limited observations started in 2014A and ended in 2017B. We used the Gemini Multi-Object Spectrograph (GMOS) and FLAMINGOS-2 near-infrared imaging spectrograph at Gemini South to survey the southern stars in the *z* and *J* bands, respectively. We also used MegaCam (an imaging CCD camera with a 1 square degree field of view) and WIRCam (a near infrared mosaic imager) at the Canada-France-Hawai'i Telescope to survey the northern stars in the same bands, respectively. Overall, the project required about 250 hours of ground-based observing time and an additional 250 hours of *Spitzer Space Telescope* / InfraRed Array Camera (IRAC) imaging at 3.6 and 4.5 microns (µm) to complete the observations.

Results from the WEIRD Survey

As giant planets have spectra that resemble T or Y dwarfs (with different surface gravities), we employed the same strategy used by those searching for brown dwarfs with wide-field imaging. The characteristically red *z-J* and [3.6]-[4.5] colors of known planetary-mass companions and young brown dwarfs were the criteria used to identify candidates (Figure 1). The search uncovered four candidate companions with the expected colors,

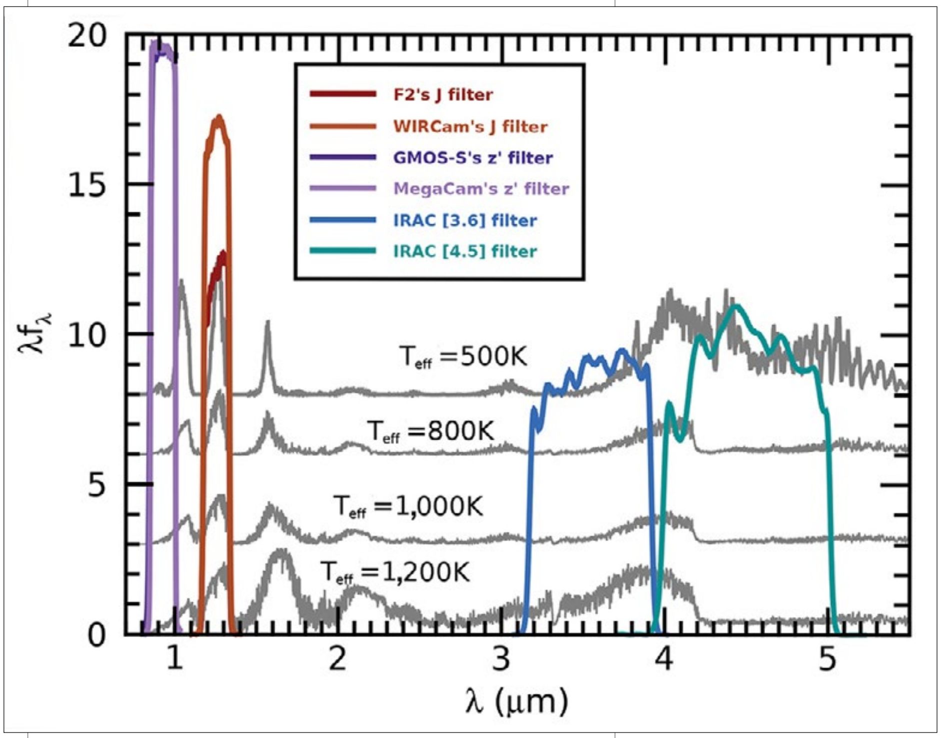
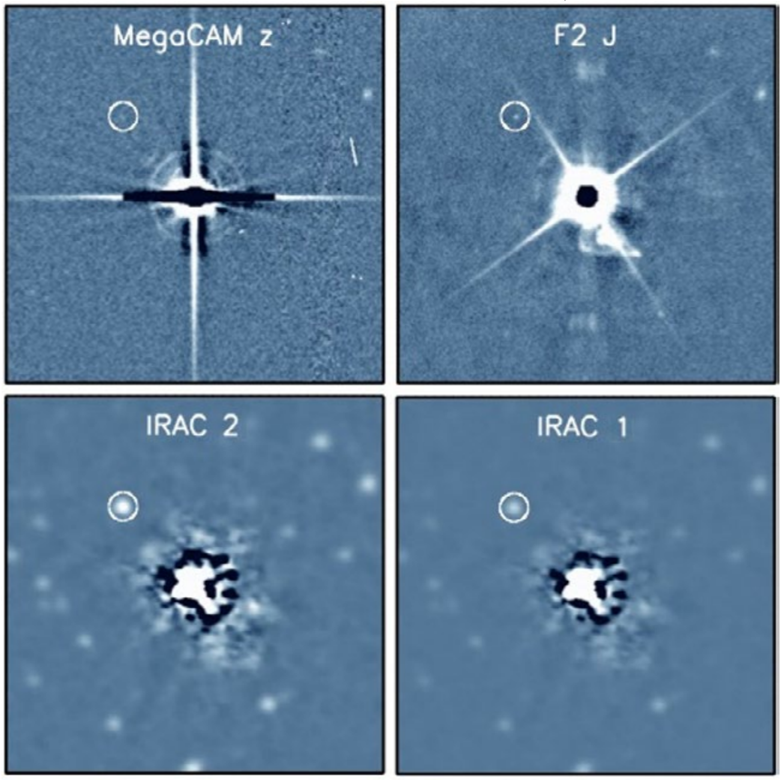


Figure 1.
Spectral energy distribution of young T to Y dwarfs. The transmission functions of the four filters used for our observations (z, J, [3.6], and [4.5]) are overlaid.

Figure 2.
Example of a planetary candidate (circled) around a young star. Clockwise starting from upper left, we see an image at 0.9 μm (CFHT, MegaCam), at 1.2 μm (Gemini-S, F2), at 3.6 μm (Spitzer), and at 4.5 μm (Spitzer). This candidate turned out to be a background object.
Credit: Frédérique Baron.

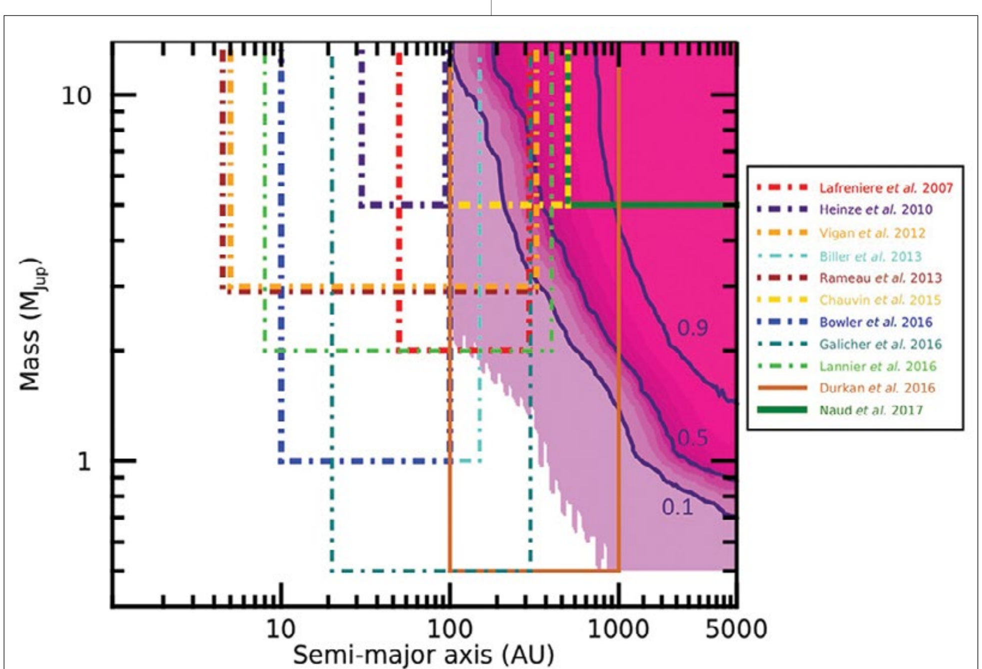


but we identified all as background objects through follow-up proper motion observations. Figure 2 shows an example of such a candidate, where you can see the very red color in *z-J*, as the candidate (circled) is barely seen in *z* (top left image) but is very well detected in *J* (top right image).

The non-detection of planetary candidates is interesting because it was unexpected. Using the occurrence rate of giant planets on wide orbits that was inferred by previous surveys — which assume that the mass function at wide separation rises for lower masses as it does for closer-in planets found by radial velocity — we expected to discover between five to eight new planets. The survey's null result is not due to a lack of sensitivity, as the expected depth was reached.

Figure 3 shows in shades of magenta the average contrast map obtained for the survey. It shows the probability of detecting a planet with a given mass between 1 and 13 M_{Jup} as a function of the planet semi-major axis. The survey reaches good completeness for companions with masses down to 2 M_{Jup}

Figure 3.
Average completeness map for the WEIRD survey. Our results are shown in shades of magenta and the contours correspond to the probability of detecting a planet of a given mass and semi-major axis. The various boxes correspond to the range in masses and semi-major axes where the surveys from other teams were sensitive. All of the dotted boxes used high contrast imaging, while the solid boxes used deep seeing-limited imaging. Our observations probe larger semi-major axes than high contrast imaging surveys, but are insensitive to semi-major axes where high contrast observations are mostly sensitive.



at separation of 1,000 AU and above, meaning that if five to eight planets were living in that range of parameters, some of them should have been uncovered. Based on the null result and the sensitivity reached for each target, we inferred that less than 3% of stars host a planet with a mass between 1 to 13 M_{Jup} and a semi-major axis between 1,000 and 5,000 AU (95% confidence level).

How Weird Is It?

This work shows that giant planets around young stars on very wide orbits are quite rare. Some previous surveys have obtained similar results, but WEIRD pushed the search a little further out in orbital separation and a little further down in planetary mass, still returning a low occurrence rate. The low frequency could be a clue toward a better understanding of the formation process of Jupiter-like objects on wide orbits. Indeed, the results are probably telling us that they don't form in the same way as planets on shorter orbits.

One possibility is that the few known planetary companions at large separations represent the low-mass tail end of the distribution of brown dwarf companions that form like stars — rather than objects that form like planets. Another possibility is that these companions were once planets on short orbits that were pushed out following interactions with other planets. A lot of questions remain unanswered, and the search for exoplanets on wide orbits continues.

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John Blakeslee

Science Highlights

GNIRS time-sequence spectra trace onset of dust and CO production in a nearby core-collapse supernova, GMOS-South monitors orbital motion to determine the mass of a record-setting ultra metal-poor star, and archival NICI data provide first epoch observations of the first exoplanet found within the gap of a transition disk.

Nearby Supernova Illuminates Early Origins of Distant Dust

Interstellar dust constitutes about 1% of the mass of interstellar matter in the Milky Way. Most of this dust is thought to originate in intermediate-mass evolved stars that ejected their outer layers as red giants or thermally pulsating asymptotic giant branch stars. Once the ejecta cool to temperatures lower than about 2,000 K, dust particles inevitably start to form from carbon and other elements. However, this process cannot explain the large amounts of dust observed in some galaxies in the early Universe, since such stars would not have had time to evolve to the dust-producing stage. The only viable explanation for the dust observed in such galaxies is production in the ejecta of core-collapse supernovae (ccSNe), and this can be tested through careful observations of ccSNe in the local Universe. Until now, detailed evolution of dust production in such supernovae, which can take place over several years, has only been followed in one object, SN 1987A in the Large Magellanic Cloud.

However, the recent explosion of SN 2017eaw in the nearby galaxy NGC 6946 has provided another excellent opportunity to follow that evolution in detail over an extended period. NGC 6946 is only about 7 megaparsecs away and is popularly known as the Fireworks Galaxy because it is a prodigious producer of supernovae, all of the core-collapse variety. SN 2017eaw was discovered in May 2017, just as its host galaxy became observable in the eastern sky before dawn. This fortuitous circumstance provided an opportunity to follow SN 2017eaw continuously from May until December, before it became too low in the western sky to observe from Maunakea.

Through a combination of Director's Discretionary Time and Fast Turnaround programs at Gemini North, a team of astronomers led by Jeonghee Rho of the SETI Institute and Gemini's own Tom Geballe were able to follow the evolution of SN 2017eaw's near-infrared (0.84-2.52 micron) spectrum in Semesters 2017A, 2017B, and 2018A. The first nine of these spectra, obtained with the Gemini Near-InfraRed Spectrometer in 2017, are shown in Figure 1. They are a gold mine of information on the abundances, nucleosynthesis, changes in ionization, and velocities of the ejecta, but the main goal of the observations was to study the formation of carbon monoxide (CO) at wavelengths from 2.0-2.5 μm. CO is a powerful coolant, which aids in making dust formation possible; its presence is detected by day 124 based on the sharp increase in signal near 2.30 μm. Evidence of dust also begins at day 124, based on the flattening of the continuum slope longward of 2.1 μm.

The resulting study, ***published in ApJ Letters***, used the spectra to estimate the CO mass produced by SN 2017eaw and found that the results qualitatively matched models for a progenitor star of roughly 15 solar masses. However, the dust production was observed at earlier times than predicted. Fits to the continuum indicate that the temperature of the dust emitting at 2.1-2.5 μm is roughly 1,300 K and that the dust is mainly graphitic, which can condense at higher temperatures than amorphous carbon. The team continued to monitor the evolution of SN 2017eaw throughout much of 2018, both spectroscopically with GNIRS and photometrically using the Near-InfraRed Imager and spectrometer. Thus, we have more to learn from the latest pyrotechnics displayed by this nearby galaxy.

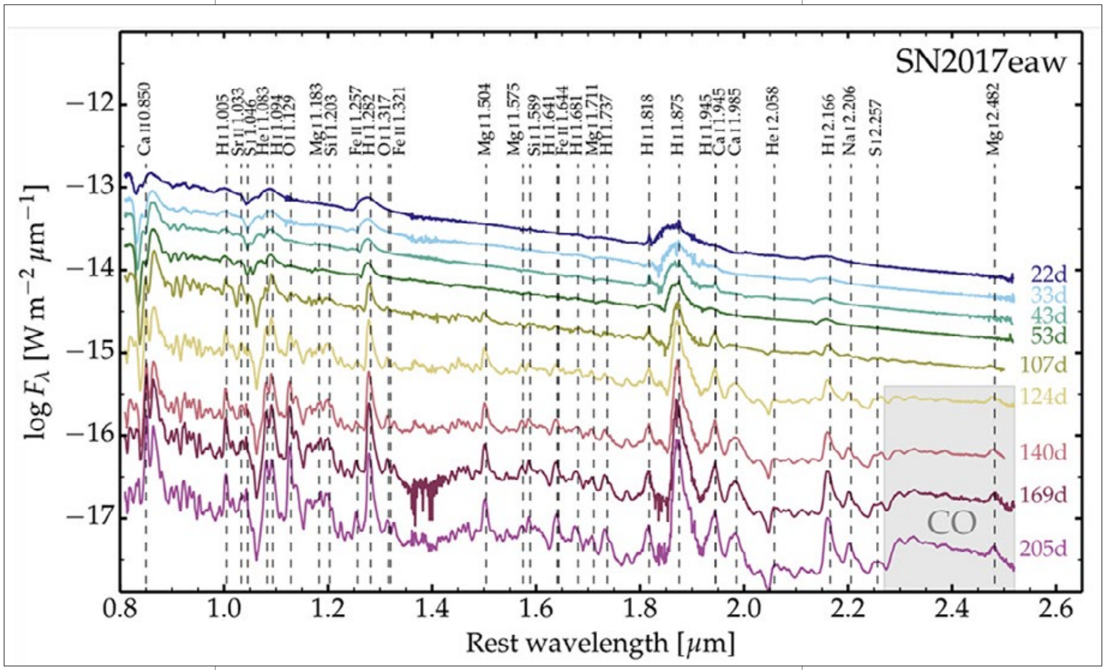


Figure 1.
Gemini/GNIRS spectra of SN 2017eaw obtained from 22 to 205 days post explosion, in time order from top to bottom. The prominent emission and absorption lines are listed. The spectra have been scaled to give a uniform vertical spacing. The gray shaded region indicates the wavelengths at which CO emission is present; the flattening of the long-wavelength continuum at 124 days and later is the signature of dust production.
[Figure reproduced from Rho et al., ApJ, ***864:*** *L20, 2018.]*

Discovery of the Lowest Mass Ultra Metal-poor Star

The properties of extremely metal-poor (EMP; with a metal to hydrogen ratio [Fe/H] < –3.0 dex), ultra metal-poor (UMP, [Fe/H] < – 4.0 dex) and hyper metal-poor (HMP, [Fe/H] < –5.0 dex) stars provide information on the early chemical enrichment of our Galaxy and the products of the first generations of stars in the Universe. Because gas composed entirely of primordial elements cannot cool efficiently, only high-mass protostellar cores have sufficient gravity to overcome their internal pressures and collapse to form stars. Thus, the first generation (Pop III) of stars in the early Universe are believed to have had high masses and short lifetimes. The exact mass range of Pop III stars remains a subject of debate, but recent simulations suggest a lower limit of about 10 solar masses ($M_{\odot}$).

In a recent study [*published in The Astrophysical Journal*](), Kevin Schlaufman of Johns Hopkins University and two collaborators discovered the lowest mass UMP star known. The star is an invisible companion to 2MASS J18082002–5104378 A, a star measured by Meléndez *et al.* (*A&A*, **585:** L5, 2016) to have a metallicity [Fe/H] ≈ –4.1 dex, placing it within the UMP category. Schlaufman and collaborators report the results of an extensive spectroscopic campaign including 14 observations with the Magellan Inamori Kyocera Echelle (MIKE) high-resolution spectrograph on the Magellan Clay Telescope and 31 observations with the Gemini Multi-Object Spectrograph at Gemini South, both in Chile. "Gemini was critical to this discovery, as its flexible observing modes enabled weekly check-ins on the system over six months," said Schlaufman. The velocities derived from the Gemini data are shown in Figure 2.

The spectroscopic data show that 2MASS J18082002–5104378 is a spectroscopic binary with a circular orbit and a well-determined period of 34.76 days. The primary star (designated A) has a derived mass of 0.76 $M_{\odot}$, which is typical for UMP stars, while the best-fit mass for the secondary (designated B) is only 0.14 $M_{\odot}$, or about 0.05 $M_{\odot}$ above the hydrogen-burning limit for this metallicity. Assuming that 2MASS J18082002–5104378 B has the same composition as the primary, it is by far the lowest mass UMP star yet discovered. Moreover, because of its low mass and metallicity, it has the smallest quantity of metals of any known star, roughly the same amount of heavy elements as contained in the planet Mercury. Put another way, if 2MASS J18082002–5104378 B had formed entirely from primordial material (hydrogen and helium), it could achieve its current metallicity by swallowing the smallest planet in our Solar System.

Another interesting finding is that the systemic motion of 2MASS J18082002–5104378 indicates that it belongs to the thin disk component of our Galaxy. The derived orbit of the system about the center of the Milky Way has a pericenter of about 5.6 kiloparsecs (kpc), an ellipticity of 0.16, and a very low inclination so that the system

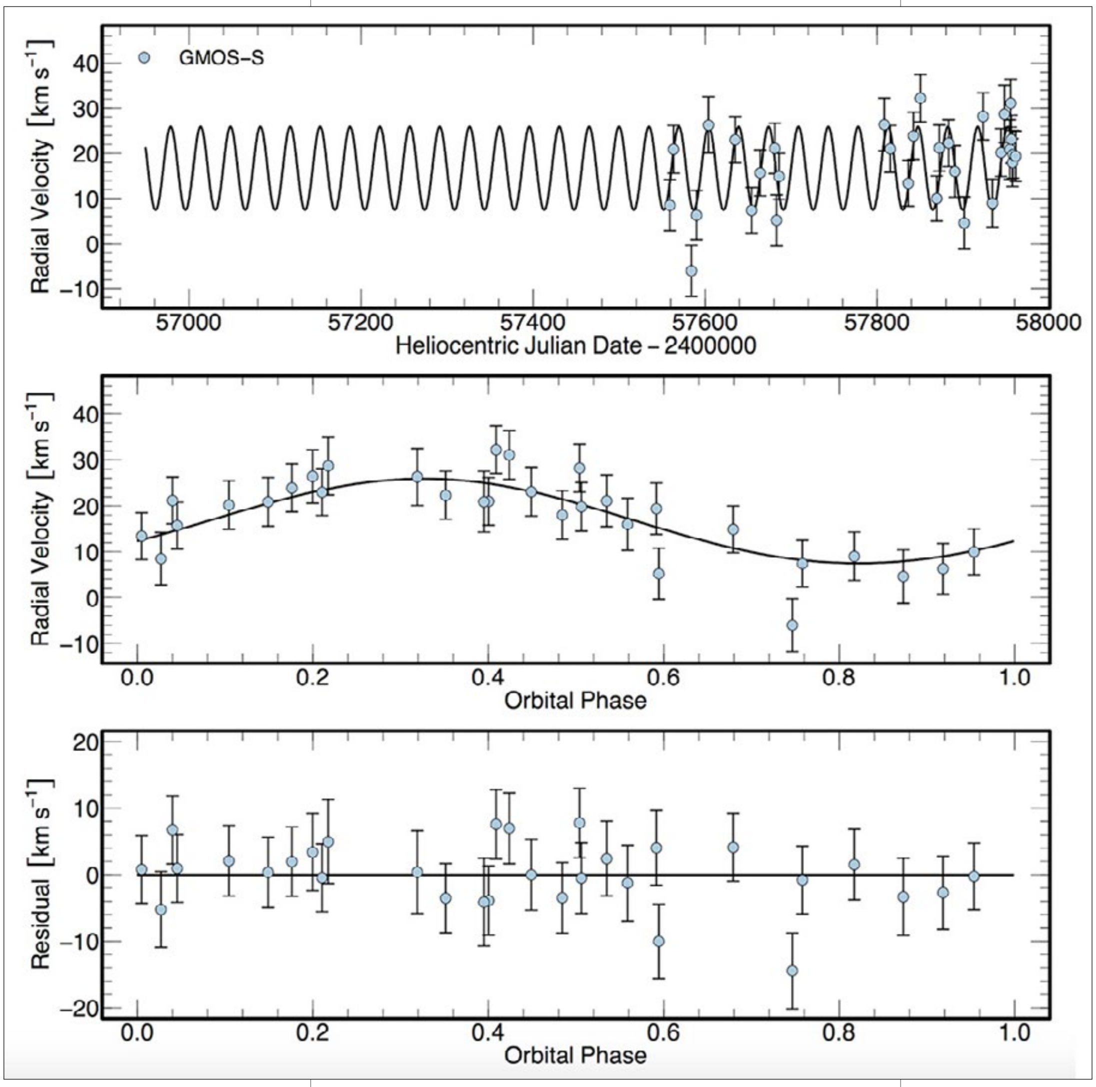


Figure 2.
Measured radial velocities of 2MASS J18082002–5104378 A from Gemini/GMOS-S compared to the best-fit Keplerian orbit, derived from the high-dispersion MIKE data. The GMOS-S observations span 31 epochs over a 13-month period from June 2016 to July 2017.
[Figure reproduced from Schlaufman et al., ApJ, ***867:*** *98, 2018.]*

never wanders more than 0.13 kpc from the Galactic plane. This makes the binary the most metal-poor star system yet discovered within the thin disk. Moreover, the study estimates that the age of the system exceeds 13 billion years, which would suggest that the thin disk may be considerably older than generally believed. However, the age is based on isochrone fitting to the primary star and is subject to systematic uncertainty.

In addition to setting astronomical records, 2MASS J18082002–5104378 B is a diminutive star with big implications. The study argues that the existence of this low-mass object, as well as a known brown dwarf within an EMP system, implies that low-mass primordial-composition stars could form as members of binaries via fragmentation within the protostellar disks of the supposed high-mass Pop III stars. If this is the case, although the primary stars would have long since burnt themselves out, the liberated low-mass Pop III secondaries could still be wandering inconspicuously about our Galaxy, just waiting to be discovered.

Gemini's Role in the Discovery of the Young Planet PDS 70b

This past July as Gemini Observatory was preparing for its triennial Science Meeting, our colleagues at the European Southern Observatory (ESO) ***announced the discovery*** of a planet caught in the act of formation within the transition disk (a debris disk with a central gap) surrounding the young low-mass star PDS 70. The star was targeted because it was known from ***previously published Gemini and Subaru observations*** to host a transition disk with a large central gap, suggestive of ongoing planet formation. PDS 70 belongs to the Scorpius-Centaurus association at a distance of 113 parsecs (determined from Gaia Data Release 2). It has an estimated age of 5.4 million years and a mass of about 0.8 $M_{\odot}$. The discovery, based on observations obtained at the Very Large Telescope (VLT) and Gemini South, was published in the ***September 2018 issue of Astronomy & Astrophysics***.

This is the first time that a young planet has been caught in the act of plowing out the central region of a transition disk. "Disks around young stars are the birthplaces of planets, but so far only a handful of observations have detected hints of baby planets in them," said Miriam Keppler of the Max Planck Institute for Astronomy. Keppler led the large team of over 100 astronomers who made the discovery. Using the Spectro-Polarimetric High-contrast Exoplanet REsearch instrument (SPHERE) on the VLT, the team detected a point source about 22 astronomical units from PDS 70 within the gap of the surrounding disk. The detection was confirmed at five different epochs using three different instruments at wavelengths ranging from 1.6-3.8 μm (Figure 3). The astrometry from the multiple epochs shows that the object has a very similar motion to that of PDS 70, and thus is likely a bound planetary companion.

The crucial first epoch was provided by an archival L′-band image taken in March 2012 with the Near-Infrared Coronagraphic Imager (NICI) on Gemini South. Although the

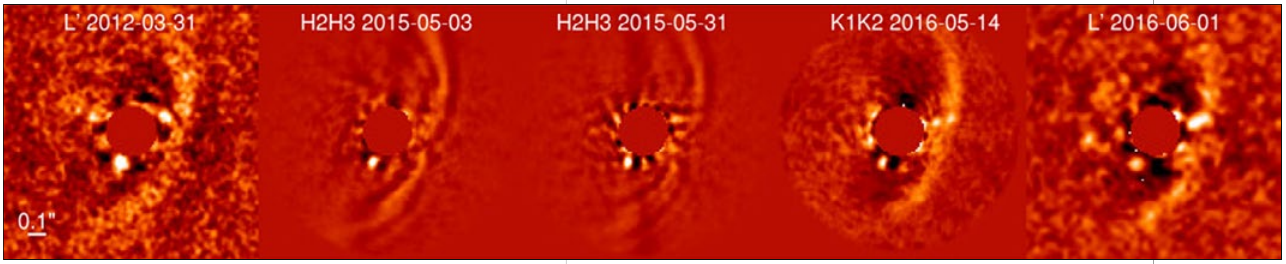
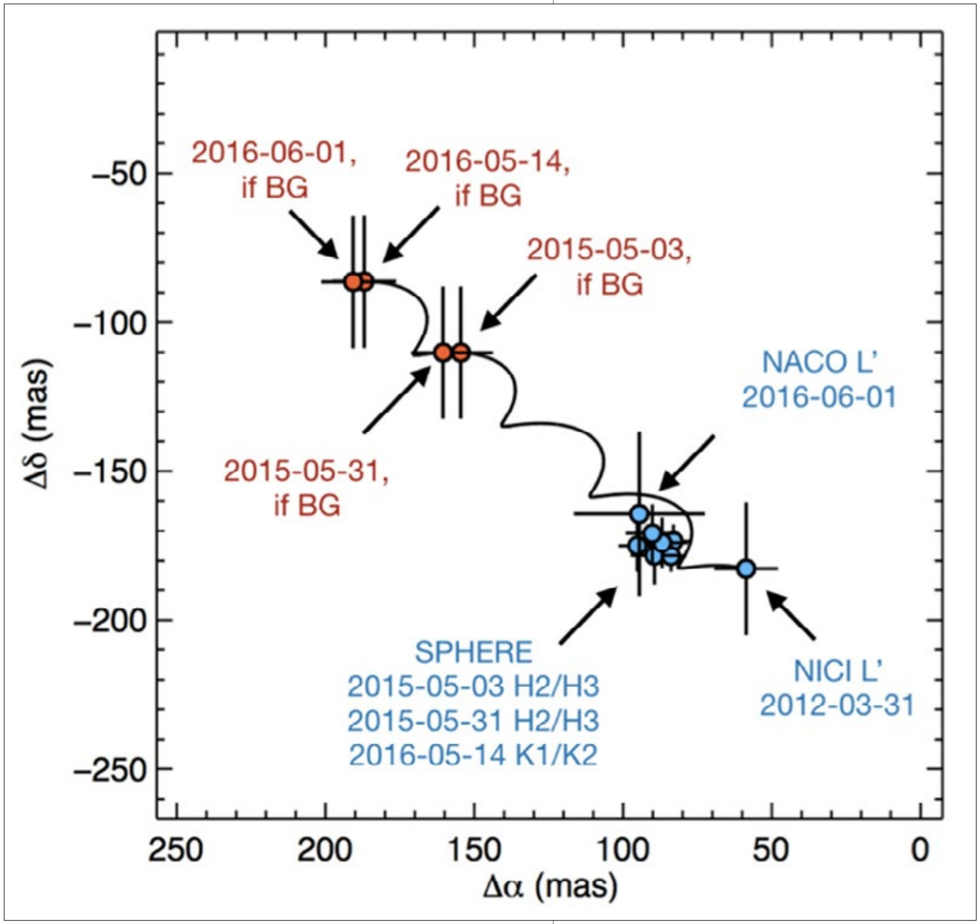


Figure 3.
Direct images of the exoplanet PDS 70b, from left to right: Gemini/NICI L′-band (2012-03-31), VLT/SPHERE H2H3-band (2015-05-03 and 2015-05-31), VLT/SPHERE K1K2-band (2016-05-14), and VLT/NACO L′-band (2016-06-01). North is up and east is to the left in all images.
[Figure from Keppler et al., A&A, ***617:*** *A44, 2018.]*

Figure 4.
The relative position of the companion object PDS 70b. The blue points show the measured positions from the Gemini and VLT data. The red points (labeled "BG") show the positions that would have been expected in the VLT data if the object detected in the first-epoch NICI observations had been a distant background object, for which the relative position would follow the plotted curve. The offset in position between the NICI and later observations is consistent with the expected orbital motion. [Figure from Keppler et al., A&A, ***617:*** *A44, 2018.]*



faint source follows the star, its relative position measured in the 2012 NICI data does not coincide precisely with the positions derived from the VLT observations taken in 2015 and 2016 (Figure 4). This is likely due to orbital motion over the four-year baseline spanned by the Gemini and VLT observations analyzed in the discovery paper. The inferred orbital motion is clockwise, which is in the same direction as the disk rotates. A *second study* adds an additional SPHERE observation from early 2018 and finds a best-fit circular orbit with a period of 118 years.

The multi-band photometric analysis combining the VLT and Gemini data indicates that PDS 70b is likely a gas giant with a mass a few times that of Jupiter and a temperature of about 1,200 K. Additional observations of PDS 70b should allow testing of theoretical predictions of the role of planet-disk interactions in the evolution of young planetary systems.

John Blakeslee is the Chief Scientist at Gemini Observatory and is located at Gemini South in Chile. He can be reached at: jblakeslee@gemini.edu

On the Horizon

Several exciting milestones for a variety of upcoming and visiting instruments were realized in late 2018. Gemini will be hosting an Open House and several other events at the 233rd annual American Astronomical Society Meeting. A contract has been finalized to return integral field unit capabilities to GNIRS. And progress continues with two visiting instruments: the GIRMOS project got underway with a Kick-Off Meeting in Toronto, Canada; and MAROON-X's Front End recently arrived in Hawai'i, where it underwent successful on-sky commissioning.

GEMMA: Leading in the Era of Multi-Messenger and Time-Domain Astronomy

With the recent announcement of the National Science Foundation (NSF) award, Gemini in the Era of Multi-Messenger Astronomy (GEMMA), work is ramping up to produce the exciting deliverables promised over the next five years. GEMMA updates will be a regular feature in this column for the duration of the program.

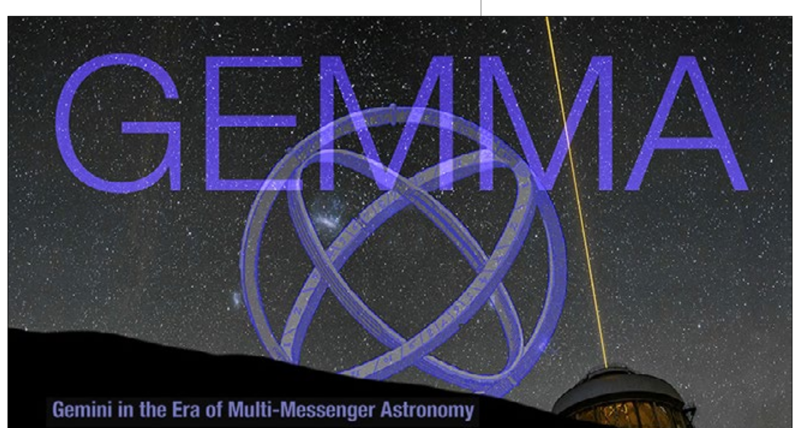


Figure 1.
The GEMMA logo incorporates an ancient astronomical instrument known as Gemma's rings.

The goals of GEMMA are broad and encompass diverse capabilities for Gemini – from instrumentation, real time software and data reduction pipelines, to public communications. The primary instrumentation capability envisioned with GEMMA is a new state-of-the-art multi-conjugate adaptive optics system for Gemini North called GNAO. Additional details on the GEMMA program can be found in this issue's Director's Message starting on page 1 of this issue.

Among the first exciting activities in 2019 is a Communications Summit in Multi-Messenger and Time-Domain Astronomy (MMA/TDA). Planning is now underway to identify and invite science communication specialists and scientists working in MMA/TDA to the summit which will focus on the unique challenges and opportunities in sharing the complexities and new scientific horizons presented by MMA/TDA.

In January 2019 the GEMMA Program Execution Plan (PEP) is slated for submission to the NSF and work will ramp up significantly following its approval. In the meantime the Gemini user community is encouraged to provide input into the GEMMA program. The Time Domain Astronomy Working Group is being formed in order to advise the Observatory on the development of the time-domain network which will facilitate the execution of time-domain observations. Secondly, Gemini is re-establishing an Adaptive Optics Working Group (AOWG) made up of staff and engaged members of the Gemini user community. For more details on getting involved in GEMMA please ***go to this link***.

Figure 2.
SCORPIO team member Amanda Bayless with an engineering grade E2V device in the clean room.
Credit: Stephen Goodsell

The GEMMA logo (Figure 1; previous page) is taken from Gemma's rings, an early astronomical instrument consisting of three rings representing the celestial equator, declination, and the meridian. The rings were created by Gemma Frisius, a 16th century Dutch physician, mathematician, cartographer, philosopher, and instrument maker.

SCORPIO Completes Two Key Reviews

The Spectrograph and Camera for Observations of Rapid Phenomena in the Infrared and Optical (SCORPIO) completed two key reviews in November 2018. We held an Optical Design Review from November 14-15 at the University of Madrid, Spain, to assess the design readiness of the instrument's six Collimator Units and eight Camera Units. An assessment panel consisting of external experts reviewed whether the long-lead optical components were ready for acquisition; after the two day detailed review, they concluded the team provided sufficient analysis to justify the early purchase of the long-lead opto-mechanical units, believing the risk of proceeding was small. We expect the SCORPIO team to place contracts for all of these items in Q1-2019.

We also held a project quarterly progress review at the Southwest Research Institute (SwRI) in San Antonio, Texas, from November 26-28. The team presented a large amount of new work and demonstrated solid progress made since the last project review in August. The schedule to a Q1-2019 Critical Design Review (CDR) remains tight as there are a number of key analyses on the final design that only occur late in the schedule; the team plans to move these items earlier so we can proceed on schedule. We will re-assess readiness for the planned March 2019 CDR in January.

During the progress review, the team presented a design for a slit viewing camera to reduce target acquisition time, and we now intend to make this subsystem part of the instrument's baseline. A slit viewing camera reduces operational overhead and generally increases overall efficiency. The project's E2V engineering grade devices arrived earlier this year (Figure 2). SwRI reported that the four science grade E2V detectors and the four HAWAII-2RG arrays have updated earlier delivery dates in Q1 2019, before CDR.

New Integral Field Units for GNIRS

Gemini has a long-term commitment to produce user-motivated upgrades to the operating instruments at both sites. The Instrument Upgrade Program (IUP) provides funding to upgrade existing operational instrumentation through community-created science-driven proposals, creating a new instrument capability at the Observatory. After the public request for proposals issued in 2017, the highest ranked proposal was to return integral field unit (IFU) capabilities to the Gemini Near-InfraRed Spectrometer (GNIRS), a project lead by Ray Sharples from the University of Durham.

Ray and his team will build and commission two new IFUs for GNIRS, to replace the one that was destroyed in a 2007 accident. The first IFU will have similar specifications to the original GNIRS IFU, with a field of view of approximately 3 x 5 arcseconds and a spatial sampling of 0.15 arcseconds. It will be optimized for observations over the full GNIRS wavelength range from 1.0 to 5.4 microns.

The second IFU will be AO-optimized over the 1.0- to 2.5-micron wavelength range, with a field of view of approximately 1.0 x 1.5 arcseconds and a spatial sampling of 0.05 arcseconds. The GNIRS IFUs will complement those of Gemini's Near-infrared Integral Field Spectrometer with extensions in wavelength out to the thermal infrared L & M bands, and spectral resolutions up to R ~ 18,000.

In December we finalized the contract with the team for the work. We will hold a project kickoff in January 2019, and commissioning and science verification of both IFUs is planned for November 2020. We plan to offer the IFUs under a shared risk mode in 2021A. Re-commissioning of the IFU mode for GNIRS will open up a unique window for spatially resolved spectroscopy on Gemini, including study of the kinematics of stellar outflows around high-mass young stellar objects, probing the active galactic nucleus-starburst connection, estimating black hole masses from infrared line diagnostics, resolved spectroscopy of gravitationally lensed galaxies, and resolving jet dynamics in Herbig-Haro objects.

The project will be entirely based at the Centre for Advanced Instrumentation (CfAI) at Durham University, where the original GNIRS IFU was designed and built. The project will exploit the in-house diamond machining facilities that have since been used to deliver successful image slicing IFU instruments for the *James Webb Space Telescope* (NIRSpec IFU) and European Southern Observatory's Very Large Telescope (KMOS). This facility was not available at the time of manufacture of the original GNIRS IFU and will enable substantial improvements in performance.

GIRMOS Project Ready to Roll

The Gemini InfraRed Multi-Object Spectrograph (GIRMOS) is a welcome addition to the Gemini Visiting Instrument Program. This powerful new instrument is being designed to have the ability to observe multiple sources simultaneously at high angular resolution while obtaining spectra at the same time (Sivanandam *et al.*, Proc. SPIE, 2018). It accomplishes this by exploiting the adaptive optics (AO) correction from both a telescope-based AO system (either the Gemini Multi-conjugate adaptive optics System (GeMS) or the prospective Gemini North AO system) and its own additional Multiple-Object Adaptive Optics system that feeds four 1- to 2.4-micron integral field spectrographs (R ~ 3,000 and 8,000) that can each observe an object independently within a 2 arcminute field of view.

GIRMOS is being designed and built by a Canadian consortium of universities led by the University of Toronto and the National Research Council-Herzberg Institute of Astronomy and Astrophysics. The GIRMOS project is just getting underway, and Gemini staff were invited to participate in the Kick-off Meeting on December 4-5 at the Dunlap Institute in Toronto, Canada (Figure 3). The meeting was extremely productive, with discussions on science cases, capabilities, schedules, and responsibilities as we move into the conceptual design phase.

In January, members of the GIRMOS team will come to Chile to participate in GeMS observing to learn more about the AO system and current telescope operations. We are very excited about working with the team on this cutting-edge new capability for Gemini, and we look forward to a fruitful collaboration over the next few years!

MAROON-X Front End Commissioning

MAROON-X is a radial velocity spectrograph being built at the University of Chicago, which is expected to have the capability to detect Earth-size planets in the habitable zones of mid- to late-M dwarf stars using the radial velocity method. The instrument is a high-resolution, bench-mounted spectrograph designed to deliver 1 meter/second radial velocity precision for M dwarfs down to and beyond V = 16. In order for MAROON-X to come to Gemini as a visiting instrument, the team had to construct a Front End that would fit on the bottom instrument port at Gemini North, while holding the fiber that runs down to the spectrograph located in the Pier Lab below.

This Front End unit recently arrived in Hawai'i, and was installed on the telescope for testing in December. The commissioning

Figure 3.
GIRMOS Principal Investigator Suresh Sivanandam (right) with Kick-off Meeting participants.
Credit: University of Toronto

has gone very well, thanks to the diligence and care that the instrument team have put into the design and construction, and the excellent support we have received from the Gemini engineering staff.

We achieved first light on the same day as installation (Figure 4), and spent a few hours over the ensuing evenings verifying that the software behaved as expected, and that the atmospheric dispersion correction and guiding met specifications. Based on the success of the Front End (Figure 5), we are looking forward to the arrival of the spectrograph itself in early 2019. Watch this space for more news in the next few months!

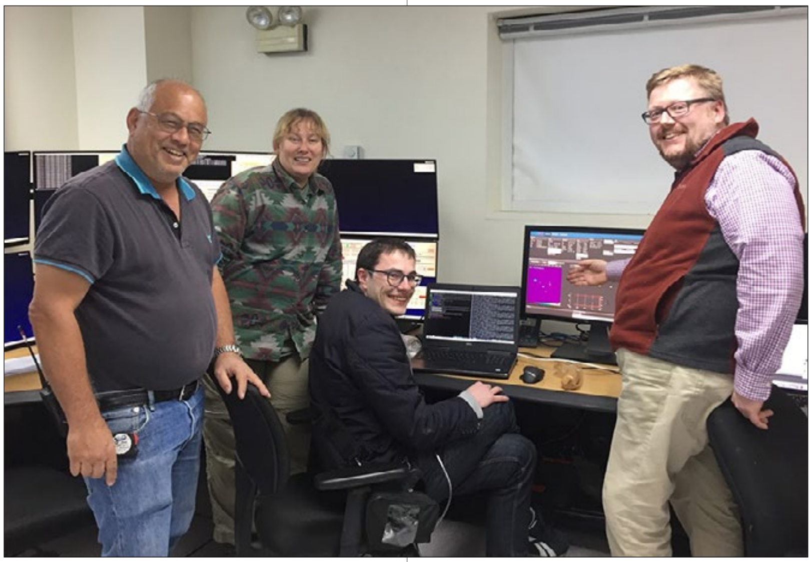


Figure 4.

Celebrating first light with the MAROON-X Front End. From left to right: Gemini senior instrumentation engineer John White, Gemini Instrument and user support scientist Alison Peck, and University of Chicago representatives Julian Stuermer and Andreas Seifahrt.

Credit: Siyi Xu, Gemini Observatory

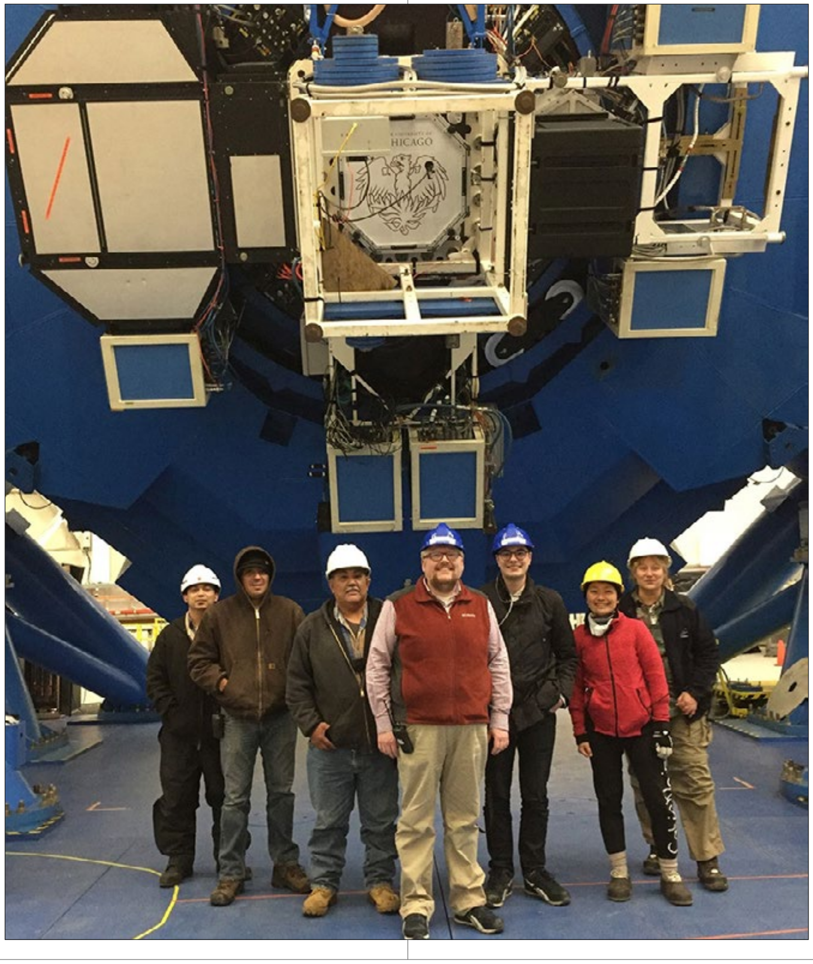


Figure 5.

Posing with the MAROON-X Front End, now installed on Gemini North. Left to right: Gemini mechanical technician Cy Bagano, electronic and instrumentation technician Eduardo Tapia, day crew member Harlan Uehara, Andreas, Julian, Gemini assistant astronomer Siyi Xu, and Alison.

Credit: John White, Gemini Observatory

Gemini staff contributions

News for Users

Catch up on the latest news for Gemini's user community. This installment includes updates on the TOPTICA laser availability at Gemini North, 2019 Large and Long Program proposal deadlines, new data reduction resources to look for in 2019, activities at the 233rd AAS meeting, and availability of the new Gemini Card Game!

Gemini North TOPTICA Laser Availability

The TOPTICA laser has been successfully commissioned for nighttime operation at Gemini North. The Laser Guide Star (LGS) mode will be available for Fast Turnaround and Director's Discretionary programs using the Phase 1 Tool released on December 11, 2018. The new laser allows us to move away from block scheduling and offer LGS mode on a greater number of nights. We are in the process of activating one Large program that was put on hold when our old LGS system failed.

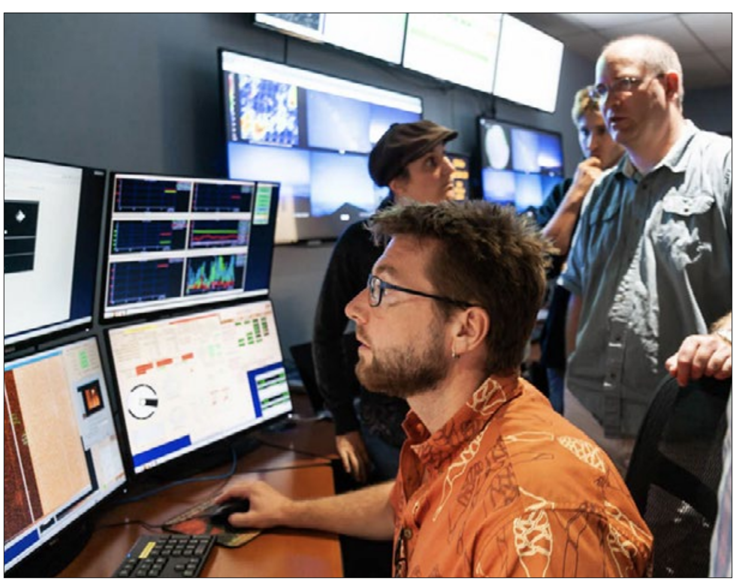


Figure 1.

Jesse Ball (foreground) operates the Gemini North telescope during on-sky commissioning of the new TOPTICA laser. Joining him are (from left to right) adaptive optics science fellow Laure Catala (in hat), optical engineer Tom Schneider, and Gemini scientist Paul Hirst.

Credit: Joy Pollard

During on-sky commissioning, we confirmed the stability of delivered power by the TOPTICA laser (Figure 1). We estimated the on-sky return to be the equivalent of an ~8 magnitude star (V mag), when propagating at zenith. This of course will vary as the sodium layer density fluctuates. In terms of image quality delivered

AO mode	NGS or TTGS V mag / separation	Seeing (@ zenith)	Elevation [deg] (seeing @ El)	NIRI imaging in K' FWHM (Moffat fit)
NGS vs LGS comparison (on-axis)				
NGS	8.75 / on-axis	0.39"	78 (0.40")	**91 mas**
LGS	12.6 / on-axis	0.40"	57 (0.44")	**102 mas**
Faint TTGS and Elevation dependance (on-axis)				
LGS	17.1 / on-axis	0.42"	67 (0.44")	**130 mas**
LGS	17.1 / on-axis	0.45"	40 (0.59")	**180 mas**
Performance Comparison off-axis				
LGS	16.4 / on-axis	0.48"	47 (0.58")	**125 mas**
LGS	16.4 / 22" off-axis	0.51"	47 (0.62")	**136 mas**

by the adaptive optics system in LGS mode, a brief summary of the commissioning results is given in the table at right.

LLP Call for Proposals

Gemini Observatory is again accepting Large and Long Program (LLP) proposals in 2019. LLPs are Principal Investigator-defined and -driven programs that, as a guideline, either require significantly more time than a partner typically approves for a single program or extend over two to six semesters, or both. Large programs are expected to promote collaborations across the partnership's communities, have significant scientific impact, and provide a homogeneous data set, potentially for more general use.

The announcement of opportunity was released on December 15, 2018, and information on proposal submission can be found within the ***Large and Long Program webpages***. All interested teams are required to submit a Letter of Intent no later than February 4, 2019, with full proposals due on April 1, 2019. In addition to the Gemini suite of instrumentation, Principal Investigators from LLP participating partners are invited to submit proposals for Subaru Intensive Programs via the Gemini-Subaru time exchange program.

New Data Reduction Resources for 2019

The FLAMINGOS-2 data reduction ***cookbook*** provides Python scripts that wrap tasks in the ***Gemini IRAF package*** and serve as a guide to the reduction and calibration of imaging and long-slit spectroscopy data. Visit the ***FLAMINGOS-2 data reduction*** webpage for more details. Comments, questions, or notifications of errors are encouraged and can be ***submitted via email*** or ***helpdesk*** request using the Gemini IRAF category.

A new, hands-on four-hour tutorial on reducing Gemini Multi-Object Spectrograph (GMOS) Integral Field Unit-1 data was presented live at the Science and Evolution of Gemini Observatory 2018 meeting in July. The participants were shown how to obtain the data and calibrations and go from raw data to a stacked cube, all the while addressing various possible data issues. An online version of the step-by-step tutorial is now available to everyone ***at this link***. Software installation instructions are included.

A ***document is now available*** describing data reduction solutions to some of the more serious issues that arose due to problems with the GMOS instrument or detectors. The document is based mostly on issues with the GMOS-South Hamamatsu data and for now only discusses imaging data. It will be expanded to cover spectroscopy in the future. Feedback is welcome (***email here***).

A new version of the ***DRAGRACES pipeline*** fixes a previously problematic wavelength calibration. Please use version 1.2, or later, from now on. If you have ever used a previous DRAGRACES version, please have a second look! Note that it is always recommended to compare your GRACES extracted spectra using DRAGRACES and OPERA (extracted spectra are distributed by the ***Gemini Observatory Archive***) before performing a detailed analysis. (Disclaimer: DRAGRACES is not a pipeline supported by the Gemini Observatory, and is therefore not required to follow the maintenance and testing standards. Visit the ***GRACES Data Reduction webpage*** for details.)

Join Gemini Staff at the January AAS Meeting in Seattle

Gemini Observatory and its partners will have many events at the 233rd American Astronomical Society (AAS) meeting in Seattle, Washington, January 6-10, 2019 (***www.gemini.edu/AAS***).

If you are at the AAS, please join us for the annual Gemini Observatory Open House on Tuesday, January 8th, from 5:30-6:30 p.m., in Room 305 of the Washington State Convention Center. We'll provide an overview of current activities and let you know how you can become involved in the ongoing developments at Gemini.

It has become a new tradition to offer personalized help at the Gemini booth at AAS winter meetings. If you have Gemini data, an active program, or even a vague project idea, come visit the Gemini booth any time during Exhibit Hall hours. You can also book an appointment in advance by emailing ***SUS_inquiries@gemini.edu***.

Also at the AAS meeting don't miss the National Optical Astronomy Observatory US National Gemini Office mini-workshop on high-resolution spectroscopy at Gemini (Tuesday, January 8th, 2:00-3:30 p.m., Room 305), the Gemini Open House (Tuesday, January 8th, 5:30-6:30 p.m., Room 305), and the Gemini Workshop on science with SCORPIO (Wednesday, January 9th, 2:00-3:30 p.m., Room 310).

Finally, we will be distributing the base decks of the new Gemini Card Game at the Gemini booth (see next story).

Get Ready for the Gemini Card Game!

Gemini is creating an original card game with unique designs and challenging gameplay (release planned for January 2019).

The Gemini Card Game is a cooperative game for two to four players who work together to complete the required number of Band-1 programs, and as many additional programs as possible, in 12 rounds (*i.e.*, a semester) — all while avoiding loss of all their Reputation Points resulting in loss of funding and losing the game.

We will distribute the 90-card basic deck at the following annual, national, or Gemini user meetings: AAS 233, 233, K-GMT 2019, CASCA 2019, and LARIM 2019. Make sure to find our booth to get yours!

Complete rules can be found ***here***.

Do you have something to contribute to the Gemini Card Game? Share your ideas, suggestions, comments, questions, experiences, *etc*. on the ***GCG Forum***.

Jason Chu (left) and Joy Pollard (right) in silhouette during on-sky laser commissioning of the Gemini North TOPTICA laser.
Credit: Joy Pollard/Gemini Observatory/NSF/AURA

AURA

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United States	Canada	Chile	Brazil	Argentina	Korea	

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