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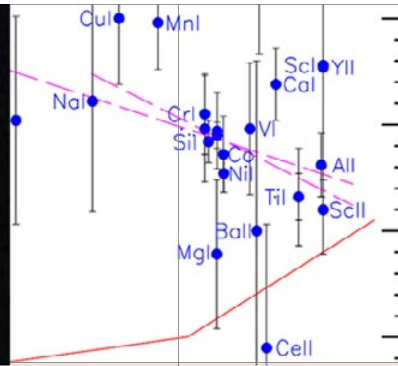
GeminiFocus

Observing a Gravitational Wave Source

page 7



ON THE COVER:

Gemini South provided critical observations of the first electromagnetic radiation from a gravitational wave event. (See details starting on page 7.)

Gemini*Focus* October 2017

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Laura Ferrarese

Director's Message

The Three Goals of a Year-long Vision

Hello, Aloha, and Hola!

I am delighted to address the Gemini community from my new role as the Observatory's Interim Director. I will hold this position for the next year, while the search for a permanent Director moves forward. As I write this (beginning of September), I have been in Hilo, Hawai'i, for almost two months, and it's been an exciting time. I have enjoyed working with the Gemini staff, whose drive, dedication, and talent were already well known to me from when I chaired the Observatory Oversight Council on behalf of the Association of Universities for Research in Astronomy (AURA).

As we speak, I am returning from a two-week visit to La Serena, Chile. During my stay, I spent time every night in the new Base Facility control room, witnessing first-hand the pride and enthusiasm with which the telescope operators and observers carefully queued up, executed, and inspected the data — each frame a new discovery. Meanwhile, the base facility in Hilo had been quiet for seven weeks during a scheduled shutdown at Gemini North (see page 18 of this issue). Nevertheless, activity on the mountain was feverish, as our day crew and engineers carried out very delicate repairs to the dome shutter mechanism. Those of you who have been on the summit of Maunakea are very well aware that at 4,200 meters even the most routine activities become challenging; you will no doubt share my amazement at what our day crew had accomplished in order to get Gemini North back on-sky, as planned, in late August.

A Year-long Vision

Now, you might be wondering what I am hoping to achieve in one year: after all, Gemini is blessed with a very strong and competent team, and this is hardly a fort that needs to be held. I am hoping to contribute to three main areas: implementing the National Center for Optical-infrared Astronomy (NCOA; a name that is still tentative), setting the Observatory on the path defined by the Gemini Board's Strategic Vision, and strengthening Gemini's partnership.

First, most of you have heard of NCOA — a vision to combine operations of the current Gemini and National Optical Astronomy Observatory facilities with the future operations of the Large Synoptic Survey Telescope, and integrate them into a single matrixed structure. NCOA has been recommended by several independent reports, including the 2010 National Research Council (NRC) Decadal Survey Report "New Worlds, New Horizons in Astronomy and Astrophysics," the 2010 National Science Foundation/ Division of Astronomical Sciences Portfolio Review Report "Advancing Astronomy in the Coming Decade: Opportunities and Challenges," and the 2015 NRC study report "Optimizing the U.S. Ground-Based Optical and Infrared Astronomy System." Driven by a coherent scientific strategic vision, NCOA will be greater than the sum of its parts. It will facilitate collaborations and partnerships and, critically, will provide opportunities for innovation that are presently beyond the scope and capacity of the individual centers.

While the potential benefits of such an integration are tremendous, the challenges are also significant. That's why my second goal is to ensure that, under NCOA, Gemini continues to develop the scientific vision that has recently been articulated by the Gemini Board (you can find it ***here***). In the next several months, it will be a privilege for me to work with Henry Roe and John Blakeslee (our new Deputy Director and Chief Scientist, respectively) to turn the Board's vision into reality.

My third goal is to ensure that NCOA remains true to the needs of Gemini's partners. In my mind, international partnership is Gemini's main strength. With their diverse communities, Argentina, Brazil, Canada, and the US each enrich Gemini's scientific atmosphere, open new opportunities for scientific and technical collaborations, and align Gemini with the global nature of modern astronomy. In the near future, I am looking forward to the possibility that Korea (currently a limited-term collaborator) might become part of the Gemini family, and I am excited about new collaborative opportunities that we are establishing with our Israeli colleagues. I am looking forward to nurturing these strategic collaborations and further enriching Gemini's diverse culture.

One final word. As I tackle these challenges, I am aware that my biggest challenge, one I am afraid I won't be able to meet, will be to live up to the standards set by Gemini's former Director, Markus Kissler-Patig. During his tenure, Markus had to contend with not only a 25% reduction in budget following the withdrawal of the UK from the Partnership, but also with the uncertainties associated with the recompetition of AURA as Gemini's managing organization. And yet, the Observatory Markus left last June is more competitive, more vibrant, and more adaptable than the one he joined only five years earlier. The Observatory, as well as the entire Gemini community, owes you a huge debt of gratitude, Markus: you are deeply missed, and we wish you all the best in your future endeavors!

Laura Ferrarese is the Gemini Observatory Interim Director. She can be reached at: lferrarese@gemini.edu

Carlos Saffe

Rocky Planet Engulfment Explains Stellar Odd Couple

To date, astronomers have found more than 3,600 planets orbiting around stars in the solar neighborhood. Nevertheless, current observational techniques challenge those searching for possible planets engulfed by their host star. By using Gemini North + GRACES high-resolution spectra in the Fast Turnaround mode, we have found a notable difference in the chemical pattern between the stars of the HAT-P-4 binary system, which could be attributed to the ingestion of at least ~10 M_{Earth} of rocky material onto the primary star.

The story begins with the star HAT-P-4, which hosts a giant planet detected by the Hungarian Automated Telescope Network (HATNet) transit survey (Kovács *et al.*, 2007). This planetary companion, designated HAT-P-4b, has a mass of 0.68 M_{JUP} (between the mass of Jupiter and Saturn), and orbits the star at a distance of only 0.04 astronomical units — about 10 times closer than the distance between Mercury and the Sun. The planet's estimated density of ~0.4 grams per cubic centimeter (g cm^{-3}) is even lower than that of Saturn (~0.7 g cm^{-3}), so we consider it as a low-density hot-Jupiter planet. Searches for additional planets around HAT-P-4 using both transits and radial-velocity techniques have met without success.

The Dance Between Two Stars and a Single Planet

A few years after the discovery of HAT-P-4b, Mugrauer *et al.* (2014) showed that HAT-P-4 (hereafter, star A) forms a wide binary system together with TYC 2569-744-1 (hereafter, star B). The two stars are separated by 91.8 arcseconds in the sky and appear nearly equal in brightness (Figure 1). In addition to having common proper motions and similar radial velocities, the discoverers also showed that both stellar components present very similar spectral types, being about G0V and G2V. To date, no planet has been detected around the B component, which was also included in the same HATNet transit survey field (called

G191) with an 8˚ x 8˚ field-of-view. In summary, we have three actors in the scene: a wide binary system with two very similar components, and a hot-Jupiter planet orbiting around the primary (star A).

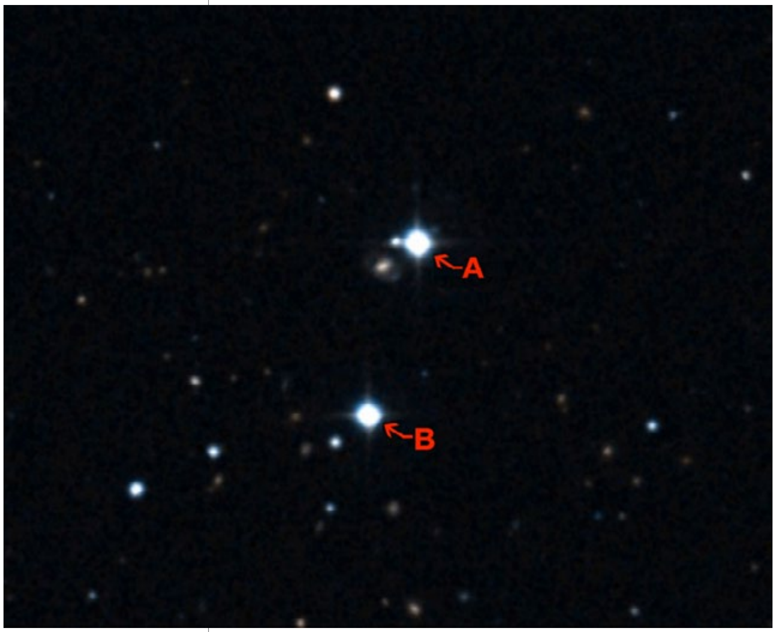

Figure 1.
Image of the HAT-P-4 binary system. The two brightest stars in the field are HAT-P-4 A and its B companion (lower left). Their Hipparcos V magnitudes are 11.12 and 11.38, respectively, and they lie 91.8 arcseconds apart.

Stars born at different times and locations in our Galaxy commonly present a different initial chemical composition due to the Galactic Chemical Evolution (GCE) effect, which leads to different chemical enrichment histories. On the other hand, it is generally assumed that individual components of wide binaries (and most multiple systems) have the same age and initial chemical composition, and formed coevally from a common molecular cloud.

This latter case is a strong advantage for comparative chemical studies, where GCE effects are greatly diminished or ruled-out; in addition, the notable physical similarity between both components of a binary system makes it possible to achieve the highest possible precision in differential chemical studies when compared to classical (*i.e.,* non-differential) methods. Such precision is a requisite in order to detect even slight differences between both stars. That HAT-P-4 is not only a binary with physical similarities between its components, but also one that harbors a planetary companion, makes it an ideal case study on the possible chemical signature of the planet formation process in a binary star system. So far, this kind of challenging analysis has been performed in only a very few systems.

A high-precision chemical abundance study requires both high signal-to-noise (S/N) and high-resolution spectra. This fact, together with the relative brightness of both stars, made the combination of Gemini North with the Gemini Remote Access to CFHT ESPaDOnS Spectrograph (GRACES) an excellent choice for the observation of this binary system. The stellar spectra were obtained under the Fast Turnaround observing mode (program ID: GN-2016A-FT-25; with the author as the Principal Investigator). We acquired the observations using the 1-fiber (object-only) observing mode, which provides a maximum resolving power of ~67,500 between 4,000 and 10,000 Ångstroms (Å). The exposure times were 2 x 16 minutes and 2 x 18 minutes for the stars A and B, respectively, obtaining a final S/N ~ 400 measured at ~6,000 Å in the combined spectra of each target.

A Surprising Chemical Difference Between Sibling Stars

We took advantage of the physical similarity between both stars and applied a line-by-line full differential technique in order to determine fundamental parameters and detailed chemical abundances. To do so, we used the FUNDPAR program (Saffe, 2011) together with ATLAS9 model atmospheres. The results showed mainly three unexpected differences in the chemical pattern of both stars. First, the exoplanet host A star is ~0.1 dex more metal-rich than its stellar companion. This difference is remarkable and much higher than most metallicity differences found in similar binary systems (see, *e.g.,* Desidera *et al.*, 2006). Second, star A shows a clear enhancement in its photo-

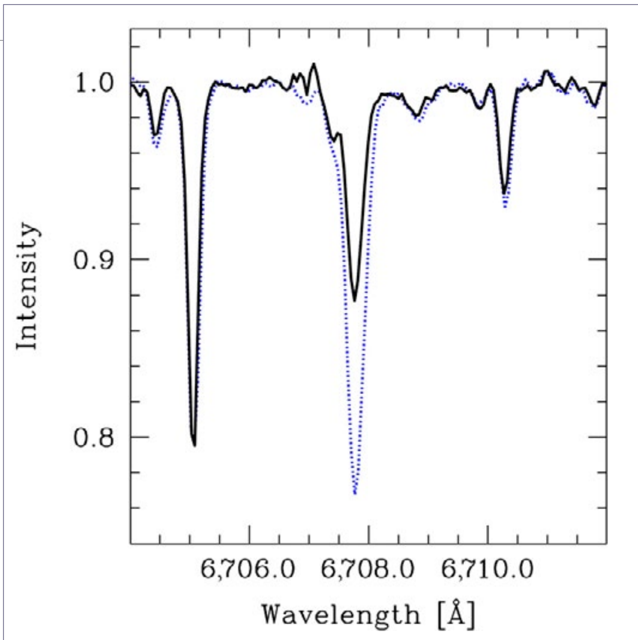

Figure 2.

GRACES spectra near the 6,707.8 Å lithium line for star A in HAT-P-4 (blue dotted line) and its B companion (black continuous line). The lithium content is notably enhanced in star A.

spheric lithium content, being about 0.3 dex more abundant than its B companion (Figure 2). As lithium is most likely destroyed when it reaches the high temperatures of the stellar interior by means of stellar convection, this great difference between two similar coeval stars is surprising and unexpected.

In addition, we also found that star A is enhanced in refractory elements when compared to its stellar companion; here we identify as "refractory" and "volatile" those species with condensation temperatures (T_C) > 900 K and < 900 K, respectively. To obtain this result, we plotted the abundance difference (B – A) between both stars versus T_C for each chemical species. Figure 3 also shows weighted linear fits (long dashed lines) to all species and only to the refractory components. A similar refractory to volatile content between both stars would correspond to null slopes in this plot. However, the negative slopes in Figure 3 point notably toward a higher content of refractory species in star A than in its stellar companion.

Chemically Peculiar Stars?

Our attempts at classifying the HAT-P-4 components to other stars with peculiar chemical patterns also brought surprises. We looked at three cases in particular: λ Bootis stars, δ Scuti stars, and blue stragglers. The so-called λ Bootis stars are a small group (only 2%) of population I stars, that show moderate to extreme surface underabundances of iron (Fe)-peak elements, but with solar abundances of carbon, nitrogen, and oxygen. In contrast, both stars A and B in the HAT-P-4 system are metal rich, and their effective temperatures are lower than those of the λ Bootis group; this allowed us to discard them as belonging to the λ Bootis class. δ Scuti stars are regularly pulsating variables with ~A6–F6 spectral types, located in the instability strip of the Hertzsprung-Russell diagram. While most of these stars present overabundances of heavy elements (between 0.5 – 1.0 dex), both the effective temperature and mass of stars A and B are not only lower than those of the δ Scuti group, but they also lie out of the instability strip boundaries. Furthermore, no stellar pulsations have been reported in either component A or B; so we also abandoned a possible δ Scuti classification. Finally, blue stragglers are stars significantly bluer than those placed on the main-sequence turnoff of the cluster (or population) to which they belong.

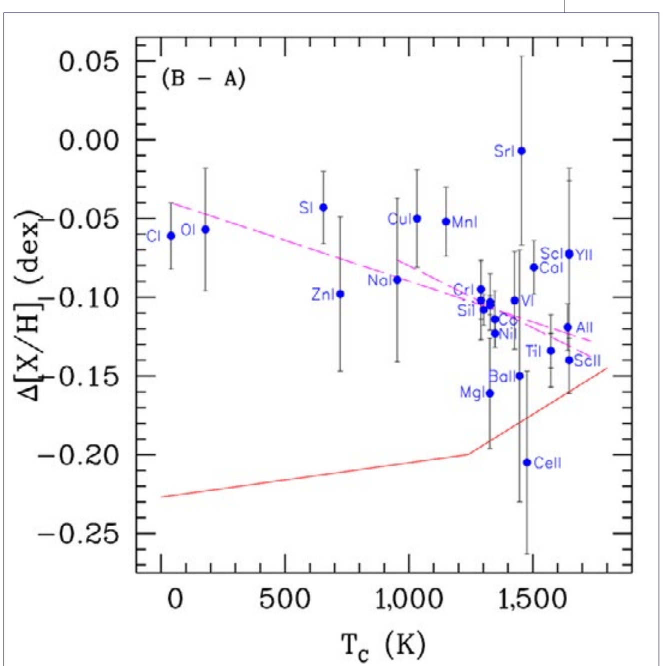

Figure 3.

Differential abundances (B - A) vs. condensation temperature T_C. Long dashed lines are weighted linear fits to all species and to refractory species. The solar-twins trend of Meléndez et al. *(2009) is shown with a continuous line for comparison.*

They also display simultaneously significant rotational velocities, activity, and very low lithium content; alas, we see none of these characteristics in the stars of the HAT-P-4 binary system.

On the Planet Engulfment Scenario

To explain the chemical abundance difference between stars A and B, we propose that at the time of planet formation, star A locked the orbiting refractory material (in the shape of planetesimals, rocky planets, or both), and formed a gas giant planet in its external disk. This was followed by the accretion of most of these refractories descending onto star A – possibly due to the migration of the detected giant planet which finally ended as a hot-Jupiter transiting planet. We estimate that some 10 M_{Earth} of rocky refractory material must have accreted onto star A in order to reproduce the observed T_C trends and metallicity. This scenario agrees with the following observational facts:

- The enhancement of ~0.1 dex in metallicity of star A compared to B. These objects do not show a peculiar chemical pattern (λ Bootis, δ Scuti, or blue straggler). In addition, the binary nature of stars A and B discards possible GCE or age effects.
- The enhancement of refractory elements in the HAT-P-4 A star compared to its B companion.
- The slightly higher mass of A compared to B, which corresponds to a lower convective mass and a lower mixing of the possible accreted material.
- The detection of a hot Jupiter and no additional planets in the A star, which do not discard a possible migration and accretion process.
- The lithium enhancement in star A compared to B.

In other words, the proposed scenario of planet engulfment fits all the observational pieces of the puzzle. Very few previous works claim a similar accretion scenario on a main-sequence star, such as the case of HD 82943 (which was then strongly disputed), or HIP 68468 (Meléndez *et al.*, 2017). That leaves HAT-P-4 as the only main candidate in a remarkable system, studied through the unique combination of Gemini North as collector with the high-resolution spectra of GRACES. We also want to stress that this work was carried out thanks to the Fast Turnaround observing mode being offered by Gemini, which is the only observatory that provides this kind of time proposal. We expect to continue this exciting study by extending the sample to other similar systems.

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Peter Michaud

Astronomers Feast on First Light From Gravitational Wave Event

Gemini Observatory "pulled out all the stops" to bring a gravitational wave source into focus and capture early optical and infrared light from the merger of two neutron stars. The critical ground-based observations spanned almost a month during the summer of 2017 and allowed astronomers to dissect the first electromagnetic light emissions ever associated with a gravitational wave event.

*Note: The following story is adapted from the Gemini Observatory press release issued on October 16, 2017. The original release (with videos and additional images) is **available online**.*

Figure 1.
*Astronomers Mansi Kasliwal of Caltech (above) and Edo Berger of Harvard (below) spoke with much excitement about gravitational waves, and the role Gemini played in understanding them, in their videos describing the 2017 summer observation event and its significance. The videos can be found **here**.*
Video credits: Caltech and Harvard University

The first-ever detection of optical and infrared light linked to a gravitational wave event initiated a time-critical sequence of observations at the Gemini South telescope in Chile. "Gemini pulled out all of the stops to get these data," said Ryan Chornock of Ohio University who analyzed the resulting flood of data in his team's study of the event. The Gemini data allowed multiple research teams to form a complete picture of the aftermath from the gravitational wave event (GW170817) localized by the Laser Interferometer Gravitational-wave Observatory (LIGO), Virgo interferometer, and Fermi Gamma-ray Space Telescope on August 17, 2017. The Gemini imaging and spectroscopy spanned a period of 25 nights — while the object's light gradually faded from view.

Researchers from around the world announced their results on October 16th at press conferences in Washington D.C., Caltech, and one hosted by the European Southern Observatory in Europe. Well over a dozen papers have also been accepted for publication in the journals ***Nature***, ***Science***, and ***The Astrophysical Journal Letters***.

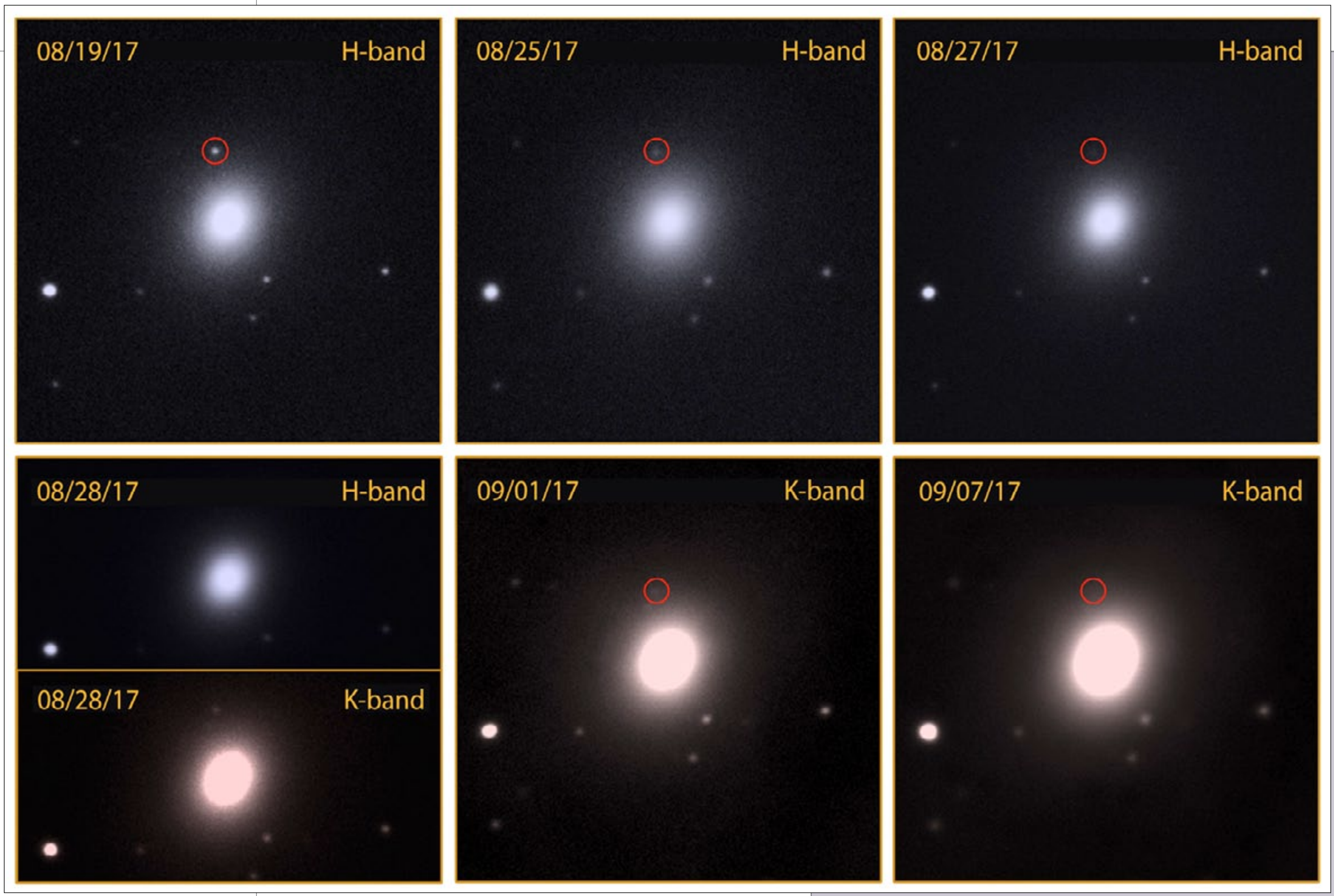

Figure 2.

The sequence above shows infrared imaging from the FLAMINGOS-2 imager and spectrograph for a period of over two weeks. The top row features images in the H-band, a shorter (bluer) wavelength of infrared light. The bottom row focuses mostly on K-band images, which are longer (redder) wavelengths of light. This sequence reveals how the object became redder as it faded from view.

Image credit: Gemini Observatory/NSF/AURA/ Edo Berger (Harvard), Peter Blanchard (Harvard), Ryan Chornock (Ohio University), Leo Singer (NASA), Mansi Kasliwal (Caltech), Ryan Lau (Caltech) and the GROWTH collaboration, Travis Rector (University of Alaska), Jennifer Miller (Gemini Observatory)

Mansi Kasliwal, Assistant Professor of Astronomy at Caltech, presented her team's findings at the Caltech press conference in Pasadena and recalls the excitement of the discovery: "Within 23 minutes of submitting our observing proposal to hunt for infrared photons it was approved by the Gemini Director!" Kasliwal, who was Principal Investigator of the worldwide Global Relay of Observatories Watching Transients Happen (GROWTH) team studying the event, continues, "On that first night the 8-meter Gemini South telescope successfully captured some of the first infrared photons ever seen from a neutron-neutron star merger — it was thrilling!"

Harvard astronomer Edo Berger, who presented at the D.C. press conference, describes the Gemini observations as, "collectively the longest-running, and finest, infrared imaging and spectroscopy of this object that we have available." Berger adds that the data directly demonstrate that the much-speculated mechanism of a neutron star binary merger caused this gravitational ripple in space and time. In the process the event formed and dispersed heavy elements, like gold, into space. "Here, for the first time, using Gemini, we showed the direct signature of the formation of heavy elements," says Berger, "[This] solves solves the decades-long mystery of the origin of

The observations of this gravitational wave source brought out the best in Gemini's staff and their commitment to obtaining the best data under extreme circumstances. Of special note are the individuals below who played critical roles in acquiring these data:

Morten Andersen	***Lindsay Magill***
Pablo Candia	***Pablo Prado***
Joy Chavez	***Ricardo Salinas***
Gonzalo Diaz	***David Sanmartim***
German Gimeno	***Alysha Shugart***
Hwihyun Kim	***Karleyne Silva***
Ariel Lopez	***Erich Wenderoth***

the heaviest elements in the periodic table." (See excerpts from a Harvard University interview of Berger in the online version of the release).

Leo Singer, of NASA's Goddard Space Flight Center, and a collaborator with Kasliwal in the GROWTH group adds, "Continued monitoring over many subsequent nights at Gemini allowed us to paint a stunning infrared portrait of neutron star mergers." In agreement with other researchers, the GROWTH team concluded that these neutron-neutron star mergers are primary sites for the production of elements heavier than iron. According to Kasliwal, "Each of these events is capable of forging over ten thousand times the Earth's mass in heavy elements such as gold and platinum — cosmic bling!"

Folding the Gemini data into observations from radio to X-rays, Eleonora Troja, of the University of Maryland, joined Berger in presenting her findings at the D.C. press conference. Troja's team focused on the time evolution of the event starting with the very early Gemini observations in the optical (visible) part of the spectrum.

"It surprised me very much when I saw how bright this was in the optical," says Troja. "The question we asked is if this really was a so-called kilonova when a neutron pair merge, or some kind of exotic transient or supernova making fun of us!" Troja and her team concluded from the optical spectra that this was not like anything they had seen before.

"We are just beginning our effort to model and understand these explosions and the physics behind them," says team member Brad Cenko from NASA's Goddard Space Flight Center. "We need to add to our models an outflow of slower and more transparent material to account for the bright optical light component. This outflow is likely responsible for the production of less precious metals, such as silver and tin."

"The joint detection of light and gravitational waves from cosmic sources is one of the holy grails of present-day astronomy," exclaims Marcelle Soares-Santos (Fermi National Accelerator Laboratory), the first author of the paper from Berger's team that reports their discovery of the optical counterpart. Both signals, light and gravitational waves, contribute unique information about extreme astrophysical events. As Soares-Santos explains, "Gravitational waves tell us about the motions and masses of the neutron stars, and light reveals the astrophysics of the event — what happened exactly as the stars merged, the mass of heavy elements produced."

"This is a game-changer for astrophysics," says Andy Howell who also spoke at the D.C. press conference. Howell leads the supernova group at the Las Cumbres Observatory and is a coauthor on a paper in *The Astrophysical Journal Letters* based on the Gemini data. He adds, "One hundred years after Einstein theorized gravitational waves we've seen them and traced them back to their source to find an explosion with new physics of the kind we only dreamed about before."

"It is tremendously exciting to experience a rare event that transforms our understanding of the workings of the Universe," says France A. Córdova, director of the National Science Foundation (NSF), which funds LIGO and a majority of the international Gemini Observatory. "This discovery realizes a long-standing goal many of us have had, that is, to simultaneously observe rare cosmic events using both traditional as well as gravitational-wave observatories. Only through NSF's four-decade investment in gravitational-wave observatories, coupled with telescopes that observe from radio to gamma-ray wavelengths, are we able to expand our opportunities to detect new cosmic phenomena and piece together a fresh narrative of the physics of stars in their death throes."

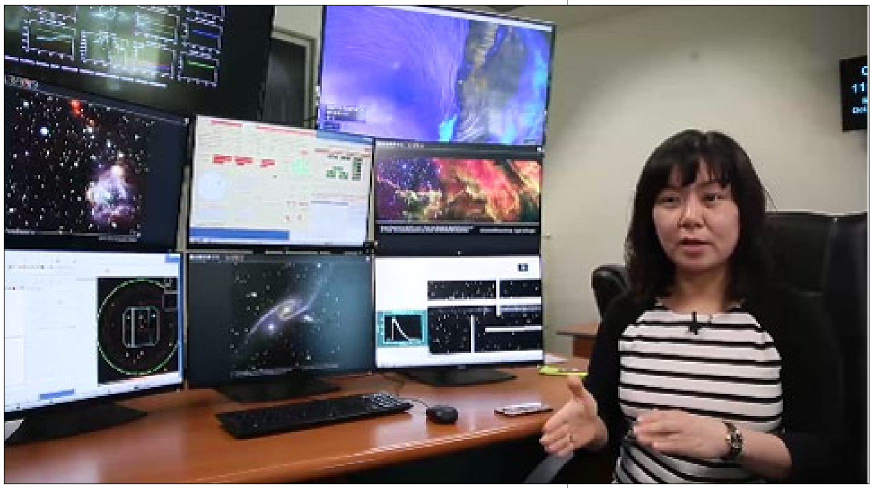

Figure 3.
*Gemini assistant scientist Hwihyun Kim describes the sequence of events at Gemini during the gravitational wave event in a video clip viewable **here**.*
Video credit: Gemini Observatory

Gemini Observatory Director Laura Ferrarese recounts the challenges faced by the flood of requests for observations once the source was pinpointed. "Several teams contacted us with requests to observe the source," according to Ferrarese. "Everybody at Gemini was terribly excited: we all knew that we were witnessing a historical event!" Ferrarese adds that the greatest challenge involved scheduling the observations so that all of the teams would receive the data they needed — a task that, in her words, "required lots of coordination, and a good dose of diplomacy!"

The challenges extended to the observations themselves, according to Gemini astronomer Hwihyun Kim, who was instrumental in obtaining the Gemini data which primarily used the FLAMINGOS-2 infrared imager and spectrograph. "We were very lucky with observing this target," says Kim. "It was not always easy to see the source, but the field had a very bright star that helped our pointing even when the object was getting lost in the glow of twilight." Kim adds that everyone in the control room was nervous as the observation window got shorter and shorter each night. "Each night we pointed the telescope until we hit the absolute lowest limit that the telescope could reach." (See interview of Kim on the online version of the release.)

"Gemini's unique combination of depth and high-cadence through the hard work of staff like Kim have generated a totally unique data set for this fascinating event," says Nathaniel Butler from Arizona State University, and also part of the team with Troja and Cenko. Butler concludes, "The Gemini observations will provide a critical perspective on gravitational waves for years to come."

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Peter Michaud

Science Highlights

Data from the Gemini Multi-Object Spectrograph on Gemini South verifies one of the most distant superluminous supernovae ever studied. Astronomers at Gemini South confirm a new class of variable stars, called Blue Large-Amplitude Pulsators. Joint Gemini and Canada-France-Hawai'i GRACES observations at Maunakea help in the study of a white dwarf star hurtling through our Galactic neighborhood 50 million years after a supernova blast. And Gemini near-infrared data from Gemini North unmask the mysterious Infrared Quintuplet at the Galactic center.

A Super-distant, Superluminous Supernova

Observations conducted with the Gemini Multi-Object Spectrograph on the 8-meter Gemini South telescope have confirmed that a brilliant explosion more than three times as bright as our Milky Way Galaxy is one of the most distant supernovae ever studied. The event, known as DES15E2mlf, occurred about 3.5 billion years after the Big Bang, at a period known as "cosmic high noon," when the rate of star formation in the Universe had reached its peak.

DES15E2mlf was initially detected in November 2015 by the Dark Energy Survey (DES). Follow-up observations at Gemini South not only confirmed the object's distance of 10 billion light years, but also revealed its unusual nature. Previous observations of superluminous supernovae show that they typically reside in low-mass or dwarf galaxies, which tend to be less enriched in metals than more massive galaxies. However, University of California Santa Cruz astronomers Yen-Chen Pan and Ryan Foley, who led the Gemini investigation as part of an international team of DES collaborators, found that the host galaxy of DES15E2mlf, is a fairly massive normal-looking galaxy, which goes counter to current thinking.

While knowing that very massive stars were exploding at that time is important, the team would now like to know the relative rate of superluminous supernovae to normal supernovae — to see if this atypical supernova is telling us something special about that time 10 billion years ago. It may be that at these earlier times in the Universe's history, even high-mass galaxies, like our Milky Way, may have had a low enough metal content to create these extraordinary stellar explosions.

Their findings appear in a paper published June 13th in the [*Monthly Notices of the Royal Astronomical Society*].

New Class of Variable Stars Confirmed

Astronomers using the Gemini Multi-Object Spectrograph (GMOS) on the Gemini South telescope have confirmed a new class of variable stars. Called Blue Large-Amplitude Pulsators (BLAPs), they are significantly bluer than main sequence stars of the same luminosity, demonstrating that they are relatively hot. Pawel Pietrukowicz (Warsaw University Observatory, Poland) led the Gemini study, following the team's discovery of 14 candidate stars as part of the Optical Gravitational Lensing Experiment (OGLE) — a variability sky survey conducted on the 1.3-meter Warsaw Telescope at Las Campanas Observatory, Chile.

The team's GMOS spectra on three of the candidate BLAPs confirmed that these stars are "low-mass giants" with helium-rich atmospheres and high surface temperatures of about 30,000 K, comparable with hot subdwarfs (Figure 1). The new pulsating stars vary with amplitudes of 0.2 – 0.4 magnitude, which is exceptionally high, given their short periods of only 20 to 40 minutes. This excludes the possibility that they are hot oscillating subdwarfs, leading to the conclusion that BLAPs form a new class of variable stars. These characteristics have not been observed in any known hot pulsators.

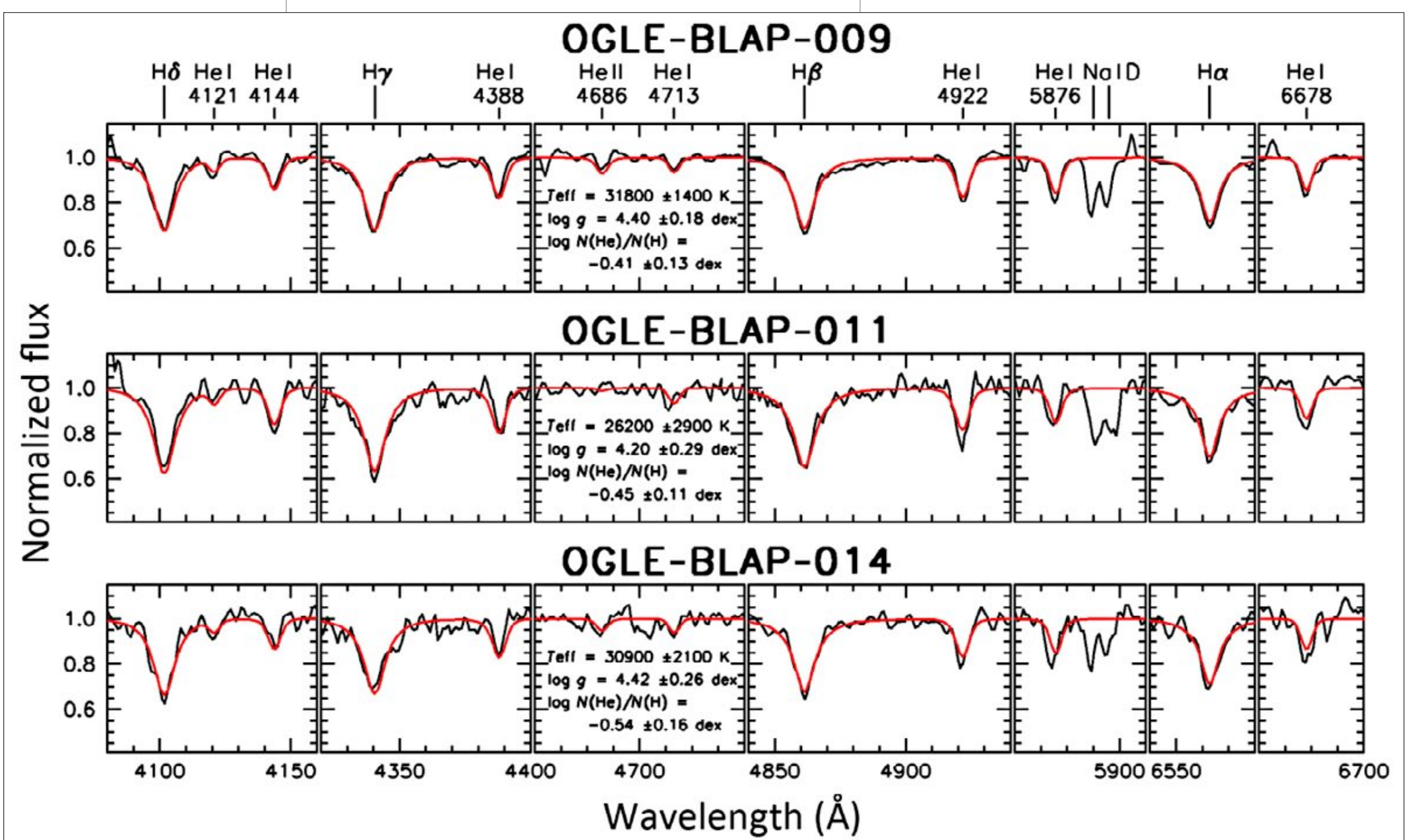


Figure 1. *Gemini South spectra for three BLAPs. Best fits of stellar atmosphere models are shown with red lines. Effective temperatures, surface gravities, and helium abundances derived for these stars are similar to the values obtained from spectra for the prototype object previously studied. This shows that all the newly discovered variables form a homogeneous class of objects.*
Image credit: Gemini Observatory/AURA/NSF

The very small number of BLAPs known so far points to a rare, unexplored episode in stellar evolution. This work is published in the journal *Nature Astronomy*, and is available ***online*** (subscription required). The article is also on ***astro-ph***.

The Little Star That Could … Survive a Supernova Explosion

Astronomers have identified a white dwarf star in our solar neighborhood moving faster than the escape velocity of the Milky Way. The international team, led by Stephane Vennes (Astronomical Institute in the Czech Republic), used telescopes in Arizona and the Canary Islands, as well as the GRACES (Gemini Remote Access to CFHT ESPaDOnS) spectrograph atop Maunakea to study this celestial speedster, which is thought to have been expelled like shrapnel from a peculiar Type Ia supernova explosion some 50 million years ago.

The speedy white dwarf, known as LP40-365, was first identified with the National Science Foundation's (NSF) Mayall 4-meter telescope at Kitt Peak National Observatory in Arizona. Over the next two years, the discovery team received critical follow-up observations from the Canary Islands and Maunakea, which they analyzed using state-of-the-art computer codes. The analysis proved the star's compact nature and exotic chemical composition, as well as its extraordinary Galactic trajectory, which puts it on a path out of the Milky Way with no return.

Astronomers once thought that nothing survives a Type Ia supernova, which occurs in a binary system that includes a white dwarf. However, a new class of models called "Subluminous type Ia Supernova" (also known as type Iax) can leave a partially burned remnant that is instantly ejected at high velocity. LP40-365 is the first observational evidence that such high-velocity remnants of failed Type Ia supernovae actually exist in our Galaxy, and therefore it is an invaluable object to improve our understanding of these cosmological standard candles.

Many more of these objects may be lurking in the Milky Way and awaiting discovery. The recent European Space Agency's *Gaia* mission may well help us discover many more of these objects and help us understand how a little white dwarf star can survive a supernova explosion.

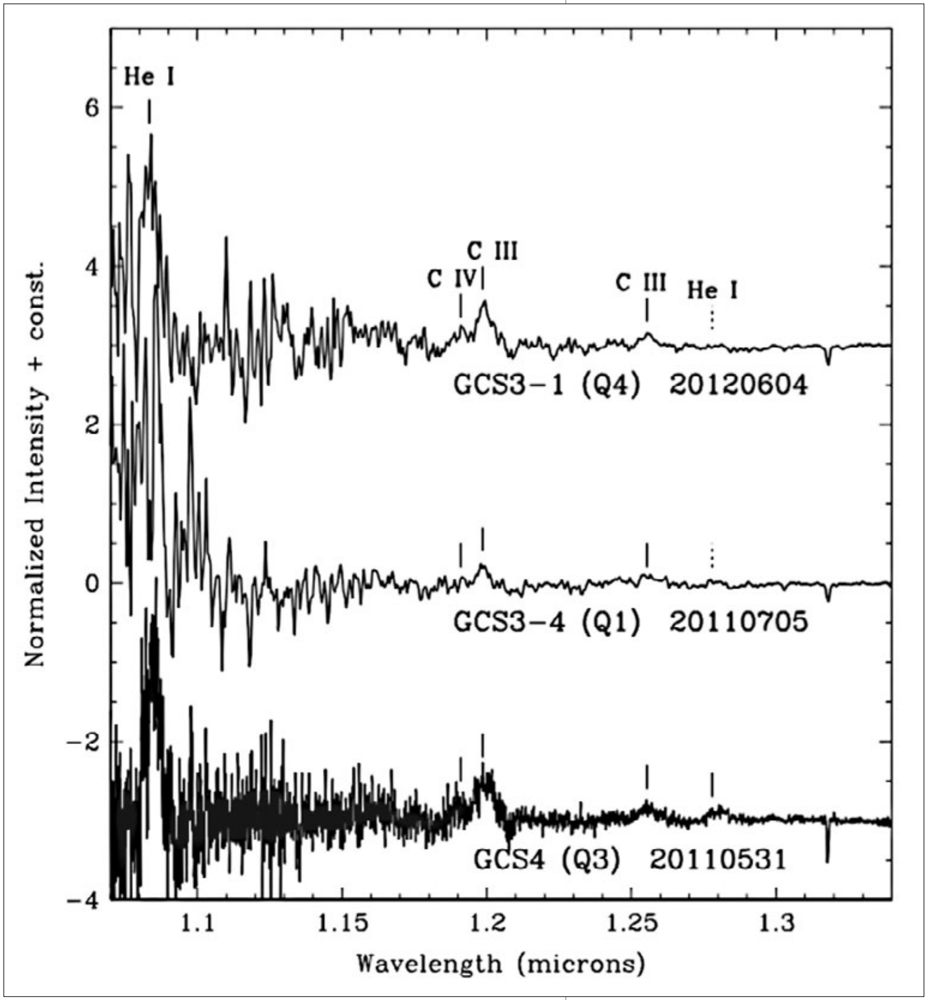
This research is published in the August 18, 2017, issue of ***Science***.

Gemini North Unmasks the Infrared Quintuplet

The "Infrared Quintuplet" has long been a mystery to astronomers. These five infrared-luminous stars lie at the center of hundreds of hot and massive stars (collectively known as the Quintuplet Cluster) only 30 parsecs from the central supermassive black hole at the core of our Galaxy. Most objects in the center of the Milky Way are highly obscured from our view by intervening dust at visible wavelengths. The stars in the Infrared Quintuplet, however, are further obscured by their own dust shells. These warm, cocoon-like shells emit bright infrared continuum radiation, diluting any infrared light from the stars themselves. The combination of these effects has made it very challenging, if not impossible, at any infrared wavelength to detect light from the interiors of the shells … or so it was thought.

As reported in the August 18, 2017, edition of ***The Astrophysical Journal***, Gemini astronomer Tom Geballe and his team used the Gemini Near-InfraRed Spectrometer (GNIRS) and Near-infrared Integral Field Spectrometer (NIFS) on the Gemini North telescope to penetrate the dusty cocoons of the Infrared Quintuplet and gather data on its members (Figure 2).

Figure 2.
J-band spectra of three of the five members of the Infrared Quintuplet showing emission lines of neutral helium and ionized carbon. The continuum radiation from the stars and their dust shells actually decrease rapidly from longer to shorter wavelengths and is barely detectable at the short wavelength edge of these spectra. In the figure the spectra have been "flattened" to more easily reveal the line emission. The increasing "noisiness" of the spectra toward their short wavelength edges demonstrates the increasing difficulty of detecting any light at all from these objects at those wavelengths.



The inspiration for the research began several years ago, when Geballe used NIFS at Gemini North for an unrelated research program and serendipitously discovered a very faint and broad emission line due to hot helium gas near 1.7 microns in the infrared spectrum of one of the Quintuplet stars. Prompted by this, he and his team obtained sensitive spectra of all five members of the Infrared Quintuplet, not only near 1.7 microns, but also down to wavelengths as short as 1.0 micron.

The team's spectra reveal the presence of emission lines from four of the five members of the Quintuplet, and have allowed the researchers to definitively identify the four as containing late-type, carbon-rich Wolf-Rayet stars, as was suspected based on the earlier imaging. These massive stars are only a few million years old, but have completely lost their outer hydrogen-rich layers and may be in the final stages of life before exploding violently as supernovae.

The existence of this Infrared Quintuplet is yet another illustration of the effects of high densities of massive stars in some clusters and of the extreme conditions at the very heart of our Galaxy.

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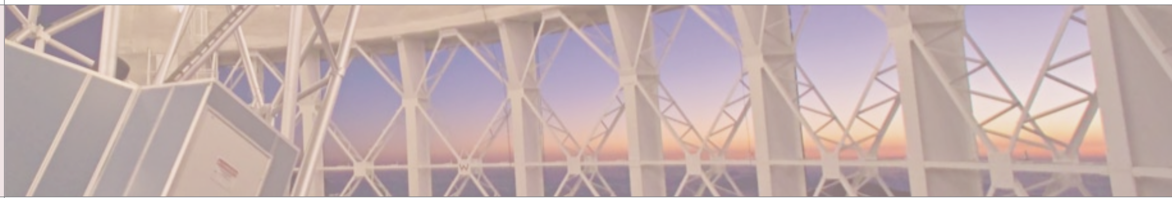


On the Horizon

NSF grant program aligns well with the Gemini Visiting Instrument Program. The OCTOCAM team and Gemini staff meet in Hilo for the new workhorse instrument's Conceptual Design Review. And Gemini's GHOST spectrograph is taking shape; to date, 74 design requirements verification reports have been submitted and accepted.

Opportunities for Visiting Instruments

The instrumentation community should note that the National Science Foundation's (NSF) Mid-Scale Innovations Program (MSIP) Call for Proposals has been announced with a deadline of November 20, 2017. These grants can be used toward a variety of astronomical activities, including the development of instrumentation and providing the community with access to telescope capabilities.

The Gemini Visiting Instrument Program is the perfect complement to this NSF program, as it provides astronomers with the opportunity to try out their own unique and innovative instrumentation on a world class telescope, while allowing all interested parties to propose for time. See the ***NSF Call for Proposals*** for more information about the MSIP. Other programs that may be of interest include the ***Astronomy and Astrophysics Research Grants*** and the ***Major Research Instrumentation Program***. Unfortunately, Gemini facility instrument and instrument upgrade proposals are not eligible for these grants.

We are planning an open videoconference discussion to present an overview of the Gemini Visiting Instrument Program. If you are interested in finding out more about how you might bring your instrument to Gemini, or how Gemini might support your instrumentation plans, please ***email*** us, and we will include you in the mailing list for this discussion.

— Alison Peck

Figure 1.
In August, the OCTOCAM team met at Gemini North in Hilo, Hawai'i, for the instrument's Conceptual Design Review. (AAO Project Manager Gabriella Baker, is not pictured.)

OCTOCAM Meetings Lead to Forward Progress

After a successful kickoff meeting in April, the OCTOCAM team worked with Gemini staff to establish a better understanding of Gemini operations and how the new instrument (an 8-channel imager and spectrograph) would be successfully integrated. The teams came together again in early August for the Conceptual Design Review in Hilo, Hawai'i (Figure 1).

Pete Roaming (Project Manager for Southwest Research Institute) and Christina Thöne (Deputy Project Manager from the Institute of Astrophysics of Andalusia in Spain) led the presentations on work accomplished during the project's first four months. An external review panel chaired by John Troeltzsch from Ball Aerospace reviewed the required documents and led a discussion of progress thus far.

The OCTOCAM team benefited from a summit tour to familiarize themselves with the telescope's physical structure, Acquisition and Guidance unit, and space envelope. A panel report was submitted to Scot Kleinman (Gemini's Associate Director of Development) to be incorporated into recommendations to the team as they advance to the preliminary design stage.

— Catherine Blough

GHOST Takes Shape

The Gemini High-resolution Optical SpecTrograph (GHOST) — the joint project between Gemini, Australian Astronomical Observatory (AAO), National Research Council Canada-Herzberg (NRC-H), and the Australian National University (ANU) — has made good progress over the past few months. In May we held a team meeting in Sydney, Australia, with members from all four institutions to plan the project's test phase and work through other outstanding project issues.

GHOST begins verification and testing over the next several months. AAO is completing the build phase of its work on the instrument's Cassegrain unit (Figure 2) and science optical cable. The ANU has completed 70% of the instrument control software and is finishing the last lines of code needed for the upcoming testing. The GHOST data reduction software, also being developed at ANU, is also progressing well.

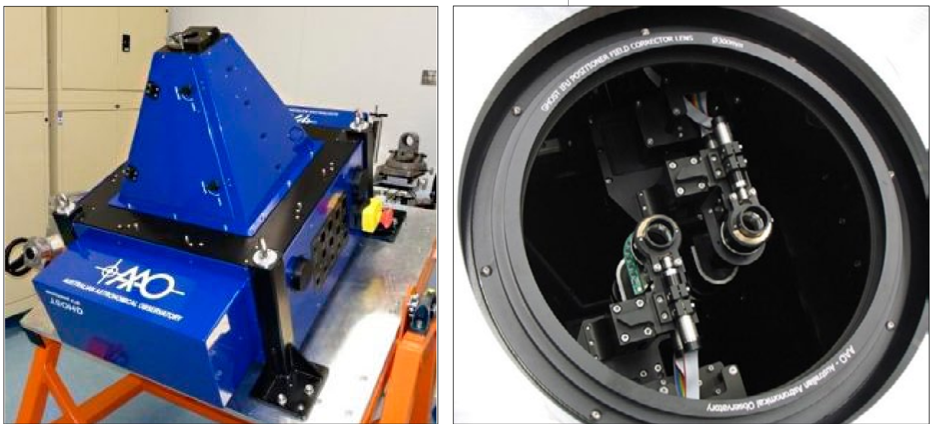


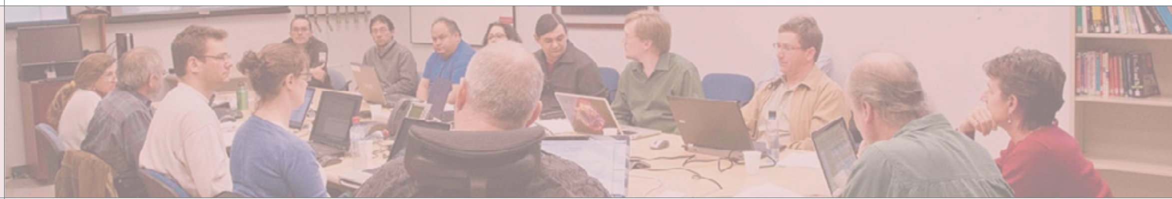
Figure 2.

AAO is completing the build phase of its work on the GHOST Cassegrain unit, including its integral field unit (IFU). Left: The IFU subassembly enclosure (blue) and mounting frame (black) attached to the Instrument Support Structure (ISS) mounting plate (silver). Right: A detailed image of the IFUs and positioning arms.

The team will test over the next two to three months to verify that requirements are met prior to shipping the slit viewer and science optical cable to Canada for integration with the spectrograph, which the NRC-H is building. The Cassegrain unit will also be tested prior to shipping with the prototype optical cable to Chile for preliminary testing on the telescope. All of this work is to ensure that everything is working in preparation for the arrival of the spectrograph later in 2018.

To date, the build team has submitted 74 design requirements verification reports to Gemini, all of which were accepted.

— Catherine Blough



Gemini staff contributions

News for Users

Registration for the 2018 Science and Evolution of Gemini Observatory conference is now open. Gemini North shutdown ends in August, returning the upper dome shutter to regular (and much smoother) operation. A new project has begun that will rethink and redesign important Observatory Control Software; progress is already being made. And John Blakeslee begins his duties as Gemini's new Chief Scientist.

Meet You in San Francisco!

The Science and Evolution of Gemini Observatory (SEG) conference kicks off with a welcome reception on the evening of July 22, 2018, and runs through July 26, 2018. With San Francisco's historic Fisherman's Wharf as a backdrop, this meeting invites the Gemini community to review recent science highlights, identify needs in the context of Gemini's evolving capabilities, and develop strategies for the future. The meeting will include

- user and staff presentations (featuring science highlights, instrumentation, and observing modes),
- informal discussions and breakout sessions,
- a conference dinner,
- and off-site visits.

Visit the ***SEG conference website*** and sign up to get update notifications.

Gemini North Shutdown Ends

On August 25th, Gemini North returned to regular night-time operations after an extensive seven-week shutdown. As quoted, the project's definition was to "place the shutter mechanism in an as-new state or better, and ensure that no major failure occurs in the coming 15 years or longer."

You may recall the failure of shutter drive boxes, which cost significant observing time in late 2013/early 2014, and again in in mid-2014. Although we fixed those failures by installing spares, a deep analysis of root causes revealed two fundamental issues: (1) the drive chains suffered differential stretching over time, and (2) the drive assemblies were not mechanically free enough within their drive boxes. These issues contributed to the further failure of a lower-shutter drive box in August 2016. At that time, we responded by locking the lower shutter in place until the work required to fix it could be planned and budgeted. As we said in the October 2016 issue of *Gemini*Focus, only complete replacement of the chains and refurbishment of the drive boxes would fully mitigate the chance of future failures.

The drive chains are essentially stationary relative to the dome arch girders; the drive boxes are attached to the dome shutters, and crawl along these chains carrying the shutters with them. Extracting and replacing the drive boxes require pinning the dome shutters at various locations; the chains can only be replaced by extracting them from the very top of the dome and inserting new chains in the same way. The top of the Gemini dome is the highest point in the Pacific, thus we needed the largest crane on the island of Hawai'i to do the chain replacement.

Figure 1 (top left). *A drive chain being extracted from the top of the arch girders. At this point, the tip of the crane is about 200 feet above ground level.*

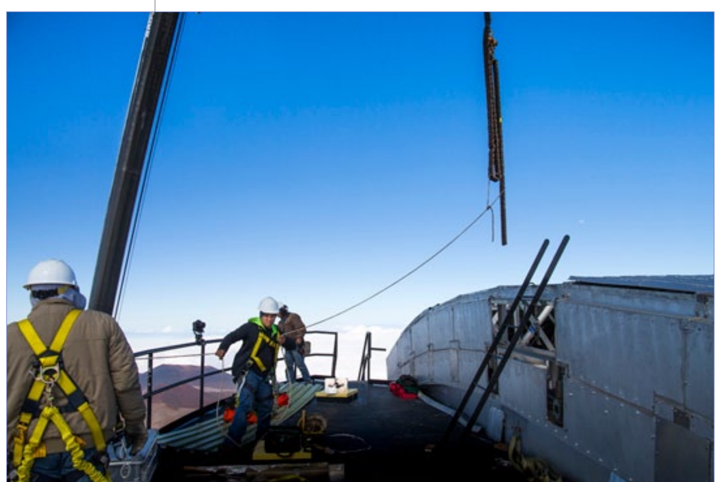


Figure 2 (top right). *Handling drive chains at the very top of the dome.*

Figure 3 (below left). *Extracting a drive box from the dome. At this point the shutter structure, to the left in this photo, has been immobilized so that it will not move once disconnected from the drive chain.*

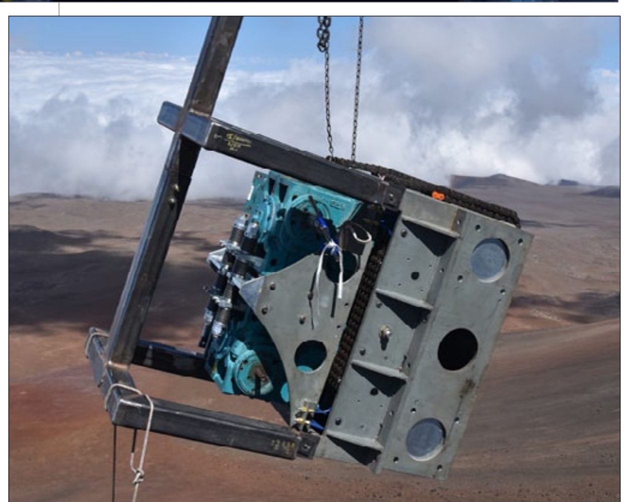


Figure 4 (right). *The extracted drive being lowered to ground level for refurbishment.*

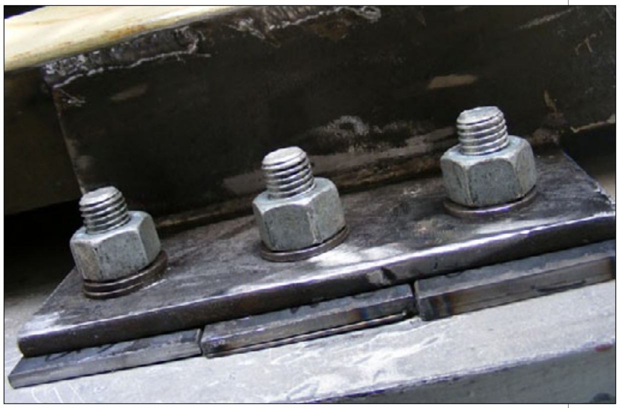


Figure 5 (left).
How the shutter was immobilized. Simple, but effective.

Figure 6 (right).
The Acquisition and Guidance unit, extracted from the heart of the telescope for maintenance.

The summit team (led by Gemini North Mechanical Engineering Group, and supplemented with occasional help from the Science Operations Specialists group) worked through their well-choreographed plan almost exactly to schedule. The weather largely cooperated, and after starting on July 10th, we were back on sky as planned on August 25th.

We expect work of this scale to produce some surprises, and one that came up late in the project was a 10- to 12-millimeter misalignment of the lower shutter. We're still working to understand this. Until we're certain, the lower shutter will be kept out of normal operations at night. Meanwhile, the upper shutter is working more smoothly than anyone can recall, and night-time operations are going well.

In parallel, we took advantage of the closed time to carry out essential maintenance on a wide variety of instruments and telescope systems. The work involved essentially all disciplines, from mechanical to instrumentation, and from electronics to software. We worked on all the following needs: maintenance of instrument optics, replacement of part of the mechanism for the Gemini Multi-Object Spectrograph on-instrument wavefront sensor, refurbishment of the Gemini Near-InfraRed Spectrometer cold heads and work on its filter wheel and focus mechanisms, and inspection of the helium hoses within the Cassegrain Rotator. We also carried out upgrades of various processors in the Enclosure Control System and made a lot of progress on our project to counter obsolescence in our real-time control systems.

Upgrading the Observatory Control Software

When it comes to observing (and preparing for observing), virtually everything Gemini and its users do relies on the Observatory Control Software (OCS) — most of which has been around for more than a decade and a half. The user software (Observing Tool and Phase I Tool, referred to as OT and PIT, respectively) are large Java packages that require users to download hundreds of megabytes per semester. New users find the organically-grown OT over-complex and opaque. Even more youthful items, such as the PIT (which was completely rewritten in 2012), have significant scope for improvement and better integration with other user tools, such as the integration time calculators.

At the business end, we store observation definitions in a very non-standard database, which does not scale well; it also feeds a "Sequence Executor" (which runs the telescope and instruments) written in TCL/TK — now essentially a dead and unsupportable language.

For all these reasons, and with the approach of Large Synoptic Survey Telescope (LSST) operations (and the likely sea of change in time-domain and transient astronomy that it will bring), the time has come to step back and rethink/redesign the OCS, and we've started a project to do that.

As the Observing Database (ODB) lies at the heart of it all, we made it an early candidate for replacement; we are now progressing on a modern Postgres SQL database design to replace the current bespoke database, and a new web-based Sequence Executor (seqexec) to go with it. Along with these changes, we're developing a new "sequence model" (which represents the detailed observing sequence within the OT), as the current model is overcomplicated and the source of many maintenance headaches.

We plan to deploy the new database with the new seqexec in early 2018; this will be usable with FLAMINGOS-2 and the Gemini Multi-Object Spectrograph, and may also enable some tests of on-the-fly scheduling typical of what the LSST will need once it becomes operational.

For proposal submission, observation preparation, and program monitoring, we anticipate a set of interconnected web-based tools to replace the current large downloadable packages. We will absolutely not simply

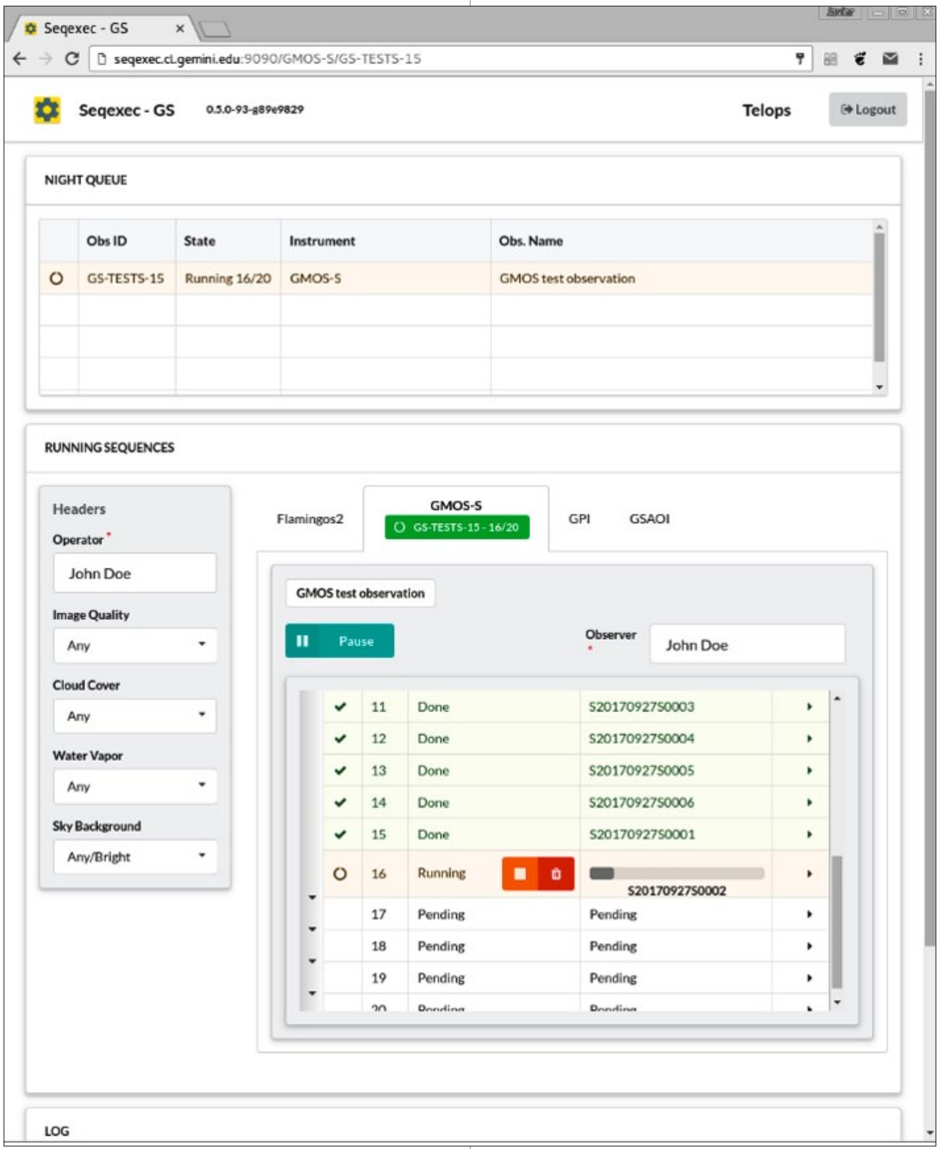


Figure 7.
The new seqexec, currently under development, running in a web browser.

take the existing tools and re-implement them on the web; we intend to take a full step back and have a clear view of requirements and usability before we even think about a line of code.

Therefore, we will be starting a working group to develop the high-level user requirements. The membership of this group will include Gemini staff, NGO representatives, and members of the user community. The working group will review all feedback we have had on the existing tools, discuss possible fundamental changes in approach, and make recommendations for top-level needs and requirements, with examples written as user stories.

Note that the fundamental change in the underlying infrastructure may also make possible some other changes, such as enabling Principal Investigators to request physical observing conditions (seeing, *etc.*) "on target" rather than by conditions percentiles.

What's the timescale for all this? A little hard to say given the scale of the work, but we hope to switch off the old OCS by the end of 2019. Meanwhile, there will be incremental releases of the various tools and facilities as they develop.

Announcing Gemini's New Chief Scientist John Blakeslee

As of the publication of this issue, John Blakeslee begins his duties as Gemini's new Chief Scientist. John comes to Gemini from the National Research Council's Herzberg Institute of Astrophysics, in Victoria, British Columbia, where he has served as an Astronomer and Senior Research Officer. Prior to that, he was a faculty member at Washington State University and a Research Scientist at Johns Hopkins University. He also held postdoctoral positions at the California Institute of Technology and Durham University in the UK. John earned his PhD from MIT in 1997, and has worked on a variety of research topics, including galaxy structure and evolution, supermassive black holes, the extragalactic distance scale, globular cluster populations, and data analysis pipelines.

John is very familiar with Gemini, and for the past several years has worked in Canada's National Gemini Office. In his capacity as Chief Scientist, John will be instrumental in setting and implementing Gemini's scientific goals and directions while working closely with our international user community from the Gemini South Base Facility in La Serena, Chile. Gemini's Interim Director Laura Ferrarese notes, "The remarkable breadth of John's scientific interests makes him ideally suited to lead Gemini's vision into the next decade. We are all looking forward to welcoming him at Gemini and working together to further enhance the role our Observatory will play in the years to come."

A gigantic "sprite" captured by one of the Gemini North cloud cams facing north towards Waimea during a thunderstorm in late July.
Image Source: Gemini Observatory/AURA. Image processing by Steve Cullen ([www.stevecullenphotography.com)](http://www.stevecullenphotography.com)

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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