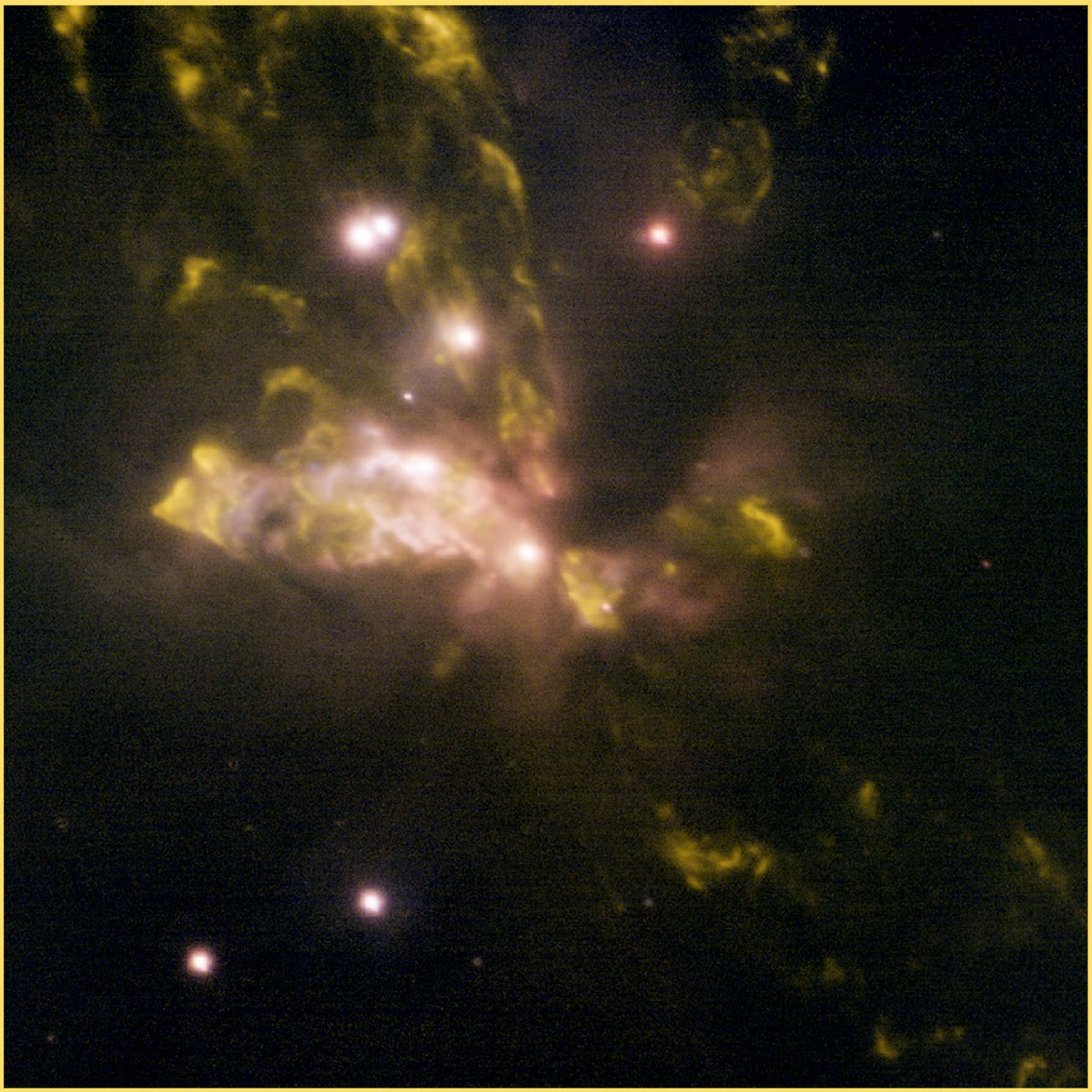
Publication of the Gemini Observatory

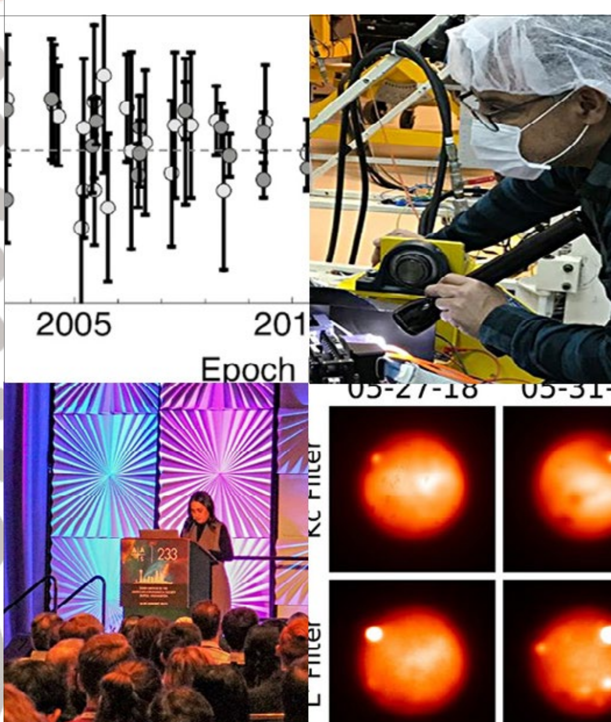
GeminiFocus



October 2019

ON THE COVER:

Gemini North / NIRI infrared image of NGC 2071-IR at the core of one of the nearest star-forming clouds to the Sun. Two recently retired Gemini staff members utilized Gemini North to capture this tantalizing view, which is the sharpest composite image of the region to date. The story behind the image appears in this issue starting on page 4.



*Gemini*Focus October 2019

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Director's Message

New Arrivals, Conflict, and the Road Ahead

I'm excited to report the October 1st official launch of the National Science Foundation's (NSF's) National Optical-Infrared Astronomy Research Laboratory! Gemini Observatory will join with the Large Synoptic Survey Telescope (LSST) operations and Cerro Tololo Inter-American Observatory, Kitt Peak National Observatory, and the Community Science and Data Center, to create a new center for NSF's ground-based optical/infrared astronomy observations and data services. I'm equally pleased to welcome Patrick McCarthy as our new Director of the National Optical-Infrared Astronomy Research Laboratory. Pat comes to the position after serving as Vice President of the Giant Magellan Telescope Organization and an astronomer at the Carnegie Institution for Science. We are very fortunate to have Pat's excellent leadership and scientific experience as we move forward into this new era. Pat is enthusiastic about working with Gemini and our international Partnership.

We should also welcome a new visitor to our Solar System — 2I/Borisov, the second confirmed interstellar object and first observed interstellar comet, discovered by amateur astronomer Gennady Borisov on August 30, 2019. On the night of September 9-10, the Gemini Multi-Object Spectrograph (GMOS) at the Gemini North telescope was able to capture multi-color images of the comet and its tail for a Director's Discretionary Time program led by Piotr Guzik at the Jagiellonian University in Kraków, Poland. Estimates of 2I/Borisov's orbital path predict that it is on its way into our Solar System, and will continue to brighten over the coming months. Needless to say, Gemini Observatory and astronomers around the world will be following its progress closely.

Fortunately, 2I/Borisov waited until Gemini's telescopes were back on-sky to make its appearance. For much of July and August, both Gemini North and Gemini South were offline due to planned engineering maintenance. At both telescopes, work included replacing parts of our helium cooling lines, maintenance on acquisition and guiding systems, and maintenance on the Cassegrain rotator systems. Instrument work included FLAMINGOS-2 at Gemini South, and GMOS, Altair, and the Gemini Near-InfraRed Spectrometer at Gemini North. Part of the MAROON-X team also joined our crew on Maunakea to install the instrument's Front End in preparation for its commissioning over the next few months.

Impact of Maunakea Conflict

Prior to the engineering shutdown, Gemini North had an unplanned four-week shutdown as a result of Thirty Meter Telescope protests blocking the Maunakea Access Road. Although we are glad to be back in operations now, that lost time resulted in a significant detrimental impact on the science of Gemini Observatory. Approximately two weeks of observing were lost during this time, impacting at least 11 different high-priority science programs which would have obtained data. The adversely affected science ranges from the Solar System to distant quasars, including four time-critical programs.

Two of these time-critical Gemini programs involved supporting observations for NASA's Juno mission at Jupiter; by the time these observations could be attempted again, Jupiter will no longer be favorably placed for ground-based observations. Additionally, we had planned to recoat our 8-meter primary mirror as part of our engineering shutdown; we decided to defer this activity until next year, which will take Gemini North offline for an additional week in 2020.

This has been an exceptionally challenging time for the Gemini North staff, our colleagues at the other Maunakea observatories, and for all those who live on the Big Island. It can be difficult to appreciate the nuances and various perspectives of all those directly impacted by the conflict on Maunakea, even for those who have lived most of their lives in Hawai'i. This is truly a community divided by different views about what is the best path forward for their future; the Gemini Observatory staff are part of that community and live this conflict every day. I'm grateful for our staff's continued dedication and professionalism, and for the time I've spent in Hawai'i supporting our staff and our mission. I am also incredibly proud of the work that Gemini does to provide opportunities and educational support to our local communities. I continue to hope for a peaceful resolution that recognizes the history of the Hawaiian people and the positive impact of Maunakea astronomy on the community of Hawai'i and the world.

Looking Ahead

Progress towards Gemini's revitalized instrument suite continues to march forward at a rapid pace. At the end of September, the NSF awarded AURA/Gemini Observatory the second half of the funding for a total of $26 million for the Gemini in the Era of Multi-Messenger Astronomy (GEMMA) program. The conceptual design for a state-of-the-art multi-conjugate adaptive optics (AO) system at Gemini North (GNAO) was reviewed by an external panel of experts in Hilo on September 26-27, an important milestone for the GEMMA program. The Request for Proposals to build the GNAO first light imager (GNAOI) was released in August, with a deadline on November 1st (***view here***).

The visiting Gemini InfraRed Multi-Object Spectrograph (GIRMOS) held its Conceptual Design Review in mid-September. Its instrument team, led by Suresh Sivanandam of the University of Toronto, is being funded through a Canadian Foundation for Innovation (CFI) award. All of these instruments are planned for delivery at Gemini North in 2024-2025.

Nearer term, the high-resolution capabilities at Gemini are set to expand dramatically in

2020. We are very pleased to announce the return of IGRINS as a long-term visiting near-infrared high-resolution spectrograph at Gemini South, available starting 2020A. Commissioning for the visiting instrument MAROON-X, a high-resolution high-stability optical spectrograph installed at Gemini North continues to go well. Finally, the National Research Council Canada-Herzberg's GHOST team has made substantial progress on the instrument's enclosure and achieved first light through the fibre cable, slit viewer, and spectrograph in July; GHOST is expected to be delivered to Gemini South in 2020. On the imaging side, work on the GeMS upgrade to its natural guide star sensor is making excellent progress, and is on-track for completion by the end of the year. This upgrade will open up significantly greater areas of the sky for multi-conjugate AO high-resolution imaging.

Engaging our Community and the World

In mid-September, I was invited to speak at the 61a. Reunión annual de la Asociación Argentina de Astronomía in Viedma, Argentina. Later that week, I visited the astronomy department at the Universidad Nacional de La Plata and the Ministerio de Educación, Cultura, Ciencia, y Tecnología. It was fantastic to speak directly with Gemini users in Argentina. I particularly enjoyed the Planetario Ciudad de La Plata's planetarium show featuring both the Gemini North and South telescopes.

More locally, Gemini's public outreach staff organized the *Journey Through the Universe* Next Generation Science Standards (NGSS) workshop held at 'Imiloa Astronomy Center on September 5-6. During this two-day workshop, over 60 K-12 teachers engaged in NGSS-aligned and astronomy-centered activities. Teachers were provided with the resources needed to take these activities back to their classrooms to use with their students. Gemini Observatory, in partnership with the Hawai'i State Department of Education (HIDOE), Maunakea Observatories, and Hawai'i Island business community have a long history of hosting the *Journey Through the Universe* program over the past 16 years.

Finally, I am looking forward to engaging with many of you at the 235th Meeting of the American Astronomical Society in Honolulu in January 2020. It should be a lively meeting, with a town hall to present the new National Optical-Infrared Astronomy Research Laboratory, a Gemini Observatory open house, and special sessions on Hawaiian culture and astronomy on Maunakea. Until then, wishing you all clear skies and unexpected discoveries!

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

A message from the editor

With the transition to Gemini's role in NSF's National Optical-Infrared Astronomy Research Laboratory, there will be changes in the format and scope of Gemini's newsletters in the immediate future. As part of this change we are also exploring ways that the Gemini partner countries can participate more directly in our communications products like *Gemini*Focus. We welcome ideas for future communications collaborations and content so please ***contact me via email*** with ideas, suggestions and feedback.

— Peter Michaud, Editor, *Gemini*Focus

Tom Geballe

NGC 2071-IR: A Who-dunnit Mystery

Two recently retired Gemini staff members (author Tom Geballe and Dolores Walther) have utilized Gemini North to obtain the sharpest composite infrared images ever of the chaotic core of one of the nearest star-forming clouds. These images, combined with key infrared spectral signatures of two of the embedded protostars, are helping astronomers determine the causes of the mayhem.

Star formation can be a messy process. When gravity causes a portion of a calm interstellar gas cloud to collapse, and a star is born, some of that infalling gas is violently blown back into the surrounding cloud, disrupting much of it. In the process, small portions of the cloud are briefly shock-heated to temperatures of thousands of degrees.

If only a single protostar at a time is engaged in this destructive activity, astronomers can usually identify it. But when more than one protostar in a cloud is doing this at the same time, understanding what is going on, including determining which protostars are responsible for which parts of the disruption, is a challenge.

Such is the case with one of the nearest star-forming clouds to the Sun, NGC 2071. The core of this cloud, known as NGC 2071-IR because of its bright infrared emission, has long fascinated Dolores Walther, who retired in 2017 as head of Gemini North's crew of Science Operations Specialists.

Walther had always wanted to use Gemini and its powerful infrared instruments to get a better look at NGC 2071-IR and solve some of its mysteries. I joined in the study and co-published the results with her in the ***April 20, 2019, issue of The Astrophysical Journal***.

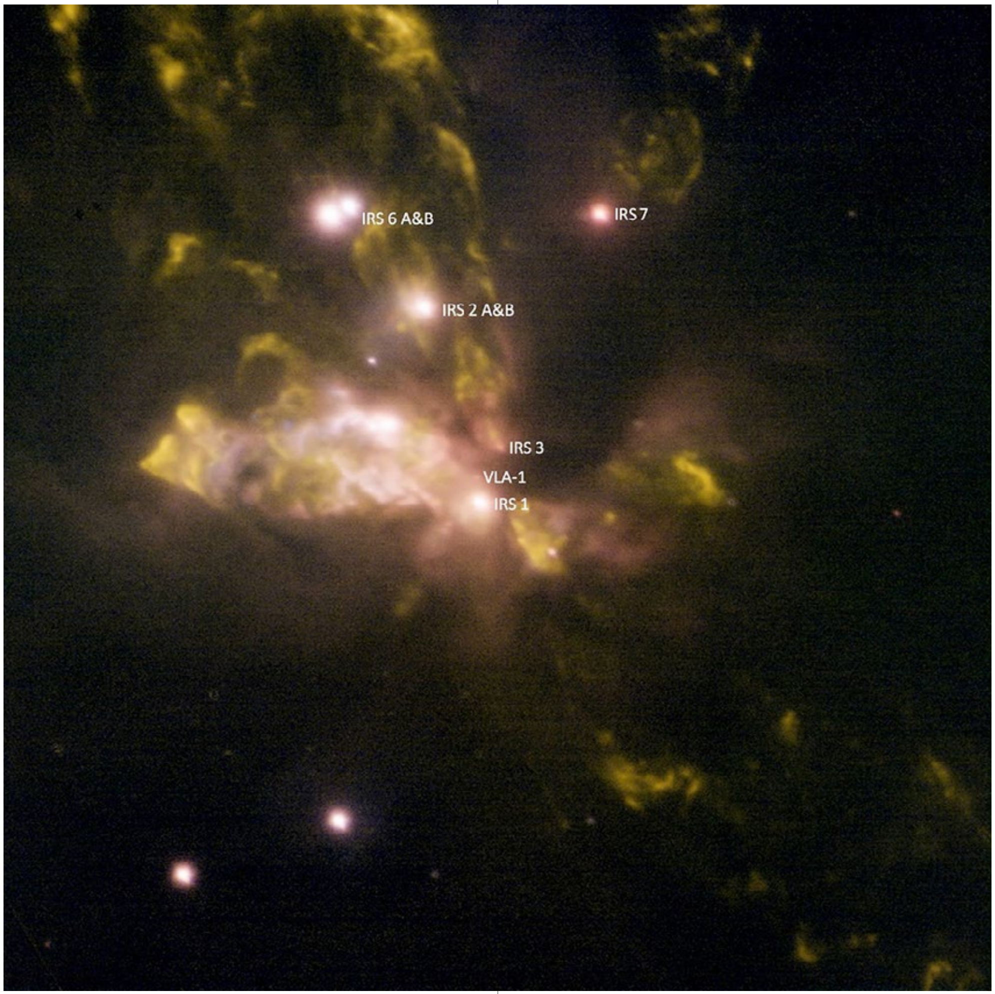

Figure 1.
Gemini North / NIRI infrared image of NGC 2071-IR in the combined light of the broad J, H, and K filters and a narrow band filter at the wavelength of a line of shock-excited molecular hydrogen (H_2). The resolution of the image is ~0.40", at least three times higher than any previously obtained images of the region. The field of view is 2′ x 2′. North is up and East is to the left. Most of the finely structured emission is from H_2, while the more smoothly distributed emission is the combined light of H_2 and starlight scattered off of dust particles. Identified protostars have been labelled.

Color composite image created by Gemini Science Operations Specialist Jennifer Miller.

To help identify the young culprits responsible for disrupting the core of NGC 2071, Walther and I used the Gemini North Near-infrared Imager (NIRI) and Spectrograph (GNIRS) in 2017 and 2018 to dig deeper into the complex region. Figure 1 shows our results — the sharpest composite infrared image ever obtained of the region. We combined images taken individually through several filters — one of which was sensitive to the emission of hot molecular hydrogen (H_2). Putting them together created a coherent picture.

Stars, light from glowing gas, and light reflected off of dust particles are readily apparent in the image. The complex V-shaped structure extending from the center of the image toward the upper left, whose left arm extends across the positions of IRS 2 A&B and IRS 6 A&B, is emitted by shock-heated molecular hydrogen, where gas ejected from a protostar is colliding with quiescent gas in the surrounding cloud. A fainter V extension can be seen at lower right. Both extend far beyond the edges of the image. Such "bipolar outflows" of gas are commonly observed from stars accreting material from their natal clouds.

While it was originally supposed that IRS 1, by far the most luminous and likely the most massive protostar in NGC 2071-IR, was generating this bipolar outflow, these new data, along with radio and infrared observations published by other scientists, strongly suggest that the less luminous IRS 3 is the culprit.

To the left of the center of the image lies the brightest region of H_2 line emission in NGC 2071-IR, which others had recently suggested might be associated with IRS 1. In our paper, Walther and I concur with this suggestion. In addition, we propose that the rather compact and amorphous appearance of this region is due to the outflow of material being directed almost exactly toward the Sun.

The Gemini image gives us a view somewhat akin to looking down the barrel of a cannon that has just been fired.

We also captured the most detailed infrared spectra ever obtained of IRS 1, the bright fuzzy object at the middle of the image, and IRS 3, the much fainter object located close to IRS 1, just to its upper right. The emission lines of atomic and molecular hydrogen, ionized iron, and hot carbon monoxide that we found in their spectra attest to both stars generating intense outflowing winds.

Other protostars within NGC 2071-IR could also be producing outflows that are disrupting the cloud. If we are correct, NGC 2071-IR may be generating more outflows simultaneously than any cloud core in the solar neighborhood. However, spectra do not exist of most of the other stars in Figure 1.

We are hoping to be granted additional time to obtain infrared spectra of all of them. A crude spectrum of IRS 7, located far from IRS 1 and IRS 3, that we obtained 30 years ago, shows strong evidence of outflow activity. One especially mysterious source, detected in the infrared for the first time by NIRI, but found earlier at radio wavelengths by the Very Large Array (in New Mexico) and dubbed VLA-1, shows signs of activity at radio wavelengths. Located between IRS 1 and IRS 3, but apparently much more deeply buried in the star-forming cloud than either of them, it may be an important key to understanding the entire region.

Identifying all of the active protostars within NGC 2071-IR will allow us to complete the picture of how these violent activities are sculpting the surrounding cloud. The active ones not only could be preventing more stars from forming, but also could be disrupting the abilities of other younger protostars to collect nearby gas, placing limits on how massive they can become. Walther and I hope that additional spectra will give a clearer understanding of the activities within this fascinating cloud.

For additional details see Walther, D. M., and Geballe, T. R., *The Astrophysical Journal*, **875:** 153, 2019, or *arXiv* 1903.03583

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Rachel Matson and Andy Stephens

Speckle Imaging Takes Gemini to Its Diffraction Limit

For nearly a decade, speckle imaging at Gemini Observatory has produced an abundance of notable results, including a monumental breakthrough in exoplanet research in binary star systems. Now with the recent addition of an innovative pair of powerful high-resolution speckle instruments to permanently reside at Gemini North and South, the Observatory stands on the forefront of high-resolution ground-based exploration.

Recently our team at the NASA Ames Research Center authored a high-impact journal article that featured key Gemini data on the transit by a giant exoplanet of one of the components of the Kepler-13AB binary star system. system. This study, led by Steve Howell, not only classified the Jupiter-sized exoplanet (Kepler-13b) in this close binary system but, in a first for ground-based imaging, conclusively determined which star the planet orbits. The Gemini press release on our finding is reprinted starting on page 10 of this issue, and *The Astronomical Journal* paper is available ***here***.

To execute this type of diffraction-limited science and uncover the hidden secrets of close exoplanet binary star systems, in which about one half of all exoplanets reside, our team designed under Howell's leadership an innovative pair of twin instruments that perform high-resolution "speckle imaging" — collecting a thousand 60-millisecond exposures every minute; after processing this large amount of data, the final images are free of the adverse effects of atmospheric turbulence which can bloat, blur, and distort star images.

Our team aptly named the two permanently mounted instruments Zorro and 'Alopeke, which come from the Spanish and Hawaiian (respectively) words for fox — because the instruments are both speedy and sly like foxes. The instruments were built to take advantage

The 'Alopeke/Zorro team preparing for instrument installation.
Credit: Alison Peck

of innovation and crafty approaches to problems with only a fraction of the resources necessary for most 8-meter-class telescope instruments.

The power of these instruments was demonstrated when Howell and his team used 'Alopeke to probe the Kepler-13AB system. 'Alopeke sharply resolved the two stars (Kepler A and B), and captured a clear drop in the light from Kepler A, proving that the planet orbits the brighter of the two stars. Moreover, as 'Alopeke simultaneously provides data at both red and blue wavelengths, the researchers could see that the dip in the star's blue light was about twice as deep as the dip seen in red light.

As a very extended atmosphere would more effectively block light at blue wavelengths, the researchers characterize Kepler-13b as a Jupiter-like gas-giant exoplanet with a "puffed up" atmosphere due to exposure to the tremendous radiation from its host star; Thus, these multi-color speckle observations give us a first tantalizing glimpse into the appearance of this distant world orbiting a star in a binary system — something we know very little about.

Our work with Kepler-13b stands as a model for future research on exoplanets in multiple star systems. The observations highlight the ability of high-resolution imaging with large telescopes like Gemini, not only to assess which stars with planets are in binaries, but also robustly determine which of the stars the exoplanet orbits.

The Rise and Promise of Speckle Imaging at Gemini

Speckle imaging at Gemini began in 2012 when the Differential Speckle Survey Instrument (DSSI; designed by Elliott Horch) came to the Observatory as a visiting instrument. This precursor to 'Alopeke and Zorro was granted 10 hours on Gemini North to observe high-priority planet candidates from NASA's (now-retired) Kepler mission, whose prime objective was to explore the structure and diversity of exoplanetary systems, including estimating how many planets there are in multiple-star systems.

To search for planets around other stars, the *Kepler Space Telescope* would stare at thousands of stars and look for a slight decrease in brightness, indicating that a planet had transited (crossed in front of) the star as viewed from Earth. While the transit method is very successful at finding planets, other phenomena can mimic the signature of a planet. Because of this, other methods must be used to confirm whether a planet caused the star's dimming.

High-resolution speckle imaging enables astronomers to not only resolve other objects near the star hosting the planet candidate, but detect or rule out other, non-planetary objects that can cause a star's light to dim (speckle cannot see planets). This is achieved by employing statistical techniques to assess whether the observed dimming is likely to be a true transit by an orbiting planet or a “false positive.” Using this technique, the DSSI observations at Gemini North in 2012 helped confirm over a dozen planet candidates, including the five-planet system Kepler-67; DSSI would eventually provide more than 2,100 observations of Kepler planet candidate host stars.

Based on the success of DSSI, and the need to validate and characterize the 4,000 exoplanet candidates discovered to date by NASA’s *Kepler/K2 Space Telescope* and the *Transiting Exoplanet Survey Satellite (TESS),* Howell initiated the design of two new speckle instruments: ‘Alopeke and Zorro, which our team went on to build at NASA Ames Research Center. The twin instruments each use two electron-multiplying CCDs and combinations of narrow-band (40- to 50-namometer-wide) filters to provide simultaneous two-color diffraction-limited photometric and astrometric information at optical wavelengths.

Each instrument can also identify background objects and companion stars — to within < 0.1 to 1.2 arcseconds of, and up to 10 magnitudes fainter than, the exoplanet’s host star — that can contaminate exoplanet transit detections. For any detected companion, speckle imaging provides the position and separation from the host star, as well as color and contrast information that greatly reduces the likelihood of false positives and improves the estimates of the exoplanet size.

Zorro and ‘Alopeke: Specifics for Users

‘Alopeke and Zorro add great new capabilities, and having identical instruments on both Gemini telescopes allows collecting homogeneous datasets over the whole sky. The speckle mode provides diffraction-limited (0.016 arcsecond Full-Width at Half-Maximum at 500 nm and 0.025" at 800 nm) resolution imaging at optical wavelengths over a narrow field of view (~6 arcseconds). The wide-field mode provides high-sensitivity natural-seeing imaging with virtually no readout delay in the standard Sloan broadband filters over a moderate field of view (~60 arcseconds).

Both instruments are considered "permanent resident" visiting instruments, meaning they are available throughout the semesters for regular queue and Fast Turnaround proposals. This makes them great for programs that need simultaneous photometry in two filters, variability studies, and rapid events like occultations, which also benefit from the flexibility of Gemini’s queue scheduling.

Differential Speckle Imaging at Gemini

Some Science Highlights

Speckle imaging at Gemini Observatory is a forefront technology allowing researchers to push the limits of high-resolution imaging. The following science references provide

Speckle image reconstruction of Pluto and Charon obtained in visible light at 692 nanometers (red) with the Gemini North 8-meter telescope using the Differential Speckle Survey Instrument (DSSI). Resolution of the image is about 20 milliarcseconds average. This is the first speckle reconstructed image for Pluto and Charon from which astronomers obtained not only the separation and position angle for Charon, but also the diameters of the two bodies. North is up, east is to the left, and the image section shown here is 1.39 arcseconds across.
Credit: Gemini Observatory/NSF/NASA/AURA

a sampling of past successes while hinting at what is possible with these instruments.

- *Pluto + Charon imaging* (Howell *et al.*, 2012).
- *TRAPPIST-1* (Howell *et al.*, 2016)
- *Half of all exoplanet host stars are binary* (Matson *et al.*, 2018)
- Kepler-13AB: see press release page 10.

Other science being pursued:

- Ages of moving groups (and imaged planets in the moving groups) via dynamical mass determinations using Gemini speckle + GPI
- Light curves of white dwarfs
- Studying multiplicity of nearby M-dwarfs, massive stars, halo binaries, massive young stellar objects
- Deriving/improving mass-luminosity relationships for low-metallicity stars and M-dwarfs

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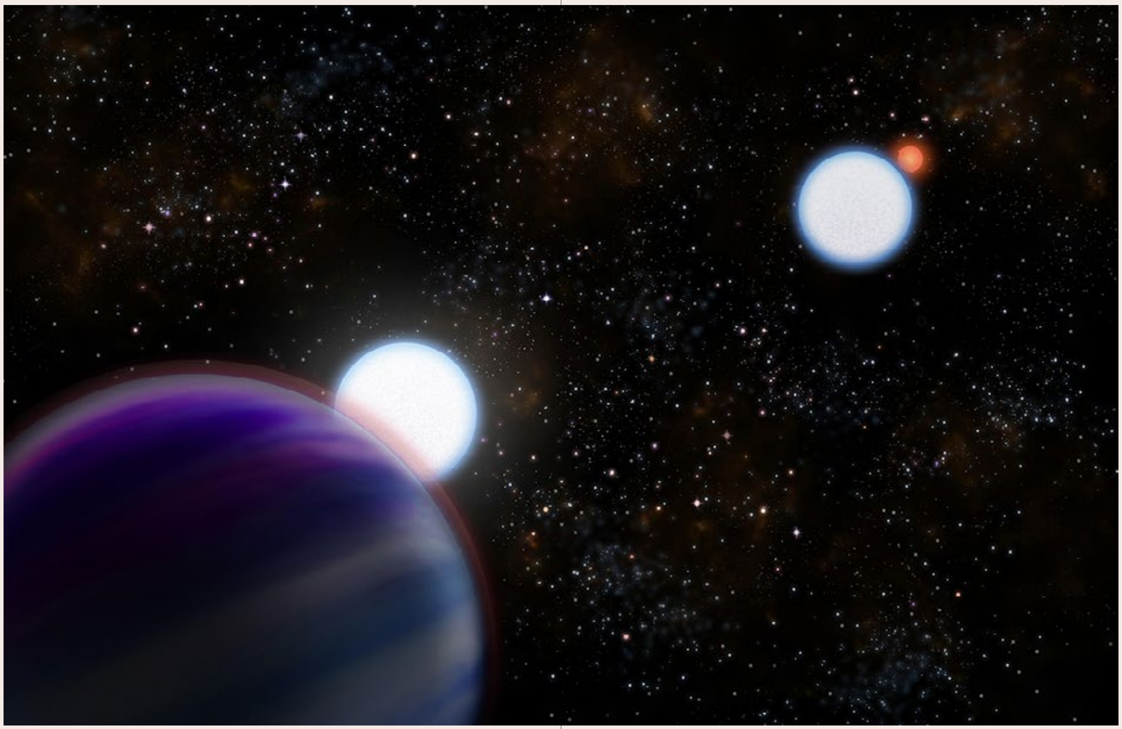
Exoplanets Can't Hide Their Secrets from Innovative New Instrument

A cunning new instrument at Gemini Observatory has achieved what was once thought impossible — namely, the characterization of an exoplanet orbiting a binary star and determining which star of the pair it orbits.

In an unprecedented feat, an American research team discovered hidden secrets of an elusive exoplanet using a powerful new instrument at the 8-meter Gemini North telescope on Maunakea in Hawai'i. The findings not only classify a Jupiter-sized exoplanet in a close binary star system, but also conclusively demonstrate, for the first time, which star the planet orbits.

The breakthrough occurred when Steve B. Howell of the NASA Ames Research Center and his team used a high-resolution imaging instrument of their design — named 'Alopeke (a contemporary Hawaiian word for Fox). The team observed exoplanet Kepler-13b as it passed in front of (transited) one of the stars in the Kepler-13AB binary star system some 2,000 light years distant. Prior to this attempt, the true nature of the exoplanet was a mystery.



Artist's conception of the Kepler-13AB binary star system as revealed by observations including the new Gemini Observatory data. The two stars (A and B) are large, massive bluish stars (center) with the transiting "hot Jupiter" (Kepler-13b) in the foreground (left corner). Star B and its low mass red dwarf companion star are seen in the background to the right.

Credit: Gemini Observatory/NSF/AURA/ Artwork by Joy Pollard

“There was confusion over Kepler-13b: was it a low-mass star or a hot Jupiter-like world? So we devised an experiment using the sly instrument ‘Alopeke,” Howell said. The research was recently published in *The Astronomical Journal*. "We monitored both stars, Kepler A and Kepler B, simultaneously while looking for any changes in brightness during the planet’s transit,” Howell explained. “To our pleasure, we not only solved the mystery, but also opened a window into a new era of exoplanet research.”

“This dual win has elevated the importance of instruments like ‘Alopeke in exoplanet research,” said Chris Davis of the National Science Foundation, one of Gemini’s sponsoring agencies. “The exquisite seeing and telescope abilities of Gemini Observatory, as well as the innovative ‘Alopeke instrument made this discovery possible in merely four hours of observations."

‘Alopeke performs “speckle imaging,” collecting a thousand 60-millisecond exposures every minute. After processing this large amount of data, the final images are free of the adverse effects of atmospheric turbulence — which can bloat, blur, and distort star images.

“About one half of all exoplanets orbit a star residing in a binary system, yet, until now, we were at a loss to robustly determine which star hosts the planet,” said Howell.

The team’s analysis revealed a clear drop in the light from Kepler A, proving that the planet orbits the brighter of the two stars. Moreover, ‘Alopeke simultaneously provides data at both red and blue wavelengths, an unusual capability for speckle imagers. Comparing the red and blue data, the researchers were surprised to discover that the dip in the star’s blue light was about twice as deep as the dip seen in red light. This can be explained by a hot exoplanet with a very extended atmosphere, which more effectively blocks the light at blue wavelengths. Thus, these multi-color speckle observations give a tantalizing glimpse into the appearance of this distant world.

Early observations once pointed to the transiting object being either a low-mass star or a brown dwarf (an object somewhere between the heaviest planets and the lightest stars). But Howell and his team's research almost certainly shows the object to be a Jupiter-like gas-giant exoplanet with a "puffed up" atmosphere due to exposure to the tremendous radiation from its host star.

'Alopeke has an identical twin at the Gemini South telescope in Chile, named Zorro, which is the word for fox in Spanish. Like 'Alopeke, Zorro is capable of speckle imaging in both blue and red wavelengths. The presence of these instruments in both hemispheres allows Gemini Observatory to resolve the thousands of exoplanets known to be in multiple star systems.

"Speckle imaging is experiencing a renaissance with technology like fast, low noise detectors becoming more easily available," said team member and 'Alopeke instrument scientist Andrew Stephens at the Gemini North telescope. "Combined with Gemini's large primary mirror, 'Alopeke has real potential to make even more significant exoplanet discoveries by adding another dimension to the search."

First proposed by French astronomer Antoine Labeyrie in 1970, speckle imaging is based on the idea that atmospheric turbulence can be "frozen" when obtaining very short exposures. In these short exposures, stars look like collections of little spots, or speckles, where each of these speckles has the size of the telescope's optimal limit of resolution. When taking many exposures, and using a clever mathematical approach, these speckles can be reconstructed to form the true image of the source, removing the effect of atmospheric turbulence. The result is the highest-quality image that a telescope can produce, effectively obtaining space-based resolution from the ground — making these instruments superb probes of extrasolar environments that may harbor planets.

The discovery of planets orbiting other stars has changed the view of our place in the Universe. Space missions like NASA's Kepler/K2 Space Telescope and the Transiting Exoplanet Survey Satellite (TESS) have revealed that there are twice as many planets orbiting stars in the sky than there are stars visible to the unaided eyes; to date the total discovery count hovers around 4,000. While these telescopes detect exoplanets by looking for tiny dips in the brightness of a star when a planet crosses in front of it, they have their limits.

"These missions observe large fields of view containing hundreds of thousands of stars, so they don't have the fine spatial resolution necessary to probe deeper," Howell said. "One of the major discoveries of exoplanet research is that about one-half of all exoplanets orbit stars that reside in binary systems. Making sense of these complex systems requires technologies that can conduct time sensitive observations and investigate the finer details with exceptional clarity."

"Our work with Kepler-13b stands as a model for future research of exoplanets in multiple star systems," Howell continued. "The observations highlight the ability of high-resolution imaging with powerful telescopes like Gemini to not only assess which stars with planets are in binaries, but also robustly determine which of the stars the exoplanet orbits."

John Blakeslee

Science Highlights

GMOS-North gets a first colorful glimpse of interstellar Comet Borisov barreling down on our Solar System; five years of NIRI AO observations uncover perplexing patterns in Io's volcanism; and daredevil star swings by the Galaxy's supermassive black hole, secure in the path mapped out by General Relativity.

Comet 2I/Borisov Breezes Through Solar System, Tail Streaming Behind

It was in October 2017, just days after this writer joined Gemini, that the first interstellar object, later designated 1I/'Oumuamua, was spotted making its expeditious escape from our Solar System. Observations by Gemini and many other observatories demonstrated that 'Oumuamua was surprisingly asteroidal in nature, with no apparent coma or tail. Moreover, judging from the dramatic variations in its light curve, this first interstellar visitor had an unusually large axis ratio, perhaps 10:1, suggesting that it may be a scattered shard from a violent collision that ejected the object long ago from its home planetary system.

Now, less than two years later, a second interstellar emissary has arrived from the direction of Cassiopeia, and it bears strikingly little resemblance to the first. If the stars are trying to tell us something, their message is inconsistent. The new object was discovered by the Crimean amateur astronomer Gennady Borisov on August 30, 2019, using a 65-centimeter telescope that he built himself. Subsequent observations have shown that its orbital eccentricity with respect to the Sun exceeds 3.3 (eccentricities above 1.0 correspond to unbound hyperbolic orbits; 'Oumuamua had an eccentricity of 1.20). Popularly known as "Comet Borisov" (even though the amateur has discovered seven other, more conventional, comets), the object received the official interstellar designation ***2I/Borisov*** from the International Astronomical Union on September 24, 2019.

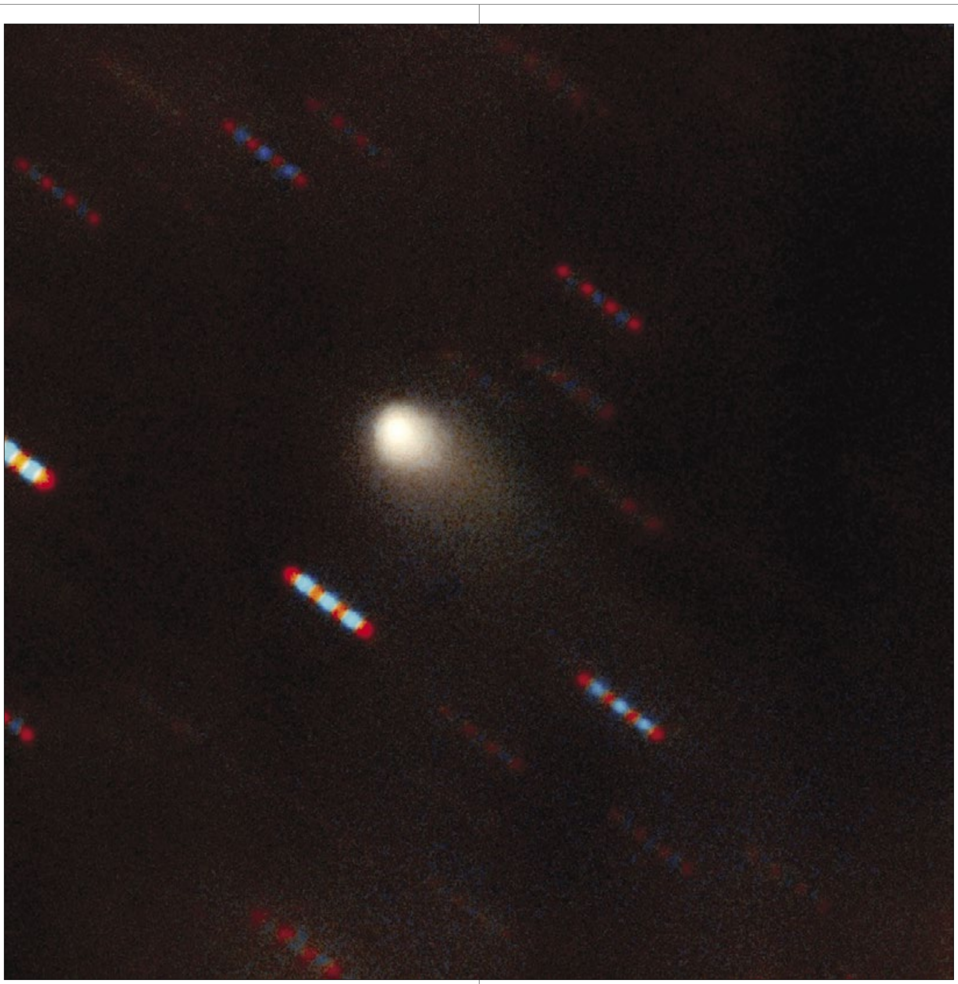


Figure 1. *GMOS-North g,r composite color image of the interstellar comet 2I/Borisov, obtained in morning twilight on September 10, 2019, at a mean elevation of less than 30° from the eastern horizon. The alternating red-blue streaks are background stars that appear trailed because the telescope was tracking the comet, which was moving non-sidereally at a rate of 75 arcseconds per hour. The comet was 3.4 au from the Earth at the time of these observations.*

Gemini Observatory was first alerted to 2I/Borisov by a Director's Discretionary Time (DDT) proposal received on the evening of September 9th, when the object was in the northern sky at a distance of 3.4 astronomical units (au) from the Earth and within 43 degrees of the Sun. Following careful review, the proposal was found to be compelling, with Gemini's large aperture being well suited for investigating possible cometary activity during the brief visibility window at the end of the night. Consequently, multi-band imaging observations with the Gemini Multi-Object Spectrograph (GMOS) on Gemini North were obtained during morning twilight, less than 12 hours after the proposal was submitted. Figure 1 displays the resulting composite color image; an extended coma and cometary tail are clearly visible. This makes 2I/Borisov the first known interstellar comet.

A study based on these Gemini North observations, with supplementary data from the William Herschel Telescope on La Palma, finds that 2I/Borisov appears quite similar to typical Solar System comets in terms of photometric color and its derived dust particle properties. Graduate student Piotr Guzik of Jagiellonian University in Poland led the study, which is currently in press at *Nature Astronomy* (a ***preprint*** is available online). The object's g-r color is only slightly redder than average for comets, and the estimated diameter of 2 km for the comet's nucelus, while highly uncertain, is well within the normal cometary range. In light of 'Oumuamua's anomalies, the apparent banality of 2I/Borisov is in itself remarkable.

The observational study of this second interstellar interloper has only just begun. Additional Gemini observations have already been obtained, and more are currently scheduled in the queue. 2I/Borisov is entering the Solar System from "above," and its visibility will gradually improve as it crosses the celestial equator in mid-November and moves towards a perihelion distance of 2.0 au, near the inner edge of the Asteroid Belt, on December 8th. It reaches a minimum distance of 1.9 au from the Earth in late December, and will continue to be visible from the Southern Hemisphere for much of next year. Thus, Gemini's access to the entire sky will enable detailed study of 2I/Borisov throughout the entire course of its visit – we are sure to have more highlights on this first interstellar comet before it leaves our corner of the Galaxy forever.

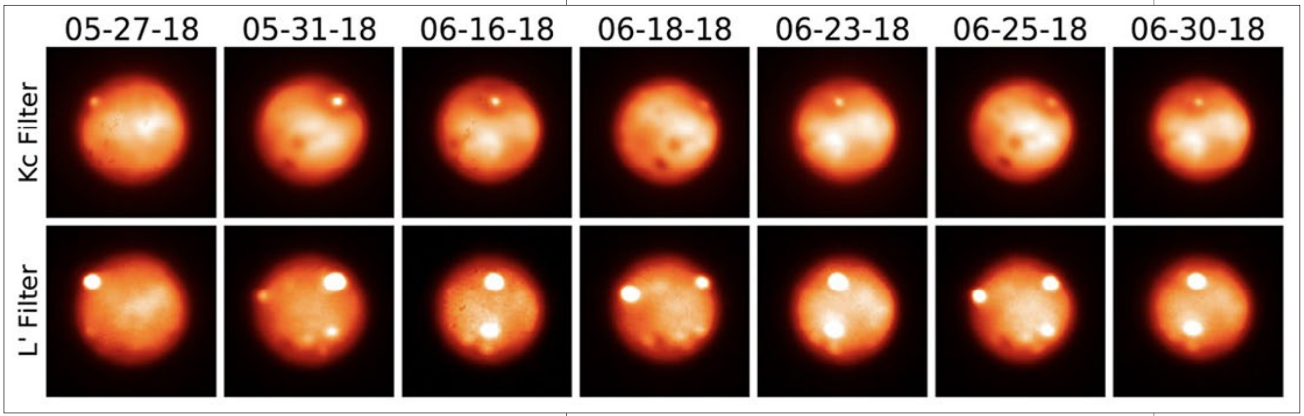
Probing for Patterns in Io's Volcanoes Using Adaptive Optics

Ever since the *Voyager* spacecrafts revealed the rampant volcanism on Jupiter's innermost large moon Io, planetary scientists have been puzzling over the variations in the timing and intensities of the splotchy satellite's many eruptions. Intense tidal heating, the stretching and squeezing of Io's crust as it follows its 1.8-day elliptical orbit around the giant planet, supplies the energy to melt interior silicates and produce magma, which eventually erupts to the surface. However, the variations in the volcanic activity generally occur on longer timescales, uncorrelated with the orbital period. This contrasts with the case for other tidally heated moons such as Saturn's Enceladus, for which the degree of activity varies predictably with its distance from the planet. Although Io and Enceladus have very similar orbital eccentricities and periods, a key difference is the viscosity of the erupting fluid, which is water on Enceladus and magma for Io.

To understand what drives the variations in the volcanism on Io, a team of astronomers led by Katherine de Kleer of the California Institute of Technology has analyzed the most detailed data set on the moon's volcanic activity to date. The observations were collected on 271 nights between August 2013 and July 2018 using the Near InfraRed Imager (NIRI) on Gemini North with the ALTAIR adaptive optics system in natural guide star (NGS) mode and the Near InfraRed Camera 2 (NIRC2) on the Keck II telescope, also using NGS adaptive optics. The Gemini/NIRI data comprise 80% of the total visits; example NIRI images are shown in Figure 2. The study has been published in [*The Astronomical Journal*] and featured in [*The New York Times*].

In total, the team has detected at least 75 unique hot spots of volcanic activity. The most active volcano, known as Loki Patera, was detected 113 times during the five-year campaign, essentially every time it was visible. Three other hot spots were each detected at least 80 times. Loki Patera appears to be erupting continuously, but its brightness in the near-infrared varies by more than an

Figure 2.
AO-assisted near-infrared images taken with NIRI on Gemini North of Jupiter's moon Io, showing the eruption of Isum Patera in May-June 2018. Isum Patera is the only bright spot visible in these Kc (2.27 μm) images; it is seen at the corresponding locations in the L′ (3.78 μm) images. The bright spot south of Isum Patera in the L′ images is Marduk Fluctus. [Figure reproduced from de Kleer et al., The Astronomical Journal, **158:** *29, 2019.]*



order of magnitude. This large data set enabled the team to uncover surprising patterns in Io's volcanic activity. For instance, of the 18 sites with the brightest eruptions, 16 are on the trailing hemisphere with respect to Io's orbital motion. This tendency remains unexplained; the likelihood of it occurring from a random spatial distribution is much less than 1%.

In a companion paper published in [***Geophysical Research Letters***](), de Kleer and colleagues show that the roughly 500-day variations in the intensity of Loki Patera's activity may be related to periodic changes in the shape of the moon's orbit. Regular gravitational perturbations from Europa and Ganymede, which respectively have 2:1 and 4:1 orbital resonances with Io, prevent the inner moon's orbit from circularizing. Instead, Io's eccentricity and semimajor axis vary cyclically with periods of 480 and 460 days, respectively. This evolution in Io's orbit is consistent with the timescale of the quasi-periodic behavior of Loki Patera.

At first, this link between orbital evolution and volcanic activity may seem surprising, since the range in the tidal stresses over a single orbit is larger than the variation in the mean tides resulting from the change in orbital shape. However, the researchers note that while magma is likely too viscous to change its flow significantly on the timescale of one orbit, it can adjust its flow over the longer period associated with the change in Io's orbital shape. If there is a connection, the peak in activity should coincide with the time of maximum orbital eccentricity, and the data confirm that this is indeed the case. Higher cadence observations are needed to test this hypothesis and rule out shorter period drivers of Loki Patera's variability.

Three Maunakea Observatories Track Relativistic Star around a Black Hole

If Einstein were alive today, he might be one of the few people tired of actually winning. Setting aside his long quarrel with quantum mechanics and all that business about a unified field theory, his formulation of General Relativity (GR) has proven to be one of the most successful descriptions of nature ever proposed. From the deflection of starlight in 1919 to the detection of gravitational waves in 2015, Einstein's General Relativity has triumphed over every observational test to date. Now a team of researchers led by Andrea Ghez at the University of California Los Angeles has tested GR in a new regime, the strong gravitational field near a supermassive black hole. The result: chalk up another one for the iconic physicist.

Although simple conceptually, the test was incredibly exacting from a technical perspective. GR predicts that luminous objects in strong gravitational fields should exhibit relativistic redshifts. This means that a star moving towards us in the vi-

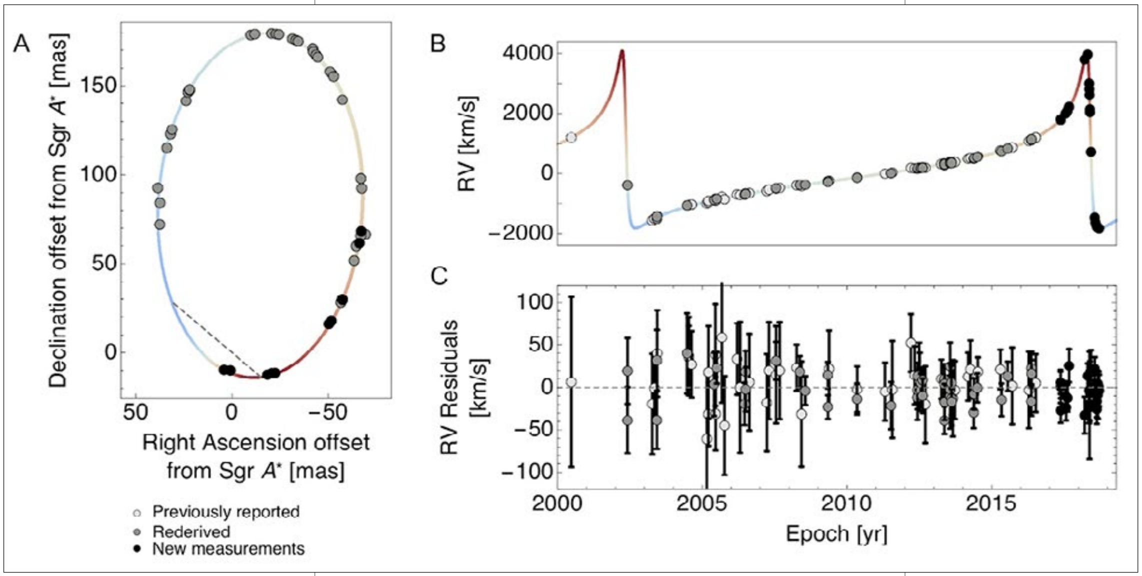


Figure 3.
Panel A: Astrometric measurements the star S0-2 over its 16-year orbit of the supermassive black hole at the center of the Milky Way, compared with the best-fitting projected General Relativistic orbit model. The black hole is located at the origin of the coordinate system, and the dashed line shows the intersection of the orbital plane with the plane of the sky. The black points represent new observations from 2017-2018, while the gray points are earlier measurements. Panel B: radial velocity measurements over the period 2000-2018 and the best-fitting model (colored curve). Open, gray, and black circles represent previous, rederived, and new measurements, respectively. Panel C: residuals from the best-fitting velocity model. [Figure adapted from Do et al., Science, **365:** *664, 2019.]*

cinity of a black hole should appear to have a smaller blueshift, and one moving away from us should have a larger redshift, than would be the case if the law of Newtonian gravity prevailed. In the most stringent test of this prediction to date, the team analyzed over two decades of astrometric and spectroscopic data, obtained using adaptive optics, on a star known as S0-2 as it followed its eccentric 16-year orbit around Sagittarius A* (Sag A*), the supermassive black hole at the center of our Galaxy. Figure 3 shows the full set of positional and velocity data.

The star reached its closest approach to Sag A* in May 2018, when it was at a distance of only 120 au and moving at 2.7% of the speed of light. During the critical months surrounding pericenter passage, the team used three different spectroscopic instruments at three different observatories, including the Near-infrared Integral Field Spectrometer (NIFS) on Gemini North, the OH-Suppressing InfraRed Imaging Spectrograph (OSIRIS) on the Keck II telescope, and the Infrared Camera and Spectrograph (IRCS) on the Subaru telescope. "The velocity of the star was changing quickly every night! So having all three observatories participate was essential," said Tuan Do (also of UCLA), the lead author of the study. Combining data from multiple instruments also allowed the team to carefully check for instrumental biases.

As shown in Figure 4, GR provides an accurate description of the star's positional and velocity data throughout its very large swing in velocity near its closest approach to Sag A*. In contrast, the observations rule out Newton's law of gravity with a high statistical significance. "The GR model is 43,000 times more likely than the Newtonian model in explaining the observations," the study concludes. The measurements also provide strong constraints on the black hole's distance and mass, 8.0 kiloparsecs and 4.0 million solar masses, respectively.

Of course, no one wins forever, and at some point, namely the event horizon of a black hole, GR must also fail. However, although S0-2 plunged precipitously near Sag A*, the minimum distance was roughly 1,000 times larger than the radius of the event horizon. Thus, it may be some time before observational limits encroach on the limits of GR's validity. Meanwhile, such observations continue to enlighten our understanding of the dynamics and evolution of the center of our Galaxy. The study appears in the journal ***Science***.

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

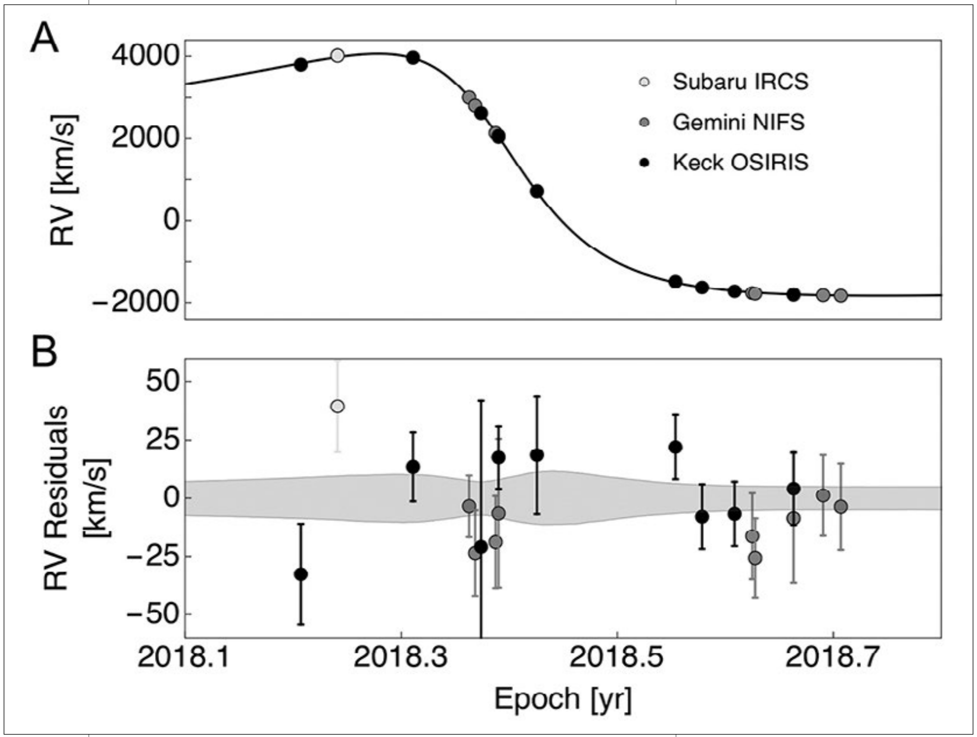
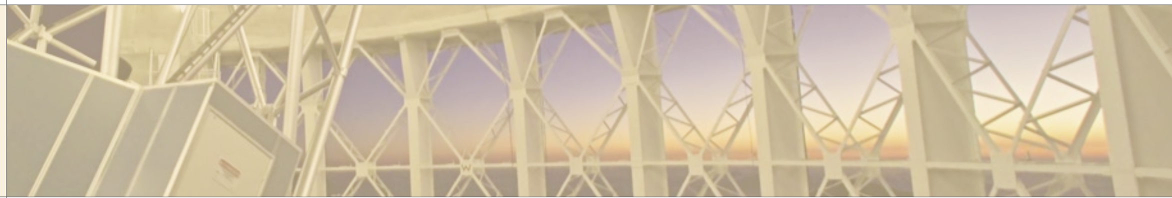


Figure 4.
Top: Zoom in on the radial velocity data from 2018, encompassing the maximum and minimum of the observed radial velocity. Measurements from the three different observatories are indicated; Gemini/NIFS and Keck/OSIRIS each provided nine measurements during this critical period, over which the observed velocity changed by 6,000 km/s. Bottom: radial velocity residuals with respect to the best-fitting General Relativistic model. [Figure from Do et al., Science, **365:** *664, 2019.]*



On the Horizon

The GHOST project nears completion of a major milestone. Gemini has released a Request for Proposals to design the Gemini North Adaptive Optics Imager. The instrument team of MAROON-X are in Hawai'i with Gemini staff preparing for commissioning. GIRMOS passes its Conceptual Design Review. IGRINS is slated to become available again in 2020. And join the excitement at the 20th Anniversary Gemini Science Meeting in Seoul, Korea.

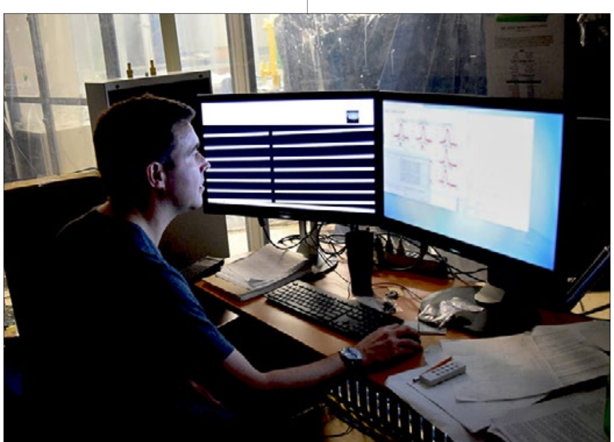


Figure 1 (top). *Alan McConnachie of HAA taking some test spectra with GHOST in the HAA integration lab.*

Credit: Scot Kleinman

Figure 2 (bottom). *Scott Roberts of HAA showing Telescope Scientist Tom Hayward of Gemini the impressive outer enclosure for GHOST.*

Credit: Scot Kleinman

GHOST: Project Build Phase Nearing Completion

The National Research Council Canada's Herzberg Astronomy and Astrophysics (HAA) Research Centre is in the final few weeks of the build phase for the Gemini High-resolution Optical SpecTrograph (GHOST). HAA staff fine-aligned the spectrograph optics and are now able to take test spectra (Figure1). The Australian Astronomical Optics (AAO) group at Macquarie University delivered the science fiber cable, slit view assembly, and associated electronics to the HAA in early July. Both groups, along with the Australian National University and Software Design Ideas, have been working together the past several months to integrate the various hardware, optics, electronics, and software into a functioning spectrograph (Figure 2).

Now that this major milestone is nearly complete, the combined teams expect to enter into the test phase in October. If all testing goes to plan, the team expects to ship shortly after the start of 2020 to Chile, where the AAO-built acquisition unit is ready to connect.

GNAOI Request for Proposals

Gemini Observatory announces an opportunity for the Gemini North Adaptive Optics Imager (GNAOI) — a planned instrument to be used with both the Gemini North multi-conjugate adaptive optics system (GNAO; which is now under development) and with a planned future ground layer adaptive optics system. We expect that this imager will be a low-cost low-risk design using a single HAWAII-4RG detector, and intend for GNAO to provide a 2-arcminute field of view with a Strehl ratio of no less than 30% over the entire field of view under median seeing conditions in K band. A Request for Proposals to design this imager has been released and is available on the ***Gemini website here***.

MAROON-X Deployed at Gemini North

MAROON-X, a new visiting high-resolution spectrograph at Gemini North (Figure 3), will be available to users in 2020. Constructed at the University of Chicago, MAROON-X is expected to be able to detect Earth-size planets in the habitable zones of mid- to late-M dwarfs using the radial velocity detection method.

The important wavelength range for the instrument is 700-900 nanometers and the resolving power approximately 80,000. To achieve this precision the instrument must be intrinsically stable and the optical setup fixed, so the entire instrument has been placed in a vacuum tank in a thermally stable enclosure, which the instrument team assembled in the Gemini North Pier Lab, four levels below the telescope. After a year of monitoring the temperature stability in the enclosure, commissioning the Front End (which mounts on the Instrument Support Structure and holds the optical fiber positioner), and integrating the spectrograph itself in the Gemini North Pier Lab, the team has begun commissioning. See a ***press release about MAROON-X*** available from the University of Chicago.

GIRMOS Conceptual Design Review a Success

The Gemini InfraRed Multi-Object Spectrograph (GIRMOS) is a powerful new visiting instrument being designed and built for the Gemini telescope by a Canadian consortium of universities led by the University of Toronto and HAA. This instrument will overcome a key limitation in existing adaptive optics (AO) facilities; where exisitng integral field spectrographs are designed to observe only single objects with adequate atmospheric correction, GIRMOS is being designed to have the ability to observe multiple sources simultaneously with high spatial resolution while obtaining spectra at the same time (Sivanandam *et al*., 2018).

GIRMOS accomplishes this by taking advantage of the latest developments in multi-object AO (MOAO) and integral field spectroscopy. It exploits the AO correction from both a telescope-based AO system (either GeMS or the prospective Gemini North AO system) and its own additional MOAO system that feeds multiple 1- to 2.4- micron integral field

Figure 3.
The MAROON-X instrument team and Gemini staff pose with the instrument, installed on Gemini North on September 23rd, and ready for first light. Although the Front End was successfully commissioned in December, now if you look closely, you can see the optical fiber that runs down to the spectrograph in the Gemini North Pier Lab below. Left to right: Paul McBride, John Randrup, Rody Kawaihae, Harlan Uehara, Eduardo Tapia (all Gemini staff), Andreas Seifahrt, David Kaspar, Julian Stuermer (all University of Chicago), and Alison Peck and John White (both Gemini staff).

Credit: Julian Stuermer

Figure 4.
GIRMOS PI Suresh Sivanandam (University of Toronto, Dunlap Institute; in shadow at the front of the room) presents the agenda to the Review Panel, project members, and participating Gemini staff at a GIRMOS Conceptual Design Review held at HAA in Victoria, British Columbia.

Credit: Marcin Sawicki (Saint Mary's University)

spectrographs (R = ~3,000 and 8,000) that can each observe an object independently within a 2-arcminute field of view.

GIRMOS is in the very early stages of development, and the team, led by Suresh Sivanandam (Principal Investigator; University of Toronto, Dunlap Institute) and Darren Erickson (Project Engineer; HAA), have been working extremely hard to complete a conceptual design for the instrument and to identify the resources needed to make the project a success. We are very happy to report that they passed their Conceptual Design Review on September 18, 2019, following a very exciting few days of presentations and discussions at the Dominion Astrophysical Observatory, in Victoria, British Columbia (Figure 4). We look forward to continuing to work with this great team as they move forward to the next stage of the project. Congratulations to the team!

Multiple Opportunities to Use IGRINS

You probably remember when the visiting Immersion GRating INfrared Spectrometer (IGRINS) came to Gemini South in 2018. This cross-dispersed near-IR spectrograph — with a resolving power of R = 45,000, covering the H and K windows (from 1.45 to 2.5 microns), in a single exposure, providing both broad spectral coverage and high spectral resolution — had a very high oversubscription rate. A large number of very impressive programs were observed, but even with the exceptional instrument team supporting 50 nights of observing, we were not able to fit in all of the great science that was proposed.

If you missed your chance to use IGRINS in 2018, never fear! We are delighted to announce that IGRINS will join us once again at Gemini South for several semesters, starting with 2020A. If you were not able to get your proposal in for the 20A deadline, don't despair, keep your eye out for IGRINS in the next several Calls for Proposals.

20th Anniversary Gemini Science Meeting

Gemini Observatory invites its international user community to Seoul, Korea, for a special 20th anniversary Gemini Science Meeting (GSM) celebrating 20 years of science operations and a look forward to even more exciting things to come. Hosted by the Partnership's newest member, the topics will include the latest scientific results from Gemini, news on current instrumentation projects, updates on operations developments, and lively discussion of Gemini's strategic plans for the coming decade. The GSM will take place June 21-25, 2020, followed by the K-GMT Users' Meeting on June 26th. (See poster, next page.) For information and updates, see the ***Gemini Science Meeting 2020 website***.


GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders
Gemini Observatory
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20th Anniversary and Beyond
Gemini Observatory invites its international user community to Seoul, Korea, for a celebration of 20 years of forefront access to the entire sky, and a preview of the even more exciting things to come. Hosted by the partnership's newest member, this special Science Meeting will feature the latest scientific results from Gemini, news on current instrumentation projects, updates on operations developments, fabulous dining, and lively discussion of Gemini's strategic plans for the coming decade.
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Ye Jin Kim
Peter Michaud
Heeyoung Oh
Ji Yeon Seok
Joanna Thomas-Osip
Soung-Chul Yang
SOC
Elliott Horch (Chair) ...Southern Connecticut State University
John Blakeslee ....Gemini Observatory
Xiaohui Fan ....University of Arizona
Denise Gonçalves .....Universidade Federal do Rio de Janeiro
Myungshin Im ....Seoul National University
JJ Kavelaars ....NRC Herzberg Astronomy & Astrophysics
Hwihyun Kim ....Gemini Observatory
Quinn Konopacky......University of California, San Diego
Jae-Joon Lee ....Korea Astronomy and Space Science Institute
Jennifer Lotz.............Gemini Observatory
Chung-Pei Ma ....University of California, Berkeley
Adam Muzzin............York University
Adam Riess ....Johns Hopkins University & STScI
Carlos Saffe..............Universidad Nacional de San Juan
Siyi Xu ....Gemini Observatory
Notes on background images: Cheomseongdae (left) is an astronomical observatory constructed in the 7th century (around 633) in Gyeongju, the capital of Korea under the Silla dynasty. Namsan Tower (right) is a modern edifice located near the conference venue on Namsan Mountain in Seoul.

Gemini staff contributions

News for Users

A successful maintenance shutdown occurs at Gemini North, while an unexpected shutdown of the Maunakea Access Road affected science at all the mountain's observatories. The annual shutdown at Gemini South goes as planned. And the Gemini Board approves the Observatory's Strategic Scientific Plan for the 2020s.

Maunakea Access and Gemini North Shutdown

On July 15th, protesters blocked the Maunakea Access Road in an effort to prevent Thirty Meter Telescope construction equipment from moving to the Maunakea Astronomy Precinct. This action quickly precipitated a protracted stoppage of all observing atop Maunakea, as observatories assessed the safety and reliability of access to the summit. By August 12th, we had received assurances of support from Law Enforcement and statements from the protestors of their intent to allow access for staff of the existing observatories. Combined with some improvements made to the "spur road" (a short segment of the old Saddle Road and a portion of a lava field) via which we now have to access the mountain, we returned to work on the planned maintenance shutdown (excluding coating of the primary mirror which has been deferred until next year). The maintenance was completed on August 30th, allowing a resumption of night-time observing and enabling the TEXES instrument to visit as scheduled. Access to the mountain remains intermittently compromised by conditions on the spur road in particular, but for now we are proceeding with operations.

Gemini South Annual Shutdown a Success

A successful annual shutdown at Gemini South ran from August 12th to August 27th. Accomplishments during this shutdown included replacement of the Cassegrain rotator encoder, repairs to the helium lines, and maintenance of the Acquisition and Guidance Unit. In the spirit of sharing resources ramping up to the National Science Foundation's Center for Optical-infrared Astronomy (NCOA), we had some excellent support from a few Cerro Tololo Inter-American Observatory technicians, doing cross-training and knowledge sharing and tightening relationships.

Figure 1.

Assistant Engineer Mariah Birchard (left) and Senior Electronic Technician Alejandro Gutiérrez (right), work on the maintenance of one of the modules of the Acquisition and Guiding Unit.

Credit: Manuel Paredes

Strategic Scientific Plan

The ***Strategic Scientific Plan*** (SSP), approved by the Gemini Board of Directors during their most recent meeting, outlines the scientific direction and activities of the Gemini Observatory in the 2020s. It also provides a timeline for the Observatory's major instrumentation and operations development efforts. The motivation for the SSP is to ensure that Gemini remains at the forefront of ground-based optical/IR astronomy and best serves the needs of our international user community throughout the coming decade. We encourage all of our users to have a look and see where Gemini is headed!

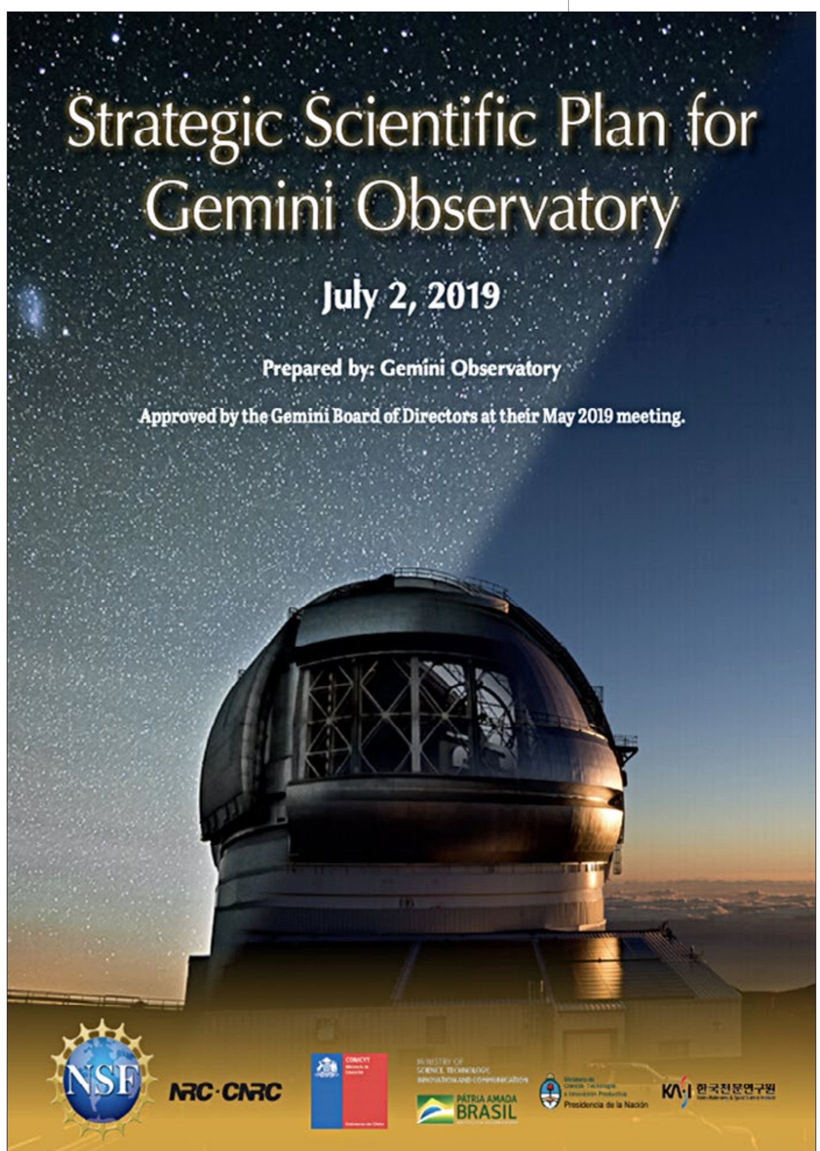

Figure 2.

Cover of Gemini's Strategic Scientific Plan, approved by the Gemini Board of Directors.

Alison Peck

Papa ‘Ōlelo Hawai‘i Kilohōkū*

Astronomers in Hawai‘i have long embraced Hawaiian culture and traditions, including finding ways to include them in the naming of astronomical discoveries. Now, through a new exciting program, hosted in part at Gemini Observatory, Observatory staff are on their way to better understanding the history and culture that shape the communities in which they live.

Figure 1.

Ka‘iu Kimura, Executive Director of ‘Imiloa, speaking to 2,000 astronomers and students at the January 2019 American Astronomical Society meeting in Seattle, Washington.

Credit: ‘Imiloa Astronomy Center

One of the many wonderful aspects of living in Hawai‘i is the strong sense of history and culture that makes these islands unique. Learning more about this culture and how it has shaped the communities we live in is an important goal for most observatory staff, whether they grew up here, have become long-term residents, or are making the most of a short-term position, like an internship or postdoctoral fellowship. In addition to everyday life in the community, we can see the ‘ano nui (importance) of Hawaiian culture through novel astronomy programs such as A Hua He Inoa, a Hawaiian phrase that refers to the practice of calling forth a name. This collaborative naming project, led by the ‘Imiloa Astronomy Center in Hilo, Hawai‘i, includes experts in Hawaiian culture, language, and astronomy and aims to weave traditional culture and practices into the process of officially naming astronomical discoveries. In January 2019, Ka‘iu Kimura, Executive Director of ‘Imiloa, was invited to give a lecture about the program at the January 2019 meeting of the American Astronomical Society in Seattle,

* *Hawaiian language lessons for astronomers*

Washington, which attracted an audience of more than 2,000 astronomers and students.

But not only astronomers work at the observatories, of course. There are engineers, technicians, librarians, accountants, educators and more, many of whom were born here in the islands. Many observatory staff have the opportunity to hear ʻōlelo Hawaiʻi (Hawaiian language) and oli (chants) through their children, who learn about important traditions and moʻolelo (stories) in school, but gaining a more in-depth knowledge and understanding requires a more concerted effort. That's why the ʻImiloa Astronomy Center recently joined forces with the University of Hawaiʻi at Hilo's (UHH) Ka Haka ʻUla O Keʻelikōlani College of Hawaiian Language to provide a weekly class on Hawaiian language and culture to staff from all observatories on Maunakea. The observatories paid the tuition for the 12 week course, and the participants purchased their own textbooks, which they kept after the classes finished.

The first class was a bit experimental, as it was difficult to gauge how many people would be able to attend the class every Friday lunchtime, and how many would be able to make time to watch the recordings and practice the lessons on their own if they were traveling or on a night shift. Nevertheless, participation was outstanding with over 100 staff from Maunakea Observatories and the UH Institute for Astronomy (both in Hilo and Mānoa on Oʻahu) registering, and attendance and enthusiasm remaining just as high throughout the semester.

In Hilo, the class met in the Lecture Hall at the Gemini North Base Facility, which is optimized for sound quality and ease of class participation. The class was streamed in realtime to sites in Waimea on the Big Island, Mānoa, and even one participant in Iowa, using videoconferencing technology that the observatories have in place to enable scientific collaboration. Although this undertaking was technically challenging at first, after a few learning experiences on the part of the organizers, the class was transmitted smoothly to all sites.

The organizers also recorded each class and made them available to all participants, so that they would not miss anything if they could not attend. This was all made possible by the outstanding skill of kumu (teacher) Kamalani Johnson (UHH), and his willingness to embrace not only the challenges of distance learning, but also an unusual set of haumāna (students) from all over the globe and all types of jobs, from scientific research and education, to engineering, computer support, and administration. With participants from diverse backgrounds, all levels of proficiency in ʻōlelo Hawaiʻi, and

Figure 2.

Maunakea observatory staff preparing for the Merrie Monarch parade in April. The Merrie Monarch is a week-long festival that honors the legacy of King David Kalākaua, who inspired the perpetuation of Hawaiian traditions, native language and arts.

Credit: East Asian Observatory

Figure 3.

Haumāna Alyssa Grace (left) and Jocelyn Ferrara (middle) present kumu Kamalani Johnson with a photo of the Maunakea observatories signed by several class participants.

Credit: Alison Peck (Gemini)

extremely varied personal and professional interests, one would expect that holding the attention of everyone in the class for 12 weeks would be a challenge. But Kamalani handled it with ease, dividing the class time between stories (legends, place names, traditions, hula) and grammar, vocabulary, and sentence structure.

Participants in the class said they looked forward to Friday lunchtime every week, and were quite sad when the course ended. We at Gemini Observatory are extremely grateful for kumu Kamalani Johnson and to Kaʻiu Kimura for their eagerness to lead this initiative, and especially for their willingness to work with the observatories on plans to continue providing these courses for observatory staff who are so grateful to have the opportunity to pursue their careers while also becoming more knowledgeable about the history and culture that shape the communities in which they are privileged to live and work.

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

Image of the Milky Way over Gemini South obtained as part of an all-sky movie shot and produced by Korean astrophotographer O Chul Kwon for Gemini.

NSF's National Optical-Infrared Astronomy Research Laboratory

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