The Mirror

Kitt Peak National Observatory returns to operations after the Contreras Fire.

Issue 4 | January 2023

NSF's NOIRLab

The Triangulum Galaxy, otherwise known as Messier 33, lies almost 3 million light-years from Earth and is a near neighbor of the Andromeda Galaxy. The galaxy is imaged here by the Nicholas U. Mayall 4-meter Telescope, located at Kitt Peak National Observatory (KPNO), a Program of NSF's NOIRLab. The Picture of the Week can be found here.

Credit: KPNO/NOIRLab/NSF/AURA

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On the Cover

A view of KPNO obtained in early December showing charred trees from the Contreras Fire in the foreground illuminated by a nearly full moon. The WIYN telescope is back on the sky in this image as KPNO facilities return to normal operations. See the article on page 20 of this issue for more information on the Contreras Fire. *Credit: KPNO/NOIRLab/NSF/AURA/R. Sparks*

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Director's Message

Patrick McCarthy

As we approach the end of 2022, we can look back at an eventful year — too eventful in many respects. A number of unplanned events, some under our control and some not, interrupted operations at one or another of our sites in 2022. Despite these challenges, the scientific output of our user community remains high and the impact of our facilities continues to grow. New instruments and new software will expand the power of NOIRLab, for new observations as well as analysis of archival data and cross-platform research.

Earlier this year Dennis Crabtree (NRC Herzberg Astronomy & Astrophysics) updated his assessment of the scientific impact of various telescopes. All of our large telescopes continue to rank highly, but the Blanco 4m telescope at CTIO stood out as the telescope with the highest fraction of high-impact papers, largely due to the Dark Energy Camera (DECam). Astro Data Lab is making it possible for the entire community to use the DECam archival data, and the range of science done with DECam continues to expand beyond the Dark Energy Survey, with high-impact programs in Solar System science, galactic structure, time-domain astronomy, and emission-line galaxies, to name but a few. Congratulations to the DECam team!

The publication rate for the International Gemini Observatory remains high, with little apparent impact from the pandemic and other challenges in Hawaiʻi and Chile. The steady stream of new instruments in the pipeline ensures that Gemini's impact will continue to grow throughout the decade. Many of the science highlights in 2022, particularly from Gemini, Blanco, and SOAR, come from the time domain. Rapid response to both targets of opportunity and novel ideas has enabled teams to conduct time-critical observations ranging from moving objects in the Solar System to distant quasars and GRBs. The ANTARES time-domain event broker is operating smoothly in collaboration with the LCOGT network as we build out our time-domain astronomy ecosystem in anticipation of the start of Rubin operations in late 2024.

NOIRLab conducted its first Lab-wide hiring campaign for science staff in 2021/2022. The result is an incoming class of ten scientists distributed across all sites. It is a highly diverse group of early career scientists that brings new energy and expertise to NOIRLab (see article on page 38 of this issue).

Climate change is here and it affects astronomy

Perhaps the most dramatic impact of climate change on astronomy is the increasing number of wildfires near observatories. As recent studies[1] have shown, wildfires became larger and more frequent since the 2000s. In June of this year, a wildfire swept through Arizona's Baboquivari Mountains, home to Kitt Peak National Observatory. As detailed in the article by Michelle Edwards et al. on page 20 of this issue of *The Mirror* (and the cover image), the fire destroyed a number of buildings on the mountain and damaged critical infrastructure. Thanks to heroic efforts by the firefighting crew, no scientific structures were significantly damaged. Six months on, however, we are still struggling to bring power, data, and roads back to pre-fire operational levels. Kitt Peak is not the first observatory to experience a wildfire: the tragic fire at Mt. Stromlo in Australia and fires at

[1] *Science Advances*, 16 March 2022, doi:10.1126/sciadv.abc0020

Mt. Graham, Mt. Wilson, and others are a sign that the threat of fire is more serious than ever, and that we must remain prepared.

Just a month after Kitt Peak had its near brush with disaster, a once-in-30-year snowstorm hit Cerro Tololo and Cerro Pachón, forcing the evacuation of both mountains and the loss of power for extended periods. Fast action by our facilities teams ensured that everyone was safe and that instruments were warmed in a controlled manner. In July we were in the unusual situation in which one of our sites was closed due to fire and another due to snow and ice.

At NOIRLab we are committed to doing our part to help combat climate change. The NOIRLab Sustainability Program guides our approach to reducing air travel, improving the efficiency of electrical appliances, phasing out fossil fuel vehicles, and most urgently, installing photovoltaic (PV) systems at our observatory sites. This year we began a project that will make Gemini South carbon neutral by installing an additional 800 kilowatts of PV power just off the summit at Cerro Pachón (see the article by Inger Jorgensen and Piero Anticona on page 17 of this issue). An NSF award supports the development of the solar power farm, and a proposal for a battery pack to support nighttime operations has been submitted. Construction will begin early next year.

Our Sustainability Program targets an overall CO_2 reduction of 50% relative to 2019 levels across all of NOIRLab. This is just a start towards our goal to achieve net zero in conjunction with local, state, and national utilities in Chile, Hawaiʻi, and Arizona.

Not all of our challenges in 2022 can be ascribed to climate change; some have been rooted in the unprecedented interruption of infrequent but critical operational tasks. In October of this year, an operational error led to glass-to-metal contact on the edge of the Gemini North primary mirror during washing and stripping in preparation for recoating. Fortunately, the damage to the mirror was minor and outside of the clear aperture. Such events require a stand-down and careful investigation and analysis. An external Incident Review Board is leading the investigation. The plan to treat the chip on the edge of the mirror is coming together, and we expect to return Gemini North to operations in early 2023 with no expected loss of performance.

The commercialization of space is growing and impacting astronomy from the ground

The launch of large constellations of near-Earth orbiting (NEO) satellites is changing the night sky. The deployment of thousands, then tens of thousands, and ultimately potentially hundreds of thousands of NEO communications satellites will impact nearly all celestial observations from the ground, particularly those from wide-field imaging systems like DECam and Rubin Observatory. NOIRLab, IAU's Center for the Protection of Dark and Quiet Skies, the AAS, and other bodies are working with satellite vendors, regulatory agencies, and engineering teams to find solutions — hardware, software, and regulatory — that will reduce the impact of the satellites on astronomy while allowing the service providers to carry out their mission of improving communications worldwide. Good progress has been made with Starlink, and conversations are progressing with other providers. The launch of the prototype AST Bluewalker 3 satellite in late 2022 heralds a new entrant — large-area cell phone towers in space. Early observations[2] show that when fully unfolded, the Bluewalker 3 satellites have visual magnitudes ranging from 0 to +4. The impact of the AST Bluewalker 3 satellites on radio astronomy may be even larger than the impact on optical astronomy.

The satellite constellations also complicate the operation of laser beacons for adaptive optics. We are making good progress in this area; look for a public announcement around the time of the January 2023 AAS meeting.

Returning to normal?

As we are learning to live with the COVID-19 pandemic, NOIRLab, like much of the world, is searching for a "new normal" in the way we work and interact with the scientific community. We have been delighted to support in-person science meetings in the second half of 2022. The Gemini Science Meeting in Seoul, the Rubin Project & Community Workshop, and the "DECam at 10 years — Looking Back, Looking Forward" conference in Tucson were all great successes. We were happy to see our colleagues in person, and we were reminded of the unique value that in-person interactions provide.

Our daily work has evolved from mostly remote to hybrid, with staff who are not required on-site coming to the office up to five days each week, with agreements from their managers. While these hybrid work agreements do accommodate the particular needs of each staff member and their teams, there is little doubt that something is lost when we are not able to meet in person, to think together around the whiteboard, to talk over coffee and during lunch, or to have that spontaneous conversation in the hallway. The debate around the right mix of remote versus on-site work will continue for some time.

[2] https://noirlab.edu/public/announcements/ann22033/

Science is a collaborative enterprise; I hope that we can rekindle more of the collaborative spirit and free-form creative dialog within our teams as we find our optimal new normal mode of working together.

The future is closer than it appears

The 2010 and 2020 decadal survey reports laid out exciting priorities for ground-based OIR astronomy and for the national centers. Rubin Observatory is one of the outcomes from the 2010 survey, and it is now in the final stages of construction. The 2020 survey recommended a bi-hemispheric system of Extremely Large Telescopes. An important step toward realizing that goal occurs in December and January when the US Extremely Large Telescope Program (US-ELTP) components, the Thirty Meter Telescope and Giant Magellan Telescope projects, conduct their first NSF design reviews. The NSF Preliminary Design Review will examine the technical status of the telescope projects along with their schedules and project execution plans. A review of the NOIRLab role in the US-ELTP will be held in mid-2023. Stay tuned.

Aerial panorama of Cerro Pachón in Chile, with the Vera C. Rubin Observatory visible in the middle.

Credit: NOIRLab/NSF/AURA/T. Matsopoulos

10.5281/zenodo.7502307

The Nearest Black Hole

Tod R. Lauer (NSF's NOIRLab)

Kareem El-Badry (Harvard-CfA; Max Planck IfA) and collaborators have used GMOS on Gemini North to help identify a 9.62 ± 0.18 $M_{\odot}$ black hole (BH) only 480 pc distant. This object, informally designated as Gaia BH1, is now the closest black hole known by a factor of three. Unlike nearly all known 'stellar-mass' BHs, that is, those having masses < ~100 $M_{\odot}$, Gaia BH1 was not detected by X-ray emission powered by gas accreted from a nearby, tightly bound, stellar companion. It is presently quiescent and was only identified by its astrometric perturbation of a Sun-like star orbiting it at a distance of 1.44 ± 0.11 AU. The large separation of its companion, which is the largest known for a BH/star binary (Figure 1), raises questions as to how the system formed and evolved to its present state. The observations and implications of the discovery of Gaia BH1 are published in El-Badry et al. (2022).

El-Badry and collaborators discovered Gaia BH1 as part of a program to find non-accreting stellar-mass BHs. While several stellar-mass BHs have been found as X-ray binaries, the very mass-accretion that makes them visible in X-rays poses the question of how much mass has been accreted since the initial formation of such BHs, presumably in the core-collapse of massive stars. Determining the initial mass function of stellar-mass BHs is a crucial test of the final evolution of high-mass stars. Backing out the subsequent mass growth of the BHs in X-ray binaries is an important, but poorly understood, correction. Astrometry over the duration of the Gaia mission, however, provides a way to find quiescent non-accreting BHs. El-Badry's team found six candidates for BHs within a large list of stars showing astrometric evidence for being bound to another object. Follow-up observations show that Gaia BH1, however, is the only candidate in this set for which the star detected by Gaia, apparently an ordinary main-sequence G-dwarf, indeed appears to be orbiting a stellar-mass BH.

Following up the Gaia astrometric observations with radial velocity observations of the G-dwarf was key to accurate determination of its orbit around its BH companion, and in

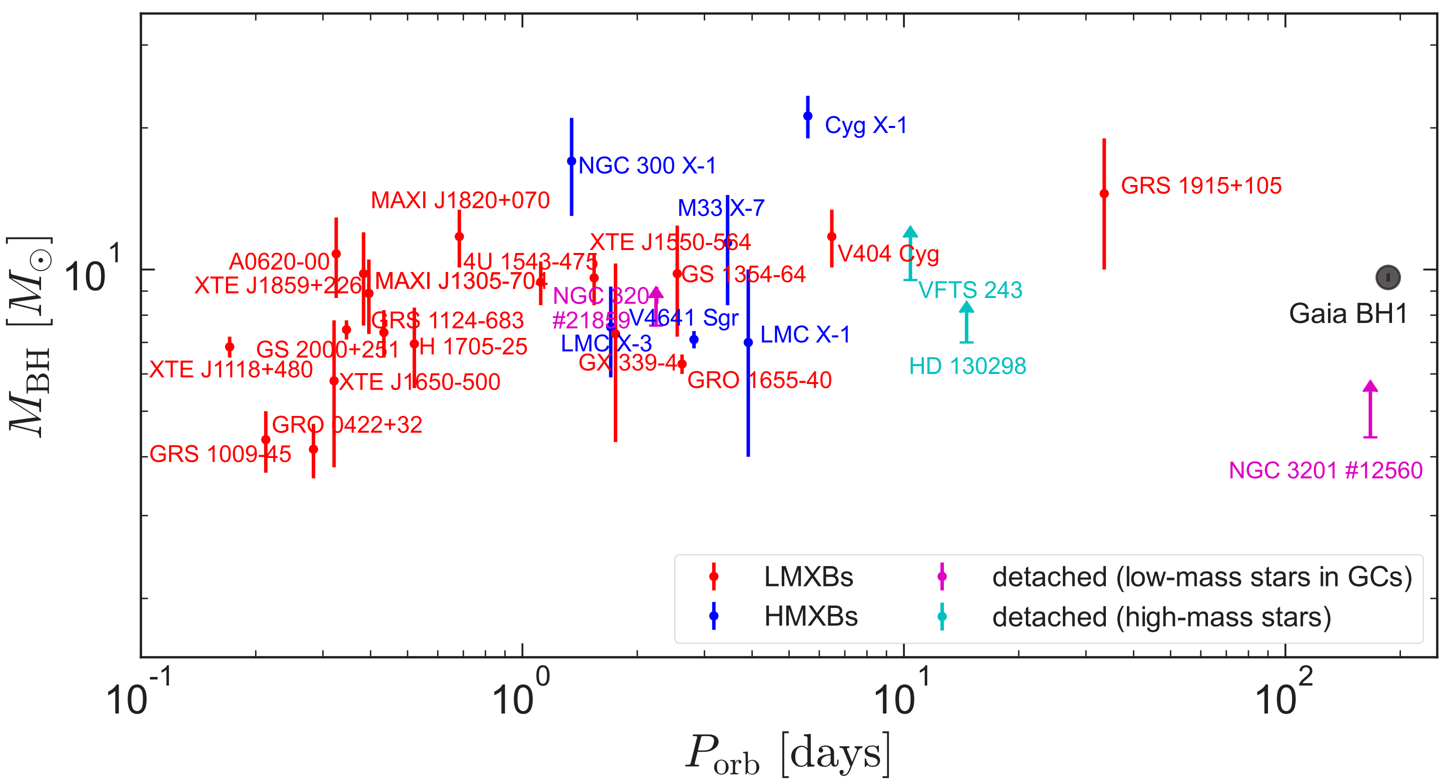


Figure 1: Mass of the BH vs. orbital period of its stellar companion is plotted for all known BH/stellar binaries. Gaia BH1 is at the right end of the figure, having a companion with the largest orbit of all known BH/stellar binaries. *Credit: Figure reproduced from El-Badry, et al. (2022).*

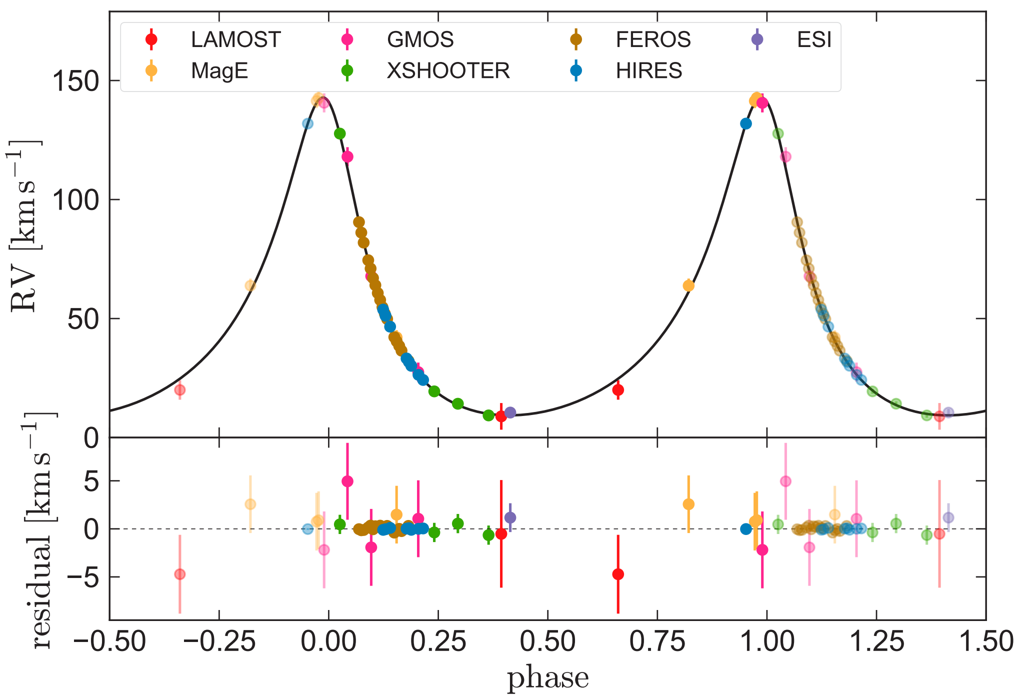


Figure 2: The radial velocity of the stellar companion of Gaia BH1 is plotted as a function of orbital phase. GMOS observations were critical for the accurate determination of its peri-center passage. *Credit: Figure reproduced from El-Badry, et al. (2022).*

turn determination of the BH's mass. Several instruments were used for this, which included GMOS on Gemini North. GMOS observations were made as part of a Director's Discretionary (DD) time program (program ID: GN-2022B-DD-202). The rapid response provided by the DD program was especially valuable as the observations could be timed to observe the peri-center passage of the G dwarf around the BH (Figure 2). With an overall 185.6-day period, this opportunity was available only within a narrow window that occurred every six months. That the central object in the system is indeed a BH is compelling, as while it contains ~90% of the mass of the system, the G-dwarf contributes all the light.

The present configuration of the Gaia BH1 system is difficult to explain under the most common stellar evolution scenarios considered by El-Badry et al. (2022). While the system did not evolve to produce a tight binary, the present orbit of the G-dwarf would have had it embedded in the envelope of the $> 20\ M_{\odot}$ supergiant that would have immediately preceded the formation of the present BH. It is unlikely that the G-dwarf companion could have survived such a 'common envelope' phase. Separately, El-Badry et al. speculate that the proximity of the Gaia BH1 means that quiescent BHs may be common. The discovery of additional systems will show if the formation of Gaia BH1 is, in the end, unusual.

Reference

El-Badry, K. et al. 2022, *MNRAS*, 518, 1057. doi.org/10.1093/mnras/stac3140

10.5281/zenodo.7502303

DESI Observations of the Andromeda Galaxy: Revealing the Immigration History of Our Nearest Galactic Neighbor

Joan Najita, Arjun Dey (NSF's NOIRLab),
and Sergey Koposov (University of Edinburgh)

DESI, the highly multiplexed multi-object spectrograph on the Mayall Telescope, is revolutionizing our ability to see the motions of individual stars in nearby galaxies. New DESI observations of the inner halo of our nearest large extragalactic neighbor, the Andromeda Galaxy (M31), reveal evidence of a galactic immigration event in exquisite detail. Intricate structures in the positions and velocities of its stars — in the form of streams, wedges, and chevrons — attest that a large galaxy fell into M31 a few billion years ago, launching its stars on migratory paths we can still see today. While hints of such structures have been previously glimpsed in M31, this is the first time they have been seen with such detail and clarity in a galaxy beyond the Milky Way.

Although the Mayall, with its 4m-diameter aperture, is today a modestly sized telescope, DESI's high efficiency and high multiplex (i.e., its ability to measure the spectra of many objects simultaneously) enable it to compete effectively with today's largest telescopes in the arena of wide-field spectroscopic studies. DESI can measure the spectra of as many as 5000 targets within a 3-degree-diameter field of view simultaneously, in a single exposure, and acquire new fields within minutes. Earlier this year, DESI turned its gaze toward M31 and in 3.75 hours of on-sky exposure time measured the spectra of more than 11,000 sources, approximately 7400 of which are stars in M31 with well-measured radial velocities.

Figure 1 shows the regions of M31 observed — including the M31 disk and Giant Stellar Stream (GSS) toward the southeast — and the stellar velocities measured. As shown in the figure, highly redshifted and blueshifted stars extend far from the disk, with the GSS appearing as a stream of blueshifted stars approaching the disk from the south. When plotted against projected distance from the center of M31, the measured stellar velocities organize into delicate spatial-kinematic patterns similar to those expected to result from a galaxy merger event: streams and nested wedge-shaped structures (Figure 2). The observed structures are remarkably similar to the predictions of dynamical models constructed to explain the spatial morphology of M31's inner halo.

While the DESI observations are the first to map out the large-scale kinematic structure of the inner halo of M31, the results affirm earlier 'pencil beam' surveys that explored small portions of the halo. The DESI data also reveal new structures not predicted by

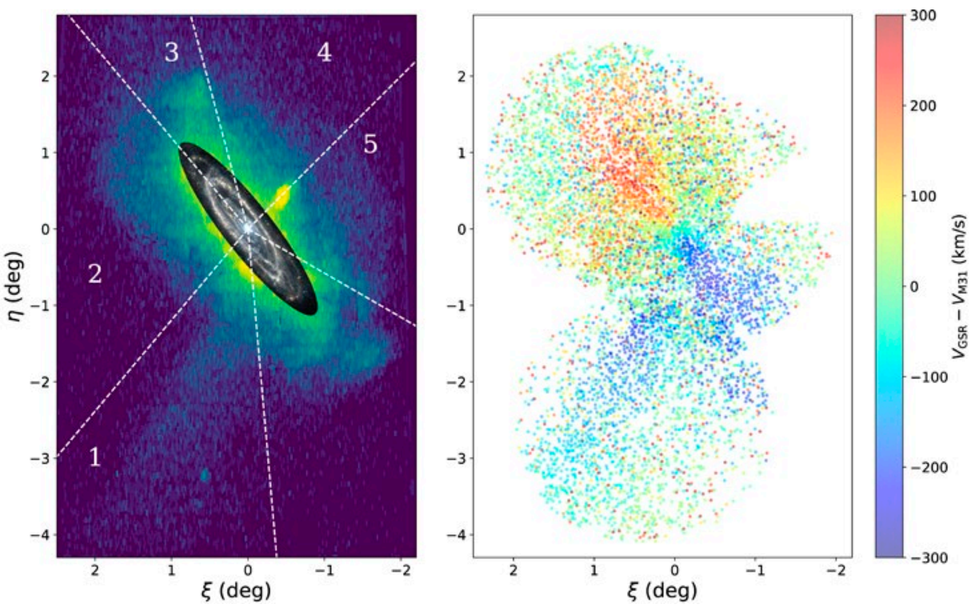


Figure 1: Image of the Andromeda Galaxy (M31, left panel) in which north is up and east is to the left. The central greyscale shows the main disk of the galaxy, and the green and purple shading shows the density of stars in the inner halo. The image in the right panel shows the locations of the stars measured with DESI, color-coded by their measured velocity relative to the motion of M31. The rotation of the disk is apparent, as are the coherent motions of the stars associated with the giant stellar stream that extends to the southeast. *Credit: Figure reproduced from Dey et al. (2022), ApJ (in press).*

existing merger simulations. The good agreement with the dynamical models suggests that much of the substructure seen in the inner halo of M31 — the GSS and the shells of stars to the northeast, west, and southeast — is the result of a single merger event with a companion galaxy a few billion years ago. The DESI spectra also show that metal-rich stars ([Fe/H] > −0.5) are present in all of the substructures, further suggesting that the immigrating galaxy was fairly massive and had an extended star formation history.

This emerging picture of M31's history echoes that of our own galaxy, whose inner halo is also believed to have been accreted in past merger events. One difference is that the Milky Way's most recent major immigration event (Gaia Sausage/Enceladus) is more ancient, having occurred more than eight billion years ago. As a result, the DESI observations of M31 may open a window onto our past, offering a view of what our own galaxy looked like billions of years ago.

More generally, these M31 results demonstrate DESI's remarkable ability to efficiently map out the kinematic structure of nearby galaxies, heralding a new era in our ability to study stars on a galactic scale and to reconstruct the immigration histories of galaxies. The results also showcase the remarkable scientific longevity of the Mayall.

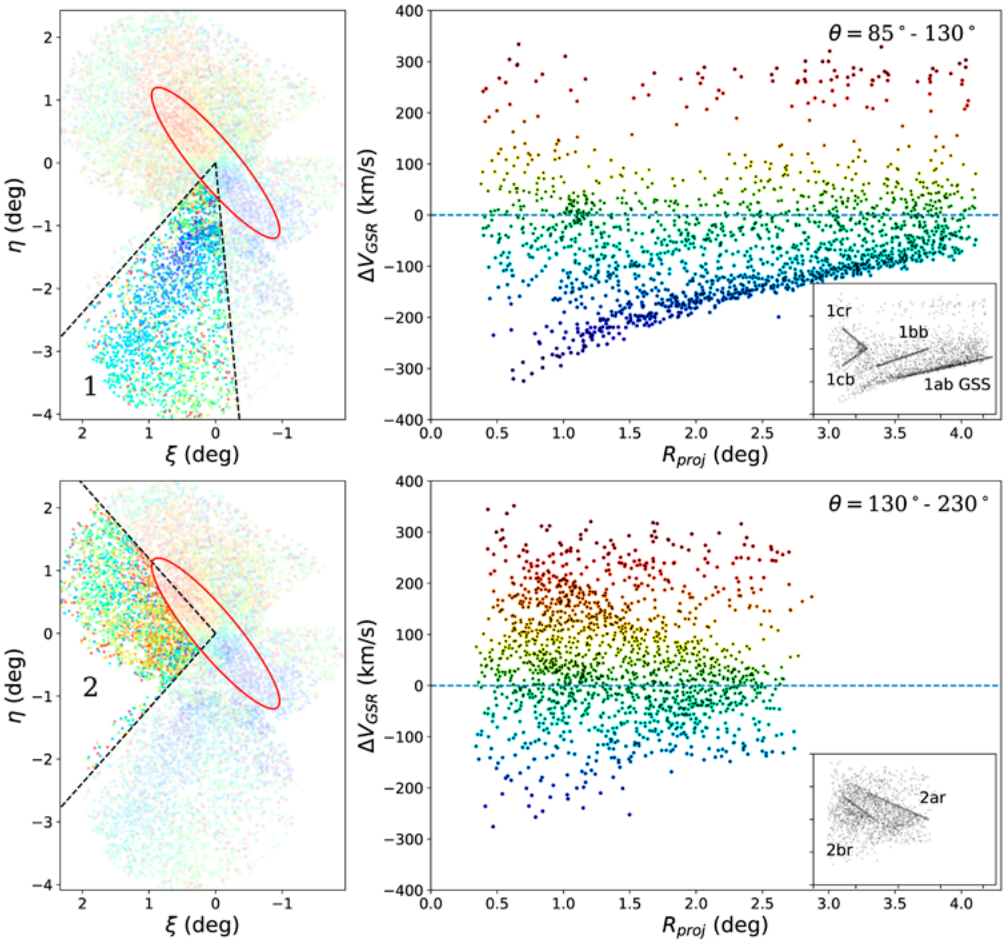


Figure 2: Line-of-sight positions and velocities for M31 stars (right panels) in angular zones of interest (left panels). Stars lying within the ellipse centered on M31 (red line) are not plotted in the position-velocity diagram. Insets highlight linear features apparent in each region (gray lines). Zone 1 (top panel) contains the Giant Stellar Stream, which appears as a prominent blue band of stars, as well as additional, more compact, features at less blueshifted velocities. Zone 2 (lower panel), which is part of the Eastern Shelf, shows nested wedges of stars in its position-velocity diagram. *Credit: Figure reproduced from A. Dey et al. (2022), ApJ (in press).*

Despite its age and modest aperture, the nearly 50-year-old Mayall Telescope remains a vital platform for frontline research.

Reference

Dey, A., Najita, J. R., Koposov, E. E. et al. 2022, ApJ, in press, arXiv:2208.11683

NGC 7020 is a barred lenticular galaxy in the southern constellation Pavo. This image from Gemini South, one half of the International Gemini Observatory, a Program of NSF's NOIRLab, clearly shows the core of NGC 7020 as hexagonal in shape. The Picture of the Week can be found here.

Credit: International Gemini Observatory/NOIRLab/NSF/AURA/H. Dottori, R. J. Díaz, G. Gimeno

10.5281/zenodo.7502330

A Reflection of His Father

NOIRLab's new Assistant Scientist Guillermo Damke is following in his father's footsteps and pursuing his dreams

Justine Schaen (NSF's NOIRLab)

Guillermo Damke recalls the moments of just him and the truly dark night sky unveiling the stars and a glowing band of light above him. These moments of solitude transformed into moments of awakening, as Guillermo desired to know the secrets beyond Earth. Guillermo's father (also named Guillermo Damke) fueled his wonder of space with alluring images of nebulae and spiral galaxies that were featured in pamphlets he would bring home from his job with AURA.

As a miner left unemployed by the impact of the Chilean economic crisis of 1982, Guillermo's father eventually found stability that December as a contractor for AURA at the Cerro Tololo Inter-American Observatory (CTIO). He worked various jobs in the Recinto from landscaping to painting and later helped in the warehouse with shipments coming from the United States. In 1984 a position within AURA opened and Guillermo's father started working as an AURA employee that May. After 34 years of dedicated service, he retired in January 2018. He was Guillermo's greatest influence, providing the spark and fuel needed to foster his ambition of becoming an astronomer and forge his own path.

Guillermo grew up in La Serena, Chile. He was naturally curious about the way things worked from objects such as radios and car engines to the intricate details of machines and the complexities of the natural world. In primary school, Guillermo enjoyed studying the natural sciences and recalls his excitement upon seeing the first images of Jupiter and Saturn released by Voyager I. Guillermo's school was known for its prestigious physics teacher, Padre Juan Bautista Picetti, who became his high school mentor and inspired generations of astronomers with the observatory on the top of the renowned Seminario Conciliar in La Serena. As a fourth grader, Guillermo made his first observation of Jupiter with the observatory's 8-inch telescope. By the time he was in seventh grade, he was a member of the school's astronomy academy and made observations every Friday night.

Guillermo and his family were aware of the challenges in becoming not just an astronomer but a *Chilean* astronomer in particular. In the early 1990s, most astronomers were from the United States and had access to extensive scientific resources. With the certainty of knowing he wanted to be an astronomer, Guillermo explored all avenues to accessing astronomical knowledge. The AURA pamphlets were a start, but books were expensive and there was no internet, making resources limited. In middle school Guillermo had two astronomy books: a generic book from his uncle and Carl Sagan's *Cosmos* from his aunt. In high school he took advantage of his father's connections, and was able to access all the books within the CTIO library.

During Guillermo's final year of high school, instructors were needed to operate a traveling planetarium that had been shipped to La Serena. Guillermo and his friend, Carlos Corco

Seven-year-old Guillermo with his family (parents and two older sisters) in 1989 standing in front of an AURA warehouse. *Credit: NOIRLab/NSF/AURA/G. Damke*

Guillermo and his father on the catwalk of the Gemini South telescope, while it was still under construction in 1998. *Credit: NOIRLab/NSF/AURA/G. Damke*

(who now works for the Southern Astrophysical Research Telescope), took advantage of this opportunity and agreed to lead planetarium presentations at the local schools. Guillermo continued these outreach events throughout his undergraduate experience and had access to even more resources when a second planetarium was obtained by Gemini South in 2003. Through engaging hundreds of people through outreach, he gained confidence in public speaking and learned the art of communicating complex ideas.

Guillermo attended the University of La Serena for his bachelor's in physics with a minor in astronomy. In parallel with his undergraduate studies, Guillermo took courses to learn the English language, realizing this was important if he wanted to be an astronomer. During his final year at the University of La Serena, Guillermo was selected to participate in CTIO's Prácticas de Investigación en Astronomía (PIA) program. As part of this intensive 10-week summer program, Guillermo had a first-hand, collaborative experience of what life, research, and operations were like at a major international observatory. It was a life-changing experience to learn from the same astronomers that he had looked up to and that were considered part of his family as a result of his father's position at AURA. As a testimony to Guillermo's work within the PIA program, Armin Rest, currently an associate astronomer at STScI, offered him a research assistant position at AURA with some work dedicated to the planetarium operations for Gemini South.

Guillermo's impact at AURA and Gemini led to a Fulbright Scholarship, providing him the opportunity to pursue astronomical research at a globally ranked institution. Guillermo attended the University of Virginia for his doctorate where he researched the spectroscopy of different Milky Way structures and tidal streams in the Sagittarius dwarf galaxy. Guillermo earned his PhD in 2016 and began work as a postdoctoral researcher for the commissioning of the APOGEE-South spectrograph, part of the Sloan Digital Sky Survey-III. In 2017 he was hired as an astronomer of data science for AURA and the University of La Serena.

Today, Guillermo is a NOIRLab assistant scientist providing user support for Blanco's Dark Energy Camera (DECam) at CTIO, where he is also in charge of site protection efforts to counteract light pollution. Part of Guillermo's initiative is to provide students with similar life-changing opportunities to his own experiences. As one of the leads of the La Serena School of Data Science, Guillermo inspires the next generation of scientists with the importance and future of "Big Data" in astronomy. The school provides senior undergraduates and early graduate students with intensive hands-on experiences learning how big astronomical datasets are processed, accessed, and analyzed utilizing reduction pipelines, databases, and scientific programming.

Guillermo is the mirror image of his father, exactly the same but in reverse. They have mutual respect and pride in each other's journey. Guillermo knows the lengths his father went through behind the scenes to help put a telescope into operation for an astronomer to use, from loading trucks to working weekends for a shipment to go up the mountain. In the reflection of his image, Guillermo's father sees his son, the astronomer who is living his dream to uncover the wonders of the Universe.

Guillermo with a telescope around 1997 while visiting ACHAYA with his father. ACHAYA is an association of Chilean amateur astronomers, based in Santiago about 300 miles south of La Serena. *Credit: NOIRLab/NSF/AURA/G. Damke*

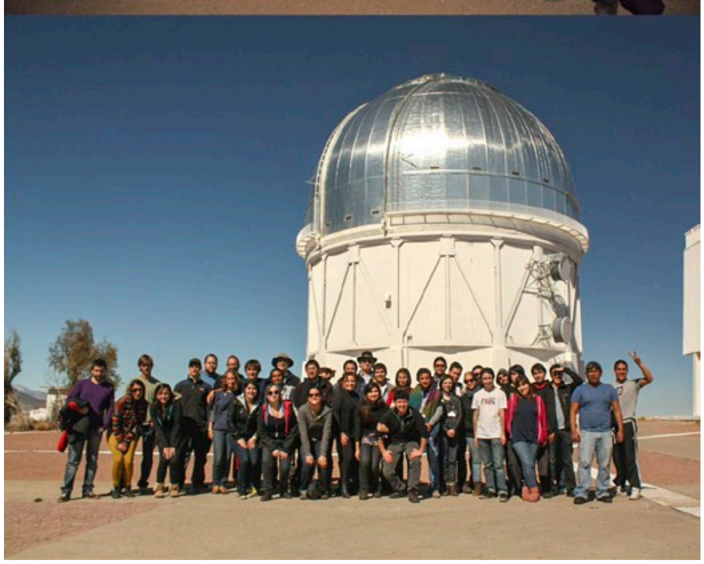
10.5281/zenodo.7502343

The La Serena School for Data Science: Tools for Data-Driven Sciences

Guillermo Damke (NSF's NOIRLab), Valeria Alejandra Mesa (AURA-O/U. La Serena)

There is no question that the new generation of astronomers will do cutting-edge research by taking advantage of the increasingly large datasets that are becoming available. In preparation, the La Serena School for Data Science (LSSDS) seeks to provide late undergraduate and early graduate students with the tools needed to succeed in this area.

Every year the LSSDS receives over 200 applications from students of several countries to participate in this intensive school in computational and statistical techniques for data science. The school is offered to undergraduate students in the last years of their programs and graduate students in the first two years of their programs in areas such as astronomy, physics, biology, medical informatics, computer science, and statistics. The school typically accepts 32–36 applicants of many nationalities comprising ~50 % from US universities, with the remainder coming from Chilean institutions as well as other Latin American countries. Hosted annually at the AURA Recinto in La Serena, the school has gained popularity since it was launched in 2013. However, the 2020 school was canceled due to the COVID-19 pandemic, and the 2021 and 2022 sessions were offered online only.



Figures 1&2 (top and bottom, respectively): LSSDS students and staff from past LSSDS workshops. *Credit: NOIRLab/NSF/AURA*

As in previous years, the 2022 curriculum was crafted by the Scientific Organizing Committee (SOC) based partly on the content of the previous — and successful— schools and the feedback from former participants. The 2022 school had the usual hands-on focus of the LSSDS, with lectures from international experts in several topics. Some of the subjects covered include supervised and unsupervised machine learning, Gaussian processes, databases, statistics, and deep learning, to name a few. The school also offered 'Group Projects', where interdisciplinary and diverse groups of students applied the tools presented by solving various problems under the guidance of a professor. The online format included daily synchronous and asynchronous sessions during the 10-day program. The SOC limited the synchronous work to three hours per day via Zoom, targeting a total daily load of six to eight hours.

Instructors provided pre-recorded 45-minute lectures. The students were given access to the videos in advance, so that they could review the lectures on a daily basis and learn the theoretical concepts offered. During the first week, the synchronous time was used for answering questions about the lectures and to review and practice the hands-on material prepared by the instructors in the form of Jupyter Notebooks. During the second week, the school transitioned into the Group Projects, where groups of five students worked together to solve a problem using the techniques learned during the first week. In total, we conducted eight Group Projects. An important addition to the online format was the participation of Teaching Assistants (TAs). We reached out to our former students from the 2017–2021 schools and invited them to participate as TAs. Funding for their stipends came from the NSF grant and funding from partners in Latin America. The TAs had a crucial role, as they supported the learning of each group during the first week and the development of the Group Project. Additionally, the Local Organizing Committee (LOC) provided a 'school welcome package' to each student as a way to foster a sense of belonging to the school. The package included items that were useful during the school and some souvenirs from the AURA observatory.

The LSSDS offers a unique formative opportunity to introduce highly talented students to data science and big data in a diverse, international, and interdisciplinary environment guided by experts. We are now planning the 2023 session, which will be in person. The school grants full scholarships to cover the roundtrip airfare from the home institutions to La Serena and room and board (except dinners) for the duration of the school.

In addition, the school includes a guided VIP visit to the AURA telescopes on Cerro Pachón and Cerro Tololo, with dinner and stargazing on Cerro Tololo.

Thanks to funding from NSF, along with other international partners, applications from students in US, Chilean, and Ecuadorian (members of CEDIA) institutions are eligible for full scholarships that cover all school expenses. Participants from any data-intensive field are welcome to apply. The announcement of the opening of applications will be made during January through the observatory social networks and the school website. We look forward to receiving your applications and meeting you in La Serena in August 2023!

Please visit La Serena School for Data Science: Applied Tools for Data-Driven Sciences to find further information about the school.

Figure 3: Web announcement graphic promoting the 2023 LSSDS workshop. *Credit: NOIRLab/NSF/AURA*

10.5281/zenodo.7502361

The Legacy Mosaic Data Rescue Project

Sean McManus, Sharon Hunt (NSF's NOIRLab), and Julie Steffen (AAS)

In the mid-1990s, telescopes at Kitt Peak National Observatory (KPNO) and Cerro Tololo Inter-American Observatory (CTIO) made the significant transition to archiving digital observational data. At that time, desktop computers could store about 1 Gigabyte, or about 1000 times less than what a modern smartphone can now store. To meet the storage needs of data-intensive astronomy at that time, magnetic tape was the most cost-effective medium.

The National Optical Astronomy Observatory (NOAO; National Optical Astronomy Observatories pre-FY2000) collected 5+ million raw data files on 9000+ unique data magnetic tapes from 1993 until 2004. Principal Investigators (PIs) received a tape copy of their program data, but at the time there was no searchable archive of all observations. By 2004, modern disk storage technology facilitated digital archives. From that point forward, nightly observations and reductions were stored in the NOAO Science Archive, which became the NOIRLab Astro Data Archive in 2019.

Fast forward to today, and 9000 8mm tape cartridges remain housed in the NOIRLab Tucson Headquarters data center. A mirror collection of the same tapes is stored on Kitt Peak. These tapes were retained after being written at the telescope but were seldom accessed thereafter. The 8mm tape format, which is similar to what video cameras of the same generation used for recording, is obsolete. Each tape can store about 7 Gigabytes, or less than a thumb drive by today's standards. The tape data have been offline for the past 20–30 years despite numerous possibilities for archival research. The Mayall 4m Mosaic-1 data are similar to modern Mosaic-3 data, facilitating direct comparison of object changes over time (Figure 1).

These legacy data also have historical significance. According to Tod Lauer, "*The tape archive contains the original images used by two separate teams to discover the effects of 'dark-energy' on the expansion of the Universe (in short, by discovering supernovae that were used as 'standard candles' to assess distances to galaxies over extremely large scales). These observations revolutionized modern cosmology and were recognized with three Nobel prizes in physics in 2011.*"

There has always been interest in recovering the data on the tapes, but there were never resources available or sufficient motivation to do the actual work. Eventually, the data will not be recoverable because the tapes will degrade and the hardware to recover them will no longer be available. The time is now to recover the tapes while current institutional knowledge can assist in processing and cataloging the data properly.

Using a bank of 20 8mm tape readers, the recovery project team (Randy Faux, Nick Foo, Sean McManus) has managed to extract 50% of the data from the tapes, so far, including nearly all Mosaic-1 wide-field-imager data. The raw files are currently being characterized and prepared for Astro Data Archive ingest. Frank

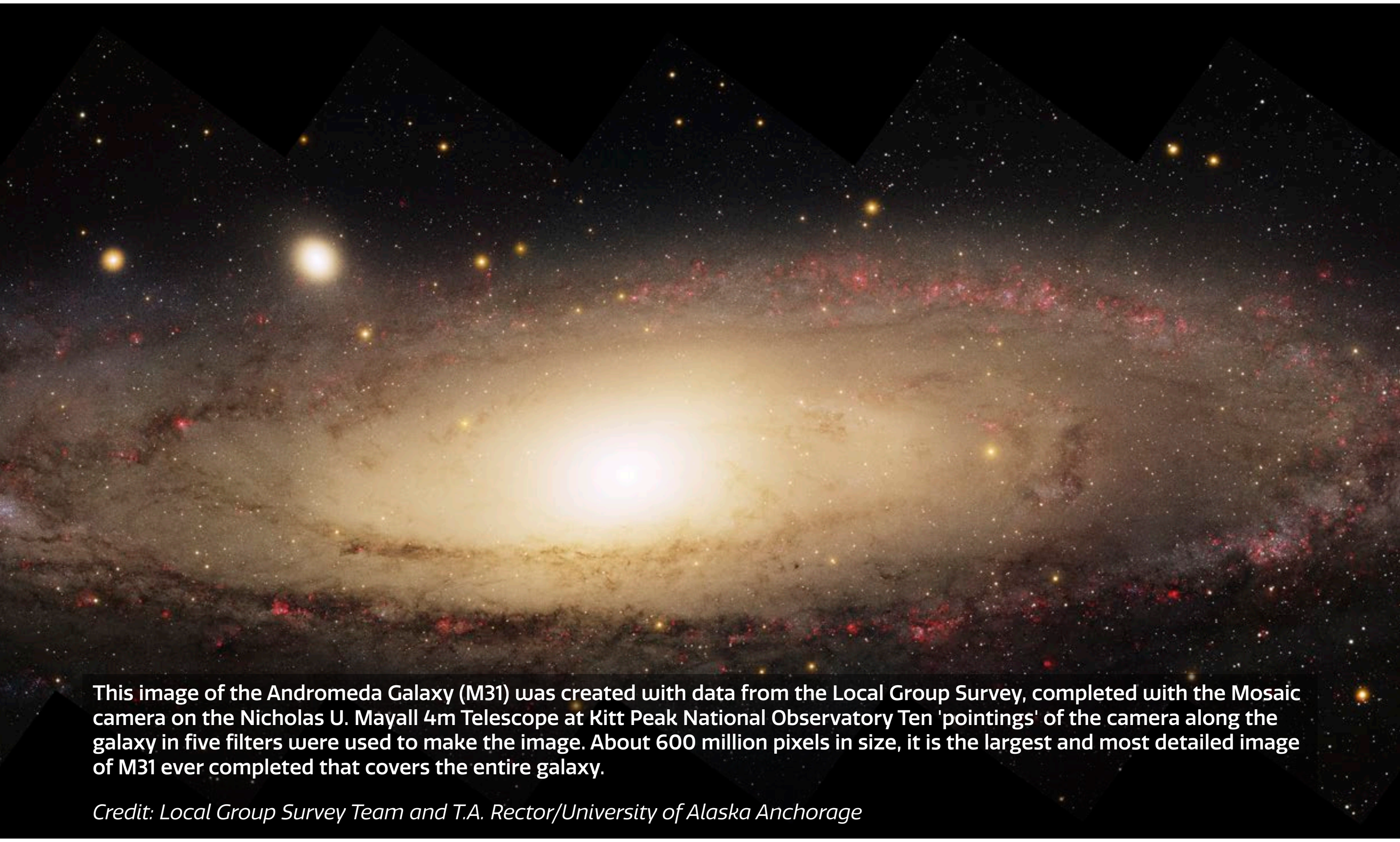
Figure 1: Exabyte tape drives for the Astro Data Legacy Tape Drive Archive.
Credit: R. Faux/NOIRLab

Valdes will adapt existing pipeline software to perform basic calibration to produce science-ready images. According to Valdes, "*Our ability to calibrate these data, both in terms of quality and computational speed, has advanced, and so the archived calibrated images produced from these imagers will be state-of-the-art*."

The American Astronomical Society (AAS) is collaborating with NOIRLab on this project. They have created an AAS Archive Fellowship for a quarter-time graduate student to work on both the Abt Archives and the Data Rescue Project. The Abt Archives is a physical collection of peer review records of approximately 35,000 manuscript files related to *The Astrophysical Journal* (ApJ) during the editorship of Helmut A. Abt (NOAO, ret.), who served from 1971 through 1999 using a manual, paper-intensive review process. The AAS Archive Fellow is logging these records into a database and repacking them into archival storage materials for preservation (Figure 2).

Figure 2: (left) Peer review files in the Abt Archives stored in archival boxes after processing; (right) files before logging and repacking. *Credit: J. Steffen/AAS*

These two archival projects are preserving important aspects of our astronomical heritage by conserving, organizing, and making accessible these two archival collections.



This image of the Andromeda Galaxy (M31) was created with data from the Local Group Survey, completed with the Mosaic camera on the Nicholas U. Mayall 4m Telescope at Kitt Peak National Observatory Ten 'pointings' of the camera along the galaxy in five filters were used to make the image. About 600 million pixels in size, it is the largest and most detailed image of M31 ever completed that covers the entire galaxy.

Credit: Local Group Survey Team and T.A. Rector/University of Alaska Anchorage

10.5281/zenodo.7502472

Toward Powering Gemini South with Zero CO_2 Emission

Inger Jorgensen and Piero Anticona (NSF's NOIRLab)

In view of the urgency of countering the increasing effects of climate change, NOIRLab has decided to lead by example with an ambitious environmental sustainability program. Our target is a 30% reduction in the organization's carbon footprint from travel and electricity usage by late 2027, based on approved 5-year funding. Additional funding may allow us to reach a 50% reduction.

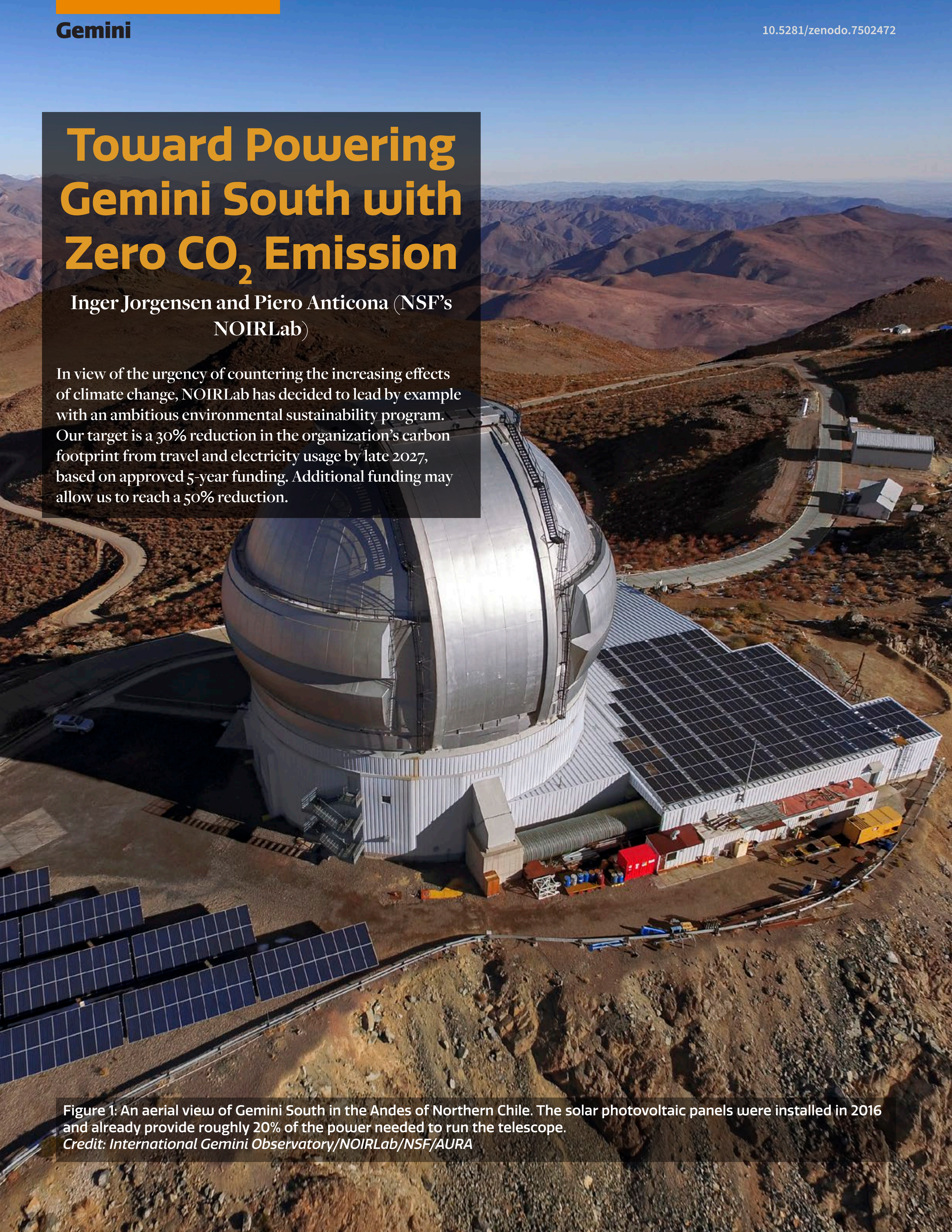


Figure 1: An aerial view of Gemini South in the Andes of Northern Chile. The solar photovoltaic panels were installed in 2016 and already provide roughly 20% of the power needed to run the telescope.
Credit: International Gemini Observatory/NOIRLab/NSF/AURA

Meeting this goal will eliminate 2500 tons of CO_2 equivalent emissions every year, or roughly the same as the emissions from 500 typical US households. The program is outlined on our website. The NOIRLab sustainability program consists of three parts: reduction of travel paid for by NOIRLab funds, installation of energy-efficient equipment, and production of renewable energy at our sites. In addition to the current projects that will get us to the 30% reduction in our carbon footprint, we have received funding from the National Science Foundation for the first phase of an ambitious project to supply all of Gemini South's mountain facility electricity needs through renewable energy.

During 2016, we installed a 207 kW solar panel array at Gemini South (Figure 1). This system produces about 20% of the electricity needed at the Gemini South telescope, or the same amount of electricity as it would take to power about 35 US residential households. This system will have paid for itself in 2023.

With the new funding from NSF, we have started the first phase of a project to install additional solar panels and, eventually, battery storage. The funding will provide solar panels with a total collection capacity of about 800 kW, four times as large as the current system. The planned location of this 800 kW system is shown in Figure 2. The new solar panel array will be located below the ridge where Gemini South and the current solar array are located. This location has sufficient space for this large system, as well as for future extensions to power Rubin Observatory, if funding for this can be secured. The system will be about 500m from the closest electrical transmission lines, so new transmission lines will be necessary as shown on the figure. The array itself will measure about 50m by 130m and consist of 2000 individual panels.

Completing the planned system of the solar panel array and battery storage system requires detailed engineering design, including a survey of the proposed site for suitability and for endangered species and historical artifacts. Additional funding will be requested to allow installation of roughly 3 MWh of battery storage, a system capable of powering ~100 typical US households for 24 hours. The system will power Gemini South for one night. The battery storage will be recharged the next day, while the solar panel array will provide the daytime electricity needs of the telescope.

We are aiming for completion of the full system, comprising the solar panels and battery storage, by the second half of 2024 if funding allows.

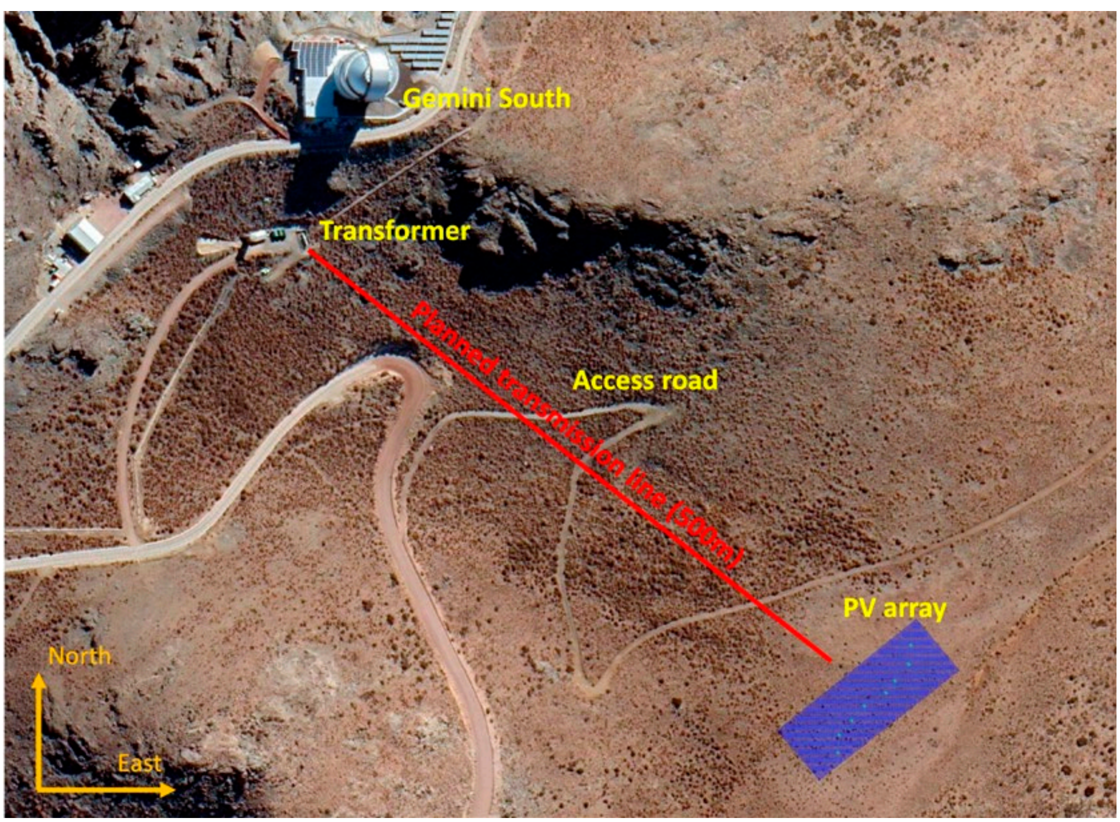


Figure 2: The planned solar panel array will consist of 2000 individual solar panels and is expected to measure 50m by 130m. The current Gemini South 207 kW solar panel array can be seen on the roof of the support building to the left of the dome and on the ground to the right of the dome. Based on a satellite image from Google Earth. *Credit: Google Earth/NOIRLab/NSF/AURA*

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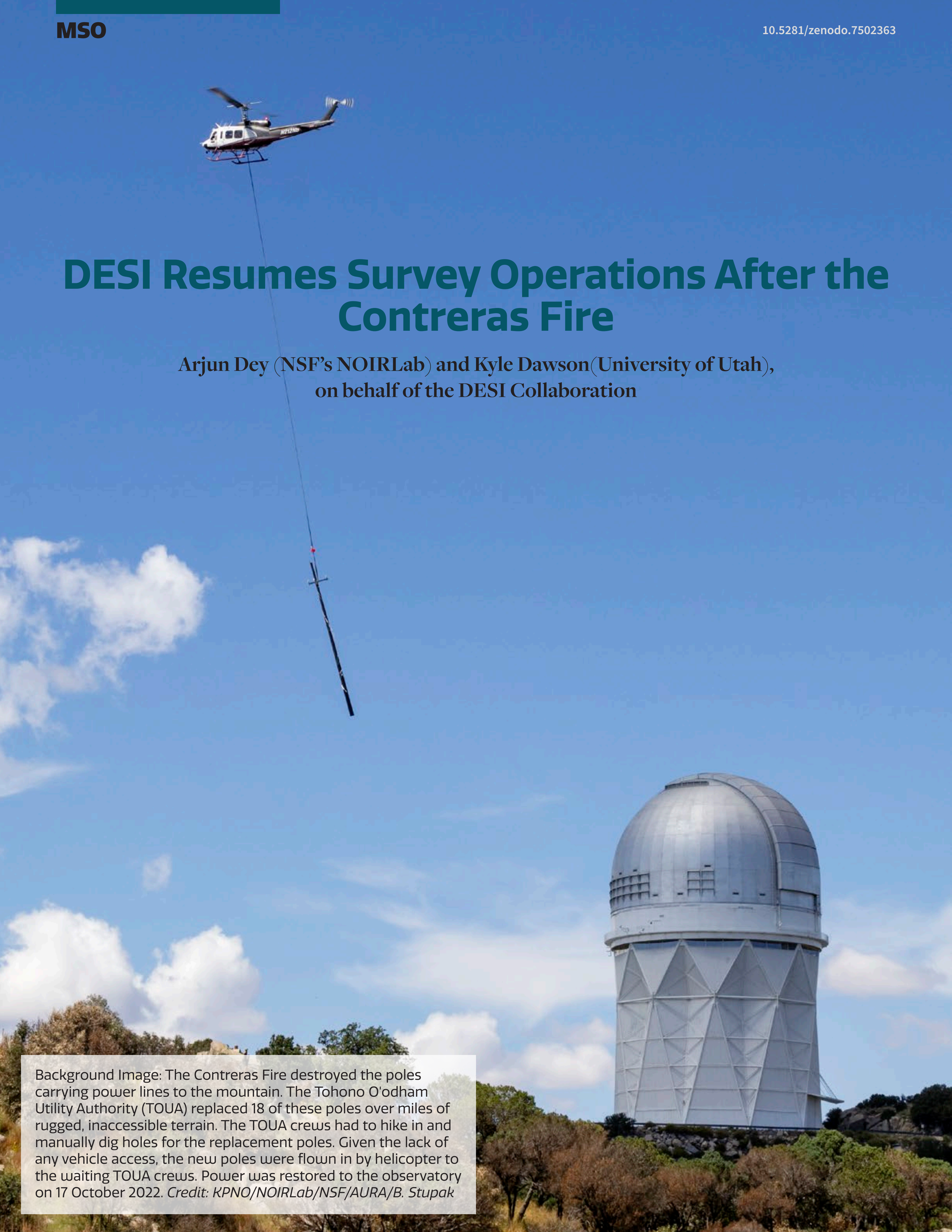
DESI Resumes Survey Operations After the Contreras Fire

**Arjun Dey (NSF's NOIRLab) and Kyle Dawson(University of Utah),
on behalf of the DESI Collaboration**



Background Image: The Contreras Fire destroyed the poles carrying power lines to the mountain. The Tohono O'odham Utility Authority (TOUA) replaced 18 of these poles over miles of rugged, inaccessible terrain. The TOUA crews had to hike in and manually dig holes for the replacement poles. Given the lack of any vehicle access, the new poles were flown in by helicopter to the waiting TOUA crews. Power was restored to the observatory on 17 October 2022. *Credit: KPNO/NOIRLab/NSF/AURA/B. Stupak*

The Dark Energy Spectroscopic Instrument (DESI) on the 4m Mayall Telescope at Kitt Peak National Observatory is back on-sky after the Contreras Fire. Although operations at Kitt Peak are still not back to normal, the DESI survey observations have resumed.

DESI, a 5000-fiber multi-object spectrograph with a simultaneous circular three-degree field of view, saw first light on the Mayall in October 2020. After an initial period of commissioning and test observations, it began its five-year survey in May 2021. DESI briefly paused operations last summer to upgrade the focal plane control electronics, but was operating smoothly after it came back on-sky in September 2021. However, all operations at Kitt Peak had to be terminated and the mountaintop evacuated when the Contreras Fire began on 11 June 2022. DESI was shut down safely in advance of the evacuation. The fire was a serious threat to the summit and its many observatories, but thanks to heroic efforts by the fire crews and mountain staff, most of the facilities escaped nearly unscathed. Some smoke from the fire entered the Mayall enclosure, but the telescope and instrument were undamaged.

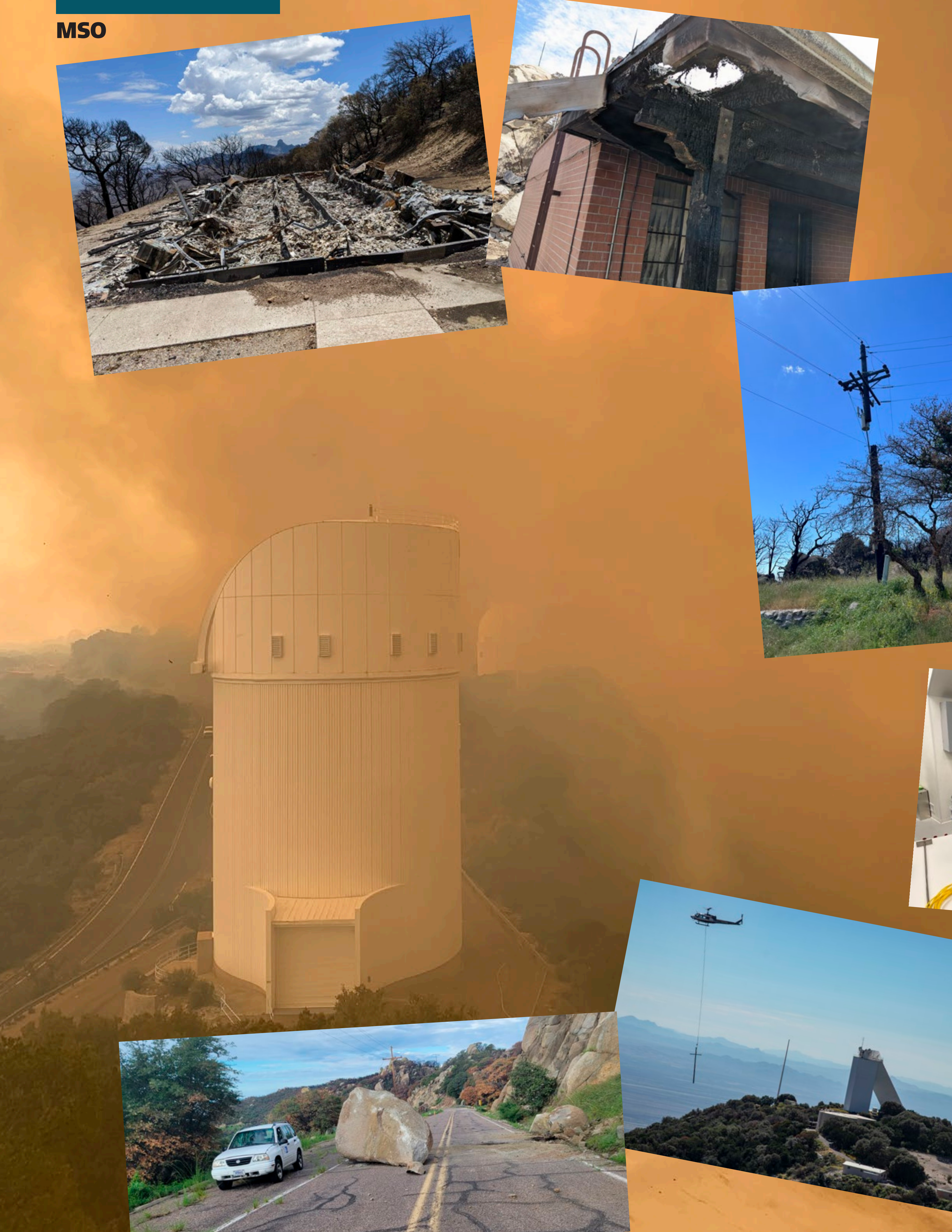
After numerous tests of the enclosure, telescope, and instrument, DESI resumed its mission on 10 September 2022. Line power was not restored to the summit until 17 October 2022. Prior to then, the Mayall was running on power from a diesel generator, which in turn was backed up by a second diesel generator. Since the wired internet connection to the mountain was also destroyed by the fire, the DESI and Mayall team have installed a temporary internet connection which provides low-bandwidth internet and allows the off-site members of the operations team to monitor the instrument and telescope telemetry. The transfer of data to Tucson and Berkeley, which used to happen automatically as data were taken, is now accomplished by writing the data to a hard disk and driving it to Tucson, where it is then uploaded to an internet-connected system for transfer. As a result of these 'innovations', DESI was back in action! Normal wired internet services were eventually restored on 07 December 2022, and DESI operations are now back to normal.

DESI's and the Mayall's five-year mission is to map the expansion history of the Universe over the last 10 billion years with unprecedented precision. It is doing so by obtaining redshift measurements for 40 million galaxies and quasars distributed over this large range in cosmic time. By measuring both the universal expansion and the time evolution of the clustering of galaxies, DESI will provide new, stronger constraints on our cosmological model and on the nature of dark energy. The DESI observations will result in the largest cosmic cartographic survey ever undertaken.

Despite the COVID-19 pandemic (which interrupted DESI commissioning and survey validation observations) and the Contreras Fire, DESI has proven itself a resilient and very efficient instrument. In only 300 nights of on-sky observations, DESI has already measured more than 15 million extragalactic source redshifts and obtained radial velocities for more than 4.7 million stars. The instrument is very efficient: the overhead time between exposures (which involves reading out the detectors while slewing the telescope, acquiring the new field, finding guide stars and initiating guiding, repositioning the fibers, and restarting the new exposure) is less than two minutes. The pipeline, which operates at Lawrence Berkeley Laboratory's National Energy Research Scientific Computing Center (NERSC), delivers a catalog of redshifts from each night's observations by the following morning. The high throughput of the system allows redshifts to be obtained for galaxies as faint as $r \sim 24$ AB mag. A recent pilot survey of the Andromeda Galaxy demonstrated that accurate radial velocities could be obtained for stars as faint as z=21.5 AB mag.

The DESI Collaboration, an international group which involves nearly 1000 scientists and engineers distributed over 69 institutions, is hard at work analyzing the data and preparing the early DESI survey validation observations for an Early Data Release, scheduled for early 2023. The collaboration has recently submitted several papers describing the DESI target classes and the overall scope of the main surveys.

The construction and operation of DESI have been supported by the Director, Office of Science, Office of High Energy Physics of the US Department of Energy under Contract No.DE-AC02-05CH11231, and by the National Energy Research Scientific Computing Center, a DOE Office of Science User Facility under the same contract. Additional support for DESI is provided by the US National Science Foundation, Division of Astronomical Sciences under Contract No. AST-0950945 to NSF's NOIRLab; the Science and Technology Facilities Council of the United Kingdom; the Gordon and Betty Moore Foundation; the Heising-Simons Foundation; the French Alternative Energies and Atomic Energy Commission (CEA); the National Council of Science and Technology of Mexico; the Ministry of Economy of Spain; and the DESI Member Institutions.



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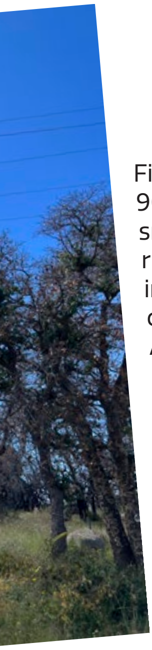
Kitt Peak Survives Contreras Fire

Michelle Edwards (NSF's NOIRLab)



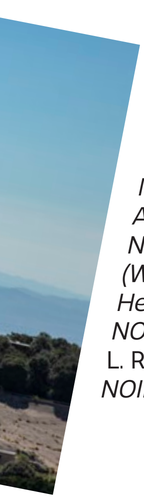


Figure 1: (Background image) 90-inch Bok Telescope with fire and smoke encroaching on the west ridge of the main summit. Overlaid images clockwise from top left: complete loss of the University of Arizona dormitory on the Southwest Ridge; significant damage to Kitt Peak staff Dormitory #3; catastrophic damage to a power pole on the Southwest Ridge; WIYN Engineer Emily Hunting working on clean-up inside WIYN after the fire; a helicopter transporting 1 of 18 power pole replacements to areas on the summit otherwise inaccessible; an 8' × 12' × 6' boulder that fell into the access road during a storm. Erosion, due to loss of vegetation, caused multiple rockslides and mudslides along State Route 386 (SR 386) throughout the monsoon season. Fortunately, no one was injured, and the Arizona Department of Transportation (ADOT) was able to clear the boulder from the lane, but SR 386 remains closed to the public. *Credits: Background:* T. "Walt" *Walter/Eastern Area Type 2 Incident Management Team; Dormitories: J. Maclean (COS/ NOIRLab/NSF/AURA); Electric pole: M. Edwards (KPNO/NOIRLab/NSF/ AURA); E. Hunting (WIYN/KPNO/ NOIRLab/NSF/AURA), S. Logsdon (WIYN/KPNO/NOIRLab/NSF/AURA); Helicopter and MMP: R. Sparks (CEE/ NOIRLab/NSF/AURA); Rock and car:* L. Reddell *(KPNO/COS/ NOIRLab/NSF/AURA)*

The Contreras Fire, which was started by a lightning strike on 11 June 2022, grew from a small five-acre fire in the Baboquivari Mountains eight miles south of Kitt Peak National Observatory into a 30,000-acre fire that burned through the Altar Valley and Quinlan Mountains range, home to the observatory.

The fire moved rapidly, giving little time for preparation. From initial contact with the Incident Commander of the Southeast Arizona Type 3 Incident Management Team on 14 June 2022 to the complete evacuation of staff by the Incident Commander of the Eastern Area Type 2 Incident Management Team on 16 June 2022, fewer than 55 hours elapsed. During this time, a skeleton crew of essential Kitt Peak (KP) personnel worked professionally and quickly to gracefully shut down instruments and computers, cover major optics, stow flammables and caustics, move vehicles, arrange water trucks, check fire hydrants, aid fire staff, and evacuate transportable expensive assets. Firefighters on the summit worked non-stop to create areas of protection around essential buildings and domes and clear brush along the ridges, while five DC-10 (Very Large Air Tankers [VLATs]) bombarded the valleys and slopes surrounding the observatory with fire retardant.

Despite the extraordinary efforts by all the teams employing every possible precautionary tactic, by the early morning of 17 June 2022, the fire crossed the Kitt Peak access road, State Road 386 (SR 386), and burned over the Southwest Ridge. The fire then turned east and northeast toward the main summit, racing up the slopes toward the WIYN 3.5m, SARA 0.9m, Bok 90", Spacewatch 36" and 72", and Mayall 4m telescopes and the staff dormitories and Administration building on the western side. Firefighters mounted a nearly 12-hour campaign to protect structures on the summit, followed by another 24 hours spent firefighting across the mountain.

Thanks to the valiant efforts of the firefighting crew and the emergency preparatory actions of the KP staff, no scientific structures, telescopes, or instruments were lost or damaged. Best of all, no firefighters or KP personnel were injured. However, two University of Arizona dormitories and two KP utility sheds were completely destroyed. Several buildings, including two staff dormitories, sustained major damage, and many buildings had minor damage or were impacted by smoke and ash.

The infrastructure of the observatory, however, was left in grave condition. The summit was without line power, data, or telephones. Over 20 utility poles were damaged or destroyed across the mountain. Basic services such as garbage pickup and fuel and cryogen delivery were halted. SR 386 also suffered damage. All guardrails in the last three miles were destroyed, and as monsoon rains arrived, mudslides, rockslides, and flooding became increasingly dangerous.

In the months following the fire, the observatory undertook a massive recovery effort. This was led by an Emergency Response Team composed of experts drawn from across NOIRLab and AURA. The team took a phased approach that slowly allowed increasing numbers of staff and tenants back to the observatory to conduct recovery and remediation efforts, only after independent assessments deemed the site free of major electrical, structural, or environmental hazards. The response team also spearheaded efforts to create and maintain direct pathways of communication with service providers and cooperators, including the Tohono O'odham Utility Authority, the Arizona Department of Transportation, and the Tohono O'odham Office of Emergency Management. These relationships helped us negotiate compromises that kept the recovery moving forward and facilitated the resolution of complex logistical challenges.

In mid-October power was restored to the main summit area. Power to the Southwest Ridge was restored by the end of November. Potable water, bathrooms, food services, and janitorial services are all restored at the time of writing (mid-September 2022). Dormitories without significant damage were thoroughly cleansed of ash and smoke, and observers and staff are back on the summit for overnight stays. Domes and telescopes were thoroughly inspected and cleaned; we are pleased to report that MDM, the University of Arizona, Mayall, and WIYN all resumed science operations in September. Clean rooms and laboratories were also cleaned and prepared for tenant use; Caltech was able to upgrade their new instrument on-site post-fire in preparation for recommissioning on the 2.1m telescope. After a very challenging installation process, fiber internet was restored to the main summit area in early December. The Southwest Ridge is still pending internet access as this issue goes to press.

We anticipate the ongoing recovery of Kitt Peak, particularly data services, the access road, and the restart of smaller tenant telescopes and the Visitor Center, will continue throughout the next few months.

We extend our sincere thanks to all who have supported our efforts, both with fire prevention and recovery: the Arizona Department of Transportation, Tohono O'odham Office of Emergency Management, Tohono O'odham Utility Authority, NSF, Bureau of Indian Affairs, NOIRLab, Kitt Peak staff and tenants.

Figure 2: This webcam image (taken by the Mayall 4m Telescope's webcam) shows the Southwest Ridge with the VLBA backlit. This image was obtained early on the morning of 17 June 2022 as the fire came up and over the ridge. *Credit: KPNO/NOIRLab/NSF/AURA*

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Wrap-up of DECam at 10 Years: Looking Back, Looking Forward Workshop

Kathy Vivas and Alistair Walker (NSF's NOIRLab)

Over 80 scientists met in Tucson on 12–14 September 2022 to celebrate 10 years of operation of the Dark Energy Camera (DECam), to present scientific projects old and new, and to discuss future instrumentation possibilities for the Víctor M. Blanco 4m Telescope at CTIO as well as the Nicholas U. Mayall 4m Telescope at KPNO, given their tight coordination and synergies.

In a remarkable coincidence, the milestone of one million images since the commissioning began was reached on the afternoon of 12 September, the first day of the meeting.

DECam, sited at the prime focus of the Blanco, is the widest-field big-telescope CCD imager until the Simonyi Survey Telescope at Vera C. Rubin Observatory begins operations.

DECam was built to carry out the Dark Energy Survey (DES), a project aimed at estimating the equation of state for dark energy by mapping the galaxy distribution over a wide range of redshifts. DES used 592.5 nights on the telescope, primarily scheduled in the B semesters, to carry out a five-band imaging survey of 5000 square degrees of the South Galactic Cap together with a survey covering 30 square degrees to discover and follow up on Type Ia supernovae.

While DES concluded in 2019, the analysis of all six years of data is still underway, and the final cosmological results are expected in 2024. So far the results confirm the ΛCDM cosmology to tighter limits than previously, but there are hints — for example from a smoother matter distribution than expected — that non-standard physics may be required

Group photo from DECam at 10 Years workshop. *Credit: NOIRLab/NSF/AURA/P. Marenfeld* for a full explanation of the results. DES itself enabled several other major investigations, of which perhaps the most important has been the discovery of many small dwarf spheroidal galaxies that are companions of our Milky Way and the Magellanic Clouds. These discoveries, and the associated follow-ups with DECam and other telescopes, also provide stringent tests of dark matter.

When not taking data for DES, DECam was used for community and Chilean projects, many of which are major surveys in themselves. For instance, the DECam Legacy Survey (DECaLS) covered the sky around the celestial equator from declination –23°S to +33°N in the *g,i,z* bands to identify targets for DESI. The range of science covered by community use of DECam ranges from Solar System asteroids to Lyman-alpha emitting galaxies forming at the dawn of the Universe, and everything in between.

DECam is more than ever a highly relevant instrument, and in the last few years, its capability has been extended with several community-purchased narrow- and medium-band filters. Results from projects with these filters were presented at the meeting, and the announcement that a new filter to be used for searching for very metal-poor stars had been successfully fabricated was enthusiastically received.

DECam is expected to be an important player in following up Rubin Observatory's Legacy Survey of Space and Time, but it has already served an important role in time-domain astronomy, for example by searching for optical counterparts of gravitational wave events. Flexible scheduling and inter-telescope cooperation are important aspects of an efficient system for following up astronomical events, and the AEON project, which enables these features, as was described by Cesar Briceño during the workshop.

Arjun Dey presented on "The NOIRLab 4m Telescopes and Their Future." This was followed by a round-the-room discussion with DOE and NSF senior personnel, and various NOIRLab directors, on Zoom. This was an animated discussion, and such discussions and planning for the future will continue.

This still image combines hundreds of time-lapse exposures that capture the entirety of the 8 November 2022 total lunar eclipse above the Nicholas U. Mayall 4m Telescope at Kitt Peak National Observatory, a Program of NSF's NOIRLab. The Picture of the Week can be found here.

Credit: KPNO/NOIRLab/NSF/AURA/P. Horálek (Institute of Physics in Opava)

10.5281/zenodo.7502394

NEID Status After the Fire

Sarah Logsdon and Jesus Higuera (NSF's NOIRLab)

It has been a busy year for NEID, the new extreme precision radial velocity (EPRV) spectrograph installed at the WIYN 3.5m Telescope at Kitt Peak National Observatory. After successfully passing an operational readiness review in summer 2021, NEID transitioned to full science operations in the 2021B semester. NEID had almost marked a year of full science operations when the Contreras Fire halted operations in June, and the instrument was warmed up to safely await the return of observatory infrastructure.

Figure1. Members of the NEID Team (L to R: Danny Krolikowski, Steward Observatory, University of Arizona; Sarah Logsdon, WIYN/NEID Instrument Scientist; and Andy Monson, Steward Observatory, University of Arizona) prepare to pump down the NEID cryostat in October 2022. *Credit: C. Bender/Steward Observatory/University of Arizona*

The WIYN team and our NEID collaborators at the University of Arizona spent the summer and early fall checking NEID subsystems for functionality and cleaning the WIYN building, including the NEID clean room, from top to bottom. As soon as line power was restored to the summit in October, the team began pumping and cooling down the spectrograph in preparation for a return to science observing. In the meantime, a backup generator, which will strengthen the power systems infrastructure for uninterrupted operations, has also been added at WIYN, thanks to a Heising-Simons Foundation grant. Early, low-precision science observations resumed on 11 November, with high-precision science expected to follow shortly.

While work is ongoing to update the NEID pipeline and verify instrument performance, preliminary analysis indicates that NEID is performing as expected. The NEID team is thrilled to be restarting science operations and is looking forward to more cutting-edge EPRV data to come.

In the midst of our restart work, we also welcomed two new NEID Queue Observers, Pipa Fernandez and Yatrik Patel (Figures 2 and 3), who join Eli Golub and Jesus Higuera on the NEID observing team.

While we have been busy at Kitt Peak bringing NEID back on line, NEID PIs have been working hard analyzing and publishing their NEID data. To date, 11 peer-reviewed papers using NEID data have been published in 2022, with more papers under review or close to submission. The published papers include the recent 'Marshmallow' world paper by Shubham Kanodia et al. (2022, AJ, 164, 81), which used both NEID and NESSI (WIYN's speckle imager) to help characterize the lowest-density Jupiter-like planet orbiting a cool red dwarf star known to date.

Figure 2. NEID queue observer Pipa Fernandez. *Credit: NOIRLab/NSF/AURA/ J. Higuera*

Figure 3. NEID queue observer Yatrik Patel. *Credit: NOIRLab/NSF/AURA/ S. Logsdon*

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Coming to a Screen Near You: The Rubin Observatory Education and Public Outreach Program

Kristen Metzger (NSF's NOIRLab/Rubin)

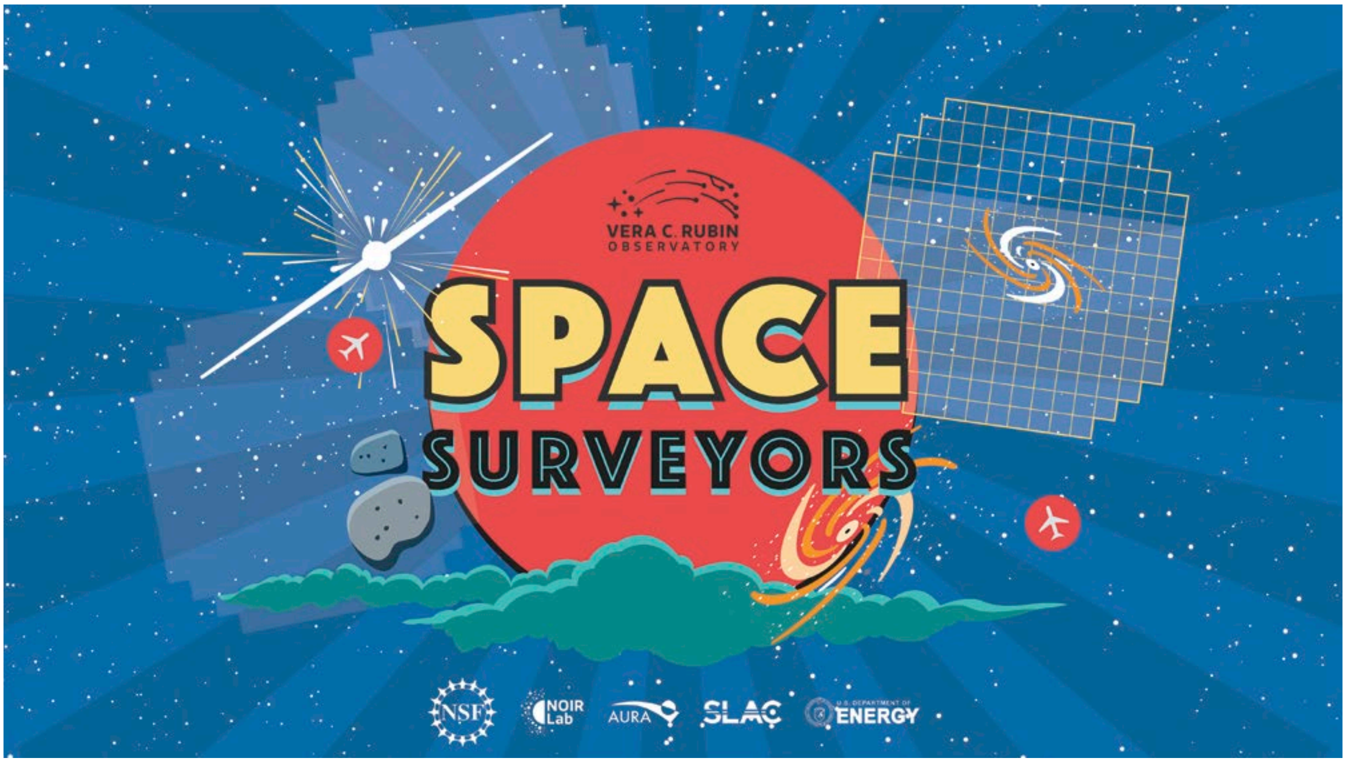

Figure 1: Space Surveyors: an interactive game that simulates operating a survey telescope.
Credit: Rubin Observatory/NOIRLab/NSF/AURA/J. Pinto)

The Rubin Observatory Education and Public Outreach (EPO) team has begun to roll out a program that invites teens and adults to engage with Rubin Observatory and explore the Universe. Like Rubin Observatory as a whole, the EPO program capitalizes on new technologies and strategies — in this case to reach a whole new audience of science-interested teens and adults who might not already be engaged with, or highly knowledgeable about, astronomy. This focus on reaching a broader audience through a data-driven, interactive EPO program appealed to the US National Science Foundation (NSF), which provided construction funding for Rubin Observatory. In fact, the Rubin EPO program is the first astronomy outreach program to be fully funded by NSF during a project's construction phase. Having the time and resources to develop this program before the start of the astronomical survey has allowed the EPO team to consider their audiences and build their program strategically — and they're excited to share the results!

The first thing to know about the Rubin EPO program is that it's all online, which means that anyone with an internet connection can access the whole range of materials developed by Rubin's EPO team. Since more and more people — especially teens and young adults — are using mobile devices to interact with digital content, the Rubin EPO team has designed the materials to be mobile-friendly and easy to navigate from a phone or tablet. The EPO program is also available in English and Spanish, so it will welcome Chilean audiences as well as Spanish speakers in the US and worldwide. Additionally, the EPO team is dedicated to following best practices for Web accessibility and strives to provide an inclusive online experience.

A pillar of the Rubin EPO program is its formal education component, which focuses on engaging advanced middle school to introductory college students with real astronomy data. The program centers around a series of investigations and a full complement of teacher support materials, all designed under the supervision of Education Specialist Ardis Herrold, who taught astronomy in the classroom for more than 35 years. Investigations are engaging and interactive and don't require special software or teachers to download data — a browser is all that's needed. Best of all, they're free! The investigations follow a progression of concepts and tasks that are necessary for students to learn the big ideas of each investigation. All materials have been tested with thousands of students and teachers to help ensure success in the classroom, and the support materials provide teachers with everything they need to easily implement these tools with their students. The EPO team will release two complete investigations initially, and there are several more in the late stages of development, so teachers can expect at least one more in the next few months. The formal education team has also started offering professional development workshops in the US and Chile to introduce teachers to the investigations and connect them with the Rubin Observatory community.

Rubin EPO also offers a range of products for the general public, including a website, animated videos, and an image gallery. While designing these, the EPO team referenced the outcomes of their evaluation effort to research what inspires (and what intimidates) people when it comes to astronomy. The result is that the new website is filled with articles written in an informal, conversational style that uses analogies and real-world examples to make astronomy concepts interesting and relevant. The website includes a section called *Rubin Voices*, which highlights the people who are working to build Rubin Observatory or preparing for the science that Rubin will enable. Each profile includes a short audio clip, so visitors can listen to people expressing their passion for science in their own words. On the website visitors will also find a gallery of visually engaging images and graphics, all available to download and share, as well as animated videos that introduce Rubin Observatory and explain some of Rubin's main science goals.

But how will people who aren't already engaged with astronomy find these opportunities? Rubin EPO's outreach program uses social media as a primary method to reach new audiences. That's where people — especially young people — are currently getting information and building communities. Rubin Observatory is building a strategic social media presence that focuses not just on sharing information but also on engaging in conversation with followers, capitalizing on trends to stay relevant, and building relationships with other influential people and organizations to expand audience reach. As Stephanie Deppe, the EPO team's Astronomy Content Strategist, explains, *"We won't rely on people to find us — we'll go to them!"*

A challenge for the EPO team as they transition to an operational state is that the astronomical data from Rubin Observatory, which will drive all the interactive features of the program, aren't available yet. So while some of the team's products are essentially ready to go, they won't be released until they can incorporate real Rubin data, giving users the full experience. Two such examples are the *Skyviewer* and the *Orbitviewer*.

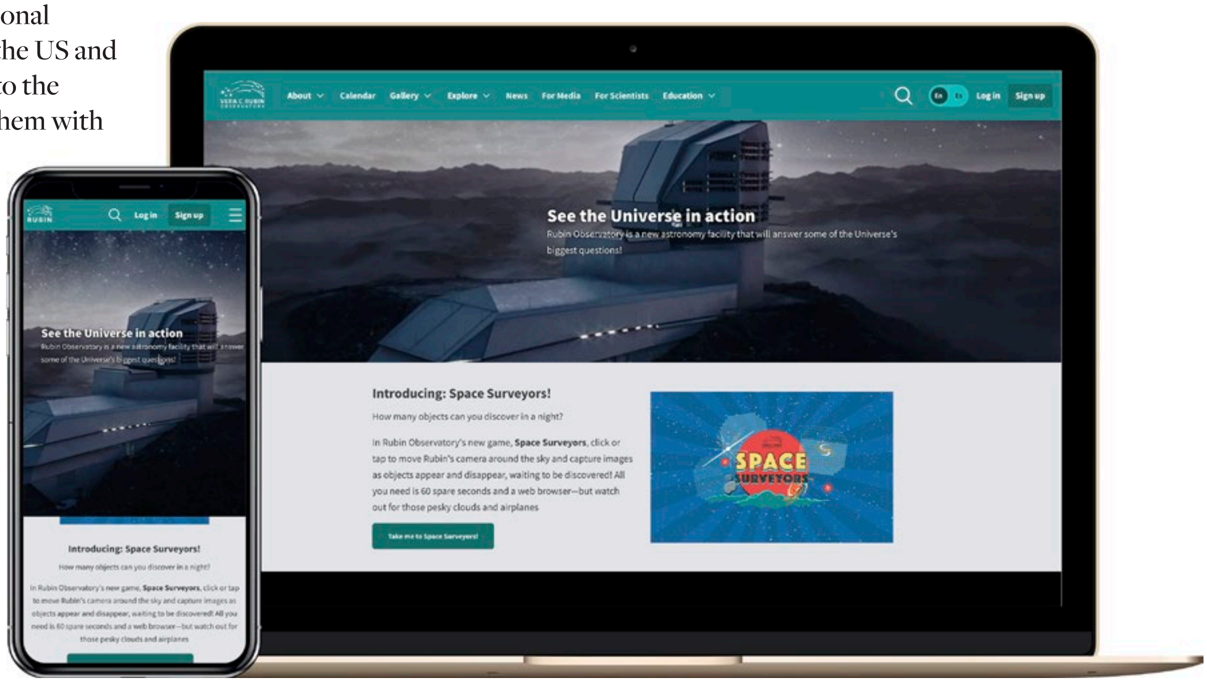

Figure 2: The new public-facing website for Rubin Observatory features engaging visuals, and information about Rubin technology and science, written in an approachable, conversational style
Credit: Rubin Observatory/NOIRLab/NSF/AURA/J. Pinto

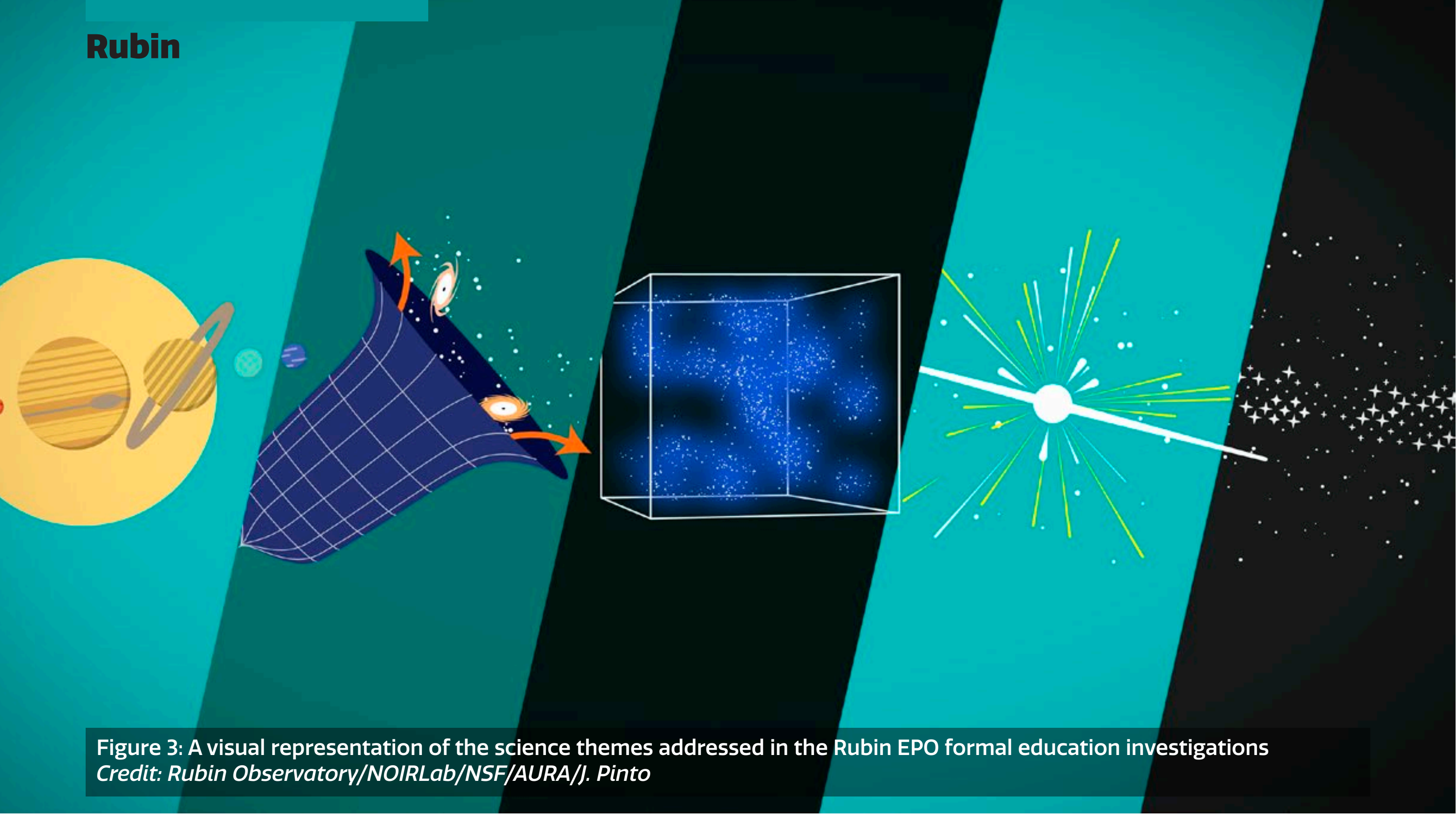

Figure 3: A visual representation of the science themes addressed in the Rubin EPO formal education investigations
Credit: Rubin Observatory/NOIRLab/NSF/AURA/J. Pinto

The *Skyviewer* is an all-sky visualization tool that enables users to navigate around the Southern Hemisphere night sky (the observatory is in Chile), as seen by Rubin Observatory, and select featured objects to learn more about them. The EPO team's user testing campaign revealed that some individuals are much more likely to engage with these types of tools if they have a more guided experience, so that option is available as well. The *Orbitviewer* is another exploratory tool that will offer both a guided and a free-form experience for people to interact with Rubin Observatory's observations and discoveries in our Solar System. Watch for these tools when Rubin starts producing data!

One other major program component that the EPO team will introduce after data starts flowing facilitates participation in Rubin science by...anyone!

The team has partnered with *Zooniverse*, a prominent citizen-science platform based at Oxford University in the UK, to develop a tool that will make it quick and easy for primary investigators to create projects and populate them with Rubin data. That's great news for scientists who need the help of lots of human eyes to interpret their data and great news for anyone who wants to contribute to real, cutting-edge astronomy.

So there's still lots to come, but the Rubin EPO team wants to educate and entertain you in the meantime — so they created a simple, fun, browser-based game called *Space Surveyors*. The game teaches players how a survey telescope works as they attempt to capture images of stars, galaxies, and moving objects in the night sky. The EPO team invites you to visit spacesurveyors.app and try for a high score!

The Víctor M. Blanco 4m Telescope at Cerro Tololo Inter-American Observatory, a Program of NSF's NOIRLab, in Chile is shown here juxtaposed against the bright Milky Way in the background. The green light above the clouds in this image is airglow. The Picture of the Week can be found here.

Credit: CTIO/NOIRLab/NSF/AURA/B. Tafreshi

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US Astronomy Community Surveys for the US–ELTP

André-Nicolas Chené and Marie Lemoine-Busserolle (NSF's NOIRLab)

The role of NSF's NOIRLab in the US Extremely Large Telescope Program (US-ELTP) is to provide user services spanning the full research life cycle from proposal preparation through data analysis and publication for US users of the Giant Magellan Telescope (GMT) and the Thirty Meter Telescope (TMT). One of the program's challenges is to ensure inclusive support for a broad community of observers and archival researchers. There are many ways to design such support, but the best way to make sure that it answers users' needs is to ask them directly.

Regular broad consultation with the astronomy community will be the norm throughout the development of the US-ELTP software tools and user support models. In the current early phase of the project, NOIRLab has conducted two surveys to grab a snapshot of users' needs and expectations. One survey was open to every astronomer in the US, while the second targeted the PIs of current and past Large and Long Programs (LLPs) at the International Gemini Observatory. We were pleased by the replies to both surveys.

Survey of the broad US astronomy community[1]

The goal of this survey was to assess the US astronomy community's potential interest in using data from GMT and TMT for their science. We also wanted to learn what data products and data services would be helpful. We wanted feedback on two core questions: 1) Are US-ELTP high-level requirements for data services aligned with the needs of the community? and 2) How should we rank requirements by order of priority so we can plan future work efficiently? Eight questions were designed around the key elements of data reduction and analysis.

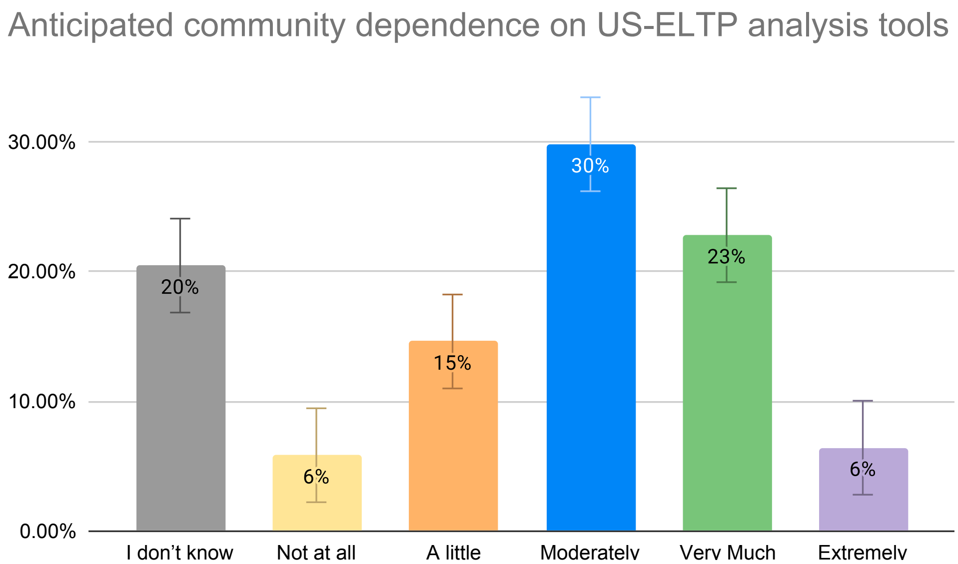

Figure 1: Distribution of responses based on answers to the question "How much would you anticipate relying on analysis tools provided by NOIRLab?" NOIRLab/NSF/AURA/A.-N. Chené

The majority of the respondents expect to use standard data reduction pipelines for GMT/TMT instruments rather than their own tools. Those who disagreed with this approach were not confident that the quality of the results from standard pipelines will be sufficient. This shows that not only will the pipelines need to be openly accessible and properly supported but also their output will need to comply with high-quality standards that will have to be clearly demonstrated, documented, and publicized.

Support for analysis tools provided by NOIRLab was much more nuanced. When asked how much they would anticipate relying on analysis tools provided by NOIRLab, respondents said, at ~20%, "a little" or "not at all"; at ~30%, "moderately"; and at ~30%, "very much" or "extremely" (Figure 1). There is therefore a need for support with basic analysis work, such as spectral fitting or PSF photometry, mostly from potential users who are not familiar with optical and infrared data or junior researchers who have limited experience. A certain number of respondents mentioned that without any support they may simply not be able to perform their analysis successfully.

The most popular observing mode the respondents expect to use on GMT and TMT was integral field spectroscopy (50%). All of the spectroscopic modes (long-slit, multi-object, and

[1] The margin of error is 7.24%, with a 95% confidence level (19 times over 20).

high-resolution), as well as broadband and high-contrast imaging, shared a comparable level of popularity (40%+). 10% of the respondents would like to use modes that are not currently planned for GMT or TMT, such as polarimetry and Fabry-Pérot spectroscopy.

Unfortunately, the survey was not successful in achieving broad demographic representation. Only a third of the respondents were junior faculty, postdocs, or students. A small portion (7.8%) were from a two- or four-year college; 14.5% were affiliated with a minority-serving institution (MSI), and one respondent's affiliation was classified as a Historically Black College and University (HBCU) or Tribal College. Future survey efforts will focus specifically on junior researchers, as well as researchers at small or under-resourced institutions (SUIs).

Survey of LLP PIs[2]

LLPs at Gemini are similar to the expected Key Science Programs at GMT and TMT. These are programs that require a large amount of observing time and/or a large number of consecutive semesters to complete. They are ambitious programs that aim at making highly impactful new discoveries. And, most importantly, they are large collaborations between people across the whole Gemini partnership. The US-ELTP staff were interested in learning more about how LLP science teams formed and communicated, what their biggest obstacles were, and what their general level of appreciation was for the technical support that was provided to them.

Every respondent said that the science team was formed either from usual collaborators or by direct invitations to individuals or groups. No one offered an open collaboration through a broad announcement. While this is not unexpected, it is a practice that will probably have to evolve to foster more inclusion of a diverse group of researchers in the near future.

There appear to be two groups with different approaches to team coordination. One group relied on conventional modes of communication, such as videoconferences (Zoom or Meet), emails, the phone, or in-person meetings. While this is a more natural approach, the main challenges were restrictions due to the COVID-19 pandemic and time zone differences. The other group used the instant messaging platform Slack, which was praised for easing quick communication and for conducting a discussion in a much more efficient way than a meeting or an email thread. However, some threads were not well-organized, and it was difficult to keep track of conversations or to find old messages. Also, because not everyone is on Slack, it could not be mandated as the official way to communicate within a team.

Collaborative work on the proposal was usually supported by the cloud-based LaTeX editor Overleaf. Most respondents had positive comments on the platform although they occasionally had minor issues. The respondents with a paid license had a better experience than those using the free version.

No respondent noted any serious roadblocks. Access to licenses was generally not an issue, yet when it was, the LLP science team was able to work with free software. A few obstacles were occasionally met during data reduction and analysis, but the team was able to handle these obstacles effectively. The majority (75%) have made advanced data products available for public release.

The next step

The results of the two surveys are already guiding the requirements for the development of the US-ELTP operation systems. They will also guide future consultations that will be more focused towards junior researchers and researchers at SUIs.

The US-ELTP thanks everyone who answered our surveys. There is a lot more information in the responses than has been presented here, and the text comments are rich in valuable information.

The US Extremely Large Telescope Program (US-ELTP) is an endeavor to develop a two-telescope, two-hemisphere single system for the next generation of ground-based telescopes. Scientists at US institutions will have equal opportunity to access 25% of the observing time on the Giant Magellan Telescope (GMT) and the Thirty Meter Telescope (TMT) to observe objects anywhere in the sky and carry out transformational research. NOIRLab will facilitate an open peer-review process, archive all science data from both observatories, and provide an extensive suite of user support and data analysis services.

[2] The response rate was 50%

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A Virtual View of NOIRLab's Programs and Facilities

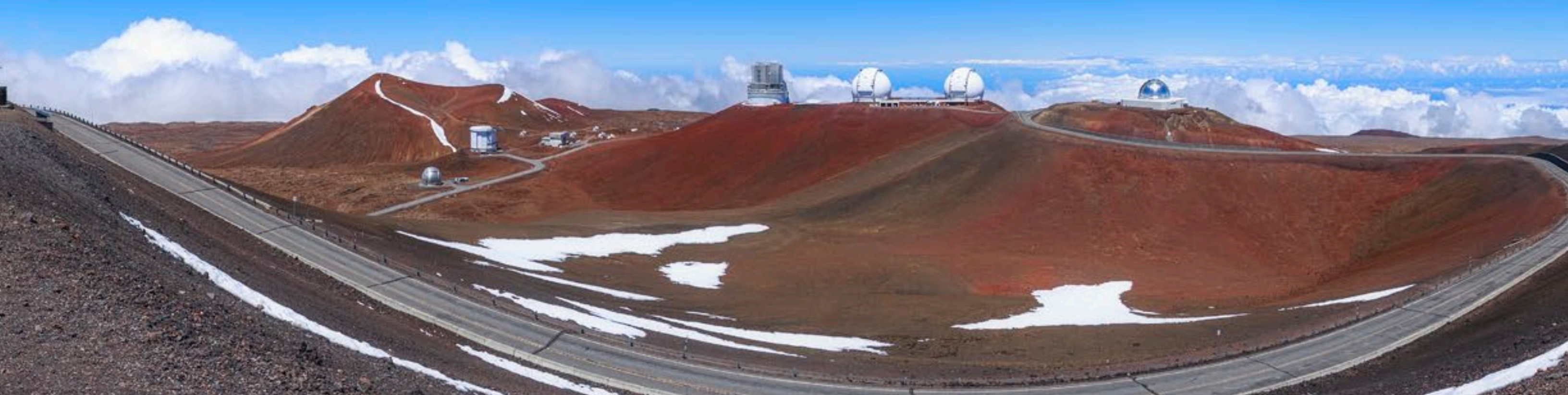
Joy Pollard (NSF's NOIRLab) and Mahdi Zamani (Zamani Visuals)

In late October 2022, we announced the release of the virtual tours for all seven NOIRLab base and summit facilities. In these tours you will find an impressive array of photospheres (images of environments digitally projected on a sphere) arranged into cohesive virtual tours of our summit facilities, staff and equipment, day and nighttime vistas, and more. Here we offer a "peak behind the curtain," if you will, of the tours and their creation.

Inception

One of the areas that the NOIRLab Communications, Education & Engagement (CEE) group has expanded into is immersive virtual experiences. Staff therefore set out on an ambitious plan to not only document our sites with ultra-high-definition video and photographs (as we never have before) with high-quality full-dome visuals to be used in planetariums, but also put them into a unified virtual experience that anyone with internet access can visit from anywhere in the world.

The International Gemini Observatory and Vera C. Rubin Observatory have both previously created virtual products, creating a virtual tour of Gemini and 360º videos during the construction of Rubin. However, with the changes to our facilities and the improvements in technologies used in virtual tours, we decided it was time for an update.



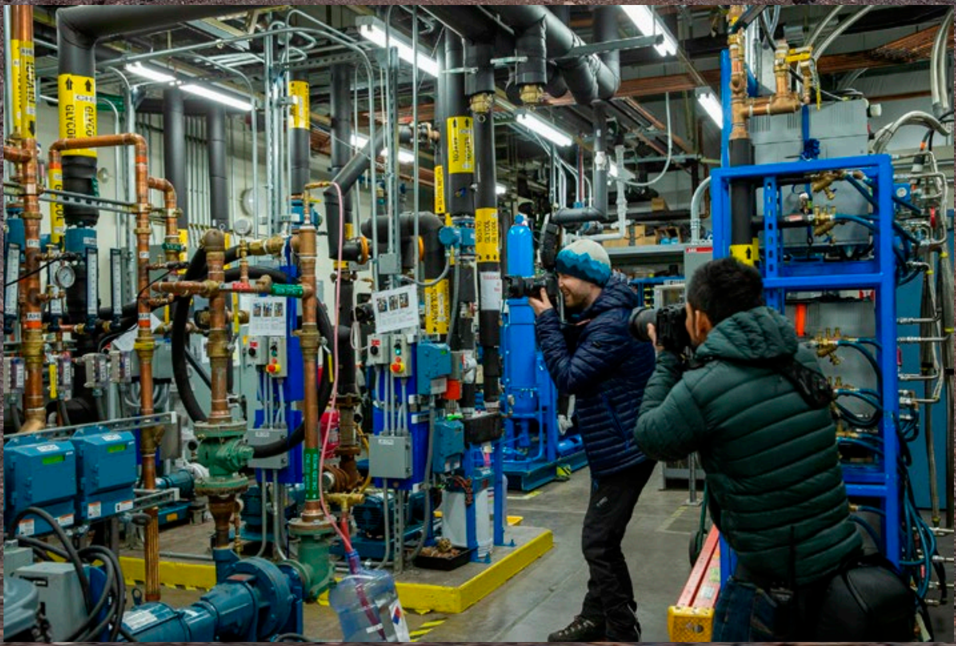
Figures 1&2: Behind the scenes photos from the 'photo expedition.' *Credit: International Gemini Observatory/NOIRLab/NSF/AURA/J. Pollard*

Background Image: Panoramic view of the Gemini North telescope, part of the International Gemini Observatory, a Program of NSF's NOIRLab. *Credit: NOIRLab/AURA/NSF/P. Horálek*

Photography

In 2022, NOIRLab arranged for three experienced photographers and videographers — Petr Horálek, Theofanis Matsopoulos, and Tomáš Slovinský (figures 1&2) — to work with NOIRLab's own photographers on a 'photo expedition'. Over the course of 21 days, the highly skilled photographers worked with local guides at each facility to fully document and capture the location, which resulted in an amazing 320 photospheres.

To achieve high-quality images, with up to 500-megapixels resolution, modified[1] DSLR cameras and special panorama equipment were used. Nighttime 360-degree photospheres are even more challenging. Much like the telescopes we are photographing, it is important to optimize the signal-to-noise ratio, such that a setting is used that is sufficiently sensitive and balanced with the exposure time (this is where the modified DSLR cameras come into play). On top of this, if the exposure time is not calculated perfectly for each shot, the sky will have shifted by the time you swing around and take the last images of the photospheres.



[1] The default integrated infrared-cutoff filter on the CMOS sensor of the cameras was replaced with a broader bandwidth filter to increase the camera sensitivity between 550 and 710 nm, particularly to significantly increase the sensitivity to the ionized hydrogen (Hα) emission line at 656 nm.

Post-Processing

After all of the images were collected, 6 to 24 photos were selected for each scene, and then stitched into a single photosphere (also referred to as “panoramas” in this article) in equirectangular plate carrée projection (mapping a sphere to a flat page, such as the globe to an equirectangular map, as shown in figure 4). After that, we ensured that natural colors in each panorama were preserved and white-balanced.

Color balancing is an important process to visually enhance the immersive experience for all of the day and nighttime images. It also ensures that colors in the nighttime images are the closest representation of what the human eye would see if capable of detecting the details and faint colors of the night sky. The limited low-light vision of human eyes does not allow for the perception of most colors in very dark conditions, like those in and around NOIRLab’s observing facilities at night.

The next step focused on manually removing stitching errors/artifacts and then color correcting each individual panorama. As the final step of post-processing, most of the panoramas were re-projected into a hemispherical image with fish-eye projection to be compatible with planetariums (figure 3).

Production

The primary objective of the virtual tour project is to produce seven different virtual tours, (one for each NOIRLab facility), including base and summit facilities. To maximize device compatibility, this meant building interfaces from scratch for each virtual tour: two for widescreen devices (one each for desktops and tablets), one for smartphones, and one for Virtual Reality (VR) headsets (figure 5). The interfaces were designed taking into account how the images look on each device, how the user will interact with them, and what kind of information will be overlaid on top of the image content.

Our production team mapped out the locations, geotagged each panorama, directed camera movement for each area of interest in every panorama, and solicited input from the content experts at each site so that we would be sure to include the areas that were most significant or interesting. We conducted an iterative process with prototypes going through alpha testing by NOIRLab colleagues and updating and then beta testing the selected version.

To increase the user interactivity and aesthetics, we implemented visual effects such as lens flare, rain, a panorama-to-panorama walkthrough effect, Virtual Reality video implementation, and informative popup text bubbles and labels. The popups were designed to be ‘discovered’

Figure 3: Fulldome image of Gemini South and the SOAR telescope on Cerro Pachón in Chile, illuminated by the Milky Way's glow. Gemini South can be seen projecting a laser guide star (LGS) into the night sky. These images are also ideal for use in planetariums. *Credit: International Gemini Observatory/NOIRLab/NSF/AURA/P. Horálek*

Figure 4: 360-degree panoramic view of the Chilean night sky as the Milky Way streaks above Vera C. Rubin Observatory and the Rubin Auxiliary Telescope (left) on Cerro Pachón.*Credit: Rubin Observatory/NOIRLab/NSF/AURA/P. Horálek*

by users who want to spend more time exploring "books" in our facilities' libraries, the night sky above the NOIRLab telescopes, or other telescopes visible in the daytime panoramas.

Accessibility and Future Updates

A critical goal of this project is to address accessibility issues inherent in visiting our remote facilities. We envision that these tours will be used by: school groups who don't have the resources or time to travel; by members of the public who, due to health or mobility concerns, are unable to go to our often inaccessible mountain summits; and by anyone who wants to come as close to experiencing the real thing as they can without actually traveling across the globe. It is our hope to continually improve accessibility and inclusion by creating highly immersive and interactive virtual experiences accessible from the comfort of home and compatible with a wide range of devices. A downloadable version for Windows and Mac desktops, which can be used without a high-speed internet connection, is available on each virtual tour web page.

With diversity and accessibility in mind, the NOIRLab Virtual Tour is a first step toward a globally accessible environment with features planned for future updates that will include toggling between preferred languages, text-to-speech for mobile users or people with limited vision using VR headsets, and live guided virtual tours for schools and group meetings.

In the coming months you can expect to see the addition of Spanish-language integration (we encourage other international partners throughout NOIRLab to consider working with us to make versions in other languages as well). We will also be considering additional locations and different perspectives to further flesh out and expand the user experience. This will include updated and additional photography, video, and new interactive elements. The virtual tour is a dynamic experience, changing and updating to keep pace with the real world changes of our sites (Vera C. Rubin Observatory moving full into operation, changes as a result of the Contreras Fire on Kitt Peak, etc.).

If you haven't had the opportunity to experience our virtual tours yet, please visit them and explore!

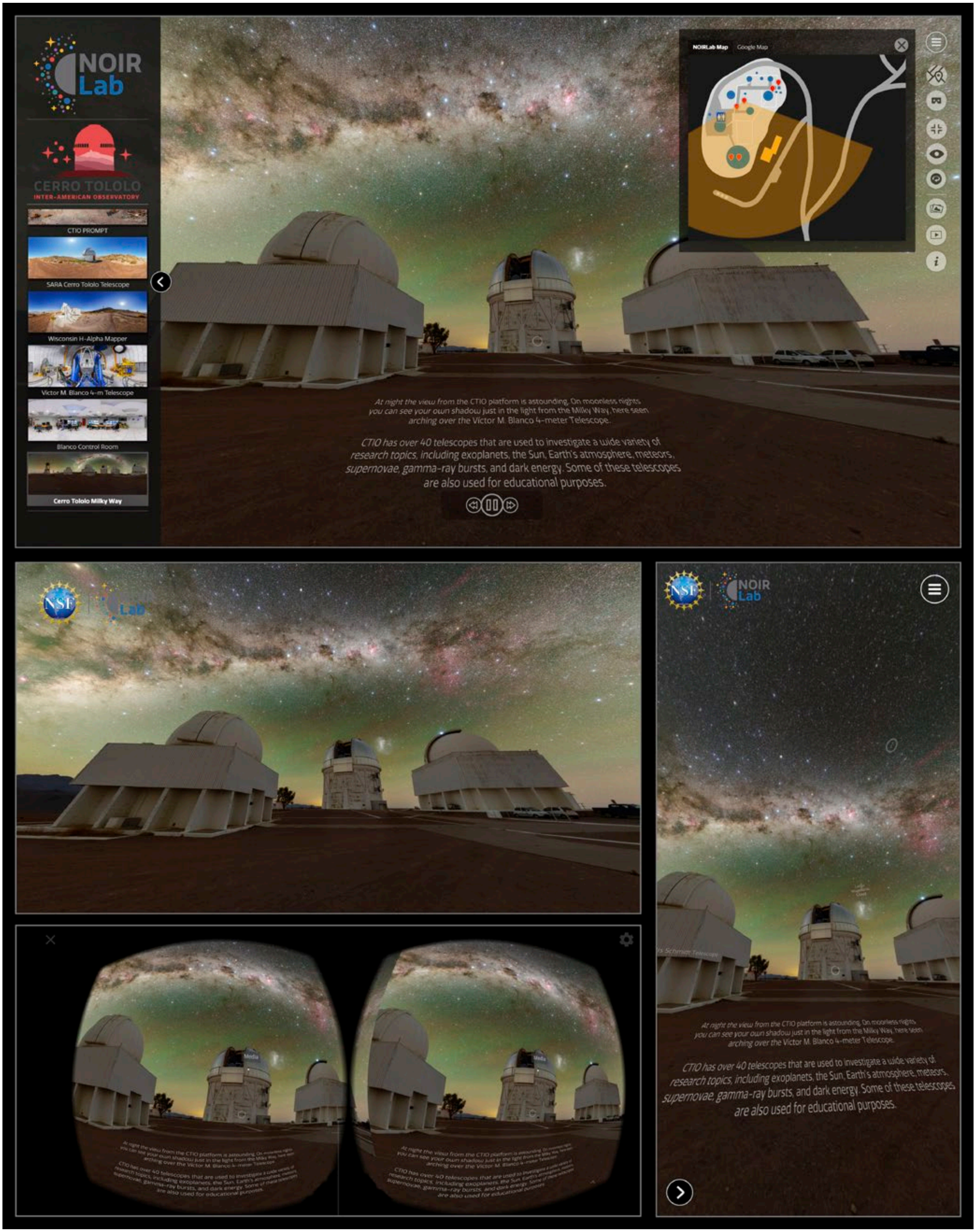


Figure 5: View of the Cerro Tololo platform as seen in the tour using different interfaces. **Top:** Browser w/full interface. **Middle left:** fullscreen no overlay. **Lower left:** VR view. **Lower right:** As seen on a mobile device. *Image Credits: CTIO/NOIRLab/NSF/AURA/T. Slovinský; Layout Credit: M. Zamani*

This long-exposure image, taken shortly before sunrise, shows stars appearing to "trail" around the south celestial pole above the Southern Astrophysical Research Telescope (SOAR Telescope). The SOAR Telescope is part of Cerro Tololo Inter-American Observatory, a Program of NSF's NOIRLab. The Picture of the Week can be found here.

Credit: CTIO/NOIRLab/SOAR/NSF/AURA/M. Paredes

10.5281/zenodo.7502498

New Scientific Staff at NOIRLab

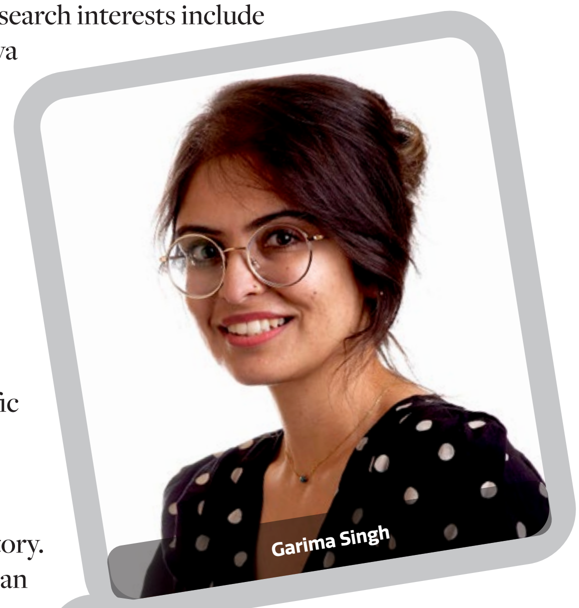
Kathy Vivas (NSF's NOIRLab)

Ten new astronomers were recruited this spring to join the NOIRLab scientific staff. They will support a wide variety of programs over all of the NOIRLab locations. This is the first time that NOIRLab's Research and Science Services has performed an integrated recruitment program aimed at hiring scientific staff. The goal was to not only fulfill specific needs for service roles throughout NOIRLab but also strengthen the scientific capabilities of NOIRLab.

Guillermo Damke

Guillermo Damke (see profile in "A Reflection of His Father" on page 10 of this issue) and **Aleksandar Cikota** have joined the scientific staff in La Serena, bringing new capabilities to the CTIO and Gemini programs, respectively. Guillermo is an expert on astroinformatics with applications to both galaxy classification and stellar populations in the Milky Way. He is also involved in research regarding the preservation of dark skies in Chile. Aleksandar brings spectropolarimetry expertise to NOIRLab. His research interests include Type Ia Supernova progenitors and supernova cosmology, dust extinction in supernova hosts, and superluminous supernovae.

Aleksandar Cikota

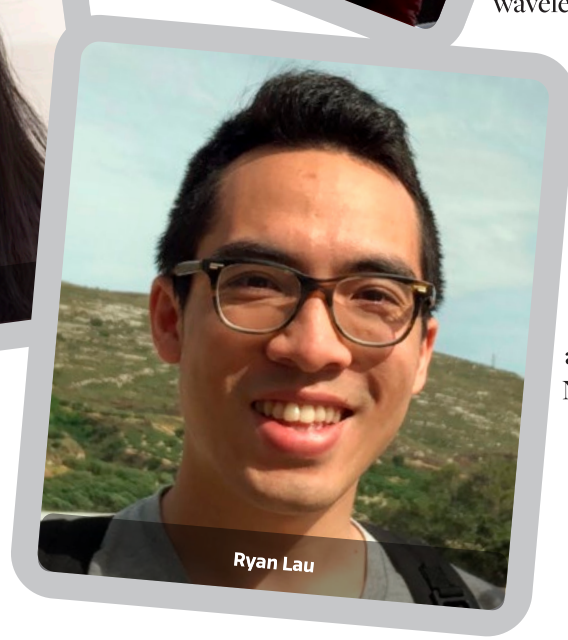


Garima Singh

Two new scientific staff in Hilo have been assigned to service roles at Gemini Observatory. **Garima Singh** is an expert on adaptive optics and direct imaging of extrasolar planets. She is expected to continue playing an important role with the Gemini Planet Imager-2.0 (GPI-2.0) instrument currently in development for Gemini North. **David Jones** has joined the Gemini Science User Support Department. His research focuses on Type Ia supernovae and their implications for cosmology, including the expansion rate of the local Universe, as parameterized by the Hubble constant, and the expansion history as a means of probing the nature of dark energy.

David Jones

Four scientific staff have joined NOIRLab in Tucson. **Eric Peng** comes to NOIRLab with wide experience in the study of the formation of galaxies using nearby "fossil" stellar populations. He has served on the Thirty Meter Telescope Science Advisory Committee and as the Project Scientist for TMT's Wide Field Optical Spectrometer. At NOIRLab, Eric will be helping to shape the US ELT Program. **Yuanyuan Zhang** is an expert on extended low-surface-brightness light in galaxy clusters, large-scale structures, cosmology, and wide-field imaging surveys. She has been assigned to service roles in the Community Science and Data Center (CSDC). **Christina Williams** and **Ryan Lau** are now part of the Rubin Community Engagement Team. Ryan will also be spending part of his time in CSDC, to bolster its role in supporting the use of Rubin data. Ryan works on the evolution and death of massive stars and their enrichment of the interstellar medium (ISM). He is particularly interested in the role of Wolf-Rayet stars as potential leading sources of dust in the ISM of galaxies, a project that he is pursuing with the JWST. Christina uses data from the X-ray through radio wavelengths to study how galaxies form and evolve. She is also a member of the JWST NIRCam science team.



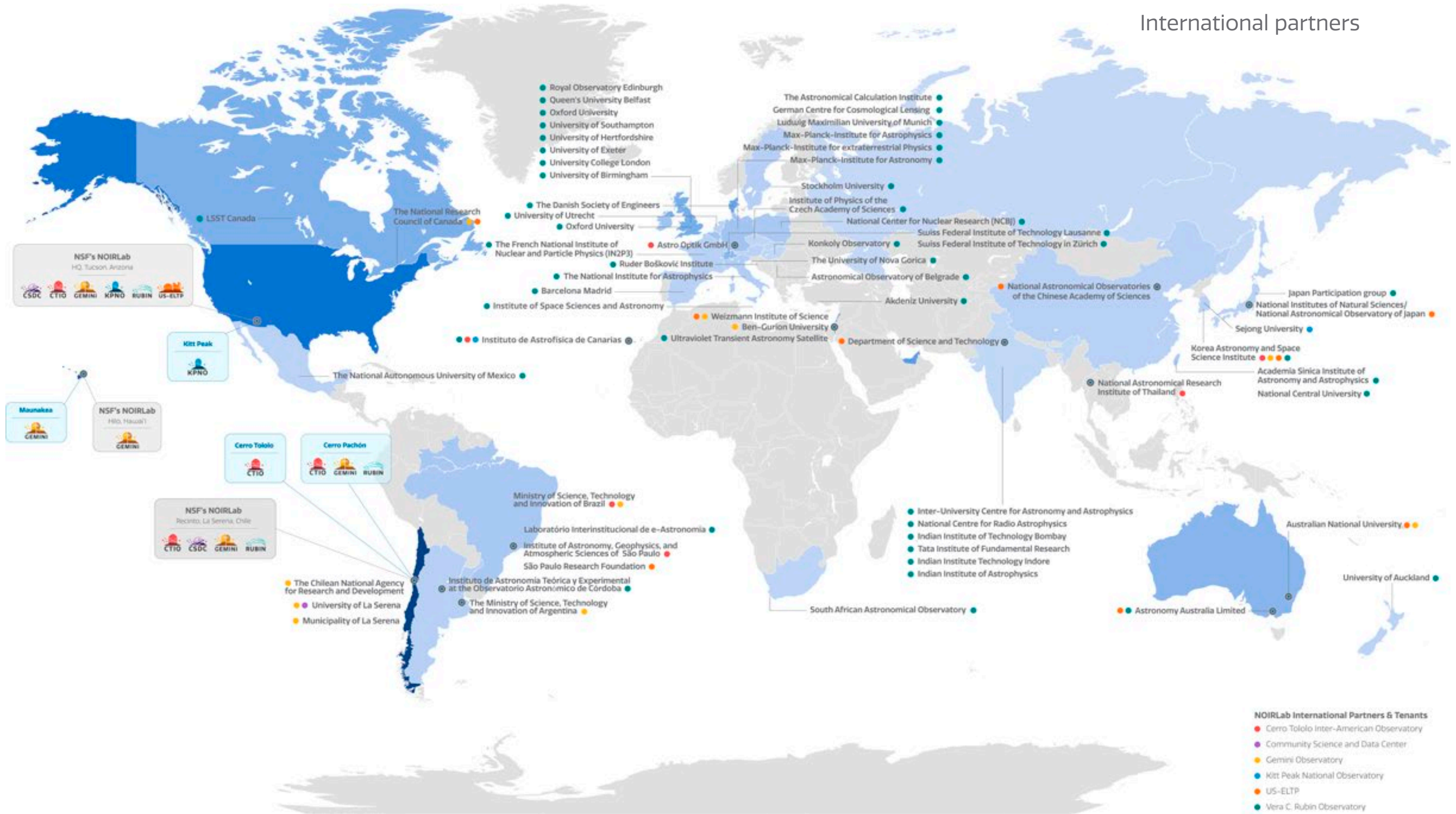
We expect two additional science staff members to arrive at NOIRLab in 2023.

A quartet of interacting galaxies is captured in this observation from Gemini South, which is one of the twin telescopes of the International Gemini Observatory, operated by NSF's NOIRLab. The four galaxies in this image are collectively known as NGC 6845 and lie roughly 270 million light-years from Earth. The Picture of the Week can be found here.

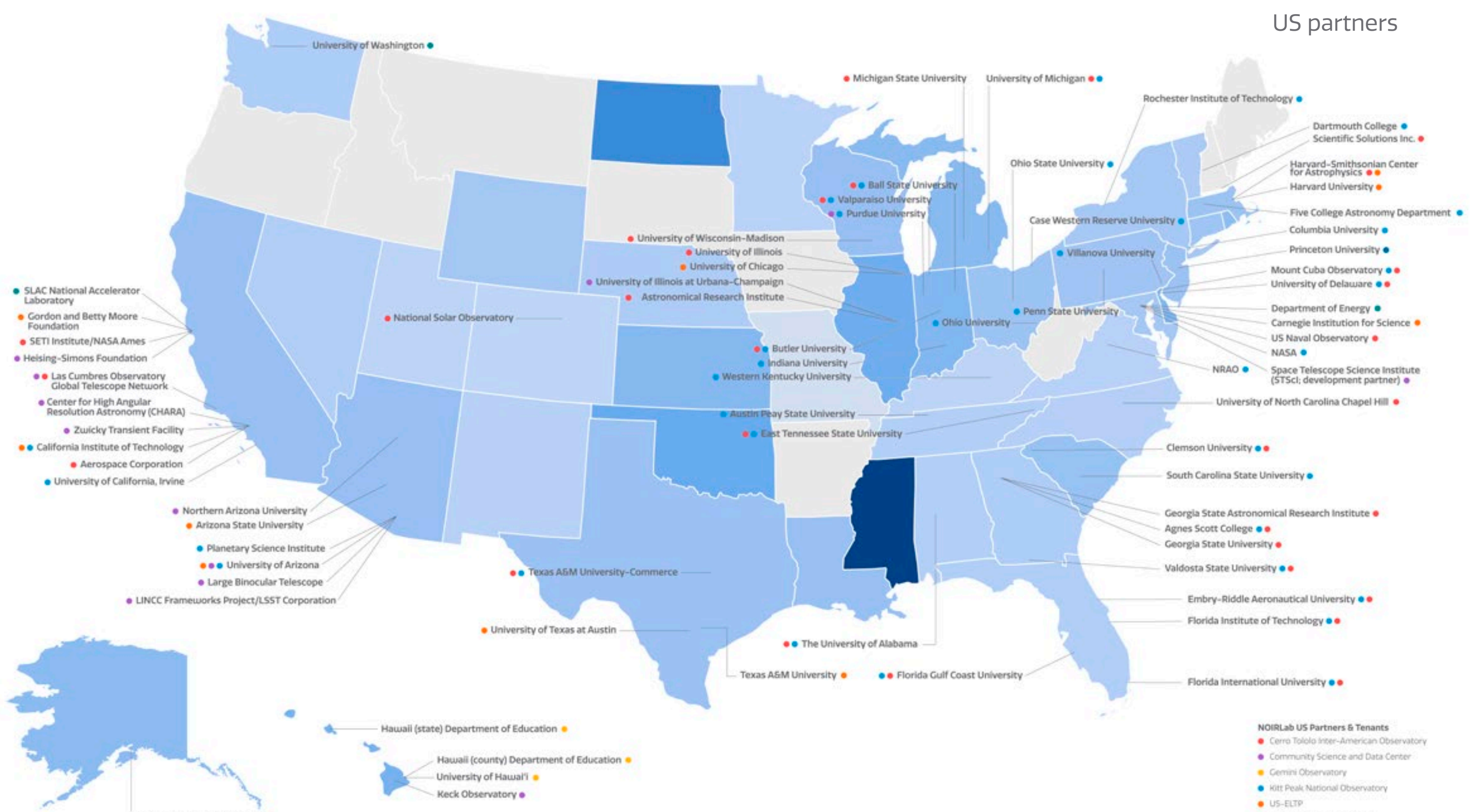
Credit: International Gemini Observatory/NOIRLab/NSF/AURA/G. Gimeno, R. J. Díaz, H. Dottori

NOIRLab Partners

International partners



US partners



Discovering Our Universe Together

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