The Mirror

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Editor-in-Chief
Tod R. Lauer

Design & Layout
Pete Marenfeld

Production Manager
Mark Newhouse

Associate Editor
Sharon Hunt

On the Cover

A galactic collision of two galaxies which began more than 300 million years ago, NGC 520 is actually made up of two disk galaxies which will eventually merge together to form one larger, more massive system. NGC 520 was discovered by William Herschel in 1784 and is one of the largest and brightest galaxies in the Siena Galaxy Atlas. *Credit: J. Moustakas/Siena College; CTIO/NOIRLab/DOE/NSF/AURA*

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950 N Cherry Ave, Tucson, AZ 85719, USA
mirror@noirlab.edu

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Director's Message

Patrick J. McCarthy

In the early morning hours of the first of August 2023, NOIRLab was subjected to a cyber incident that attempted to take down our systems. This was not the result of hacking by bored teenagers, but rather appears to have been the work of professionals who attack organizations around the world. Fortunately, these hackers had not fully done their homework — they struck at 2 a.m. on a Monday morning, apparently not realizing that observatories operate at night! Our crack IT team spotted the attack in real-time and disconnected Gemini North and all of Cerro Pachón and Cerro Tololo from the outside world just 40 minutes after the attack began. The hackers managed to encrypt many servers in Hawaii, but failed to have broader effects before being interrupted by our IT team's fast action. Crucially, we prevented our online backups from being affected. Nonetheless, it has been a long road back to "normal" operations. Following this incident, we have continued to enhance our security posture. Our internal network has undergone additional security enhancements to prevent intrusions and to limit any impact should another incident occur.

Unfortunately, cybercrime is on the rise, and other observatories, national laboratories, government agencies, universities, municipalities, nonprofits, and large corporations have been targeted. The frequency and sophistication of such attacks are increasing rapidly, and we are therefore in a constant race to keep our protections up to date. For example, all of us at NSF's NOIRLab participate in the "KnowBe4" security awareness training program.

NOIRLab management and our IT team learned a number of valuable lessons from this cyber incident. The first and foremost lesson is simple: be prepared, have a plan, and follow the plan. Our up-to-date Incident Response Plan was the key playbook in the hours and days following the attack. It greatly facilitated our ability to act swiftly, to work across all our sites, and to coordinate with NSF and AURA Corporate. Regular training and frequent full-scale incident response drills paid off when the real incident occurred.

A second lesson is that multi-factor authentication is a critical line of defense against attackers. It requires an extra step when logging in, but it is key to preventing unauthorized access to Lab networks.

Another key lesson that we will take away from this incident is that we must continue to focus on our communications with various stakeholders. We communicated closely with funding agencies and partners during the early days of our response efforts. However, in the future we will also focus on our communications with users of the mountain sites in Chile so they understand the state of the network and the timeline for restoration of services. Balancing caution with the need to keep people informed is a challenge, particularly when the security of our communications is in doubt.

The highest-level lesson from this experience, and the Kitt Peak fire, is that when we identify a high-impact risk we move with alacrity to mitigate it. We had a very sound plan and quickly implemented our IT security plan, but *we can always do better and move faster*. We have become very good at recovering from incidents, but *we must continue to focus on prevention*.

Part of what apparently made NOIRLab a tempting target for hackers is our transparent approach to operations and collaboration. Our mission as a national laboratory for astronomy and our commitments to our domestic and international partners require that we support many diverse users of our systems. Remote observing, rapid response to ToOs, citizen science programs, distributed collaborations, and close coordination between telescopes in the north and south are all best served with a network that is easy to access and easy to navigate. The power of this collaborative approach is documented in this edition of *The Mirror* through articles about Multi-Messenger Astrophysics, the *Cool Neighbors* citizen science project, the La Serena School for Data Science, and others. The story of the "Finch" luminous fast blue transient by Ashley Chrimes is a great example of multi-platform time-critical coordination.

Institutions with a scientific mission all face this challenge — science is best served by openness and collaboration — yet we must protect ourselves and our users from bad actors in the cyber domain. Our system was built over a number of decades to support scientific collaboration. In the past few months, we have optimized it from the ground up, enhancing our security while still supporting our mission. We hope that our experience can serve as a wake-up call for others so that they will not have to learn these lessons the hard way.

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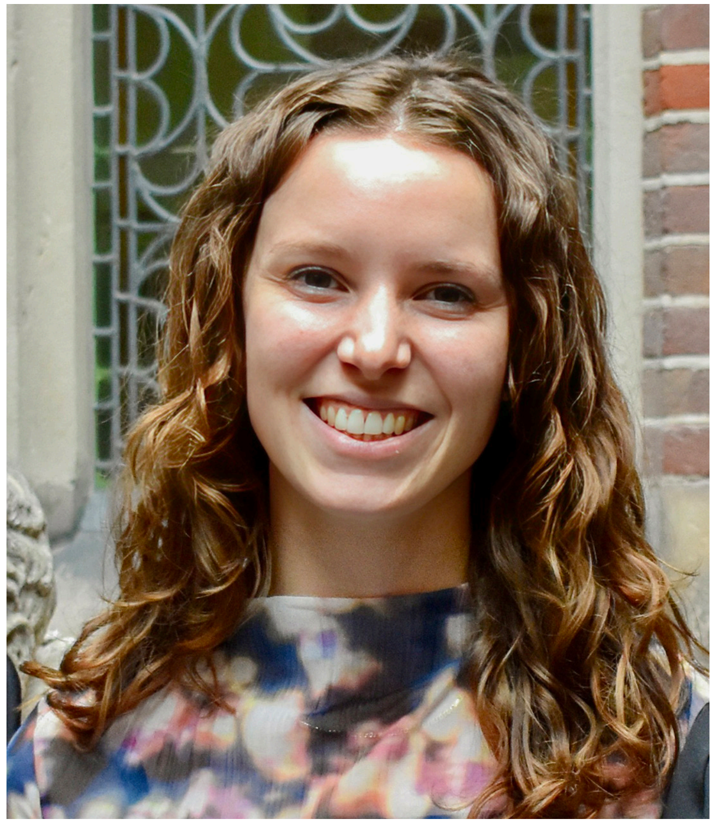

NSF's NOIRLab Postdoctoral Research Fellowship

In 2023, NSF's NOIRLab established the three-year NOIRLab Postdoctoral Research Fellowship, an opportunity for outstanding postdoctoral scholars to carry out independent research broadly related to the mission of NOIRLab. The fellowship is also intended to help develop the next generation of science and technology innovators and leaders in ground-based OIR astronomy.

The Fellow will spend most of their time on an independent research program of their choosing. They will also have the opportunity to work with NOIRLab staff on activities related to the development and deployment of optical and/or infrared capabilities, techniques, data sets, and analysis tools, in order to, for example, advance their research program and interests. During the first two years of the fellowship, the Fellows will dedicate up to approximately 25% of their effort to a coherent plan of activities that promote diversity and equity in science.

The individuals chosen to be the inaugural NOIRLab Postdoctoral Fellows are Arvind F. Gupta (based in Tucson) and Anniek Gloudemans (based at Gemini North in Hilo).

Arvind completed his PhD in Astronomy & Astrophysics at the Pennsylvania State University. His dissertation explored the design of exoplanet surveys with extreme precision radial velocity spectrographs, with a particular focus on the detection of Earth-like planets. At NOIRLab, he will continue to work on radial velocity exoplanet surveys as well as on studies of the formation of hot and warm Jupiters.

Anniek obtained her PhD at Leiden Observatory in the Netherlands, where she worked on observing radio-loud quasars into the cosmic dawn using multi-wavelength data. During her fellowship, she will continue building samples of these rare sources and studying their extraordinary properties. Her goal is to start new outreach initiatives for the local community and set up a mentoring program within NOIRLab.

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IAU Symposium #385 "Astronomy and Satellite Constellations: Pathways Forward"

Connie Walker

Credit: Antonio González (www.cielos-lapalma.es)

The IAU Symposium #385 (IAUS385) "Astronomy and Satellite Constellations: Pathways Forward" took place 2–6 October 2023 in La Palma, Canary Islands. Connie Walker, Head of the Office of Site Protection at NSF's NOIRLab and Co-Director of the IAU Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference, chaired the Scientific Organizing Committee for this event.

The symposium was a huge success, and the IAU CPS was heavily involved with the preparation of the sessions. The CPS Hubs who attended in person were SatHub co-leads Siegfried Eggl (University of Illinois Urbana-Champaign) and Mike Peel (Imperial College London); Policy Hub co-leads Richard Green (University of Arizona) and Andrew Williams (ESO); Community Engagement Hub co-lead Jessica Heim (University of Southern Queensland); and Industry and Technology Hub co-lead Tim Stevenson (SKAO).

The SatHub sessions concentrated on challenges to radio and optical astronomy, spectroscopy, space-based observations, and amateur astronomy. They also addressed strategies for co-existence in these categories, including the various approaches developed in recent years in optical astronomy. There are now better models and data for satellite brightness, which are key to enabling any sort of mitigation, for active avoidance, and for use in compliance checks. Future observations by the CPS SatHub observing network will determine whether some coatings and Bragg mirrors on reflective surfaces of Starlink satellites will help, and if so how well. For spectroscopy, better modeling and understanding of satellite spectra will enable satellite emissions to be calibrated out of astronomical data. Autonomous imagers on large spectroscopic facilities can help identify when an exposure was contaminated. For space-based observatories there are software solutions (Starunlink) for streak detection and elimination that may be helpful. Ultimately SatHub is bringing all stakeholders together to tackle the impact of satellite constellations on astronomy.

The Policy Hub sessions focused on ways to raise awareness and encourage coordination. The Policy Hub is engaging a growing network of ~140 people in research and policy work conducting regular interactions with government affairs representatives from several national astronomical societies, observatories, and spectrum managers. These sessions also included discussions on deliverables from the

Credit: Antonio González (www.cielos-lapalma.es)

work packages the Policy Hub has undertaken (a position paper, Space Sustainability Rating, consolidating recommendations from the SATCON-related workshops [SATCON1, SATCON2], lunar policy, etc.).

The Community Engagement Hub aims at the establishment of a fair-minded forum for the conscious and respectful discussion of satellite constellations with all stakeholders involved and communities affected, especially communities outside of professional astronomy. Toward this goal, the Community Engagement sessions at IAUS385 included presentations from Elder Wilfred Buck and other traditional knowledge keepers. The speakers shared perspectives on their relationship with the sky and cosmos and discussed ways to co-create collaborative endeavors related to the night sky and space. Speakers with a background in history and science and technology studies explored past and present space and astronomy issues from different lenses and the environmental and cultural aspects of these topics.

The Industry and Technology Hub session panel included a representative from SpaceX, who provided an update on Starlink satellites and their mitigation measures. The Q&A highlighted a number of concerns regarding relationships with regulators, the state of the market and limits to it, and the flow of information from operators to support independent researchers.

Progress in policymaking in countries throughout the world was also highlighted at the symposium. The general message conveyed was that steady interaction with policymakers and industry is required to raise awareness and promote the protection of dark and quiet skies. There are a growing number of high-level entities who have recognized the importance of dark and quiet skies, including the European Council, ESA Clean Space Charter, G7, Earth Space Sustainability Initiative, and UN Committee on the Peaceful Uses of Outer Space (COPUOS).

Next steps for the IAU CPS include examining the information presented at the symposium, developing collaborations on the topics addressed at the symposium, and encouraging individuals to join the IAU CPS.

My presentation to the National Academies of Science, Engineering, and Medicine (NASEM) Committee on Astronomy and Astrophysics Fall 2023 Meeting summarizing IAUS385 is available on the NASEM website.

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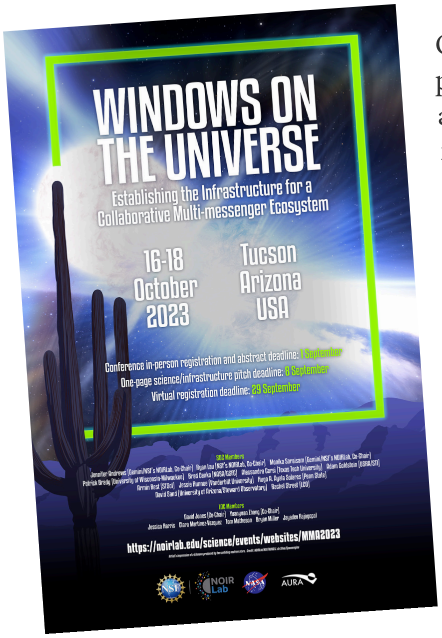
Windows on the Universe: Establishing the Infrastructure for a Collaborative Multi–messenger Ecosystem

Jennifer Andrews

Over the course of three days, 16–18 October, NSF's NOIRLab, in partnership with NSF and NASA, held a workshop titled "Windows on the Universe: Establishing the Infrastructure for a Collaborative Multi-messenger Ecosystem." Multi-messenger astronomy (MMA) uses some combination of electromagnetic radiation, gravitational waves, neutrinos, and cosmic rays to understand astrophysical phenomena more comprehensively than just one messenger would allow. The processes MMA is particularly suited for include massive star explosions, mergers of neutron stars and black holes, and tidal disruption events.



The workshop brought together more than 200 attendees, both in-person and virtually, from all around the world. The agenda included both invited and contributed talks, as well as panels and discussions to allow as much community input and engagement as possible. Researchers from a variety of multi-messenger observatories including ICECube, HAWC, LIGO, Swift, Hubble, *JWST*, NOIRLab, Keck, and MMT (just to name a few) were present, as well as representatives from NSF and NASA, who were particularly interested in the outcomes of the workshop.

Over the course of the three days, the past, present, and future of multi-messenger astronomy were discussed, in particular how the infrastructure (software, hardware, and people) has worked and how it will need to be improved in the future to optimize the science return. NOIRLab staff who attended and presented at the meeting also took special note of how to help optimize NOIRLab facilities to be at the forefront of MMA. The focus of the workshop was on communication, cooperation, and collaboration. These three themes will also be at the forefront of the white paper that is being written to summarize the state of the field and to make recommendations to funding agencies for future ways forward. This document will be relied on heavily by NSF in producing a spring solicitation for their Windows on the Universe: The Era of Multi-Messenger Astrophysics (WoU-MMA) funding opportunities.

Special thanks are due to the organizing committees for making this workshop successful!

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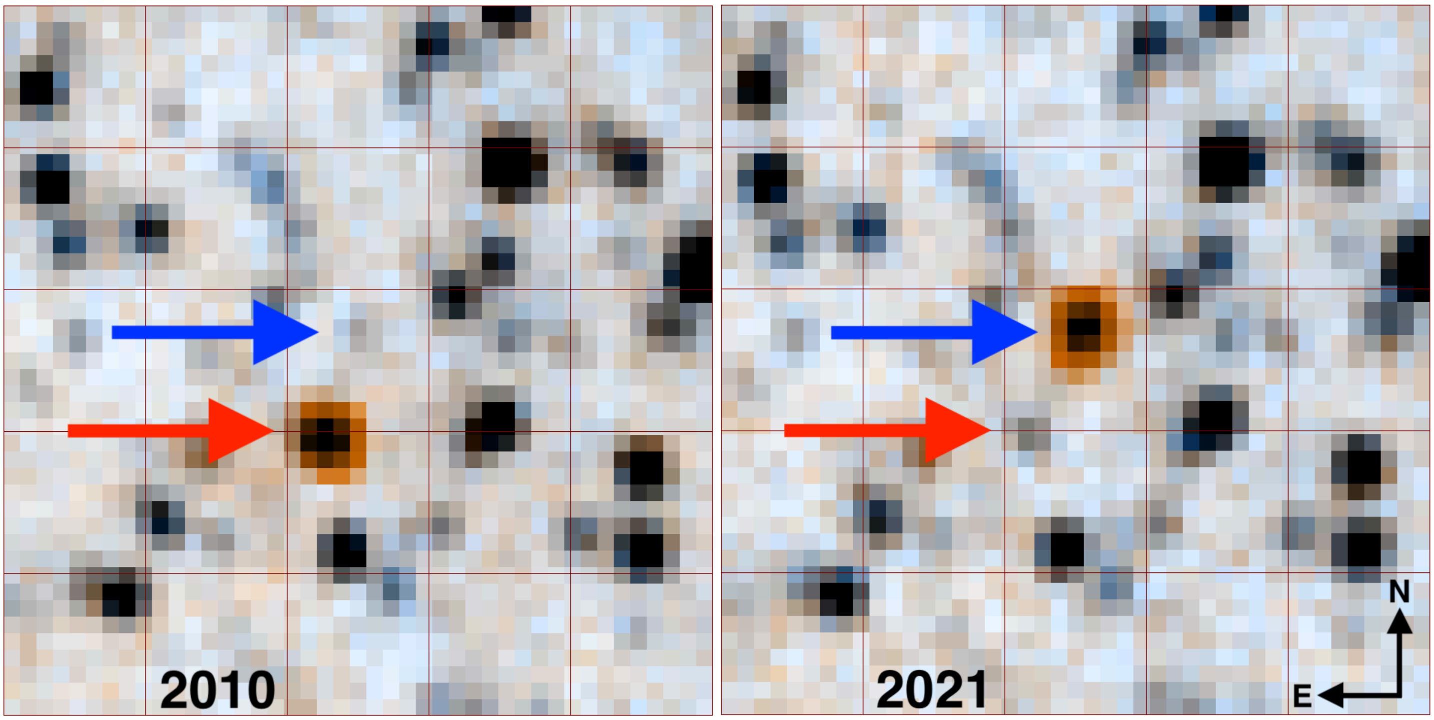
NOIRLab Launches *Cool Neighbors* Citizen Science Project

Aaron Meisner

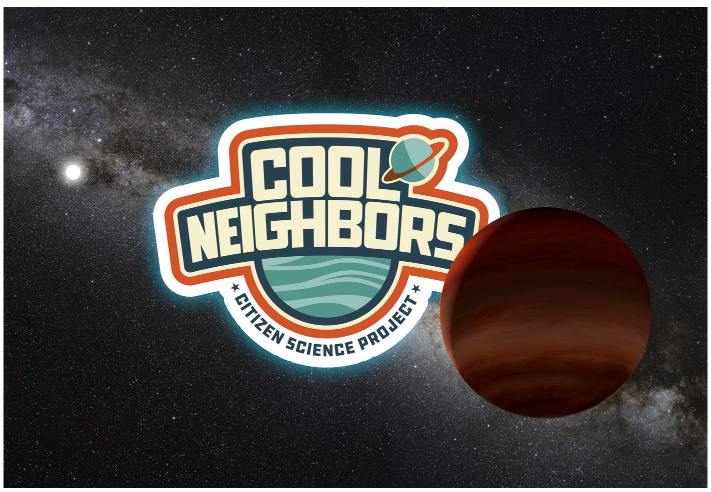


A known brown dwarf seen moving in a *Cool Neighbors* "flipbook" movie of WISE data. The brown dwarf's 2010 (2021) position is indicated by a red (blue) arrow in each panel, and its orange-ish hue signifies its cold temperature. *Cool Neighbors* volunteers scour for more subtle examples of motion relative to background stars/galaxies, indicative of a very nearby distance.
Credit: NOIRLab/NSF/AURA/WISE/NEOWISE/coolneighbors.org/A. Meisner

Have we found all of the Sun's closest neighbors? Our census of the solar neighborhood, especially its population of cold and faint brown dwarfs, is still growing at a brisk clip (Kirkpatrick et al. 2021). Brown dwarfs, intermediate in mass between the smallest red dwarf stars and the largest giant exoplanets, provide unique laboratories for revealing the low-mass terminus of star formation, and by proxy, the atmospheric properties of Jupiter-like giant exoplanets.

In today's data-driven astronomy era, there exist vast archives of wide-area survey data, which have immense potential for unveiling new cold and nearby neighbors of the Sun, including surveys such as WISE, DECaLS, and DES (Wright et al. 2010; Dey et al. 2019; Abbott et al. 2018). However, large datasets already in hand have yet to be fully searched for substellar objects. Completing the local Galactic census will require a combination of available techniques, including machine learning and citizen science. The citizen science approach for discovering brown dwarfs has proven particularly valuable in disentangling true — and extremely rare — substellar object discoveries from much more common artifacts, such as image noise and diffraction spikes.

Co-founded in 2017 by NSF's NOIRLab astronomer Aaron Meisner, the *Backyard Worlds: Planet 9* citizen science project has pioneered the use of crowdsourcing for discovery of nearby brown dwarfs. *Backyard Worlds: Planet 9* has discovered nearly 4,000 brown dwarf candidates to date (Meisner et al. 2020), which have been followed up with NOIRLab facilities including the SOAR Telescope, both telescopes of the International Gemini Observatory, and the Víctor M. Blanco 4-meter Telescope. Still, *Backyard Worlds: Planet 9* is not optimized for discovering brown dwarfs, but rather for finding hypothesized planets in the outer solar system.



In June 2023, the NOIRLab-led *Backyard Worlds: Cool Neighbors* spinoff project officially launched on Zooniverse. *Cool Neighbors* is the next generation of *Backyard Worlds*, catalyzing more rapid discovery of cold brown dwarfs by using machine learning to preselect the candidates shown to online volunteers. *Cool Neighbors* thus exemplifies the growing trend of synergistic cooperation between citizen science and machine learning, the latter sometimes referred to as "artificial intelligence."

The *Cool Neighbors* launch was supported by an innovative type of NASA grant called the Citizen Science Seed Funding Program (CSSFP), meant to incubate exciting crowdsourcing projects in their early, pre-launch phases. Thanks to this NASA funding and additional support from NOIRLab, three summer undergraduate interns — Austin Humphreys (Maryland), Grady Robbins (Florida), and Eden Schapera (Georgia) — were able to experience cutting-edge research at NOIRLab while building and launching *Cool Neighbors*.

Since launch, *Cool Neighbors* has been highly successful at both engaging the general public and discovering brown dwarfs. Within just its first few months, *Cool Neighbors* had already exceeded a million total "classifications" and blazed through its initial set of 30,000 brown dwarf candidates. Thanks in part to *Cool Neighbors*, the *Backyard Worlds* project as a whole has now surpassed 10 million total classifications since launch! *Cool Neighbors* has also reached a diverse group of participants drawn from all 50 US states plus Washington, DC, and at least 89 countries across the globe. In September 2023, *Cool Neighbors* founding co-investigator and amateur astronomer Dan Caselden was awarded the Astronomical Society of the Pacific's Gordon Myers Amateur Achievement Award.

As *Cool Neighbors* turns toward following up its initial crop of brown dwarf candidates, infrared-capable NOIRLab facilities such as Gemini, Blanco, and SOAR are likely to play key roles. Given that *Cool Neighbors* participants are sifting through tens of thousands of brown dwarf candidates faster than expected, *Cool Neighbors* also plans a pivot toward using the NOIRLab Source Catalog (Nidever et al. 2021), which covers 85% of the sky with excellent red-optical sensitivity, for future preselection of its substellar candidates. The combination of machine learning and citizen science demonstrated by *Cool Neighbors* will only grow in importance over the coming years, as the Vera C. Rubin Observatory's Legacy Survey of Space and Time (LSST) creates its astronomical catalog an order of magnitude larger than any before.

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Searching for Snapshots of Giant Exoplanet Migration

Arvind Gupta

NEID, an extreme precision Doppler spectrograph on the WIYN 3.5-meter Telescope at Kitt Peak National Observatory (a partnership between Indiana University, University of Wisconsin-Madison, Pennsylvania State University, Princeton University, Purdue University, NSF's NOIRLab, and NASA), is helping unravel the origin of hot Jupiters. These giant exoplanets, orbiting their host stars with periods of less than 10 days, have challenged our understanding of planet formation for decades. Our own gas giant neighbors, Jupiter and Saturn, could only have grown to their current size by accumulating a high mass of volatile materials that were only present in the more distant reaches of the early Solar System. Numerous theories for the formation of hot Jupiters have been proposed, many of which predict that these exoplanets formed several AU from their host stars, at similar orbital separations to Jupiter, before migrating inwards to their present locations. If so, we should expect to see not only hot Jupiters but also an intermediate population of migrating "warm" Jupiters on longer-period orbits if we surveyed enough stellar systems. The demographics of this population may hold the key to understanding which formation channels dominate. However, the population of warm Jupiters amenable to detailed study is relatively sparse, in part due to the intrinsic rarity of planets in this class and in part because of observational biases that disfavor the detection of long-period signals.

NASA's *Transiting Exoplanet Survey Satellite* (*TESS*) is helping to unearth a new sample of warm Jupiter candidates. I have been leading an initiative to use NEID to confirm and characterize many of these exoplanets. By first observing candidates with the NN-EXPLORE Exoplanet Stellar Speckle Imager (NESSI), also on the WIYN 3.5-meter Telescope, we efficiently determine whether each signal detected by *TESS* is indeed an orbiting exoplanet, rather than a background source, and is thus worthy of follow-up observations. With NEID, we then monitor the stellar radial velocity (RV) signal and check for the periodic variations characteristic of an orbiting exoplanet.

In addition to the advantages conferred by NEID's exquisite Doppler precision, the logistical framework of

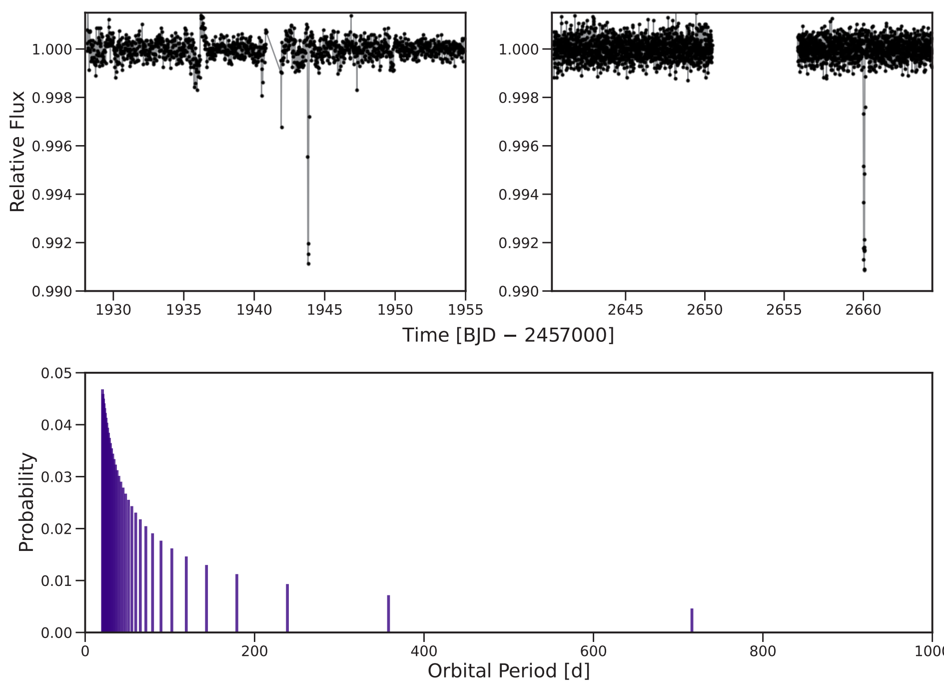

Figure 1: (Upper) *TESS* photometry for a warm Jupiter candidate; (Lower) Possible orbital periods and corresponding probabilities based on orbital geometry. Two transits were detected, but they are separated by 716 days. The available data allow for 35 possible period aliases, ranging from just 20 days up to the observed 716-day separation.

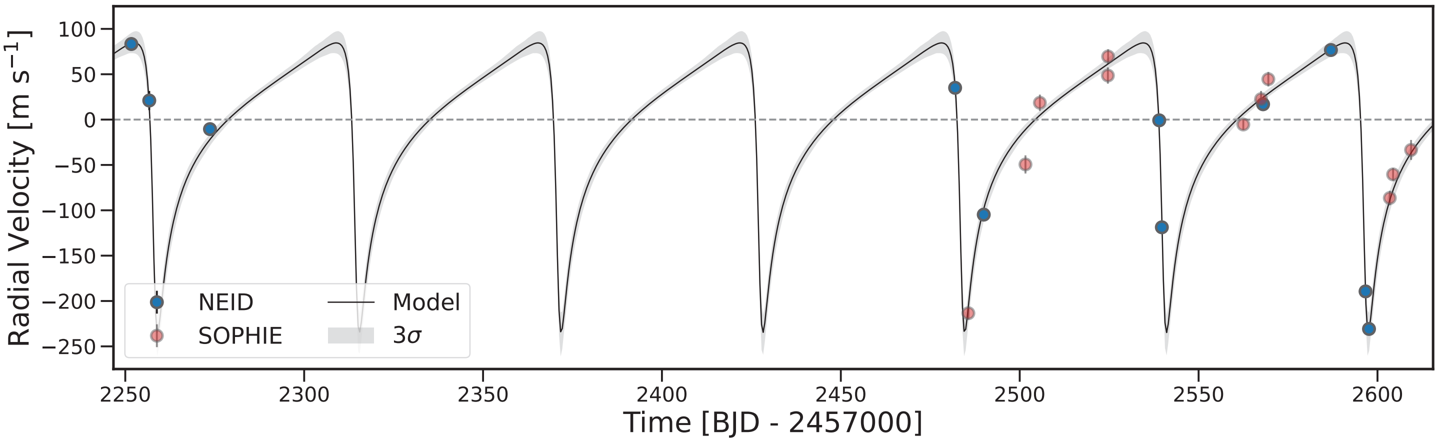

Figure 2: Radial velocity curve for TOI-4127 b. The final NEID measurements were strategically scheduled to capture the large velocity excursion near periastron.

NEID observations has played an important role in aiding this effort. Unlike a classically scheduled instrument, the NEID queue provides the flexibility for adjustments to be made as new data are collected and analyzed, on timescales of weeks rather than semesters. This flexibility is essential for studies of exoplanets with longer orbital periods. Because *TESS* sacrifices temporal baselines in favor of all-sky coverage, the sample we are selecting from is composed primarily of candidates for which *TESS* detected either a single transit or just a few transits separated by months to years (Figure 1). As a result, the orbital periods are initially unknown. However, as the corresponding RV signals begin to take shape, we are able to adaptively update our observing schedule and capture the exoplanets at key orbital phases to more efficiently measure their orbital parameters.

Earlier this year, we published the discovery of TOI-4127 b, the first warm Jupiter to be confirmed through our observing program (Gupta et al. 2023). With an orbital eccentricity of e ~ 0.75, this planet perfectly illustrates the utility of the NEID queue, which allowed us to sample the narrow periastron passage window on very short notice (Figure 2). TOI-4127 b is of scientific interest when placed in the context of one of the most intriguing — and plausible — hot Jupiter formation channels. This channel requires that the progenitor exoplanet is first excited onto an extremely eccentric orbit such that it passes very close to the host star during periastron. During these close encounters, tidal interactions with the host star will sap energy from the orbit, causing it to shrink and circularize, ultimately producing the hot Jupiters that we see today. The discovery of HD 80606 b (Naef et al. 2001), a giant exoplanet with a highly eccentric orbit in the midst of tidally circularizing, helped create a cohesive narrative linking the observed hot Jupiter population to a well-understood formation pathway. However, few similar systems have been identified in the intervening decades, and none as clear-cut as HD 80606 b. And despite its high orbital eccentricity, TOI-4127 b falls short as well. The orbit is still not eccentric enough for tidal migration to take hold, and the initial excitation mechanism for this system is unclear. Still, this adds a valuable point to the warm Jupiter sample, and further observations will provide more clues to its origin and trajectory.

In the coming months, we expect to share additional results from our program, including more exciting exoplanet discoveries and insights about the warm Jupiter population.

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10.5281/zenodo.10535712

A New Atlas of Large Galaxies

John Moustakas (Siena College)

Figure 1: Optical mosaic of the galaxy merger NGC 520. This system ranks among the largest and brightest galaxies in the SGA–2020. *Credit: J. Moustakas/Siena College; CTIO/NOIRLab/DOE/NSF/AURA*

Large angular-diameter galaxies occupy a special place in the history of astronomy and continue to play a pivotal role in observational cosmology and in the study of galaxy formation and evolution. So-called "large galaxies," >10–20 arcsec in angular diameter, are important because they are spatially well-resolved, making it possible to study them in significantly greater detail than more distant galaxies.

In large, nearby galaxies we can study the properties and stellar populations of their disk and spheroidal components as separate, distinct features; identify bars, rings, disk asymmetries, and other dynamical structures; discover and characterize their low surface-brightness features such as stellar streams, tidal tails, and outer envelopes; unveil faint, low-mass satellites; and more.

Long before their physical nature was known, the study of galaxies, or "spiral nebulae," began with concerted efforts to catalog them. This work began in 1774 with Charles Messier's *Catalogue des Nébuleuses et des Amas d'Étoiles*, which included 40 (now-famous) galaxies among a full catalog of 110 objects. Subsequently, building on the naked-eye surveys of William Herschel and his sister Caroline and son John (Herschel 1786, 1864), John Louis Emil Dreyer spent more than two decades assembling the *New General Catalogue of Nebulae and Clusters of Stars* (NGC) and the *Index Catalogues* (IC), a sample of approximately 15,000 Galactic and extragalactic objects whose designations are still in widespread use today (Dreyer 1888, 1912).

The NGC, IC, and other early catalogs laid the foundation for several important galaxy atlases published in the second half of the 20th century, including the *Catalogue of Galaxies and of Clusters of Galaxies* (CGCG; Zwicky et al. 1968); the *Uppsala General Catalog of Galaxies* and its Addendum (UGC and UGCA; Nilson 1973, 1974); the *Morphological Catalog of Galaxies* (MCG; Vorontsov-Velyaminov & Krasnogorskaya 1974); the *ESO/Uppsala Survey of the ESO (B) Atlas* (ESO; Lauberts 1982); and the *Principal Galaxies Catalogue* (PGC; Paturel et al. 1989). Eventually, data from these and other catalogs were assembled into the indispensable

Third Reference Catalog of Bright Galaxies (RC3; de Vaucouleurs et al. 1991; Corwin et al. 1994), which has facilitated thousands of wide-ranging scientific investigations.

Building on this rich astronomical and scientific heritage, we have assembled a new digital atlas of large galaxies called the Siena Galaxy Atlas (SGA; Moustakas et al. 2023). The 2020 version of the Atlas, the SGA-2020, includes optical and infrared mosaics of nearly 400,000 galaxies limited to approximately r = 18 AB mag and an angular diameter of 25 arcsec; it uses optical (*grz*) imaging from the Dark Energy Spectroscopic Instrument (DESI) Legacy Imaging Surveys collected at Cerro Tololo Inter-American Observatory and Kitt Peak National Observatory, both Programs of NSF's NOIRLab, and at the University of Arizona's Steward Observatory (Dey et al. 2019), as well as custom mid-infrared imaging from the unWISE image stacks from Meisner et al. (2021).

Figure 2: Optical mosaics of 42 galaxies from the SGA-2020 sorted by increasing angular diameter from the top left to the bottom right, illustrating the tremendous range of types, sizes, colors, internal structure, and environments of the galaxies in the atlas. The horizontal white bar in the lower left corner of each panel represents 1 arcminute, and the mosaic cutouts range from 3.2 to 13.4 arcminutes.

The SGA-2020 includes multi-wavelength mosaics (Figures 1 and 2), azimuthally averaged optical surface-brightness profiles (Figure 3), archival metadata, and much more for the full sample of galaxies covering roughly 20,000 sq. deg. (nearly three-quarters of the extragalactic sky, |b|>20°; Figure 4). Notably, for many of the largest (NGC/IC/ Messier) galaxies in the sky, the SGA-2020 delivers the first reliable measurements of the optical positions, shapes, and sizes of large galaxies since the RC3 was published more than 30 years ago.

The SGA-2020 will facilitate a renewed effort to tackle several outstanding problems in extragalactic astrophysics and will support studies of time-domain and multimessenger astronomical events, which are often hampered by incomplete or heterogeneous catalogs of large, nearby galaxies (e.g., Abbott et al. 2020). Moreover, within the 14,000-sq.-deg. DESI footprint, the SGA-2020 is ensuring high photometric completeness for the DESI Bright Galaxy Survey (BGS) and is facilitating high-impact ancillary science through a variety of secondary targeting programs (DESI Collaboration et al. 2023).

Finally, the SGA-2020 will continue to help promote astronomy by engaging the broader public with visually striking color mosaics of large, well-resolved, nearby galaxies, enabling a myriad of educational and public outreach activities.

We expect the SGA-2020 to have lasting legacy value for a wide range of studies of relatively nearby, spatially resolved galaxies. But we do not plan to stop with the SGA-2020. In the next version of the catalog, we intend to incorporate additional Dark Energy Camera (DECam) *i*-band imaging, as well as ultraviolet and infrared imaging (and surface-brightness profiles) from GALEX and unWISE, respectively; to increase the completeness and homogeneity of the sample, particularly in terms of optical surface brightness; to improve the deblending and masking of galaxies around bright stars, in crowded cluster fields, and for close companions (e.g., galaxy mergers); and to incorporate all the available DESI spectroscopy into the final data products. Stay tuned!

Acknowledgments

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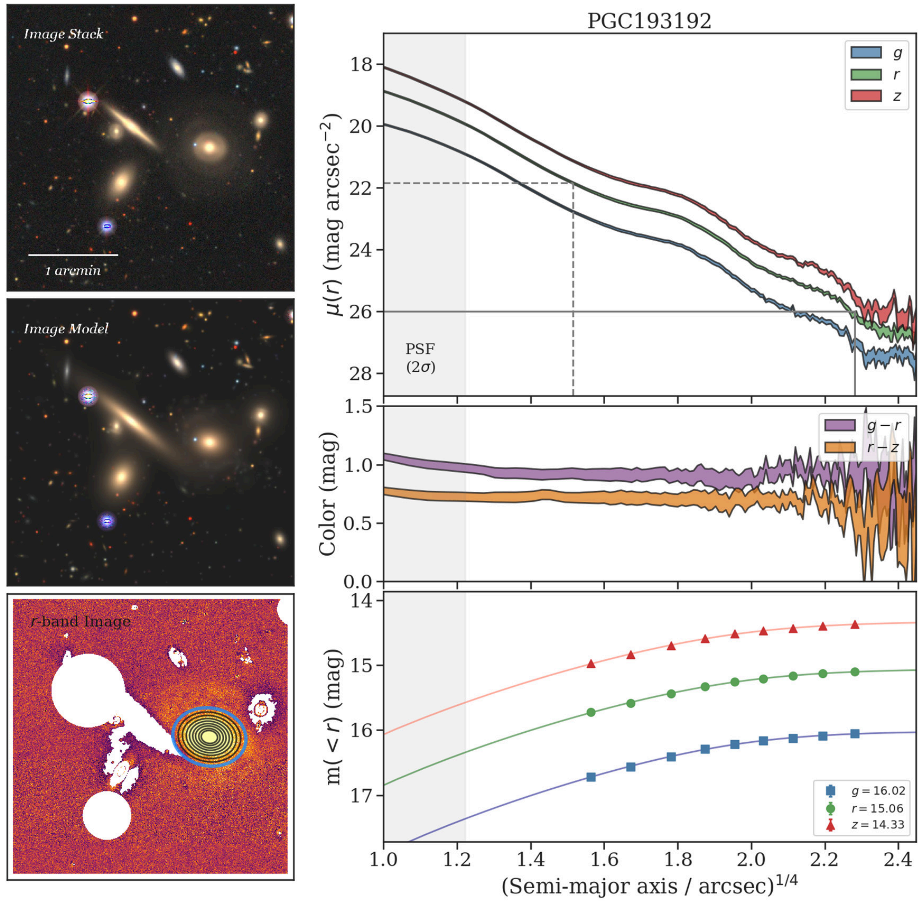

Figure 3: Illustration of the key steps and data products of the SGA-2020 for PGC 193192, the second-largest member of the PGC 193199 Group. The three panels on the left-hand side show (top left) a color montage of the optical imaging; (middle left) a color montage of the corresponding model image; and (bottom left) the r-band image with masked pixels zeroed out (white pixel values). The right-hand panels show (top right) the azimuthally averaged g- (blue), r- (green), and z-band (red) surface-brightness profiles as a function of the semimajor axis; (middle right) the observed-frame g – r (purple) and r – z (orange) color profiles; and (bottom right) the curve-of-growth of PGC 193192 in g (filled blue squares), r (filled green circles), and z (filled red triangles).

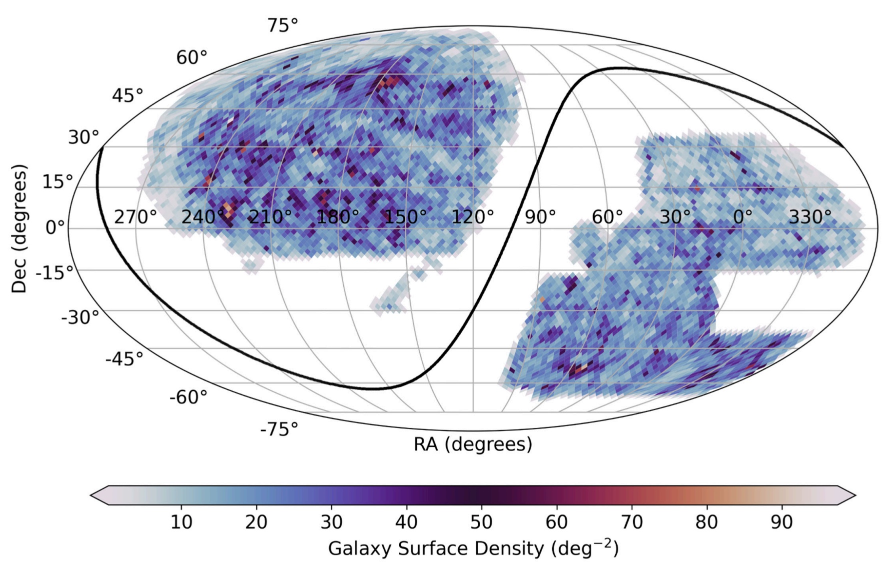

Figure 4: Celestial distribution of the 383,620 galaxies in the SGA-2020 in an equal-area Mollweide projection in equatorial coordinates.

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An Extremely Nearby, Extremely Low–Mass, Extremely Isolated Dwarf Galaxy

Michael Jones (University of Arizona)

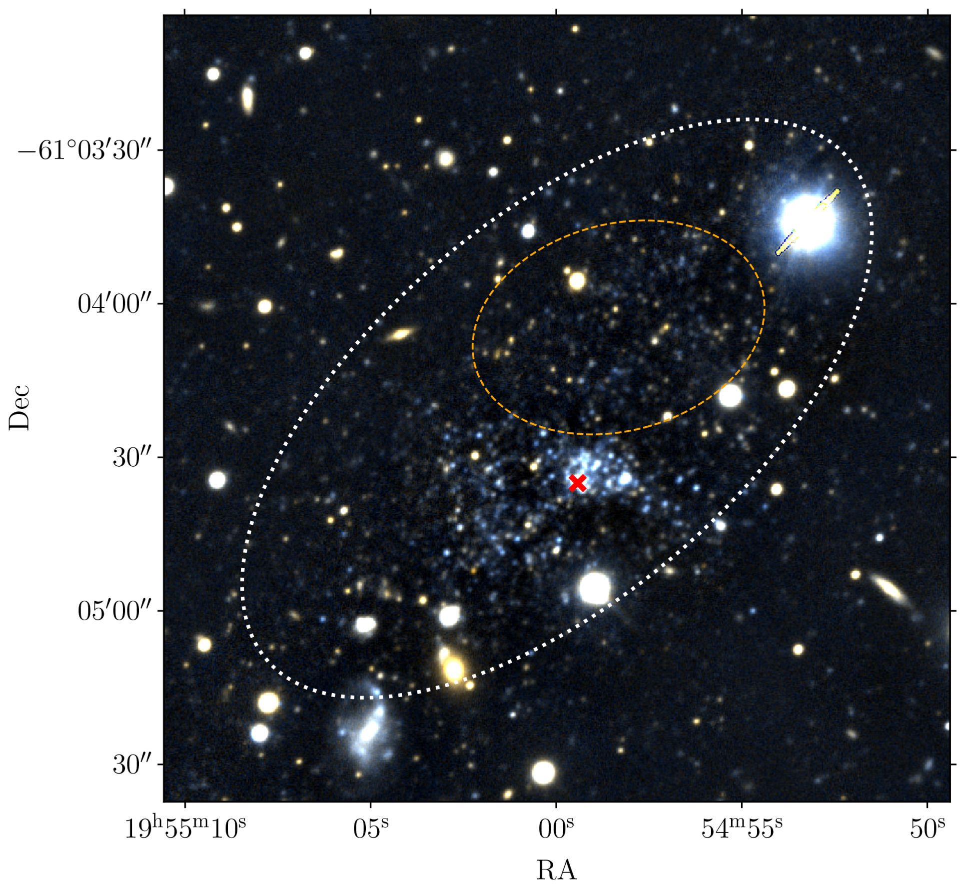

Figure 1: IMACS g+r color image of Pavo. The central regions of Pavo are dominated by the blue light of young stars, but its stellar body can be traced out to the white dotted ellipse. The orange dashed ellipse shows a region that mostly contains old red giant branch stars that were used to determine the distance to Pavo. There is a particularly bright star near the center of Pavo; however, this star has measurable proper motion and is therefore a foreground object. It is crossed out with a red x in the figure.

My collaborators and I recently discovered the Pavo dwarf galaxy, one of the lowest mass star-forming galaxies known. It was identified via a novel search technique that relied on machine learning classification of galaxy candidates identified in the DESI Legacy Imaging Surveys (using data collected at Cerro Tololo Inter-American Observatory and Kitt Peak National Observatory, both Programs of NSF's NOIRLab, and at the University of Arizona's Steward Observatory). Despite only being 2 Mpc away, Pavo is also remarkably isolated, with no other known galaxy within 600 kpc. Its minute stellar mass, estimated to be just 4 x 10^5 $M_\odot$, combined with its isolation make Pavo an ideal target for understanding how star formation proceeds in some of the lowest mass galaxies in the universe. Full details of the discovery are published in Jones et al. (2023).

The gravitational potential wells of the lowest mass galaxies are so shallow that the gas they contained in the early Universe was not dense enough to self-shield from any external UV radiation. During cosmic reionization, when the Universe first began forming stars en masse, these galaxies lost all of their cold gas, never to regain it again. Thus, reionization is thought to have permanently quenched their star formation. At marginally higher dark matter halo masses, the potential wells of galaxies were just deep enough to retain (or re-accrete) some cold gas and thus continue forming stars to the present day. These are therefore the lowest mass star-forming galaxies in today's Universe, and Pavo is one of just a few such galaxies that are currently known.

Pavo was discovered with a modified version of the SMUDGes (Zaritsky et al. 2019) pipeline, which was originally intended to identify much more distant low surface brightness galaxies. The initial search catalog contained hundreds of thousands of candidates across the full Legacy Surveys footprint, far too many to inspect manually. These were passed to a convolutional neural network (CNN) classifier that had been trained on known nearby objects including low-mass star-forming galaxies, ultra-faint dwarfs, and Milky Way globular clusters. This CNN filtered out the enormous number of spurious and uninteresting objects picked up in the initial search, selecting just those most likely to be extremely low-mass, nearby galaxies, one of which was Pavo. Rapid follow-up imaging with the Inamori-Magellan Areal Camera and Spectrograph on the Magellan Baade Telescope resolved the brightest stars in Pavo, revealing the existence of both an ancient and a young stellar population. The tip of the red giant branch in the color-magnitude diagram was used as a standard candle to estimate the distance to Pavo as 2 Mpc.

Given this distance and its location in the sky, Pavo is extraordinarily isolated, with no known neighboring galaxy within over 600 kpc. This isolation is key and makes Pavo an ideal laboratory to study how star formation proceeds in such exceptionally low-mass galaxies. Although cosmic reionization is expected to have a strong influence on the gas and early star formation in these galaxies, there is very little direct observational evidence for what those effects are. The evidence that does exist comes almost exclusively from low-mass galaxies within the Local Group. However, given their low masses, these galaxies are also highly susceptible to environmental effects, such as ram pressure and tidal stripping. As there is no way to know definitively how long satellites galaxies within the Local Group have been group members, it is impossible to conclusively separate the imprint of reionization on their star formation histories from those that resulted from environmental effects. Thus, extremely low-mass galaxies such as Pavo, that are close enough to study in detail with space telescopes yet still far enough away to be isolated, are a scarce but vital resource for understanding the evolution of the lowest mass galaxies.

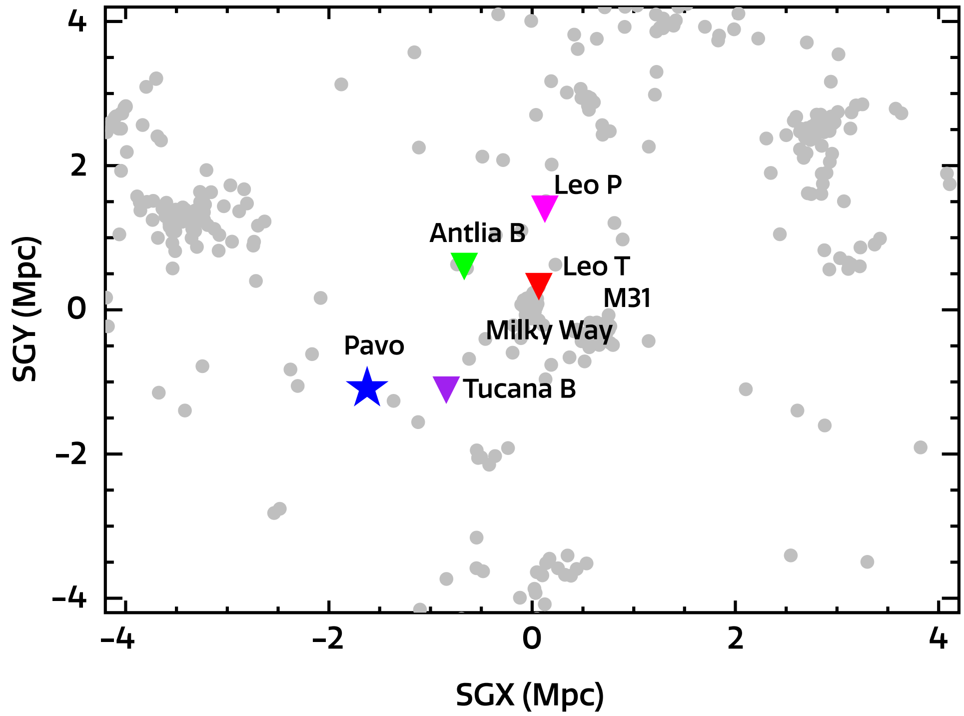

Figure 2: Supergalactic XY projection showing all nearby galaxies with known distances. The Local Group is in the center. Pavo and several other notable nearby, extremely low mass dwarfs are highlighted. Both Leo P and Tucana B are considered isolated, but Pavo's isolation is even more extreme. It is in a direction away from any known nearby structure. Its apparent nearest neighbors are only nearby in projection. In three dimensions Pavo has no known neighbor within over 600 kpc.

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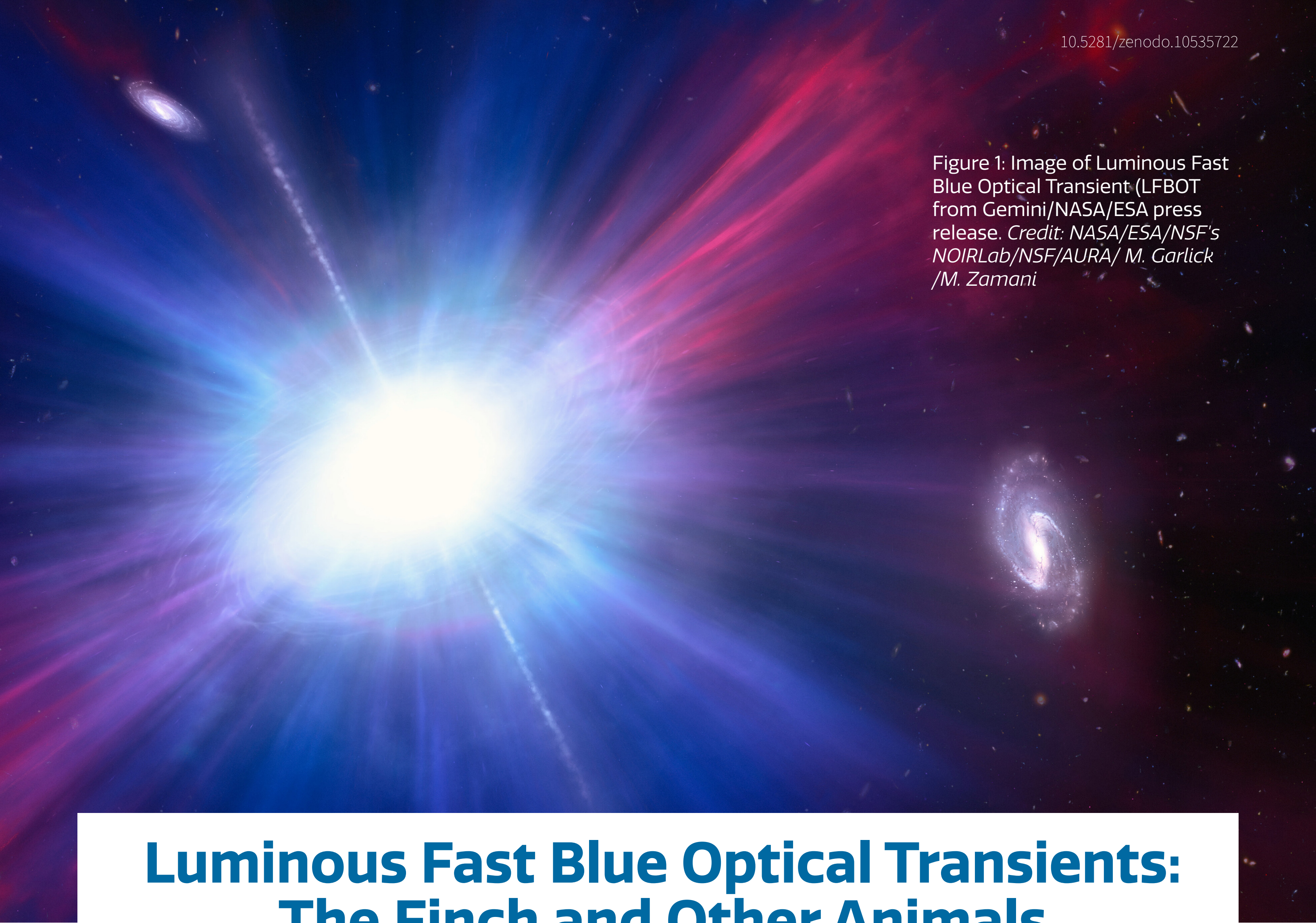

Figure 1: Image of Luminous Fast Blue Optical Transient (LFBOT from Gemini/NASA/ESA press release. *Credit: NASA/ESA/NSF's NOIRLab/NSF/AURA/ M. Garlick /M. Zamani*

Luminous Fast Blue Optical Transients: The Finch and Other Animals

Ashley Chrimes (ESA/ESTEC), Peter Jonker (Radboud University), and Andrew Levan (Radboud University)

This year we defined a multi-facility joint observing program to characterize a new Luminous Fast Blue Optical Transient (LFBOT) in detail. The program included time on the International Gemini Observatory, the *Hubble Space Telescope*, the Very Large Array, and the Chandra X-ray Observatory. On April 10, a new LFBOT candidate was discovered by ZTF (the Zwicky Transient Facility) — AT2023fhn ("the Finch"). Following reports that it had a featureless spectrum, we triggered our program, obtaining Gemini, *Hubble*, and Chandra data shortly after. A Chandra X-ray detection confirmed the LFBOT nature of the event. From ground-based observations, the location of the transient appeared to be consistent with a galaxy at z = 0.24. The high angular resolution of *Hubble*, however, revealed the object to have a large angular offset from two nearby galaxies — an unusual place to find a core-collapse event, which was a favored explanation for LFBOTs. Gemini spectroscopy was crucial in demonstrating that the fainter, presumed satellite galaxy was at the same redshift as the brighter galaxy, a barred spiral.

With the advent of wide-field, high-cadence, and deep-sky surveyors (e.g., ZTF, ATLAS, GOTO, BlackGEM), the discovery of rapidly evolving transients has become possible. Fast evolving (>0.3 magnitudes per day) and blue (g-r < -0.3) transients with follow-up spectroscopy are typically found to be infant supernovae. But in 2018, a new class of transient with these features was discovered. AT2018cow — colloquially known as the "the Cow" — was fast and blue and had a featureless, hot spectrum at early times. The host galaxy yielded a redshift, giving an absolute magnitude of ~-21 – much brighter than regular supernovae. The event also produced bright X-ray and radio emission. This combination of properties was unlike

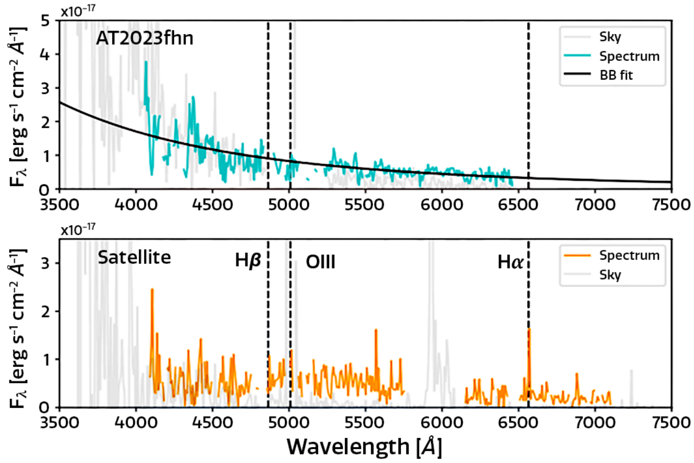

Figure 2: Gemini spectra of AT2023fhn and the satellite galaxy. *Credit: Chrimes et al. 2023*

any transient seen before. Such transients are now discovered at a rate of 1–2 per year and are known as Cow-like, or luminous fast blue optical transients (Ho et al. 2023). Their key feature is the inability for ^{56}Ni decay models to explain both the rapid lightcurve decay and the peak absolute magnitude, in addition to the X-rays (implying the presence of a central engine) and long-lasting radio emission (pointing towards a dense, extended circumstellar medium). Models invoked to explain LFBOTs include ultra-stripped supernovae with a central engine, the tidal disruption of a white dwarf around an intermediate mass black hole (IMBH), or the merger of a black hole and Wolf-Rayet star. Despite growing interest, none of the events following AT2018cow (e.g., the Koala, Camel, or Tasmanian Devil) were observed in as much detail (but neither were any as nearby).

The location of the Finch is atypical for any of the leading LFBOT theories. Neither massive stars nor IMBHs are expected at such large spatial offsets from their host galaxies, but neither is the offset so large as to completely rule out either scenario. Furthermore, the presence of an underlying stellar cluster, hosting the transient but presently outshined by it, cannot be ruled out.

The origin of the Finch — and the other LFBOTs so far — therefore remains uncertain. The discovery of UV and X-ray emission from AT2018cow several years afterwards points towards an accreting black hole as the central engine, but the origin of the black hole (formed in the event or pre-existing?), the material being accreted (white dwarf, stellar envelope?), and its mass (stellar or intermediate?) remain unknown. Detailed observations of future LBFOTs, ideally those nearby, like AT2018cow, are crucial to narrow down their environments, emission processes, and, ultimately, progenitors.

This article describes the observing program presented in Chrimes et al. (2023), which includes the following co-authors: Deanne Coppejans (University of Warwick), Nicola Gaspari (Radboud University), Ben Gompertz (University of Birmingham), Paul Groot (Radboud University), Daniele Malesani (University of Copenhagen), Andrew Mummery (University of Oxford), Elizabeth Stanway (University of Warwick), and Klaas Wiersema (University of Hertfordshire).

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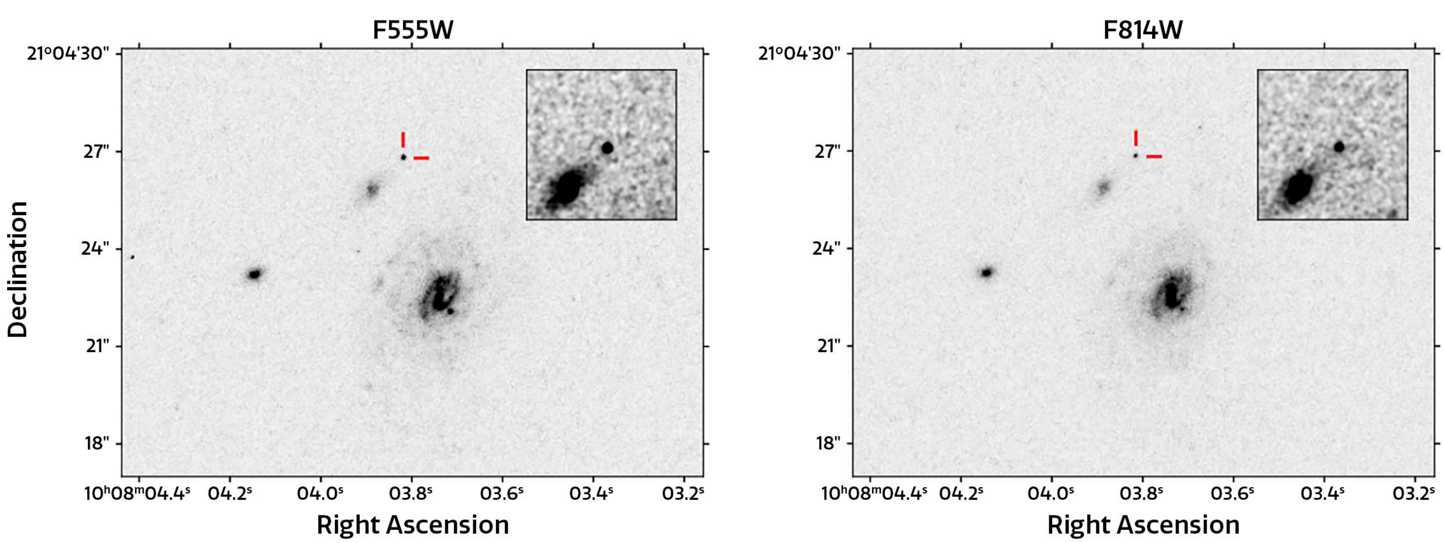

Figure 3: *Hubble* images (~g and ~r band) of the transient location. *Credit: Chrimes et al. 2023*

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US NGO Completes the Science Verification of the GNIRS XD Pipeline

Brian Merino, Vinicius Placco, and Letizia Stanghellini

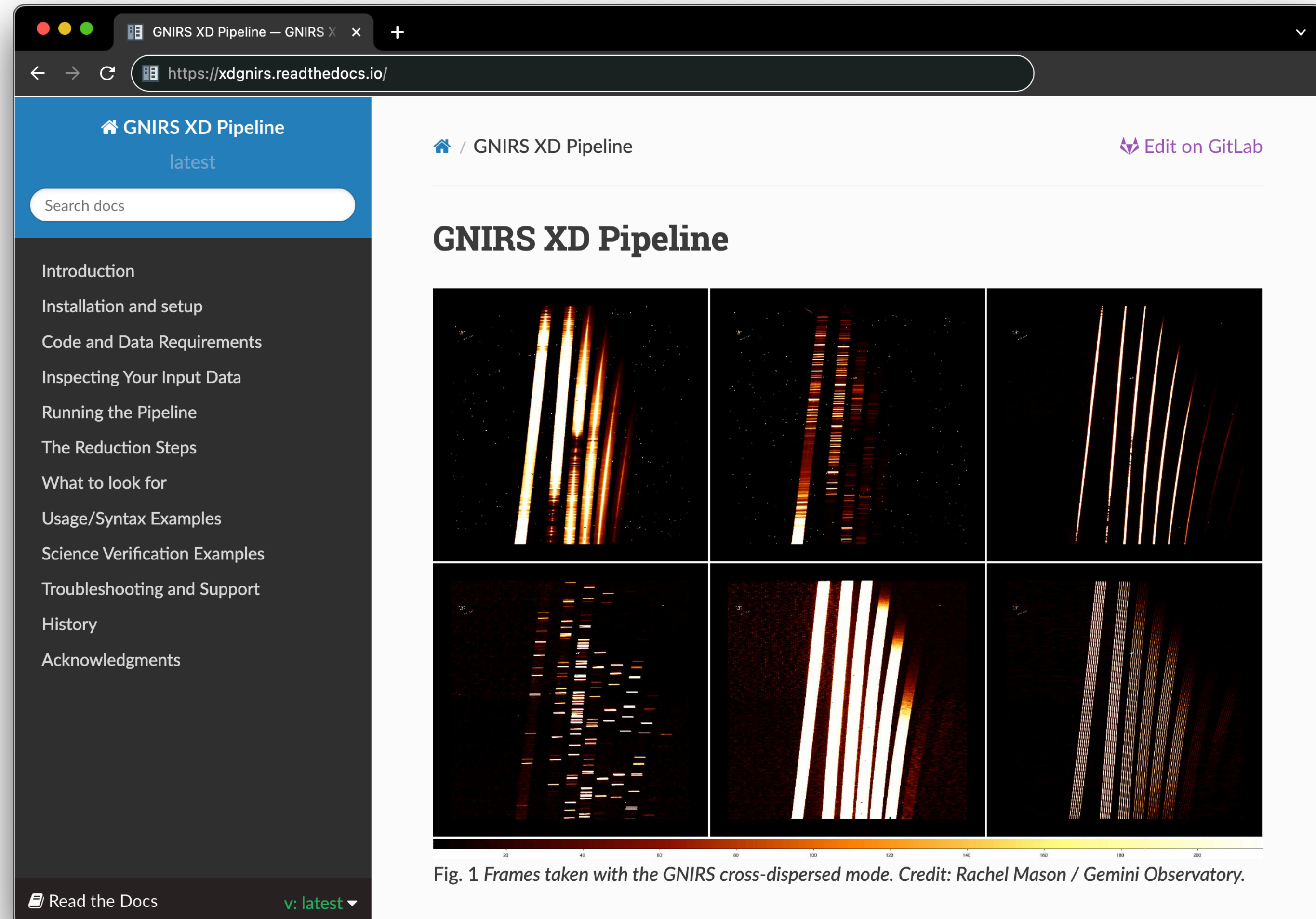

Figure 1: Front page of the website with the updated documentation for XDGNIRS

The Gemini Near-IR Spectrograph (GNIRS) instrument was built 20 years ago in Tucson, Arizona, at NOAO (now part of NSF's NOIRLab). Capable of low-, medium-, and high-resolution spectroscopy, GNIRS was designed to observe the 0.8–5.4μm wavelength regime. Once the instrument was completed in 2003, it was moved to the Gemini South Telescope on Cerro Pachón, part of the International Gemini Observatory, and made available to the public during the 2004B semester. Four years later, GNIRS was damaged and moved to Gemini North on Mauna Kea for repairs. The restoration was completed in 2010, and GNIRS was mounted on its new home on Gemini North, where it has remained ever since.

Today, GNIRS is the second most subscribed instrument on Gemini North, accounting for nearly 20% of its total yearly science exposure time. When requesting time for spectroscopy with GNIRS, users have been able to choose between two modes: single long-slit (sensitive to 1.0–5.4μm) or cross-dispersed (0.8–2.5μm). As of 2023, low- and high-resolution IFU capabilities have been added to the instrument. In addition to the impressive spectroscopic capabilities of GNIRS, it can also be used for imaging with a field of view of around 10 arcseconds, compatible with broad and narrow band filters.

GNIRS's most popular configuration, 32 mm XD (cross-disperser mode), has an unofficial semi-automatic data reduction pipeline (XDGNIRS, built on Gemini IRAF tasks) that had not been verified to produce science-grade products. This pipeline can be used in addition to other current software (Gemini IRAF, IDL, and Python) used to reduce GNIRS data. The US National Gemini Office (US NGO) staff performed a science verification and modernization project on the XDGNIRS pipeline between October 2022 and July 2023. The project involved testing the pipeline on various astronomical sources, updating the code's syntax to be compatible with Python 3.7.11, and ensuring that the code complies with the software installed in the latest version of the Gemini Virtual Machine.

The science verification began with reducing data for the brown dwarf WISE0410 and the galaxy NGC3031. After successfully processing the data for these two objects using XDGNIRS, the US NGO staff partnered with the Brazilian NGO head, Alberto Ardila, who has abundant experience using the GNIRS instrument. A list of eight galaxies with published spectra and varying weather conditions was compiled, as denoted on the Gemini Observatory Archive. All eight example datasets were successfully processed through the new version of XDGNIRS, and an inspection of the final results confirmed that all the

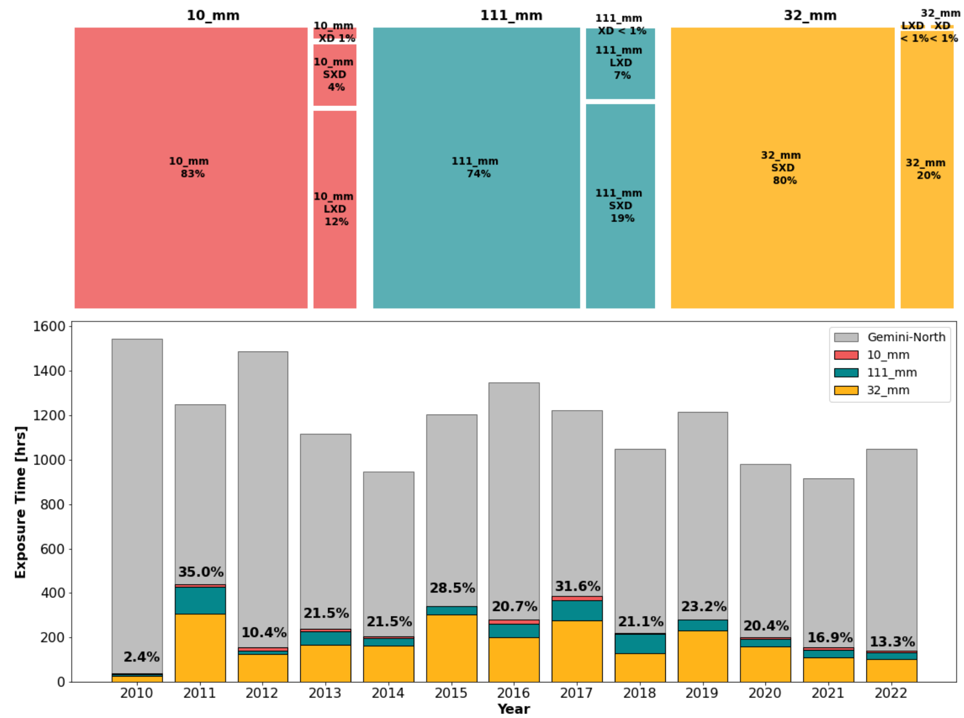

Figure 2: GNIRS usage over time. Data taken from the Gemini Observatory Archive.

emission/absorption lines identified in the published spectra were also present in the spectra generated by the new version of the pipeline. XDGNIRS also handled data marked as "poor quality" without any issues. The reduced spectra closely resembled the published versions.

In addition to updating the pipeline's code, two new resources were created for the users: a GitLab repository and a Read the Docs version of the pipeline's updated user manual. The GitLab repository contains the pipeline's code and the 15 datasets used to test the pipeline, which includes the reduced data products so users have a template for comparison. The documentation contains all the information included in the original manual and instructions for the new features that were added in this version, including an updated ability to query SIMBAD for a source's redshift. The documentation also includes a section that displays all the acceptable inputs that either allow the user to manually perform specific tasks or perform additional tasks that the pipeline does not perform by default, such as the 'shift_to_rest' command, which obtains the source's redshift from SIMBAD and shifts the reduced spectrum into the rest frame.

The updated version of XDGNIRS is now available to all Gemini users and can be accessed through this GitLab repository. A more detailed project summary can be found on the US NGO website.

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Seven New NOIRLab Survey Programs

Tod R. Lauer

NSF's NOIRLab supports proposals for large observational surveys in addition to the standard telescope proposals awarded for single semesters at a time. Surveys are defined as programs that require large uniform datasets to answer important scientific questions and, crucially, that can support leading-edge archival research beyond the science goals of the original proposers. In return for the large allocation of resources, the proposers are required to return high-level data products to NOIRLab. These data products are made available for community use through services provided by the Community Science and Data Center.

The opportunity to propose new surveys is typically offered yearly, dependent on the resources available to support new programs. In our most recent call, we offered time on the Cerro Tololo Inter-American Observatory Víctor M. Blanco 4-meter Telescope and SOAR Telescope for programs to begin in the 2023B semester. We received 21 survey proposals, which were evaluated by a survey TAC panel selected specifically for this call, based on the preliminary letters of intent that we received in advance of the proposal deadline. Five proposals primarily using Blanco/DECam and two proposals primarily using SOAR were recommended and will be scheduled as follows:

GW-MMADS: Gravitational Wave Multi-Messenger Astronomy DECam Survey: This survey plans to use "target-of-opportunity" observations to characterize kilonovae and merging black hole systems identified as counterparts to gravitational wave events.

The DECam MAGIC Survey: Mapping the Ancient Galaxy in CaHK: This is a 54-night survey to chemically map 5500 square degrees of the Milky Way and its structures (e.g., the LMC, SMC, Sagittarius stream, and ultra-faint dwarfs) using the new narrow-band CaHK filter on DECam. This will enable broad, high-impact galactic archaeology studies connected to the first stars, early galactic evolution, and the formation of the Milky Way and the Magellanic Clouds.

CIDER: Charting Ionization During the Epoch of Reionization: CIDER was awarded 45 nights to do narrow-band imaging of a 12-square-degree field, using DECam. The goal is to identify hundreds of Lyman alpha galaxies and thus determine the IGM neutral fraction at redshift $z = 7.3$.

Efficiently Mapping the z >2 Universe with Medium-Band Filters: This program will use 90 nights of DECam medium-band imaging survey over a 1000-square-degree area to provide an object catalog that will enable a detailed study of the $z > 2$ universe using DESI spectroscopy. Imaging this footprint with three new, medium-band filters spanning 4224–5036 A will allow selection of 0.5 million $2.4 < z < 3.2$ Lyman Break Galaxies (LBGs) and 1.6 million Lyman-Alpha Emitters (LAEs).

Survey for Potentially Hazardous Small Aphelion NEOs Using DECam: DECam will be used near twilight to find small aphelion Near-Earth Objects (SA-NEOs) inside the Earth's orbit. This population of potentially hazardous objects (PHOs) is difficult for more standard opposition surveys to detect because they spend most of their time in daylight and are seen only when they fortuitously cross the Earth's orbit into the view of an opposition survey. The total twilight time used will be equivalent to six full nights.

SOARly Needed Spectra of Southern VLBI Sources: This survey will use nine nights on the Goodman spectrograph to determine AGN spectral types for a complete sample of radio sources detected with very long baseline interferometry (VLBI) observations at dec < -30, where there is currently a dearth of VLBI sources due to fewer baselines and VLBI observing sessions.

A Near-Infrared Spectral Extension to the MaStar Optical Spectral Stellar Library: The program will use TripleSpec for 42 nights on SOAR. Spectra with R=3500, over the 0.8–2.47μm wavelength range, will be used to extend the continuous spectral library coverage for 600+ prime stars from the SDSS-IV MaNGA Stellar Library (MaStar; Yan et al. 2019), to 0.36–2.47μm, with good flux calibration.

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Figure 1. LSSDS students attending the introduction course at the AURA Lecture Hall in the AURA campus. *Credit: NOIRLab/NSF/AURA/D. Munizaga*

The La Serena School for Data Science 2023: 10 Years Training Students and Return to In-Person Format

Valeria Alejandra Mesa (AURA-O/University of La Serena) and Guillermo Damke

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. 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. Thirty-two students from around the world (United States, China, Senegal, Taiwan, Colombia, Chile, India, México, Ecuador, Brazil) united in La Serena, Chile, for this unforgettable data science experience 7–17 August 2023.

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

Figure 2: LSSDS group photo outside the Víctor M. Blanco 4-meter Telescope at Cerro Tololo Inter-American Observatory. *Credit: NOIRLab/NSF/AURA/G. Damke*

Figure 3: Thirty-two students from around the world attended the LSSDS 2023 on 7–17 August.
Credit: NOIRLab/NSF/AURA/M. Paredes

astronomy, physics, biology, medical informatics, computer science, and statistics. The school typically accepts 32–36 applicants comprising ~50 % from US universities, with the remainder coming from Chilean institutions as well as other Latin American countries. Hosted annually at the AURA campus 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 virtually only. The 2023 LSSDS was held in an in-person format.

As in previous years, the 2023 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 School activities were broken down into lectures, hands-on activities, and small group projects. The 2023 School began with an introductory lecture on data science, including data collection. Lecture topics for the first week included introductory statistics, introductory supervised and unsupervised machine learning methods (such as decision trees and random forests), Bayesian methods, and Gaussian processes. These lectures were complemented by hands-on "laboratories" covering the use of high-performance computing (HPC), databases, time-series analyses, deep learning, and topics related to biology. Most of the curriculum was presented in the form of downloadable Jupyter notebooks, providing the opportunity for students to interactively modify and explore the sample codes and applications discussed during the lectures.

During the second week, the school transitioned into group projects, where students worked together in groups of four to solve a problem using the techniques learned during the first week of school. In total, we conducted eight group projects. An important aspect (incorporated from the online format) was the participation of Teaching/Learning Assistants (TAs). We reached out to our former students from the 2017–2022 schools and invited them to participate as TAs. Funding for their stipends came from a grant we obtained from NSF. The TAs had a crucial role, as they supported the learning of each group during the first week and the development of the group

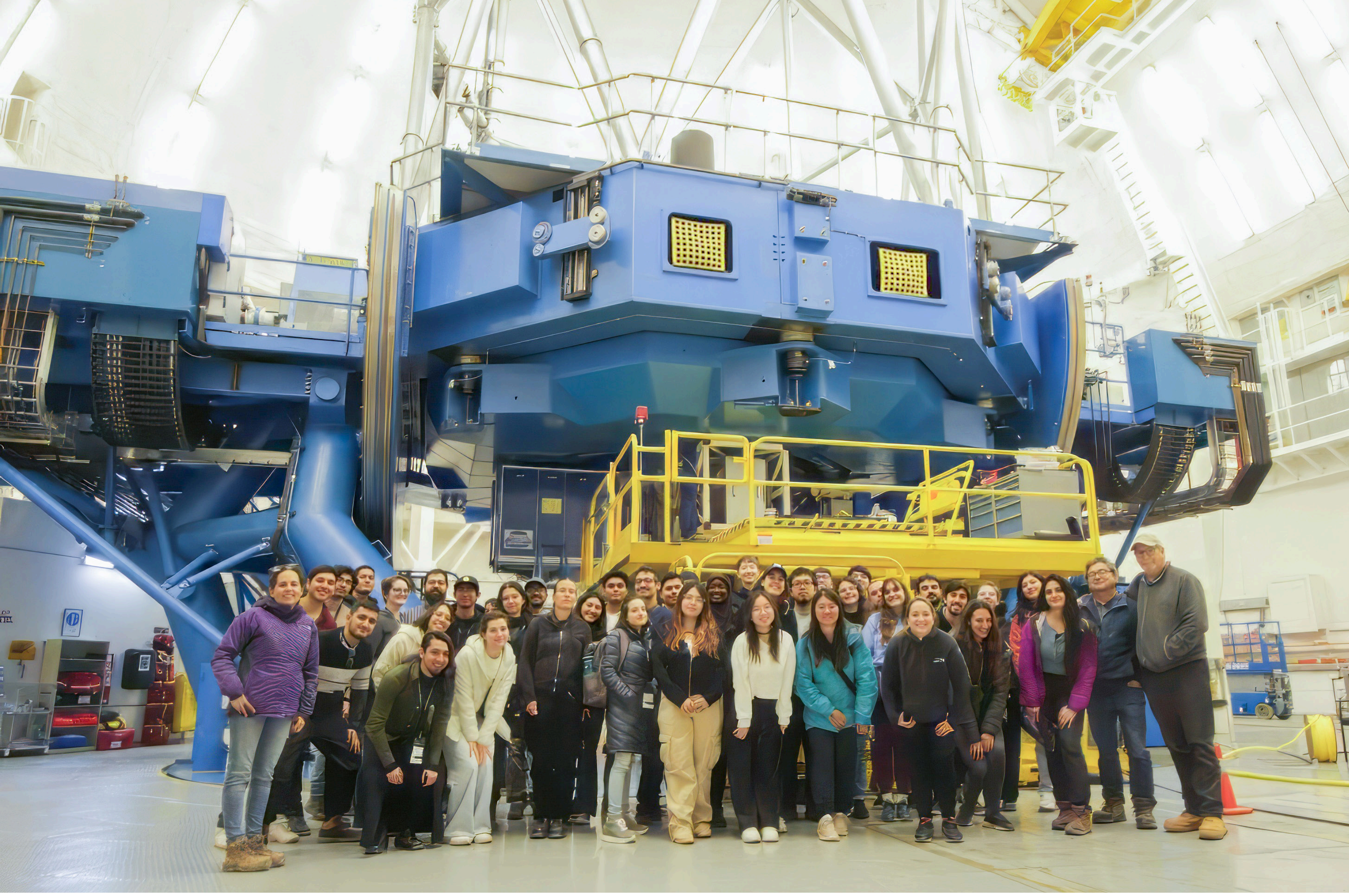

Figure 4: LSSDS students and faculty tour the Gemini South telescope with Electrical Supervisor Paul Collins.
Credit: NOIRLab/NSF/AURA/G. Damke

project. The previous experience of the TAs in the School was crucial because of their familiarity with the curriculum. Additionally, the Local Organizing Committee prepared an “LSSDS welcome package” as a way to generate a *sense of belonging* to the school. The package included items that were useful during the School, a technical book on machine learning to support their learning and serve as a tool for the future, and some souvenir items from the NSF’s NOIRLab telescopes.

During their stay in Chile, the group of students also toured NOIRLab’s telescopes at Cerro Tololo Inter-American Observatory and Cerro Pachón, including the Vera C. Rubin Observatory, SOAR, and Gemini South, and ended their day with stargazing led by Guillermo Damke.

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. Since LSSDS began 10 years ago, we have trained more than 230 students in data science. We are now planning the 2024 session! 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 visit to the AURA telescopes on Cerro Pachón and Cerro Tololo.

Thanks to our funding from NSF, along with support from other international partners, applications from students in US, Chilean, Ecuadorian (members of CEDIA), and Latin American (members of RedCLARA) 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 NOIRLab’s social networks and the School website. We look forward to receiving your applications and meeting you in La Serena in August 2024! Please visit the La Serena School for Data Science: Applied Tools for Data-Driven Sciences website for further information about the School.

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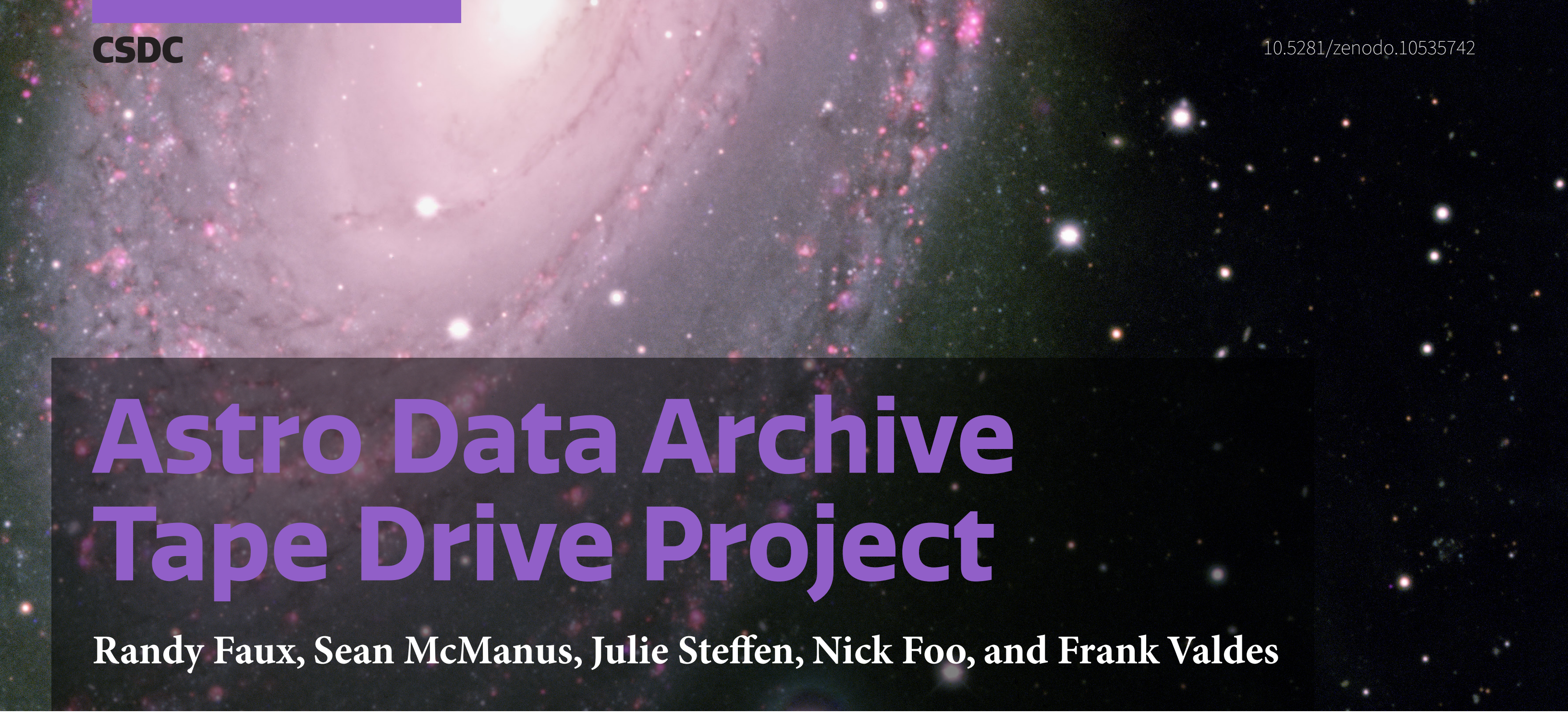

Astro Data Archive Tape Drive Project

Randy Faux, Sean McManus, Julie Steffen, Nick Foo, and Frank Valdes

Observations at Kitt Peak National Observatory (KPNO) and Cerro Tololo Inter-American Observatory (CTIO) obtained from May 1987 to September 2000 were archived to 8mm data tape for long-term storage. During this period approximately 9300 tapes were written, for a total of ~ 50TB of scientific data. The tapes closely resemble those used in consumer video camcorders from that time (Figure 1). This recording technology is now obsolete, and up until just recently, millions of science observations contained within the tapes were "dark data" and at risk of being lost forever.

The data in the tapes are still scientifically useful and thus worthy of recovery and proper archiving. For instance, the Mayall legacy Mosaic-1 observations are similar to the contemporary Mosaic-3 data, facilitating direct comparison of object changes over time. These data also have historical significance. According to astronomer Dr. 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 supernova 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."

8mm tape technology has been abandoned since the late 1990s, and therefore the hardware needed to transcribe data has become increasingly scarce. That, in combination with the threat of physical tape degradation, means that permanent data loss is imminent. These factors provided the urgency to design and implement the Tape Data Rescue Project (TDRP).

A timely opportunity presented itself at NSF's NOIRLab in collaboration with the American Astronomical Society (AAS). The AAS Archive Fellowship was created for a quarter-time graduate student to work on both the Abt Archives and the TDRP. The Abt Archives is a physical collection 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. These two projects are preserving aspects of our astronomical heritage by conserving, organizing, and making important archival collections available.

The TDRP was initiated in 2019 with a computer workstation connected to 20 recycled exabyte tape drives. Progress halted at the start of the COVID-19 pandemic and resumed in 2021. The initial reading of all of the primary tapes was completed by 2022. During this period many

Figure 1: The picture shows the galaxy M81 imaged in the lines of H-alpha and [OIII] with the Mosaic-1 camera on the Mayall 4-meter telescope at Kitt Peak National Observatory. The observations were from 23 exposures and 3 proposals taken between 2001 and 2002 and recovered from the Save-the-Bits tapes (Seaman 2000). The image is from 1/8th of the wide-field camera. The color composite is rendered with H-alpha in red, [OIII] in blue, and green from the narrowband continuum near [OIII]. The emission lines are characteristic of HII regions that produce the many pink/blue/violet features in the star-forming arms of M81. One value of the recovered Mosaic data is the large selection of filters used over the roughly four years of tape archived data. *Credit: NOIRLab/NSF/AURA/F. Valdes/T. Rector*

tape drives failed and had to be replaced with "creative procurements" from various surplus equipment markets. Physical tape failure also occurred many times throughout the process of reading tapes.

Analysis of the retrieved data revealed that some degradation of the tapes had taken place since they had been written 20–30+ years ago. Some tapes had files with either partial or complete data corruption. Fortunately, the effects of tape degradation were mitigated by redundant tape copies stored at mountaintop facilities. A final accounting of the recovery success rate is pending.

Despite numerous logistical challenges, the TDRP is nearly complete and will soon be publicly available. Some recovered datasets have already been delivered to the original PIs. Data are currently being characterized and prepared for public release via the Astro Data Archive, part of the Community Science and Data Center. Dr. Frank Valdes is using existing pipeline software to perform basic calibration to produce science-ready images (Figure 2). According to Dr. 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."

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Figure 2: 9300 8mm tapes stored in cabinets at NOIRLab Headquarters, Tucson, Arizona. *Credit: NOIRLab/NSF/AURA/R. Faux*

10.5281/zenodo.10535760

Creating the International Gemini Observatory's Long-Range Strategic Vision: Looking to the 2030s

David Jones

We encourage any member of the astronomical community to fill out the 2024 Gemini Strategic Vision Survey. Use this QR code, or the direct link.

The International Gemini Observatory, operated by NSF's NOIRLab, has begun the process of formulating its long-range strategy for the next decade. We are looking for broad feedback from both our users and the astronomy community at large in the coming months. This process is a chance to set a path for building the capabilities, priorities, and community of Gemini in the next decade and beyond.

The previous Gemini strategic vision was created in 2016 (approved in 2017), with a view toward operations in 2021 and beyond. The report paid particular attention to synergies with *JWST*, the Rubin Observatory, and future Extremely Large Telescope (ELT) projects. The goal of the strategic vision was to solicit broad community feedback, with all possibilities for the Gemini Observatory considered "on the table."

The final report included the following (paraphrased) recommendations:

1. Leverage Gemini's flexible scheduling model and Gemini South's geographic location to be the premier facility for the follow-up of targets identified by the Vera C. Rubin Observatory's Legacy Survey of Space and Time (LSST).
2. Remain an observatory predominantly devoted to Principal Investigator (PI)-led science. This is in contrast to having Gemini transition to running large community surveys, for example.
3. Gemini should be the premier hosting facility for ambitious and impactful visitor instruments. We want to particularly engage our partner countries in creating new Gemini instruments to benefit the community as a whole.

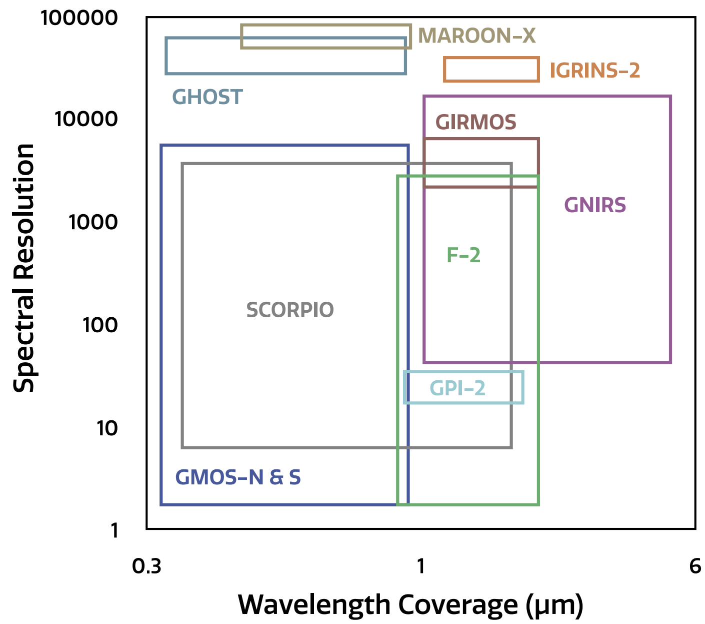


Figure 1: Spectral resolution and wavelength coverage for Gemini's current and upcoming instrumentation

4. The future direction of the Gemini telescopes should be allowed to diverge. Given their different geographic locations, overlap with, e.g., LSST, may create an advantage for having specific capabilities in the South versus the North.

These recommendations have helped to facilitate, for example, the development of new instruments like SCORPIO at Gemini South, an eight-channel optical-to-IR imager designed to enable community follow-up of LSST targets. Similarly, because of Maunakea's excellent seeing conditions, the development of multi-conjugate adaptive optics at Gemini North is an example of taking advantage of the capabilities at each site. In light of both LSST and multi-messenger astrophysics, the recommendations emphasized the need for dynamic, real-time scheduling, which will be available through the forthcoming Gemini Program Platform. They emphasized Gemini's commitment to multiple avenues for PI-driven proposals (e.g., Fast

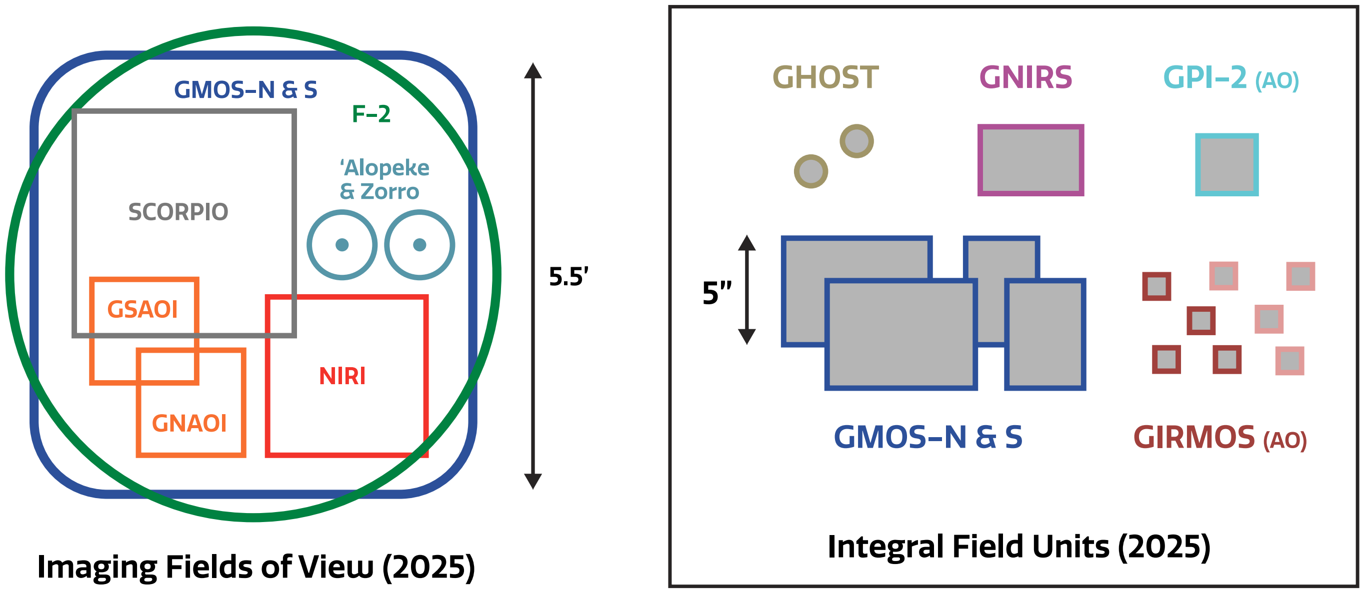


Figure 2: Illustration of Gemini's imaging (left) and IFU (pp) fields of view

Turnaround, Large-and-Long) and Visitor Instrument solicitations.

The new, upcoming formulation of Gemini's strategic vision will require us to plan for the 2030s and anticipate the needs of our community in the next decade. We will begin with a survey for any member of the astronomical community (see QR code), asking for their opinions on Gemini's role in overlapping or complementary science with upcoming facilities, the next big instrumentation projects that the community would like to see Gemini undertake, other areas of potential Gemini infrastructure development (data reduction, scheduling, proposals, etc.), how Gemini can better engage with its user community, and how Gemini can better serve diverse and underrepresented communities — including both astronomers and the general public.

These survey results will be presented to our User's Committee, Science and Technology Advisory Committee, and Board of Directors for integration into the strategic vision. We see this process as a chance not only to evaluate the direction and capabilities of the Gemini Observatory but also to change the direction of current instrumentation and development as needed. Our goal as an observatory is to remain flexible in light of new science and technology. We are committed to enabling the best science from our partners and user community while realizing new opportunities in the coming decades.

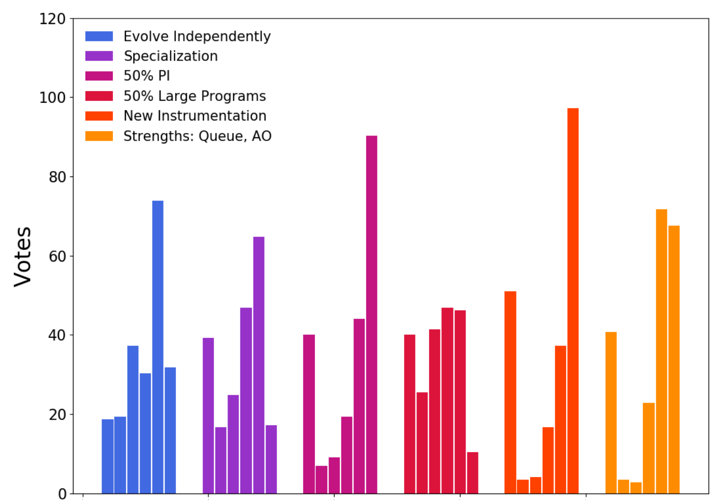


Figure 3: Results from the 2016 strategic vision survey indicating respondents who strongly disagree (0) to strongly agree (5) with the following scenarios: a) Gemini South and Gemini North can evolve independently, b) Gemini North and/or Gemini South can move to a partial or full specialization, c) Gemini should maintain at least 50% of the time for PI-driven science, d) Gemini should increase time allocation for very large, very high impact projects that use up to 50% of all telescope time, e) Gemini should enable access to the latest technology through new instrumentation, upgrades to current instrumentation, and a visitor instrumentation program, and f) Gemini should build on current strengths, such as the operational agility of queue observations and the investment in adaptive optics. Histograms for each scenario show their distributions of scores from 0 (left) to 5 (right).

10.5281/zenodo.10535771

GHOST: High–Resolution Optical Spectroscopy at Gemini South

Fredrik Rantakyro, Venu Kalari, and Vinicius Placco

GHOST, the **G**emini **H**igh-resolution **O**ptical **S**pec**T**rograph, is the latest facility instrument at Gemini South, part of the International Gemini Observatory. GHOST delivers advanced high-resolution spectroscopic capabilities with broad simultaneous wavelength coverage and high throughput. This new instrument empowers astronomers to answer a variety of scientific questions, such as studying the intergalactic medium using observations of quasars, how the Universe evolved by observations of very old metal-poor stars, and identifying and characterizing exoplanetary systems.

This sophisticated instrument comprises three key elements: a Cassegrain unit mounted on the telescope, a spectrograph bench housed in a highly stable enclosure at the pier lab, and a fiber cable connecting the two. The on-telescope Cassegrain unit encompasses the positioning system for the object and sky fiber Integral Field Units (IFUs), with each object IFU incorporating mini-ADCs (atmospheric dispersion correctors). Interested users should consult the GHOST web pages for further details.

The GHOST System Verification (SV) was successfully carried out on 9–17 May, and it was allocated a 40-hour time block at Gemini South. Most of the high-priority observations across the various programs were completed during this timeframe. Raw data from the SV run is now accessible in the public Gemini Observatory Archive. For comprehensive details regarding the conducted observations during the SV run and ongoing data evaluations, please refer to the GHOST science web page. Moreover, the reduced data is also currently accessible in the archive. The SV team, composed of Gemini observatory personnel and community representatives, planned, conducted, reduced, and evaluated the SV observations. A subset of this group, the Instrument Science Team (IST), was primarily responsible for developing observations for SV and reducing and analyzing those datasets. The IST was chosen in consultation with the Gemini Directorate, Science and Technology Advisory Committee (STAC), and the National Research Council (NRC)-led GHOST instrument team.

To foster community engagement and share outcomes from the SV process, a series of GHOST webinars took place in late July / early August 2023. Additional information can be found on the GHOST Webinar Series web page.

The dedicated GHOST Shared Risk Call for Proposals through the Fast Turnaround program has been successfully concluded. The anticipated GHOST observation block was scheduled from 30 November to 19 December. The 15 submitted proposals included 10 from the US, 3 from Canada, 1 from Brazil, and 1 from South Korea, collectively requesting 71.37 hours. Out of these, 14 proposals were accepted (9 from the US, 3 from Canada, 1 from Brazil, and 1 from South Korea), with a total grant time of 51.47 hours (49.22 hours for Band 1 and 2; 2.25 hours for Band 3). 80% of the time allocated was observed. All B1 and B3 programs were completed, with 8 out of 10 Band 2 programs also completed.

GHOST was offered fully in the 24A Call for Proposals. Based on preliminary information, the requested time for GHOST appears to be close to 20% of the total requested time at Gemini South.

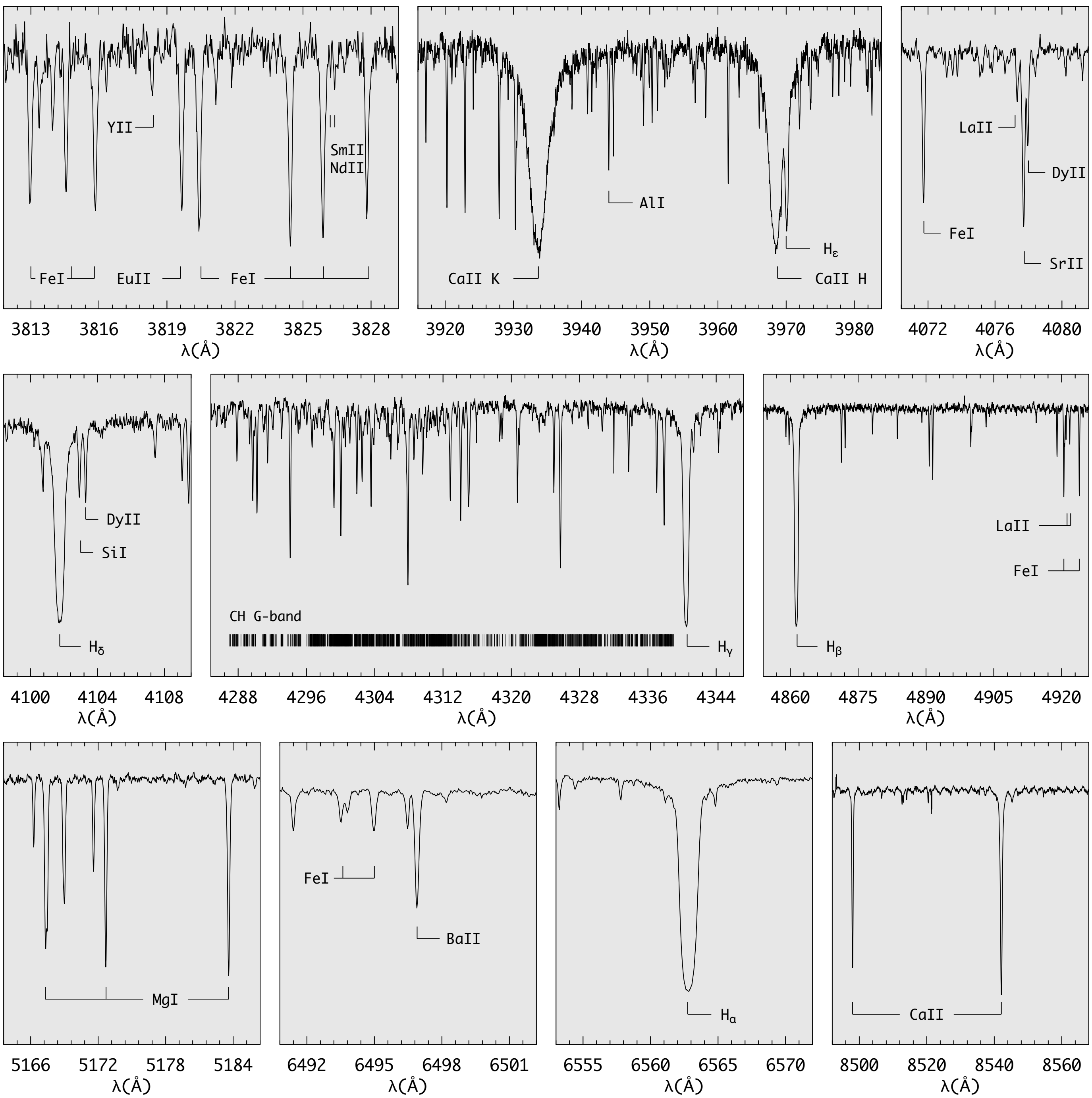
Early Scientific Results Using GHOST SV Data

During the GHOST System Verification, data were taken of a chemically peculiar star in the halo of the Milky Way. The analysis of these data was recently published in Placco et al. (2023). The object, SPLUS J142445.34–254247.1, was first observed in 2019 with GMOS at Gemini South. Observations confirmed its low iron content, and it was selected as a potential target for high-resolution follow-up. The GHOST data, taken with the standard resolution mode (R~50,000), allowed for the determination of chemical abundances for 36 elements from the periodic table, from carbon to thorium. With an iron abundance about 2500 lower than the Sun, SPLUS J1424–2542 is one of the lowest metallicity stars with measured thorium. It also has the highest thorium-to-europium ratio observed to date, making it part of the "actinide-boost" category. Such stars can help constrain the operation of the rapid neutron-capture process (r-process) in the early Universe.

The analysis suggests that the gas cloud from which SPLUS J1424–2542 was formed must have been enriched by at least two events. The light-element ($Z \leq 30$) abundance pattern is consistent with the yields from a supernova explosion of metal-free stars with 11–13 solar masses, and the heavy-element ($Z \geq 38$) abundance pattern can be reproduced by the yields from a neutron star merger event. An analysis of how the star is moving across the Milky Way also reveals that SPLUS J1424–2542 is a low-mass, old halo star with a likely in situ origin, not associated with any known early merger events in the Milky Way.

Reference

Placco, V. M., et al. 2023, ApJ, 959, 60



Sections of the GHOST spectrum of SPLUS J1424–2542 showing selected absorption features used for chemical abundance determinations

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DESI Crosses the Half-Way Mark

Arjun Dey

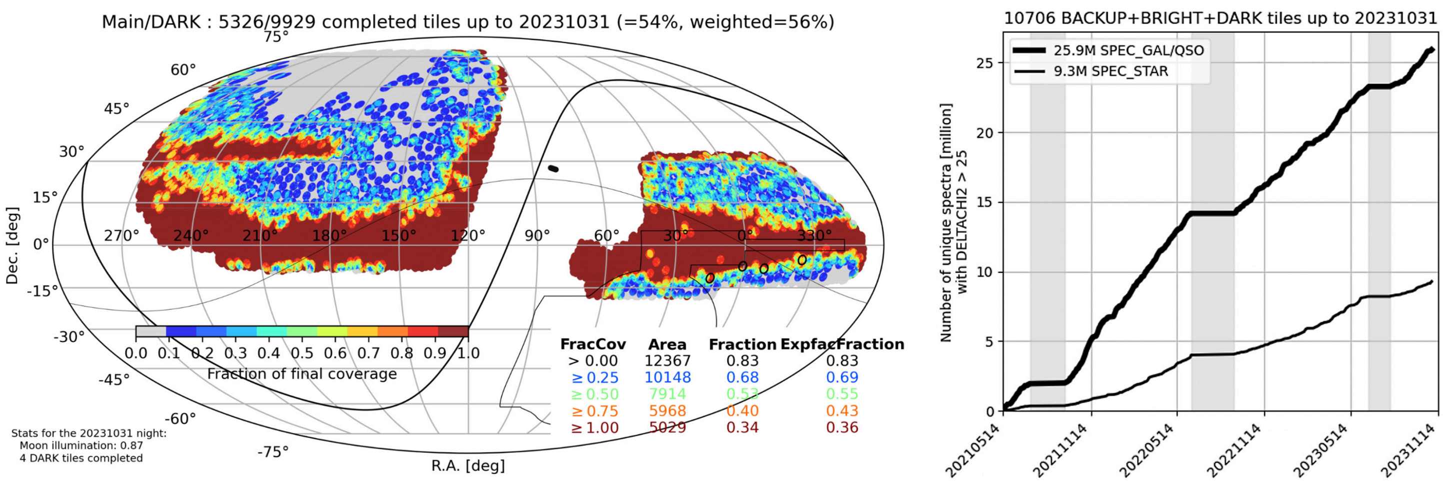

Figure 1: Left: Current sky coverage of the DESI dark-time survey as of the end of October, showing that the survey is 54% complete. Right: Progress of the survey as measured by the number of extragalactic redshifts (25.9 million) and stellar spectra (9.3 million) measured so far. *Credit: LBNL/DESI/A. Raichoor*

The Dark Energy Spectroscopic Instrument (DESI) on the Nicholas U. Mayall 4-meter Telescope is currently running at a blistering pace: it measures 10 million extragalactic redshifts and 3.5 million stellar spectra every year! The 5-year DESI survey project, which began in May 2021, has now passed its half-way point (see Figure 1). On the night of 23 September 2023, the observing team, which included Amy Robertson, Luke Tyas, Tristan Fraser and Francesco Sinigaglia, marked this milestone by completing the 4965th dark-time tile (of 9929 in total) on the night of 23 September 2023. In short, despite the interruptions due to COVID-19, the Contreras Fire, and the cybersecurity incident, the DESI project is on track to complete its planned observations by mid-2026; in fact, the bright-time survey is already more than 75% complete, allowing the Collaboration to add an extra tiling of their footprint (and thus more than 20% more targets!) to the plan.

The DESI Collaboration has been hard at work analyzing the data and has already published nearly 180 papers. The early results from DESI are promising. The baryon acoustic oscillation signature is clearly detected in the early galaxy clustering data (Moon et al. 2023; see Figure 2) and in the early quasar Lyman-alpha forest (see Figure 4 of Gordon et al. 2023). These will include results in measurements of unprecedented precision of the expansion history of the Universe to over a wide redshift range. The Collaboration expects to publish the cosmological results derived from the first year of DESI data in April 2024. The DESI Milky Way Survey is providing the largest ever collection of stellar spectra. It has also targeted stellar streams, a few dwarf galaxy companions of the Milky Way, and the Andromeda Galaxy. The millions of DESI spectra also enable searches and investigations of a wide variety of rare populations of astrophysically interesting sources (e.g., high-redshift QSOs, changing-look QSOs, coronal-line-emitting galaxies, very metal poor stars, rare white dwarfs, etc.).

DESI spectra are also likely to be an important complement to the Vera C. Rubin Observatory's Legacy Survey of Space and Time. For example, DESI redshifts will be used for calibrating Rubin/LSST photometric redshifts and for providing (in combination with Rubin proper motions) 3-d space motions of

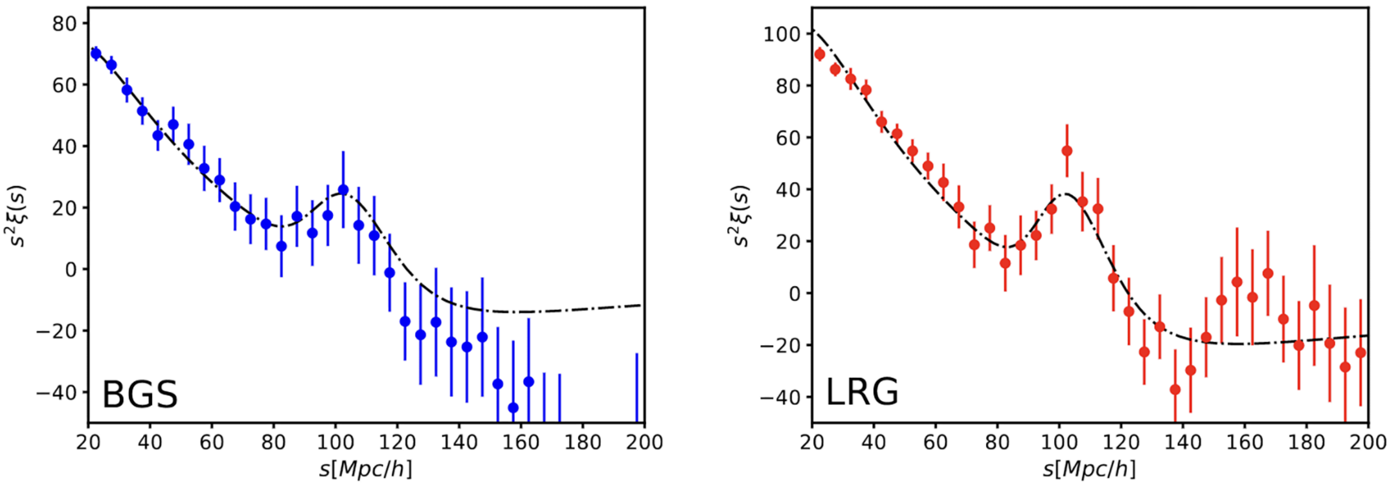

Figure 2: The baryon acoustic oscillation (BAO) peak at ~100 Mpc/h is easily detected in the two-point correlation function of the bright galaxy (BGS) and luminous red galaxy (LRG) samples as measured in the early data from DESI. The colored points show the measurements obtained with only 26% (BGS) and 12% (LRG) of the total survey area, and the dot-dashed curve shows models based on linear theory. The BAO feature is detected at 5(3)-sigma confidence with 1.7% (2.6%) precision in the LRG (BGS) samples (from Moon et al. 2023).

Milky Way stars. As a result, the DESI and the LSST Dark Energy Science Collaboration have formed a joint team (the DESC-DESI Coordination Team) to explore how the two projects can support each other and to coordinate activities of common scientific interest.

As reported in *The Mirror* issue #5, the DESI Collaboration has made public an Early Data Release, which included spectra of nearly 2 million astronomical sources. The next data release is expected in late 2024 and will include spectra of all sources targeted during the first year of the DESI survey. We also anticipate the first cosmology science results, based on the first year data, to be released by this time.

DESI construction and operations is managed by the Lawrence Berkeley National Laboratory. This research is supported by the U.S. Department of Energy, Office of Science, Office of High-Energy Physics, 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 U.S. National Science Foundation, Division of Astronomical Sciences under Contract No. AST-0950945 to the NSF's National Optical-Infrared Astronomy Research Laboratory; 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; the National Council of Science and Technology of Mexico; the Ministry of Science and Innovation of Spain, and by the DESI Member Institutions. The DESI Collaboration is honored to be permitted to conduct astronomical research on Iolkam Du'ag (Kitt Peak), a mountain with particular significance to the Tohono O'odham Nation.

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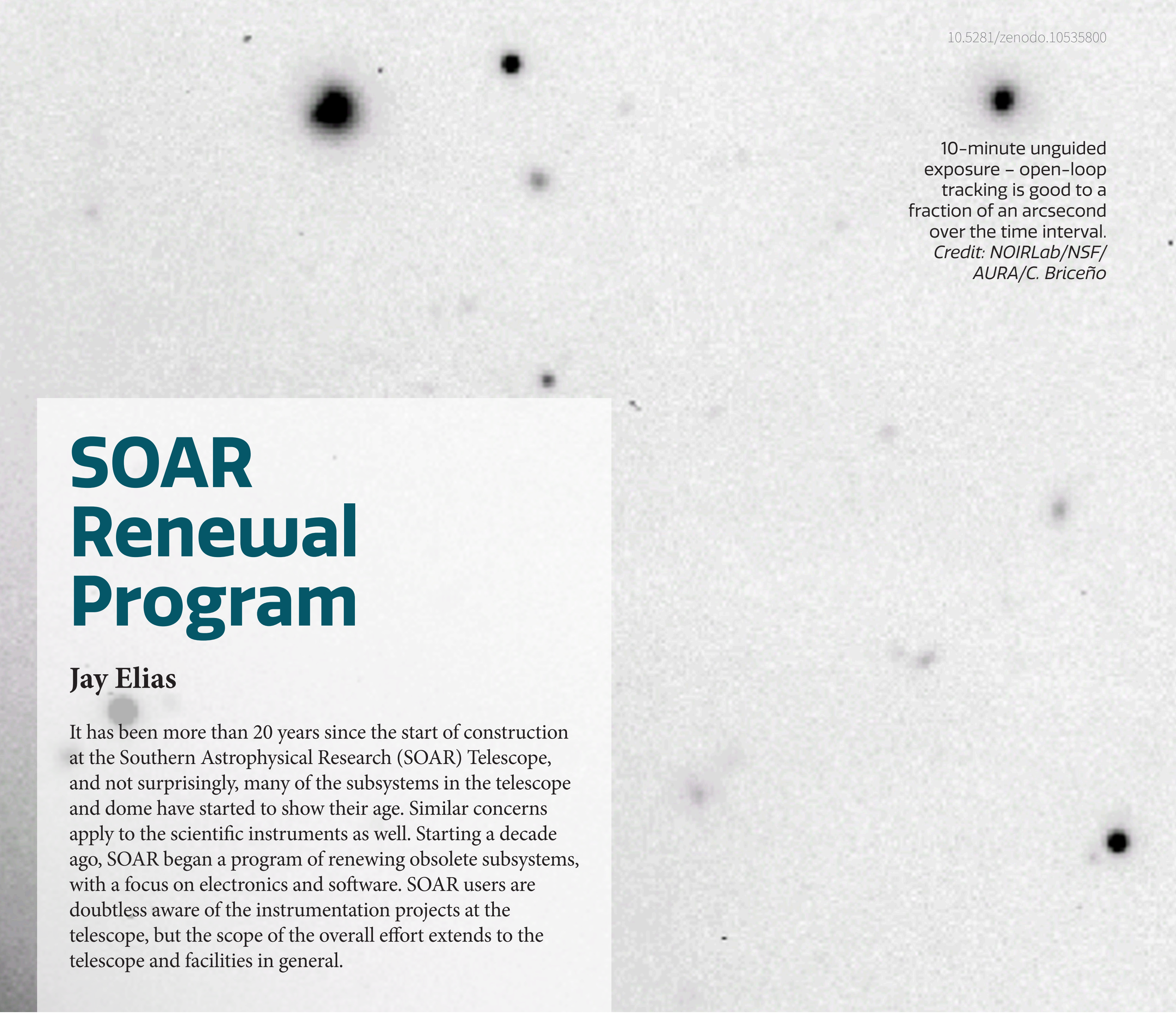

10-minute unguided exposure – open-loop tracking is good to a fraction of an arcsecond over the time interval. *Credit: NOIRLab/NSF/AURA/C. Briceño*

SOAR Renewal Program

Jay Elias

It has been more than 20 years since the start of construction at the Southern Astrophysical Research (SOAR) Telescope, and not surprisingly, many of the subsystems in the telescope and dome have started to show their age. Similar concerns apply to the scientific instruments as well. Starting a decade ago, SOAR began a program of renewing obsolete subsystems, with a focus on electronics and software. SOAR users are doubtless aware of the instrumentation projects at the telescope, but the scope of the overall effort extends to the telescope and facilities in general.

Instrumentation

Regular users of SOAR will be familiar with the instrumentation suite, but a brief overview will help supply perspective. In some cases, new instruments are part of the original development plan, while in others they are replacing older capabilities.

The following two instruments represent the final deliveries of the initial instrument suite for SOAR:

- ***SOAR Integral Field Spectrograph (SIFS).*** The SOAR IFU spectrograph was finally commissioned at SOAR in early 2017, with science verification during both the 2017A and B semesters. Since then it has seen regular use by the Brazilian community, with less frequent use by observers from other SOAR partners. The instrument capabilities are described on the NOIRLab Science website; the original design paper is Lepine et al. (2003).
- ***STELES.*** The SOAR Echelle Spectrograph is currently undergoing final integration at SOAR, including limited on-sky testing by early CY 2024. This work was delayed by multiple factors, including the COVID-19 pandemic. The original design paper is Castilho et al. (2004).

Two additional instruments are replacing older capabilities:

- ***TripleSpec 4.1*** is a version of the original TripleSpec IR spectrograph that was originally built for the Víctor M. Blanco 4-meter Telescope and subsequently adapted for use at SOAR. It replaced the OSIRIS IR spectrograph, which was decommissioned in 2015 after major failures. Instrument information for users is also provided on the NOIRLab Science website, while the relevant design papers are Schlawin et al. (2014 — Blanco version) and Herter et al. (2020 — SOAR modifications and performance). It has been in regular use since the 2019A semester.
- We are upgrading the Blanco **IR imager (ISPI)** and moving it to SOAR rather than attempt a major upgrade of Spartan. The Spartan IR imager is nearing the end of its useful lifetime, as its detectors and electronics are deteriorating and cannot easily be repaired. The ISPI upgrade was determined to present lower technical risk and cost. The new capability will offer a similar field of view to Spartan (approximately 5x5 arcmin) but with a single monolithic array and pixels better matched to SOAR image quality. ISPI will continue to provide a set of narrowband and broadband filters covering the near-infrared from Y through K bands. Work on the upgrade is underway, and it will likely be commissioned soon after STELES.

The ***Goodman High-Throughput Spectrograph*** was delivered in 2004 and saw regular science use starting in semester 2008A, at which time it quickly became the most-used instrument on the telescope. Since then, it has seen several upgrades aimed at improving its efficiency and reliability, including addition of a second, red-sensitive camera as an alternative to the original blue camera (2016B) and provision of a dedicated target acquisition camera (2015B).

Telescope Systems

The telescope itself has not been neglected, and a series of projects have been underway since 2014. Of these, the most significant are the following:

- Upgrades to the original telescope control system (TCS). The original SOAR TCS (Schumacher et al. 2004) has an architecture that is shared with the Blanco and (to a large extent) Rubin telescopes. Improvements implemented for Blanco as part of DECam installation (Warner et al. 2012) were subsequently applied to SOAR, starting in 2014 and completing in 2016.
- Upgrades to the telescope mount control and power drive units (MCU and PDU). This project started in late 2017 and is largely complete as of late 2023 (initial concept in Cancino et al. 2018). This project can be thought of as the "next layer down" from the TCS. It involved replacing original obsolescent proprietary hardware and software with modern hardware and software. The new system is also generally compatible with other NOIRLab telescopes. Furthermore, better telemetry provides better diagnostics of failures, which means recovery can be quicker. The figure shows an example of the mount performance with the upgraded system.
- Upgrades to the telescope active optics controls. Two subsystems have been upgraded:
  - ▹ The control system for the primary mirror actuators has been upgraded to provide faster response times, which allow telescope slews in elevation to complete more rapidly. This work was completed in 2018.
  - ▹ The calibration wavefront sensor (CWFS), which is used for tuning the active optics at the start of every night, replaced obsolete cameras and a lenslet array (David et al. 2020). This work was completed in 2021 (working under pandemic conditions).
- Wavefront-sensing guiders. The original guiders provided only guiding (including fast guiding driving the tip-tilt function of the tertiary mirror). This meant that changes in telescope focus during the night required pausing to determine a new focus setting. Additionally, experience with the active optics showed that residual astigmatism could develop during the night. The only solution in this case was to re-tune the optics using the calibration wavefront sensor. After several experimental investigations, a design was developed that would support guiding, auto-focus, and astigmatism correction, using a 2x2 Shack-Hartmann sensor (Tokovinin et al. 2018). The new design also had to fit within the existing instrument support structures at both the optical and IR Nasmyth foci. The guiders are similar but not identical, because the internal layout at each focus is different. The guider for the optical Nasmyth was installed in July 2022 and fully commissioned during subsequent months. The guider for the IR Nasmyth was installed in September 2023, and commissioning of all functions is underway. In both cases basic guiding was implemented as part of the initial installation. Both guiders use modern EM-CCD cameras, as the devices on the original guiders are no longer supported.

Observing Modes

SOAR was intended to provide a robust remote observing capability, in particular because the two university partners (Michigan State University and University of North Carolina, Chapel Hill) wanted to use the telescope for training students and early-career staff. Additionally, the SOAR design allowed rapid switching between instruments — a few minutes at most.

Ease of access and flexibility meant that SOAR could support programs that required frequent observations — for example, monitoring of supernovae or near-Earth objects on a monthly time scale. This approach is satisfactory for large programs, which can use full nights on a monthly cadence. It was recognized that this type of classical scheduling was not ideal for smaller programs or those requiring more frequent observations. SOAR does support target of opportunity programs, but it is not practical to support too many of them, because the impact on standard observing programs would be too severe.

Queue observing was an obvious solution, but SOAR needed it to be cost-effective; queue observing can be labor-intensive and too expensive for a small facility. The solution was to implement a highly automated queue as part of the Astronomical Event Observatory Network (AEON), in collaboration with the Las Cumbres Observatory (Street et al. 2020; see also Elias and Briceño 2020). In its present form, the AEON queue supports the two most-used instruments at SOAR (Goodman HTS and TripleSpec 4.1); somewhat more than 20% of the observing time is scheduled in this mode, providing a weekly cadence or better. At present, most of the AEON time is NOIRLab time, with some additional Chilean time.

Acknowledgments

This work is the result of efforts by many engineering and scientific staff, primarily in Chile but also at SOAR partner institutions. Without their hard work over the last decade, SOAR would not be the productive facility that it is today.

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Rubin/LSST In-kind Contribution Program Produces Mutual Benefits

International contributors provide value for Rubin Observatory in return for data rights

Bob Blum, Phil Marshall (SLAC), Kristen Metzger, and Aprajita Verma (University of Oxford) and the In-kind Program Team

Program Overview

The Vera C. Rubin Observatory In-kind Program offers the opportunity for international organizations to obtain Rubin data rights in return for contributions that will enhance the science impact of Rubin Observatory's Legacy Survey of Space and Time (LSST). Launched in 2019, the program spans many varied in-kind contributions providing resources and support to Rubin Operations and the Rubin Science Community. As of late 2023, the Rubin In-kind Program involves 153 contributions from 43 individual teams from 28 countries, plus the US and Chile. The program is facilitated by the Rubin International Program Coordination (IPC) Team (see Table 1), which reports to the Rubin Director and Deputy Director of Operations. Now wrapping up its second full year of contribution effort by the participating teams, the program has proven successful by filling needs in the Rubin ecosystem, while meeting the desire for Rubin data rights in the international community, as the observatory gets closer to starting science operations.

Table 1: The Rubin IPC Team

Agnès Ferté (SLAC)	Software contributions and general pool coordination
Greg Madejski (SLAC)	Community Engagement Team Liaison
Steve Margheim (NOIRLab)	Telescope time and dataset contributions (primary contact)
Phil Marshall (SLAC)	Contributions to Rubin, Data Rights Agreements and list (Deputy Director of Operations)
Knut Olsen (NOIR Lab)	Independent Data Access Centers and other computing resources
Stephen Ridgway (NOIRLab)	Telescope time and datasets contributions (secondary contact), NSF's NOIRLab Community Science and Data Center Liaison
Susan Ridgway (NOIRLab)	Software contributions
Aprajita Verma (Oxford)	Software contributions and SC/Recipient Liaison (IPC Team Lead)
Heather M. Shaughnessy (SLAC)	Data rights holder database management, office hours coordination (Program Operations support)
Sierra Villarreal (SLAC)	Independent Data Access Centers technical coordinator

Rubin Data Rights

There will be two types of Rubin data: prompt products, which most notably include the alert stream, and data release products, which will be generated approximately annually. Alerts will be world-public, while the data releases will have a proprietary period of two years, during which they will be available only to people with Rubin data rights. All US and Chilean scientists will have Rubin data rights, as will non-US scientists covered by data rights agreements with the US agencies (or their designates) through this in-kind program. Because Rubin data is poised to revolutionize the fields of astronomy and astrophysics, there is significant desire for data rights agreements from institutions outside the US and Chile.

This model of in-kind participation in Rubin's LSST widens the ways in which international teams can contribute to include time, expertise, and/or access to existing infrastructure of providing for data rights access. The guiding principle set up by NSF and DOE is that these in-kind contributions should benefit the US science enterprise, whether directly related to Rubin and the LSST or not.

Getting off the Ground

The In-kind Program was introduced in the northern fall of 2019 with an invitation to contributing institutions holding MOAs under the previous program, as well as to other groups that had expressed interest in obtaining Rubin data rights. Contributors were asked to submit Letters of Intent (LOIs) in November, after which the two funding agencies reviewed and confirmed the proposed contribution ideas. Detailed proposals followed in the northern spring of 2020 — contributing organizations were encouraged to work closely with Rubin teams or Science Collaborations to develop their proposals, ensuring that the proposed contributions were well aligned with Rubin needs and contained appropriate mechanisms for ongoing communication and engagement.

Rubin leadership established a special In-kind Contribution Evaluation Committee (CEC) to review these proposals. The CEC recommended successful proposals, which were then approved by Rubin directors and then formally accepted for further development by NSF and Department of Energy (DOE). As of this writing, the In-kind Program has broad participation from around the world (see Figure 1). While the basic scope of each In-kind Program contribution has been approved by Rubin Observatory, NSF, and DOE, the actual Data Rights Agreements (which are made between either AURA and a program, or SLAC and a program) have not been approved for signature by either NSF or DOE as those agencies make their final review of these formal agreements.

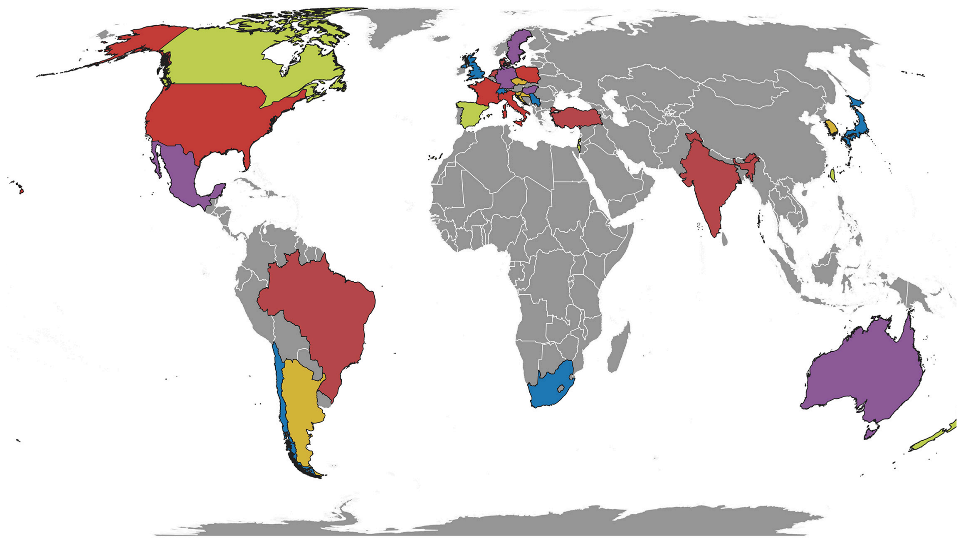

Figure 1: Countries with data rights to the Legacy Survey of Space and Time. Different colors aid in seeing distinct countries with data rights by virtue of an in-kind program, host country (Chile), or lead (USA).

A Range of Contributions

Current in-kind contribution projects span a diverse set of projects that benefit different elements of the Rubin system, as shown in Figure 2. The financial value of these contrib-utions is significant. The total and relative amounts per category are shown in Figure 4. How these contributions connect to the LSST Science Collaborations is detailed in Table 2.

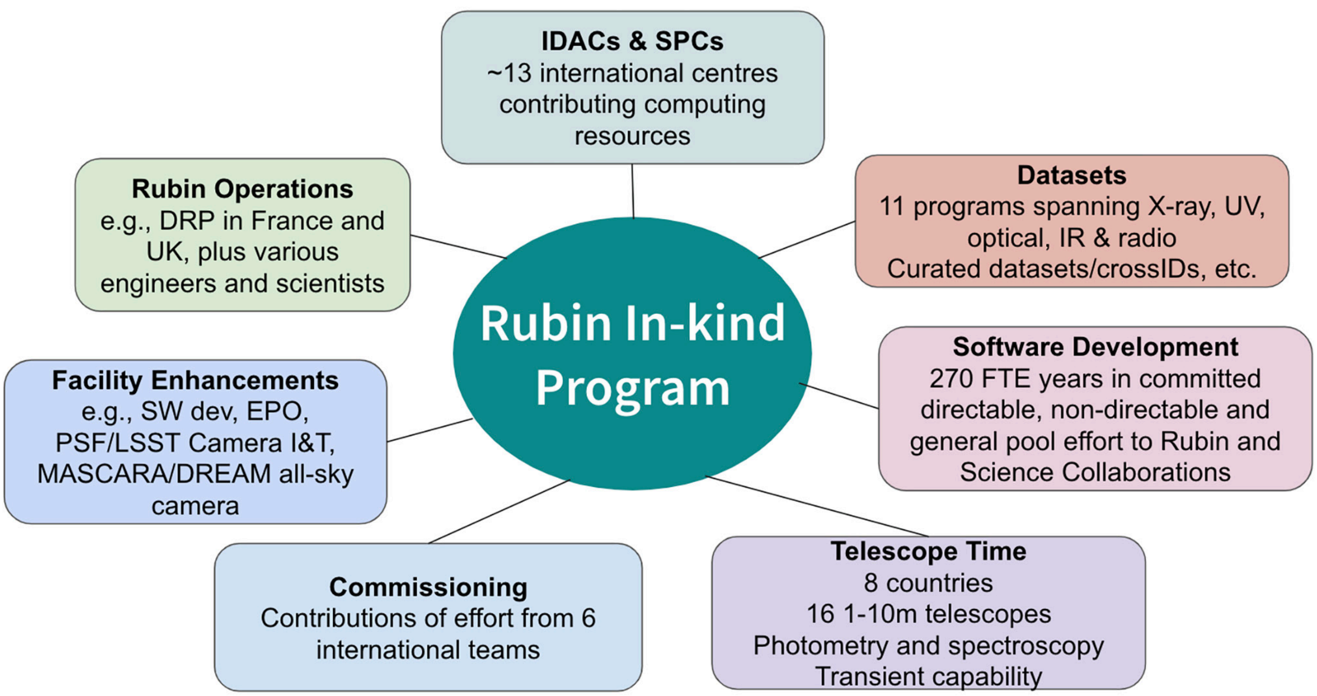

Figure 2: Summary of the current Rubin In-kind Program by category

Contribution Lifecycle

After proposal acceptance and agreeing on a start date for the work, each contributor is responsible for setting up a program work plan in liaison with the recipient group; this outlines the work to be done towards the contribution with objectives and milestones. Quarterly updates ensure that progress remains on track, and an annual evaluation gives a holistic view of what was achieved during the prior year. Contribution groups are encouraged to maintain a high level of engagement with the Rubin team or Science Collaboration that is benefiting from their contribution. If lapses in communication or engagement occur, the IPC Team steps in to facilitate. Each individual program of contributions is managed by a local Program Manager (PM) who is responsible to maintain an overview of the status of a program and its constituent contributions, ensuring good communications, progress, and reporting. Participants have access to a suite of resources, including a comprehensive handbook, and the IPC hosts assemblies, about once per quarter, to communicate with stakeholders in an inclusive way.

Table 2: Current Contribution Breakdown by Science Collaboration

Primary Recipients	Type	Number of Contributions	Equivalent Value ($M)
AGN	Telescope Time and Datasets	1	0.1
AGN	Directable SW Effort	7	4.3
DESC	Telescope Time and Datasets	4	2.4
DESC	Non-directable SW Effort	6	3.5
DESC	Directable SW Effort	24	17.3
Galaxies	Non-directable SW Effort	3	2.5
Galaxies	Directable SW Effort	8	4.3
Solar System	Directable SW Effort	2	1.2
SMWLV	Non-directable SW Effort	1	1.2
SMWLV	Directable SW Effort	3	2.0
Strong Lensing	Non-directable SW Effort	1	0.3
Strong Lensing	Directable SW Effort	2	1.6
TVS	Telescope Time and Datasets	3	2.7
TVS	Non-directable SW Effort	3	1.7
TVS	Directable SW Effort	12	10.1
	Totals:	80	55.1

Example Contributions

The diversity of contributions that have already started are providing valuable returns to the Observatory. For example, the expertise of system engineers from the Italian Istituto Nazionale di Astrofisica (INAF) program have been on-site to help with efforts towards commissioning and Systems Verification and Validation. They have been requested to return to the observatory site in FY24. This is part of a substantial committed pool of effort involving US and international teams providing support for commissioning activities to Rubin Observatory. Several contributions involve staff effort provided to Rubin Operations teams, as a way of offsetting the cost to the US funding agencies and broadening international participation in the observatory's workings. The French Institut National de Physique Nucléaire et de Physique des Particules (IN2P3) and LSST:UK in-kind programs are making major contributions in the areas of data release processing (at the Rubin France and UK Data Facilities) and LSSTCam commissioning and maintenance (following a many-year collaboration between Rubin and the IN2P3 laboratories on the camera's construction).

As another example, the Korean in-kind program, led by the Korea Astronomy and Space Science Institute (KASI), is contributing two Observing Specialist postdocs to the nighttime operations team, with the first one entering via a new collaborative KASI-KIPAC Fellowship program. Alongside the other Observing Specialist postdocs, the KASI-KIPAC Fellow will spend two years in Chile troubleshooting the telescope and camera at night and then return to Stanford's Kavli Institute for Particle Astrophysics and Cosmology (KIPAC) for two years of LSST science research. The fellowship can be rounded out with a final two years at KASI, providing a unique six-year experience for the successful applicant as well as much-needed humanpower at the Summit Facility. This fellowship is planned to be duplicated at NSF's NOIRLab, with the first search for a KASI-NOIRLab Rubin Observing Specialist Fellow tentatively scheduled to start in October 2025.

Preparation for defining additional computational resources (processing and data access) brought in through the international program is well underway. A dedicated workshop held in March 2023 was organized by coordinator Knut Olsen jointly with the UK and Brazilian Independent Data Access Center (IDAC) teams to explore the science use cases that will shape the requirements on the data access and scientific processing centers. The initial program also includes some significant telescope time resources that will be offered and allocated to the US science community through NOIRLab. Coordinator Steve Margheim together with Rachel Street (Las Cumbres Observatory) organized an Observatories Workshop, bringing together the international teams with AEON[1] specialists to help them prepare resources for the time offered, particularly for integration with AEON. Many software contributions have started under the direction of their recipient groups including a community software resource — the General Pool of software experts. Several projects have kicked off to provide varied resources to Rubin and to the Rubin/LSST Science Collaborations that develop infrastructure or tools that enhance elements of the recipient group's system or pipelines and cover scheduling to science. This is managed by coordinators Agnès Ferté and Aprajita Verma. The opportunity to request effort from the General Pool remains open all year round; please contact the relevant Rubin Recipient Groups if you have a use case for this resource.

Upcoming Plans

The IPC, in conjunction with Rubin leadership, is planning a targeted expansion of the In-kind Program to meet remaining resource needs in the Rubin community. After specific needs are established, proposals will be accepted on a rolling basis to match the needs with contributions from existing and prospective groups, including teams in the US and Chile. The NOIRLab community is invited to explore resources (including telescope time and datasets) that might be of value to the US community and follow the same guiding principle as the original In-kind program. These can be proposed through the simple form at ls.st/ikc-rn.

For more information about the Rubin In-kind Program, visit the program web page. The In-kind team can be contacted via jikh@lsst.org.

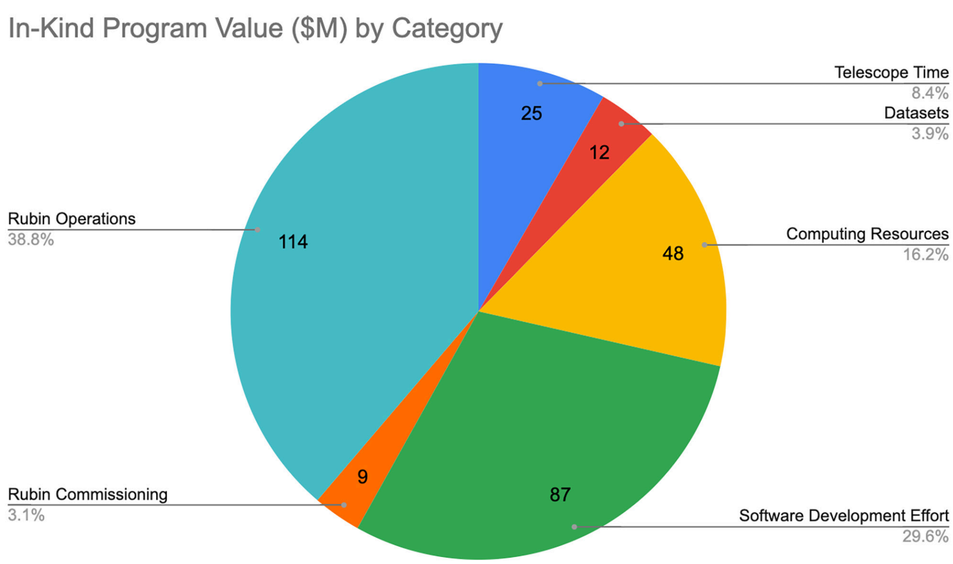

Figure 3: Distribution and value of currently accepted international in-kind contributions by category

[1]AEON (Astronomical Event Observatory Network) is a collaboration between Las Cumbres Observatory and NSF's NOIRLab to support real time follow-up of Rubin or other alerts on a network of telescopes including those run by LCO and NOIRLab (SOAR, Gemini, Blanco initially). See https://noirlab.edu/public/projects/aeon/.

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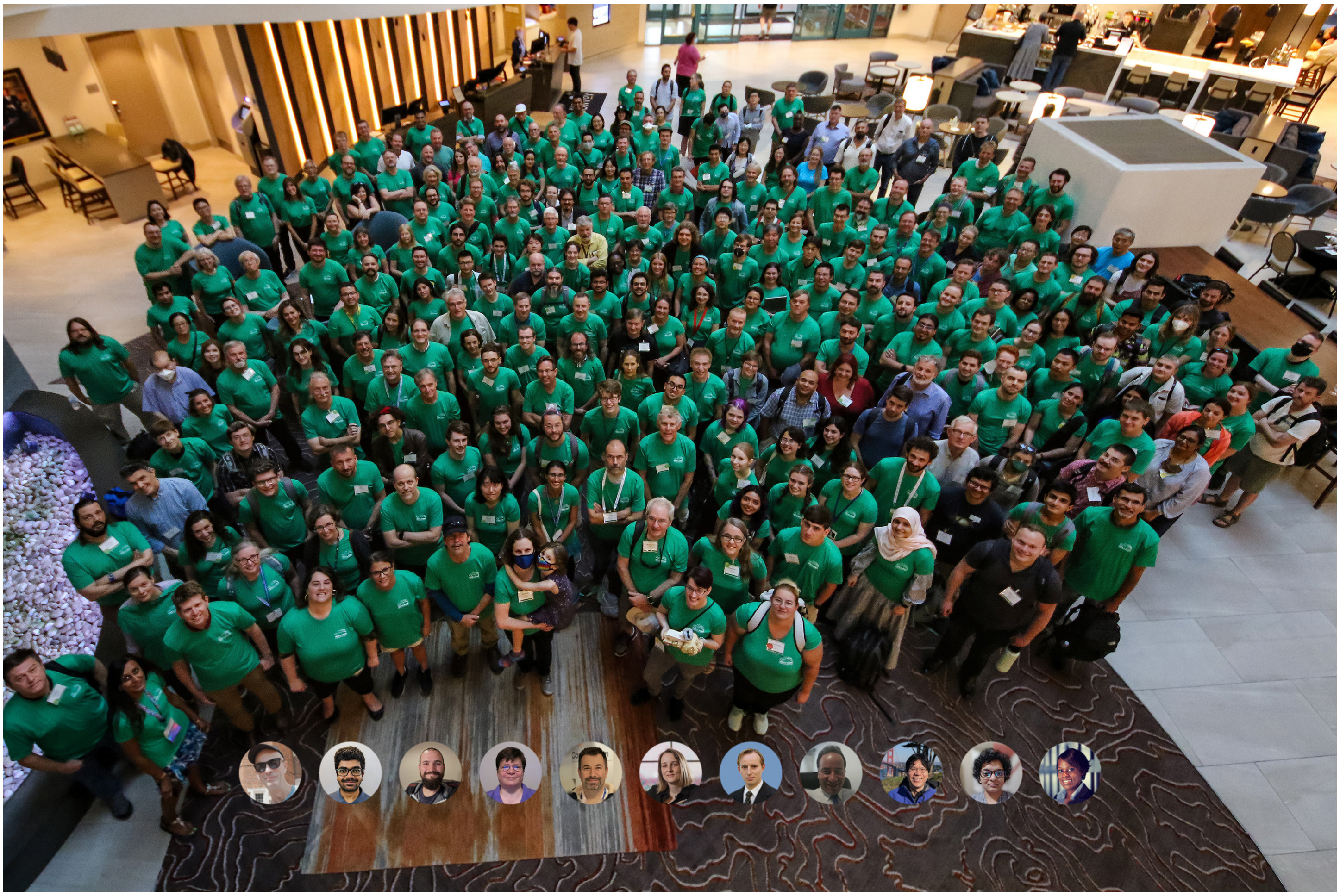

Rubin Project and Community Workshop 2023—Operations Team Takes the Helm

Kristen Metzger

The Rubin Operations team hosted its first Rubin Project and Community Workshop (PCW) in August 2023, after more than 15 years of annual meetings facilitated by the Rubin Construction Project. Construction leadership and many staff members still participated in the meeting, but this year's agenda had a stronger focus on preparations for using Rubin data and other topics of interest to the growing Rubin science community. More than 300 people attended the meeting in person at the University Marriott in Tucson, Arizona, and an additional 160 people registered to participate virtually in plenaries and select breakout sessions.

Rubin 2023 began on Monday, August 7, with a morning meeting of the Science Advisory Committee and a block of afternoon breakout sessions followed by the opening plenary session. The plenary featured opening remarks by Rubin leadership, an update on Construction milestones achieved during the last year, and a presentation on workplace culture initiatives. The session concluded with flash talks from half of the 19 undergraduate students attending the conference supported by the LSST Discovery Alliance (formerly known as the LSST Corporation). The students hosted a poster session in the foyer after the plenary ended.

Bob Blum, Director of Rubin Observatory Operations, began Tuesday morning's plenary session with a presentation on progress made by the Operations team over the last year. He also outlined upcoming plans and scheduled activities leading up to the start of the LSST survey. The rest of the undergraduate student group then gave their flash talks and invited attendees to a second post-plenary poster session. On Tuesday evening, conference participants made the short trip next door to a local restaurant for a reception. In a repeat of events at Rubin 2022, a summer monsoon thunderstorm rolled in to soak the venue before everyone arrived, but this year it was more of a gentle rain than a torrential downpour, and it stopped in time for partygoers to enjoy their food and drinks — and a spectacular rainbow — outdoors.

The Wednesday morning plenary featured short presentations from each of Rubin's eight science collaborations. Then came four "Lightning Stories" from Rubin team members Julio Constanzo, Agnès Ferté, Clare Higgs, and Ryan Lau. The plenary was followed by a poster session, with posters contributed by members of the Rubin science community (these posters were on display through Thursday morning). After more breakout sessions, the day ended with four parallel "Unconference" sessions on topics proposed and voted on by conference attendees.

Thursday morning began with the Keynote Plenary Session, featuring two speakers. First, Aaron Roodman, Deputy Director of Rubin Construction for SLAC, gave a talk on the LSST Camera, describing its unique features and the remaining work to be done before shipping to Chile this fall. Then, Dara Norman, Deputy Director of NSF's NOIRLab's Community Science and Data Center, spoke about Rubin's response to recommendations made in the Astro2020 Decadal Survey report and discussed resources being developed to further promote best practices in research inclusion. Thursday's well-received keynote talks were followed by another busy day of breakout sessions. A final set of concurrent sessions and a "session summary" wrapped up the meeting at midday on Friday.

This year's meeting offered familiar opportunities to share work and ideas with colleagues, but many details of the meeting — from the vibrant downtown venue to the advances in Rubin science preparations — signaled a new direction and growing anticipation. The beginning of Rubin science operations is coming soon! Congratulations to the Operations team's organizing committee for the first in what is sure to be a series of productive annual meetings. Details about the dates and format for next year's meeting will be available soon.

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Figure 1: US-ELTP exhibit at AAS Meeting #242 in Albuquerque, New Mexico, with staff from the three partners. *Credit: NOIRLab/NSF/AURA*

Update on the US Extremely Large Telescope Program

Lucas Macri and the US-ELTP team

The US Extremely Large Telescope Program (US-ELTP) is a joint endeavor of NSF's NOIRLab and the organizations building the Giant Magellan Telescope (GMT) and Thirty Meter Telescope (TMT). It was ranked as the highest ground-based priority by the community in the Astro2020 Decadal Survey report, *Pathways to Discovery in Astronomy and Astrophysics for the 2020s*. The US-ELTP system will provide astronomers in the US with nationally funded access to observing time on both the Giant Magellan Telescope in the southern hemisphere from Chile and the Thirty Meter Telescope in the northern hemisphere.

The US astronomical community will be able to use the US-ELTP system to observe objects anywhere in the sky and carry out transformational research on topics ranging from the search for life outside the Solar System to the nature of dark matter and dark energy. With their complementary designs and a diverse set of instruments, the two next-generation telescopes will offer great synergy with each other as well as other facilities in space and on the ground. The 50% sky overlap between the telescopes will facilitate observations of the most interesting objects in the sky with both observatories. Being situated in substantially different time zones on the globe will allow the two telescopes to observe astronomical phenomena for longer spans of time — which is important for studying rapidly changing objects.

The role of NSF's NOIRLab is to provide the end-to-end system for proposal submission and evaluation; generation of observing programs for adaptive, integrated scheduling; operation of robust automated standard data reduction pipelines; data curation; and support of a data science platform, based on the heritage of its efforts for the Gemini and Rubin Observatories and the Community Science and Data Center.

Our team had a strong presence at the summer AAS in Albuquerque, where our booth was well attended. NOIRLab's Communications, Education, and Engagement Service worked with our US-ELTP partners to develop a traveling exhibit that has already been deployed at the fall meetings of SACNAS, SHPE, and NSBP. We are also proud to celebrate the launch of the new US-ELTP website, which will continue to grow over the next few months. As this article goes to press, we are looking forward to our jointly organized meeting, "ELT Science in Light of JWST" to be held at UCLA on 11–15 December. NOIRLab's US-ELTP Project Scientist (Eric Peng) is a co-chair of the SOC and a member of the LOC, while our Community Engagement Scientist (André-Nicolas Chené) is a member of the LOC. This will be the first in a series of three meetings on the topic, with the next one planned for early June in Japan and the last one to be held in Germany sometime during fall 2024.

Figure 2: NOIRLab's US-ELTP team members conducting a scope workshop in Hilo. From left to right: Eric Peng, François Pradeau, Steven Berukoff, Mike Fitzpatrick, Marie Lemoine-Busserolle, André-Nicolas Chené. *Credit: NOIRLab/NSF/AURA.*

The NSF provided $15.3M in one-year awards to the US-ELTP in late September 2023, to support further design and development of advanced optical technologies and user services. The NOIRLab team recently met with the newly appointed Interim Division Director of the Division of Astronomical Sciences, Dr. R. Chris Smith, and with various Program Officers in the Division to provide updates on our efforts and discuss upcoming milestones. As this article goes to press, the NOIRLab team is working towards a Conceptual Design Review to be held at the end of 2024, while the telescope teams are planning for Final Design Reviews. Around the time the NSF awards were announced, our GMT partners celebrated the casting of their seventh primary mirror segment at the University of Arizona's Richard F. Caris Mirror Lab. Meanwhile, over 90 of the TMT primary mirror roundels have been polished, and their fabrication continues to accelerate with the expansion of facilities dedicated to this effort.

The members of NOIRLab's US-ELTP technical team are holding regular in-person and frequent Zoom workshops to further develop the design of the software and user services that will enable US community access to the ELTs. This critical work includes refining requirements and their traceability, defining processes and systems to support them, and identifying key risks and challenges ahead.

The NOIRLab US-ELTP team recently welcomed François Pradeau, our Software Architect. He is responsible for establishing and improving the scalable and extensible architecture of the US-ELTP user services platform. François has over 25 years of experience in the software and data engineering world, working on a wide range of products for different industries. We bid farewell to Tim Sacco, who started an LSST Discovery Alliance Catalyst Fellowship at the University of Arizona's Department of Sociology. Before departing, Tim helped put together a tiger team of sociologists to review and make suggestions for the next release of the US-ELTP Toolkit of Collaborative Practice.

10.5281/zenodo.10535821

Bringing the Public Back to Our Observatories!

Lars Lindberg Christensen and Leonor Opazo

Nestled atop towering mountain summits, astronomical observatories serve as gateways to the cosmos, allowing scientists to peer into the depths of space and unravel the mysteries of the Universe. While these observatories are typically reserved for cutting-edge research, it's important that their doors are open to the public. Allowing the public to visit large astronomical observatories at mountain summits not only fosters a sense of awe and wonder but also plays a crucial role in education, inspiration, and the promotion of scientific literacy. Arranging visits to a working research facility located at a high-altitude and remote location, however, can be challenging.

Our partner and funding agency, the National Science Foundation (NSF), encourages broad participation and diversity in US research. One goal of NSF is to broaden participation in science and engineering on the part of underrepresented groups, including women, minorities, Indigenous peoples, persons with disabilities, and veterans. Another goal is to encourage broad understanding of the astronomical sciences by a diverse population of scientists, policymakers, educators, and the public. Astronomy is considered to be a gateway science. This presents an opportunity to use its wide appeal to the public to encourage interests in science, technology, engineering, and mathematics (STEM). An important component of NSF's NOIRLab's Broader Impacts program is the public, open, and (mostly) free public visits, catering especially to previously underserved audiences in our locations.

Guided observatory tours help to demystify complex astronomical concepts, making them accessible to people of all ages. Visiting the vast expanse of a mountain summit observatory has a profound impact on individuals. The experience fosters a sense of humility and connection to the cosmos. These moments of awe and wonder can inspire individuals, particularly the younger generation, to pursue careers in STEM. It is an opportunity for people to engage with scientists, ask questions, and gain insights into the latest discoveries. This direct interaction fosters a sense of curiosity and critical thinking, empowering individuals to better understand and appreciate the scientific process.

After the creation of NOIRLab on 1 October 2019, NOIRLab's Communications, Education & Engagement planned to upgrade and streamline the operations of the public visits program. The goals of this program are to attract, facilitate, and implement free visits by 5000 public visitors a year to the summits and base facilities in Hawai‘i and Chile and paid visits by 16,000 public visitors a year to Kitt Peak National Observatory in Arizona. In addition, we host at least 50 media visits a year to all sites combined and assist the site directors in hosting VIP visits. All of this must be done in compliance with safety rules and other regulations.

One of the cornerstones of our community engagement activities is to create an appreciation for the role of NOIRLab in astronomy and to share the sense of belonging to the places where the observatories are located. These important communities include the Tohono O'odham Nation in Arizona, the local and native Hawaiians in Hawai‘i, and the local communities around our observatories in Chile. We want the local communities to feel welcome and to share the magnificent facilities that are used to carry out the science.

Stewardship and Sustainability

Being a good steward of both Earth and the sky is a core principle of NOIRLab. This commitment begins in our local host communities in Arizona, Chile, and Hawai‘i. NOIRLab operates its facilities in an economically, socially, and environmentally sustainable manner. The visits are a unique chance to share information about NOIRLab's Environmental Sustainability Program. Steps towards sustainability include shrinking the carbon footprint of our activities, preserving dark skies, and being attentive to the lands that host our facilities.

A goal for any observatory is to preserve the dark skies in its surrounding areas. The visiting public,

Figure 1: Aerial view of Kitt Peak National Observatory. *Credit: KPNO/NOIRLab/AURA/NSF/P. Marenfeld*

local authorities, and the media can learn about the importance of avoiding light pollution in order to continue the scientific research, which in turn helps support the local economy.

Safety

A strong safety culture at NOIRLab and AURA makes safety our single most important issue, requiring effective communication between the local directors, safety experts, visits team, and local science operations teams. To provide visits at the four summits and three base facilities, NOIRLab-wide procedures and rules were developed and discussed with all stakeholders at the individual observatories; with NOIRLab's safety officers; with stakeholders at our managing agency, AURA; and with the Services at NOIRLab. Manuals for the daytime and nighttime guides were written, and a training program was set up.

Inviting laypeople to mountain summits ranging from 2200 meters to 4300 meters in altitude involves considerable attention to safety, increasing in importance with the elevation. The ascent to the observatory exposes visitors to a reduction in atmospheric pressure, which can result in altitude sickness, typically involving headache, dizziness, and lightheadedness. The sunlight at the observatories can be exceptionally bright, and the temperature significantly lower than at the base and with high winds. And there's usually no fuel or food available in the vicinity.

Figure 2: The first public visitors to Kitt Peak National Observatory after the pandemic and the June 2022 Contreras Fire. *Credit: KPNO/NOIRLab/NSF/AURA*

Public Visits to Observatories

There are two types of public visits at NOIRLab: free visits to NOIRLab's Hawaiʻi and Chile locations and fee-based visits to Kitt Peak National Observatory (KPNO), which contribute to offsetting most of the costs of the Kitt Peak Visitor Center (KPVC), approximately $1 million/year.

Kitt Peak National Observatory, Tucson, Arizona, USA

Two of the highest priorities of the KPNO public visits are to work closely with the Tohono O'odham Nation community in the definition of the educational offerings and to keep the site open to free visits from the Tohono O'odham Nation tribal members, who own the land the observatory is located on.

At Kitt Peak the new Windows Center beginning in late 2024 will provide interactive exhibits and educational programs, and visitors will experience

Figure 3: The Gemini North telescope (middle) on Maunakea at sunset. The ridge is dotted with about a hundred visitors enjoying the almost otherworldly experience on the dormant volcano. *Credit: International Gemini Observatory/NOIRLab/NSF/AURA/J. Chu*

the iconic architecture of the McMath-Pierce Solar Telescope and unique live daytime solar disk viewing, interactive spectroscopy, and nighttime viewing of bright objects.

Private vehicles can be driven all the way to the summit on the scenic AZ State Road 386, which was repaired after the June 2022 Contreras Fire.

A website aimed at visitors provides information and access to booking. Guests can also purchase walk-in tickets if there is availability. The fee-based tickets at KPNO are sold via the established ticket provider Eventbrite, which has a standard credit card payment portal in place that respects all local and national regulations.

Daytime Tours: The KPVC offers three daily 1.5-hour-long daytime tours to the 2.1-meter Telescope, the 4-meter Nicholas U. Mayall Telescope, and the McMath-Pierce Telescope. More than 20 telescope domes can be seen during the tours, and close-up access to one of them is possible. The tours focus on the important contemporary astronomy research being done at Kitt Peak, but some elements from KPNO's impressive history are also touched upon. Important cultural, biological, and geological elements of Kitt Peak's impressive "Sky Island" are shared with the guests.

Nightly Observing Program (NOP): Every evening the 4.5-hour Nightly Observing Program is offered. This involves getting to know the constellations, using binoculars, and observing with one of the KPVC telescopes.

Overnight Telescope Observing Program (OTOP): The Overnight Telescope Observing Program is offered on eight nights a month around the New Moon and gives up to four guests the full observatory experience of using one of the four KPVC telescopes. The guests eat with the astronomers and get to sleep in one of the astronomers' dorms after a long (or short) night of observing.

Hawai'i and Chile Observatories

Visits to the Chile and Hawai'i locations are free. For the free visits, a booking system was developed using a consolidated process with one entry point for booking. The system implements all the rules and procedures agreed with all stakeholders, while still making it as simple to book the tickets as possible.

Gemini North: The most majestic of the free visit locations is arguably the Gemini North telescope on Maunakea (MK). Because of its elevation at 4200 meters (nearly 14,000 feet) above sea level, these visits require some preparation. Only 4-wheel-drive vehicles are allowed on the mountain road leading up to the summit. At the Hale Pohaku 2800-meter (9200 foot) level, a one-hour stop is made to acclimatize visitors to the altitude and provide a safety briefing describing precautions and typical symptoms of altitude sickness.

Visitors are able to see the control room where the astronomers work, the coating chamber to learn more about the engineering that supports astronomy research, and the telescope with the 8.2-meter-diameter mirror and instruments that capture the light from distant galaxies and stars.

Figure 4: View of Cerro Pachón with the SOAR Telescope in the foreground, Gemini South in the middle and the Simonyi Survey Telescope at the Vera C. Rubin Observatory at the back. *Credit: Rubin Observatory/NOIRLab/NSF/AURA/T. Matsopoulos*

Cerro Tololo and Cerro Pachón, Chile: The weekly visits to Cerro Tololo Inter-American Observatory (CTIO) and Cerro Pachón in Chile are the most popular NOIRLab visits. At Cerro Tololo a total of more than 40 smaller or larger telescopes can be seen from either afar or up close. The Tololo tours have taken place for decades and are well known to Chileans and tourists. The Cerro Pachón visit alternates between the Gemini South telescope and the SOAR Telescope. When the construction is finished, the visits will include parts of the Vera C. Rubin Observatory.

In Chile, driving safety rules were recently upgraded, which means that the public can no longer drive their own cars on the gravel roads to the two summits. Instead, outsourced bus transport has been introduced, which has increased visitor safety.

Visits to Base Facilities

The three base facilities in Tucson, Arizona (HQ); La Serena, Chile; and Hilo, Hawaiʻi (HBF), are opened to the

Figure 5: Visitors to Cerro Tololo Inter-American Observatory in Chile. *Credit: CTIO/NOIRLab/NSF/AURA/L. Opazo*

public once or twice a month. Visitors are able to learn how engineers build telescopes and astronomers perform astronomical observations remotely, to talk about astronomy and local cultures, and to ask questions about NOIRLab.

Moving Forward

The pandemic provided an unusual challenge for face-to-face events and visits at NOIRLab. As a result of the July 2022 Contreras Fire at KPNO, the Arizona Department of Transportation had to close the KPNO access road to the public until September 2023.

The first several months of slow ramping-up of the NOIRLab public visits have been a significant success, with lots of excited guests and mostly five-star reviews. For a new consolidated organization like NOIRLab, the combined visits program has provided a chance to work across the organization and involve more than 30 stakeholders in the organization.

Figure 6: The NOIRLab Headquarters base facility in Tucson, Arizona. *Credit: NOIRLab/NSF/AURA/P. Horálek*

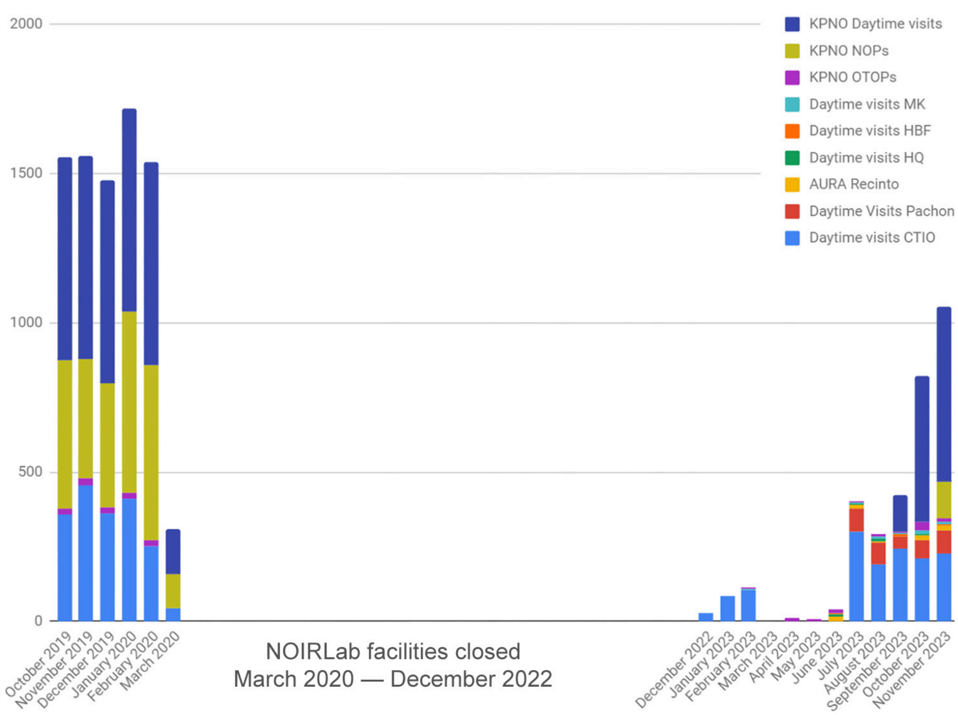

Figure 7: The number of visitors to NOIRLab's facilities before (left), during (middle), and after the COVID-19 pandemic (right). The number of visitors is still picking up, especially at Kitt Peak National Observatory. Not all NOIRLab sites were open to public visitors before the pandemic.

Discovering Our Universe Together

NOIRLab Headquarters
950 North Cherry Avenue
Tucson, AZ 85719 USA

General Inquiries
+1 520 318 8000
noirlab.edu
info@noirlab.edu

Cerro Tololo Inter-American Observatory
Recinto de AURA
Avda. Juan Cisternas 1500
La Serena, Chile

User Support
+56 51 205200
ctio@noirlab.edu

Community Science and Data Center
950 North Cherry Avenue
Tucson, AZ 85719 USA

User Support
+1 520 318 8421
csdc@noirlab.edu

Gemini North Base Facility
670 N. A'ohoku Place
Hilo, Hawai'i, 96720 USA

User Support
+1 808 974 2500
gemini@noirlab.edu

Gemini South Base Facility
Recinto de AURA
Avda. Juan Cisternas 1500
La Serena, Chile

+56 51 2205 600
gemini@noirlab.edu

Kitt Peak National Observatory
950 North Cherry Avenue
Tucson, AZ 85719 USA

User Support
+1 520 318 8135 & 8279
kpno@noirlab.edu

Visitor Center / Public Programs
+1 520 318 8726
www.visitkittpeak.org

Vera C. Rubin Observatory
950 North Cherry Avenue
Tucson, AZ 85719 USA

+1 520 881 2626
lsst.org
contact@lsst.org