NOIRLab Capabilities 2024

AURA

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On the Cover: The Gemini IGRINS-2 red-arm colorized 2D spectrum of NGC 7027, one of the visually brightest planetary nebulae whose complex gas layers make it an interesting first-light target for IGRINS-2. The spectrum measures light from around 2.05 μm to 2.40 μm.

Credit: International Gemini Observatory/NOIRLab/NSF/AURA

Introduction

The services and instruments introduced here are currently offered to the astronomy community by NOIRLab through its Programs. Services offered by the Community Science & Data Center can be freely accessed online. Interested astronomers can request time to use the instruments listed below through the *NOIRLab Call for Proposals*, subject to availability in a given semester.

Time Allocation Committee

NOIRLab Time Allocation Committee (TAC)

Overview

- The NOIRlab TAC allocates time on more than 10 telescopes, both NOIRLab and privately operated.
- Proposals for most telescopes are submitted through the Time Allocation System.
- The submitted proposals are reviewed by panels defined by scientific area.
- Generally, NOIRLab receives about 400 proposals per semester (~50% of them for Gemini time).

Procedures and Policies

- Dual Anonymous Review Process (DARP).
  - Anonymized proposals are reviewed by anonymous panel members.
  - Implemented as a two-stage review process.
- Open Skies
  - US-allocated time on telescope facilities is equally open to everyone regardless of access to private facilities or affiliation.
  - International applicants are required to specify why they need access to US-served facilities.

Available proposal types and observing modes

- Standard (every six months)
  - [A] semester (1 Feb – 31 Jul): Submission deadline is 30 September of the previous year.
  - [B] semester (1 Aug – 31 Jan): Submission deadline is 31 March of the current year.
  - Target of Opportunity option: The exact target cannot be specified in advance; it is possible to interrupt other observations.
  - Long-Term option: Scientifically necessary time allocated for up to three consecutive semesters.
- NOIRLab Survey (annual)
  - Suitable for science programs that require several semesters to complete.
  - Completed datasets must have legacy value.
  - Time awarded for up to six consecutive semesters.
- Queue and Classical observing
  - Support for classical or queue observing depending on the site/telescope.
- Astrophysical Event Observatories Network (AEON).
  - Science may require the use of multiple telescopes, dynamic scheduling, and/or queue (or queue-like) observing.
  - Currently available for SOAR and Gemini, with other telescopes added as public time is available.

COMMUNITY SCIENCE AND DATA CENTER

Data Service & Science Platform Capabilities

ANTARES

- **Facility:** Community Science & Data Center
- **Type:** Real-time alert broker
- **What:**
  - Allows users to receive, process, and filter alerts from surveys.
  - Users can design their own filters that run in ANTARES.
  - Archive all the alerts.
  - Currently ingests public alerts from the Zwicky Transient Facility survey.

Astro Data Archive

- **Facility:** Community Science & Data Center
- **Type:** Data archive facility
- **What:**
  - Data for 40+ telescope and instrument combinations from MSO.
  - Pipeline-reduced data products for DECam, Mosaic, and NEWFIRM wide-field imagers.
  - Graphical and programmatic web user interfaces.
  - **Total holdings**: 18.8 million files; 2.8 Petabytes

Astro Data Lab

- **Facility:** Community Science & Data Center
- **Type:** Archive and data analysis facility
- **What:**
  - Open-access, open-data science platform for big-data astronomy.
  - Enables efficient exploration and analysis of very large datasets.
  - Hosting 220+ TB of photometric catalogs, from surveys conducted on NOIRLab telescopes (e.g. DESI, DES, LS, NSC, etc.), and also co-located copies of many high-value external surveys (e.g. Gaia, WISE, SDSS, LSST SIM, etc.).
  - Home to high-level science products from Gemini LLPs.
  - Access to 3 PB of astronomical image data, including through the Astro Data Archive.
  - Powerful data services and tools, e.g. SQL/ADQL queries, cross-match, image cutout, and massively-multiplexed spectroscopic data retrieval service.
  - Dedicated Jupyter notebook server (on-prem and cloud), with a wealth of example notebooks.
  - Generous remote-user file storage and remote-user DB spaces.
  - Sharing data and analysis workflows with collaborators.
  - User engagement and support..

Astronomical Event Observatory Network (AEON)

- **Facilities:** SOAR Telescope, International Gemini Observatory, and the Las Cumbres Observatory telescope network
- **Type:** Integrated system of telescopes and software tools optimized for follow-up of astronomical transients and time-domain science
- **What:**
  - Observations are requested via the Las Cumbres Observation web portal or through APIs supported by the TOM Toolkit.
  - SOAR offers an AEON automated queue on selected nights, with optical imaging/spectroscopy, and near-IR spectroscopy.
  - AEON welcomes all types of science (not only time domain).

KITT PEAK
NATIONAL OBSERVATORY

Kitt Peak National Observatory Capabilities

Dark Energy Spectroscopic Instrument (DESI)

- **Facility:** Kitt Peak National Observatory, Nicholas U. Mayall 4-meter Telescope
- **Type:** Multi-object survey spectrograph
- **What:**
  - The most efficient spectroscopic survey machine in the world, dedicated to the DESI project.
  - Mapping the expansion history of the Universe and the structure/shape of the Milky Way.
  - Simultaneous fiber spectroscopy of ~5000 targets over a 3-degree-diameter field of view.
  - Wavelength Coverage: 360–980 nm (simultaneous).
  - Spectral Resolution: *R*~2000–5000.
  - Spectroscopic redshifts of >30 million galaxies, ~2.7 million quasars.
  - Spectra of ~8 million stars over a 14,000-square-degree footprint.
  - DESI construction and operations are managed by the Lawrence Berkeley National Laboratory. This research is supported by the US Department of Energy, Office of Science, Office of High-Energy Physics, and by the National Energy Research Scientific Computing Center. Additional support for DESI is provided by the US NSF under contract to NSF's NOIRLab; the Science and Technology Facilities Council of the United Kingdom; the Gordon and Betty Moore Foundation; the Heising-Simons Foundation; the French Alternative Energies and Atomic Energy Commission; the National Council of Science and Technology of Mexico; the Ministry of Science and Innovation of Spain, and by the DESI Member Institutions.

NEID

- **Facility:** Kitt Peak National Observatory, 3.5-meter WIYN Telescope
- **Type:** Extreme-precision RV spectrograph
- **What:**
  - Echelle design with prism cross-disperser.
  - High-precision radial velocities (cm s^{-1}).
  - Wavelength Coverage: 380–930 nm.
  - Spectral Resolution: *R*~110,000 (high-resolution) and *R*~60,000 (high-efficiency).

One Degree Imager (ODI)

- **Facility:** Kitt Peak National Observatory, 3.5-meter WIYN Telescope
- **Type:** Imager
- **What:**
  - Broadband Filters: *u', g', r', i', z'.*
  - Narrowband Filters: *NB422, NB695, NB746, H-alpha.*
  - Pixel Scale: 0.11 arcsec $pixel^{-1}$.
  - FoV: 40 arcmin × 48 arcmin focal plane.

Hydra

- **Facility:** Kitt Peak National Observatory, 3.5-meter WIYN Telescope
- **Type:** Multi-object spectrograph
- **What:**
  - Fiber-fed (90 red, 83 blue).
  - Wavelength Coverage (blue): 300–800 nm.
  - Wavelength Coverage (red): 400–1100 nm.
  - FoV: 60 arcmin diameter.

WIYN High-Resolution Infrared Camera (WHIRC)

- **Facility:** Kitt Peak National Observatory, 3.5-meter WIYN Telescope
- **Type:** High-resolution IR camera
- **What:**
  - Wavelength Coverage: 900–2500 nm.
  - Filters: *J, H, Ks,* and 10 narrowband filters.
  - Pixel Scale: 0.10 arcsec $pixel^{-1}$.
  - FoV: 202 arcsec × 202 arcsec.

NN-Explore Exoplanet Stellar Speckle Imager (NESSI)

- **Facility:** Kitt Peak National Observatory, 3.5-meter WIYN Telescope
- **Type:** Speckle imager
- **What:**
  - Modes: Wide Field (83 arcsec × 83 arcsec) and Speckle (19 arcsec × 19 arcsec).
  - Broadband Filters (SDSS): *u, g, r, i, z.*
  - Narrowband Filters: *467, 562, 716, 832.*
  - Pixel Scale: 0.08 arcsec $pixel^{-1}$ (Wide Field) and 0.02 arcsec $pixel^{-1}$ (Speckle).

CERRO TOLOLO
INTER-AMERICAN OBSERVATORY

Cerro Tololo Inter-American Observatory Capabilities

Dark Energy Camera (DECam)

- **Facility:** Cerro Tololo Inter-American Observatory, Víctor M. Blanco 4-meter Telescope
- **Type:** Wide-field optical imager
- **What:**
  - 62 science CCDs with a total of 520 megapixels.
  - Broadband Filters: *u, g, r, i, z, Y, VR.*
  - Narrowband Filters: *N395, N419, N501, N540, N662, N673, N708, N964, N1008.*
  - Pixel Scale: 0.26 arcsec pixel^{-1}.
  - FoV: 3 square deg.

NEWFIRM

- **Facility:** Cerro Tololo Inter-American Observatory, Víctor M. Blanco 4-meter Telescope
- **Type:** Wide-field near-IR Imager
- **What:**
  - Four 2048 x 2048 arrays arranged in a 2 x 2 mosaic.
  - Broadband Filters: *J, H, Ks.*
  - Narrow band filters: *1.64 μm [FeII], 2.12 μm H2, 2.17 μm Brackett-γ.*
  - Pixel Scale: 0.4 arcsec pixel^{-1}.
  - FoV: 27.6 × 27.6 arcmin.

Goodman

- **Facility:** Cerro Tololo Inter-American Observatory, SOAR Telescope
- **Type:** Imager and high-throughput spectrograph
- **What:**
  - Two cameras available: blue, red (only one can be used on a given night).
  - **Imaging:**
    - SDSS Filters: *u, g, r, i, z.*
    - Bessell Filters: *U, B, V, R, I.*
    - Other filters available (e.g. narrowband).
    - Pixel Scale: 0.15 arcsec pixel^{-1}.
    - FoV: circular, 7.2 arcmin diameter, monolithic detector.
  - **Spectroscopy:**
    - Multi-slit object (MOS) capability with laser-cut slit masks.
    - Wavelength Coverage: 300–900 nm.
    - Spectral Resolution: *R*~800–15,000.
    - FoV (MOS mode): 3 arcmin × 5 arcmin.
    - Long-slit Length: ~3.5 arcmin (from 0.45 arcsec to 5 arcsec wide).

TripleSpec4.1

- **Facility:** Cerro Tololo Inter-American Observatory, SOAR Telescope
- **Type:** Spectrograph
- **What:**
  - Cross-dispersed, single-object, long slit, IR imaging spectroscopy.
  - Wavelength Coverage: 1000–2400 nm, in four orders.
  - Spectral Resolution: *R*~3500.
  - Pixel Scale (imaging mode): 0.27 arcsec pixel^{-1}..

Spartan

- **Facility:** Cerro Tololo Inter-American Observatory, SOAR Telescope
- **Type:** Near-IR camera
- **What:**
  - Broadband Filters: *Y, Z, J, H, K.*
  - Narrowband Filters: *HeI [FeII], HeI/CIV, H2, Brackett-γ, CO.*
  - Several Continuum Filters (see SOAR Filters page).
  - Pixel Scale (f/12): 0.066 arcsec pixel^{-1}.
  - FoV (f/12): 5.04 arcmin × 5.04 arcmin, across four (2 x 2) detectors.

SOAR Adaptive Module (SAM)

Facility: Cerro Tololo Inter-American Observatory, SOAR Telescope

- **Type:** Laser-assisted, Ground Layer Adaptive Optics system + Optical Imager
- **What:**
  - 4k × 4k CCD imager.
  - Broadband Filters: Kron-Cousins (*B, V, R, I*) and SDSS (*g, r, i, z*).
  - Narrowband Filters: *H-alpha, NI, [NII],* and *[SII].*
  - FoV: 3 arcmin × 3 arcmin.

SOAR Integral Field Spectrograph (SIFS)

- **Facility:** Cerro Tololo Inter-American Observatory, SOAR Telescope
- **Type:** Integral Field Spectrograph
- **What:**
  - 0.30 arcsec per fiber.
  - Wavelength Coverage: 425–780 nm.
  - Gratings: 700 l mm^{-1} and 1500 l mm^{-1}.
  - Spectral Resolution: *R*~4200–9500.
  - FoV: 15 arcsec × 7.8 arcsec.

International Gemini Observatory Capabilities

NORTH

Gemini Near-InfraRed Spectrograph (GNIRS)

- **Facility:** Gemini North
- **Type:** Near-infrared (0.8–5.4 μm) long-slit, cross-dispersed and integral field spectroscopy
- **What:**
  - Spectral Resolution (long-slit mode): *R*~1200–18,000.
  - **Cross-dispersed spectroscopy**
    - Wavelength Coverage: 0.8–2.5 μm.
    - Spectral Resolution: *R*~1700.
    - Partial coverage at R~5900.
  - **Integral field unit**
    - Low-resolution IFU (ALTAIR-compatible): 4.80 arcsec × 3.15 arcsec FoV, R~1700/7200.
    - High-resolution IFU (ALTAIR-optimized): 1.25 arcsec × 1.80 arcsec FoV, R~5000/18000 (expected to complete commissioning in 2024).
  - 'Keyhole' imaging mode with a 0.1–0.35 arcmin^2 field of view (varies with filter/camera choice).

ALTitude conjugate Adaptive optics for the InfraRed (ALTAIR)

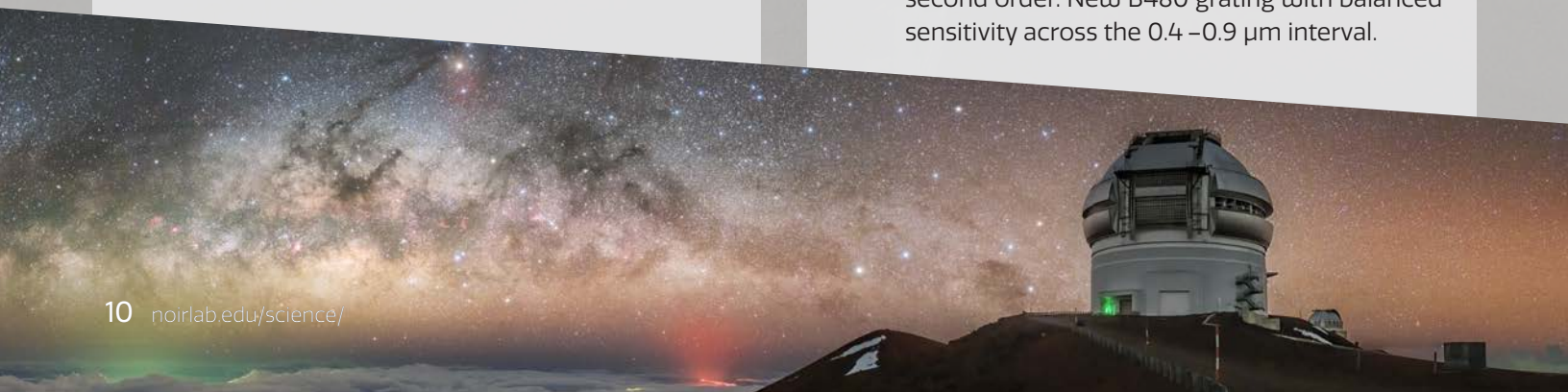
- **Facility:** Gemini North
- **Type:** Adaptive optics system
- **What:**
  - Used in conjunction with GNIRS.
  - Natural Guide Star mode: FWHM ~0.07 arcsec with Strehl ratios up to 40%.
  - Laser Guide Star mode: FWHM ~0.08 arcsec with Strehl ratios up to 20%.
  - 'Super Seeing' mode: Nearly full sky coverage yields FWHM ~0.3 arcsec.

Immersion GRating INfrared Spectrograph 2 (IGRINS-2)

- **Facility:** Gemini North
- **Type:** Near-infrared (1.49–2.46 μm) long-slit and cross-dispersed spectroscopy
- **What:**
  - *H* & *K* simultaneous observations.
  - Compact design with no moving parts, fixed spectral format.
  - Wavelength Coverage: 1.49–1.80 μm (*H*-band), 1.96–2.46 μm (*K*-band).
  - Spectral Resolution: *R*~40,000.
  - Based on IGRINS visiting instrument at Gemini South.
- To be offered to the community in late 2024 after finishing on-sky testing and system verification.

Gemini Multi-Object Spectrograph, North and South (GMOS-N & GMOS-S)

- **Facility:** Gemini North and Gemini South
- **Type:** Spectrograph
- **What:**
  - Broad- (*u'*, *g'*, *r'*, *i'* and *z'* Sloan) and narrow-band optical imaging.
    - FoV: 5.5 arcmin × 5.5 arcmin.
  - Long-slit, multi-object and integral field spectroscopy 0.36 –1.03 μm.
  - Integral field spectroscopy.
    - FoV: 5 arcsec × 7 arcsec or 5 arcsec × 3.5 arcsec.
  - Nod and Shuffle spectroscopic mode (all modes, including IFU for GMOS-S).
  - Spectral Resolution: R~150–8700 in 1st order, up to R~12,000 with some gratings in the second order. New B480 grating with balanced sensitivity across the 0.4 –0.9 μm interval.



SOUTH

Gemini Multi-Conjugate Adaptive Optics System (GeMS)

- **Facility:** Gemini North
- **Type:** Multi-Conjugate Adaptive Optics System
- **What:**
  - Multi-conjugate adaptive optics system uses two deformable mirrors, five laser guide stars, and three natural guide stars.
  - Strehl ratios up to 30% in *K* band.
  - Spectral Resolution: up to FWHM ~0.06 arcsec.
  - FoV: 85 arcsec × 85 arcsec.
- Currently used with GSAOI; other instruments (FLAMINGOS-2 and GMOS-S) under development.

Gemini High-Resolution Optical Spectrograph (GHOST)

- **Facility:** Gemini South
- **Type:** Fiber-fed, echelle optical spectrograph
- **What:**
  - Two-target simultaneous spectroscopy.
    - FoV: 7.5 arcmin field.
    - Spectral Resolution: *R*~50,000.
  - Single-target spectroscopy
    - Spectral Resolution: *R*~75,000.
  - Simultaneous Wavelength Coverage: 0.36–0.95 µm.
  - PRV accuracy down to ~10 m s^{-1} within 0.43–0.75 µm.
- First full semester 2024A.

FLAMINGOS-2

- **Facility:** Gemini South
- **Type:** Near-infrared imager and multi-object spectrograph
- **What:**
  - Near-infrared imager.
    - Filters: *J_low, J, H, Ks, K_blue, K_red.*
  - Wavelength Coverage (spectroscopy): 0.9–2.4 µm.
  - Spectral Resolution: *R*~300–4500.
  - FoV: 6.1 arcmin diameter.
  - Multi-object spectroscopy.
    - FoV: 2 arcmin × 6 arcmin.
    - Maximum of 72 or 153 slits depending on sky-subtraction strategy.

Gemini South Adaptive Optics Imager (GSAOI)

- **Facility:** Gemini South
- **Type:** Near-infrared imager
- **What:**
  - Used with GeMS
  - 6 broadband and 16 narrowband filters.
  - Wavelength Coverage: 0.9–2.5 µm.
  - Filters: *Z, J, H, Ks, K', K, CH_4 (short and long), He I, HeI (2p2s), Paschen-γ, Paschen-β, Brackett-γ, [FEII], H_2O, H_2 1-0 S(1) & 2-1 S(1), CO Δv=2, J, H, K* short & long continuum.
    - Near diffraction-limited imaging in the *K* band.
  - FoV: 85 arcsec × 85 arcsec, sampling 20 milliarcsec.

Learn more about Gemini's observing modes at:
https://www.gemini.edu/observing/start-here

Visiting instruments

Immersion GRating INfrared Spectrometer (IGRINS)

- **Facility:** Gemini South
- **Type:** Visiting instrument: Near-infrared spectrograph
- **What:**
  - *H* & *K* simultaneous observations.
  - Compact design with no moving parts, fixed spectral format.
  - Wavelength Coverage: 1.45–2.45 μm (continuous).
  - Spectral Resolution: *R*~45,000.
- Offered only until April or early May 2024

'Alopeke & Zorro

- **Facility:** Gemini North and South
- **Type:** Visiting instrument: Speckle Imager
- **What:**
  - Dual-band optical-wavelength instruments for speckle or fast natural-seeing imaging at both sites.
  - Speckle mode:
    - Provides diffraction-limited (~0.02 arcsec at 650 nm) imaging of targets a s faint as *V*~18.
    - FoV: 2.5 arcsec.
  - Natural-seeing mode:
    - Exposure Time: as short as ~0.01 second.
    - FoV: ~35 arcsec.

MAROON-X

- **Facility:** Gemini South
- **Type:** Visiting instrument: high-resolution optical spectrograph
- **What:**
  - Optimized for precise radial velocity measurements.
  - Wavelength Coverage: 0.5–0.92 μm (continuous).
  - Spectral Resolution: *R*~82,000–88,000.
  - Radial Velocity Precision: ~10 cm s^{-1}.

Gemini Planet Imager-2 (GPI-2)

Note: **GPI is the Gemini Planet Imager** for extreme AO with coronagraphic integral-field spectroscopy and polarimetry. It provides diffraction-limited NIR images over a 2.8 arcsec × 2.8 arcsec FoV with contrast of ~ 10^{-5} at 0.4 arcsec radius. It is in the process of being upgraded and is scheduled to commission at Gemini North in 2024.

Gemini Science Flexibility

In addition to standard observing modes (classical, queue, Director's Discretionary Time), Gemini offers proposal modes that enable science programs requiring both more rapid and longer execution timescales.

Gemini Fast Turnaround Programs

Around ten percent of the time on each telescope is allocated via the innovative Fast Turnaround program, which accepts new proposals every month from participating partners. Proposals are reviewed by other proposers during that round. PIs are notified of the outcome within three weeks, and accepted programs are observed within one to four months. Graduate students may review proposals with a PhD PI or Co-I designated as a 'mentor', giving them valuable early insight into science peer review.

https://www.gemini.edu/observing/phase-i/ft

Gemini Large and Long Programs

Large and Long Programs (LLPs) occupy up to 20% of Gemini observing time of the participating partners (United States and Canada). LLPs require significantly more time than is typically approved for a single program, or extend over multiple semesters, or both. The annual announcement of opportunity is issued late each year, with Letters of Intent due in early February and a proposal deadline in early April. Observations begin in the subsequent B semester.

https://www.gemini.edu/observing/phase-i/llp

Gemini Priority Visitor Observing Mode

Priority Visitor (PV) observing mode allows PIs (or team members) to visit Gemini for a period during which they observe their program if the conditions are as good as (or better than) required, and other approved queue programs if not. Any unobserved portions of the PI's program can then be executed within the regular queue. PV mode is the default for Band 1 LLPs and may also be requested by other PIs.

https://www.gemini.edu/observing/phase-i/pv

Gemini Targets of Opportunity (ToOs)

Gemini provides ToO modes for the time domain, and for follow-up of ongoing surveys. For the most urgent time-domain targets, Gemini interrupts the ongoing queue to execute observations triggered either manually by the PI or programmatically via an application programming interface (API). The shortest reaction times to a ToO yield a timescale of three to five minutes for starting the requested imaging or spectroscopy. The DRAGONS real-time, quick-look pipeline will reduce imaging and GMOS long-slit spectroscopy data and upload them to the International Gemini Observatory Archive upon completion of the observations.

https://www.gemini.edu/observing/phase-i/too

Gemini Remote Eavesdropping

Remote eavesdropping allows a PI to remotely monitor data-taking on their program, while observations are carried out by the Gemini night staff. PIs sign up for particular dates in advance, and, depending on the circumstances, we may call the PI if and when we're about to start observations.

https://www.gemini.edu/observing/phase-i/eavesdropping

Gemini Welcomes Visiting Instruments

Visiting Instruments expand the capabilities we offer to all users. Outstanding results have been produced by instruments such as GRACES, 'Alopeke, Zorro, MAROON-X and IGRINS. If you have an instrument you would like to bring to Gemini, contact us at

gemini-vip@gemini.edu


Summary
THE SCIENTIFIC OPPORTUNITIES

Discovering Our Universe Together

NSF's NOIRLab is the US national center for ground-based, nighttime optical and infrared astronomy. The Association of Universities for Research in Astronomy, Inc. (AURA) operates these facilities and NSF's NOIRLab under a cooperative agreement with the National Science Foundation (NSF).

Through its five programs — Cerro Tololo Inter-American Observatory (CTIO), the Community Science and Data Center (CSDC), the International Gemini Observatory, Kitt Peak National Observatory (KPNO) and Vera C. Rubin Observatory once operational — NOIRLab serves as a focal point for community development of innovative scientific programs, the exchange of ideas, and creative development. NOIRLab's infrastructure enables the astronomy community to advance humanity's understanding of the Universe by exploring significant areas of astrophysics, including dark energy and dark matter, galaxies and quasars, the Milky Way, exoplanets, and small bodies in our own Solar System.

The astronomical community is honored to have the opportunity to conduct astronomical research on Iolkam Du'ag (Kitt Peak) in Arizona, on Maunakea in Hawai'i, and on Cerro Tololo and Cerro Pachón in Chile. We recognize and acknowledge the very significant cultural role and reverence that these sites have to the Tohono O'odham Nation, to the Native Hawaiian community, and to the local communities in Chile, respectively.

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