# NOIRLab Capabilities 2023

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**On the Cover:** Colorized 2D spectra of the star Gliese 486 as seen with MAROON-X. The two spectra are from the two camera arms of MAROON-X. Each spectrum covers the 500–670 nm wavelength range and the color-coding corresponds to how a human eye would perceive the colors.

**Credit:**
International Gemini Observatory/NOIRLab/NSF/AURA/A. Seifahrt
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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.
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 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:** 18,137,382 files; 2.7 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 ≥45+ TB of photometric catalogs, from surveys conducted on NOIRLab telescopes (e.g. 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, massively-multiplexed spectroscopic data retrieval service.
  - Dedicated Jupyter notebook server (compute close to the data), 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 and is a good choice for programs requiring small amounts of time or sky coverage).
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:**
  - 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.
  - **Wavelength Coverage:** 360–980 nm (simultaneous).
  - **Spectral Resolution:** $R \sim 2000–5000$.
  - **FoV:** 3 deg diameter.
  - Spectroscopic redshifts of >30 million galaxies, ~2.7 million quasars.
  - Spectra of ~8 million stars over a 14,000 square-degree footprint.
  - DESI is supported by: the US Department of Energy’s Office of High Energy Physics; the US National Science Foundation Division of Astronomical Sciences under contract to NSF’s NOIRLab; the Science and Technologies Facilities Council of the United Kingdom; the Gordon and Betty Moore Foundation; the Heising-Simons Foundation; the French Alternative Energies and Atomic Energy Commission (CEA); the National Council of Science and Technology of Mexico; the Ministry of Economy of Spain; and DESI member institutions. It was built and is operated by the DESI Collaboration.
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$^{-1}$).
  - Spectral Resolution: $R\sim110,000$ (high-resolution) and $R\sim60,000$ (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:**
  - 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).

Half-Degree Imager (HDI)
- **Facility:** Kitt Peak National Observatory, WIYN 0.9-meter WIYN Telescope
- **Type:** Imager
- **What:**
  - Strömgren Filters: $u$, $v$, $b$, $y$.
  - Narrowband Filters: H-beta and calcium.
  - FoV: 29 arcmin.
Cerro Tololo Inter–American Observatory Capabilities

**Dark Energy Camera (DECam)**
- **Facility:** Cerro Tololo Inter–American Observatory, Victor 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.
  - Pixel Scale: 0.26 arcsec pixel$^{-1}$.
  - FoV: 3 square deg.

**NEWFIRM (coming soon)**
- **Facility:** Cerro Tololo Inter–American Observatory, Victor M. Blanco 4–meter Telescope
- **Type:** Wide-field Near-IR Imager
- **What:**
  - 2x2 mosaic of 2048$^2$ InSb detectors.
  - Wavelength 1–2.4 microns.
  - Broadband Filters: J, H, Ks.
  - Narrowband filters: TBA following instrument commissioning.
  - Pixel scale 0.4 arcsec pixel$^{-1}$.
  - FoV: 28 × 28 arcmin.

**Tek2K**
- **Facility:** Cerro Tololo Inter–American Observatory, SMARTS 0.9–meter Telescope
- **Type:** Optical imager
- **What:**
  - Broadband Filters: B, V, R, I.
  - Pixel Scale: 0.401 arcsec pixel$^{-1}$.
  - FoV: 13.6 arcmin × 13.6 arcmin.

**Goodman High–Throughput Spectrograph**
- **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~1800–15,000.
    - FoV (MOS mode): 3 arcmin × 5 arcmin.
    - Long-slit Length: ~3.5 arcmin (from 0.45 arcsec to 5 arcsec wide).

**CHIRON**
- **Facility:** Cerro Tololo Inter–American Observatory, SMARTS 1.5–meter Telescope
- **Type:** High-resolution spectrograph
- **What:**
  - Fiber-fed Cross–dispersed Echelle Spectrograph.
  - Modes: Fiber Mode and Slicer Mode.
  - Spectral Resolution: R~27,000 (fiber mode) or R~80,000 (slicer mode).
SOAR Optical Imager (SOI)
- **Facility:** Cerro Tololo Inter-American Observatory, SOAR Telescope
- **Type:** Optical imager
- **What:**
  - Narrowband Filters: [O III], [S II], H-alpha (see SOAR Filters page).
  - Pixel Scale: 0.077 arcsec pixel$^{-1}$.
  - FoV: 5.2 arcmin × 5.2 arcmin (two 2048 × 4096-pixel CCDs, with a 102-pixel gap).
  - SOI is currently out of service.

SOAR Adaptive Module (SAMI) + Imager
- **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.

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.
  - 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, Brgamma, 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.

SOAR Integral Field Spectrograph (SIFS)
- **Facility:** Cerro Tololo Inter-American Observatory, SOAR Telescope
- **Type:** Integral Field Spectrograph
- **What:**
  - 0.30 arcsec per fiber.
  - 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

**Gemini Near–InfraRed Spectrograph (GNIRS)**
- **Facility:** Gemini North
- **Type:** Near-infrared (0.8–5.4 µm) long-slit and cross-dispersed spectroscopy
- **What:**
  - Spectral Resolution (long-slit mode): $R \sim 1200$–18,000 in long-slit mode.
  - Cross-dispersed spectroscopy
    - Wavelength Coverage: 0.8–2.5 µm.
    - Spectral Resolution: $R \sim 1700$.
    - Partial coverage at higher resolution.
  - Integral field unit (replacing NIFS capabilities in late 2023)
    - FoV (natural seeing): 5 arcsec $\times$ 3 arcsec ($R \sim 1700/6000$).
    - FoV (with ALTAIR): 1 arcsec $\times$ 1.5 arcsec ($R \sim 5000/18000$, anticipated early 2023, to replace NIFS IFU).

**Near–Infrared Imager (NIRI)**
- **Facility:** Gemini North
- **Type:** Near-infrared imager
- **What:**
  - Three cameras giving different FoV and pixel scales.
  - FoV: 22 arcsec $\times$ 22 arcsec, 51 arcsec $\times$ 51 arcsec, or 120 arcsec $\times$ 120 arcsec.
  - Wavelength Coverage: 1–5 µm.
  - Spectral Resolution (with ALTAIR): $R \sim 0.08$ arcsec at 2.2 µm.
  - 8 broad-band and 21 narrow-band filters.

**Near–Infrared Integral Field Spectrograph (NIFS)**
- **Facility:** Gemini North
- **Type:** Near-infrared integral field spectrograph and coronographic imager
- **What:**
  - Spatially-resolved spectroscopy on 0.15-arcsec scales with Altair adaptive optics system.
  - Wavelength Coverage: 0.95–2.4 µm.
  - Spectral Resolution: $R \sim 5000$–6000.
  - FoV: 3 arcsec $\times$ 3 arcsec.
- Final planned full semester at Gemini-N: 2023A.

**ALTitude conjugate Adaptive optics for the InfraRed (ALTAIR)**
- **Facility:** Gemini North
- **Type:** Adaptive optics system
- **What:**
  - Used in conjunction with GNIRS, NIFS, or NIRI.
  - Natural Guide Star mode: FWHM $\sim 0.07$ arcsec with Strehl ratios up to 40%.
  - Laser Guide Star mode: FWHM $\sim 0.08$ arcsec with Strehl ratios up to 20%.
  - Super Seeing mode: Nearly full sky coverage yields FWHM $\sim 0.3$ arcsec.

Learn more about Gemini’s observing modes at: https://www.gemini.edu/observing/start-here
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:** $R \sim 150–8700$ in 1st order, up to $R \sim 12,000$ with some gratings in the second order. New B480 grating available in 2023 with balanced sensitivity across the 0.4 –0.9 µm interval.

Gemini South Adaptive Optics Imager (GSAOI)

- **Facility:** Gemini South
- **Type:** Near-infrared imager
- **What:**
  - Used with Gemini Multi-Conjugate Adaptive Optics System
  - 6 broadband and 16 narrowband filters.
  - **Wavelength Coverage:** 0.9 –2.5 µm.
  - **Filters:** Z, J, H, Ks, K', K, CH₄ (short and long), He I, He I (2p2s), Paschen–γ, Paschen–β, Brackett–γ, [FeII], H₂O, H, 1–0 S(1) & 2–1 S(1), CO Δυ=2, J, H, K short & long – continuum.
  - Near diffraction-limited imaging in the $K$ band.
  - **FoV:** 85 arcsec × 85 arcsec, sampling 20 milliarcsec.

Gemini Multi-Conjugate Adaptive Optics System (GeMS)

- **Facility:** Gemini South
- **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.

FLAMINGOS-2

- **Facility:** Gemini South
- **Type:** Near-infrared imager and multi-object spectrograph
- **What:**
  - Near-infrared imager.
  - **Filters:** $J_{low}$, J, H, Ks, $K_\text{blue}$, $K_\text{red}$.
  - **Wavelength Coverage (spectroscopy):** 0.9–2.4 µm.
  - **Spectral Resolution:** $R \sim 300–4500$.
  - **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 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:** $R \sim 50,000$.
  - Single-target spectroscopy
    - **Spectral Resolution:** $R \sim 75,000$.
    - **Simultaneous Wavelength Coverage:** 0.36–0.95 µm.
    - PRV accuracy down to ~10 m s$^{-1}$ within 0.43–0.75 µm.
  - To be offered for community science in 2023.
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:** $R \sim 45,000$.

**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:** $R \sim 82,000–88,000$.
  - **Radial Velocity Precision:** $\sim 10$ cm s$^{-1}$.

**‘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 as faint as $V \sim 18$.
    - **FoV:** 2.5 arcsec.
  - Natural-seeing mode:
    - **Exposure Time:** as short as ~0.01 second.
    - **FoV:** ~35 arcsec.

**Gemini Remote Access to CFHT ESPaDOnS Spectrograph (GRACES)**
- **Facility:** Gemini South
- **Type:** Visiting instrument: high-resolution optical spectrograph
- **What:**
  - 270-m optical fibers feeding a spectrograph at the CFHT Telescope.
  - **Wavelength Coverage:** 0.4–1.0 µm (continuous).
  - **Spectral Resolution:** $R \sim 40,000–60,000$.
  - Final planned full semester at Gemini-N: 2023A.

**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 $\times 2.8$ arcsec FoV with contrast of $\sim 10^{-5}$ 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 within three weeks of the outcome, 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 period of rapid growth in astronomy and astrophysics has been characterized by numerous discoveries based on astronomical data (dark energy, dark matter), the discovery of exoplanets, cosmology, and the growth of the scientific community. The fields of astronomy and astrophysics have grown exponentially in the last decade, and the scientific opportunities are vast. The need for a comprehensive, well-coordinated program of research is more critical than ever. This report provides an overview of the current landscape of international astrophysical research, the major opportunities and challenges, and the priorities for future research.

The report begins with a discussion of the current state of international astrophysics, including the status of observational programs, theoretical models, and data analysis techniques. It then moves on to discuss the major opportunities and challenges facing the field, including the need for new observatories, improved data analysis tools, and increased international collaboration.

The report concludes with a discussion of the major priorities for future research, including the need for new observational programs, the development of new data analysis techniques, and the need for increased international collaboration. It also discusses the need for increased funding for astrophysical research, both at the national and international levels.

The report is intended to provide a comprehensive overview of the current state of international astrophysics, the major opportunities and challenges facing the field, and the priorities for future research. It is intended to serve as a valuable resource for policymakers, researchers, and the public.
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. The lab’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.