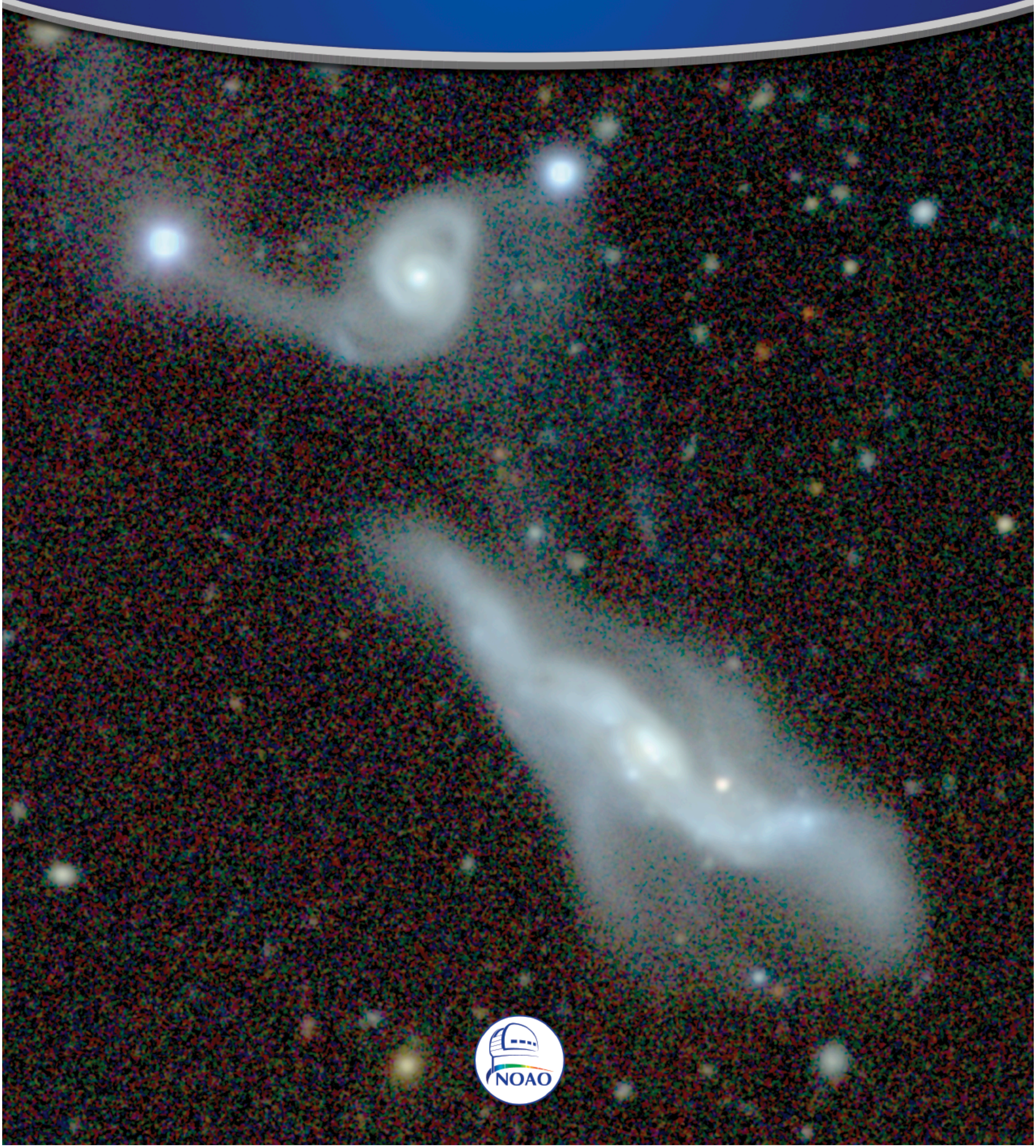
NOAO NEWSLETTER

Issue 112, September 2015



On the Cover

An image from the Dark Energy Camera Legacy Survey (DECaLS), a public survey mapping 6700 square degrees, approximately one-sixth of the sky, using the Blanco 4-m telescope at the Cerro Tololo Inter-American Observatory. The image shows the interacting galaxy system UGC 12589 at a distance of 470 million light-years. The distorted morphologies and diffuse light result from the gravitational interaction between the galaxies. (Image credit: John Moustakas and Kevin Napier/Siena College.)

NOAO Newsletter

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editor@noao.edu

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NOAO Director's Corner

David Silva

The purpose of NOAO is to "serve as the US national center for ground-based OIR astronomy; to coordinate/integrate/operate observational, technical, and data-oriented capabilities available throughout the US OIR system of federal and non-federal assets." So states the new Cooperative Agreement between the National Science Foundation (NSF) and the Association for Universities for Research in Astronomy (AURA) for the management of NOAO in the period FY16–FY20, with possible extension to FY25. That document further summarizes the NOAO mission as "to enable discovery in ground-based optical and infrared (OIR) astronomy." What has NOAO been doing lately to fulfill its purpose and mission?

After two years of operations, Dark Energy Camera (DECam) is already producing an exciting harvest of scientific results as well as creating rich data sets for future scientific exploration and exploitation. In this Newsletter, you can find articles about the discovery of 9 new ultra-faint (UDF) galaxy candidates in the Local Group (with 8 more candidates announced as this issue goes to press, for a total of 17) as well as about how the NEOWISE team is using DECam for NEO follow-up. In terms of public data sets, all Dark Energy Survey (DES) Year 1 raw and processed images are available from the NOAO Science Archive, as well as the Year 2 raw images (the processed images will follow later this year). Initial public data products (including catalogs) from the NOAO Survey program "DECam Legacy Survey (DECaLS)" are also available (see the DECaLS article for details). Meanwhile, the DES Collaboration has been steadily publishing early results, including a demonstration that the Blanco/DECam delivered image quality is good enough over long-enough periods of time to construct high-quality, wide-field weak lensing maps and thereby dark matter distribution maps.

Within the next three years, the NOAO Science Archive will contain processed images and derived object catalogs for approximately 15,000 square degrees and maybe as much as 20,000 square degrees. These images will have better image quality, and the catalogs will be up to 2 magnitudes deeper in *grz* than existing imaging surveys such as SDSS and PS-1. Many spectra already exist in these areas, thanks in large part to the various SDSS spectroscopic surveys, but the Dark Energy Spectroscopic Instrument (DESI) will produce tens of millions more to fainter magnitudes. In order to maximize the community's ability to exploit the scientific potential of these new rich data sets and relevant legacy data sets, NOAO has initiated the Data Lab project, which you can read more about in this Newsletter.

Meanwhile, new optical and near-IR spectrographs (COSMOS, *www.noao.edu/nstc/kosmos/*, and TS4-ARCoIRIS, *www.ctio.noao.edu/noao/content/Arcoiris*) have been released at the Blanco 4-m, completing our modernization of its instrumentation suite. Improvements to the SOAR Goodman optical spectrograph nicely complement the new Blanco capabilities. In the North, NOAO provided significant technical and financial support for upgrading the WIYN 3.5-m telescope ODI wide-field imager to a 40 x 48 arcmin field-of-view with 0.11 arcsec pixels. In other WIYN-related news, NASA has asked for detailed instrument design studies from two teams for the Extreme Precision Doppler Spectrometer (EPDS). Funded by NASA, NOAO will work closely with these teams, especially in the areas of telescope and facility preparation and interfaces development. At the KPNO 2.1-m, we are excited to be working with a Caltech / U. of Hawai'i / Inter-University Centre for Astronomy and Astrophysics (IUCAA; Pune, India) collaboration that will install a robotic adaptive optics imager (Robo-AO) on that telescope. While most of the KPNO 2.1-m time will be used by the Robo-AO team, approximately 60 nights per year will be available to the community through the NOAO TAC. Finally, the DESI project continues to stay on track for installation in 2018 and operations start in 2019.

In the midst of instrumentation and public data services developments, NOAO continues to provide services and leadership in the arena of community coordination and organization. In the last six months, the NOAO scientists have helped organize and execute major community meetings about the science-driven futures of Gemini and TMT, as well as workshops on DECam community science and tools for astronomical big data. NOAO scientists are also involved in various activities related to enabling LSST research by the community-at-large. Collectively, we are deeply engaged in US OIR System development through participation on governance boards and/or science advisory committees for many forefront OIR facilities and projects, including Gemini, the Giant Magellan Telescope, LSST, the Thirty Meter Telescope, SOAR, WIYN, and the Zwicky Transient Factory. Looking forward, the recent National Research Council (NRC) OIR Optimization Study group report (chair: D. Elmegreen, Vassar) recognized past efforts by NOAO to develop and coordinate the US OIR System and recommended that NOAO pursue a broad range of new activities in that arena. We welcome these recommendations and look forward to working with the NSF and the community to bring them to fruition as resources permit.

New instrumentation, new public data sets, new data services, new community coordination activities—all for the benefit of the research community-at-large. NOAO is well positioned for many years into the future to fulfill its core, NSF-defined mission to enable experimentation and discovery by all.

DECam Legacy Survey Announces First Data Release

Two images from the Dark Energy Camera Legacy Survey (DECaLS), a public survey mapping 6700 square degrees, approximately one-sixth of the sky, using the Blanco 4-m telescope at the Cerro Tololo Inter-American Observatory. The left panel shows the interacting galaxy system UGC 12589 at a distance of 470 million light-years. The distorted morphologies and diffuse light result from the gravitational interaction between the galaxies. The right panel shows the barred spiral galaxy UGC 11782 at a distance of 56 million light-years. These color images were constructed by Dr. John Moustakas and Mr. Kevin Napier of Siena College from the *g*-, *r*- and *z*-band DECaLS data.

The DECam Legacy Survey (DECaLS) is delivering a new publicly available data set that will allow astronomers to probe the structure of the Milky Way, the nature of dark energy, and many other topics in astrophysics. The survey leads, David Schlegel (Lawrence Berkeley National Laboratory) and Arjun Dey (NOAO), announced the first data release from the survey earlier this year (*http://legacysurvey.org/dr1/description/).*

Designed to be significantly deeper (g=24.7, r=23.9, z=23.0 AB) and to have better image quality than the earlier Sloan Digital Sky Survey (SDSS) or Pan-STARRS surveys, DECaLS covers 6700 square degrees of extragalactic sky (-20 < d < +30 degrees) using the Dark Energy Camera (DECam) on the Blanco 4-m telescope. The imaging survey overlaps the SDSS/BOSS extragalactic footprint. As a result, DECaLS imaging complements the spectroscopic trove of 2.5 million extragalactic objects from the SDSS, SDSS-II, SDSS-III/BOSS, and SDSS-IV/eBOSS surveys.

This combination of imaging and spectroscopy will allow the survey team to study the Milky Way halo and its satellite galaxies as well as the dark and baryonic matter distributions in galaxy halos. Beyond these immediate goals, DECaLS imaging will also provide valuable input into target selection for the future Dark Energy Spectroscopic Instrument (DESI) survey, which aims to provide spectra of additional tens of millions of galaxies and QSOs.

The survey team has challenged itself to release reduced data and catalogs within months of taking the data in order to maximize the science impact of the survey. The DECam data included in the first data release (DR1) were obtained primarily from August 2014 to January 2015. DR1, made in June 2015, covers a disjoint 3100-square-degree footprint of the survey area (in at least one filter) and describes the properties of approximately 140 million unique sources. Stacked image bricks and catalogs are available at the survey website (*http://legacysurvey.org/dr1*). Calibrated single-epoch images are available through the NOAO Survey Archive. Future data releases are anticipated at six-month intervals.

Images from DR1 can be perused using the DECaLS Sky Viewer (*http://legacysurvey.org/viewer*), which displays images from DECaLS and NASA's Wide-field Infrared Survey Explore (WISE). Built by Dustin Lang (Carnegie Mellon University), Sky Viewer uses Leaflet, an open-source Javascript library for interactive maps (*http://leafletjs.com*).

Catalogs are constructed using a forward modeling approach, in which objects are detected and represented by simple parametric models and fit to individual images. This process (the Tractor*)* was developed by Dustin Lang and David Hogg (NYU) to generate catalogs from multipass, multiband imaging data (*http://thetractor.org*). The Tractor avoids resampling and interpolating data when combining multiple frames and bands, while also preserving the noise properties of the data. In addition, data with widely differing bands and spatial resolution can be combined. The Tractor has been used previously to compare SDSS and WISE imaging data, (Lang et al. 2014, *http://arxiv.org/abs/1410.7397,* arXiv:1410.7397). Catalogs report fluxes and source morphology (point source, exponen-

continued

DECam Legacy Survey Announces First Data Release continued

tial disk, de Vaucouleurs profile, or a composite) for DECaLS data as well as publicly available DES data within the DECaLS footprint (primarily in the region of Stripe 82) and forced photometry for all DECaLS sources from WISE images. Matched catalogs for SDSS photometry and spectroscopy are also included in the data release. Subsequent data releases will include forced photometry (i.e., photometry assuming a source shape and position) for multiple epochs.

Software used to produce the data products is publicly available at *http://legacysurvey.org/dr1/description/*. The open-data, open-software policy was adopted by the survey to encourage creative reuse of the survey products.

The survey team welcomes feedback regarding problems or anomalies discovered in the data and data products. Contact the team via their DECaLS Google Group (*https://groups.google.com/forum/#!forum/decam-legacy-survey*).

References:
Lang, D. et al., 2014, arXiv:1410.7397

New Horizons Gets a Sharp Look at Pluto

Tod R. Lauer (NOAO)

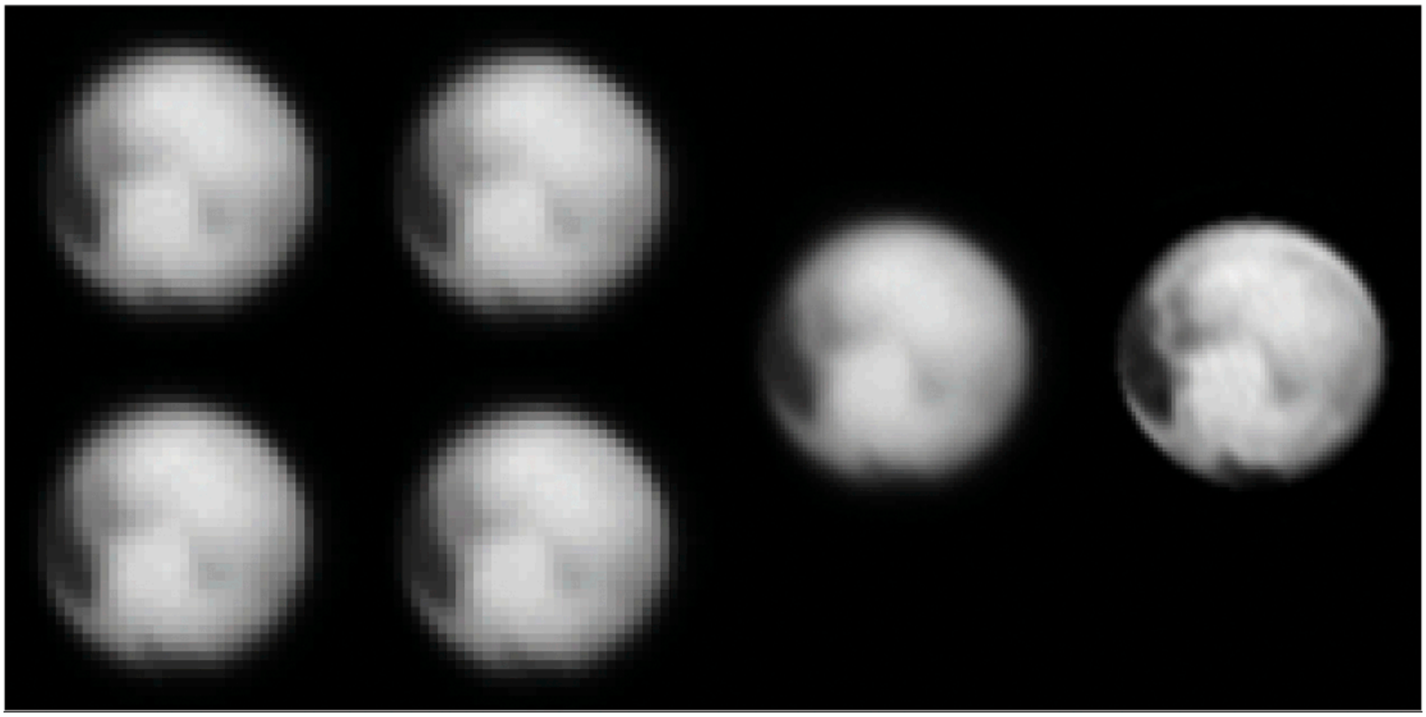

Figure 1. Four "raw" images (left) obtained by the *New Horizons* LORRI camera on July 2 are combined with the Fourier algorithm of Lauer (1999) to make a Nyquist-sampled "super image" with 2x subsampling (middle). The super-image is then deconvolved with Lucy-Richardson deconvolution. The Pluto hemisphere shown is that imaged at the time of closest approach 12 days later on July 14. (Image credit: NASA/JHUAPL/SwRI.)

On July 14 the *New Horizons* probe blazed past Pluto, revealing it to us in vivid detail. *New Horizons* is a NASA mission launched in 2006 to provide the first close look at Pluto and its environment. It is operated by the John Hopkins University Applied Physics Laboratory (APL) in collaboration with the Southwest Research Institute (PI: Alan Stern, SwRI). It has been my privilege to work with the team of *New Horizons* scientists and engineers to help get the sharpest details out of images of Pluto and its moon Charon obtained with the *New Horizons* LORRI (Long-Range Reconnaissance Imager) camera. LORRI is a 20.8 cm reflector feeding a 1024 × 1024 CCD, imaging in white light. During the approach to Pluto the *New Horizons* team used LORRI to look ahead for objects posing physical hazards to the spacecraft, as well as to obtain the first detailed images of Pluto and Charon. At the time of closest approach, LORRI provided the highest-resolution details on Pluto and Charon and, in conjunction with other *New Horizons* cameras and spectroscopic instruments, helped map the composition of the surfaces of both bodies. Image processing algorithms for recovering information from under-sampled images and correcting for the blurring of the point spread function (PSF) with deconvolution were central to the effort and draw on experience with recovering high-resolution details from *Hubble Space Telescope* images. This is a brief description of

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New Horizons *Gets a Sharp Look at Pluto continued*

how we used these techniques to get sharp images of Pluto in support of the *New Horizons* mission.

The LORRI pixel-scale is 1.02 arcsec, which slightly under-samples the core of the LORRI PSF, which also has broad and asymmetric wings that induce significant blurring and loss of contrast in the images. Under-sampling causes aliasing, which misrepresents the fine-scale structure in the images, but this can be corrected for in a data set of "dithered" images in which the camera is shifted at the sub-pixel level to reveal how the images change with sampling phase. Dithering is a standard procedure for the *Hubble Space Telescope,* but *New Horizons* does not have the fine pointing-control to do this directly. Fortunately, many LORRI imaging sequences obtained several nominally identical images in rapid succession, with dithering occurring as the spacecraft drifted slightly under attitude control of its hydrazine thrusters. These dithers do not fall in a regular pattern, but with the Fourier reconstruction technique of Lauer (1999), the images could be combined without any loss of information to create a well-sampled "super-image" with 2× subsampling.

as a function of position over the LORRI field. The deconvolution itself was done with the Lucy (1974) – Richardson (1972) algorithm, but using an ad hoc "prior" image (modeling Pluto and Charon as uniform disks) to help suppress edge effects at the bright limbs of the objects. Lucy-Richardson deconvolution of well-sampled images is highly photometrically reliable, and the output can be used directly in quantitative analysis. Figure 1 shows the *New Horizons* image of Pluto produced on July 2 after decovolution; LORRI images of Pluto and Charon were obtained on a roughly daily cadence starting from the end of May, continuing until the rapid data-taking sequences on the day of the encounter itself.

The best images of Pluto were obtained, of course, at closest approach, and at this writing, most of the images have yet to be downloaded from the spacecraft, a process that will continue into next year. Several hours before closest approach, however, LORRI obtained a fantastic full-disk image of Pluto (Figure 2), which was returned in a highly compressed form. Just as deconvolution assisted in clarifying the distant encounter images, it remained useful for even the highest-resolution images.

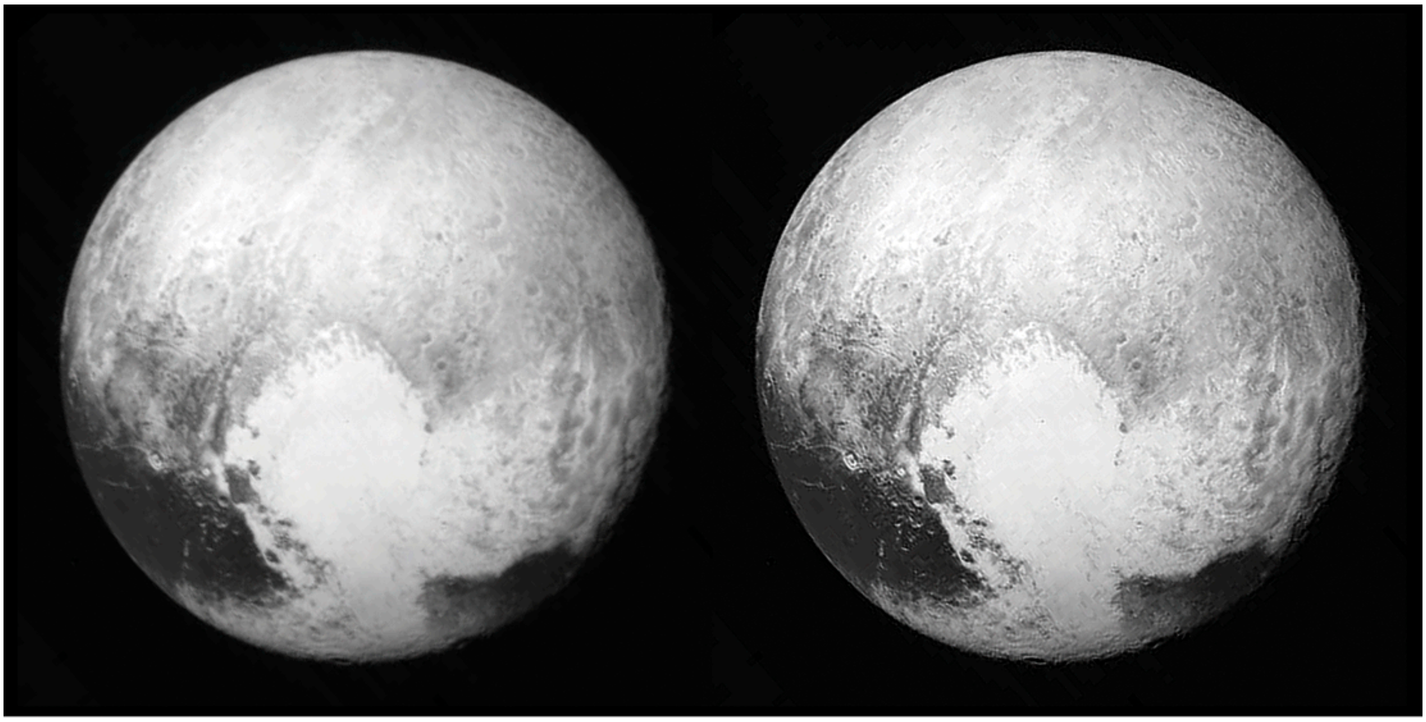


Figure 2. The New Horizons LORRI full-disk image of Pluto taken on July 13, shortly before the closest approach to Pluto on July 14. The raw compressed image downlinked (left) is compared to the deconvolved image (also corrected for JPEG block artifacts). (Image credit: NASA/JHUAPL/SwRI.)

The super-image provides a useful way to represent all the information in a complete imaging sequence, but it can be improved further by correcting for the PSF by standard deconvolution methods. Deconvolution requires accurate knowledge of the PSF, but fortunately the *New Horizons* team obtained rich observations of open-cluster star-fields during their long cruise to Pluto, allowing sub-sampled PSFs to be constructed

Figure 2 shows the last full-disk LORRI image of Pluto returned before closest approach. A Fourier-filter developed to partially mitigate the compression artifacts was applied and the result deconvolved. The complex and rich view of Pluto is fantastic. The *New Horizons* team and I look forward to working with the rich image set as it is transmitted back in the months ahead.

Milky Way Satellite Galaxies Discovered in First-Year Dark Energy Survey Data

Keith Bechtol (University of Chicago)

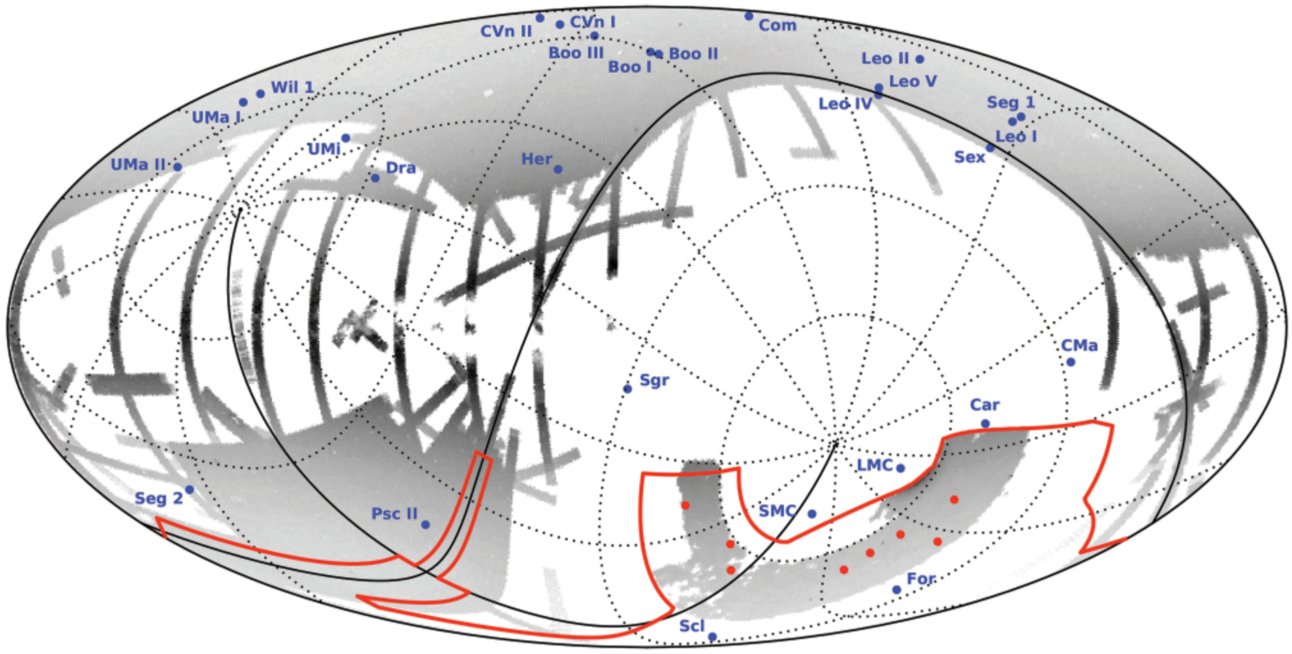


Figure 1: All-sky map of Milky Way satellite galaxies known prior to 2015 (blue) and new satellite galaxy candidates reported by Bechtol and collaborators (red) in Galactic coordinates. The grayscale represents the stellar density mapped by SDSS and DES. The DES footprint (red outline) opens discovery space in the Southern Hemisphere near the Magellanic Clouds. (Image credit: DES Collaboration.)

Milky Way satellite galaxies include the lowest-luminosity, least chemically evolved, and most dark matter–dominated galaxies in the known universe. These extreme objects have reshaped our definition of a "galaxy" and provide a unique opportunity to study the low-luminosity threshold of galaxy formation and test the Cold Dark Matter paradigm at the smallest scales. Whereas numerical simulations predict thousands of dark matter subhalos orbiting the Milky Way, the much smaller number of luminous detected satellites may imply a subtle connection between the baryonic and dark matter components of galaxies. Still, our current census of the Milky Way environs is almost certainly incomplete.

The Dark Energy Camera (DECam) is an ideal wide-field imager with which to search for such rare ultra-faint galaxies, as illustrated by the flurry of results that emerged earlier this year. Alex Drlica-Wagner (Fermilab) and I, along with our Dark Energy Survey (DES) collaborators, reported the discovery with DECam of eight new companions to the Milky Way. Examining the publicly released DES data, Sergey Koposov (Cambridge) and collaborators independently uncovered the same galaxies and one additional system. One of these systems was also discovered independently by Dongwon Kim (Australian National University) and collaborators in data from the Stromlo Milky Way Satellite Survey. Several additional satellite galaxy candidates were announced within weeks of these reports, increasing the total number of known Milky Way satellite galaxies by as much as a dozen—nearly 50%—in the span of a month. Eleven of the twelve discoveries involved data from DECam.

The DES data are particularly well-suited to the search for ultra-faint galaxies, because of the depth ($r \sim 24$ mag), sky coverage (5000 square degrees), and footprint of the survey in the less explored South Galactic Cap (Figure 1). Ultra-faint satellite galaxies are identified as arcminute-scale statistical overdensities of individually resolved stars. The least luminous and most distant of the new satellites have only tens of stars detected in the DES images. The DES team employed an array of search strategies—visual inspection of coadd images, peak-finding in binned maps of the stellar density field, and a maximum-likelihood matched-filter algorithm—to identify and characterize candidates. After excluding false positives (e.g., from imaging artifacts and misclassified galaxies), there remained several faint stellar overdensities unassociated with previously known objects. The low surface brightnesses and large galactocentric distances of the DES systems are more compatible with known satellite galaxies in the Local Group than with globular clusters (Figure 2).

There are several notable features of the DES galaxy candidates. The congregation of satellites near the Magellanic Clouds suggests that some may be associated with the Magellanic system. The most distant of the new objects, Eridanus II, is located just beyond the virial radius of the Milky Way, which typically separates the outer gas-rich dwarf irregulars from inner gas-poor dwarf spheroidals. If Eridanus II has experienced recent star formation, it would be the lowest-luminosity star-forming galaxy known, and this may have implications for the minimum halo mass required to sustain star formation over billion-year timescales. The

continued

Milky Way Satellite Galaxies Discovered continued

nearest of the new satellites, Reticulum II, has now been dynamically and chemically confirmed as a dark matter–dominated galaxy through spectroscopic follow-up analyses by Josh Simon (Carnegie Observatories) and collaborators and Matthew Walker (Carnegie Mellon University) and collaborators.

Milky Way satellite galaxies are also excellent laboratories in which to probe the particle nature of dark matter. In regions of high dark matter density, including dwarf galaxies, dark matter particles may annihilate into energetic Standard Model particles at rates that would be detectable by gamma-ray telescopes. Searches targeting confirmed dwarf galaxies from the Sloan Digital Sky Survey (SDSS) era already constrain weakly interacting massive particles (WIMPs) to have masses greater than roughly 100 GeV if they annihilate at the canonical thermal relic cross section. The DES Collaboration teamed up with the Fermi Large Area Telescope Collaboration to search for excess gamma-ray emission in the directions of the new galaxy candidates from DES. Alex Geringer-Sameth (Carnegie Mellon University) and Dan Hooper (Fermilab/University of Chicago) led two teams performing similar analyses. Although an intriguing hint of a gamma-ray excess was observed toward Reticulum II, no statistically significant signal was found from the new DES satellites as a whole.

The second season of DES observations, completed in February 2015, increases the survey coverage from ~1800 to over 4000 square degrees, and it is anticipated to yield additional Milky Way satellite discoveries.

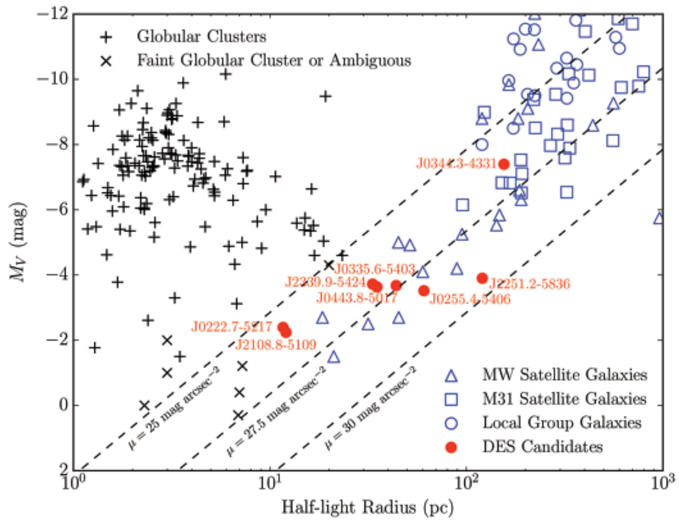


Figure 2: Local Group satellite galaxies are generally larger and have lower surface brightness than Milky Way globular clusters. Most of the new systems found in the DES Y1 data have structural parameters similar to known ultra-faint satellite galaxies. Follow-up spectroscopic observations are needed to definitively classify the new systems. (Image credit: DES Collaboration.)

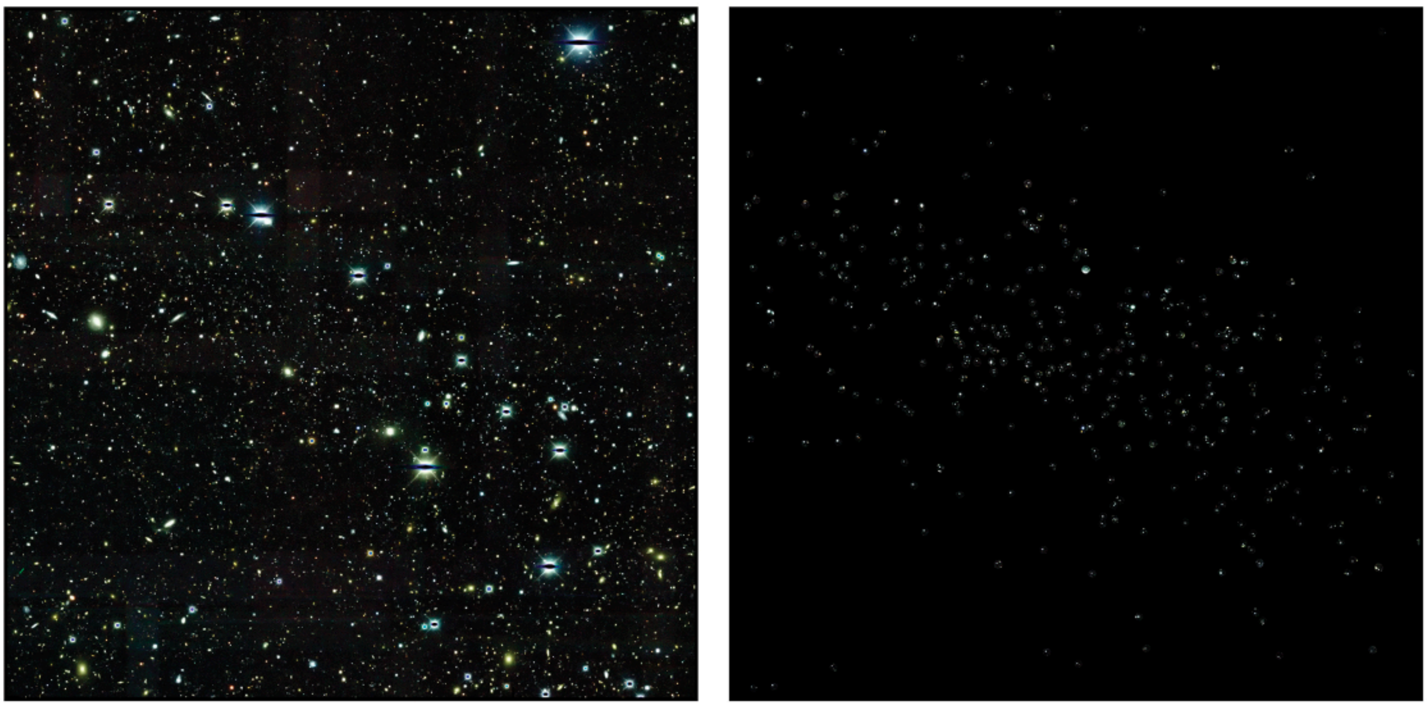


Figure 3: These two images show the most conspicuous new dwarf galaxy found in the first year of Dark Energy Survey data. The first image is a false-color coadd image of the 0.3 deg x 0.3 deg region centered on Reticulum II. The second image shows the detectable stars that likely belong to this object, with all other visible matter blacked out. Reticulum II sits roughly 100,000 light-years from Earth and contains very few stars — only about 300 could be detected in the DES data. Dwarf satellite galaxies are so faint that it takes an extremely sensitive instrument like the Dark Energy Camera to find them. (Image credit: Fermilab/Dark Energy Survey.)

As this issue went to press, the DES Collaboration announced the discovery of eight new ultra-faint (UDF) dwarf candidates. For more details, see arXiv:1508.03622, *http://arxiv.org/abs/1508.03622.*

Science Highlights

Measuring Orbits and Sizes of NEOWISE Near-Earth Asteroids with DECam

Sarah Sonnett (Jet Propulsion Laboratory)

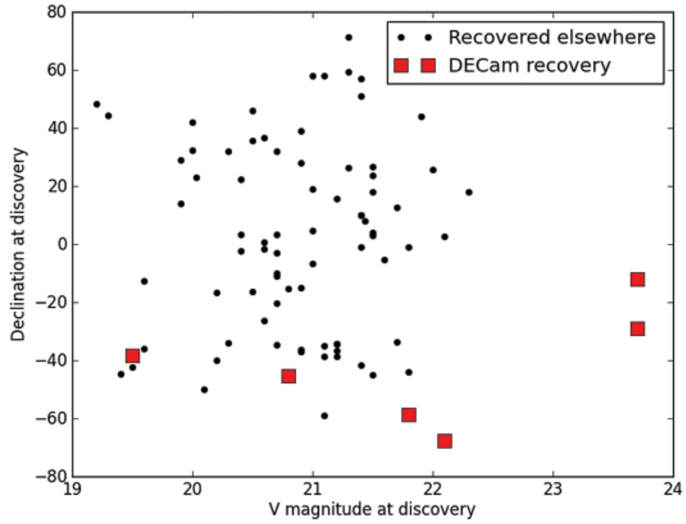
Near-Earth Objects (NEOs) are asteroids or comets that pass within 1.3 AU of the Sun. Because of their close proximity to Earth, telescopes can image very small NEOs and probe a size regime that is inaccessible in other asteroid populations. However, this same closeness makes NEOs a potential threat. Determining the orbit and size of NEOs is essential in evaluating the likelihood that any given NEO will impact the Earth or explode close to the Earth's surface, as in the 14 February 2013 event in Chelyabinsk, Russia.

Determining the size and orbital distribution of NEOs is key to understanding their history, which further provides clues to their supply rate from other small body reservoirs (e.g., the main asteroid belt) and how they will dynamically evolve. Surface properties also offer important insights into NEO behavior and provide valuable constraints on the dynamical and physical evolution of small bodies. Some NEOs are good candidates for robotic or manned space missions. The precise determination of the surface/physical properties of NEOs is critical to assessing the feasibility and engineering needs for a rendezvous, but only a few NEOs are sufficiently studied in this respect.

The first step toward these goals is to discover NEOs and determine their basic properties. This is the mission of NEOWISE, the asteroid-hunting component of NASA's Wide-field Infrared Survey Explorer (WISE), which set out in December 2013 on its approximately three-year mission to discover and characterize NEOs (Mainzer et al. 2014). NEOWISE is currently detecting approximately one new NEO per week but has no internal follow-up capability.

Without timely follow-up, astrometric uncertainties associated with the original images will grow within a few weeks to tens or hundreds of degrees, and the discoveries will be lost, their orbits unknown. Follow-up optical observations, when paired with NEOWISE infrared magnitudes and thermal modeling, are also needed to measure the albedos (or surface reflectivity) of NEOs. We therefore initiated a small target-of-opportunity follow-up program on the Blanco 4-m telescope with the DECam instrument.

Because many of our discoveries are best observed in the Southern Hemisphere, are very faint (V ~ 22.5), and have typically large position uncertainties (1–2° on the sky), DECam, with its large field of view (2° diameter) has played a critical role in characterizing our NEO discoveries. Since February 2014, DECam has recovered six of our NEO discoveries on the brink of being lost. Time-critical observations of asteroids such as the Apollo-class asteroid 2014 BE63 have shown that while the object will cross the Earth's orbit, its closest approach to Earth will be a safe 0.13 AU away.



Declination and V-band magnitude of all NEOWISE discoveries since July 2014 for objects that were recovered by DECam (red squares) and objects that were recovered on other telescopes (black dots). Since the discoveries are made in the infrared, the V-band magnitudes are estimates based on average surface properties of NEOs. The plot shows that DECam can reach V magnitudes of ~23.5, highlighting its ability to recover very faint objects.

The DECam observations have also identified NEOs with unusual orbital properties. One of these, 2014 PP69, has an eccentricity of approximately 0.9 and orbital inclination of about 93°. With an average heliocentric distance beyond the main asteroid belt, it is 1 of only 18 known members of the Amor IV dynamical group and 1 of only 3 NEOs with orbital inclination greater than 90°.

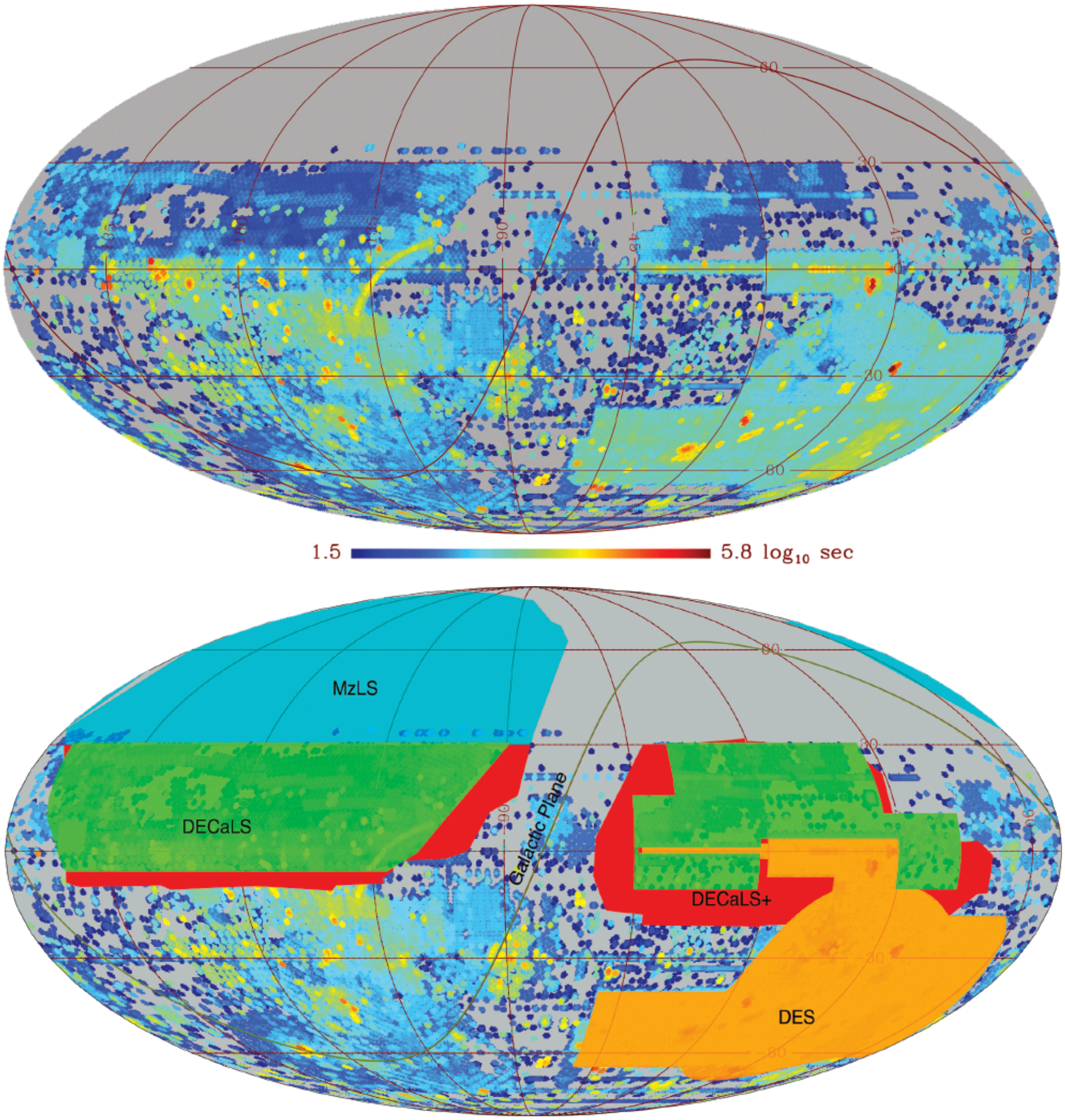
NEOWISE has also uncovered the first (and so far only) Earth Trojan, a NEO that librates around Earth's L4 Lagrange point. Trojans are geometrically difficult to detect, but they have important implications for the dynamical evolution of the inner solar system because precise dynamical conditions are needed to scatter an asteroid into such an orbit (Connors et al. 2011). Other NEOWISE discoveries include large, dark, potentially hazardous asteroids (PHAs) that are difficult for current ground-based surveys to detect. The wide range of NEO albedos primarily results from differing surface compositions and irradiation effects. More such discoveries are expected from the DECam observations.

References:

Connors, M., et al. 2011, Nature, 475, 481
Mainzer, A., et al. 2014, ApJ, 792, 30

An Introduction to the NOAO Data Lab

Mike Fitzpatrick, Knut Olsen & Betty Stobie



Top: A map showing the total exposure time for DECam science images (>30s exposure times) stored in the NOAO Science Archive as of June 2015. The gridlines indicate equatorial coordinates, while the S-shaped line shows the location of the Galactic plane. Bottom: The outlines of the Dark Energy Survey and three of the DESI targeting surveys (DECaLS, DECaLS+, and the proposed MzLS) are overlaid on the current exposure map. These imaging surveys will be available through NOAO within the next few years.

NOAO has been a leader in providing the community with wide-field instruments on its telescopes for the past two decades. The Dark Energy Camera (DECam) and Dark Energy Survey (DES) currently provide the community with a cutting-edge wide-field camera, imaging data processing system, and data products. These are expected to be joined by the massively multiplexed Dark Energy Spectroscopic Instrument (DESI) in the next few years. With such capabilities it is easy to predict that NOAO-based surveys will continue to grow in size and complexity and that more of the community will want to exploit them in their research.

continued

An Introduction to the NOAO Data Lab continued

To illustrate this trend, the image on page 9 shows a map of the DECam science observations currently stored in the NOAO Science Archive (NSA), along with the predicted coverage of the completed DES and three of the DESI imaging targeting surveys (DECaLS, DECaLS+, and the proposed MzLS). The map shows that after just two years of operation, DECam has already touched most of the southern sky through a combination of DES and community-led observations. The resulting image set totals 270TB of 32-bit floating-point data. With continued DECam observations and the completion of the DESI targeting surveys in the near future, the NSA will contain a nearly all-sky imaging survey and approach 1PB of science imaging data. These massive surveys are also producing very large catalogs, which are crucial to making scientific use of the data. The DES catalog database is expected to total 45TB, with up to tens of TB more for the catalogs from community-led programs.

We are developing the NOAO Data Lab to help the community take advantage of these and future large surveys and to prepare them for the era of LSST. The Data Lab will allow users to

1. access, search, and filter databases containing large catalogs;
2. create custom databases and analyses from large catalogs using familiar tools;
3. combine catalog databases with data from NOAO telescopes, analysis results, and data from external archives in one place;
4. share custom results easily with collaborators and create and publish catalogs derived from large data sets through a central workspace;
5. experiment with tools being developed for LSST using existing large data sets.

The goal of the Data Lab is to provide a common framework and workspace for science collaborations and individuals to use and disseminate data from large surveys, using the best available tools. It is intended to grow into a clearinghouse for knowledge on best practices for handling specific large data sets and for sharing software developed in the community to work on these data sets in an Open Source manner.

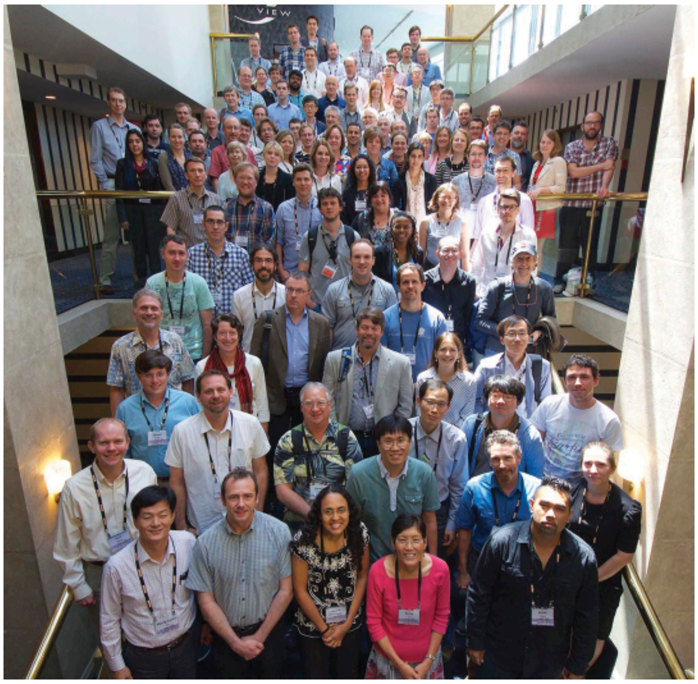
The Data Lab successfully completed a Conceptual Design Review (CoDR) in March 2015 and is now in development, with the goal of having a first public demonstration in 2016 and a first public release in 2017. Tools and services will be released to interested test users throughout the development cycle as they are finished. In particular, data services for several NOAO Survey Program will become available in the coming months, as will a core set of tools to access and operate on these data.

For additional information and updates, see the project website at *http://datalab.noao.edu/*.

The Future and Science of Gemini Observatory 2015 (FSG15)

Ken Hinkle & Letizia Stanghellini

Every three years the Gemini Observatory sponsors a gathering of Gemini users and stakeholders in one of the partner countries. The 2015 meeting was held June 15–18 in Toronto. The US National Gemini Office (NGO) is based at NOAO. Letizia Stanghellini, the head of the US NGO, was on the Scientific Organizing Committee for the FSG15 meeting, and both Letizia and Ken Hinkle attended to represent the US. The program was approximately 75% science highlights, including some invited talks, with the rest of the meeting organized around perspectives and discussions on the future of the observatory.



FSG15 meeting group photo. (Image Credit: Stephane Courteau/Queen's University and Gemini Observatory.)

Gemini Director Markus Kissler-Patig gave two presentations discussing the hurdles faced by Gemini over the next 5 to 10 years. Markus noted the multinational, multipartner nature of Gemini, the complex governance of the observatory, and the divergent goals of the partners. In particular, he noted that the current 65% US share of Gemini is far different from Gemini being a US telescope. His focus was largely on the 2018 assessment point leading to the renewal of the partnership in 2021. The program also included presentations by the directors of Subaru, Keck, and LSST. They focused on plans for the next decade. These observatories have much-narrower missions than Gemini, and they provided sharp contrast.

A theme of the meeting was making Gemini competitive in the era of JWST and LSST. Of particular interest to the US community were presentations by the four teams developing concepts for Gemini

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The Future of Science of Gemini Observatory 2015 continued

Instrument Feasibility Studies (GIFS). While differing in design, all four instruments are driven by the need to investigate transient objects that will be discovered by JWST, LSST, and LIGO. All four teams pointed out that Gemini's locations in Chile and Hawaii combined with Target of Opportunity (ToO) scheduling and a flexible instrument complement are great advantages for carrying out this work. Possible instrument suites constrained by the Gemini four instrument plus adaptive optics (AO) model were topics of discussion.

Many of the presentations can be found in pdf format on the website *http://www.gemini.edu/fsg15/program*. NL

The 2015 TMT Science Forum

Mark Dickinson

The theme of the third annual Thirty Meter Telescope (TMT) Science Forum, held on 23–25 June 2015 in Washington, DC, was "Maximizing Transformative Science with TMT." That admittedly ungainly and buzzwordy title captures two important foci of the meeting. First, there is the "transformative science" that will be enabled by a telescope whose collecting area will be an order of magnitude larger than that of today's largest optical/infrared telescopes and whose diffraction-limited angular resolution will be nearly five times sharper than that of the James Webb Space Telescope at similar wavelengths. Second, this year's Forum considered how to "maximize" the scientific return from TMT through innovative international collaborations, observatory operations, data management, and instrumentation. One hundred thirty-nine participants gathered at the headquarters of the American Association for the Advancement of Science (AAAS), and at the Mayflower Renaissance Hotel, to review the status of the project, to discuss TMT science, to plan future TMT observing programs, and to consider ways to run the observatory that will yield the best and most science.

Two days of plenary sessions alternated between invited science talks and discussion sessions. The science talks used current forefront research as a springboard to the future potential of TMT for achieving new breakthroughs. Topics spanned a huge range, including small body solar system science (Karen Meech, IfA), exoplanet atmospheres (Jayne Birkby, CfA), star and planet formation (Gregory Herczeg, KIAA-PKU), stellar chemical abundances (Wako Aoki, NAOJ), nearby galaxies and near-field cosmology (Alan McConnachie, NRC-HIA), supermassive black hole demographics (Jenny Greene, Princeton), early galaxy evolution (Shelley Wright, UCSD), and the intergalactic medium (R. Srianand, IUCAA).

The discussion sessions were among the liveliest parts of the meeting. Most addressed topics related to observatory operations. Each featured two short presentations by experts from operating observatories, who highlighted past experiences and potential lessons for TMT, followed by audience discussion. Topics included time allocation and the balance of small and large science programs, observatory operations and scheduling modes, and data management and archives. Another session focused on education, public outreach, and workforce development. There were also presentations on the status of the TMT project and on planning for the next generation of TMT instrumentation. Doug Simons (CFHT) gave an inspiring presentation about astronomy, Mauna Kea, and Hawaii, which was timely and relevant given the complex challenges faced by TMT as it starts construction, including protests by some members of the Hawaiian community.

The middle day of the meeting featured parallel sessions organized by the TMT International Science Development Teams (ISDTs) on topics ranging from the solar system to cosmology. In addition to invited and

Participants at the 2015 TMT Science Forum, held at the AAAS Headquarters in Washington, DC, listen to Wako Aoki (NAOJ) discuss the exploration of galaxy evolution through the fossil history of stellar chemical abundances. (Image credit: Tony Travouillon/ TMT.)

contributed talks, the participants held extensive discussions about possible "key project" science programs for TMT. One lesson from past experience is that a balance of smaller and larger science programs can be important for the scientific health and productivity of an observatory. The TMT partnership has been discussing ways to enable and encourage large science projects that might span its international community, and the ISDTs have been asked to develop ideas for such projects in order to explore their scientific potential and to consider their implications for TMT operations, data management, and future instrumentation. Participants in the parallel sessions brainstormed on key project concepts, and the ISDT organizers summarized these discussions to the full conference audience on the last day of the meeting.

A few messages can be drawn from the plenary discussion sessions and the ISDT working sessions. Unsurprisingly, there were abundant ideas for large science projects with TMT, and it will be important to implement a cross-partnership time allocation mechanism for large and long-term projects. Such projects can achieve transformative science and can also generate valuable, coherent data sets that could be mined by a wider research community if they are properly reduced, archived, and distributed. Well-run data management, including data reduction software or pipelines and a suitable archive, can significantly amplify the scientific output of an observatory and would help more astronomers squeeze the most science out of precious and unique TMT data. Several of the "key projects" discussed at the Forum (and no doubt many smaller programs as well) would benefit from modes of flexible or queue scheduling, implemented for at least part of TMT's observing time. This is particularly

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The 2015 TMT Science Forum continued

true for time-domain science, including some observations of solar system objects, exoplanets, transient events, and temporal monitoring of various sorts, many of which would be difficult to carry out efficiently with purely classical scheduling. Many important TMT science programs also require diffraction-limited observations taken in the best atmospheric conditions; these can also benefit from queue scheduling. A queue is also well-suited for efficient execution of small observing programs. Several ISDTs are looking beyond TMT's first-light instrumentation suite, and they presented projects that would use high-resolution spectroscopy (both at infrared and optical wavelengths), mid-infrared observations, multiplexed integral field spectroscopy, enhanced performance for high-contrast imaging, and spectropolarimetry. Finally, there was widespread recognition that communications, outreach, STEM education, and workforce development are integrally important to TMT's mission and to its success. There was considerable interest in, and expertise about, these issues among the astronomers attending the meeting and valuable dialogue between people who have been part of the TMT project for years and astronomers who were attending a TMT meeting for the first time.

The TMT Forum is also an opportunity to develop and strengthen ties between TMT and US astronomers outside the current TMT partner institutions (Caltech and the University of California, along with international partners Canada, China, India, and Japan). AURA is an associate member of the TMT International Observatory, with representatives on its governing board and Science Advisory Committee. As part of a cooperative agreement between TMT and the National Science Foundation (NSF), NOAO and the US TMT Science Working Group (SWG) serve as liaisons between the broader US astronomical community and TMT and are helping to develop a model for potential NSF partnership in the observatory. Eighty-two participants at this year's TMT Forum (roughly 60% of the total) came from US institutions outside the partnership, including many US members of the TMT ISDTs. Some were TMT habitués who have attended two or even three Forum events, while others were newcomers. It was a valuable occasion for the US TMT SWG to gather more information about the US community's interests and aspirations, which will inform the SWG's report to the NSF.

The TMT Detailed Science Case: 2015 edition
The Detailed Science Case (DSC) is the highest-level statement of the motivations for building the Thirty Meter Telescope. It provides examples of the transformative science that TMT can accomplish, from our solar system to cosmology. The original DSC was written in 2007, and it has now been thoroughly updated in a community-based effort involving the TMT International Science Development Teams (ISDTs). The ISDTs are topical science groups that advise and assist the TMT project and plan ahead for future TMT science programs. They are one of the best ways for US community astronomers to get involved in TMT, with annual calls for membership. More than 140 scientists worldwide contributed to DSC-2015, including about 40 from US institutions other than the current TMT partners. You can read DSC-2015 at *http://arxiv.org/abs/1505.01195*. NL

Phoenix Moves to Gemini South

Ken Hinkle, Dick Joyce & Verne V. Smith

On the morning of June 8, Caty Pilachowski (Indiana University) took the last observation using the Phoenix near-IR spectrograph combined with the Kitt Peak Mayall 4-m telescope. This observation marks the end of Phoenix use at Kitt Peak. Phoenix was the last f/16 instrument on the Mayall, so this was also likely the last use of the f/16 secondary. The decommissioning of Phoenix at the 4-m is part of the planned move to lower-cost operations as the Mayall transitions toward DESI.

The Phoenix-Gemini interface and Phoenix handling fixtures stored outside the Gemini South dome. (Image credit: Steve Margheim/Gemini.)

Phoenix, however, remains a popular instrument with long-slit, high-resolution capabilities over the entire 1–5 micron region that are not otherwise available. The need for a high-resolution near-IR spectrograph is particularly acute in the Southern Hemisphere since the ESO/VLT equivalent instrument CRIRES is out of commission for a few years as part of an upgrade. To fill this lack of capability in the south, NOAO and Gemini have agreed to offer Phoenix as a visitor instrument at the Gemini South telescope. Phoenix was last offered at Gemini South as a queue instrument in 2010B. Potential users should note that as a visitor instrument, observations will be blocked into a single run each semester.

Currently, Phoenix is in the Tucson lab being refitted to the Gemini instrument interface. When Phoenix was shipped to Kitt Peak in 2011, there was no plan to return it to Gemini. We believed that the Gemini interface would never again be used. Some months ago we started searching for the parts needed to prepare the instrument to go back to Gemini. Fortunately, the interface was found outside the Gemini South dome. The budget for moving Phoenix to Gemini does not include funding for upgrades, and the move will not go forward if there are major problems. However, so far all is going well, and we anticipate shipping Phoenix to Gemini South in the last quarter of 2015. The tentative plan is to schedule a block of Phoenix time in the second half (May–July) of the 2016A semester.

NOAO Proposal Preparation Information and Submission Help for Semester 2016A

Verne V. Smith & Dave Bell

The Call for Proposals and proposal-related information, such as available instruments and updates, is no longer included in the *NOAO Newsletter*. All information specifically related to proposing for telescope time via the NOAO Time Allocation Process is available through the NOAO "Proposal Information" web pages and links (see below). The NOAO website is the definitive location for the most current information available to proposers. The Semester 2016A NOAO Call for Proposals will be posted and open on the NOAO website on 1 September 2015. We note that the NASA-NSF Exo-Planet Observational Research (NN-EXPLORE) program will continue in semester 2016A on the WIYN 3.5-m telescope. Please see the 2016A Call for Proposals for the details.

Help with proposal preparation and submission is available via the Web addresses below:

Proposal Preparation and Submission Help

Web proposal materials and information	*www.noao.edu/noaoprop/*
TAC information and proposal request statistics	*www.noao.edu/gateway/tac/*
Web submission form for thesis student information	*www.noao.edu/noaoprop/thesis/*
Request help for proposal preparation	*noaoprop-help@noao.edu*
Gemini-related questions about operations or instruments	*gemini-help@noao.edu*
	ast.noao.edu/nssc/sus
CTIO-specific questions related to an observing run	*ctio@noao.edu*
KPNO-specific questions related to an observing run	*kpno@noao.edu*

First Light for TS4-ARCoIRIS: Installation and Commissioning, April–June 2015

David James, Terry Herter & Everett Schlawin (Cornell University)

NOAO has recently taken receipt of its new, moderate-resolution, facility-class infrared spectrograph to be called TS4-ARCoIRIS—the **A**stronomical **R**esearch using the **Co**rnell **I**nfra**R**ed **I**maging **S**pectrograph—which was constructed by a partnership between Cornell University (PI: Dr. Terry Herter) and NOAO, funded through a Renewing Small Telescopes for Astronomical Research (ReSTAR) award from the NSF. The instrument arrived on Cerro Tololo on 24 April 2015, and after undergoing post-shipping testing, instrument preparation, and software link-up, it was installed at the f/8 Cassegrain focus of the Blanco 4-m telescope on April 29 (Figure 1). First light was achieved the same night with spectra acquired from a 20-seconds, AB-nod sequence of the V=8 A0V star, HD 139295 (Figures 2a and 2b).

NOAO's ARCoIRIS instrument is a cross-dispersed, single-object spectrograph, containing no moving parts, based on an updated design of the three existing TripleSpec spectrographs installed on the 3.5-m telescope at Apache Point Observatory, on the 5-m Hale telescope, and on the 10-m Keck II telescope. ARCoIRIS features a fixed slit with width and length of 1.1 arcsec and 28 arcsec, respectively, and is accompanied by two flanking outriggers, which are 1.1-arcsec-square slit boxes some 4 arcseconds offset from the main slit aperture. These outriggers can be used for better defining a spatial-spectral wavelength calibration (in the X–Y plane), allowing a better interpolation of the spectrum background. Spectrograms are fixed-format images, recorded by a 2048 x 2048 Hawaii-2RG HgCdTe array having 18μm pixels, covering the entire z'YJHK

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First Light for TS4-ARCoIRIS continued

Figure 1: On 29 April 2015, ARCoIRIS was installed at the Cassegrain focus of the Blanco 4-m telescope on Cerro Tololo. In attendance were David James (ARCoIRIS Project Scientist, NOAO, front right), Everett Schlawin (graduate student, Cornell University, middle right) and Chuck Henderson (mechanical engineer, Cornell University, back right). (Image credit: Terry Herter/Cornell University.)

photometric range and yielding a full wavelength coverage of approximately $0.80 < \lambda < 2.47$ µm with R~3500. ARCoIRIS is also equipped with a J-band slit viewer/guider array that has a 4 x 4 arcminute field-of-view sampled at 0.27 arcsec/pixel. Operated in Double Correlated Sample mode, the spectrograph detector's readout noise is ~14 e^-/pixel, which drops to 4.5 e^-/pixel for Fowler sampling with 16 samples. The user interface consists of a series of LabView GUIs, similar to those that control the COSMOS and Goodman spectrographs. The instrument is attached to an image rotator at the Cassegrain focus, which allows users to align the slit with the parallactic angle or to specific objects in crowded regions, or to change the slit axis orientation for extended object observing.

During the first two (of four planned) commissioning and science verification observing runs, the instrument's software and hardware performance, as well as its sensitivity, have been thoroughly characterized and tested. In Figures 3a and 3b, for instance, we show extracted ARCoIRIS spectra for the planetary nebulae NGC 7009 (Saturn nebula) and NGC 3918 that exhibit a substantial number of hydrogen (Brackett- and Paschen-series) and helium emission lines across the near-infrared z'YJHK region. This spectrum is qualitatively similar to previously published planetary nebula spectra in the near-IR and strongly resembles that of existing spectra. We further tested the instrument's performance by obtaining spectra of Saturn's moon Titan and of the dwarf planet Pluto (see Figures 4a and 4b, respectively). These two outer solar system objects exhibit very clear signs of atmospheric absorption by hydrocarbons in their spectra, especially by molecular methane. As the *New Horizons* space probe has recently demonstrated with its discovery of methane ice on Pluto's north pole, even demoted solar system planets can reveal

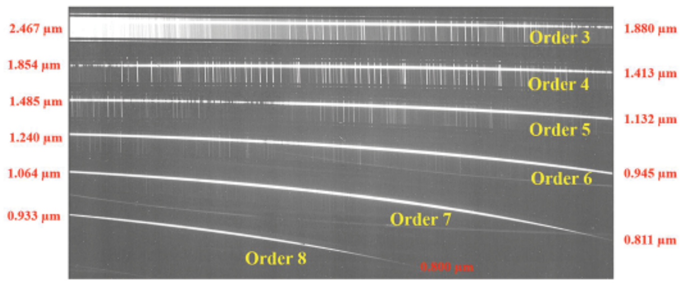

Figure 2a: A raw first-light spectrum from ARCoIRIS for HD 138295, a V=8 mags. A0V calibrator star. In photometric terms, one can think of each spectral order as being approximately equivalent to 2MASS-like JHK filters, the Y-filter, and a Sloan-like z′ filter, viz., K=3, H=4, J=5, Y=6, and z′=7. For each spectral order, we provide start- and end-point wavelengths.

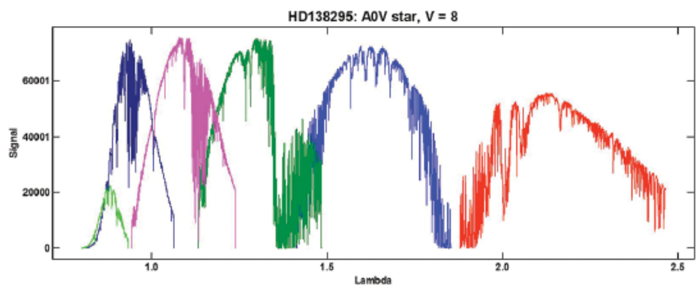

Figure 2b: An extracted first-light ARCoIRIS spectrum of HD 138295 is plotted, in counts vs. wavelength (in microns) space, where each of the spectral orders are color coded. The exposure consists of an AB-sequence of 20 seconds per nod.

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remarkable and unexpected astrophysical phenomena, something to aspire to for ARCoIRIS users!

Initial analysis shows that the sensitivity of ARCoIRIS is qualitatively quite similar to that of the TripleSpec exemplar installed on the Hale 5-m telescope on Mt. Palomar, and in fact, the NOAO version of the instrument boasts considerably better sensitivity blueward of 1.2μm thanks to improvements in the anti-reflection coatings used on various optics. In time, we will create an exposure time calculator for the instrument, but for observation planning purposes, proposers can expect that for a V=15 A0V star, an AB-nod sequence totaling 100 seconds (Fowler16) yields a S/N of ~10 spectrum. NOAO is working in collaboration with Dr. Katelyn Allers (Bucknell University) in order to create an ARCoIRIS-specific reduction package (written in IDL), which we should have available in time for the 2016A semester, the first semester for which the instrument is available for community-wide use.

With this new acquisition of ARCoIRIS, the Blanco 4-m telescope now boasts three facility-class instruments. At the f/8 Richey-Chrétien Cassegrain focus, ARCoIRIS complements the COSMOS optical spectrograph, while the Dark Energy Camera (DECam) sits at the f/2.7 prime focus of the telescope. Operationally, choosing between Cassegrain and prime focus instruments leads to substantial scheduling restrictions for the observatory. Such instrument selection constraints are important because of the need to install the f/8 secondary mirror on the bottom of the DECam barrel (thereby rendering the camera inoperative) for Cassegrain instruments, an activity which occurs only during daylight hours, typically with a night of f/8 engineering to follow. Swapping in, or out, of the f/8 secondary mirror never occurs at night. In order to maximize observatory efficiency, NOAO community users should note that Cassegrain instrument time requests are generally serviced in contiguous blocks of time (especially near to the full Moon for ARCoIRIS); therefore, some scheduling limitations can be expected. If specific nights or observing epochs are required for executing an ARCoIRIS (or COSMOS) program during the semester, proposers should explicitly and specifically state their ephemeris requirements in their proposals.

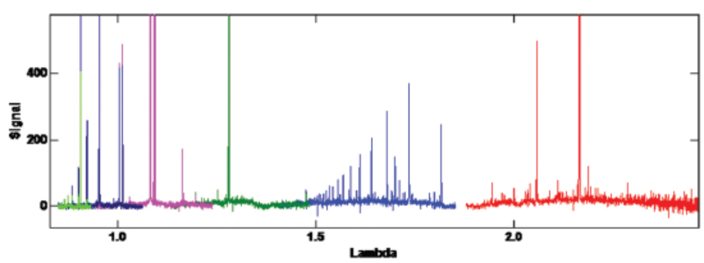


Figure 3a: An extracted ARCoIRIS spectrum for the Saturn planetary nebula (NGC 7009) is plotted, in counts vs. wavelength (in microns) space, where each of the spectral orders is color-coded. The spectrum consists of a 100-seconds exposure on-slit, followed by the subtraction of a 100-seconds exposure off-slit (for sky background removal).

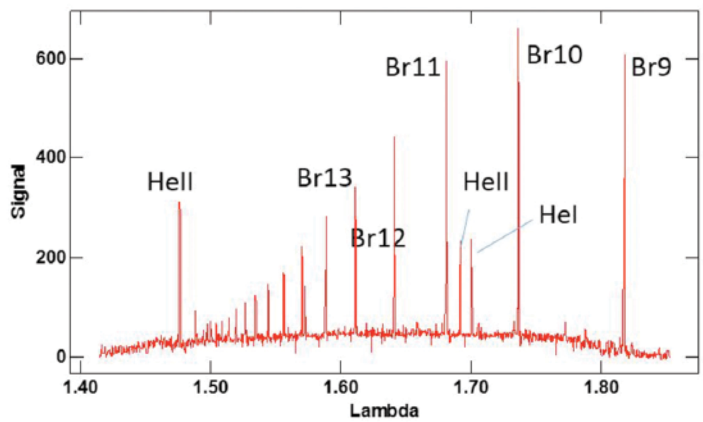


Figure 3b: A zoom-in of the H-band spectrum of the planetary nebula NGC 3918 is shown, in counts vs. wavelength (in microns) space, highlighting several helium emission lines as well as the Hydrogen Brackett series from Br9 → Br24.

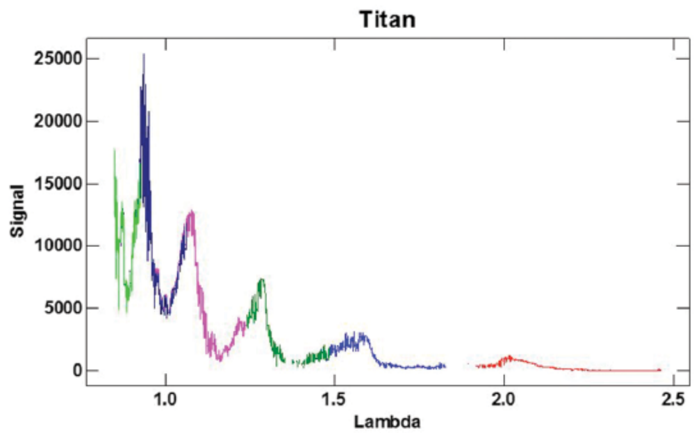


Figure 4a: An extracted ARCoIRIS spectrum for Saturn's moon Titan is shown, in counts vs. wavelength (in microns) space. Massive broad-band absorption by hydrocarbon species (e.g., methane) is evident across the z'YJHK wavelength region. Observation is an ABBA sequence–acquired 2015-07-02, @10-seconds per nod.

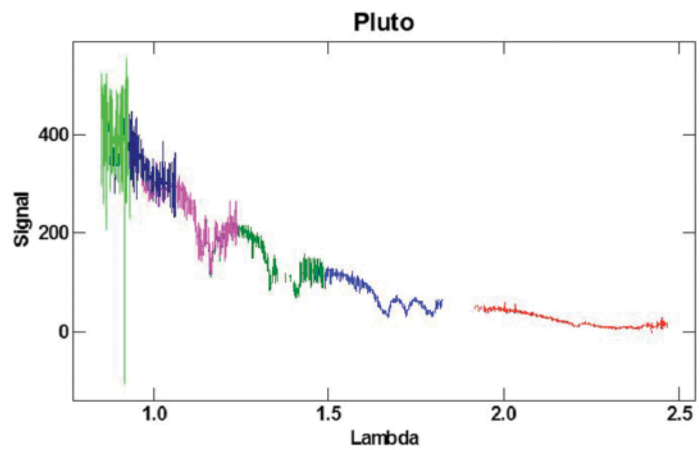


Figure 4b: An extracted ARCoIRIS spectrum for the dwarf planet Pluto is shown, in counts vs. wavelength (in microns) space. An absorption triplet, observed in each of the YJH bands, arises due to molecular methane in Pluto's tenuous atmosphere. Observation is an ABBA sequence–acquired 2015-07-02, @60 seconds per nod. NL

Robo-AO to Take Over Operation of the KPNO 2.1-m Telescope

Reed Riddle (California Institute of Technology) & Lori Allen

As the second major telescope to be constructed on Kitt Peak, the 2.1-m saw first light in 1964, and it has been in continual operation ever since. The history of the telescope includes many important discoveries in astrophysics, including the Lyman-alpha forest, the first gravitational lens, the first pulsating white dwarf, and the first comprehensive study of the binary frequency of solar-type stars. Following the Portfolio Review, the National Science Foundation (NSF) determined that it could no longer provide operational support for the 2.1-m telescope at Kitt Peak. Instead of shutting the telescope down, NSF and NOAO put out a call for proposals for parties interested in operating it. After a review process at both NOAO and NSF, a bid by Caltech to outfit the 2.1-m with Robo-AO and operate the telescope for the next three years was selected.

Robo-AO is the only autonomous laser guide star adaptive optics (AO) instrument; it robotically operates a telescope, laser, AO system, and science camera to observe several different classes of astronomical objects (Baranec et al., 2014). Robo-AO was developed by Caltech and the Inter-University Centre for Astronomy and Astrophysics in Pune, India (IUCAA).

Robo-AO was installed on the automated Palomar Observatory 1.5-m telescope in 2011 for initial testing, with first science and robotic operations occurring in the summer of 2012. Robo-AO has executed more than 18,000 robotic observations at the ~0.12” visible-light diffraction limit during 141 scheduled nights over three years; Robo-AO observes at a cadence of ~20 targets per hour for 1- to 3-minute science observations. With a 25- to 40-second overhead after telescope slew, the robotic observing system is able to observe targets far more efficiently than any other AO system currently available.

Robo-AO science highlights include the largest single survey of nearby companions to Kepler exoplanet host candidates (Law et al., 2014), helping to discover the second known case of an exoplanet in a quadruple star system (Roberts et al., 2015; *https://www.nasa.gov/jpl/planet-reared-by-four-parent-stars*) and surveys of solar-type dwarfs (Riddle et al., 2015), among several other science results already published or in press. More information about Robo-AO can be found at *www.ifa.hawaii.edu/Robo-AO/*.

Robo-AO KP will transform the 2.1-m into a dedicated adaptive optics observatory, which will enable routine high-angular-resolution imaging with an acuity of ~0.08 arcseconds in the visible and ~0.17 arcseconds in the near infrared (with a guide star magnitude limit of m_V~17). By transferring the Robo-AO system to the 2.1-m telescope, it will be able to take advantage of the larger aperture as well as Kitt Peak’s much more favorable observing conditions to routinely acquire much-sharper and higher-contrast images than on the 1.5-m telescope at the Palomar Observatory. Perhaps more importantly, Robo-AO KP will be the only instrument mounted on the 2.1-m telescope and will be used year-round to support long-duration observing campaigns not currently possible at the heavily oversubscribed 1.5-m telescope.

Community access was not a requirement to take over 2.1-m operations. However, the Robo-AO KP team will contribute one-sixth of the observing time each year to give the US astronomical community access to this unique capability. This time will be allocated through the standard NOAO TAC process. More information on the available instrument suite and performance will be included in a call for observation proposals for 2016A that will be released once Robo-AO KP is operational.

Robo-AO in operation at the Palomar Observatory 1.5-m telescope. The laser beam is not visible to the human eye; a camera sensitive to ultraviolet light was used to capture this image. (Image credit: Christoph Baranec/University of Hawai‘i.)

Robo-AO KP is a collaboration among Caltech, the University of Hawai’i, and IUCAA. The Robo-AO KP team are Prof. Shri Kulkarni (PI, Caltech); Dr. Reed Riddle (Project Scientist, Caltech); Prof. Christoph Baranec (Robo-AO PI, U. Hawai’i); Dr. Dmitry Duev (Data Scientist, Caltech); and Prof. A. N. Ramaprakash (Detector Scientist, IUCAA). Please contact Dr. Riddle (*riddle@caltech.edu*) for more information.

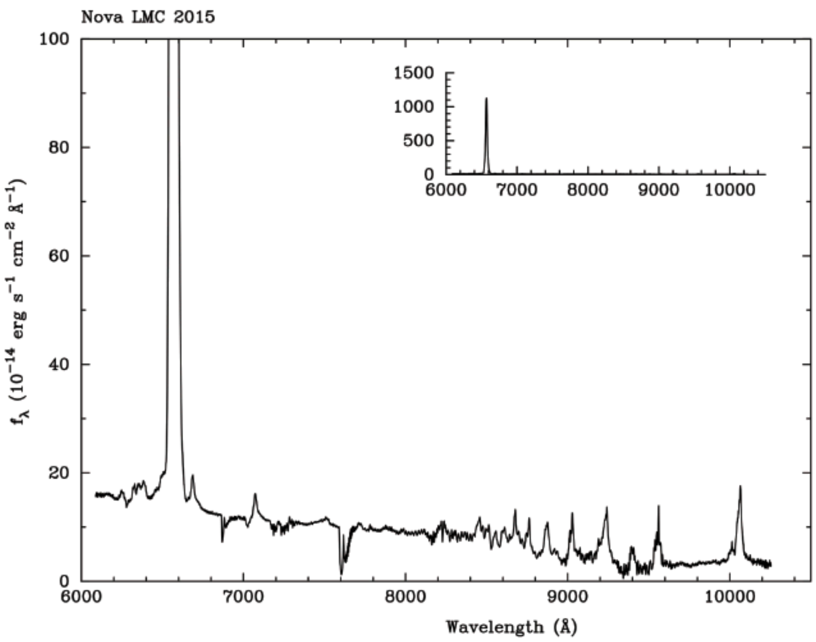
The future of the Coudé Feed? The Coudé Feed has been one of the most productive telescopes at KPNO. The Robo-AO KP team has not made any plans for it, and the team would be interested in discussions and collaborations with others who would be interested in putting the Feed to good use.

COSMOS Begins Regular Science Operations

Sean Points

The first science result of the Cerro Tololo Ohio State Multi-Object Spectrograph (COSMOS) was a spectrum of Nova LMC 2015 that was obtained by Dr. Frederick Walter of Stony Brook University. This nova was discovered in the All-Sky Automated Survey for Supernovae (ASAS-SN; *www.astronomy.ohio-state.edu/~assassin/index.shtml*) and first reported as ASASSN-15fd and proposed to be a nova in the LMC in The Astronomer's Telegram #7269 and #7313 (*www.astronomerstelegram.org/?read=7269* and *www.astronomerstelegram.org/?read=7313*), respectively. Dr. Walter confirmed that identification using the Chiron echelle spectrograph on the SMARTS/CTIO 1.5-m telescope (*www.astronomerstelegram.org/?read=7350*).

N LMC 2015 was a ToO observed during a program to observe fainter, older novae. The large (3500–10,000Å) spectral range is ideal for observing novae because of the wide range of phenomena visible, and because the broad spectral coverage includes lines with a large range of ionizations and excitations, this aids the dissection of the various parts of the nova environment. Furthermore, the nova had faded to V ~ 13 magnitude by the time of the COSMOS observations, making the continuum and the weak lines hard to detect with CHIRON. The spectrum shown in the figure is the mean of four 100-second integrations taken through the 3-pixel (0.9") red slit with the red disperser. This instrument configuration covers the wavelength range between 6100Å and 10000Å. The strongest line seen in this figure is Hα. The spectrum also shows strong lines of He I 6678Å and 7065Å. To the far red end lies the Hydrogen Paschen series Pa-δ through Pa-13. Other lines visible include O I 8446Å and the Ca II near-IR triplet. The deep absorption features in the figure are the telluric Fraunhofer A and B bands of O_2.



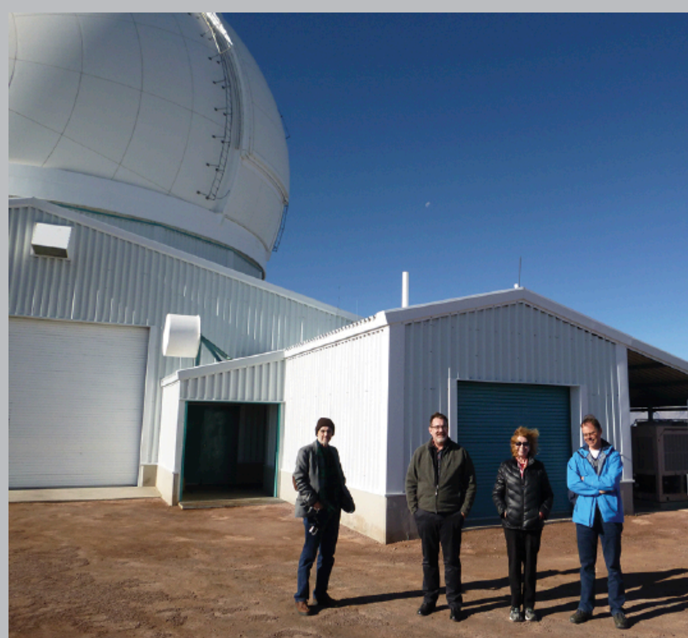
Spectrum of Nova LMC 2015 obtained with COSMOS during its first community science observations. The figure inset in the upper right shows the spectrum over the full intensity range and the strength of the Hα line. The main figure shows the spectrum on a limited intensity range, so the weaker lines on He I, O I, Ca II, and the Hydrogen Paschen series are clearly seen.

SOAR News

2015 SOAR External Review

Every five years during the course of observatory operations, SOAR holds an external review—roughly the equivalent of a visiting committee at universities. SOAR held its second such review this past June 24–26 in La Serena and on Cerro Pachón. In addition to hearing presentations from the director, the board, and the Science Advisory Committee, the committee visited the telescope.

At the end of the review, the committee provided an initial debrief, and its final report has now been provided to the board for its consideration.



External review committee at SOAR. From left to right, Walter Maciel (U. São Paulo), Darren DePoy (Chair, Texas A&M), Jean Brodie (UC Santa Cruz) and René Rutten (Gemini). Note the quarter moon in the upper center! (Image credit: Jay Elias/SOAR.)

Instrument News—Goodman HTS Improvements

Jay Elias (SOAR)

The Goodman high-throughput spectrograph is the most heavily used instrument at SOAR, so even modest gains in efficiency have an impact on the observatory. Two recent projects are nearing completion, both of which should help many observers.

Red Camera

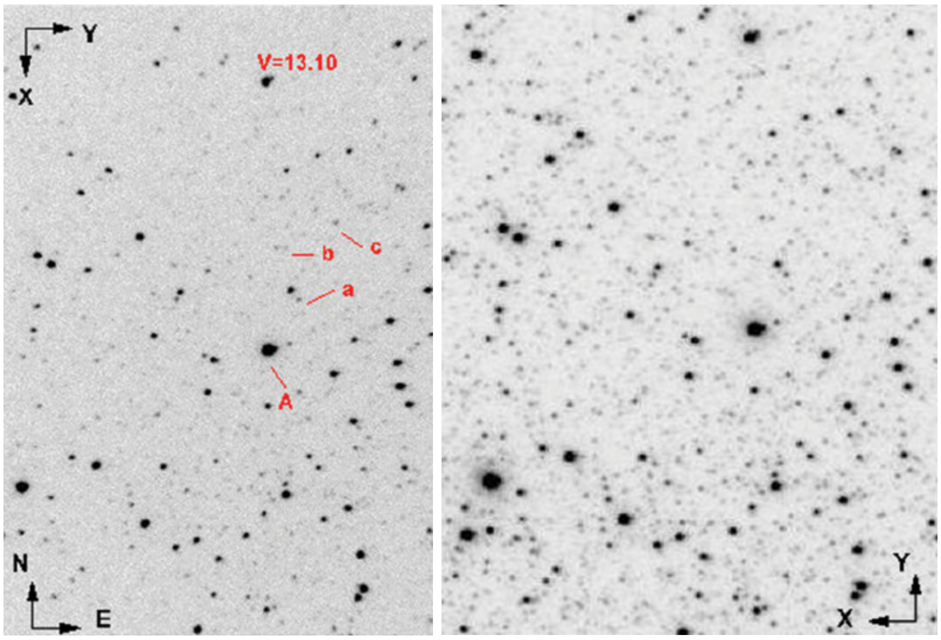
Last year, the SOAR Board authorized the purchase of a second CCD dewar for the spectrograph, to be equipped with an e2v CCD similar in characteristics to those used in Mosaic 1.1, COSMOS, and KOSMOS. The project plan also included modification of the spectrograph to allow both dewars to be installed, though not for simultaneous use. Switching between the CCDs will normally be a day-time operation, requiring manual operation of a fold mirror ("in" for the red camera, "out" for the blue camera). There will be separate computers for each dewar, and the current Goodman detector computer will be upgraded; this means that the computer systems act as "hot spares" for one another, reducing potential down time. Most of the red camera work is being carried out at the University of North Carolina at Chapel Hill (led by Chris Clemens and Erik Dennihy).

Once the upgrades have been installed and tested (probably midway through the 2015B semester), we will offer the red camera to users who might benefit. For future users, the following characteristics are relevant:

- Over most of the spectral range, there should be little difference between the two CCDs.
- In the blue/ultraviolet, the current Fairchild CCD ("blue camera") should have higher quantum efficiency than the e2v CCD.
- In the red/far-red, the e2v CCD ("red camera") should have higher quantum efficiency than the Fairchild CCD, as well as reduced fringing.

Acquisition Camera

We have also purchased a small commercial CCD camera that will be fed by a newly added flip-in mirror that goes behind the spectrograph slit. This camera will view the focal plane through the slit (or with the slit removed) to allow acquisition of objects without the need to move gratings or change camera angles, which substantially reduces observing overheads. As shown in the figure, the imaging performance for the acquisition camera is quite good for short exposure times. This project is being led by Andrei Tokovinin (NOAO South).

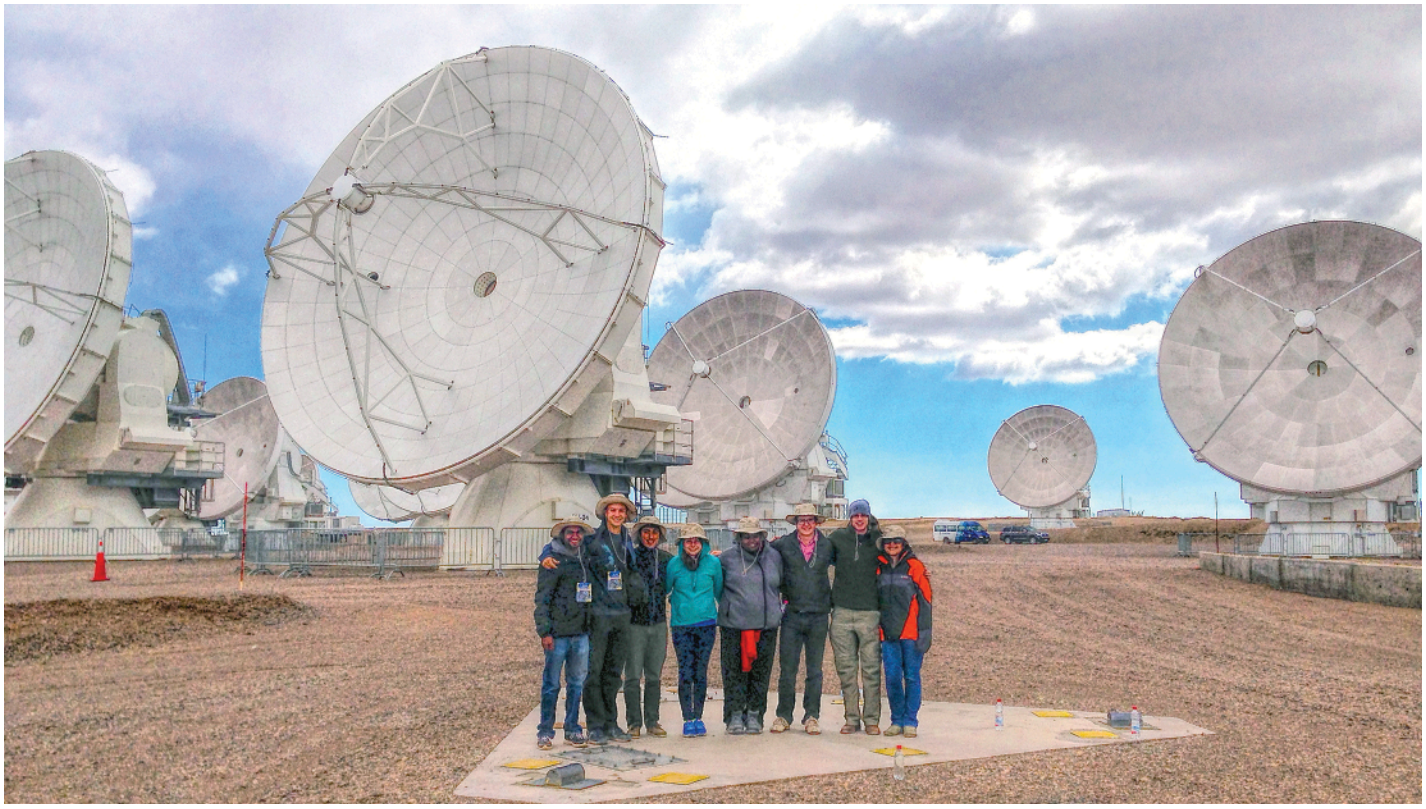


Left: 0.25-sec exposure with the acquisition camera. Right: 10-sec exposure with Goodman in imaging mode (SDSS-g filter). The longer exposures possible with Goodman do go deeper, but otherwise the acquisition camera provides very comparable performance.

While this camera should save significant time for some programs, for others it will not help much, and users should plan to use Goodman imaging mode for acquisition. Specifically:

- The limiting magnitude is around magnitude 18 for reasonable exposure times; in general, the camera is not recommended for targets fainter than 17th magnitude. Goodman itself can take much longer images and can therefore go considerably deeper.
- The field of view is roughly 1 x 1.5 arcminutes; this means that the camera cannot be used for multislit mask alignment, and it is not recommended for fields where the target cannot be unambiguously identified within such a small field.
- Programs that can use the acquisition camera are therefore those with bright, single targets. These are typically programs where the actual exposure times are short, so savings in overheads provide a greater proportional gain in efficiency.

Although the camera has been tested on the spectrograph, it is still lacking the safety interlocks to allow it to be used by regular observers without risk to the spectrograph optics. These will be added, probably on a similar timescale to the red camera commissioning. Once the acquisition camera is cleared for general use, it will be offered to scheduled observers.



The 2015 CTIO REU and PIA students visited the Atacama Large Millimeter Array (ALMA), outside of San Pedro de Atacama, Chile. From left to right: Md Tanveer Karim (REU), Alexander Gagliano (REU), Tomás Cassanelli (PIA), Brittany Howard (REU), Cherish Prickett (REU), Scott Carlsten (REU), Samuel Castle (REU), and Pamela Soto (PIA). (Image credit: Catherine Kaleida/NOAO/AURA/NSF.)

A Successful Year for the CTIO Undergraduate Internship Programs in Chile

Catherine Kaleida

During January–March 2015, the Cerro Tololo Inter-American Observatory (CTIO) hosted eight university students from a variety of disciplinary backgrounds for a 10-week astronomy research internship. Six undergraduate research assistantships were awarded for US undergraduate students through the NSF-funded Research Experiences for Undergraduates (REU) program. The CTIO-funded Prácticas de Investigación en Astronomía (PIA) program was run concurrently with the REU program and offered two research assistantships for Chilean students. Participants in both programs lived and worked alongside the professional astronomers on the compound of the observatory offices in La Serena, with occasional visits to the telescopes on Cerro Tololo.

The 2015 cadre of REU/PIA students included not only astronomy majors but also students majoring in astronomy-related fields who were interested in trying their hand at astronomy research. The selected participants for the 2015 REU/PIA program included students specializing in astronomy, physics, engineering, computer science, and mathematics. This diversity of educational backgrounds provided for a unique environment for group discussions and peer-mentoring among the students, as each participant brought a different expertise to the table.

While at CTIO, the REU and PIA students participated in a variety of astronomy-related activities designed to give each student a taste of what it is like to work as a professional astronomer in an international observatory setting. The students' time was divided between working on cutting-edge astronomy research under the direction of their mentor, participating in weekly group research meetings, attending seminars and colloquia, and learning about astronomical instrumentation and telescope design through tours of the CTIO, Gemini South, SOAR, and ALMA observatories. The CTIO summer students also had the opportunity to observe Targets-of-Opportunity (ToOs), using the Small & Moderate Aperture Research Telescope System (SMARTS) 0.9-m telescope on Cerro Tololo.

During the final week of the 2015 program, the REU/PIA students shared their results with the CTIO, Gemini, and SOAR scientific staff in the form of a written report and a short presentation in the annual CTIO REU/PIA Student Symposium. Thus, in a short 10 weeks, the 2015 REU/PIA students experienced the thrill of contributing to new scientific discoveries through practicing the three main tasks of a professional observational astronomer: observation, analysis of results, and subsequent reporting and publication. The students will be submitting their results for presentation at the upcoming winter American Astronomical Society (AAS) meeting in Kissimmee, Florida. We invite you to stop by the CTIO student posters at the AAS meeting to see the fruits of their labor!

Seeking Applicants for the 2016 CTIO REU Program

Want to see what it's like to be a professional astronomer and experience life in the rich Chilean culture, or do you know a student who would? The Cerro Tololo Inter-American Observatory (CTIO) will be offering a Research Experiences for Undergraduates (REU) program for six US interns in 2016. The CTIO REU program provides exceptional opportunities for students considering a career in astronomy to engage in substantive research activities with scientists working at the forefront of contemporary astrophysics. Student participants work on specific research projects in close collaboration with members of the observatory scientific and technical staff, such as galaxy clusters, gravitational lensing, supernovae, planetary nebulae, stellar populations, star clusters, star formation, variable stars, and interstellar medium. The CTIO REU program emphasizes observational techniques and provides opportunities for direct observational experience using the state-of-the-art telescopes and instrumentation on Cerro Tololo.

Participants in the REU program must be enrolled as full-time undergraduate students at a US university during the REU program, must be citizens or permanent residents of the US, and must be majoring in astronomy, physics, or a related field (e.g., engineering, computer science, geology, mathematics, etc.). It is not necessary to have a valid passport to apply for the program, but students will need to apply for or update their passports immediately after being admitted. Assistance can be provided for those who are unfamiliar with the passport application process. As this is the first trip out of the country for many of our students, a CTIO staff member accompanies the students on their initial journey from the US to Chile.

The program will run for 10 weeks, from January to March 2016. A two-night observing run on Cerro Tololo and a field trip to visit the Gemini and SOAR observatories in Chile are highlights of the program. These positions are full-time, and those selected will receive a stipend and subsidized housing on the grounds of the offices of CTIO in La Serena, as well as travel costs to and from La Serena. In addition, the students usually attend the American Astronomical Society (AAS) winter meeting to present their research the year following the program, in this case the 2017 AAS meeting in Grapevine, Texas.

The application Web form for the 2016 CTIO REU program will be available starting in late August 2015 and will be due in October 2015. More information can be found at *www.ctio.noao.edu/noao/REU*. Women and candidates from underrepresented minorities in the sciences are particularly encouraged to apply.

Colors of Nature Summer Academy

Rob Sparks & Stephen Pompea

The National Optical Astronomy Observatory's Education and Public Outreach group led the Colors of Nature Summer Academy June 8–19. This was the fifth Summer Academy in the program. The academy was held at the Art Department building on the University of Arizona campus, with 30 students from the Tucson area attending the two-week academy.

The Colors of Nature Summer Academies are held each summer in Tucson and at the University of Alaska, sponsored by an NSF Advancing Informal STEM Learning (AISL) grant for "Project STEAM: Integrating Art with Science to Build Science Identities among Girls" (Co-PI: S. Pompea). Students are selected through a competitive application process, and 93 girls applied for the 30 available spots in Tucson.

The four-year program is a collaboration of the University of Alaska–Fairbanks, the University of Washington–Bothell, and NOAO, and it explores how science identities are formed in middle school girls. NOAO staff working on the academy included Katie Kaleida (Instructor), Rob Sparks (Tucson Program Coordinator), Kathie Coil (Logistics), and NOAO undergraduate student Will Roddy (Assistant Instructor). Other undergraduate students, including Rebecca Levy, Zack Watson, and Ryleigh Fitzpatrick, provided instructional support. Laura Conners (Geophysical Institute, University of Alaska–Fairbanks) is the project PI, with Mareca Guthrie (University of Alaska Museum of the North), Carrie Tzou (University of Washington–Bothell), and Stephen Pompea (NOAO) as Co-PIs.

Students in the academy explored the role color plays in nature through a variety of activities. The biological functions of color were explored through laboratory and field activities, including a trip to the Arizona-Sonora Desert Museum. The students explored pigments and color mixing while dying their own scarves with vegetable-based pigments and using a spectrometer to measure reflectance curves. Additive color mixing was explored by using red, green, and blue lights. The popular sodium room featured a low-pressure sodium light source to allow the students to explore a monochromatic world. Students explored fluorescence and its role in biology using ultraviolet light. Polarized light and optically active substances were used to create colorful patterns viewed with polarizing filters. Students kept a notebook of their sketches and observations.

Throughout the camp, students applied what they learned in a series of design challenges. In one design challenge, students had to create a stop-

continued

Colors of Nature Summer Academy continued

Students experiment with light painting during the Colors of Nature Summer Academy. (Image credit: Pete Marenfeld, NOAO/AURA/NSF, and Rob Sparks, NOAO/AURA/NSF.)

motion animation illustrating the role of color in nature. Another design challenge was to build a pinhole camera. Another involved the creation of artworks using polarized light.

Students used the knowledge gained during the academy in their final projects: creating a fictional plant or animal that uses color to survive. The students designed a poster illustrating their plant or animal as well as a costume they could wear to illustrate the plant's or animal's properties. Students explored the materials they used in their costumes by taking photomicrographs and reflectance spectra of the fabrics and other materials in their costumes. The costumes and posters were displayed in a public reception at the University of Arizona College of Optical Sciences building on June 19.

The students will reunite for a trip up Kitt Peak for tours and a star party this fall. NOAO will also host science cafes throughout the year for the students and their families. In the upcoming year, the Colors of Nature program will be developing teaching kits and hosting a professional development workshop for educators.

The Summer Academy was also held at the University of Alaska in Fairbanks in July with 30 girls. The format of the program was similar to the one in Tucson. The next phase of the project is to refine the instructional materials created by the project and to create new professional development materials in order to allow a broader dissemination of the activities and design challenges developed in the program. The project's research on science identity formation is being presented at meetings such as the National Association for Research in Science Teaching and the American Educational Research Association.

The Colors of Nature program is in the third year of its four-year program. Applications for the 2016 Summer Academies in Tucson and Fairbanks will open in the spring of 2016.

Undergraduates Observe at the 0.9-m Telescope

Anne Jaskot (Smith College)

Last January was a busy time at the 0.9-m telescope. Eleven undergraduate students from four eastern colleges (Amherst College, Mt. Holyoke College, Smith College, and UMass–Amherst) spent a total of seven nights observing, possible because Smith College is a member of the 0.9-m consortium. Led by Dr. Anne Jaskot, this was the introduction to their upper-division observing class. Their goal was to obtain multiwavelength images of a sample of starburst galaxies, using HDI, the new half-degree imager at the 0.9-m. During the day, we toured the mountain and Saguaro National Park. Most of the students had never been to Arizona before, and none of the students had observed at a professional telescope. During the day, they had tours from NOAO staff members of the Mayall 4-m telescope, the McMath-Pierce Solar Telescope, and the WIYN 3.5-m telescope, as well as talks on the history of Kitt Peak and the Tohono O'odham Nation.

Back in Massachusetts, the students proposed their own research projects based on the 0.9-m observations and reduced all the data. They spent the rest of the semester working on their proposed projects: quantifying starburst morphologies, comparing starburst morphologies with those of high-redshift galaxies, searching for faint companions or merger signatures, relating starburst morphologies and HI gas kinematics, mapping starburst ionization structure, and relating the starbursts' star formation to their environment.

At the end of the course, the students shared their results in a poster presentation to the full Five College Astronomy Department. Two students are now working on related projects as part of their senior theses, and they plan to publish their results upon the completion of their work. Dr. Jaskot plans to be back in January 2016 with a new group of students.

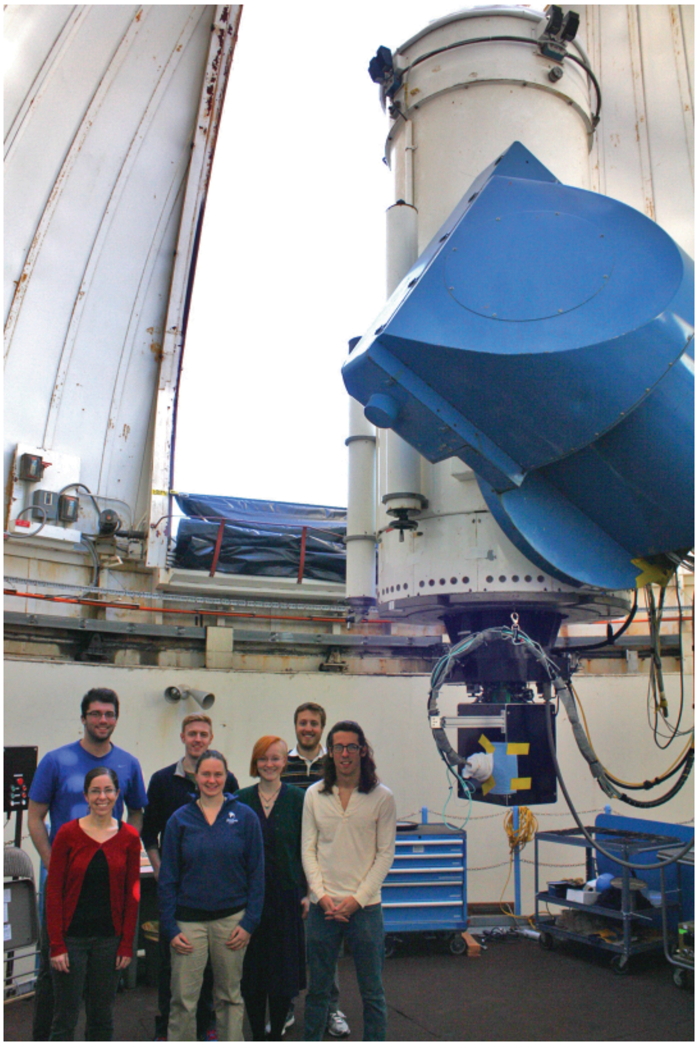


Fig. 1: In order to accommodate all the students enrolled, the group was split into two, with each group having three or four nights of observing. The first group is shown here at the 0.9-m. (Image credit: Anne Jaskot/Smith College.)

Fig. 2: The second group tours the Mayall 4-m telescope. (Image credit: Anne Jaskot/Smith College.)

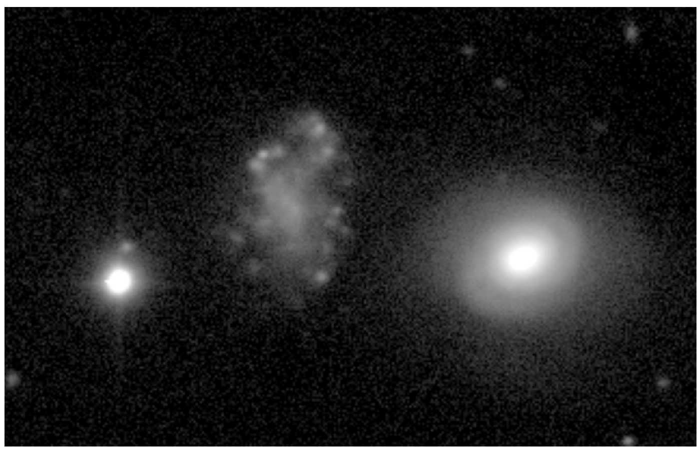


Fig 3: Broadband (clear filter) image of the irregular galaxy AGC 210804 shows clumpy structure but no obvious interactions. The spiral to the right is in the same group. (Image credit: Anne Jaskot/Smith College.)

NOAO Staff Changes at NOAO North and South

(16 February 2015–15 August 2015)

New Hires

Araya, Mauricio	Telescope Mechanic 3, SOAR TelOps	South
Gibson, Rose	Summer Research Assistant (KPNO REU)	North
Jeraldo, Alex	Mountain Assistant, Facilities Operations	South
Jones, Logan	Summer Research Assistant (KPNO REU)	North
Juelfs, Elizabeth	Summer Research Assistant (KPNO REU)	North
Paleo, Juan José	Administrative Speciaist 8, Facilities Operations	South
Patt, Anthony	Observing Assistant	North
Pezzato, Jacklyn	Summer Research Assistant (KPNO REU)	North
Rojas, Luis Alberto	Maintenance Man 4	South
Sandberg, Erik	Summer Research Assistant (KPNO REU)	North
Zaidi, Tayeb	Summer Research Assistant (KPNO REU)	North

Promotions

Aguirre, Samuel	Commissary Man 1, Facilities Operations	South
Andrade, Juan	Instrument Specialist 4, TelOps	South
Caceres, Blas	Driver 1	South
Donaldson, John	Electronic Tech Supervisor	North
Hartman, Mia	Administrative Coordinator III, TAC	North
Jeraldo, Alex	Administrative Specialist 8, Facilities Operations	South
Newhouse, Mark	Senior Web Developer	North
Rajagopal, Jayadev	Associate Scientist	North
Santa Maria, Luis	Auto Mechanic 2	South
Valencia, Patricia	Administrative Specialist 7, Facilities Operations	South

New Positions

Benfante, Maria	Receptionist/Secretary	North
Hunt, Sharon	Librarian/Publications Coordinator	North

Transfers

Bird, Nanette	From NOAO to NSO	North

Retirements/Departures

Atlee, David	Research Associate (Postdoc)	North
Carlsten, Scott	Summer Research Assistant (CTIO REU)	South
Castle, Samuel	Summer Research Assistant (CTIO REU)	South
Fraps, Barbara	Publications Coordinator	North
Gagliano, Alexander	Summer Research Assistant (CTIO REU)	South
George, James (Ron)	Electronics Tech Supervisor	North
Guvenen, Blythe	Public Programs Specialist 2	North
Howard, Brittany	Summer Research Assistant (CTIO REU)	South
Inami, Hanae	Research Associate (Postdoc)	North
Jutras, Matthew	Craftsperson I	North
Karim, Md Tanveer	Summer Research Assistant (CTIO REU)	South
Levy, Rebecca	Special Projects Assistant	North
Mathis, Hillary	Telescope Operations Manager	North
Moore, Elizabeth (Beth)	Administrative Assistant II	North
Ocaranza, Isidro	Janitor, Facilities Operations, La Serena	South
Ortega, Calvin	Special Projects Assistant	North
Prickett, Cherish	Summer Research Assistant (CTIO REU)	South
Salyk, Colette	Research Associate (Postdoc)	North
Ume, Ugochukwu	Student Assistant	North
Wallace, Spencer	Public Program Specialist	North
Weintraub, Shelley	Administrative Assistant	North

2015 AURA Outstanding Achievement Awards

Service	Dickinson, Mark	North
Technology/Innovation	Phillips, Marie (AURA-NOAO)	North

continued

NOAO Staff Changes continued

2015 NOAO Excellence Awards

Service	Bird, Nanette	North
Service	Corson, Charles	North
Service	Hunt, Sharon E.	North
Service Team	*Mayall Mirror Lift Upgrade Project Team:* Danny Abraham, Keith Blaine, John Donaldson, Derek Guenther, Mike Hawes, Jose Montes, Victor Moreno, Larry Reddell, and Bob Stupak	North
Service Team	*CFO:* Brenda Kouratou, Earl Shackelford, Bill Porter, Luis Villarreal, Rod Rutland, Karen Ray, and Robert Dawson	North
Service	Silva, Mariela	South
Service	Martinez, Manuel	South
Service	Rojas, Alfonso	South
Service Team	*Blanco Primary Mirror Support Upgrade Team:* Tim Abbott, Victor Aguirre, Rodrigo Alvarez, Rolando Cantarutti, Omar Estay, Luis Godoy, Rodrigo Leiva, Andrés Montané, Victor Pinto, Rossano Rivera, Victor Robledo, Patricio Schurter, Roberto Tighe, Alistair Walker, and Mike Warner	South

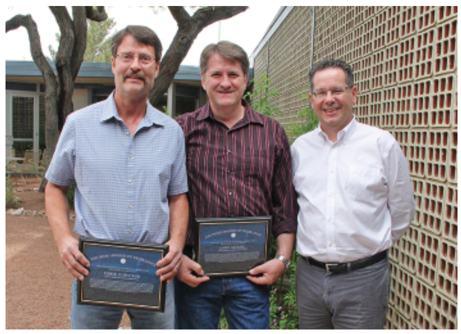
Sharon Hunt

Charles Corson

Nanette Bird

Brenda Kouratou, Bill Porter, Karen Ray, Rod Rutland, Earl Shackelford, Robert Dawson, and Luis Villarreal

John Donaldson, Victor Moreno, Danny Abraham, Keith Blaine, Bob Stupak, and Mike Hawes



Derek Guenther and Larry Reddel

Manuel Martinez

Tim Abbott, Victor Aguirre, Rodrigo Alvarez, Rolando Cantarutti, Omar Estay, Luis Godoy, Rodrigo Leiva, Andrés Montané, Victor Pinto, Rossano Rivera, Victor Robledo, Patricio Schurter, Roberto Tighe, Alistair Walker, and Mike Warner

Victor Robledo, Victor Pinto, and Luis Godoy

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NOAO
950 North Cherry Avenue
Tucson, AZ 85719 USA

Main Number: 520/318-8000
Director's Office: 520/318-8283
Outreach Office: 520/318-8230

Web Site: *www.noao.edu*
General Information: *outreach@noao.edu*

NOAO Science Archive User Support
sdmhelp@noao.edu
IRAF Software Information:
www.iraf.noao.edu
Observing Proposal Information:
sdmhelp@noao.edu

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

Research Support Office: 520/318-8135 & 8279
General Information:
kpno@noao.edu

Visitor Center/Public Programs: 520/318-8726
Visitor Center Web Site:
www.noao.edu/outreach/kpoutreach.html

Cerro Tololo Inter-American Observatory
Casilla 603
La Serena, Chile

Phone: (011) 56-51-205200
General Information: *ctio@noao.edu*

NOAO System Science Center
950 N. Cherry Avenue
Tucson, AZ 85719
USA

Phone: 520/318-8421

Web Site: *www.noao.edu/nssc*
General Information: *nssc@noao.edu*