NOAO NEWSLETTER

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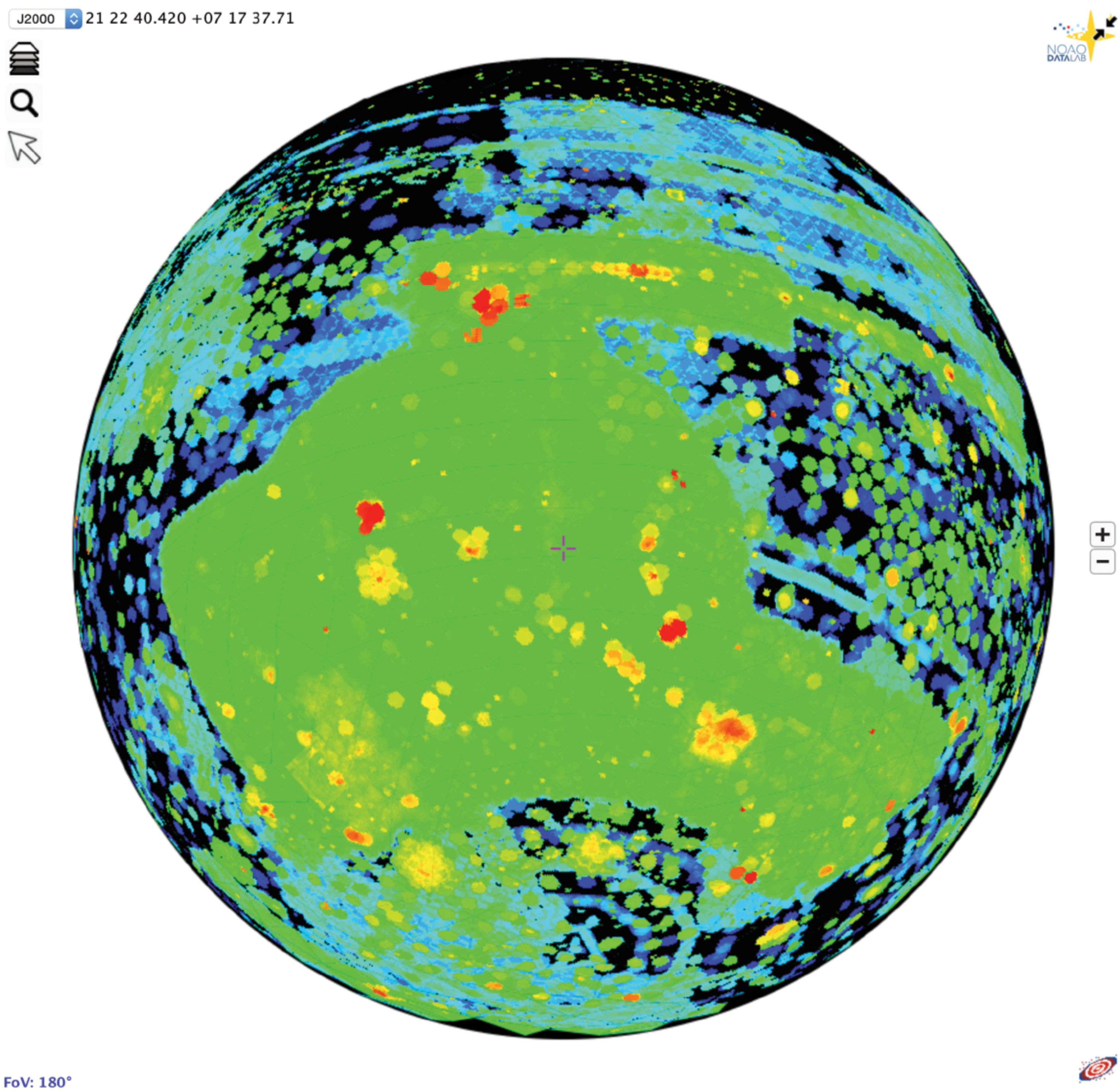

On the Cover

The cover shows a map created using the NOAO Data Lab Data Discovery Tool. This rendition shows the total exposure in science frames taken with any of the DECam, or KPNO and CTIO Mosaic imagers. The sky has been rotated to center on the Dark Energy Survey "footprint." The Data Discovery Tool allows users to compare the exposure map with other surveys, overlay a catalog of field centers, and interactively identify the metadata of the individual images that contribute to the exposure map. (Image credit: L. Huang, P. Marenfeld, and K. Olsen/NOAO/AURA/NSF.)

NOAO Newsletter

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Director's Corner

Any organization can get captured by the now, lose sight of the future, and then lose the future. To enable continued scientific leadership in ground-based optical-infrared (OIR) astronomy and astrophysics by community scientists today and tomorrow, NOAO has engaged in eight strategic initiatives, as described in the *NOAO Strategic Plan: A Forward Look* (*https://www.noao.edu/dir/strategic_plan/NOAO_Strategic_Plan2016.pdf*). Some initiatives focus on enabling research excellence before 2020, while others look towards 2030 and beyond. What are these initiatives and what are current illustrative activities?

Maintaining the vitality of our **observational research infrastructure** on Kitt Peak, Cerro Tololo, and Cerro Pachón (as well as the associated base facilities) requires constant attention. Outside the telescope enclosures, NOAO has been recently focused on our mountain-based water and power distribution systems as well as rehabilitation and modernization of our main buildings in Tucson and La Serena. Inside the telescope enclosures, we have completed or are making progress on instrumentation and control system modernization programs on all four 4-meter-class telescopes. Farther afield, NOAO is working with neighboring observatories in Arizona and Chile to maintain and extend dark sky protections. For NOAO and our tenants (including Gemini South and LSST), this work is absolutely critical for maintaining these sites as cost-effective, world-class research parks.

In the area of **US OIR System optimization**, NOAO has received implementation directives from NSF based on recommendations contained in a 2015 National Research Council (NRC) report (*http://sites.nationalacademies.org/bpa/BPA_087934*). In early FY17, NOAO will submit a plan and supplementary funding request to execute the NSF directives. In the meantime, wherever possible, NOAO has endeavored to shape our existing, funded program to be consistent with the spirit of the NRC recommendations, as noted below.

The amount and quality of **premier survey data products** enabled and/or served by NOAO continues to expand rapidly, currently driven by surveys underway with the Dark Energy Camera (DECam) at the CTIO Blanco 4 m and the Mosaic-3 Imager at the KPNO 4 m. An overview of major surveys is available online (*http://ast.noao.edu/data/surveys*). NOAO is also seeking deeper relationships with other major survey data providers.

Data science tools and services was the central theme of the NOAO presence at the June 2016 AAS meeting in San Diego. In particular, the NOAO Data Lab (*http://datalab.noao.edu*) was publicly demonstrated for the first time. In the meantime, the ANTARES (*www.cs.arizona.edu/projects/tau/antares/*) event broker project (a collaboration with the U. of Arizona Department of Computer Sciences) has been meeting regularly with the time domain research community and making steady progress on completing a fully functioning prototype. As an aside, developing event brokers was one of the NRC OIR System Optimization study recommendations. Both projects are being implemented to serve community research aspirations now as well as during the LSST era.

Looking towards **LSST operations and community research support** in the early 2020s, the partnership between LSST and NOAO has grown significantly in recent months as joint planning has become more detailed and richer. The Kavli Foundation–sponsored, NSF-endorsed community workshop on desired research infrastructure in the LSST era is one manifestation of closer LSST/NOAO collaboration, as well as being a joint follow-up to another one of the NRC OIR System Optimization study recommendations. Further LSST/NOAO collaboration can be seen in the participation of former and current NOAO personnel in LSST operations planning. As a final example, discussions are underway between LSST, Gemini, and NOAO about how to collaborate on day-to-day technical operations as well as how NOAO and Gemini facilities will support observational research programs motivated by LSST survey results. Looking forward, it is clear that the intellectual and technical collaboration between LSST, Gemini, and NOAO in Arizona and Chile will be strong and broad.

Although less concrete progress has been made recently in the area of **GSMT operations and community research support**, NOAO is well aware of strong community interest in significant public access to the Giant Magellan Telescope (GMT) and/or Thirty Meter Telescope (TMT) projects, no matter when these projects reach fruition. Alas, the path to federal funding for such access remains highly uncertain. The mid-decadal progress report on implementing the recommendations of the 2010 Decadal Survey is due shortly and will likely opine on this topic. In the meantime, NOAO continues to manage a community engagement program on behalf of a cooperative agreement between the NSF and TMT, while NOAO scientists participate in GMT science program activities.

What lies **beyond LSST and GSMT** in the 2030s and later? During the past year, I have asked this question often in small and large groups. One common answer appears to that the Next Big Thing is still GSMT, that the science case for such a machine is still very strong, and that the US public community needs access to such a machine to remain competitive at the world level. But the question still remains, what science-driven aspirations exist for something big beyond GSMT? Today, the answer seems to be "none," which I find surprising. There is no lack of ideas for giant machines in the worldwide space and radio communities. What does the lack of new ideas from the ground-based OIR community say about the state of our field? Clearly, this is a topic with broader community discussion, with a NOAO organized workshop as one forum.

As do all our strategic initiatives, **public engagement in the NOAO science enterprise** also requires continuous improvement and modernization. Over the next 12–18 months, we will be extensively renovating and expanding facilities, scientific displays, and observing capabilities at our popular visitor centers on Kitt Peak and Cerro Tololo. A major theme is to better illuminate how large surveys and data sets as well as time domain exploration are enabling experimentation and exploration by NOAO and community scientists in the nearby Universe (including cislunar space and the solar system) as well as on cosmological scales.

In short, although "the now" keeps us plenty busy, NOAO has not lost sight of the future and what we need to do in collaboration with community scientists, community institutions, and our AURA partners to create the strongest possible future.

Onward!

Mapping the Sky for All: An Update on the DECaLS and MzLS Surveys

Arjun Dey (NOAO), David Schlegel (Lawrence Berkeley National Laboratory), and Dustin Lang (Dunlap Institute, University of Toronto)

The Dark Energy Spectroscopic Instrument (DESI; *http://desi.lbl.gov*) is a 5000-fiber, 8 sq. deg. field-of-view multi-object spectrometer currently under construction for the Mayall 4 m telescope that will undertake the great cosmography survey of the next decade. It will determine redshifts for more than 30 million galaxies and quasars and thereby provide constraints on cosmological parameters with sub-percent precision. In preparation for the DESI spectroscopic survey, NOAO telescopes are being used to produce a public imaging survey covering 14,000 sq. deg. of the extragalactic sky. The goal is to complete the imaging surveys prior to the start of DESI operations in 2019.

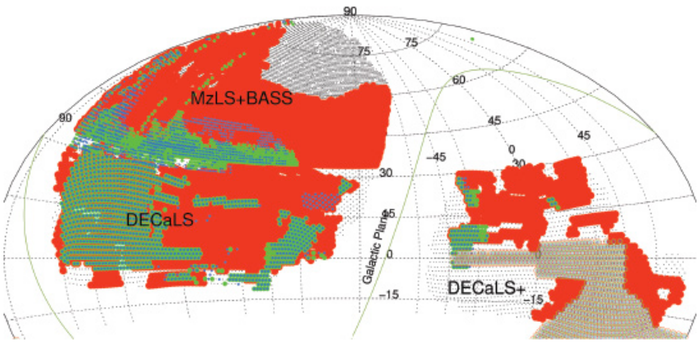

Figure 1: The footprints of the DECaLS, MzLS, and BASS surveys. The small black dots show the footprint of the planned DESI survey. The blue, green, and red symbols represent, respectively, the regions with at least one g, r, or z-band Legacy Survey observation. A portion of the DESI footprint in the South Galactic Cap region lies within the footprint of the Dark Energy Survey (DES; e.g., Dark Energy Survey Collaboration 2016). These DES data are reduced by the NOAO Community Pipeline and included in the Legacy Survey data releases.

The DECam Legacy Survey (DECaLS; NOAO Prop. ID 2014B-0404; PIs: David Schlegel and Arjun Dey) is using the Dark Energy Camera (DECam) on the Blanco 4 m telescope at CTIO to cover the DESI footprint south of δ ~ +34° in three optical bands (g, r, and z) to 5-σ point source depths of at least g = 24.0, r = 23.4, and z = 22.5 AB mag. The survey, which began in 2014B, has completed approximately 35% of the imaging. The Mayall z-band Legacy Survey (MzLS; NOAO Prop. ID 2016A-0453; PI: Arjun Dey) is using the newly upgraded Mosaic-3 camera on the Mayall telescope at KPNO to map the DESI footprint north of δ ~ +34° in the z-band to the same depth. The MzLS survey is roughly 50% complete. These two surveys are complemented by the Beijing-Arizona Sky Survey (BASS; PIs: Xu Zhou, NAOC, and Xiaohui Fan, University of Arizona), which will provide g- and r-band coverage over the MzLS footprint. The coverage of the surveys is shown in Figure 1.

The DECaLS and MzLS surveys are imaging the sky in three passes, with at least one pass providing photometric and good-seeing images. The observing is being carried out in a highly optimized observing mode. The integration times for each exposure are dynamically tuned according to observing conditions to ensure a roughly uniform depth survey. The observing is done by software ("obsbot," publicly available at *https://github.com/legacysurvey/obsbot*) that analyzes the images as they are taken, creates the necessary observing scripts, and updates the observing queues.

The raw data (from all three surveys) are publicly available as soon as they appear in the NOAO Science Archive, typically within a few hours of being obtained. The calibrated data from DECaLS and MzLS surveys are publicly available, and calibrated data from the BASS survey are expected to be available in the coming months. In addition, the Legacy Survey project releases catalogs and other data products on six-month timescales, with the first two data releases available at *www.legacysurvey.org*. An image viewer, constructed by Dustin Lang, is available at *www.legacysurvey.org/viewer/*.

Figure 2: A frame from the interactive image viewer (*www.legacysurvey.org/viewer*) centered near RA = 346.33 and DEC = 0.826. Users can search the survey images and other related data products and explore the catalog. Access to the catalog is also available from the NOAO Data Lab TAP service at *http://dldb1.sdm.noao.edu/tap*.

The Legacy Survey data releases also include forced-photometry catalogs of the new full-depth WISE images (Meisner et al. 2016). Future releases will include time-resolved mid-infrared photometry from WISE for all optically detected sources within the DECaLS+MzLS footprint. The image viewer also contains new renderings of these WISE data, which recently resulted in the unambiguous confirmation of the X-shaped nature of the Milky Way bulge (Ness & Lang 2016).

DECaLS data releases will be made available through the NOAO Data Lab as soon as its data publication services are ready, likely in early 2017. For additional information about the Data Lab, visit the web page at *datalab.noao.edu* and see the article, "The NOAO Data Lab at the AAS Meeting," elsewhere in this *Newsletter*.

The DECaLS and MzLS projects are being run as public efforts and are jointly supported by the DESI Project, LBNL, and NOAO. Astronomers interested in participating are encouraged to contact the PIs.

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The NEWFIRM-HETDEX Survey: Probing the Growth of Galaxies with Cosmic Time

Steven Finkelstein & Matthew Stevans (The University of Texas at Austin)

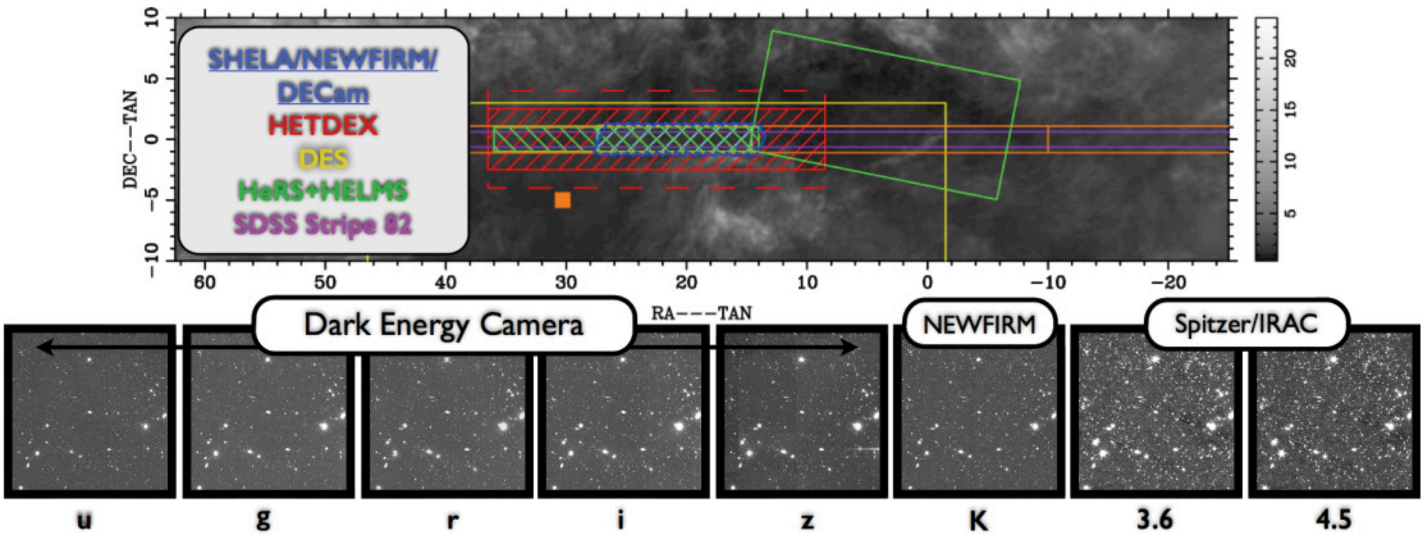

Figure 1: Top: The 24 square degree footprint of HETDEX/SHELA (dark blue). Also shown are the footprints of the HETDEX equatorial field, the Dark Energy Survey, and two Herschel/SPIRE surveys, as well as SDSS Stripe 82. Bottom: Cutouts showing a 10 arcmin region of the HETDEX/SHELA field in our optical DECam data, near-IR NEWFIRM data, and mid-IR IRAC data.

Similar to the common nature-versus-nurture debate for human development, we do not yet know the importance of environment when it comes to the growth of galaxies. And galaxies do grow—our Milky Way galaxy is now 100 to 1000 times more massive than the earliest galaxies we can see in the Universe. Clearly, galaxies must grow their stellar masses (through the process of forming new stars out of gas) over the age of the Universe. Do galaxies grow mostly in isolation, calmly absorbing gas from the all-encompassing intergalactic medium (known as secular evolution), or are galaxy mergers, cataclysmic events marked by episodes of intense star formation, the dominant mechanism for growth? We have embarked on a large spectroscopic and imaging survey to help address these questions. A key component of this work is the NEWFIRM-HETDEX survey, which is operated under the NOAO Survey Programs. The NEWFIRM-HETDEX survey was awarded time on the Kitt Peak National Observatory (KPNO) Mayall 4 m telescope to use the NEWFIRM camera to obtain near-IR images of the survey area.

Our understanding of how galaxies evolve has been revolutionized over the past few decades, as powerful space telescopes and large ground-based observatories have allowed us to peer back to within less than one billion years from the Big Bang. However, the story of galaxy evolution is still far from complete, as many deep surveys probe only relatively small regions in the Universe and therefore do not allow us to understand the role environment plays in galaxy evolution. There is a strong need for a new survey, one that is both large in area, allowing us to see the wide range of cosmic environments from lonely empty voids to the metropolises of the Universe (galaxy clusters), and deep in nature, allowing us to see very faint, distant galaxies.

Over the past few years, a team of astronomers at the University of Texas at Austin, Texas A&M University, and Penn State University has been working to build such a survey, known as the Spitzer-HETDEX Exploratory Large Area (or SHELA) survey (Figure 1). HETDEX stands for the Hobby Eberly Telescope Dark Energy Experiment, which will be obtaining spectroscopy over this full field starting fall 2016. This survey got its start, as the name hints, with Spitzer Space Telescope mid-infrared imaging of a 24 square degree region of the night sky (a region nearly 20,000 times larger than the deepest Hubble fields, >10 times larger than the largest deep ground-based survey). We soon augmented our survey with optical imaging from the Dark Energy Camera at NOAO's CTIO Blanco 4 m telescope and far-IR imaging from the Herschel Space Observatory.

The size of this survey is optimal for studying galaxy growth as a function of environment, as we expect it to contain more than 10 Coma cluster progenitors and more than 100 Virgo cluster progenitors—the data set is not yet complete. While the imaging available would allow us to in principle measure the rates of star formation in these galaxies by the intensity of a galaxy's light, it would not allow us to correct for light blocked by the cosmic dust ubiquitous in galaxies across the Universe. For this, we needed imaging to link our optical and mid-infrared imaging, which is where NEWFIRM comes in. While near-infrared imagers like NEWFIRM are becoming more common, NEWFIRM has one of the largest fields-of-view for a near-IR camera, allowing a survey of the size of SHELA to be done. The NEWFIRM-HETDEX survey was thus born, with an initial allocation of 66 nights on the KPNO Mayall 4-m telescope.

Our final observing runs will take place this fall, at which time we will have completed the imaging of our full 24 square degree field with NEWFIRM and can fully begin to understand how environment affects galaxy evolution. In the meantime, we have already begun to use this exquisite data set to search for some of the rarest, brightest galaxies in the distant universe (Figure 2), with early results pointing to more of these galaxies than one would expect based on searches in smaller fields. This implies that there are many interesting aspects of the distant Universe awaiting discovery, and our survey provides a unique data set to contribute to this exciting field.

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The NEWFIRM-HETDEX Survey continued

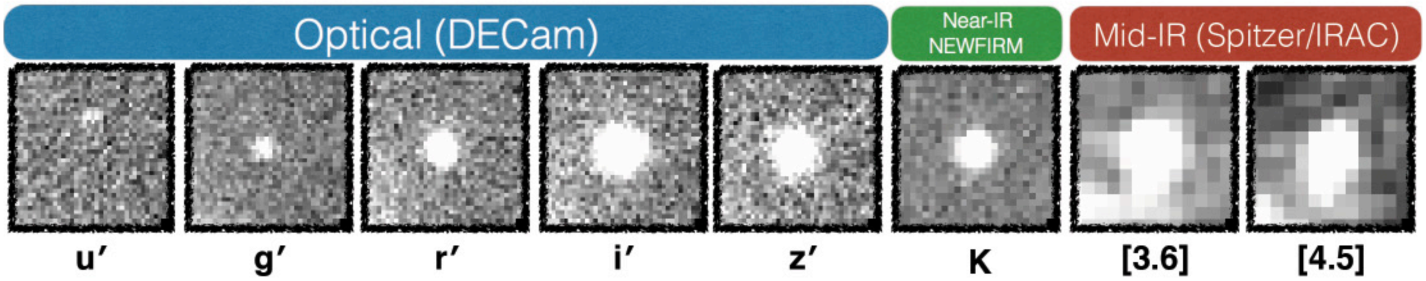

Figure 2: Stamp images of the brightest galaxy found at z ~ 4 in our galaxy sample. The detection of this galaxy in the NEWFIRM imaging not only allows a robust measurement of its rate of star formation but also allows us to place better constraints on its redshift.

A Young Mammoth Cluster of Galaxies Sighted in the Early Universe

Kyoung-Soo Lee (Purdue University)

Kyoung-Soo Lee and a team of collaborators that includes Arjun Dey (NOAO), Naveen Reddy (University of California, Riverside), Michael Cooper (University of California, Irvine), Hanae Inami (Observatoire de Lyon, France), Sungryong Hong (University of Texas, Austin), Anthony Gonzalez (University of Florida), and Buell Jannuzi (University of Arizona) confirmed the discovery of one of the largest and most overdense high-redshift structures, located 12 billion light-years away in the constellation of Boötes. The team identified the candidates of structure members using the NOAO Mayall 4 m telescope and then measured their cosmological redshifts using the Keck DEIMOS spectrograph. The confirmed structure will evolve into one of the most massive galaxy clusters by the present time, appearing similar to the Coma cluster and having a total mass larger than 10^{15} $M_{\odot}$. The young forming cluster, dubbed as the PC217.96+32.3 protocluster, will allow astronomers to directly witness and study the formation histories of cluster galaxies in young universe.

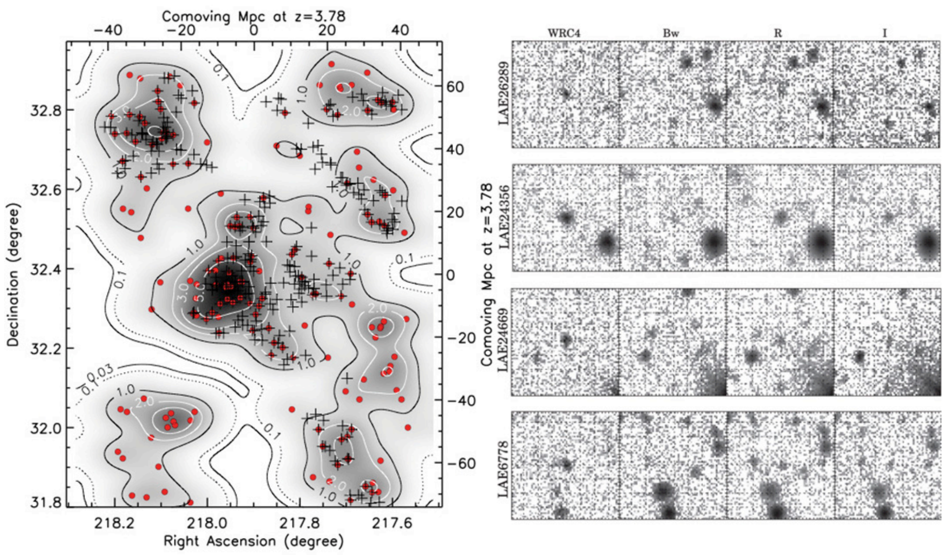

Figure 1: Left: The angular distribution of 165 candidates of Ly-α emitting galaxies. Each galaxy is marked as red circles, while the grey scale shade and contours show the smoothed density map of the imaged field. Crosses mark the positions of galaxies with spectroscopic observations Right: Examples of Ly-α emitting galaxies. At z = 3.78, Ly-α emission redshifts into the WRC4 filter. Galaxies with strong Ly-α emission at this redshift will appear brighter in the WRC4 filter than in the others.

Galaxy clusters are the largest, most massive structures in the Universe that are bound together by gravity. According to the theory of galaxy formation, it is expected that galaxy clusters mark the sites of the highest-density peaks of the initial matter fluctuation. The relative density enhancement of these regions grows throughout the cosmic time. Galaxy formation within a protocluster may possibly start earlier and at a larger scale than occurs in the lower-density field environment. Locally, it is well established that high-density cluster environments have a profound effect on the physical properties of their members. Cluster galaxies are older and more massive than field galaxies; they also predominantly have elliptical morphologies and show little star formation. This suggests that the present-day cluster galaxies may have formed the bulk of their stars at high redshift and subsequently evolved passively with little star formation (Stanford et al. 1998, Van Dokkum & van der Marel 2007; Eisenhardt et al. 2008; Snyder et al. 2012). However, the detailed star formation and mass assembly histories of typical cluster galaxies and how these differ from those of field galaxies is not well understood. It is also unclear how and when their star formation was "quenched." Crucial information on these processes may be obtained by witnessing directly how galaxies form and evolve within structures that will likely evolve to a massive cluster.

PC217.96+32.3 was initially discovered as a concentration of five galaxies at z = 3.78 (Lee et al. 2013). At that redshift the Ly-α emis-

continued

sion line (the strongest nebular emission in a normal galaxy) is redshifted into the NOAO narrow-band WRC4 (Wolf-Rayet CIV) filter at 5820Å. Any galaxy with strong Ly-α emission will appear brighter in that filter than in other filters (Figure 1, right). Using this observational signature, the team conducted deep imaging of a large area with multiple filters, including the WRC4 filter centered on these five galaxies, and identified 165 candidates for Ly-α emitting galaxies. At z = 3.785, the imaged area covers ~150 Mpc × 70 Mpc in a comoving transverse area. The angular distribution of these galaxies revealed a region showing a high concentration of galaxies surrounded by a vast void (Figure 1, left; Lee et al. 2014; Dey et al. 2016).

The team then used the Keck DEIMOS optical spectrograph to observe 100 of the 165 candidates to measure their cosmological redshifts. Redshift measurements unambiguously confirmed that the candidates are indeed nearly at the same distance (Figure 2, left) and that these regions represent unusually high overdensities of galaxies (Dey et al. 2016). Furthermore, the team discovered that the highest overdensity region consists of two distinct groups, with a small velocity offset and "streams" of galaxies towards these groups (Figure 2). The observed kinematic structure of PC217.96+32.3 strongly suggests that it is undergoing an active stage of merging and assembly, in qualitative agreement with the theoretical expectation that massive structures such as galaxy clusters form hierarchically by merging with one another over cosmic time.

Based on the size and level of overdensity of PC217.96+32.3, the team estimated that, by the present time, the structure will evolve to a Coma-like galaxy cluster with total masses of ~1015 $M_{\odot}$. As the most massive high-redshift cluster progenitor confirmed to date, PC217.96+32.3 serves as a rare cosmic laboratory to study how galaxy clusters and their constituents form. To that end, the team is continuing their effort to further identify and characterize the members of PC217.96+32.3. In parallel, they are also searching larger areas of sky to uncover more examples of such massive protoclusters. A large sample of protoclusters is needed to carry out a statistically robust study and to understand the possibly varied formation history of cluster galaxies.

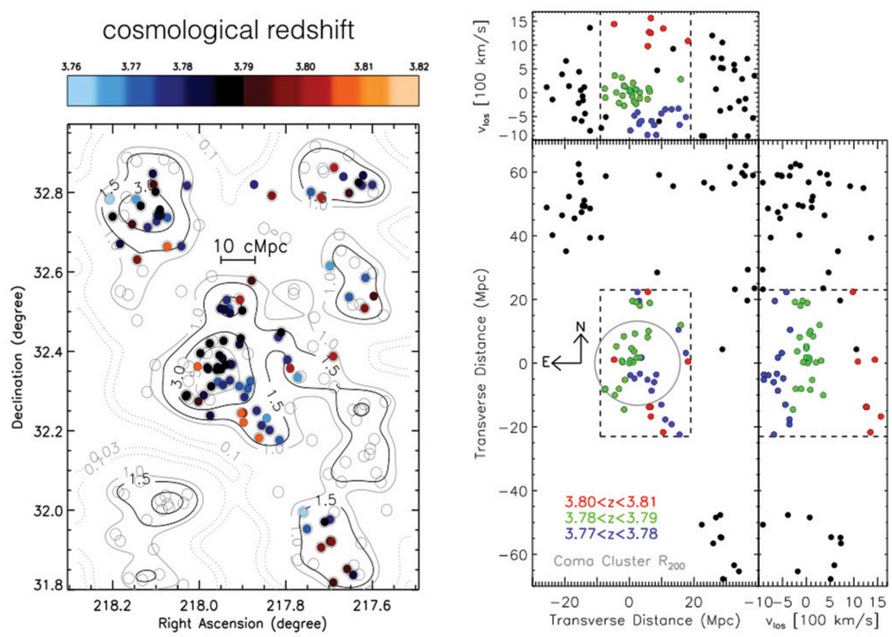

Figure 2: Left: Same as Figure 1 (left) and color-coded by redshifts. Only galaxies with z = 3.76–3.82 are marked with color-filled circles. PC217.96+32.3 (center of image) consists of a large number of confirmed galaxies at the same distance (color). Right: The three-dimensional spatial distribution of spectroscopically confirmed galaxies in PC217.96+32.3. Each circle shows a galaxy with measured redshift in three color groups: z = 77–3.78 (blue), 3.78–3.79 (green), and 3.80–3.81 (red). The top and side panels show projections in velocity space relative to the protocluster center at z = 3.785. The gray circle denotes the radius for the Coma cluster scaled appropriately in comoving angular size. PC217.96+32.3 appears to be made up of at least two groups of LAEs (blue and green dots) separated by ~500 km/s. Smaller groups or streams of galaxies are also present.

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New Objects Discovered Beyond the Outer Edge of the Kuiper Belt

Scott S. Sheppard (Carnegie Institute of Science)

The hunt for Planet X, a possible ninth major planet in our solar system, has led to the discovery of several new objects located beyond the Kuiper Belt. We have been conducting the widest, deepest survey ever obtained to find distant solar system objects. We are interested in objects that are decoupled from the giant planets and inner solar system in order to understand the dynamics and structure of the distant outer solar system. The initial survey was begun in 2007 and used the Mosaic cameras on the Kitt Peak Mayall 4 m and the CTIO Blanco 4 m, SuprimeCam on Subaru, and IMACS on Magellan. Even with these powerful instruments, it was hard to cover tens of square degrees to faint magnitudes. The survey went into high gear with the advent of the Dark Energy Camera (DECam) at the CTIO 4 m. Within the first few months

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New Objects Discovered Beyond Outer Edge of the Kuiper Belt continued

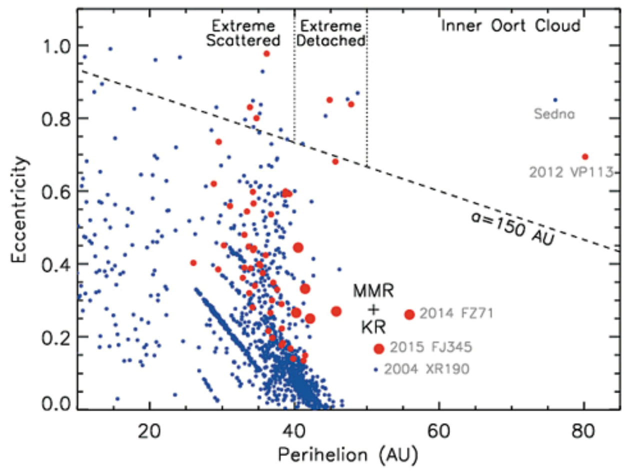

Figure 1: All well-known outer solar system objects with their perihelia and eccentricity. Red circles show objects discovered during this survey, mostly with DECam (large red circles are the focus of the new work). Objects above the dashed line (a > 150 AU) are considered extreme. Objects beyond the Kuiper Belt with high perihelia but moderate eccentricity are likely created by a combination of Neptune Mean Motion Resonances (MMRs) and the Kozai Resonance (KR). (From Sheppard et al. 2016.)

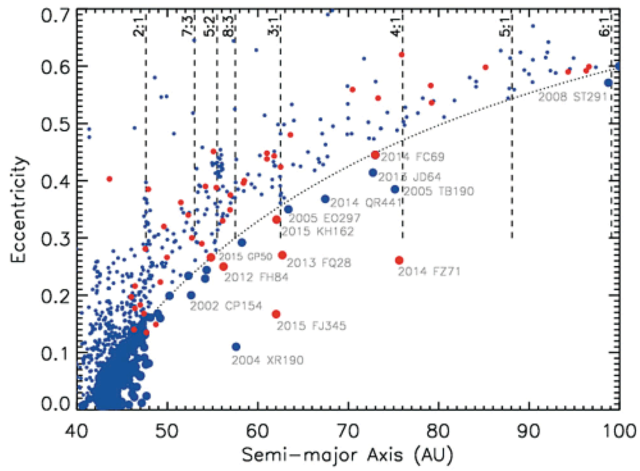

Figure 2: Similar as Figure 1 but now semi-major axis versus eccentricity. The larger circles show objects with perihelia above 40 AU, which is shown by the dotted line. Most of the objects well below the 40 AU line are near strong Neptune Mean Motion Resonances. (From Sheppard et al. 2016.)

of DECam becoming operational, we covered as much sky as all our previous surveys and discovered 2012 VP113, which has the most distant perihelion known. It was through this discovery that Trujillo & Sheppard (2014) noticed that the extreme outer solar system objects, those with high perihelia (q > 35 AU) and distant semi-major axes (a >150 AU), clustered in their orbital angles. This led Trujillo and Sheppard to predict that a Super-Earth to mini-Neptune-mass planet in the outer solar system beyond a few hundred AU is likely shepherding these extreme objects into similar types of orbits.

Our continuing survey, which includes myself, Chad Trujillo (Northern Arizona University), and David Tholen (University of Hawaii), has covered over a thousand square degrees and has now found two objects, 2014 FZ71 and 2015 FJ345, that have the third and fourth most distant perihelia (Figure 1). Interestingly, the orbits of these new objects don't have large semi-major axes or eccentricities like those of the extreme objects 2012 VP113 or Sedna. In fact, these new objects have moderate eccentricities and semi-major axes, and they occupy the region of space just beyond what is known as the Kuiper Belt edge at 48 AU. As such, these objects would not be strongly affected by the hypothesized distant Planet X, but they do provide information on the orbital migration of Neptune in the early history of the solar system.

We find that these new objects have significant inclinations (I > 20 deg) and are near strong Neptune Mean Motion Resonances (MMRs), which suggests they were placed into this region through Neptune interactions (Figure 2). These objects likely obtained their unusual orbits by being scattered by Neptune, and through a combination of Neptune's MMRs and the Kozai-Lidov high inclination resonance (KR), their orbits were stabilized and lifted beyond the Kuiper Belt. A companion paper by Kaib & Sheppard (submitted) shows that these kinds of objects have orbits that were shaped by Neptune's ancient orbital migration. Thus these objects give new insights into how slow and grainy the movement of Neptune was during its outward migration.

From numerical simulations with the eight major planets, we find that the new objects have stable semi-major axes, but their inclinations and eccentricities can vary widely from MMR+KR interactions. The inclinations were found to vary between about 10 and 35 degrees, and the eccentricities were found to vary inversely with inclination between 0.2 and 0.65. A simulation including the possible massive outer ninth planet predicted by Trujillo & Sheppard (2014), with the rudimentary orbit Batygin & Brown (2016) derived for it, show that it would have no effect on the stability of these objects.

Another interesting discovery from the survey is 2012 FH84. This object has a high perihelion but very low inclination (3.6 degrees) and is just beyond the Kuiper Belt edge. 2012 FH84 cannot be explained by the MMR+KR mechanism and likely has a very different origin. 2012 FH84 is in the outer classical Kuiper Belt. These are a handful of objects that are just beyond the 48 AU Kuiper Belt edge and have low inclinations. These objects are likely related to the low inclination main classical Kuiper Belt between 44–48 AU, but their true nature is not fully understood and should further constrain how the outer Kuiper Belt has been sculpted over time.

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Hunting for Electromagnetic Counterparts to Gravitational Wave Events with DECam

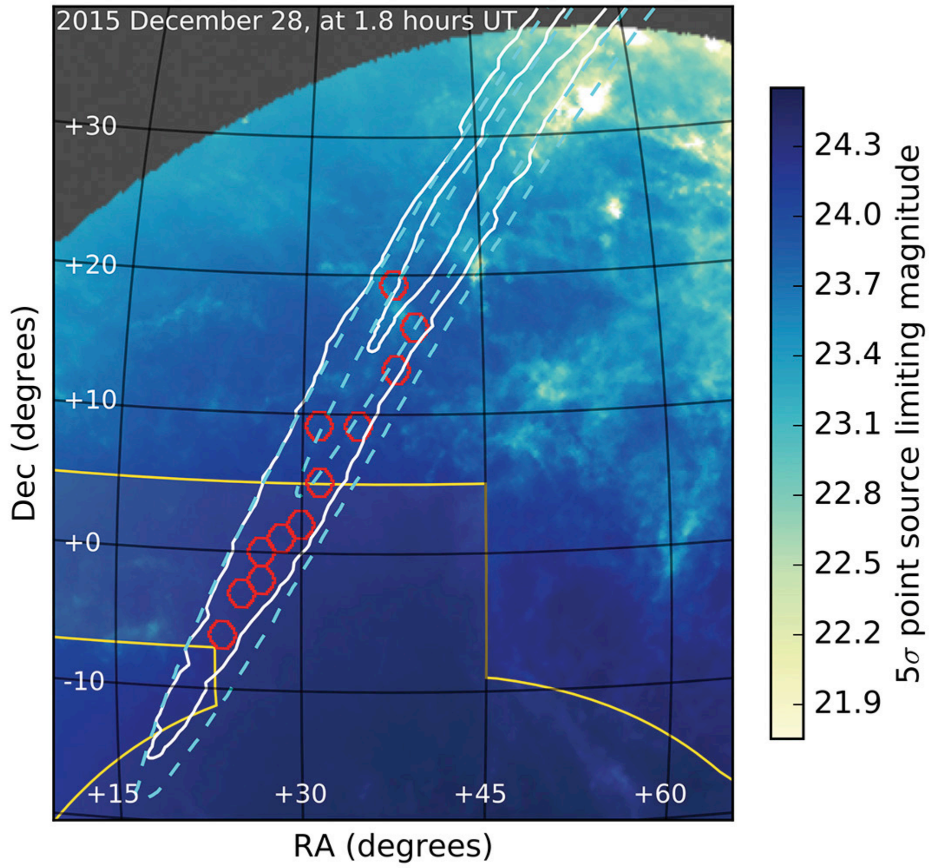
Philip Cowperthwaite (Harvard CfA)

A new era of astronomy began on 14 September 2015 when the Advanced Laser Interferometer Gravitational Wave Observatory (LIGO) made the first direct detection of gravitational waves (GW). The event, designated GW150914, was determined to result from the inspiral and merger of two stellar mass black holes. This was the first observational evidence that such systems exist and merge. Advanced LIGO detected a second high-significance event, GW151226, on 26 December 2015. This event, like GW150914, was consistent with the merger of a binary black hole (BBH) system comprised of two stellar-mass black holes at a redshift of $z \approx 0.09$.

These are monumental discoveries that usher in an exciting new regime of gravitational-wave astronomy. A major open question, however, is the nature of electromagnetic (EM) counterparts associated with GW events. The first step to answering this question is to find a counterpart by any of radio, IR, optical, X-ray, or gamma-ray emission. The Dark Energy Camera (DECam) at the CTIO Blanco 4 m telescope provides an excellent instrument for optical-counterpart searches, and it has already been "battle tested" in the search for counterparts to GW150914 and GW151226.

In the case of a merger involving at least one neutron star (NS), the most promising counterpart is the kilonova, a short-lived isotropic optical/NIR transient powered by the radioactive decay of r-process elements synthesized in the merger. However, when considering the merger of a BBH system, there are no strong theoretical predictions for the expected EM counterpart at this time. Nevertheless, it is still important to conduct follow-up observations for events like GW150914 and GW151226 as the identification of an EM counterpart would be a novel discovery and dramatically improve the science gains from the GW detection.

Unfortunately, the large localization regions associated with a GW detection present an enormous observational challenge for follow-up efforts. Both GW150914 and GW151226 were localized to sky regions that were several hundred square degrees. This makes the DECam wide-field imager, with its 3 deg^2 field-of-view, an ideal tool to follow up sky localization regions in the Southern Hemisphere. To this end, our DES-GW program is a joint effort between members of the Dark Energy Survey (DES) and the community using DECam to conduct follow-up observations of GW events detected by Advanced LIGO. Our program has conducted follow-up observations of both GW150914 (Soares-Santos et al. 2016; Annis et al. 2016) and GW151226 (Cowperthwaite et al. 2016) and is one of the most competitive programs for optical follow-up.



Visual representation of the sky region covered by our DECam observations. The 12 red hexagons indicate our DECam pointings covering the 50% and 90% probability region contours from the localization maps for GW151226. The background color indicates an *estimated* 5σ point source limiting magnitude for a 90 s i-band exposure as a function of sky position. The yellow contour indicates the Dark Energy Survey (DES) footprint. Our observations correspond to 3% of the probability in the initial localization sky maps. The coverage of the LIGO localization region was limited by poor weather and the time available to observe this sky region given its high airmass ($X \approx 1.5$–2.5).

In the case of follow-up for GW151226, our program conducted observations covering four epochs from 2–24 days after the initial GW detection in i- and z-band to median 5σ sigma depths of $i \approx 22.2$ and $z \approx 21.9$ mag. We were able to cover 28.8 deg^2 of sky corresponding to 3% of the contained probability in the localization sky maps (see the Figure).

When sifting through these data for an EM counterpart, we must contend with the contamination that results from numerous other variable and transient sources that occupy the large localization regions. The effect of this contamination can be mitigated by developing prior constraints on the expected source behavior. In the case of GW151226, we searched our data for rapidly declining transients. This was

continued

New Objects Discovered Beyond Outer Edge of the Kuiper Belt continued

motivated by considering the generic example of optical emission similar to a short gamma-ray burst (SGRB) afterglow. If the afterglow is viewed far off-axis, then at the distance to GW151226 the emission will be too faint and undetectable in our observations. If the source is viewed moderately off-axis or on-axis, then it will be detectable during our first epoch and will decline throughout subsequent epochs. Similar arguments can be applied to a transient resulting from a non-relativistic outflow, as this is likely to involve a low amount of ejecta mass and thus become optically thin quickly, leading to fading emission.

Following this line of reasoning we searched our data for rapidly declining transients, finding no credible counterpart associated with GW151226. However, one particularly interesting candidate was discovered on the outskirts of a nearby galaxy ($z = 0.041$). It exhibited a red i-z color of i-z = 0.3 mag along with a rapid decline of 0.12 mag/day in i-band. This decline is shallower than expected for a SGRB afterglow. We also compared this behavior to that expected for a kilonova, finding that while the timescale roughly agrees, the i-z color was bluer than expected.

As it happens, this source is the supernova (SN) PS15cdi, which was first discovered by the Pan-STARRS Survey for Transients (PSST) 94 days prior to the detection of GW151226. The most likely explanation for the behavior seen in our data is that PS15cdi was a Type IIP SN undergoing a rapid decline during the transition out of its hydrogen recombination driven plateau phase. Both the timing of our observations (≈100 days post-explosion) and red color i-z ≈ 0.3 are consistent with observations of this transition in other Type IIP light curves (e.g., SN2013ej).

The question then becomes, "How unlucky is the appearance of PS15cdi in our data?" Answering these types of questions allows us to better understand unexpected sources of contamination that appear during these follow-up efforts. We estimated that the expected number of events within our search area is about 0.04. The detection of PS15cdi, during this phase of its light curve, was unlikely, and we expect less than one such event in a typical GW localization region.

While the appearance of PS15cdi in our data was unlucky, the light curve features presented are interesting. If we were conducting follow-up of a GW event thought to contain at least one neutron star, then PS15cdi would satisfy a set of cuts used to identify a kilonova (e.g., red i-z colors and rapid decline). This would have resulted in using other photometric and spectroscopic resources to chase down a false positive. PS15cdi is a clear reminder of the impact of contamination on these follow-up efforts, and its appearance highlights the important albeit difficult task of conducting real-time identification and follow-up of GW events.

The second Advanced LIGO observing run (designated O2) is set to begin in fall 2016. This run will be longer in duration and feature improved sensitivity compared to the fall 2015 observing run (O1). O2 is expected to yield numerous new GW detections, and our program is well poised to continue our follow-up efforts.

References

Annis, J., Soares-Santos, M., Berger, E., et al. 2016, ApJ, 823, L34

Cowperthwaite, P. S., Berger, E., Soares-Santos, M., et al. 2016, arXiv:1606.04538

Soares-Santos, M., Kessler, R., Berger, E., et al. 2016, ApJ, 823, L33

The NOAO Data Lab at the AAS Meeting

Pat Norris

Figure 1: Data Lab team member Ken Mighell discusses the project with students visiting the booth. (Image credit: Pat Norris/NOAO/AURA NSF.)

Figure 2: Jim Ulvestad, NSF Division Director for Astronomical Sciences, is shown Data Lab tools by Project Scientist Knut Olsen. (Image credit: Pat Norris/NOAO/AURA/NSF.)

The Data Lab team successfully met the milestone of demonstrating proof-of-concept tools at the 228th meeting of the AAS in San Diego, CA. The team showed off their hard work with a display that highlighted the Big Data mission at NOAO.

The booth had Data Lab demos displayed on an iMac and on a larger display. A movie of the build-up of NOAO's optical image holdings over time was displayed when demos were not being presented. The movie showed the primary motivation for building the Data Lab: whereas a decade ago, NOAO's archived images amounted to a sprinkling of data over a small fraction of the sky, today they cover nearly the entire sky. The Data Lab aims to provide infrastructure to allow the community to efficiently explore these enormous data holdings.

Members of the team were available to answer questions and discuss the flexibility of the Data Lab approach (Figure 1). The team members demonstrated the new Data Discovery tool, an image access service, interactive data tools, and an array of examples written as iPython notebooks. Links to these tools are available on the Data Lab web page (*http://datalab.noao.edu*).

The booth attracted a diverse group. Attendees were interested in the new technologies and concepts behind the Data Lab. Some of the more experienced folks brought questions about how their legacy tools could be accommodated. The Data Lab team was pleased to have the opportunity to present to teams from other institutions and to several NSF staff, including Jim Ulvestad, Pat Knezek, and Ed Ajhar (Figure 2). All questions were duly noted for consideration in future Data Lab development, as the entire meeting represented an important opportunity for feedback from community members.

With the planned public release in summer 2017 now less than a year away, the Data Lab team was pleased to have successfully exhibited proof-of-concept versions of multiple tools. Overall, the Data Lab generated a great deal of interest, leaving team members looking forward to a busy schedule to meet expectations with the planned public release.

The 2016 TMT Science Forum in Kyoto

Mark Dickinson

This year's Thirty Meter Telescope (TMT) Science Forum took place May 24–26 in Kyoto, Japan, the first time this annual event has been hosted outside the United States. The Asian venue was highly relevant to this year's meeting theme: International Partnership for Global Astronomy. Astronomical research programs and observatories are now often international efforts, as the worldwide scientific community combines its intellectual and financial resources to accomplish increasingly complex and costly projects. The TMT International Observatory (TIO) unites astronomers in Canada, China, India, Japan, and the United States to build and operate a telescope whose sensitivity and angular resolution will enable ground-breaking discoveries in nearly every aspect of astronomy and astrophysics. This year's meeting stressed the ways in which TMT's partners are working together to plan TMT's future science programs, its instrumentation and AO capabilities, and the observatory operations.

Future-generation instrumentation was a special focus at the Kyoto meeting. TMT plans three early-light instruments: a diffraction-limited Infrared Imaging Spectrometer (IRIS), a seeing-limited Wide Field Optical Spectrometer (WFOS), and an AO-assisted Infrared Multi-object Spectrometer (IRMS). The Forum featured plenary talks covering a wide range of possible future instruments, including near-infrared and optical high-resolution spectrographs, thermal-infrared instrumentation, extreme high-contrast imagers and spectrometers, and wide-field, AO-

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The 2016 TMT Science Forum in Kyoto continued

Participants at the TMT Science Forum, 2016 May 24–26, Kyoto, Japan. (Image credit: Fumihide Iwamuro/Kyoto University.)

assisted, near-infrared spectrographs using multiple deployable integral field units. A full day was devoted to parallel sessions: morning breakout sessions organized by science theme, where participants discussed ambitious science programs and the instrumentation they would need to accomplish them, followed by afternoon breakout sessions organized by classes of instrument capabilities. A final session gathered everyone together to summarize these discussions. These Forum sessions serve as input to the TMT Science Advisory Committee, which will continue to discuss and synthesize the TMT community's priorities before a call for competitive instrument design studies, anticipated in 2017.

The Kyoto Forum featured talks by astronomers from all of the TIO international partners, who examined TMT's capabilities to advance research on the solar system, exoplanets, star and planet formation, stellar and interstellar medium chemical evolution, close binary stars, gravitational wave sources, supernovae, supermassive black holes, and the formation and evolution of galaxies. There were discussions of cross-partnership coordination for TMT key project science and for observatory operations. Gordon Squires (TMT) and Lisa Hunter (director, Akamai Workforce Initiative) presented TMT's ongoing development of international programs for education, public outreach, and workforce training. Subaru Telescope director Nobuo Arimoto discussed international collaboration for astronomy in Asia and the future evolution of Subaru's instrumentation and operations plans as Japan moves into the era of TMT.

Although TMT's first light is still a decade away, the high level of enthusiasm among the Kyoto Forum participants demonstrated the many ways in which the members of TMT's international consortium are working together toward an era of new science with giant telescopes. As part of its cooperative agreement to develop a model for possible US national participation in TMT, the National Science Foundation (NSF) supported travel to Kyoto for 29 US scientists from the US-at-large community, many of whom gave invited or contributed talks or participated in the science and instrumentation discussions as members of TMT's International Science Development Teams. AURA is an Associate Member of TMT International Observatory on behalf of the US national astronomical community, and NOAO and the US TMT Science Working Group represent the US community's interests in TMT to both the project and to the NSF.

For more information:

2016 TMT Science Forum online presentations and videos:
https://conference.ipac.caltech.edu/tmtsf2016/

NOAO's TMT Liaison office:
http://ast.noao.edu/system/us-tmt-liaison

TMT Site Update

TMT construction remains on hold pending a new contested case hearing and vote by the Board of Land and Natural Resources in Hawai'i. A hearing officer has been selected for the contested case and the process is moving forward. The governing board of the TMT International Observatory has stated that Maunakea remains the preferred site for TMT. At the same time, the TMT project is evaluating alternate sites in both hemispheres where TMT could be built if there is no clear path to restarting construction in Hawai'i by 2018. Sites in Chile, China, India, Mexico, and Spain are under consideration. Concurrent with the site activities, work continues on all aspects of the TMT observatory in the partner countries.

New Faces in the NOAO Datasphere

Adam Bolton

With the advent of wide-field surveys using the Dark Energy Camera (DECam) on the Blanco 4 m telescope at CTIO and the Mosaic-3 camera on the Mayall 4 m telescope at KPNO, and in anticipation of the community-science opportunities to be delivered by DESI and LSST, NOAO has recently established new initiatives to support data science and archival research in both the static-sky and time domain regimes. In support of these initiatives, NOAO has completed a major hiring initiative. We are excited to welcome the following staff members, who will contribute their experience, knowledge, and skills to expanding and improving the capabilities for data-intensive astronomical research available to the US community.

Lijuan (Wendy) Huang, Senior Software Engineer (Data Lab)
Wendy received her master's degree in computer and information technology from the University of Pennsylvania in 2012. She worked as a software engineer in industry during the years following her degree, most recently as an applications developer for the CSAA Insurance Group in Phoenix, AZ. She brings critical expertise to the Data Lab group in her knowledge of web development platforms; data mining, visualization, and machine learning techniques; and a diverse array of programming languages.

Stephanie Juneau, Associate Scientist (Data Lab)
Stephanie comes to NOAO from a staff scientist position at CEA Saclay in France. She received her PhD in astronomy from the University of Arizona in 2011 under the supervision of NOAO's Mark Dickinson. Her research interests are focused on the evolution of galaxies and supermassive black holes across cosmic time. She brings to the Data Lab team a wealth of experience and ideas in developing and applying new methods for turning large survey data sets into scientific knowledge.

David Nidever, Associate Scientist (Data Lab)
David comes to NOAO most immediately from the LSST Data Management and Steward Observatory, where he led LSST's Science Quality and Reliability group. He received his PhD in astronomy from the University of Virginia in 2009. David's research is in the formation, structure, and evolution of galaxies as exemplified by the stellar populations of the Milky Way and its close neighbors. He has extensive survey-science experience, both as an architect of the SDSS APOGEE spectroscopic survey and pipeline and as PI of the SMASH DECam imaging survey of the Magellanic Clouds.

Robert Nikutta, Assistant Scientist (Data Lab)
Robert is coming to NOAO from a postdoctoral fellowship at Pontificia Universidad Católica (PUC) in Santiago, Chile. He received his PhD in astronomy from the University of Kentucky in 2012. Robert's research interests are in the study of the structure of active galactic nuclei through a combination of theoretical, computational, statistical, and multi-wavelength observational methods. Driven by this research, he has developed an impressively broad technical skill set that will be a great asset to the Data Lab team.

Monika Soraisam, Postdoctoral Research Associate (ANTARES)
Monika will receive her PhD in the summer of 2016 from the Max Planck Institute for Astrophysics in Garching, Germany, where she has worked with Marat Gilfanov and Rashid Sunyaev. Her thesis research has focused on progenitors of Type Ia supernovae through studies of novae. She joins the Arizona-NOAO Temporal Analysis and Response to Events System (ANTARES) team, a collaboration between NOAO and the University of Arizona Computer Sciences Department to build a scalable real-time astronomical alert broker system for LSST and other surveys.

Peter (Pete) Wargo, Senior Systems Administrator (Data Management Operations)
Pete comes to NOAO with over 25 years of experience in IT management across multiple industries, most recently with Rensselaer Polytechnic Institute and Albany Molecular Research Incorporated, both in upstate New York. He has managed platforms ranging from desktops to supercomputers. Pete will split his time between the maintenance of Data Management Operations (DMO) IT infrastructure and the development of new systems to support Data Lab services.

Benjamin (Ben) Weaver, Associate Scientist (DESI, SDSS, and Data Management Operations)
Ben received his PhD in physics from UC Berkeley in 2001. Since 2008, he has been a data archive scientist at New York University, where he has played the central role in designing and operating the data management systems of the third Sloan Digital Sky Survey (SDSS-III) and the Dark Energy Spectroscopic Instrument (DESI). At NOAO, Ben will continue to lead the construction of DESI data management systems, contribute to the SDSS-IV project, and lend his considerable expertise in survey-scale data archiving to the Data Management Operations group.

NOAO Time Allocation Process

Verne V. Smith and Dave Bell

Proposal Preparation Information and Submission Help
All information and help related to proposing for telescope time via the NOAO Time Allocation Process is available through the NOAO "Proposal Information" web pages and links. The NOAO website is the definitive location for help with proposal preparation and submission as well as for the most current information available to proposers. See the table below for specific URLs and email addresses.

Accessibility
NOAO is committed to observing accessibility for all qualified proposers. Many of the telescopes available through NOAO support remote observing. To inquire about remote observing and other forms of access, or to request specific accommodations, please contact any of the following indivduals:

Dr. Verne Smith, NOAO TAC Program Head and acting Head of U.S. National Gemini Office (*vsmith@noao.edu*)
Dr. Lori Allen, NOAO Associate Director for KPNO (*lallen@noao.edu*)
Dr. Steve Heathcote, NOAO Associate Director for CTIO (*sheathcote@noao.edu*)
Dr. Adam Bolton, NOAO Associate Director for System Science and Data (*bolton@noao.edu*)

Proposal Preparation and Submission	
Proposal Information and Online Proposal Form	*http://ast.noao.edu/observing/proposal-info*
Time Allocation Committee (TAC) information, approved program lists, proposal request statistics, and telescope schedules	*www.noao.edu/gateway/tac/*
Online Thesis Student Information Form	*www.noao.edu/noaoprop/thesis/*
Assistance	
Proposal preparation	*noaoprop-help@noao.edu*
Gemini-related questions about operations or instruments	Verne Smith (*vsmith@noao.edu*)
CTIO-specific questions related to an observing run	*ctio@noao.edu*
KPNO-specific questions related to an observing run	*kpno@noao.edu*

Getting Ready for the Dark Energy Spectroscopic Instrument (DESI)

R.D. Blum

It has been an exciting and busy year for NOAO and the Dark Energy Spectroscopic Instrument (DESI) project. DESI has moved through its independent project reviews successfully, imaging surveys are covering the sky to provide DESI targets, the science collaboration is growing, and ProtoDESI (see below) is about to be deployed on Kitt Peak.

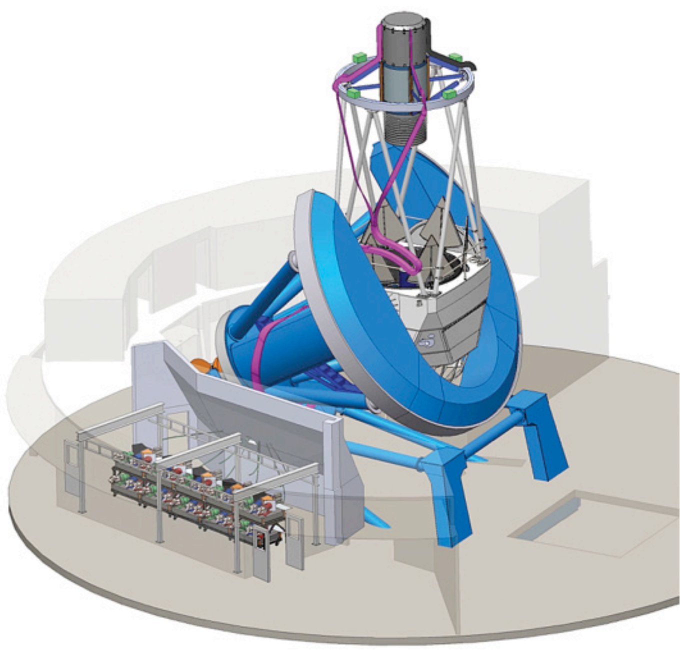


Figure 1: The DESI focal plane and corrector barrel mounted at the top end of the Mayall. The 5000-fiber bundle is routed down the telescope tube and into the Mayall Coudé room. Ten three-channel spectrographs receive 500 fibers each in the environmental enclosure. The enclosure is being designed and delivered by Ohio State University. (Drawing credit: DESI Project, LBNL, NOAO/AURA.)

continued

Getting Ready for DESI continued

DESI is a Department of Energy (DOE) dark energy experiment slated for the NSF Mayall 4 m telescope on Kitt Peak, which is operated by NOAO. The project is led by DOE's Lawrence Berkeley National Lab (LBNL). The instrument will be a state-of-the-art robotic focal plane deploying 5000 robot fiber positioners over an approximately 8 square degree field of view at the Mayall prime focus. The fibers will feed 10 spectrographs (each with three distinct channels to cover the blue to near-infrared, 0.32–1 μm) located in a new environmentally controlled space inside the Mayall Coudé room. A schematic of the instrument on the Mayall is shown in Figure 1.

The instrument will be used to execute a five-year galaxy and quasar survey. The survey is designed to investigate dark energy using the baryon acoustic oscillation (BAO) technique, making a three-dimensional map of the Universe. The survey will measure the redshifts of more than 30 million galaxies providing geometric constraints over a large volume (14,000 square degrees and to distances equivalent to up to approximately 11.5 billion light-years) to place the most precise constraints to date on the expansion history of the Universe and hence the effects of dark energy. DESI will be sensitive to the effects of gravity as well through redshift-space distortions and may possibly test non-standard models of gravity. The observations will also be used to measure the sum of the neutrino masses since the precision of the galaxy survey is expected to be able to detect the effect on the expansion history by the total neutrino mass. Finally, the survey will provide a sample of 10^7 stars in the Milky Way that will be used to investigate the character and history of assembly of the galaxy's dark matter halo.

The DESI Collaboration is preparing the tools needed to exploit this data set for dark energy science. The data will be proprietary for a period, allowing the team to produce the dark energy results, which are being funded by the DOE. However, the data will eventually become public, forming a valuable legacy data set much like the SDSS but to greater depth.

The survey is set to begin in 2019, which is a few short years away. Not surprisingly the project team and science collaboration are busy getting ready. The DESI project is of the order of $50M in direct costs just for the hardware and installation. The bulk of this support comes from the DOE, which runs a rigorous set of independent reviews of the project at various stages from the conceptual design to the final design. In May of this year, the DOE final design review (so-called critical decision three, or CD-3, review) was held in Berkeley at LBNL. The project team successfully passed the review, and the DOE issued a formal CD-3 in June, setting the stage for "full steam ahead!"

The project is now in the full swing of the fabrication phase, with most components to be delivered by 2018 for installation on the Mayall. If the team keeps to its aggressive schedule, then the instrument could receive its first photons in late calendar year 2018.

Indeed, many of the DESI components are well on their way, in part due to early funding from non-federal (US) sources. Figure 2 shows one of the main elements in the optical corrector as it arrived at NOAO for storage until it will be shipped to a special vendor for coating. The lens cells for the corrector are nearly complete at University College London, where the lenses will eventually be installed and aligned into the corrector barrel assembly (the structure that holds all the lenses together to form the complete optical corrector).

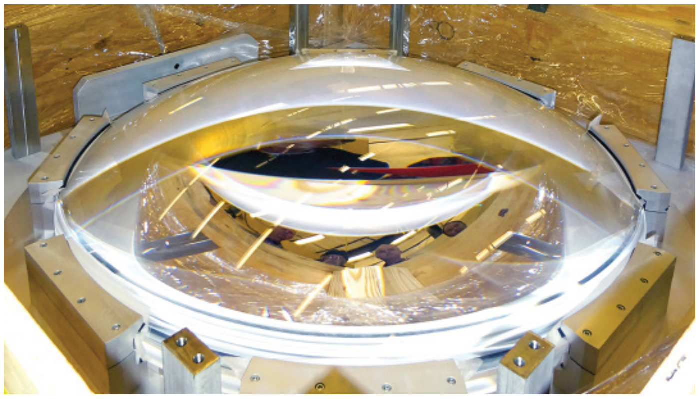


Figure 2: Corrector element C4 (from L3 Brashear) in its shipping container at NOAO. NOAO engineers and scientists (L-R) Gary Poczulp, Ron Probst, Dick Joyce, and Ming Liang view the optic upon its arrival. (Image credit: NOAO/AURA, LBL, DESI Project.)

The initial spectrograph (unit 1 of 10) is well underway in France at the Winlight corporation. The spectrograph is undergoing testing as of this writing and should be complete later this year (see Figure 3). The entire barrel assembly, which holds the corrector elements, focal plane assembly, and electronics, is essentially complete at Fermilab. Fabrication of the ring and cage structure that will hold the barrel to the telescope tube is planned for later this year. Initial units of the fiber robot positioners are being completed at the University of Michigan and will be delivered to LBNL for testing and installation into the ProtoDESI instrument (see below). Fiber cables have been demonstrated at Durham University in the UK as well as the fiber slit assemblies. "Flight" cables and slit assemblies will start fabrication later this calendar year at Durham. The fiber sections (and associated splicing apparatus) that run from the focal plane to the cables are being developed at LBNL.

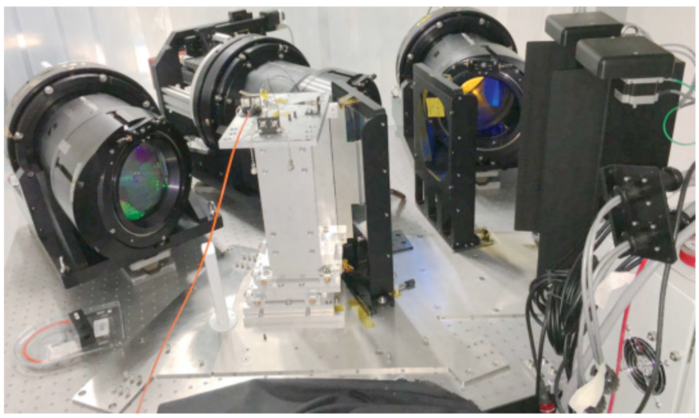


Figure 3: The DESI unit 1 spectrograph in test at Winlight in France. The three channels are (L-R) near-infrared (to 1 μm), red, and blue. (Image credit: Winlight, LBNL.)

This summer and fall, key technologies will be tested at the Mayall using the ProtoDESI instrument. This instrument will test the aspects of source acquisition and guiding. The full instrument must be able to place fibers on 5000 galaxies, stars, and sky positions within approximately one minute after slewing to a new field. This is an incredible technical challenge. ProtoDESI will test aspects of the system needed to accomplish this task. This includes a guide camera with precise metrology in the focal plane

continued

Getting Ready for DESI continued

relative to fiducial locations (that can be backlit and imaged) whose positions are accurately known relative to the guide CCD pixels and positioners. The DESI system locates the fibers in practice by imaging the focal plane (fibers and fiducials are backlit) from the primary mirror hole with a Fiber View Camera (FVC, developed at Yale). The FVC and positioning of sources on multiple fibers will be tested with ProtoDESI.

If all remains on schedule, then all this activity should result in the end to normal science operations at the Mayall in August or September 2017. At that point, the telescope top end will be deconstructed and various areas of the Mayall will be prepared for DESI. Components of the system will begin to arrive in Arizona soon after, and by early 2018, major parts of the Mayall-DESI system will begin to be put together.

Of course to accomplish the survey the Mayall and DESI will have to know precisely which targets to point at. To that end, NOAO has been working with DESI and three related imaging surveys that will be used by the DESI Collaboration to derive the "target list." Most (9000 square degrees) of the DESI footprint is being observed in g-, r-, and z- band filters using the Dark Energy Camera on the Blanco 4 m telescope in Chile. This is a major imaging survey whose data are available immediately to the public. The third data release, comprising more than 1000 square degrees in all three filters and more than 5000 square degrees in one or two filters, is set for later this summer. The survey is being executed by the DECaLS collaboration as a NOAO survey program (closely allied with DESI), and the data may be accessed at *http://legacysurvey.org*.

The northern part of the DESI footprint is being observed using the Mayall telescope itself (z-band filter) and the Bok 90 inch telescope (g- and r-bands, also from Kitt Peak). Both these surveys are part of the DESI Collaboration and both are public. Data will be available through the same website as for DECaLS. The Mayall z-band Legacy Survey, MzLS, is using approximately 250 nights with the Mosiac-3 imager (see the cover image and caption in the March 2016 issue of the *NOAO Newsletter* for information on this new camera) in 2016A and 2017A. The survey is half complete, and all the raw images are already available through the NOAO archive. The Beijing Arizona Sky Survey (BASS) is more than 30% complete, and those raw images are also available at the NOAO archive. BASS is being executed by a group from the Chinese National Academy of Sciences in collaboration with the University of Arizona.

Catalogs of sources have been released on the legacy site for DECaLS, and additional and updated catalogs for all three surveys will continue to be released at regular intervals (again with the next release in late summer 2016) until all the final catalogs are produced. See the "Mapping the Sky for All" article elsewhere in this *Newsletter* for more on the BASS, MzLS, and DECaLS surveys.

DESI is an exciting multi-year project at the forefront of cosmology and astrophysics. It promises to be one of the premier dark energy experiments ever undertaken and will also provide an incredible legacy data set for research by the broader community in the years following the DESI survey. The project has passed its last major review and is ramping up quickly into fabrication. The associated imaging surveys are producing unprecedented data in depth and areal coverage. Products are available now and more are coming in the near future. Stay tuned!

The GMOS Data Reduction Cookbook

Dick Shaw and Dara Norman

The twin GMOS spectrographs have been the most heavily used instruments on the Gemini telescopes since their installation in the early 2000s. They are popular in part because of the variety of available observing configurations: imaging, and low- and intermediate-resolution long-slit spectroscopy, MOS spectroscopy, and IFU spectroscopy. However, this flexibility means that data reduction can be a complex task for even straightforward observing programs.

To streamline the reduction process, we have developed the *GMOS Data Reduction Cookbook*. A Web-based document, the *Cookbook* provides a high-level overview of the workflow and a comprehensive overview of the prerequisite set of tools and reference material. It also steps through a set of detailed examples in which real data are reduced. Individual chapters of the *Cookbook* provide

- a brief overview of the GMOS instrument
- a guide to getting started, with instructions on installing the processing software and retrieving data
- detailed tutorials on processing images as well as long-slit, MOS, and IFU spectra
- extensive supplementary material that describes supporting tasks and includes calibration reference files and references to external calibration data
- links to other online sources of information, including other GMOS data reduction presentations, software tools, and relevant literature references
- a glossary of technical terms used in describing GMOS reductions

The data reduction tutorials include start-to-finish scripts (for both the IRAF and PyRAF environments) and detailed instructions for reducing data from actual observing programs. These scripts can easily be generalized to other GMOS data sets.

To view the *Cookbook*, direct your browser to the website of the US National Gemini Office and follow the link to GMOS data reductions or go directly to *http://ast.noao.edu/sites/default/files/GMOS_Cookbook/*.

Your comments and corrections are welcome. Please write to the Gemini Helpdesk at *www.gemini.edu/sciops/helpdesk/*.

The NN-EXPLORE program at WIYN

Jayadev Rajagopal

In February 2015, NOAO announced that the WIYN telescope will be the future home of an extreme precision radial velocity spectrometer, a state-of-the-art instrument that will detect and characterize planets outside our solar system (exoplanets). The sensitivity of the spectrograph is targeted in particular to discover Earth-like worlds. NASA had issued a request for proposals to build such an instrument to be used by the astronomical community at large. This will be the cornerstone of a newly established partnership between NSF and NASA (NASA-NSF Exoplanet Observational Research: NN-EXPLORE) to advance exoplanet science using the NOAO share of WIYN.

The project has progressed at a rapid pace, driven by the aggressive schedule required to have the instrument ready to support the NASA Transiting Exoplanet Survey Satellite mission (launch scheduled for mid-2018). TESS will provide data on transiting exoplanets. A prime goal for the community will be to carry out follow-up spectroscopy with the new instrument to provide vital characterization of these planets.

NASA initially picked two teams from the responses to its solicitation to carry out a six-month Instrument Concept Study (ICS) in collaboration with NOAO. In parallel, NOAO provided concept designs for a fiber feed that would send starlight to the spectrograph from the WIYN telescope as well as for the enclosure that would house the instrument, for each of the two teams (see Figures 1 and 2). Both systems are very challenging, with the fiber feed (called a Port Adaptor) needing to stabilize the image motion to a fraction of an arcsecond and the enclosure required to provide extreme (tenth of a degree) temperature control and stability (over years).

In March of this year, NASA selected the team to build the instrument. NEID[1] (see Figure 3), as it is called, will be built by a team led by Prof. Suvrath Mahadevan at Pennsylvania State University (PSU) and will start operations at WIYN in 2019.

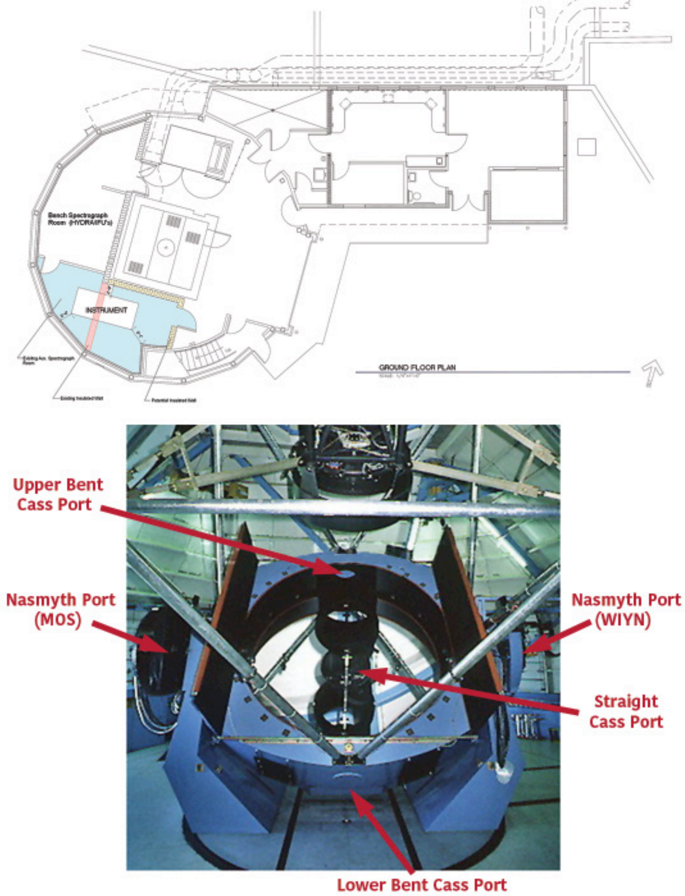


Figure 1: Top: Plan view of the observatory to show the location of the NEID spectrometer, marked in blue next to the square structure of the telescope pier. Bottom: The WIYN telescope showing the location of the Port Adaptor.

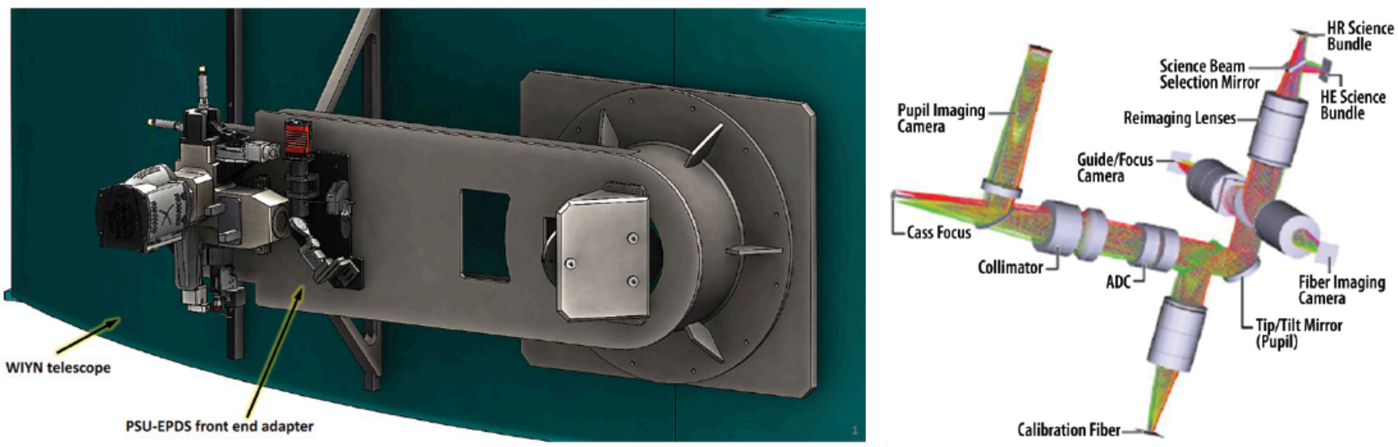


Figure 2: NEID Port Adaptor concept design developed by NOAO during the ICS phase, with optical elements shown in image on right.

continued

[1]NEID is short for NN-EXPLORE Exoplanet Investigations with Doppler Spectroscopy. The name is derived from a word meaning "to discover/visualize" in Tohono O'odham, the native language of the Tohono O'odham, upon whose land Kitt Peak National Observatory is located.

The NN-EXPLORE program at WIYN continued

Among the baseline science goals for NEID (from the team's concept study report) are the following:

- Provide the US exoplanet community with a precision Doppler spectrometer capable of single-point radial velocity precision of ~27 cm/s on bright stars.
- Discover Earth and super-Earth mass habitable-zone planets that are prime candidates for future NASA direct imaging missions.
- Facilitate follow-up spectroscopy of transiting exoplanets discovered by TESS and K2 to measure planet mass, density, and orbital dynamics.
- Enable accurate spectroscopic characterization of exoplanet host stars.

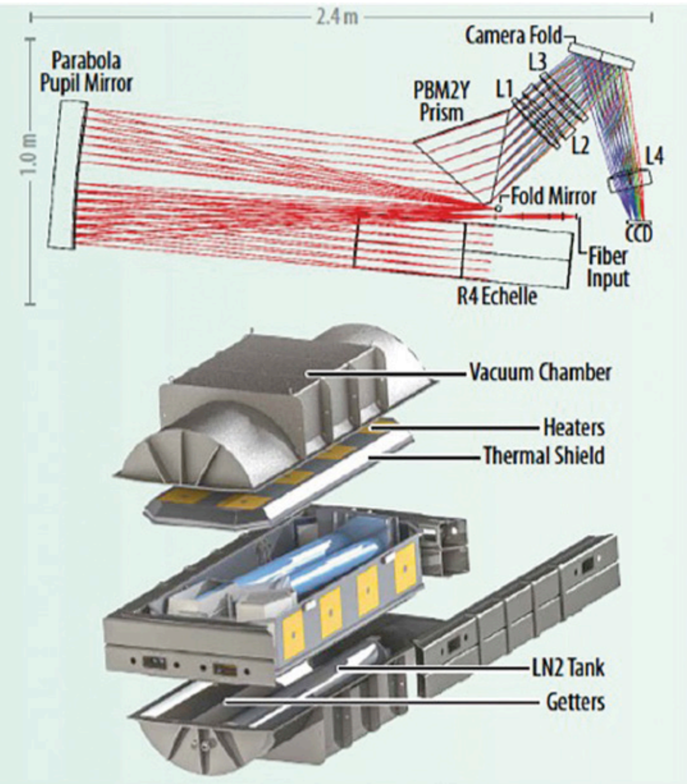


Figure 3: The NEID spectrometer optical design and vacuum chamber. (Courtesy of PSU team.)

The key elements of the NEID system design are a proven, simple optical layout, active environmental control (mK temperature stability of the optics, which are housed in a microTorre-class vacuum chamber), precise spectral calibration using a laser frequency comb, and a cutting-edge data pipeline.

The next year will see a flurry of activity at WIYN as we strive to ensure that the facility modification needed to house NEID and the Port Adaptor to feed it starlight are ready and tested well ahead of time for the instrument's scheduled arrival in late 2018.

In the next few months the WIYN team, in close collaboration with PSU, will advance the optical and mechanical designs for the Port Adaptor to meet a preliminary design review currently scheduled for November this year. At the same time, our facility engineering team will work with design consultants to produce a detailed design for the enclosure modifications. We aim to be ready for a detailed design review for both these major systems in the spring of 2018.

NEID will provide the US astronomical community with a world-class tool to advance exoplanet research for the next decade. In the meantime, exoplanet researchers are using WIYN to study known exoplanetary systems. Currently in its third semester, the NN-EXPLORE Guest Observer (GO) program utilizes existing instrumentation on WIYN to characterize exoplanet host stars with spectroscopy and speckle imaging, to search for faint stellar companions to exoplanet systems, and to study the atmospheres of exoplanets (see Figure 4 for an example). GO proposals for WIYN are accepted during the regular NOAO proposal call, as described on the proposal information website (*http://ast.noao.edu/observing/proposal-info*).

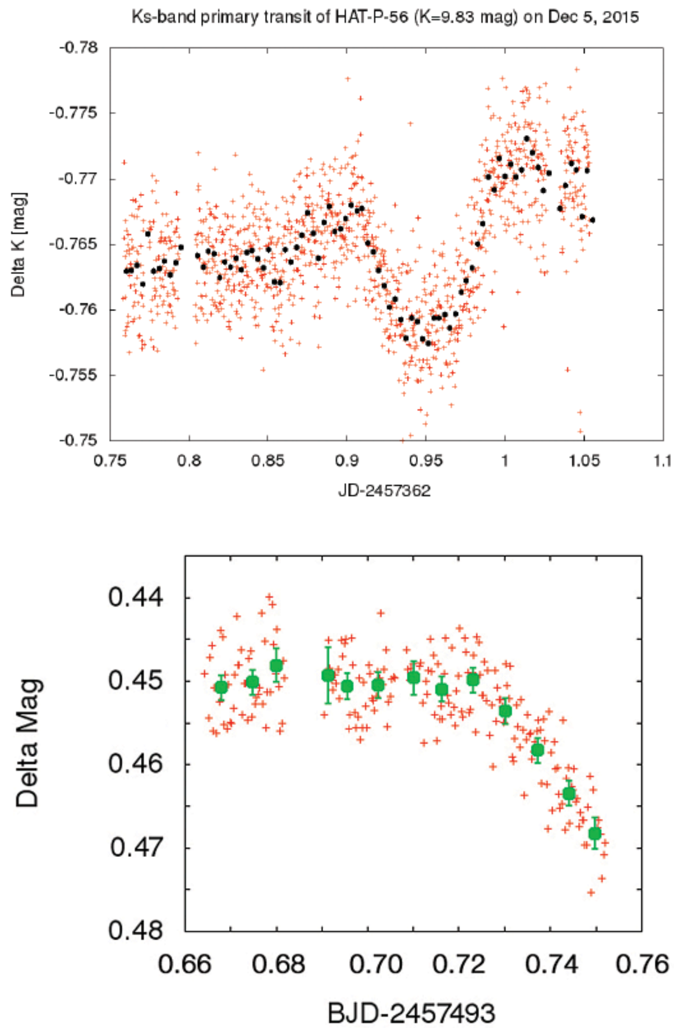


Figure 4: Follow-up of HATnet (geographically distributed network of small telescopes for transit detection) exoplanet candidates at WIYN through the NN-EXPLORE GO program. The WIYN/WHIRC near-IR camera has been used to observe 9 primary or secondary transit events in J or K bands. The top example is a K-band primary transit for HAT-P-56b. The bottom is a J-band ingress for a candidate that based on WHIRC data has been determined to be a blended eclipsing since it has a much deeper transit in the J-band than in the R-band. (Figures and text with permission from J. Hartman/Princeton University.)

Phoenix Moves to Gemini South

Ken Hinkle

The conversion of the Mayall 4 m telescope to the DESI survey means finding a new home for the Phoenix high-resolution near-infrared spectrograph, an instrument that supports a substantial user community.

Phoenix was designed for use at *f*/16 telescopes. Since first light in the late 1990s, it has been used at the Kitt Peak 2.1 m and 4 m and at Gemini South. Following the removal of Phoenix from the 4 m, Gemini agreed to allow its use at Gemini South as a visitor instrument. Gemini visitor instruments are available in block scheduled queue mode. This is different from facility instruments that are available throughout the semester.

Phoenix's last night at the 4 m was 7 June 2015. Phoenix was shipped to Gemini South in early February 2016 and arrived in good condition at Cerro Pachón two weeks later. NOAO staff members Ken Hinkle and Daryl Willmarth travelled to Pachón in March to unpack the instrument. Gemini graciously provided help from its day crew. Their expertise in lifting and moving the cryostat and in reattaching the refrigeration lines was especially valued.

The first observing run was in May. Again this was accomplished through a collaboration between NOAO and Gemini staff. Rolando Rogers (Gemini) provided engineering oversight. Tom Geballe (Gemini), Ken Hinkle (NOAO), German Gimeno (Gemini), and Steve Margheim (Gemini) provided observing support. Unfortunately the run was nearly totally lost to winter weather. However, we were able to take a few spectra and confirm that Phoenix was operating as expected.

It is NOAO's plan to offer Phoenix at Gemini South as long as there is visitor demand. It is capable of observing over the 1–5 micron region. The wavelength range over which spectroscopy is possible makes Phoenix different from the latest generation of infrared spectrographs. Phoenix also offers long-slit spectroscopy. Until CRIRES returns to service at Paranal, Phoenix is the only high-resolution infrared spectrograph in the Southern Hemisphere.

Figure 1: Attaching the Gemini interface unit to Phoenix. L-R, Hector Figueroa (Gemini), Claudio Araya (Gemini), and Ken Hinkle (NOAO). (Image credit: D. Willmarth/NOAO/AURA/NSF.)

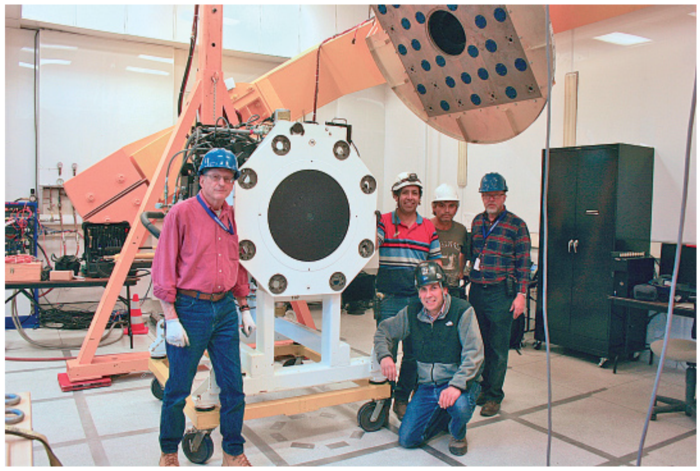


FIgure 2: The unpacking team with Phoenix in the Gemini South instrument lab. L-R, Daryl Willmarth (NOAO), Claudio Araya (Gemini), Rolando Rogers (Gemini; kneeling), Hector Figueroa (Gemini), and Ken Hinkle (NOAO). (Image credit: D. Willmarth/NOAO/AURA/NSF.)

New Instrumental Capabilities at SOAR

Jay Elias (SOAR), Andrei Tokovinin (NOAO), and Cláudia Mendes de Oliveira (University of São Paulo)

The investigators associated with two "visitor" instruments at SOAR, the HRCam and SAM Fabry-Perot, are offering limited access to observers outside of the instrument teams. This access is expected to continue through semester 2017A; please see the NOAO call for proposals (*http://ast.noao.edu/observing/proposal-info*) or the SOAR website (*www.ctio.noao.edu/soar/*) for further details. In both cases, the instrument teams will provide support for observers in exchange for participation in the scientific results. Proposers should coordinate with the instrument PI before submitting a proposal.

For updates on these and other instrumental capabilities, please refer to the SOAR website.

HRCam

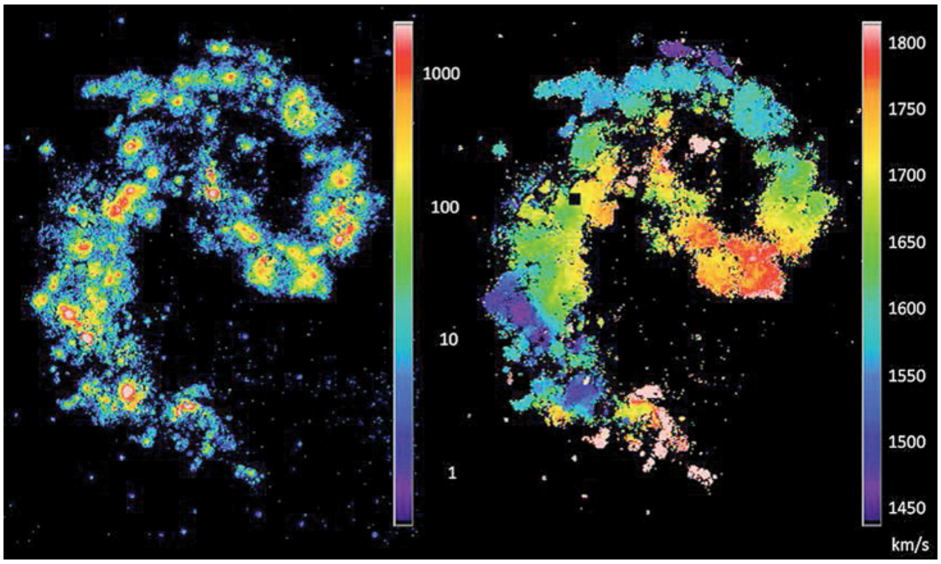
HRCam is an instrument developed by Andrei Tokovinin (NOAO) that can be used for speckle interferometry. Details of the instrument can be found at *www.ctio.noao.edu/~atokovin/speckle/index.html*. It can be used with or without operating the adaptive optics system. The *second* mode is

continued

preferred for bright targets as overheads are lower; the *first* mode is preferred for fainter targets.

Support for the instrument is provided by Tokovinin, who will assist both with the actual observations and with data reduction—proposers should expect to get fully reduced data shortly after the run ends. Please contact Tokovinin (*atokovinin@noao.edu*) before preparing a proposal.

For NOAO proposers, the instrument should be specified as "HRCAM" if you are proposing to work without adaptive optics activated and as "SAMHR" if you are proposing to work with the adaptive optics. Note that in the latter case, all the constraints associated with laser use apply (early submission of target lists for clearance, etc.).



Monochromatic image (left panel) and velocity field (right panel) of the antenna. North is up and east is to the right. The monochromatic image has arbitrary units (given that the data are not flux calibrated), and it is in log scale.

SAM Fabry-Perot

SAM can also operate with a Fabry-Perot (F-P) etalon inserted in the collimated beam. This capability was developed by Cláudia Mendes de Oliveira, her collaborators, and Tokovinin.

This capability is less mature than HRCam, so it is being made available on a phased basis. An initial four-night science verification (SV) run was scheduled in 2016B. Our expectation is that a similar block of time will be offered in 2017A. Please see the NOAO call for proposals or the SOAR website for details. Prospective proposers should coordinate with Cláudia Mendes de Oliveira (*claudia.oliveira@iag.usp.br*) before submitting a proposal.

Support for the observations, including data reduction, will be provided by the F-P team. Since this capability also normally makes use of the adaptive optics, all the constraints associated with laser use also apply.

An example of SAM F-P data is shown in the figure; see the call for proposals and the 30 Doradus preprint (*www.ctio.noao.edu/soar/sites/default/files/30Doradus.pdf*) for more examples.

A Torrent of New Data at the CTIO/SMARTS 0.9 m Telescope

Todd Henry (Georgia State University)

Since June 1993, the venerable ARCON (ARray CONtrol) data acquisition system has slogged along on the CTIO/SMARTS 0.9 m telescope, acquiring imaging data for countless astronomers. In May 2016, our enduring friend ARCON was disconnected from the Sun workstation and removed from the 0.9 m.

In ARCON's place, a new Torrent system was connected to the same Tek2K CCD camera, bringing the data acquisition system at the 0.9 m into the 21st century. The new Torrent is similar to Torrents working on the CHIRON spectrograph on the CTIO/SMARTS 1.5 m and to the COSMOS spectrograph on the Blanco 4 m telescope.

The 0.9 m Torrent system was created by the engineering team of Marco Bonati and Peter Moore, who were present at the 0.9 m for installation on 16 May 2016. With their diligent help, the first science data were acquired by Todd Henry and Leonardo Paredes on May 21, after a few engineering and cloudy nights. The new Torrent system offers several advantages over ARCON:

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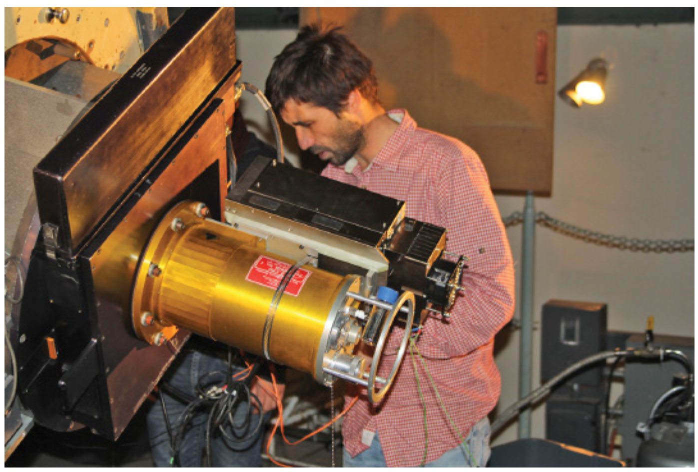


Engineer Marco Bonati installing Torrent on the CCD camera of the 0.9 m telescope. (Image credit: T. Henry/Georgia State University.)

A Torrent of New Data at the CTIO/SMARTS 0.9-m telescope continued

1. An intuitive GUI that is much easier to use than the command-line interactions of ARCON.

2. A smooth connection between Torrent and the 0.9 m Telescope Control System that provides not only correct image headers but also the ability to move the telescope directly from the data acquisition station.

3. A modern computer with roughly 0.5 terabytes of image storage space (which can be expanded)—a vast improvement over the 16 gigabytes available with ARCON.

4. Reduced uncertainty for the 0.9 m operations team, who always worried about where the next Sun workstation might be found should a meltdown occur.

Since 2003, when SMARTS assumed responsibility for the operation of four telescopes on Tololo, including the 0.9 m, members of the RECONS team have been directly involved in supporting observers and troubleshooting the ins and outs of the ARCON system. The ARCON system on the 0.9 m telescope was the last of the ARCONs used by NOAO. We would all like to tip our hats to our sometimes-fickle ARCON *amigo*.

Maintenance Work on the Blanco Telescope Dome

Steve Heathcote

The dome of the Blanco 4 m telescope is something that visiting astronomers can safely ignore most of the time—so long as it works. To ensure that the forty-year-old mechanisms for this rotating 400,000 kg structure continue to work reliably and safely, various maintenance tasks are underway or planned. This is especially important since the large surveys now using DECam require more frequent dome motion and more accurate positioning.

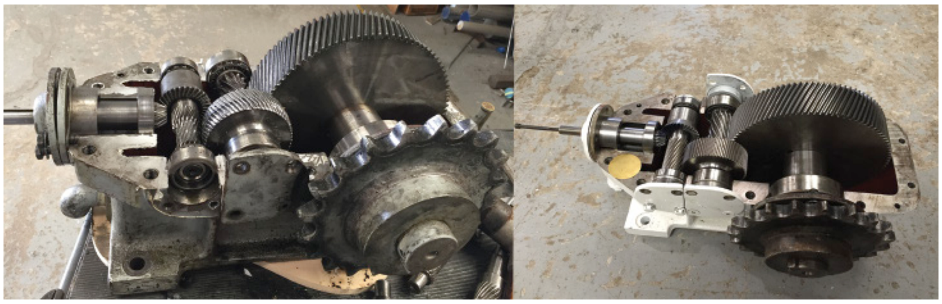


Figure 1: Reduction gearbox for Blanco dome azimuth drive before (left) and after (right) repair. (Image credit: Andrés Montané/ NOAO/AURA/NSF.)

The reduction gearbox for one of the three dome azimuth drive motors failed in November 2014 as a result of the accumulated wear on the gears. Fortunately, little telescope time was lost because the dome can be turned with only two drives working. The failed gearbox was repaired in the La Serena machine shop by replacing all the gears with new components purchased or manufactured in-house. Subsequently we have refurbished an old gearbox discarded from the Mayall telescope to make a complete spare box, and with this in hand, we are now in the process of swapping out and refurbishing the other two drive trains.

There has also been an increase in the frequency of bearing failures on the 32 trucks upon which the dome rides. This is a problem that has been seen at several other observatories with similar domes built in the 1980s. A careful study of the original drawings and documentation by Engineering and Technical Services mechanical engineer Andrés Montané has led to the rediscovery of some design secrets that had been forgotten over the years, in particular concerning the alignment of the dome trucks. He is now working with the mountain-based telescope mechanics to systematically realign and adjust the dome trucks to restore the proper alignment. This has required the development of special tools to measure and adjust the position of the trucks, each of which weighs 2,100 kg.

Figure 2: Telescope mechanics Jorge Briones and Christian Diaz work to measure the alignment of one of the trucks for the Blanco telescope dome. Proper operation requires quite precise adjustment of the 2,100 kg truck. (Image credit: Andrés Montané, NOAO/AURA/NSF.)

Once winter is over a contractor will begin work on the outside of the dome to repair damage to the trademark aluminum foil covering of the Blanco dome, which helps to prevent nighttime overcooling of the dome, which leads to air turbulence and degraded seeing. Over the next two years, we will also be working to upgrade the drive mechanism and emergency brake for the upper shutter of the dome to ensure their continued proper and safe operation.

2016 Millikan Medal Awarded to Stephen M. Pompea

The American Association of Physics Teachers (AAPT) has awarded NOAO's Stephen M. Pompea the 2016 Robert A. Millikan Medal. This award recognizes educators who have made notable and intellectually creative contributions to the teaching of physics. Pompea, the program head of Education and Public Outreach at NOAO, thanked his colleagues: "This award is a testament to the collective efforts of my many dedicated and creative colleagues and to the outstanding teachers who influenced me. The NOAO EPO team in Tucson and La Serena is world class, and this award reflects on our teamwork and what we have accomplished. I have also had the honor of working with the Galileoscope and International Year of Astronomy teams and with great science education teams at UC Berkeley and across the country."

Stephen Pompea accepts the Millikan Medal from AAPT past president and Awards Committee chair Mary Elizabeth Mogge. (Image credit: AAPT.)

The award noted that "Steve has applied research in physics education and contributed to that literature base. Across all these contributions is a high level of creativity, professionalism, and quality." His contributions include papers on problem solving, optics education, misconception research, teaching with museum exhibits, dark skies and lighting education, and models for out-of-school science camps, as well as a number of papers in astronomy research, optical physics, and instrumentation.

The award also highlighted some of his efforts at NOAO as a leader in physics education developing "innovative research experiences for high school teachers such as the NSF-funded Teacher Leaders in Research Based Science Education. Lasting over a decade, this program engaged hundreds of teachers and their students in physics and astronomy research." He was later able to expand these research experiences to integrate teachers and students into research teams with the NASA Spitzer Space Telescope. In the undergraduate outreach and mentoring program he helped start at NOAO, over 35 undergraduate students have worked on research and outreach programs at the national observatory over the past eight years, two of which have since completed PhDs in astrophysics, with many others now leading similar outreach efforts.

Steve Pompea is also an Affiliate Professor of Steward Observatory of the University of Arizona and a Fellow of SPIE and OSA, which awarded him its Esther Hoffman Beller Medal in 2011. See the AAPT press release on the Millikan Medal at *https://www.aapt.org/aboutaapt/pressreleases/2016-Millikan-Medal-Awarded-to-Stephen-M-Pompea.cfm*.

NOAO at the Summer 2016 AAS Meeting

The NOAO booth at the 2016 summer AAS meeting in San Diego gave us a chance to meet with colleagues and students, and to feature some of our current projects. NOAO Director Dave Silva and Deputy Director Bob Blum were present, along with many of our scientific staff.

Participants in the Kids Day student event at the summer 2016 AAS meeting engage in a polarization activity led by NOAO staff. (Image credit: Jessica Rose/NOAO/AURA/NSF.)

The NOAO Education & Outreach group helped with the Kids Day student event by organizing an opportunity for students to experiment with polarization. The activity was based on a tape art activity developed at NOAO as part of the NSF-funded Hands-On Optics project. The activity allowed students to use several polarizing sheets to see birefringent color effects in transparent tape. By using multiple layers of tape, students could create different color patterns that were visible when the tape was placed above a light table and between polarizers. Rotating one polarizer caused the color pattern to shift as well.

The featured topic at the NOAO booth was our big data initiative. This centered on a demonstration of Data Lab software. The Data Lab project is designed to help the user community explore large data sets that are being collected with the NOAO wide-field 4 m telescopes, including the catalogs derived from the pixel data (have a look at *http://datalab.noao.edu* for an overview of the concept). Public release is scheduled for mid-2017. The demo showcased how archived images can be used to discover faint Milky Way dwarf companions, like those recently found by the Dark Energy Survey (DES) and by the SMASH survey. See the article "The Data Lab at the AAS Meeting" elsewhere in this *Newsletter*.

Quality Lighting Teaching Kits: Professional Development at a Distance

Constance E. Walker and Stephen M. Pompea

The International Year of Light in 2015 was an opportunity to bring awareness of light pollution issues, and lighting solutions based on the principles of quality lighting, to a younger generation. Under the sponsorship of IAU and the OSA Foundation, the NOAO Education and Public Outreach (EPO) group developed and tested an educational kit for ages 11–14 to be used either in classrooms or in out-of-school programs. (See "Quality Lighting Teaching Kits," *NOAO Newsletter*, March 2016, p. 27.) The kit provides problem-based learning activities on six common light pollution issues.

One hundred Quality Lighting Teaching (QLT) Kits were built in late 2015. In early 2016, kits were sent to 88 stakeholders in 30 countries (including Argentina, Armenia, Chile, Colombia, Ethiopia, India, Latvia, Nigeria, Tanzania, and Zambia). The recipients were chosen by our project partners: SPIE–The International Society for Optical Engineering, CIE–International Commission on Illuminations, OSA–The Optical Society, the International Dark-Sky Association, and the IAU Office of Astronomy Development. Although the kit recipients were experts in the fields of illumination engineering, light pollution mitigation, and astronomy education, there was a better chance of the kits being used if recipients received extended training on using them.

The geographic extent of the project precluded providing professional development in person to lighting educators. Instead, tutorial videos on each of the six learning activities were developed in the spring of 2016. The videos were narrated by our EPO undergraduate students who had assembled the kits. The videos are posted on the project's webpage, *www.noao.edu/education/qltkit.php*. Each video is seven to fourteen minutes in length, concisely and clearly spelling out how to perform the activities using a problem-based learning approach.

The video-based training is augmented by 14 Google+ Hangouts (each one hour long) that can provide additional Internet video-based discussion of the activities. The Hangouts provide an opportunity for kit recipients to interact directly with the kit creators and expert guests, who are happy to field questions. A viewer can text questions to the host and live guests. For the convenience of the viewers, two Google+ Hangouts are done per topic, one for the Australian/Asian side of the world and one for the African/European side of the world. People in the Americas can attend either.

Demonstration of the Quality Lighting Teaching Kit at the "Starlight, Beyond Light Pollution" workshop in the Canary Islands attended by astro-photographers, local teachers, astronomers, and staff from the La Palma Office of Tourism. (Image credit: Valentin Grigore, president of the Romanian Society for Meteors and Astronomy [SARM].)

Reactions from kit recipients who have utilized the tutorial videos have been extremely positive. Peter Offor, scientific officer at NASRDA–Centre for Basic Space Science in Nsukka, Nigeria, said, "The video tutorials added flesh to the whole activities … going through the videos, I could appreciate each activity better." He added that "the Hangouts I participated in gave me courage to go out and teach our younger generation what I have learnt." Other participants felt that the Hangouts helped create an engaged community of teachers using the kits. The SPIE student chapter from the Universidad Nacional de Tucumán in Argentina organized a meeting before the Hangouts began in which they watched the tutorial videos and performed the activities. They felt that the videos made everything quicker and easier to learn. This student outreach group also translated 10 of the 11 posters included in the kit into Spanish and performed the activities in classrooms.

The Internet video-based workshops have been an excellent method for reaching the many project partners around the world. Even though alternative ways were created to train people on activities at a distance, traditional workshops are still done when possible. The emphasis is on regions of astro-tourism at sites surrounding observatories such as the island of La Palma in the Canary Islands, Yerkes Observatory, Kitt Peak National Observatory, and Cerro Tololo Inter-American Observatory.

Visiting Students at CTIO

Kathy Vivas and César Briceño

CTIO hosted three research interns during June through August 2016: Catherine Clark and Piera Soto, who worked with César Briceño, and Michelle Gurevich, who worked with Kathy Vivas.

Catherine is a senior at the University of Michigan in Ann Arbor, majoring in astronomy. She spent 10 weeks in June through August at CTIO, working with César Briceño on the reduction and analysis of echelle spectra of known and candidate T Tauri stars in the Orion OB1 association, obtained with the multi-fiber M2FS instrument on the Magellan telescope. She confirmed young members using youth indicators such as the H-α emission line and the Li I absorption characteristic of pre-main sequence K- and M-type stars and characterized the H-α profile to determine objects accreting from a circumstellar disk. Catherine also looked for [OI], [NII], and [SII] emission features, which are signatures of a jet and star or disk wind.

Piera received a Ms.Sc. in astronomy from Universidad de La Serena. During her stay at CTIO in July and August, she carried out a detailed analysis of VISTA ZYJHK images of nearly 1500 newly confirmed T Tauri stars in the Orion OB1 association to look for wide binary and multiple systems (from ~1–2.5 arcsec, equivalent to 400–1000 AU) and characterize their separations and flux ratios. Her work is part of an extensive study of binarity of Orion young populations, with CTIO astronomer Andrei Tokovinin, that uses VISTA data and adaptive optics instruments at SOAR and VLT.

Michelle spent 8 weeks in July and August at CTIO. She is a junior at the University of Michigan in Ann Arbor, majoring in mathematics and astronomy. Michelle was involved in a project aimed to identify variable stars in satellite galaxies of the Milky Way. Her work included the reduction and photometric analysis of data recently acquired with the Goodman imager at the SOAR telescope, as well as time-series analysis to identify and classify variables stars.

The Harbour School Visits Kitt Peak

Robert T. Sparks

The Education and Public Outreach (EPO) program hosted an astronomy camp May 17–20 on Kitt Peak for students, parents, and staff from the Harbour School. This primary and secondary international school located in Hong Kong, China, uses an American curriculum adapted for a diverse international student body. During the camp, the EPO staff incorporated activities from many of their projects, including Galileoscopes, Dark Skies activities, and Hands-On Optics activities.

Thirteen middle school students and seven teachers, school administrators, and parents spent three nights on Kitt Peak, observing late on each night. The group stayed in the dorms and had meals in the dining halls. Several EPO staff worked with the group including Stephen Pompea, Robert Sparks, Will Roddy, Mattie Tigges, and Ricky Maciel. Juan Seguel and Kadur Flores, EPO staff visiting from CTIO, also participated.

The Harbour School astronomy camp on Kitt Peak. (Image credit: Robert T. Sparks, NOAO/AURA/NSF.)

After checking into their dorms on Tuesday afternoon, the group was treated to a tour of the Mayall 4 m telescope. Following this tour, each individual built and used a Galileoscope, a high-quality, low-cost telescope developed for the International Year of Astronomy 2009. After dinner they toured and observed the sunset using the McMath-Pierce Solar Telescope. The group also participated in a special binocular and Moon-watching program led by Tim Hrutkay, a Kitt Peak Visitor Center guide. They had the special opportunity to observe the Moon on the McMath-Pierce telescope with visiting observers.

The second observing night was interrupted by clouds, but Jayadev Rajagopal (NOAO) gave a tour of the WIYN 3.5 m telescope to the group while they waited for the clouds to pass. Students learned how to use computerized tele-

The Harbour School Visits Kitt Peak continued

scopes and Dobsonian telescopes in addition to their Galileoscopes. They went to the 16" Levine telescope where they selected targets for imaging with a DLSR camera. Students imaged the Moon, Mars, Jupiter, Saturn, M57, M82, M13, M4, and M51.

Students had another evening of observing with a variety of telescopes on Thursday. Don McCarthy (University of Arizona) joined them at the Levine telescope and brought along an astronomical CCD camera. The students were able to achieve much deeper images than with the DLSR camera, imaging Jupiter, Saturn, M3, M5, M44, M51, M57, M65, M104, Mizar, and M97.

During the days, students learned about light and spectroscopy. After discussing the wave nature of light, they explored spectra using diffracting gratings and an Ocean Optics spectrometer. The group observed the Sun using a variety of telescopes with white light filters and H-α filters.

Don McCarthy led a solar system walk around the lake on Kitt Peak to help students understand the scale of the solar system. This activity was followed with an activity called "Worlds in Comparison" where students made a scale model of the planets in the solar system using Play-Doh. The students also visited the VLBA radio dish, where they learned about radio astronomy and the Event Horizon Telescope.

In addition to working on Kitt Peak, the group visited other Tucson attractions including the Arizona-Sonora Desert Museum and the Pima Air and Space Museum. The students received memory sticks containing all the images they had obtained at Kitt Peak. They gained a variety of skills during their time on Kitt Peak including building and using Galileoscopes, using cell phones to photograph through telescopes, and operating a variety of telescopes.

NOAO South Personnel Changes

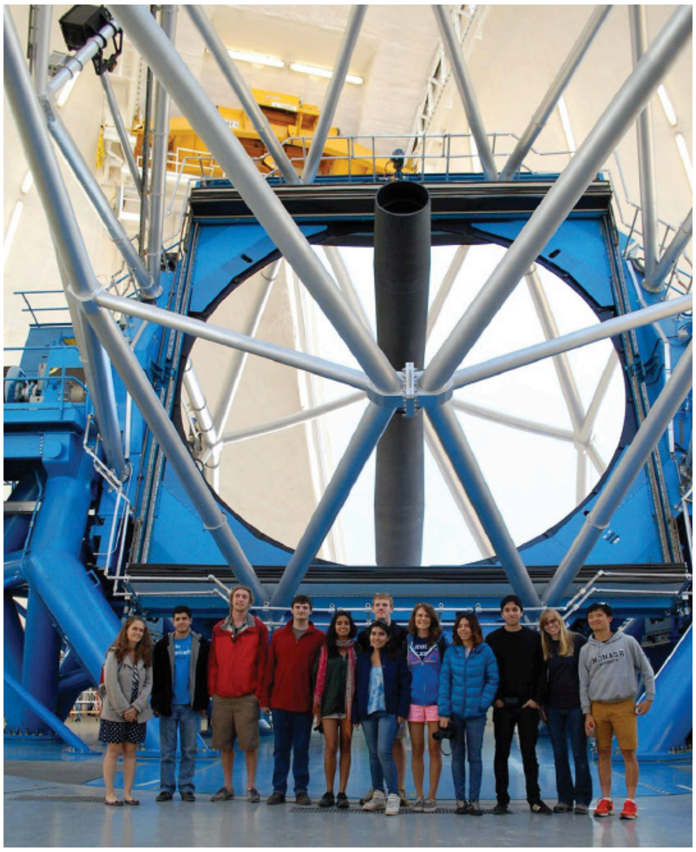
Scientific Staff Departures from NOAO South

Steve Heathcote

Catherine (Katie) Kaleida joined the CTIO staff in September 2011 as a postdoctoral fellow and director for the CTIO summer student programs: Research Experiences for Undergraduates (REU) and the parallel Práctica de Investigación en Astronomía (PIA). Over the five years Katie ran these programs, she devoted tremendous energy and enthusiasm to giving the diverse group of students (six US REU students and two Chilean PIA students each year) the opportunity to learn about science through participation in an astronomical research program with a mentor from the CTIO, SOAR, or Gemini South scientific staff, culminating in presentation of a poster at the January AAS meeting. The students obtained their own data observing on the 0.9 m telescope; went on field trips to the local telescopes on Cerro Tololo and Cerro Pachón, and farther afield to the VLT and/or ALMA; and became thoroughly immersed in a different culture. The best testimony to her success comes from the students of the 2014 REU/PIA cohort:

> *For the past [five] years, students have had the experience of a lifetime here at CTIO due, in large part, to Katie's skills as program director. From her intuition in picking a varied yet cohesive and complementary group of students to her split-second and stressful planning of a terrific outreach trip to Punta de Choros, this experience has been nothing short of amazing for all of us. Katie clearly goes above and beyond what is expected to make this adventure as great as it can be. In addition to her professionalism and planning, she gets to know each student personally and is a willing ear for any concerns or suggestions we have. She has been saddled with the job of not only being a professional mentor and role model, but also with the challenging task of integrating us into this foreign, exciting, and sometimes dangerous environment.*

Katie joined STScI as an archive scientist in June 2016.

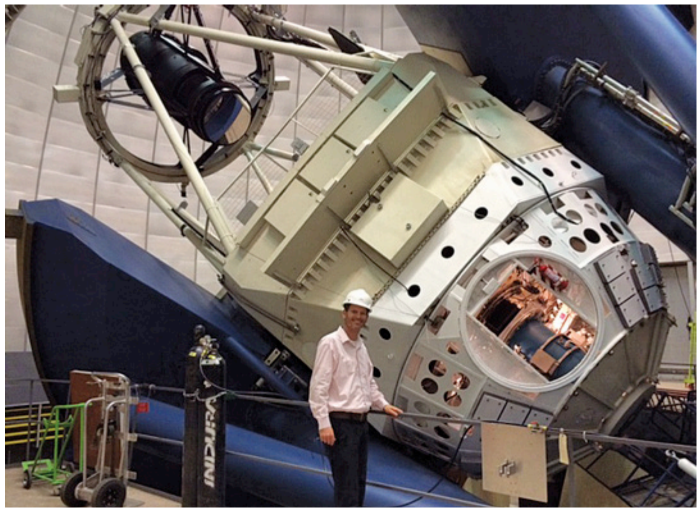


Katie with REU/PIA students at the Gemini South 8 m telescope. (Image credit: Daniel Munizaga/NOAO/AURA/NSF.)

continued

NOAO South Personnel Changes continued

David James joined the tenure track science staff at CTIO in January 2011. He quickly became fully engaged in the support of visiting astronomers using a wide range of instruments on the Blanco 4 m telescope. He served as the Hydra instrument scientist during an intense period of use before it was retired in preparation for DECam. He has also been a key member of the "DECam help team," spending many nights on the mountain doing observer starts. As the CTIO scientist responsible for the DECal calibration system, David spent a large fraction of cloudy nights running scans to measure the sensitivity of the system for each filter to ensure the accuracy and stability of the instrument calibrations, although this year's El Niño has provided more cloudy nights than even David could use. He became instrument scientist for the TripleSpec4 near-infrared spectrograph soon after his arrival at CTIO, participating in that project from the requirements definition for the CTIO version of the instrument through to its successful commissioning and first science use on the telescope. David returns to the US where he will be spending quality time with his young family while continuing to pursue his research from home.



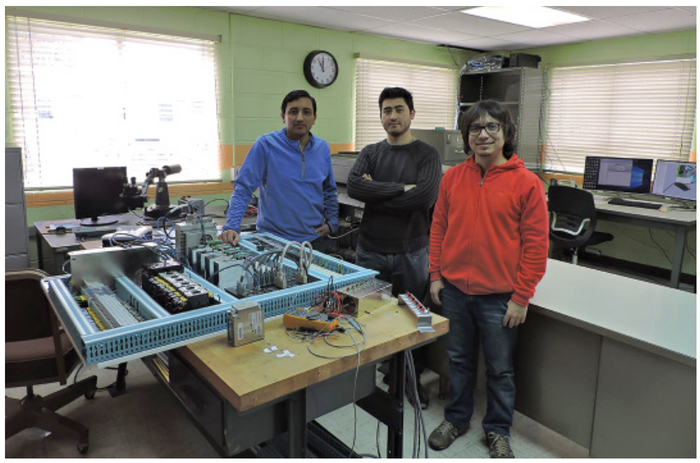
David James and the TripleSpec4 near-infrared spectrograph. (Image credit: Freddy Nuñoz/NOAO/AURA/NSF.)

Comings and Goings in NOAO South Engineering and Technical Services

Manuel Martínez and Roberto Tighe

The La Serena–based NOAO South Engineering and Technical Services (ETS) division provides engineering, design, and precision fabrication resources primarily to support maintenance and improvements to the Blanco and SOAR telescopes and, at a smaller level, to the other projects based in Chile including Gemini South and LSST. The group has seen considerable staff turnover in recent months, with staff moving to, or spending an increased fraction of their time working for, other programs in Chile and new staff being recruited to replace them. This healthy process of exchange between the AURA programs allows cross-fertilization of ideas and is good for staff career development, although it does keep our middle managers, and the HR staff, busy with the recruiting process.

Two new electronics engineers have been added to the La Serena–based electronics group: Braulio Cancino graduated in 2016 from La the Pontificia Universidad Católica de Chile with the degrees of Ingeniero Civil Electrico and Magister en Ciencias de la Ingeniería and has a strong interest in automation and microelectronics. Norman Díaz graduated from La Pontificia Universidad Católica de Valparaíso in 2015 with the degrees of Ingeniero Civil Electrónico and Licenciado en Ciencias de la Ingeniería and is working on the degree of Magíster en Ciencias de la Ingeniería con mención en Ingeniería Eléctrica. He has expertise in data mining, machine learning, automation, and electronic instrumentation. They will be learning from and preparing to take over part of the workload of senior staff engineering staff, who will increasingly be working on projects related to LSST.



New members of the ETS Electronics laboratory staff. From left to right: Guillermo Dubó, Norman Díaz, and Braulio Cancino. (Image credit: Manuel Martínez/NOAO/AURA/NSF.)

Electronic technician Guillermo Dubó has moved from a position at the SOAR telescope on Cerro Pachón to the La Serena Electronics Laboratory, where he replaces Rodrigo Alvarez who has taken up a position at Gemini South. Mechanical engineer Freddy Munoz has moved to a position with LSST where he will be participating in the integration of the dome and telescope on site in Chile. We are currently recruiting a replacement.

continued

NOAO South Personnel Changes continued

Staff Changes in NOAO South Facilities Operations

Nicole van der Bliek

The NOAO South Facilities Operations (FO) department is responsible for operations and maintenance of the physical infrastructure shared by programs hosted by AURA Observatory (AURA-O) in Chile, both in La Serena and on Cerro Tololo and Cerro Pachón. The department also provides and oversees a set of services available to the programs, such as restaurant and hotel services, medical emergency services, and security services. Over the last year and a half, the department has undergone a transformation, grouping the staff by responsibilities rather than location and adding several new staff members.

The hotel services and many of the other common services, such as reception, transport, and guards, are managed by Patricia Valencia. Patricia has been working in the department since 2001, and since April 2015, she has taken over management of the customer service part of the Facilities Operations department. Samuel Aguirre continues to manage the kitchen crew.

In April 2015, two mountain assistants were appointed: Alex Jeraldo and Juan José Paleo. In addition to handling the day-to-day operations of the hotel, they are the point of contact after office hours and for emergencies. In December 2015, Patricio Verdello, senior electric engineer, joined the FO staff to lead the group, which takes care of all common electric infrastructure as well as the infrastructure for the other utilities (water and gas) and the radio communication system. In June 2016, Fabrizzio Bruno joined the FO staff as head of the infrastructure group, which takes care of all common civil works, focused on road and building maintenance, and includes the garage.

In addition to these key personnel additions and changes, we are in the process of reinforcing the groups by hiring additional staff. These changes will allow us to continue improving the services provided by the Facilities Operations department.

The 2016 Colors of Nature Summer Academy

Robert T. Sparks and Stephen Pompea

The National Optical Astronomy Observatory's Education and Public Outreach group led the 4th Arizona Colors of Nature Summer Academy, which was held at the University of Arizona School of Art 13–24 June 2016. Attending this year were 30 students from the Tucson area and the Tohono O'odham Nation. Students were selected through a competitive application process, and a record 125 students applied this year for the 30 spots available.

The Colors of Nature program is sponsored by an NSF Advancing Informal STEM Learning (AISL) grant: "Project STEAM: Integrating Art with Science to Build Science Identitites among Girls." NOAO staff working on the academy included Rob Sparks (Tucson Program Coordinator), Jessica Rose (Logistics), and NOAO undergraduate student Will Roddy (Assistant Instructor). Other undergraduate students participated, including Mattie Tigges, Ricky Maciel, Carlton Stant, Ted Smith, and Bryan Tamborski. Former University of Arizona student Becca Levy took time off from her graduate studies at the University of Maryland to work with the Colors of Nature students and share her interests and research in spectroscopy. The project PI is Laura Conners from the Geophysical Institute of the University of Alaska–Fairbanks, with Mareca Guthrie (University of Alaska Museum of the North), Carrie Tzou (University of Washington–Bothell), and Stephen Pompea (NOAO) as Co-PIs. The project team has experts in optics, science education, biology, art, and art education.

The academy focuses on the role color plays in nature. The students were given a notebook on the first day to record their observations and sketches during the academy. They learned how to make careful observations of phenomena for both scientific and artistic purposes. The students explored the biological functions of color through a variety of hands-on activities, which included a trip to the Arizona-Sonora Desert Museum where they photographed and sketched a variety of plants and animals. They also explored the various ways that colors are produced.

Students experimented with light painting during the Colors of Nature Summer Academy. (Image credit: NOAO/AURA/NSF.)

Pigments were explored using a spectrometer to measure reflectance curves of various pigmented surfaces. Additive color mixing was studied by using red, green, and blue lights. The popular "sodium room" gave students the opportunity to explore a monochromatic world using the light from a low-pressure sodium lamp. Students learned about ultraviolet light and various forms of luminescence including numerous biological examples of these phenomena.

Iridescence and thin film interference were explored as part of the "structural color" activities. Students learned about how polarized light and

continued

The 2016 Colors of Nature Academy continued

optically active substances could be used to create colorful patterns. They explored how the eye focuses, using a large camera obscura with a lens projecting light onto a retinal-type backdrop. Students conducted a dissection of a cow's eye, led by our team biologists, who were also assisted by ophthalmologists from the University of Arizona Medical Center.

After learning about the various ways to produce color, students applied their knowledge in a series of design challenges. Students created artwork using polarized light, produced stop-motion animations illustrating the role of color in nature, and built pinhole cameras.

The Colors of Nature program is completing the fourth and final year of its current grant. The Summer Academy was also held at the University of Alaska–Fairbanks in July with 30 girls. NOAO plans to continue the Colors of Nature program in future years and is currently exploring what type of program we can offer next summer in southern Arizona. The Colors of Nature staff will be analyzing research data collected from the Summer Academies. The research focuses on building science identities, and results will be presented at a variety of professional meetings and submitted to journals.

Future plans for the Colors of Nature team include efforts to disseminate the program nationally. Over the past four years, the Colors of Nature team has developed a strong model for a two-week summer academy, created excellent project kits, and refined a professional development model. The team hopes to expand the reach of the program to girls and out-of-school program leaders across the nation.

Confirmation of *NOAO Newsletter* Subscription

We are currently updating our subscriber database for the printed edition of the *NOAO Newsletter*. If you wish to continue receiving a hard copy, please provide an up-to-date physical address via email to *newsletter@noao.edu* or via regular mail to *NOAO Newsletter*, c/o Newsletter Managing Editor, P.O. Box 26732, Tucson, AZ, USA, 85726.

If you do not confirm your subscription by December 31, 2016, we will assume you no longer wish to receive a printed edition of the *NOAO Newsletter*, and we will remove your name from our printed edition distribution list.

We encourage you to access the *Newsletter* online. Issue number 30 (1992) through the current issue are available online at *www.noao.edu/noao/noaonews.html*. Issue numbers 1–29 are available in hard copy format by contacting *editor@noao.edu*.

Preparing Offices for LSST at NOAO South

Steve Heathcote and Nicole van der Bliek

Aerial view of existing (white) and new (yellow/grey) office buildings on the La Serena compound. (Image credit: Andes Architect Group/Chile.)

In preparation for the start of LSST operations, the office buildings on the La Serena compound will be expanded to provide the additional offices, laboratories, and major data center needed. Rather than construct a separate stand-alone building, AURA, LSST, and NOAO are implementing a joint project to extend and refurbish the existing building to house their combined staff.

Renovation of the existing offices, to bring them up to a standard similar to that of the new construction, will start in the coming months. The renovation will be carried out in phases, to avoid relocating all staff at once. When visiting the La Serena compound in the coming year, expect to see much activity in the existing building and be prepared to look for staff who might have temporarily moved out of their offices.

The construction of the new office wing and data center, and a major upgrade of the supporting power and communications infrastructure, will proceed in parallel. Construction is expected to start in the first few months of 2017 and will last well into 2018. The final step in the renovation and construction project will be the relocation of the NOAO South computer room and the conversion of this area into a conference center.

This building expansion and renovation will allow coordinated operation of facilities and encourage close collaboration between the scientific and technical staff responsible for operation and maintenance of the different telescopes. It will also place the AURA administrative staff and NOAO South Facilities Operations staffs, who serve all programs, in a more accessible location.

NOAO Staff Changes

(16 February 2016 – 15 August 2016)

New Hires/Rehires

North

Arnold, Zade	Cook
Baucco, Alexandria	Public Program Specialist 1
Christensen, Robert D.	Senior Engineer
Demmer, Paul C.	Technician I
Huang, Lijuan (Wendy)	Senior Software Engineer
Hunting, Emily	Assistant Engineer
Lutz, Jennifer L.	Program Manager
Martinez, Antonio R.	General Maintenance Person I
Narayan, Gautham S.	Research Associate
Nidever, David	Associate Scientist
Siquieros, Johnathan M.	Public Program Specialist 1
Tamborski, Bryan	Special Projects Assistant I
Tigges, Mattie	Special Projects Assistant I
Wargo, Peter L.	Senior Systems Administrator
Weaver, Benjamin	Associate Scientist

South

Bruno, Fabrizzio B.	Associate Engineer
Cancino, Braulio J.	Assistant Engineer
Diaz, Norman C.	Assistant Engineer
Tejada, Eduardo	Admininstrative Specialist 6
Torres, Simon N.	Research Assistant 3

Retirements/Departures

North

Hawes, Michael T.	Kitt Peak Facilities Manager
Head, Amanda L.	EHS Technician
Lavoie, Tammie L.	Risk Manager
Reetz, Kristin M.	Observing Associate
Schirmer, Karianne H.	Research Associate
Stobie, Elizabeth B.	Data Lab Project Manager

South

Alvarez, Rodrigo	Electronics Technician 1
Carignano, Natalia	Summer Research Assistant (REU)
Etheridge, Sarina	Summer Research Assistant (REU)
Gomez, Gerardo	SOAR Site Coordinator
Gordon, Alex	Summer Research Assistant (REU)
Kaleida, Catherine C.	Research Associate
Loerincs, Jacqueline A.	Summer Research Assistant (REU)
Muñoz, Freddy	Associate Mechanical Engineer
Pajkos, Michael A.	Summer Research Assistant (REU)
Stevenson, Sarah	Summer Research Assistant (REU)

Promotions

North

Abraham, Daniel	Craftsperson II
Best, Tanya S.	General Maintenance Person I
Dawson, Robert D.	Technical Associate II
Everett, Mark E.	Assistant Scientist
Garcia, Leander	Craftsperson I
Kouratou, Brenda J.	Assistant Administrative Manager
Marenfeld, Pete	Creative Manager
Paat, Anthony M.	Observing Associate
Sparks, Robert T.	Science Education Specialist II
Taghon, Stacy J.	EHS Technician
Timmermann, Erik R.	Software Engineer II
Uribe, Marcos	Craftsperson II
Villarreal, Luis A.	Craftsperson II
Zazueta, Alfredo	Craftsperson II

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