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Currents

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Meeting on Developing a Time Domain Follow-up System*:* To foster the development of a time domain follow-up system capable of meeting community needs in the LSST era, NOAO and Las Cumbres Observatory will host a workshop on "Building the Infrastructure for Time-Domain Alert Science in the LSST Era" **22-25 May 2017** in Tucson. Read more…

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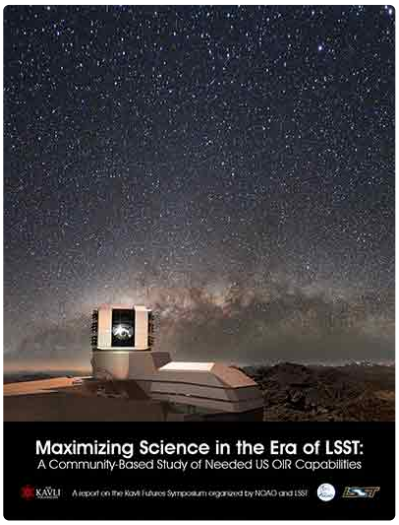
In this Issue

Maximizing Science in the Era of LSST: Study Report Posted

The Large Synoptic Survey Telescope (LSST) will be a discovery machine for the astronomy and physics communities, revealing astrophysical phenomena from the Solar System to the outer reaches of the observable Universe. While many discoveries will be made using LSST data alone, taking full scientific advantage of LSST will require ground-based optical-infrared (OIR) supporting capabilities, e.g., observing time on telescopes, instrumentation, computing resources, and other infrastructure.



Maximizing Science in the Era of LSST report cover.

A recent community-based study identifies, from a science-driven perspective, capabilities that are needed to maximize LSST science. Expanding on the initial steps taken in the 2015 OIR System Report (*Optimizing the U.S. Optical and Infrared System in the Era of LSST*, Elmegreen et al. 2015), the study takes a detailed, quantitative look at the capabilities needed to accomplish six representative LSST-enabled science programs that connect closely with scientific priorities from the 2010 decadal surveys (*New Worlds, New Horizons* and *Vision and Voyages for Planetary Sciences in the Decade 2013–2022*). The study, led by NOAO and LSST, is funded by the Kavli Foundation and the study concept endorsed by NSF/AST.

The study report [6.9 MB PDF], recently published on arXiv and at the study website, (1) quantifies and prioritizes the resources needed to accomplish the science programs and (2) highlights ways that existing, planned, and future resources could be positioned to accomplish the science goals. The results overlap closely with and expand on those of the OIR System Report. The study recommendations, reproduced below, relate to the capabilities that were found to have particularly high priority and high demand from multiple communities.

Study Recommendations:

Develop or obtain access to a highly multiplexed, wide-field optical multi-object spectroscopic capability on an 8m-class telescope, preferably in the Southern Hemisphere. This high priority, high-demand capability is not currently available to the broad US community. Given the long lead time to develop any new capability, there is an urgent need to investigate possible development pathways now, so that the needed capabilities can be available in the LSST era. Possibilities include implementing a new wide-field, massively multiplexed optical spectrograph on a Southern Hemisphere 6-8m telescope, e.g., as in the Southern Spectroscopic Survey Instrument, a project recommended for consideration by the DOE's Cosmic Visions panel (arxiv.org/abs/1604.07626 and arxiv.org/abs/1604.07821); open access to the PFS instrument on the Subaru telescope in order to propose and execute new large surveys; and alternatively, joining an international effort to implement a wide-field spectroscopic survey telescope (e.g., the Maunakea Spectroscopic Explorer at CFHT or a future ESO wide-field spectroscopic facility) if the facility will deliver data well before the end of the LSST survey.

Deploy a broad wavelength coverage, moderate-resolution (R = 2000 or larger) OIR spectrograph on Gemini South. The Gen 4#3 instrument is an ideal opportunity. It is critical that development plans for these capabilities proceed in a timely way so that the capabilities are available when LSST operations begin. A basic, workhorse instrument, deployed early in the LSST mission, is greatly preferred to a multi-mode instrument that arrives later in the mission. A wavelength range of at least 0.36–2.5 microns would provide the highest scientific impact.

Ensure the development and early deployment of an alert broker, scalable to LSST. Public broker(s), and supporting community data and filtering resources, are essential to select priority targets for follow-up. The development of an alert broker that can process the LSST alert stream has challenges beyond the field of astronomy alone. The key questions can be best addressed by computer scientists working with astronomers on this multi-disciplinary problem, and support is needed to enable effective collaboration across the relevant fields.

Support into the LSST era high-priority capabilities that are currently available. Wide-field optical imaging (e.g., DECam on the Blanco 4m at CTIO) is one valuable, but relatively uncommon, capability, as is AO-fed diffraction limited imaging (e.g., NIFS on the 8m Gemini telescope). Other important capabilities are standard on many facilities. Those called out in this report include

- *single-object, multi-color imaging on < 5m facilities*
- *single-object R = 100–5000 spectroscopy on 3–5m facilities*

Support costs for these capabilities include those associated with routine operations as well as timely repair and refurbishment.

Support OIR system infrastructure developments that enable efficient follow-up programs. Two of LSST's strengths are the large statistical samples it will produce and LSST's ability to provide rapid alerts for a wide variety of time domain phenomena. An efficient OIR system can capitalize on these strengths by (i) developing target and observation management software and increasing the availability of (ii) follow-up telescopes accessible in queue-scheduled modes, as well as (iii) data reduction pipelines that provide rapid access to data products. Following up large samples will be time and cost prohibitive if on-site observing is required and/or large programs and triage observations are not part of the time allocation infrastructure. To develop and prioritize community needs along these lines, we recommend a study aimed at developing a follow-up system for real-time, large-volume, time domain observations. As part of this study, discussions with the operators of observing facilities (e.g., through targeted workshops) are important in developing workable, cost-efficient procedures.

Study and prioritize needs for computing, software, and data resources. LSST is the most data-intensive project in the history of optical astronomy. To maximize the science from LSST, support is needed for (i) the development and deployment of data analysis and exploration tools that work at the scale of LSST; (ii) training for scientists at all career stages in LSST-related analysis techniques and computing technologies; (iii) cross-disciplinary workshops that facilitate the cross-pollination of ideas and tools between astronomy and other fields. We recommend a follow-on systematic study to prioritize community needs for computing, software, and data resources. The study should account for the capabilities that will be delivered by the LSST project and other efforts, the demands of forefront LSST-enabled research, and the opportunities presented by new technology.

Continue community planning and development. It is critical to continue the community-wide planning process, begun here, to motivate and review the development of the ground-based OIR System capabilities that will be needed to maximize LSST science. The current study focused primarily on instrumentation. Further work is needed to define the needs for observing infrastructure and computing, as described above. Regular review of progress (and lack thereof) in all of these areas is important to ensure the development of an OIR System that does maximize LSST science. Studies like these form the basis for a development roadmap and take a step in the direction envisioned by the Elmegreen committee that "a system organizing committee, chosen to represent all segments of the

community … would produce the prioritized plan. NSF would then solicit, review, and select proposals to meet those capabilities, within available funding."

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Milliarcsecond Astrophysics Through Open Access to the CHARA Array

Doug Gies, Georgia State University

The Georgia State University Center for High Angular Resolution Astronomy (CHARA) Array at Mount Wilson Observatory is now open to investigators interested in exploring the universe at milliarcsecond resolution in the optical and near-infrared. A long-baseline interferometer, the CHARA Array offers the longest operating baselines in the world and enables diverse investigations, such as the measurement stellar angular diameters and shapes, and studies of orbiting companions and circumstellar environments. Community access to CHARA is funded by an NSF/MSIP award.

Located at Mount Wilson Observatory, the CHARA Array consists of six 1-m aperture telescopes arranged in a Y-shaped configuration with baselines ranging from 33 to 331 meters. By combining the light from these distributed telescopes, the angular resolution is equivalent to that of a single aperture telescope more than 300 meters in diameter, making it the highest angular resolution optical telescope in the world. A complement of six beam combiners offers interferometric capability in the wavelength range 0.5 to 2.5 microns. Multibeam combiners (up to six telescopes) support interferometric imaging studies. Depending on the spectral resolution and number of telescope beams feeding the combiner, the faint magnitude limit ranges from 5 to 9. However, these limits will undoubtedly improve with the introduction of adaptive optics now underway.

Open access to the Array will be phased in beginning in the 2017B observing semester, and some 50 to 75 nights per year will be available to the community. Proposals will be selected through the NOAO time allocation process. Many potential investigators may be new to interferometry, so CHARA scientists are planning to host a series of community workshops at locations around the US beginning in 2017. In addition, a new CHARA Visitor Support Scientist will work with visiting astronomers to help design, implement, and analyze CHARA observations. Financial support will be offered to those astronomers who opt to travel to Mount Wilson to make observations with the Array. The NSF/MSIP funding will also support the development of an open database of CHARA archival data and the renewal of several subsystems to optimize performance during the open access time.

For further information, please visit the CHARA and NOAO web pages at:

- http://www.chara.gsu.edu/
- https://www.noao.edu/gateway/chara/

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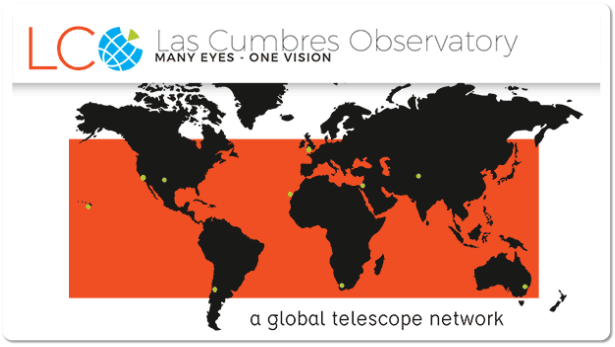
NSF/MSIP Funds Open Access to Las Cumbres Observatory Global Telescope Network

Todd Boroson, Director of Las Cumbres Observatory



Starting in 2017, US community open-access time will be available on the Las Cumbres Observatory global telescope network through an NOAO time allocation process. Specific goals for the use of this open-access time are (a) to effectively follow up on current time domain surveys, especially those with public distribution of data and alerts, and (b) to help the community prepare for time domain research in the LSST era by developing relevant programs, methods, and technologies.

The LCOGT network comprises nine 1-m and two 2-m optical telescopes, optimized for time- domain studies, and operated as a single observatory. There are 2-m telescopes in Australia and Hawaii, and 1-m telescopes in Texas, Chile, Australia, and South Africa. Additional 1-m telescopes are planned for China and Canary Islands.

The 2-m telescopes are instrumented with 10 arcmin field-of-view imagers and R=500 spectrographs. The 1-m telescopes are instrumented with 26 arcmin field-of-view imagers. A set of fiber-coupled, R=50,000 spectrographs is nearing completion, and deployment to the 1-m sites will begin by the end of 2016. Telescopes and instruments run robotically.

Observation requests are submitted at any time through a web form or a programmatic API. Requests may be single observations, sequences with a given cadence, or rapid-response (<15 minutes from now). A scheduler dynamically assigns observations to telescopes.

Data are pipeline processed to remove instrumental signature and may be downloaded from an archive, through a web form or a programmatic API in as little as 15 minutes after the shutter closes. After 12 months, proprietary data becomes public. Additional, detailed information about sites, telescopes, and instrument capabilities and performance is available on the LCOGT website. The website also has links to tools for planning or requesting observations.

Approximately 1300 hours of 1-m time and 220 hours of 2-m time will be available to the U.S. community per semester. Time is charged as it is used, including observation overhead, but not weather or technical downtime. The first "semester" will entail a special call for proposals, and will run April – November, as the schedule is adjusted to align better with the NOAO TAC process. Subsequent semesters will run December-May (for the September 30 deadline) and June-November (for the March 31 deadline).

In addition, U.S. community members are invited to participate in the next round of key project proposals to LCOGT. These are large-scale projects provided with time from the LCOGT share and aimed at highlighting the unique characteristics and capabilities of the LCOGT network. A call for these proposals has been issued by LCOGT (http://www.lco.global/astronomers/key-project-call-2016/), and letters of intent to submit key project proposals are due by 1 November 2016.

(An earlier version of this story referred to Las Cumbres Observatory by the acronym LCO. This has been updated to LCOGT to avoid confusion with Las Campanas Observatory.)

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Zwicky Transient Facility Community Workshop at January AAS meeting (Grapevine, TX, 3 Jan 2017, 1-5 pm)

Steve Ridgway (NOAO), ZTF Community Science Advisory Committee Chair

A community workshop, to be held at the January AAS meeting, will enable community input into public surveys to be carried out with the Zwicky Transient Facility (ZTF). Feedback from the workshop will help determine the final survey parameters.

A next-generation optical time-domain survey, ZTF will feature significantly expanded capability compared to the successful Palomar Transient Factory (PTF) survey. An NSF/MSIP award for ZTF will fund two public surveys, to be carried out in 2017-2020, in order to enable a wide variety of community science. Current plans envision these surveys:

- Northern Sky Survey: a 3-day cadence survey of the visible Northern Sky, similar to the LSST Wide-Fast-Deep Universal Cadence.
- Galactic Plane Survey: a 300-visit per year survey of the Northern Galactic Plane.

All ZTF data will be made public eventually, along with the complete PTF and iPTF archives. Photometric data (images, catalogs, and lightcurves) will be released periodically.

The community workshop will present the instrument capabilities, details of the two surveys, and the planned data products and release schedule. In the second half of the workshop, actual and projected observing programs for PTF, ZTF, and LSST will be compared using the LSST Metrics Analysis Framework. Feedback from the workshop will help the PI team determine the final survey parameters.

The workshop will take place on 3 January 2017, in the afternoon on the day of the opening reception of the AAS meeting. The members of the ZTF Community Science Advisory Committee encourage anyone with an interest in ZTF, and particularly its community survey, to arrive early at the AAS meeting and join us at this special workshop.

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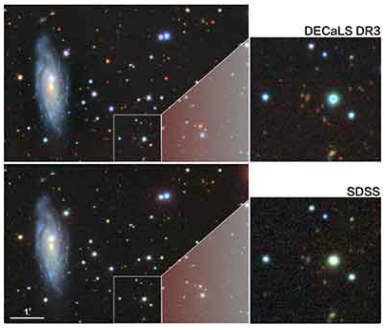
Third Data Release for DECam Legacy Survey



DECaLS DR3 data (top) reach significantly deeper than SDSS images (bottom). In addition to foreground stars, nearby galaxy UGC4640 and many distant galaxies are visible within this 7.5'x5' field-of-view.

The DECam Legacy Survey (DECaLS) has announced its third data release. An NOAO Survey Program led by co-PIs David Schlegel (LBNL) and Arjun Dey (NOAO), DECaLS uses the Dark Energy Camera (DECam) on the CTIO Blanco 4m telescope to image nearly square degrees of the extragalactic sky in three bands (g, r and z). Earlier data releases were made in June 2015 (DR1) and February 2016 (DR2). The current status of the survey is shown here.

The third data release (DR3), which covers [4300, 4600, 8100] square degrees in [g, r, z] bands respectively, includes catalogs and images obtained between August 2014 and March 2016. DR3 also incorporates public data within the DECaLS footprint from other NOAO observing programs and photometry

from NASA's Wide-Field Infrared Surveyor's maps of the sky.

The final DECaLS sky coverage will extend in declination from approximately -18 to +30 degrees, and cover Galactic latitudes |b| > 18 degrees. The survey also overlaps the SDSS/BOSS extragalactic footprint. DECaLS will allow astronomers to probe the structure of the Milky Way, the nature of dark energy, and many other topics in astrophysics. All data are immediately non-proprietary and the project schedules two data releases per year.

The DR3 release includes raw data, individual calibrated DECam exposures, image coadds in 0.25x0.25 square degree "bricks", source catalogs containing approximately 478 million unique sources, and an interactive sky viewer interface. An Image Gallery of Large Galaxies constructed by Dr. John Moustakas is also available. For further information regarding DR3, please see the survey website http://legacysurvey.org.

DECaLS is one of three surveys that will jointly image 14,000 square degrees—nearly one-third of the sky—to provide targets for the Dark Energy Spectroscopic Instrument cosmology project. The other two projects are the Mayall z-band Legacy Survey (MzLS), which began in February 2016, and the Beijing-Arizona Sky Survey (BASS), currently underway at the Bok Telescope on Kitt Peak. MzLS and BASS will provide g- ,r-, and z- band imaging at declinations north of +34 degrees.

DECaLS DR3 data products are available through the NOAO Science Archive and ftp server. In addition, the NOAO Data Lab has developed a database to query all DR3 catalogs, which is available by contacting the Data Lab directly (datalab@noao.edu).

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Building the Infrastructure for Time-Domain Alert Science in the LSST Era (Tucson, AZ, 22-25 May 2017)

The era of large-scale time-domain astronomical surveys has arrived. Current projects (e.g., Catalina Sky Survey, the Palomar Transient Factory, Pan-STARRS) demonstrate the tremendous scientific potential of the time domain, and future facilities (e.g., Zwicky Transient Facility and LSST) are about to expand exponentially the scale of time-domain astronomy. Because the volume and rate of alerts will be well beyond the ability of individual investigators to process, the astronomical community will need a time-domain ecosystem equipped with software to generate, validate, and filter alerts, as well as systems to schedule, coordinate, and analyze follow-up observations.

Open access time on federally-funded facilities (e.g., SOAR, Blanco, Gemini, Las Cumbres Observatory), in combination with public brokers and alert streams, offers the opportunity to develop a full-fledged time-domain follow-up system. To foster the development of such a system, NOAO and Las Cumbres Observatory (LCOGT) will host a workshop on "Building the Infrastructure for Time-Domain Alert Science in the LSST Era" **22-25 May 2017** in Tucson.

The first portion of the workshop will bring together astronomers and others working on a wide variety of technical issues related to time-domain alerts. The second part of the workshop will focus on the science that can be done with the LCOGT network. It will also begin the planning and implementation of a time-domain system

infrastructure that can take advantage of the resources available now as well as lay the groundwork for the opportunities LSST will present.

The goal of the workshop is to produce, for NOAO, LCOGT, and the ground-based OIR system, a plan for development of the time-domain ecosystem infrastructure and science programs that can begin to take advantage of resources available now. Please visit the meeting website to request further information, including registration details.

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Contact Us

Your input is welcome on any of these issues. Please send your thoughts to: currents@noao.edu.

Currents is a sparkplug for communication between NOAO and our community. It provides updates—and solicits community input—on NOAO observing opportunities and NOAO programs and policies on a more rapid timescale than is possible with the *NOAO Newsletter*.

NOAO is the national center for ground-based nighttime astronomy in the United States and is operated by the Association of Universities for Research in Astronomy (AURA), Inc. under cooperative agreement with the National Science Foundation.