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This month's issue of E-News brings you up to date on a very significant project development, our successful completion of the NSF Preliminary Design Review (PDR). As we grind our way down the funding path, development of the Cerro Pachón site continues, including a delicate and successful preservation of indigenous plant species. Other E-News articles feature staff, science, and the LSST Operations Simulator as we strive to keep our extended community of readers informed and engaged.

In This Issue

FROM THE PROJECT OFFICE

The Division of Astronomical Sciences (AST) of the National Science Foundation (NSF) convened a Preliminary Design Review (PDR) of the Large Synoptic Survey Telescope (LSST) project August 29 through September 2, 2011 in Tucson, Arizona. The review, the most significant the project has undergone so far, was in response to submission of the LSST Construction Proposal to the NSF. Although the PDR focused on project management and the project's NSF-funded design work, the 12-member panel spent nearly five days reviewing every aspect of the project in great detail, including both the privately funded work on the major optics and the design of the camera, which is funded separately by the Department of Energy (DOE).

The scientific case for LSST was not the focus of the review; that was taken as a given because the project had already received the number one endorsement for a new ground-based facility from the Decadal Survey. However, reference was made throughout the PDR to the tremendous community support of the project through the science collaborations, as well as all the exciting scientific opportunities described in the Science Book.

A short plenary session was followed by a total of 12 extensive breakout sessions led by senior project managers, covering the telescope & site, camera, data management, education and public outreach, project management, systems engineering and simulations, and operations and commissioning. The team was well prepared, due in large part to a Board of Directors' non-advocate review held a few weeks earlier to assess readiness for PDR.

The PDR panel concluded that the LSST project met the requirements for PDR. In particular, the Panel reported that it was "very impressed by the strength of the project team" and that "the design is well advanced and the Panel had no design related issues." The Panel also found that the project is using appropriate management techniques and that the schedule, budget, and contingencies are reasonable.

The NSF Preliminary Design Review Committee visits the Steward Observatory Mirror Lab to inspect the LSST Primary Mirror

At a verbal debriefing on the meeting's final day, the PDR review committee used words like "great progress" and "great review" in their assessment of the LSST. The PDR panel has since completed its 45-page Panel Report containing 36 specific recommendations to assist the project team as they complete the Design and Development phase and make the transition into construction. These recommendations will be very helpful as we plan the final years of design and development.

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LSST Project Team, as rendered by E. Acosta, 2011 Image credit: LSST

Even though the PDR was completed successfully, the path is far from over. Immediately, the construction proposal must be resubmitted to reflect the LSST construction project's new status as an AURA Center. Then a proposal will be submitted to take us from FY13 (when current funding expires) through construction start. Of course, with the budget situation as it is in Washington, DC, the date of construction start still eludes us. An excellent article describing the squeeze on construction of large facilities through the NSF appeared in Science VOL 333 9 SEPTEMBER 2011. Taking the stance of planning for success, the LSST team remains hard at work on those things within its control.

Article written by S. Jacoby and D. Sweeney

WILD GARDENS OF LSST PRESERVE ENDANGERED PLANT SPECIES FROM EL PEÑÓN

Rescue, maintenance and relocation of Eriosyce aurata from El Peñón (photos by Enrique Bustos Bernard)

Initial site leveling of El Peñón peak on Cerro Pachón has been completed, shortening the summit by nine vertical meters and removing approximately 19,000 cubic meters of rock and earth. While this massive engineering enterprise is both impressive and necessary to prepare for the LSST summit facility, calibration telescope, and roads, it displaces more than lifeless rubble. Cerro Pachón is home to a vibrant desert ecosystem.

Both LSST and the government of Chile are concerned about the impact of the project on native, endangered flora and fauna. From the beginning of LSST's relationship with Chile, the protection of threatened species – and in particular the relocation and replanting of flora in need of preservation – has been part of the site development plan. An Environmental Impact Declaration (DIA) was submitted by Enrique Figueroa, AURA Strategic Projects Coordinator, on behalf of LSST/AURA to CONAMA, the environmental agency of Chile. The CONAMA resolution approving the DIA stipulates that prior to excavation work "all the native flora that was identified as having conservation problems in the Baseline Study of the Flora and Vegetation will be relocated as recommended by that study."

The rescue, relocation, and propagation program, conducted by botanical specialists at the University of La Serena, began in 2009 and is already demonstrating success.

The program established a three-hectare protected area with geographical biodiversity similar to El Peñón and created wild gardens to which rescued specimens would be relocated. In addition to the rescue and transplantation of mature plants from the summit, the program collected fruit from Eriosyce aurata and cuttings from Anisomeria coriacea in summer of 2009 in order to propagate 70 specimens of each species. After

Cactacae - Eriosyce aurata (photo by Fundación Jardín Botánico Nacional de Viña del Mar, under Creative Commons license)

the purpose, the propagated specimens are repopulated in the wild gardens. Rescued and propagated specimens are tended and their survival monitored at regular intervals.

A July 2011 report from consulting agronomist Enrique Bustos Bernard

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Wild Gardens... (Cont.)

described the successful rescue, relocation, and transplantation of 25 specimens of the endangered cactus species Eriosyce aurata. The report also testified to the good condition of specimens that had been rescued in April.

"Propagation of Eriosyce aurata and Anisomeria coriacea," a report prepared by Gina Aracancio of the University of La Serena, indicates successful propagation of Eriosyce aurata. Unfortunately the program was unable to collect any viable Anisomeria coriacea seeds from El Peñón and propagation from cuttings has proven disappointing, however of the 300 Eriosyce aurata seeds collected, 270 have germinated. The seedlings are being cultivated in a greenhouse and eventually will be transplanted to El Peñón.

Eriosyce aurata seedlings at six months (photo by Gina Aracancio)

With the completion of LSST's site leveling activities, and with the encouraging results of the rescue and propagation programs, Mario González Kemnis, AURA Safety and Environmental Engineer, anticipates that replanting on El Peñón will begin in January or February 2012. Like the previous transplantation to the wild gardens, this revegetation of the LSST site will be an important step in an ongoing program of conscientious and responsible site stewardship by LSST/AURA under the direction of Chilean biologists and environmental agencies.

Article written by Robert McKercher with contributions by Jeff Barr

THE OPERATIONS SIMULATOR

The LSST will operate as a survey telescope, robotically scanning the sky in a pre-programmed sequence of observations, then storing images in a public database for use by professional and citizen scientists exploring the wide range of LSST science topics. Much like scheduling an elevator to minimize wait time for riders, this sequence of observations, the "observing cadence", must be optimized to provide data that enables the most science as efficiently as possible. The task of determining the optimum observing cadence to maximize the science is the job of the LSST Operations Simulator.

During its ten-year survey, LSST will acquire about 5.6 million 15-second images, spread over about 20,000 square degrees— their distribution on the sky, over time, and among its six filters has a strong impact on how useful these data are for almost any astronomical investigation. The LSST Project has developed an Operations Simulator (LSST OpSim: http://www.noao.edu/lsst/opsim) to verify whether the current telescope design can acquire a set of observations suitable to address the questions from each of the four main science themes. Currently the question of which field to observe next is answered by ranking fields which are "requested" by each of the science programs. We are exploring a variety of scheduling algorithms to determine the optimal strategy for the design of the scheduler which will drive the largely robotic observatory. The simulator will remain an important tool for operations, allowing LSST to adapt and evaluate its observing strategy in response to the changing scientific demands of the astronomical community.

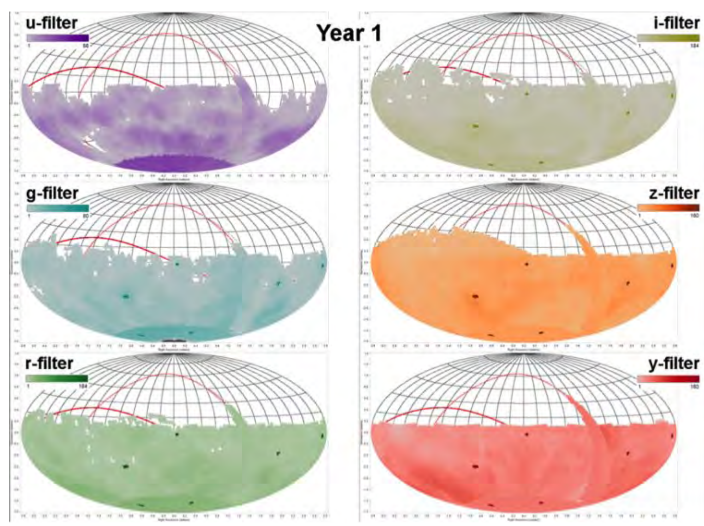

Figure 1. The number of visits to a field in each filter in the first year of a 10-year survey (plotted in Aitoff-Hammer projection) is relatively uniform and an estimate of the depth achieved for that field. Darker colors indicate more complete coverage. Note the six "spots" scattered on the sky that appear darkest – they are the LSST "deep drilling fields", areas of special interest

The Operations Simulator uses detailed models of site-specific conditions (e.g., cloud cover, seeing) and telescope opto-mechanical capabilities (e.g., the time required to slew to a new position) to create realizations of the set of observations the telescope will make. One output of the simulator is an observing log which includes, among the 50 visit-specific characteristics: the position on the sky, time, and filter of each visit, and the brightness of the sky in that

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filter. Post-processing adds additional sky brightness estimates (from different sky brightness models) and the signal-to-noise ratio achieved. An analysis pipeline has been developed, which generates a standard report containing measures of the characteristics of the survey, such as the distribution of the mean seeing per field for all visits in a filter, estimates of the depth of the final stacked images in each filter as a function of position on the sky (Figure 1), or other figures of merit relevant to particular science goals (Figure 2).

We are continuing to work on how to best control the survey progress by altering the algorithms and parameters that describe each science program. In the next version of the simulator, we will be developing additional scheduling strategies to explore the effectiveness with which we can address each of the four key science goals. We are working with the LSST Science Collaborations (who have been provided with a username and password to gain access to simulated survey data and analysis on the website) to refine our current cadences by asking them to develop additional figures of merit to measure how well a particular simulated survey can do their science.

Article written by Cathy Petry

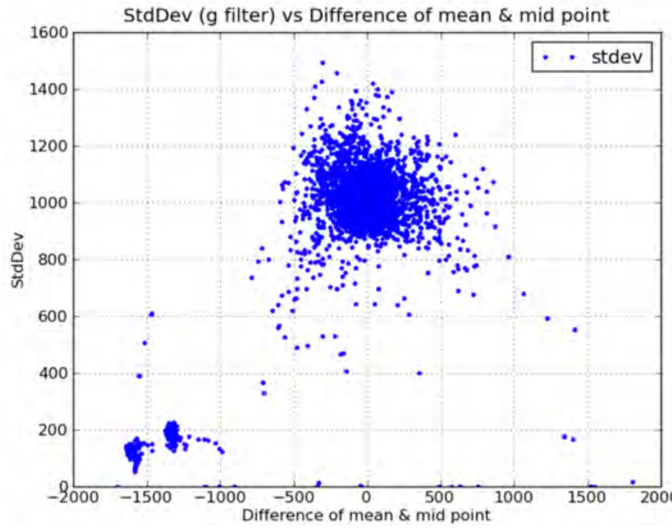

Figure 2. A figure of merit designed to measure how uniformly in time each field is visited over the 10 year duration of the survey. For each field observed in the g-filter, the sequence (distribution) of visits in days is determined. The mean of this sequence is compared to the midpoint of the survey (x-axis) and plotted against the standard deviation of the distribution (y-axis). This plot separates fields that are observed uniformly in time (center of plot) from ones that are visited more episodically.

SQUIDS HAVE BEAKS AND OTHER MYSTERIES OF THE UNIVERSE – ANDY RASMUSSEN

Andy Rasmussen (photo by Natalie Hidaka)

Physicist Andy Rasmussen works with the SLAC-based Camera Team to develop and build the sensor array at the heart of the LSST camera, an instrument of unprecedented scale and scope. Rasmussen describes the scale of the camera's focal plane as "mind boggling: three billion pixels, comprised of 189 science sensors, each segmented into 16 channels, all read out in two seconds – incredible!" The same enthusiasm evident in Rasmussen's description of the LSST focal plane has been manifest in his lifelong love of research beginning as an amateur biologist.

"My (literal) first interest in research came at an early age, probably age 8 or so. I was fascinated by Nature. In Japan, where I grew up, there were many, many species of insects that defied imagination. In front of my eyes there was specialization of body parts, finite life cycles, metamorphoses. Once I decided to buy a fresh squid from the local fish shop, dissect it and carefully illustrate the structure of the body, internal organs, eye, the membranes, and so on. Imagine my surprise when I discovered that squids have beaks! I did have a copy of The Universe, a Time/Life science library book, with lots of pictures of galaxies and globular clusters – and that was pretty dull by comparison."

Rasmussen joined the LSST team at SLAC in 2005 because of the ambitious project goals, the unique challenge of the work, and the opportunity to engage in a project that promises to have a huge impact in the field. Andy explains, "The survey data acquired using LSST will enable scientific fields that have historically been data-starved. It will provide multi-band photometric data with frequent coverage, which should yield many new discoveries in the time domain, including regular discoveries of distant supernovae, proper motions of many, many stars, and solar system objects. The plentiful, short exposures will enable routine stacking of deep images into even deeper images that won't be compromised by the poor image quality that accompanies long exposure times."

One of the more challenging demands of Rasmussen's work is maintaining optimal imaging performance over the entire focal plane all at once. He described it as a complex, systems related task. "Achieving this will be a first; nothing like it has been achieved to date," he said. "One detail I pay particular attention to is how we will position the 189 individual sensor surfaces to fall within a planar volume only 10 microns thick – one tenth the thickness of a typical human hair!"

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Andy Rasmussen... (Cont.)

In his off hours, Rasmussen continues to indulge his curiosity regarding how things work. Recently he repaired his "old, beloved Volvo." What began as a simple DIY project to prolong the life of a car "loaded with sentimental value and engine problems" proved to be more complicated and challenging than he intended. "Having slogged through that," he said, "I now understand the value of that shop class I missed in high school. I also know why I am not a mechanic!"

With the temper of a scientist, Rasmussen engages in what he considers the most satisfying aspect of his work: quantitatively simulating the LSST performance. The LSST Image Simulation group provides high fidelity end-to-end simulations of the sky that mimic conditions to be observed during the LSST survey. These simulated images and catalogs are used in designing and testing the LSST system, and they provide realistic LSST data to the science collaborations to evaluate the expected performance of LSST.

Beyond Rasmussen's enthusiasm for LSST's technical and engineering ability to reveal the wonders of the universe, he stresses the practical contribution to the scientific community by the project's data. "The public nature of LSST data," he said, particularly the short latency period, "is a different and new approach compared to almost every other field. In my experience with space-based astronomical data, there was a proprietary period giving advantage to the proposer or principal investigator – in some cases as much as 12 months following its capture. With LSST, there is no Time Allocation Committee or proposal review panel, so the data goes public almost immediately... The combination of LSST data will be high quality, with high availability. This promises to change the astronomical/research world considerably."

By Robert McKercher and Andy Rasmussen

LSST LOOKS AT THE BIG PICTURE: LARGE-SCALE STRUCTURE OF THE UNIVERSE

This E-News article is based on Chapter 13 of the LSST Science Book: Large-Scale Structure and Baryon Oscillations. The Authors of Chapter 13 are:

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What is the large-scale structure of the Universe and how did it come to be? This is perhaps the most fundamental question of cosmology. Scientists studying the large-scale structure of the Universe explore the "big picture" of how the Universe is organized over immense distances and time. With unprecedentedly large samples of galaxies from LSST, scientists will be able to move closer to definitive answers about how the Universe that we observe came to be.

We see the Universe today as stars, which collect into larger organizations called galaxies and from these into clusters of galaxies and even superclusters – ever larger accumulations of matter. In the standard model of cosmology, these structures grew mostly under the influence of gravity from tiny seeds, which came from quantum fluctuations in the very early Universe with important modification by radiation and baryons (essentially hydrogen and helium plasma) within the first 400,000 years of the history of the Universe. So the large-scale structures we observe today encode critical information about the contents of the Universe, the origin of the fluctuations, and the cosmic expansion background in which the structures evolved.

Cosmology is the study of the origin, structure, and evolution of the Universe. The Big Bang Theory is the cornerstone of modern cosmology.

LSST will observe the Universe across a broad range of wavelengths and will provide huge volumes of data. Its sample of ten billion galaxies over 20,000 square degrees, the largest photometric galaxy sample of its time, will allow a precise characterization of the distribution and evolution of matter on extragalactic scales. Scientists will be able to use LSST survey data to constrain cosmology through galaxy spatial correlations, counts of galaxy clusters, and the correlation between galaxy overdensities and the cosmic microwave background (CMB) temperature fluctuations.

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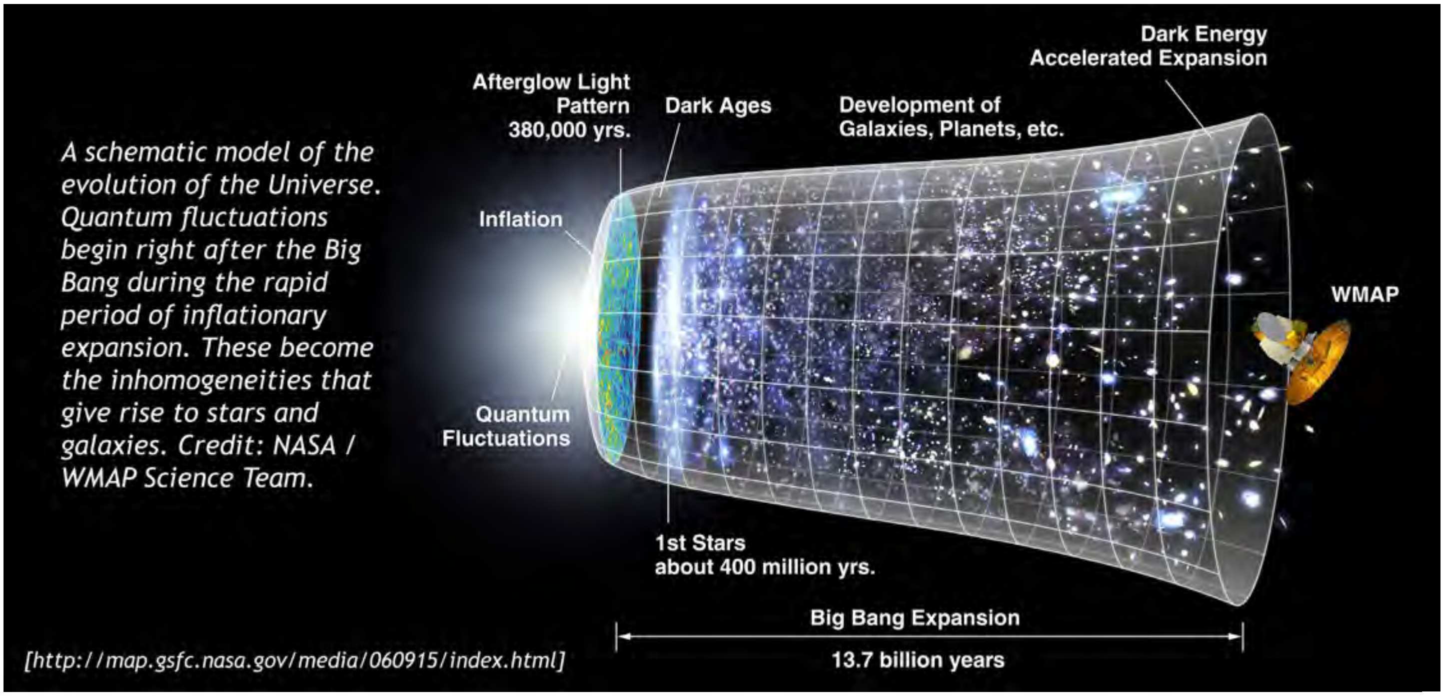


A schematic model of the evolution of the Universe. Quantum fluctuations begin right after the Big Bang during the rapid period of inflationary expansion. These become the inhomogeneities that give rise to stars and galaxies. Credit: NASA / WMAP Science Team.

[http://map.gsfc.nasa.gov/media/060915/index.html]

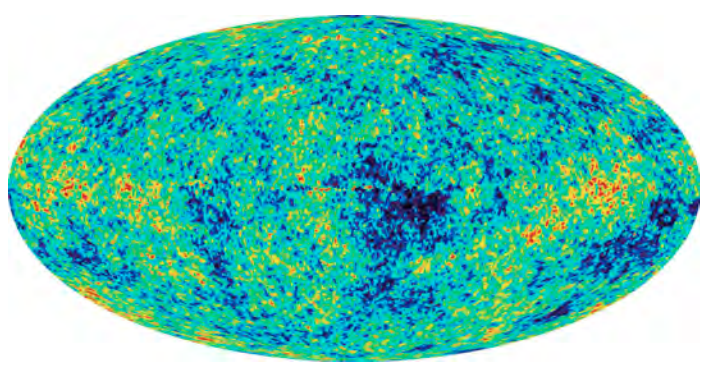
Of particular interest to scientists is the imprint of Baryon Acoustic Oscillations (BAOs) on galaxy clustering, because the BAO features can be used as a standard ruler to measure distances and to constrain cosmology. At early times, the Universe was so hot and dense that the primary elements, hydrogen and helium, formed a plasma tightly coupled to photons. Acoustic waves propagated in this highly relativistic plasma, supported by photon pressure. BAOs are a record of the phases of these waves.

As the Universe expanded, it cooled. Eventually, about 380,000 years after the Big Bang (at a redshift of z=1,100), the Universe was cool enough that protons and electrons formed neutral hydrogen atoms. This is the event called recombination, which decoupled photons from matter. Without the photons supplying the pressure, the acoustic waves were essentially frozen after recombination, showing up as BAOs in the galaxy distribution.

For the photons, decoupling means that the Universe became transparent, so that they could move freely through the Universe. Today we observe these photons as the CMB radiation.

The characteristic scale of the BAO features in the galaxy spatial distribution shifts only slightly after recombination due to nonlinear evolution and thus can serve as a CMB-calibrated standard ruler for measuring the angular-diameter distance and thereby constrain cosmological parameters including the dark energy equation-of-state.

Joint analyses of LSST's sample of billions of galaxies with a map of the cosmic microwave background radiation from either the Wilkinson Microwave Anisotropy Probe (WMAP) or the Planck satellite can provide additional information about the Universe. LSST will measure the late-time Integrated Sachs-Wolfe (ISW) effect, the gravitational redshift of photons from the CMB, through correlation between the foreground galaxy distribution and background CMB temperature fluctuations, which will provide insight into the nature of dark energy. Correlating CMB fluctuations with different subsamples of galaxies selected by redshift or type will allow scientists to measure how the ISW signal changed over the history of the Universe. ISW is the best means to detect whether or not the dark energy field can cluster.



The Cosmic Microwave Background (CMB) temperature fluctuations from WMAP. This projection shows temperature variations over the celestial sphere. The average temperature is 2.725 Kelvin (degrees above absolute zero; absolute zero is equivalent to -273.15°C or -459°F), and the colors represent tiny temperature fluctuations, as in a weather map. Red regions are warmer and blue regions are colder by about 0.0002 degrees. Credit: NASA / WMAP Science Team [http://map.gsfc.nasa.gov/media/080997/index.html]

One important challenge for cosmologists is to understand the physics of the initial conditions of the Universe (e.g., inflation physics). LSST's addition of large-scale structure data will significantly improve knowledge about very large-scale primordial fluctuations in the matter distribution, which entered the horizon after the epoch of matter-radiation equality (approximately 50,000 years after the Big Bang, redshift z=3,100) and have grown primarily due to gravity since that time. These fluctuations preserve the imprint of primordial quantum perturbations, which can help refine models of inflation.

LSST will also produce a large catalog of clusters of galaxies. The cluster abundance can probe the dynamical and geometrical aspects of the cosmological model as a function of redshift, which is a powerful way to discover the nature of dark energy and any deviations from standard gravity. A number of methods to find clusters exist. They differ in their emphasis on different aspects of the cluster galaxy populations. All methods provide a list of cluster positions, photometric redshifts, and observable properties such as richness, total luminosity, and so on. The LSST survey will find so many clusters that scientists will be able to use comparison of different catalog construction methods and different selection cuts on the survey data itself as a powerful control of the selection function and systematics.

The unparalleled volume and depth of LSST's observations will map the Universe over the largest scales of time and space. Revealing this full picture of the large-scale structure of the Universe will take scientists back to the very beginning in order to answer the fundamental questions of cosmology.

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