The Project Office welcomes you to the October 2009 issue of E-News, where we begin a new feature—Science! Each month we will highlight a chapter of the Science Book, describing possible results to come from LSST and how LSST will influence various areas of astronomy. Thanks to Beth Willman and the Milky Way and Local Volume Structure Science Collaboration for starting us off. And speaking of the Science Book, V2.0 goes to press in early October. We expect print and CD copies to be available at the January 2010 AAS meeting and online distribution to begin later this month.

Watch www.lsst.org for an update.

PROJECT MANAGER’S CORNER

On August 17 the LSSTC formally submitted a proposal to the National Science Foundation titled the “LSST Final Design Phase,” which will provide substantial support to the LSST project from April, 2010 to the beginning of construction, a period of time between 18 and 30 months depending on the pace of federal action on LSST funding. The Final Design Phase takes the project from the Preliminary Design Phase to the point that construction is ready to begin. It’s also an important precursor for the last major NSF review called the Critical Design Review.

This proposal is the first submission we expect to result in funding from the NSF coming directly to the LSSTC; our previous NSF money was awarded through the NOAO Cooperative Agreement. Institutional accreditation of the LSSTC by the NSF is currently pending, and action is due soon.

The LSST management team has also decided to use this Final Design period of up to 30 months to initiate the formal project management techniques and control tools that are required by both the NSF and DOE during the construction phase. While we’ve used these tools to plan the construction phase, we haven’t used them to manage the daily activity of the project. Now is the perfect time to exercise these tools to learn the full details and discipline necessary that’s required during construction.

We started with 3 days of formal training of the entire management staff. We hired a consultant to review details of Primavera, a schedule and resource management software tool. We reviewed concepts for integrated work-packages, schedule and budget control. This software also interfaces with an accounting package so that we can implement certified earned-value management. The consultant will continue involvement in the project to assist us and critique our progress.

Pushing the button on the Final Design Proposal. (L-R) Don Sweeney, Daniel Calabrese, Sidney Wolff

Continued on p. 2
Our subsystem leads and their teams are now working to create a work breakdown structure, define activities, assign resources and schedule tasks during the 30-month Final Design period. This will all be coded into the Primavera database. We will track progress against the activities and milestones as a function of time and resources consumed (i.e., earned-value). This will jump start the management processes required during the hectic construction phase.

So far, we are off to a good beginning. This earlier than necessary adoption of a formal project management control system will give us the time and tools to deal with any issues that emerge.

Article written by LSST Project Manager Don Sweeney

MIRROR NEWS

More than a year ago the LSST Primary/Tertiary (M1/M3) monolithic mirror blank emerged from the oven at the Steward Observatory Mirror Lab (SOML). Since that time the honeycomb structure has been cleaned out and moved into the large polishing area of the lab where the back surface has undergone months of loose abrasive grinding and then polishing, a process which finished up in early September. Over the next few months, hardware will be installed on the backside of the mirror blank in preparation for turning the blank over and placing it in the polishing cell for another two years of front surface grinding and optical polishing. As we follow this construction path, we gain an appreciation for mirror production as the longest lead time item in building the LSST. It really is a lot of work “just” to prepare a piece of glass to hold a few ounces of aluminum!

Of course the hardware that holds the mirror is critical as well, and work on this important element began in earnest this past month. Senior Optical Engineer Bill Gressler describes work underway now in the LSST Mirror Support Hardware Lab.

While the LSST M1/M3 mirror blank enters the final 2-year stage of front surface grinding and optical polishing at SOML, a parallel hardware engineering effort has begun at the Telescope and Site office at NOAO. There, the LSST Mirror Support Hardware Lab enables performance and environmental testing to assist with prototyping and final design selection of the M1/M3 support components. LSST plans to design, fabricate, assemble, and deliver qualified subassemblies for integration of the M1/M3 and telescope cell in early 2012.

The M1/M3 support system provides positioning of the mirror and surface figure control to remove bending modes and figure errors due to gravity and thermal fluctuations. Support forces are safely distributed through the mirror via 156 loadspreaders and 6 hardpoint wedges bonded onto the flat backplate. The M1/M3 support system consists of 6 hardpoint actuators that define the mirror’s position within the telescope and 156 axial support actuators. There are 52 single axis and 104 dual axis actuators, to total 260 axial actuators.

The baseline LSST axial actuator design is a pneumatic system incorporating successful features from LBT and Magellan. Specific tests of the cylinder types, valve control units, and load cells can be performed in the lab via a data recording test stand. Cylinder response (force vs. psi), resolution, repeatability, stiffness, and frequency response can all be charted for analysis. The stringent cadence requirements of the LSST (5 second slew and settle for an adjacent field move) mandate quick temporal response with minimal hysteresis and stiction. An alternate electromechanical approach based upon proven SOAR hardware will also be investigated.

The system development plan allows for analysis and comparison of competing designs to permit final component selection by mid 2010. This schedule enables fabrication and delivery of a mirror cell and support components for integration with the completed M1/M3 mirror, which is slated for delivery to LSST in early 2012.

Bill Gressler & Suzanne Jacoby contributed to this article.
Just outside of Philadelphia, Beth Willman "runs her life in triage mode," and does a fine job of it. Balancing a new baby, a new job at Haverford College, and ongoing, professionally demanding research collaborations as well as leading the efforts on the Milky Way and Local Volume Structure chapter of the LSST Science Book keep her life from ever getting boring.

This year she will offer a beginning astronomy course at Haverford, an academic base she chose somewhat unexpectedly. Beth had intended to pursue her career at a large research university, but during her second post-doc (at the Harvard-Smithsonian Center for Astrophysics (CfA)) she found that a lot of her professional satisfaction came from motivating students and project teams. The Haverford community seemed the ideal match for her skills, desires, and career trajectory.

Beth is a leading researcher in ultra-faint galaxies. She just received NSF funding to support her search for the least luminous galaxies, including hiring a post-doc. Her projects fall into three research areas. The first includes: the search for these galaxies in smaller datasets that go deeper than projects such as SDSS (such as the RCS2 dataset), developing new algorithms for finding the least luminous galaxies in datasets deeper than SDSS, and searching both public SDSS data and the upcoming Southern Sky Survey data in collaboration with the Stromlo Missing Satellites collaboration. Two students, Dylan Hatt (Haverford 2010) and Jen Campbell (Haverford 2011) are working with her on this research.

A second area of focus for Beth is studying the spectroscopic properties (both kinematics and abundances) of the least luminous satellites recently discovered around the Milky Way, trying to determine whether they are dark matter dominated dwarf galaxies (and if so, how much dark matter they contain) or star clusters. Alex Warres (Haverford 2010) is working with her on this research.

A final area of study concentrates on defining the photometric properties of the ultra-faint dwarf galaxies - their structures and star formation histories, in particular looking for evidence of tidal disturbance and for evidence of extended epochs of star formation. Gail Gutowski (Haverford 2010) is working on this with Beth.

Beth began her path to LSST (and other research pursuits) when a professor at Columbia sent her a letter wondering whether she had any interest in studying astronomy in college. She did. After graduating from Columbia University, she pursued a doctorate at the University of Washington and followed this as a James Arthur Fellow at New York University Center for Cosmology and Particle Physics and then as a Clay Fellow at the CfA. Beth says her time at CfA re-energized her interest in astronomical research, working with students, and seeking leadership positions. While Beth is certainly the architect of her career, putting in immense time and effort, she is quick to acknowledge the positive impact that others have had.

The research experience obtained in these projects provided half of the class with the foundation for successful research experiences in astronomy this past summer.

Beth spends her time searching for galaxies that are about one millionth the luminosity of the Milky Way. These objects are totally invisible and were unknown until the Sloan Digital Sky Survey, but LSST is ideally well-suited to search for them. "Is the luminosity so low because of nature or nurture? We really don’t know. But they do have the highest dark matter ratio of observed galaxies. And so the search is important because they have great potential to reveal the properties of dark matter and the effects of environment and feedback on galaxy suppression," Beth reflects, obviously captivated by both the questions and the search.

"The satisfaction of seeing astronomical objects that no one has ever seen before is incredible—both exciting and deeply moving. LSST should provide the opportunity for seeing a lot of ultra-faint galaxies for the very first time."

Anna Spitz worked with Beth Willman on this article.
Individual stars in the Milky Way and the galaxies nearby can be resolved by the LSST. These stars then provide a fossil record—a Rosetta Stone—that can be decoded to determine how these galaxies were formed. LSST will revolutionize the study of this fossil record.

The region of space within a distance of about 10 Megaparsecs (Mpc), or 32 million light years, from the Milky Way is called the Local Volume (LV) because, astronomically speaking, it is so nearby. The last decade has seen a renaissance in the study of our own and other galaxies in the LV, based in large part on the multi-dimensional maps provided by the vast numbers of stars cataloged by the Two Micron All-Sky Survey (2MASS), Sloan Digital Sky Survey (SDSS), and others. This renaissance has revolutionized our view of the Milky Way by facilitating cross-sectional views of its global structure and revealing a vast menagerie of substructures, including a new population of satellite galaxies with a millionth the luminosity of our Galaxy and a halo replete with lumps and streams that betray its formation.

LSST will provide an excellent resource for mapping the structure and accretion history of the Milky Way and LV in a way that the present generation of surveys has only hinted at. LSST is anticipated to catalog over 1 billion stars, for 200 million of which we will also have measured photometric chemical compositions. (For comparison, SDSS measured about 50 million stars.)

These maps, which will include information about the spatial distribution, motions, and chemical compositions of individual stars are key to understanding what our Galaxy looks like, how far it extends, how it and other galaxies formed, and how much dark matter exists and where it is located.

Science enabled by LSST includes mapping the 3D distribution of dust throughout the Milky Way’s disk; understanding the smooth distribution of stars in the MW and other nearby galaxies; understanding large-scale chemical gradients in the MW; discovering lumps and streams in metallicity and phase-space; inferring the mass distribution in the MW; discovering ultra-faint galaxies throughout the Local Volume as overdensities of resolved stars.

A Milky Way Map

Chapter 7 says that LSST will provide a “uniform, multidimensional, star-by-star phase space map of all Milky Way components.” What this means is that LSST will measure the positions, proper motions (i.e., motions across the plane of the sky), and chemical compositions of millions of individual stars in the Milky Way. The Galaxy consists of three main parts: a spherical bulge in the central region, a disk of young and old stars, and a low density halo of stars and dark matter that extends about half way to the Andromeda galaxy. The LSST survey will provide a complete picture of the spatial, kinematic, and chemical makeup of the Galaxy and its components (halo, bulge, and disk). LSST will enable a complete characterization of these three components, which leads to a better understanding of how the Galaxy as a whole formed and evolved.

LSST will be able to find two orders of magnitude more stars than the number of stars currently catalogued from all previous sky surveys. The analysis of these stars, with LSST’s unique combination of an ultraviolet u-band filter, near-IR y band, well-sampled time domain information, which enables the study of variable stars, proper motion measurements of faint stars, and the depth and wide-area coverage make the exceptional mapping possible.

Questions that LSST data will answer include:

- How have mergers with other galaxies affected the structure of the Milky Way? Small galaxies that have been swallowed up by the Milky Way leave traces in the form of narrow streams of stars with common proper motions and similar chemical compositions.
- What is the total mass of the Galaxy? How far out does it extend? Does the dark matter form a spherical halo around the Galaxy or does it have a flattened shape?
- Are there truly any “missing” Galactic satellites?
Mapping the Milky Way... (cont.)

The Milky Way and Cosmology

Proper motion measurements for millions of main sequence stars and hundreds of tracer objects in the outer halo will provide the data for major steps in understanding the Milky Way in a cosmological context.

One open issue in galaxy formation today is the seeming contradiction between the hierarchical model of galaxy formation, which says that large galaxies are built by mergers of many small galaxies, and the observations of the preponderance of Milky Way sized galaxies, which have thin, cold (in this context, cold means that the stars are moving at low velocities relative to one another) disks. Large numbers of violent mergers should stir up the orbits of stars, making the disk thicker and the stellar velocities higher than are actually observed. Detailed studies of the Milky Way can provide valuable boundary conditions for models of the formation and evolution of galaxies with disks.

Evidence from all-sky surveys and theoretical models suggest that the LV is filled with low surface brightness structures such as faint dwarf galaxies, tidal streams, and exotic objects. Resolved stars can be used to map these objects and explore outer disks, external galaxies, and even discover new galaxies and intragroup stars. The measurements of the outer halo and orbits of Milky Way satellite galaxies are critical to the modeling of the formation of dwarf galaxies.

Finally, globular clusters are found associated with all but the faintest dwarf galaxies. They can be used to probe formation epochs, assembly mechanisms, and evolution of galaxies. "LSST will give a complete photometric characterization of globular cluster systems of essentially every galaxy within ~ 30 Mpc."

The Darkest Galaxies

The discovery of ultra-faint dwarf galaxies around the Milky Way and Andromeda galaxies has made available new paths of investigation into galaxy formation and cosmology. Some have absolute magnitudes as faint as that of a single red giant and contain so few stars one might think they’re star clusters and not galaxies at all. Yet, studies of their internal motions imply that unlike star clusters, these objects do contain dark matter. How did such small, faint galaxies form? Are they remnants of more luminous objects? Did they ever contain more stars than the number they do today? Why is there a discrepancy between the number of dark matter halos predicted to orbit around the Milky Way and the number lit up by the eleven dwarf galaxies?

Willman says, “These ultra-faint dwarfs consist of only a few thousand stars and a luminosity range below the average globular cluster. They are also the most dark matter rich and metal poor galaxies known. We want to find out why the luminosity is so low—is it nature or nurture—were they formed that way or did something happen in their evolution?”

The LSST’s deep and wide field survey will enable a complete census of the Milky Way’s satellite galaxies and reveal distant ultra-faint dwarfs. The analyses of these data will provide insights into the nature of dark matter and the limits of galaxy formation.

The challenge of the coming decade will be to move beyond the past decade’s “checking of models” and instead to use resolved stellar structure throughout the LV to untangle galaxy formation in general—to use the LV as “a laboratory for testing how stars form over a range of timescales, within a variety of masses of dark matter halos, in different environments in the early Universe, and with different interaction histories.” LSST’s unparalleled maps of the stellar distribution in the LV will provide a census of structures (galaxies, velocity streams, etc.) and show how the properties of structures (morphology, density, and extent) vary by location. With LSST’s ability to observe faint stars at large distances, scientists will be able to generalize results from high-resolution spectroscopic studies of nearby Milky Way stars to larger scales. Using various tracers within the Milky Way and LV, scientists will make new maps and address fundamental questions about formation of the structures of the Universe.

This article written by Anna H. Spitz, Beth Willman, and Sidney Wolff
Plans for Education and Public Outreach (EPO) have been part of LSST since the beginning. An EPO section (and budget) was written into the initial Design & Development proposal and an awareness of our EPO responsibilities is pervasive throughout the project. This long-term outlook gives us the advantage of collaborating now with EPO projects that LSST can leverage in the future. Several such projects have had good news recently from the National Science Foundation (NSF) concerning their grant proposals as described below. LSST is keeping an eye on these exemplary efforts.

1. CitizenSky: Help Solve a 175-year old Mystery!

Supported by a three-year grant from the Informal Science Education division of the NSF, CitizenSky will recruit, train, and coordinate public participation in understanding Epsilon Aurigae, an unusual visual eclipsing binary star system with a 27 year period that has mystified astronomers for nearly two hundred years. Led by the American Association of Variable Star Observers (AAVSO), CitizenSky emphasizes participation in the full scientific method. Suzanne Jacoby is on the advisory board of CitizenSky; AAVSO Director Arne Henden is on the LSST EPO Advisory Board; LSST Science Collaboration team member and NOAO astronomer Steve Howell heads a CitizenSky team. Citizen Sky gives us a chance to work more closely with the amateur community, and to see how citizen science observations and metadata can be integrated with the AAVSO database.

2. Research Based Science Education (RBSE) for Undergraduates

Travis Rector at the University of Alaska Anchorage just received word that his Type 2 proposal to the NSF Course, Curriculum, and Laboratory Improvement (CCLI) program was funded to implement and assess the effectiveness of integrating scientific research with education at the undergraduate level. Classroom research using real data is central to the LSST EPO program in formal settings, middle-school through undergraduate. Travis’s current work builds on experience with the NOAO RBSE program. He and his postdoc Andy Puckett, who serves on the EPO Outreach Advisory Board, are currently refining five modules available at http://uranus.uaa.alaska.edu/rbse:

- **Nova Search**—Students blink WIYN 0.9m images of M31 to look for novae
- **Killer Asteroids**—Students use SDSS and WIYN 0.9m data to refine orbits of asteroids
- **Variable Stars**—Students use coudé spectra to study semi-regular variables
- **AGN Spectroscopy**—Students use KPNO 2.1m spectra of radio sources to search for quasars
- **Photo Z**—Students use NDWFS data to find high-redshift galaxies via photometric redshift

This Type 2 CCLI award supports testing the curricula at six other universities, including LSST partner University of Washington. LSST datasets will be used in RBSE-based learning experiences for students and professional development of educators.

3. Zooniverse—Conquering the Data Flood with a Transformative Partnership between Citizen Scientists and Machines

As we go to press, this proposal led by Dr. Lucy Fortson at the Adler Planetarium and submitted to the NSF Cyber-Enabled Discovery and Innovation (CDI) program has been funded! The Zooniverse is an online citizen science gateway currently under development by teams of scientists, programmers, and educators primarily in the United Kingdom and the United States. When complete, the Zooniverse will provide a home for the already existing Galaxy Zoo project and a series of planned new projects that will extend the Galaxy Zoo concept and methodology to new data sets including biology, lunar science, solar science, and the humanities. Resources will also be developed for utilizing these datasets for machine learning. The goal of Zooniverse is to create a sustainable future for large-scale, internet-based citizen science, tapping the mental resources of a community of lay people in an innovative manner that promises a profound impact on our ability to generate and apply new knowledge. LSST anticipates developing a suite of citizen science projects that will eventually be made available in the Zooniverse framework. We will begin working directly with Zooniverse in six months to prototype Light Curve Zoo within LSST’s Final Design Phase. LSST EPO team member and GMU professor Kirk Borne
is a co-investigator on the Zooniverse proposal; Suzanne Jacoby is a member of the Advisory Board. Zooniverse collaborators Jordan Raddick (JHU / SDSS Education Lead) and Lucy Fortson (Adler) are on the LSST EPO Advisory Board.

4. GMU's NSF/DUE/CCLI award: A Curriculum for Undergraduate Data Sciences Education

Kirk Borne (LSST EPO team member) and his colleagues at George Mason University have been funded by the NSF CCLI program to develop an undergraduate program in data sciences within GMU’s new Department of Computational & Data Sciences. The primary emphasis of the GMU CUPIDS program (Curriculum for an Undergraduate Program in Data Sciences) is to train students in 21st century workforce skills that demand an understanding of and skills in the uses of data for today’s information-driven enterprises in academia, business, and government, most especially in the sciences. LSST data and databases will provide rich raw material for the courses in Scientific Data & Databases, Data & Information Visualization, and Scientific Data Mining. Using other large scientific databases now (such as SDSS), and LSST in the future, students are trained to access large data repositories, to conduct meaningful scientific inquiries into the data, to mine and analyze the data, and to make data-driven scientific discoveries.

5. Summer FaST program

Again this summer, supplemental NSF funding allowed LSST to support Faculty and Student Teams (FaST) at Brookhaven National Lab, SLAC National Accelerator Laboratory, and the University of Washington (UW). Hakeem Oluseyi, faculty member at Florida Institute of Technology and Alabama A&M, and his students spent the summer working with UW astronomer Andrew Becker. This team worked on the LSST object detection pipeline software, simulating the sensitivity of the software to different types of transient objects. Their work will be presented as part of the LSST poster lineup at the January 2010 meeting of the American Astronomical Society in Washington, DC.
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