Large Synoptic Survey Telescope

www.lsst.org

The Stellar Populations of the Milky Way and Nearby Galaxies

Knut A. Olsen[1], K. Covey[2], A. Saha[1], T. C. Beers[3], J. Bochanski[4], P. Boeshaar[5], P. Cargile[6], M. Catelan[7], A. Burgasser[8], K. Cook[9], S. Dhital[6], D. Figer[10], Z. Ivezic[11], J. Kalirai[12], P. McGehee[13], D. Minniti[7], J. Pepper[6], A. Prsa[14], A. Sarajedini[15], D. Silva[1], J. A. Smith[16], K. Stassun[6,17], P. Thorman[5], B. Williams[11], LSST Stellar Populations Collaboration

[1]NOAO, [2]Cornell University, [3]Michigan State University/JINA, [4]Penn State University, [5]UC Davis, [6]Vanderbilt University, [7]Pontificia Universidad Católica, Chile, [8]UC San Diego, [9]LLNL, [10]RIT, [11]University of Washington, [12]STScI, [13]IPAC/Caltech, [14]Villanova University, [15]University of Florida, [16]Austin Peay State University , [17]Fisk University

The LSST will produce a multi-color map and photometric object catalog of half the sky to r=27.5 (AB mag; 5-sigma) when observations at the individual epochs of the standard cadence are stacked. Analyzing the ten years of independent measurements in each field will allow variability, proper motion and parallax measurements to be derived for objects brighter than r=24.5. These photometric, astrometric, and variability data will enable the construction of a detailed and robust map of the stellar populations of the Milky Way, its satellites and its nearest extra-galactic neighbors--allowing exploration of their star formation, chemical enrichment, and accretion histories on a grand scale. For example, with geometric parallax accuracy of 1 milli-arcsec, comparable to HIPPARCOS but reaching more than 10 magnitudes fainter, LSST will allow a complete census of all stars above the hydrogen-burning limit that are closer than 500 pc, including thousands of predicted L and T dwarfs. The LSST time sampling will identify and characterize variable stars of all types, from time scales of ~1 hr to several years, a feast for variable star astrophysics; LSST's projected impact on the study of several variable star classes, including eclipsing binaries, are discussed here. We also describe the ongoing efforts of the collaboration to optimize the LSST system for stellar populations science. We are currently investigating the trade-offs associated with the exact wavelength boundaries of the LSST filters, identifying the most scientifically valuable locations for fields that will receive enhanced temporal coverage compared to the standard cadence, and analyzing synthetic LSST outputs to verify that the system's performance will be sufficient to achieve our highest priority science goals.

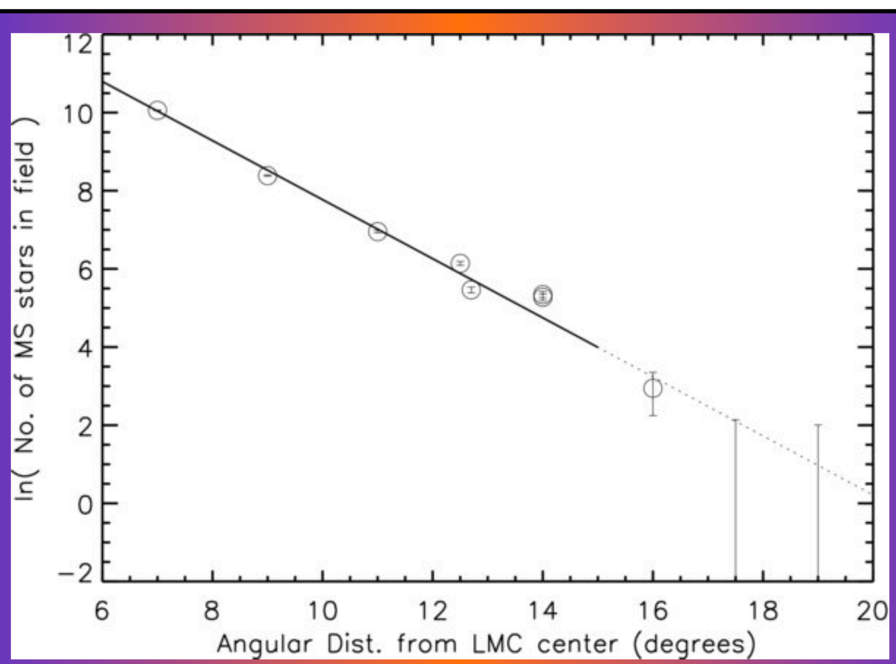
LSST will deliver:

Deep combined images (r' ~ 27.5, 5s)
Deep single-epoch images (r' ~ 24.5, 5s)
Accurate parallaxes (10 percent error at 1 mas for r' ~ 24.5)
Accurate proper motions (0.2 mas/year = 10 km s^{-1} at 10 kpc, r'~24.5 mag)
Timescales from 1 hr to several years
Accurate photometry in 6 bands: u',g',r',i',z,Y
(with errors of 0.005 mag relative to local objects
0.01 mag over all sky on native system
0.02 mag on Sloan u'g'r'i'z system)

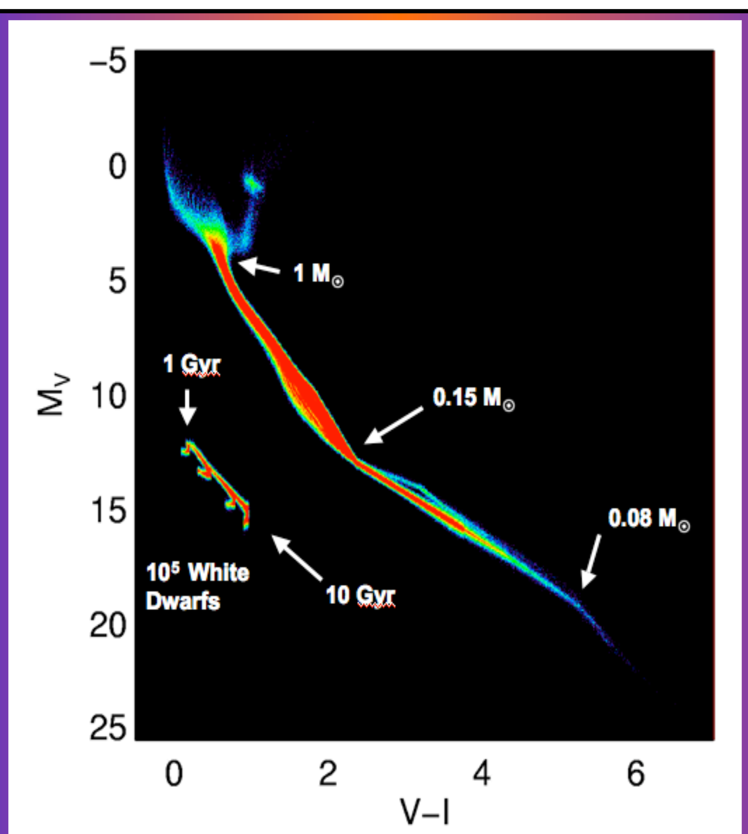
With Tremendous Impact for Studies of:

The Magellanic Clouds and their Environs
Star Formation Histories of Nearby Galaxies
The Distance Ladder through Cepheids, LPVs, and RR Lyrae
Milky Way Star Clusters
Individual Stellar Ages in the Milky Way
The Most Metal-Poor Stars of the Milky Way
Cool Stars
The Solar Neighborhood
Eclipsing Binaries
Rare Events
White Dwarfs

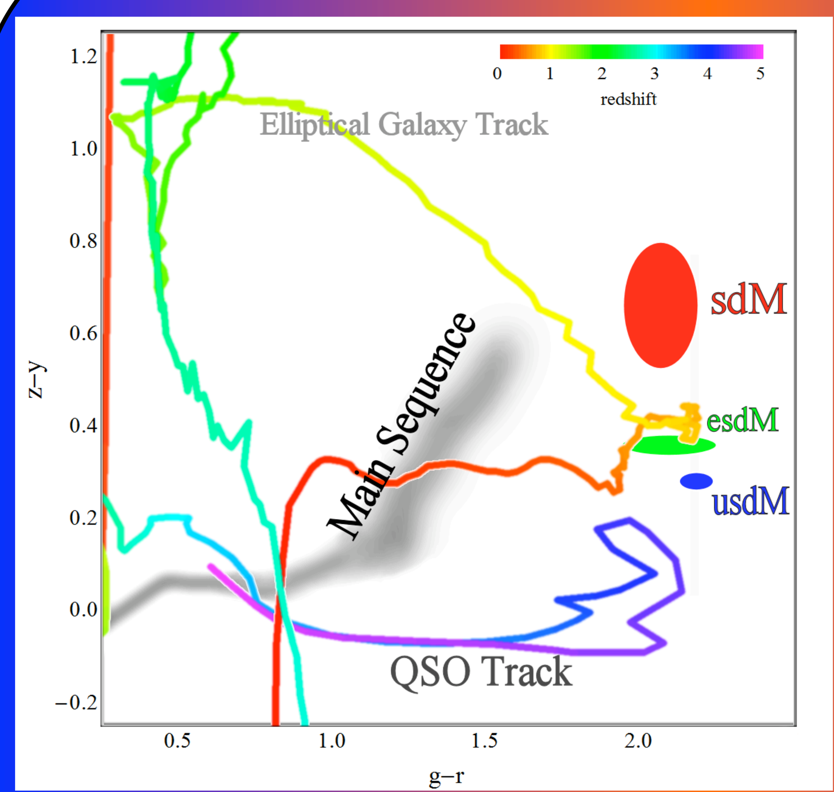
...and many other exciting topics!



How extended are the Magellanic Clouds? The surface density of LMC main sequence and turnoff stars is shown as a function of projected distance due north from the LMC center, as measured by the Outer Limits Survey (Saha et al. 2010). The ~16 sq. degree survey reveals that the exponential disk extends to at least 16 degrees in angular radius from the LMC center, or ~14 kpc at the LMC distance. LSST will cover thousands of square degrees in the environs of the Magellanic Clouds.

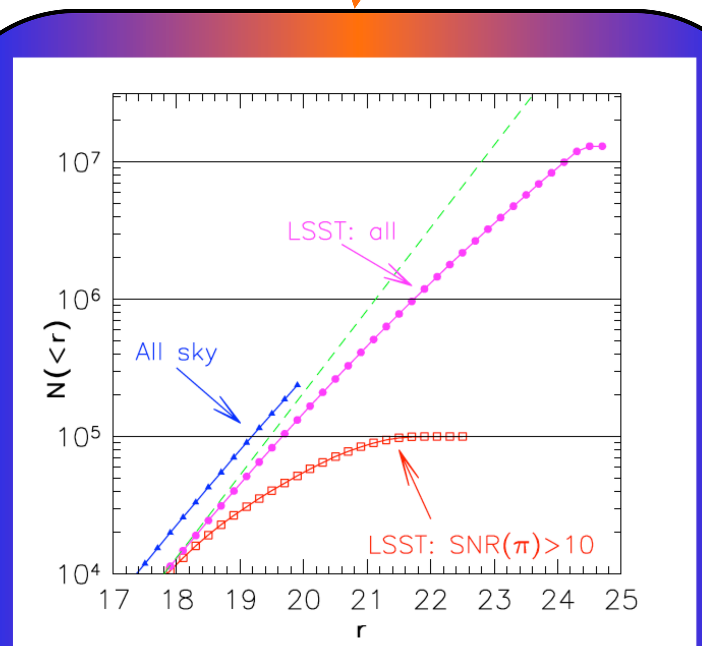


Simulation of the stellar populations detectable by LSST within 200 pc of the Sun. Stars with parallax errors <10% and photometric errors < 0.1 magnitudes are plotted in this image representation of a color-magnitude diagram, where warm colors denote increasingly high densities of stars. The simulation follows the Galactic disk star formation history of Bertelli & Nasi (2001), and incorporates the stellar IMF measured by Reid, Gizis, & Hawley (2002) and the sub-stellar IMF of Burgasser (2004). V and I magnitudes for the 1.1×10^6 objects were calculated using the Girardi et al. (2000) stellar isochrones, the white dwarf models of Richer et al. (2000), and the Baraffe et al. (2003) isochrones for sub-stellar masses. It is assumed that all stars are uniformly distributed within the volume.

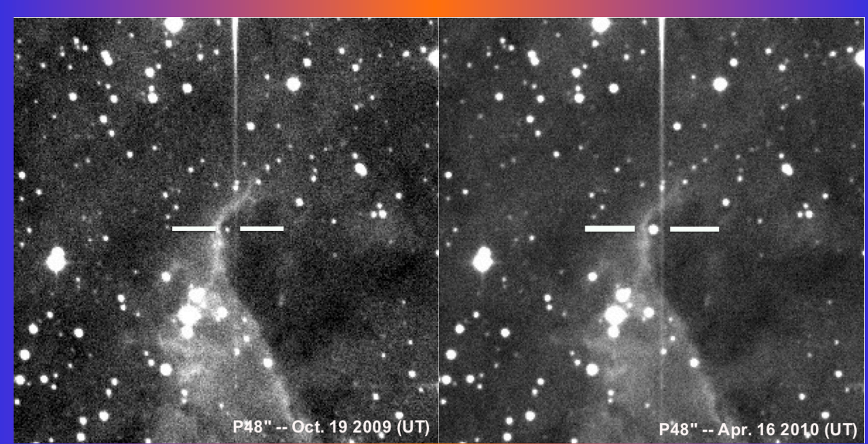


Identifying subdwarfs with LSST. LSST will open the way for a study of the halo on a grand scale by detecting all M-type subdwarfs within 1 kpc of the Sun. LSST will allow use of color selection to separate subdwarfs from normal main sequence stars and from QSOs, and proper motion to distinguish extreme- and ultra-metal-poor subdwarfs from unresolved elliptical galaxies. Using estimated metallicity classes for the halo stars based on the LSST colors, we will measure the rough metallicity distribution over an unprecedented sample of >500,000 objects.

In this figure, stellar colors are from Pickles (1997) spectra, the elliptical template is from Coleman et al. (1980), and the QSO template is from Vanden Berk (2001) with IGM absorption from Songaila (2004). Subdwarf colors are from Lepine (2008), with z-y colors from subdwarf spectra courtesy of Adam Burgasser.

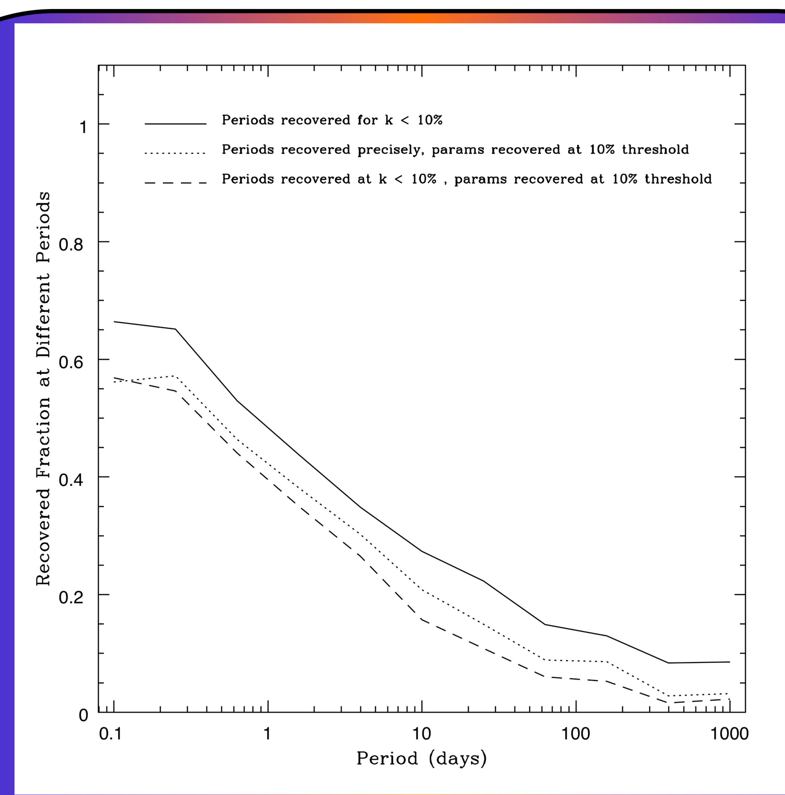


A comparison of cumulative white dwarf counts for several samples. The triangles (blue curve) show the counts over the full sky in the magnitude range corresponding to Gaia survey (r' < 20). The squares (red curve) show the counts of white dwarfs expected in the LSST parallax survey of the solar neighborhood. The circles (magenta curve) show the counts of all white dwarfs from the LSST survey that will have proper motion measurements (r' < 24.5). The predicted magnitudes are not corrected for the interstellar dust extinction. The dashed line shows the behavior expected for a spatially uniform distribution of sources ($\log[N(<r)] \propto 0.6r$); LSST will be able to use white dwarfs as probes of Galactic structure.



Pre- and post-outburst images of PTF10nvg (left and right, respectively), an outbursting young star recently discovered in a Palomar Transient Factory monitoring campaign of the North American Nebula (Covey et al. 2010).

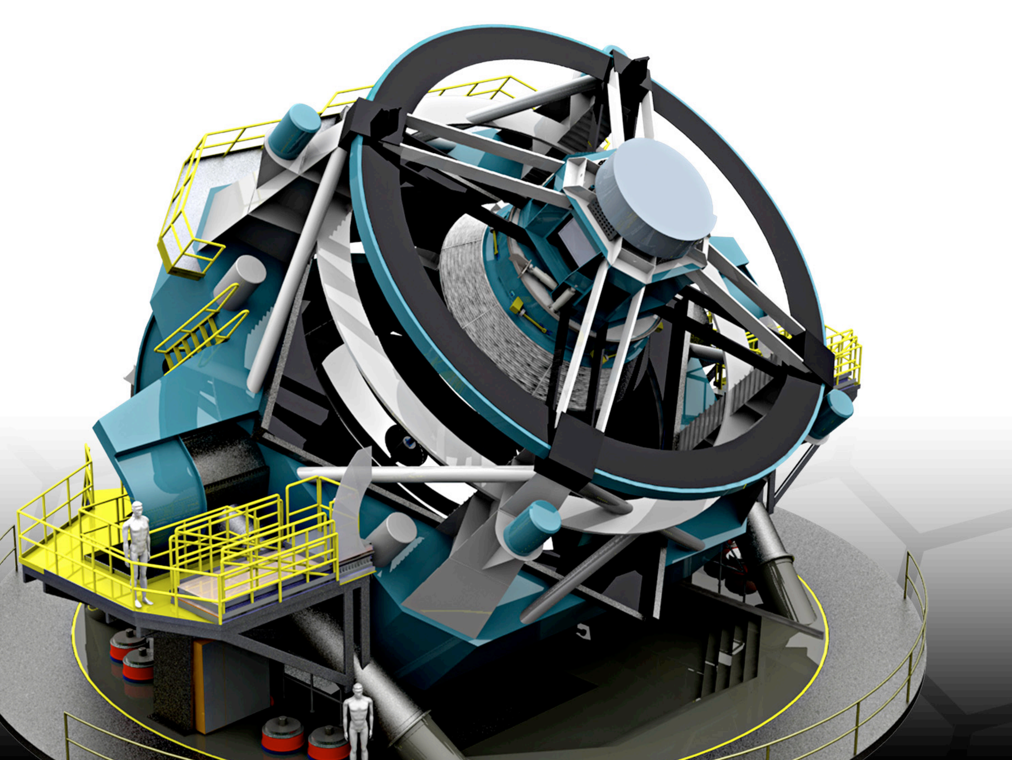
Identification and characterization of young stellar outbursts: Outbursts are a common phenomenon for many young stars, and various classifications have been defined (e.g., FU Orionis, Exor, and V1647-like) based on the duration and morphology of the outburst. We still lack, however, a robust measurement of the relative frequency of each of these types of outbursts, and do not understand how those frequencies depend on underlying stellar properties such as mass and age. Until now, stellar outbursts have been identified largely via serendipitous detections in sporadic, inhomogeneous surveys of active star formation regions. LSST will provide regular, homogeneous coverage of all Southern star forming regions, and enable the first rigorous measurement of the frequency and character of each of these types of events.



The expected yield of eclipsing binary stars for LSST. 10,000 eclipsing binary light curves are synthesized and sampled according to the LSST universal cadence and passed through a period finder. The phased data are then passed to a neural network-based estimator of principal eclipsing binary parameters. The solid line depicts the fraction of sources where the correct period is within 10% of the actual value. The fractions of sources for which the principal physical parameters are recovered to 10% accuracy are shown with exact periods (dotted line) and the recovered periods (dashed line); these represent the ideal and realistic expected yields, respectively. Overall, we estimate that LSST will observe ~16 million eclipsing binaries down to r'~22 with useful S/N. Our yield calculations here suggest that ~1.6 million of these eclipsing binaries are likely to be successfully recovered and their physical parameters well estimated by the automated EB Factory pipeline that we are developing (see LSST Science Book, section 6.10).

References

Baraffe, I., et al. 2003, A&A, 402, 701
Bertelli, G., and Nasi, E. 2001, AJ, 121, 1013
Burgasser, A.J. 2004, ApJS, 155, 191
Coleman, G.D., et al. 1980, ApJS, 43, 393
Covey, K.R., et al. 2010, arXiv:1011.2565
Girardi, L., et al. 2000, A&AS, 141, 371
Lepine, S., and Scholz, R.-F. 2008, ApJL, 681, 33
LSST Science Book, arXiv:0912.0201v1
Pickles, A.J. 1997, VizieR On-line Data Catalog
Reid, I.N., Gizis, J.E., and Hawley, S.L. 2002, AJ, 124, 2721
Richer, H.B. et al. 2000, ApJ, 529, 318
Saha, A. et al. 2010, AJ, 140, 1719
Songaila, A. 2004, AJ, 127, 2598
Vanden Berk, D.E., et al. 2001, AJ, 122, 549



January 2011

LSST is a public-private partnership. Design and development activity is supported in part by the National Science Foundation. Additional funding comes from private gifts, grants to universities, and in-kind support at Department of Energy laboratories and other LSSTC Institutional Members.