Large Synoptic Survey Telescope

Stellar Populations and Nearby Galaxies with the LSST

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The LSST will produce a multi-color map and photometric object catalog of half the sky to g~27.5 (5σ). Strategically cadenced time-space sampling of each field spanning ten years will allow variability, proper motion and parallax measurements for objects brighter than g~25. Accurate multi-band photometry will permit photometric parallaxes, chemical abundances and a handle on ages via colors at turn-off for main-sequence stars at all distances within the Galaxy, permitting a comprehensive study of star formation histories (SFH) and chemical evolution for field stars in the Galaxy. With a geometric parallax accuracy of 1 milli-arc-sec, the LSST will produce a robust complete sample of the solar neighborhood stars. While delivering parallax accuracy comparable to HIPPARCOS, LSST will reach more than a 10 magnitudes fainter and will be complete to M_V ~15. In the Magellanic Clouds too, the photometry will reach M_V ~+8, allowing the SFH and chemical signatures in the expansive outer extremities to be gleaned from their main sequence stars. The LSST time sampling will identify and characterize variable stars of all types, from time scales of ~ 1 hr to several years, which has wide applications in stellar astrophysics. Cepheids, Miras and LPVs will be detected and measured in galaxies up to ~ 5 Mpc in distance. The combination of wide coverage, multi-band photometry, time sampling and parallax taken together will address several key problems, from fine tuning the extragalactic distance scale, extending the faint end of the galaxy luminosity function, tracing intergalactic stars, and mapping the large scale structures of nearby galaxies. Especially in the Magellanic Clouds, LSST coverage can reveal their interaction amongst each other as well as the halo of the Milky Way.

Data from LSST:

Depth of combined images in main survey:	g ~ 27.5 mag at 5σ
Depth of single epoch image:	g ~ 25.0 mag at 5σ
Attainable parallax over whole survey period:	10 percent error at 1 mas
Attainable proper motion over whole survey period:	0.2 mas/year = 10 kms^{-1} at 10 kpc (to g ~ 25.0 mag)
Timescales sampled by cadence:	1 hr to several years Time sequences will be patterned to minimize period aliasing given operational constraints
Photometry:	6 bands: u',g',r',i',z,Y
Accuracy requirements:	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

Derivatives from Proper Motions and Parallaxes

(HIPPARCOS accuracy to V ~ 25):

1) Complete sample of all objects as faint as hydrogen burning limit within 500pc

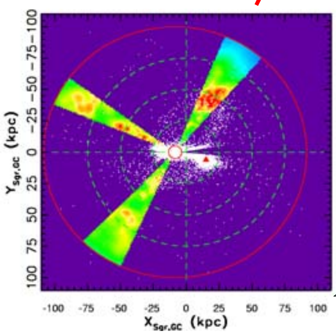
2) Proper motions commensurate with radial velocities throughout the Galaxy (20 kpc) for stars brighter that M_v = 8:
   a) Space velocities for stars with radial velocities - parsing populations kinematically, statistical parallax distances, etc.
   b) **Two** components of velocity vector for stars without radial velocities

3) Proper motions of stars in nearby galaxies, e.g. LMC, SMC, and systemic motions of dwarf spheroidals

4) Detection of low-mass binary companions from "wiggles" in proper motion

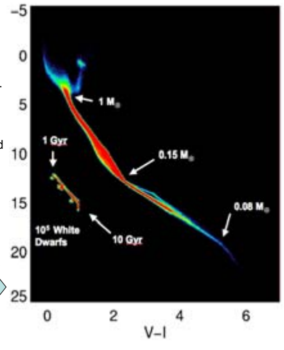
5) Cluster memberships and census of low mass "escaped" stars

LSST limit for RR Lyrae: 400 kpc



The structure of the outer Milky Way (Ivezic et al. 2004). The number density multiplied by the cube of the galactocentric radius for 923 SDSS candidate RR Lyrae stars within 10° from the Sgr dwarf tidal stream plane. The triangle marks the position of the Sgr dwarf core.The clumps at (X,Y) of (20,-35) and (-20,25) are definitely associated with the tidal stream, as is discernible from the distribution of 2MASS M giants (Majewski et al. 2003), shown as the white dots. Other clumps, while consistent with being part of the stream, could also be unrelated super-Poissonian fluctuations, such as those suggested by Bullock et al. (2001). LSST will extend such mapping to about 50 times larger volume.

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 1.1x10^6 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.



Derivatives from Multiband Photometry:

Photometric parallaxes for main sequence (MS) stars within Galaxy. For external systems (where individual stars are resolved and lend themselves to population analysis) distances derived from other, independent methods, e.g. variable stars.

Wide spectral range (u' through Y) provides good handle on reddening and extinction, both Galactic and within a target galaxy

Methods of deriving ***star formation histories (SFH)*** (*the distribution of star formation rate as a function of time and chemical composition*) from Hess diagrams given photometry and star counts in 2 or more bands (and comparing with synthetic models) is adequately developed , e.g. Dolphin (2002).

For extragalactic systems and in the solar neighborhood, where distances are known independently, the 5 band data can be used to self-consistently solve for extinction and SFH. This is more complicated if distances are not known independently, such as within the Galaxy, but even here, along lines of sight with low extinction, the SFH can be derived using some select types of stars.

Multi-band photometry in the Magellanic Clouds will reach well into the main sequence, and will be identified with ease. These stars are:

i) unbiased tracers of extended structure
ii) color-magnitude diagrams (especially given u' passband) very effective for deciphering chemical composition and age distributions

Derivatives from Time Sampling:

Detection and characterization of variable stars of all kinds. Especially good for serendipitously discovering rare, and perhaps currently unknown kinds of objects that vary, whether periodic, irregular, or transient.

Distribution of various classes of variables with structural components of the Milky Way.

Identify RR Lyraes to 400 kpc: delineate the stellar halo of the Galaxy, and trace it past the equi-potential surface with M31. Trace the stellar halos and tidal debris of the Magellanic Clouds.

Homegeneous (unprecedented) time sampled data for Long Period Variables LPV

Find Cepheids in all galaxies with young stars out to 10 Mpc.

Examples of Unique Science Opportunities:

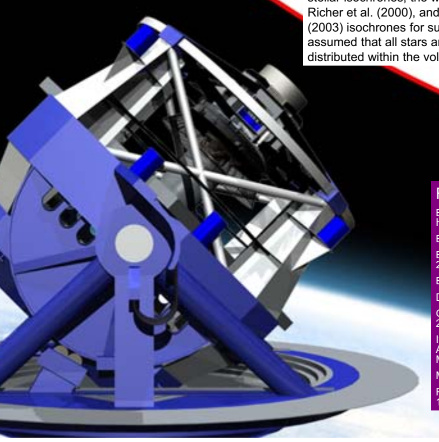
(from combinations of astrometry / photometry / variability aspects of the LSST surveys)

Survey 1000 square degrees around the LMC and SMC. Photometry (both magnitudes and multiple colors) identify main sequence stars related to these objects in their outer extremities.
CMDs furnish ages and chemical compositions. Proper motions (to ~50 kms^{-1} per star) reveal kinematic behavior: disk or halo or tidal stream? Photometric parallaxes (colors and mags) show the stars from the Milky Way halo that are spatially interspersed with stars from the Clouds. Combined with proper motions, they reveal how these components have interacted. A more select search for metal poor and old stars in the extremities of the Clouds come from the discovery of RR Lyraes in this extended region of sky.

Discovery and multi-band measurement of Cepheids in nearby galaxies (especially Sculptor group) will have the precision to investigate the universality (or lack thereof) of the P-L and P-C relations, and correlations if any with parent populations (from multi-band photometry of the bright stars of the host galaxies). This is currently the weakest link in the standard candle based extragalactic distance scale.

Dwarf galaxies within ~10 Mpc that are too faint to detect from surface brightness enhancements will be revealed via overdensities of their red giant stars. Additional information will come from the CMDs of their brightest stars, with distances from the brightness of the RGB tip. This systematic census will extend the faint end of the luminosity function of galaxies.

Novae and LPVs discovered by LSST can trace the presence of intergalactic stars out to the Fornax and Virgo clusters.



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