Large Synoptic Survey Telescope

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Mapping the Stellar Content of the Milky Way with LSST

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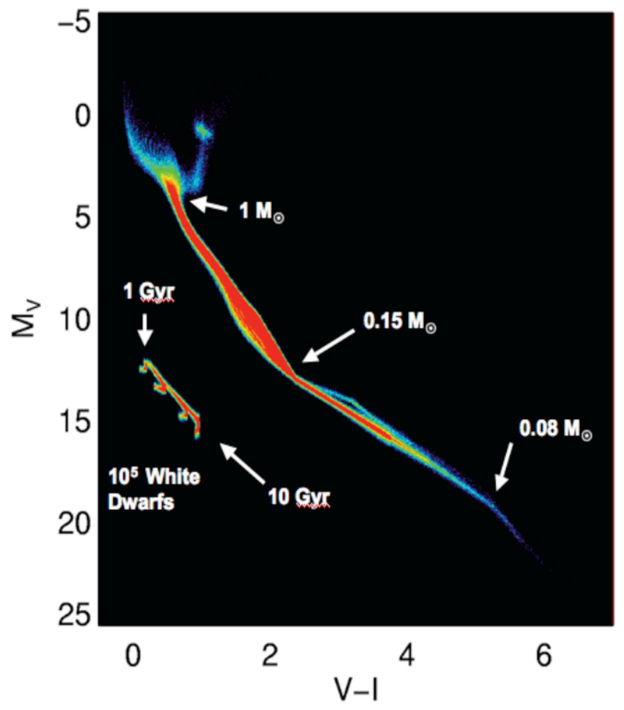
The Large Synoptic Survey Telescope (LSST) will map half of the sky in six filters down to r = 27.5 (AB mag; 5σ), with calibration zero-point accuracy of 0.01 mag and precision (repeatability) of 0.005 mag at the bright end. The ten year baseline of the survey will provide about a thousand multi-epoch observations for objects brighter than r = 24.5, yielding variability, proper motions and trigonometric parallax measurements for hundreds of millions of stars. The resulting photometric and astrometric catalogs will enable novel and unique investigations, detailing the formation and evolution of the Milky Way's stellar populations, as well as neighboring galaxies. We highlight some of the enabled science studies, including results from the output source catalog derived from simulated LSST images. A few examples of the stellar populations projects are shown: constructing a census of the MLT population in and beyond the solar neighborhood; mapping the structure and stellar metallicity content of the Milky Way's disk and halo; assembling catalogs of eclipsing binaries, subdwarfs and white dwarfs, suitable for measuring fundamental stellar parameters; and measuring the Milky Way's star formation history using stellar ages determined from gyrochronology and rotation periods, as well as the white dwarf luminosity function. We also highlight the studies enabled by the "Deep Drilling" fields, patches within the LSST footprint that will be imaged at a higher cadence over the course of the survey.

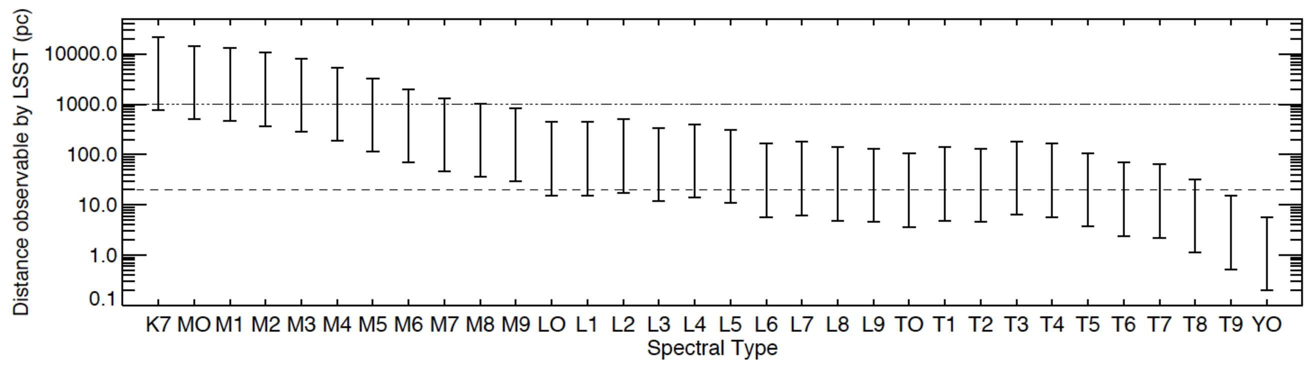
Introduction

Stellar population studies will be revolutionized by the depth, precision and cadence of LSST photometry. These investigations span a range of scales and distances: from detections of nearby dwarfs having spectral type MLTY to measuring the structure of the Large Magellanic Cloud. LSST time-series photometry will also be crucial for identifying eclipsing binaries and tracking the temporal evolution of open cluster members and field stars, both crucial for testing stellar models. In each section below, we detail some of the stellar population studies that will be enabled by LSST.

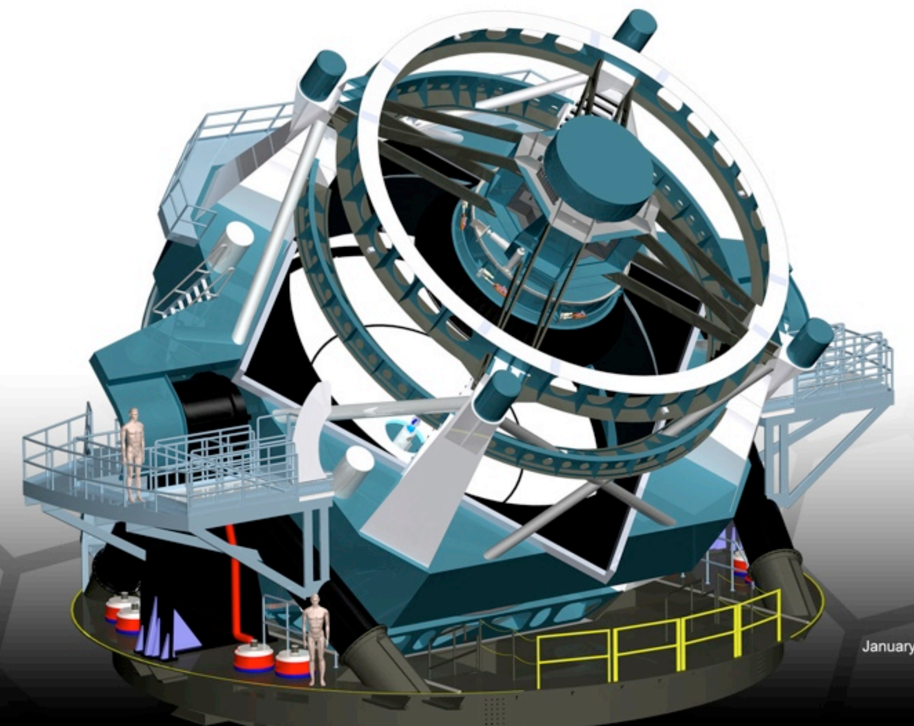
Solar Neighborhood



The image shows the color-magnitude diagram from a 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 initial mass function (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



The plot shows the approximate distance limits for MLTY dwarfs for a single z-band LSST exposure. The dash-dotted line denotes the approximate boundary between the thin and thick disk, and the dashed line marks 20pc, the traditional definition of the Solar neighborhood. LSST imaging will be ideal for mapping out local Galactic structure with M dwarfs and for completing the census of L and T dwarfs within 100 pc. LSST will also be sensitive to nearby cold brown dwarfs (T_{eff} < 500 K) within ~10 pc.



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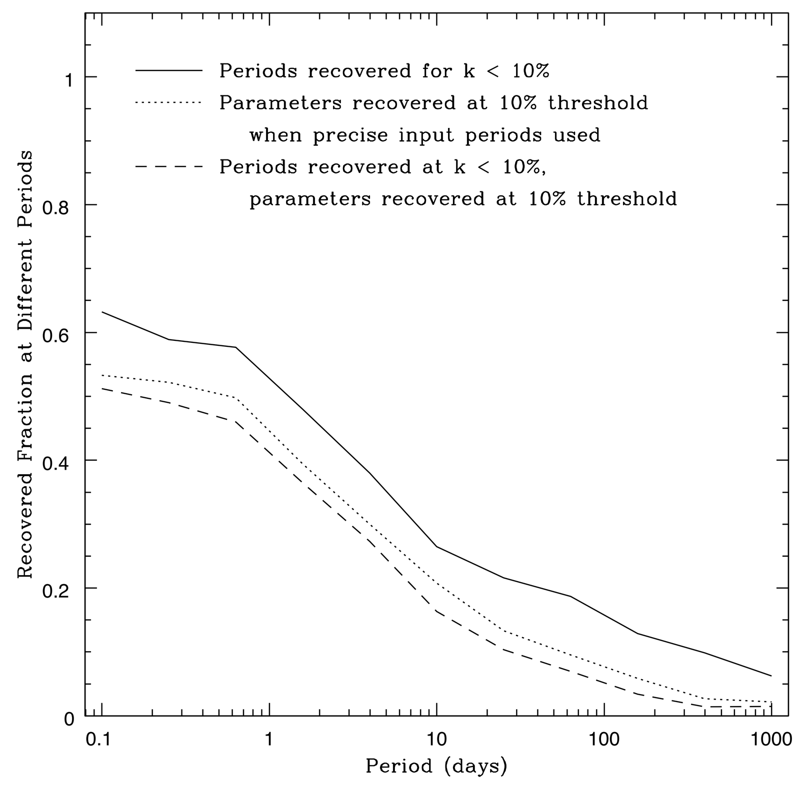
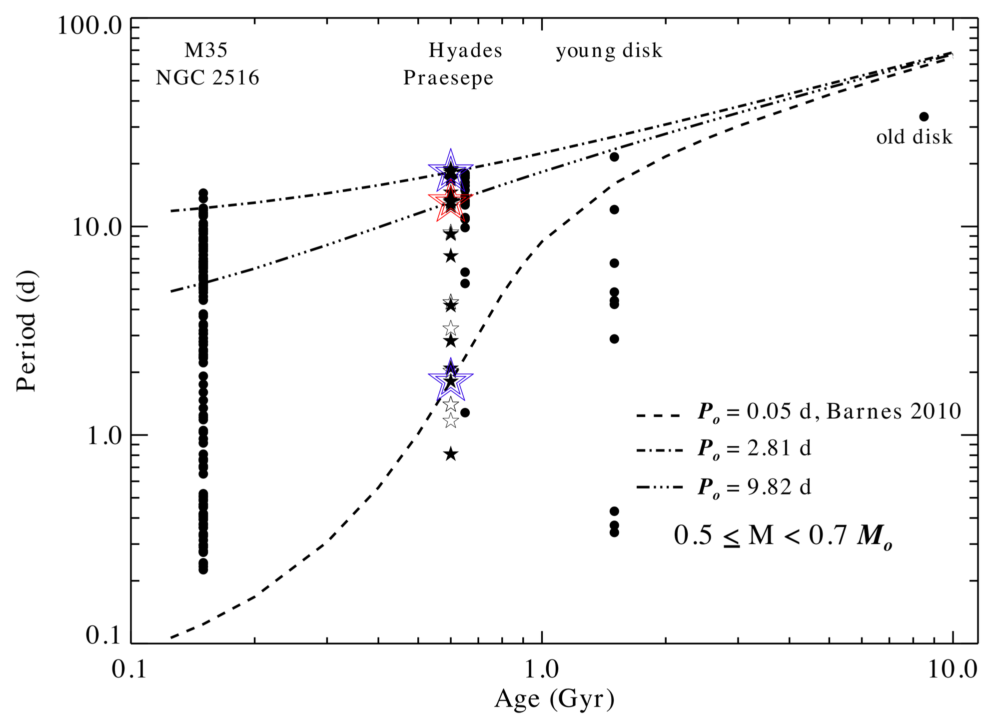
Eclipsing Binaries



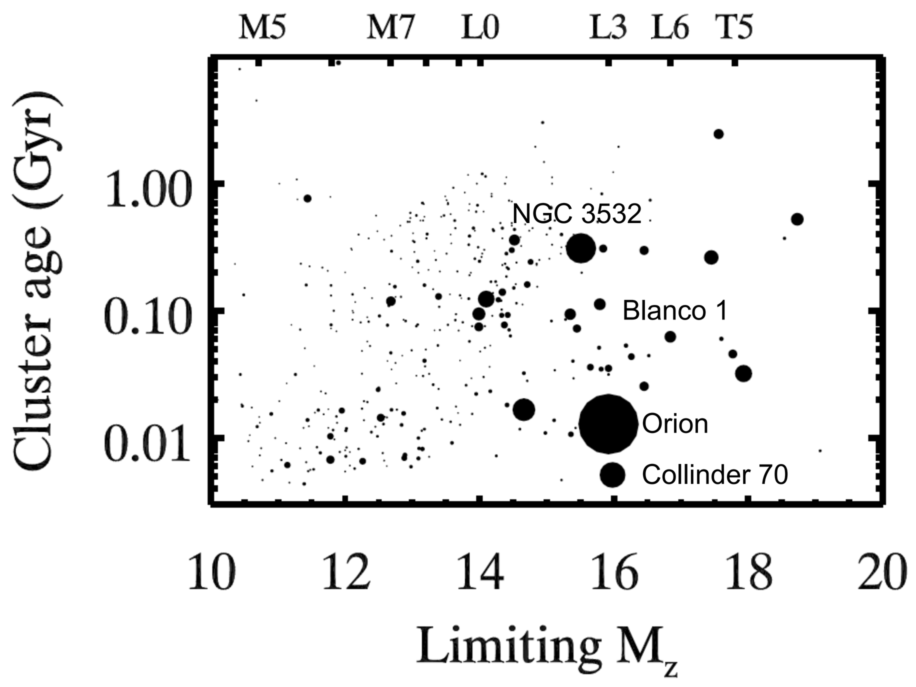
The plot above illustrates our expected efficiency at recovering eclipsing binary properties as a function of period. We simulated 10,000 eclipsing binary light curves and sampled them according to the adopted LSST cadence. The light curves were passed to a period finder and the phased data were then sent to a neural network-based estimator of principal eclipsing binary parameters. The solid line depicts the fraction of sources where the recovered period is within 10% of the actual value. The fractions of sources for which the principal physical parameters are recovered at < 10% accuracy when exact input periods are used (dotted line) and using the recovered periods (dashed line) are also shown; 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 suggest that ~1.6 million of these eclipsing binaries are likely to be successfully recovered and their physical parameters will be well estimated by the automated EB Factory pipeline that is currently under development (see LSST Science Book, section 6.10).

Gyrochronology



The angular momentum evolution of low-mass stars is poorly understood, especially at ages greater than ~700 Myr. The lack of old M dwarfs with precise ages, coupled with their intrinsic faintness, makes the calibration of age-activity-rotation relations very difficult, especially at old ages. This figure, from Agüeros et al. (2011), compares rotation period distributions of low-mass stars for populations of different ages to the predictions of Barnes (2010). The red star symbol is the median period for the Hyades/Praesepe, while the blue star symbols denote the upper and lower 10% percentile. In general, the models agree well with younger stars, but fail to produce the behavior at older (> 1 Gyr) ages. LSST will provide valuable observational constraints in this regime, through kinematic ages (from proper motions) and rotation periods, as well as cluster observations.

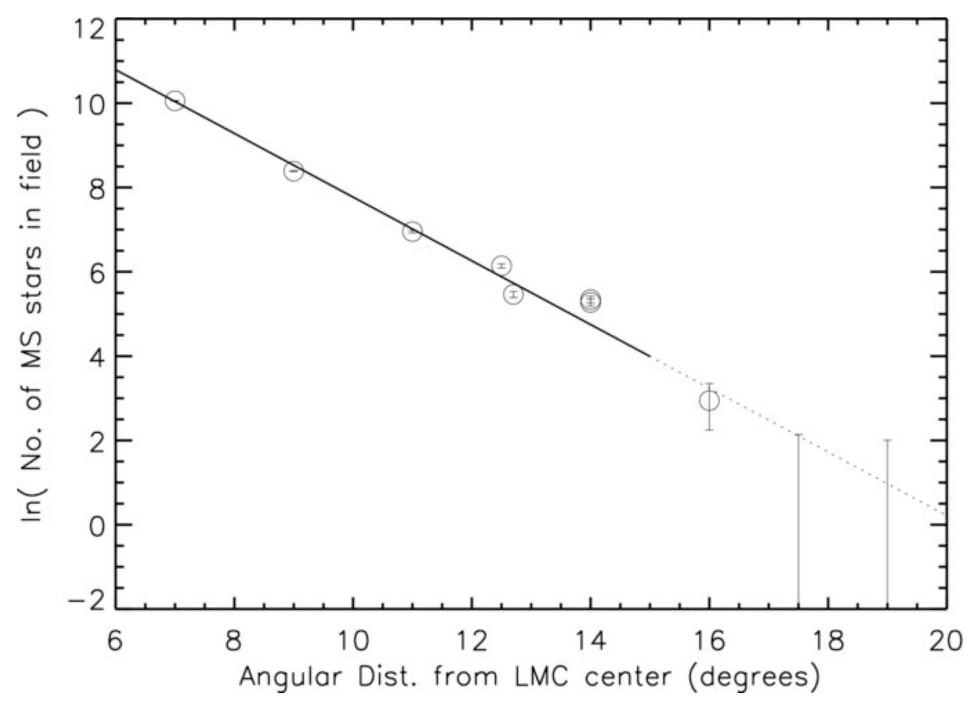
Cluster Studies



Southern open clusters of various ages are plotted above, with the diameter of the symbols scaled to the number of members (the smallest dots correspond to 50 members). With LSST's deep single-epoch imaging (z = 23.3), we will detect L and T dwarfs in many clusters, probing photometric variability on the timescales of hours (due to weather or cloud evolution) to days (due to star spots). These data will map out the angular momentum evolution in fully convective stars and brown dwarfs, particularly in clusters located within the footprints of LSST's deep drilling fields.

Using the co-added images (which will reach ~3 magnitudes deeper), we will detect brown dwarfs in clusters of a range of known ages and metallicities, allowing us to calibrate the brown dwarf cooling models and estimate their physical properties. Moreover, identification of brown dwarf eclipsing binaries in clusters will provide benchmark measurements of their fundamental parameters (masses, radii, temperatures, luminosities) for testing models.

Large Magellanic Cloud



How extended are the Magellanic Clouds? The surface density of LMC main sequence and turnoff stars is shown as a function of distance 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 and map the structure of the Milky Way's neighbors.

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