Large Synoptic Survey Telescope

www.lsst.org

Eclipsing Binary Science with the LSST

Joshua Pepper[1], K. Stassun[1], A. Prsa[2]

[1]Vanderbilt Univ., [2]Villanova Univ.

Among the many science products of the planned Large Synoptic Survey Telescope (LSST) will be the discovery of large numbers of variable stars, including eclipsing binaries (EBs). These objects are of great use in determining fundamental physical properties of stars, testing stellar evolution models, and obtaining accurate distances. We have modeled the discovery rate of EBs with LSST, the distances out to which certain interesting EB types (e.g. those with M-dwarf components) can be detected, and the overall ability to determine the fundamental parameters of the detected EBs.

Importance of Eclipsing Binaries

EBs provide calibration-free fundamental physical properties of stars: Mass, Radius, T_{eff}, and Luminosity, without ambiguity due to inclination. The masses and radii of the stars are measured typically with an accuracy of ~3%, and in the best cases with accuracy of better than 1%. Accurately measured parameters yield:

- Accurate stellar distances
- Precise stellar ages
- Stringent tests of stellar evolution models

The products of EB modeling help to:

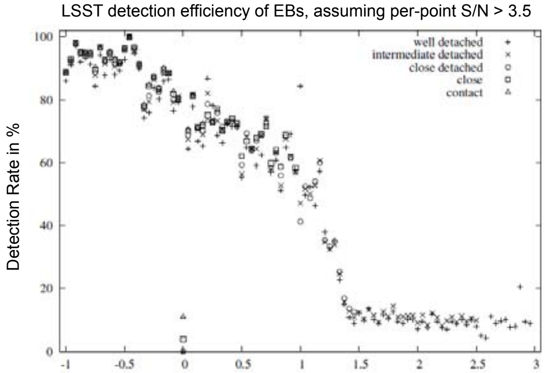
- Calibrate the cosmic distance scale
- Map clusters and other stellar populations (e.g. star-forming regions, streams, tidal tails, etc) in the Milky Way
- Determine initial mass functions and studying stellar population theory
- Understand stellar energy transfer mechanisms (including activity) as a function of T_{eff}, metallicity and evolutionary stage
- Calibrate stellar color-temperature transformations, mass-radius-luminosity relationships, and other basic relations
- Study stellar dynamics, tidal interactions, mass transfer, accretion, chromospheric activity, etc.

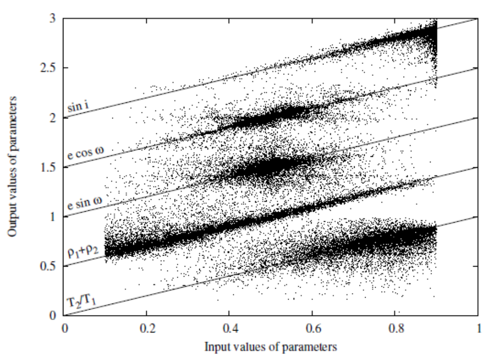
Maximum Distances For Detecting Fiducial EBs

Sample Binary Type	Binary Absolute Magnitude	Distance For *r* = 24 (per-point S/N=3.5)	Distance For *r* = 20 (per-point S/N=100)
M5V + M5V	12.9	1.7 kpc	0.2 kpc
M2V + M2V	9.0	10 kpc	1.6 kpc
K0V + K0V	5.0	63 kpc	10 kpc
G2V + MxV	4.6	76 kpc	12 kpc
G5III + GxV	2.9	166 kpc	26 kpc

Based on calculations of expected sensitivity, we find that LSST will achieve per-point S/N of 3.5 for r=24 and per-point S/N of 100 for r=20. For these calculations, we define a detection as an EB in a typical field with minimum number of points observed in eclipse. The S/N per point is determined from a single 15s exposure, assuming 0.2 arcsec/pixel and read noise of 6 electrons. With those S/N values, valuable EBs can be detected at extreme distances, assuming a favorable cadence.

LSST detection efficiency of EBs, assuming per-point S/N > 3.5





Physical Parameters

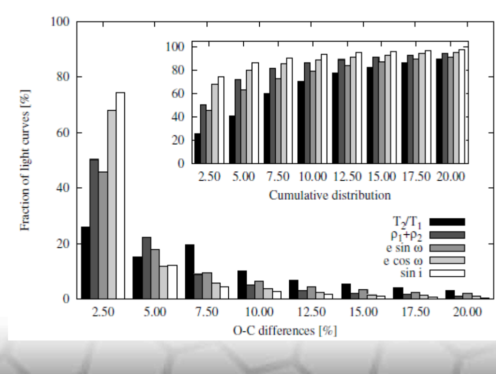
Subscript 1 is the primary star in the binary, subscript 2 is the secondary component

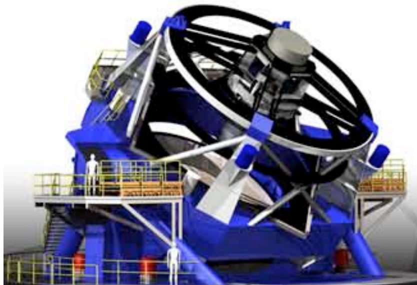
T_2/T_1 – effective temperature ratio
$\rho_1 + \rho_2$ – sum of stellar radii relative to semimajor axis
e – orbital eccentricity
ω – argument of periastron
i – orbital inclination

Simulations and Results

To estimate LSST detection effectiveness, we synthesized 10,000 lightcurves for EBs of different morphology types and physical parameters: T_2/T_1, $\rho_1 + \rho_2$, $e\ \sin(\omega)$, $e\ \cos(\omega)$, and sin(i). After sampling the model lightcurves using the LSST cadence simulator, we then tested the recoverability of the periods and physical parameters. We find that in optimal circumstances, most short-period EBs are correctly detected regardless of morphology type, while only 10% of those with P > 30 days are found. Detection is defined as a minimum number of points observed in eclipse. For those found with the correct periods, physical parameters are recovered to within 10% of the input values in ~80% of the cases.

Although the expected LSST harvest of detached EBs drops off to ~10% for periods longer than 30 days when using nominal cadence, LSST's deep drilling mode comes to rescue. Fields covering approximately 500 square degrees (5%) of the southern sky will be observed ~50 times per hour per passband in consecutive 15 sec exposures. Deep drilling will provide a much better phase coverage and allow significantly improved modeling of short period binaries, but it will also increase the detection efficiency for the longer period binaries whenever the eclipse is observed during deep drilling. Since deep drilling fields have not been determined yet, we postpone any quantitative estimates to later.





January 2010

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.