Calibration of LSST Instrument and Data

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for the LSST Collaboration

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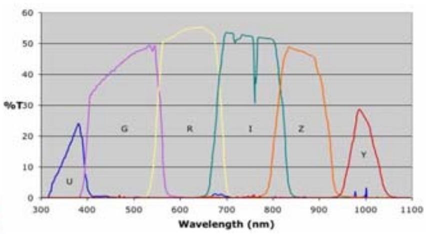
Science studies made by the Large Synoptic Survey Telescope will reach systematic limits in nearly all cases. Requirements for photometric measurements accurate to 1% are particularly challenging. Advantage will be taken of the rapid cadence and pace of the LSST survey to use main sequence stars to calibrate stability and uniformity of astrometric and photometric data. A new technique using a tunable laser is being developed to calibrate the wavelength dependence of the total telescope and camera system throughput and response. Spectroscopic measurements of atmospheric extinction and emission will be made continuously to allow the broad-band optical flux observed in the instrument to be corrected to flux at the top of the atmosphere. Calibrations with standard stars will be combined with instrumental and atmospheric calibrations.

LSST Photometric Specifications and Precursor Data

The LSST optical photometric bands (*u,g,r,i,z,y*) are similar to those used in the Sloan Digital Sky Survey (SDSS) (Fukugita et al. 1996). The combined efficiencies of the optics and filters, sensor quantum efficiency, and typical atmospheric extinction are shown in the figure.



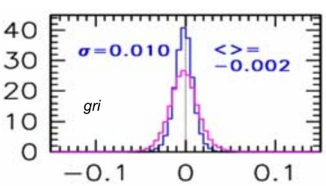
Design specifications for LSST stellar photometry are given below. The first three specifications are relative quantities defined within the native LSST photometric system in AB magnitudes. These are for bright stars not limited by photon statistics in a single exposure (e.g. r < 21).

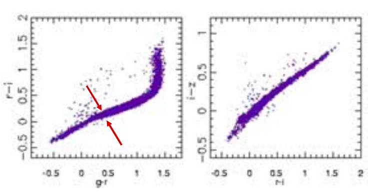
LSST Design Specifications for Stellar Photometry

Repeatability	Spatial Uniformity	Color Uniformity	Absolute
(AB rms)	(AB rms)	(AB rms)	(AB rms)
0.005	0.010	0.005	0.020

Precision of photometric measurements in present-day large surveys, such as SDSS and CFHT, have approached the specifications for LSST (Stoughton 2002; Ivezic 2004; Magnier 2004). But measurements with ground-based telescopes typically produce errors a factor of two or so larger.

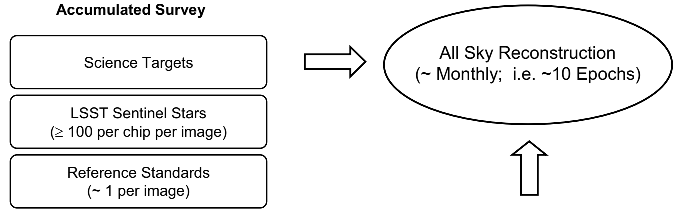
Global all-sky multi-epoch ("über-cal") analysis of data taken in good photometric conditions have reached LSST specifications (Ivezic 2006; Padmanabahn 2007).





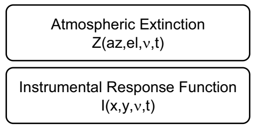
LSST All Sky Reconstruction

The LSST process decouples establishment of an internal relative calibration from assigning absolute optical flux to celestial objects. The latter task requires determination of a single zero point for each filter band for the accumulated multi-epoch data set. Celestial sources will be used to define the internal photometric system. Standardization of photometric scales will be done through observation of stars with well-understood SEDs in science images.



There will be ≥ 100 main-sequence stars with 17 < r < 20 on every chip in every LSST image. An internal network of sentinel stars will be established during LSST commissioning, and will be periodically optimized with increasing precision and definition as the multi-epoch survey proceeds. This effectively utilizes the best observing conditions to define the internal LSST photometric scales.

Well understood DA white dwarf stars (WDs) will be reference standards for LSST photometry. The density of DA WDs with magnitudes 17 < *g* < 20 is great enough (Eisenstein 2006) that, even at high galactic latitudes, one will be in a large fraction of LSST science images. The spectra and magnitudes of several DA WDs visible from Cerro Pachǒn have been measured from above the atmosphere with HST (Bohlin 2001).



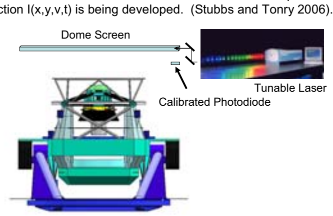
Measurement of Atmospheric Composition and Extinction

Spectra of probe stars in or near each LSST field will be monitored by the 1.4 meter Auxiliary Telescope (AT) to determine changes in atmospheric composition. The AT will also measure broad-band photometric magnitudes of LSST standard stars (e.g. DA WDs) over wide ranges of zenith angles. These will be combined with atmospheric models (e.g. MODTRAN4) to extract accurate corrections for atmospheric extinction Z(az,el,ν, t) in real time at arbitrary wavelengths.

The AT will be instrumented with a low-resolution (R ≅ 100) spectrograph and imager. Cumulative stellar counts at the North Galactic Pole extracted from SDSS data (Iveciz 2006) confirm ~ 300 stars in each LSST field with u < 15 AB. These measurements will be tied to the sentinel stars in each LSST science image to improve resolution of spatial structure across the FOV. The photometric imager will be able to measure the photometric magnitudes of stars with magnitudes r < 18 to ~ 0.5% precision in exposures ~ 1 minute. This provides overlap with the LSST dynamic range, and the ability to use reference standards (e.g., DA white dwarfs) with well-understood magnitudes and SEDs to control systematic errors.

Measurement of Instrument Response

A system to use a tunable laser to calibrate the combined telescope and camera response function I(x,y,ν,t) is being developed. (Stubbs and Tonry 2006).



A photodiode calibrated to ~ 0.1% relative accuracy (NIST98) from 450nm to 950nm monitors the integrated optical exposure. Spatial uniformity of light from the screen need only be ~ 10%, but the angular distribution must be uniform (Lambertian) over the 3.5° LSST FOV. First tests of a similar system on the CTIO Blanco telescope have been reported (Stubbs 2006).

References

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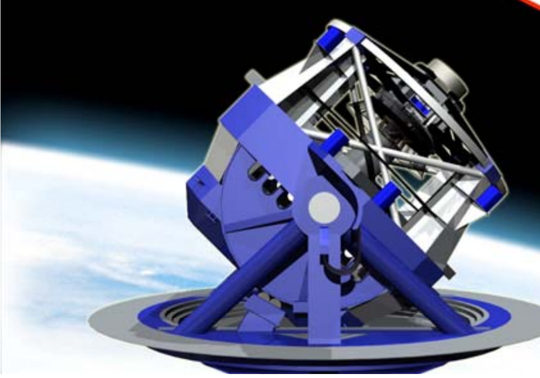

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