Large Synoptic Survey Telescope

Calibration of LSST Instrument and Data

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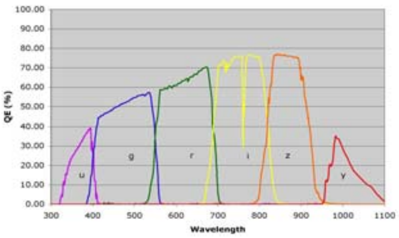
Science studies made by the Large Synoptic Survey Telescope will reach systematic limits in nearly all cases. Requirements for photometric measurements accurate to better than 1% are particularly challenging. Advantage will be taken of the rapid multi-epoch cadence of the LSST survey to use stars to 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. Repeated observations of standard stars in the accumulated survey will be combined with instrumental and atmospheric throughput measurements to calibrate data releases. Observational studies with existing telescopes and simulations are underway to validate and optimize this strategy.

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.



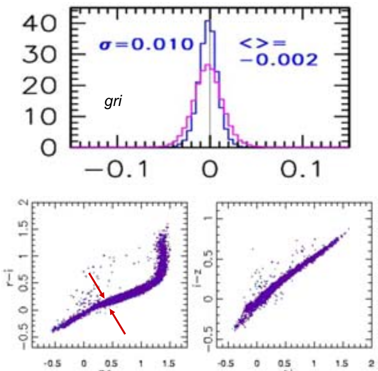
Design specifications for LSST stellar photometry are given below. The first three specifications are relative quantities defined within the native LSST photometric system in AB magnitudes. These are for bright stars not limited by photon statistics in a single exposure (e.g. r < 21).

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

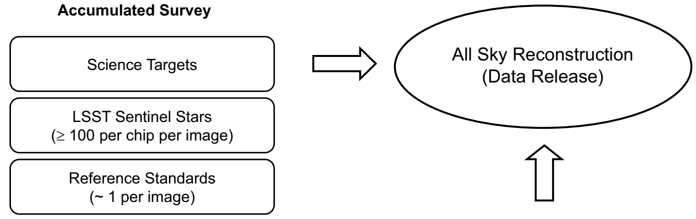
Precision of photometric measurements in present-day large surveys, such as SDSS and CFHT, have approached the specifications for LSST (Stoughton 2002; Ivezic 2004; Magnier 2004). But measurements with ground-based telescopes typically produce errors a factor of two or so larger.

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



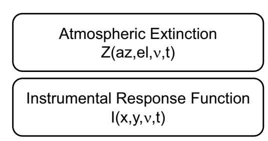
LSST All Sky Reconstruction

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.

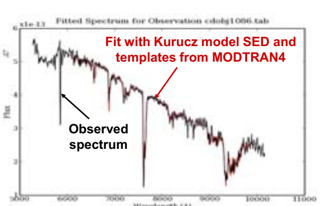


Measurement of Atmospheric Composition and Extinction

Modern atmospheric transport codes (ref. MODTRAN4) can be used to compute accurate templates for scattering and absorption of light by various atmospheric components. The LSST will use an Auxiliary Telescope (AT) to acquire spectra of stars and use these in conjunction with computed templates to extract measurements of atmospheric extinction Z(az,el,v, t) in real time at wavelengths across the LSST filter bands.

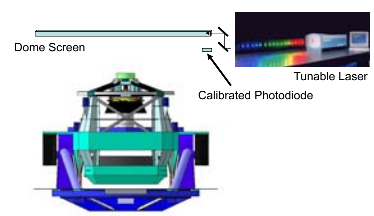
The functional requirement of the AT is to provide relative spectro-photometry of stars with magnitude r < 15 AB with resolution R > 100 and S/N > 200 across the LSST bandwidth. The data acquisition is to maintain cadence with the LSST survey at all celestial coordinates. The magnitude requirement is chosen to guarantee sufficient density of target stars at the galactic cap, and the resolution and sensitivity chosen to guarantee sufficient definition of various atmospheric components responsible for scattering or absorption of light. These lead to a baseline specification of a 1.4m diameter telescope.

Observational studies of these techniques are now underway with existing telescopes. Shown below is a spectrum taken of an F0 star through 1.25 airmasses with the 1.5m SMARTS telescope on Cerro Tololo at CTIO. A fit of a model spectrum and characteristic signatures of extinction by Rayleigh scattering and absorption by ozone, O2, water vapor, and other trace elements is quite good. Repeated measurements of a pattern of stars through varying airmass as they move across the sky allows extraction of atmospheric extinction coefficients. Analysis of multiple nights of such data is in progress.



Measurement of Instrument Response

A system to use a tunable laser to calibrate the combined telescope and camera response function I(x,y,v,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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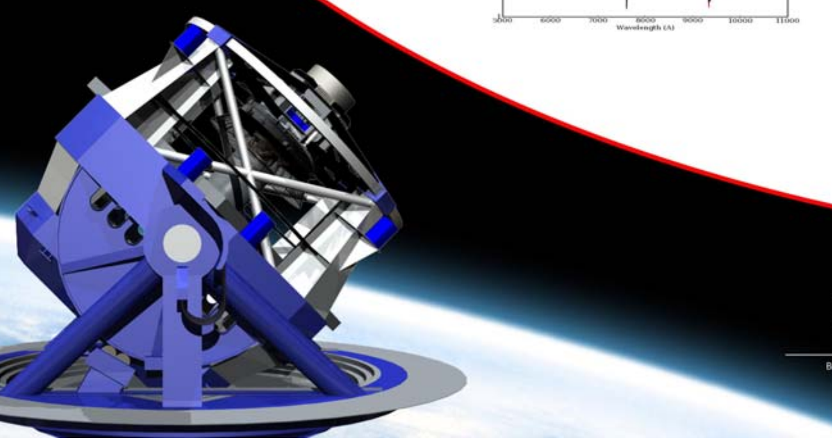

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