Large Synoptic Survey Telescope

Photometric Redshift Calibrations for LSST

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Proper calibration of photometric redshifts (photo-z's) for LSST is of the utmost importance, as many cosmological measurements depend critically on a well understood photo-z distribution. The mean redshift of each photo-z bin must be known to better than ~0.002(1+z) if cosmological measurement errors are not to be degraded. We are obtaining deep imaging in LSST filters using Subaru/Suprime-Cam to forecast LSST precision. We investigate the use of deep multiwavelength photometry of a small portion of the LSST area as an intermediate calibrator between faint galaxies and a bright sub-sample with spectroscopy. We also explore using the cross-correlation between galaxies in a photometric redshift bin and a bright spectroscopic sample in order to reconstruct the photo-z redshift distribution in detail, even if the spectroscopic data is highly incomplete. With currently planned samples these methods can reach LSST calibration goals.

New Tests with Observations

We are now assembling a variety of datasets for testing calibration techniques. This involves both gathering larger spectroscopic samples in fields with LSST-like photometry, and obtaining LSST-like photometry in fields with spectroscopy. Spectroscopic redshifts can then be used to test and calibrate photo-z's. Most of these efforts are building on the recently-completed Deep Lens Survey (DLS) dataset which has obtained *BVRz*' imaging in seven 2x2 degree fields, providing one of the largest deep imaging datasets to date. Tests of both photometric redshift algorithms and methods for template and filter curve refinement using DLS data are now underway (**Margoniner et al. 2007, Schmidt et al. 2008**, in prep).

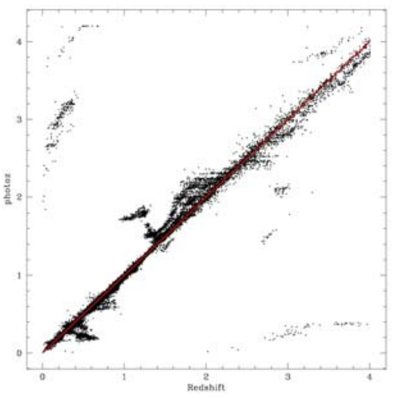


Figure 1: Monte Carlo simulation of 6-band LSST photometric redshifts, including magnitude and type priors. Our critical task is to calibrate the bias and errors in photo-z's to high precision for 0<z<3. Galaxies in problem areas of color space can be excluded from most cosmological analyses with minimal impact (**Jain, Connolly, & Takada 2006**).

Because LSST will utilize different passbands than DLS(*ugrizy* as opposed to *BVRz'*), we are now working to supplement the DLS imaging with Subaru/Suprime-cam *grizy* to allow direct comparisons. Campaigns to obtain many more spectra in DLS fields are underway using the Keck Telescopes (with the DEIMOS and LRIS-B instruments; PI: J. A. Tyson), Magellan (using IMACS; PI: D. Eisenstein) and the Anglo-Australian Telescope (with AAOmega; PI: B. Schmidt).

LSST will reach magnitudes too faint for large spectroscopic samples to be feasible. Therefore, photo-z calibrations can rely on spectroscopic redshifts only for brighter objects. We are now exploring several techniques to deal with this. One promising method is to obtain both deep spectroscopy and many-band, deep, multi-wavelength photometry (from UV to near-IR) in some limited set of fields. Multi-wavelength photometric redshifts (**Tyson, Connolly, & Newman 2006**)("super-photo-zs") are more robust than those based solely on optical photometry, due to the presence of degeneracy breaking features (e.g. the Lyman break and 1.6μm bump) which are strong in galaxies of almost all star-formation histories (see **Figures. 1 & 2**). Super-photo-z's for faint galaxies can then be used to train the 6-band LSST photo-z's.

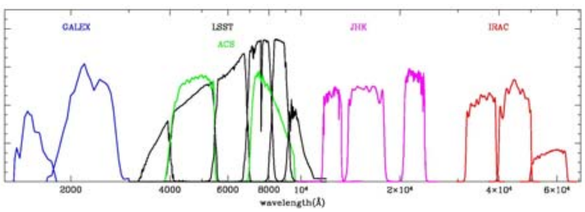


Figure 2: The set of 16 filters, including GALEX, Hubble ACS, NIR JHK, and Spitzer IRAC bands, used for the super-photo-z's in Fig. 3. The wide wavelength baseline covers multiple broadband features in a galaxy's spectral energy distribution, breaking photo-z degeneracies.

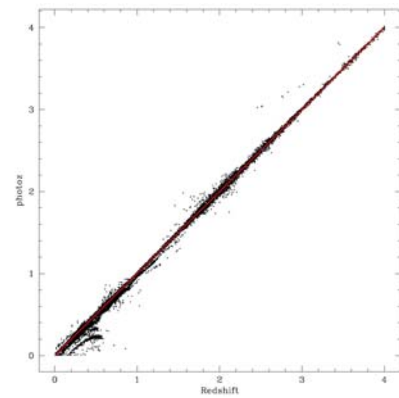


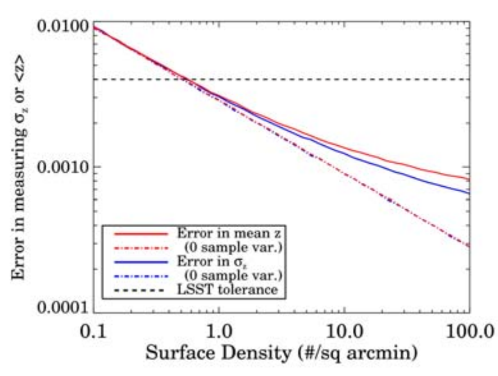
Figure 3: A test of a simulated super-photo-z system using the filter set from Figure 2, including LSST *ugrizy*. With wavelength coverage from 0.15 to 6 μm, photo-z errors are σ_z<0.03 at most redshifts, and the number of outliers is greatly reduced. Galaxies with super-photoz-z's will be used as secondary calibrators to better train the 6-band photo-z's.

Large-Scale Structure-based Calibrations

Even at magnitudes much brighter than LSST will reach (*R*~24 vs. *r*~27), spectroscopic samples are far from 100% complete. This poses a significant problem for calibrating photo-z's, especially if the SEDs of brighter galaxies do not span the range of fainter ones (as is true locally, and may be a worse issue at high *z)*. Calibrations which rely on large-scale structure (LSS) information can avoid these problems. All populations of galaxies cluster with each other in three dimensions, and hence also cluster in projection. Since this clustering is local, the observed angular clustering between two sets of galaxies will depend on the degree to which they overlap in *z*, in addition to the strength of their clustering in 3D (i.e., their 'bias').

One application is to measure correlations on the sky between galaxies in separate photo-*z* bins (**Schneider et al. 2006**). These correlations are proportional to the overlap between the bins' *z* distributions, yielding a test for outliers. Higher precision results can be obtained by measuring cross-correlations between a photometric sample (e.g. objects in a single photo-*z* bin) and members of a spectroscopic sample, as a function of the spectroscopic *z* (**Newman 2007; Figure 4**). This provides sufficient information to reconstruct the *z* distribution of the photometric sample even when the spectroscopic data is incomplete. This method can achieve LSST calibration requirements with spectroscopic samples currently underway. Tests with simulations are promising (**Wittman et al. 2008**, in prep.; **Figure 5**).

Figure 4: Predicted errors in measuring both the mean and width (‹z› and σ_z) as a function of the surface density of objects in a photo-*z* bin, given a sample of 25,000 spectroscopic redshifts per unit *z (*comparable to current samples) and σ_z=0.1. The black, dashed line indicates the tolerances for LSST at *z*~1. Errors are well within LSST requirements unless surface densities are very low (**Newman 2007**).



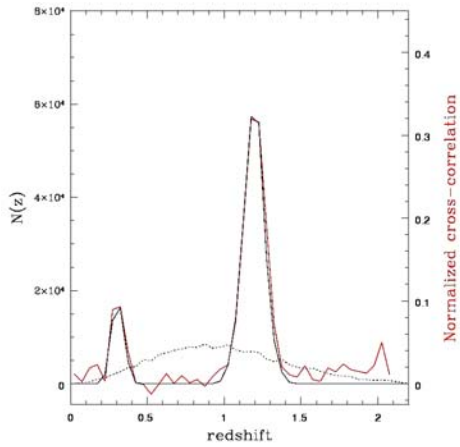
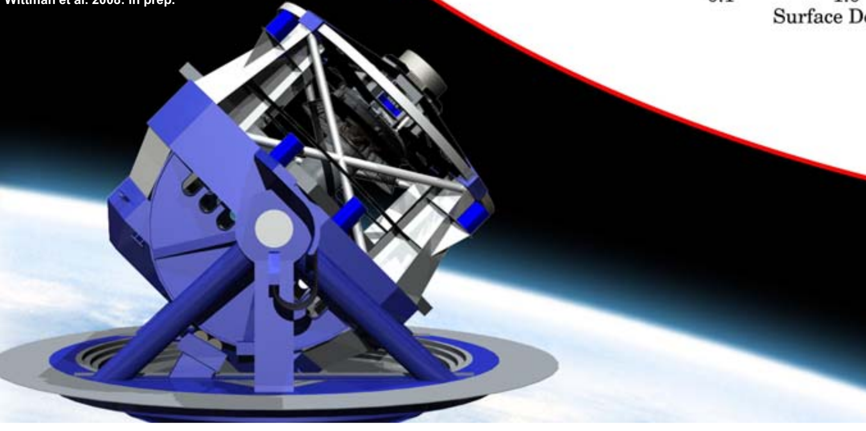


Figure 5: A preliminary test of cross-correlation reconstruction using a mock catalog from the N-body simulations of M. White (Wittman 2008). In black is shown the true *z* distribution for a multimodal photo-z bin; in red is the distribution recovered using cross-correlations with a spectroscopic sample given by the black, dotted curve.

For more details see:
Margoniner et al. 2007: astro-ph/0707.2403
Tyson, Connolly, & Newman 2006: http://www.lsst.org/Science/photoz.shtml
Jain, Connolly, & Takada 2007: JCAP, 03, 13
Newman 2007: Ap. J., submitted http://astro.berkeley.edu/~jnewman/xcorr/xcorr.pdf
Schmidt et al. 2008: in prep.
Schneider *et al.* 2006: *Ap. J.*, 651, 14
Wittman et al. 2008: in prep.



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