Large Synoptic Survey Telescope

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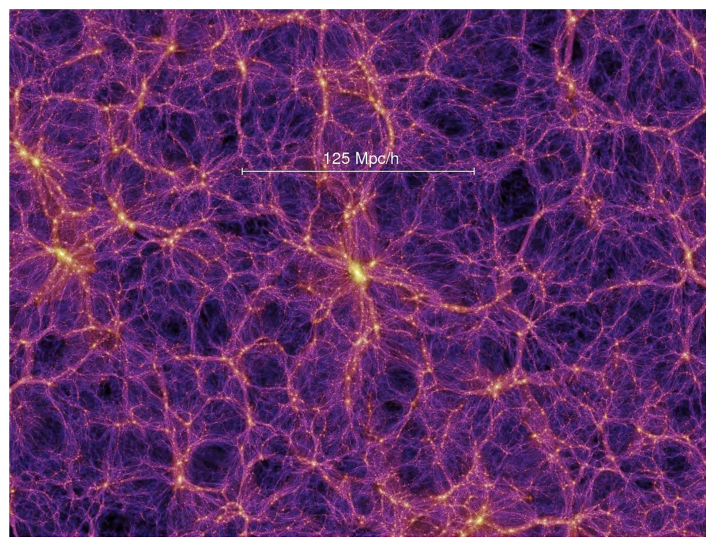
Simulating Galaxies & Active Galactic Nuclei in the LSST Image Simulations

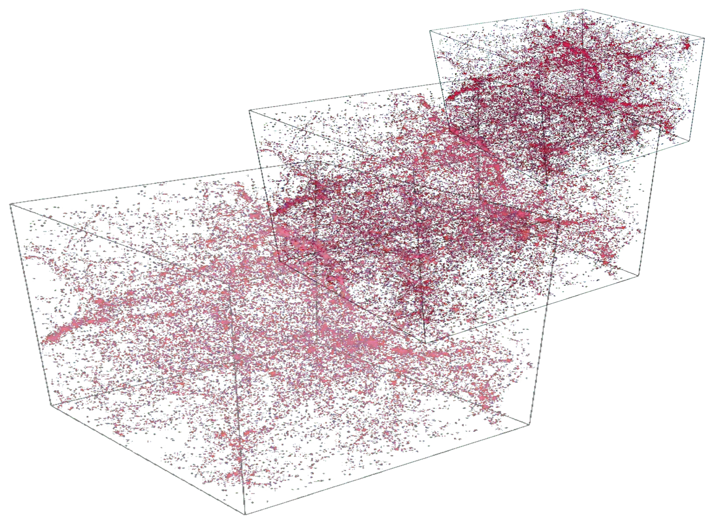
James Pizagno[1], Z. Ahmad[2], J. Bankert[2], D. Bard[3], A. Connolly[1], C. Chang[4], R. R. Gibson[1], K. Gilmore[5], E. Grace[2], M. Hannel[2], J. G. Jernigan[6], L. Jones[1], S. M. Kahn[4], S. K. Krughoff[1], S. Lorenz[2], S. Marshall[4], Y. Shen[7], S. M. Shmakova[3], N. Sylvestri[1], N. Todd[2], M. Young[2]

[1]University of Washington, [2]Purdue University, [3]KIPAC [4]Stanford University, [5]University of Stanford, [6]Space Science Laboratory, [7]Harvard-Smithsonian Center for Astrophysics

We present an extragalactic source catalog, which includes galaxies and Active Galactic Nuclei, that is used for the Large Survey Synoptic Telescope Image Simulation effort. The galaxies are taken from the De Lucia et. al. (2006) semi-analytic modeling (SAM) of the Millennium Simulation. The LSST Image Simulation effort requires full SED information and galaxy morphological information, which is added to the catalog by fitting Bruzual & Charlot (2003) stellar population models, with Cardelli, Clayton, Mathis (1989) dust models, to the BVRIK colors provided by the De Lucia et. al. (2006) SAM. Galaxy morphology is modeled as a double Sersic profile for the disk and bulge. Galaxy morphological information and number counts are matched to existing observations. The catalog contains galaxies with a limiting r-band magnitude of m_r=28, which results in roughly one million galaxies per square degree. An existing AGN catalog (MacLeod et. al. 2010) is matched to galaxy hosts in the galaxy catalog using SDSS observations. AGN are morphologically modeled as variable point sources located at the center of the host galaxy. We demonstrate how this extragalactic source catalog allows LSST to plan for extended object extraction, variable extragalactic source detection, sensitivity level determination after image stacking, and perform various other cosmological tests.

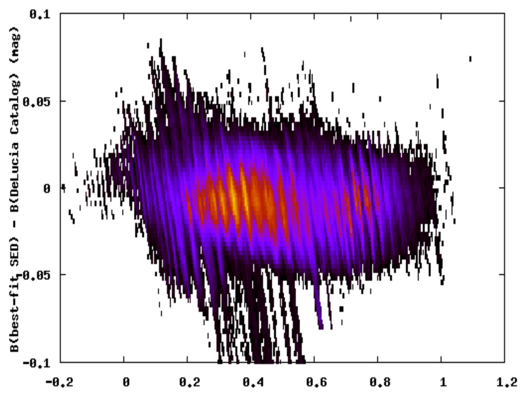
Making A Light Cone from the Millennium Simulation

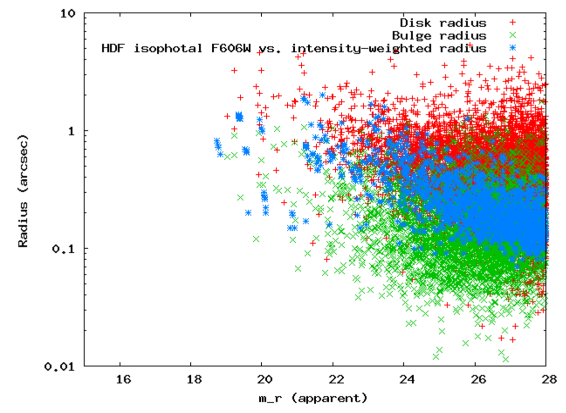


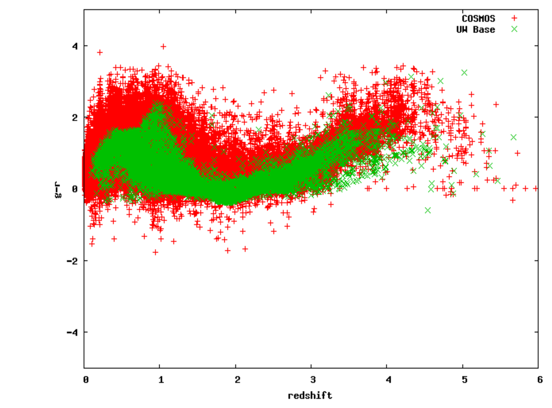


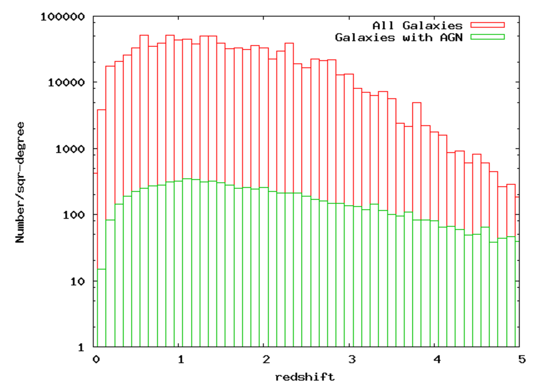
The galaxy catalog is generated using the Millennium Simulation, with baryon physics included using the semi-analytic model as described in De Lucia et.al. (2006). DeLucia et.al. (2006) provides BVRIK luminosities for the bulge and disk, along with disk sizes, and stellar masses. Light Cone software from the N-body shop at the University of Washington department of Astronomy is used to turn the Millennium Simulation output into a catalog containing the sky positions (ra/dec) and redshift for every galaxy in a 4.5x4.5 sqr-degree patch.

Galaxy Spectra, Sizes, and AGN



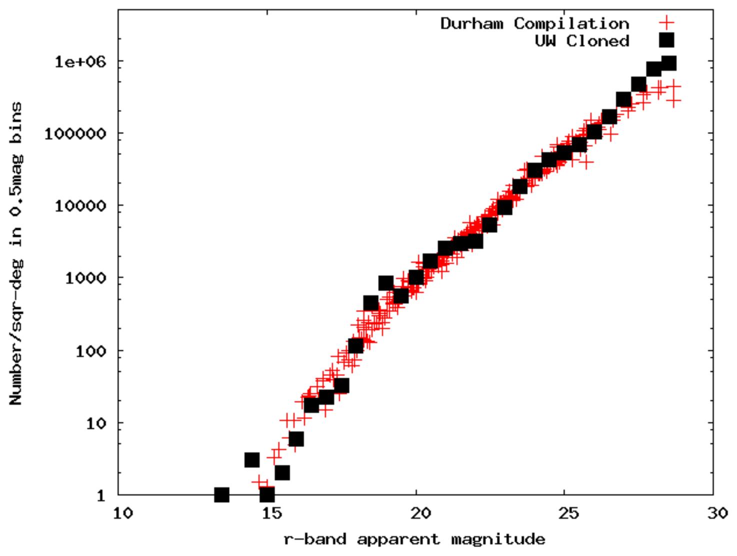


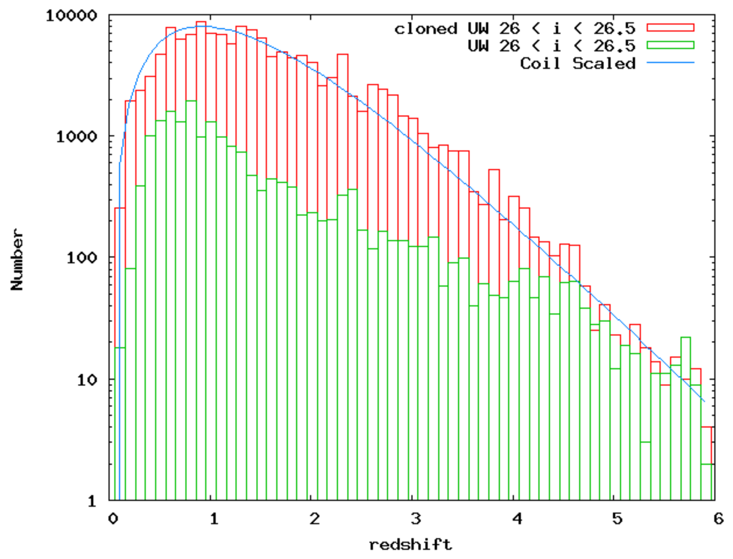




The LSST Image Simulator requires a detailed Spectral Energy Distribution (SED) for ray-tracing each photon through the system. Bruzual & Charlot (2003) SEDs are fit separately to the BVRIK colors of the disk and bulge. The SEDs are modified by a Cardelli, Clayton, Mathis (1989) extinction curve to account for dust in the disk. The free parameters in the fitting process are the SED age, SED metallicity, SED star formation history, and dust content (disk only). In the top-center figure, disk and bulge apparent sizes are compared to the apparent sizes of galaxies in the Hubble Deep Field. Bulge sizes were derived from the observations of bulge luminosity-size relations. Note that the apparent magnitude range extends down to m=28. The top-right figure, shows the (g-r) color as a function of redshift for a 1 sq-degree patch, compared to COSMOS data colors. The figure to the left shows the AGN and Galaxy number counts as a function of redshift for a 1 sqr-degree patch in the galaxy catalog. AGN are matched to a population of host galaxies having a range of (u-r) color and stellar mass that resemble SDSS observations of AGN host galaxies.

Matching Observed Number Counts and Redshift Distributions

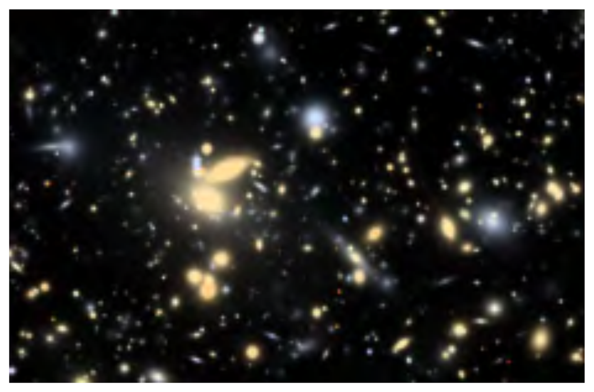


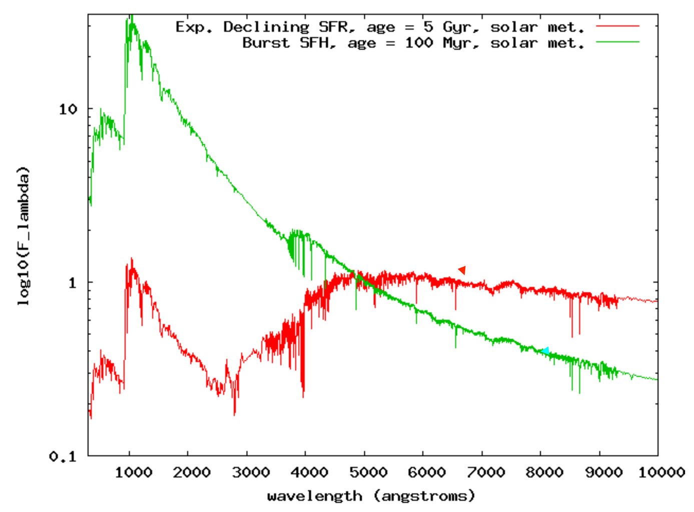


Cloning software was run on the catalog so that the redshift and apparent magnitude distributions agree with existing observations. In this figure, the r-band number counts are compared to a compilation of optical surveys, compiled by the Extragalactic Astronomy & Cosmology Research Group at Durham University.

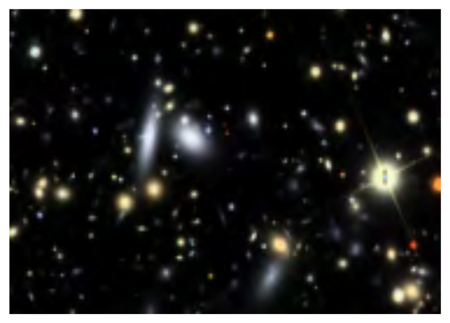
This figure shows the redshift distribution before (green histogram) and after (red histogram) cloning. The redshift distribution was cloned to the observations in Coil et.al. (2004). Each galaxy is assigned a cloning factor depending on its redshift and apparent magnitude. That cloning factor determines the number of times that galaxy is repeated in the catalog.

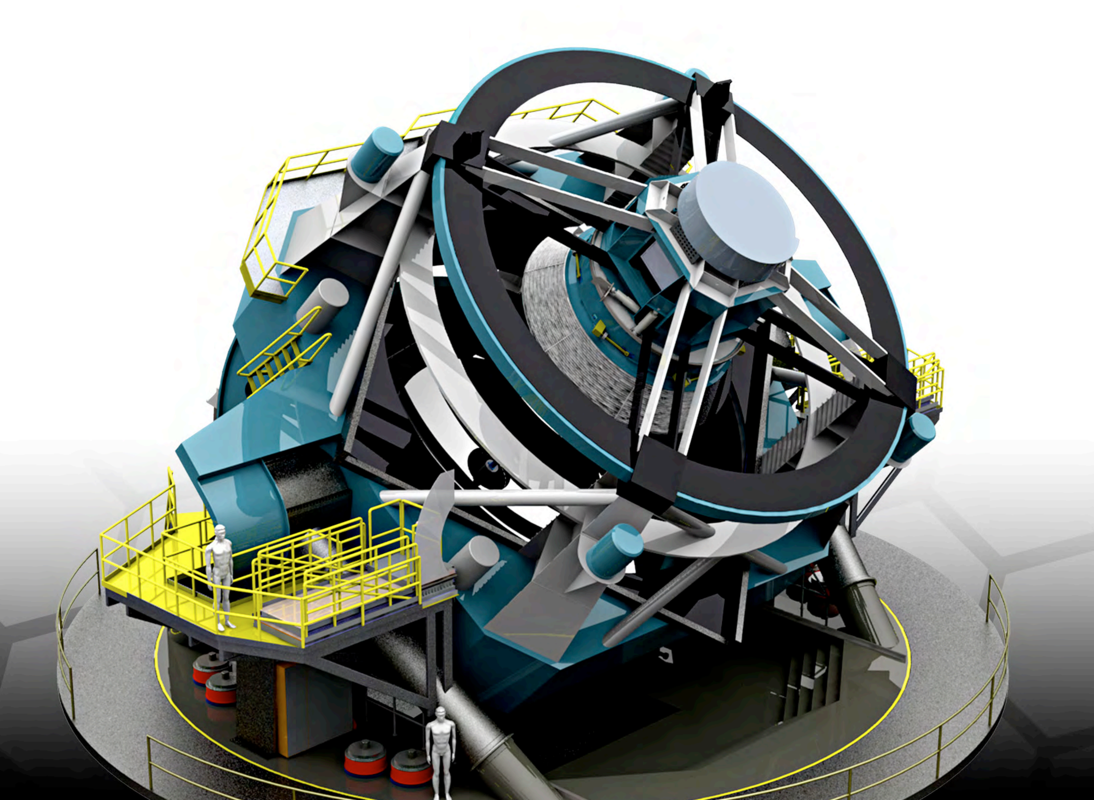
Simulated Images



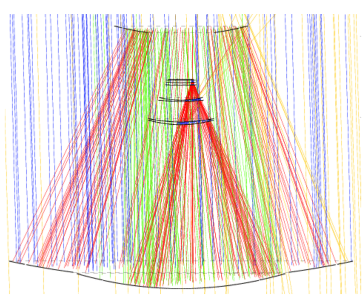


This figure shows the resulting image of galaxies and stars after ray-tracing. A range of morphologies can be seen, along with color variation. The inclination of each galaxy is determined from the amount of dust (determined during the SED-fitting) and the observed relation between dust-luminosity-Sersic index seen in SDSS observations (Maller et.al 2009). The arrows show typical galaxy-SED associations. The resulting morphology of each galaxy can be used to test extended object extraction, test photometric redshift determination, and can be used during various stages of the data reduction pipeline. AGN will show up as variable point sources in the centers of galaxies in the resulting images, which can be used to test variable extragalactic object extraction.





Ray-Tracing



Photons from all objects are traced through a multi-layer atmosphere, through the telescope optics, and into the detector. Instrument signatures are included in the processing. Noise due to background sky glow, and detector noise are included in the generation of images.

References:
Bruzual, G., Charlot, S. 2003 MNRAS, 344, 1000
Cardelli, J. A., Clayton, G. C., Mathis, J. S. 1989 ApJ 345, 245
Coil et.al. 2004 ApJ, 617, 765
De Lucia, et.al. 2006 MNRAS, 366, 499
MacLeod, et.al. 2010 ApJ, 721, 1014
Maller, A. H., Berlind, A. A., Blanton, M. R., Hogg, D. W. 2009 ApJ, 691, 394

Durham University Number Counts:
http://astro.dur.ac.uk/~nm/pubhtml/counts/counts.html

Future Work

In the future, Supernovae will be added to galaxy hosts, according to the galaxy host's star formation rate (a parameter available in the De Lucia et.al. (2006) catalog). Future work also includes putting emission lines in the SEDs. For nearby galaxies, the simulator can include FITS maps of imaging data from existing telescopes. Therefore, future work will also make use of existing imaging data in SDSS or from HST.

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