Large Synoptic Survey Telescope

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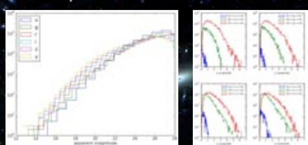
Simulating the LSST

Andrew J. Connolly[1], J. R. Peterson[2], J. G. Jernigan[3], R. Abel[8], J. Bankert[2], C. Chang[9], C. Claver[4], R. Gibson[1], K. Gilmore[5], E. Grace[2], L. Jones[1], Z. Ivezic[1], J. Jee[6], M. Juric[7], S. M. Kahn[5], V. Krabbendam[4], S. Krughoff[1], S. Lorenz[2], J. Pizagno[1], A. Rasmussen[5], N. Todd[2], T. Tyson[6], M. Young[2]

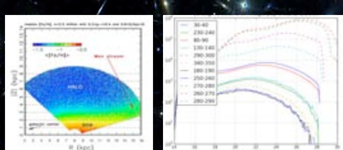
[1]Univ. Of Washington, [2]Purdue Univ., [3]SSL/UCB and KIPAC/SLAC, [4]NOAO, [5]SLAC, [6]UC Davis, [7]Center for Astrophysics, Olympic College[8], Stanford Univ.

Extracting science from the LSST data stream requires a detailed knowledge of the properties of the LSST catalogs and images (from the detection limits to the accuracy of the calibrations to how well galaxy shapes can be characterized). These properties will depend on many different aspects of the LSST including the design of the telescope, the conditions under which the data are taken and the overall survey strategy. To prepare the data and science analysis systems for the LSST data stream, the LSST Image Simulation group is undertaking the development of an LSST simulation framework. This consists of galaxy, stellar and solar system catalogs designed to match the depth of the LSST (to r=28), and high fidelity image simulations that trace photons through the atmosphere and telescope to the detector. We describe here the progress towards the development of this end-to-end simulation system.

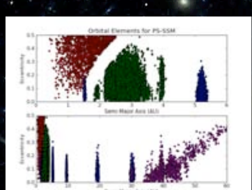


Millennium survey Springel et al (2005)

The cosmology model within the LSST simulation framework is derived from the Millennium simulation catalogs of De Lucia et al (2006). From these data a lightcone is generated and bulge-to-disk models and spectral energy distributions are associated with the sources. The number counts and redshift distributions of the resulting sources extend to r<28 and z>6.

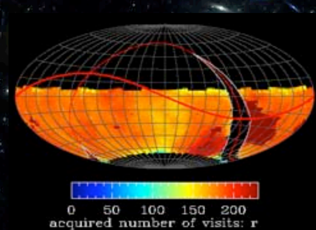


The Galactic structure is derived from the models of Juric et al (2008) which match the colors and dynamics of stars within the SDSS but extended to a depth of r<28. All sources include an associated spectral energy distribution, proper motion and parallax. Of these, 10% of sources are defined as variable (where the variability can be periodic or transient).

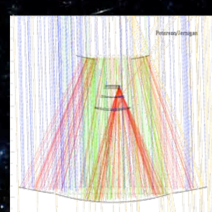


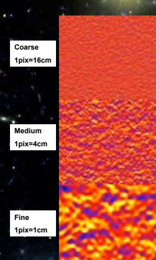
The LSST Solar System model is populated using the distribution of orbits from Grav et al (2007). With Near-Earth Objects, Main Belt Asteroids, Trojans, and Trans-Neptunian Objects, the base catalog contains 10 million Solar System sources. For each pointing the LSST the database is queried to determine those sources within the field of view. Accurate ephemerides are then generated on the fly for this subset of asteroids.

By querying the underlying cosmological, Galactic and Solar System models, catalogs of the sky are constructed from the pointings defined by the Operations Simulator. Variable and moving sources are integrated into a series of LSST observations generating catalogs above and below the atmosphere. This parameterized view of the sky is then simulated, one photon at a time, generating an LSST stream of images. Passing these images through the data management pipelines, we close the loop by comparing the input data to catalogs derived from analysis. The current Data Challenge DC3b simulation run will result in 47TB of simulated LSST images – equivalent to seven years of operations of the Sloan Digital Sky Survey. The background on this poster shows a simulated image covering 0.5% of the LSST focal plane. Over 1000 dithered visits in six bands will be obtained for each of 2000 pointings in the ten year survey of 20,000 square degrees.

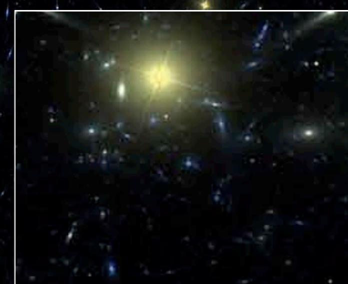


The coverage of the sky in one of the six bands derived from a run of the LSST Operations Simulator. The number of observations for each pointing is given by the color of the point. Each of the pointings comes with an associated time, sky background and sky condition (including the effects of airmass and time varying cloud cover).





All photons are traced through a multilayered atmosphere (assuming a frozen screen approximation where the screens move at velocities derived from historical measurements of the site). By simulating each photon, wavelength dependent effects due to the atmosphere and optical system can be modeled accurately. After passing through the atmosphere, a fast ray-trace algorithm simulates the photon path through the optical system and camera.



Combining the catalogs, operations and image simulations result in deep CCD images of the LSST fields. The figure above zooms into a 15 second exposure showing a bright star (including bleed trail and diffraction spikes) and a range of different morphological types. As all systems are modeled in sequence we can consider each optical component in isolation or as part of the overall system. The lower figure shows the effect of turning on progressively more components within the simulation, demonstrating how each element contributes to the PSF (e.g. how the wind is responsible for the homogenization of the PSF). Simulations can be done with the active optics wavefront sensing system turned off or on.

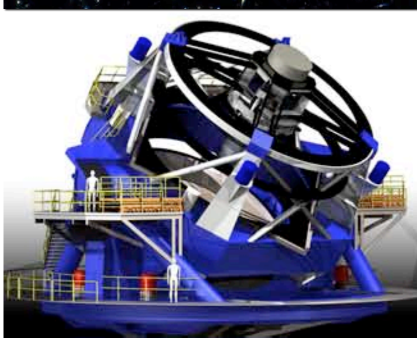
References:

De Lucia, G., et al., , 2006., Monthly Notices Royal Astronomical Society, 366, 499

Grav, T., et al., 2007, Bulletin of the American Astronomical Society, 39, 807

Juric, M., et al. 2008, Astrophysical Journal, 673, 864

Springel, V., et al., 2005, Nature, 435, 629



The simulation framework for the LSST is designed to provide high fidelity simulations of the entire LSST optical system (from above the atmosphere to the camera output). Combined with the Operations Simulator these catalog and image simulations are used as inputs for a series of Data Challenges. These Challenges drive the development of the LSST reduction and analysis pipelines - including the development of algorithms for the co-addition and subtraction of images, the detection of variable and moving sources and the classification of transient events. Through the continued development of this framework the LSST Image Simulator will validate the design of the survey and the sensitivity of the science to statistical and systematic effects.

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