Large Synoptic Survey Telescope

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Simulating the LSST

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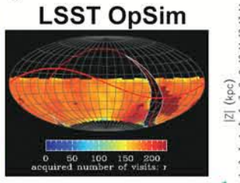
The science that will be derived from the LSST (from studies of weak lensing to detection of variable and moving sources) depends on a detailed knowledge of the statistical properties of the sources detected within the LSST data stream together with a careful characterization of the statistical and systematic errors. The goal of the LSST Image Simulation group is to develop detailed simulations of images for the LSST. This includes catalogs of stars and galaxies to a depth of r=28th magnitude, variable sources including high proper motion stars, asteroids, and supernovae, extended sources and potential artifacts. From these catalogs high-fidelity image simulations incorporating a multi-layer turbulent atmosphere,detailed models of the optical system for the telescope, camera and control system are derived by ray-tracing individual photons; simulating the full LSST field-of-view. We describe the development of the image and catalog simulations and their use in testing and validating the LSST data processing and science requirements.

Life of a Photon

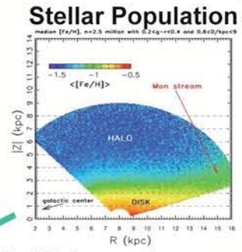
Sky Model

Cosmology

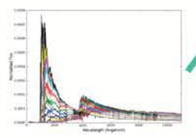
LSST OpSim



Stellar Population

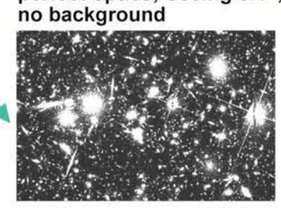


Spectral Models



Base Catalog Synthesis

Ideal Reference Image: perfect optics; Seeing 0.1"; no background

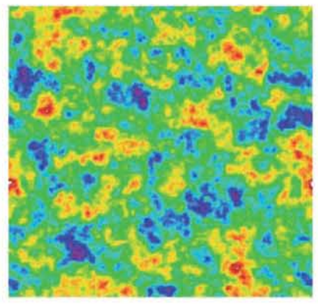


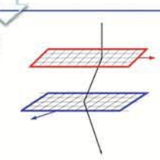
Source	RA	Dec	r	SED	Size	Type	Inc	Size	Size	Size	Size
object	22.13	-0.19	28.2	SEDS/Galaxy_v2/bc2003_hr_m62_57.sed	3.412	galaxy	1.0	0.86	0.189	1.32	1.881
object	22.161	-0.20	26.73	SEDS/Galaxy_v2/bc2003_hr_m62_57.sed	3.424	galaxy	1.0	1.39	0.307	1.1742	2.
object	22.12	-0.24	28.24	SEDS/Galaxy_v2/bc2003_hr_m62_57.sed	3.455	galaxy	1.0	2.052	0.44236	1.31	0.02103

We simulate the sky above the atmosphere using a combination of Galactic structure models, galaxy catalogs from the Millennium survey and stellar population models. The galaxy catalogs extend to r=28 (with approximately 10^7 galaxies within the LSST focal plane) and each source is represented by a spectral energy distribution and a series of morphological parameters. The "observations" of this base catalog are defined by the outputs from the LSST operational simulator (OpSim).

Atmospheric Model

Sample Atmospheric Screen



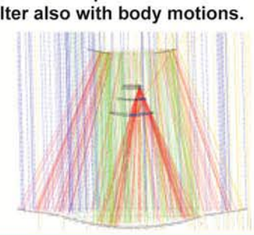


Two Layer Concept (typical model is a 12 layer structure function)

The atmosphere is modeled by a series of layers each with an independent 3D Kolmogorov model that is averaged into an equivalent screen with refractive index variations in 2D. The time dependence of the atmospheric seeing is modeled by the frozen translating screen approximation with a wind velocity and direction. The single photon history is traced through each layer of the atmosphere via a newly invented technique.

Telescope and Camera Model

Geometric raytrace of the LSST optics: Primary M1, Secondary M2 and Tertiary M3 mirrors with perturbations and body motions; Camera Lens L1, L2 and L3, and filter also with body motions.

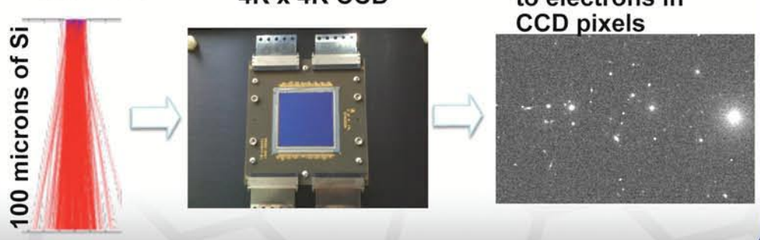


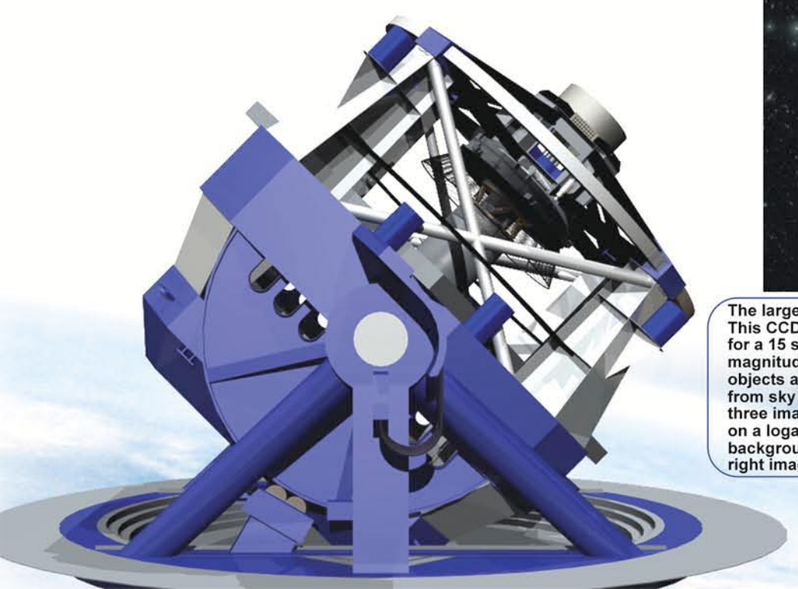
Detector Model

Photons Enter CCD

4K x 4K CCD

Simulated Image: Photons convert to electrons in CCD pixels





The large simulated image above is one LSST CCD (4K x 4K) with 0.2" pixels, 0.4" seeing and a field of view ~13.7 ' x ~13.7'. This CCD is one of 145 fully illuminated CCDs that comprise the LSST focal plane. The image includes all photons (~$3x10^{10}$) for a 15 second exposure emitted by stars and galaxies in the base catalog. The brightest stars in the image are ~12 magnitude. An object of brightness ~33 magnitude would emit ~1 photon in a 15 second exposure. The catalog includes objects as faint as ~43 magnitude. This high fidelity image was generated by computing the "life" of each emitted photon from sky source to conversion into an electron captured in the well of a CCD pixel. The image is a true color composite of three images (g, r and i filters mapped into B, G and R colors respectively: display RGB color table). Each color channel is on a logarithmic intensity scale. The pair of smaller simulated image shows the result of adding the expected sky background light for a 15 second exposure. The left image is a redisplay of the large image without background and the right image is a version with the sky background added.

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