Large Synoptic Survey Telescope

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LSST Image Simulations

En-Hsin Peng[1], J. R. Peterson[1], J. G. Jernigan[2], A. J. Connolly[3], Z. Ahmad[1], J. Bankert[1], D. Bard[4], C. Chang[5], C. F. Claver[6], R. R. Gibson[3], D. K. Gilmore[4], E. Grace[1], M. Hannel[1], M. Hodge[1], L. Jones[3], S. M. Kahn[4], K. S. Krughoff[3], S. Lorenz[1], S. Marshall[4], S. Nagarajan[1], A. Rasmussen[4], M. Shmakova[4], N. Silvestri[3], N. Todd[1], A. Winans[1], M. Young[1]

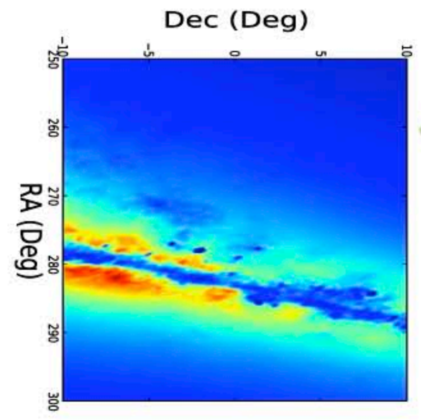
[1]Purdue University, [2]UC Berkeley, [3]University of Washington, [4]SLAC, 5Stanford, [6]NOAO

The Large Synoptic Survey Telescope (LSST) Image Simulation group is leading the effort to build a high fidelity framework to simulate the LSST system and to provide users a tool to generate LSST images from astrophysical sources. This end-to-end simulation is essential for understanding systematic uncertainties and achieving precise measurements planned for the telescope. First, the input astrophysical object catalogs that include stars based on a galaxy model, asteroids, and cosmologically-based galaxy catalogs with morphological parameters are synthesized. A novel photon Monte Carlo approach is then used to simulate images. We draw photons from the objects using their spectral energy distributions and propagate those photons through the Universe, atmosphere, telescope, and camera. We describe the catalog and image simulation framework and discuss new improvements to the physics model deployed for the system.

Catalog Simulations

the Universe is parameterized in catalogs

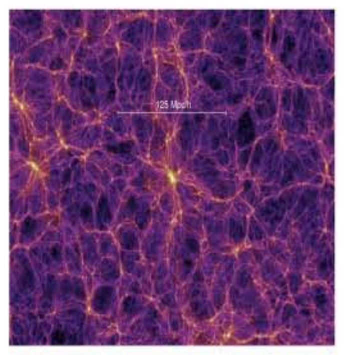
Milky Way Model



The model of the Galaxy is based on the model by Jurić et al. (2008). It includes thin disk, thick disk and halo components. In addition to the stellar distribution model, the simulated stars are embedded in a Galactic dust model from Amores and Lepine (2005) normalized to the Schlegel, Finkbeiner and Davis (1998) dust maps.

The plot to the right shows the density of stars as a function of equatorial coordinate. The obscuring dust in the plane of the Galaxy is clearly visible as a dark blue band.

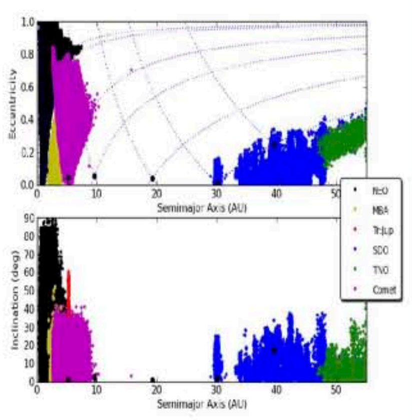
Galaxy Model



The galaxies are distributed based on the Millennium simulation using light cone software from the N-Body shop at the University of Washington. Physical properties were derived from semi-analytic models of De Lucia et al. (2006). Galaxies have disk, bulge, and AGN components each with an extinction model and SED.

The figure above shows the density of particles in the Millennium simulation. We use a four degree radius light cone to populate the base catalogs.

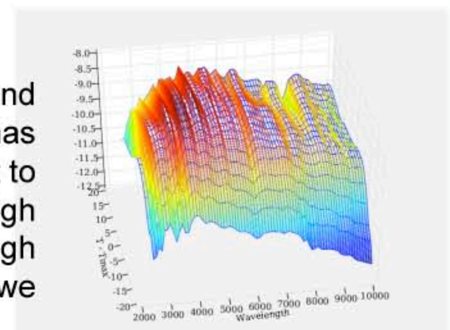
Solar System



The solar system model is based the model presented in Grav et al. (2010). Since the astrometric precision must be good to 10 mas, great care is taken to enable precise calculation of ephemerides quickly. 10 million individual orbits are realized on one day intervals resulting in > 1 billion database entries for 1 year.

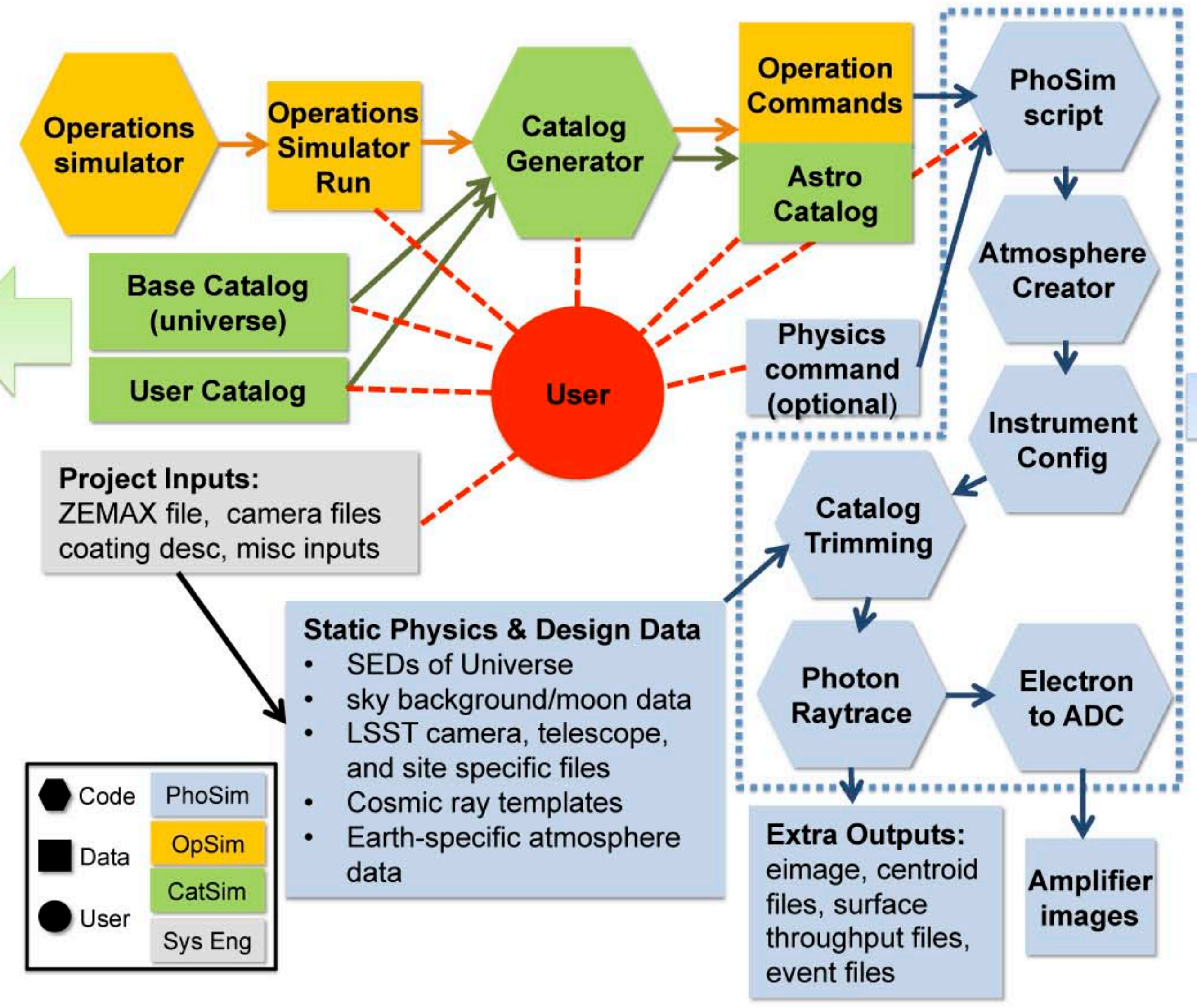
The figures to the right show the different solar system groups that make up the model. The black dots are the locations of the planets.

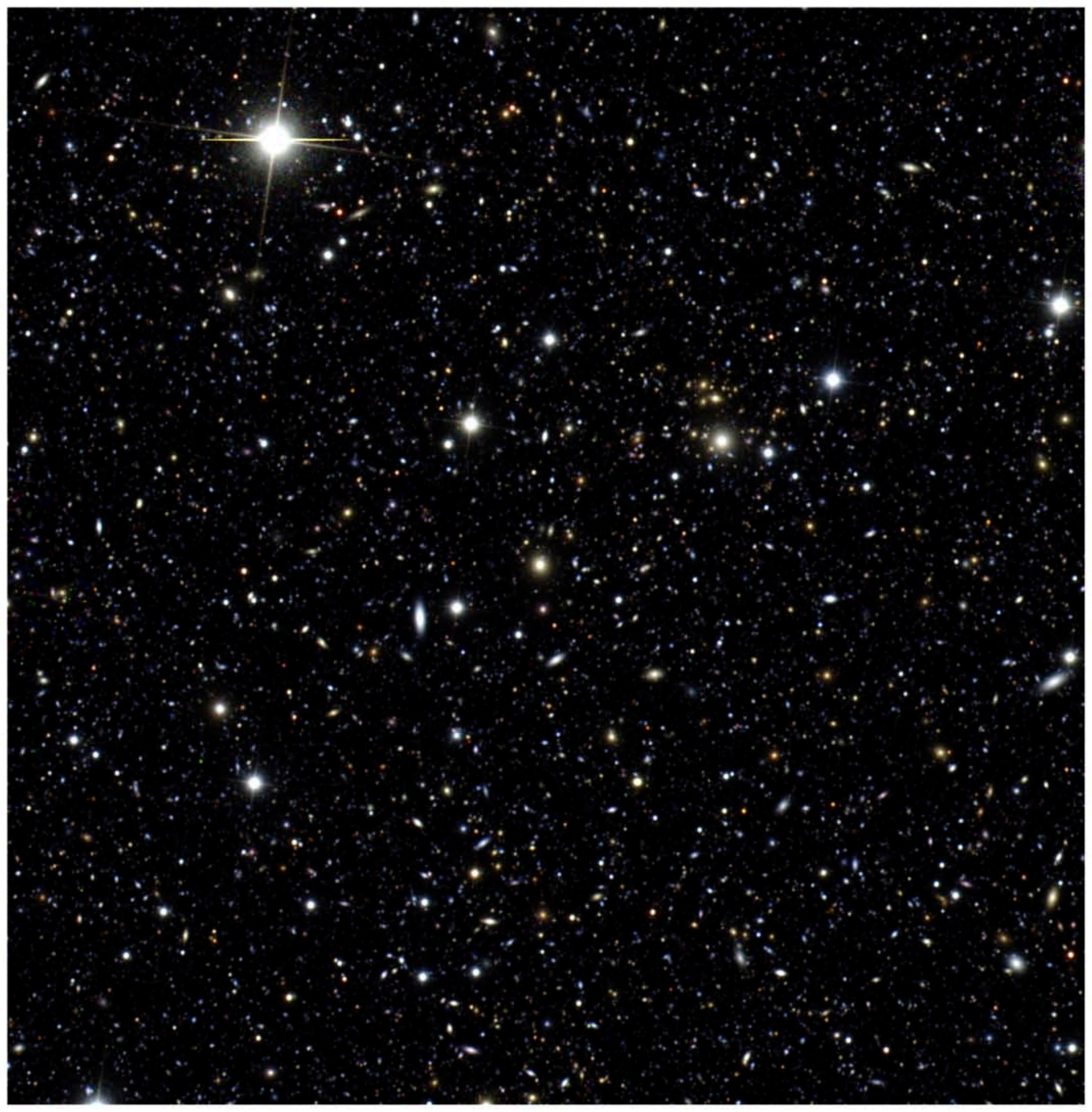
Variable Sources



LSST will catalog more periodic, transient, and moving sources than any single survey has done to date. Thus it is particularly important to be able to simulate the variable sky to high fidelity. We include periodic sources through single band light curves. Where known, we can include full spectro-temporal variability

For example, see the average type Ia supernova variability surface to the right (SALT: Guy (2005)). Capabilities for simulating stochastic variability including stellar flares and AGN variability are in place.

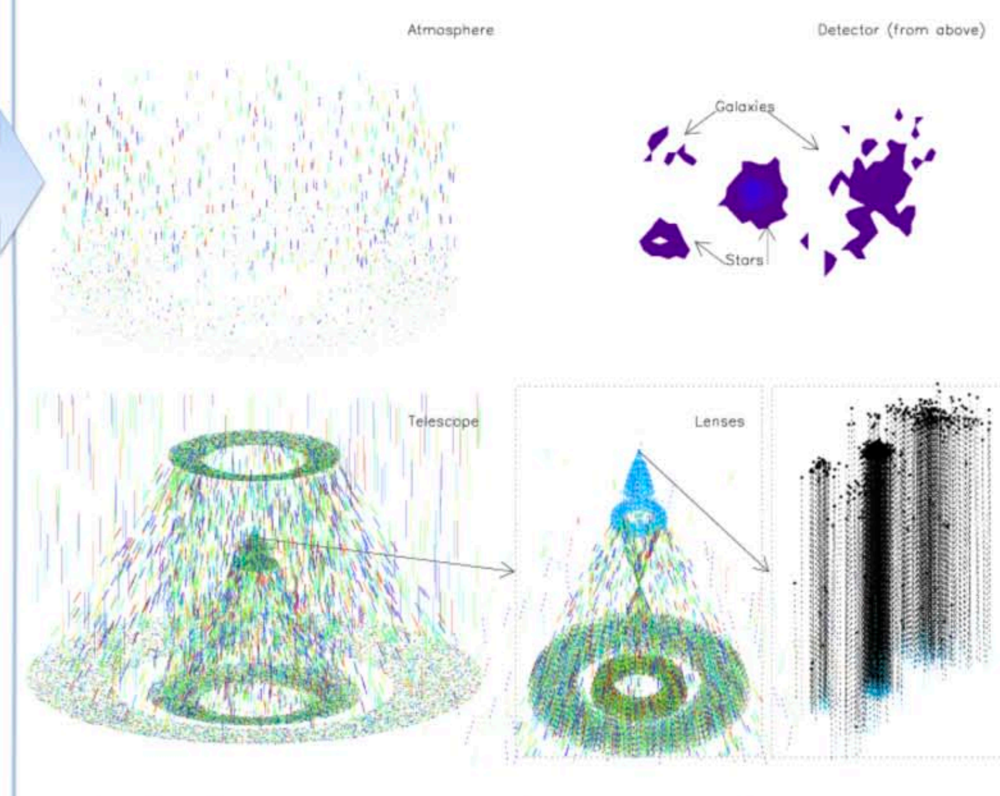




A 3-color composite image simulation (g,r,i) of stars and galaxies covering a single chip of LSST's focal plane. Every photon has been raytraced through the full physical model. The image covers about 13 by 13 arcminutes. LSST will produce 189 images of this size, a total of 3 gigapixels, in every 15 seconds.

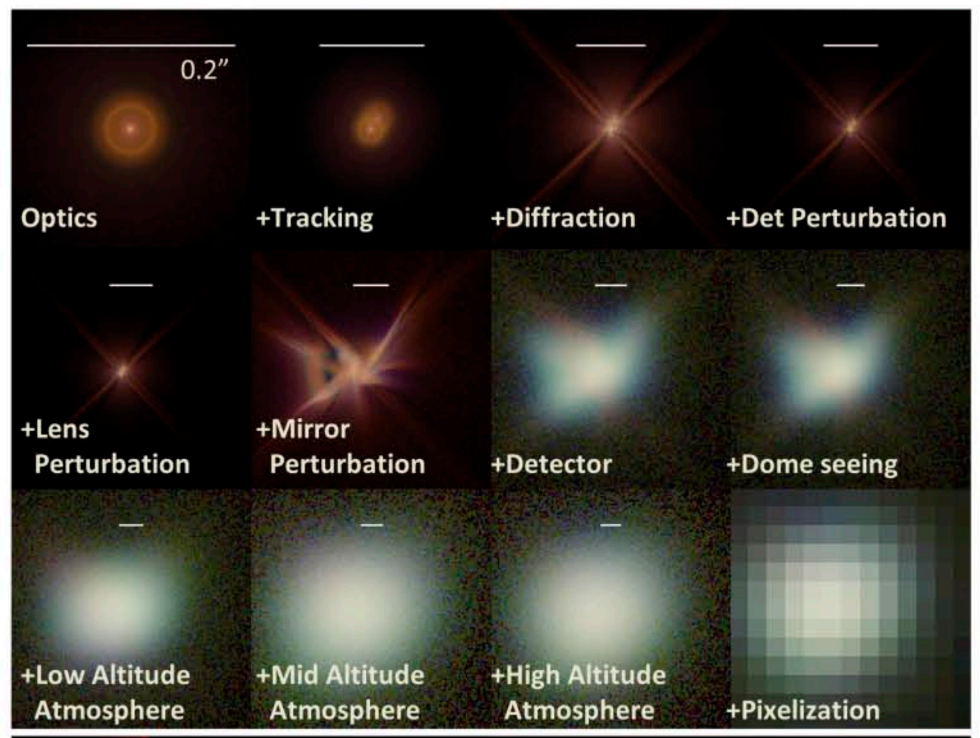
Photon Simulations

a high fidelity photon Monte Carlo turns the catalogs into images

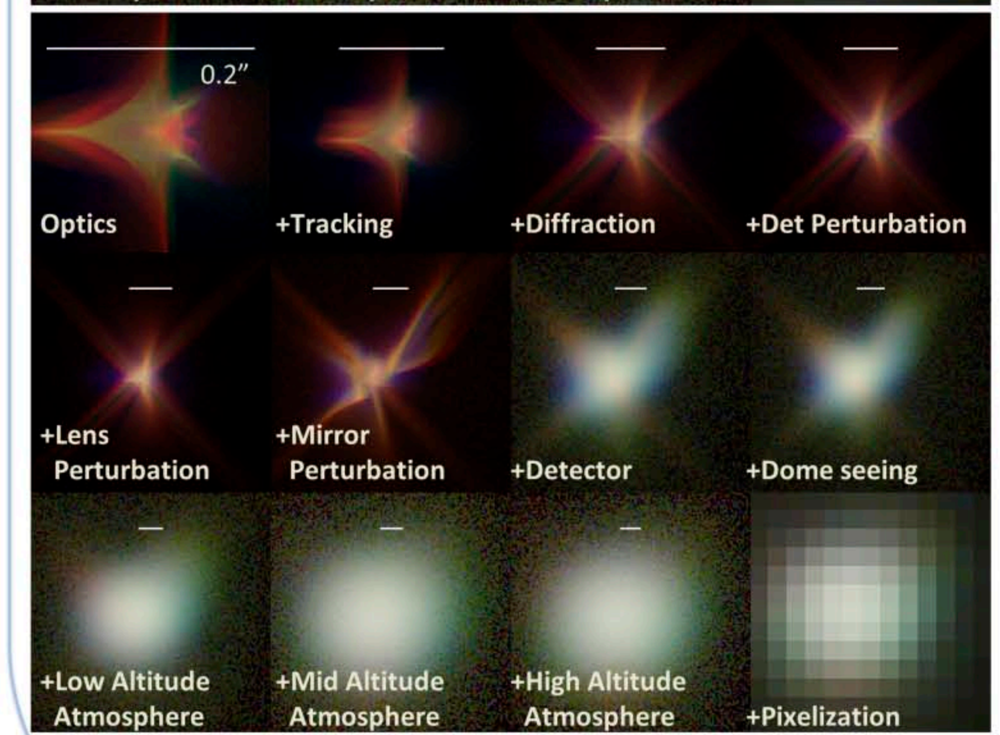


We use a photon Monte Carlo approach to choose photons from the catalog of objects using their spatial properties and SEDs. We then propagate these photons through the atmosphere, telescope, and into the silicon of the CCD where they are convert into photoelectrons. The images are then built one photon at a time. The images to the left shows the paths of the photons on several different scales. The colors represent the actual colors of the photons.

High Fidelity Physics

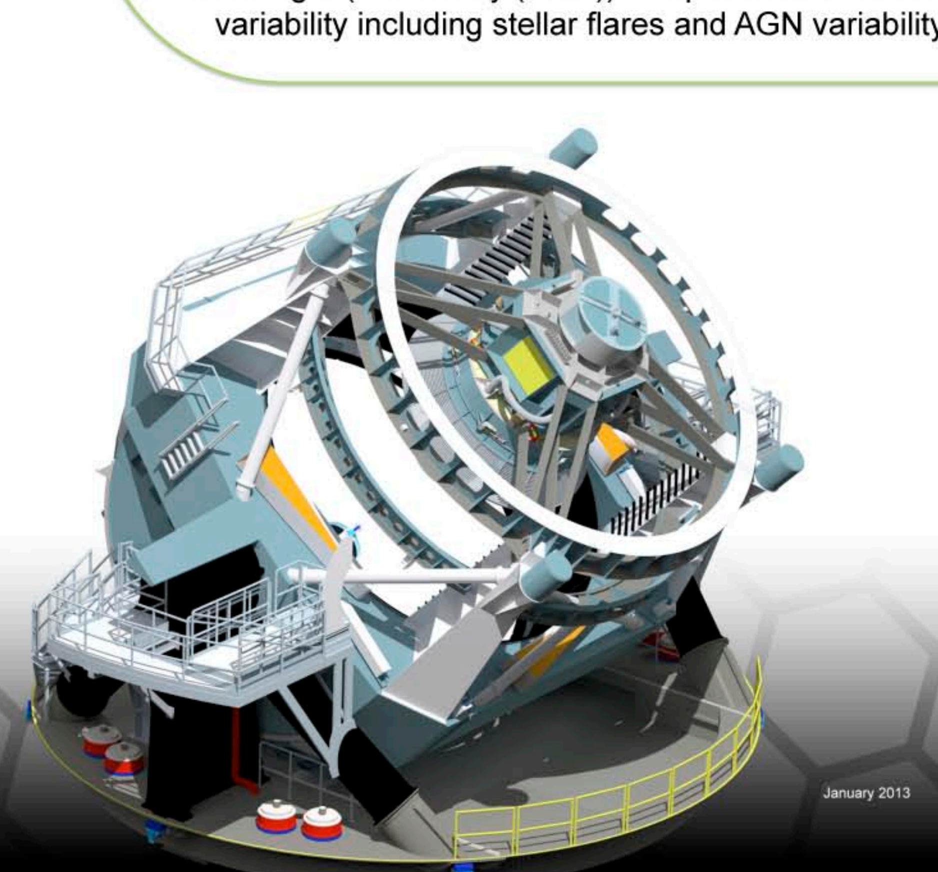


We have a variety of physical models that alter the photon's trajectory or destroy photons as they are being raytraced. The most important effects are the turbulence in the atmosphere, the misalignments and perturbations of the optics, and the charge diffusion in the CCD. The PSF images to the left shows simulations of a single star on-axis (top) and off-axis (bottom) with more physical effects being added to the simulation. The colors combine separate band simulations to demonstrate the wavelength-dependence of these effects.



New Perturbation Physics Framework

We are building a new model of perturbations by predicting the physical stresses (e.g. thermal, vibrational, pressure, and gravitational), fabrication and assembly errors, and the control system feedback on the various optical elements. A deviation from the ideal design will be predicted for each degree of freedom to build a more physical model of the perturbations and misalignments in a real telescope. We develop this model to test the science performance and study the predicted wavefront images.



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