Large Synoptic Survey Telescope

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Inventorying the Solar System with LSST

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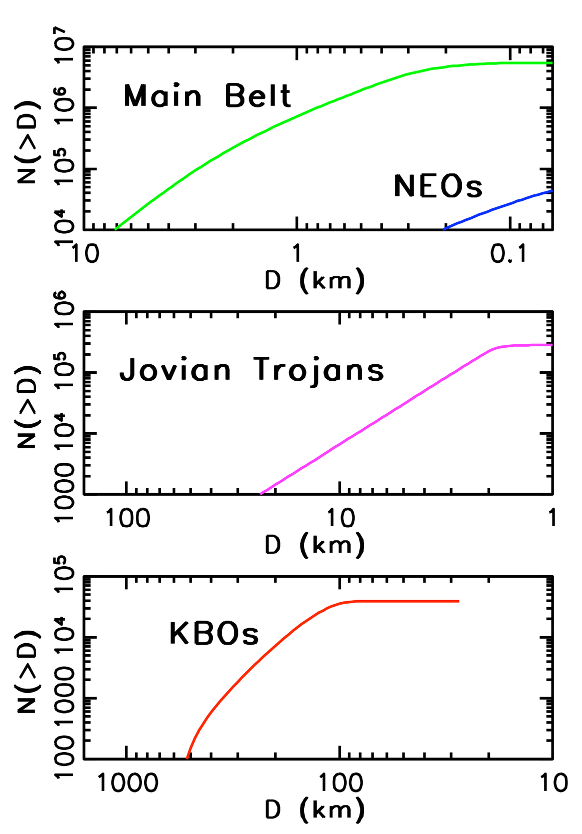
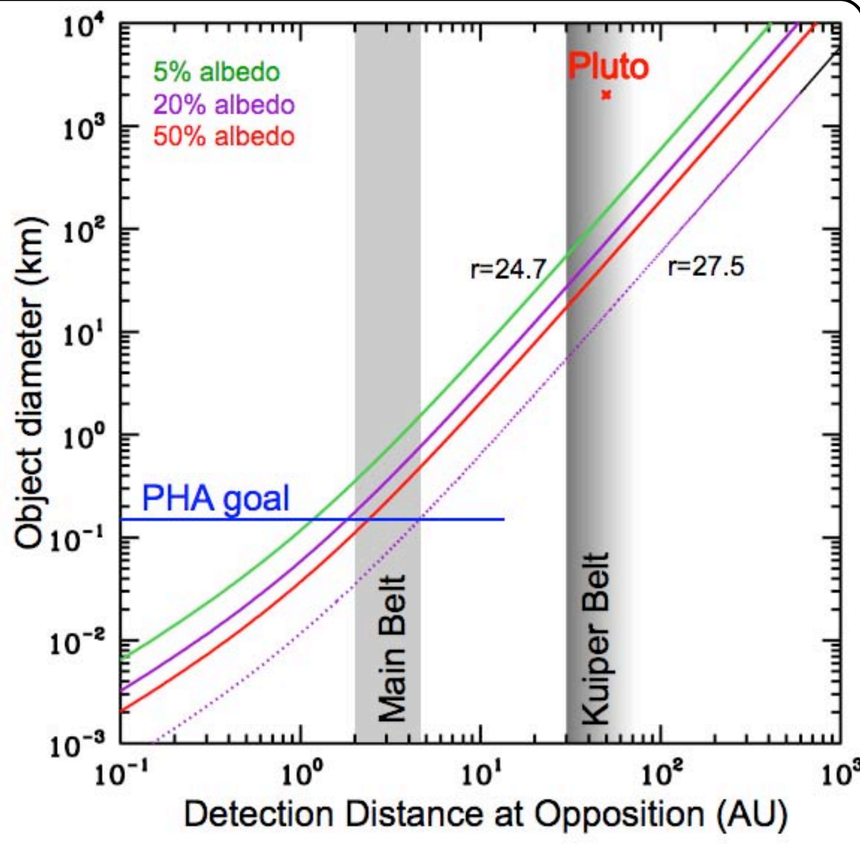
LSST's extremely wide sky coverage (>30,000 square degrees), coupled with a faint limiting magnitude (r~24.7 per image), and a rapid observational cadence -- each field is observed twice per night, ~4-5 times each month -- result in a survey telescope with powerful potential for detecting small moving objects. Near the ecliptic, LSST is expected to detect approximately 4000 moving objects per 9.6 square degree field of view; automated software will provide the means to link these individual detections into orbits. The result will be catalogs of hundreds of thousands of NEOs and Jupiter Trojans, millions of asteroids, tens of thousands of TNOs, and thousands of other objects such as comets and irregular satellites of the major planets.

These catalogs will be publicly available, both final orbits and the underlying multi-color observations, with highly accurate measurements in absolute astrometry (~50 mas) and photometry (~0.01 mag). With these large datasets, LSST will provide new insights into links between populations of moving objects, such as the relationship between Main Belt asteroids and NEOs. Models of solar system evolution, such as the Nice model, can be tested against an order of magnitude larger statistical sample, providing much stronger constraints than are currently possible. Detection of populations of objects beyond Neptune at a wide range of ecliptic latitudes, together with a well-characterized measurement of cometary populations will permit measurements of the nature of the inner and outer Oort cloud. Using high accuracy multicolor photometry, lightcurves and colors will be determined for a significant fraction of the objects detected. Through sparse lightcurve inversion, spin state and shape models will be derived for tens of thousands of main belt asteroids. Derivation of proper elements for Main Belt asteroids will greatly enlarge existing asteroid families, particularly at smaller sizes, and precise color information will facilitate further divisions.



LSST Detections (left)
Extrapolating from current models of solar system populations and including the results of the Operations Simulation, we expect LSST will detect approximately 100,000 NEOs, almost 6 million Main belt asteroids, around 300,000 Jupiter Trojans, and almost 50,000 TNOs.

Detection Limits (right)
Moving objects with diameters as small as 200m in the Main Belt and Pluto-sized objects out to 200 AU can be detected in individual images. Specialized 'deep drilling' observing sequences will detect KBOs only tens of kilometers in diameter

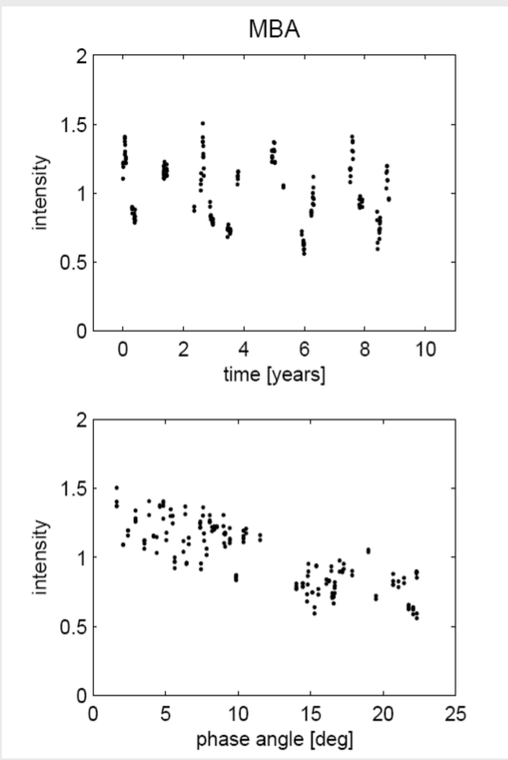


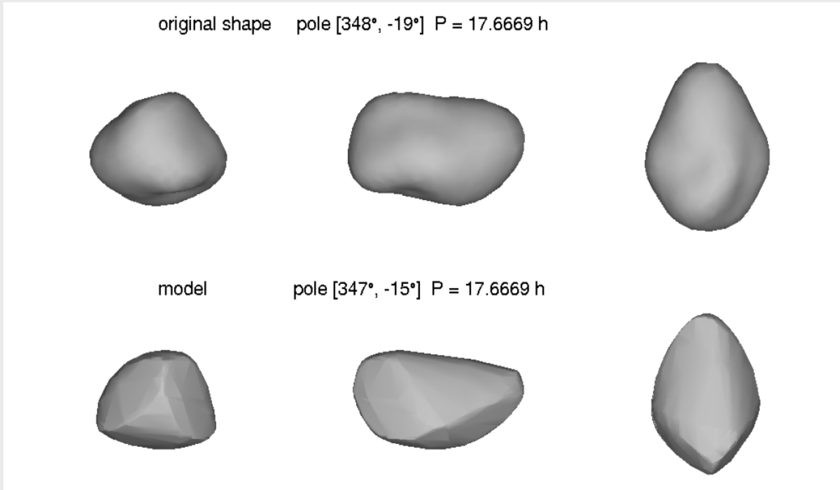
Sparse Light Curve Inversion

Through so-called "sparse light curve inversion" techniques, we expect to derive models of global shape, spin axis direction, and rotation period for about 10^4 to 10^5 main-belt and near-Earth asteroids from LSST photometry, which means that we will be able to map a substantial part of the asteroid population. Roughly speaking, once we have at least ~100 sparse brightness measurements of an asteroid over ~5 years, calibrated with a photometric accuracy of ~5% or better, a coarse model can be derived. The sparse data inversion gives correct results also for fast (0.2-2 h) and slow (>24 h) rotators. (Durech et al. 2007)

For TNOs, the viewing/illumination geometry changes very slowly and the full solution of the inverse problem is not possible. However, accurate sparse photometry can be used for period determination. Moreover LSST sparse photometry can be also used for detecting (but not modeling) 'non-standard' cases like binary and tumbling asteroids. A fully synchronous binary system behaves like a single body from the photometric point of view. Its binary nature can be revealed by the rectangular pole-on silhouette and/or large planar areas of the convex model. In some cases - when mutual events are deep enough - asynchronous binaries can be detected from sparse photometry. Interesting objects can be then targeted for follow-up observations.

Right: Simulated sparse photometric observations, reduced to unit distances to Earth and Sun, of a main belt asteroid. The time series at top shows that the object is detected at over a dozen apparitions during the ten-year simulation. The phase angle coverage with these data is depicted at bottom.



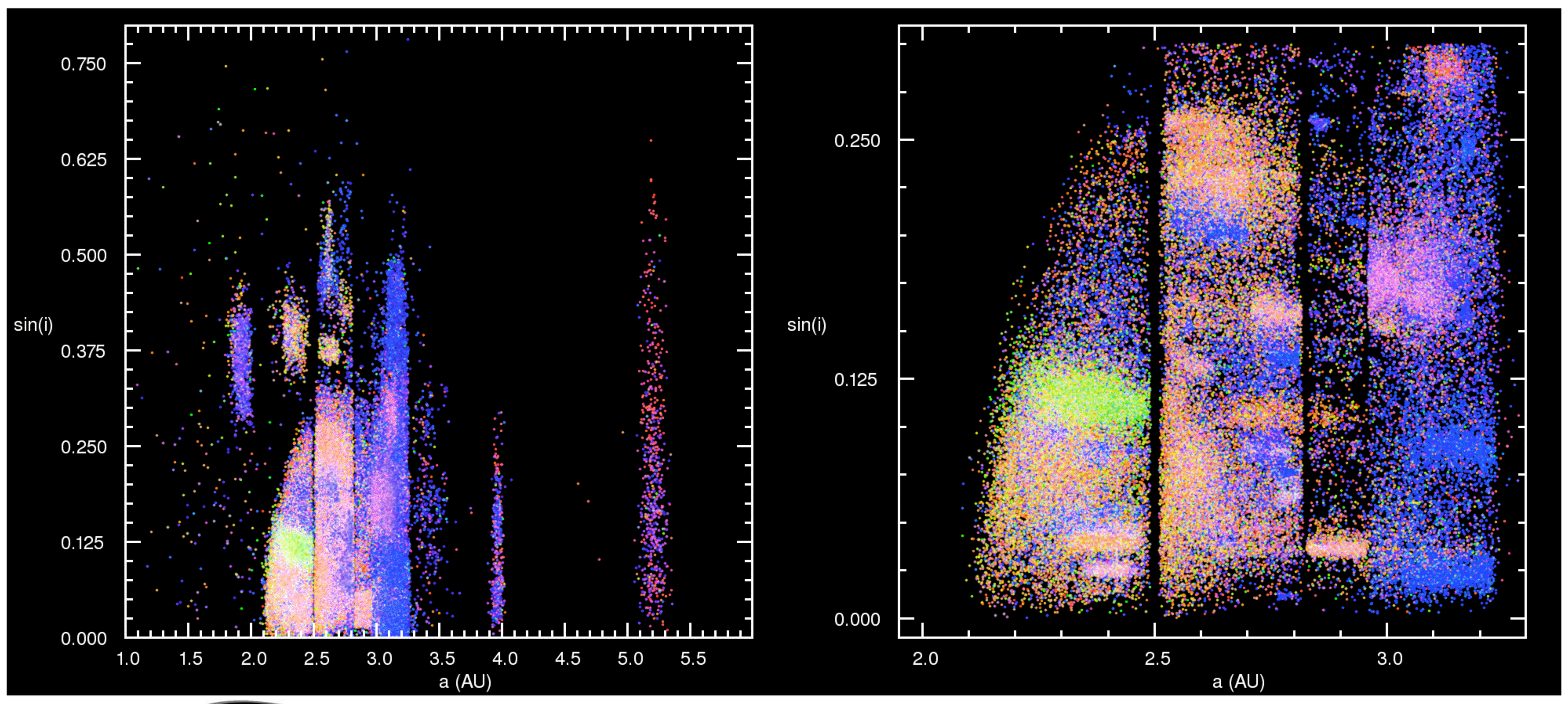


Above: Simulated and estimated shape obtained through sparse lightcurve inversion with a main belt asteroid.

Discovering Links Between Populations

As we learn more about the small bodies in our Solar System, it becomes clear that they are not as disparate as we had once thought. Main belt asteroids migrate into Near Earth Object orbits due to gravitational perturbations, replenishing the supply of NEOs. Inner Oort Cloud objects transfer slowly into Centaur orbits under the influence of the galactic tide and passing stars. These linkages are hard to study, as the sample sizes for many of these populations are small or non-overlapping in size ranges, but sometimes there are clear indications -- Main belt comets (asteroids showing cometary activity) and Damocloids (asteroids on cometary orbits) are two examples.

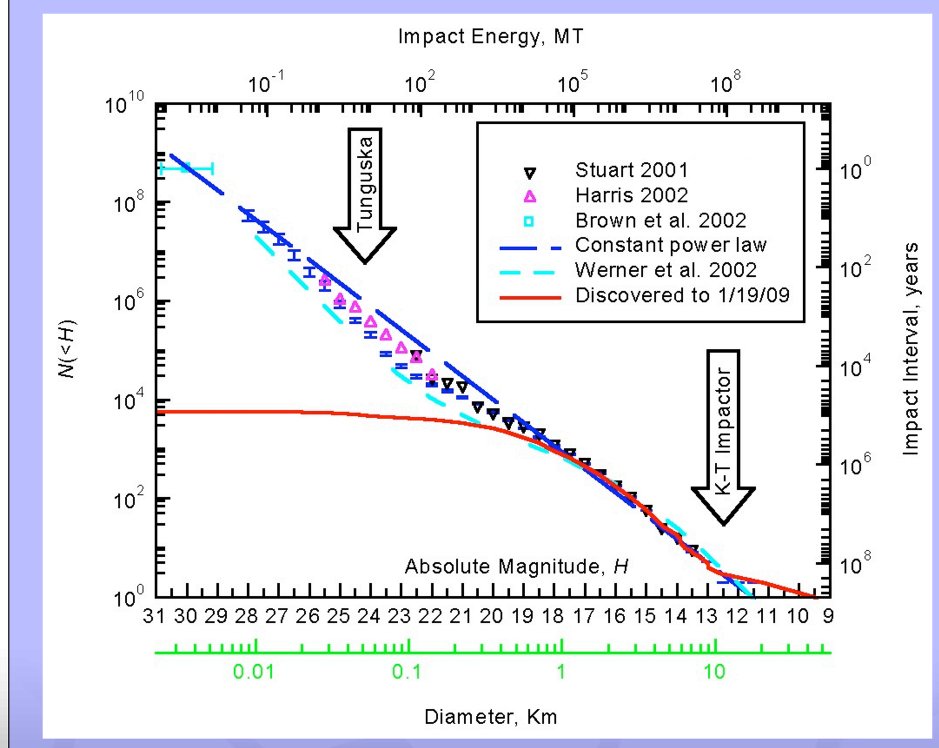
LSST will survey a wide range of ecliptic latitudes to faint limiting magnitudes, allowing discovery of high-inclination objects that may help constrain models of the transfer of comets from the inner and outer Oort Cloud. By detecting a large sample of Main belt asteroids below a kilometer in size, LSST will also enable us to study the Main belt precursors of the NEOs. The survey will also be able to generate a sample of several hundred Damocloids and Main belt comets. We will also have, for the first time, large samples of planetary Trojans. What other linkages will become apparent with these increased sample sizes, where each object comes complete with accurate orbits and well-measured colors?

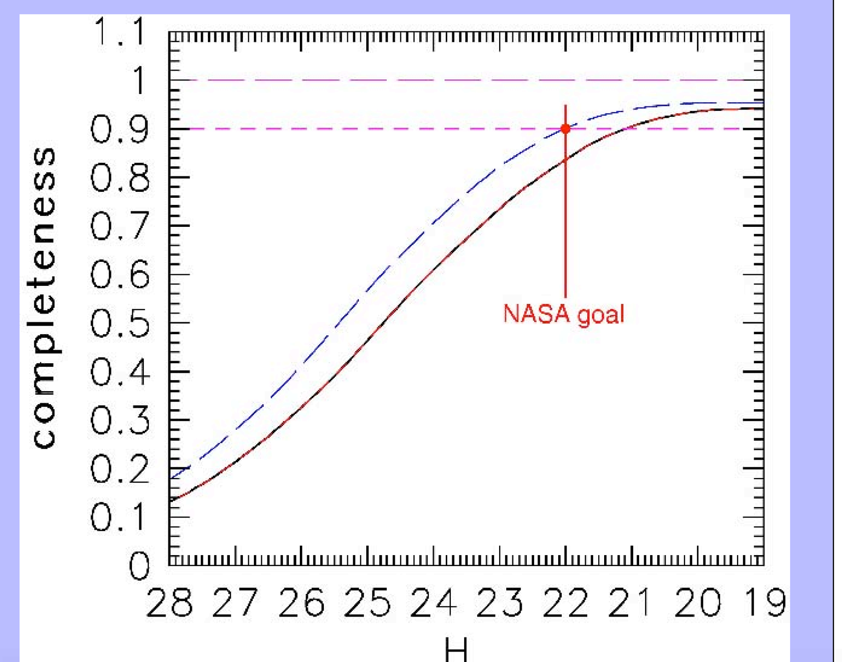


The Earth Impact Hazard

In December 2005 Congress directed NASA to implement a near-Earth object survey that would catalogue 90% of NEOs larger than 140m. Under the baseline survey, LSST would discover ~80% of the target population within ten years. Reaching the Congressional goal of 90% would require a modified and extended NEO-Optimized survey, dedicating 15% of survey time to higher airmass searches near sun and along the northern ecliptic. This survey option would measurably impact other LSST science drivers, and thus requires additional funding and extended survey operations, but would benefit other solar system science beyond NEOs.

NEO-optimized or not, LSST will assess the hazard to Earth from asteroid impacts by constraining the orbital and size distribution of the near-Earth population, allowing concrete estimates of the impact frequency as a function of size. Moreover, measurement of colors and spin states will allow for the physical characterization of discoveries as requested by Congress, including refined estimates of mass and size, which are critical for NEO deflection considerations.





Left: Number of potential impactors as a function of size/impact energy (Harris; modified from the 2007 NASA NEO report).
Right: LSST detection completeness as a function of size, after 10 years (solid line) and after 12 years of NEO-emphasized observing (upper dashed line).

Detecting Asteroid Families

Orbital parameters of Main Belt Asteroids, color-coded according to ugriz colors measured by SDSS. The figure to the left (above) shows osculating elements, the figure to the right (above) shows proper elements - note the asteroid families visible as clumps in parameter space. (Ivezic, Juric & Lupton, 2007). By providing colors as well as highly accurate orbits for millions of asteroids, LSST will enable the detection of many more asteroid families, including families over a wide range of ages. This will help constrain space weathering, the collision rate in the Main belt, and physical parameters of asteroids.

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