Large Synoptic Survey Telescope

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Inventorying the Solar System with LSST

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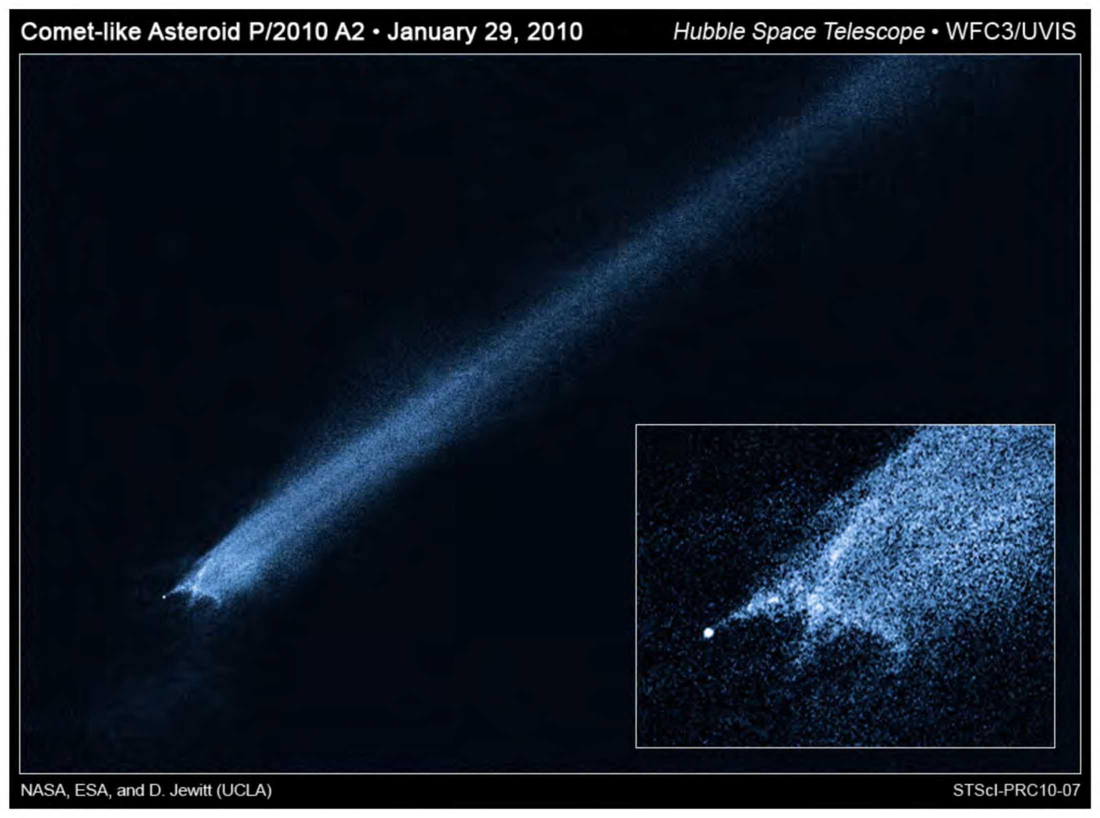
Near the ecliptic, LSST is expected to detect approximately 4000 moving objects per 9.6 square degree field of view. Each pointing (with mag limits r~24.5) will be revisited within 30-45 minutes, several times per month. Automated software will provide the means to link these individual detections into orbits. The result will be publicly available catalogs of hundreds of thousands of NEOs and Jupiter Trojans, millions of asteroids, tens of thousands of TNOs, as well as thousands of other objects such as comets and irregular satellites of the major planets. These catalogs will contain final orbits as well as the individual (multi-color) observations, calibrated to high precision in 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. With high accuracy multi-color photometry, lightcurves and colors will be determined for a significant fraction of the objects detected. Using 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 division. Additional discoveries, such as the potential for observing a real-time collision, could lead to new insights into physical properties, the size distribution at very small diameters, the orbital evolution of asteroids, or the discovery of possible spacecraft mission targets.

Exploring New Frontiers

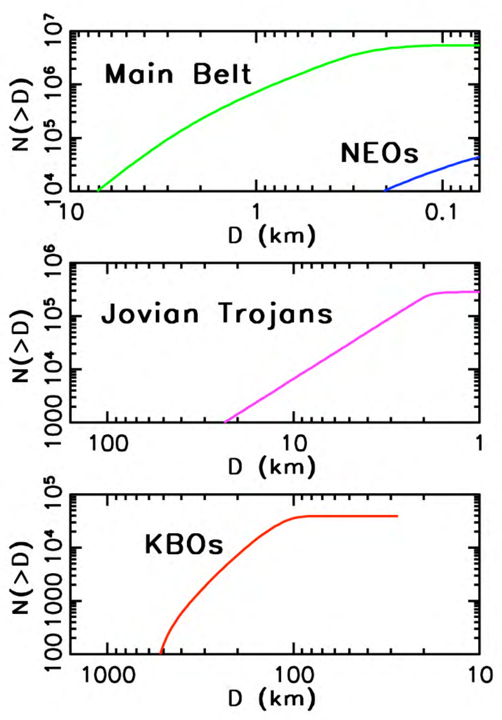
LSST will be very good at discovering rare types of objects or events, such as retrograde TNOs (like 2008 KV42 - Gladman et al, 2009, AJ) or other objects on extraordinary orbits (such as Sedna - Brown et al, 2004, AJ), comets outbursting for the first time, or collisions between ordinary asteroids. An example of an asteroid collision serendipitously discovered by LINEAR is shown to the right. P/2010 A2 was first thought to be perhaps a main belt comet undergoing an outburst; followup observations indicate that it is more likely to be the result of an collision (Snodgrass et al, 2010, Nature; Jewitt et al, 2010, Nature).

LSST will also significantly improve our samples of all currently known populations. It is already known that Main belt asteroids migrate into the NEO population and Oort Cloud objects transfer slowly into Centaur orbits due to gravitational perturbations, but the details of these links are difficult to study with the current limited populations. What other linkages will become apparent with these increased sample sizes, where each object comes complete with accurate orbits and well-measured colors?



Estimated Sample Sizes

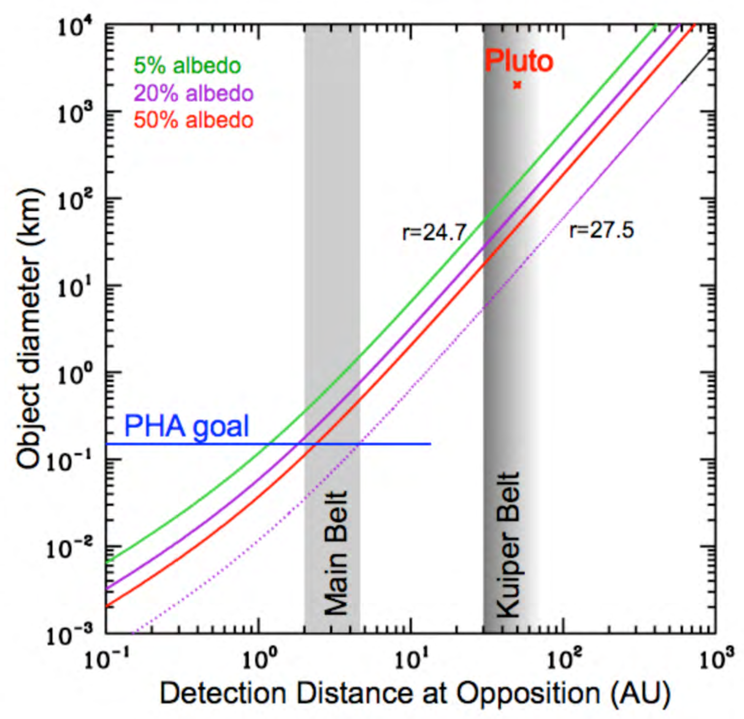
Extrapolating from current models of solar system populations and including the results of the Operations Simulation, we expect LSST will detect approximately 100,000 NEOs, almost 6 million Main belt asteroids, around 300,000 Jupiter Trojans, and almost 50,000 TNOs.



Detection Limits

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 TNOs only tens of kilometers in diameter

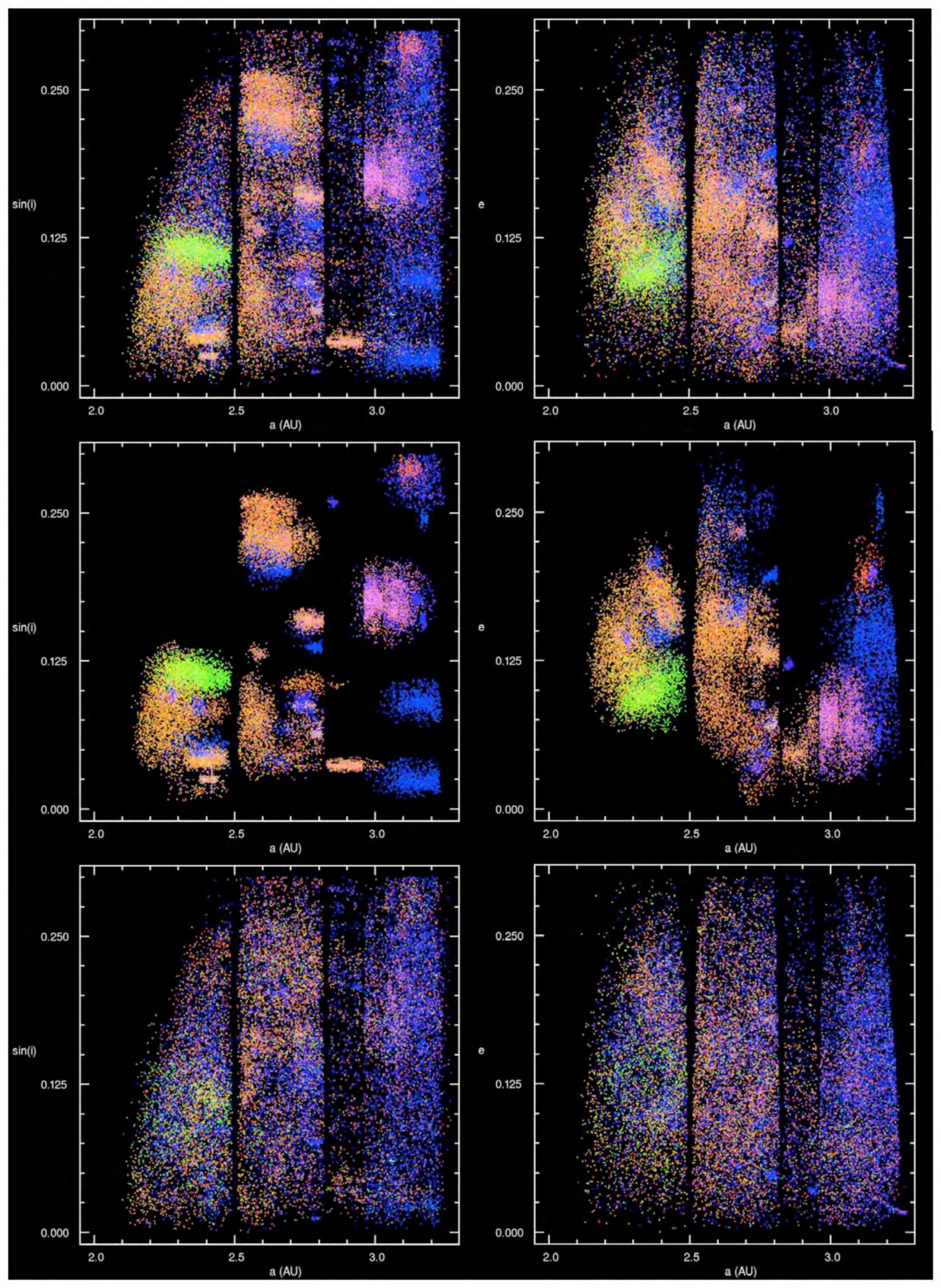
Filter	Visits	Mag Limit
u	70	23.9
g	100	25.0
r	230	24.7
i	230	24.0
z	200	23.3
y	200	22.1

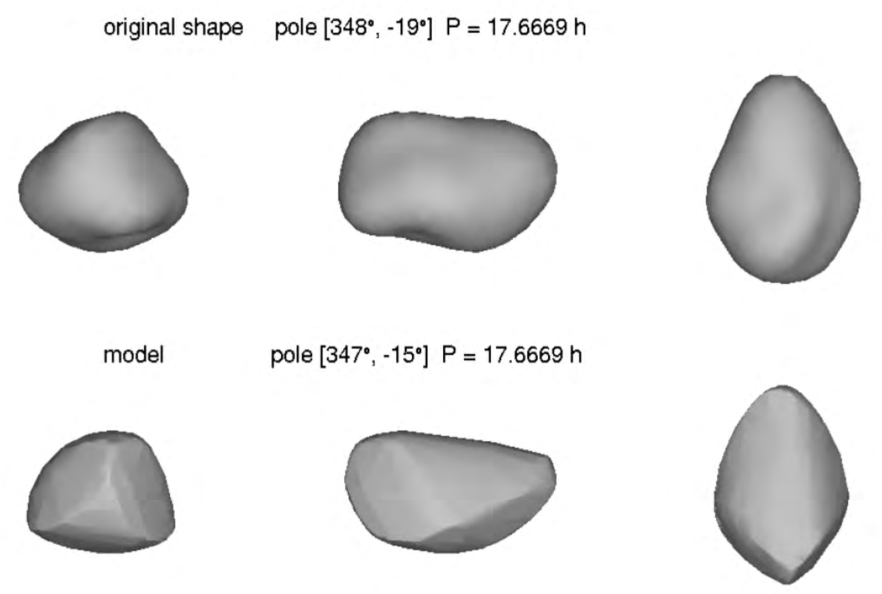


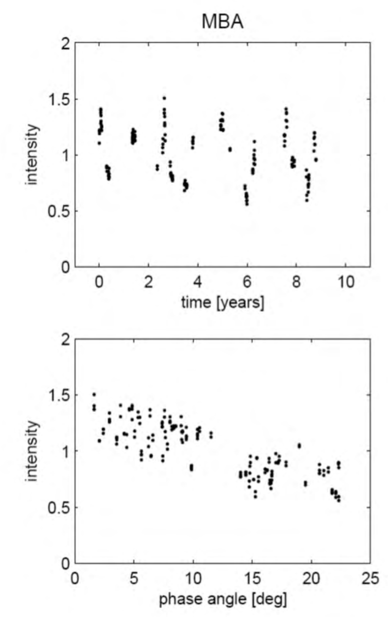
Detecting Collisional Families

The figure to the right shows the proper orbital parameters of Main Belt Asteroids, color-coded according to ugriz colors measured by SDSS (Parker, etal. 2008, Icarus). Note how the asteroid families become visible as clumps in proper elements and colors, even when viewing the entire population (as in the top panels). Families can be separated from the background population (as in the middle and bottom panels, respectively). Without separating collisional families from the general background population, it is difficult to apply the measured size distributions as constraints on accretion or collision models. The properties of the families also provide unique insight into collision physics, the historical collision rate, injection rates into the NEO and comet populations, interior structure of the asteroids, the interpretation of small body colors, space weathering, and many other outstanding questions in the study of the solar system.

By providing precise colors as well as highly accurate orbits for 10-100 times the currently known population of small solar system bodies, LSST will enable a more detailed characterization of known families and detection of many more families in populations throughout the solar system.







Left: 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.

Far Left: Simulated and estimated shape obtained through sparse lightcurve inversion of a main belt asteroid.

Sparse Lightcurve Inversion

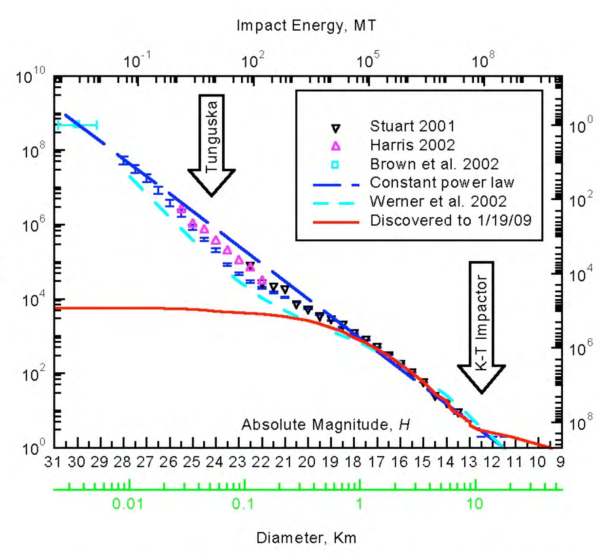
Using "sparse light curve inversion" techniques, we expect to derive models of global shape, spin axis direction, and rotation period for about 10^4 to 10^5 main-belt and near-Earth asteroids from LSST photometry, which means that we will be able to map a substantial part of the asteroid population. 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, A&A)

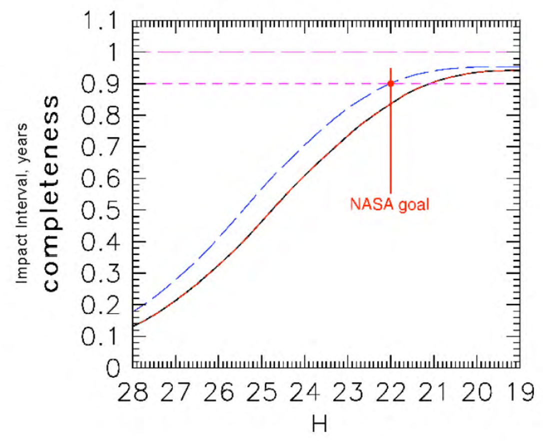
For TNOs, the viewing/illumination geometry changes very slowly and the full solution of the inverse problem is not possible. However, accurate sparse photometry can be used for period determination. Moreover LSST sparse photometry can be also used for detecting (but not modeling) 'non-standard' cases 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.

Near Earth Objects

In 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.

NEO-optimized or not, LSST will help 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. LSST will also identify potential targets for spacecraft missions, searching for objects with small relative velocities to Earth.





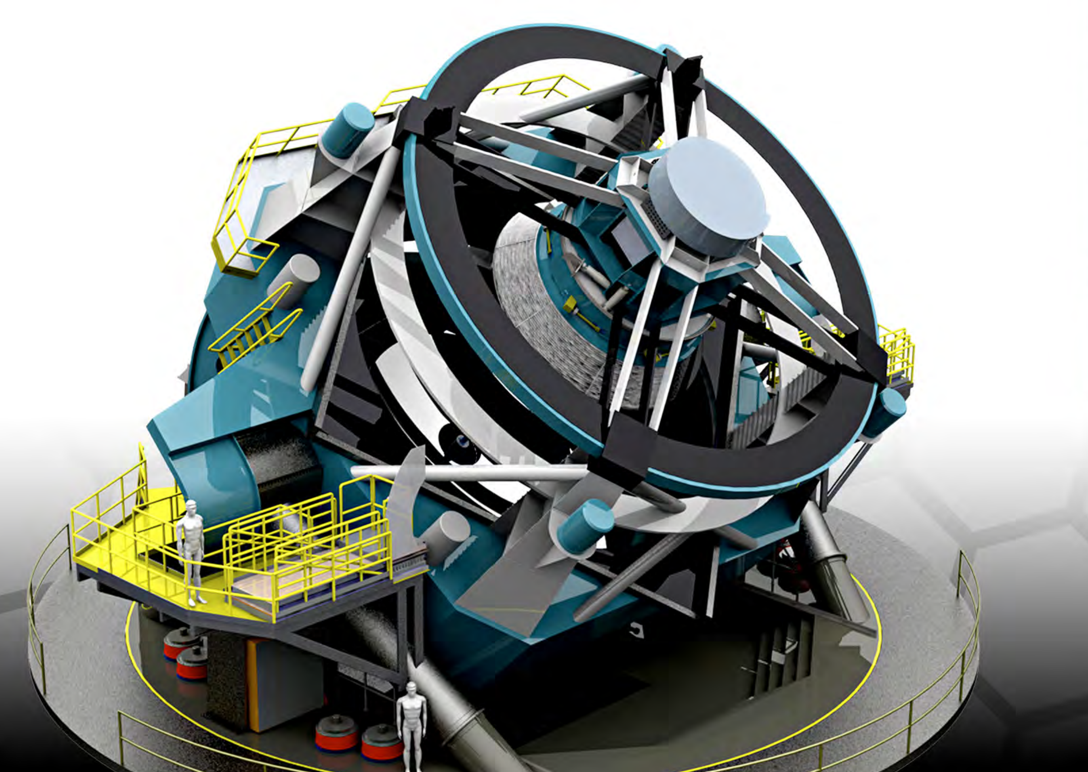
Left: Number of potential impactors as a function of size/impact energy (Harris; modified from the 2007 NASA NEO report). Right: LSST detection completeness as a function of size, after 10 years (solid line) and after 12 years of NEO-emphasized observing (upper dashed line).

Artist's depiction of the DAWN spacecraft orbiting Ceres (Credit: McREL)

If you have a QR-tag app on your phone, scan this tag for a link to a PDF of this poster.

The Solar System Science Collaboration

Although there are many years until first light for LSST, the collaboration is already considering how to optimize science return on such a large amount of data. These include: followup observations (including occultation campaigns), scalable software for determining proper orbital elements for millions of asteroids, new clustering algorithms to identify collisional families, algorithms to interpret multiple photometric measurements to search for variable lightcurves, and ways to federate visible photometry from LSST with measurements from other telescopes, perhaps at other wavelengths. The collaboration is also working with LSST to determine a cadence and field pointing strategies for the 'deep drilling' fields and to evaluate simulations of moving object detection.



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