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LSST Opportunities for Small Bodies Science

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Abstract

The Large Synoptic Survey Telescope (LSST) is an 8m-class observatory currently under construction on Cerro Pachón, Chile. Over a ten-year period starting in 2022, LSST will generate the largest catalog of Solar System objects to date. This will be enabled by LSST's 9.6 square degree field of view, a 3.2 Gigapixel camera and a rapid observational cadence enabling it to cover the entire visible sky every 3-4 days to typical single-exposure depths of r=24.5mag. The resulting dataset will enable a range of studies, spanning from understanding the history of the Solar System, discoveries of interstellar objects, and searches for distant planets in the Solar System.

1. System and Data Overview

The Large Synoptic Survey Telescope (LSST; http://lsst.org) is an 8-meter, wide-field, ground-based survey program that will survey half the sky every few nights in six optical bands from 320 to 1050 nm. The LSST telescope is currently being constructed at Cerro Pachón, Chile, with first light expected in 2020 and start of survey operations in 2022.

The LSST is slated to make a significant contribution to the study of the Solar System, delivering over a billion highly precise observations of millions of Solar System objects (5mmag photometry and 10mas astrometry, per observation, at the bright end). Current estimates show yields ranging from ~100,000 new discoveries of nearby NEOs [3], to 5.5 million for the main belt, and ~40,000 for KBO populations [2]. The majority of these objects will receive hundreds of observations in multiple bandpasses.

To enable Solar System science, the LSST will employ a suite of specialized software tools and generate a number of Solar System-specific data products. These are designed to enable both detection (rapid identification, alerting, and orbit determination) and characterization (delivering information such as color and variability). Solar System processing will occur on three distinct cadences. In near real-time, trailed moving objects will be identified and alerts sent to the community within minutes of observation (Table 1). These will be a part of the LSST's alert stream, with flags set to denote they are trailed [4]. At the end of each night of observing, a HelioLinC [1] type algorithm will be utilized to identify, link, determine orbits, perform precovery, and submit new asteroid detections to the Minor Planet Center. This will result in an updated orbit catalog, published daily. In addition to orbital solutions, this catalog will include element covariances, absolute magnitude and slope parameter estimates, quality metrics, light curves, and other useful information ([5], Table 2). Finally, all LSST data will be reprocessed on an annual cadence, to derive better astrometric and photometric solutions. A separate "LSST only" orbit catalog will also be delivered to support population debiasing and studies (Table 3).

All discovery data submitted to the MPC (photometry, astrometry and derived orbits) will be world-public. Physical parameter datasets will be immediately available to the U.S. and Chilean astronomical communities, and LSST's international contributors, and released broadly after a 2-year proprietary period.

Table 1. Real-time Alerts, within 60 seconds of obsv. (>=2M SSO observations/night)

Astrometry	±10 mas (bright; ±140 faint)
PSF flux	±10 mmag (bright end)
Aperture flux	±10 mmag (bright end)
Trailed source fit	Flux and on-sky motion for fast-moving (trailed) objects
Appearance characterization	Moments and extendedness of the object's image

Spuriousness score	Probability that the detection is an artifact
Nearby static objects	Information on adjacent objects (up to three)

Table 2. Daily Solar System Products (>= 5.5M objects)	
Orbits	Adopted from MPCORB
Light-curve characterization	Period, light curve shape, other features
Absolute magnitude estimates	Estimates of (H, G_{12}) in u,g,r,i,z,y bands
MOID	Minimum Orbit Intersection Distance to Earth
Extendedness indicators	Is/was the object comet-like in its appearance.

Table 3. Annual Solar System Data Release Products	
High-fidelity reprocessing	Catalogs derived from re-reductions of all survey data using improved calibrations and a well-characterized, software release.
The LSST Catalog of Solar System Objects	A catalog, suitable for population studies, of objects detected by LSST with orbits estimated using only LSST data.

2. Science Expectations

LSST's dataset will enable a very broad range of Solar System investigations [6], including:

- **NEOs:** Compilation of an NEO catalog with high completeness and orbit quality. Measurement of the orbital, absolute magnitude, and taxonomy distributions within the NEO population, enabling the identification of correlations between taxonomy and orbital properties for all NEOs and the determination of the orbital distribution of fifty-meter+ scale objects.
- **Inner Solar System:** Determination of colors and taxonomy for a large sample of asteroids, including Jupiter's irregular satellites, Mars and Jupiter Trojans, Hildas, Cybeles, and Phobos and Deimos to identify correlations with dynamical and taxonomic information with implications for understanding the formation of the inner solar system (e.g., chemical distribution in the primordial disk; collisional family parent bodies and formation events).
- **Outer Solar System:** Discovery and orbital classification of objects on unusual or extreme orbits, especially inner Oort cloud objects (i.e. Sedna-like objects) with high perihelia ($q > 40$AU) and objects with very high inclination ($i > 40$ deg), to place constraints on proposed origin scenarios (e.g., the putative Planet 9).
- **Oort cloud and beyond:** Tens of interstellar objects, and over 10,000 comets.

We invite the reader to consult the LSST Solar System Science Collaboration (SSSC) Roadmap [6] for more details, and consider joining the LSST SSSC.

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