Large Synoptic Survey Telescope

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Comet Science with LSST

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The LSST will detect an unprecedented number (~10,000) of comets over a ten year time frame. We simulate characteristic comet orbits through the LSST observational cadence and demonstrate that the LSST will observe individual Jupiter Family Comets (JFC) hundreds of times over their entire orbit, tracing each comet's evolution from presumed dormancy at large heliocentric distances, through the onset of out-gassing, and then back to inactivity. Simulations of Long Period Comets predict that LSST will make dozens of observations of each such comet, either on their way into or out of the Solar System, allowing in many cases early detection of these objects, or a number of observations while passing through perihelion, where the comets are the most active and variable.

Comets in the LSST

Based on the comets found in the SDSS, the LSST is projected to observe on the order of 10,000 comets. This vast quantity of data will radically shift the photometric study of comets into areas of study, such as robust population statistics, family determination, light curve measurements, that are currently only possible with the populations of asteroids. Even without taking the coma into effect, the vast majority of Jupiter Family Comets known today will be visible over much of their orbits by LSST, and Long Period Comets stand to be detected much earlier and often by the LSST observing cadence then they do today.

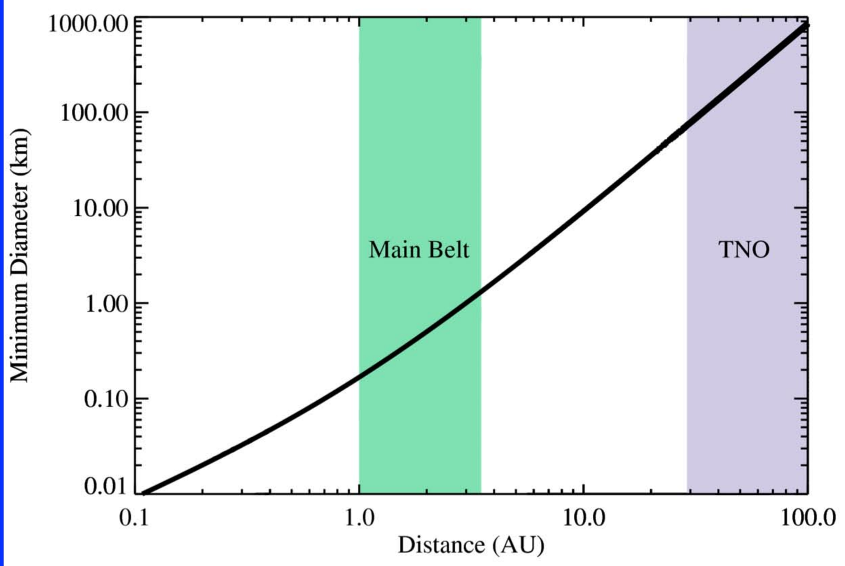


Fig. 1 (Left): The minimum diameter observational limit of LSST (at magnitude 24.5) for solar system bodies with 0.04 albedo observed at opposition. For albedos different than 0.04 the Minimum Diameter scales as (albedo)$^{-1/2}$. The range of the Main Belt Asteroids and the Trans-Neptunian Objects are indicated

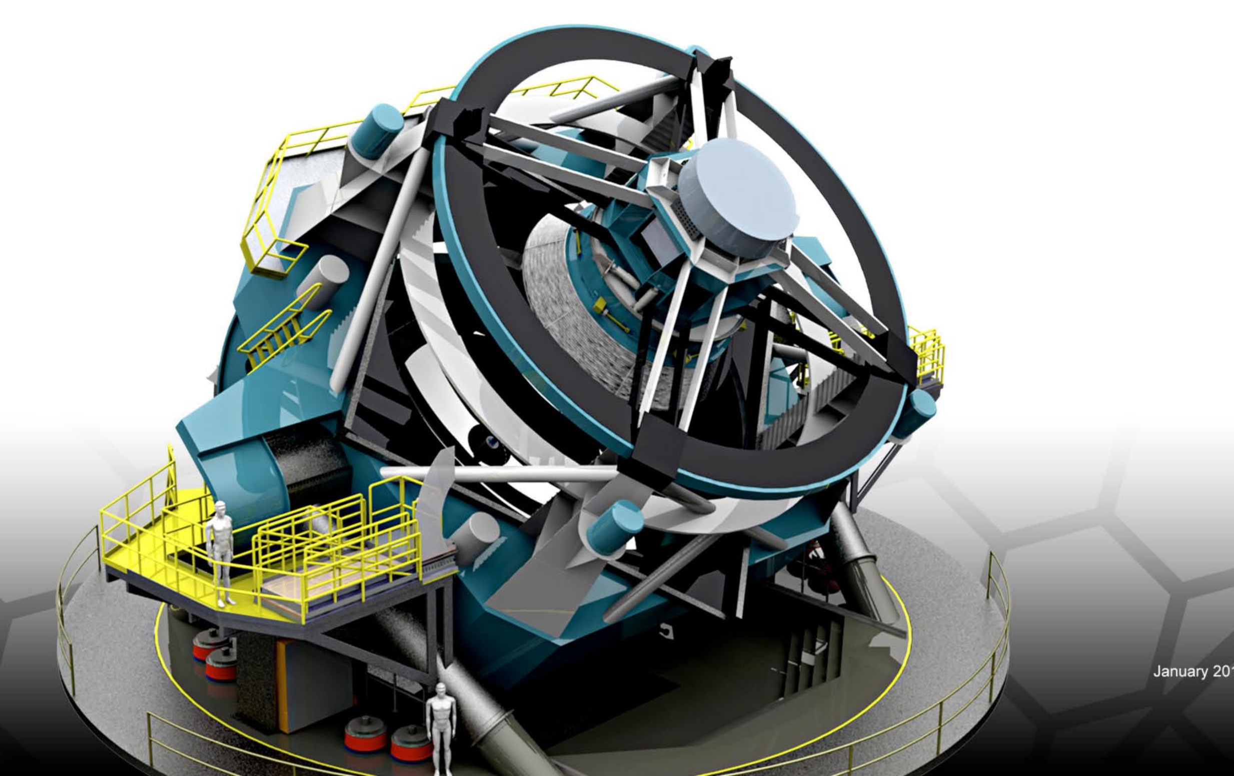
Simulations

We simulate LSST observations of comets by generating 20 years of ephemerides for each comet. These ephemeris positions are then cross-referenced against the the LSST main deep-wide-fast survey cadence. Matches in both position and time are checked to determine the LSST observations of a comet. The simulations are then shifted by 10 days to vary the date of perihelion passage with respect to the survey, and rechecked against the LSST cadence.

Comet Science in the LSST era

LSST will produce an unprecedented number of photometric observations of comets, allowing detailed studies of not only individual comets, but also their population statistics in a way that is currently not possible. This vast amount of data will allow the populations of comets in the solar system in a way that we can now study the asteroids including:

- Robustly measured size distributions, including for the first time LPC populations.
- Identification of comet families based on dynamics and color.
- Rotation rates
- Measurements of the phase function
- Dust and gas production measurements over entire orbits for thousands of comets.
- Secular light curves for thousands of comets.
- Observing the onset and ending of coma emissions.
- Identification of comets undergoing sudden outbursts.
- Early detection of LPCs.



Jupiter Family Comets

Jupiter Family Comets (JFC) generally have low-inclination, prograde orbits, thought to originate in the reservoir of the Kuiper Belt. These comets will be well observed by the LSST as the survey will be able to detect a 1 km diameter body with a cometary albedo (0.04) 3 AU away from the Earth, and a 2 km diameter body would be observable out to about 5 AU (assuming a limiting magnitude of 24.5), meaning that the vast majority of JFCs known today should be observable by LSST over most, if not all, of their orbits as JFCs are generally 1-10 km-scale bodies, with aphelia generally within 6 AU.

Hundreds of observations of each Jupiter Family Comet, over the entirety of their orbits, will allow the secular light curves of these objects to be measured in a well calibrated manner. These observations will trace the time evolution of the JFCs, from presumed inactivity at aphelion, through the initiation of outgassing as they approach the sun, and then transition back to inactivity. LSST frequent cadence of observations allows for unpredictable events, such as outbursts to be observed.

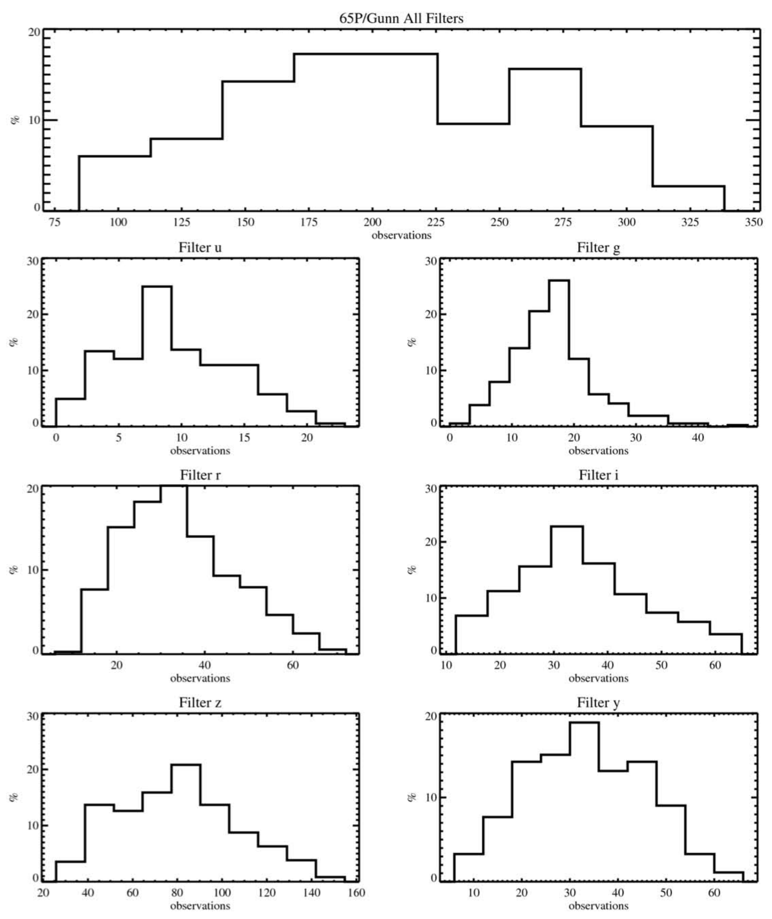
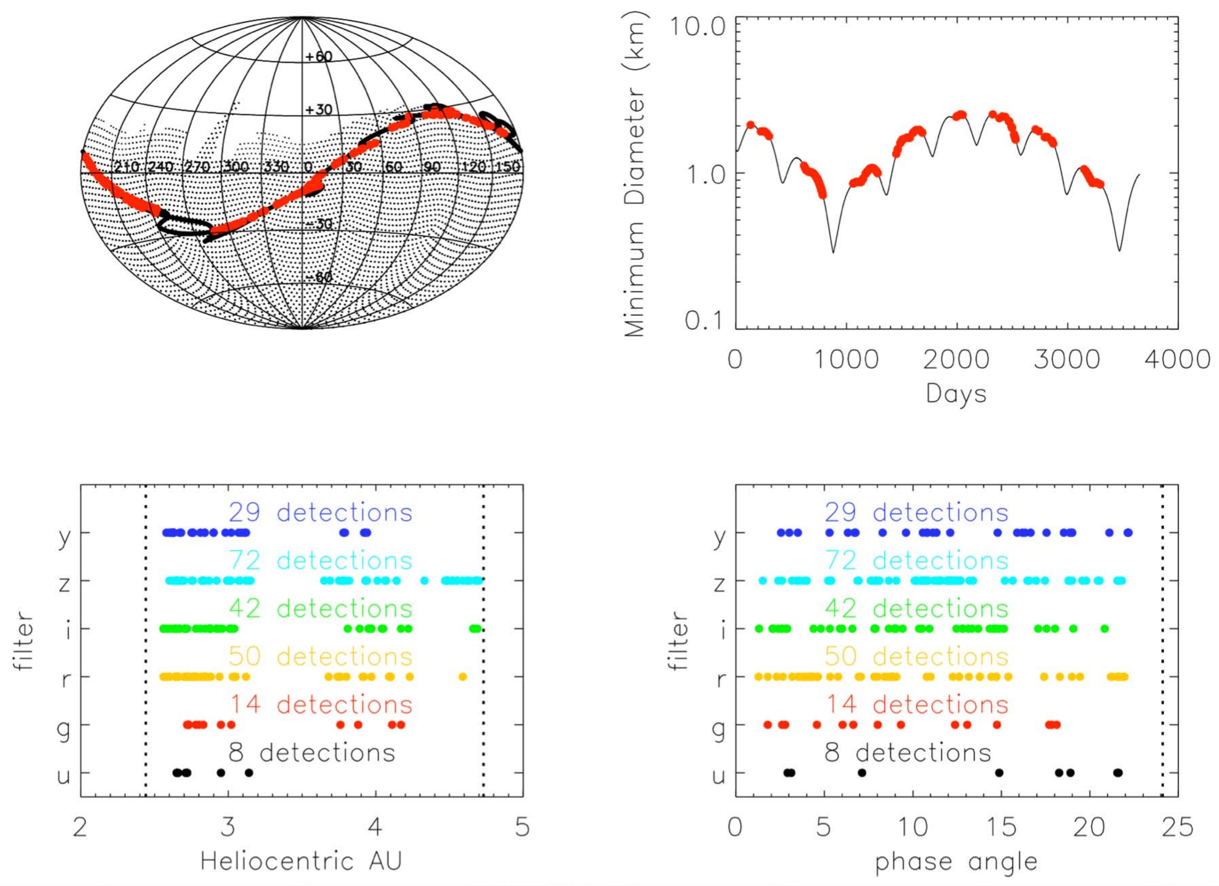


Fig. 2 (left): Histograms of the number of observations LSST will make of a comet on a JFC orbit like that of comet 65P/Gunn (a = 3.59AU, e = 0.32, i = 10.39°) as a percentage of the 365 simulations of that orbit (each shifting the date of perihelion by 10 days). The top panel shows the histogram for the total number of LSST observations of this comet in any filter, and the six smaller panels show the breakdown in each of the six LSST filters (*u,g,r,i,z,y*). A comet with a ~2km radius would be within LSST limits throughout the orbit.

Fig. 3 (below): JFC 65P/Gunn results from the simulation. **Upper Left:** A projection of the RA and Dec positions of the comet (black line) and LSST pointings (black dots) over 10 years. Positions where the comet is observed are in red. **Upper Right:** A plot the maximum diameter (albedo 0.04) body that could be observed at LSST limiting magnitude over the course the simulation, with possible observations in red. **Lower Left:** The number of observations and range in heliocentric distances of the observations in each filter (ugrizy). **Lower Right:** The number of observations and range in phase angle of the observations in each filter (ugrizy). The vertical dotted lines in the lower two panels show the range of values the comet can can have.



Long Period Comets

Long Period Comets (LPC) fall into the inner solar system from all directions, because their inclination are constrained to the Ecliptic. These comets will also be well sampled by LSST. Those reaching perihelion in the **Northern** Hemisphere sky will be observed on their way into and out of the Solar System, allowing LSST to detect them long before they would be serendipitously discovered, with hundreds of observations being possible for large comets. For those reaching perihelion in the **Southern** hemisphere sky, LSST will be in position to make dozens of observations of the comet during the most active and variable portion of its orbit.

To characterize the potential LSST observations of LPCs we simulate two distinct orbital orientations: one in which the comet approaches the inner solar system from below the Ecliptic, reaches perihelion above in the north, and the exits below again. The second case is the orbital reverse, where the comet comes in and leaves from north of the Ecliptic, reaching perihelion to the south of it.

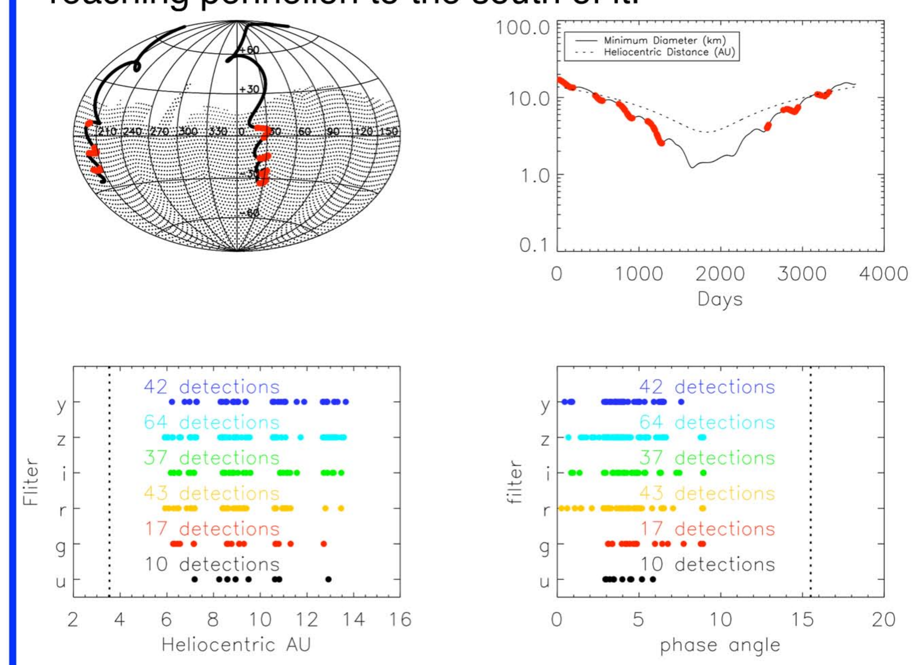


Fig. 4 (left): Results from a single simulation run of a **northern** perihelion LPC, with the comet's perihelion occurring at the survey's midpoint. The four panels are as described in Fig. 3, with the exception that the panel in the upper right contains both a plot of the minimum diameter in km of an observable comet nucleus (solid line) and the comet's heliocentric distance in AU (dotted line).

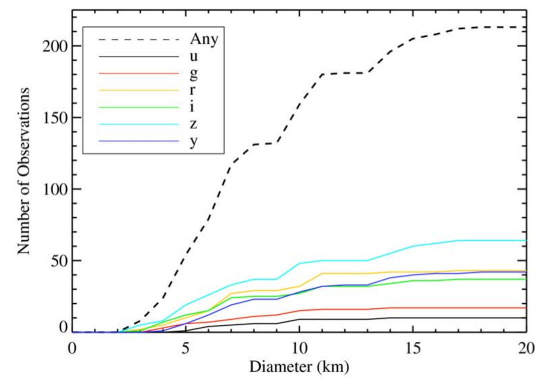


Fig. 5 (left): The number of observations of a **northern** perihelion LPC at various diameters, both total and filter-by-filter, from a single simulation with the comet perihelion occurring at the survey midpoint. The large range of heliocentric distance makes the size of the comet a critical factor for determining the number of observations in this case.

Fig. 6 (right): Results from a single simulation run of a **southern** perihelion LPC, with the comet's perihelion occurring at the survey's midpoint. The four panels are as described in Fig. 4, and as can been seen, due to the comet's orbital orientation it will be observed during perihelion passage only.

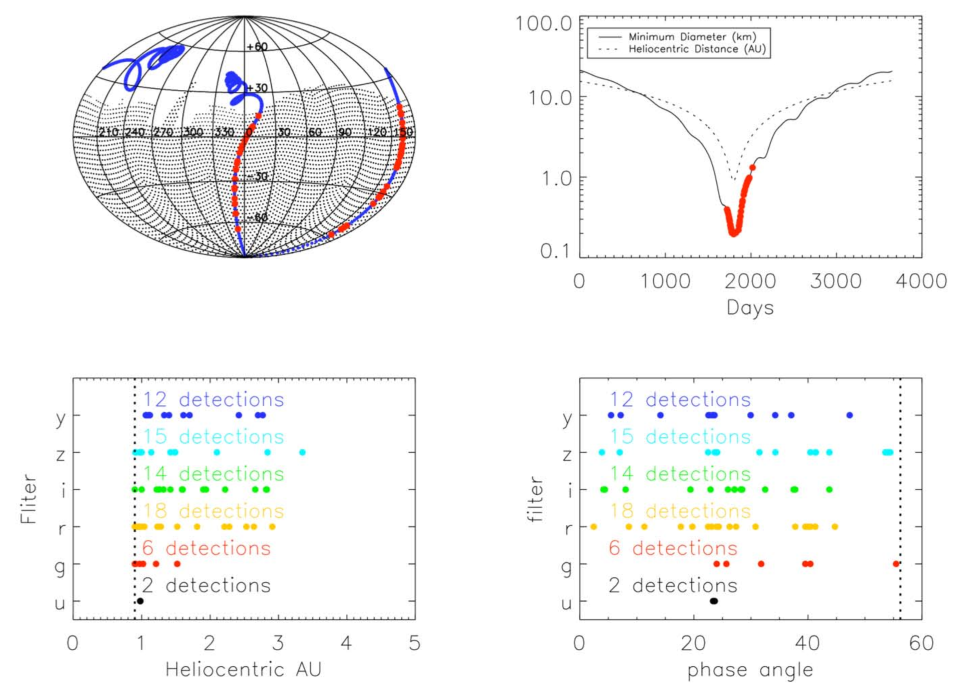
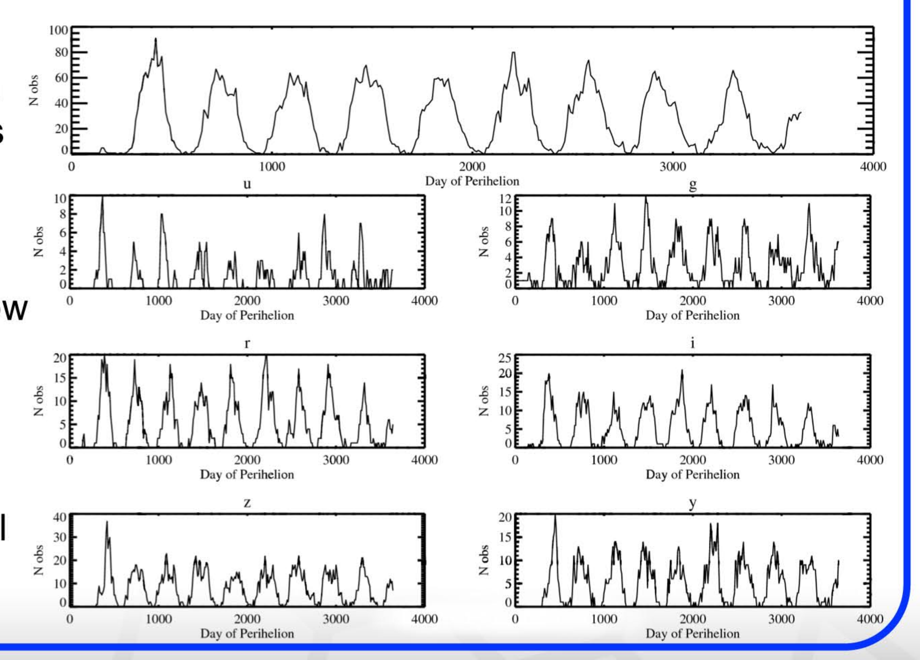


Fig. 7 (right): Results of simulating an LPC with perihelion in the **south** through LSST. The top panel shows the total number of LSST observations if the comet reaches perihelion on a given day of the survey. The remaining 6 panels show the number of observations of the comet in each of LSST's 6 filters. LSST observed the comet in over 95% of the simulations. Despite the strong dependence on the seasonal perihelion date the comet is observed in 96% of the simulations



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