Supernova Science from a "Standard" LSST Cadence

Large Synoptic Survey Telescope

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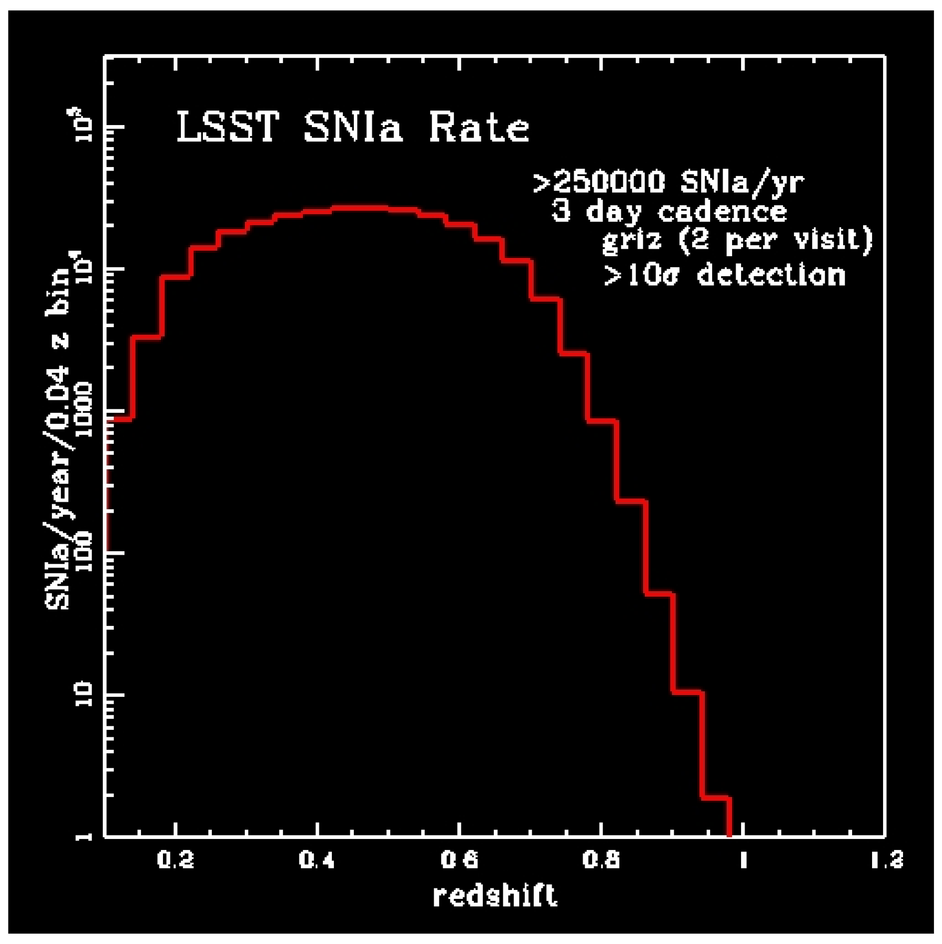
ABSTRACT: The Large Synoptic Survey Telescope (LSST) will likely have several cadences, but one of the most general will be a cadence which covers a large portion of the available sky repeatedly in a limited number of filters in a short period of time, for example every 3 to 5 nights. Such a cadence is useful not only for identifying and tracking moving sources such as Near Earth Objects (NEOs), but also for identifying and following moderately long-term (month timescale) transient events such as supernovae. Given a sample general cadence, we investigate the number of type Ia likely to be discovered per year with LSST. We also investigate the resulting light curve and multi-filter sampling and how these data might best be used for studying SN rates, dark energy models and other science programs based on obtaining a large sample of supernovae.

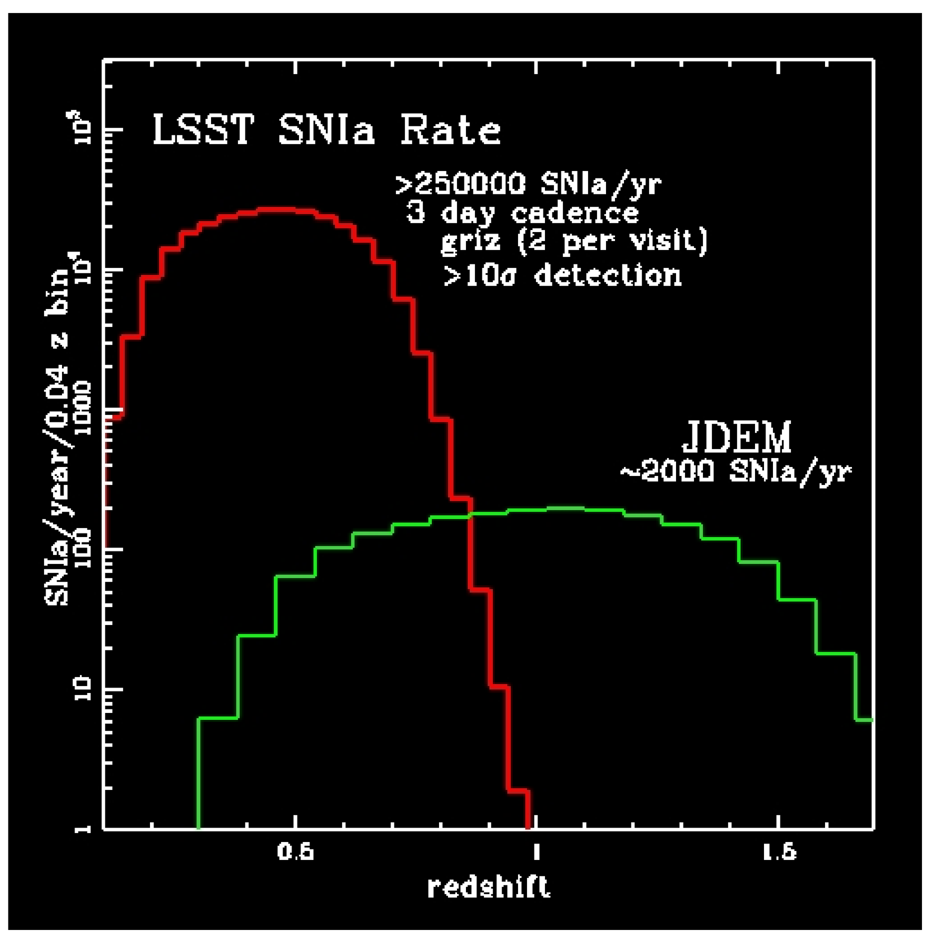
Cadence: The sky coverage per night and how often the same piece of sky is observed by LSST are determined by the science goals. It is expected that several experiments with a widely varying cadences will be conducted over the life-time of the LSST. Initially, there are three science projects that drive the LSST observing cadence:

- Search for Near Earth Asteroids (NEA) – single filter, two images separated by >30 min
- Weak Lensing Survey – no time domain restrictions, but limits on seeing and sky brightness
- Supernova Search – multiple filters, repeat field every 3 to 6 nights, span of at least 30 days

An optimum observing strategy is being developed that will achieve the science goals in a minimum time. The optimum cadence will be similar to (see the Cook et al. poster):

- Fields visited every three days for a span of 60 days, two filters per visit
- 2x10 second exposures per pointing, 2 sec readout
- r filter at least every 6 days, g,i filters during dark time, z,y filters during bright time

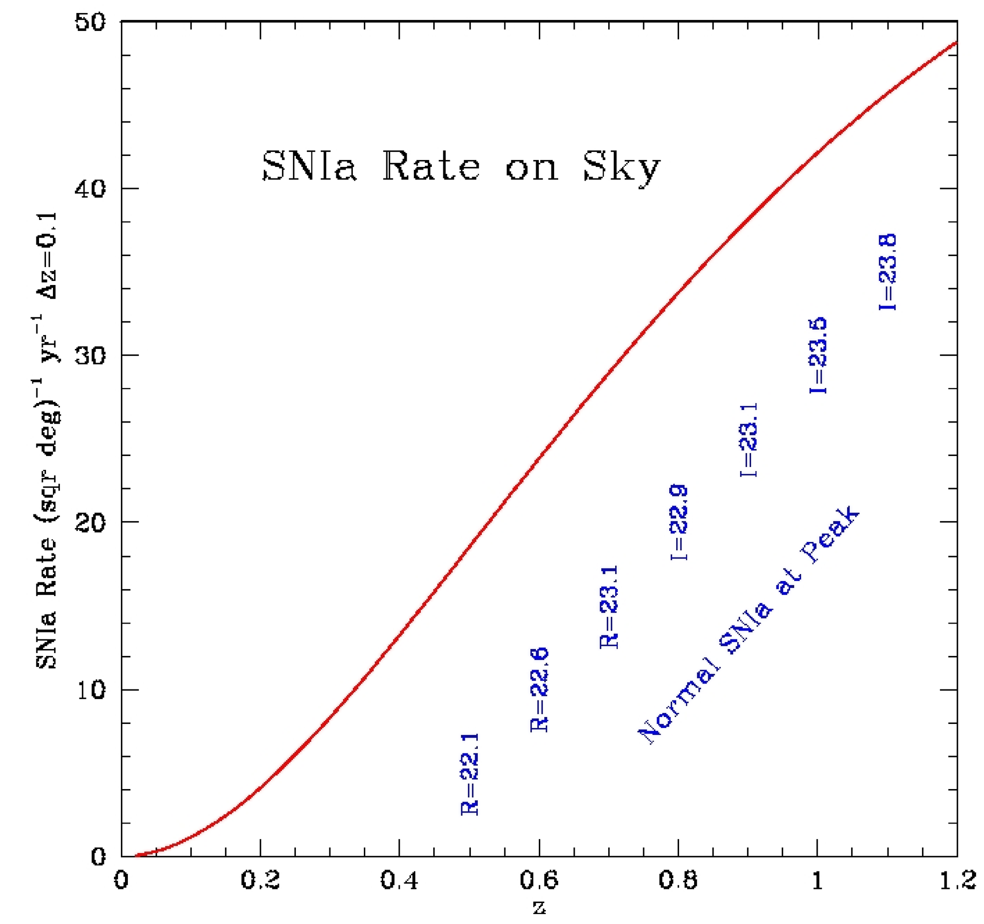




SN Ia Rate and Redshift Distribution - a SN search simulator (Tonry, private communication) shows that the LSST with a standard cadence will discover a total of ~280,000 SN Ia per year. The redshift distribution will be relatively flat between 0.3<z<0.7. These Type Ia SNe span the epoch over which the universe makes the transition from deceleration to acceleration. This sample will nicely complement a higher redshift samples, such as those that would be discovered by a future JDEM search.

Type Ia Supernovae Are Plentiful: There are 200 SN Ia per square degree per year out to z=1

The type Ia supernova rate on the sky as a function of redshift based on the results of the High-z Supernova Search (Tonry et al. 2002)



Supernova Properties: The large number of supernovae discovered by the LSST will make spectroscopic follow-up for the majority of events difficult. Light curves and color properties must be well-determined so that the following parameters can be obtained from photometry alone (see Barris & Tonry 2004, ApJ, 613, L21; also Prieto et al., in prep):

SN type, redshift, decline rate, total extinction

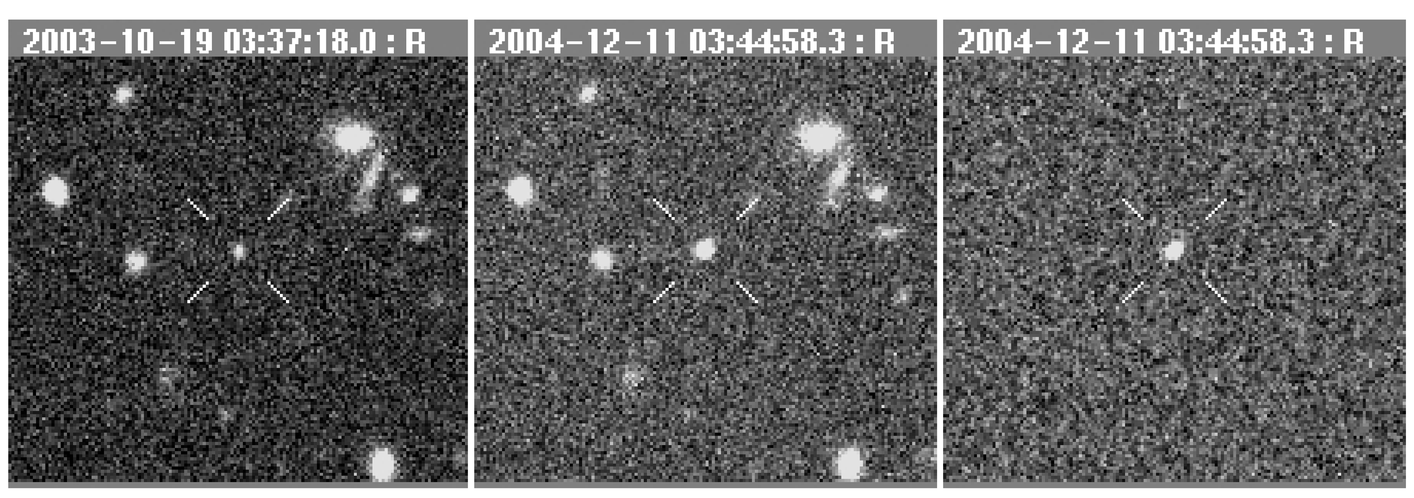
Science: A quarter of a million type Ia supernova light curves per year is a tremendous resource for the study of:

- Dark Energy – precisely mapping the expansion history of the Universe using the brightness of SN Ia can constrain the "equation of state" of the dark energy. The large numbers of SN Ia studied by LSST will allow binning into supernova sub-types reducing problems of systematic errors. The direct measurement of the derivative of the Hubble law will provide an independent estimate of the equation of state.
- Type Ia progenitor environments and host galaxies – statistical studies of the host properties as a function of SN Ia characteristics will provide clues to the SN Ia progenitor(s). The large sample will permit a study of the evolution of SN Ia properties with redshift that may further reduce systematic errors in the estimate of the dark energy equation of state.
- Weak lensing by large-scale structure – the brightness of the supernovae will be affected by the foreground matter density so SN Ia provide another probe of weak lensing which complements the galaxy shear also studied by LSST. SN Ia probe higher frequencies of the matter power-spectrum than shear lensing which may have a higher amplitude than expected (Williams & Song 2004, MNRAS, 351, 1387).
- Strong lensing – only a small fraction of supernovae are predicted to be strongly lensed (multiple images), but that still means hundreds of lensing events per year with the LSST sample. The light curves of SN Ia are simple and predictable, so time delays between images will be accurately measured. Lensing through galaxy clusters should also be observed.

Precursor Project: The NOAO Survey Program "ESSENCE" searches in real time for supernovae every-other half night on the CTIO 4m from September to December and has discovered hundreds of supernovae over the past three years. The 4-day cadence is similar to that planned for LSST. A sample difference image (Ia SN @ z=0.4) and sample R & I light curves (Ia SN @ z=0.5) for a typical SN Ia are shown at right. For more information, see

http://www.ctio.noao.edu/essence

ESSENCE Project



Type Ia @ z = 0.5 spectroscopically confirmed