Large Synoptic Survey Telescope

Supernova Science and Cosmology with the LSST

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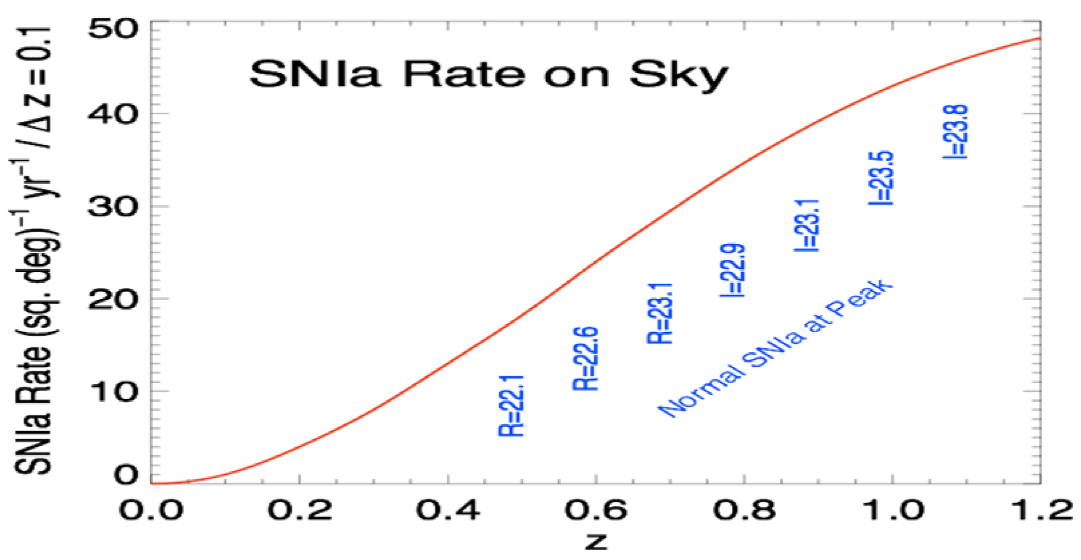
The LSST will open up new opportunities for SN science, including SN cosmology. LSST will detect millions of SNe, enabling precise investigations of the equation-of-state parameters of dark energy from a self-consistently calibrated system. We discuss recent developments in photometric redshift determinations that are distance-modulus independent – a requirement for making photometric-only SNe observations useful for cosmology. While the concern for future SN cosmology experiments is generally with the systematics rather than numbers of SNe, it is important to note that the unprecedented number of SNe that will be found by the LSST will provide a means to detect and calibrate many of these important systematic effects.

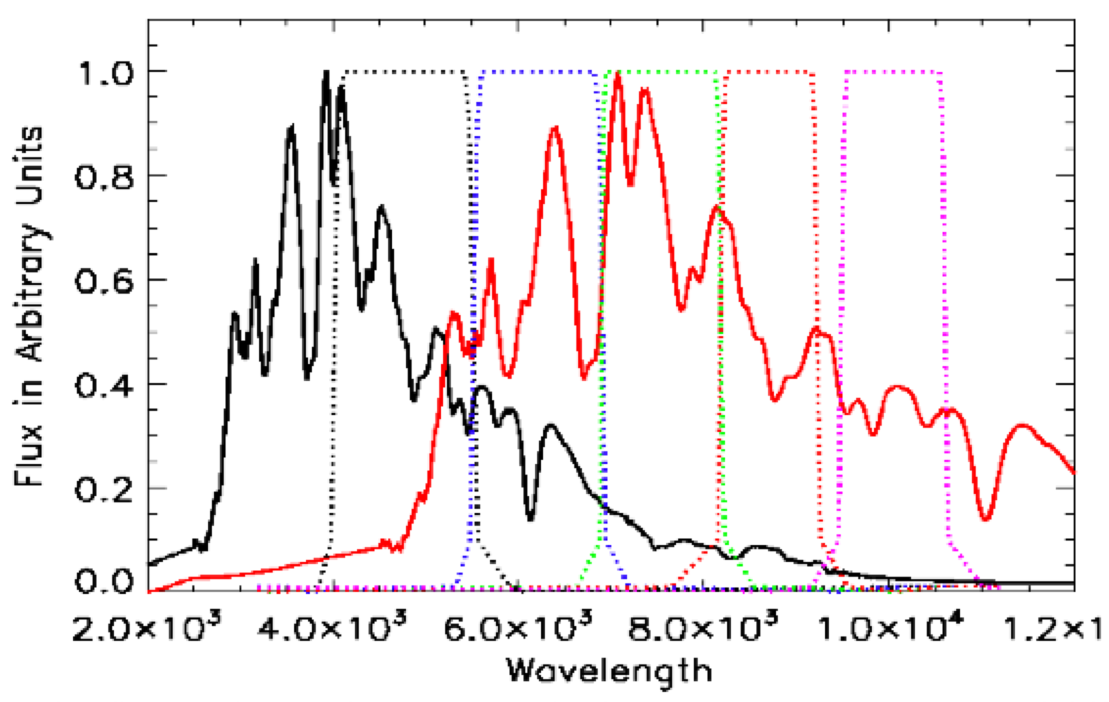
Supernova Sample



The currently planned LSST "universal" cadence will be used to survey ~20,000 square degrees comprised of ~2500 overlapping fields of ~10 square degrees to a depth of r~24.5 with a pair of visits separated by ~30 minutes collected every few days. Based on the observed SNIa rates, shown in the figure above, this survey will detect ~2.5 million SNIa/yr with z <~0.8. In addition, a special "deep-drilling" cadence is being planned to observe ~6 fields to a depth of i~26 every day. This survey will produce well sampled light curves of ~10 thousand SNIa/yr with z <~1.2. Comparable numbers of other SN types will also be detected and characterized by these surveys.

Photometric Redshifts

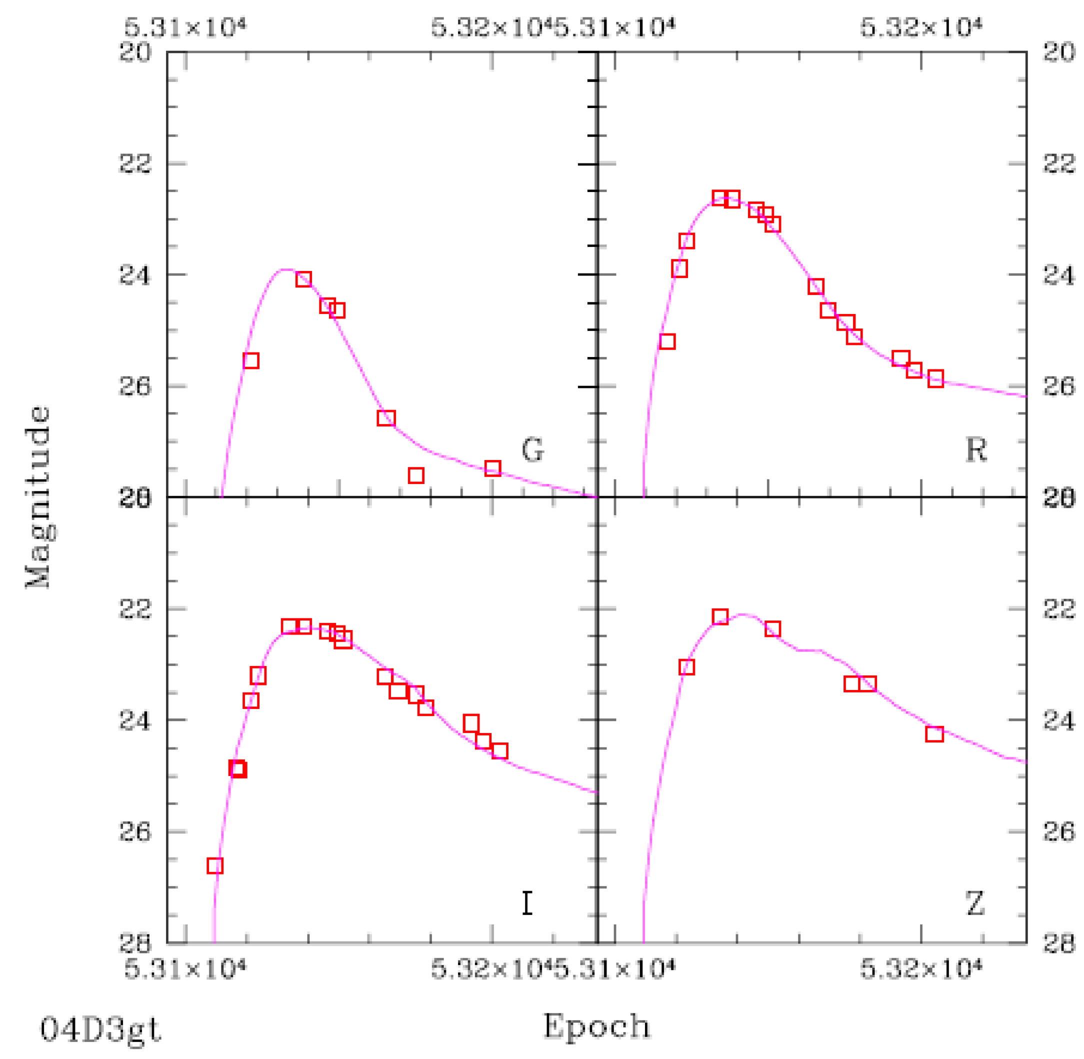
Because of the large numbers of SN that will be detected with LSST, spectroscopic follow-up will be impractical for the majority of the objects. Therefore, redshift information for most SN will be derived from photometric measurements of the SN or the host galaxy. The LSST SN Science Team is currently studying the accuracy with which the redshifts of SNIa can be estimated using the broadband photometry provided by the LSST observations.



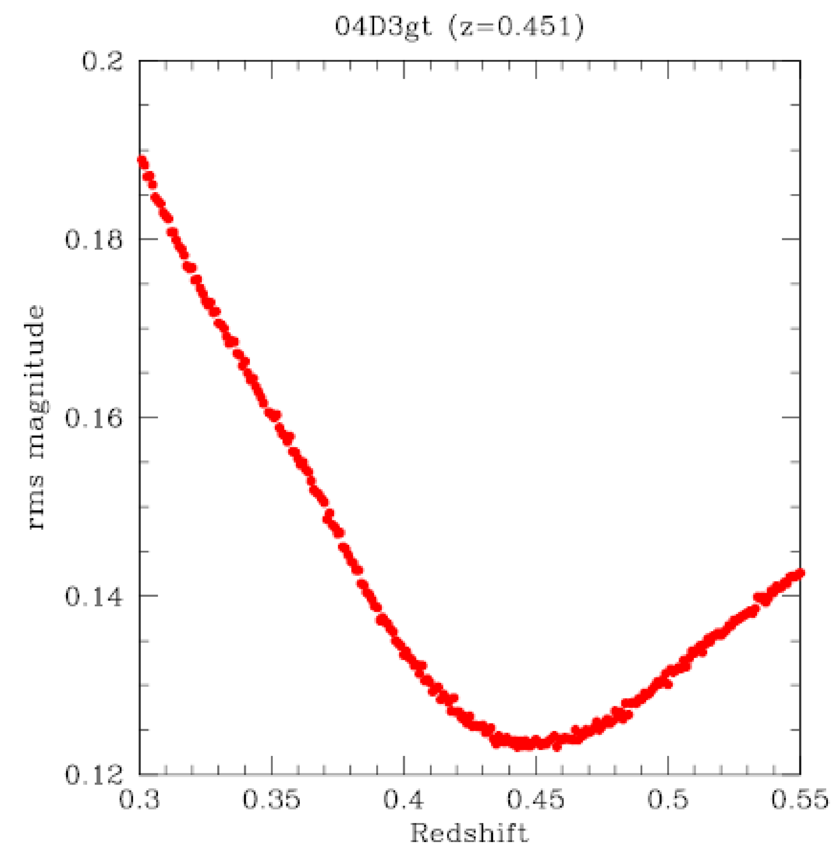
The figure above shows a nominal SNIa spectrum at two redshifts along with the wavelength bands for the LSST grizY filters. If the intrinsic spectrum is well known, the colors will accurately determine the redshift. Errors in this redshift estimate will be introduced by noise in the photometric measurements as well as variability in the intrinsic spectrum. Since SNIa spectra evolve in time, errors in the redshift estimate are also introduced by imprecise knowledge of the epoch of observation. However, this time evolution also provides an opportunity to use observations at multiple epochs in order to improve the redshift estimation.

Photometric Redshift Analysis

Redshifts estimates for SNIa can be computed by calculating the expected multi-color light curves based on SNe template spectra as a function of redshift and then comparing these light curves to the observed photometric data to determine the redshift at which the observations are best fit by the model light curves. It is important to note that this procedure does not directly use the apparent brightness as an indicator of redshift, since the relationship between apparent brightness and redshift is a function of the assumed cosmology. The figure below illustrates the results of this procedure for SNLS SNe 04D3gt, which has a spectroscopic redshift of 0.451.

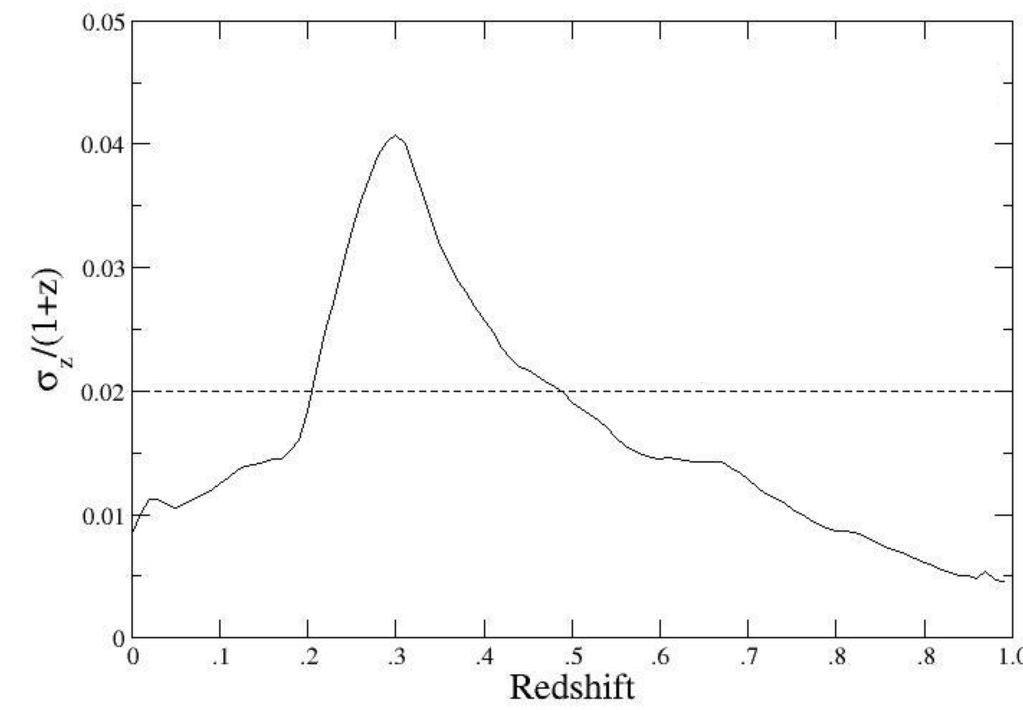


In the figure above, red squares are observed SNLS photometric data for SN 04D3gt, and purple lines are best fit light curves derived from template spectra.

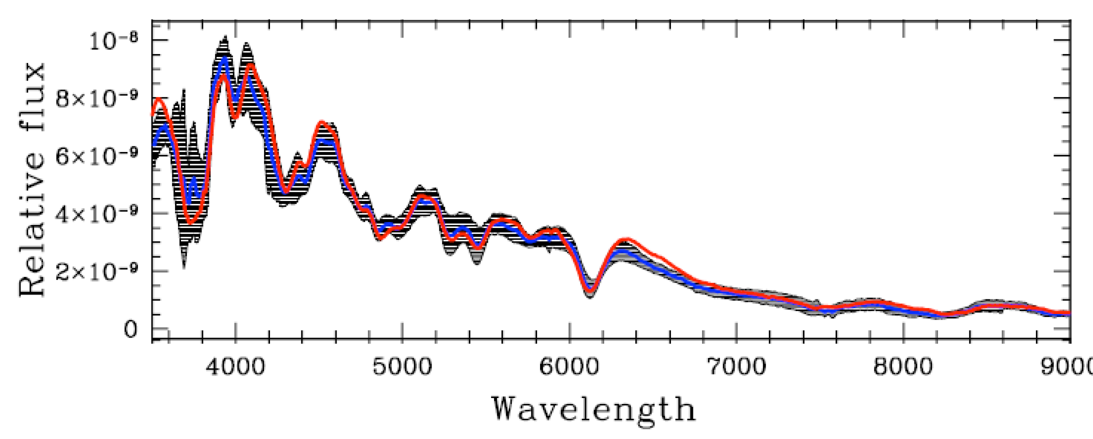


The figure above shows rms value of the offset between model light curve magnitudes and the observed photometric data for SNLS 04D3gt as function of model redshift. In this example, the best fit to the photometric data occurs at a redshift that is within 0.5% of the spectroscopic readshift

Photometric Redshift Errors

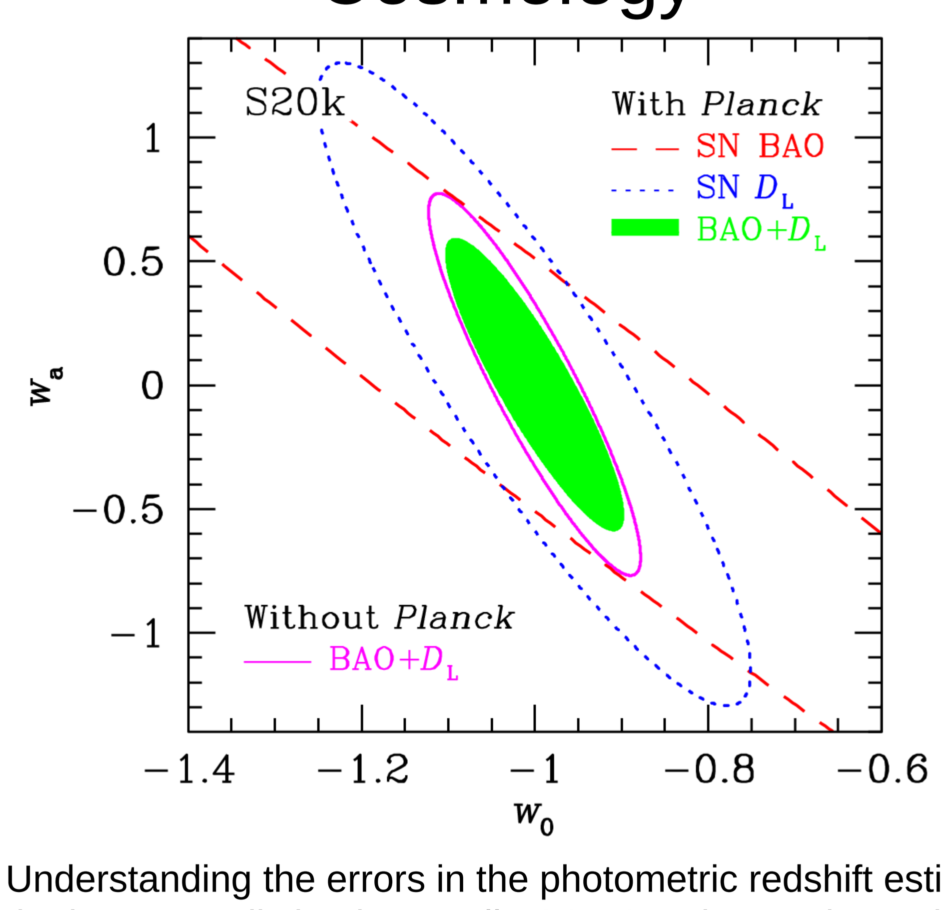


Errors in photometric redshift estimates will be introduced by noise in the photometric measurements. The figure above shows a plot of the rms error in the photometric redshift estimate for an idealized case in which the errors are due solely to photometric errors, set at 5% for this example.

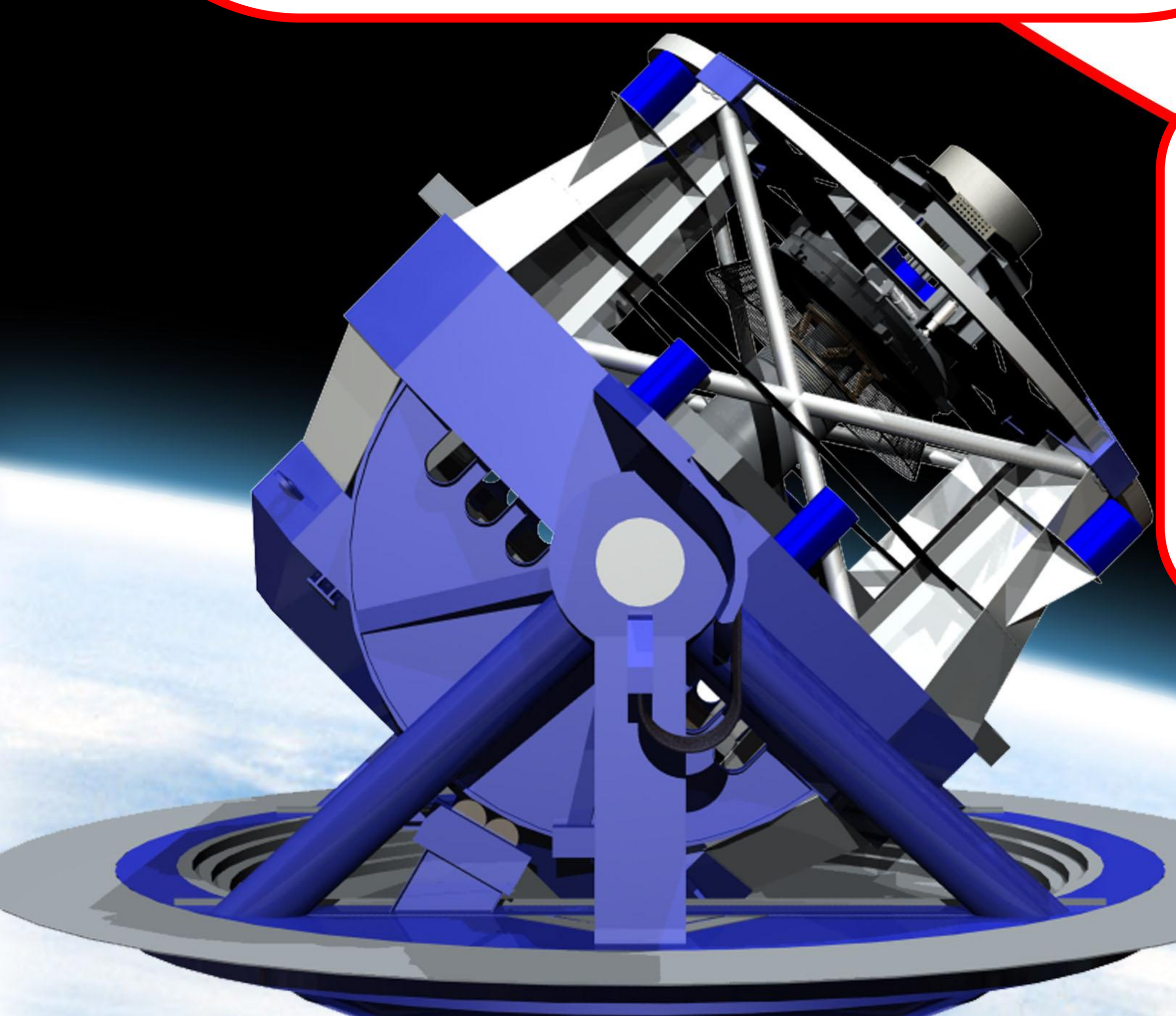


Errors in photometric redshift estimates will also be caused by intrinsic variability in the spectra. The figure above shows a plot of the spectral variability observed at the epoch of V-band maximum. The red line indicates Nugent's spectral template; the blue line is the average observed spectrum, and the shaded area represents one-sigma limits on the average. The next step will be to propagate the observed spectral variability at all epochs through the photometric redshift analysis to compute the error in the derived redshift estimate.

Cosmology



Understanding the errors in the photometric redshift estimates are the key to predicting how well LSST SN observations will help constrain the cosmological parameters. The figurue above shows one-sigma error contours of the dark energy equation of state parameters w_0 and w_a from SN luminosity distances (blue dotted line), baryon acoustic oscillations in the SN distribution (red dashed line), and the two combined with (green shaded area) and without (magenta solid line) Planck. We have assumed a 20000 sq. deg SN survey to z = 0.8, photo-z rms of 0.02(1+z), and a total of 7 million SNe accumulated over 10 years.



The LSST is expected to detect millions of SNIa during a 10 year survey. With accurate methods for estimating SNIa redshifts using photometric measurements, LSST SNIa observations will enable precise investigations of the dark energy equation-of-state. The LSST SN Science Team is investigating the accuracy with which photometric measurements can be used to derive SNIa redshifts, and the resulting capabilities for measuring cosmological parameters. In addition, SNe of all types will be discovered by LSST, and we anticipate that the wealth of data will allow astronomers to address many outstanding questions concerning the nature of SNe and late-stage stellar evolution using a combination of the SNe observations and the simultaneous observation of billions of stars in our own galaxy.

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