Core Collapse Supernovae Observed with the LSST

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Abstract

Attention has been focused on the opportunities for precision cosmology using Type Ia supernovae discovered and followed on the LSST. Core collapse supernovae - Types II and Ib/c - will also be discovered in equal numbers with a redshift limit of z~0.8 for a typical Type II. The LSST will be able to measure precise stellar death rates for massive stars to this redshift. Coupled with spectroscopy, distances can be measured using the "standard candle" method of Hamuy & Pinto (2002), and the Expanding Photosphere Method, allowing for an alternate method for measuring acceleration provided that the distance errors can be reduced from the present scatter of ~ 0.3mag. Finally, a large dataset of Type Ib/c supernovae can be used search for evidence of the class of supernovae responsible for GRBs, but whose axis of gamma emission is not aligned with the direction toward the Earth.

Luminosity Distances from Type II SNe

The traditional method for measuring distances to Type II supernovae uses the "expanding photosphere method." This method, which results a direct geometric distance based on the observed photospheric velocity, brightness, and effective temperature (calculated from colors) produces distances only good to ~20%, compared to 6% distances from Type Ia events. (Schmidt et al 1994, Hamuy 2001).

A new technique, called the "standard candle method" uses the empirical relationship between the luminosity and expansion velocity (Fig 1a) at 50 days after explosion to derive distances accurate to ~9% (Fig 1b, top panel)

$$L \propto v_p^3, \quad f = L / 4\pi d^2 \rightarrow d \propto v^{3/2} / f^{1/2}$$

Unresolved questions limiting distance accuracy:

- what are the intrinsic colors for Type IIp SNe?
- are there luminosity variations due to inclination effects from non-spherical explosions?
- how accurate are the K-corrections?

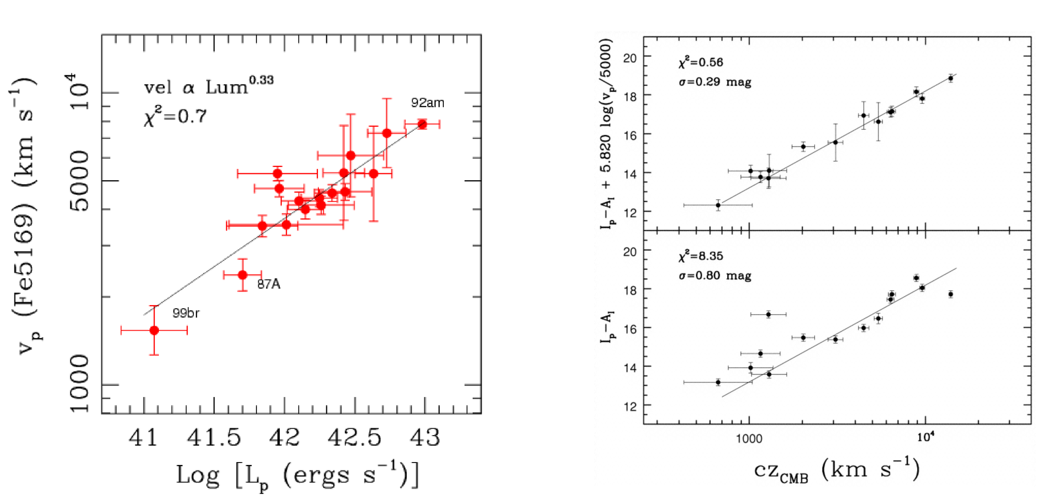

Figure 1. Left: photospheric expansion velocity 50^d after explosion. Right: Hubble diagram for Type IIp SNe. from Hamuy & Pinto (2002)

Stellar Death Rates

The best nearby and distant CC rates have been measured by Capallaro et al (1999) and Dahlen et al (2004), shown in Figure 2.The discovery of $>10^5$ core-collapse SNe per year with LSST will allow us to measure the stellar death rates to very high precision in the redshift range $0.05 < z < 0.8$ with the nearby supernova rates being limited by the saturation limit of the LSST. Besides the stellar death rates, we will be able to measure the stellar rates in all Hubble galaxy types as a function of redshift.

The long/soft (classical) GRBs are probably collapsars with the rotation axis pointed to within a few degrees of the line-of-sight. These GRBs are likely to be associated with energetic and/or luminous Type Ic events – so called "hypernovae" ($L > 10^{52}$ ergs). Since Type Ic's are ~15% of CC SNe, and ~1-5% are hypernovae (Podsiadlowski et al 2004), we should still have ~300 HN per year in our sample. These would represent GRBs where the axis was not aligned towards us.

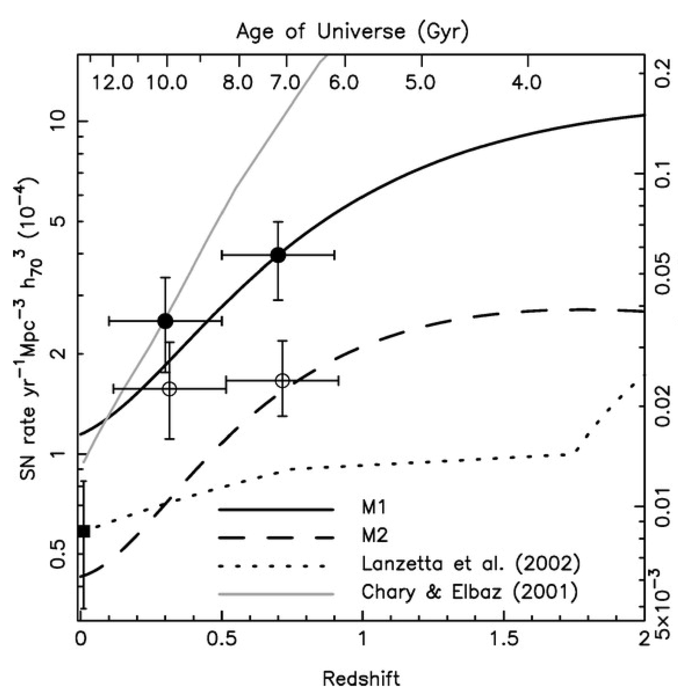

Figure 2. The SN rate in the nearby Universe. Note the rapid increase from z~0 (Cappallaro et al 1999) to z~0.5 (Dahlen et al 2004). Closed and open circles are with and without dust corrections – see Dahlen et al.

Nearby Observational Studies

The LSST will provide light curves for CC SNe but there will be little spectroscopic followup for most events. Will we be able to classify the supernovae, measure the reddening, and estimate the distance modulus *only* with photometry? The LSST should give us photometry with greater precision than in the past – 0.005mag or so. Can the photometric techniques such as Gel-Yam et al. 2004 and Barris & Tonry 2004 be expanded to allow us to not have to resort to spectroscopy?

Nearby supernova studies with very precise photometry, such as the 5-year Carnegie/CTIO Supernova Project and the European RTN project should give us a nearby sample accurate to better than 0.01mag. These will be critical for estimating intrinsic colors and K-corrections.

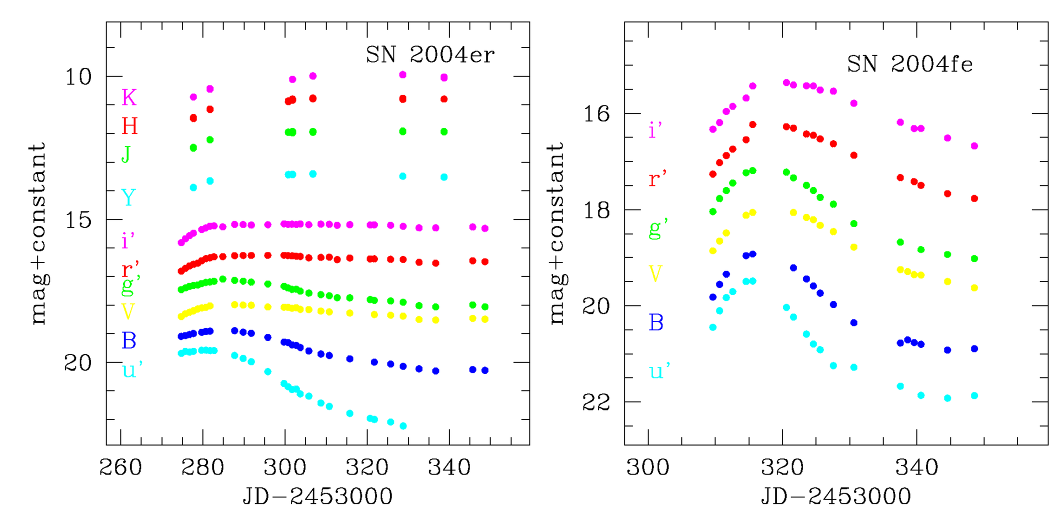

Figure 3. Recent CC SNe from the CSP. Left; Type IIp: right Type Ic.

References

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