Rise-time of underluminous SNe Ia

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Abstract

Underluminous type Ia supernovae (SNe Ia) are fainter and decline more rapidly than the bulk of the population. They represent a challenge for progenitor scenarios and explosion mechanisms. A vital tool for determination of such explosion models, particularly the amount of ^{56}Ni synthesized, is the light-curve (LC) rise-time. In this study, we present the LCs of 18 underluminous photometrically identified SNe Ia in the Supernova Legacy Survey at $0.1<z<0.6$ and we fit the rise-time to a simple quadratic model. We obtain individual rise-times ranging from 10 to 14 days, corresponding to a stretch corrected rise-time of 17.55 +/-1.32 days. Such explosions are powered by 0.04-0.36$M_\odot$ of ^{56}Ni.

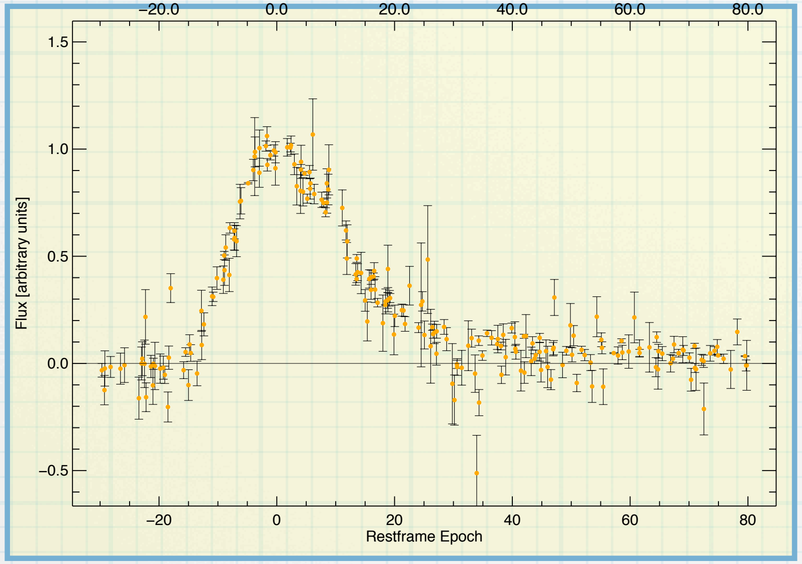


Figure1: Overlaid B-band rest-frame light-curves of underluminous SNe Ia from the SNLS. They are K-corrected, flux normalized and scaled to s and (1+z).

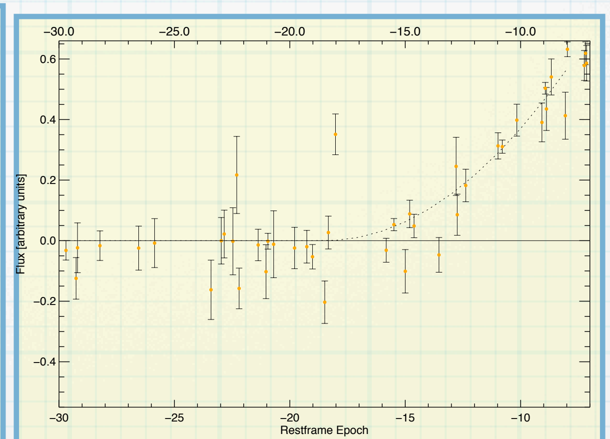
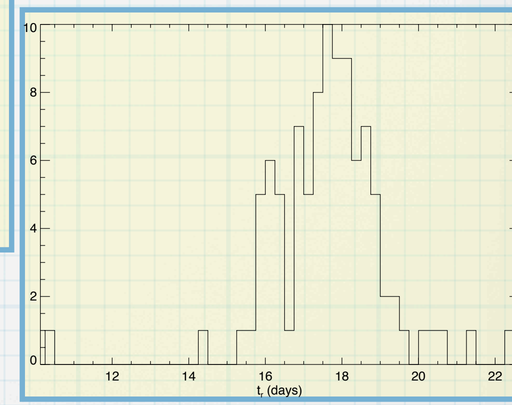


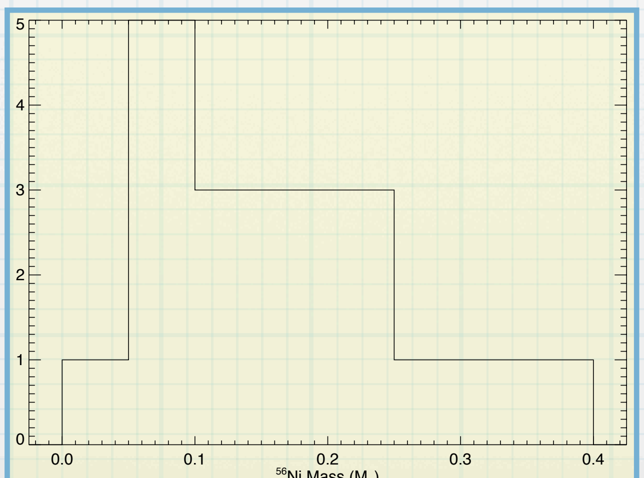
Figure2: Early-time overlaid B-band rest-frame light curves of underluminous SNe Ia from the SNLS. The dashed line is the best quadratic fit to the raw data with 18.47 days rise-time. Systematic errors are not taken into account.

Figure3: Histogram of 100 MC rise-time fits of the underluminous SNe Ia. Each simulation uses the fit parameters of the SNe randomly moved within their errors. The mean rise-time is 17.55+/-1.32 days.



Rise-time

The early data ($t<-7d$) of the rest-frame, normalized and stretch-corrected LCs of underluminous SNe Ia, objects with stretch<0.8, are fitted to a simple quadratic model: $f(t)=\alpha(t+\tau)^2$. This is done for 100 realizations by varying the redshift, stretch and color of each SN according to their covariance matrix. The best rise time, i.e. the mean of all simulations, is $\tau_{und}=17.55\pm1.32$ days. This is in agreement with the rise-time found for the core SN Ia sample following the same steps, $\tau_{bulk}=17.43\pm0.35$ days, demonstrating the validity of SNe Ia as standardizable candles down to low-stretch values. With stretches down to s=0.6, the indiviudal rise-times of underluminous, span 10 to 14 days.



^{56}Ni-masses

The bolometric luminosities and rise-times can provide us the amount of ^{56}Ni used in the explosion of the SN, letting the radioactive decay power the peak luminosity via equation: $M_{Ni}=L_{bol}[6.31e^{-\tau/8.8}+1.43\ e^{-\tau/111}]^{-1}$ (Nugent et al. 1997). We integrate the fit SED though all observed wavelengths and assume an additional standard ~20% IR luminosity. This provides a broad estimate of the ^{56}Ni mass for the underluminous SNe Ia: 0.04-0.36, in comparison to a standard ~0.5 $M_\odot$ for normal ones.

Conley et al. (2006), AJ, 132, 1707
Nugent, E.P. (1997), Ph.D. Thesis