SN 2010kd - A Superluminous Pair-Instability Supernova?

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Superluminous supernovae

In the last decade a new class of stellar explosions was discovered: Superluminous Supernovae (SLSNe). While being spectroscopically diverse, their common property is the very high peak brightness -- they are all brighter than -21 magnitude in all optical bands (Quimby, 2011; Gal-Yam, 2012).

SN 2010kd was discovered by the ROTSE Supernova Verification Project with the ROTSE-IIIb telescope at McDonald Observatory on Nov.14, 2010 (Vinko et al. 2010). Its redshift was estimated from the narrow Hα emission of the underlying host galaxy as z = 0.101, implying a distance of ~415 Mpc (adopting H_0 = 73 km/s/Mpc). The measured brightness of 17 mag corresponds to -21 absolute magnitude, suggesting that SN 2010kd is a SLSN.

Spectroscopic evolution

Fig.1: Observed spectra of SN 2010kd. The lack of both H and He means a peculiar Type Ic, similar to 2007bi (Gal-Yam et al., 2009; Young et al. 2010).

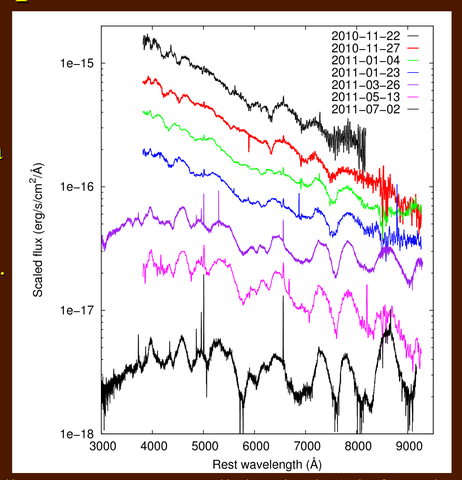


Table 1: Physical parameters (age, blackbody radius, temperature, radial velocity) inferred from the spectra.

Date of observation	Age in rest-frame (days)	R_{BB} (10^{15} cm)	T_{BB} (K)	v_{OI} (km/s)	Telescope
2010-11-22	+36	2.16	13554	9960	HET
2010-11-26	+40	2.11	13999	10276	HET
2010-11-27	+41	2.47	12263	11012	HET
2010-11-28	+42	2.55	12128	9750	HET
2011-01-04	+75	2.99	11130	9785	HET
2011-01-23	+93	3.42	9734	9504	HET
2011-03-26	+149	3.86	7013	7297	Keck
2011-05-13	+192	2.30	7376	7156	HET
2011-07-02	+238	2.48	5818	6771	Keck

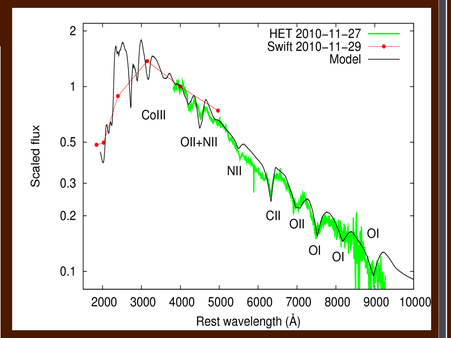


Fig.2: SYNOW model of the pre-maximum spectrum, dominated by CII, OII and OI. The drop of the UV-flux observed by *Swift* can be fitted with CoIII.

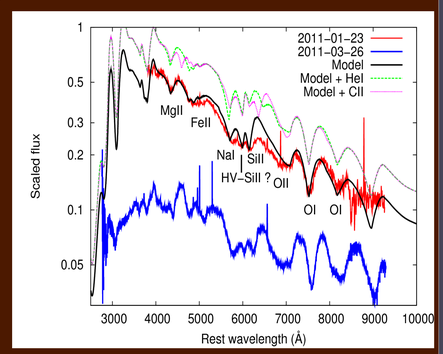
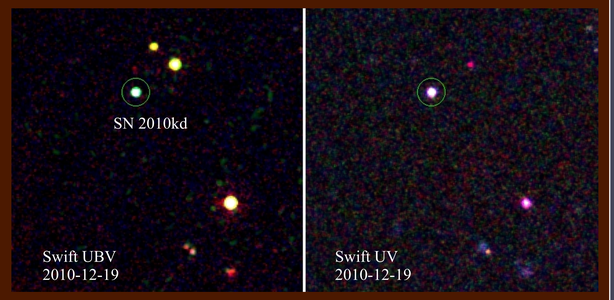


Fig.3: SYNOW models for post-maximum spectra. Mg II, SiII and FeII features have strengthened. HeI and CII are unlikely to be present.

Photometry and light curve fitting

Ground-based UBVRI-photometry was carried out at Aryabhatta Research Institute, Nainital, India. In addition, *Swift* UVOT and XRT observations were obtained around maximum light. The SN was detected as a strong source in UV, but not in X-rays.

Fig.4: *Swift* UVOT optical (left) and UV (right) true-color image of SN 2010kd.



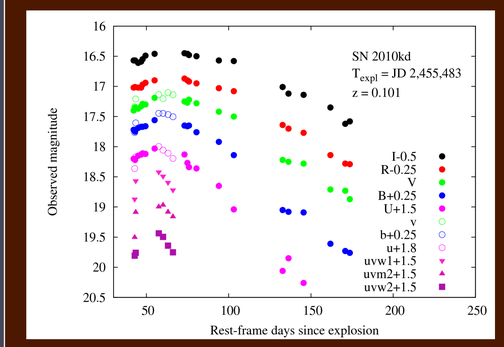
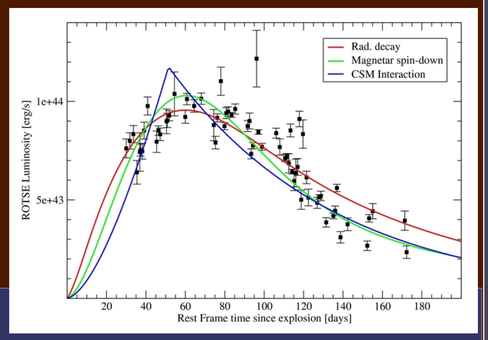


Fig.5: Ground-based (filled circles) and Swift UVOT (open circles, filled squares and triangles) light curves of SN 2010kd. The SN reached maximum brightness on 2010-12-22, about 60 rest-frame days after explosion.

Fig.6: Light curve models of Ni-Co-Fe radioactive decay (red), magnetar spin-down (green) and shock-heated CSM interaction (blue; see Chatzopoulos et al. 2012) fitted to the ROTSE data.



Conclusions

The observed peak brightness needs 56-Nickel mass of M_{Ni} ~10 M_{Sun}, which may suggest a Pair-Instability (PI) explosion. However, the observed risetime is indicative of ejected mass between 20 - 30 M_{Sun}, a factor of 2 lower than the theoretical lower mass limit (~65 M_{Sun}) of the PI mechanism (Chatzopoulos & Wheeler, 2012). Alternative models for the power source of the light curve, such as magnetar or CSM interaction, cannot be ruled out.

The host galaxy

There are 3 objects on the SDSS frame within the error circle of ROTSE. The brightest one is SDSS J120800.90+491333.1, a galaxy with a photo-z of 0.095.

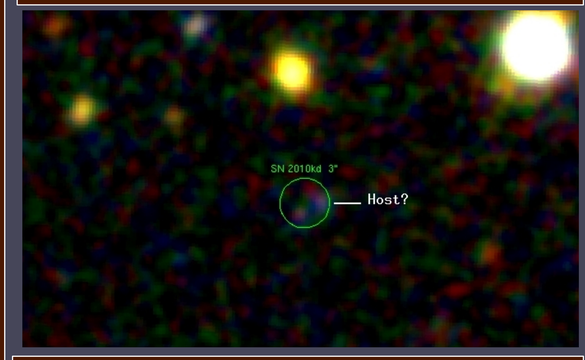
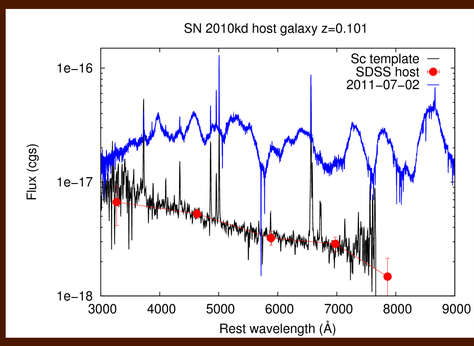


Fig.7: the host galaxy on the SDSS DR8-frame. Absolute magnitude is M_g = -16.8 mag.

Fig.8: the SED of the presumed host galaxy (SDSS, red circles) is well fitted by an Sc-type galaxy template. From the observed narrow emission features (blue curve) we derive 12+log(O/H) = 7.88 ± 0.05.
The host is a metal- poor dwarf galaxy, similar to other SLSNe hosts.



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