SN 2017hpa: A Carbon-rich High Velocity Gradient Supernova

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Abstract: We present optical broadband photometry and low resolution spectroscopy of Type Ia (SN) 2017hpa. The observations of 2017hpa was carried out with the **Himalayan Chandra Telescope** located at IAO, Hanle. The observations span from **-8.8 days to +108.2 days** since the maximum light in B-band. Photometric analysis shows 2017hpa as a normal type Ia SN with decline rate in B band $\Delta m_{15}(B) = 1.08\pm0.03$ and $M_B = -19.38\pm 0.05$. Spectroscopic analysis shows 2017hpa as a **High Velocity Gradient(HVG)** SN with prominent **C II λ6580** feature in the pre-maximum spectra.

Quick Details of the Object under study:

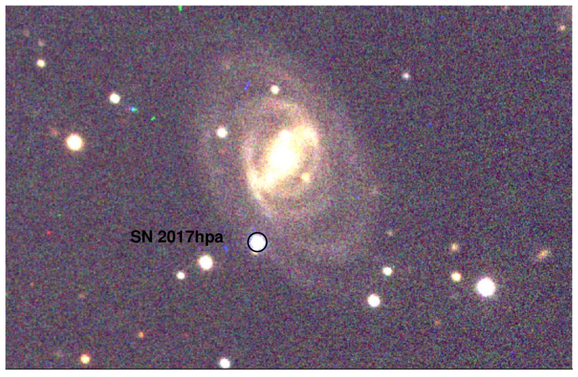


Fig. 1: Color Composite Image of the field of 2017hpa at -8.8 days since B-max.

- RA (J2000): $04^h:39^m:50^s.73$
- DEC (J2000): $+07^\circ03'55.22''$
- Discovery Date: t_d = 2017 October 25 08:18 (UTC) (JD 2458051.84)
- Date of B-band Maxima: t_o = 2017 November 08 17:45 (UTC) (JD 2458066.24 ± 0.05)
- Host Galaxy : UGC 3122
- Redshift: 0.0156 ± 0.000027
- Decline rate: $\Delta m_{15}(B)$ = 1.08±0.03
- Absolute Magnitude: M_B = -19.38± 0.05
- Distance Modulus: μ = 34.11 ± 0.02 mag
- Peak Luminosity: L_{max} = 43.03±0.03 erg/s
- ^{56}Ni mass: $M_{Ni} = 0.39\pm0.01\ M_\odot$
- Ejected Mass: $M_{ej} = 1.21\pm0.14\ M_\odot$
- Velocity Gradient: $\dot{v}$ = 127.9 ± 6.1 km/s/day
- Kinetic energy: E_K = 0.69±0.20 foe

Study of Light Curve:

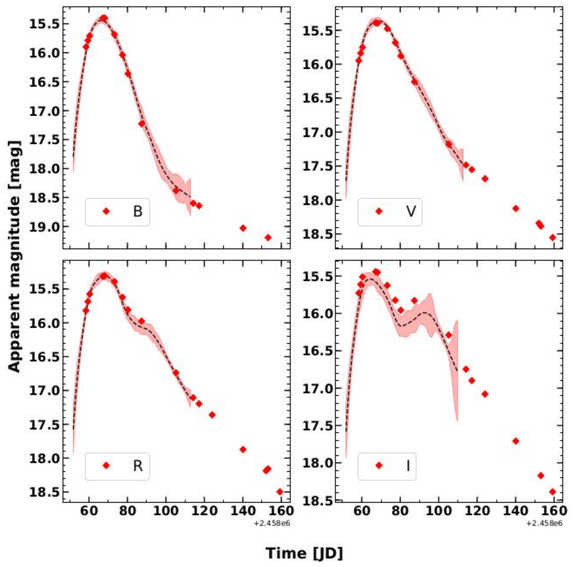


Fig. 2: SALT2 fit of BVRI LC of 2017hpa

- The maximum of I band occurs before the maximum of B band.
- The I band LC shows distinct secondary maximum which is related to the ionization evolution of Fe Group elements (IGE's) in the SN ejecta.
- The decline rate in B band is faster than V, R and I band from 30-80 days since B-band maxima, which is due to redistribution of flux from bluer wavelengths to redder wavelengths as a result of the presence of Fe group elements.
- The (B-V) color at maximum is $(B-V)_{max}$ = -0.16 ±0.02 which is bluer than normal type Ia.
- SALT2 fit to the BVRI LC shows the Distance Modulus to be 34.11±0.02 mag, assuming H_o= 72 km/s/Mpc.
- MLCS2k2 fit to the BVRI LC gives the Distance Modulus as 34.03±0.03 mag, with a host extinction of 0.089±0.03 (R_V = 3.1)
- The Quasi Bolometric LC constructed with UBVRI photometry gives a ^{56}Ni mass of 0.39 ±0.01 $M_\odot$ with a rise time to maximum as 14.78 days.
- The ejecta mass has been estimated to be 1.21±0.14 $M_\odot$ assuming a constant optical opacity of κ = 0.08 cm^2/g in the ejecta.
- The Kinetic energy has been calculated to be 0.69 ± 0.20 foe with a velocity of 9,850 ± 250 km/s derived from Si II absorption feature.

Spectroscopic Study:

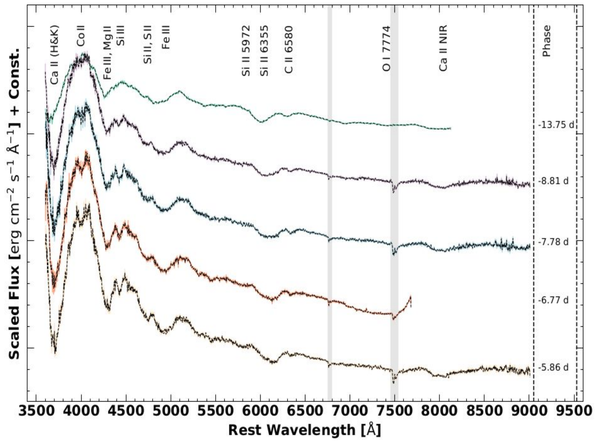


Fig. 3: Pre-maximum phase spectra of 2017hpa

- The pre-maximum phase spectra (3500-9100 Å) shows prominent **C II λ6580** feature characteristics of ongoing burning.
- The blueshift of the absorption feature of Si II λ6355 traces the photosphere.
- The velocity gradient measured from maximum is $\dot{v}$ = 127.9 ± 6.1 km/s/day which places 2017hpa as a **HVG SN**.
- Based on the ratio of the pseudo-equivalent(pEW) widths of Si II λ5972 and λ6355 feature in the spectra of type Ia SN, 2017hpa is placed in the core normal(CN) class.

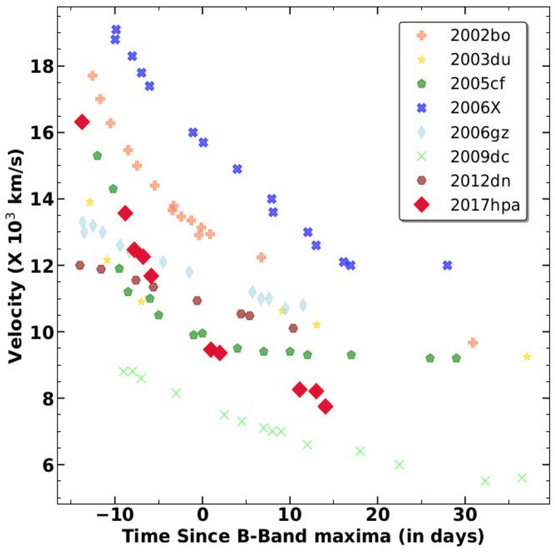
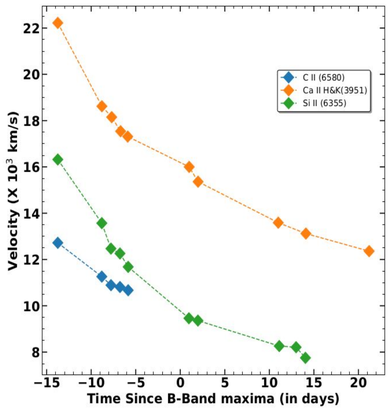


Fig. 4: Comparison of Si II λ6355 velocity evolution with other type Ia SNe.

Line Velocity Evolution:



- The line velocity evolution of Si II λ6355 has been shown along with C II λ6580 and Ca II(H&K) λ3951.
- The C II velocity evolution is significantly lower than Si II which indicate ejecta asymmetry.

Fig. 5: Line Velocity Evolution of different elements for SN 2017hpa

Summary and Discussions:

- **The photometric properties show 2017hpa as a normal type Ia SN.**
- **The spectroscopic properties show 2017hpa as a CN, HVG SN.**
- **Typically, C II is associated with low velocity gradeint (LVG) type.**
- **The (B-V) color at maximum is redder in HVG type which is contradictory to 2017hpa.**
- **For a given spectrum, any velocity of an ion below the photospheric velocity indicate ejecta asymmetry, that is the actual velocity of the C II line and the velocity at photosphere (v_{phot}) are the same but instead of forming in a shell at the observed velocity, the C II is formed in clumps at v_{phot} at an angle to the line of sight.**
- **Pulsating delayed detonation model of explosion produces more Carbon in the outer ejecta.**

Few Selected References:

1. G. C. Anupama, D. K. Sahu, and J. Jose. Type Ia supernova SN 2003du: Optical observations. A&A, 429:667–676, Jan. 2005
2. S. Benetti, et al. The Diversity of Type Ia Supernovae: Evidence for Systematics? ApJ, 623(2):1011–1016, Apr. 2005.
3. Guy J. et al. SALT2: using distant supernovae to improve the use of type Ia supernovae as distance indicators, 2007 A&A, 466; 11-21

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