Bridging between type IIb and Ib supernovae: SN IIb 2022crv with a very thin Hydrogen envelope

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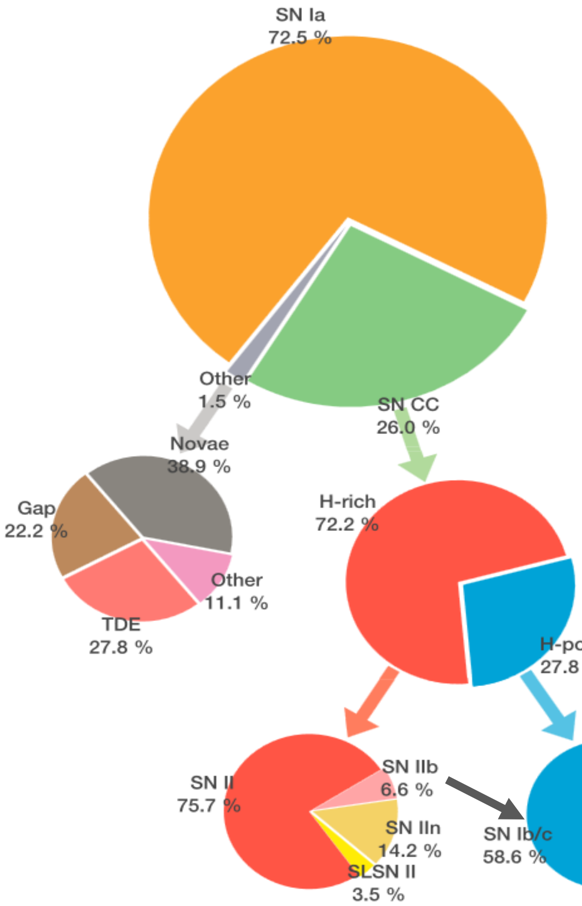
Seimei Users Meeting

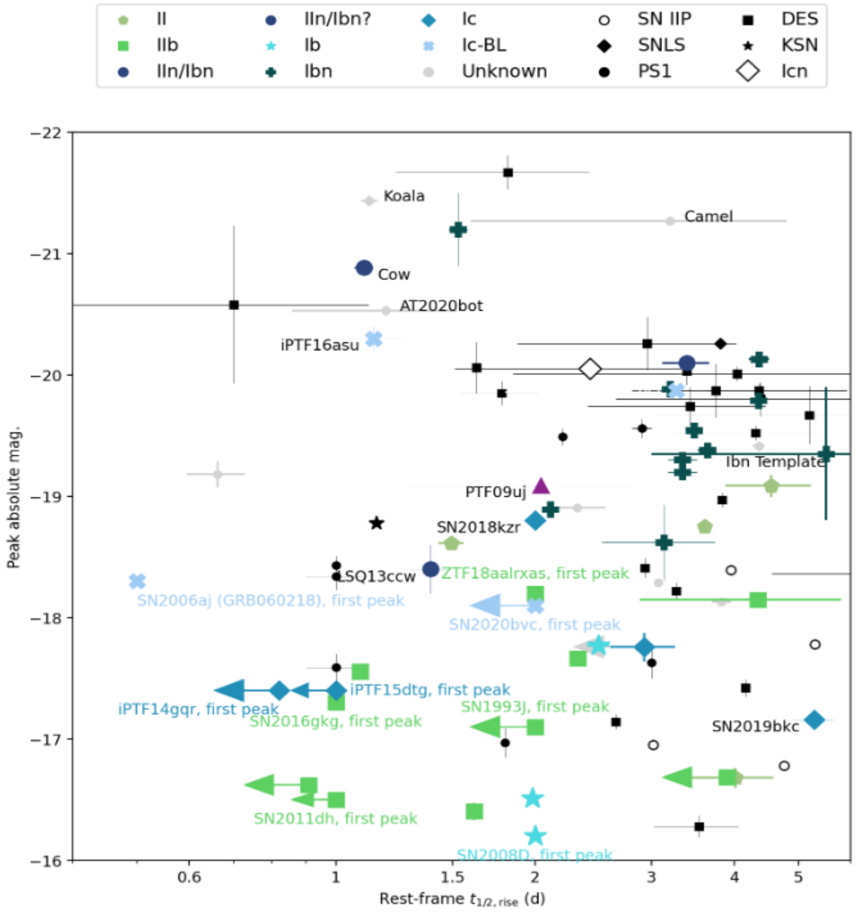
The extragalactic transient space

Ho et al. 2021



Perley et al. 2020

Continuity of outer envelope ??

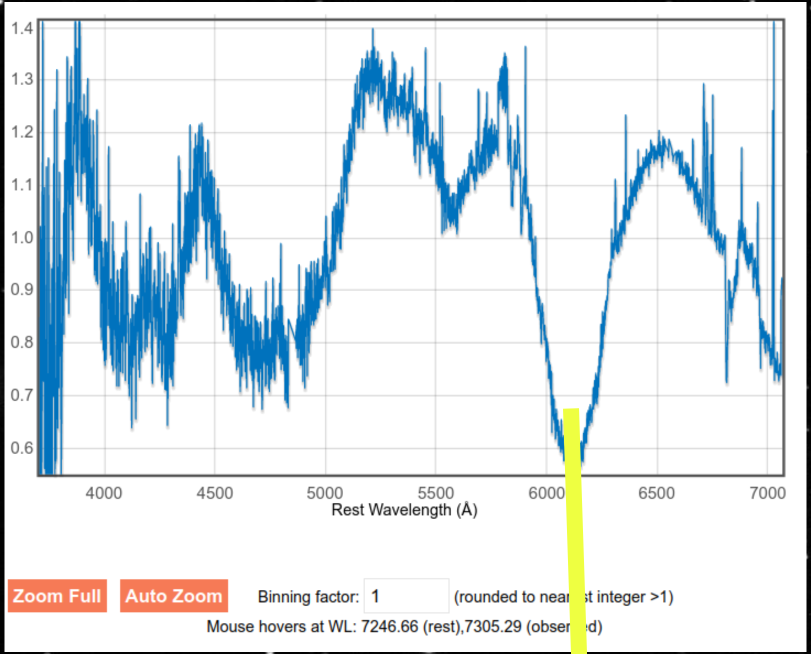


Are the classes distinct or linked by a outer layer ?

- Spectroscopically, SNe IIb are differentiated from SNe Ib by the presence of Hα, which gradually diminishes over time, and He I feature takes over.
- From their synthetic spectra, (Hachinger et al. 2012) concluded that even 0.025 − 0.033 $M_\odot$ can produce strong Hα absorption feature, suggesting that there is a blending between SNe IIb and SNe Ib.
- Prentice & Mazzali (2017) created two further SE-SNe subcategories: the SNe IIb(I), having moderate H-rich spectra in which the Hα P-Cygni profile is dominated by the absorption component relative to the emission profile, and the Ib(II), whose having residual weak Hα, but, no other Balmer lines more energetic than Hα.
- Thus, findings by Prentice & Mazzali (2017) along with Hachinger et al. (2012) indicate that SNe IIb and SNe Ib are linked more physically than thought before.

SN 2022crv : Discovery

SN 2022crv was first discovered as a SN Ib by Dong et al. 2022 on 19th February. The classification spectrum was taken by Andrews, Jennifer et al.2022.



Ryder et al. 2022 reported the radio detection at 5.5 and 9 GHz using Australia Telescope Compact Array and reported flux densities of 0.7 mJy and 0.5 mJy at 9.0 and 5.5 GHz respectively.

NGC 3054 SN 2022 crv

The dip at 6200 Ang and interaction in radio???

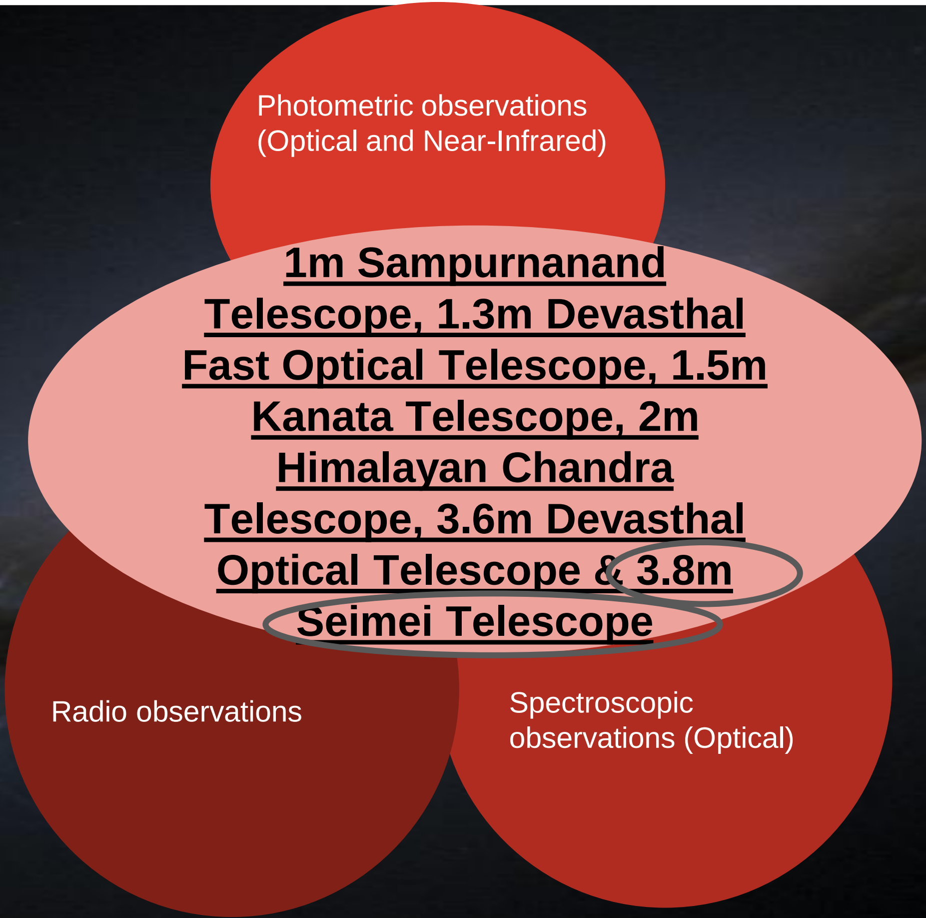
Observing run of SN 2022crv:

Photometric coverage:

-8 day to 86 day post maxima

Spectroscopic coverage:

-15 day to 33 day post maxima



Radio Observations:

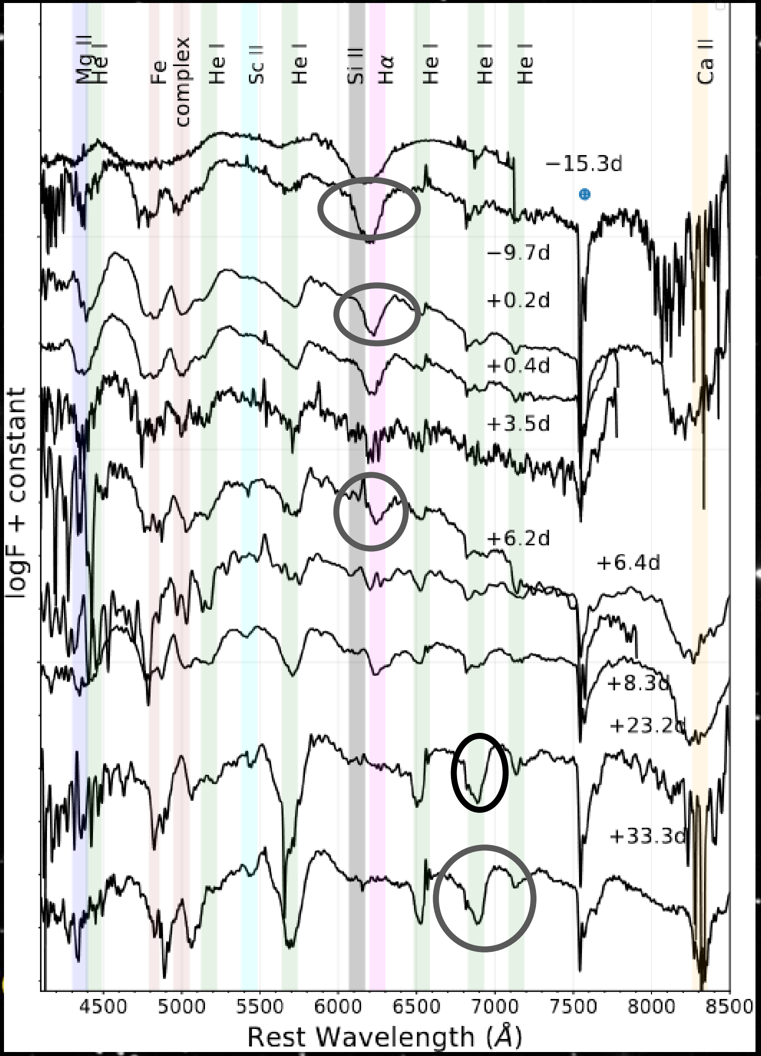
uGMRT: upgraded Giant Meter Radiowave Telescope (4 epochs in 0.7 and 1.37 GHz respectively).

Archival ATCA points added.

Spectral Evolution:

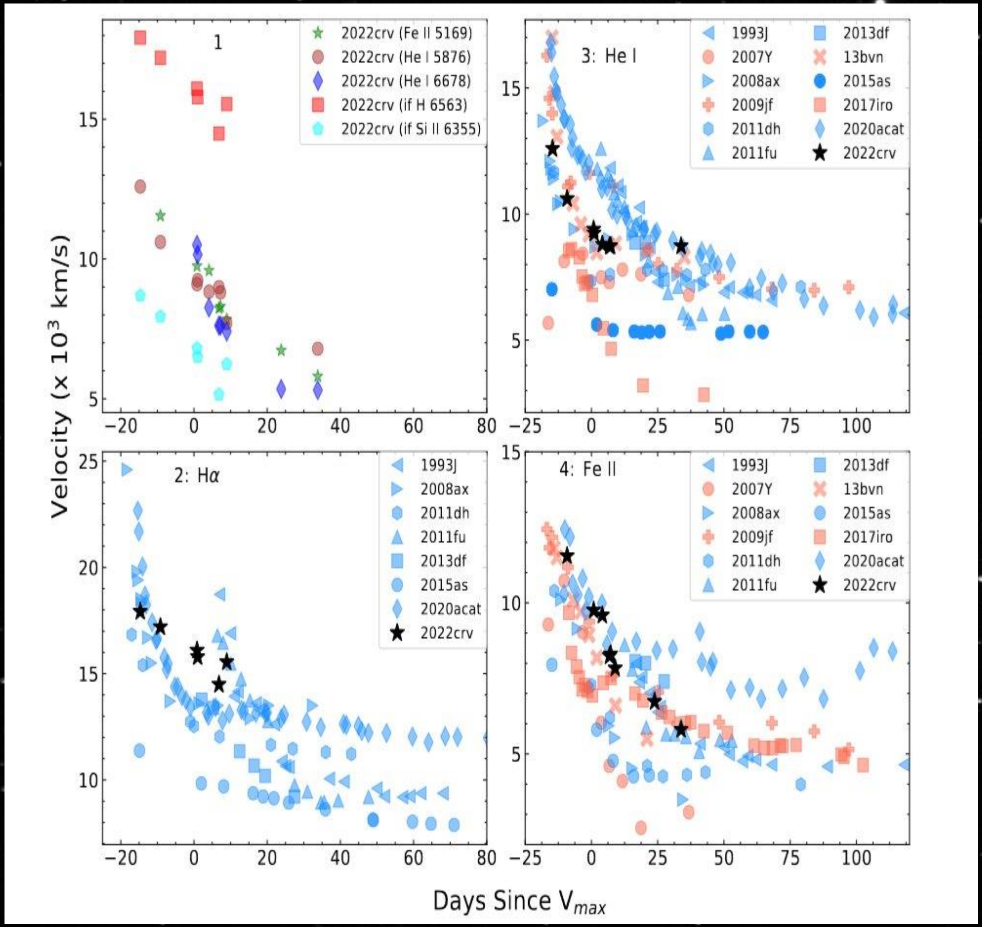
- The absorption at 6250 Ang is moving with a velocity of 18,000 km s−1 showing a high-velocity ejecta.
- Fe multiplets could be seen.
- The spectra also shows a “W” shaped absorption feature centered around 5000 Ang.
- Mazzali et al. (2008) explains the origin of these features due to Fe ii complexes, whereas Silverman et al. (2009) consider that the features arise due to a combination of Ciii, N iii and O iii and their high velocities.
- We also see prominent lines of He I 5876, 6678 and 7065 Ang appearing with time.

NGC 3054 SN 2



Velocity evolution:

- The absorption at 6250 Ang is moving with a velocity of 19,000 km s^{-1} showing a high-velocity ejecta.
- If the feature is due to Si II, the velocities are less than the photospheric velocities.
- So, the feature is likely due to the combination of Halpha + Si II.
- We also see prominent lines of He I 5876, 6678 and 7065 Ang appearing with time.
- The velocities are consistent with He velocities.

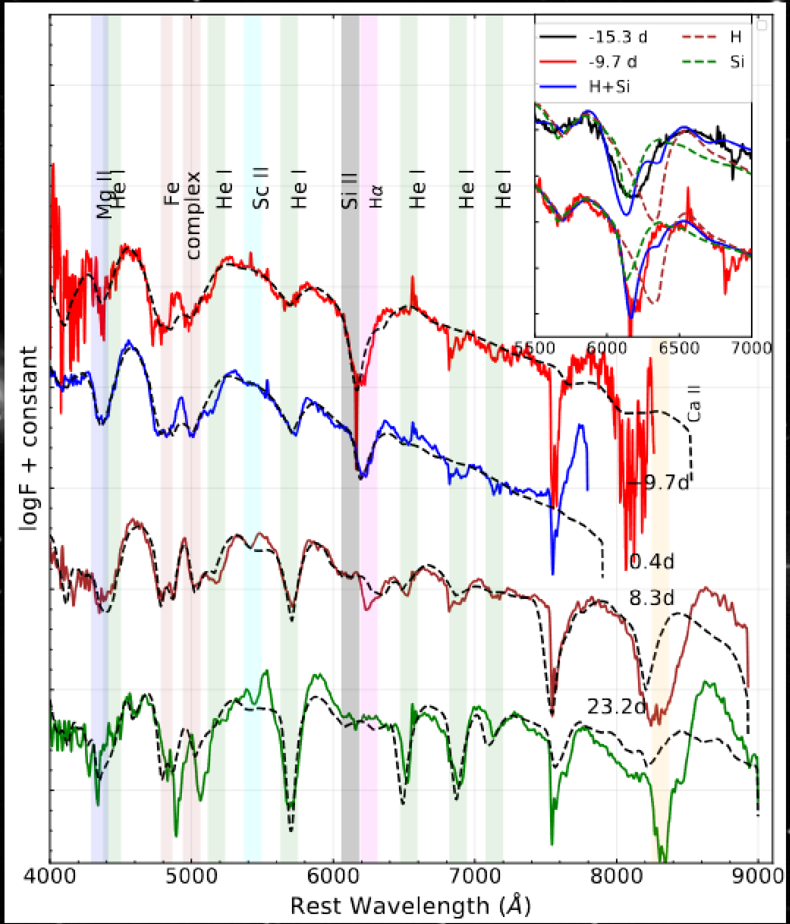


NGC 3054 SN 2022 crv

SYNAPPS:

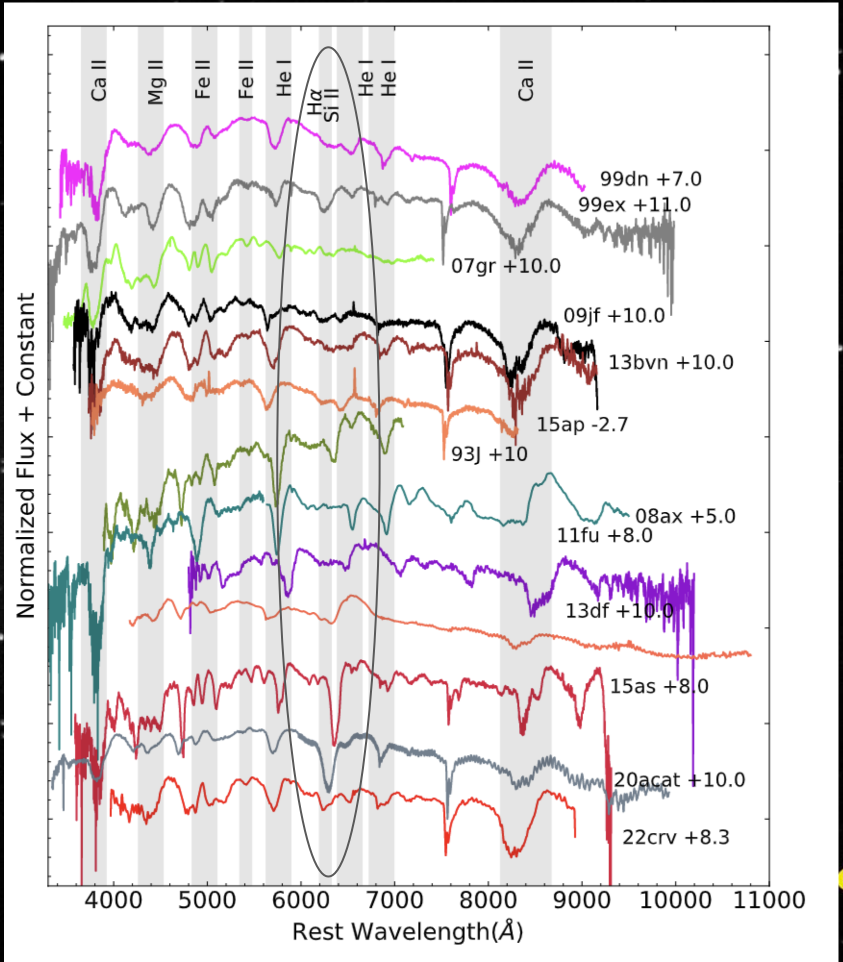
- For generating the absorption dip in the −9.7 d spectrum, a combination of Hα and Si ii were used. For modelling SN 2022crv spectra, we used H i, He i, O i, Mg ii, Ca ii, Fe ii and Sc ii species. The maximum velocity for all the ions from the fitting is 30,000 km s−1.

Consistent with the SN IIb with a thin H envelope (along with Si II) which vanished with time.



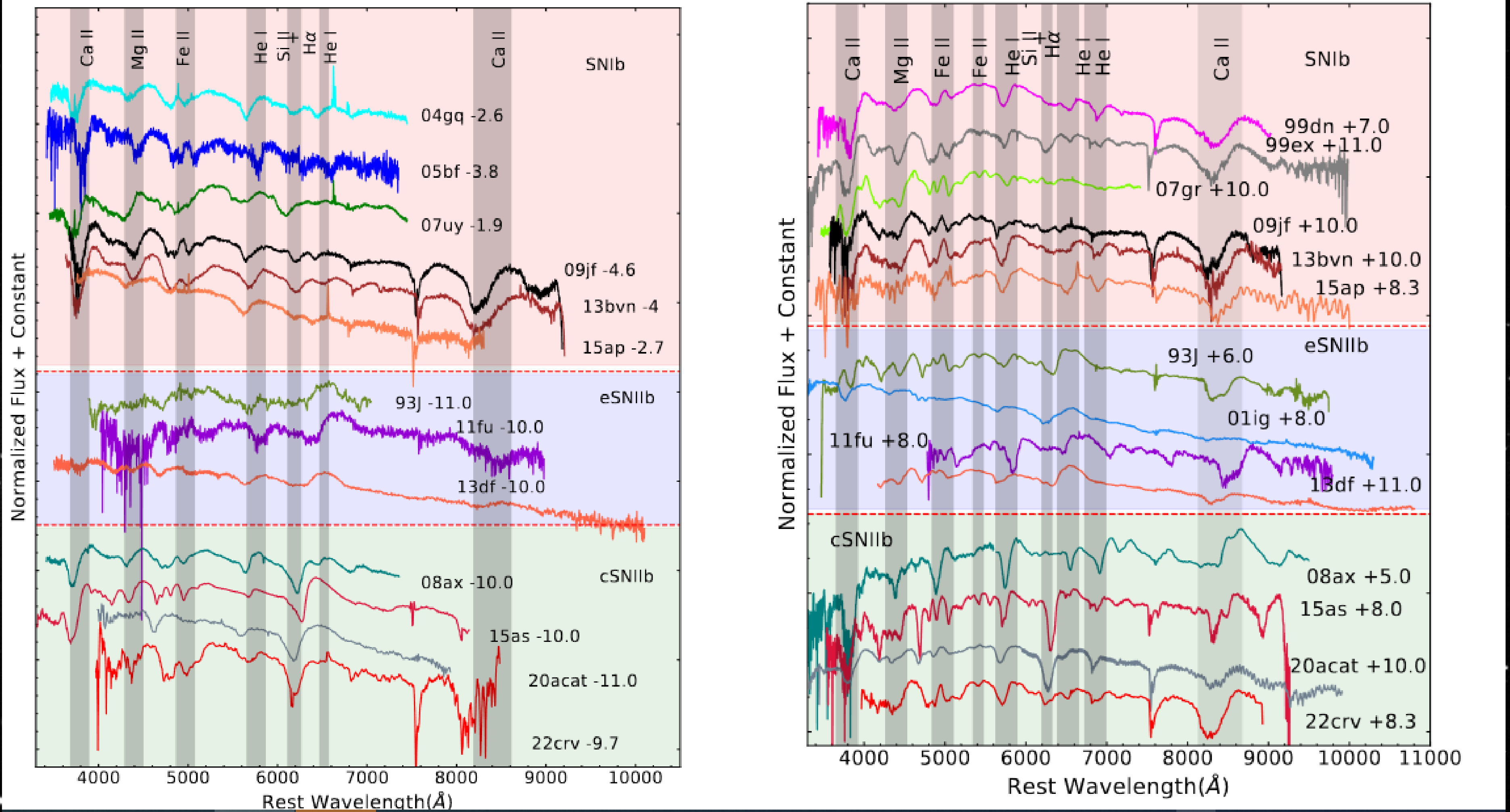
NGC 3054 SN 2022 crv

What makes this SN interesting?



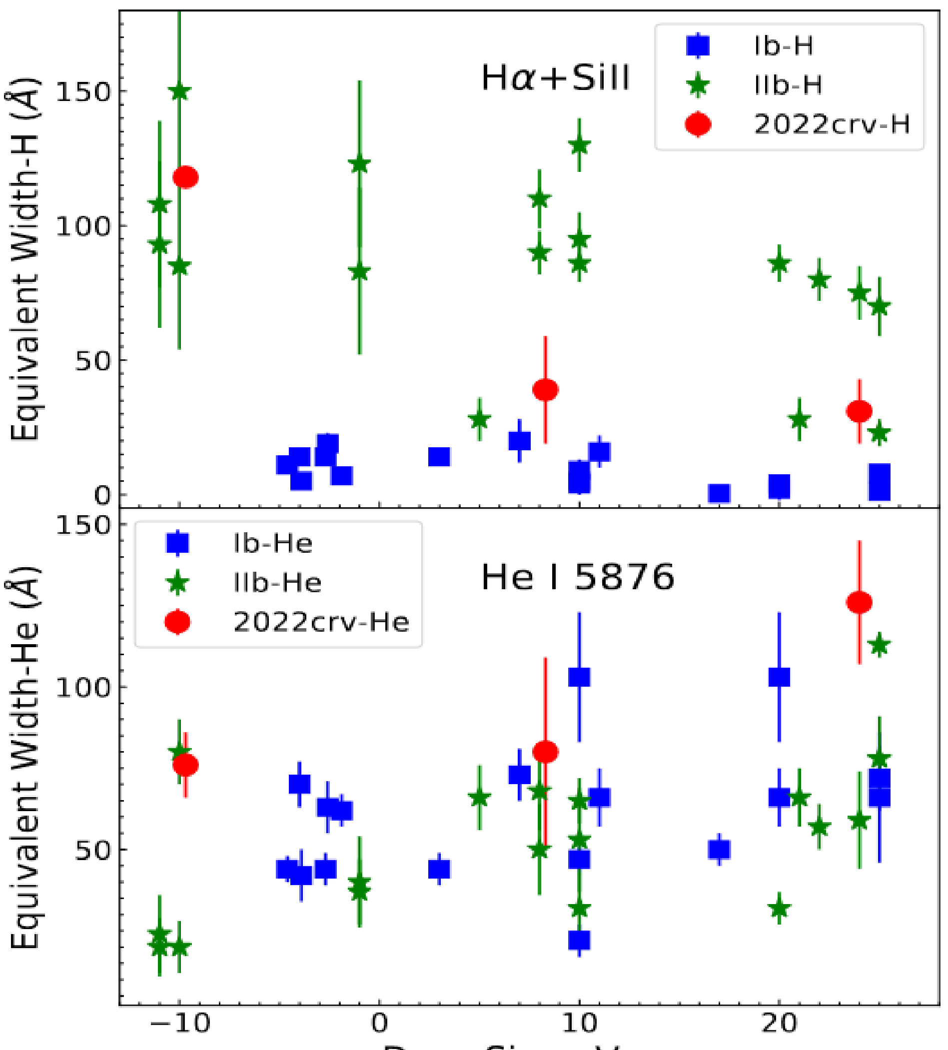
- The +8.3 d spectrum of SN 2022crv shows a very small absorption dip at the Halpha position.
- At similar epochs all other SN IIb shows a prominent Halpha as seen in the Figure.
- The Halpha dip of most SN IIb shows a prominent dip almost ~40-50 days post maximum.

This makes us suggest that this is a SN IIb which retained a very thin H envelope!!!

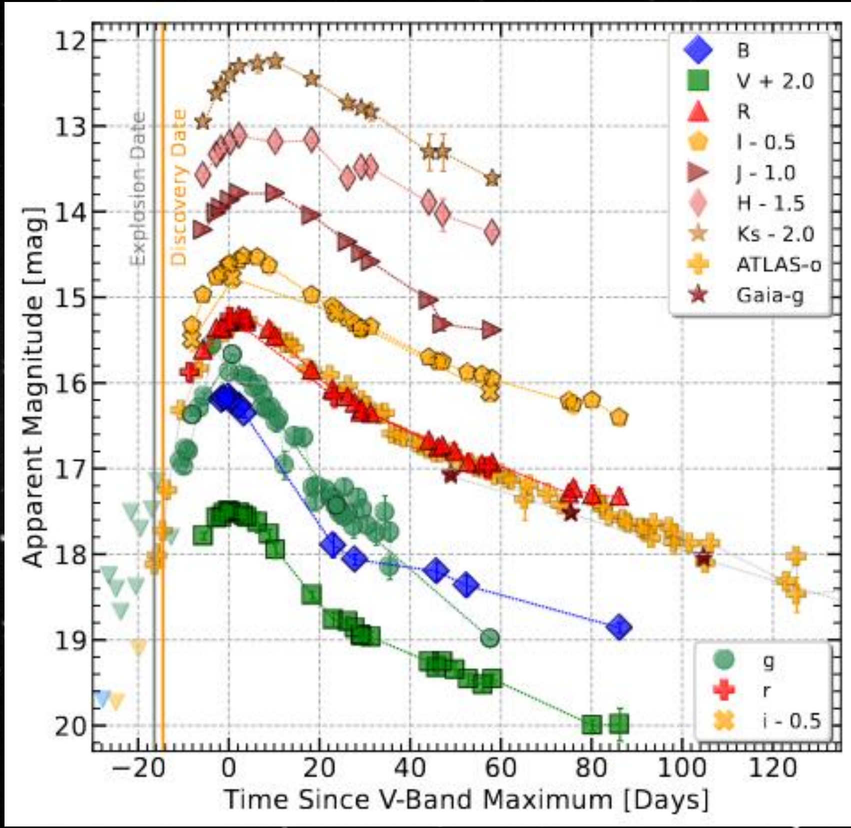

Ca II
Mg II
Fe II
He I
Si II
Hα
He I
Ca II
SNIb
04gq -2.6
05bf -3.8
07uy -1.9
09jf -4.6
13bvn -4
15ap -2.7
eSNIIb
93J -11.0
11fu -10.0
13df -10.0
cSNIIb
08ax -10.0
15as -10.0
20acat -11.0
22crv -9.7
Normalized Flux + Constant
Rest Wavelength(Å)
Ca II
Mg II
Fe II
Fe II
He I
Si II
Hα
He I
He I
Ca II
SNIb
99dn +7.0
99ex +11.0
07gr +10.0
09jf +10.0
13bvn +10.0
15ap +8.3
eSNIIb
93J +6.0
01ig +8.0
11fu +8.0
13df +11.0
cSNIIb
08ax +5.0
15as +8.0
20acat +10.0
22crv +8.3
Normalized Flux + Constant
Rest Wavelength(Å)

Also validated from Equivalent width plot:

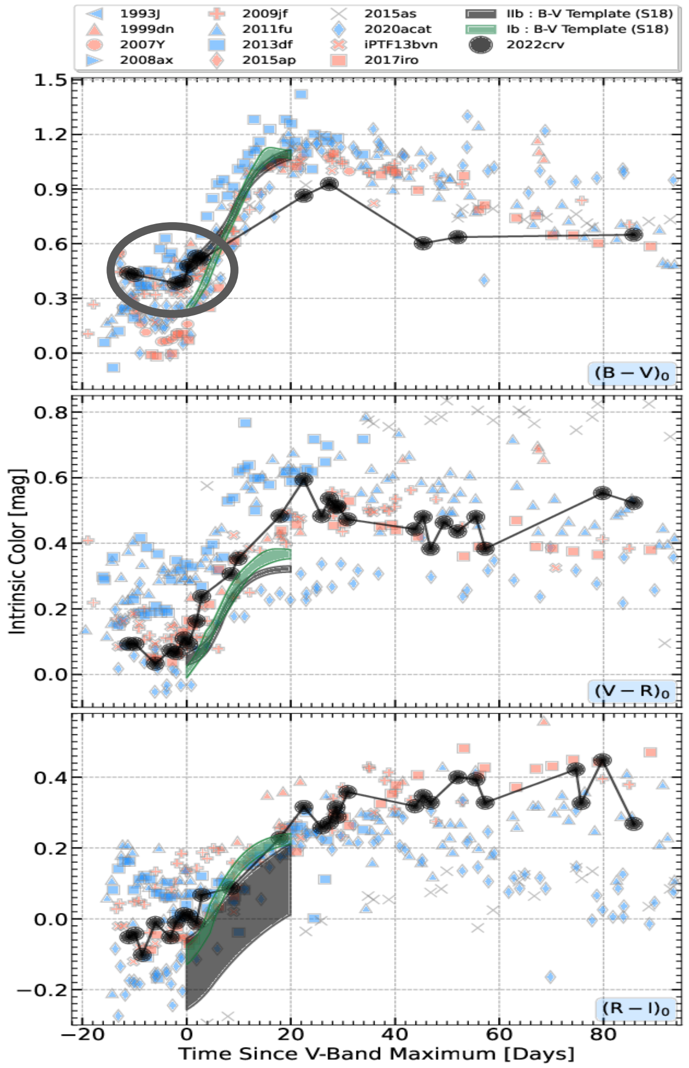
- Initially, the EW of Hα+Si II is similar to all other SNe IIb.
- As time progresses, the equivalent width of Hα+Si II decreases and the feature becomes equal to a SN Ib and much lesser than SN IIb.



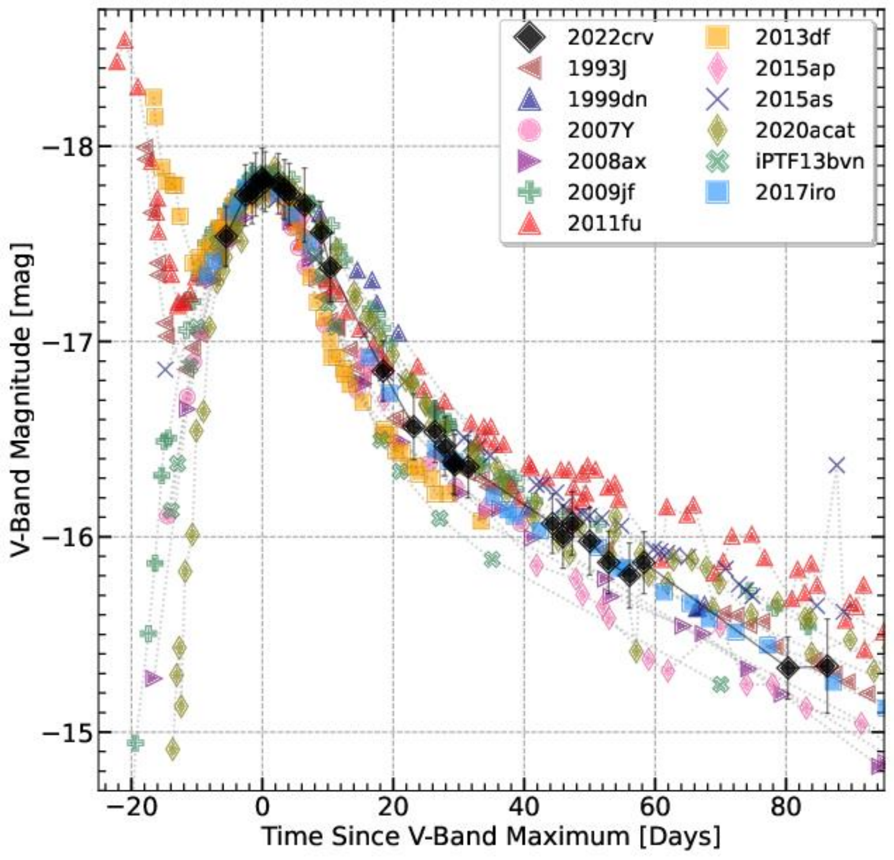
Apparent magnitude light curves and color curves of SN 2022crv



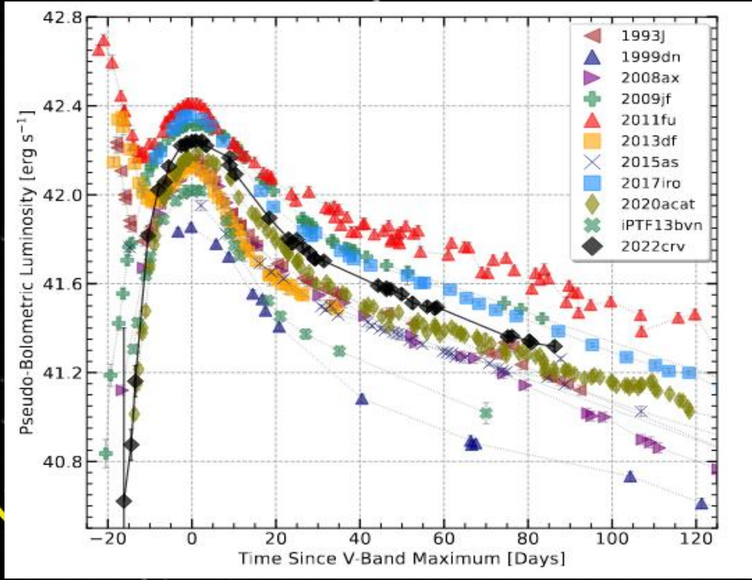
Gangopadhyay, Maeda, Singh et al. 2023, ApJ,under revision

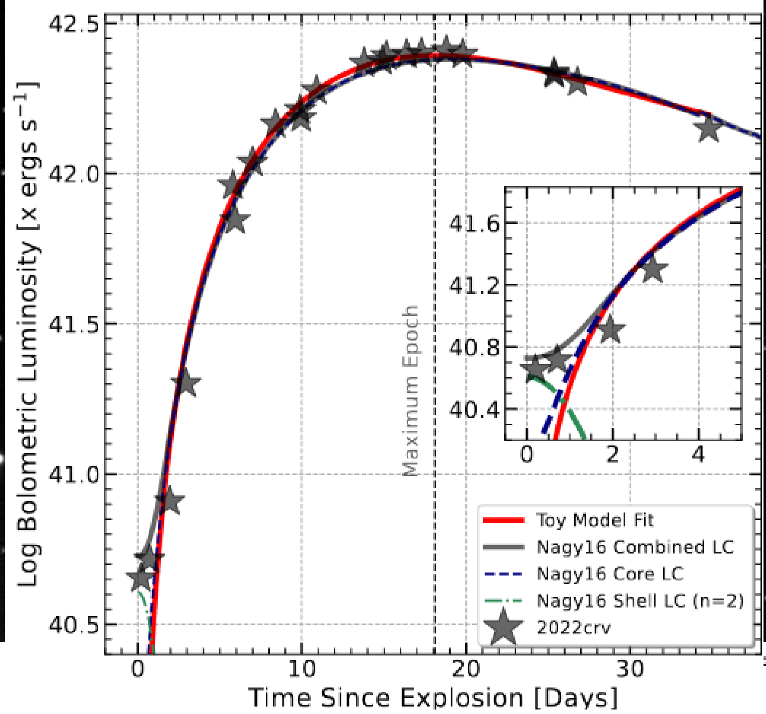


Absolute magnitude & Bolometric light curves:



- The V-band absolute magnitude of the SE-SNe group typically lies between −16.5 mag to −19.5 mag. Our obtained Mv =-17.82±0.17 mag are consistent with SN IIb (−17.40±0.55 mag), but are brighter than the average SN Ib (−17.07±0.56 mag).





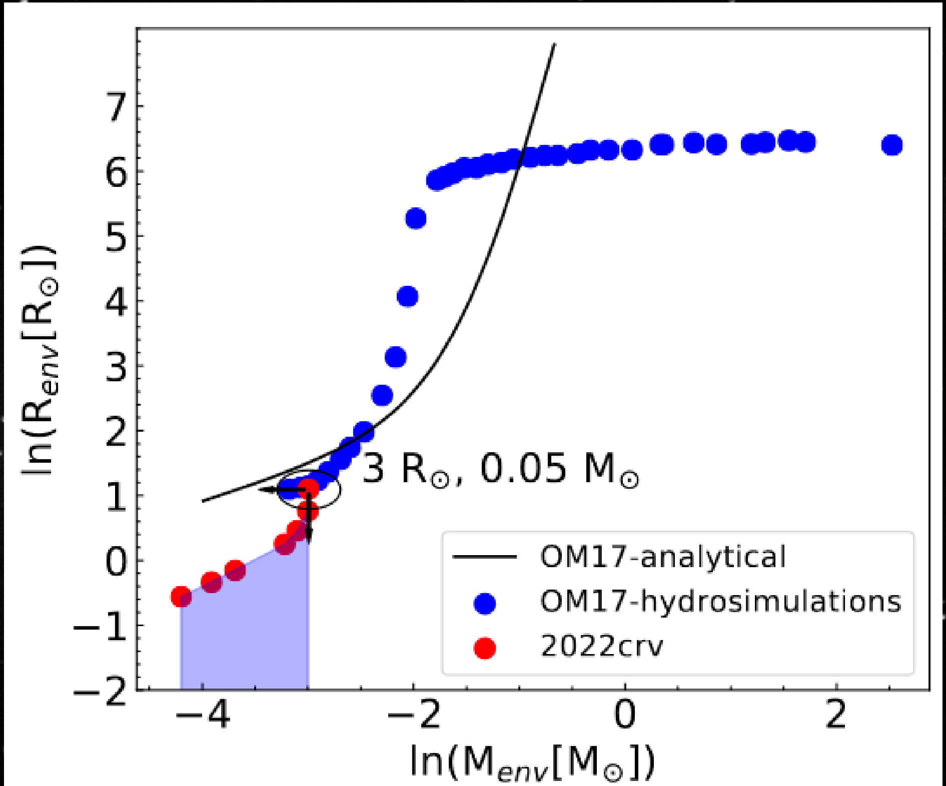
Bolometric light curve modelling :

	(K=0.06 cm^2 g^{-1})	(K=0.24 cm^2 g^{-1})	Remarks
R_0(cm)	0.2 x 10^{11}	0.27 x 10^{12}	Initial radius of the ejecta
$T_{rec}(K)$	5500	0	Recombination Temperature
$M_{ej}(M_\odot)$	3.9	0.015	Ejecta mass
$M_{Ni}(M_\odot)$	0.112	0.0	Nickel mass
E_{Th}	0.7	0.05	Thermal energy
E_{Kin}	3.4	0.30	Kinetic energy

- Two component ejecta configuration : Extended H-rich outer envelope and denser, compact He-rich core.

With the assumption that the outer layer retained some H (Arnett & Fu 1989), = 0.4 cm^2 gm^{-1} is selected as the Thompson scattering opacity for this layer, while the core is assumed to be composed only by He, and has = 0.24 cm^{2}g^{-1}

Estimating radius-mass limits of the progenitor space:



Ouchi & Maeda (2017) calculated a grid of binary evolution models for a SNe IIb that have extended progenitors. They derived an observational relation between the progenitor radii and estimated the envelope mass as a consequence of non-conservative mass transfer in the final phase of progenitor evolution.

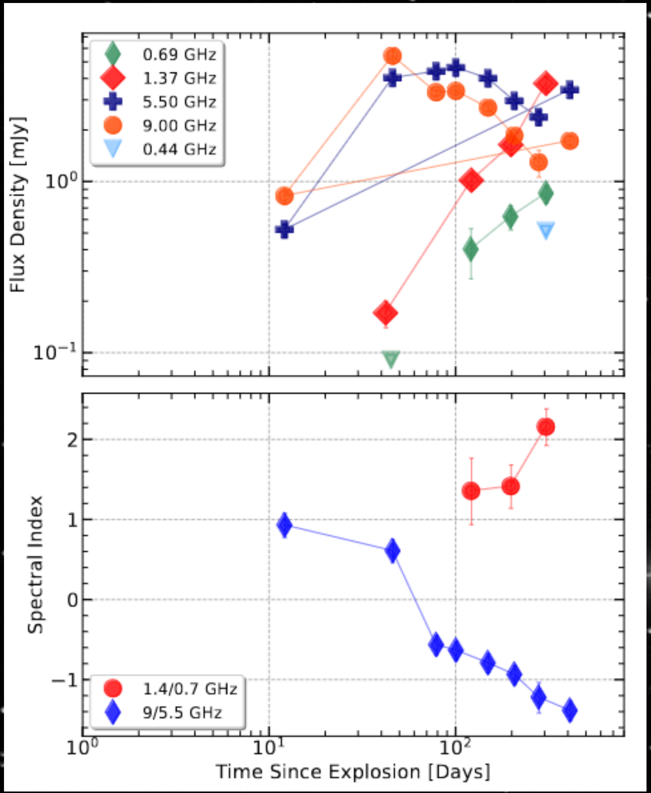
We used the Nagy and Vinko model to estimate an allowed range of radius for which we could estimate the envelope masses. We found that our progenitor is quite compact with the limits on the R_{env} , M_{env} to be 3 $R_\odot$, 0.05 $M_\odot$ respectively. However, we want to remark that this estimates are limits because large uncertainty is involved in the first point. The low-estimated value of Hydrogen envelope mass suggests that even Hydrogen is present for this SN in the early times, it was thin and quickly diminished than other SNe IIb.

NGC 3054 SN 2022 crv

Radio observations:

Date of Observation	JD	Age[a]	Frequency (GHz)	Flux density[b] (mJy)
		uGMRT		
2022 Mar 31.58	2459670.08	+42.33	1.37	0.17 ± 0.03
2022 Apr 03.54	2459673.04	+45.29	0.69	< 0.09
2022 Jun 18.35	2459748.85	+121.10	0.69	0.40 ± 0.13
2022 Jun 19.47	2459749.97	+122.22	1.37	1.01 ± 0.11
2022 Sep 03.30	2459825.80	+198.05	0.69	0.62 ± 0.10
2022 Sep 04.26	2459826.76	+199.01	1.37	1.63 ± 0.19
2022 Dec 20.87	2459934.37	+306.62	1.37	3.72 ± 0.38
2022 Dec 20.96	2459934.46	+306.71	0.69	0.85 ± 0.10
2022 Dec 21.04	2459934.54	+306.79	0.44	< 0.51
		ATCA		
2022 Mar 01.4	2459639.90	+12.15	5.5 (GHz)	0.52 ± 0.04
2022 Apr 04.4	2459673.90	+46.15	5.5 (GHz)	4.01 ± 0.24
2022 May 07.3	2459706.80	+79.05	5.5 (GHz)	4.37 ± 0.20
2022 May 29.2	2459728.70	+100.95	5.5 (GHz)	4.60 ± 0.12
2022 Jul 17.1	2459777.60	+149.85	5.5 (GHz)	3.98 ± 0.08
2022 Sep 12.9	2459835.40	+207.65	5.5 (GHz)	2.94 ± 0.06
2022 Nov 24.6	2459908.10	+280.35	5.5 (GHz)	2.36 ± 0.22
2023 Apr 05.4	2460039.90	+412.15	5.5 (GHz)	3.41 ± 0.09
2022 Mar 01.4	2459639.90	+12.15	9.0 (GHz)	0.82 ± 0.09
2022 Apr 04.4	2459673.90	+46.15	9.0 (GHz)	5.40 ± 0.56
2022 May 07.3	2459706.80	+79.05	9.0 (GHz)	3.30 ± 0.12
2022 May 29.2	2459728.70	+100.95	9.0 (GHz)	3.36 ± 0.08
2022 Jul 17.1	2459777.60	+149.85	9.0 (GHz)	2.69 ± 0.11
2022 Sep 12.9	2459835.40	+207.65	9.0 (GHz)	1.85 ± 0.07
2022 Nov 24.6	2459908.10	+280.35	9.0 (GHz)	1.29 ± 0.23
2023 Apr 05.4	2460039.90	+412.15	9.0 (GHz)	1.72 ± 0.11

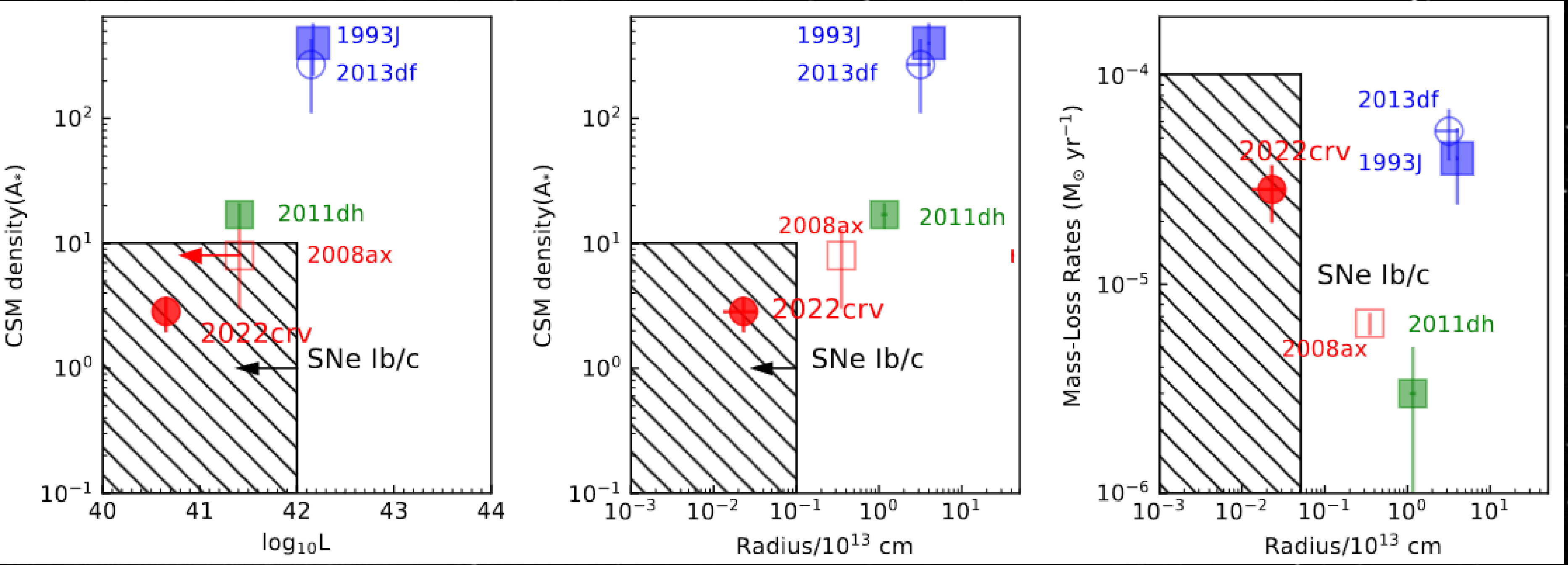
- uGMRT observations were carried out. The observations were done in band-3 (250−500 MHz), band-4 (550−950 MHz) and band-5 (1050−1450 MHz).



The near-simultaneous spectral indices between 1.37 and 0.69 GHz are 1.38±0.50, 1.45±0.29 and 2.15 ±0.23 at t ~ 120, 197 and 305 days, respectively. These are flatter than (5/2), indicating inhomogeneties in the magnetic field or relativistic electron distribution in the emitting region.

NGC 3054 SN 2022 crv

An adaptation from Maeda et al. 2015



Comparatively compact progenitor
Fairly luminous
We see a fairly compact progenitor
Bridging the gap ???

Mass-loss rates ~

NGC 3054 SN 2022 crv

Summary

- SN IIb with very thin Halpha, prominent Halpha changing to Helium within few days.
- A very compact progenitor, with a upper limit of 3 Msun.
- LInked by a continuity of hydrogen layer
- No interaction si ... on

Why ??? The possible answers to this question could be:

- If the CSM is present but not super dense, then signatures in optical become challenging to discern, or it shows up at later stages due to inhomogeneities.
- The interaction signatures in thin less dense shell will be absorbed completely in optical,
- The estimated mass loss rate from radio observation is 10^{-5}, which is also not so high.
- At the same time, we see that the optical light curves are highly powered by the radioactive decay of Iron group elements synthesized in the explosion.
- Moreover, the star must have been massive and compact if the optical luminosity is overwhelmingly dominated by radioactive decay.

Future work with Seimei: (In collaboration with Avinash Singh, Miho Kawabata, Kenta Taguchi, Masayuki Yamanaka)

- Estimating Metallicities of Host Environments of Core-Collapse Supernovae

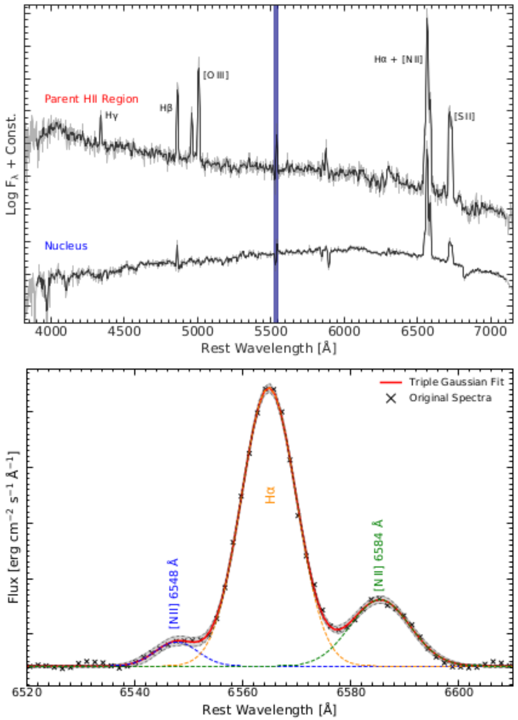


Figure 1: *Top panel*: **Spectrum of the nucleus of the host galaxy NGC 2276 and the parent H ii region of SN 2016gfy**. *Bottom panel*: A triple Gaussian fit is performed on the H α emission line blend with the [N II] doublet.

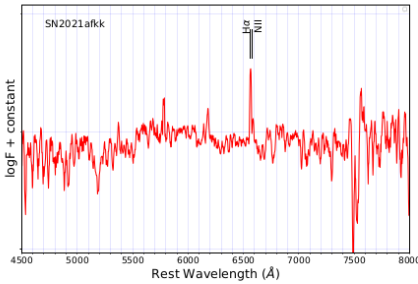


Figure 2: The spectra of SN 2021afkk taken on 19-10-2022 using KOOLS-IFU (VPH6) using an integration time of 15 mins. The blue part of the obtained spectrum is quite noisy, but, we could trace distinct Hα and N II in the obtained spectrum which we use as a tracer of metallicity estimates.

A glimpse of people at work during Kanata Mirror alumnizing work!

The picture perfect Hiroshima

Courtesy : https://www.thetravel.com/pics-of-what-hiroshima-looks-like-today/

Questions, Suggestions are welcome !!!