Tenth International Fermi Symposium

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SN 2016iyc: A Type IIb supernova arising from a low-mass progenitor

Amar Aryan*

Shashi B. Pandey, WeiKang Zheng, Alexei V. Filippenko, Jozsef Vinko, Ryoma Ouchi et al. 2022.
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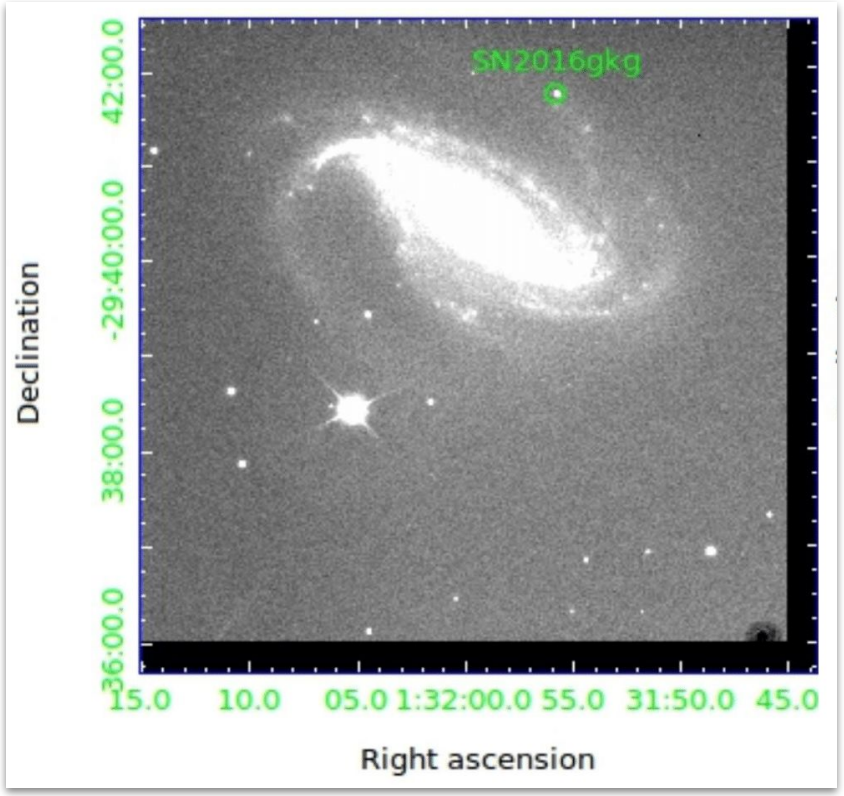
*amar@aries.res.in and amararyan941@gmail.com

What are Supernovae (SNe)

- The bright explosions that mark the death of stars.
- Death of stars : Brief and Dynamic.
- Responsible for the enrichment of the universe.

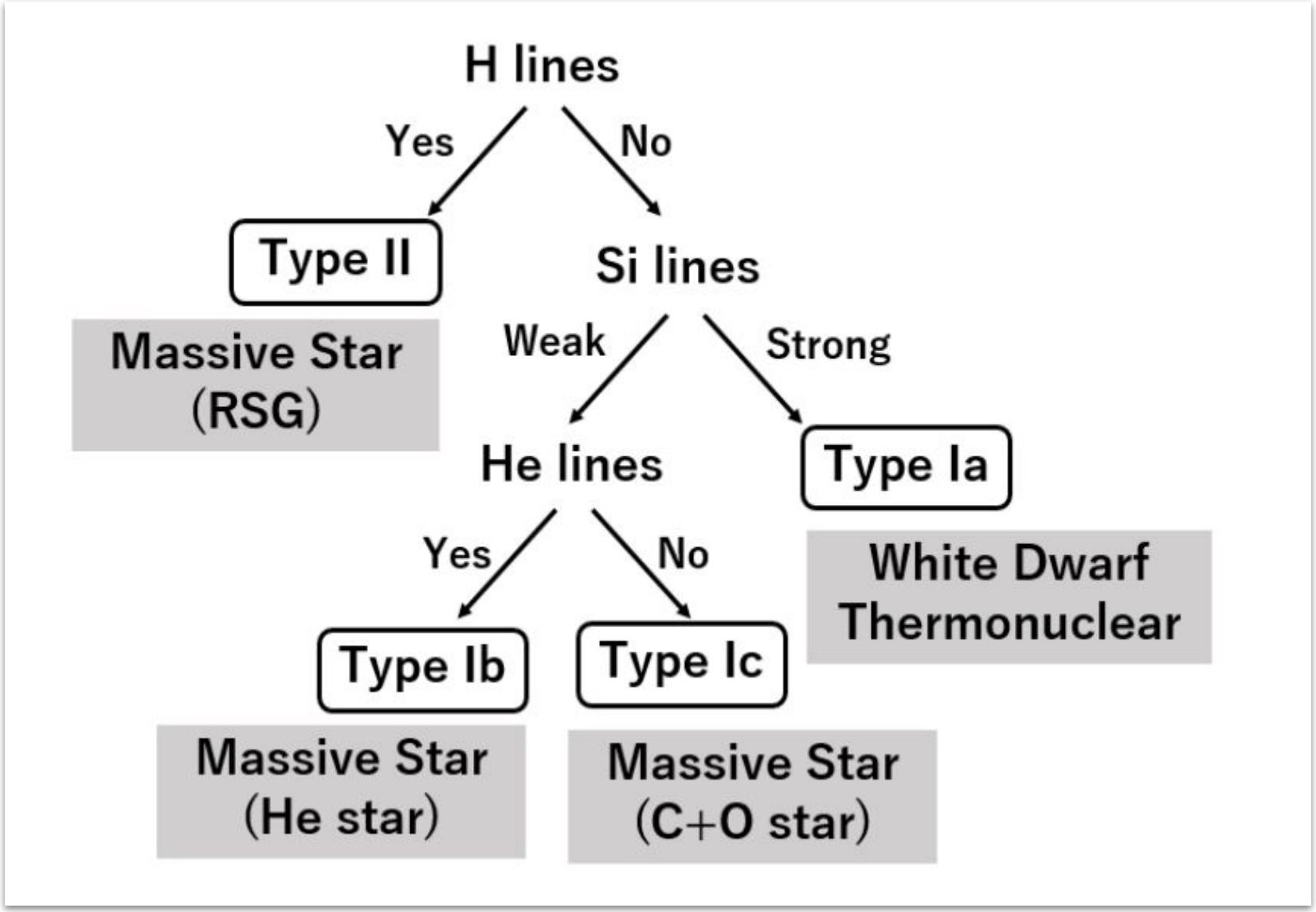
Left behind are :

- SN remnant : Shell of the exploding star
- Birth of compact objects, eg., Neutron Stars and Black Holes.



SN 2016gkg images from 3.6m DOT at ARIES

Well celebrated SNe Classification on the Basis of Spectra



H lines

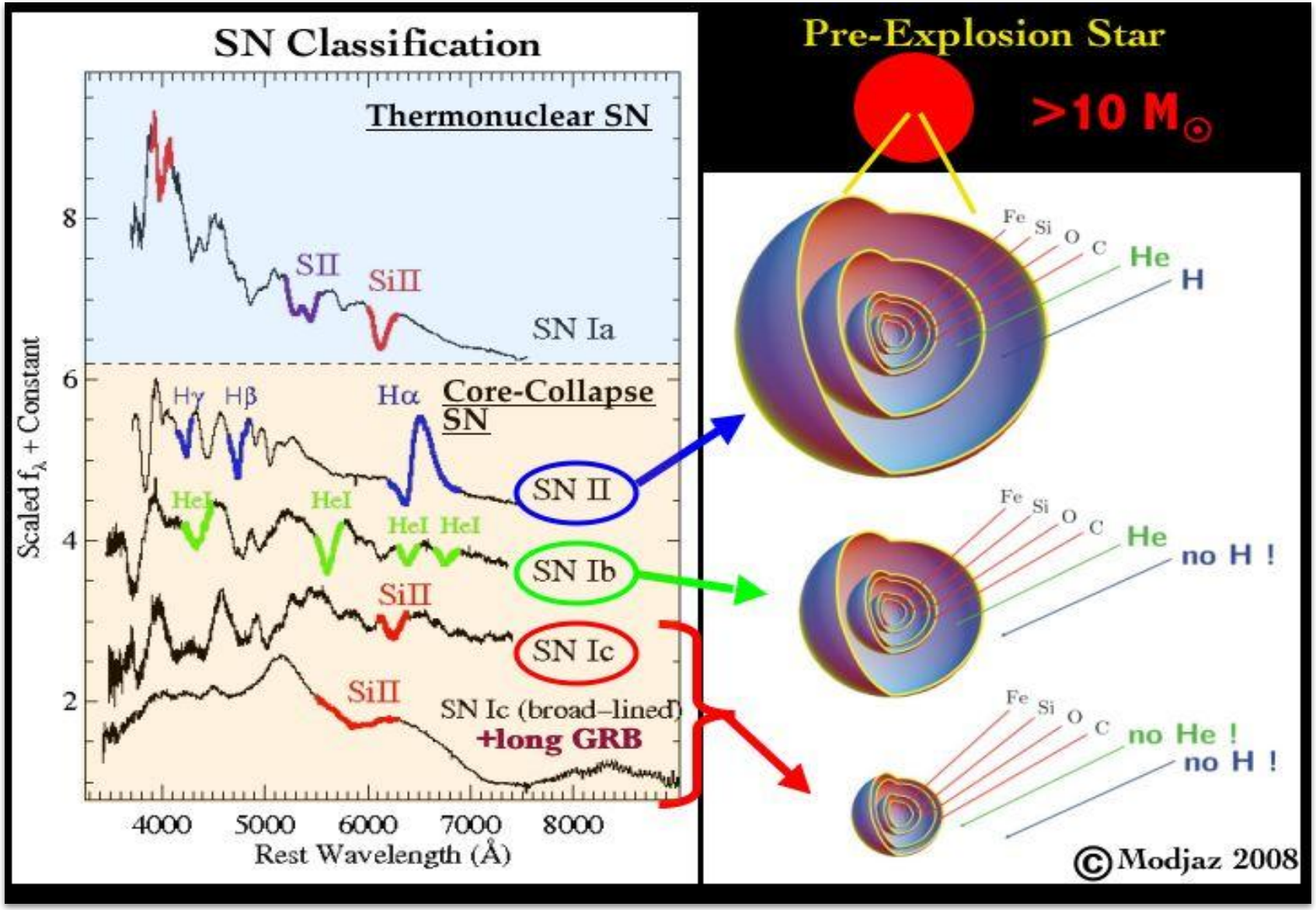
↓ eh…

Type IIb

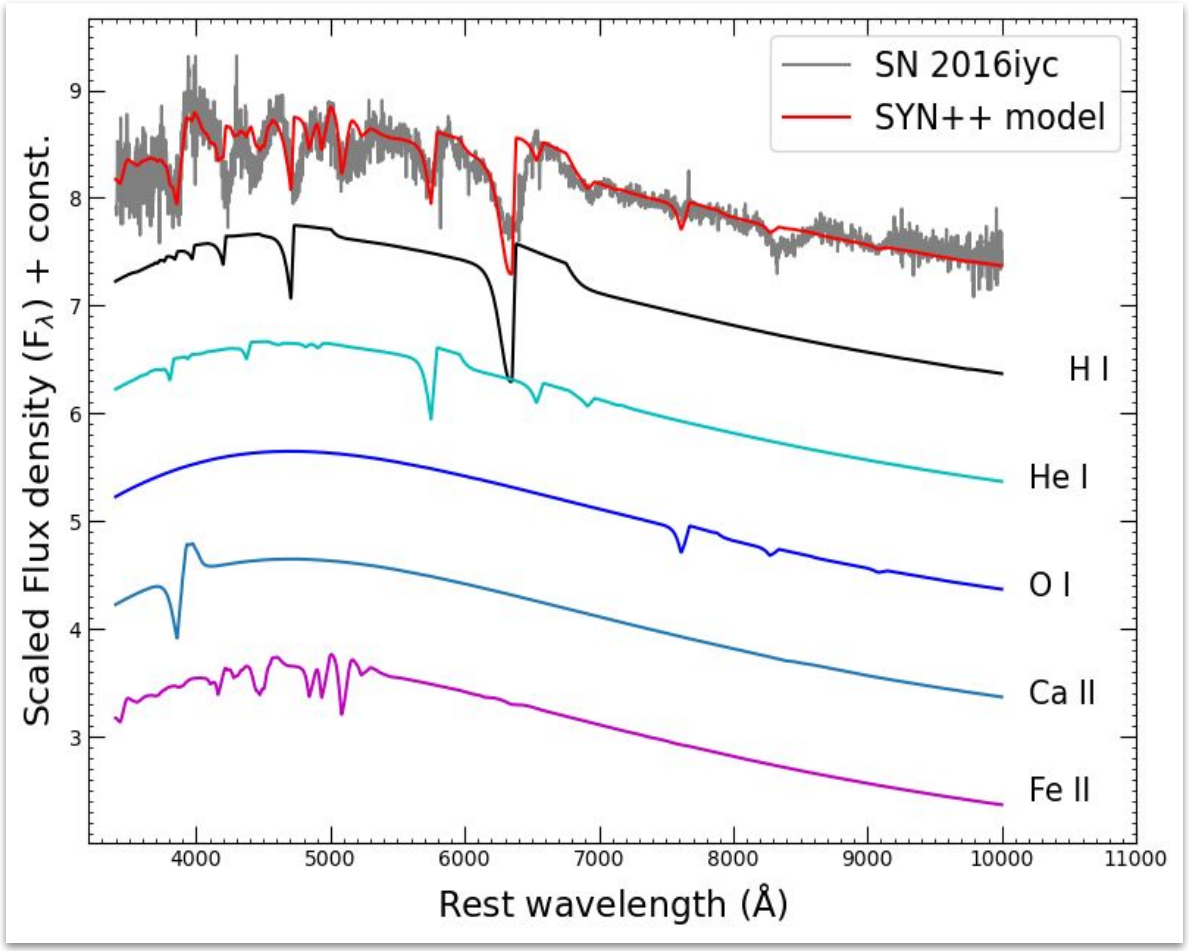
Massive WRs / Extended YSG

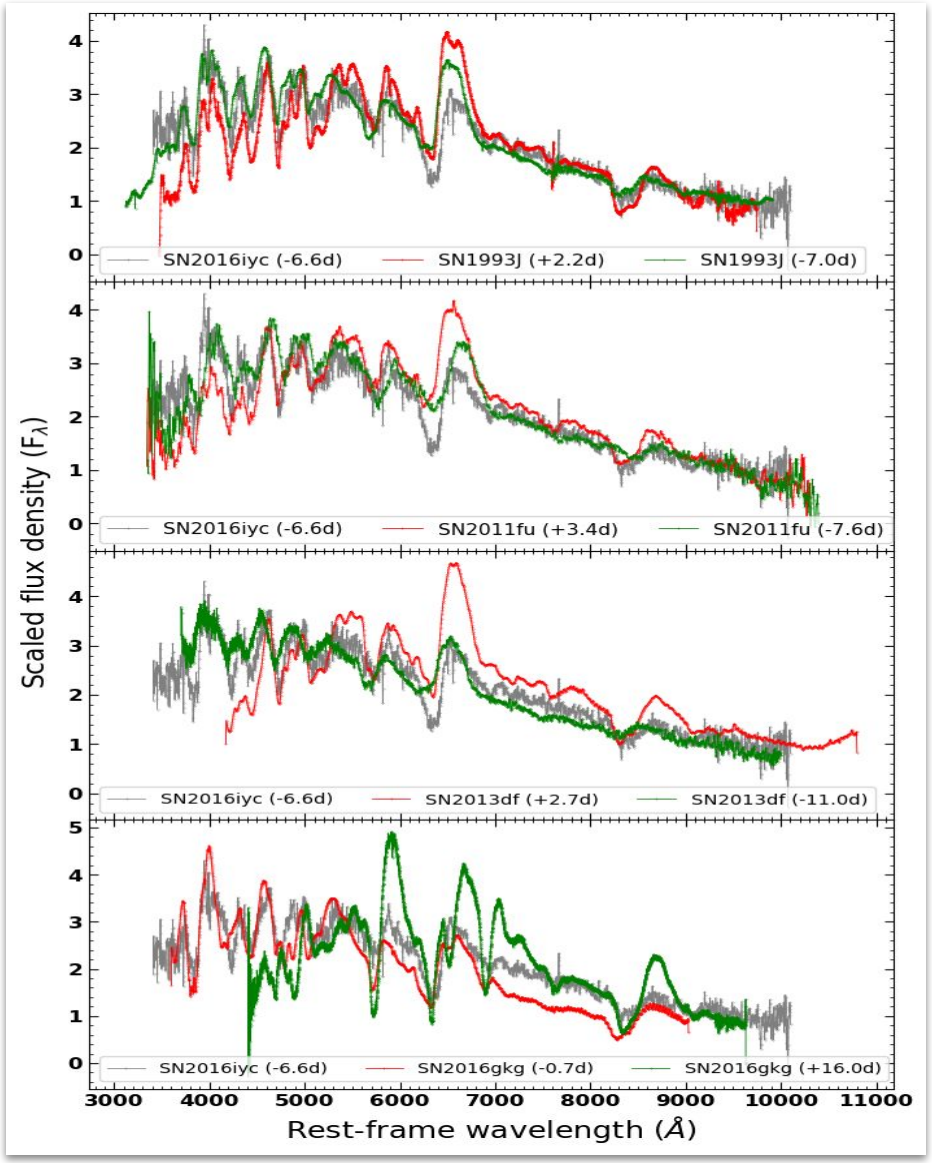
Source: *Maeda 2022*

Why do few elements show strong presence or absence in particular SNe spectra???



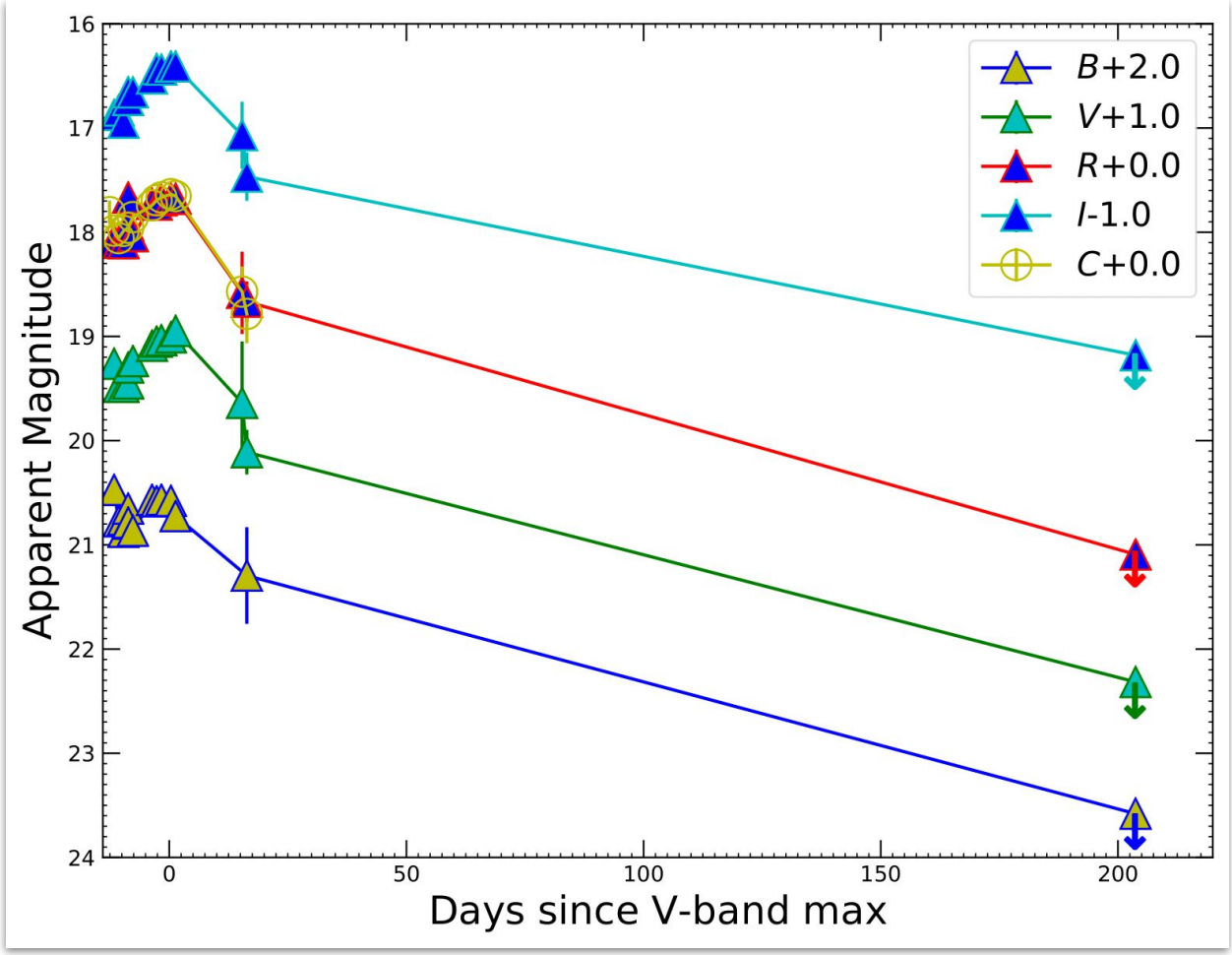
SN 2016iyc: Spectral Properties

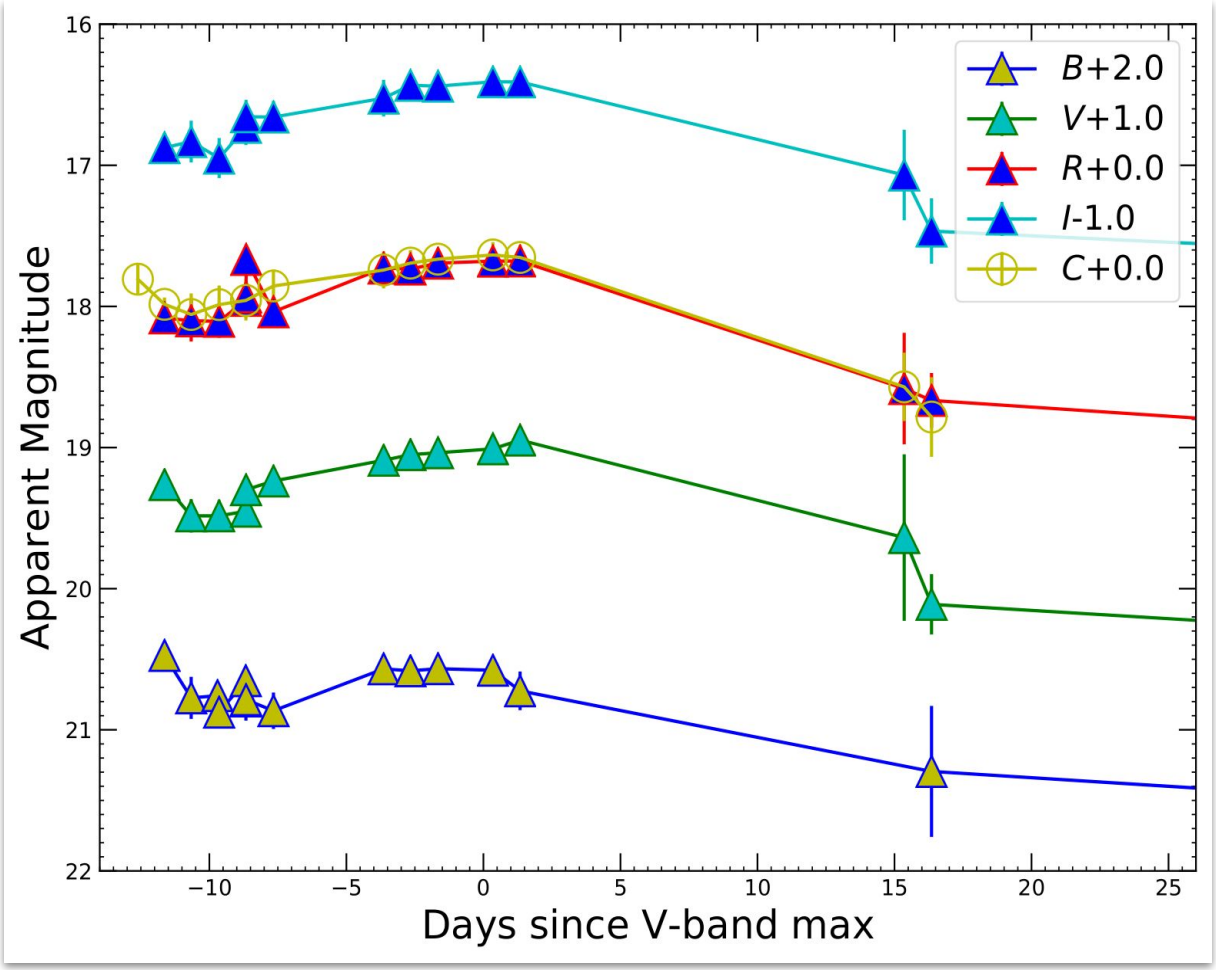




***Left*:** Spectral modelling, ***Right*:** Spectral comparison with similar Supernovae. **Source:** *Aryan et al. 2022, doi:10.1093/mnras/stac2326*

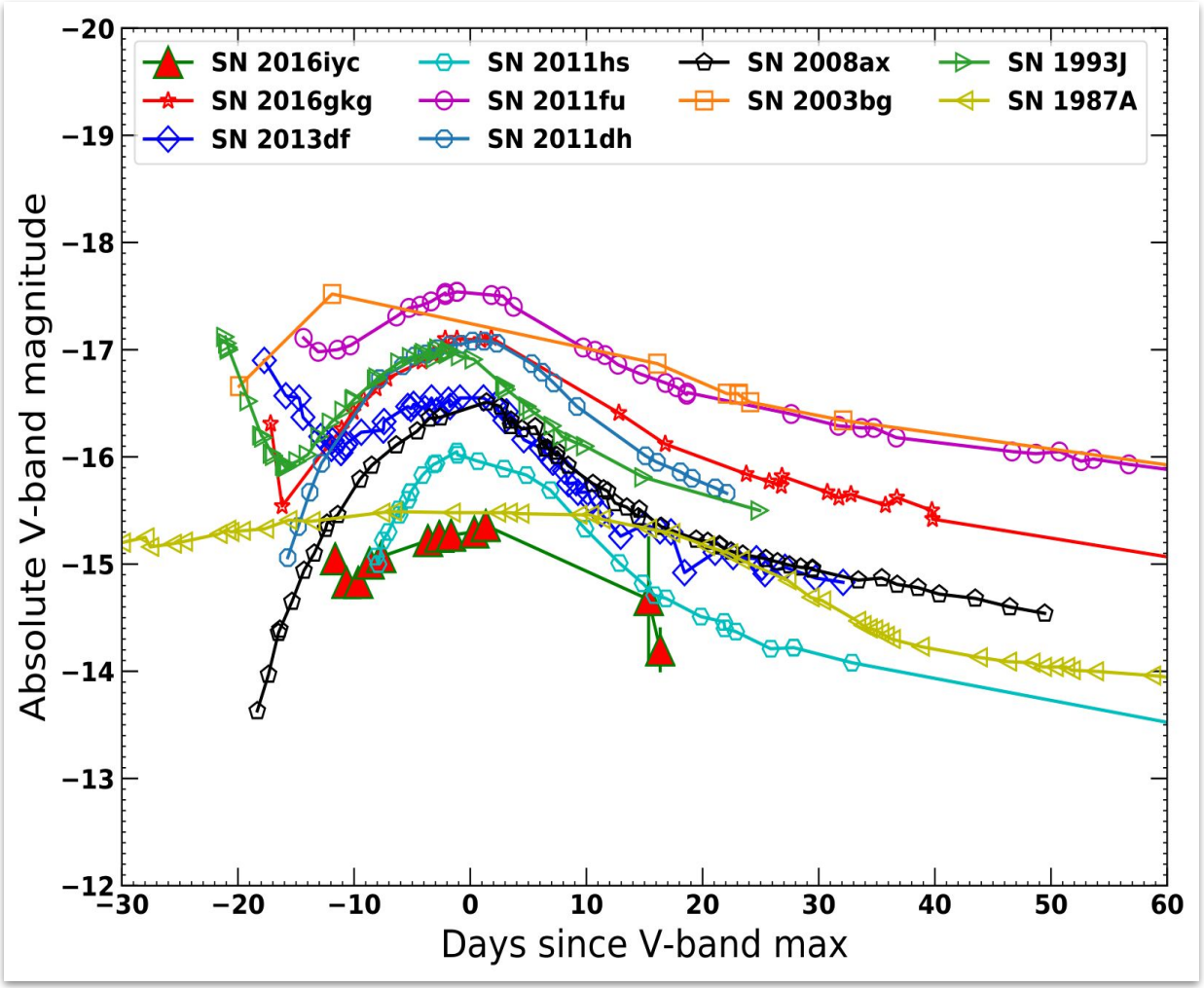
SN 2016iyc: Photometric Properties

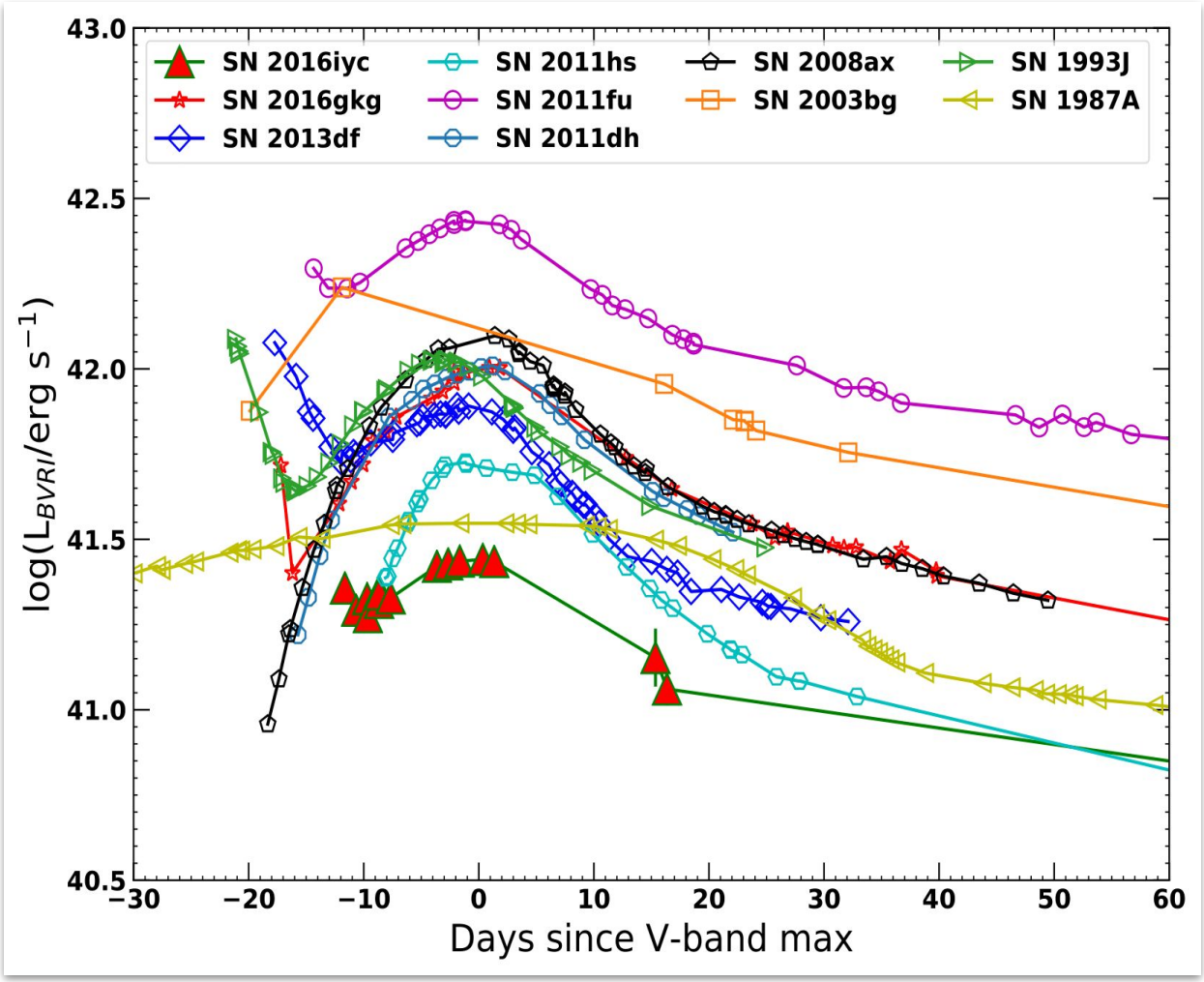




***Left*:** The *BV RI*- and *C*-band light curves of SN 2016iyc, obtained with **KAIT** along with the upper limits in each band using the **Las Cumbres Observatory** global telescope network, ***Right*:** Zooming in to early phases shows the generic extended-SBO feature of SNe IIb. **Source:** *Aryan et al. 2022.*

SN 2016iyc: Photometric Properties ...continued

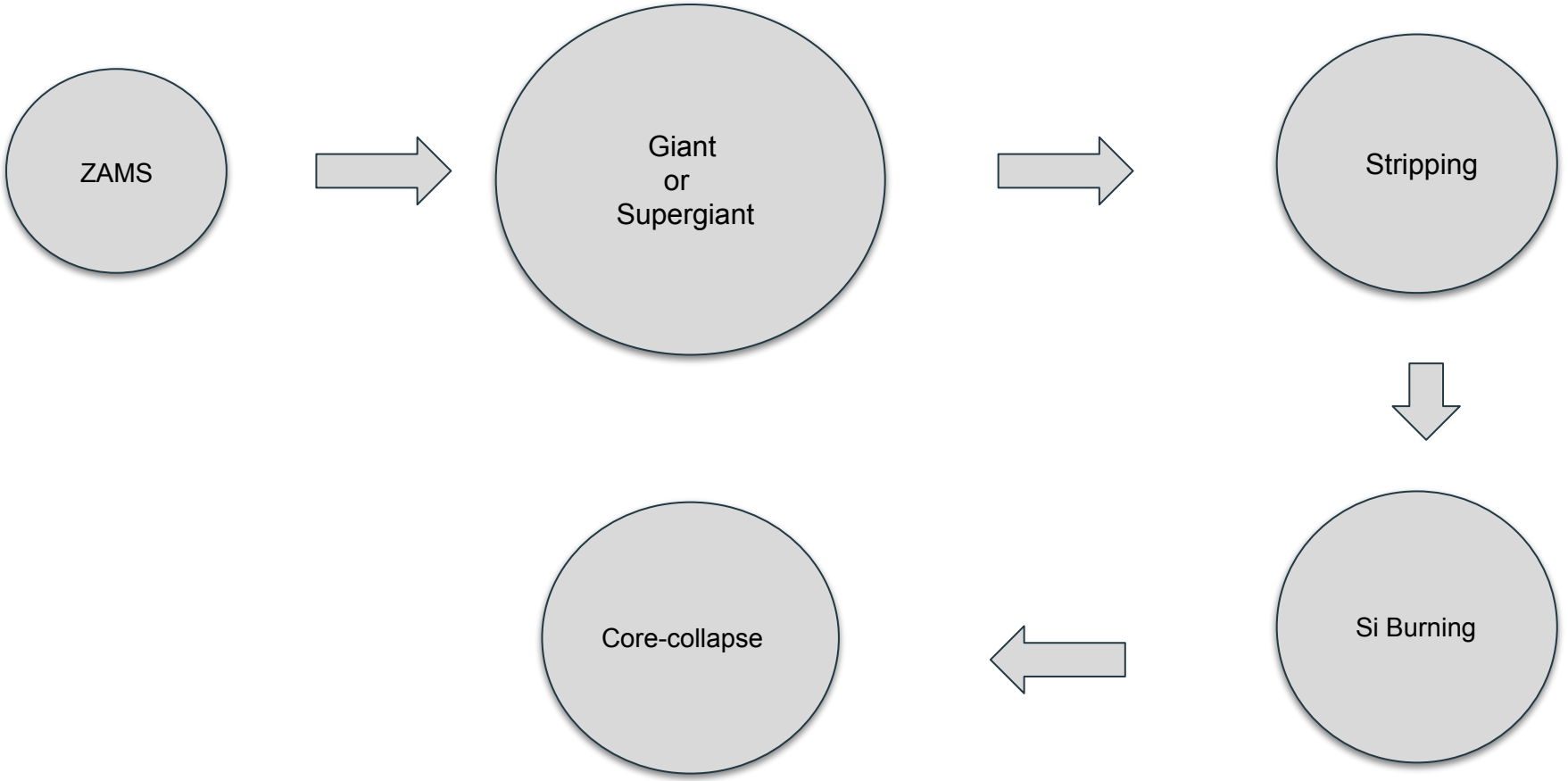




***Left*:** Comparison of the absolute V-band light curve of SN 2016iyc with similar SNe, ***Right*:** Comparison of the quasi-bolometric light curve of SN 2016iyc with similar SNe. **Source:** *Aryan et al. 2022.*

SN 2016iyc: Possible Progenitor Modelling using MESA[1]

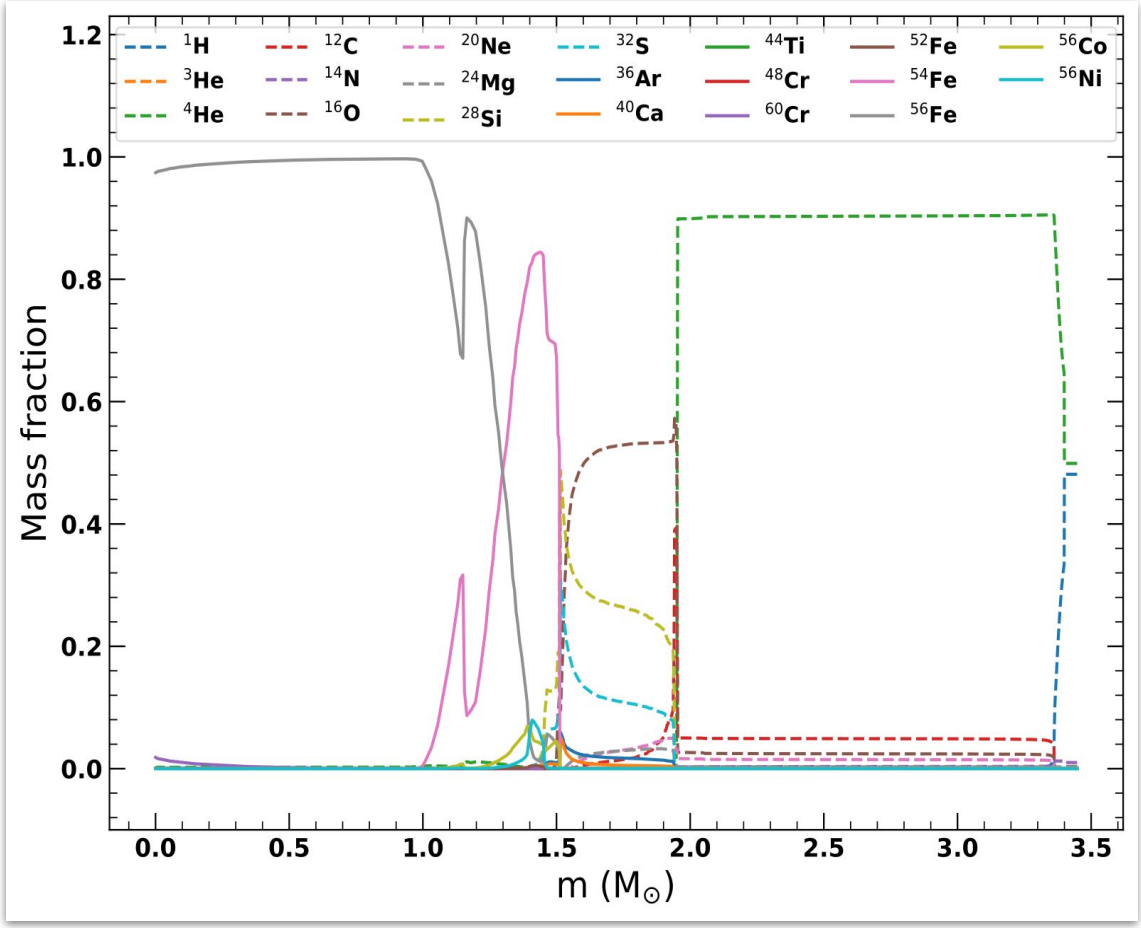
- Non-rotating, 9 - 14 $M_{\odot}$ ZAMS stars as possible progenitors
- Sub-solar, solar and super-solar metallicities
- Models evolve from ZAMS upto the stage of core-collapse

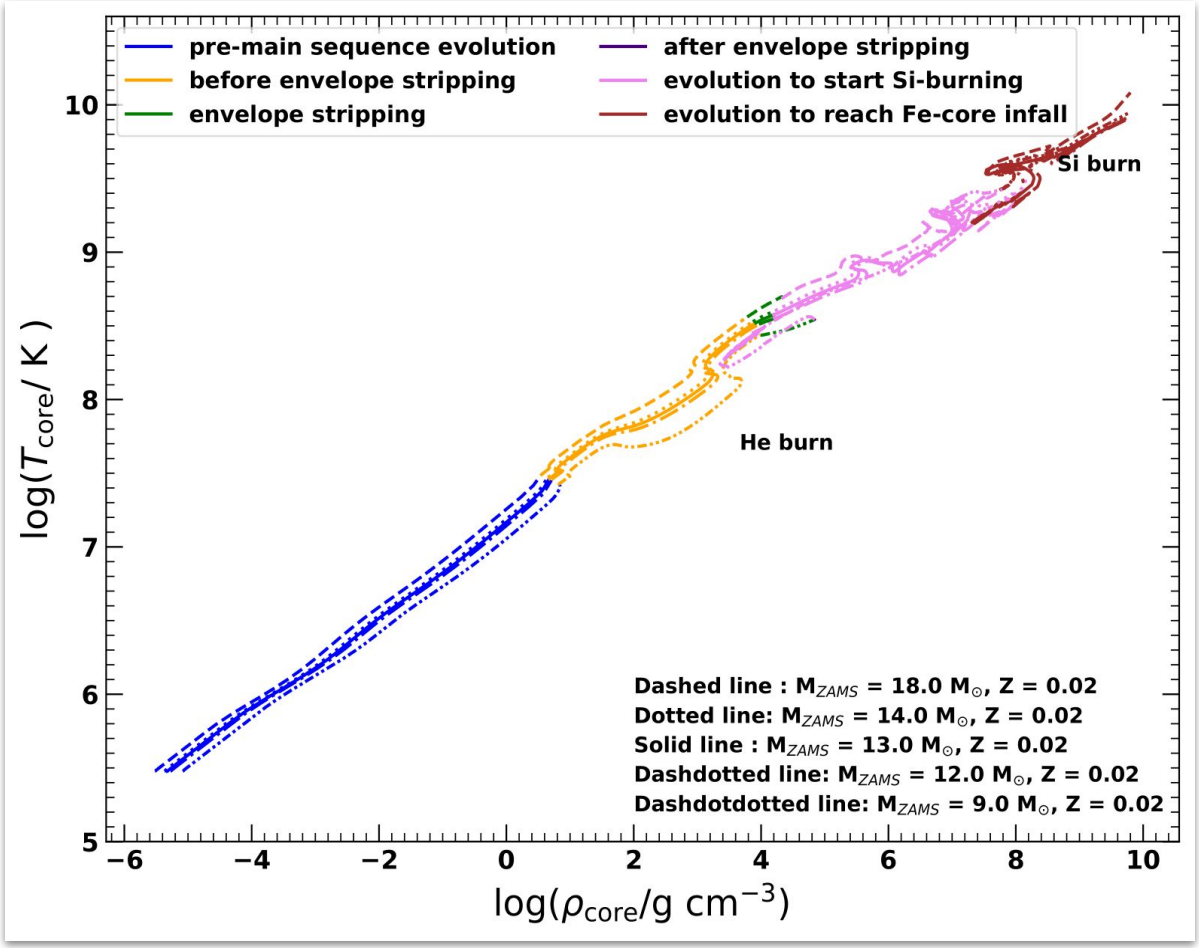


[1] https://docs.mesastar.org/

Various stages of evolutions

Chemical Compositions and Physical Properties of models at the beginning of core-collapse





Left: The mass fraction of various elements at the stage of the onset of core-collapse of a 12 $M_\odot$ ZAMS progenitor. ***Right***: The variation of core-temperature and core-density throughout the course of evolution upto core-collapse. **Source:** *Aryan et al. 2022.*

SN 2016iyc: Synthetic Explosions of Various Models Using SNEC[1] and STELLA[2]

Table 3. MESA model and STELLA/SNEC explosion parameters of various models for SN 2016iyc.

Model Name	$M_{\rm ZAMS}$ ($M_\odot$)	Z	$M_{\rm H}^a$ ($M_\odot$)	R_0^b ($R_\odot$)	f_{ov}^c	$M_{\rm f}^d$ ($M_\odot$)	$M_{\rm ci}^e$ ($M_\odot$)	$M_{\rm cf}^f$ ($M_\odot$)	$M_{\rm ej}^g$ ($M_\odot$)	$M_{\rm Ni}^h$ ($M_\odot$)	$E_{\rm exp}^i$ (10^{51} erg)
M9.0_Z0.0200_Mni0.034_E0.56	9.0	0.0200	0.013	0.14	0.007	2.17	1.4	1.4	0.77	0.034	0.56
M12.0_Z0.0215_Mni0.02_E0.33	12.0	0.0215	0.035	596	0.007	3.96	1.54	1.54	2.42	0.02	0.33
M12.0_Z0.0185_Mni0.03_E0.35	12.0	0.0185	0.055	315	0.007	3.49	1.46	1.46	2.03	0.03	0.35
M12.0_Z0.0200_Mni0.025_E0.35	12.0	0.0200	0.05	300	0.007	3.45	1.52	1.52	1.93	0.025	0.35
M12.0_Z0.0200_Mni0.09_E0.35	12.0	0.0200	0.05	300	0.007	3.45	1.52	1.52	1.93	0.09	0.35
M13.0_Z0.0200_Mni0.024_E0.28	13.0	0.0200	0.04	204	0.007	3.79	1.64	1.90	1.88	0.024	0.28
M13.0_Z0.0200_Mni0.01_E0.32	13.0	0.0200	0.04	204	0.007	3.79	1.64	1.64	2.15	0.01	0.32
M13.0_Z0.0185_Mni0.02_E0.35	13.0	0.0185	0.06	318	0.007	3.92	1.53	1.56	2.36	0.02	0.35
M13.0_Z0.0215_Mni0.03_E0.40	13.0	0.0215	0.015	10	0.007	3.81	1.61	1.62	2.19	0.03	0.40
M14.0_Z0.0200_Mni0.03_E0.50	14.0	0.0200	0.03	55	0.007	4.23	1.54	1.54	2.69	0.03	0.50

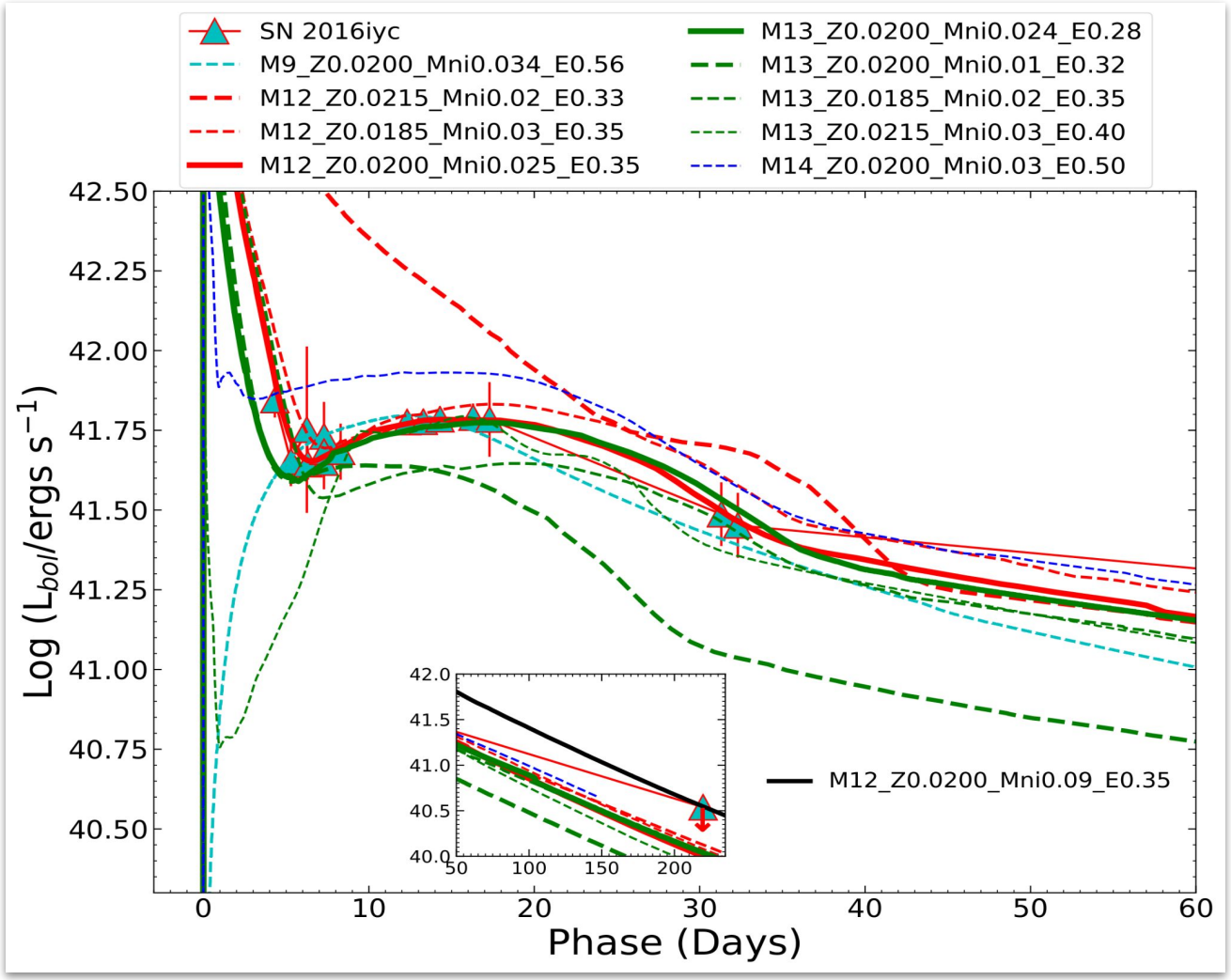
[a] Amount of hydrogen retained after stripping. [b]Pre-SN progenitor radius. [c]Overshoot parameter. [d]Final mass of pre-SN model. [e]Initial mass of the central remnant. [f]Final mass of the central remnant. [g]Ejecta mass. [h]Nickel mass. [i]Explosion energy.

Source : *Aryan et al. 2022*

[2] https://stellarcollapse.org/index.php/SNEC.html

[3] https://ascl.net/1108.013

SN2016iyc: Results of Synthetic Explosions



Source : *Aryan et al. 2022*

SN2016iyc: Outcomes of the Analyses

- SN 2016iyc lies near the faint end among the distribution of similar supernovae.
- The progenitor modelling using MESA and the synthetic explosions using SNEC and STELLA shows :

1. SN 2016iyc rises from a ZAMS progenitor of mass (12 – 13) $M_{\odot}$.

2. The progenitor has a pre-supernova radius of (240 – 300) $R_{\odot}$.

3. SN 2016iyc has an ejecta mass of (1.89 – 1.93) $M_{\odot}$.

4. SN 2016iyc has an explosion energy of (0.28 – 0.35) $\times 10^{51}$ erg.

5. SN 2016iyc synthesized no more than 0.09 $M_{\odot}$ of Nickel mass.

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Thank you for your attention!

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*amar@aries.res.in and amararyan941@gmail.com