The transitions in interacting supernovae

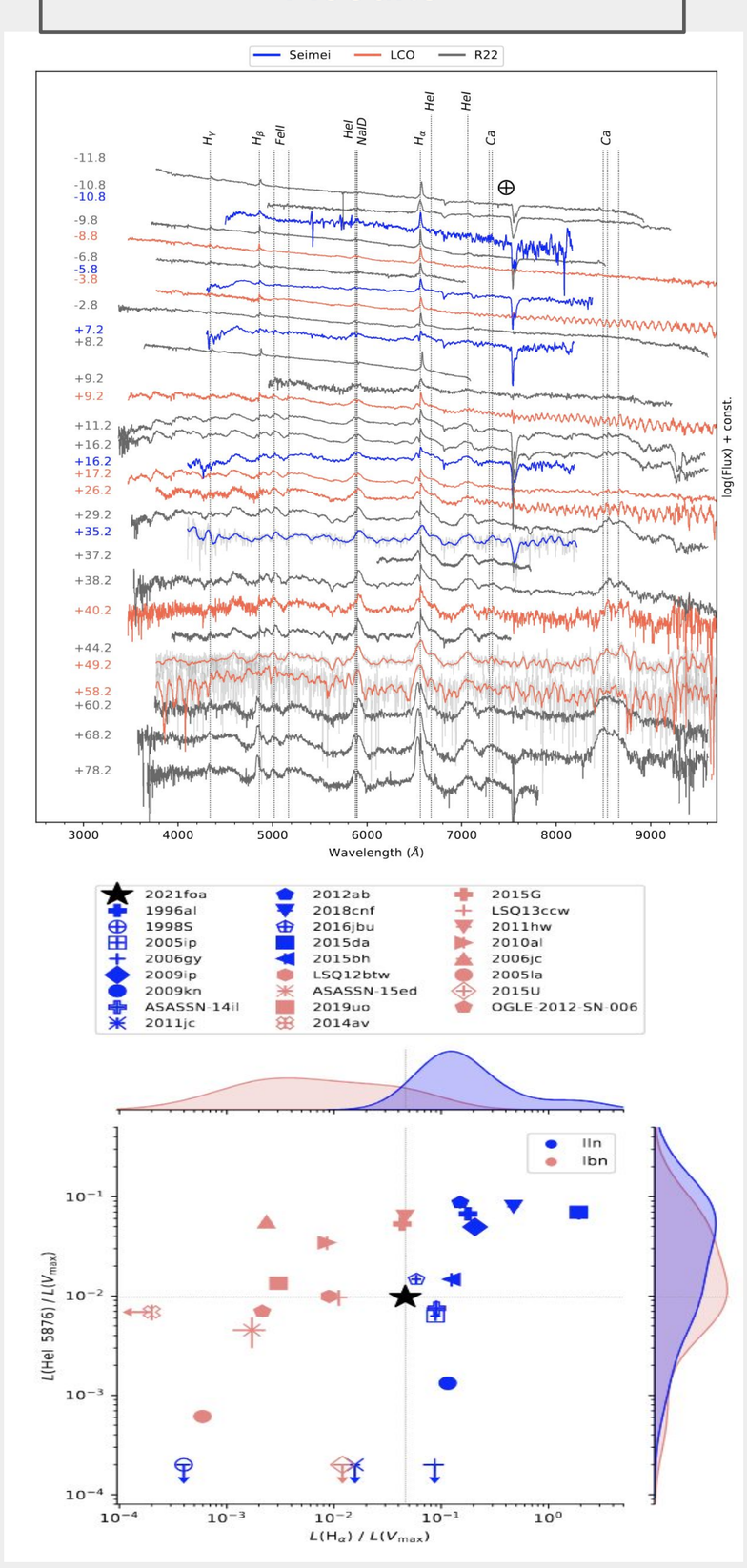
Anjasha Gangopadhyay[1], Jesper Sollerman[1], Naveen Dukiya[2], Keiichi Maeda[3], Konstantinos Tsalapatas[1], Takashi J. Moriya[4] et al.

1. Oskar Klein Centre, Department of Astronomy, Stockholm University, AlbaNova, SE-106 91 Stockholm, Sweden
2.Aryabhatta Research Institute of Observational Sciences, Manora Peak 263001, India
3.Department of Astronomy, Kyoto University, Kitashirakawa-Oiwake-cho, Sakyo-ku, Kyoto 606-8502, Japan
4.National Astronomical Observatory of Japan, National Institutes of Natural Sciences, 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan

Motivation & Basics

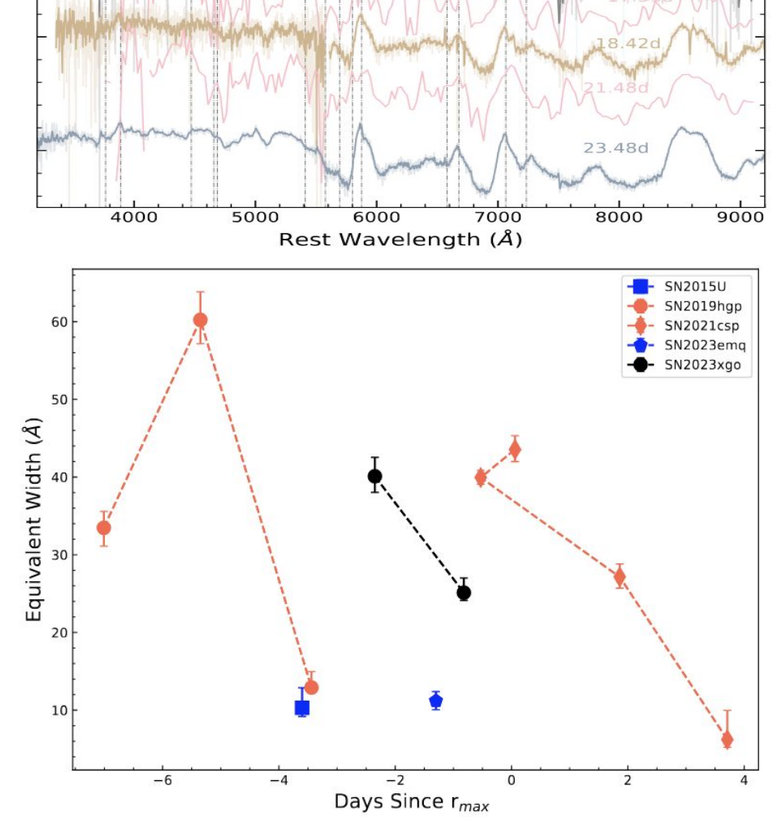
- **Traditional Type IIn, Ibn, Icn:** Narrow H, He and C,O emission lines due to interaction with dense circumstellar medium (CSM).
- **Transitions in 2021foa and 2023xgo:** SN 2021foa **(IIn→Ibn)** and SN 2023xgo **(Icn→Ibn)** trace sequential envelope stripping or composition changes in the progenitor, revealing a layered pre-SN mass-loss history.
- **Scientific importance:** Such events uniquely constrain the timing, geometry, and evolution of mass loss in the final years before core collapse, directly testing binary evolution and massive-star death models.

Results



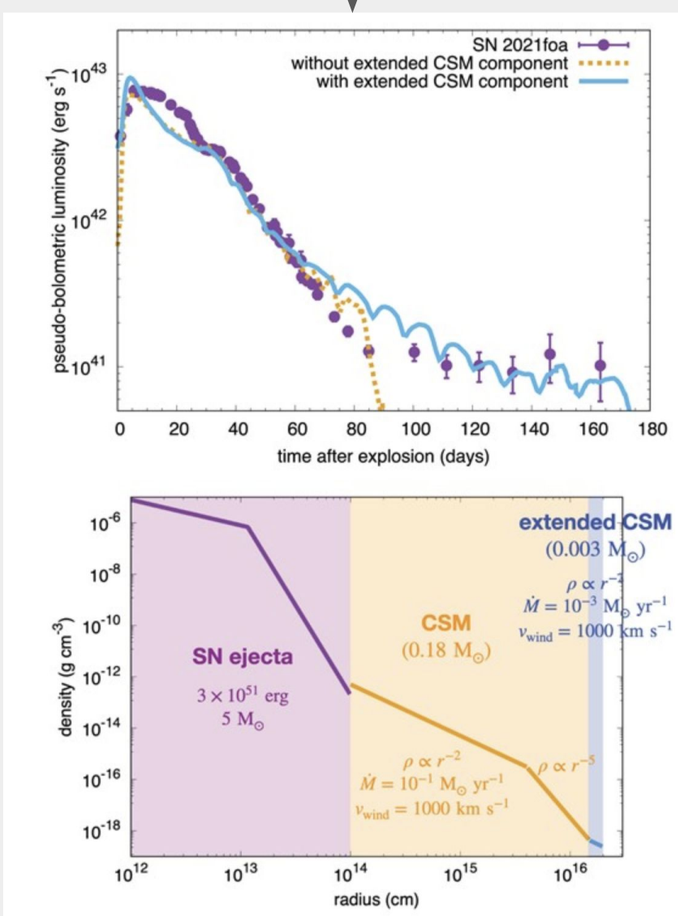
Upper panel of figure shows the complete spectral evolution of SN~2021foa which transitioned from IIn to Ibn.Around +17 d, both H and He shows equal strength. Lower panel of figure shows that it is H which governs the separation between the subclasses.

SN 2023xgo (Icn to Ibn)



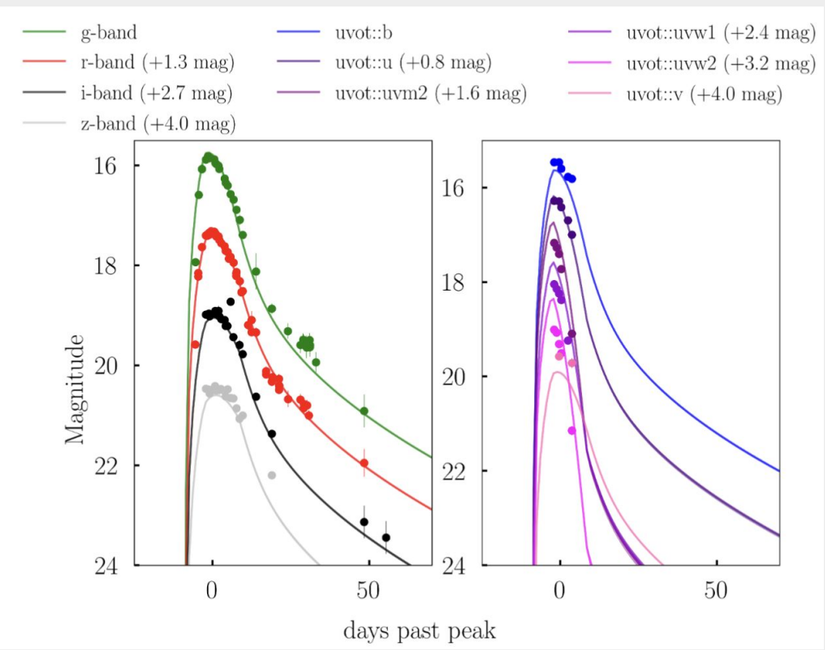
Upper panel of figure shows the complete spectral evolution of SN~2023xgo which transitioned from Icn to Ibn. Around +0.53 d, the spectrum becomes dominated by He lines. Lower panel of figure shows that the equivalent width of carbon is comparable to all other Icns at early phases.

SN 2021foa (IIn to Ibn)



Hydrodynamical lightcurve modelling of SN 2021foa which shows a multi-staged density structure in the lightcurve evolution, varying mass-loss rate and a CSM mass of 0.18 Mo.

Lightcurve and inference drawn



Parameters	Priors	Best fitted values
f_{Ni}	$\log \mathcal{U}$ [0.002, 0.6]	$0.324^{+0.001}_{-0.002}$
M_{ej} [$M_\odot$]	$\log \mathcal{U}$ [0.1, 15]	$0.1230^{+0.0002}_{-0.0002}$
$f_{Ni} \cdot M_{ej}$ [$M_\odot$]	$\log \mathcal{U}$ [0.001, 0.04]	$3.99^{+0.01}_{-0.03} \times 10^{-2}$
E_{kin} [erg]	$\log \mathcal{U}$ [5×10^{49}, 10^{52}]	$5.005^{+0.068}_{-0.037} \times 10^{49}$
M_{CSM} [$M_\odot$]	$\log \mathcal{U}$ [0.001, 15]	$22.147^{+0.003}_{-0.004} \times 10^{-2}$
T_{floor} [K]	$\log \mathcal{U}$ [10^2, 10^4]	$7127.0^{+90.6}_{-98.1}$
t_0 [MJD]	$\mathcal{U}$ [$t_{detection} - 6$, $t_{detection}$]	$60254.03^{+0.01}_{-0.01}$
η	$\mathcal{U}$ [0, 2]	$3.3^{+4.4}_{-2.4} \times 10^{-3}$
ρ [g cm^{-3}]	$\log \mathcal{U}$ [10^{-15}, 10^{-9}]	$4.8^{+0.1}_{-0.1} \times 10^{-12}$
r_0 [AU]	$\log \mathcal{U}$ [10^{-1}, 10^2]	$0.104^{+0.006}_{-0.003}$

Discussion

SN 2021foa (Gangopadhyay et al. 2025, MNRAS)

- **IIn↔Ibn bridge:** Early H-rich CSM (IIn-like) + strong He I (Ibn-like).
- **Lightcurve:** $\dot{M} \approx 10^{-3}$–10^{-1} $M_\odot$ yr^{-1}; M_CSM ≈ 0.18 $M_\odot$.
- **CSM**: Two-component, disk-like; extended.

SN 2023xgo (Gangopadhyay et al. 2025, under revision)

- **Ibn/Icn transition:** Early C III λ5696 (Icn-like) → Ibn features.
- **Lightcurve:** Low ejecta, CSM mass, very low Nickel mass.
- **CSM:** structured at two length scales.

Progenitor channels

- **Massive LBV→WR:** Dense, extended CSM (2021foa).
- **Low-mass He star (~3 M⊙):** Structured CSM (2023xgo).
- **Continuum:** Multiple IIn/Ibn/Icn evolutionary paths.

Scan here!

Gangopadhyay et al. 2025a, MNRAS
Gangopadhyay et al. 2025b, MNRAS