The multi-peaked light curve of SN 2021efd:
Probing the mass-loss histories of stripped-envelope supernova progenitors

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Introduction

Stripped-envelope (SE) supernovae (SN) are explosions of massive stars that have lost significant most of their outer layers

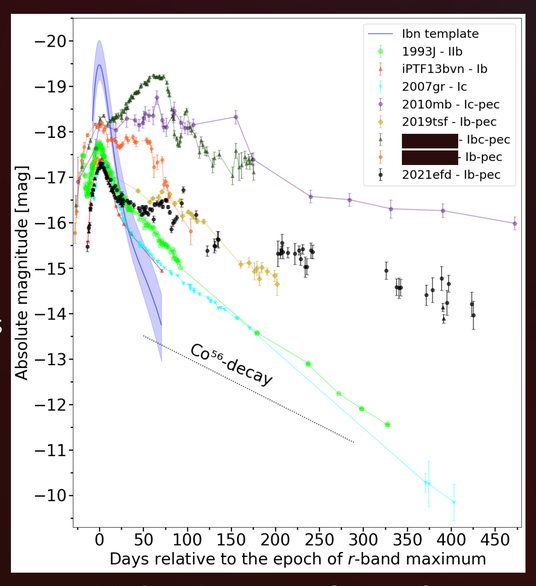
Hydrogen stripping in Type IIb/Ib progenitors is likely caused by binary interaction [1,2]

Helium layer stripping mechanism is unknown

Recently, many SESNe with peculiar light curves (LC) have been observed

They show excess late-time luminosity beyond ^{56}Ni and ^{56}Co decay

A common cause for this is interaction with circumstellar medium (CSM)



Light Curves of regular and peculiar SESNe

These SESNe can reaveal the mass-loss mechanisms behind the envelope stripping

Early spectra are usually similar to normal SESNe

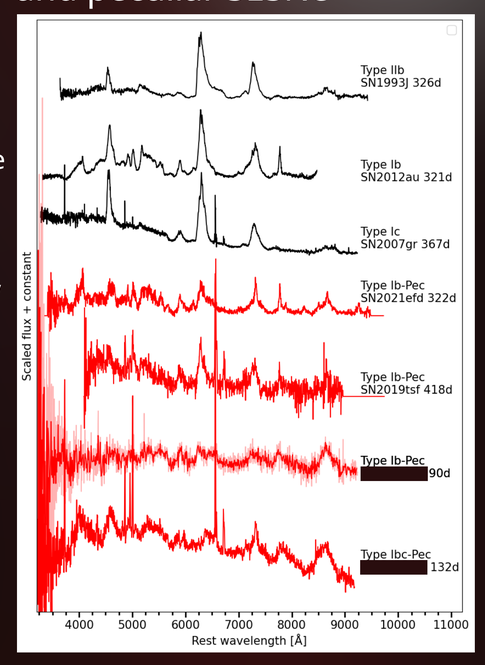
Some have narrow hydrogen lines, indicating interaction with H-rich CSM

In some interacting SESNe nebular spectroscopy can reveal peculiar features

- Narrow peaks on some lines

- Blue continuum excess

Nebular spectra of regular and peculiar SESNe



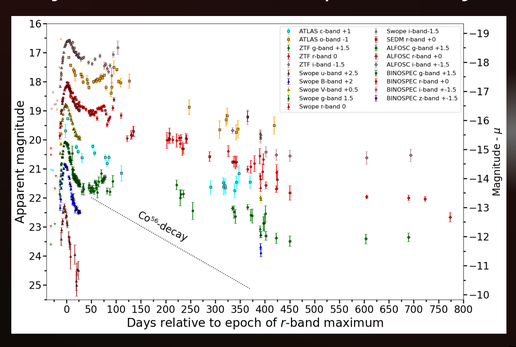
SN2021efd Pyykkinen et al. A&A 2026

The LC shows at least 3 peaks

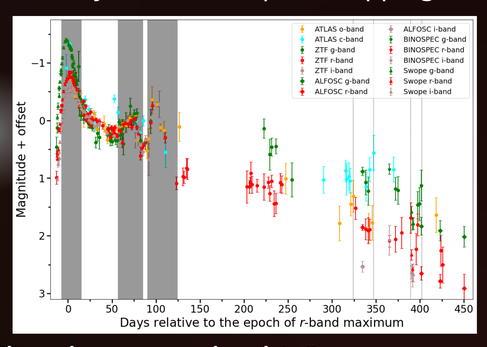
The first peak follows Typical Type Ib evolution and is likely mainly powered by ^{56}Ni decay

Around 30 days from the initial peak, the SN begins to show excess luminosity and eventually rises to two new peaks

LC decay is much slower than predicted by Co-56 decay even at complete trapping



LC of SN 2021efd

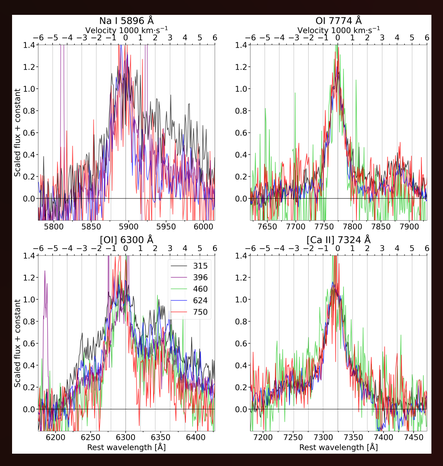


The three peaked LC structure of SN 2021efd

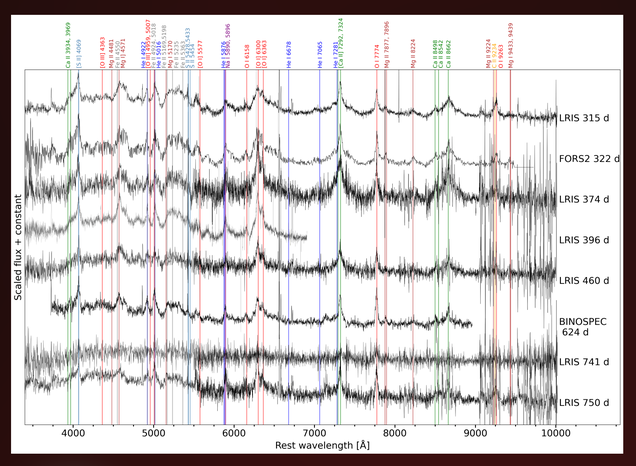
The early-time spectra and other features are normal for SESNe

Narrow components appear in both forbidden and permitted lines from multiple elements, which are only present in the ejecta

There is a blue continuum excess, which has been observed in other interacting SNe



Line profiles and velocities of SN 2021efd



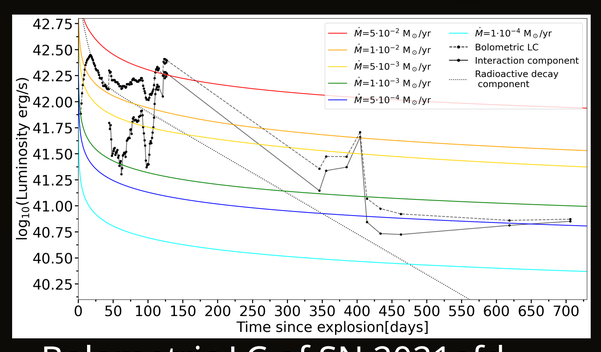
Nebular phase spectroscopy of SN 2021efd

We compare the bolometric light curve of SN 2021efd with semi-analytical interaction calculations [2]

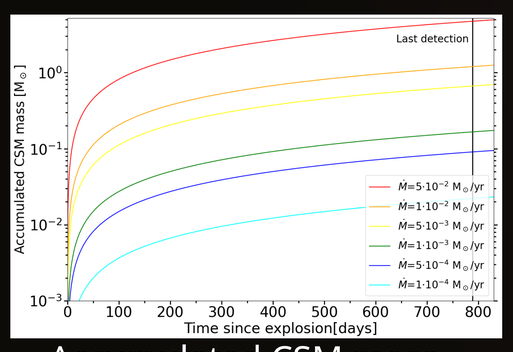
The models assume spherical mass-loss at a steady rate and wind velocity of 100km/s

We estimate a mass-loss rate around 10^{-3}-10^{-2} Ms/yr

The CSM mass accumulated by the ejecta during the observation period is at minimum several times 0.1 Ms



Bolometric LC of SN 2021efd compared to model LC



Accumulated CSM mass over time

The mass-lossrate is higher than expected of binary interaction [5]

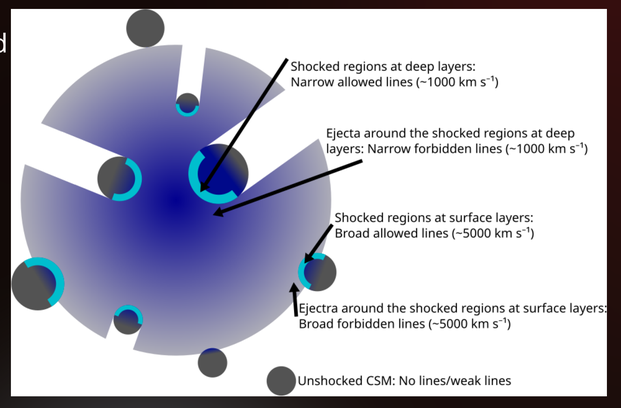
The CSM is likely He-rich as it should originate from the progenitor and the early spectra show He emission

- The mass-loss mechanism should be related to He-layer stripping in SESNe progenitors

The progenitor was likely surrounded by dense CSM clumps

This suggests episodic mass loss periods in the late-stage evolution of the progenitor

Inferred timescale of the He-layer stripping ~10^1-10^3 years



Schematic of the preferred interpretation of CSM distribution

References:
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Pyykkinen at al 2026,
The hydrogen-free circumstellar interaction in the Type Ib supernova 2021efd:
A clue to the mechanism of the helium-layer stripping

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