A thermonuclear supernova interacting with H- and He- deficient circumstellar material

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A SN Ia-CSM unlike others

SN 2020aeuh initially evolved as an ordinary SN Ia. A post-peak **classification spectrum** was best-matched to the **subtype Ia-91T**.

Surprisingly, during its decline a **rebrightening** resulted in a clear and separated **second peak**. The follow-up campaign revealed that the **powering mechanism** of this rebrightening was the **interaction** of the ejecta with circumstellar medium (CSM). **A second peak** in the light curve of a **SN Ia-CSM** is seen for the **first time** in the case of SN 2020aeuh.

However, the most **unique** feature of this explosion is the **composition** of the nearby **CSM**.

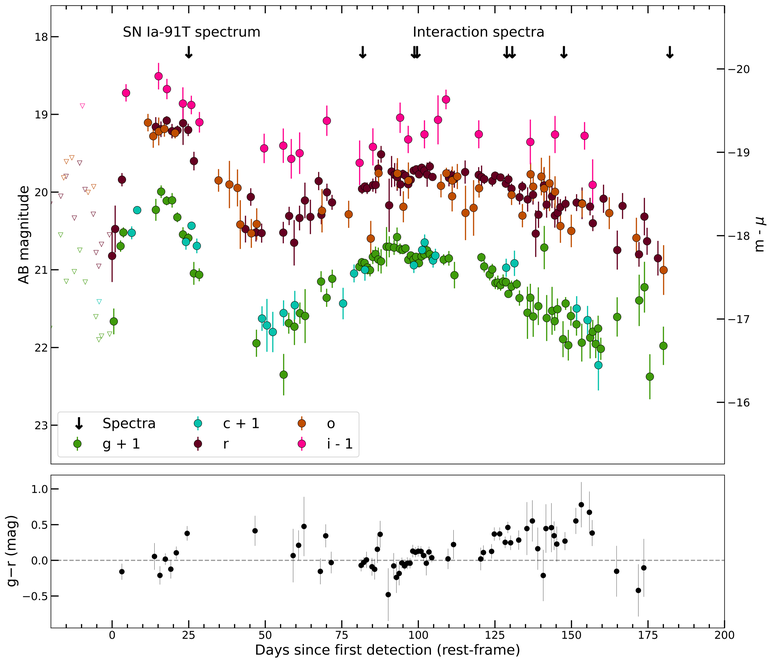

Figure 1. Light-curve and $g-r$ colour evolution of SN 2020aeuh. Corrected for MW extinction. Phases are in rest-frame days since first detection.

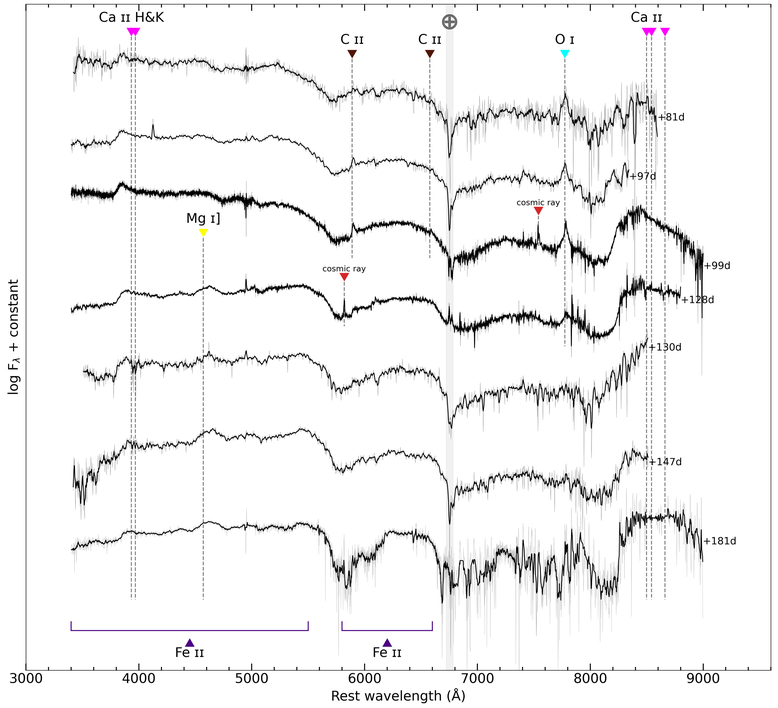

Figure 2. Spectral evolution of SN 2020aeuh during the interaction dominated phase.

Spectral evolution during the interaction dominated phase

SN 2020aeuh is **lacking** the narrow **hydrogen** lines that **characterise SNe Ia-CSM**. It is **also lacking** the narrow **helium** lines that was seen for a first time in the Ia-CSM SN 2020eyj.

The few **narrow lines** that **appear** in the spectral sequence are identified as **carbon** and **oxygen** lines. These lines have **never been seen** in any previous **SN Ia-CSM**.

Until now, the class of **Ia-CSM** has been the **best evidence** for the **existence** of the **single degenerate (SD) progenitor channel** for thermonuclear explosions. That is because in the **SD** channel, the white dwarf's **companion** is a **low/intermediate mass non-degenerate star**. Such **companions** can easily **produce hydrogen** or **helium rich CSM** through **stellar outflows** or **binary interaction** stripping.

Envisioning a SD scenario in the case of SN 2020aeuh is tricky due to the unusual composition of the CSM.

Fitting the second peak with an interaction model

The $\sim$ 100 d evolution of the second peak would require $\sim$ **70** $M_\odot$ of CSM **if photon diffusion** through **optically thick CSM** was responsible for the rebrightening, which is **unphysical**.

Instead, we used the Moriya (2023) model for CSM interaction. In their **prescription**, the **evolution timescale** is **dictated** by the **dynamical time-scale of the shock** crossing through the CSM. The fitting yielded **moderate amount of CSM** ($\sim 1-2$ $M_\odot$) with a density profile that is **increasing outwards** ($s \sim -1$).

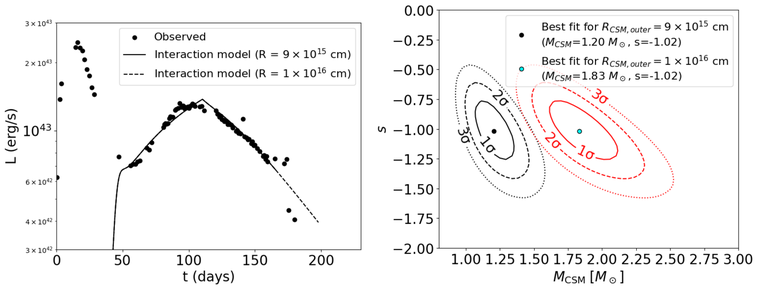

Figure 3. Best-fitted second peak of SN 2020aeuh (left panel) and confidence intervals in the free parameters' space (right panel).

Take-away points

- SN 2020aeuh is a unique Type Ia-CSM exploding in a **H, He poor medium.**
- The clear **rebrightening** is better explained through interaction with CSM which has a rising (outwards) density profile.
- The inferred, **moderate** $M_{CSM} \sim 1-2$ $M_\odot$ **does not confidently exclude** the single degenerate or the double degenerate channels.

References

Takashi J. Moriya. On the nature of slowly rising interaction-powered supernovae. , 524(4):5309–5313, October 2023. doi: 10.1093/mnras/stad2197.

Find the preprint

https://arxiv.org/abs/2507.08532

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