SN 2024ehs: A correlation between the strength and velocity of spectral lines in core-collapse supernovae

W. Sand Hellman, Stockholm University

Stockholms universitet

Context

The classification of supernovae (SNe) has played an important role in SN research for almost a century (Baade & Zwicky 1934; Minkowski 1941). Most of these classifications are done on the basis of spectral lines, the presence or absence of certain lines as well as their shape and strength. Decoding what these spectral behaviours suggest about the progenitor system is a key aspect of astronomy and will help us further understand the commonalities and differences between SN events. Within this work, focused on the object **SN 2024ehs**, investigations into some unusually weak helium lines and comparisons to models using **SUMO** *suggest a correlation between line strengths and explosion velocities, to our knowledge not previously observed.*

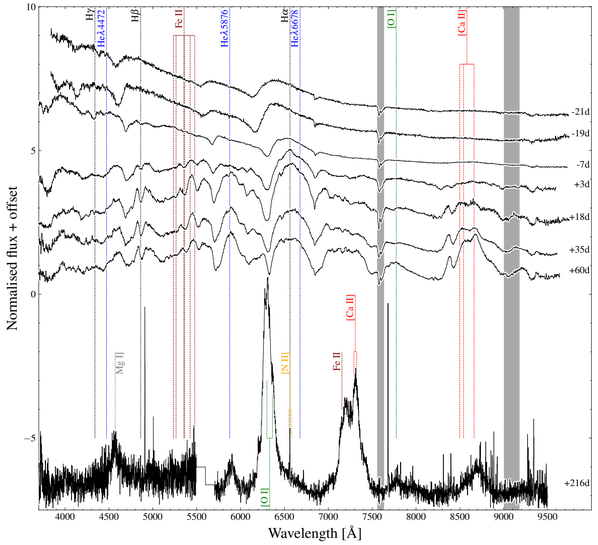

Figure 1: Spectral sequence of SN 2024ehs, with phase in relation to r-band maximum.

SN 2024ehs

SN 2024ehs was discovered in nearby spiral galaxy NGC 3443 on March 15 2024 and observed until November 10 of the same year. Photometric data has been obtained through the Zwicky Transient Facility (ZTF) survey in g, r and o band. Spectroscopic observations were made in the optical using the ALFOSC instrument on the Nordic Optical Telescope (NOT) . Through light curve and spectral comparisons, SN 2024ehs is **classified as a Type IIb**, *though the spectra shows a significant lack of helium in its photospheric phase*. Significantly, the Hα line develops into a broad boxy profile, almost completely lacking the helium absorption in the middle typically seen in Type IIb. In comparison to similar objects, in particular SN 1993J (Filippenko et al. 1993) and SN 2020acat (Medler et al. 2022), **the helium absorptions of SN 2024ehs are weaker and also display higher velocities**.

Modelling

Nebular models from Barmentloo et al. (2024) using the non-local thermodynamic equilibrium (NLTE) Monte Carlo code **SUMO** (Jerkstrand, 2011), primarily used for spectral simulations of SNe in the nebular phase, suggests a relatively large helium core mass of ~6.0 $M_\odot$ for SN 2024ehs. We push the model with this mass to the earliest phase possible to model in **SUMO**, reaching the **late photospheric phase**. Figure 2 shows three model spectra, with the contributions from the most prominent elements filled in, compared to a SN 2024ehs spectrum in the same phase. **The only difference between the three models is the explosion velocity, set at 4 000, 5 000 and 6 000 km/s, respectively.**

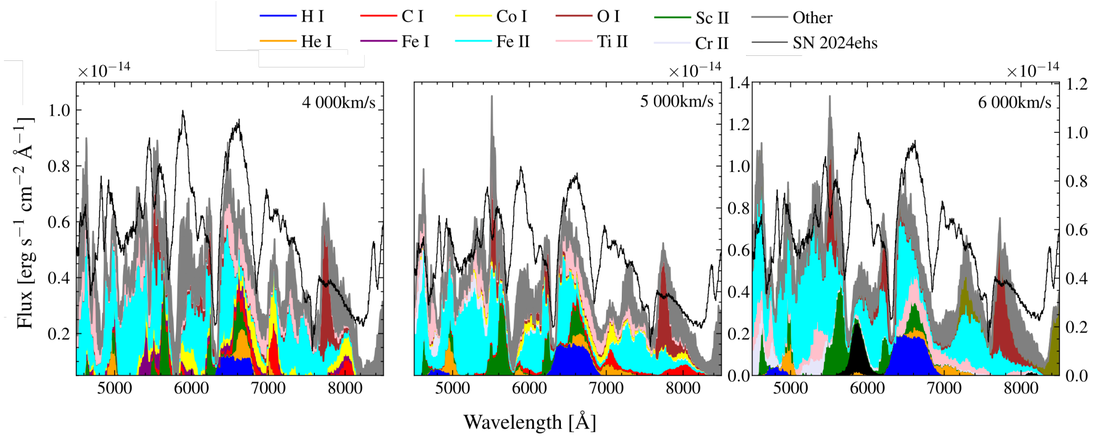

*Figure 2: **SUMO** models of the late photospheric phase (~80 days post explosion), with the most prominent elements filled in. A SN 2024ehs spectrum from the same phase is shown in black. The three models share features and abundances but varying explosion velocities, 4 000, 5 000 and 6 000 km/s respectively. Note how the contribution from different elements varies with velocity.*

Results

While none of our photospheric **SUMO** models perfectly match the observed spectrum of SN 2024ehs, the interesting feature of Figure 2 is the **apparent correlation between the explosion velocity and the line contributions from different elements**. In particular the helium contribution (in orange) weakens with increasing velocities. This, taken together with the observationally established correlation between line strength and velocity, may be the key to explain the lack of helium lines in the spectra of SN 2024ehs. The most probable explanation for this is an opacity link: *higher explosion velocities will decrease the density faster, thus decreasing the opacity.*

This is, to my knowledge, the first time **SUMO** has been used for photospheric modelling, and a lot of future work is required to verify and further develop these conclusions.

Conclusions

- The composition of spectra may not be due only to abundances in the progenitor, as **velocity variations** impact the appearance of certain lines.
- This variation is due to the decreasing **density** that higher velocities entails, which lowers the **opacity**.
- *This work is planned to be continued in an upcoming paper.*

Sources

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Contact: Wilmer.s.hellman@gmail.com