Type IIn Supernova

Investigating the light curve properties and the volumetric rate of Type IIn supernovae

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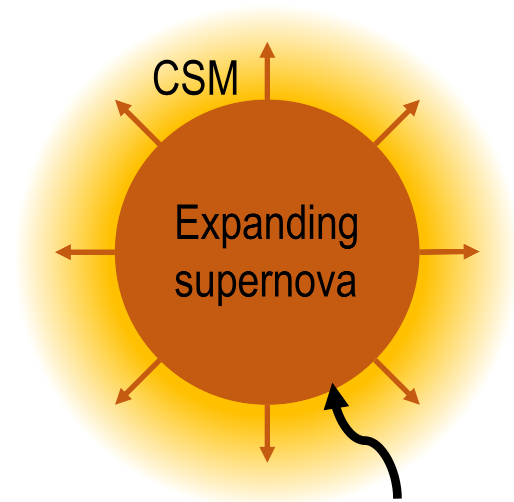
- Type II supernovae are the explosions of massive stars (greater than 8 times the mass of the Sun) at the end of their lifetime.
- For Type IIn supernovae (a subtype of Type II supernovae), the light we see from the explosion is due to the interaction of the supernova with the material surrounding the star – the **circumstellar medium** (CSM).
- The CSM mainly consists of hydrogen gas. During the interaction, the CSM gas is ionised by the expanding supernova. This produces **narrow hydrogen lines** in the spectrum of the explosion, which is how we identify a Type IIn supernova.
- The light curve (a plot of the brightness of the explosion over time) can also tell us information about the exploding star and the material surrounding it.



Interaction with the CSM

supernova (SN) *singular*, supernovae (SNe) *plural*

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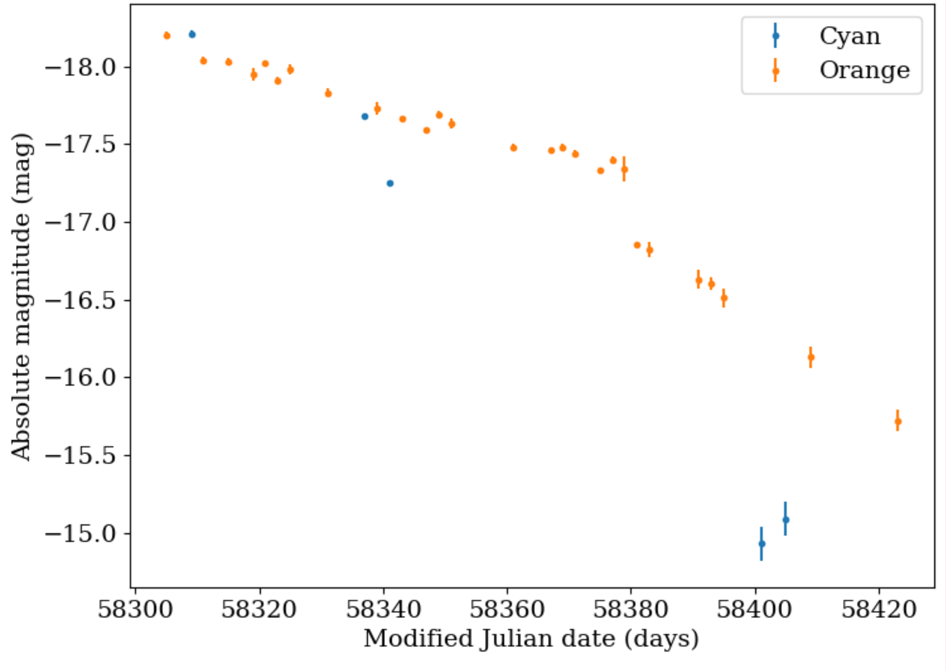
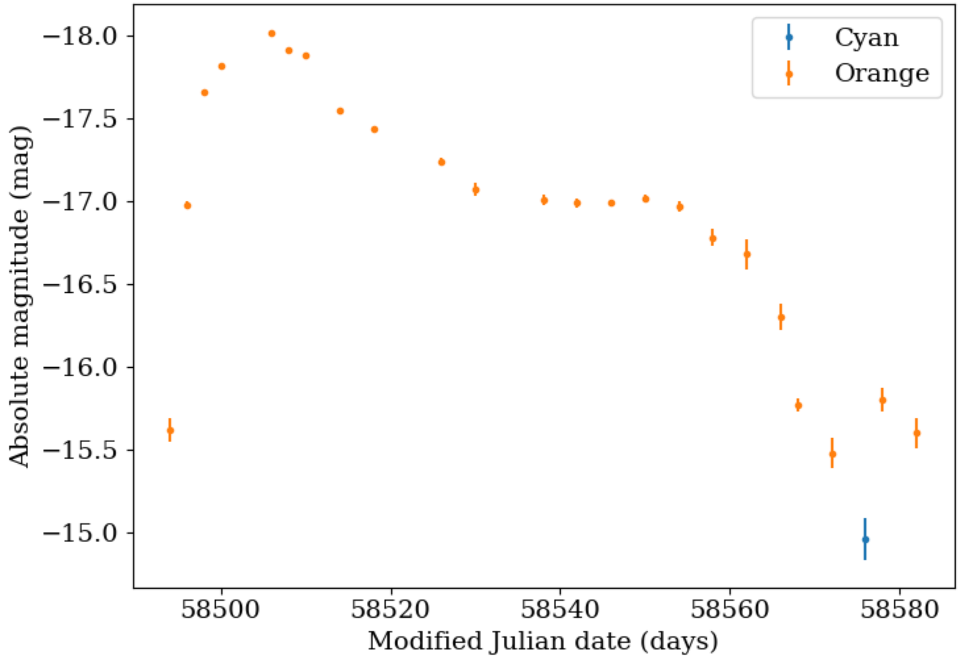
Light curves

Light curves are a plot of the brightness (also known as the **absolute magnitude**) of the supernova over time. In the following examples, two wavelengths of light were detected (orange and cyan).





SN 2018cvn: There is a significant drop in brightness around 58380 days, and the curve subsequently declines with a steeper gradient. This could be due to non-uniformity in the CSM; for example, if there was an outer, less dense layer (or shell).

SN 2019rz: This light curve shows a quick rise and then a slight decline before a plateau of roughly 20 days. This could belong to a sub-type of Type IIn SNe known as IIn-P, where the 'P' indicates the presence of a plateau.

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Volumetric rate

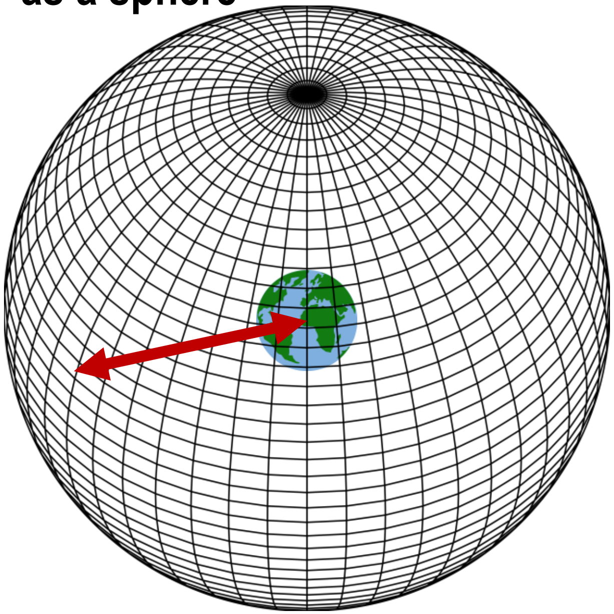
The volumetric rate of Type IIn supernovae is the **number** of supernovae occurring **per year per volume** of space.

- A lot of previous supernova research has focused on **brightness-limited** surveys.
- This means that fainter objects were not being detected and, as a result, the current SN volumetric rates could be inaccurate.
- The **ATLAS** (Asteroid Terrestrial-impact Last Alert System) survey collected a SN sample across 2.5 years and within the local universe (in a range of ~100 Mpc). This is a **volume-limited** survey.
- Looking at the local universe is the best way to detect fainter SNe, as closer objects appear brighter.

$$\text{Rate} = \frac{\text{Number of SNe}}{\text{Volume} \times \text{Time}}$$

The number of Type IIn SNe in this sample was 16. Therefore, the volumetric rate is $0.213 \times 10^{4}\ \text{N(SNe)}\text{yr}^{-1}\text{Gpc}^{-3}$.

Volume of space approximated as a sphere



Radius = 100 Mpc

Not to scale.

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Discussion and conclusion

- The Type IIn SNe in this sample displayed a wide variety of light curves.
- The properties of the light curves (such as their peak brightness and decline rates) were analysed.
- In the future, with a larger sample size, it could be possible to group all the Type IIn SNe into sub-types (such as IIn-P) based on these properties.

- Our Type IIn SNe volumetric rate is approximately half the value determined by the Lick Observatory Supernova Search (LOSS) survey [1,2].
- This suggests that Type IIn SNe are **rarer** than previously thought.
- Going forward, the ATLAS group aims to calculate volumetric rates for different types of supernova using the sample from the local universe. This will allow us to determine whether the current SN volumetric rates are accurate.

Acknowledgements

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[1] N. Smith et al., 2011 https://arxiv.org/abs/1006.3899

[2] W. Li et al., 2011 https://arxiv.org/abs/1006.4613

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