# Photometric and Spectroscopic Analysis of the Type II SN 2020jfo with a short plateau

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## ABSTRACT

We present high-cadence optical observation of SN 2020jfo from ~3 to ~434 days. It is a Short Plateau SN (SPSN) with a plateau duration of 67.05±0.38 days. When compared to other SPSNe, SN 2020jfo has a fainter peak absolute V-band magnitude ($M_V$ =−16.87±0.53 mag) and a lower $^{56}$Ni mass of 0.03±0.01 $M_\odot$. The progenitor mass is estimated to be in range of 12–15$M_\odot$..

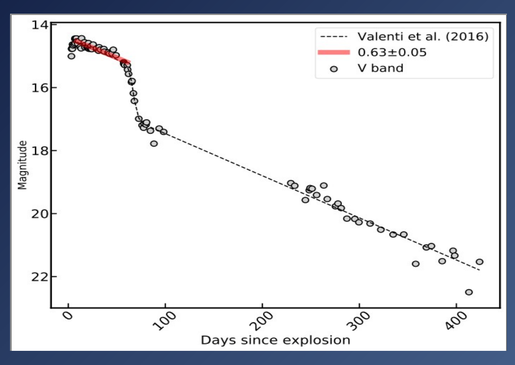
## INTRODUCTION

- Core-Collapse Supernovae (CCSNe) represent the end stages of stars, having Zero Age Main Sequence (ZAMS) masses $\gtrsim$ 8 $M_\odot$. These SNe emerge from the gravitational collapse of the degenerate core of massive stars.
- Type II SNe show features of hydrogen in their spectra around maximum light. Further the Type IIP SNe with a pronounced plateau of 80-120 days (Barbon et al. 1979) and Type IIL SNe following a linear decline show a continuous distribution in light curve morphologies (Anderson et al. 2014).
- Some Type IIP SNe have shorter plateau lengths between 50-70 days and are termed as Short Plateau SNe (SPSNe, Hiramatsu et al. 2021). The plateau phase in SPSNe has been claimed to be powered by the $^{56}$Ni decay unlike other Type IIP SNe (Hiramatsu et al. 2021). Hiramatsu et al. 2021 identified SPSNe as a transitional class between Type IIL and IIb SNe with a narrow H-rich envelope mass ($M_{Henv}$ ≃1.7 $M_\odot$) window.

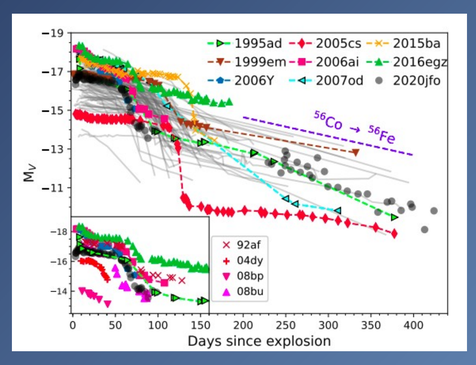
## SN 2020jfo

- SN 2020jfo (also known as ZTF20aaynrrh), located in the outskirts of M61 (z = 0.00522, NED), was discovered on 2020-05-06 (58975.2 MJD) by the ZTF survey using the Palomar Schmidt 48-inch (P48) Samuel Oschin telescope (Bellm et al. 2019) at a magnitude of 16.01±0.04. The discovery was also independently reported by ATLAS, PS2, Gaia and MASTER.
- SN 2020jfo was classified as a Type IIP SN based on the spectroscopic features.
- We report the earliest photometric and spectroscopic observations of this transient at less than 17 hours since the discovery.

## LIGHTCURVE ANALYSIS



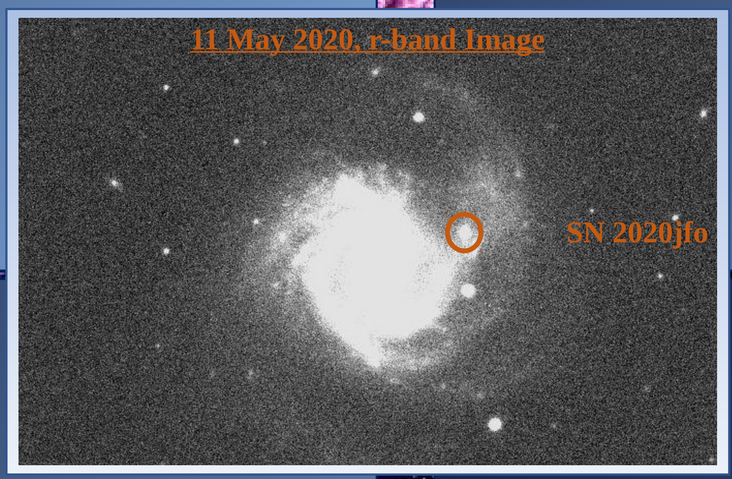

1. Evaluation of the rate of decline in V-band during the plateau phase ($s_{50V}$) and best fit describing the linear parametric equation (from Valenti et al., 2016).




2. Absolute V-band lightcurve of SN 2020jfo compared with the SNe in the comparison sample. The grey lines represent the lightcurves of 116 Type II SNe having different plateau lengths (Anderson et al. (2014)). The inset plot contains SPSNe.

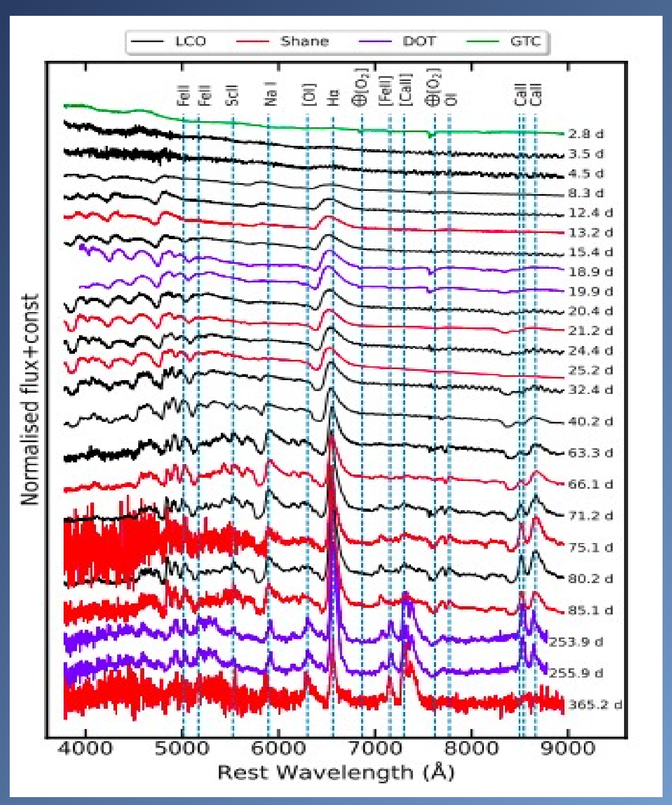
| Plateau Length ($t_{pt}$) | Magnitude drop from plateau to tail phase ($a_0$) | Decline rate of tail phase ($p_0$) | Duration of transiton phase ($6w_0$) |
|---|---|---|---|
| 67.05±0.38 days | 1.68±0.01 mag | 0.01 mag/day | 13.31±2.76 days |

- Using tail V-band magnitudes and following Hamuy (2003), $^{56}$Ni mass is estimated to be 0.03±0.01 $M_\odot$ which is less than 0.05 $M_\odot$, defined for SPSNe.

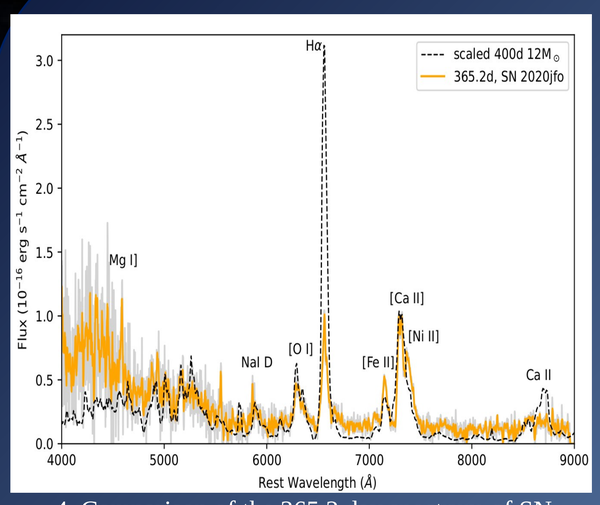



## SPECTROSCOPIC ANALYSIS

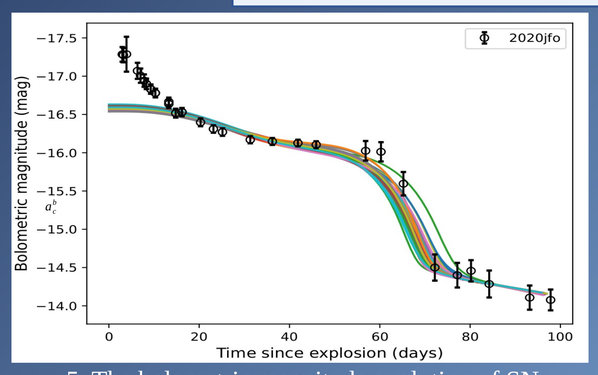
3. The spectral evolution of SN 2020jfo from 2.8 day to 365.2 day since explsion with the prominent spectral features marked. At the early phase of the evolution (2.8 – 4.45 day), broad P Cygni profiles of H Balmer lines can be seen superimposed on a blue continuum. The spectra from 8.26 day reflect the transition from hot to cool SN envelope as the photosphere begins to penetrate deeper into the metal – rich ejecta. These spectra mark the emergence of other lines from heavier atomic species such as Ca, Fe, Sc, Ba, Ti and Na. Among these, the Fe II (λ λ 4950, 5169) lines appear from 18.96 day.




## EXPLOSION PROPERTIES



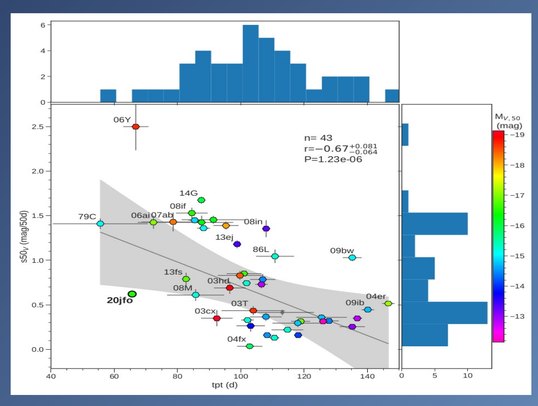

4. Comparison of the 365.2 day spectrum of SN 2020jfo with that of the scaled model spectra from Jerkstrand et al. 2014. The [O I] flux in the SN 2020jfo spectrum is comparable with the model spectrum, suggesting a progenitor ZAMS mass of ∼12 $M_\odot$ for SN 2020jfo.



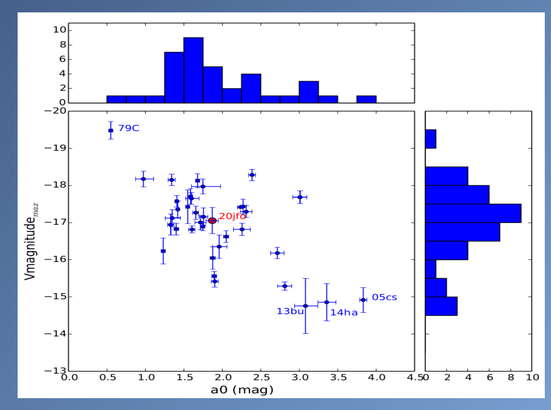

5. The bolometric magnitude evolution of SN 2020jfo is shown with the 50 best fit lightcurves over-plotted following Nagy & Vinkó (2016) and Jäger et al. (2020). The best fitted parameters are shown in table. The early luminosity excess in SN 2020jfo indicates pre-explosion mass loss, the envelope stripping in the progenitor of SN 2020jfo is significantly less violent than in the other SPSNe.

| Radius of Ejecta $R_0$ | Ejecta Mass $M_{ej}$ | Kinetic Entergy $E_{kin}$ | Thermal Energy $E_{th}$ |
|---|---|---|---|
| 6.89X10$^{13}$ cm | 12.3 $M_\odot$ | 2.9 foe | 0.066 foe |

## COLLOCATION OF SN 2020JFO IN THE SN II PARAMETER SPACE




6. The correlation between $s_{50V}$ and $t_{pt}$ are shown. The objects are colour-coded with respect to the absolute V-band magnitude at 50 day. It shows that SNe with longer plateau tend to decline slowly. We have shown the 3σ confidence interval with the gray shaded region. SN 2006ai falls within the 3σ confidence interval whereas SN 2020jfo falls outside the 3σ confidence interval.




7. The peak magnitude in V-band against $a_0$ of SN 2020jfo is shown here along with those of other SNe II. In general SNe with higher peak magnitudes have shorter plateau lengths. SN 2020jfo follows the trend, although the plateau length of SN 2020jfo is shorter and slowly declining as compared to other SPSNe.

## SUMMARY

- In this work, we present the photometric and spectroscopic analysis of a Type IIP SN 2020jfo. Although the plateau length of SN 2020jfo lies in the range of the plateau length of SPSNe (50-70 days, Hiramatsu et al. 2021) but SN 2020jfo is fainter with peak absolute *V*-band magnitude -16.87±0.53 mag in comparison to the luminous optical peaks of SPSNe ( ≲-18.4 mag). The steep decline phase observed in V-band up to ~ 20 d in SPSNe is not seen in SN 2020jfo. The Ni mass yield in SN 2020jfo is less than that of SPSNe.
- Despite being a short plateau SN, SN 2020jfo exhibit remarkably strong H I absorption features in the plateau phase indicating a relatively high H envelope mass. SN 2020jfo also show strong metal lines in comparison to the SPSNe at similar epochs.
- The above estimates and observables collectively indicate that SN 2020jfo is an atypical Type II SN with features resembling those of normal Type IIP SNe but with a remarkably short plateau length in comparison to the normal events.
- The progenitor mass of SN 2020jfo from nebular phase spectral modelling and semi-analytical modelling is estimated to be in the range of 12 – 15$M_\odot$.
- The disparity between SN 2020jfo and other SPSNe suggests there is diversity in the observed propoerties of SPSNe II.

## REFERENCES

**1.** Barbon, R. et al., 1979, A&A, 72, 287 **2.** Anderson, J. ~P. et al., 2014, ApJ, 786, 67 **3.** Hiramatsu, D. et al., 2021, ApJ, 913, 55 **4.** Bellm E. C., et al., 2019, PASP, 131, 068003 **5.** Valenti, S. et al., 2016, MNRAS, 459, 3939, 6. Hamuy, M. et al., 2003, ApJ, 582, 905, **7.** Jerkstrand, A. et al., 2014, MNRAS, 439, 3694, 5. **8.** Nagy, A. P. et al., 2016, A&A, 589, A53, **9.** Jäger Zoltán, J. et al., 2020, MNRAS, 496, 3725.