Observations of Type Ia Supernova 2014J for Nearly 900 Days and Constraints on Its Progenitor System

Wenxiong Li (THU)

Collaborators: X. Wang, M. Hu, Y. Yang, J. Zhang, J. Mo, Z. Chen, T. Zhang, S. Benetti, E. Cappellaro, N. Elias-Rosa, F. Huang, P. Ochner, A. Pastorello, A. Reguitti, L. Tartaglia, L. Tomasella and L. Wang

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Outline

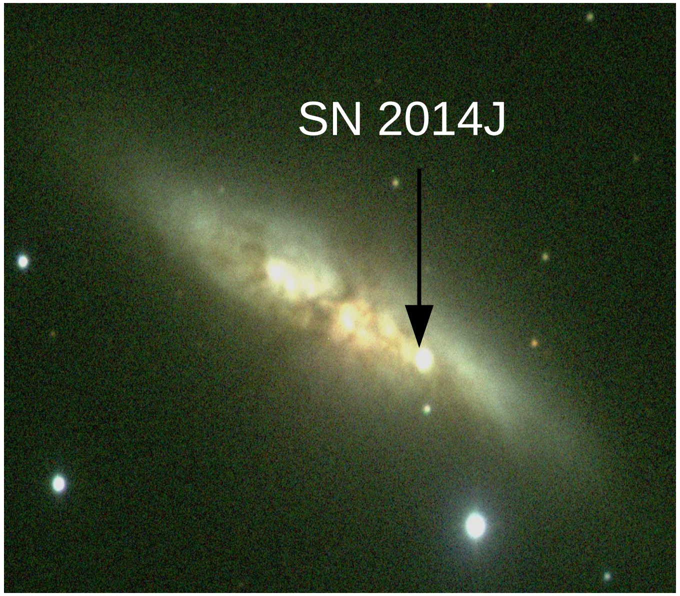
- Introduction of SN 2014J
- Evidence of CSM in the first five months
- Nebular phase evolution

SN 2014J

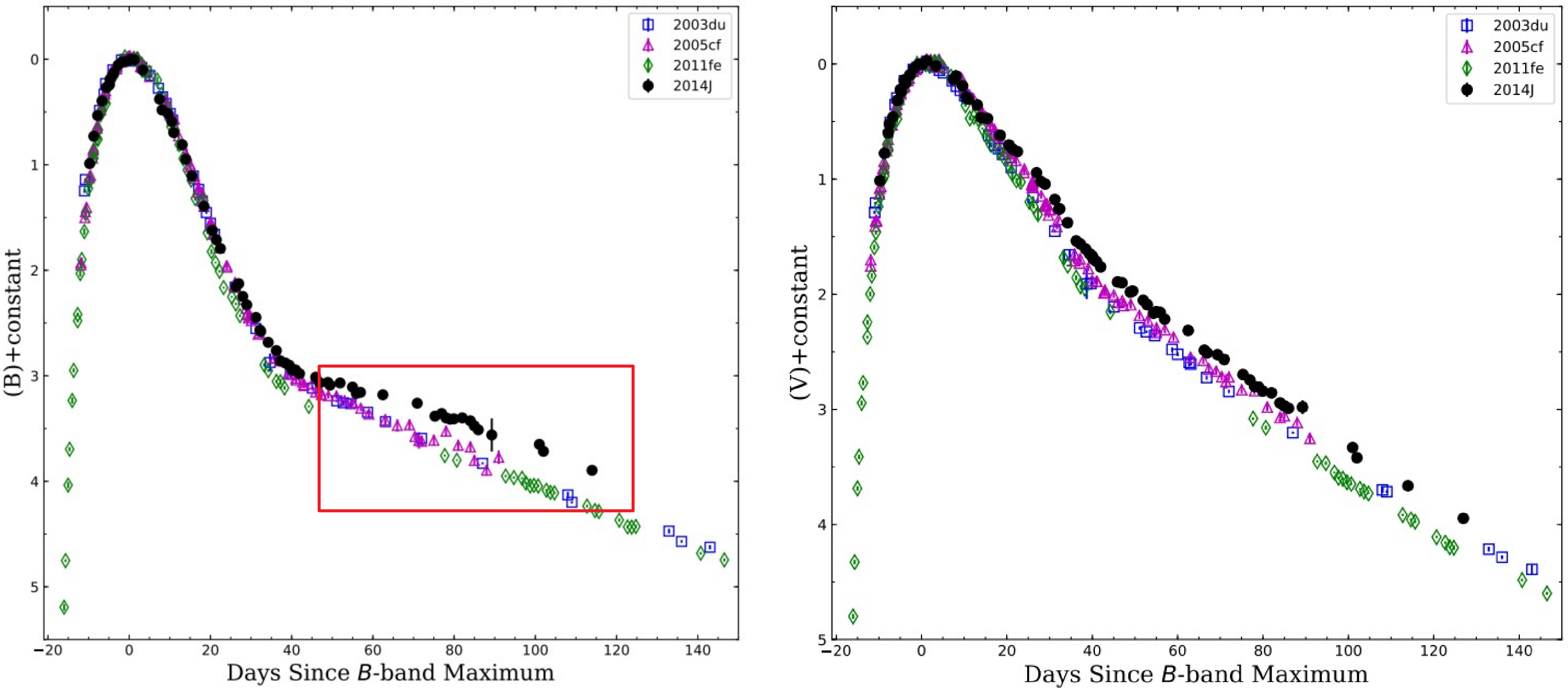
A nearby (~3.5 Mpc), normal and highly reddened (EBV = 1.2 mag) SN Ia.

Progenitor system: the companion is unlikely to be a RG with steady mass transfer or a luminous symbiotic system, e.g., Margutti+(2014) Perez-Torres+(2014) and Kelly+(2014).

Environment: CSM?
e.g., Brown+(2015), Foley+(2014) and Yang+(2018)



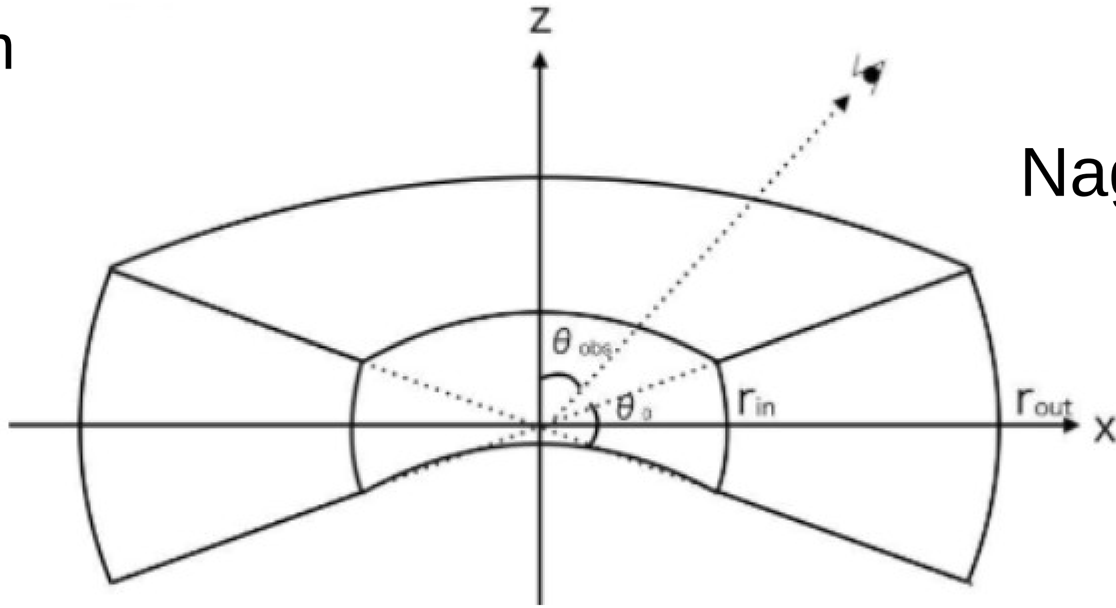
Evidence of CSM in the first five months



Dust disk scatter model:

ρ∝r^{-2}
5 – 500nm

Disk:

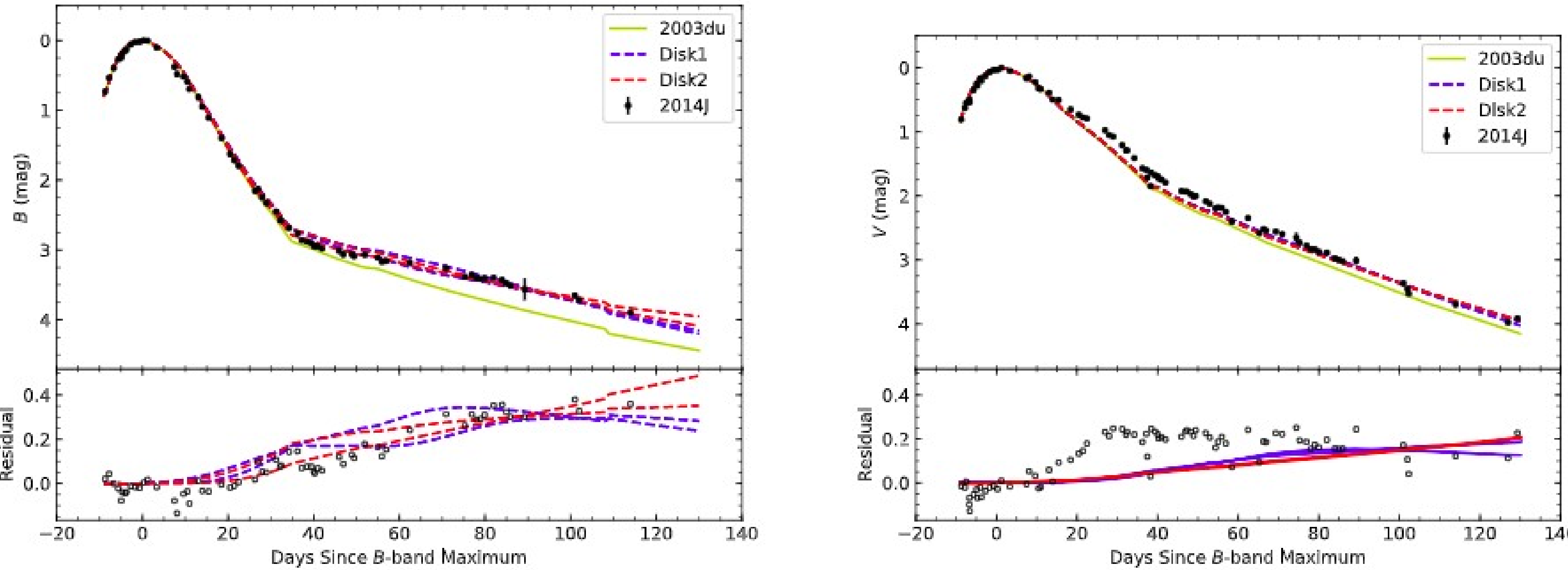


Nagao et al. (2017)

Hu et al. in prep.

Table 7. Parameters of the Dust Structure

Parameter	Range
θ_{obs}	[10°, 60°]
θ_{disk}	[15°, 30°]
R_{in}/light day	[20, 110]
R_{wid}/light day	[20, 110]
τ_B	[0.2, 2.0]



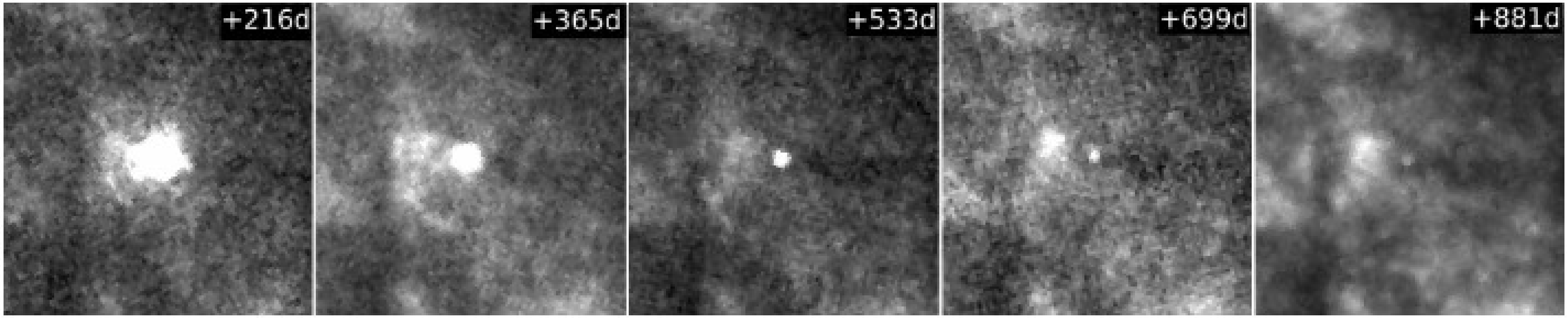
(a) B band (b) V band

Comparison of the LCs of SN 2014J with simulations.

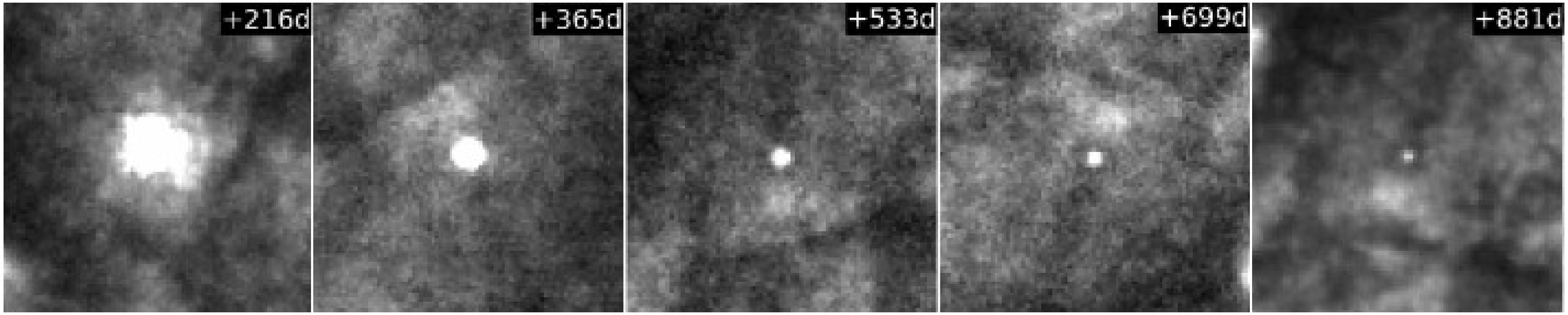
Table 8. Results from Monte Carlo Simulation

θ_{obs}	θ_{disk}	R_{in}/light day	R_{wid}/light day	τ_B
		Disk 1		
30.0°	15°	40	40	0.9
60.0°	15°	40	40	0.9

Nebular Phase Evolution

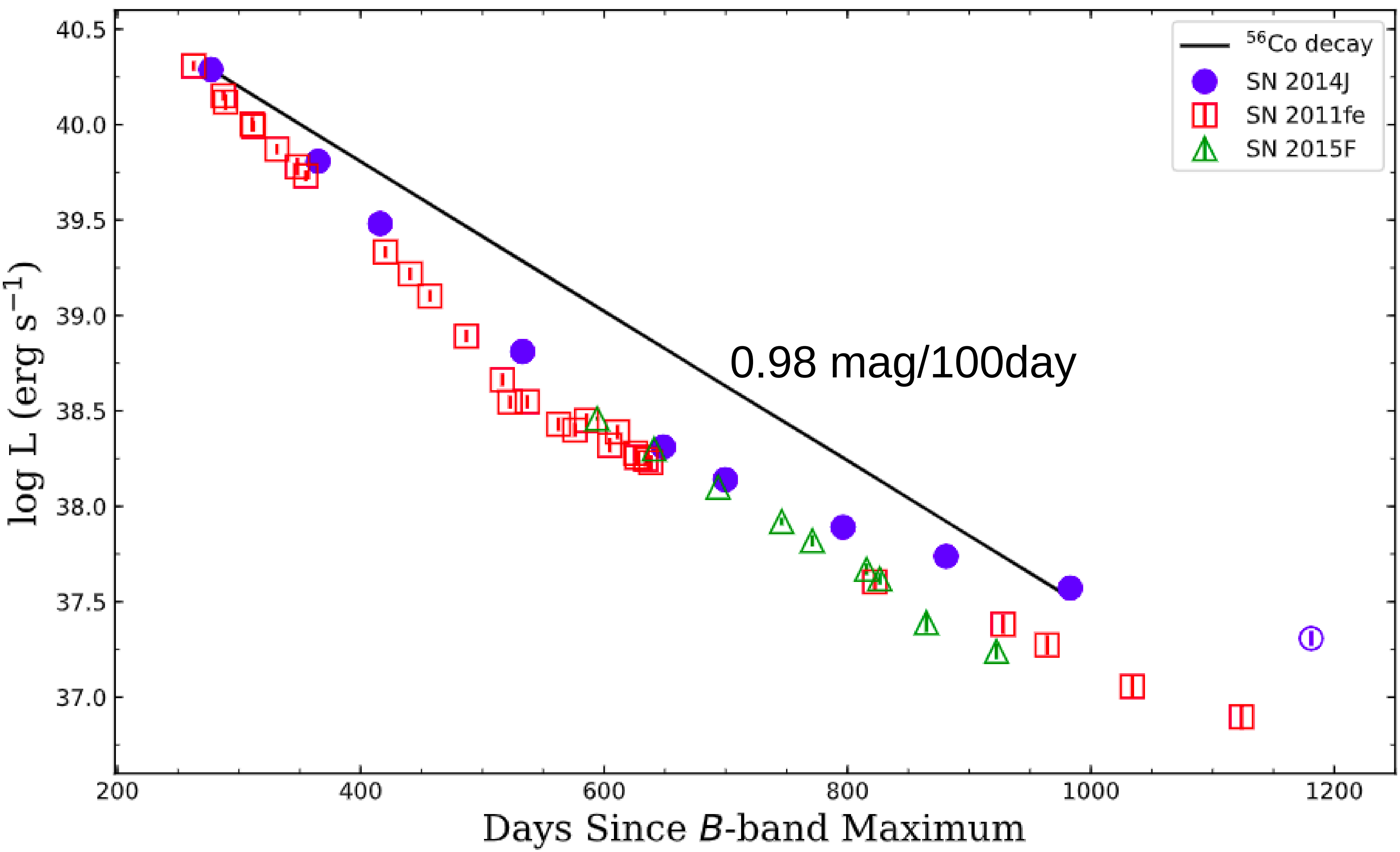


(a) *HST* WFC3/UVIS F438W images



(b) *HST* WFC3/UVIS F555W images

HST images of SN 2014J from 216 to 882 days after B_{max}



Luminosity evolution of 11fe, 14J and 15F. The last point of 14J is from Yang et al. (2017).

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Tsinghua University

Table 9. Late-time Decline Rate of the Bolometric Light Curve of SN 2014J

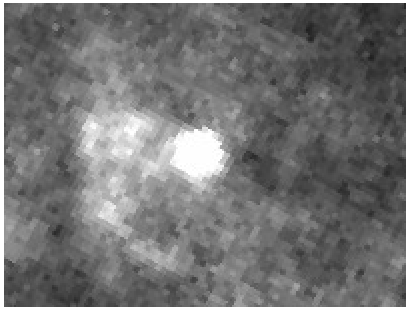
Period(days)	decline rate(Δmag/100 days)
277 – 365	1.37 ± 0.02
365 – 416	1.60 ± 0.03
416 – 533	1.43 ± 0.02
533 – 649	1.08 ± 0.04
649 – 700	0.84 ± 0.07
700 – 796	0.64 ± 0.04
796 – 881	0.45 ± 0.03
881 – 983	0.40 ± 0.05

Cause of flattening:

^{56}Co decay 0.98 mag/100 days

81% $^{56}\mathrm{Co} + e^{-} \rightarrow {}^{56}\mathrm{Fe} + \cancel{\gamma} + \nu_e$

19% $^{56}\mathrm{Co} \rightarrow {}^{56}\mathrm{Fe} + \cancel{\gamma} + \nu_e + e^{+}$

Unresolved light echo  excluded by Yang et al. (2018)

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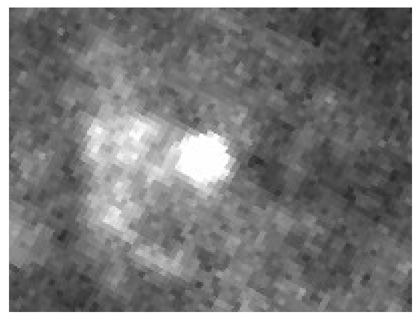
Unresolved light echo



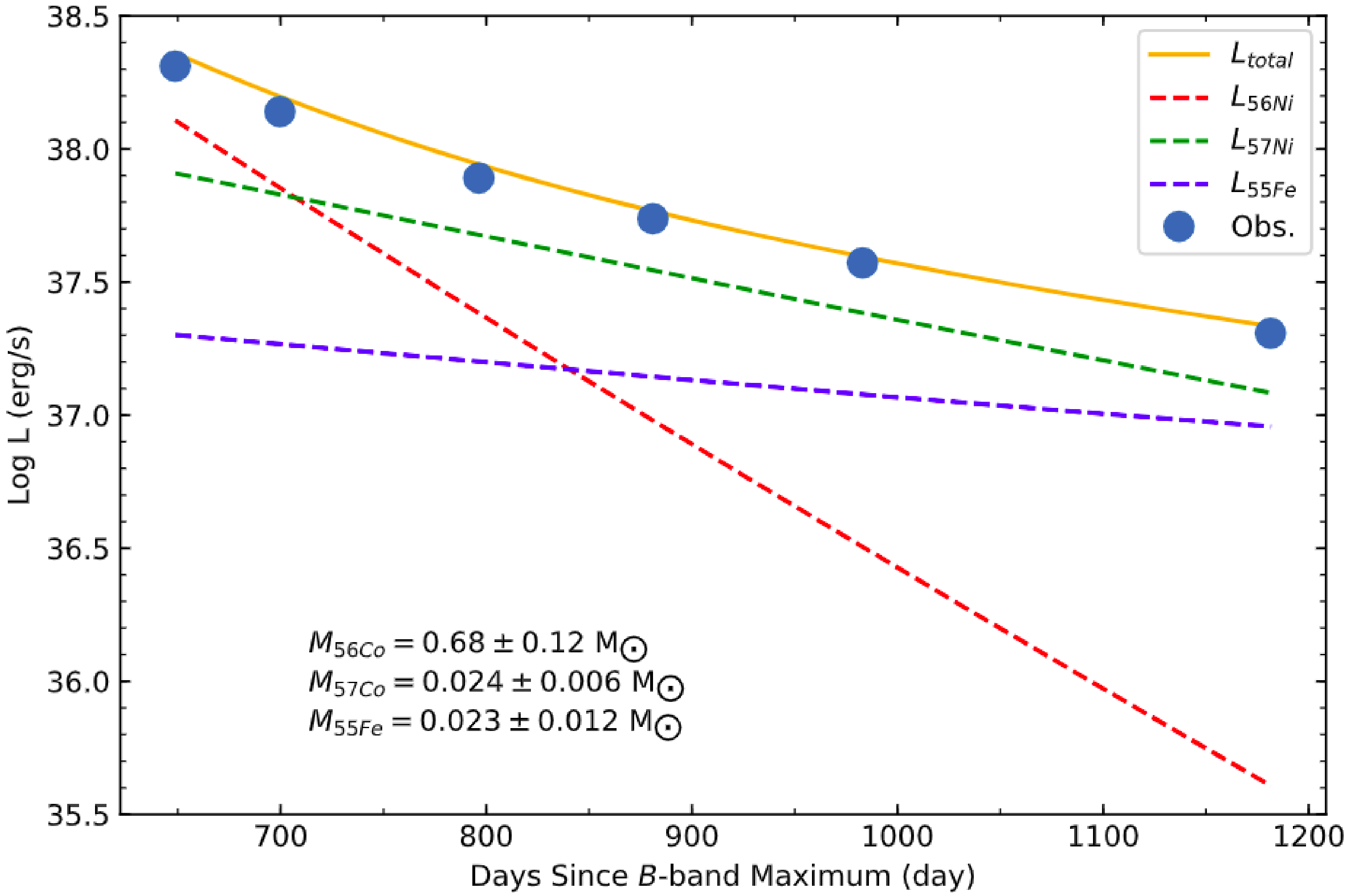
excluded by Yang et al. (2018)

Other radioactive decay: ^{57}Co, ^{55}Fe …

We consider: ${}^{57}\mathrm{Co} \xrightarrow{t_{1/2}=271.8\mathrm{d}} {}^{57}\mathrm{Fe}$ and ${}^{55}\mathrm{Fe} \xrightarrow{t_{1/2}=999.7\mathrm{d}} {}^{55}\mathrm{Mn}$

$$L_A(t) = 2.221 \frac{\lambda_A}{A} \frac{M(A)}{\mathrm{M}_\odot} \frac{q_A^l f_{Al}(t) + q_A^X f_{AX}(t)}{\mathrm{keV}} \exp(-\lambda_A t) \times 10^{43} \mathrm{erg}$$

(Seitenzahl et al. 2014)



$^{57}\mathrm{Ni}/^{56}\mathrm{Ni} = 0.035 \pm 0.011$, consistent with delayed-detonation simulation (Maeda et al. 2010, Seitenzahl et al. 2013) rather than violent merger (Pakmor et al. 2012).

Summary

Flux excess in blue band

↓

CSM disk in ~10^{17} cm

↓

SD scenario (recurrent NV)

Summary

Flux excess in blue band → CSM disk in ~10^{17} cm → SD scenario (recurrent NV)

Late-time flattening → Energy from ^{57}Ni, ^{55}Fe decay → Delayed-detonation model

SD scenario (recurrent NV) + Delayed-detonation model