Red vs. Blue: Two distinction populations of SNe Ia?

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VILLUM FONDEN

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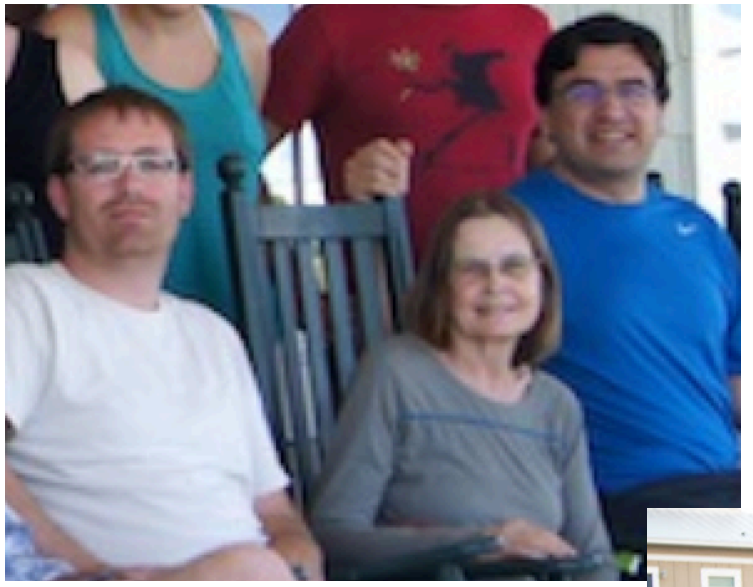
ASAS-SN

NOT UNBIASED TRANSIENT SURVEY

“Nidia, the monk astronomer”, Wojtek

- Your humility, honesty & integrity
- Extreme dedication (du Pont TO & astronomer, +20%)
- Fantastic educator
- Supportive of numerous young *and* old researchers
- Always responses to requests and provides comments on a majority of manuscripts!
- Is one cool grandma, friend and serves as mom of the CSP!



AUTHORS

Morrell, N	250
Phillips, M	86
Stritzinger, M	69
Contreras, C	59
Hamuy, M	55

Potential of Early Observations

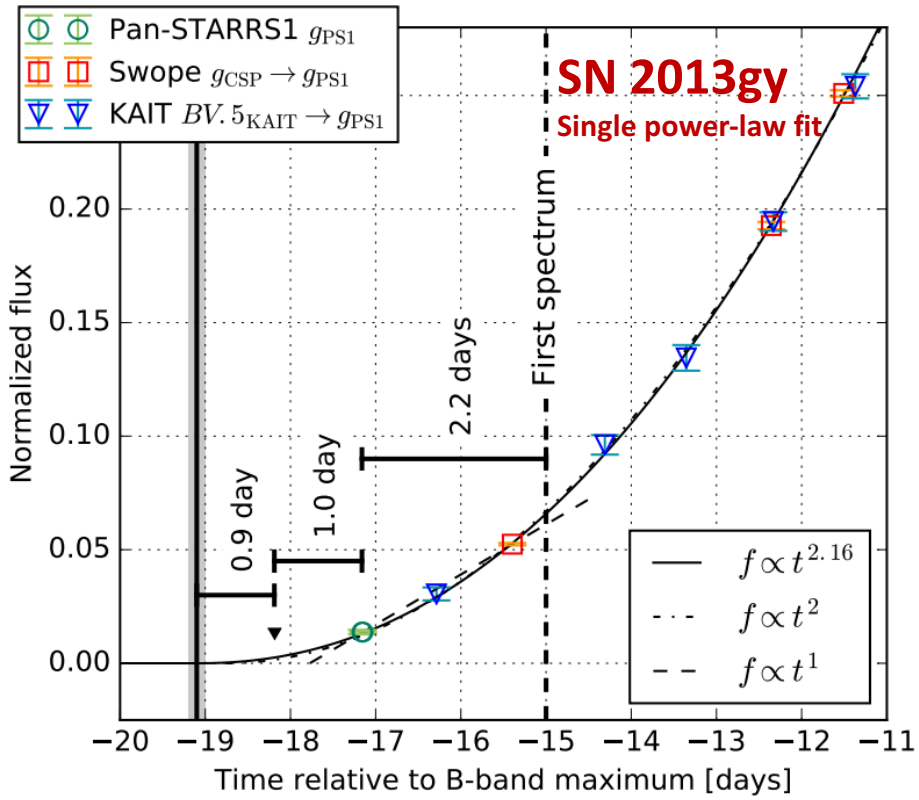
- Avenue to constrain the primary radius and the radius of any companion,
  e.g., SN 2011fe; Nugent+11, Li+11 Bloom+12

- Possibility to constrain the explosion trigger

- A window to interaction between the outer SN ejecta and CSM and/or companion star

Diversity of early light curve evolution

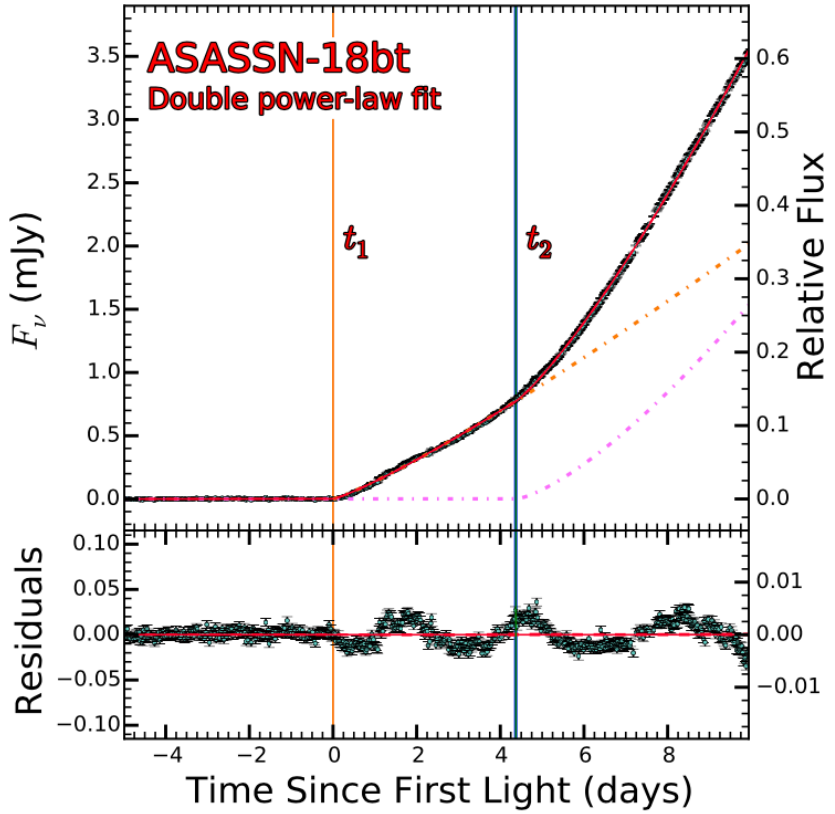
Holmbo+arXiv:1809.01359



- Exhibits an exponential rise

→ single power law

Shappee+in press



- Several day linear rise in flux followed by a exponential rise

→ double power law fit

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Red versus Blue: Early Observations of Thermonuclear Supernovae Reveal Two Distinct Populations?

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Abstract

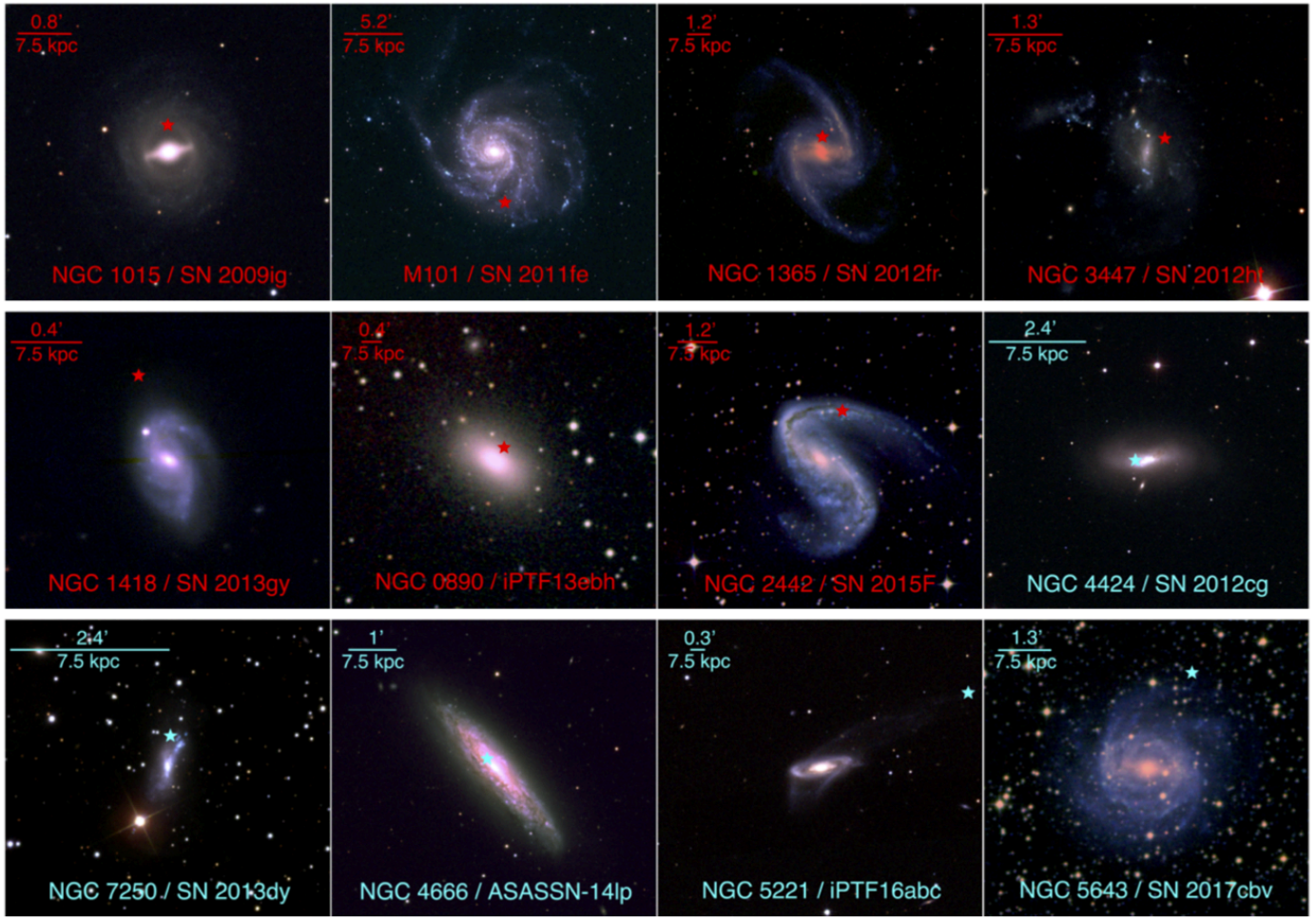
We examine the early phase intrinsic $(B-V)_0$ color evolution of a dozen SNe Ia discovered within three days of the inferred time of first light ($t_{\rm first}$) and have $(B-V)_0$ color information beginning within five days of $t_{\rm first}$. The sample indicates there are two distinct early populations. The first is a population exhibiting blue colors that slowly evolve, and the second population exhibits red colors and evolves more rapidly. We find that the early blue events are all 1991T/1999aa-like with more luminous, slower declining light curves than those exhibiting early red colors. Placing the first sample on the Branch diagram (i.e., ratio of Si II $\lambda\lambda$5972, 6355 pseudo-Equivalent widths) indicates that all blue objects are of the Branch shallow silicon (SS) spectral type, while all early red events except for the 2000cx-like SN 2012fr are of the Branch Core Normal (CN) or CooL (CL) type. A number of potential processes contributing to the early emission are explored, and we find that, in general, the viewing-angle dependance inherent in the companion collision model is inconsistent with all of the SS objects with early-time observations being blue and exhibiting an excess. We caution that great care must be taken when interpreting early phase light curves as there may be a variety of physical processes that are possibly at play and significant theoretical work remains to be done.

Key words: supernovae: general

Early B-V color: sample

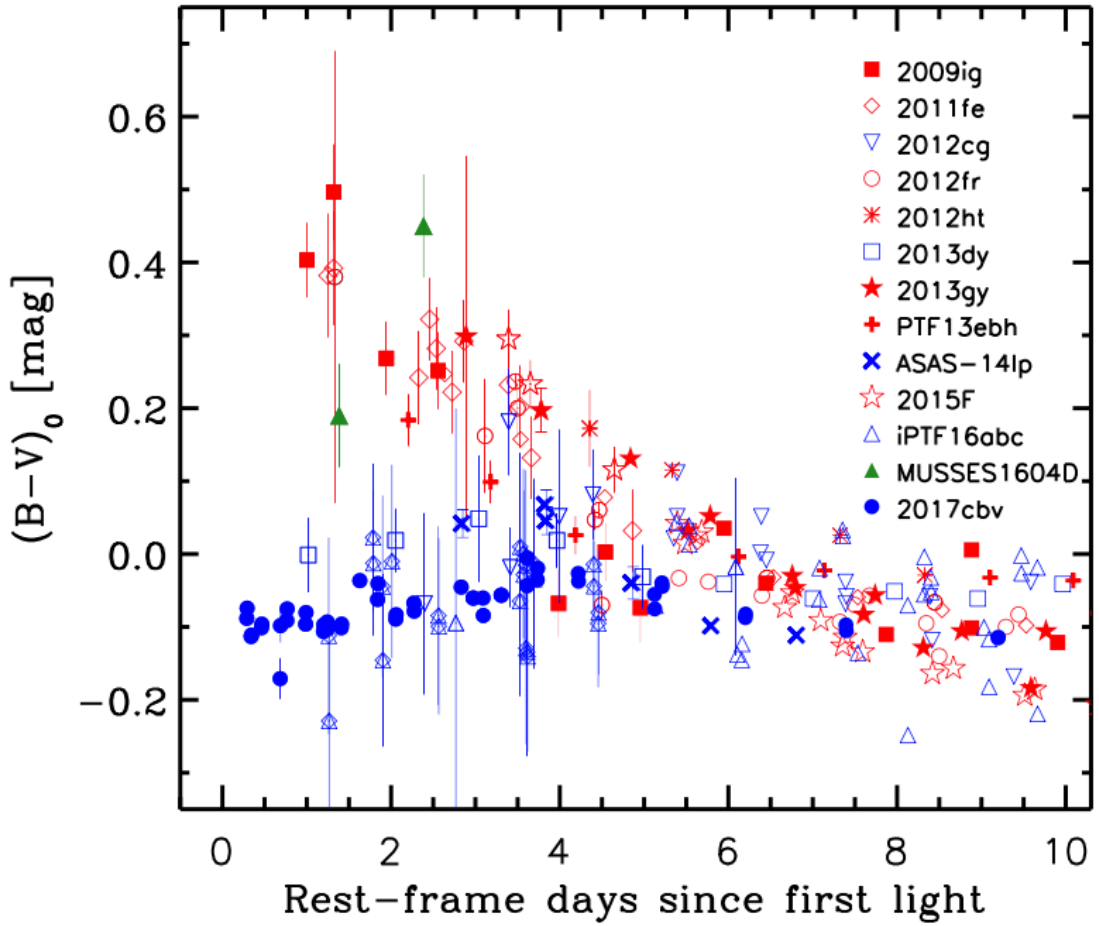
Sample selection criteria:

- Discovered within 3 days of t_{first}
- B-V color obtained within 5 days of t_{first}



Stritzinger+18c

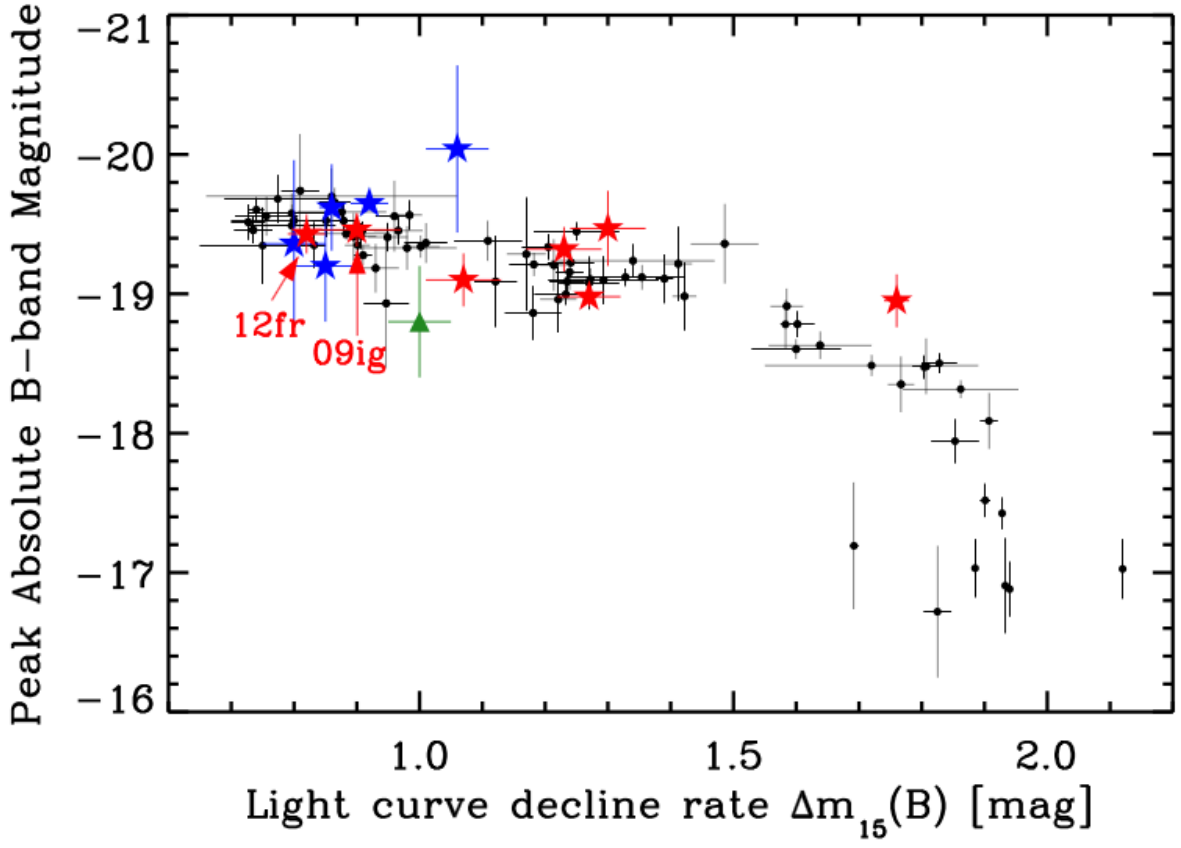
Early sample $(B\text{-}V)_0$ color evolution



Red vs. Blue populations

- Blue objects, slowly evolve
- Red objects, rapidly evolve
- 50% difference in flux

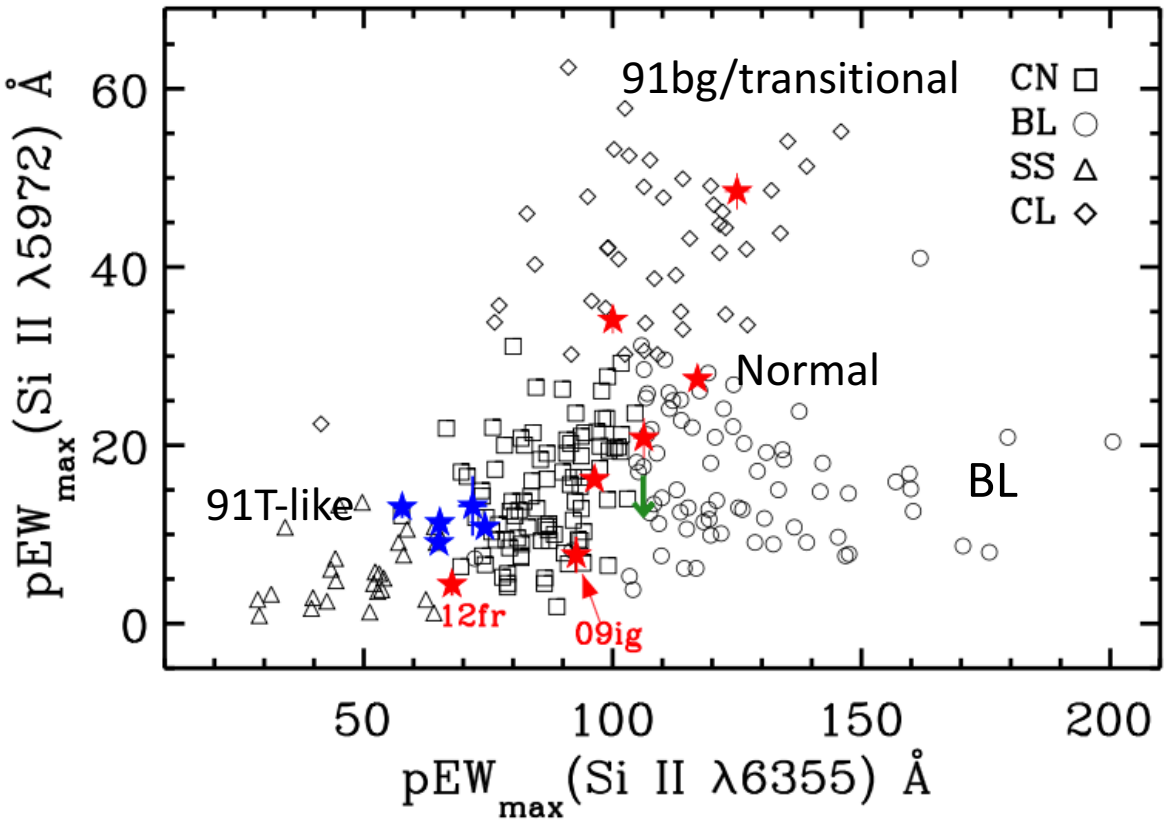
Red vs. Blue: Phillips relation



- Blue objects are generally brighter
- Red objects are generally fainter

- Note peculiar 2000cx-like objects 2009ig & 2012fr

Red vs. Blue: Branch+06 Diagram



- Blue objects are either 1991T or 1999aa-like concentrated in the SS area extending to CN
- Red objects are CN or CL, except peculiar 2000cx-like SN 2012fr

A connection between early blue UV colors and spectral sub-type was also recently found *independently* by Jiang+18

Conclusion

- Identified two distinct early populations: red vs. blue

- All hosts are spirals: no trends between early color & host properties or locations

- Blue objects are 1991T/1999aa-like and SS with slowly declining light curves
- Red are CN/CL with more rapidly declining light curves

- Range of potential emission processes that must be considered:

1. SN ejecta / non-degenerate companion interaction (inconsistent with red vs. blue findings?)
2. ^{56}Ni mixing to high velocity (degrades spectral fits?)
3. explosive He burning on the surface → double detonation scenario (needs work)
4. Interaction with CSM associated with tidally disrupted material from a WD+WD merger (needs work)
5. Composition/opacity differences in the outer layers (unburned carbon)

- Great care should be taken when interpreting early-phase observations

- Significant theoretical work remains to be done [talks by Jiang & Maeda-san]

“If I could, I would make all data that I obtain public on the www immediately!”

Early Sample of Type Ia supernovae

Table 1. Early Color Evolution Sample Parameters.

SN	Host	Red-shift	$E(B-V)_{MW}$ [mag]	$E(B-V)_{host}$ [mag]	t_{first} [MJD]	t_{rise} [days]	$\Delta m_{15}(B)$ [mag]	M_B [mag]	Spectral-type[a]	Color	References(s)
2009ig	NGC 1015	0.00877	0.032	···	55062.9	17.1	0.90 ± 0.07	-19.46 ± 0.12	CN, HV	red	(1)
2011fe	M101	0.00080	0.008	···	55796.7	17.8	1.07 ± 0.06	-19.10 ± 0.19	CN, normal	red	(2)
2012cg	NGC 4424	0.00146	0.018	0.18 ± 0.05[b]	56061.8	19.5	0.86 ± 0.02	-19.62 ± 0.31	SS, 91T/99aa-like	blue	(3)
2012fr	NGC 1365	0.00546	0.018	0.03 ± 0.04[c]	56225.8	16.9	0.82 ± 0.03	-19.43 ± 0.14	CN+SS, HV	red	(4)
2012ht	NGC 3447	0.00356	0.025	0.05 ± 0.01[c]	56278.0	17.6	1.27 ± 0.05	-18.98 ± 0.07	CN, normal	red	(5)
2013dy	NGC 7250	0.00389	0.140	0.21 ± 0.01[d]	56483.4	17.7	0.92 ± 0.03	-19.65 ± 0.04	SS, 91T/99aa-like	blue	(6)
2013gy	NGC 1418	0.01402	0.049	0.11 ± 0.06[c]	56629.4	19.1	1.23 ± 0.06	-19.32 ± 0.16	CN, normal	red	(7)
iPTF 13ebh	NGC 890	0.01327	0.067	0.07 ± 0.02[c]	56607.9	14.8	1.76 ± 0.02	-18.95 ± 0.19	CL, normal	red	(8)
ASASSN-14lp	NGC 4666	0.00510	0.021	0.35 ± 0.01[c]	56998.5	16.7	0.80 ± 0.05	-19.36 ± 0.60	SS, 91T-like	blue	(9)
2015F	NGC 2442	0.00489	0.175	0.16 ± 0.03[c]	57088.4	18.5	1.25 ± 0.05	-19.47 ± 0.27	CN, normal	red	(10)
iPTF16abc	NGC 5221	0.02328	0.028	0.05 ± 0.03[e]	57481.6	17.9	0.85 ± 0.05	-19.20 ± 0.40	SS, normal/91T-like	blue	(11)
MUSSES1604D	···	0.11737	0.026	···	57481.8	22.4	1.00 ± 0.07	-18.80 ± 0.40	BL, HV	red	(12)
2017cbv	NGC 5643	0.00400	0.150	···	57821.9	18.3	1.06 ± 0.05	-20.04 ± 0.60	SS, 91T-like	blue	(13)