The fate of the progenitors of Luminous Red Novae

NIR and MIR observations years after the outburst

Andrea Reguitti

Padova, 2 April 2025

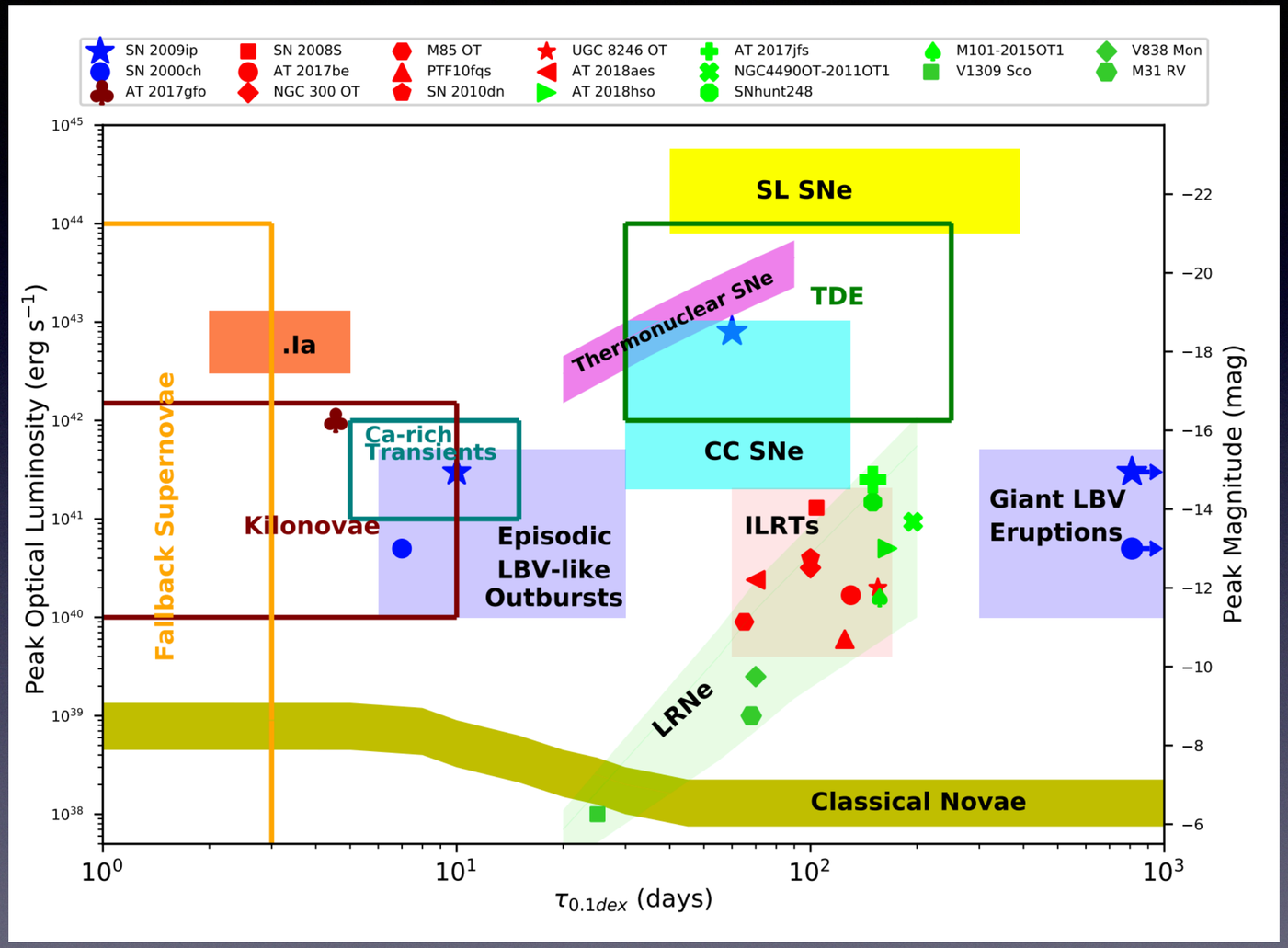
Gap Transients

Interacting events, at peak
$-10 < M_V < -15$ mag

Evolutionary timescales: weeks to months
(Pastorello & Fraser 2019)

Among them: Luminous Red Novae

See Morgan's talk

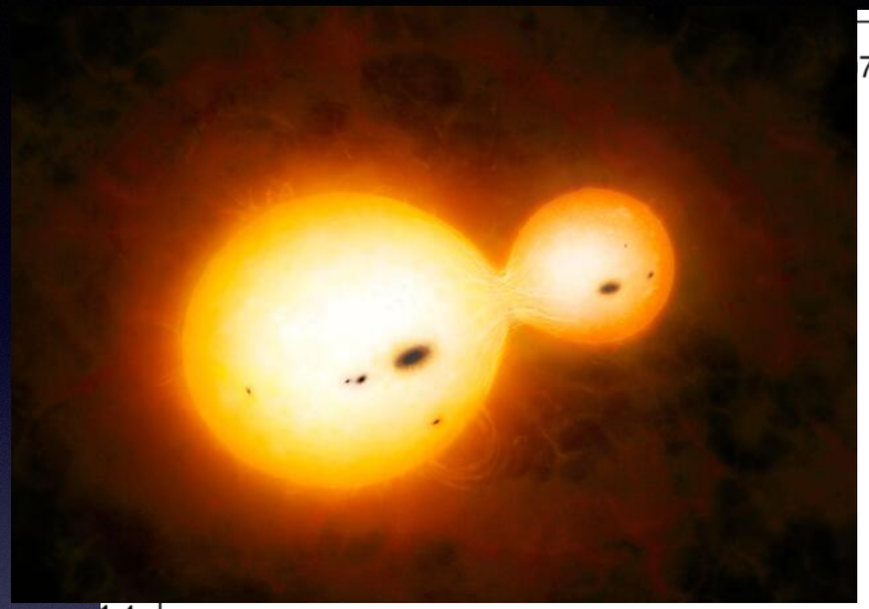


From Cai+22b

Luminous Red Novae

Coalescence of 2 non-degenerate stars within a Common Envelope (Pastorello+19d)

Faint observed in MW, bright only outside



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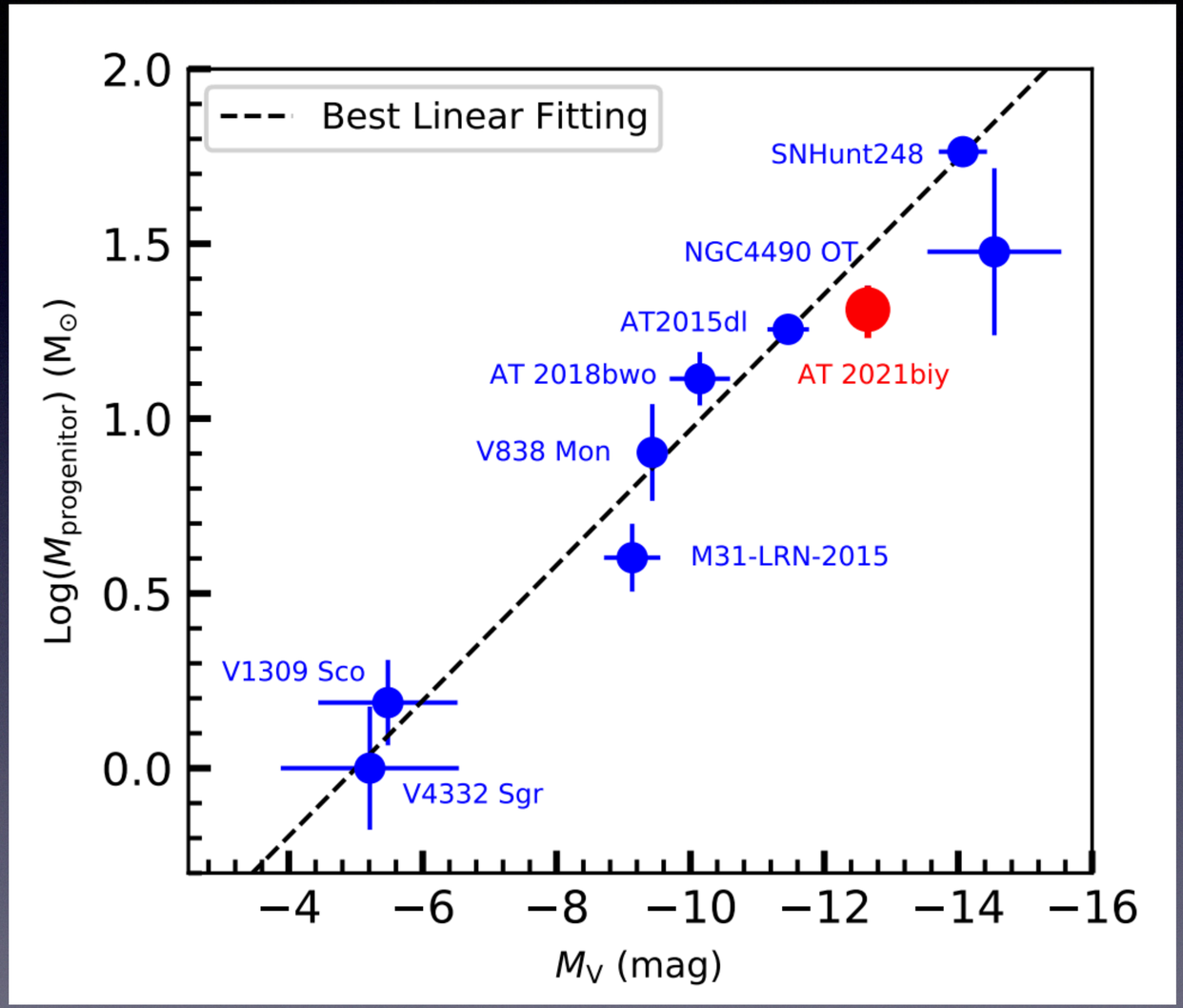

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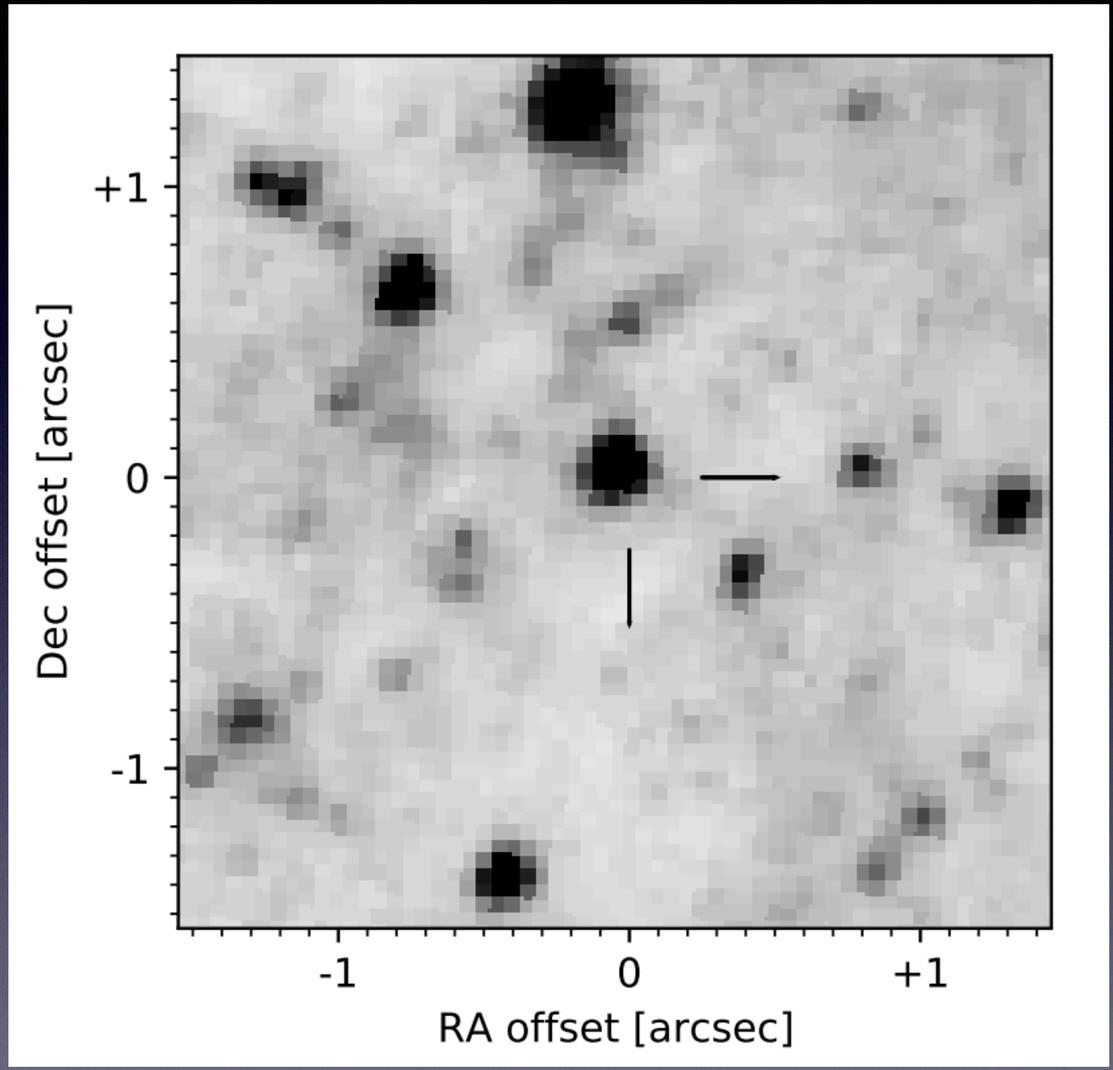
Progenitors identified by HST as YSG with M~15-30 $M_\odot$



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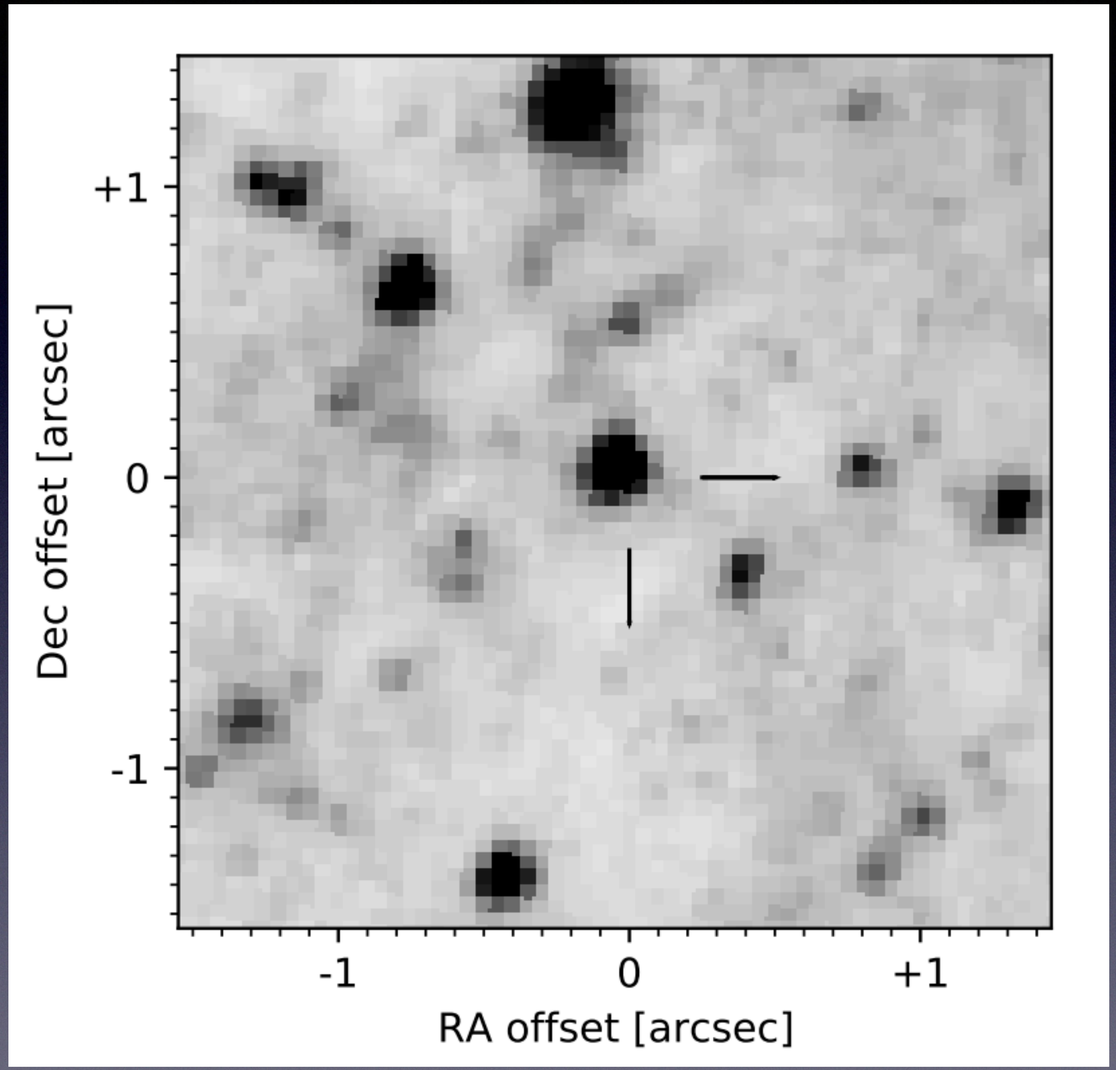
Which is the outcome of the LRNe events?



From Cai+22a

Sample

Table 1: The LRN sample analysed in this paper.

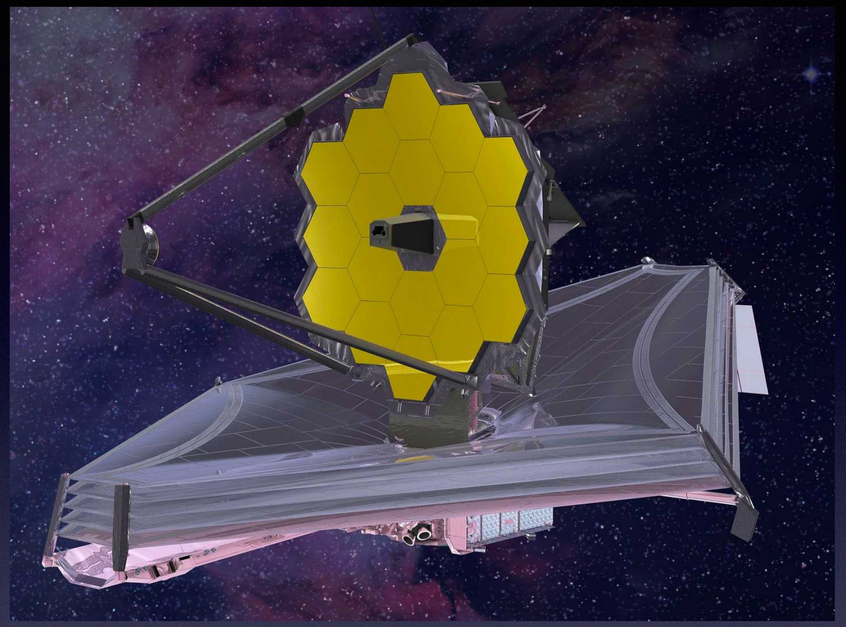
Object name	Host galaxy	Distance (Mpc)	$E(B-V)$	MJD of 1st peak	Reference
AT 1997bs	NGC 3627	9.4±0.3	0.04	50560	(1)
AT 2007sv	UGC 5979	18.85±1.0	0.83	<54454[1]	(2)
AT 2011kp[2]	NGC 4490	9.6±1.3	0.32	55797	(3)
AT 2013lw[2]	UGC 12307	39.7±2.7	0.22	56481[3]	(4)
AT 2015fx[2]	NGC 2748	23.8±2.0	0.024	57069	(5)
AT 2015dl[2]	M 101	6.4±0.5	0.008	57070	(6)
AT 2018bwo	NGC 45	6.8±0.5	0.02	<58252[1]	(7)
AT 2019zhd	M 31	0.78±0.01	0.055	58892	(8)
AT 2020hat	NGC 5068	5.2±0.2	0.37	58954	(9)

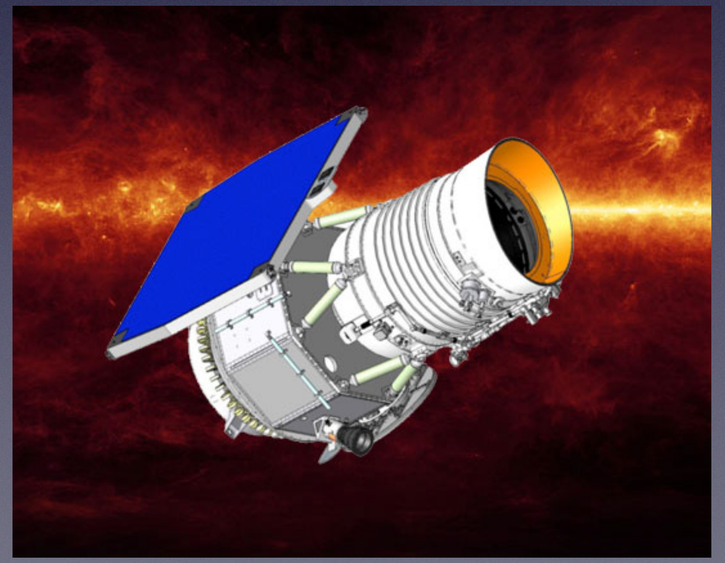
9 extragalactic LRNe already studied in literature

>5 yrs old (oldest from 1997)

From 0.8 to 40 Mpc

Archival searches



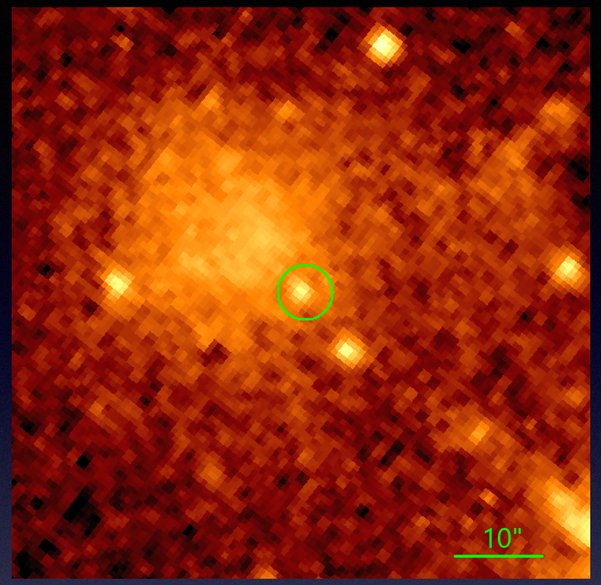


Post-outburst public archival data from Spitzer, WISE, HST, JWST

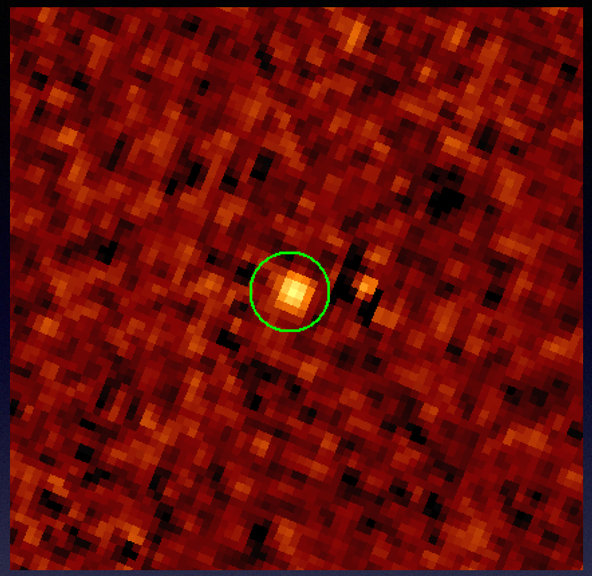
Focus on NIR/MIR data

Images from many years later

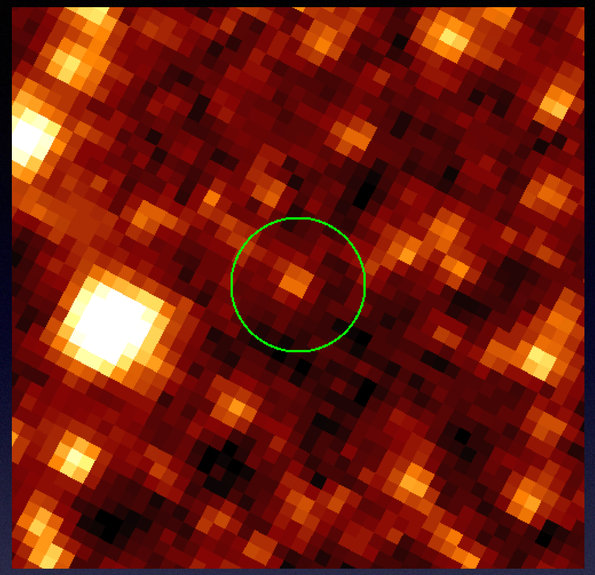
Detected in MIR; still visible!



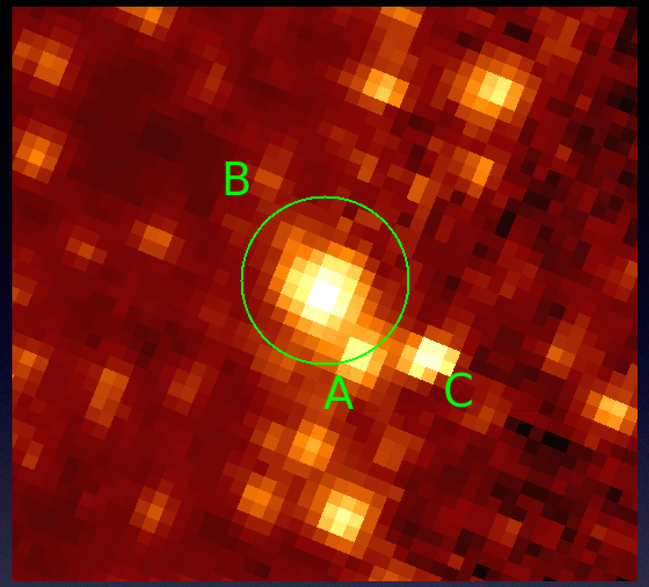
AT 2007sv in 2010 (SST)



AT 2013lw in 2014 (SST)

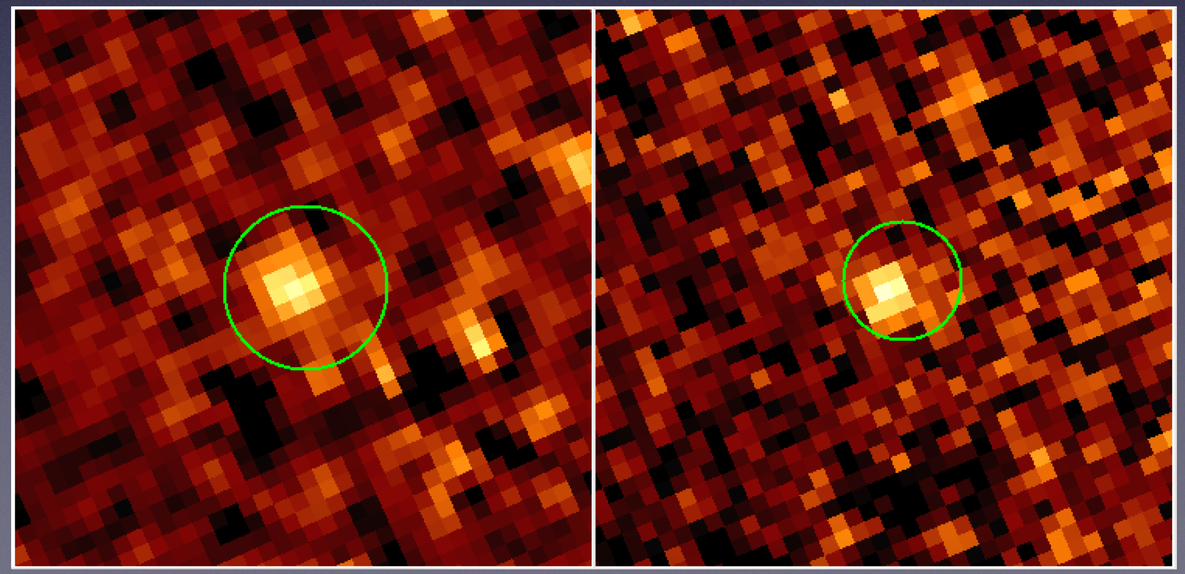


AT 2018bwo in 2022 (HST)



AT 2019zhd in 2022 (HST)

AT 2020hat
in 2019 (SST)



AT 2020hat in
2020 (WISE)

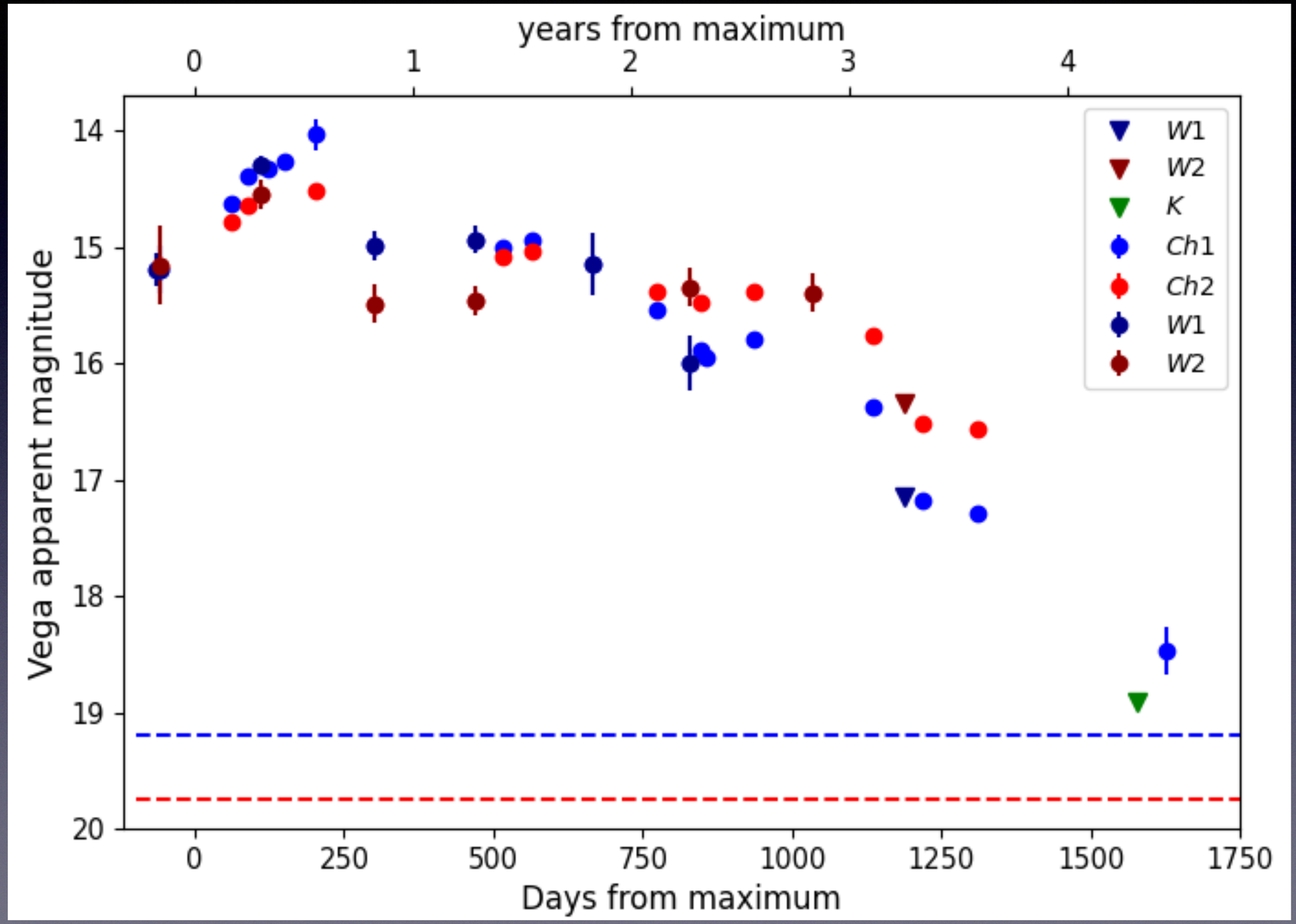
AT 2015dl

Studied by Blagorodnova+17

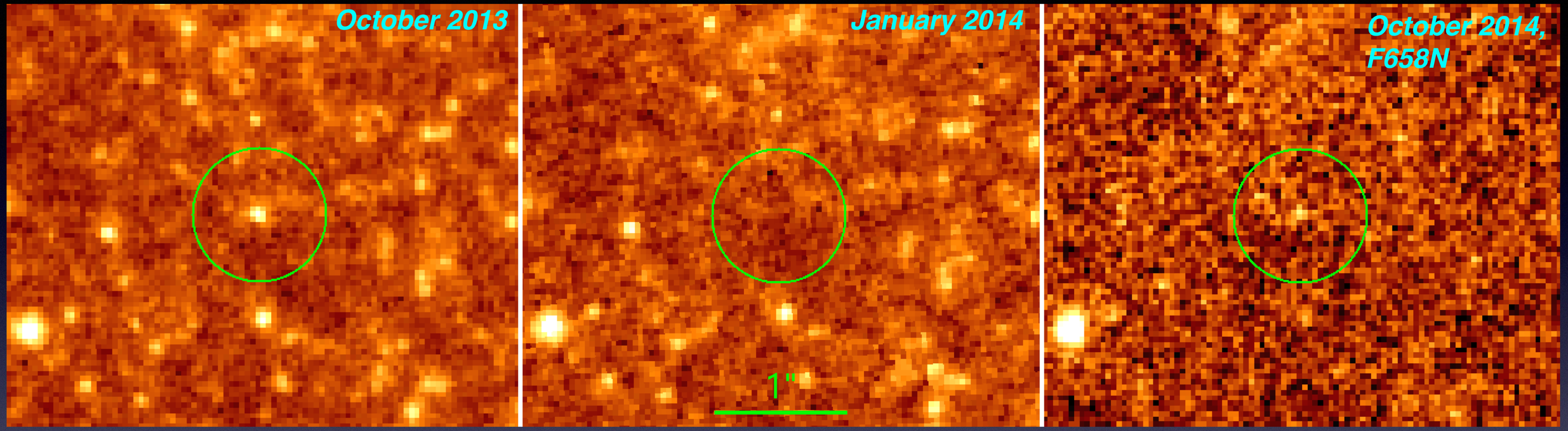
In 2017, *r-[3.6]* > 10 mag!

Visible by SST for 4.5 yrs

Dramatic change in MIR color



NGC4490-OT2011 (HST)



Studied by Smith+16

Disappeared in HST F814W and F547M

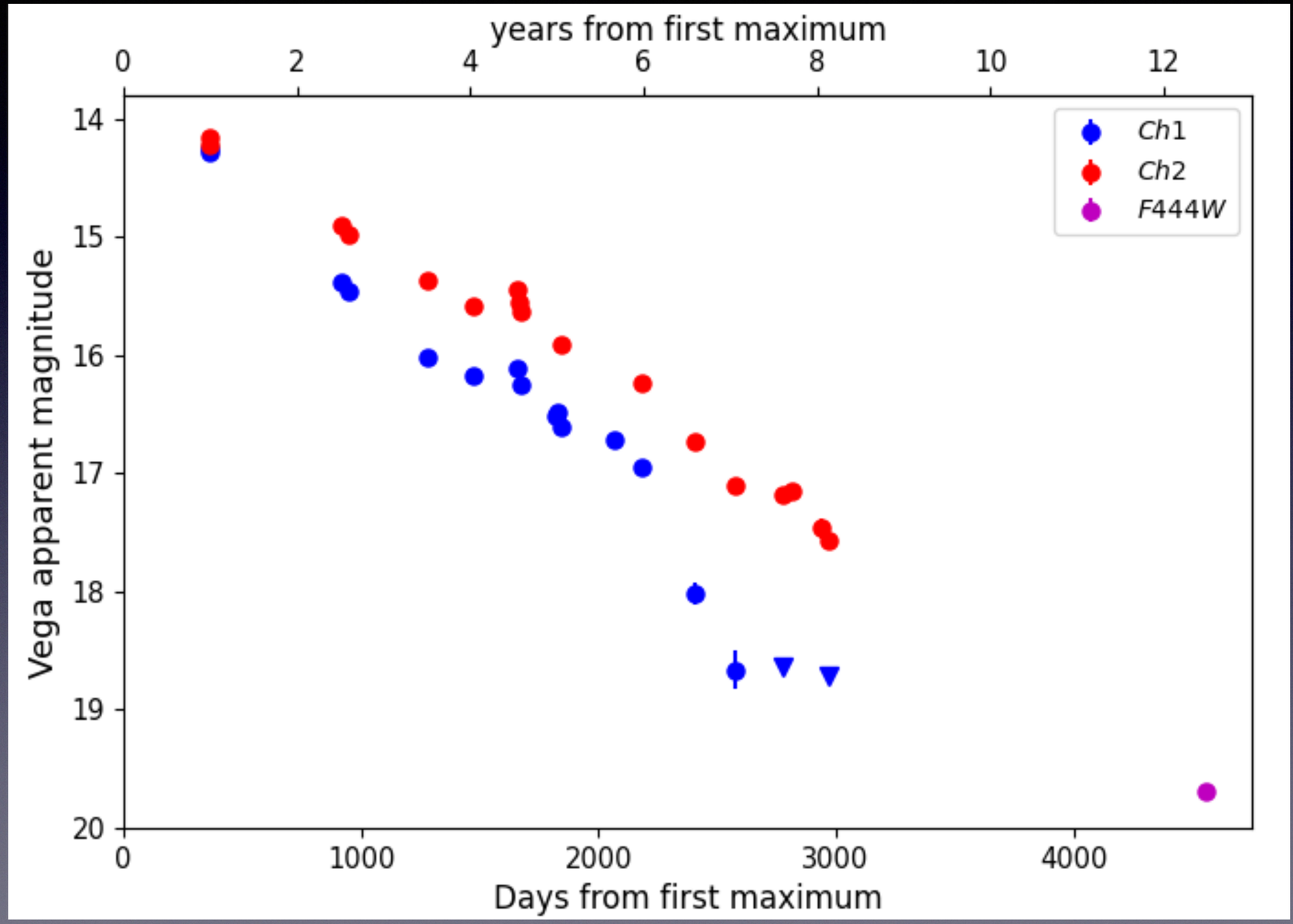
But still detected in F658N

NGC4490-OT2011 (SST)

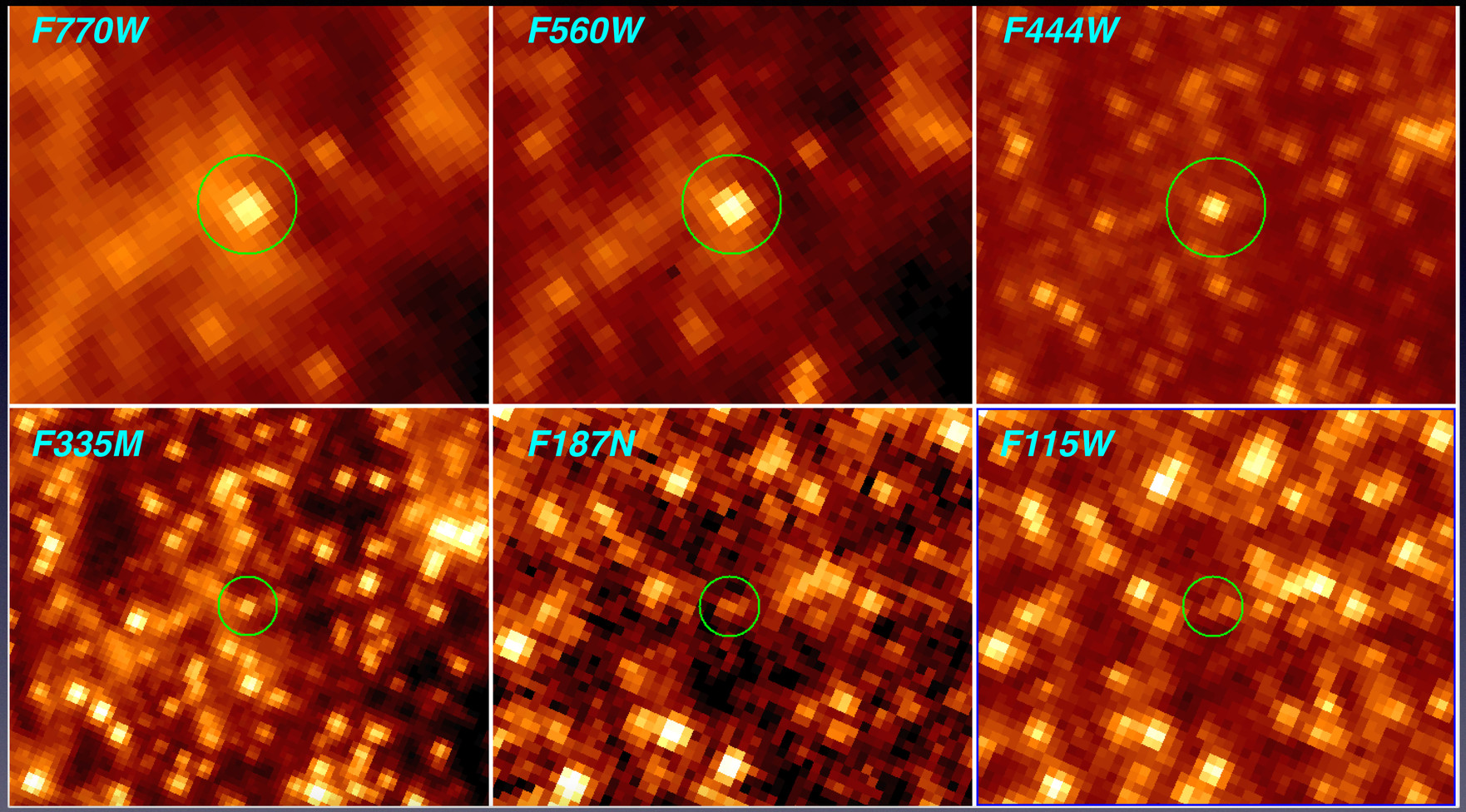
8-yrs SST MIR LC!

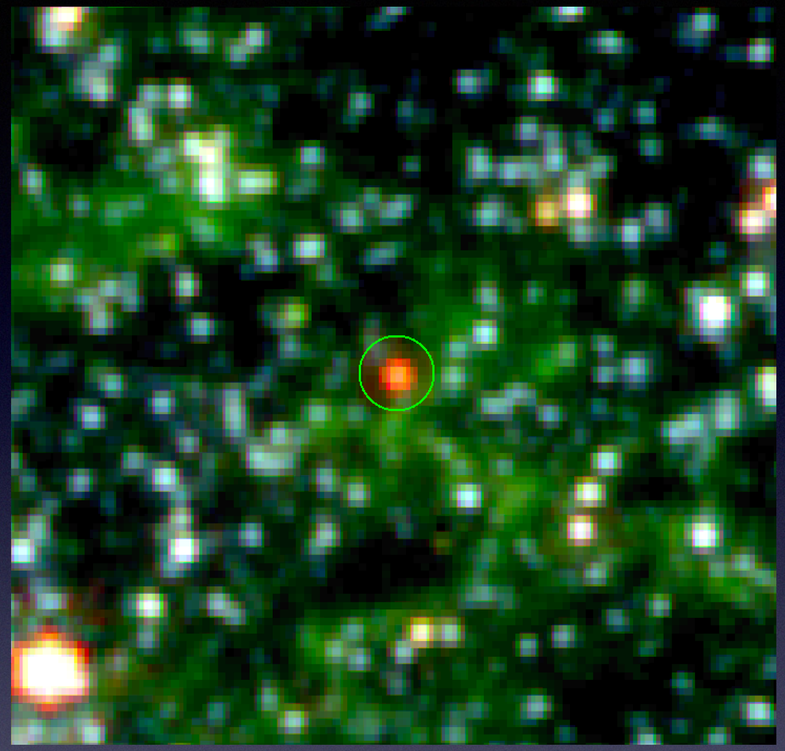
Linear decline

Minor color evolution



NGC4490-OT2011 (JWST)





Still visible in 2023! (+12.5 yrs)

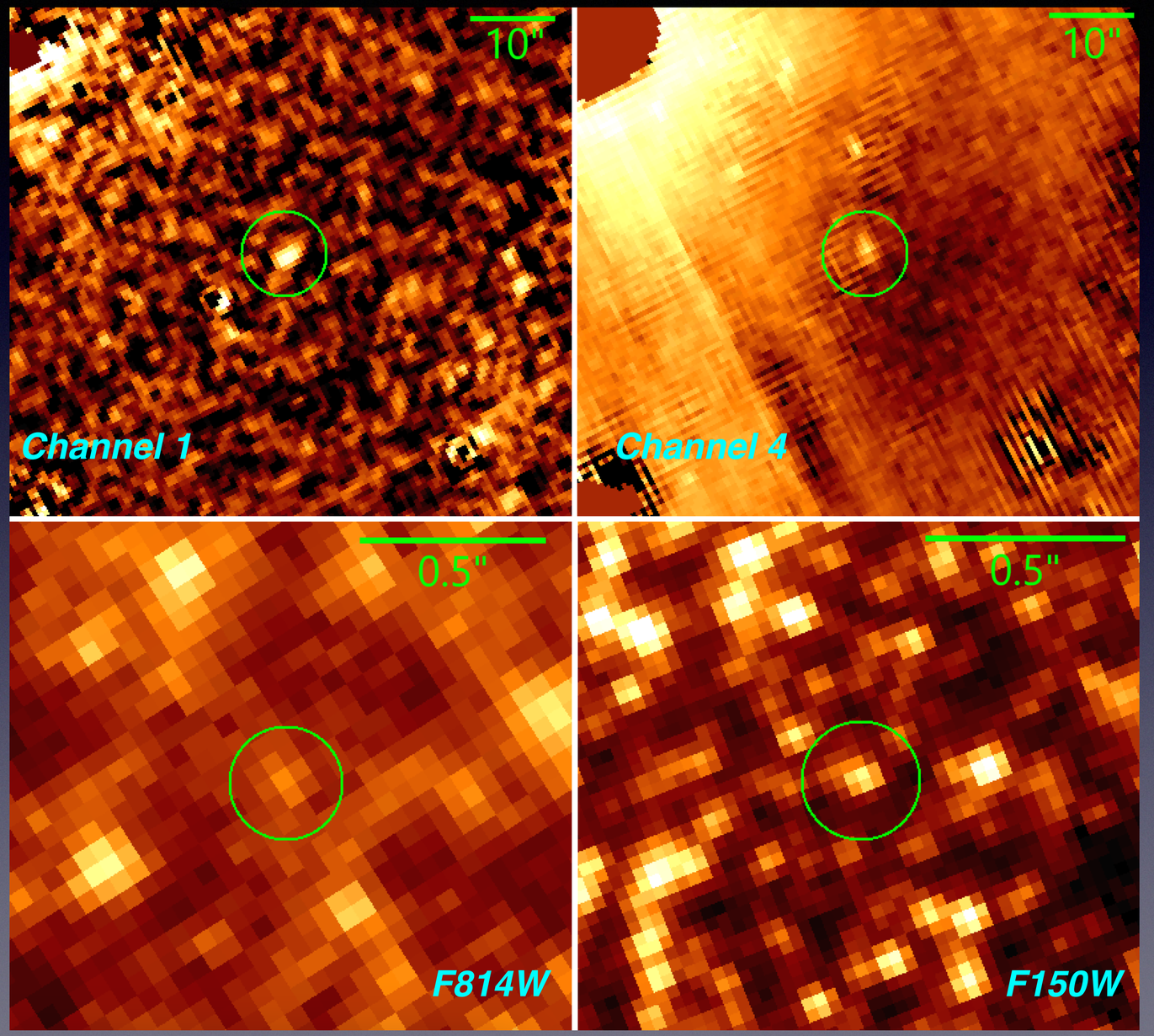
Detected in F187N → Paα emission

AT 1997bs

Studied by Van Dyk+99,00 (SN impostor)

Recovered SST detections in 2004 (all channels)

Thanks Enrico for the template subtraction tool



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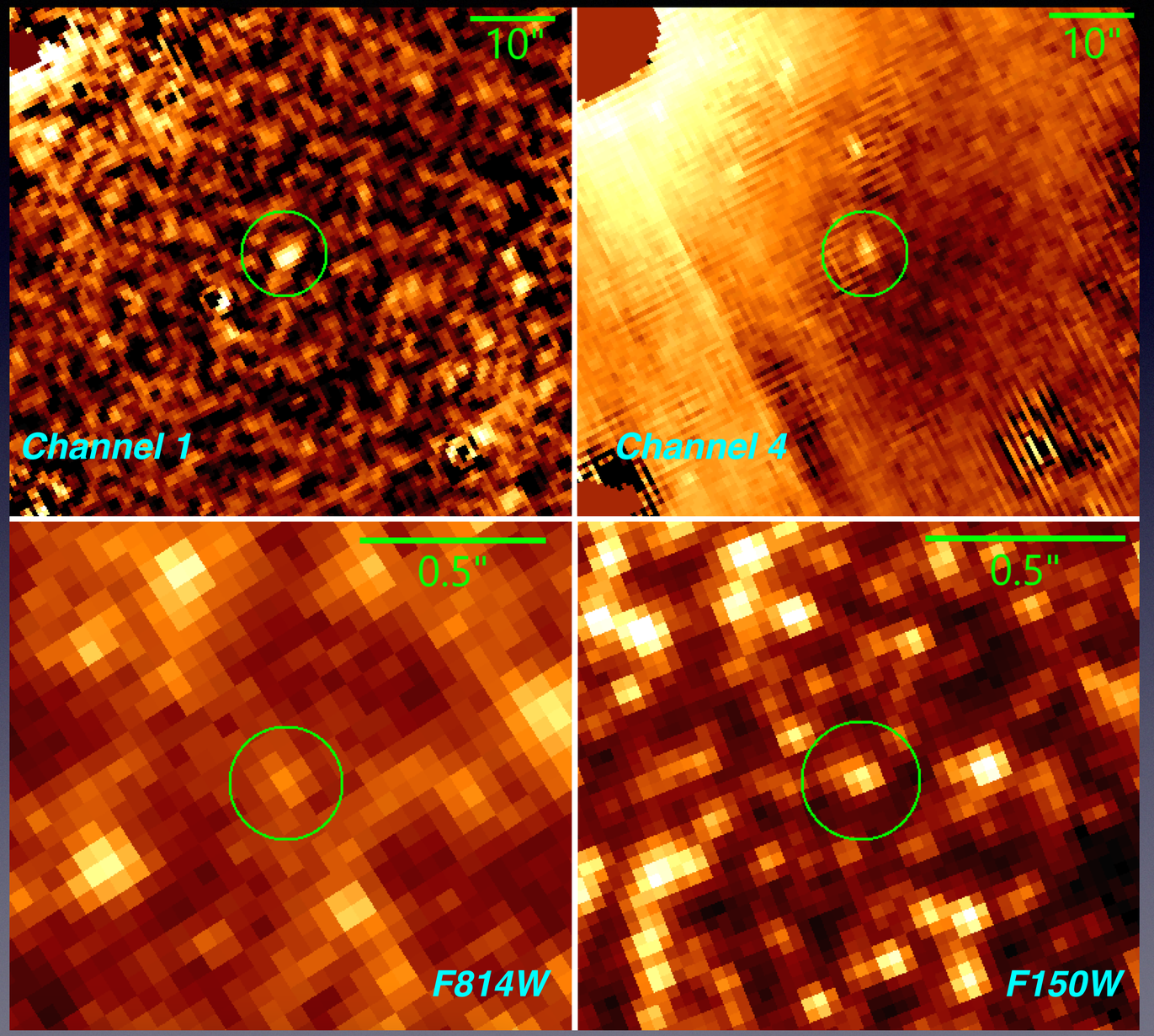
Detected by HST (F814W) in 2023!, at same mag as in 2014 (Adams & Kochanek 15)…

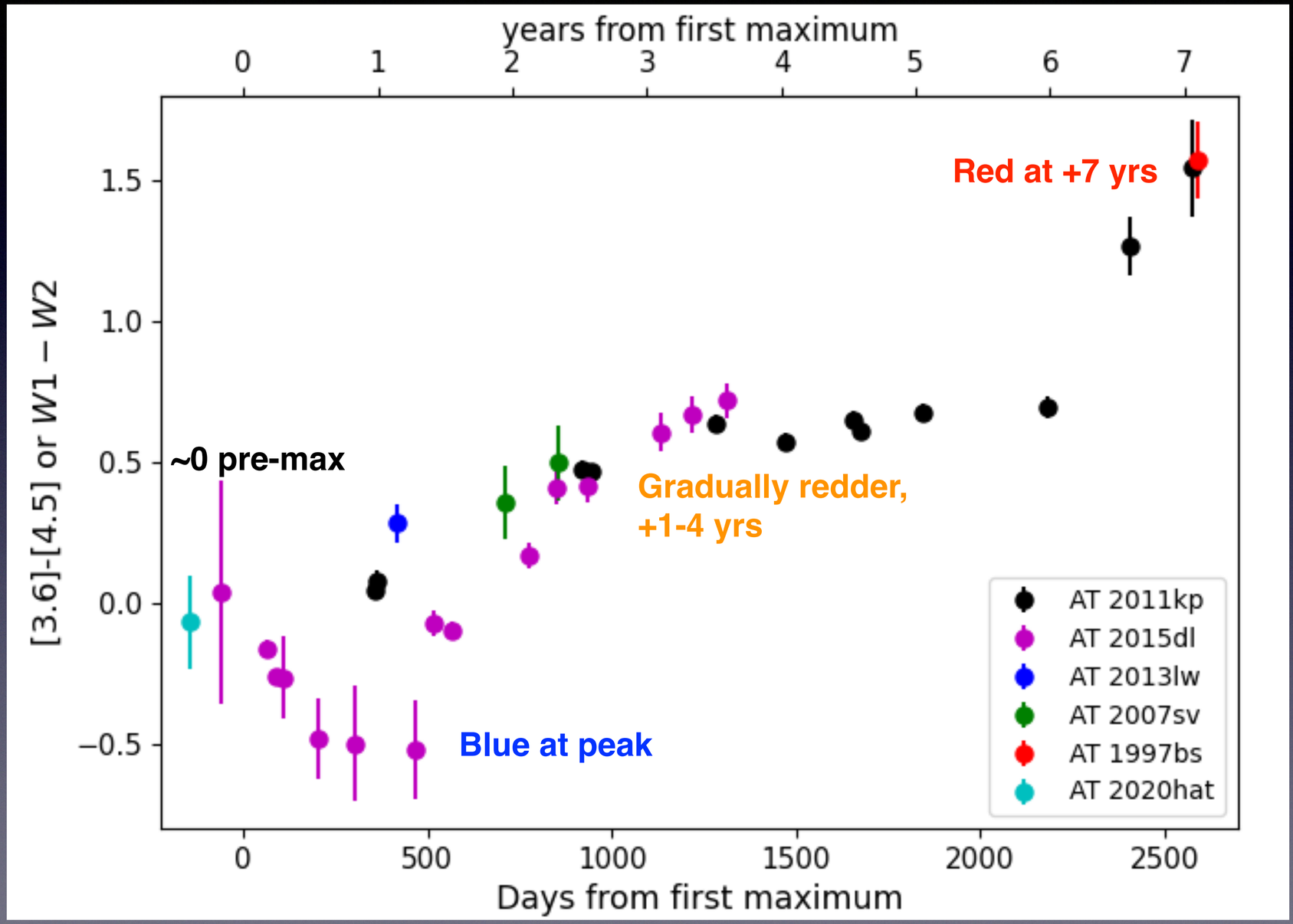
And by JWST/NIRCam in 2024 (+27 yrs)!



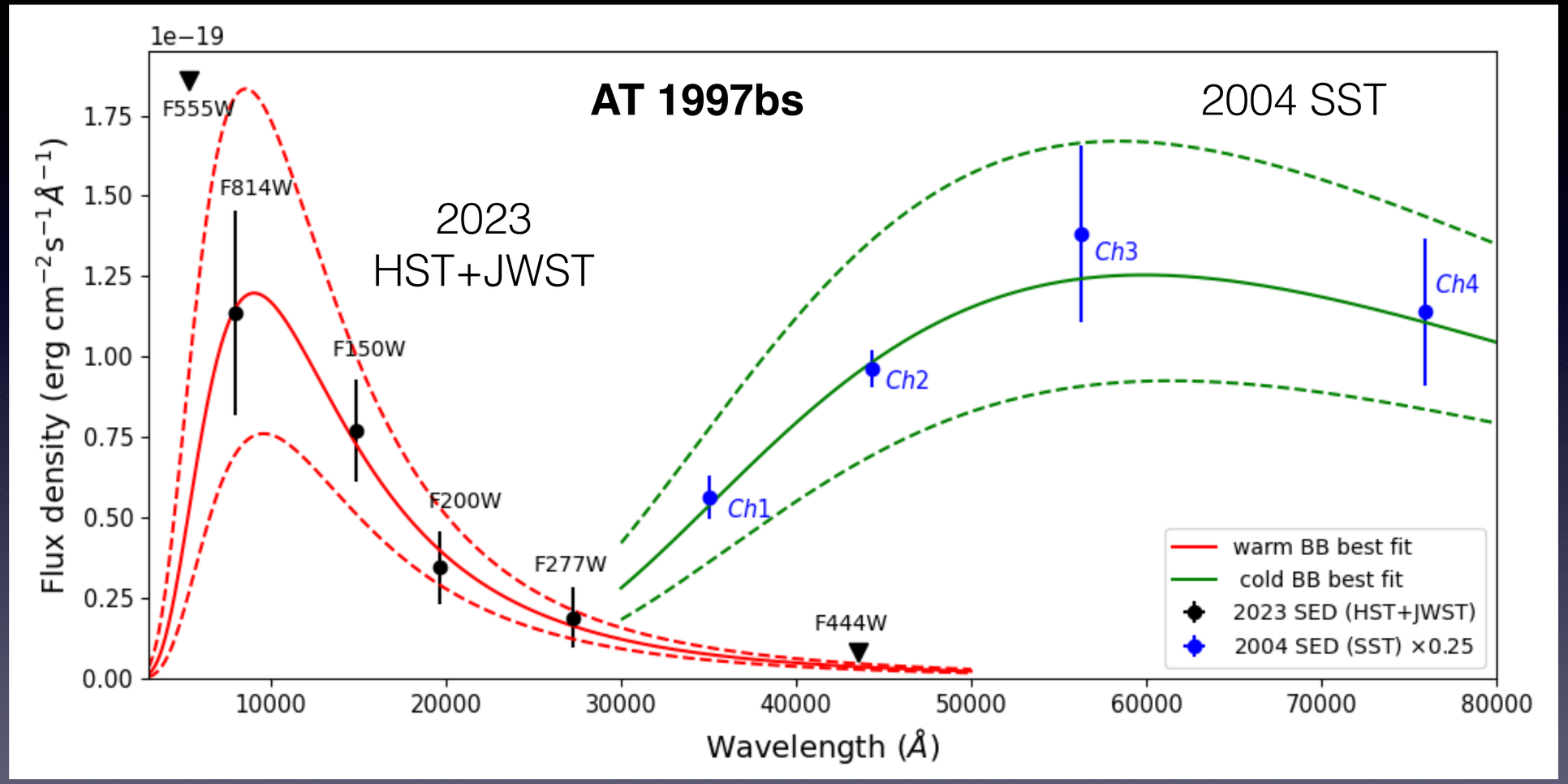
MIR color curves

Similar evolution among different objects

LRNe tend to remain bright in MIR for years



SEDs



2004 SST:
T_{BB}=484±12 K,
R_{BB}=234±20 AU

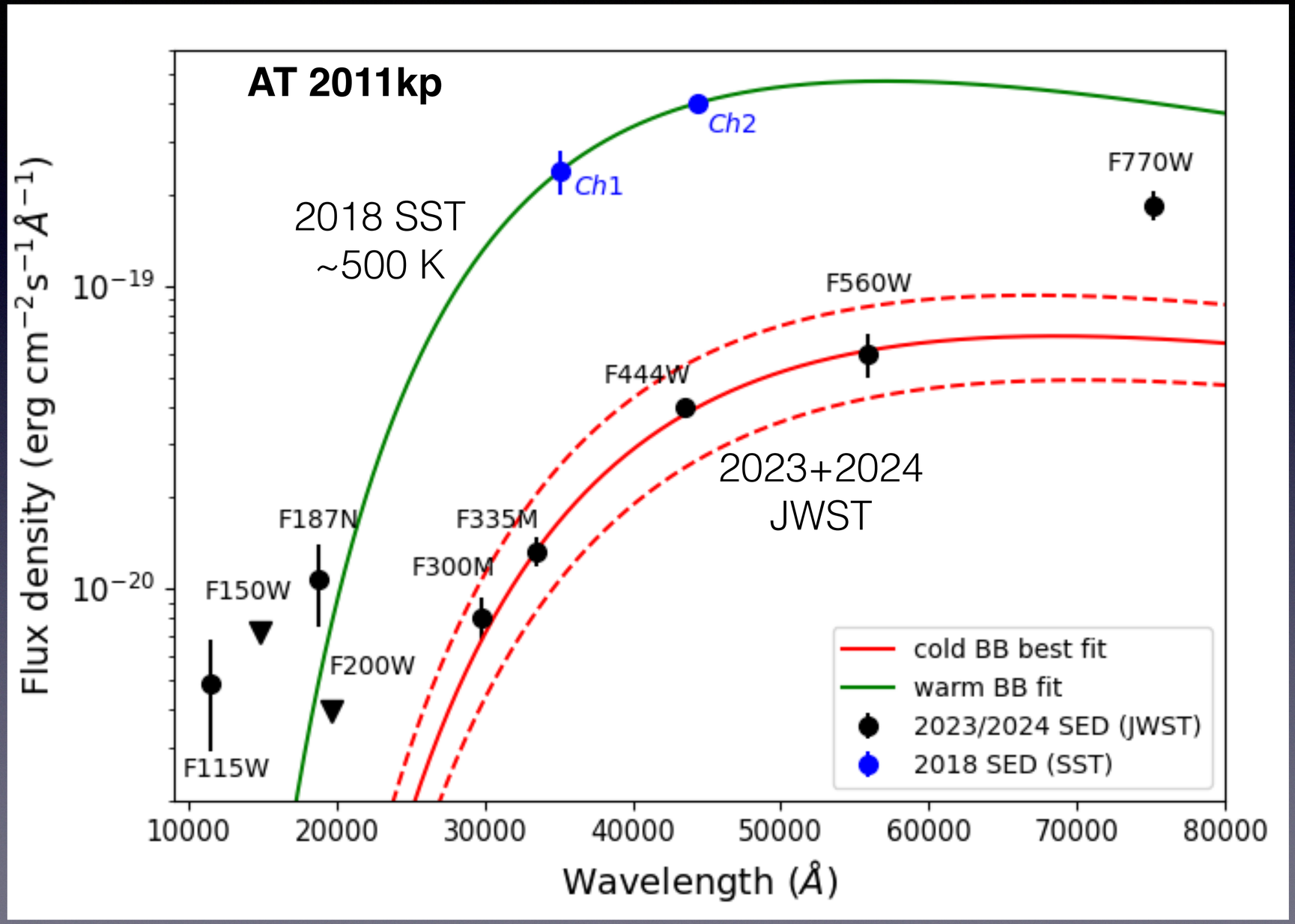
2023 HST+JWST:
T_{BB}=3200±150 K,
R_{BB}=220±20 $R_\odot$

→ merger survivor
expanded, cool object,
~RSG (M6-7 III)

See also Steinmetz+25

Envelope
fragmentation

SEDs



2023+2024 JWST:
T_{BB}=425±10 K,
R_{BB}=123±13 AU

3 clear excess:

- F115W (warm remnant?)
- F187N (Paα line)
- F770W (IR echo?)

3 emitting BBs ?

Dust masses

$$F_\lambda = \frac{M_d B_\lambda(T_d)\kappa_\lambda(a)}{D^2}$$

Dust species	AT 2015dl (+3.6 yrs)		AT 1997bs (+7 yrs)		AT 2011kp (+7 yrs)		AT 2011kp (+13 yrs)	
	M_d ($\times 10^{-6} M_\odot$)	T_d (K)	M_d ($\times 10^{-6} M_\odot$)	T_d (K)	M_d ($\times 10^{-6} M_\odot$)	T_d (K)	M_d ($\times 10^{-6} M_\odot$)	T_d (K)
Graphite $a = 0.1\,\mu$m	1.26	569	32.6±1.3	373±16	17.1	405	6.2±1.4	350±8
Graphite $a = 1.0\,\mu$m	0.16	773	3.0±0.6	470±13	2.22	496	0.80±0.16	416±10
Silicates $a = 0.1\,\mu$m	1.83	731	30.2±4.4	463±9	25.5	479	9.0±1.9	405±9
Silicates $a = 1.0\,\mu$m	1.19	683	25.4±6.4	429±14	16.5	458	6.0±1.2	389±9

- Assume optically thin dust shell
- $\kappa_\lambda(a)$ from Fox+10 and Valerin+25a
- ≠ chem. composition and grain sizes

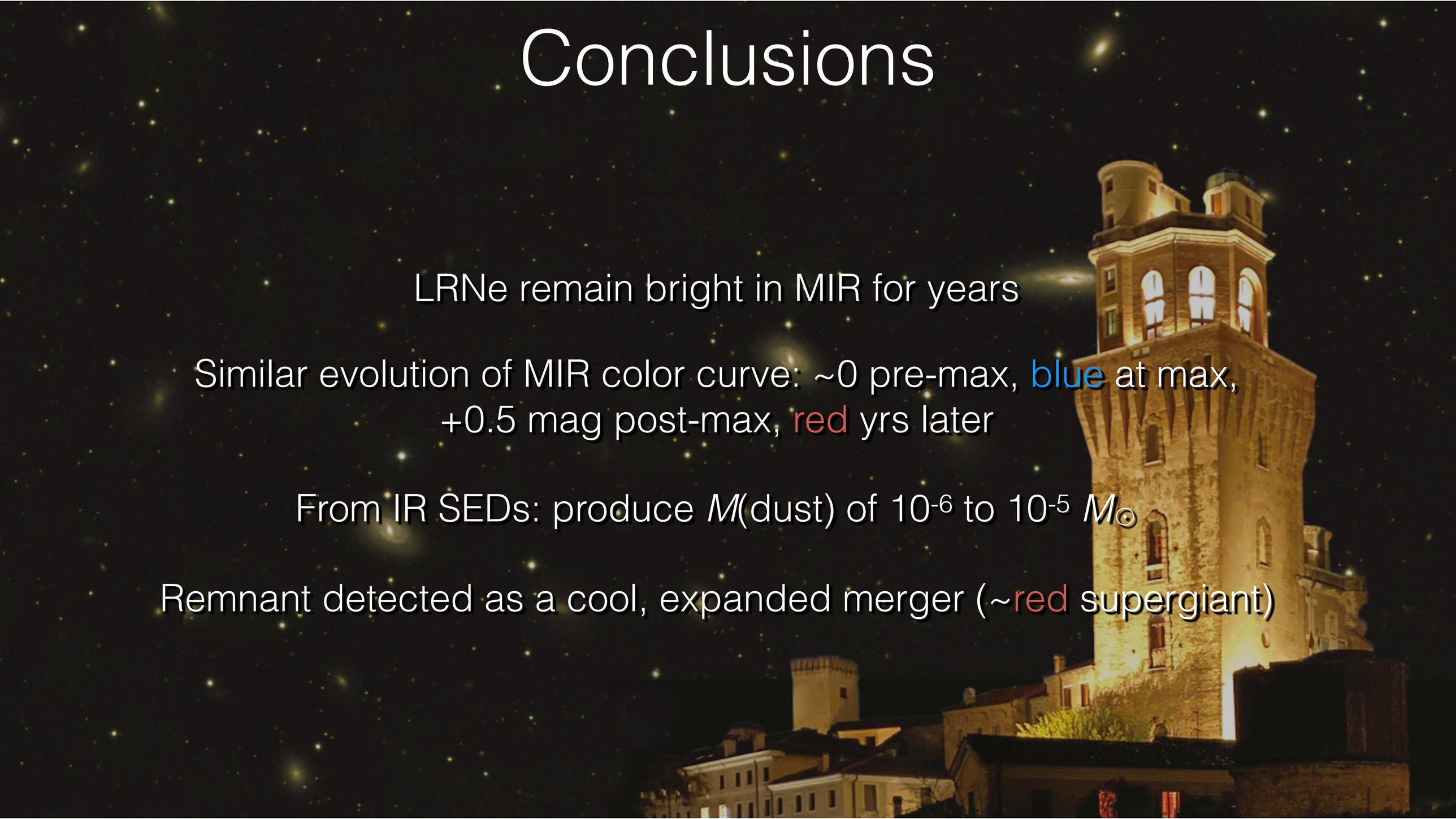
T~350-500 K

M_d~10^{-7} to 3x10^{-5} $M_\odot$

See Kasliwal's talk

Next step: use *Cloudy* to model the SEDs

Conclusions



LRNe remain bright in MIR for years

Similar evolution of MIR color curve: ~0 pre-max, blue at max,
+0.5 mag post-max, red yrs later

From IR SEDs: produce M(dust) of 10^{-6} to 10^{-5} $M_{\odot}$

Remnant detected as a cool, expanded merger (~red supergiant)