

# Giant Eruptions (Supernova Impostors)

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# Supernova Impostors

- Observed outburst with  $\sim 10^{49-50}$  erg, i.e., comparable to that of a SN
- Many impostors spectroscopically resemble SNe IIn, but, photometrically show erratic light curves which only reach  $M_{\text{peak}} \sim -14$  (or less)
- Supernova: only compact remnant left
- SN impostor: the star (by-and-large) survives  
**superoutbursts of LBVs or LBV-like stars?**

# Evolution of The Most Massive Stars

Giant eruptions are necessary

Galactic Wolf-Rayet Stars (WRs)

have  $M_{WR} \leq 20 M_{\odot}$   
(Crowther 2007)

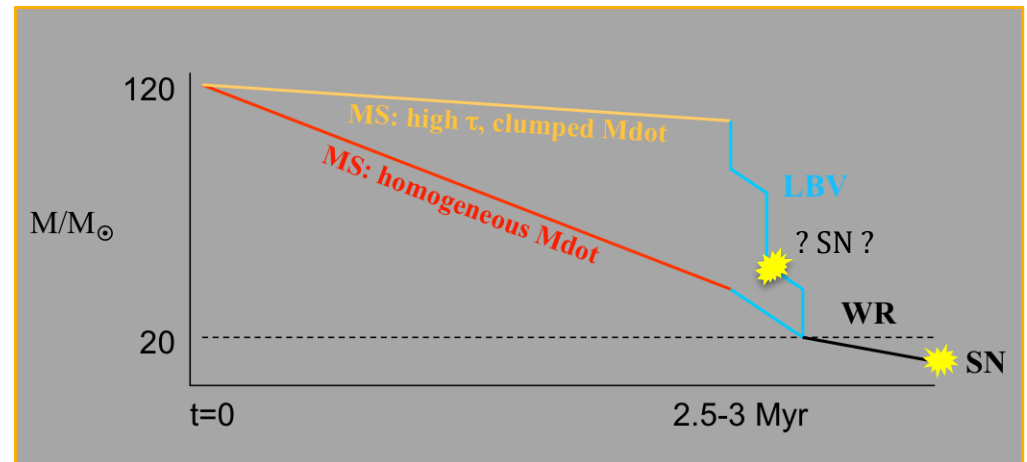
Continuum-driven wind  
(Smith & Owocki 2006)

or

explosive (Smith 2012)  
mass loss?

What is the mechanism?

Vink, Arnett talks



(figure stolen from a talk by Nathan Smith)

# But, what are Supernova Impostors?

- Things were so simple back at the Tetons meeting....
- Some (all?) impostors are dusty
- Some impostors have exploded as SNe
- Some impostors *still* have not exploded
- Some impostors may not even be impostors  
(or are they?)
- We just have way more objects now  
(and way more impostor lovers....)

# Supernova Impostors

SN 1954J	SN 2001ac	SN 2006qq
SN 1961V*	SN 2002bu	SN 2007sv
NGC 2366-V1	SN 2003gm	SN 2009ip**
SN 1997bs	NGC 4656-OT1 (?)	UGC 2773-OT2009-1
SN 1999bw	SN 2006bv (?)	SN 2010C
SN 2000ch	SN 2006fp	SN 2010da
PSN J10523453+2256052?	TCP J09495016+1241356?	SN 2010dn
PSN J12304185+4137498	PSN J12355230+2755559	PSN J17592296+0617267
NGC 5908-OT2012-1	PSN J09454377+4107380	(eta Car?)

\*RIP?    \*\*RIP

# (Far?) Less Certain or NOT Impostors

SN 2008S ??

NGC 1511-OT2010-1 ?

NGC 5775-OT2012-1 ?

SNHunt79 ?

SNHunt41 ?

M85 OT2006-1 ??

SN 2003hy (not an impostor)

TCP J07592325+1625109 ?

SNHunt51 ?

SNHunt151 ?

NGC 300-OT2008-1 ??

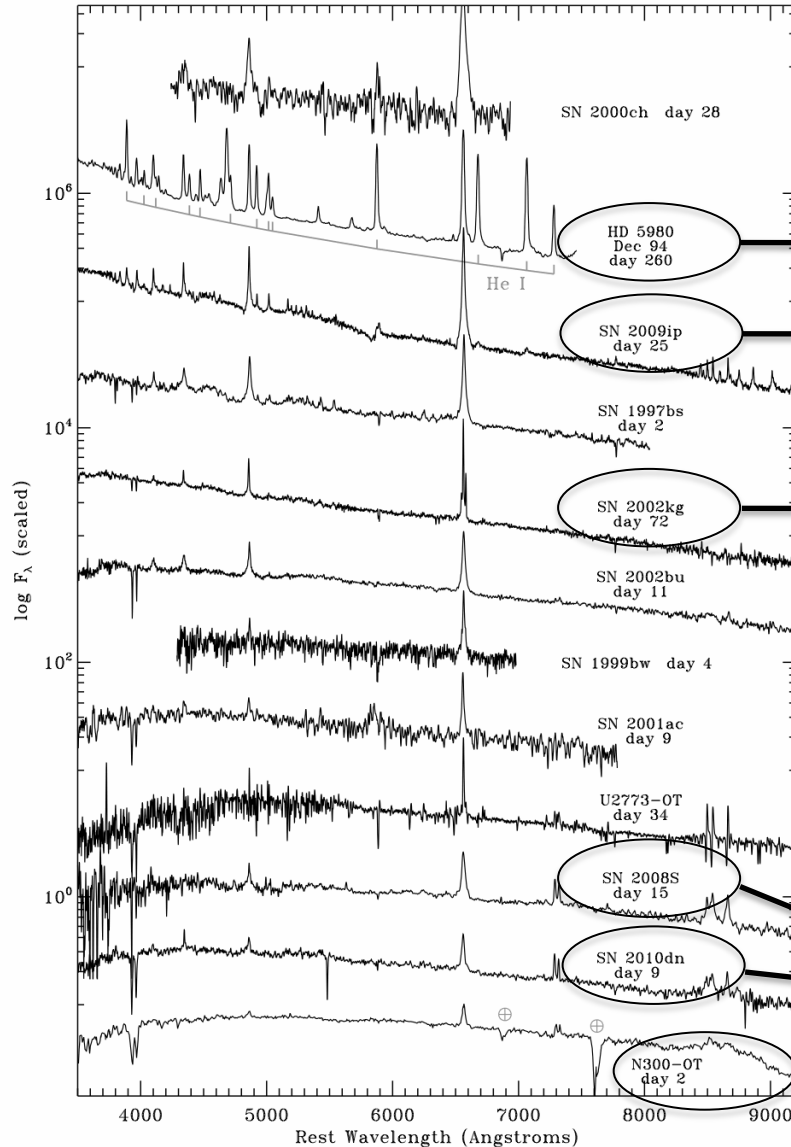
SN 2010U (luminous nova)

PSN J15250852+3757494 ?

SNHunt45 ?

# Supernova Impostors

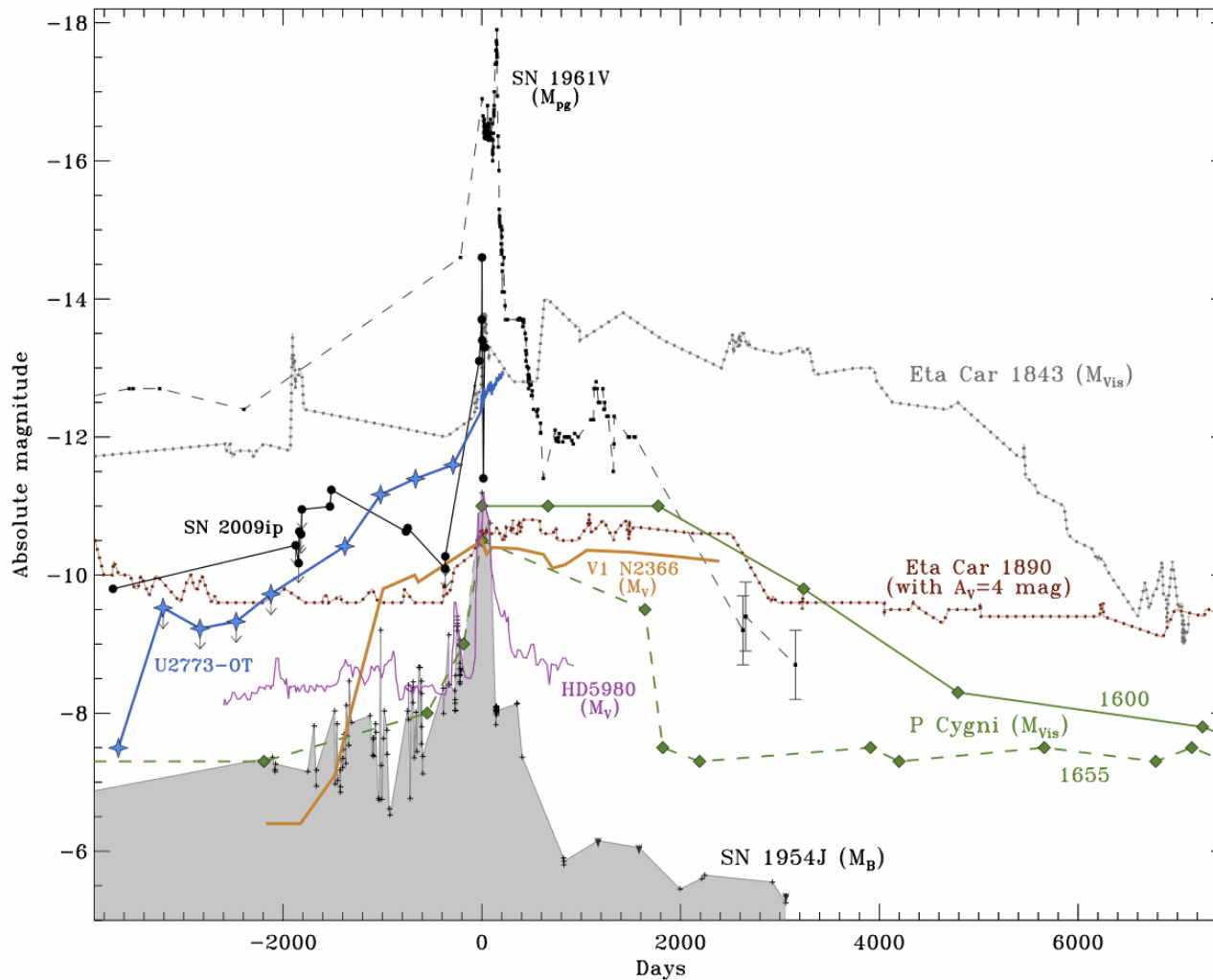
N. Smith et al. (2011)



A variety of spectral properties

impostors?

# Supernova Impostors



N. Smith et al. (2011)

also  
Van Dyk & Matheson  
(2012a)

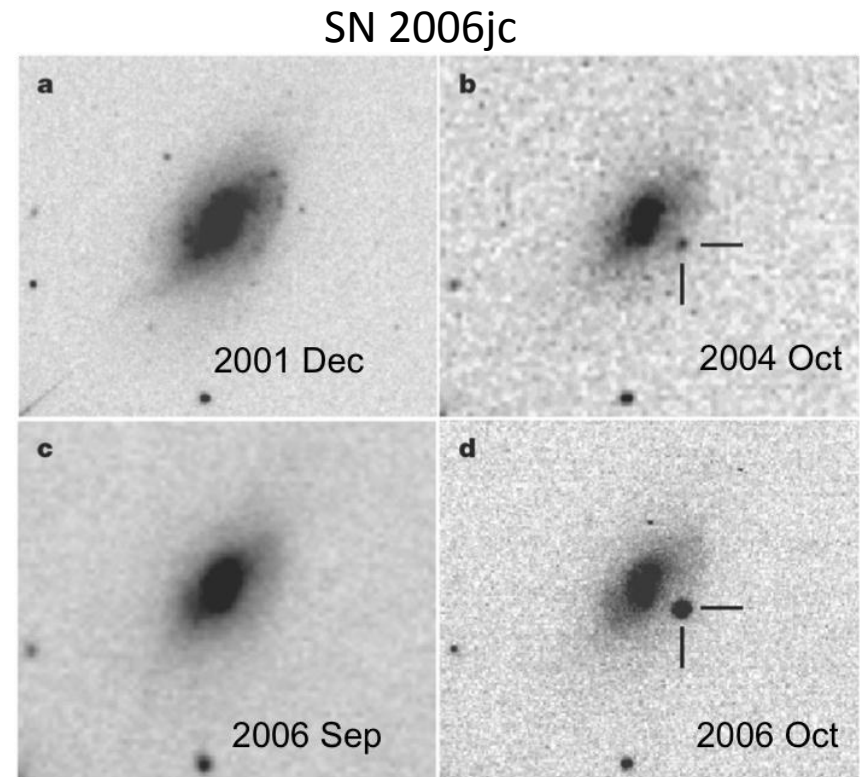
A variety of  
light curve  
properties



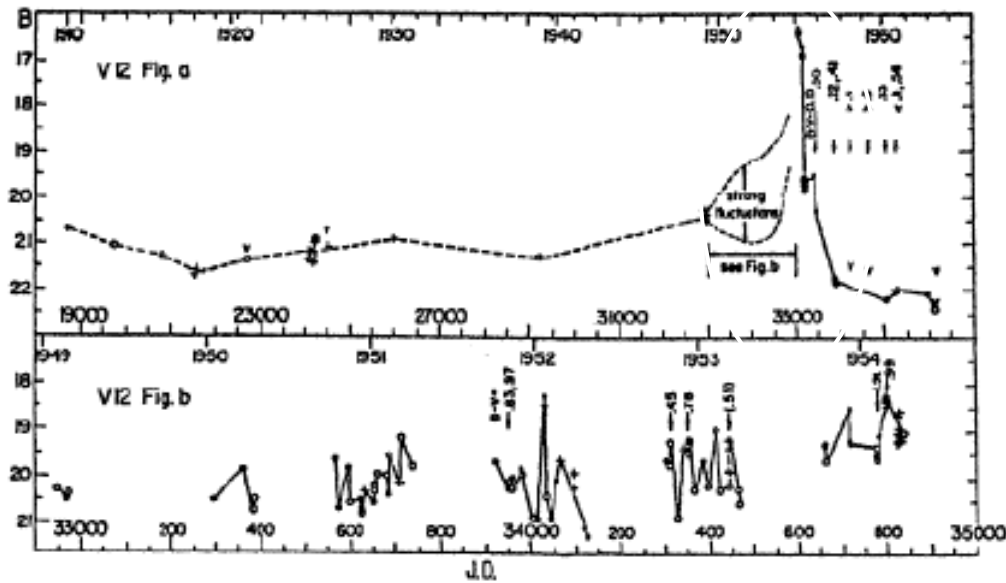
# Supernova Impostors

## Connection to SNe

- the pre-explosion outburst of the progenitor of SN Ibn 2006jc (Foley et al. 2007; Pastorello et al. 2007)
- The progenitor of SN IIn 2005gl (Gal-Yam & Leonard 2009)
- the highly luminous SN IIn 2006gy (Ofek et al. 2007; Smith et al. 2007)
- SN IIn PTF 09uj (Ofek et al. 2010)
- SNe IIn show evidence for high pre-SN  $\dot{M}$ , consistent with LBV eruptions (Kiewe et al. 2010)
- **“SN 2009ip” → SN IIn 2009ip (Mauerhan et al. 2012)**

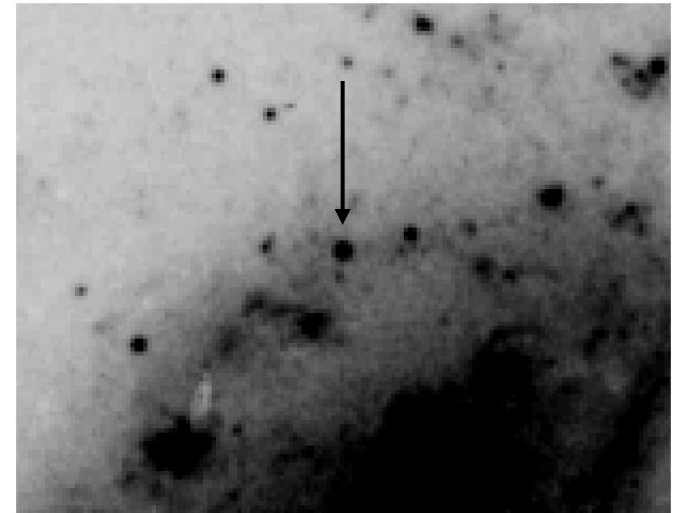


# SN 1954J/Variable 12 in NGC 2403



(Tammann & Sandage 1968)

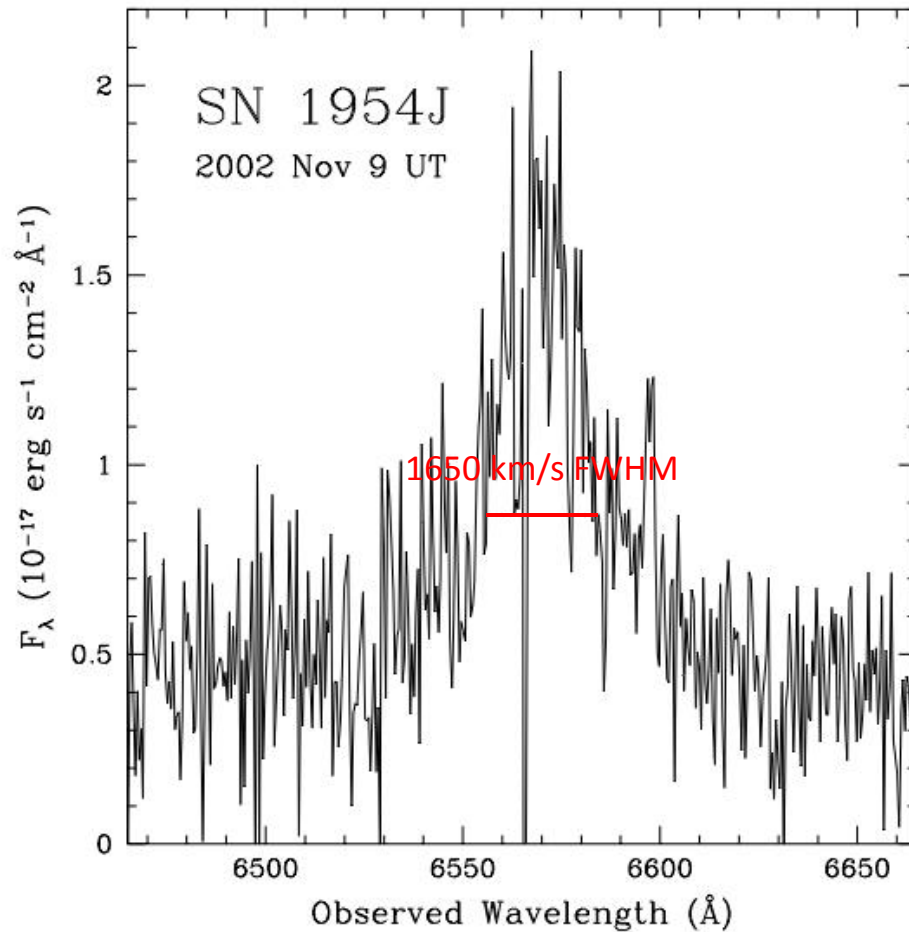
Distance = 3.4 Mpc



POSS-I from 1955

No spectrum

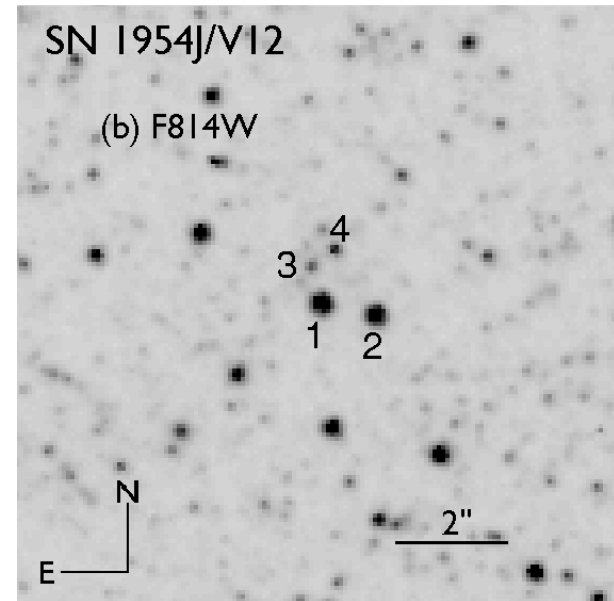
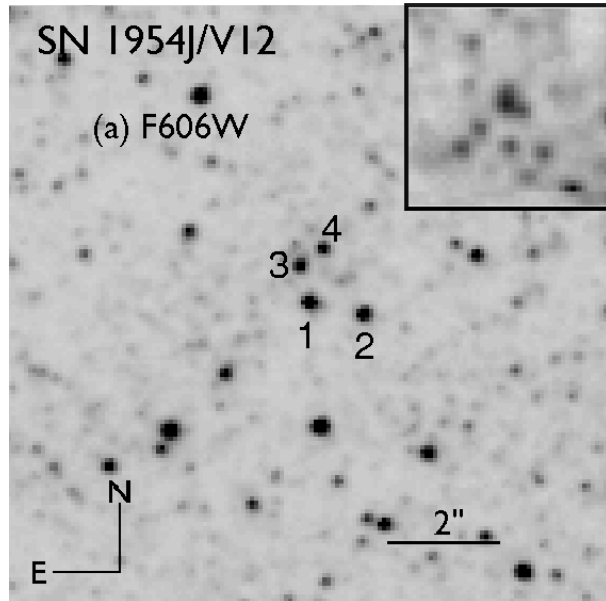
# SN 1954J/Variable 12 in NGC 2403



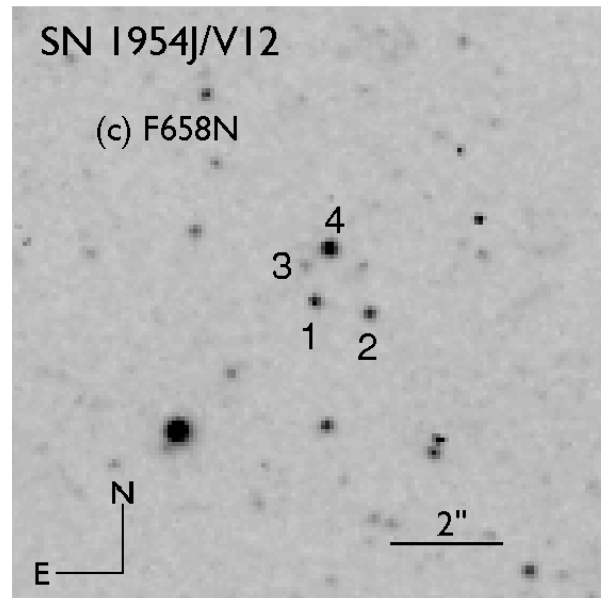
Keck-II ESI  
40-min exposure  
 $\sigma \sim 700$  km  $s^{-1}$

Van Dyk et al. (2005)

# SN 1954J/Variable 12 in NGC 2403



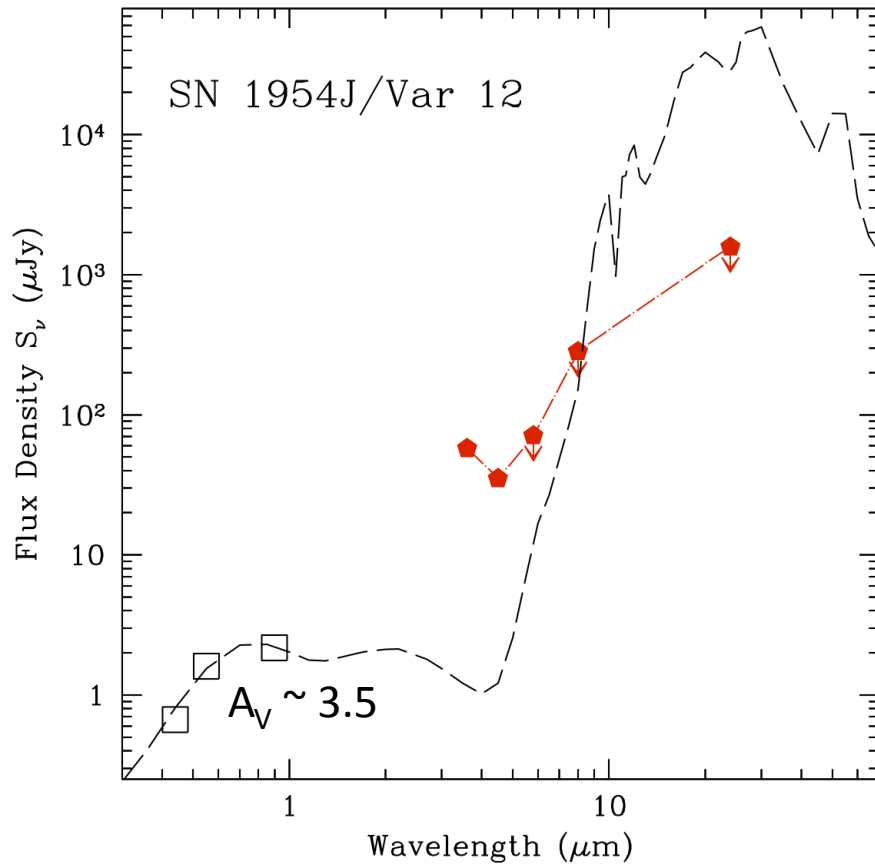
HST ACS/WFC  
in  
2004



Survivor  
Van Dyk et al. (2005)

see also  
Smith, Humphreys, &  
Gehrz (2001)

# SN 1954J/Variable 12 in NGC 2403



DUSTY model with  
amorphous fayalite & olivine  
grains 0.03--2  $\mu\text{m}$

$R_{\text{in}} \sim 1.3 \times 10^{17} \text{ cm}$   
 $T_{\text{dust}} \sim 200 \text{ K}$

$V - \mu_0 = -4.0 \text{ mag only}$

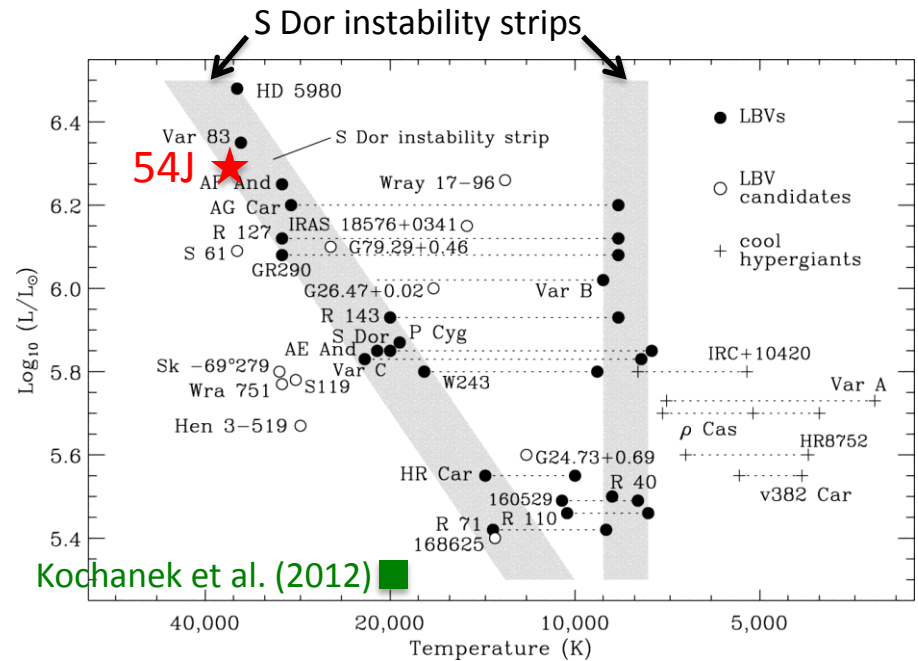


Figure from Smith, Vink, & de Koter (2004)  
(adapted from Humphreys & Davidson 1994)

# SN 1961V in NGC 1058

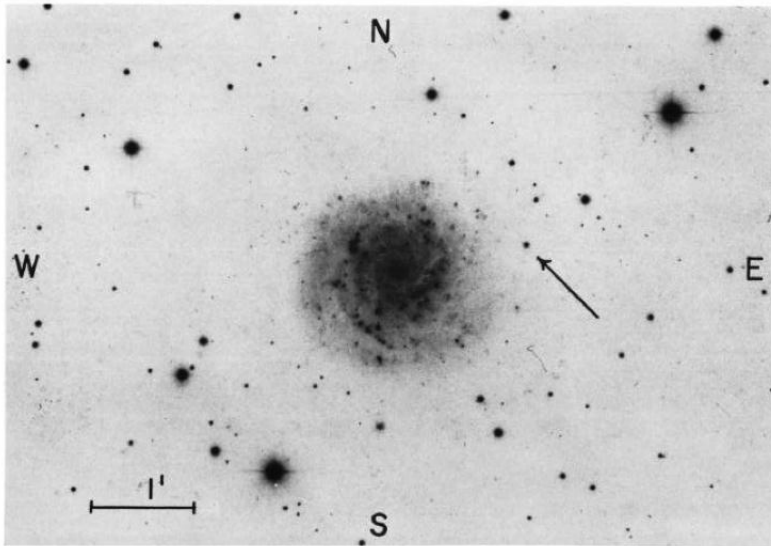


FIG. 1.—Photograph of the spiral galaxy NGC 1058 at R.A.  $2^{\text{h}}40^{\text{m}}29^{\text{s}}$  and decl.  $+37^{\circ}03'$  (Epoch 1950.0), obtained on October 22, 1962, with the 200-inch Palomar telescope on emulsion 103a-O, exposure time 20 minutes, seeing 1-2. The scale is as indicated. The supernova is marked by the arrow. The galactic longitudes and latitudes of NGC 1058 are, respectively,  $115^{\circ}$  and  $-20^{\circ}$ .

Distance = 9.3 Mpc

Bertola (1964) and Zwicky (1964)  
progenitor detection?

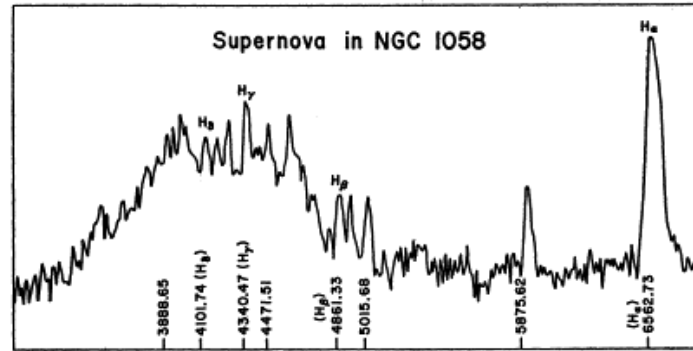
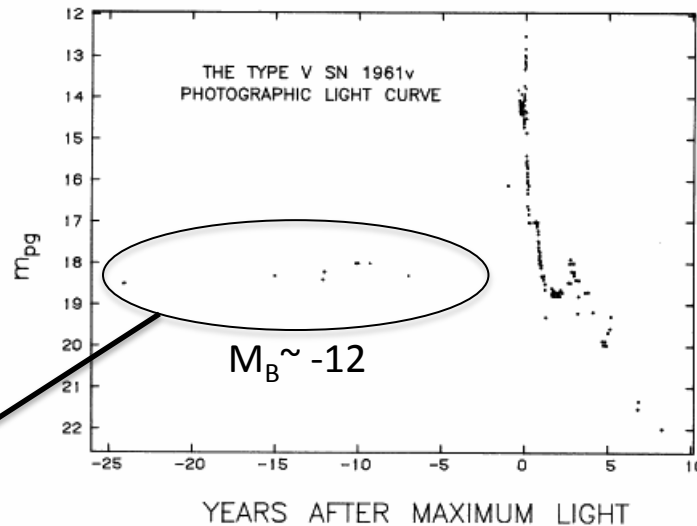


FIG. 2.—Direct tracing of a spectrogram of the supernova in NGC 1058 obtained with the 200-inch prime focus spectrograph on February 1, 1962. Emulsion 103a-F, dispersion  $400 \text{ \AA/mm}$ , exposure time 65 min at seeing 3. In addition to the Balmer lines, which are indicated, many emission lines due to He I and Fe II are clearly discernible.

(velocity width  $\sim 2000 \text{ km s}^{-1}$ ; note asymmetric profiles)

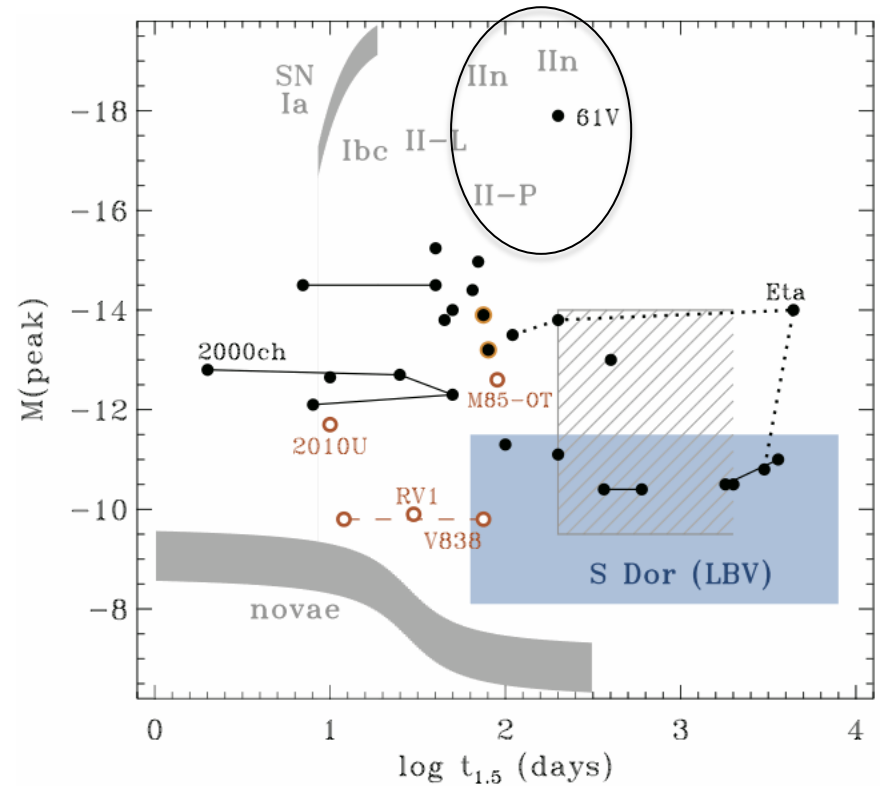
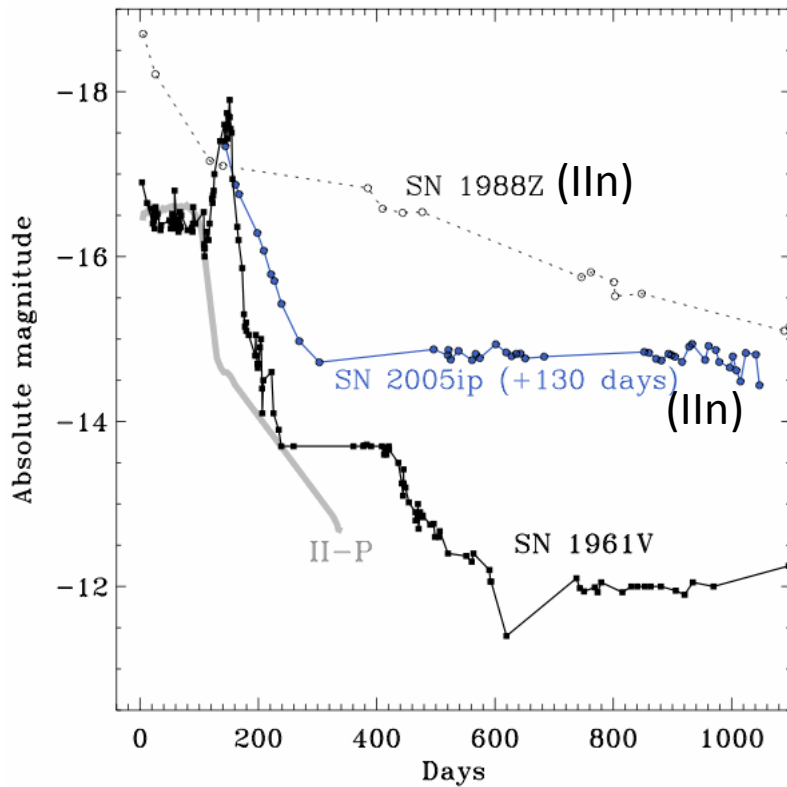
Zwicky (1964)  
"Type V"



Doggett & Branch  
(1985)  
(from Bertola 1964;  
Bertola & Arp 1970)

Also  
Humphreys &  
Davidson (1994)

# SN 1961V: A Hybrid Supernova?

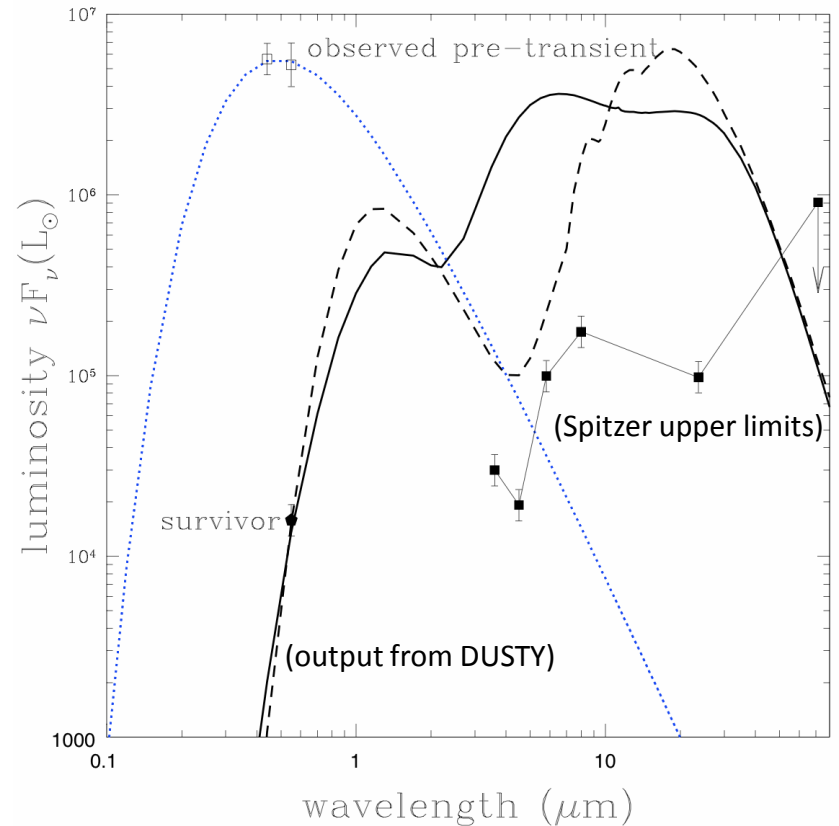


(Smith et al. 2011)

# SN 1961V: An Impostor Impostor?

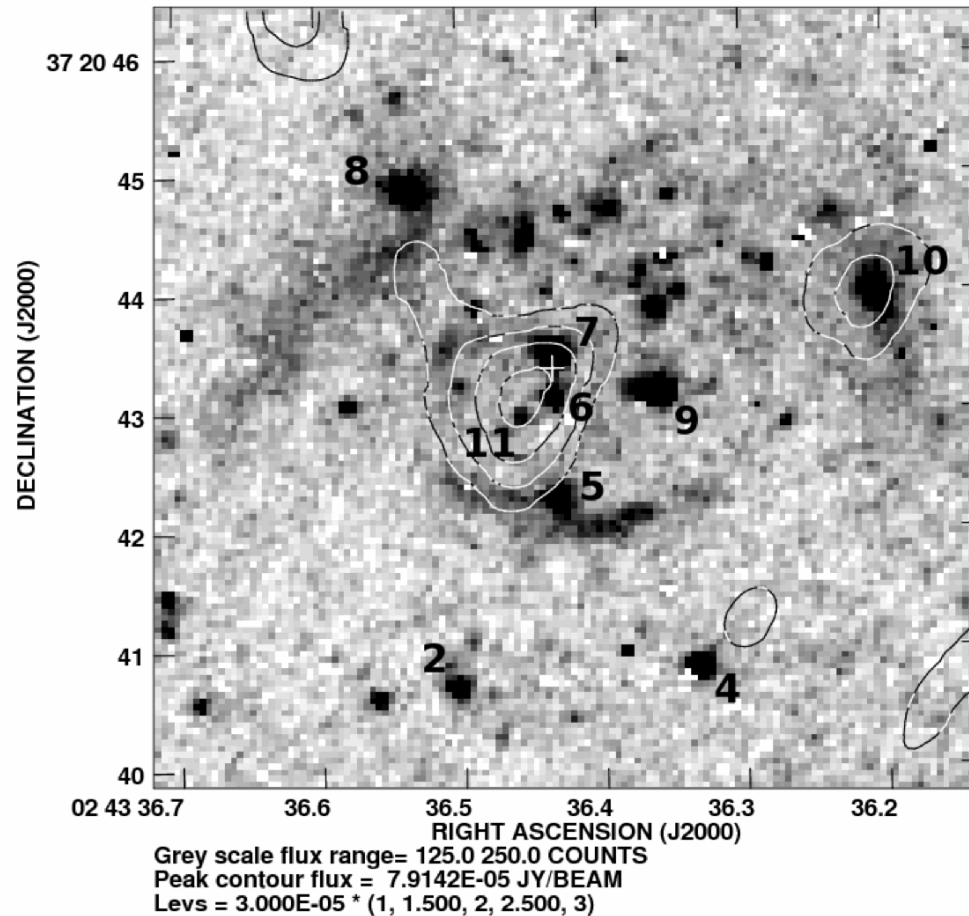
- If it were an “eta Car analog,” 61V should be the most IR luminous object in its host galaxy

(Kochanek et al. 2011)





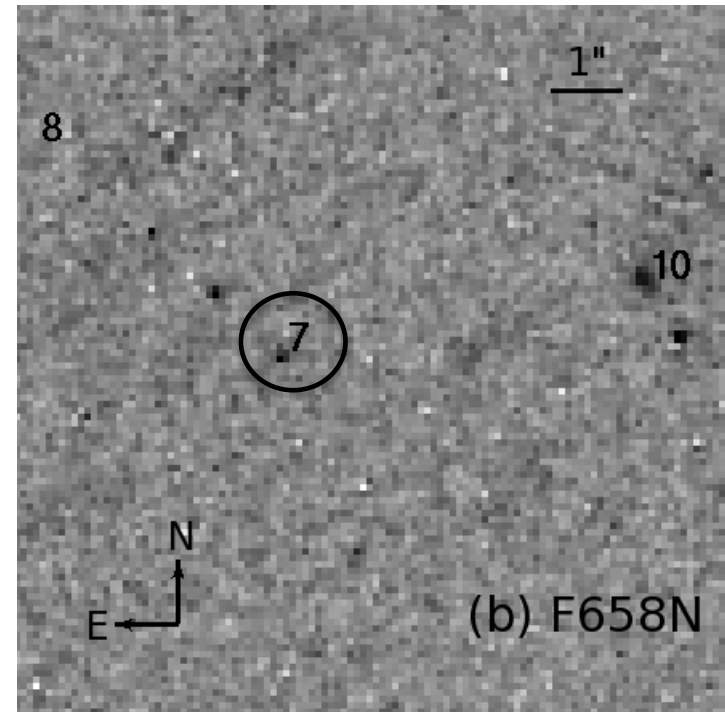
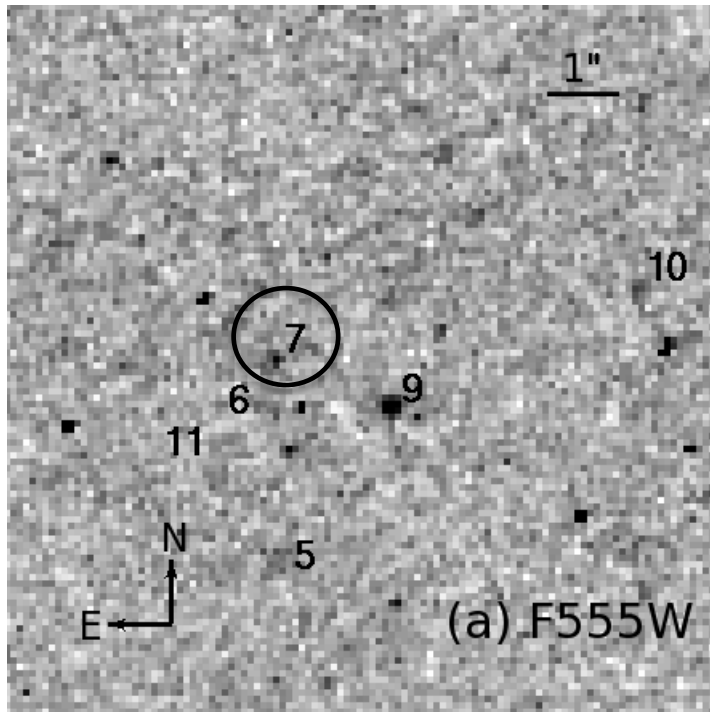
# Radio emission near the site is offset from 61V



HST STIS 50CCD  
imaging from 2002;  
Stockdale et al. 6 cm  
VLA data;  
Absolute SN position  
from Klemola (1986)

(Van Dyk & Matheson 2012b)

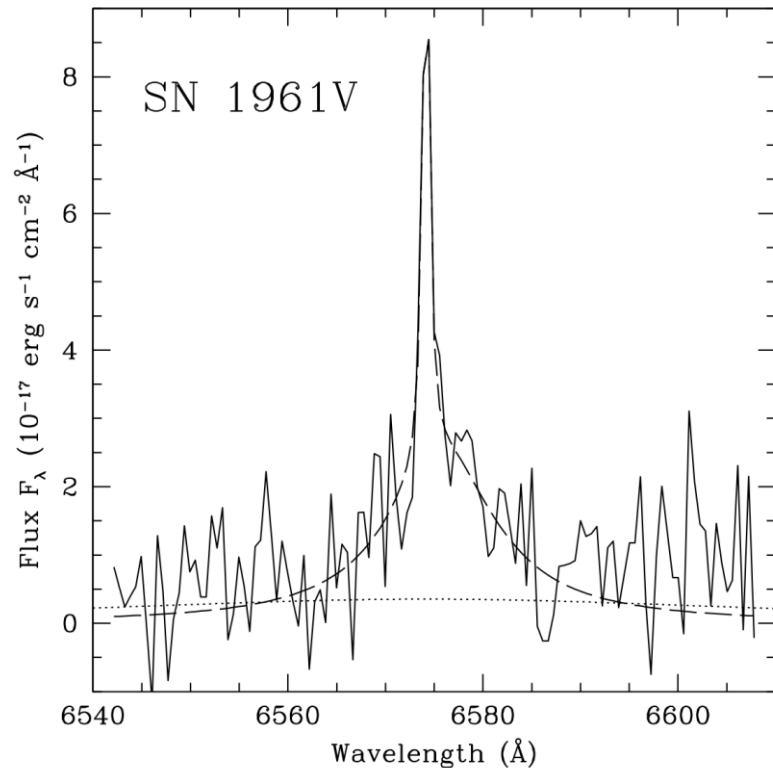
# We claim that SN 1961V survives as Object 7



HST WFPC2 imaging from 2008

(Van Dyk & Matheson 2012b)

# The 61V survivor resembles a LBV



HST STIS spectrum from 2002 (Chu et al. 2004)

## Object 7

velocity width of broad component  
 $\sim 311 \text{ km s}^{-1}$

similar to that currently for  $\eta$  Car A

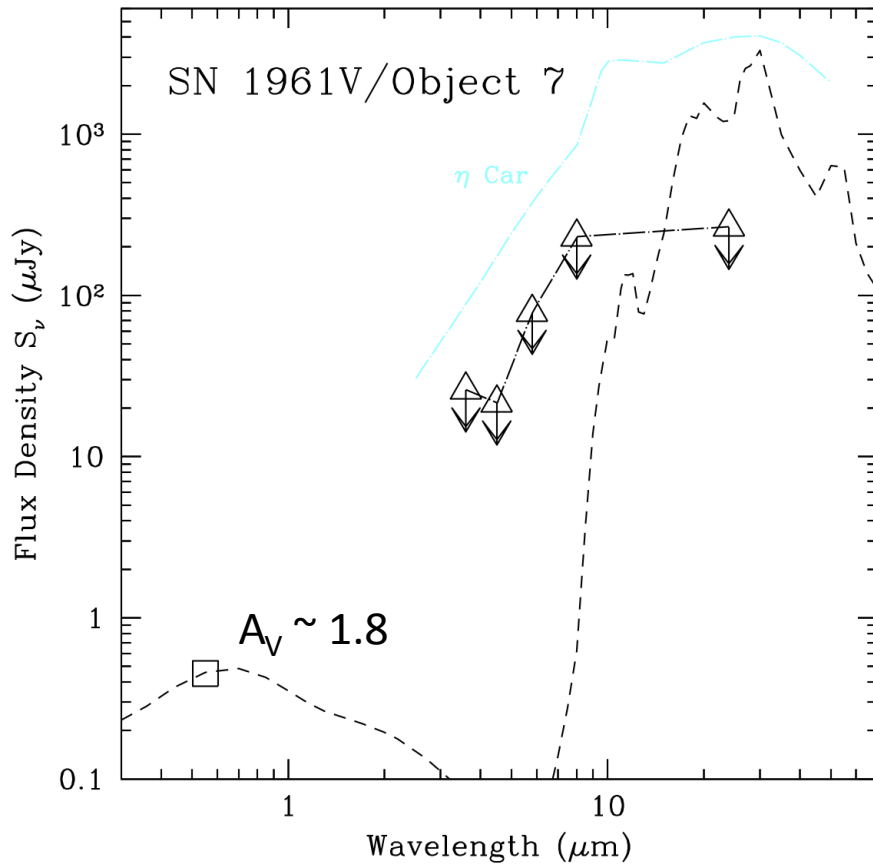
Same asymmetric profile as in 1961

Line flux matches F658N flux

(dashed line is the  $\sim 2000 \text{ km s}^{-1}$   
component from 1961)

(Van Dyk & Matheson 2012b)

# SN 1961V Survivor, Object 7



DUSTY model with  
amorphous fayalite & olivine  
grains 0.03--2 μm

$R_{in} \sim 2.7 \times 10^{17}$  cm  
 $T_{dust} \sim 148$  K

$V - \mu_0 = -5.1$  mag only  
 $L(H\alpha 61V) \sim 10 \times L(H\alpha 54J)$

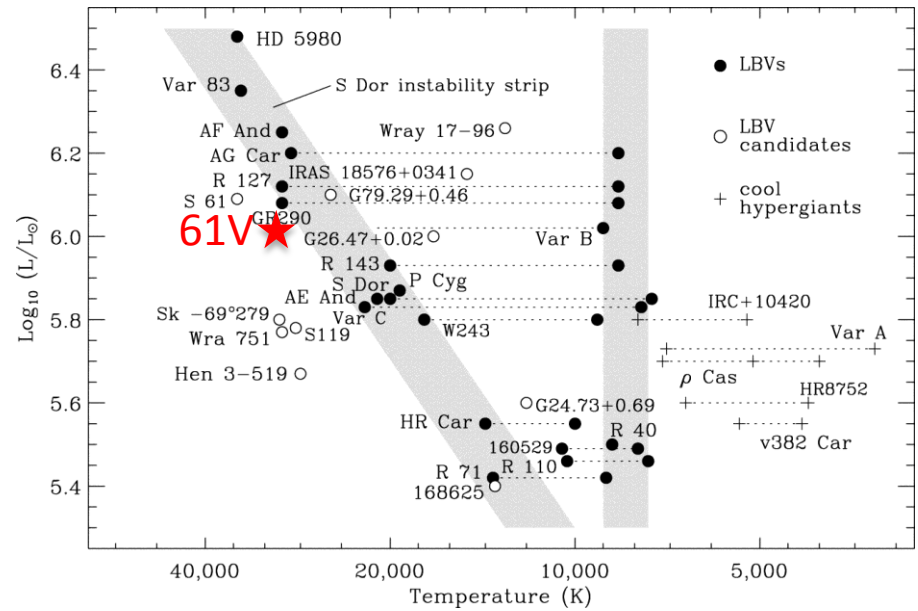
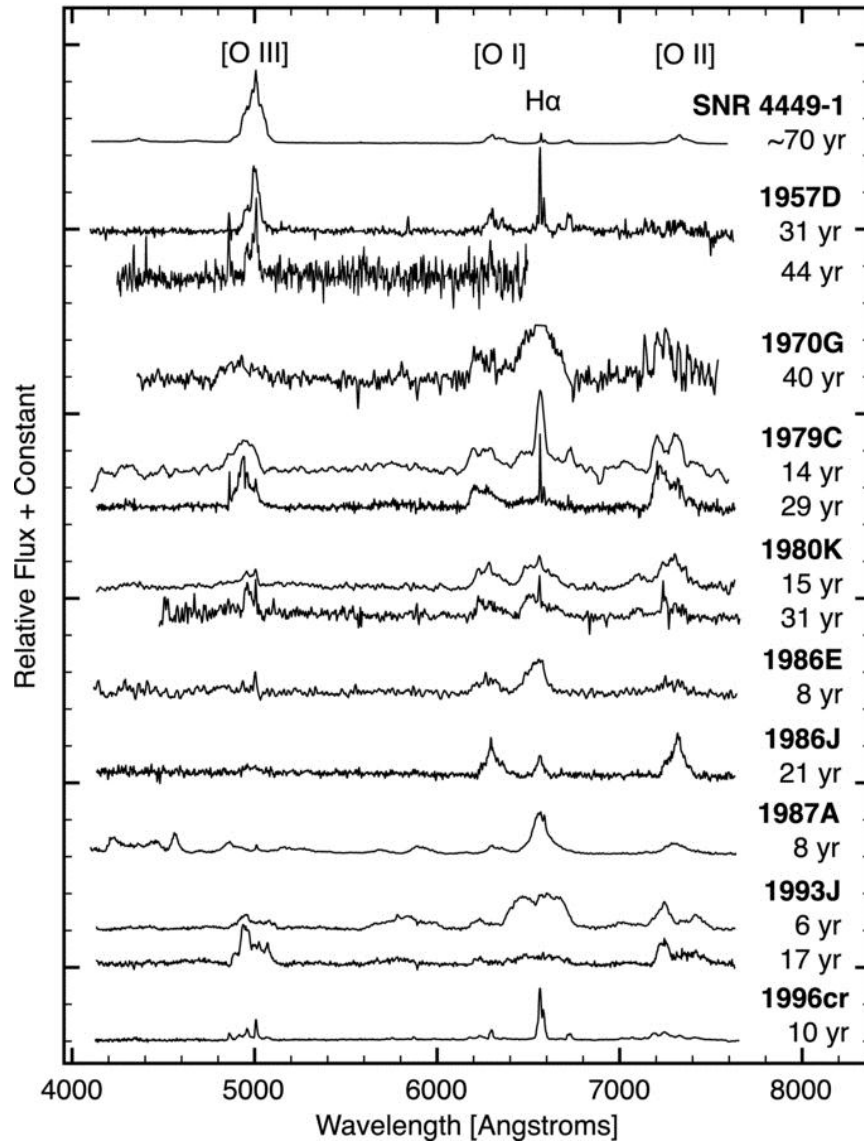


Figure from Smith, Vink, & de Koter (2004)

THIS IS SOMETHING OF  
A PARADOX

# What if 61V *were* an old SN?



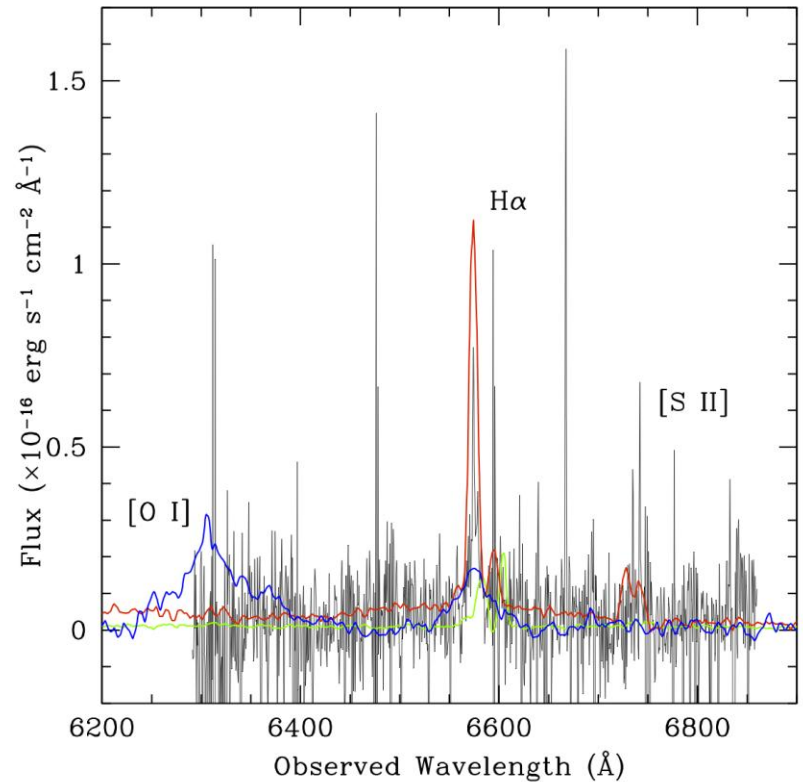
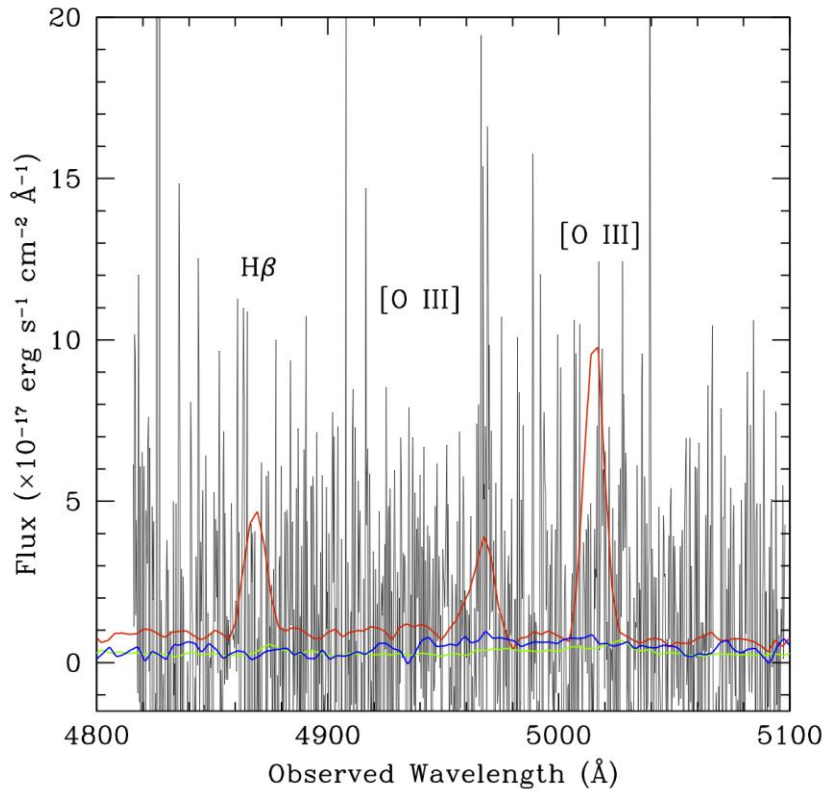
Milisavljevic et al. (2012)

Spectra of old SNe with  
 $\gtrsim 2000 \text{ km s}^{-1}$  HWZI

Wouldn't we expect 61V to  
look sort of like one of  
these by now?

# What if 61V *were* an old SN?

HST STIS G430M and G750M spectra of SN 1961V from 2002 (Chu et al. 2004)

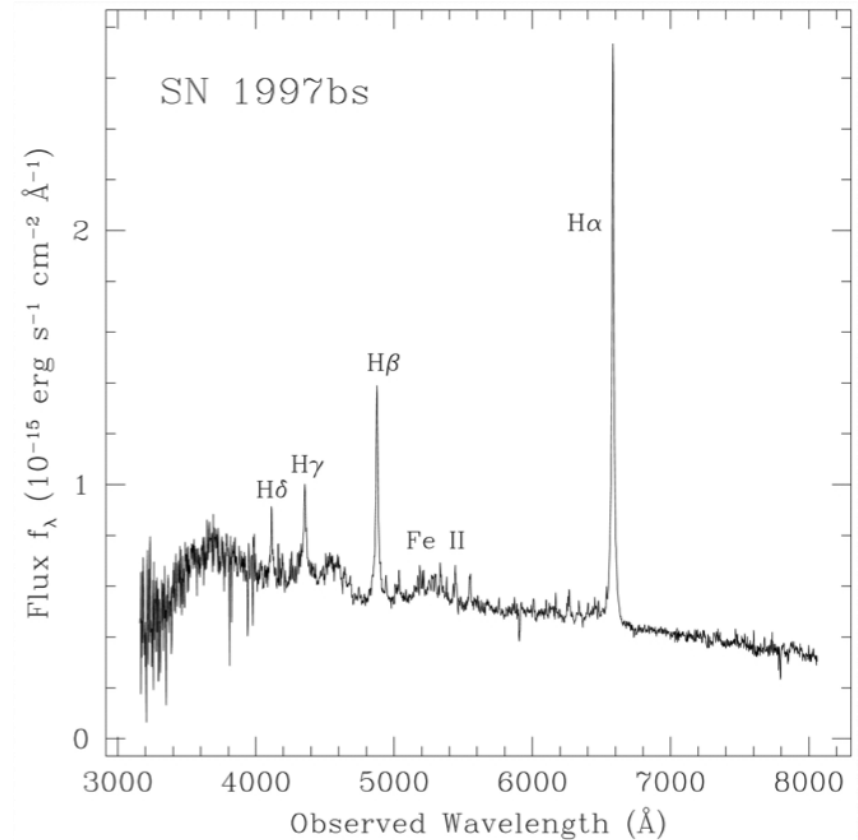
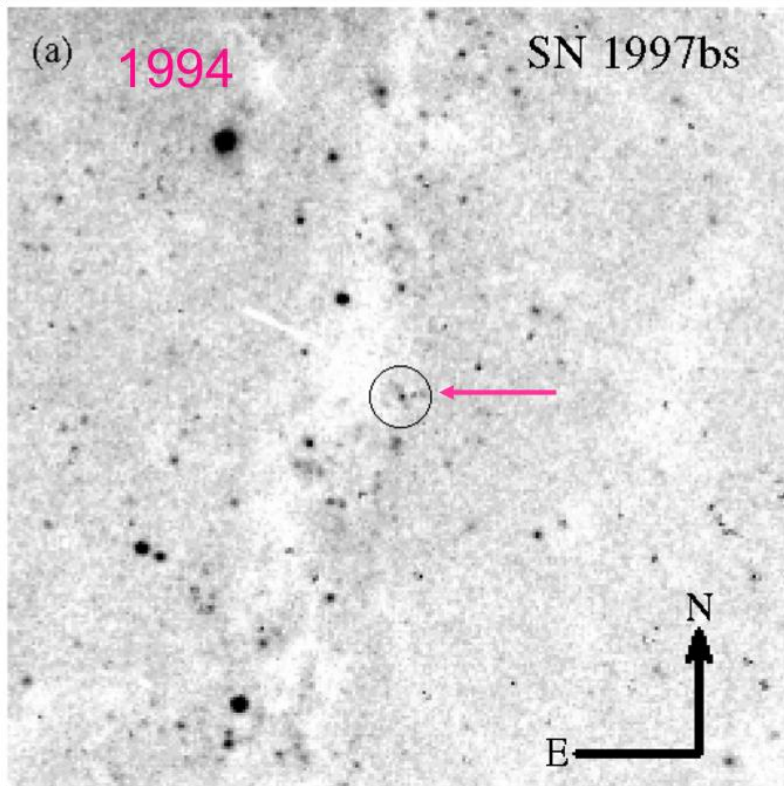


Old SNe spectra from Milisavljevic et al. (2012)  
(scaled to 61V distance and  $A_V[\text{Gal}]$ )

SN II<sub>n</sub> 1986J, SN II-L 1970G,  
SN (type?) 1957D

# SN 1997bs in M66

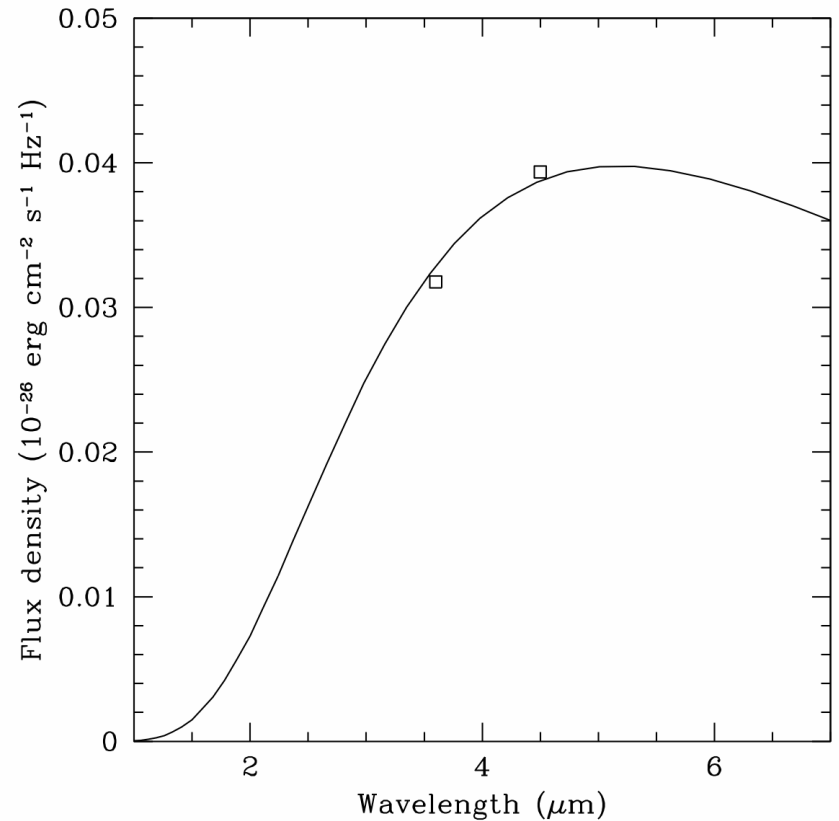
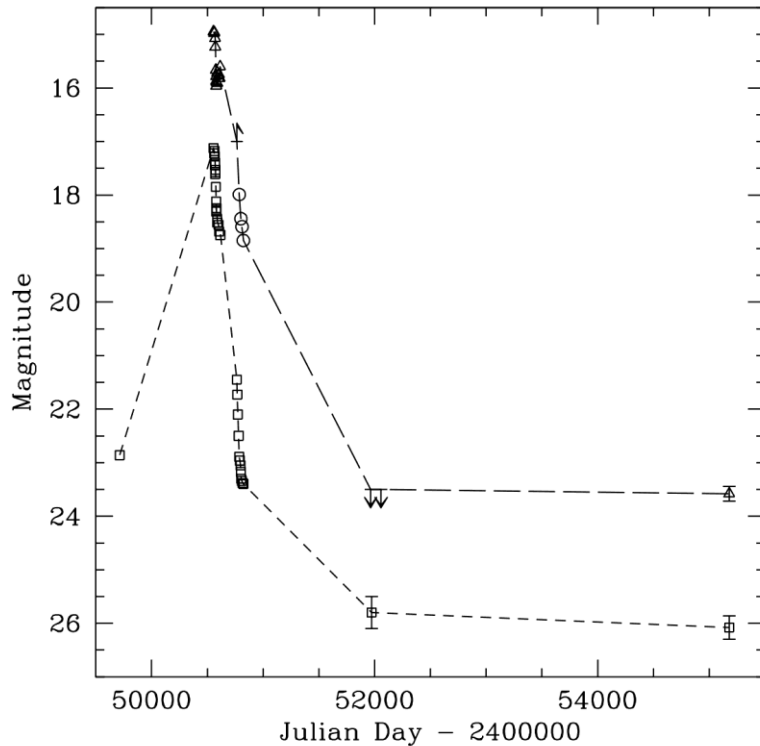
(where we first coined the term, “impostors”)



Precursor  $M_V \sim -8.1$  mag  
Van Dyk et al. (1999, 2000)

# SN 1997bs Survivor

- Obscured by grey dust? Or, a neighbor star?



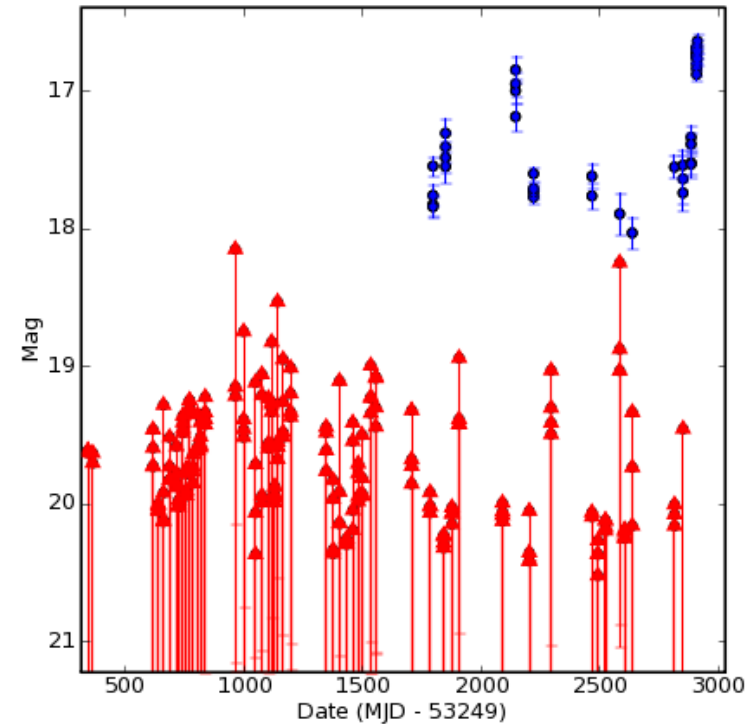
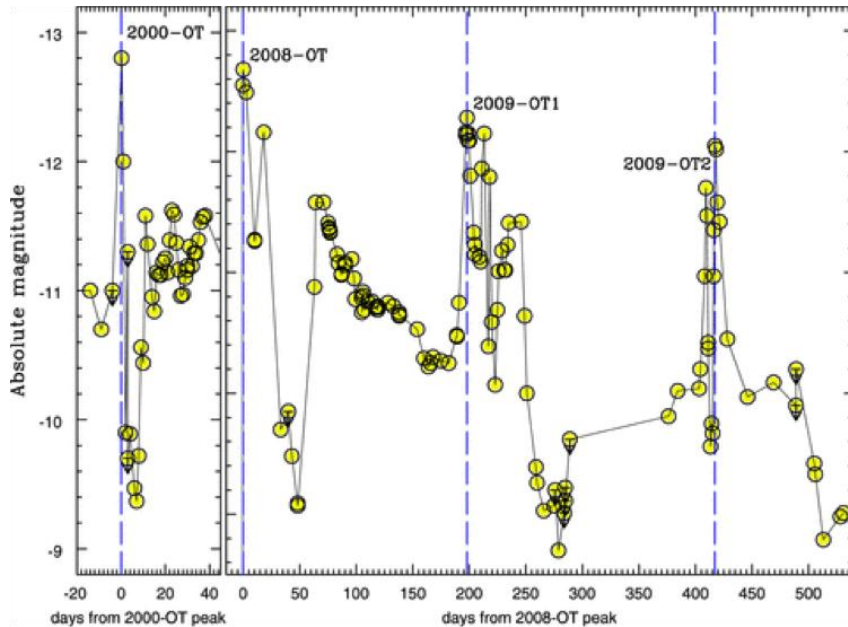
$$T_{\text{dust}} \sim 1000 \text{ K}, \quad R_{\text{dust}} \sim 100 \text{ AU}, \quad L \sim 3.2 \times 10^5 L_{\odot}$$



# SN 2000ch, SN 2009ip continuing outbursts

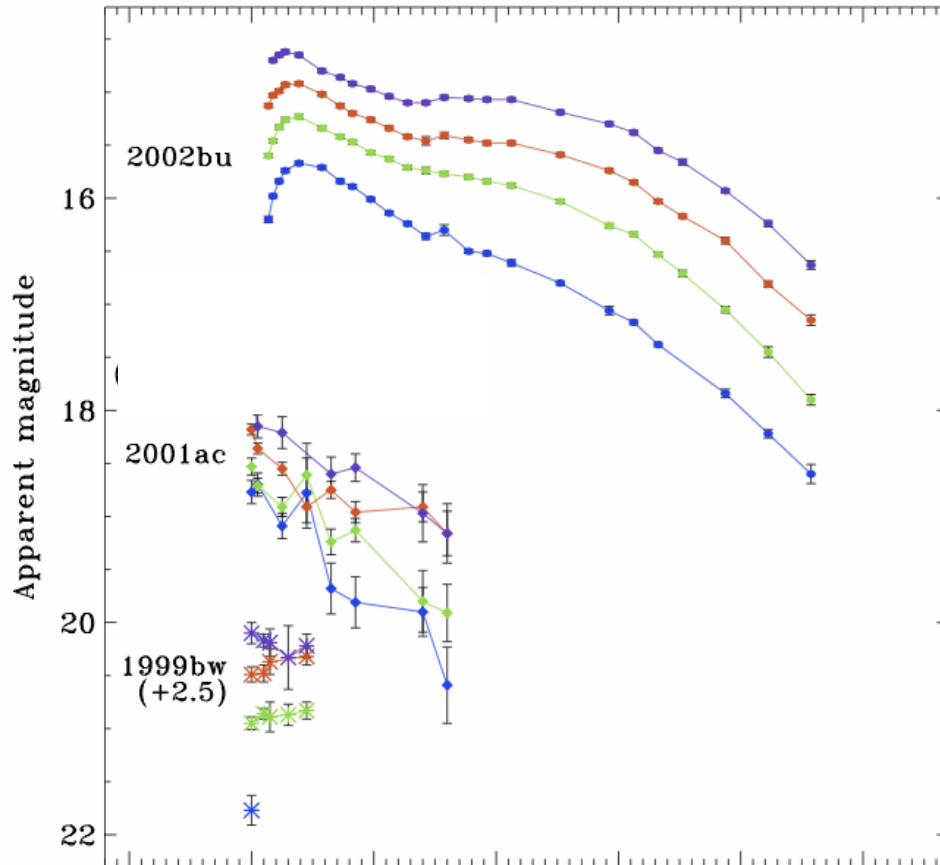
SN 2000ch (Pastorello et al. 2010)

SN 2009ip (CRTS, 2012)

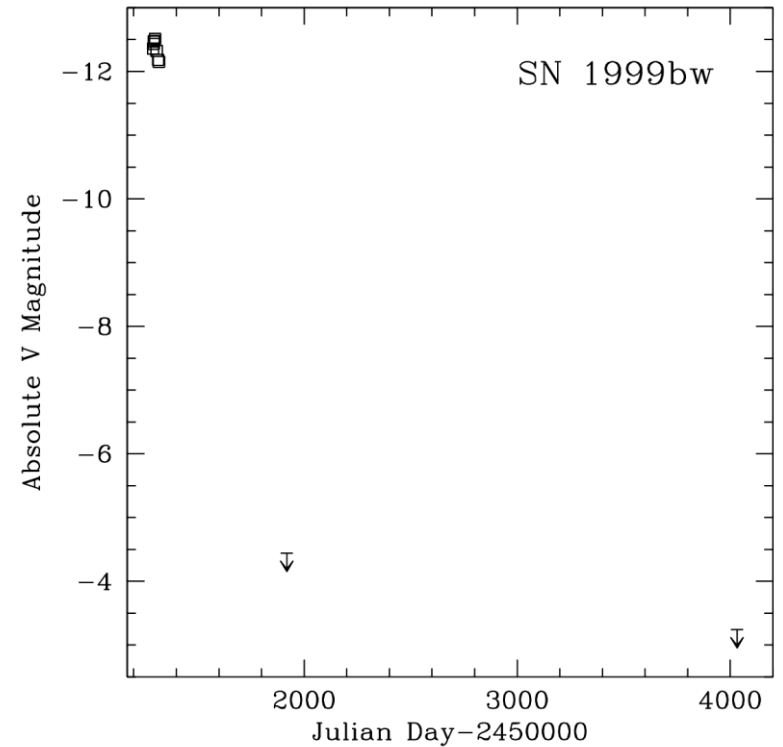


WE SHOULD ALL BE KEEPING AN EYE  
ON THIS ONE!

# SNe 1999bw, 2001ac, 2002bu



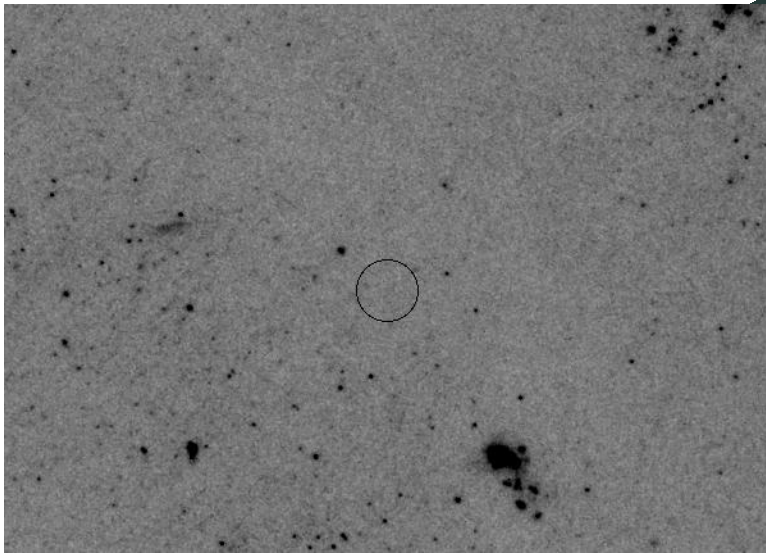
N. Smith et al. (2011)



Van Dyk & Matheson (2012a)

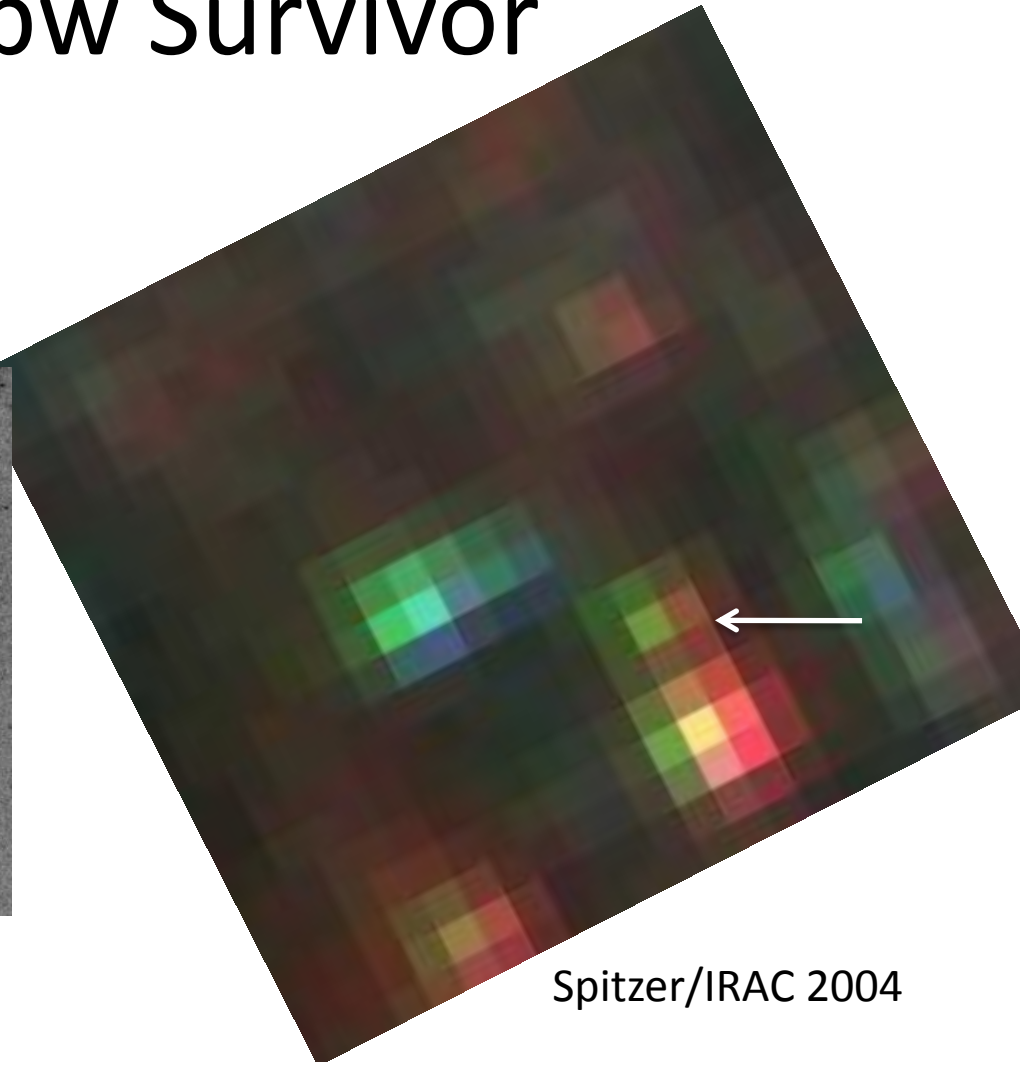
# SN 1999bw Survivor

- Dust-embedded



HST ACS/HRC 2006

Kochanek talk

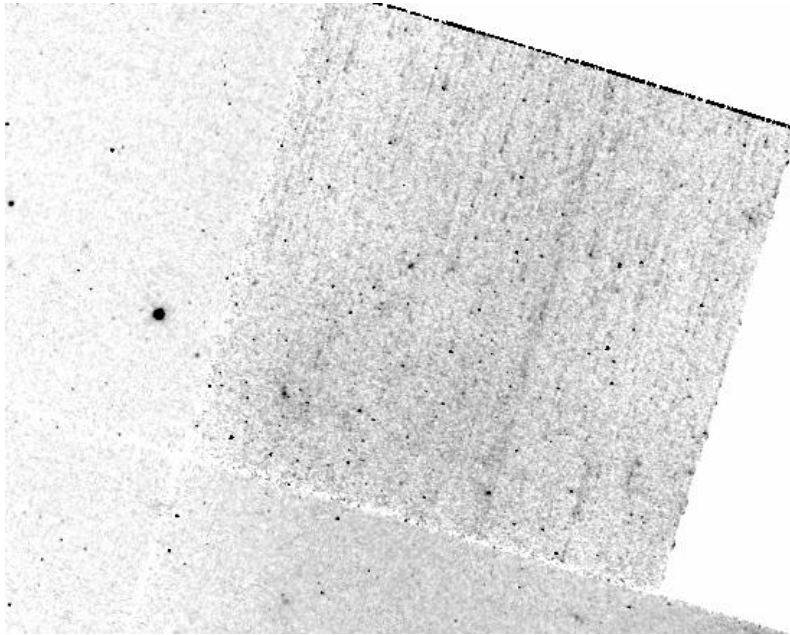


Spitzer/IRAC 2004

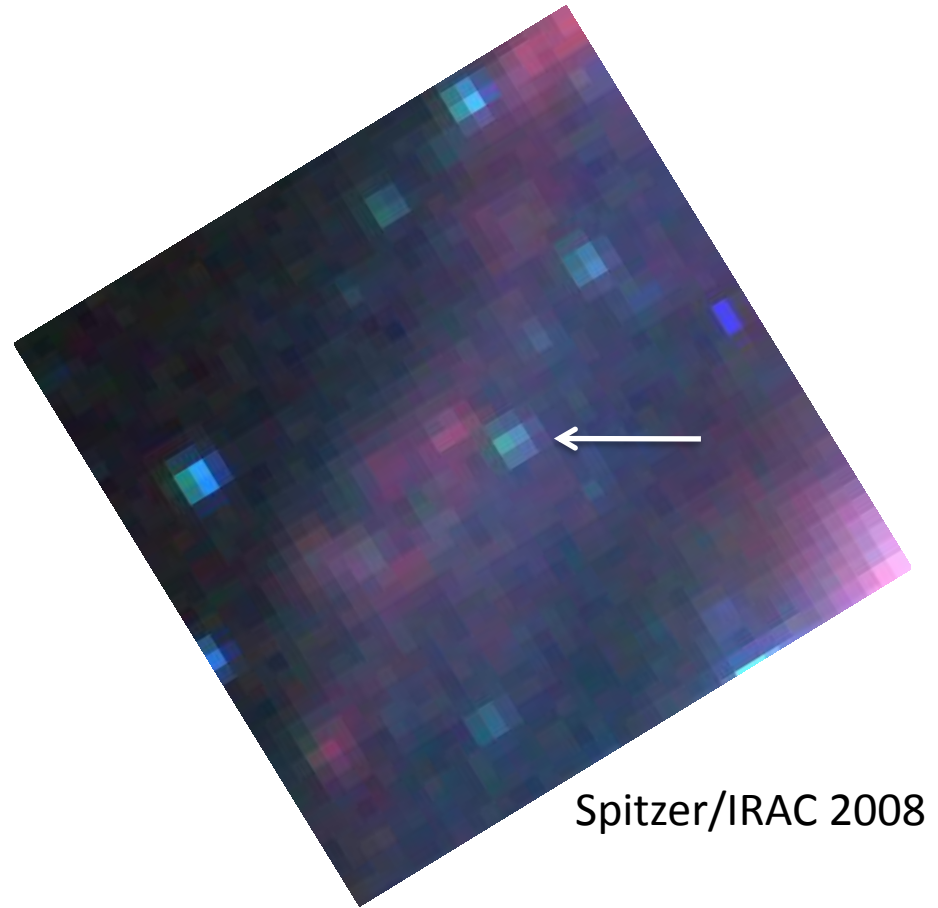
Declined in flux in  
2005, 2006, 2008

# SN 2001ac Survivor

- Dust-embedded



HST WFPC2 F814W 2008



Spitzer/IRAC 2008

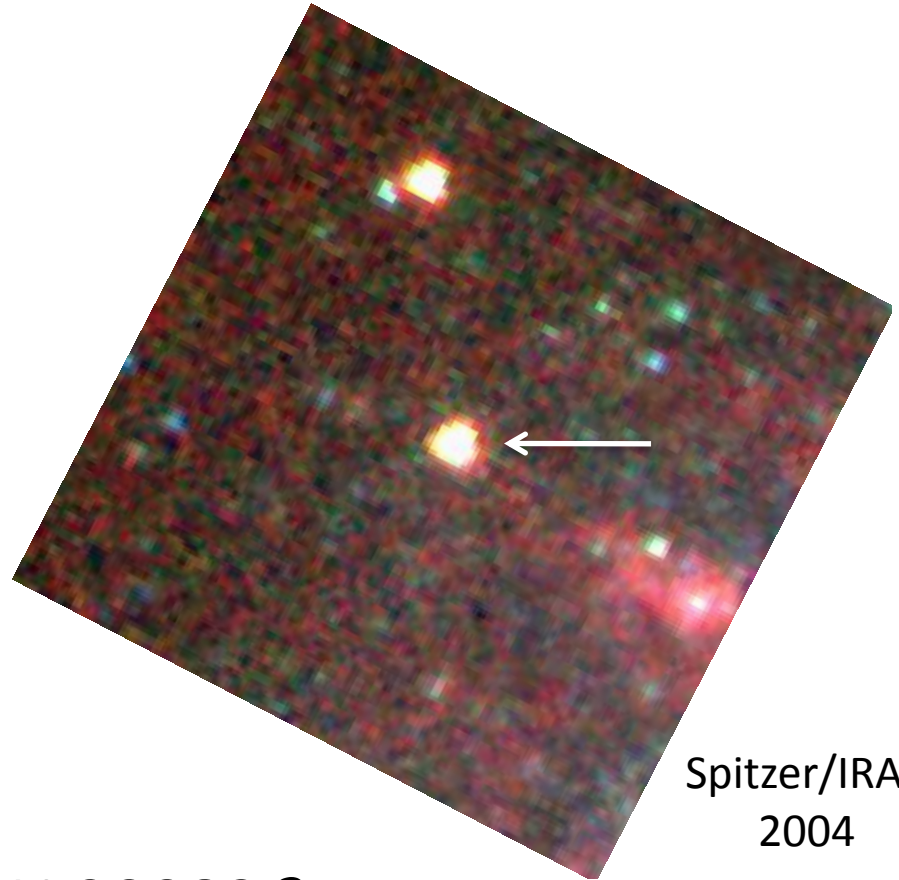


# SN 2002bu Survivor

- Dust-embedded



HST ACS/HRC F814W 2005

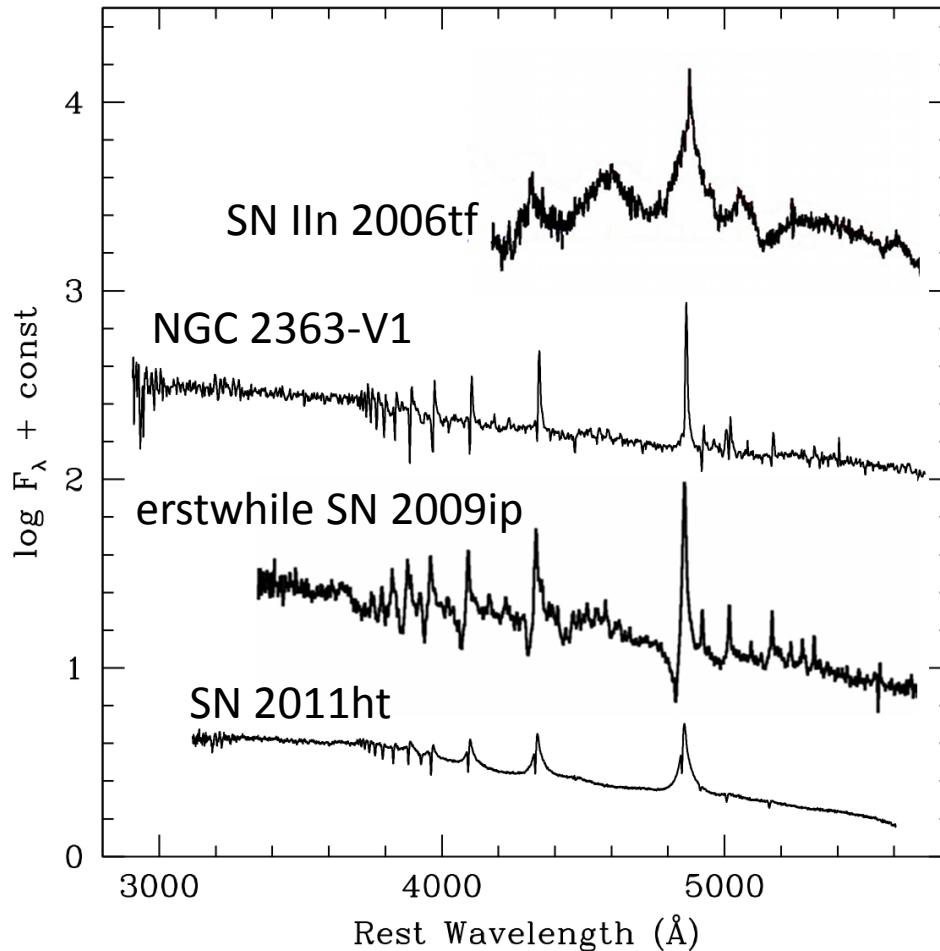


Spitzer/IRAC  
2004

*Are these objects like SN 2008S ?*

A “new kind” of supernova  
or  
a “new kind” of impostor?

# Supernova or Impostor?



## Spectral comparison

Smith et al. (2008)

Drissen et al. (2001)

Smith et al. (2010)

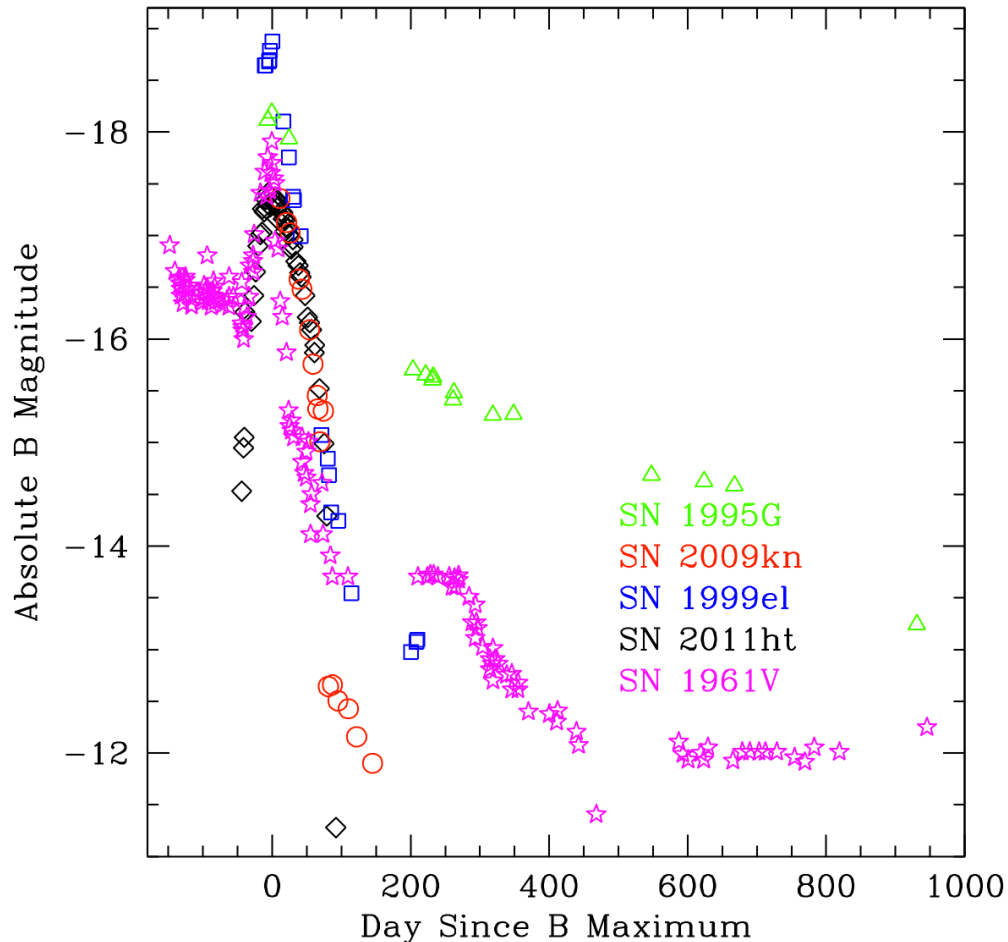
Foley et al. (2011)

Mauerhan et al. (2012)

Humphreys et al. (2012)

Roming et al. (2012)

# Supernova or Impostor?



Light curve  
comparison

Pastorello et al. (2002)

Kankare et al. (2012)

DiCarlo et al. (2006)

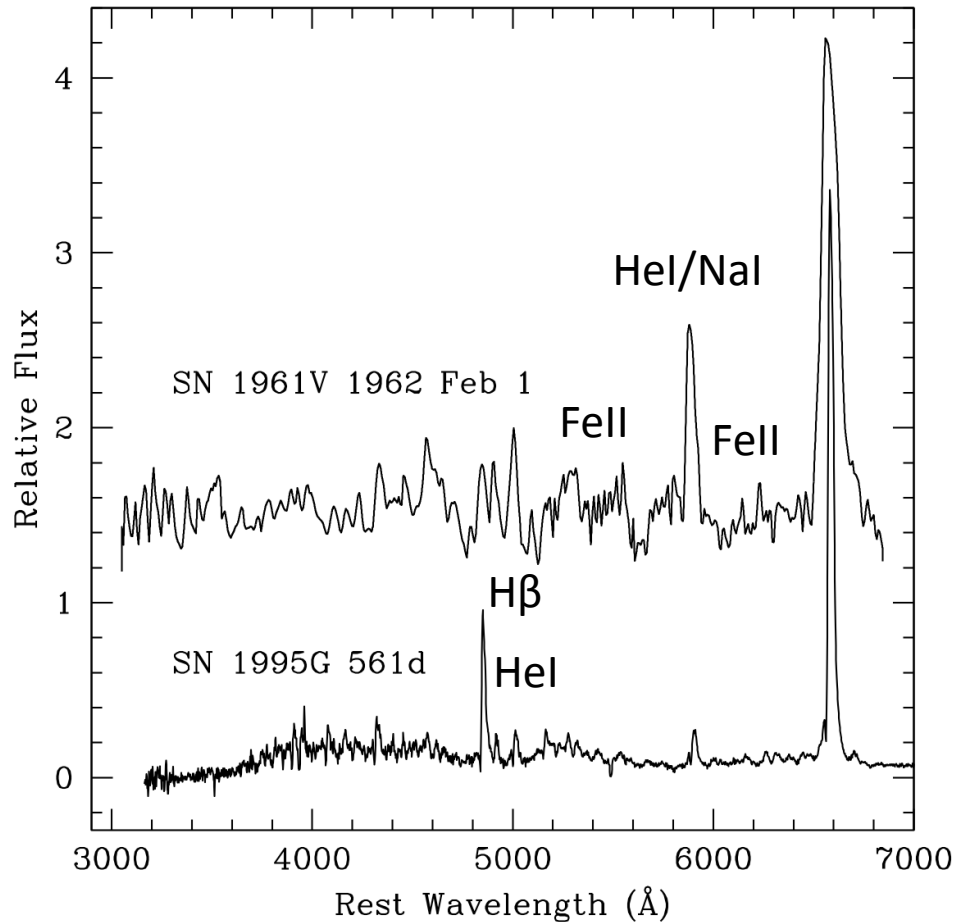
Roming et al. (2012)

Mauerhan et al. (2012)

Doggett & Branch (1985)



# Supernova or Impostor?



Comparison of  
SN 1961V with  
SN 1995G  
(94W/11ht-like)  
at late times

Zwicky (1965)

Pastorello et al. (2002)

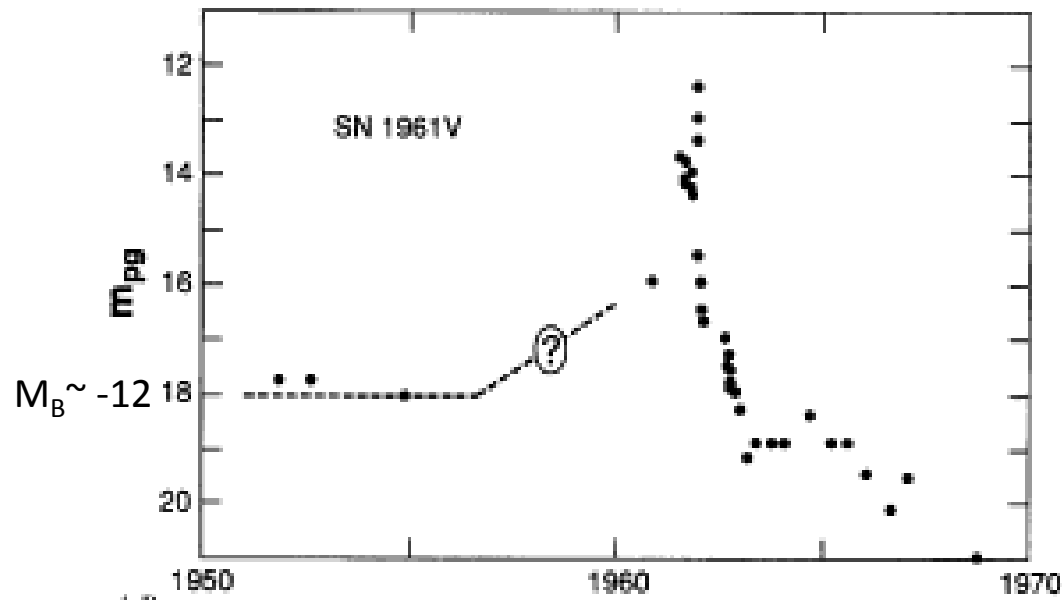
# Conclusions

- A rich variety of impostors, which muddy the waters
- SN impostors are progenitors for some SNe IIn (also SNe Ibn)
- Survivors of impostor eruptions have been identified
- Some (all?) SN impostors do become dust-obscured
- Are we seeing a new kind of SN or new kind of impostor? (Or, is this the same old kind of impostor?)

# Extras

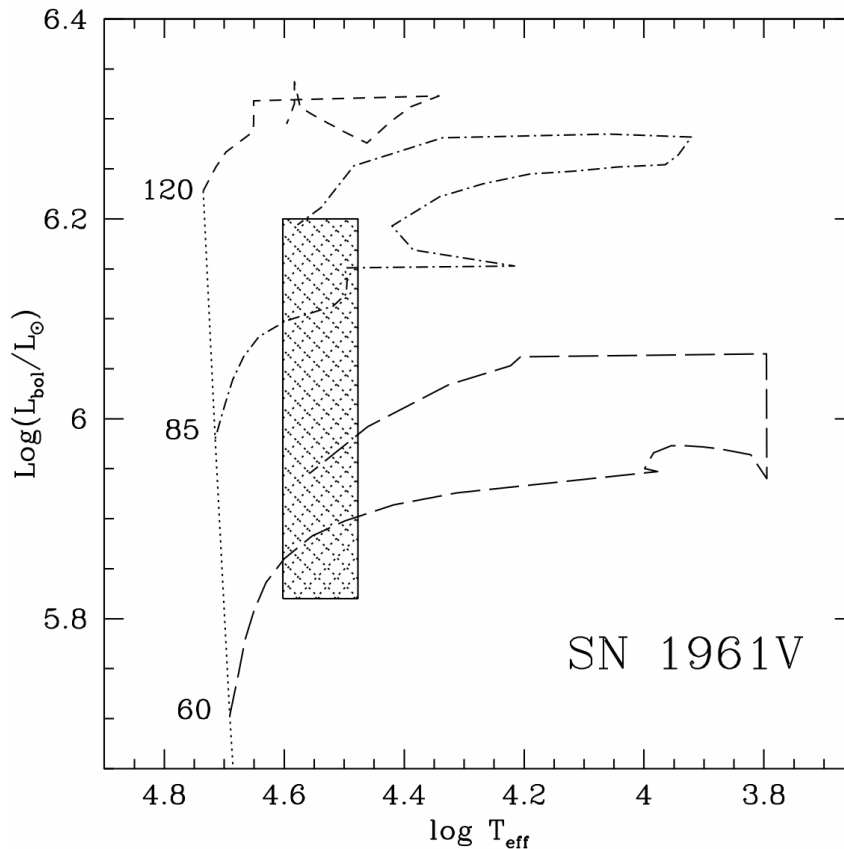
# SN 1961V: LBV Superoutburst before explosion?

- Did the 61V precursor was experience a LBV outburst prior to explosion (Smith et al. 2011)?



(Humphreys & Davidson 1994,  
Figure 1)

# The 61V Survivor is Consistent with a LBV



Object 7

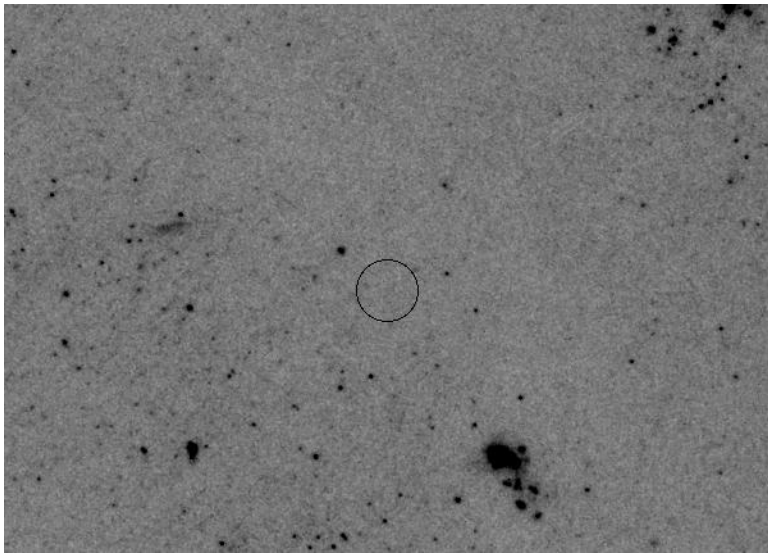
physically consistent  
model (hashed region)

Subsolar evolutionary tracks

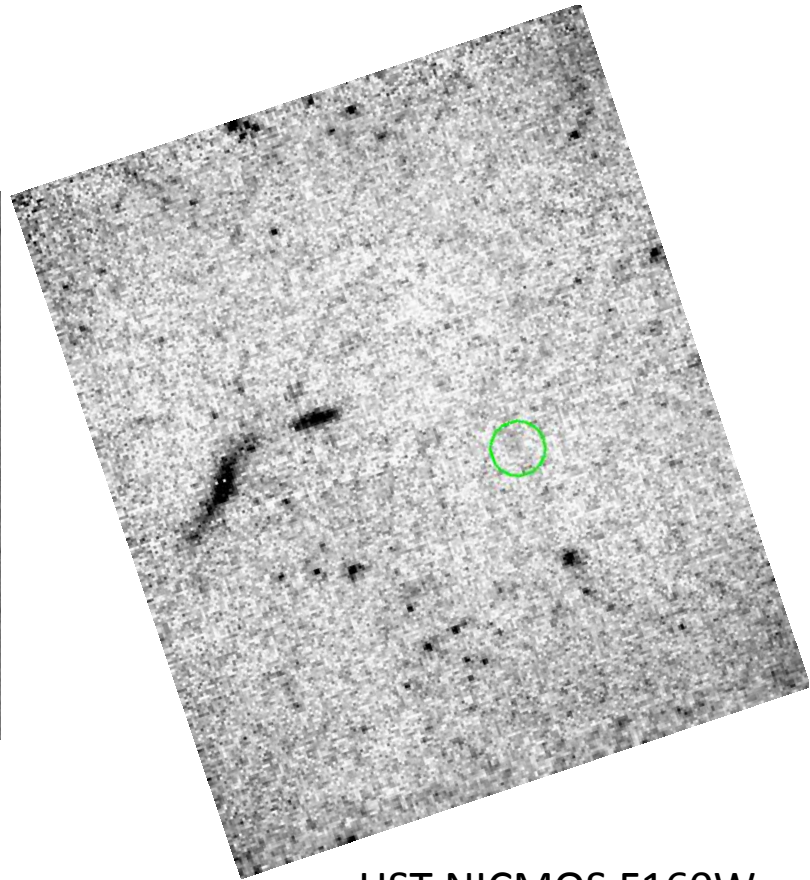
(Van Dyk & Matheson 2011)

# SN 1999bw Survivor

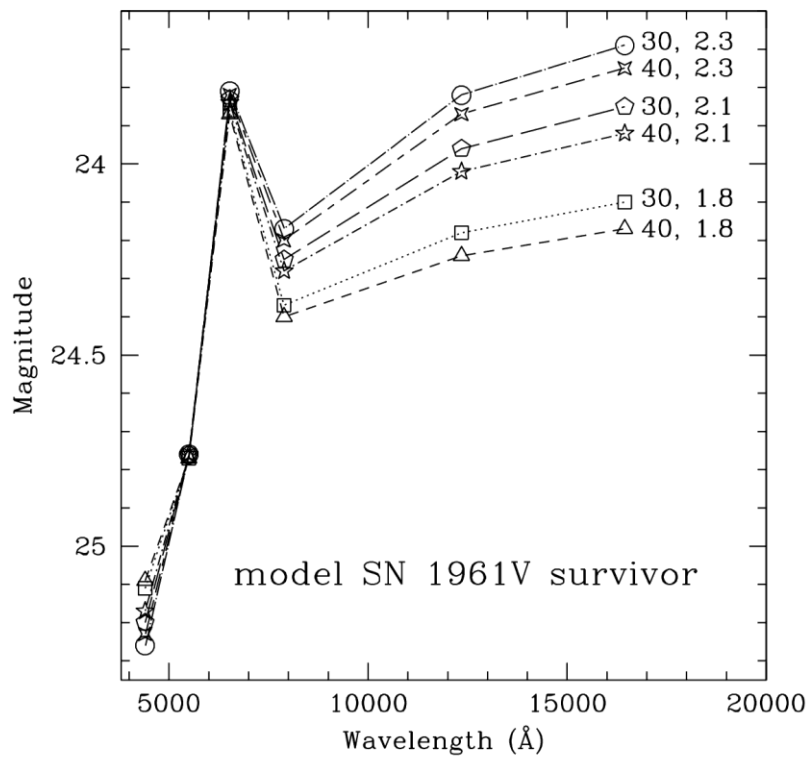
- Dust-embedded



HST ACS/HRC 2006

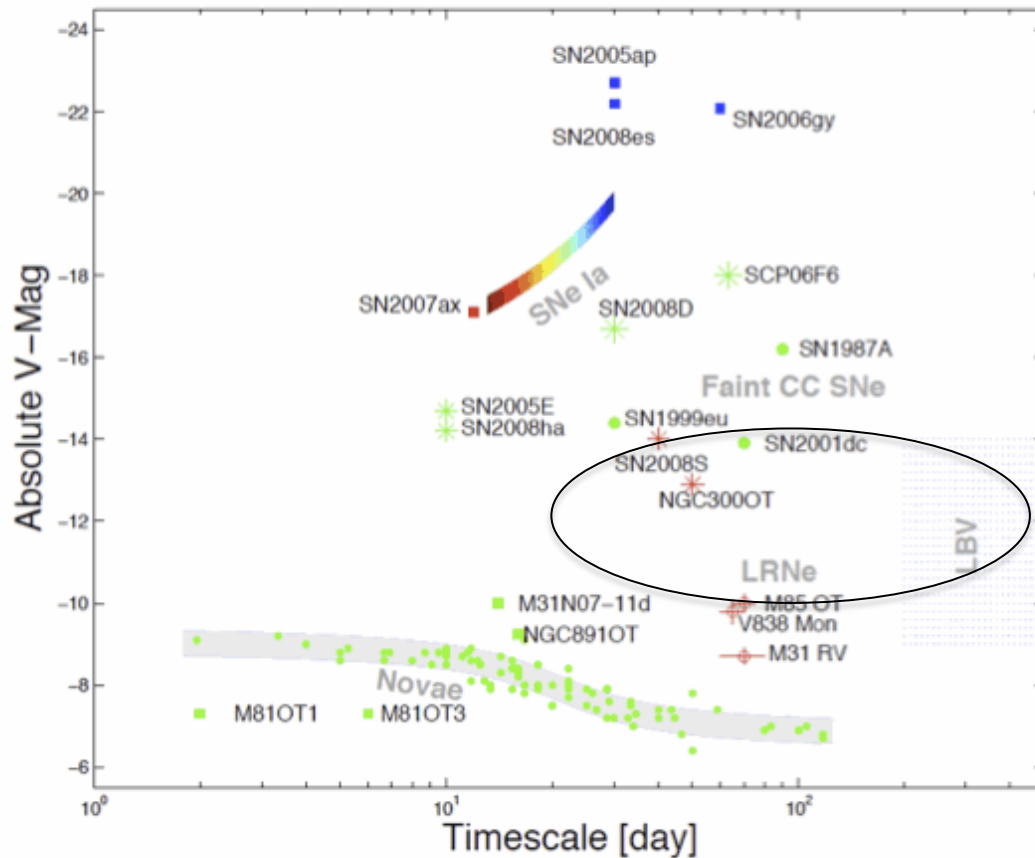


HST NICMOS F160W  
2008

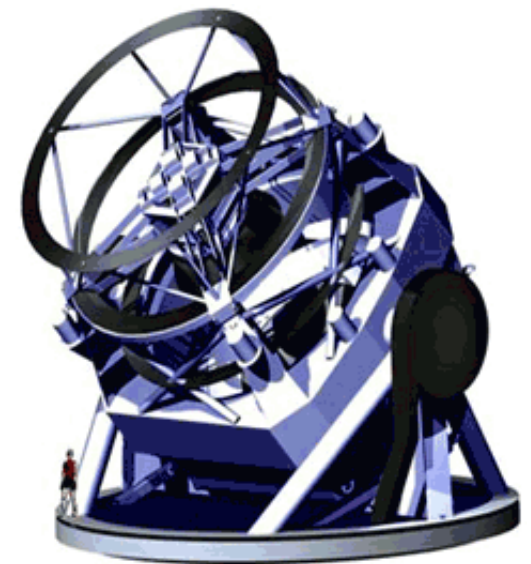


# Supernova Impostors

## Connection to Transient Surveys



(Kulkarni & Kasliwal 2009)



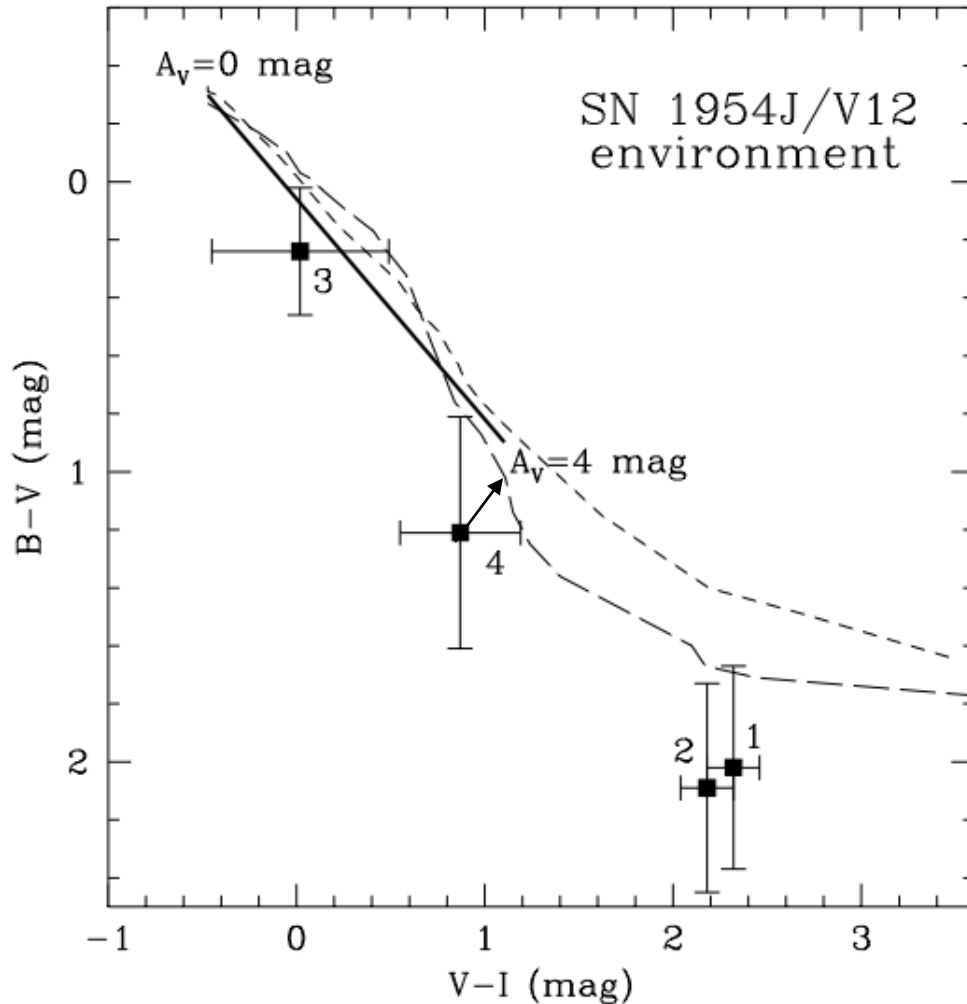


The image shows the four members of The Beatles standing in a row, dressed in their iconic Sgt. Pepper's Lonely Hearts Club Band military uniforms. From left to right: Paul McCartney in a pink uniform, George Harrison in a yellow uniform, Ringo Starr in a blue uniform, and John Lennon in a red uniform. They are all looking towards the camera against a bright yellow background.

# SN 1961V is Dead

- Smith et al. (2011), Kochanek et al. (2011)

# SN 1954J/Variable 12 in NGC 2403



Stars 1, 2: M supergiants,  
low reddening

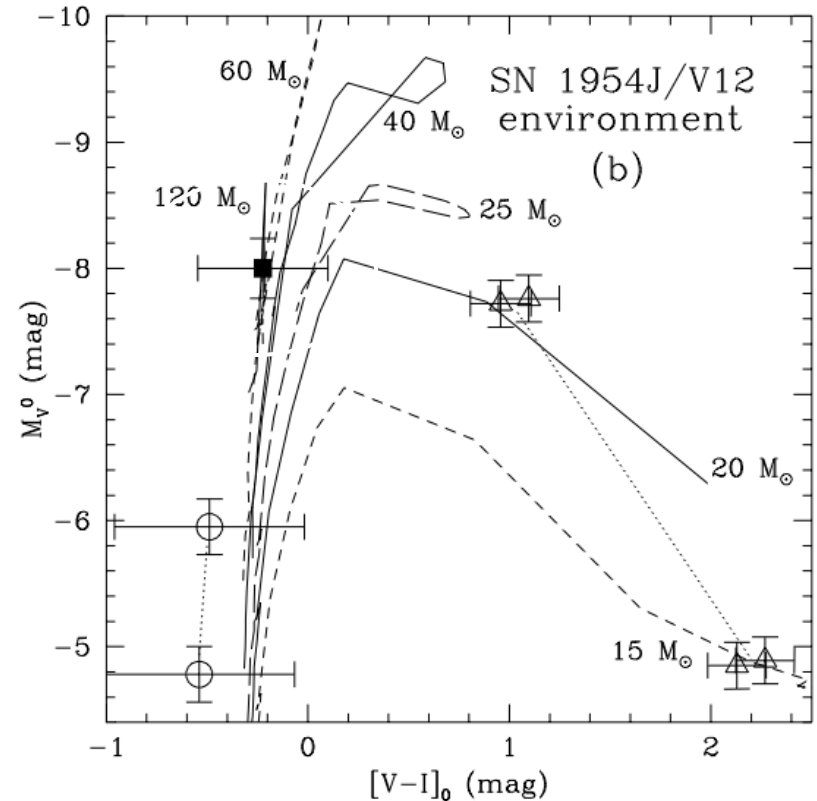
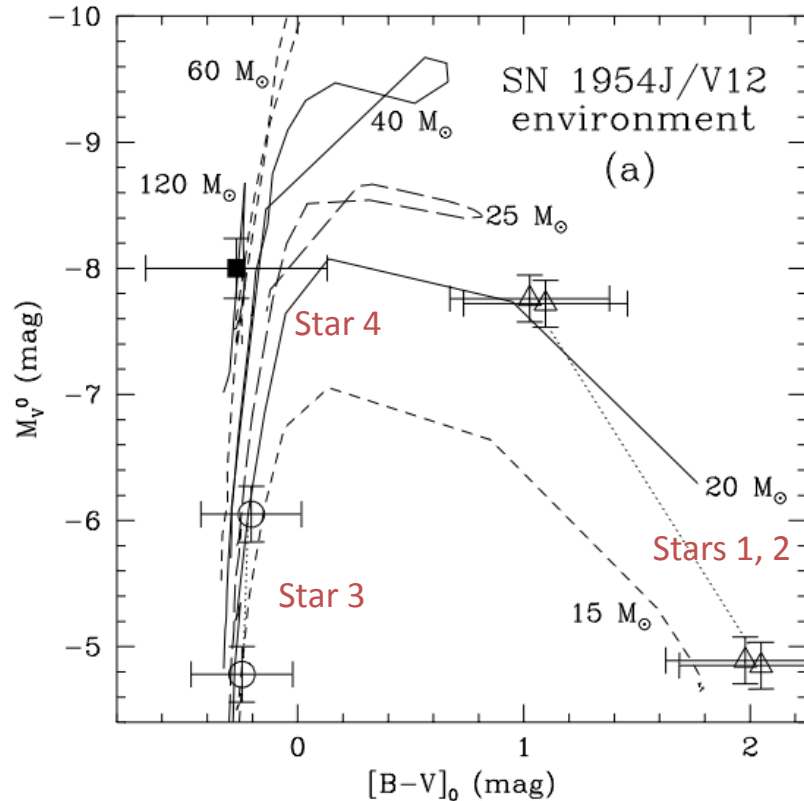
Star 3: A-type dwarf (?),  
low reddening

Star 4: early-type supergiant  
behind  $A_V \sim 4$  mag ??  
...OR...

F-type supergiant  
behind  $A_V = 0.11$  mag ??

Van Dyk et al. (2005)

# SN 1954J/Variable 12 in NGC 2403



- Star 4: A very luminous, very massive supergiant enshrouded in a dusty, Homunculus-like nebula
- Not unlike  $\eta$  Carinae!