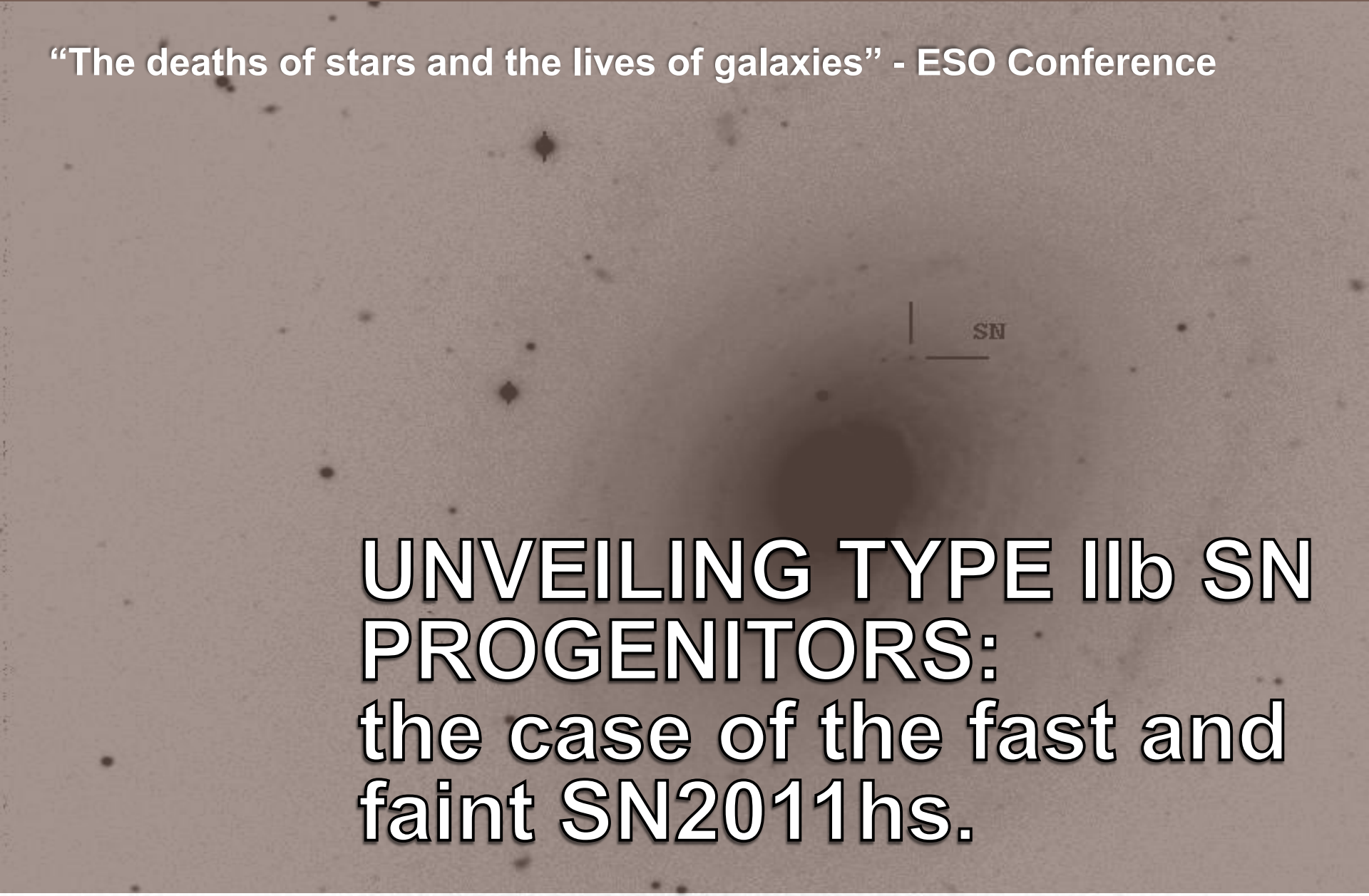

UNVEILING TYPE IIb SN PROGENITORS: the case of the fast and faint SN2011hs.

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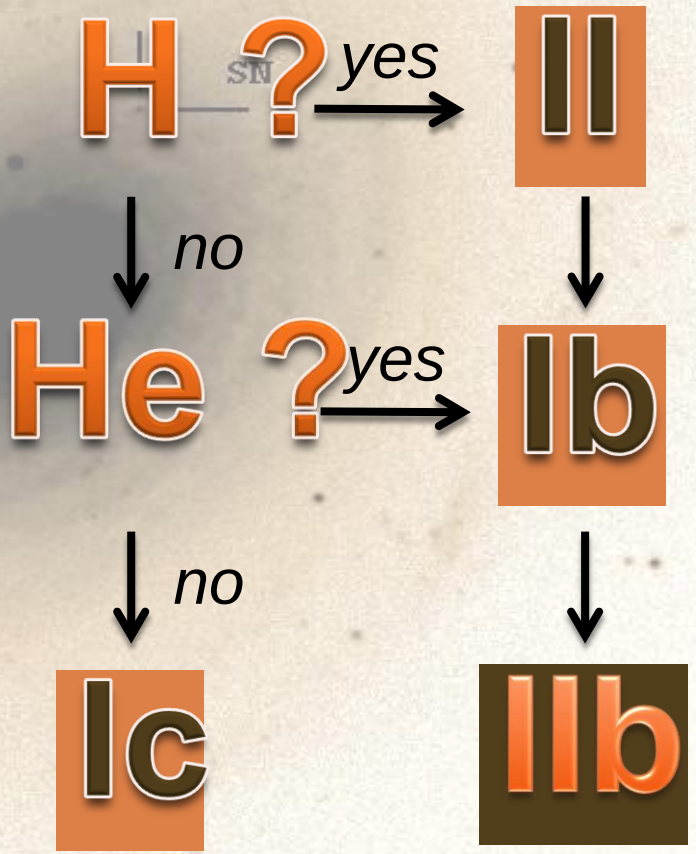
Universidad Andrès Be

Santiago, Chile,
April 8 - 12, 2013

What's a Type IIb SN ?

CORE COLLAPSE SNe
are the final phases of massive stars with mass (> 8 Msun)

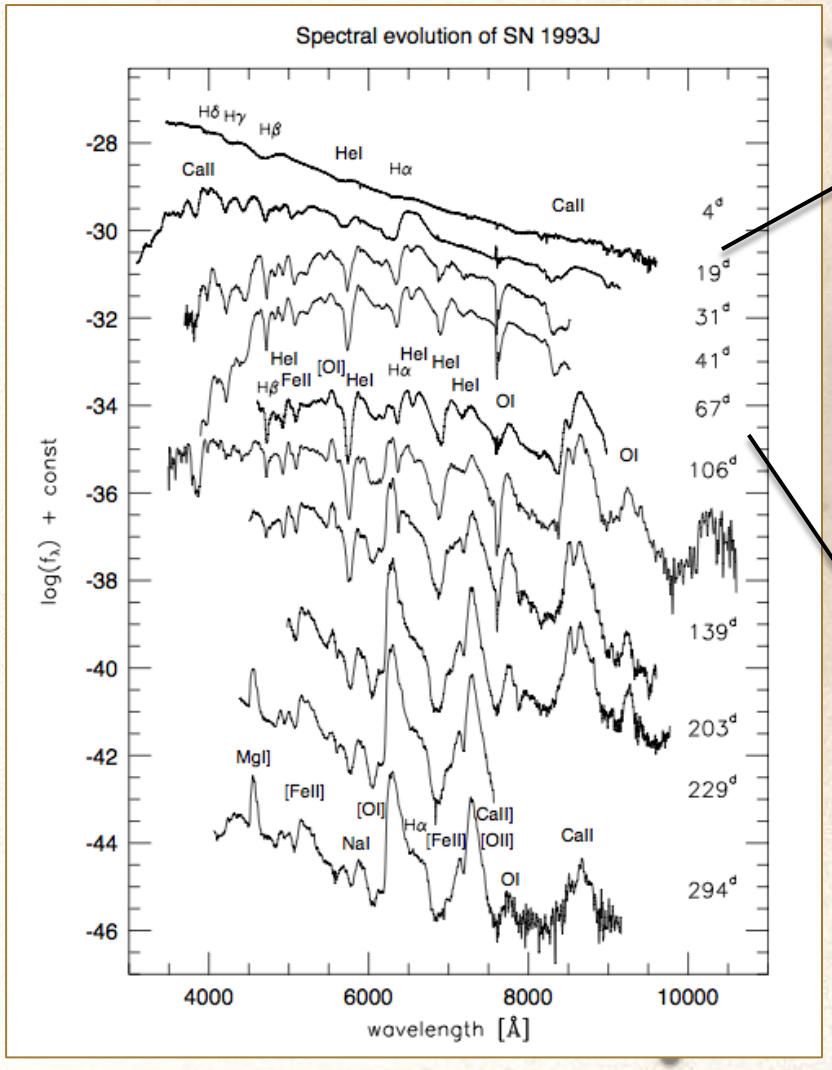
Classification based on spectroscopic feutures:



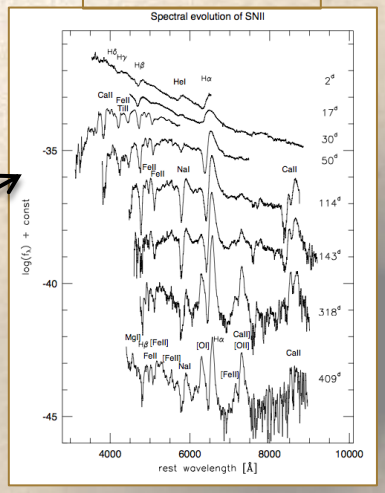
some CC SNe undergo a peculiar spectral metamorphosis during their <u>early</u> evolution, changing their spectral aspect
from Type II to Type Ib

What's a Type IIb SN ?

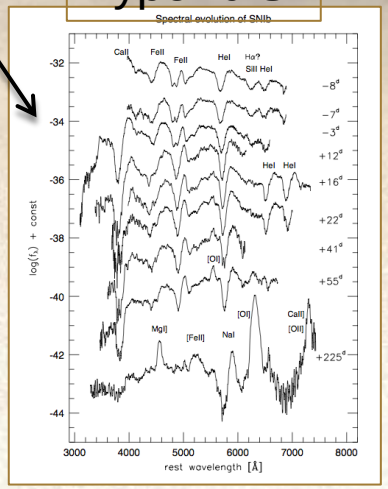
SN 1993J- the prototype



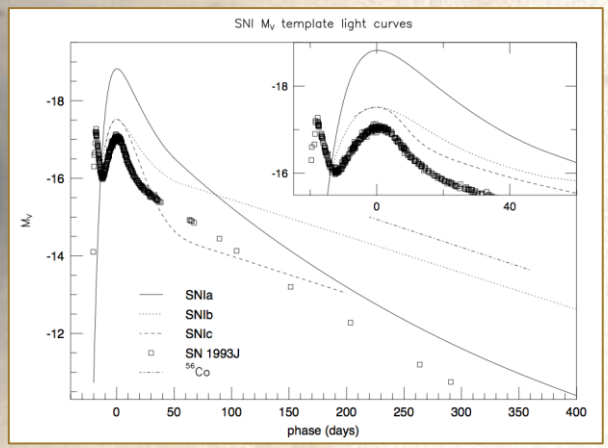
Type II SN

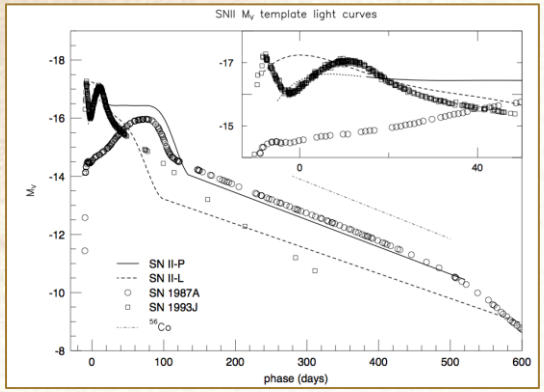


Type Ib SN



The Light Curve





from Wheeler & Benetti, 2000, Allen's astrophysical quan

What's a Type IIb SN progenitor?

SN Ib **SN IIb** **SN II**

increasing H envelope mass

Their progenitor kept only a thin hydrogen layer (~ 0.01 Msun, Nomoto 1993, *Nature* **364**, 507) at the time of the explosion, but the mechanism is still under debate.

MASS LOSS MECHANISM :

stellar winds in a massive SINGLE star (M ≥ 25-30M⊙; Heger+03; Georgy+09)
or eruptive episodes (Smith&Owocki 06)

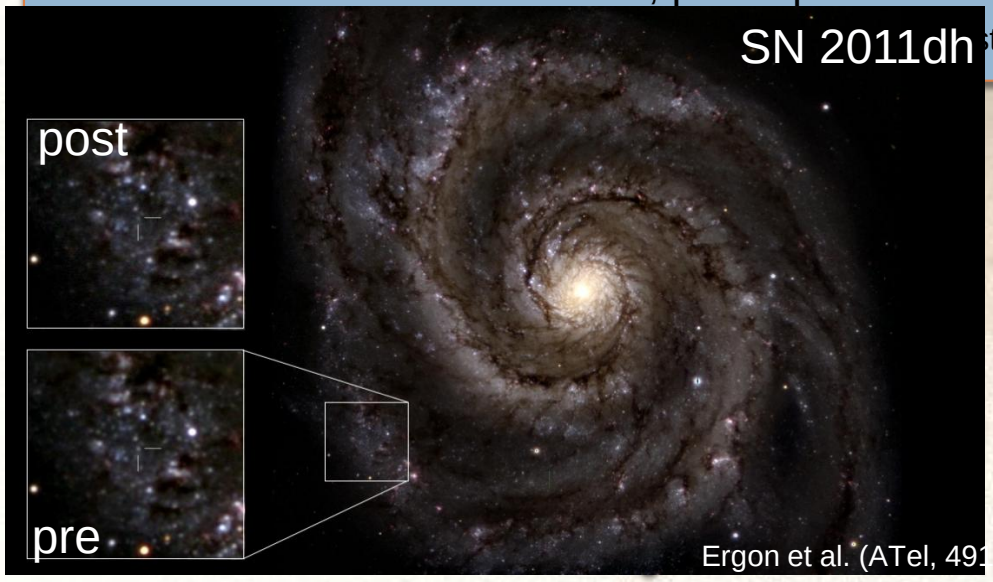
mass transfer in a close BINARY SYSTEM (Podsiadlowski+93; Yoon+10)

What's a Type IIb SN progenitor?

PROGENITOR ?:

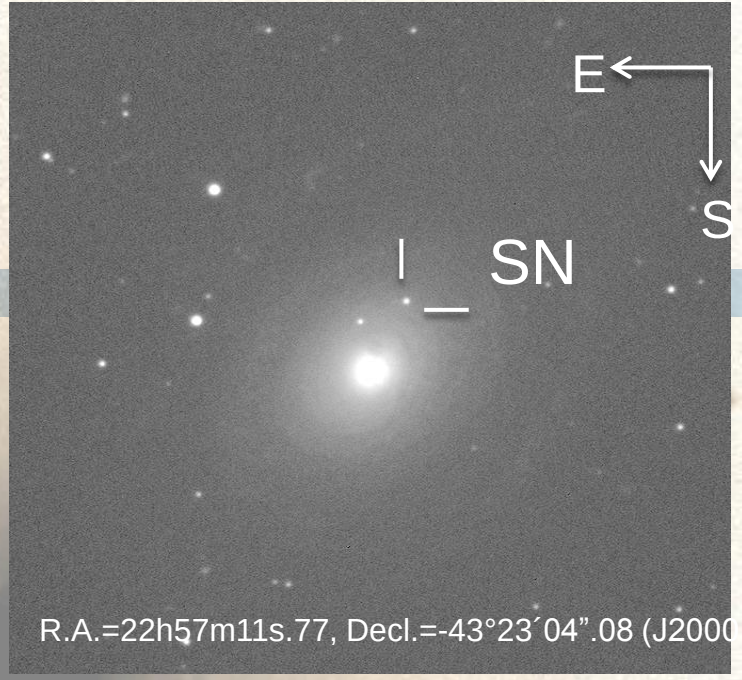
<u>COMPACT star</u> like a Wolf Rayet star (similarly to SNe Ibc, Georgy+12)
Rotation plays an important rule in the evolution of the star (Maeder&Maynet 11)
LBV a possible pre-explosion scenario (20-25 Msun, Groh+12).

<u>EXTENDED star</u> like a RSG/YSG
SN 1993J progenitor star detected in pre-explosion images (Maund+, 04)
SN 2011dh, pre-explosion imaging and numerical modeling compatible to a
sten+,12)



Direct detection of the progenitor in pre-/post-explosion images is <u>not</u> always possible.
Obtain information about the progenitor and the geometry of the explosion from multiwavelength observational data and spectral lines and the light curve fitting.

SN 2011hs:



- Discovered at **very early phase** (on Nov. 12.5 UT; Milisavljevic+CBET 2902)
- Nearby SN: **z=0.0064** ± 0.0001(from host galaxy H_α emission line) → μ= 32.11 ± 0.03 mag (H_0=73 km $s^{-1}$$Mpc^{-1}$, Ω_Λ=0.73 and Ω_M=0.27)
- **$E(B-V)_{Milky\ Way}$ = 0.011 mag** (Schlegel+98)
- **$E(B-V)_{Host}$= 0.159 ± 0.075 mag** (using EW(NaID) relation from Poznanski+12)
- **Very high line velocities**, resembles the fast expanding SN IIb, SN2003bg (Hamuy+09; Mazzali+09)
- No significant X-ray emission is detected at the SN position (Margutti, Atel 3678).

Results will be published in Bufano+13 (in pre

Spectral Evolution

- EARLY SPECTRA:

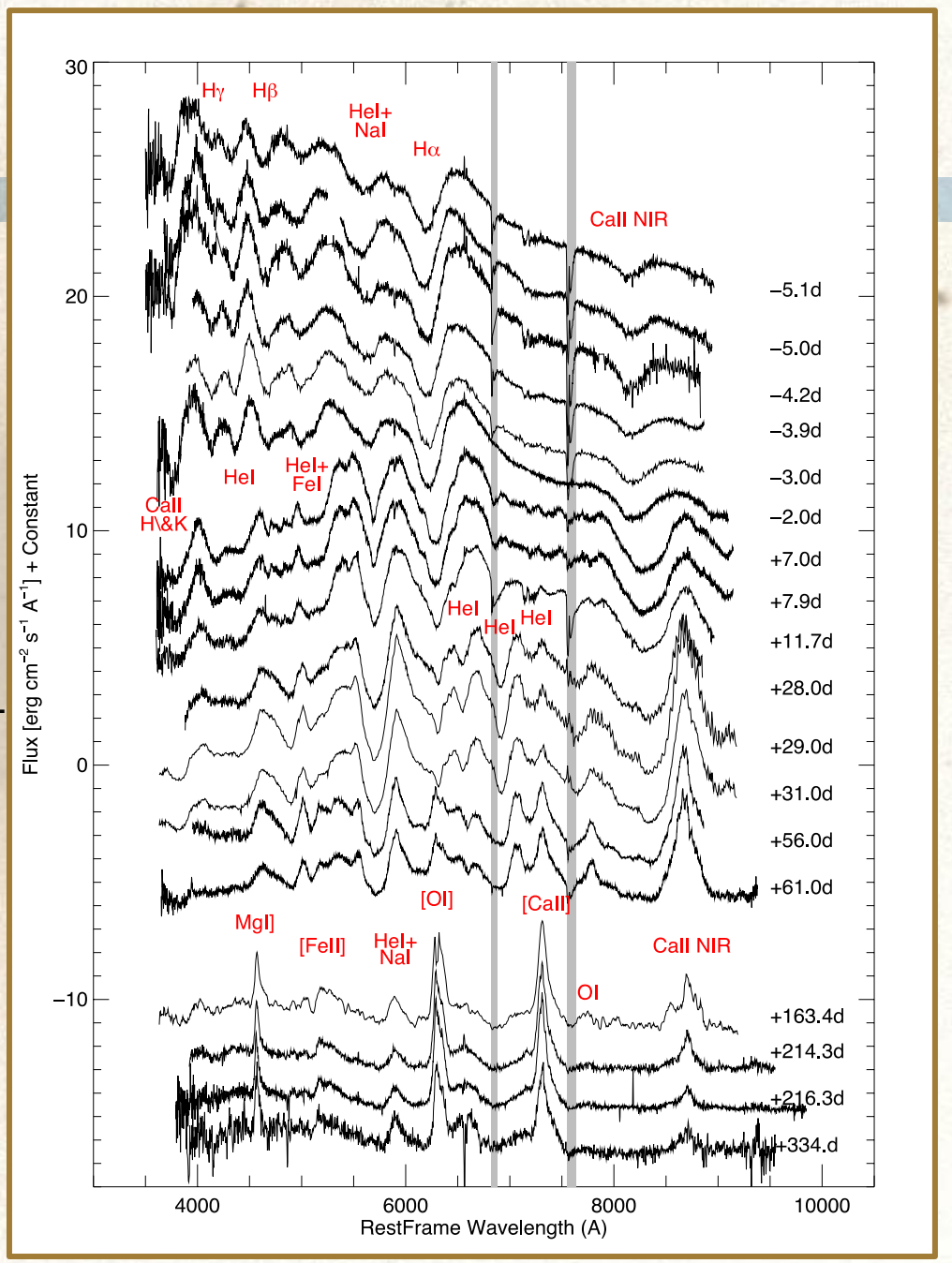
Balmer Lines at 1.7-1.4 x 10^4 km/s
HeI lines λλ4472 and 5876
(the latest likely blended with NaI)
CaII both H&K and NIR triplet

- AFTER MAXIMUM LIGHT:

Dominant HeI λλ6678, 7065 and 7281
Fe lines emerge in the blue range

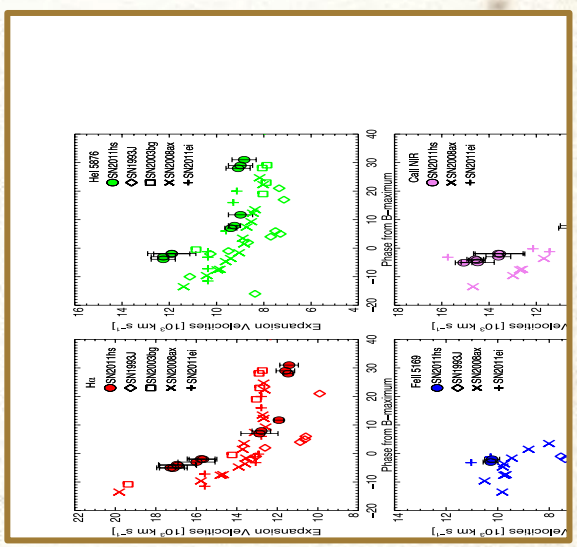
- NEBULAR SPECTRA:

prominent emission lines from
MgI] λ4571,
[OI] λ5577, [OI] λλ6300, 6364 and
[CaII] λλ7291,7324



Spectral Comparison

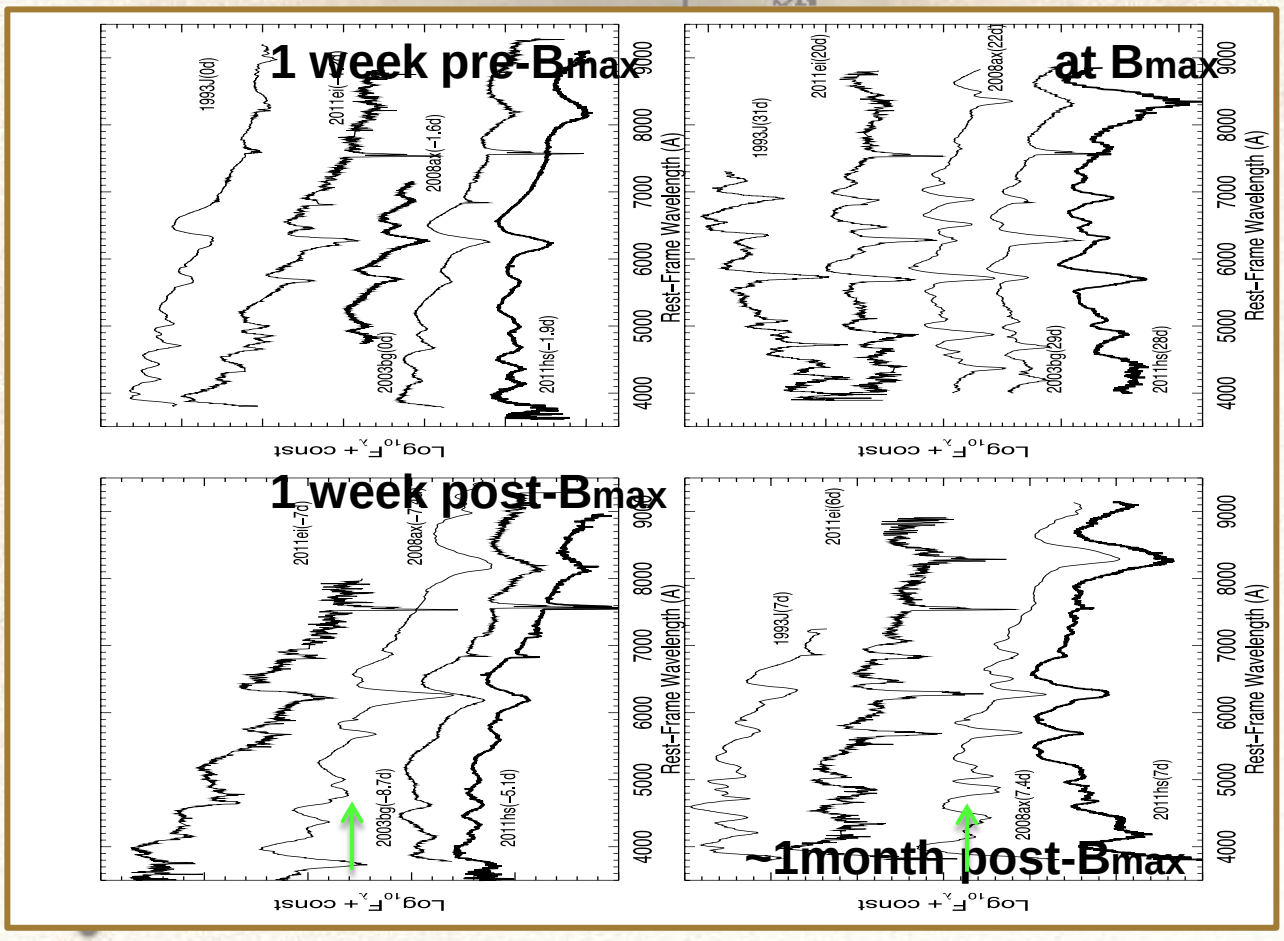
Expansion Velocities
minimum position measurements



High Ek/Mej

SiII at ~12,000 km/s or **HI high velocity features** (outer fast moving shell at ~20,000 km/s) **?**

SN2011hs line velocities are similar to those of SN2011ei (Milisavljevic+13) but different line profiles, spectral shape resembles more fast-expanding IIb SN2003bg (Hamuy+09, Mazzali+09)

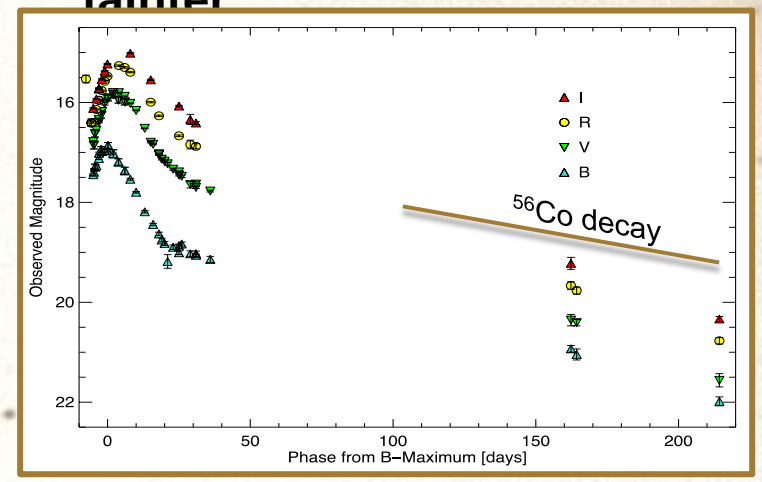


Light Curves

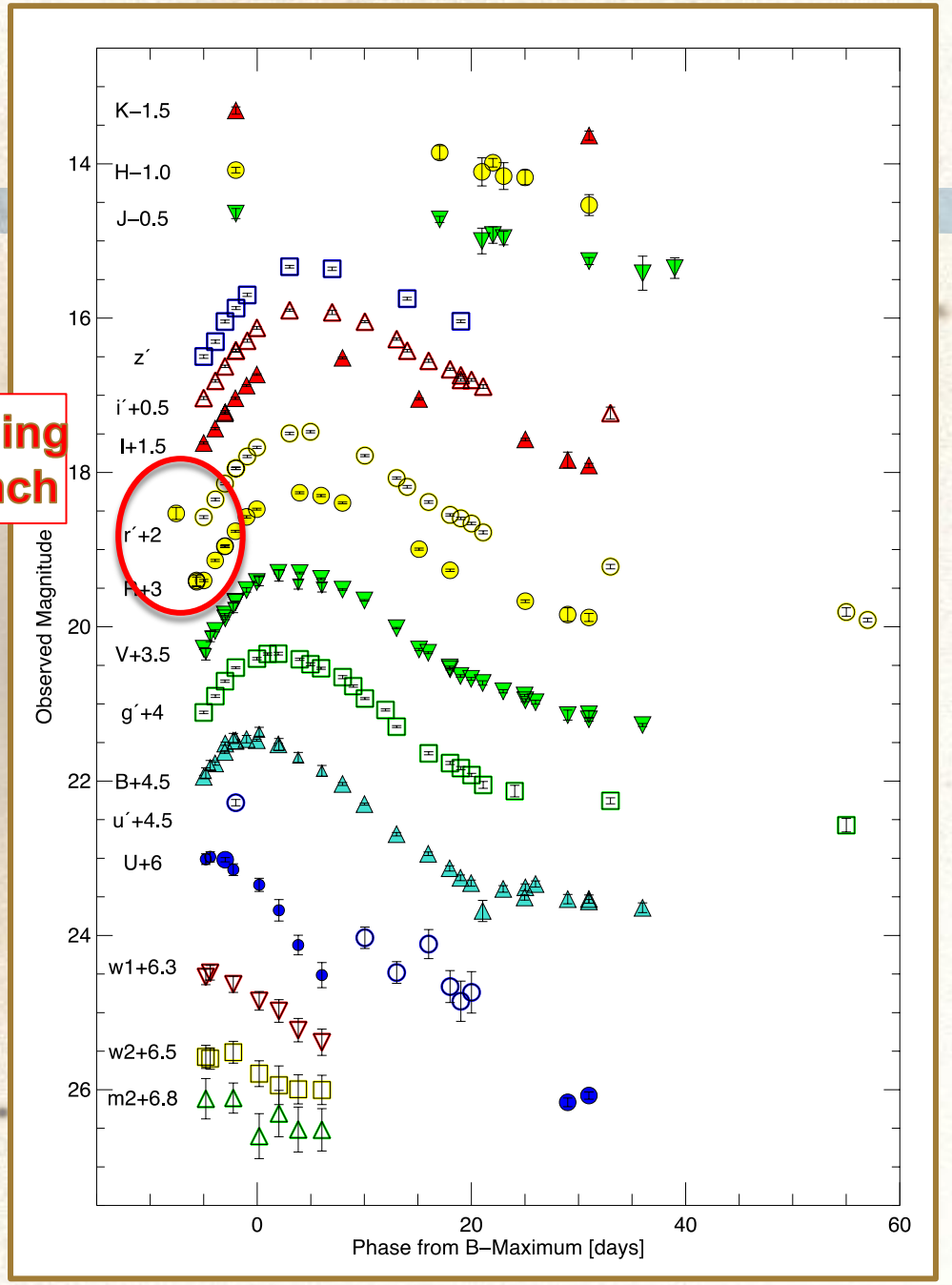
Filter	Peak Day JD+2,400,000	Peak Observed mag	Rise Rate[a] mag/100d	Decline Rate[b] mag/100d
U	55,881.5±1.0	17.00±0.02	—	16.2±1.7
B	55,885.5±1.0	16.93±0.01	-9.2±0.4	9.0±0.1
V	55,888.5±1.0	15.80±0.01	-7.9±0.2	9.0±0.1
R	55,889.5±1.0	15.28±0.01	-5.9±0.3	7.4±0.1
I	55,890.5±1.0	15.01±0.01	-5.4±0.2	7.4±0.2
g'	55,887.5±1.0	16.35±0.01	-6.8±0.4	9.2±0.1
r'	55,889.5±1.0	15.46±0.01	-6.3±0.3	8.5±0.1
i'	55,890.5±1.0	15.36±0.01	-5.1±0.4	7.7±0.1
z'	55,890.5±1.0	15.30±0.02	—	5.6±0.2

[a] Decline within 5 d before peak.
[b] Decline within 15 d from peak.

Blue band light curves peak very early and much fainter



cooling branch



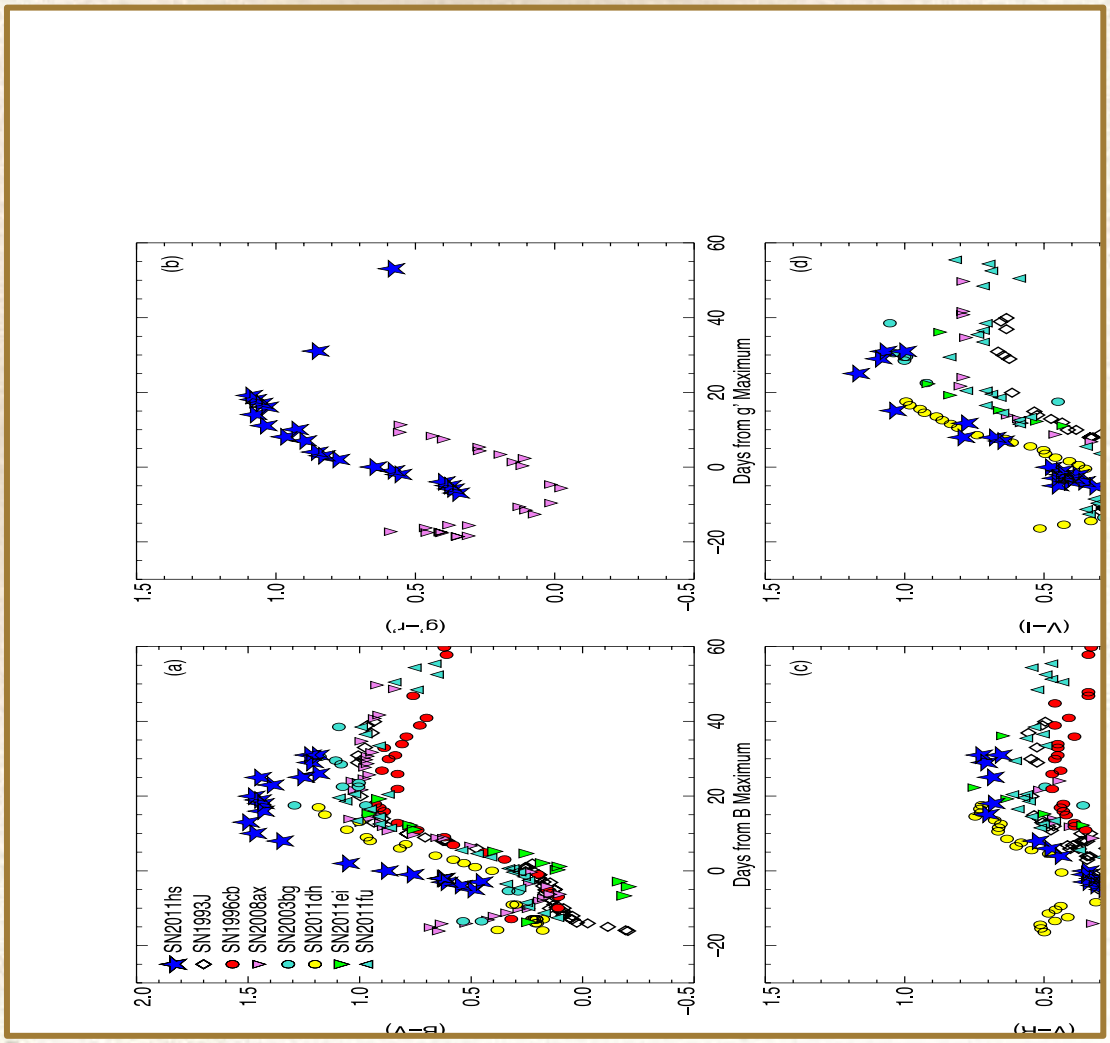
Color Curves

- SN 2011hs color generally REDDER than most of the previously observed Type IIb SNe

- (B-V) evolution resembles SN 2011ei

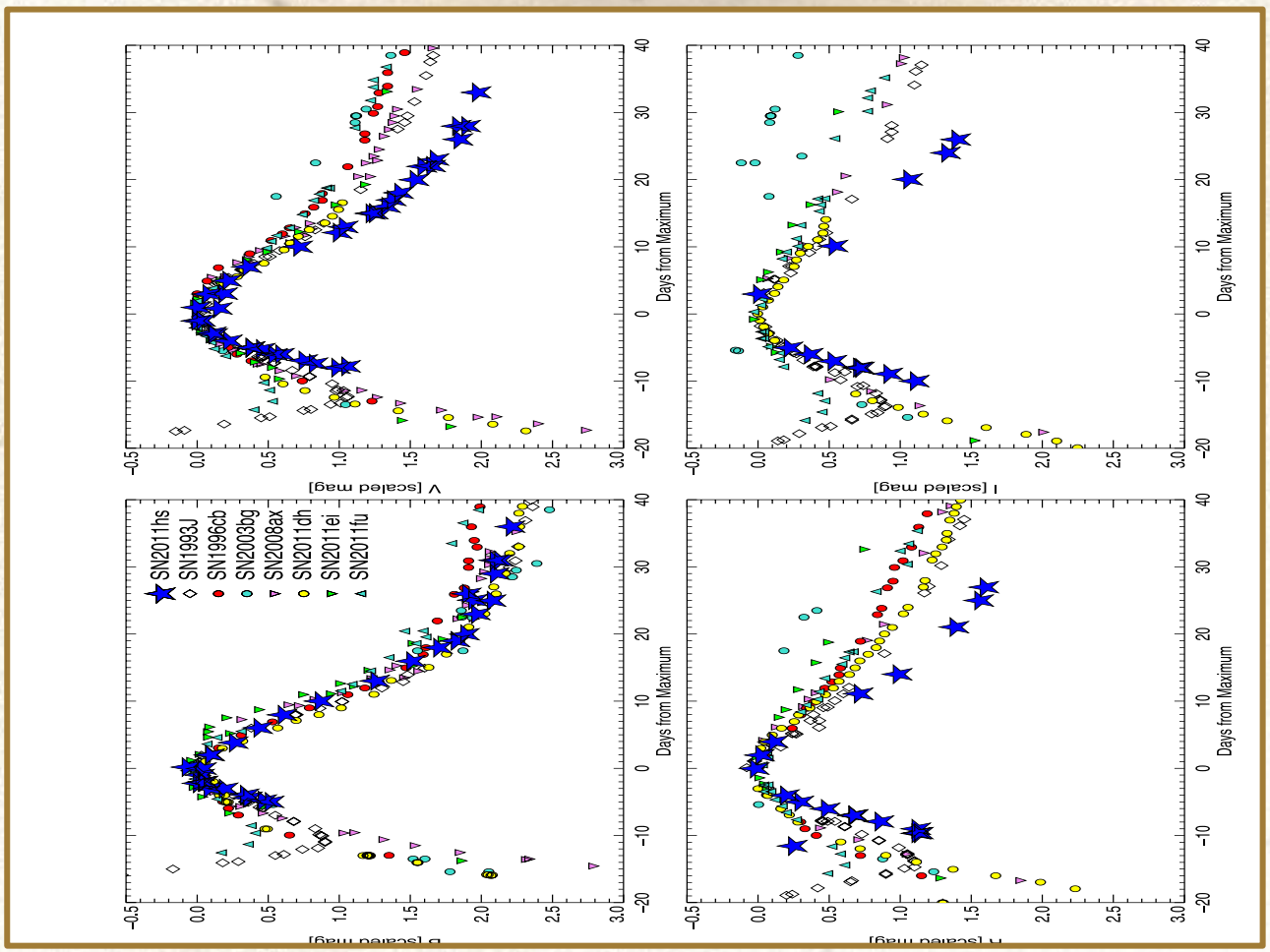
- Similar RED colors evolution

Reddening effects
or
Intrinsic color difference ?



Light Curve Shape Comparison

Fast Evolution!



Bolometric Light Curve and Explosion Parameters

narrow and faint!

~0.03 $M_\odot$ ≤ M_{56Ni} ≤ 0.06 $M_\odot$

Arnett's relations

$$\tau_{peak} \propto M_{ej}^{+3/4} E_k^{-1/4}$$

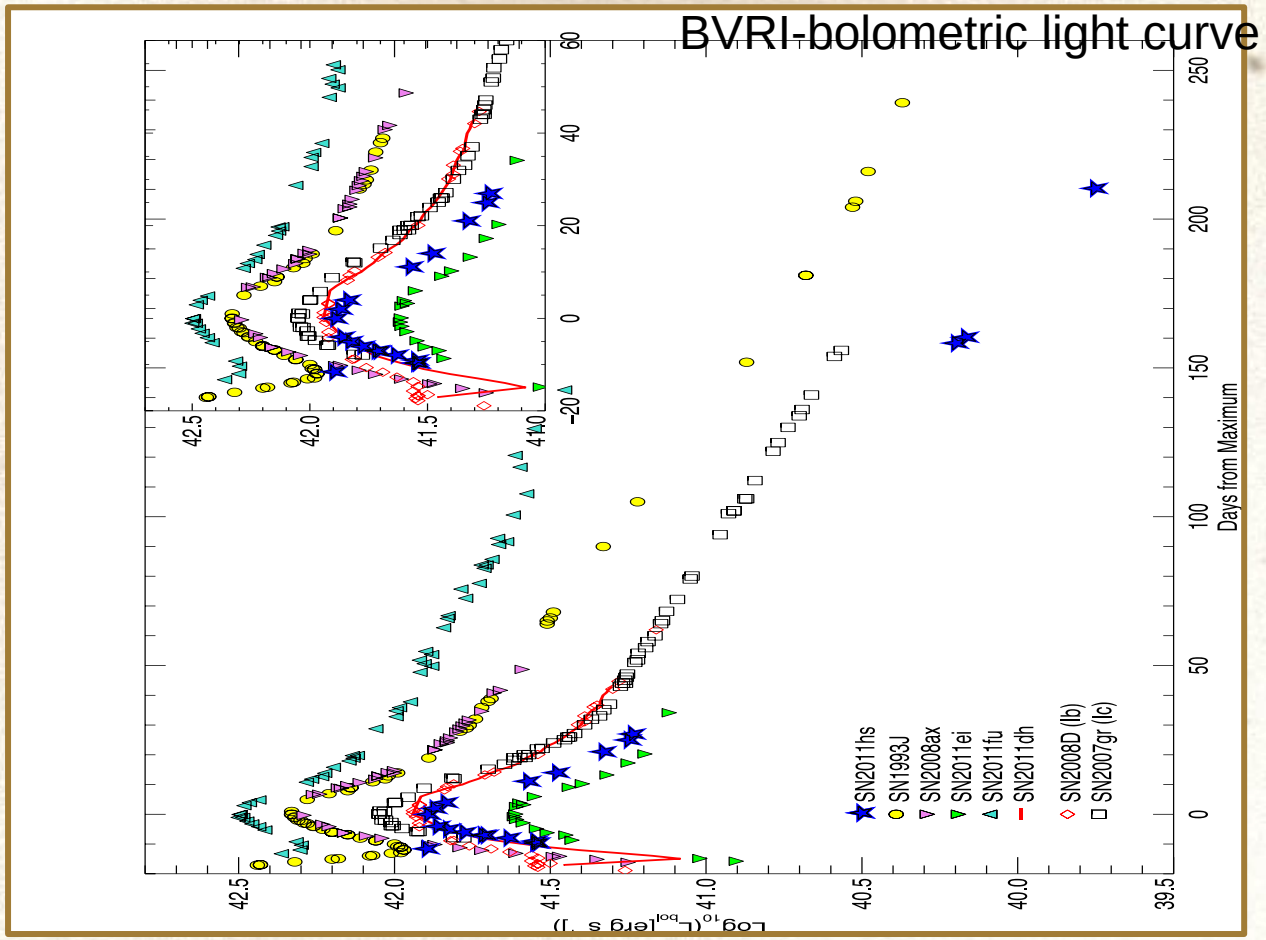
$$v_{ph} \propto M_{ej}^{-1/2} E_k^{+1/2}$$

Pseudo-bolometric light curve shape
+ expansion velocity of FeII @ max
compared with previous SE-SNe

Mej ~ 1-2.3 $M_\odot$

E_k~ 0.8-1.8 foe

BVRI-bolometric light curve



Numerical modeling needed…

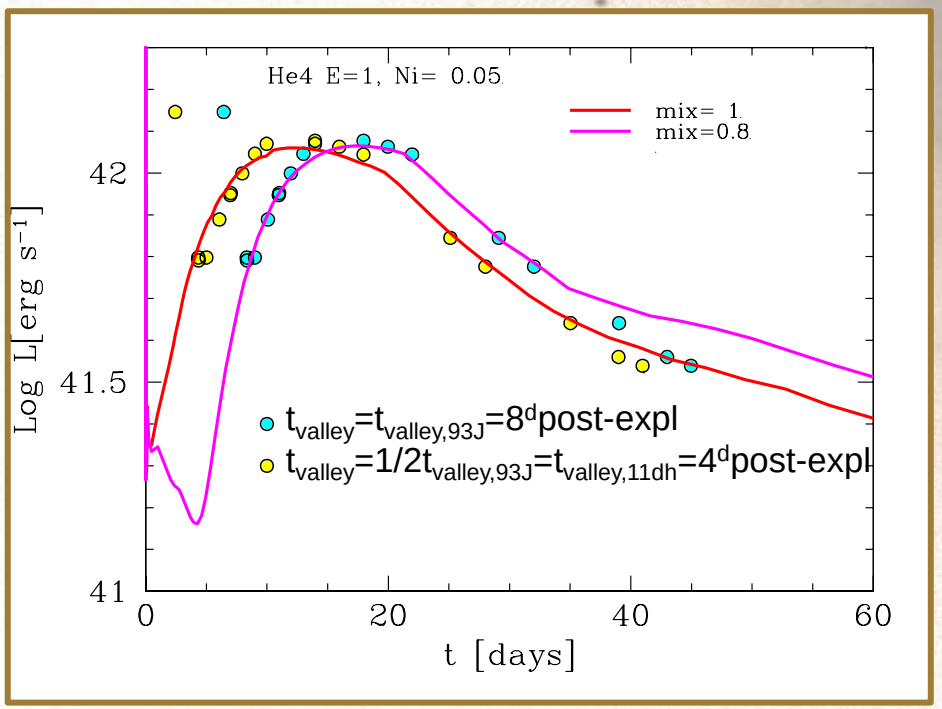
Hydrodynamic modeling:
light curve + expansion velocity (Bersten+11)

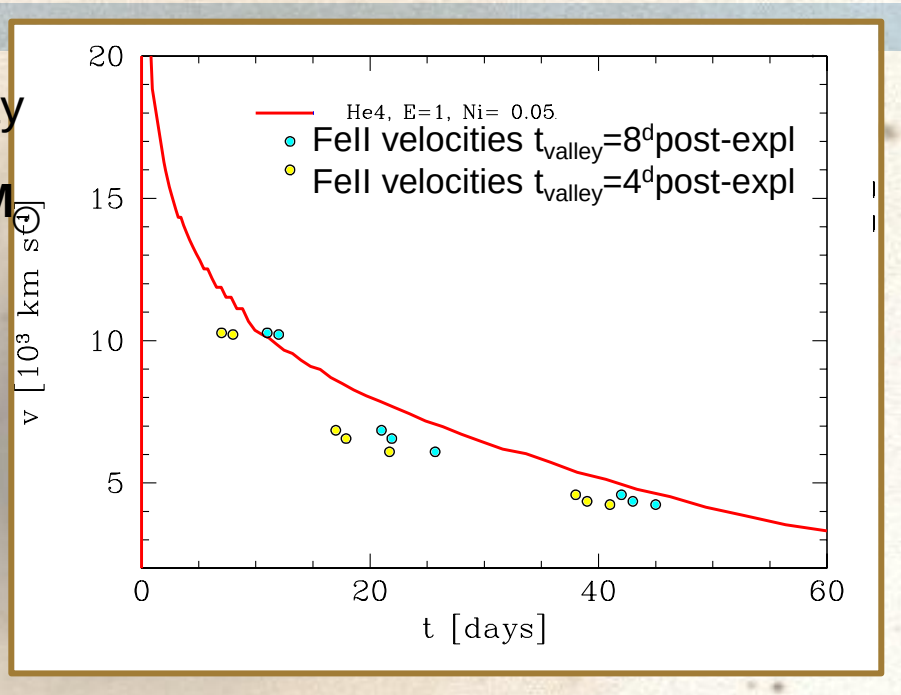
Modeling LC second peak + FeII line velocity

M_{He}= 4 $M_\odot$ → M_{ej}=2.5$M_\odot$ and M_{ZAMS}= 15 $M_\odot$

E= 1 x 10^{51} ergs

M_{Ni}= 0.05 $M_\odot$

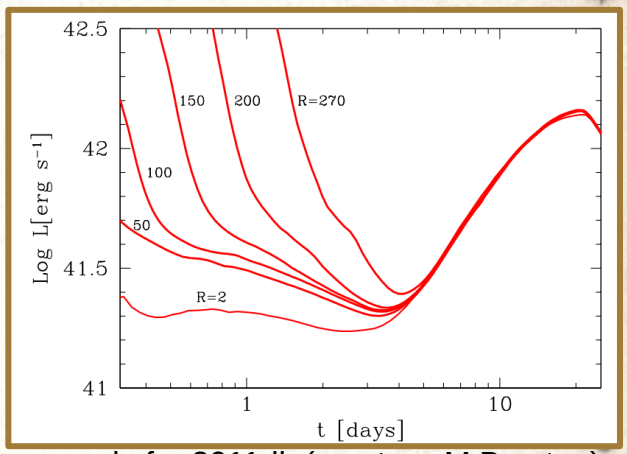




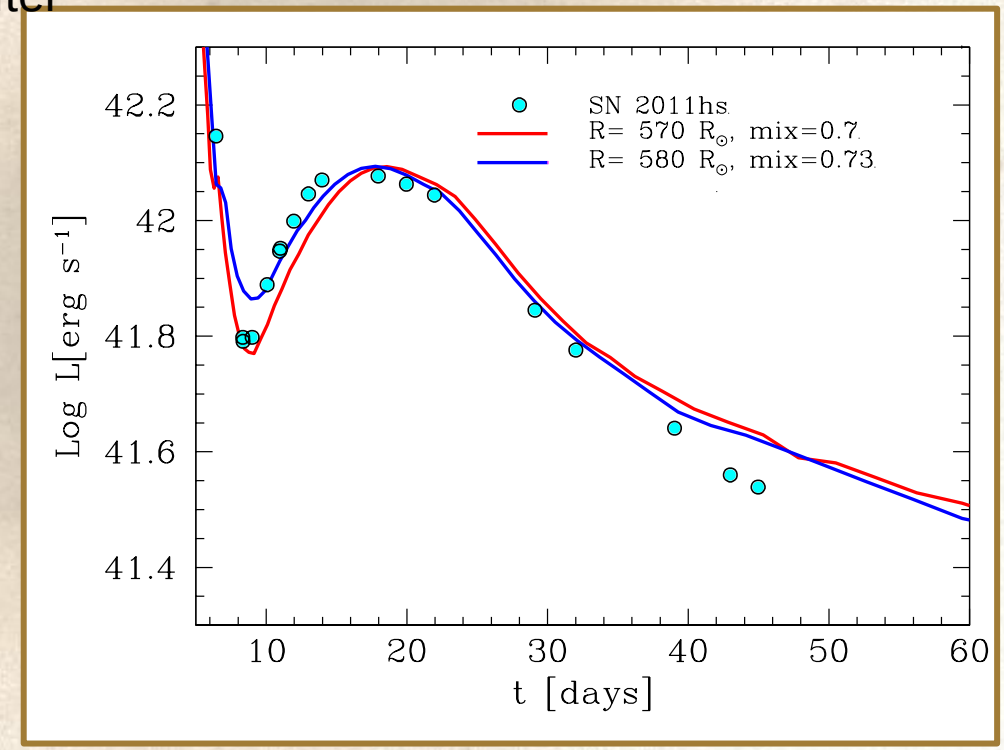
Uncertainities on the explosion epoch requi
different mixing of ^{56}Ni
(mix=0.8 ^{56}Ni linearly mixed out to 80% of initial mass
mix=1 mixing out to the He envelope)

Hydrodynamic modeling:
size of the progenitor (Bersten+11)

From the **cooling phase** (decline after the shock break-out and before the reheating by radioactive decay)



example for 2011dh (courtesy M.Bersten)



PROGENITOR RADIUS

R ≈ 550-600 R$_\odot$ → Extended progenitor

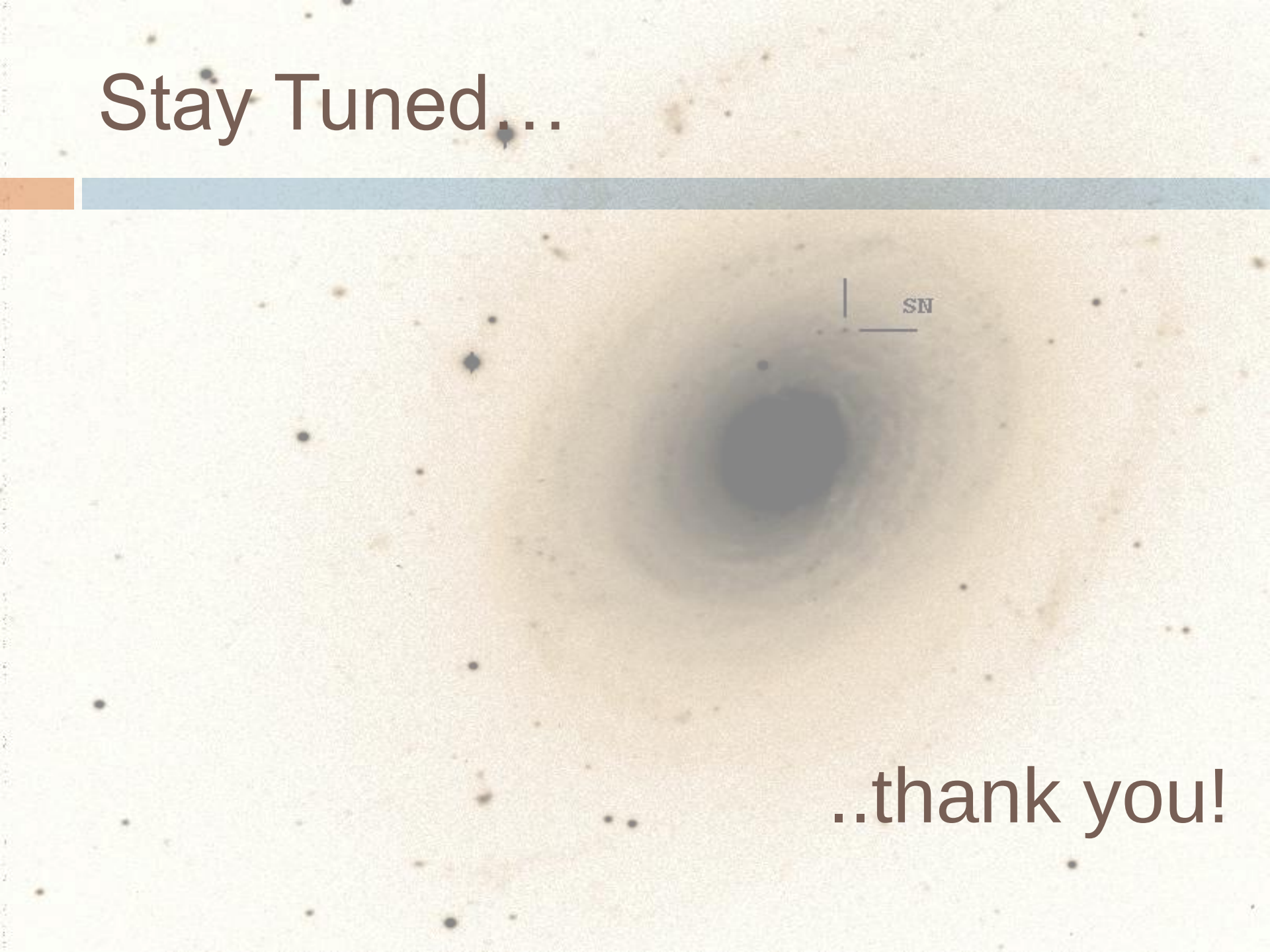
Conclusions

- **SN 2011hs**:
  -- Evidences for an EXTENDED progenitor star;
  -- Possible progenitor star with a 4 $M_{\odot}$(15 $M_{\odot}$ on the ZAMS);
  -- Explosion energy 1 x 10^{51} ergs;
  -- Very low $M_{56Ni} \cong 0.05 M_{\odot}$

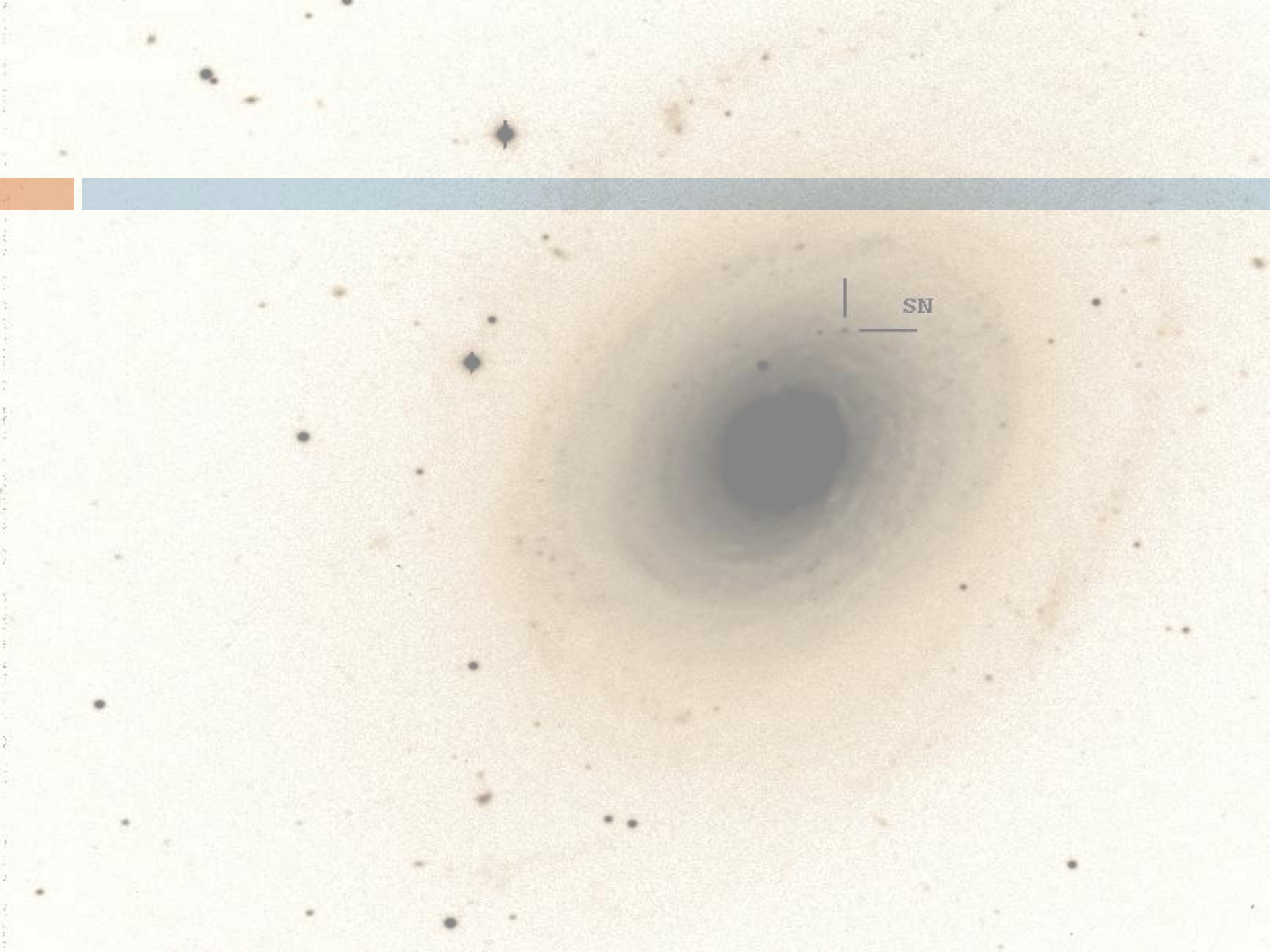
- Importance of observational campaign @
  -- Very Early Phases to catch the adiabatic cooling phase and avoid spectroscopic misclassifications;
  -- Late Phases to get information on the explosion geometry and structure of the environment

- Importance of multiwavelenght coverage
  X-ray and Radio obs. help in understanding if a dence CSM is present and its structure (binary system?)

Stay Tuned…



..thank you!


SN

Asymmetries?

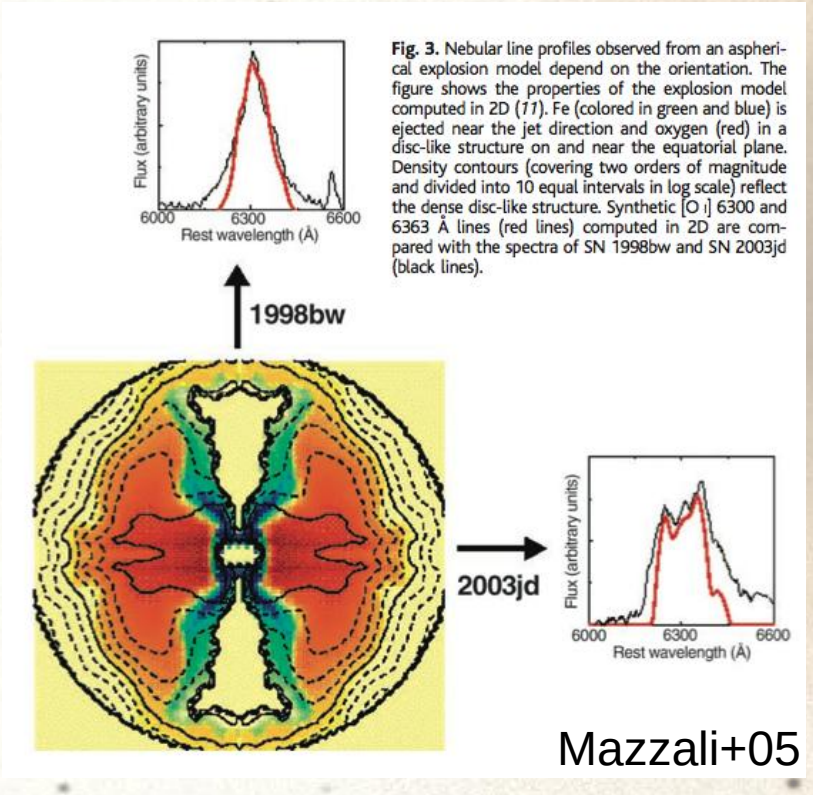
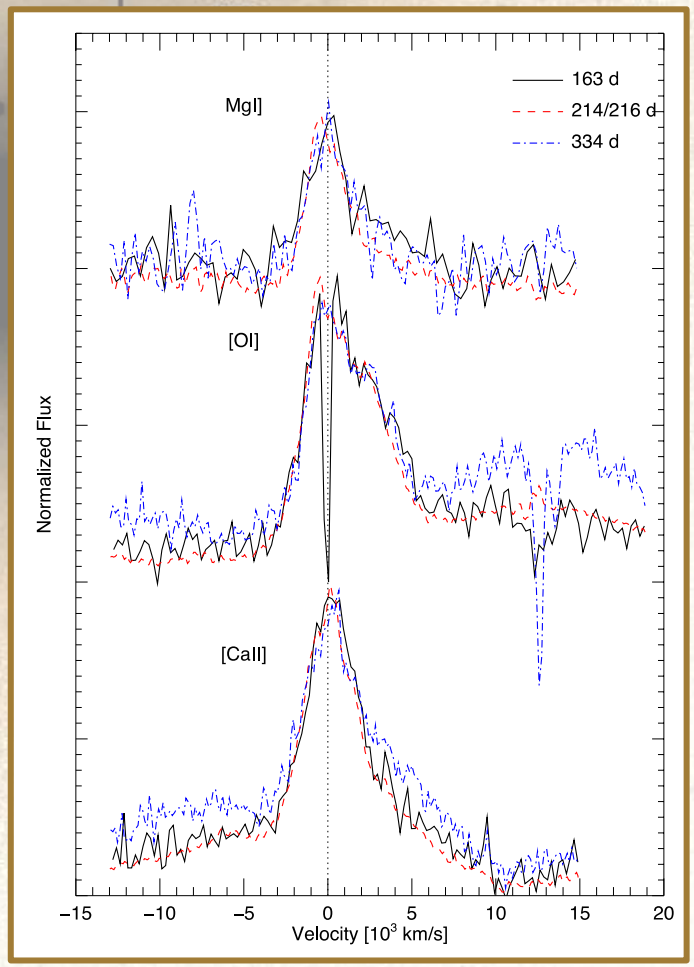


Fig. 3. Nebular line profiles observed from an aspherical explosion model depend on the orientation. The figure shows the properties of the explosion model computed in 2D (*11*). Fe (colored in green and blue) is ejected near the jet direction and oxygen (red) in a disc-like structure on and near the equatorial plane. Density contours (covering two orders of magnitude and divided into 10 equal intervals in log scale) reflect the dense disc-like structure. Synthetic [O I] 6300 and 6363 Å lines (red lines) computed in 2D are compared with the spectra of SN 1998bw and SN 2003jd (black lines).

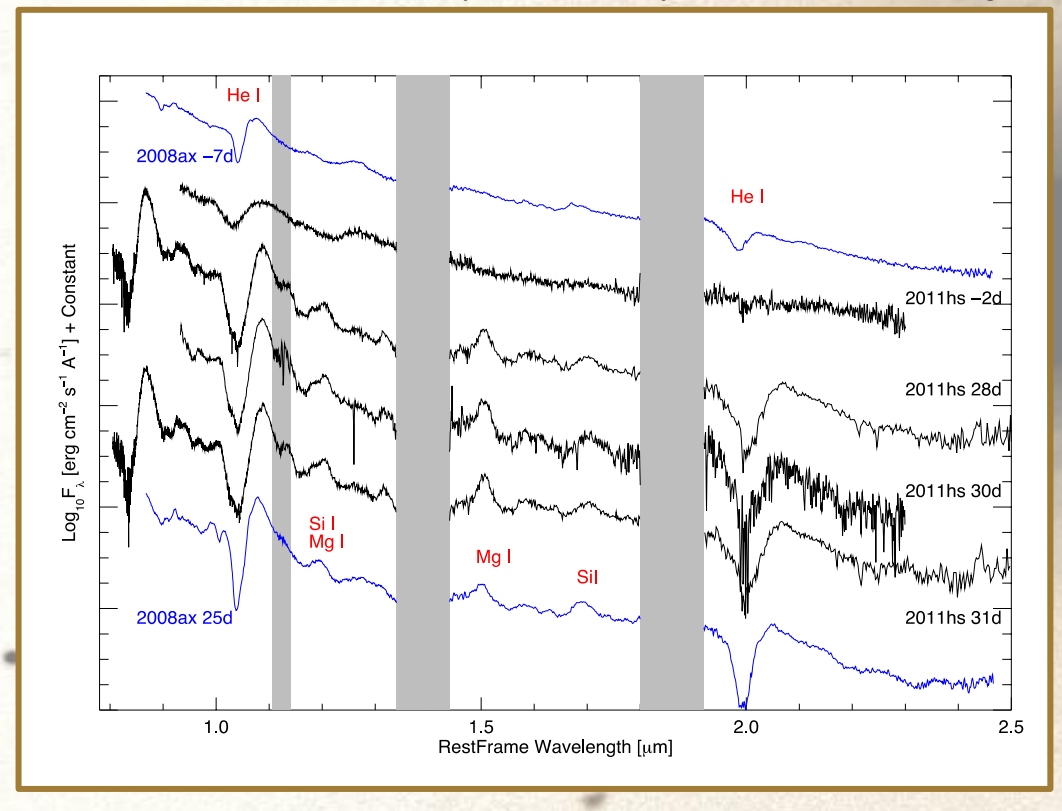
Mazzali+05

No Asymmetric
Nebular Lines Profile



NIR spectroscopy

(2008ax NIR spectra from Taubenberger+11)



Binary System?

No Modulation in the Radio Light Curves

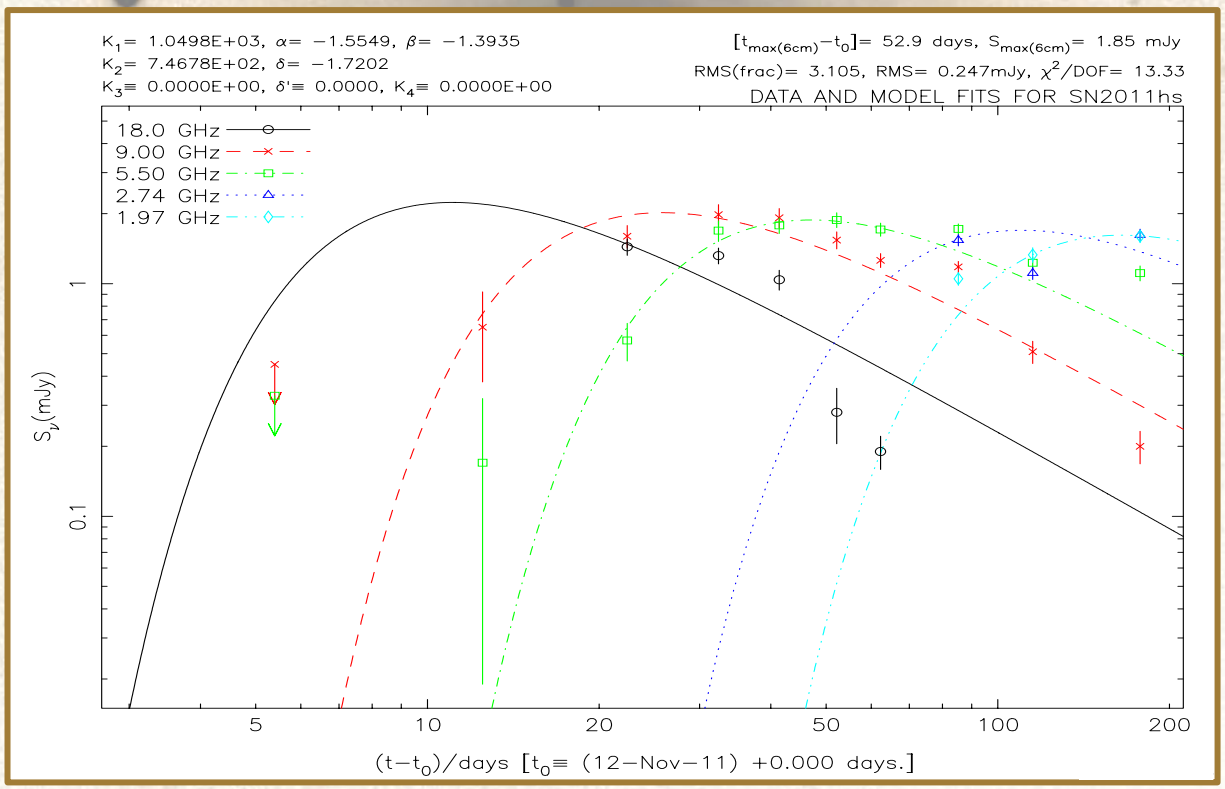
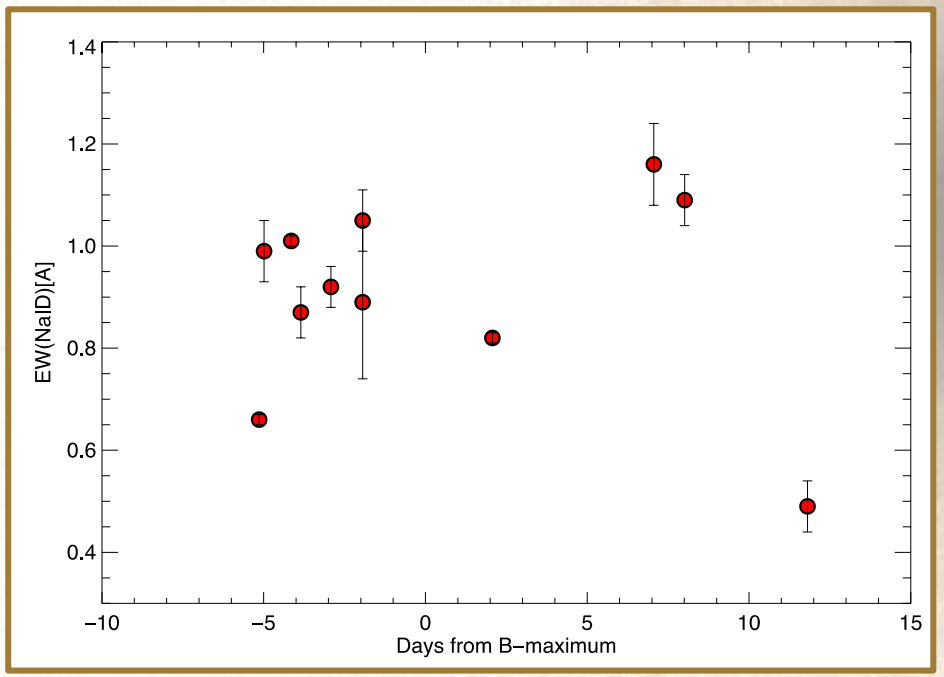


Table 5. Properties of various SE-SNe.

SN	Type	$M_{B,max}$	μ^a (mag)	$E(B-V)_{tot}$ (mag)	^{56}Ni mass ($M_\odot$)	Ejecta mass ($M_\odot$)	E_{kin} (10^{51} erg)	Reference
2008ax	IIb	-17.32 ± 0.50	29.92 ± 0.29	0.4 ± 0.1	0.07–0.15	2–5	1–6	This work
		-17.32 ± 0.50	29.92 ± 0.29	0.4 ± 0.1	0.07–0.15	1.9–4.0	0.7–2.1	Maurer et al. (2010a)
		-16.87	29.92 ± 0.29	0.3	0.06	2.9	0.5	Roming et al. (2009)
		-17.06	29.92 ± 0.29	0.3	0.11	2.3	1.5	Tsvetkov et al. (2009)
2008D	Ib	-16.30	32.16	0.6 ± 0.2	0.05–0.10	3–5	2–4	Soderberg et al. (2008)
			32.45	0.65	0.09	7	6	Mazzali et al. (2008)
2007gr	Ic	-16.75	29.84 ± 0.16	0.09 ± 0.02	0.06–0.10	2.0–3.5	1–4	Hunter et al. (2009)
2007Y	Ib/IIb	-16.20	31.43 ± 0.55	0.11	0.06	1–2	0.5–2.0	Stritzinger et al. (2009)
1999ex	Ib/c	-17.42	33.54 ± 0.23	0.30 ± 0.04	0.16	5–6	2.7	Stritzinger et al. (2002)
1993J	IIb	-17.23	27.80 ± 0.08	0.2	0.10–0.14	1.9–3.5	1.0–1.4	Young et al. (1995)
			27.80 ± 0.08	0.2	0.10	1.3	0.7	Richardson et al. (2006)

ISM/CSM ?

EW of NaID evolution with time

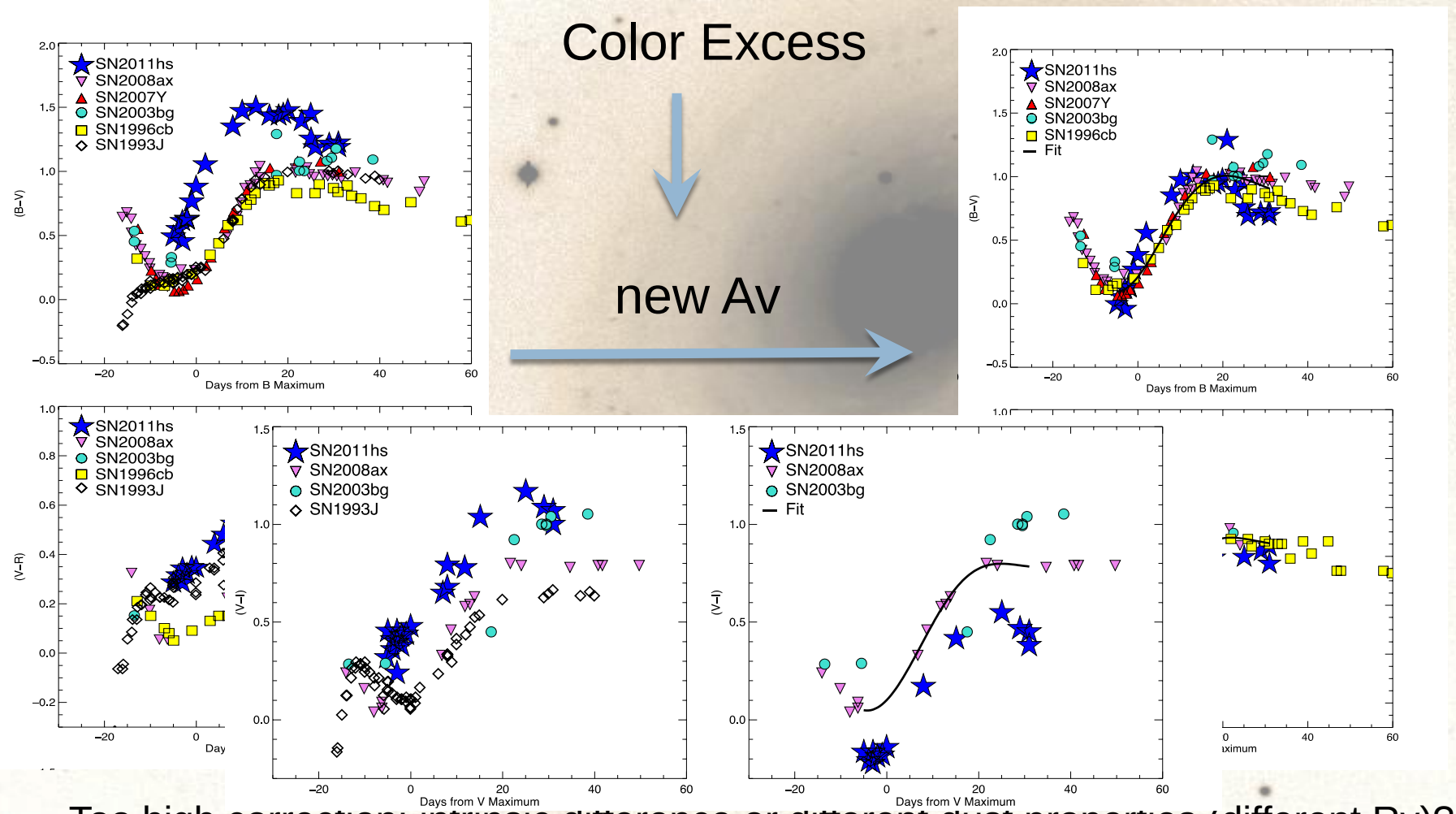


Time-variability of the EW NaID features
interpreted as originating in the CSM (SN2006X, Patat+07) : variations are ionization changes in CSM within the progenitor system due to the radiation from the SN.

CaII H&K **not** detectable

Geometrical effects cannot be ruled out.

Color Excess



Too high correction: intrinsic difference or different dust properties (different Rv)?
Their effects cannot be disentangled!