Supernova Variety and Nucleosynthesis Yields

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+ a number of Post-Docs and Students (many of them have been PIs of follow-ups and papers!)

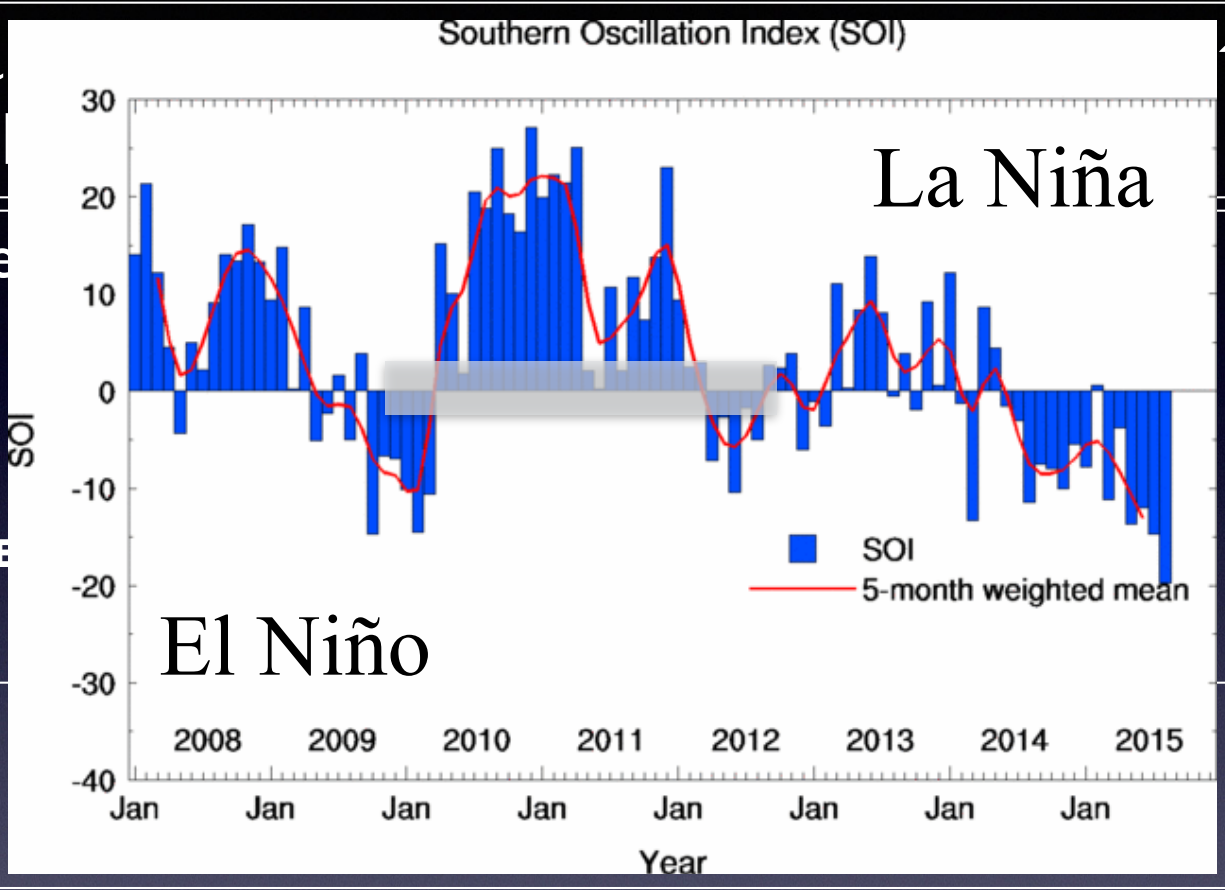
Nations: Italy, ESO, Sweden, Germany, Australia, France, Finland, England, TNG.

Collaborations with QUB, Chilean, Indian groups (S. Smartt, G. Pignata; CSP - M. Stritzinger; K. Misra)

Some numbers:

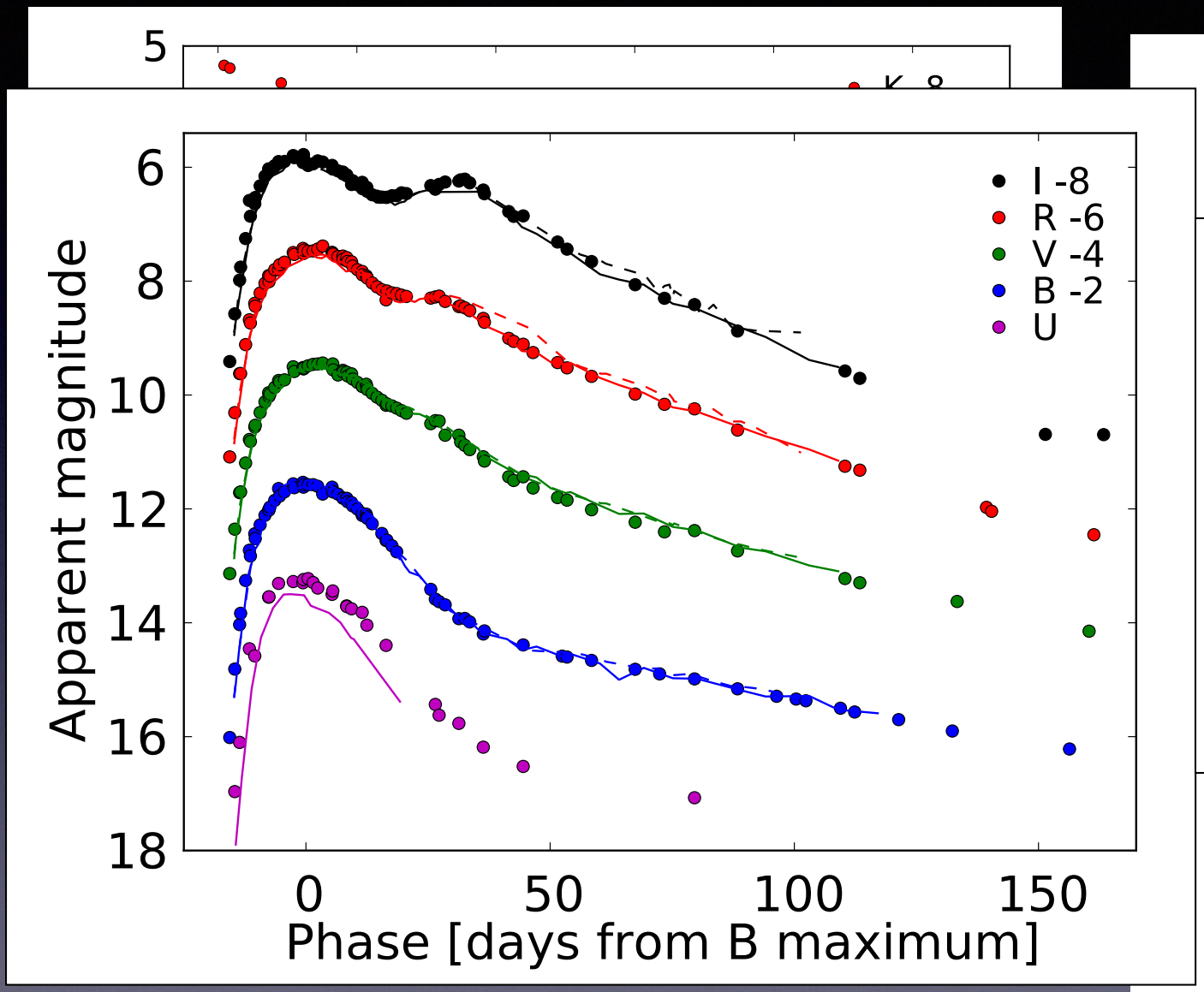
120 nights gra … to P91)
after P89 ⟶ …

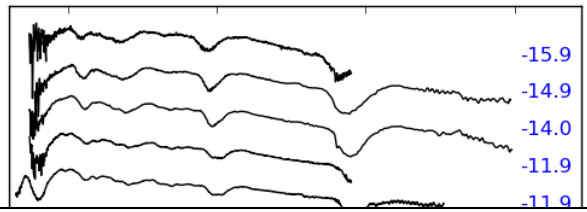
Period	Te…	avg seeing (“)
84 (Oct09-Mar10)		1.1
85 (Apr10-Sep10)		1.4
86 (Oct10-Mar11)		1.4
87 (Apr11-Sep11)		1.2
88 (Oct11-Mar12)		1.0
89 (Apr12-Sep12; PE…		-
mean		1.2



Many facilities: TNG+LRS+NICS (110h/semester for 2 year); VLT +XShoo (GTO Italian time)+FORS; LBT; WHT; NOT+ALFOSC; CA2.2m+CAFOS; AS1.82m+AFOSC; LT; Prompts; REM

The case of SN Ia 2009ig:

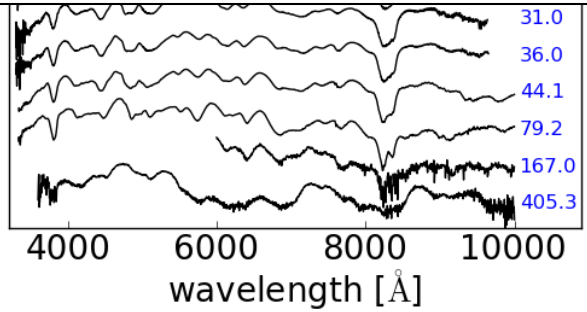




data from:
EFOSC2+AFOSC
+ALFOSC+RATCam
+CAFOS+FORS2+Prompt

homogenised with s-corr

— Foley+ 2012
--- Marion+ 2013



Benetti+ in prep

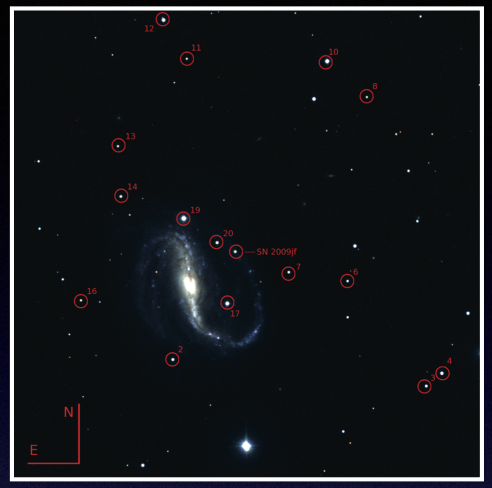
Goals of the project:

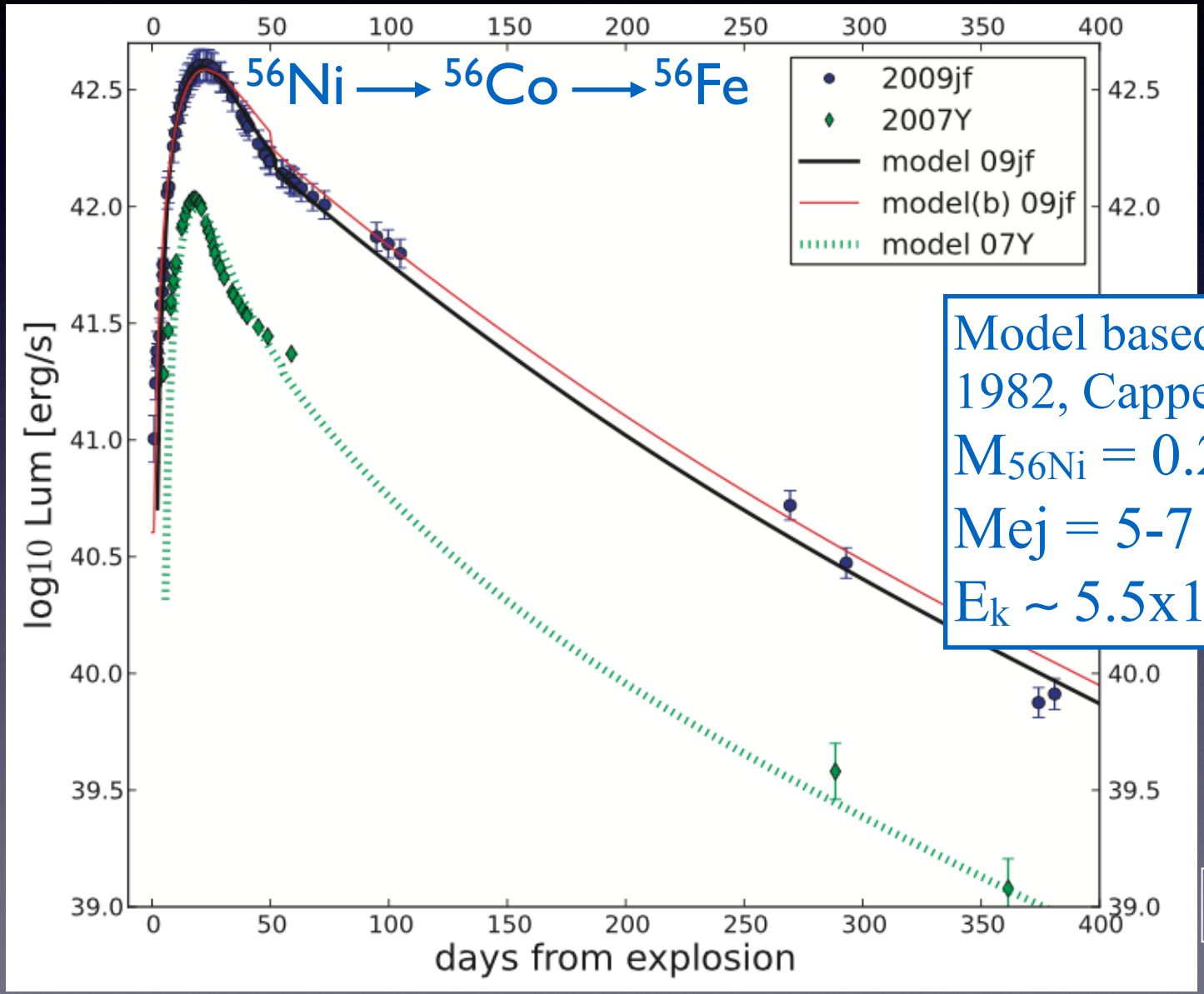
a) Determining the contribution to the chemical enrichment by different SNe (Nucleosynthesis).

b) Progenitor SN connection (RSG-IIP; YSG-IIL; LBV-IIn; WR-Stripped envelope, Ib/c-Ibn)

c) Study the extremes of the SN population (Variety)

Nucleosynthesis: ^{56}Ni
The case of SN 2009jf





Model based on formalism of Arnett 1982, Cappellaro+ 1997:

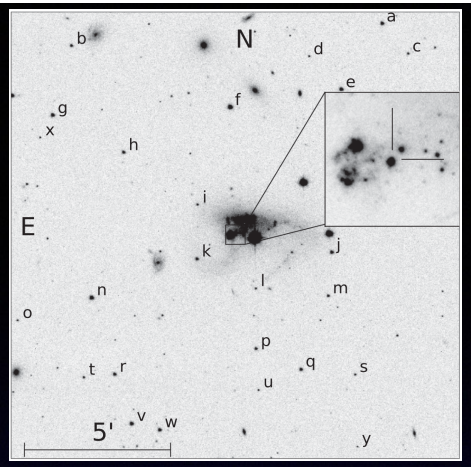
$M_{56Ni} = 0.23 \pm 0.02\ M_\odot$

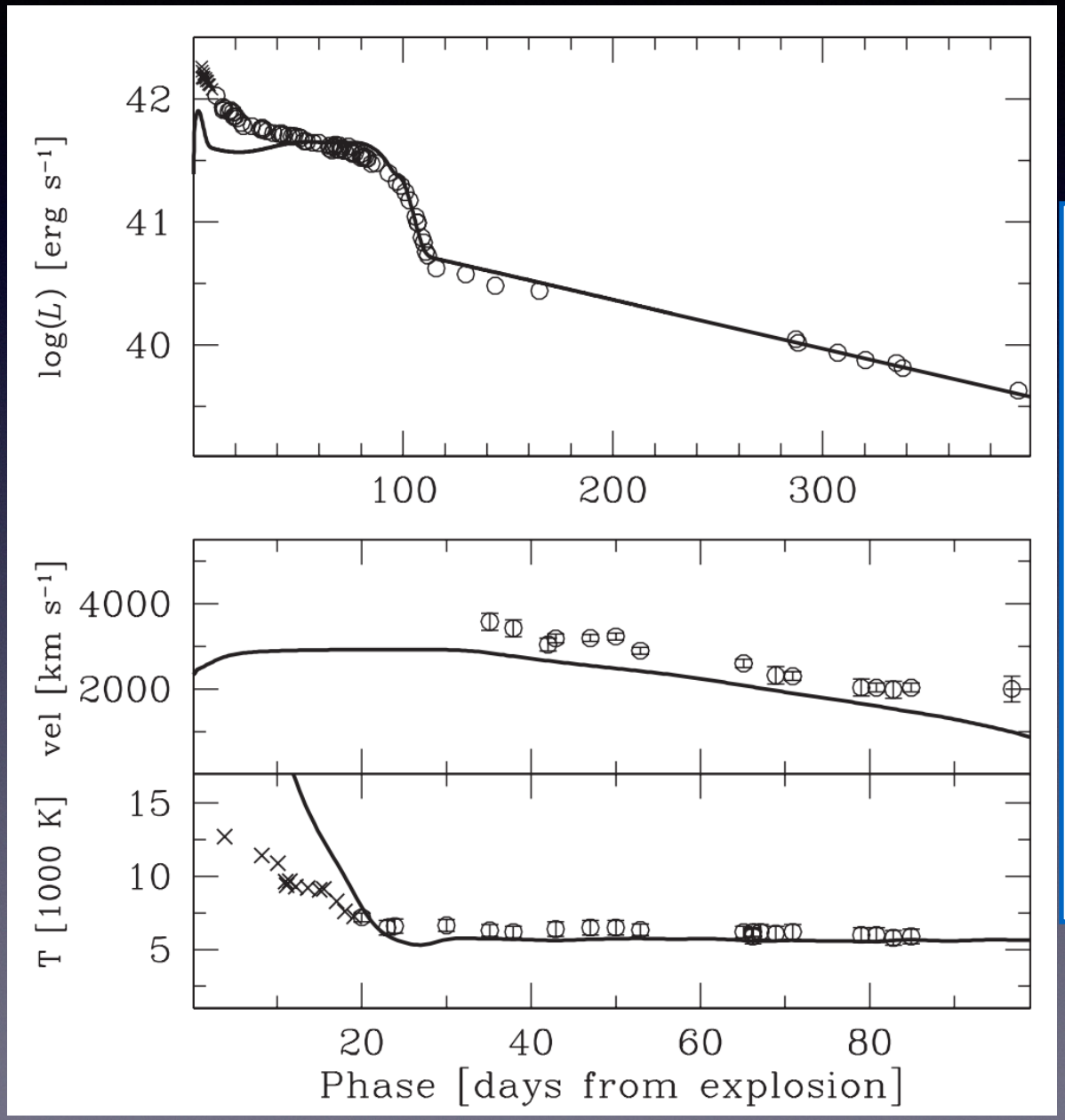
$Mej = 5\text{-}7\ M_\odot$

$E_k \sim 5.5 \times 10^{51}$ erg

Valenti+ 2011, MNRAS

Massive SNe IIP: the case of SN 2012A





Models need to take into account recombination energy from H/He layers (see relativistic hydro. models of Pumo & Zampieri 2011, 2013):

$M_{^{56}Ni} = 0.011 \pm 0.004\ M_\odot$

$E_T \sim 0.48 \times 10^{51}$ erg

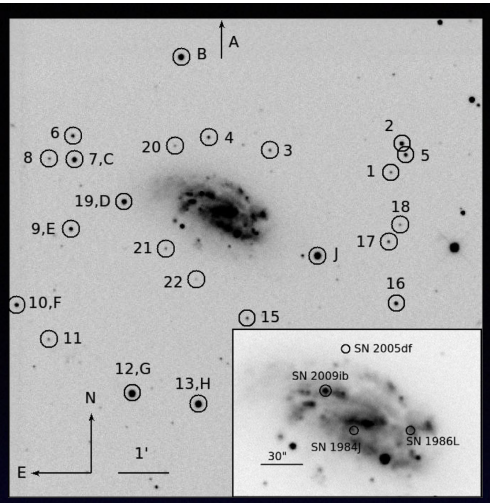
$R_i \sim 1.8 \times 10^{13}$ cm ($\sim 260 R_\odot$)

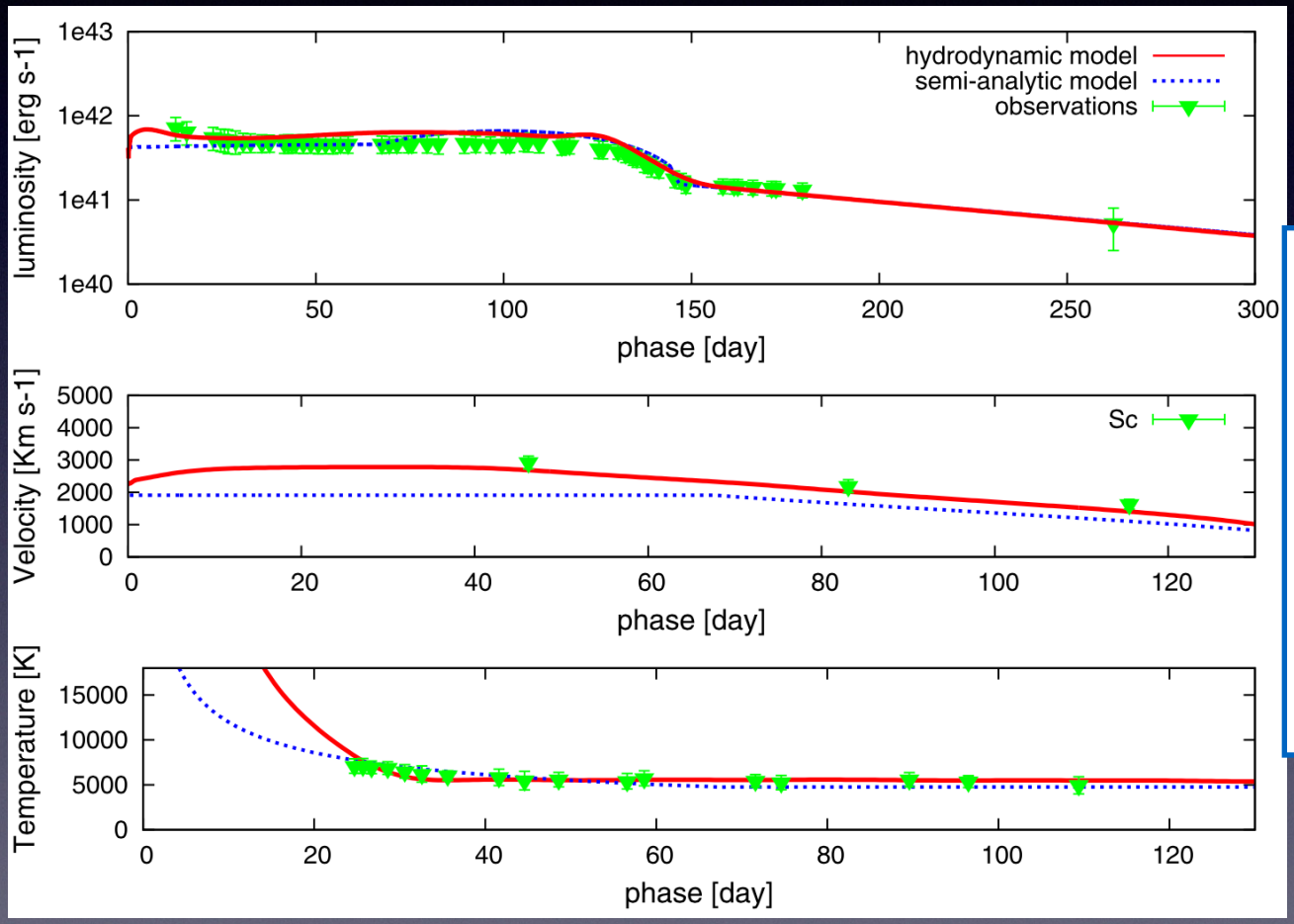
$Mej = 12.5 \pm 1.9\ M_\odot$

$M_T \approx 15\ M_\odot$

Tomasella+ 2013, MNRAS

Massive SNe IIP: the case of SN 2009ib





Models:

$M_{56Ni} = 0.046 \pm 0.004\ M_\odot$

$E_T \sim 0.55 \times 10^{51}$ erg

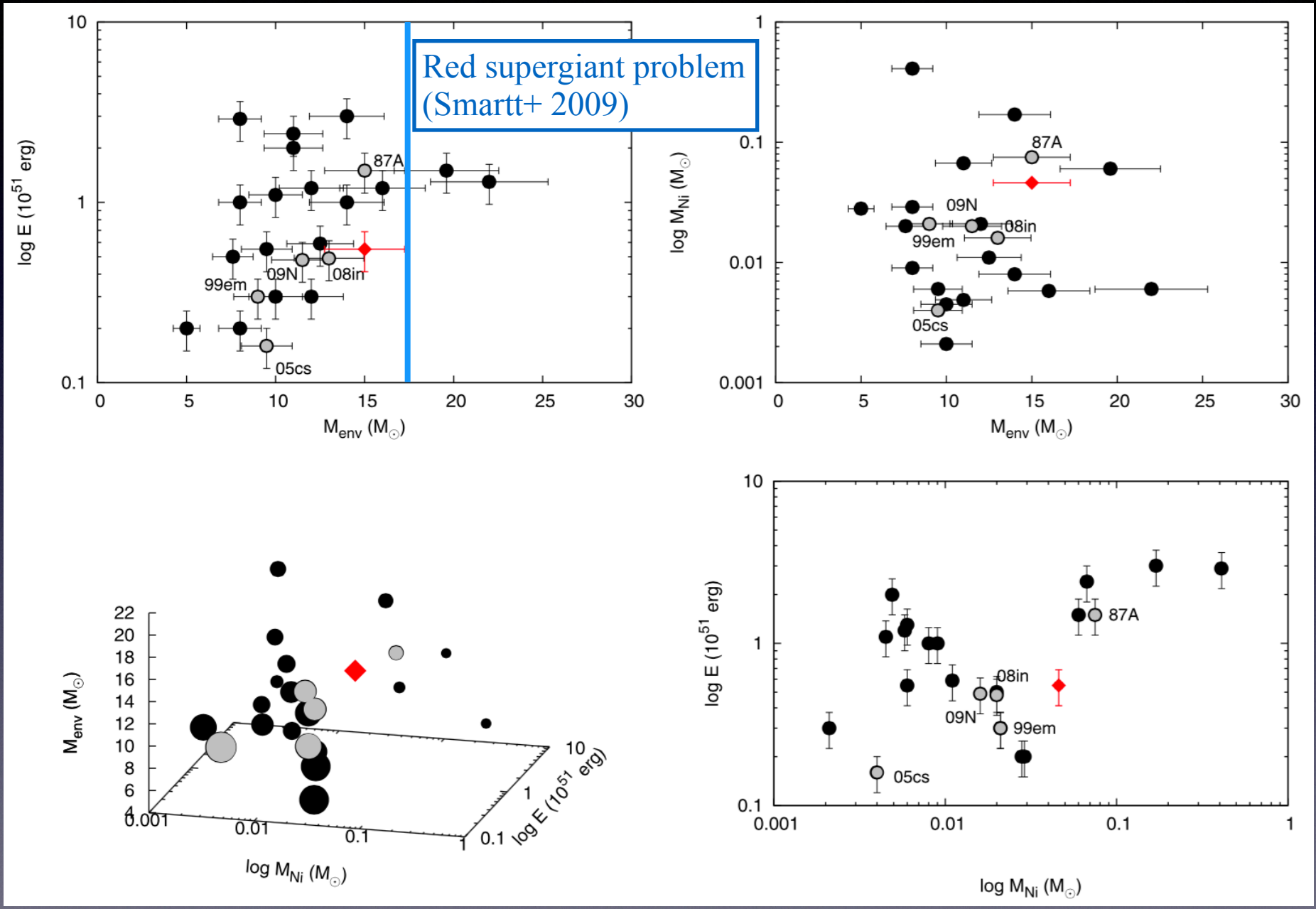
$R_i \sim 2.8 \times 10^{13}$ cm ($\sim 400 R_\odot$)

$Mej = 15 \pm 2.2\ M_\odot$

$M_T \sim 16.5\ M_\odot$

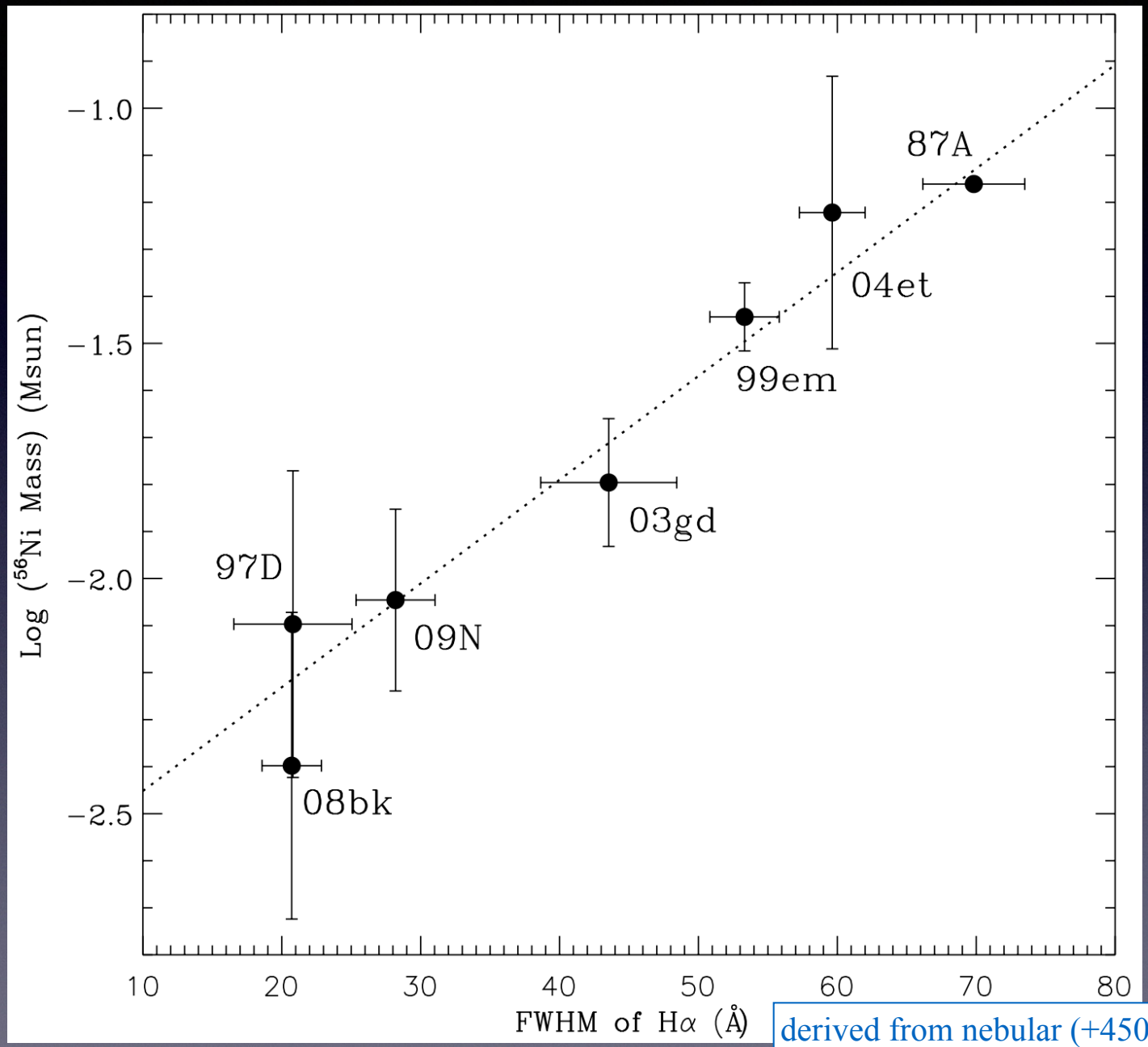
Takáts+ 2015, MNRAS

Massive SNe IIP: some statistic



Takáts+ 2015, MNRAS

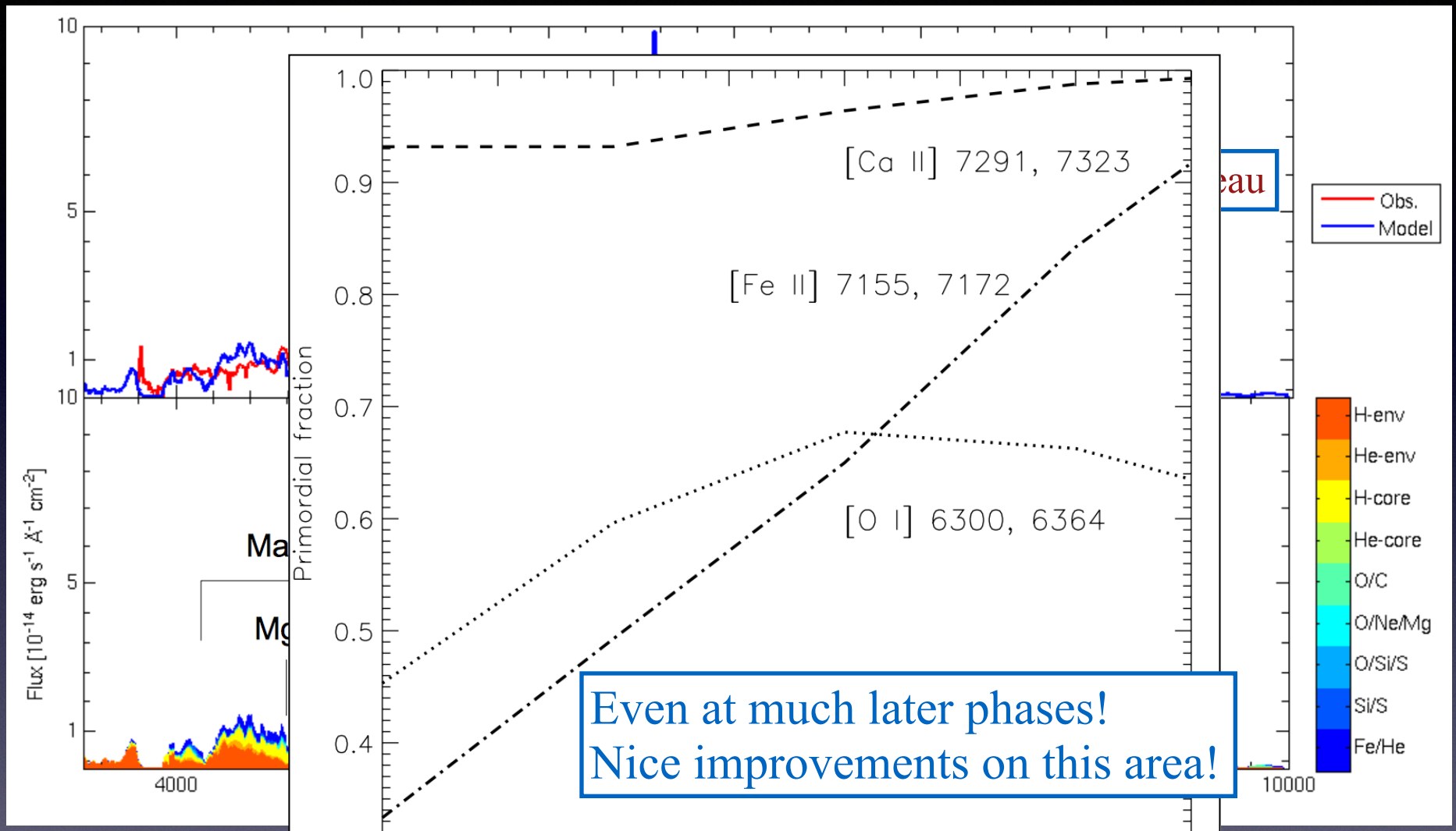
Massive SNe IIP: ^{56}Ni mass ~ E_K



derived from nebular (+450^d) spectra

Maguire+ 2012, MNRAS

What about others elements?

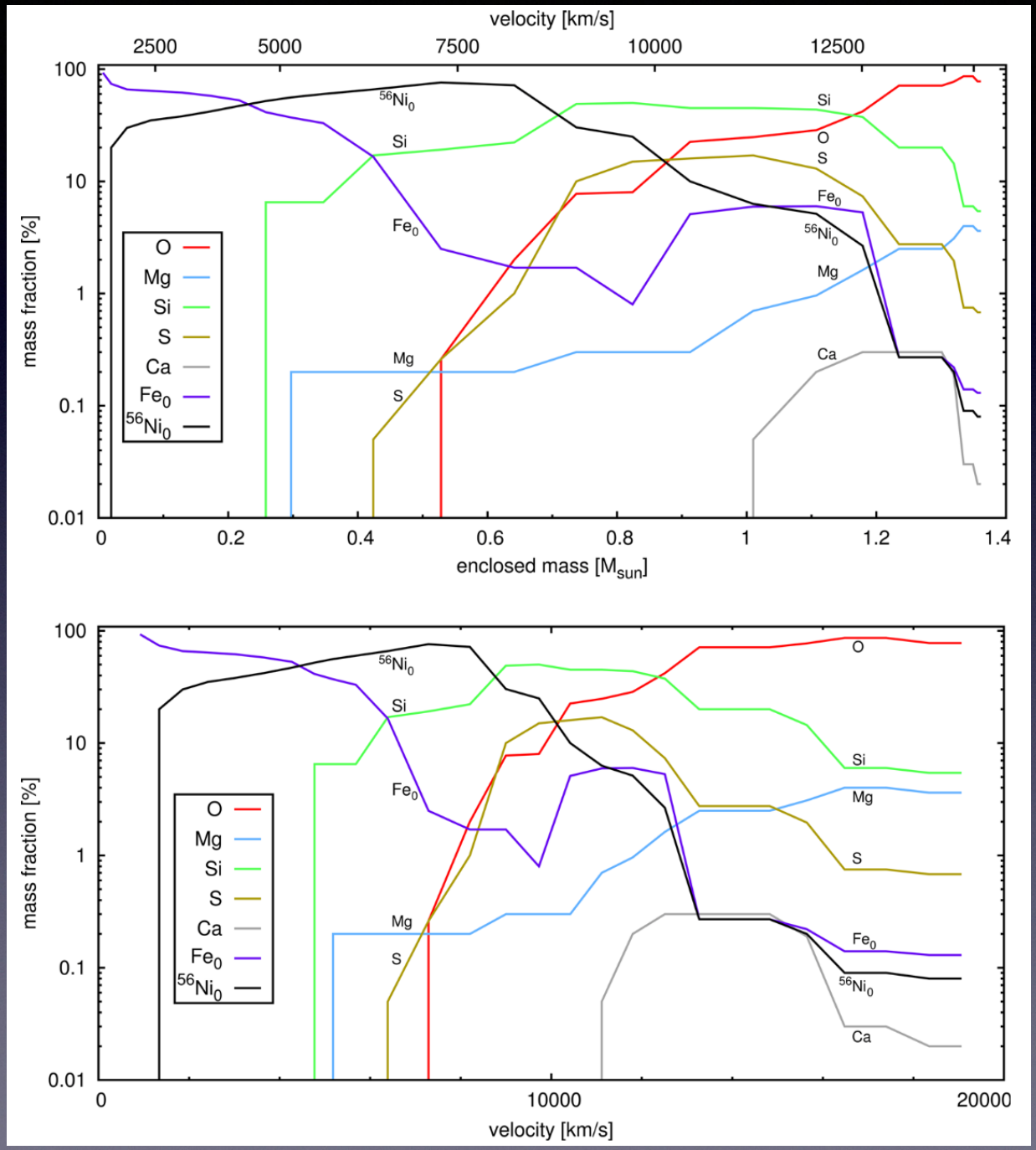


Even at much later phases!
Nice improvements on this area!

Jerkstrand 201

Maguire+ 2012, MNRAS

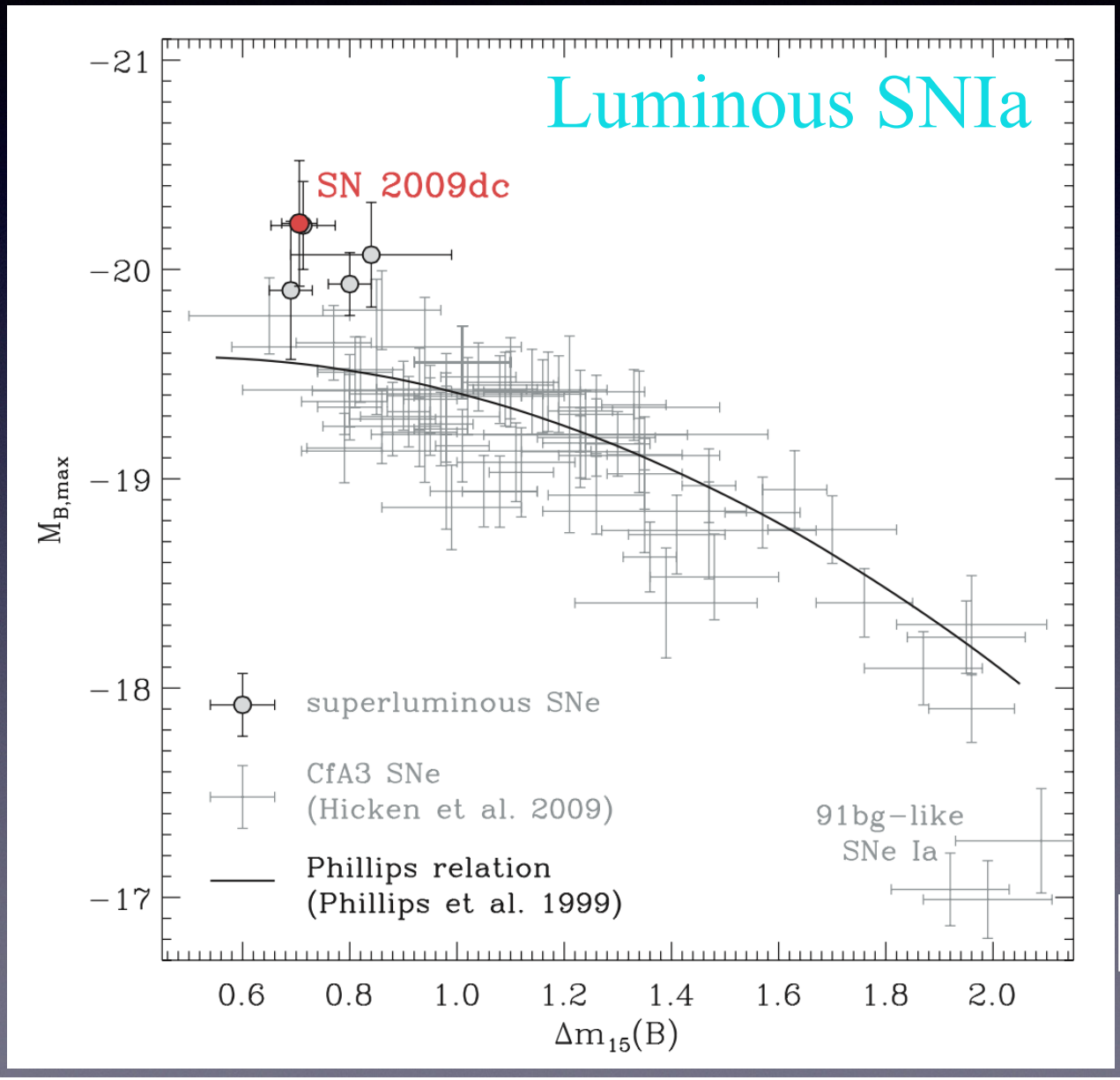
Tomography of Type Ia SN 2011fe



Somehow less complicate for stripped envelope SNe: we are able to recover the chemistry of the exploded star, modelling its complete spectral evolution!

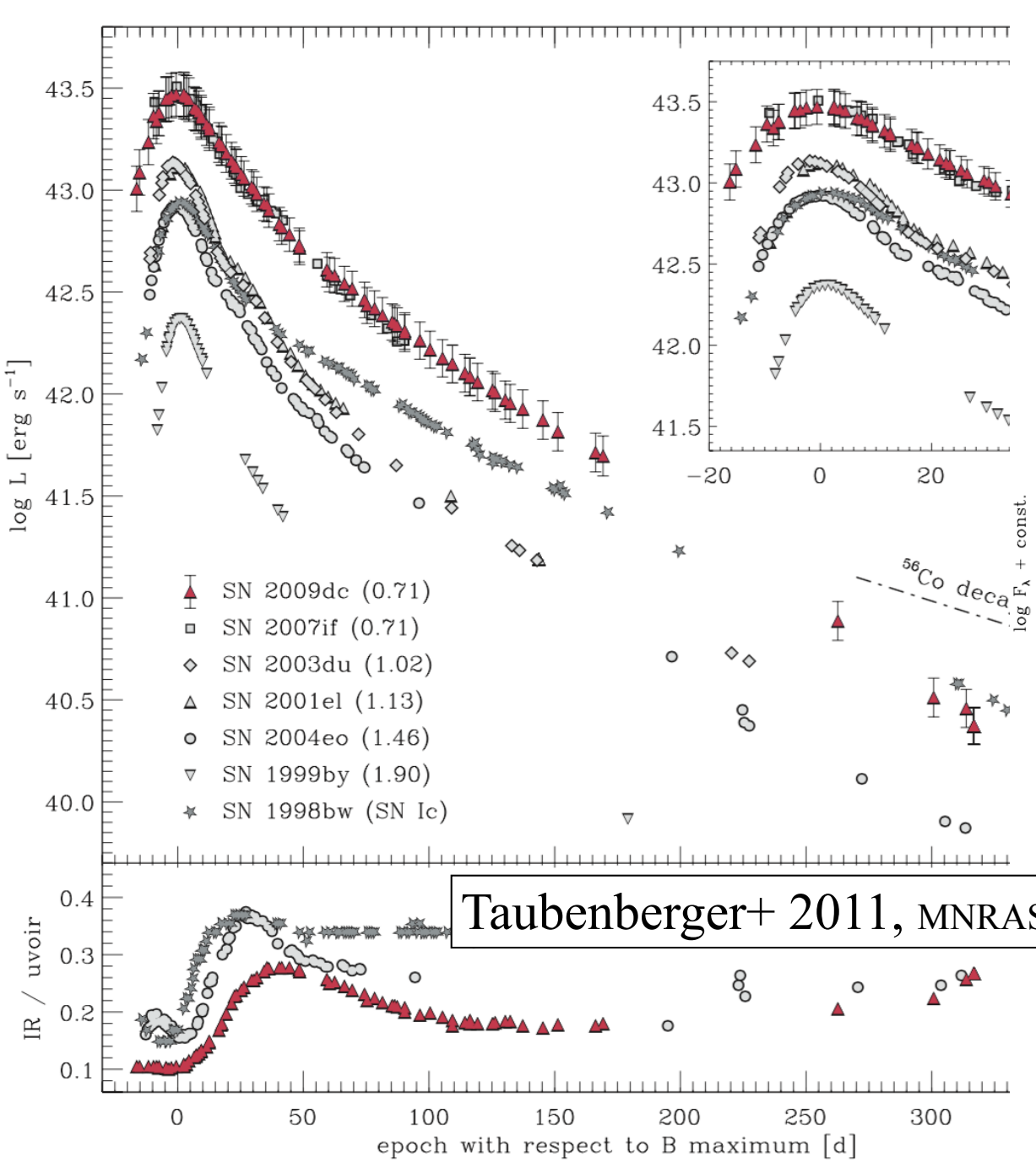
Mazzali+ 2015, MNRAS

Variety:
Thermonuclear explosions

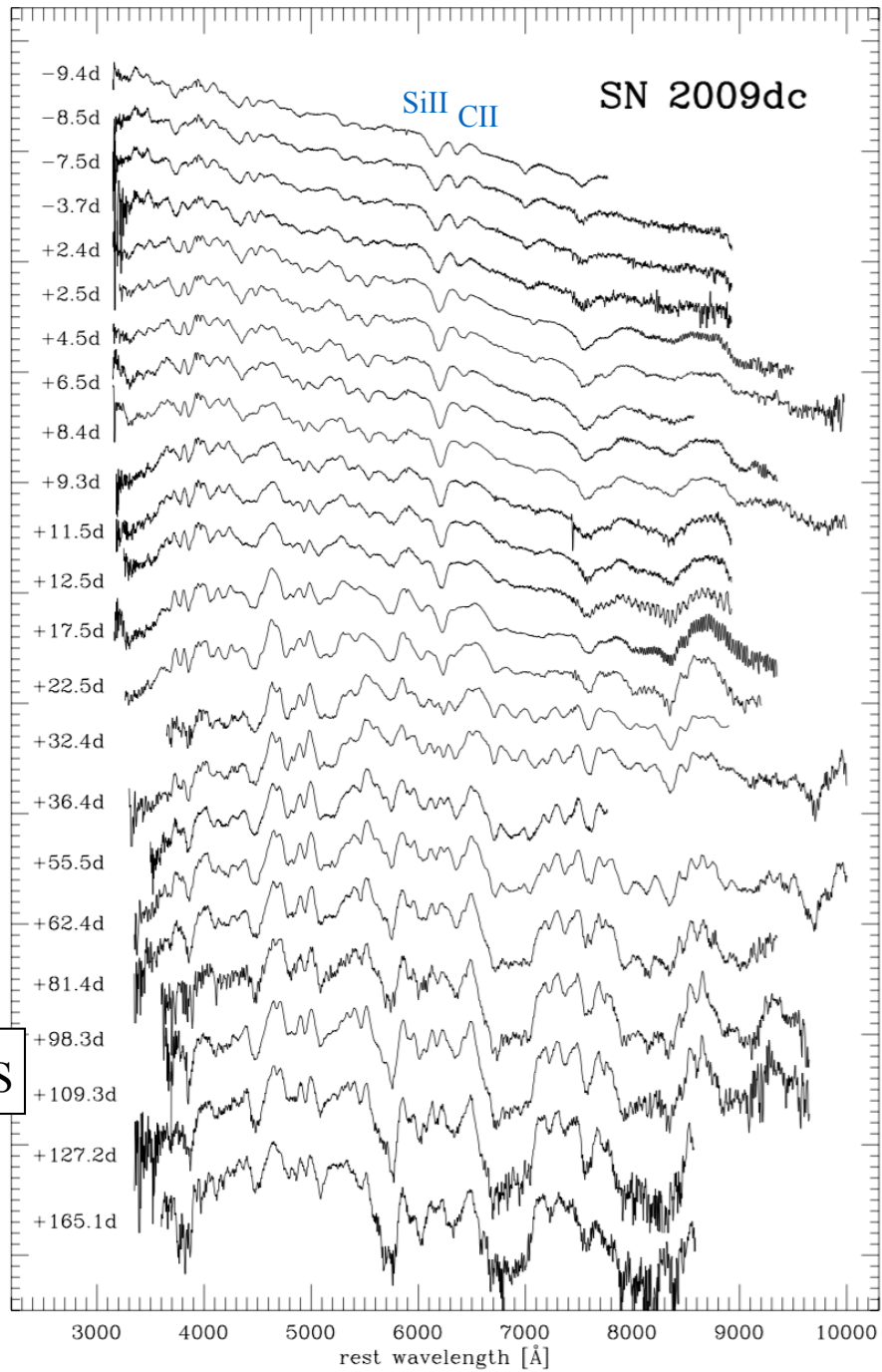


Taubenberger+ 2011, MNRAS

Luminous Type Ia SN 2009dc

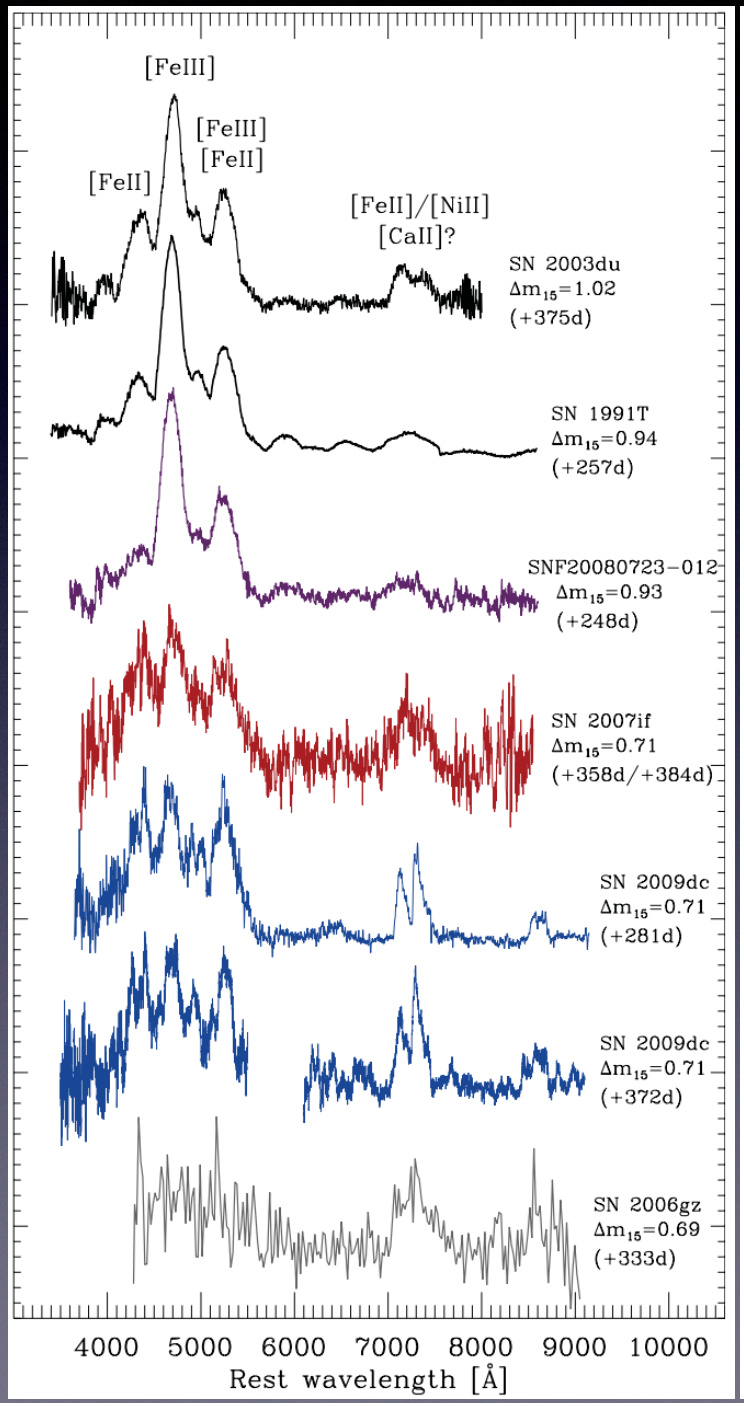


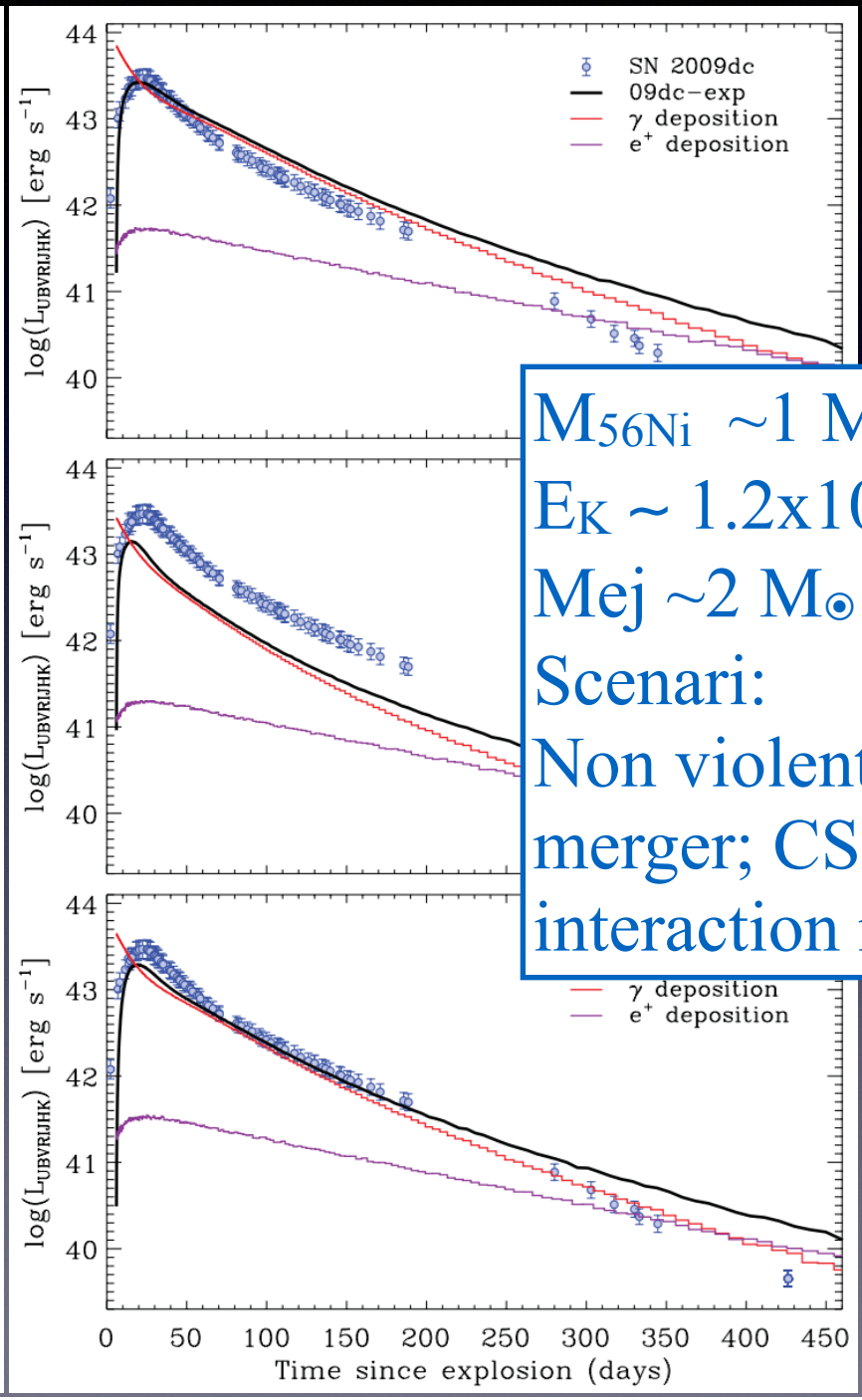
Taubenberger+ 2011, MNRAS



SN 2009dc

Taubenberger+ 2013, MNRAS





M_{56Ni} ~1 $M_\odot$

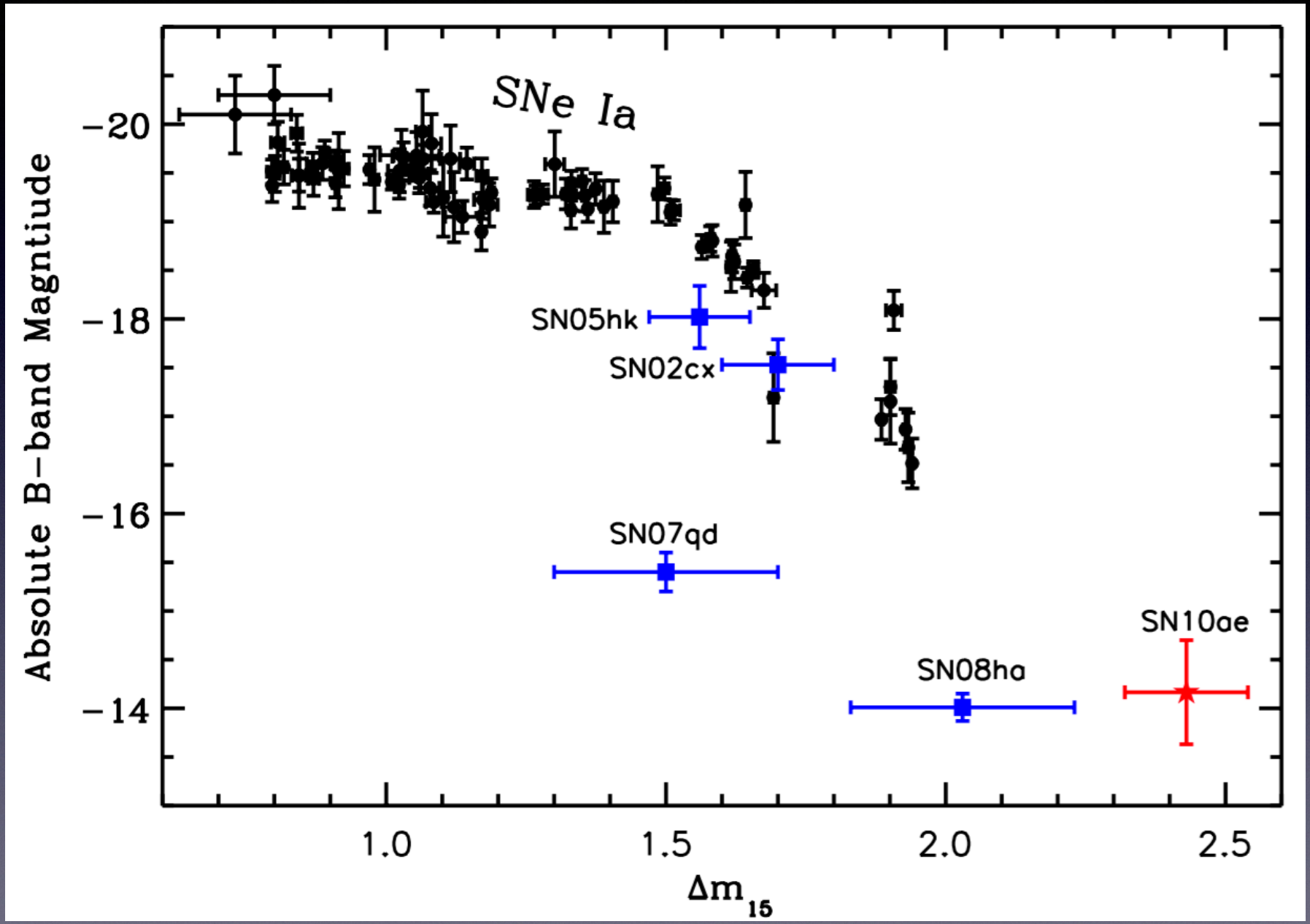
E_K ~ 1.2x10^{51} erg

Mej ~2 $M_\odot$

Scenari:

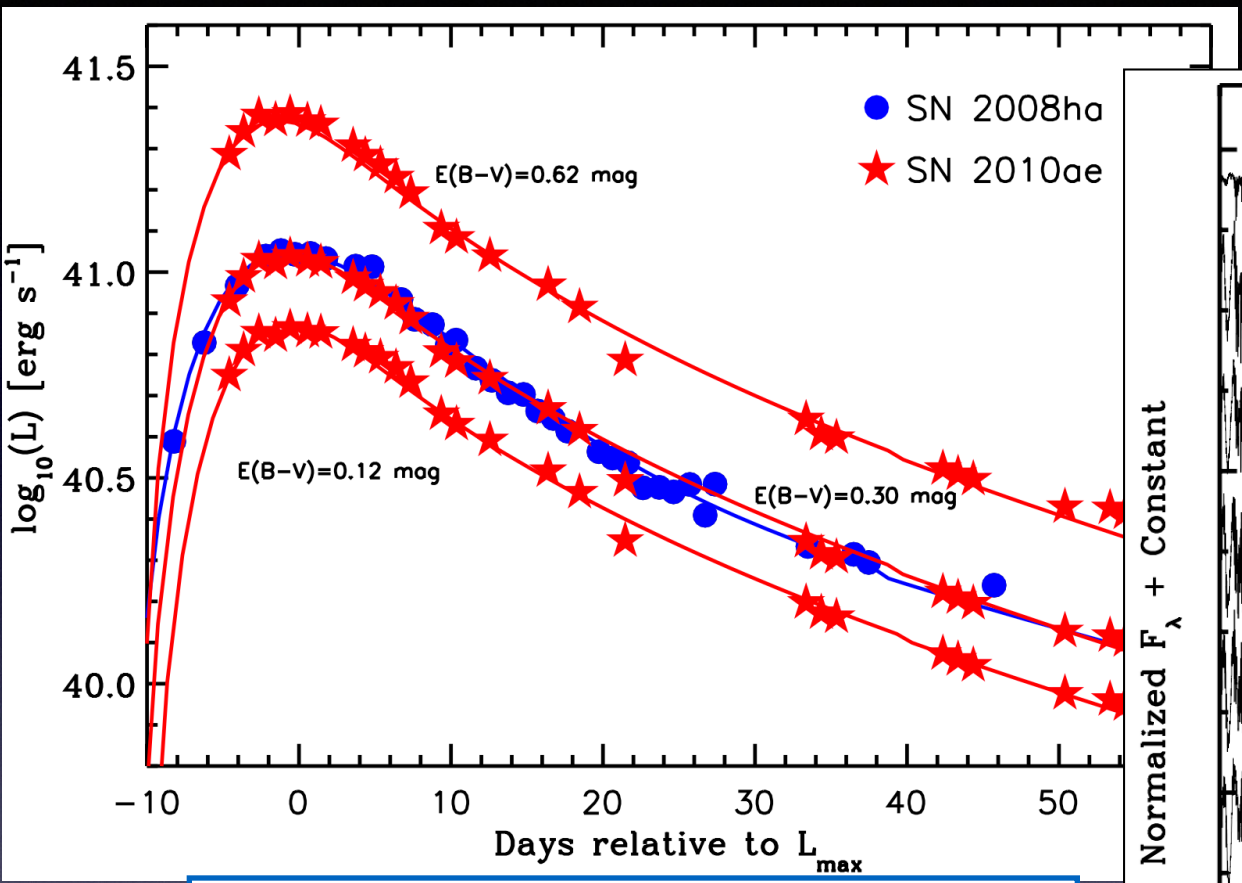
Non violent WD+WD merger; CSM-ejecta interaction may play a role?

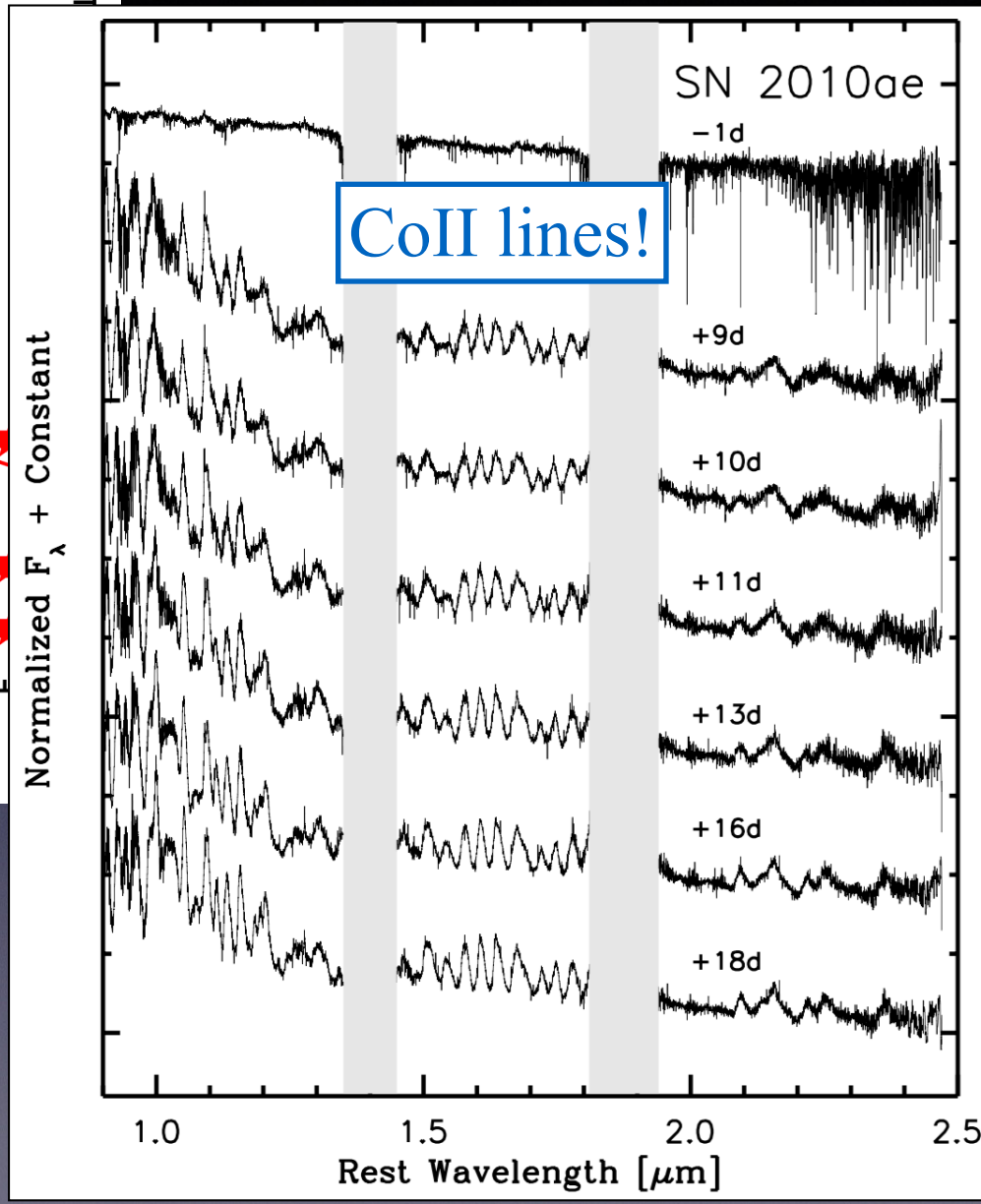
Subluminous Type Iax SN 2010ae



Stritzinger+ 2014, A&A

Subluminous Type Iax SN 2010ae





M_{56Ni} ~0.005 $M_\odot$

E_K ~ 0.04-0.30x10^{51} erg

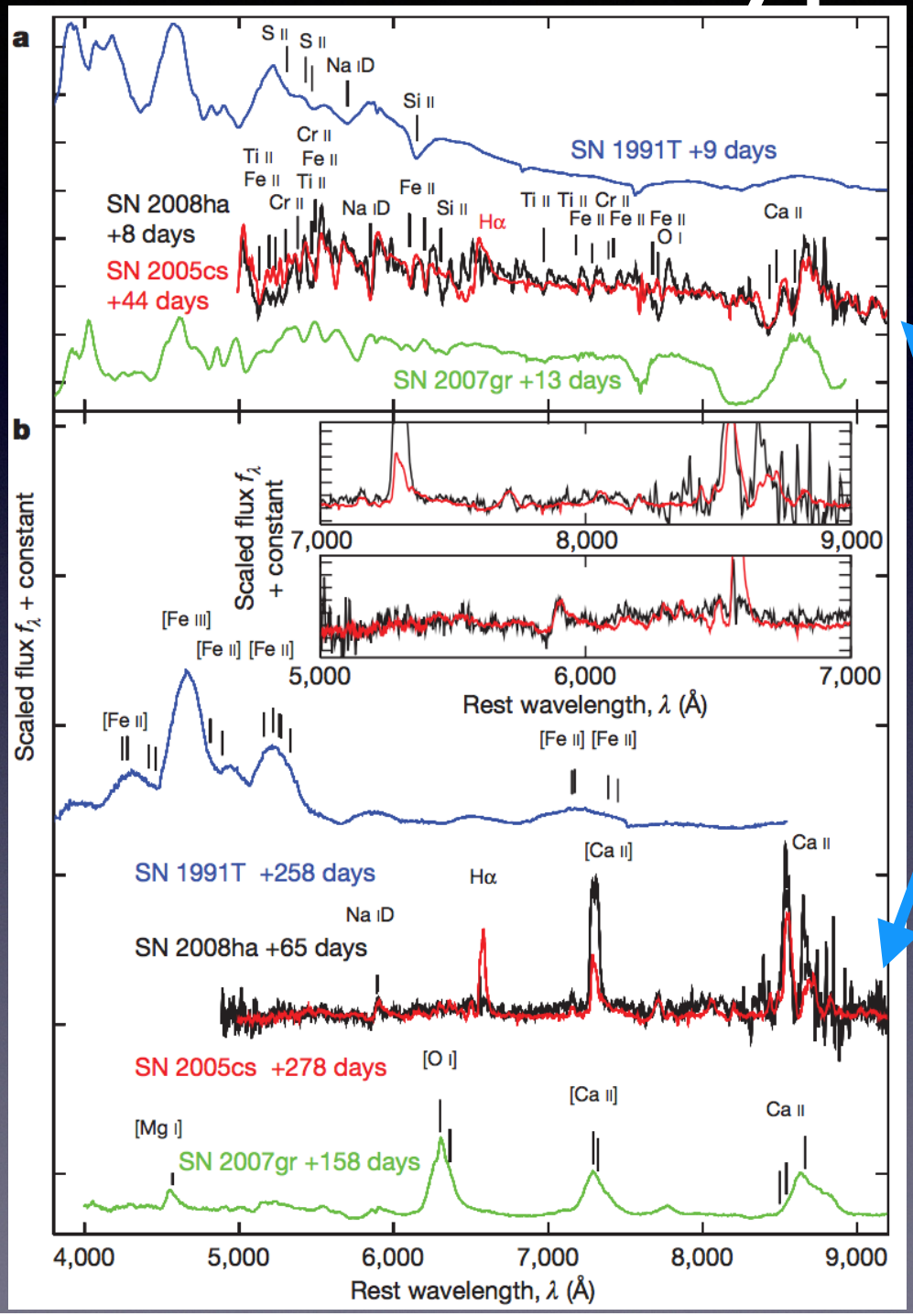
Mej ~0.3-0.6 $M_\odot$

Scenari:

Deflagration of a sub-Ch C/O WD, edge lit He layer?

Stritzinger+ 2014, A&A

Subluminous Type Iax SN 2008ha

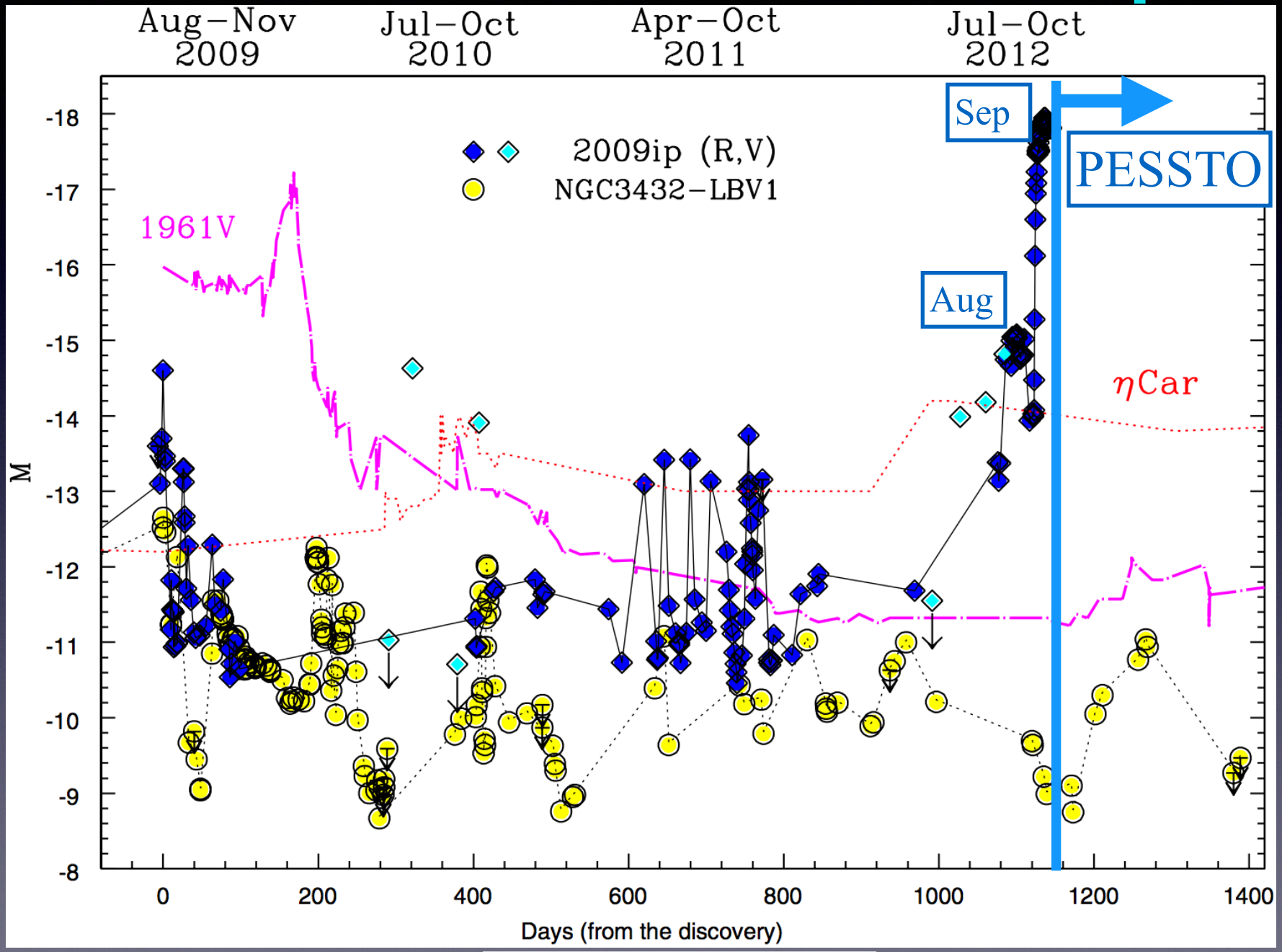


Spectra of SN2008ha very similar to CC SN 2005cs - H

Two SNe Iax channels?!?

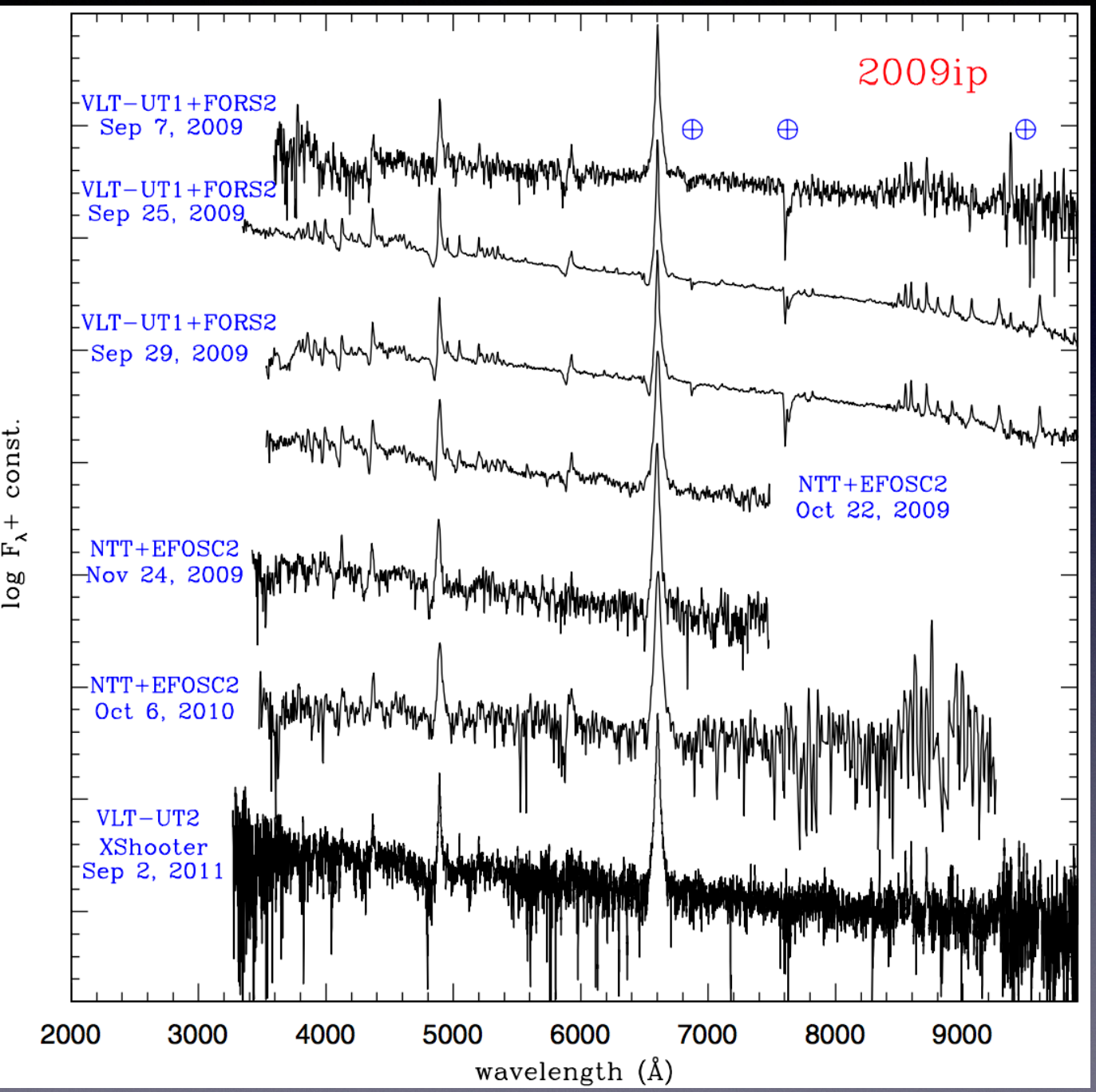
Valenti+ 2011, Nature

SN impostor SN 2009ip



Pastorello+ 2013, ApJ

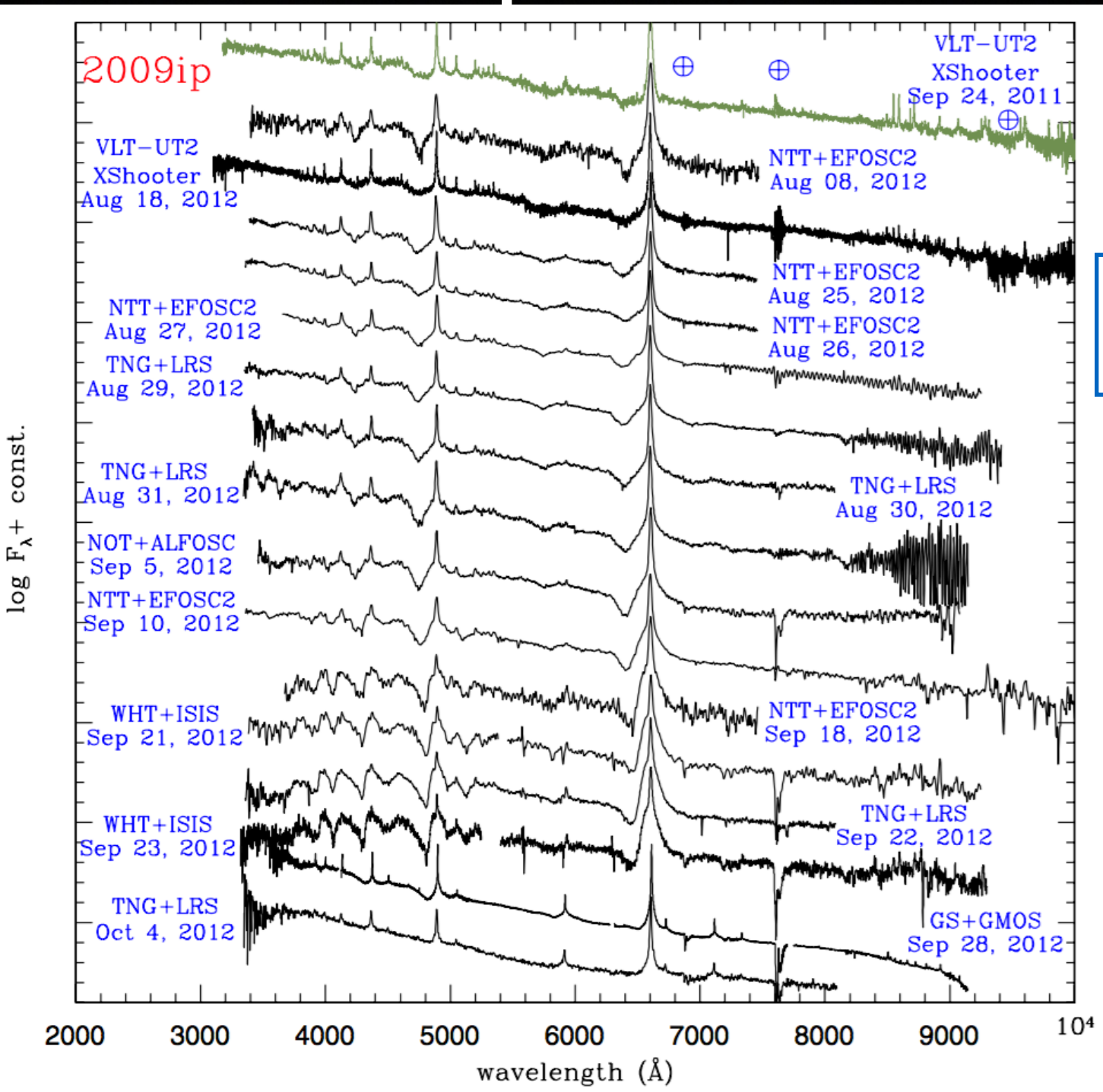
SN impostor SN 2009ip



pre-Aug2012outburst LP spectra!

Pastorello+ 2013, ApJ

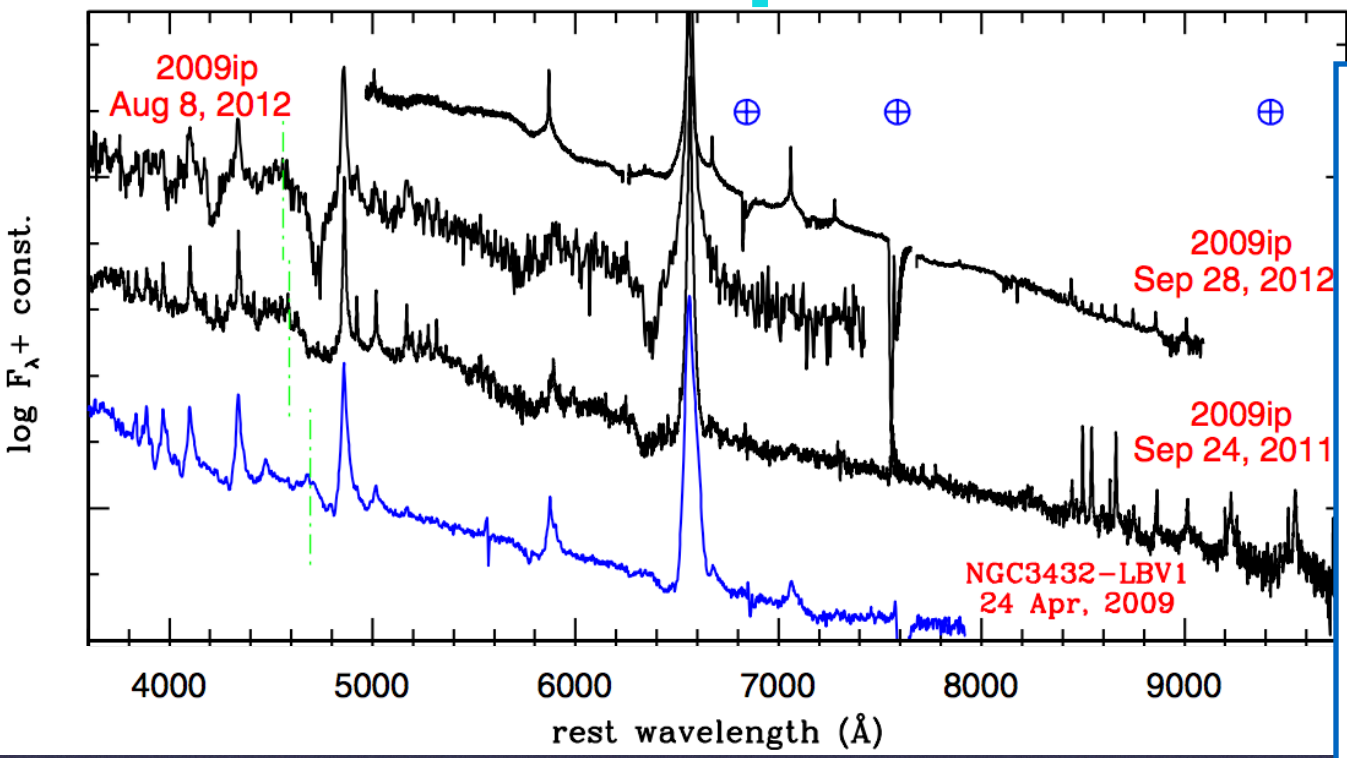
SN impostor SN 2009ip

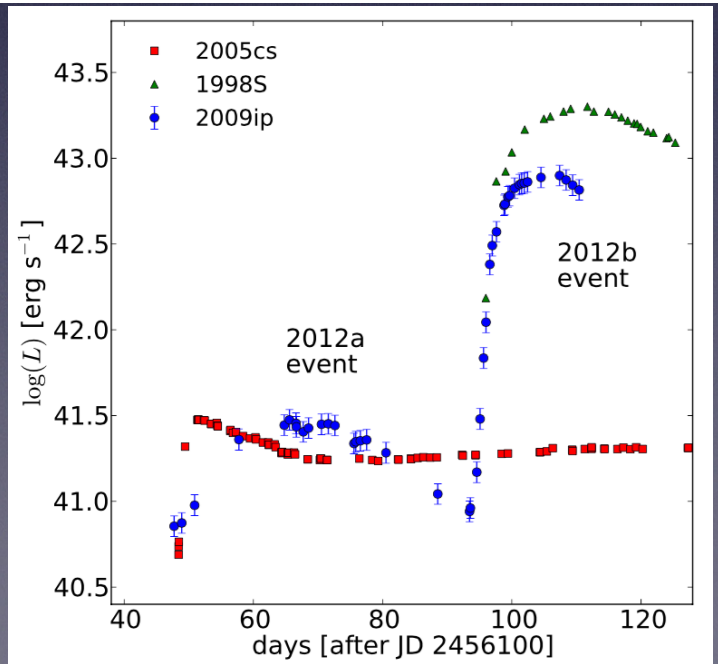


Aug-Sep12 outbursts;
LP spectra!

Pastorello+ 2013, ApJ

SN 2009ip: a SN explosion?





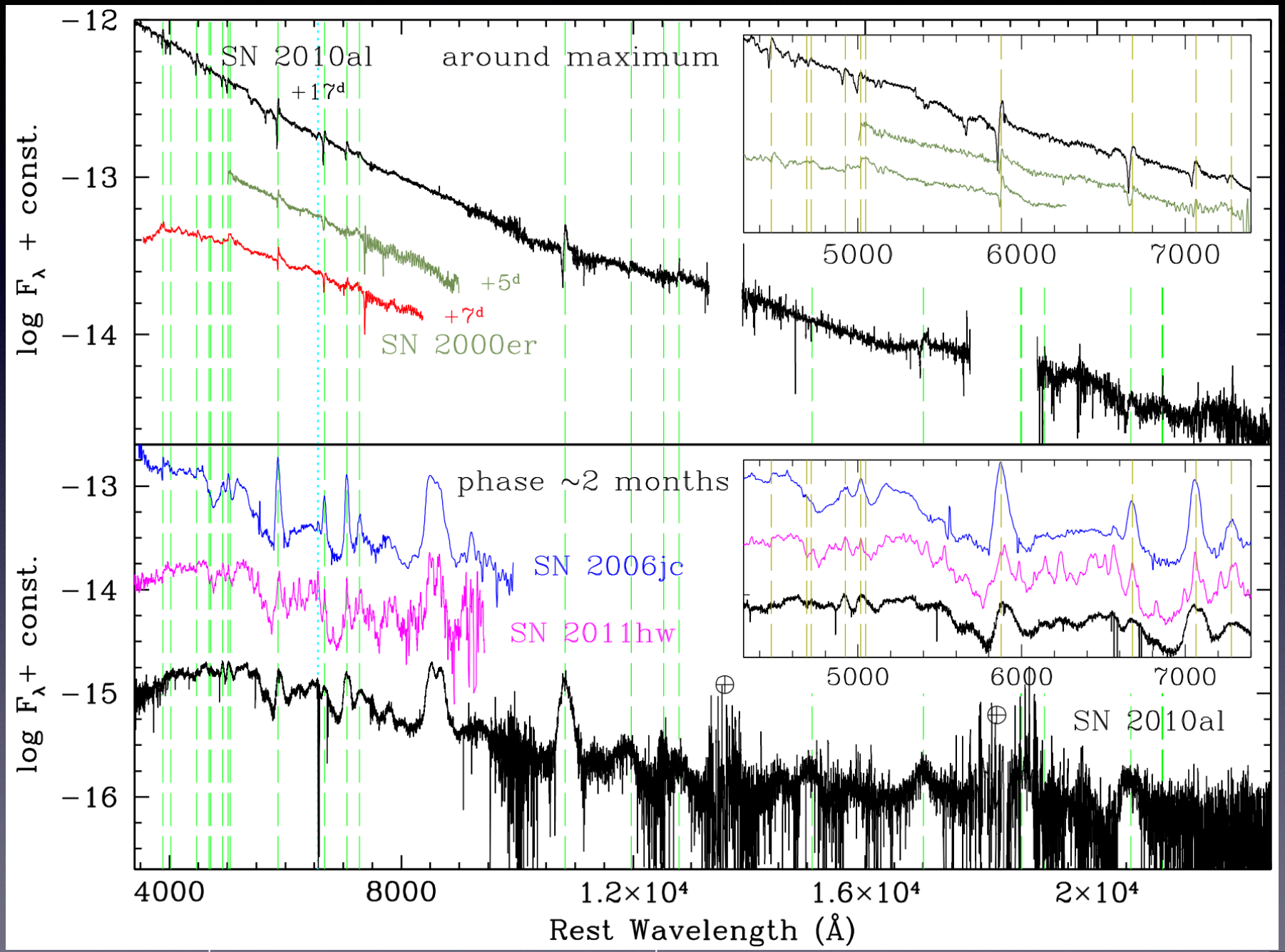
expansion velocity in 2011 ≲13000 km/s! => velocity is not a final clue!

Scenari:

- pre-Aug12 burst: LBV activity;
- Aug12 massive shell eruption/ final SN explosion
- Sep12 main peak: shell/ ejecta interaction with a massive CSM;
- Waiting for the transient to fade!

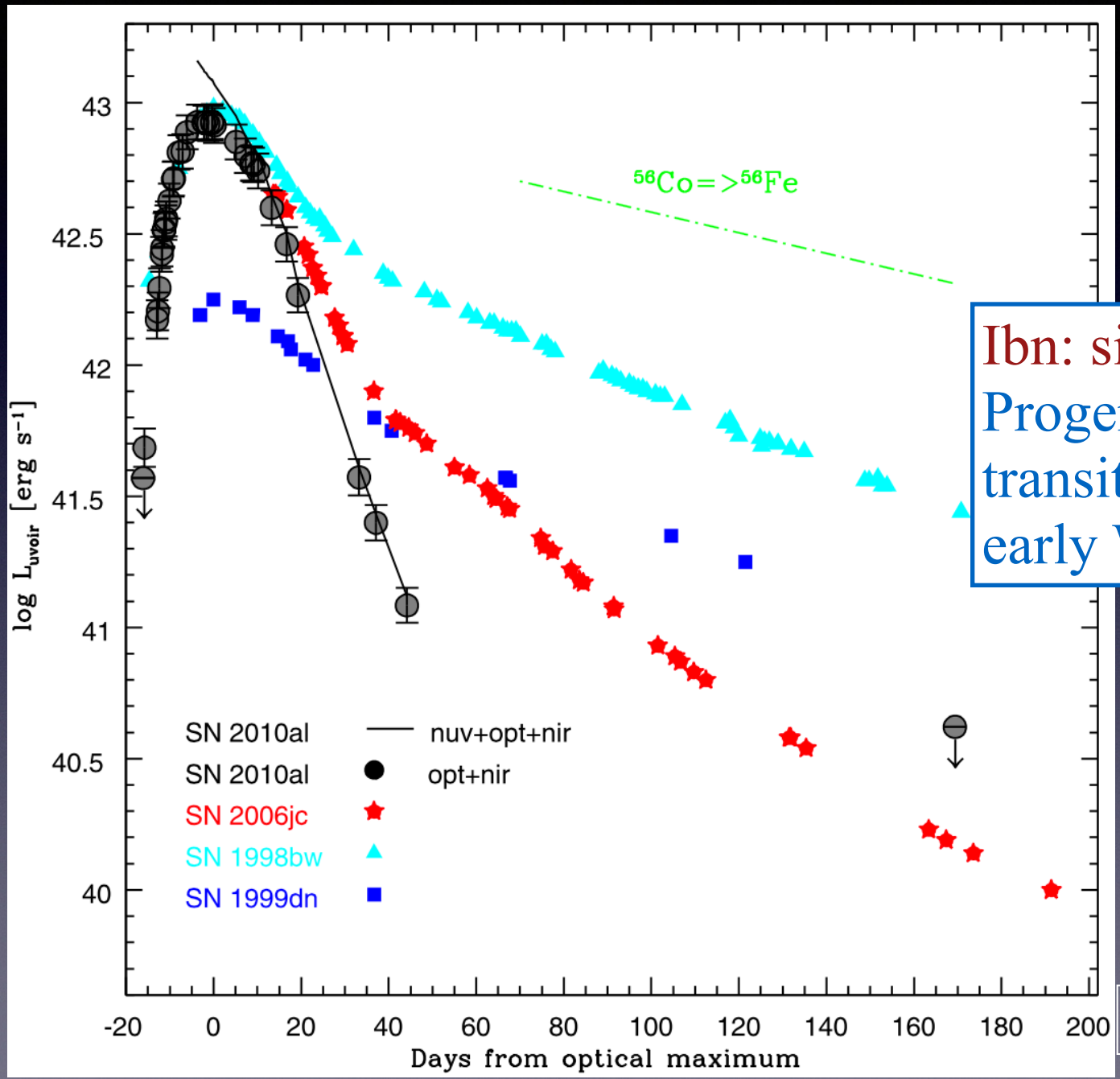
Pastorello+ 2013, ApJ

2010al - 2011hw: Type Ibn



Pastorello+ 2015, MNRAS

2010al - 2011hw: Type Ibn

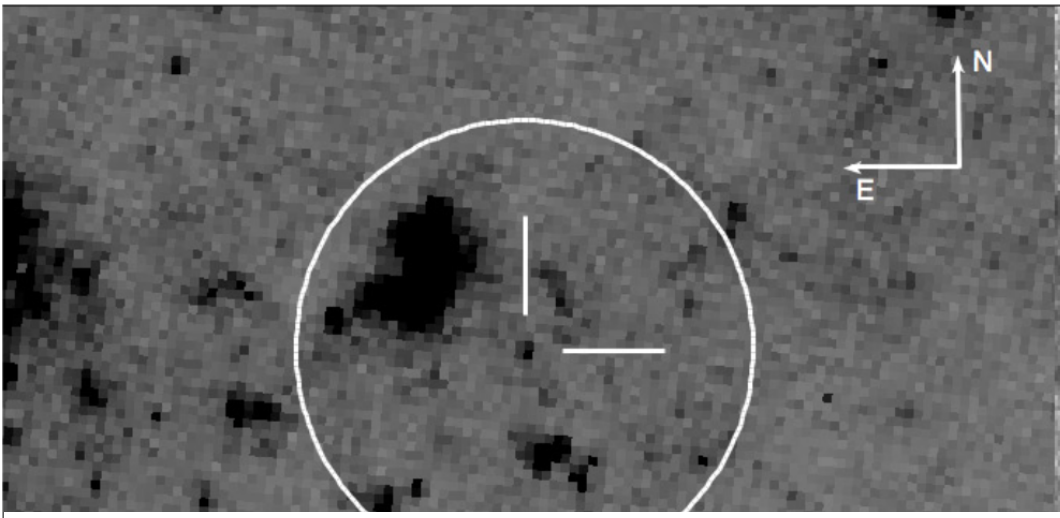


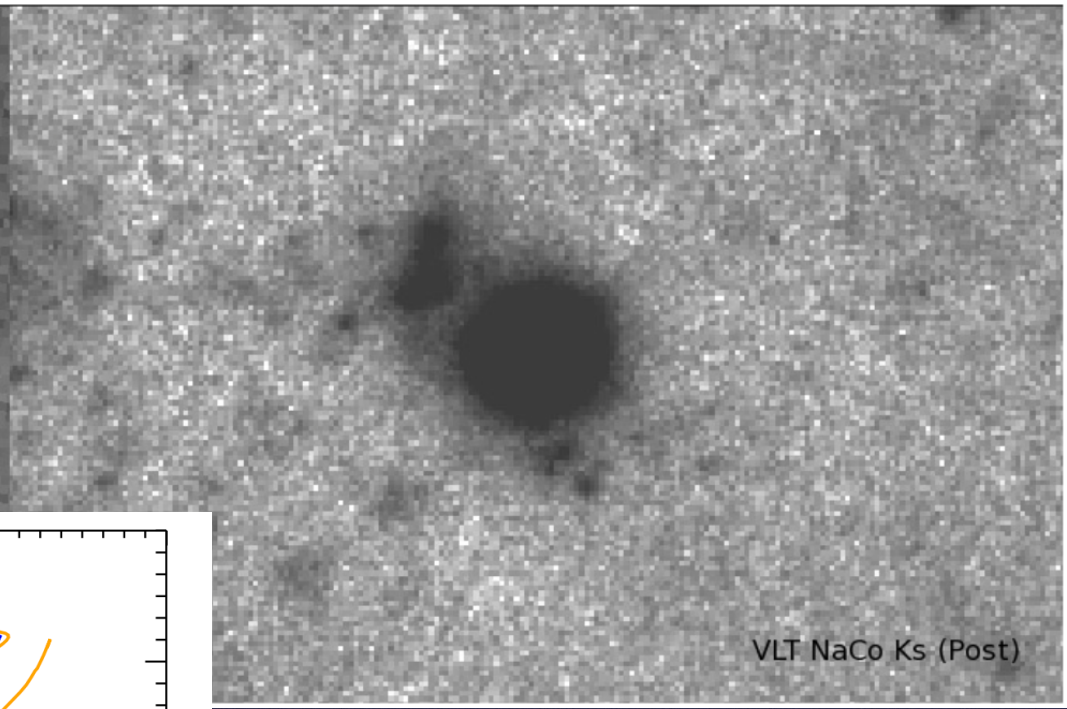
Ibn: similar to IIn with no H

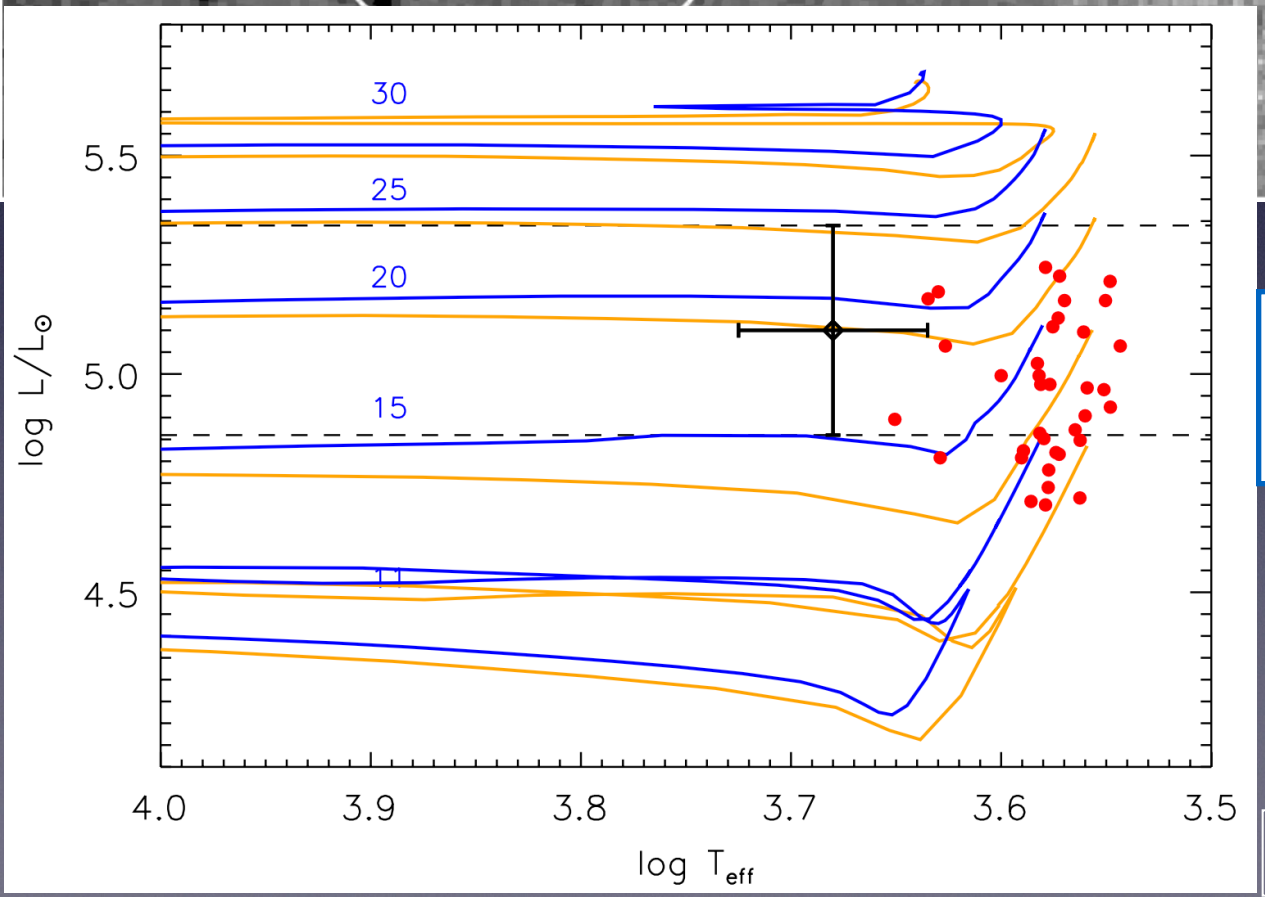
Progenitors:
transition from LBVs to early Wolf-Rayets

Pastorello+ 2015, MNRAS

Progenitor of SNIIL 2009kr





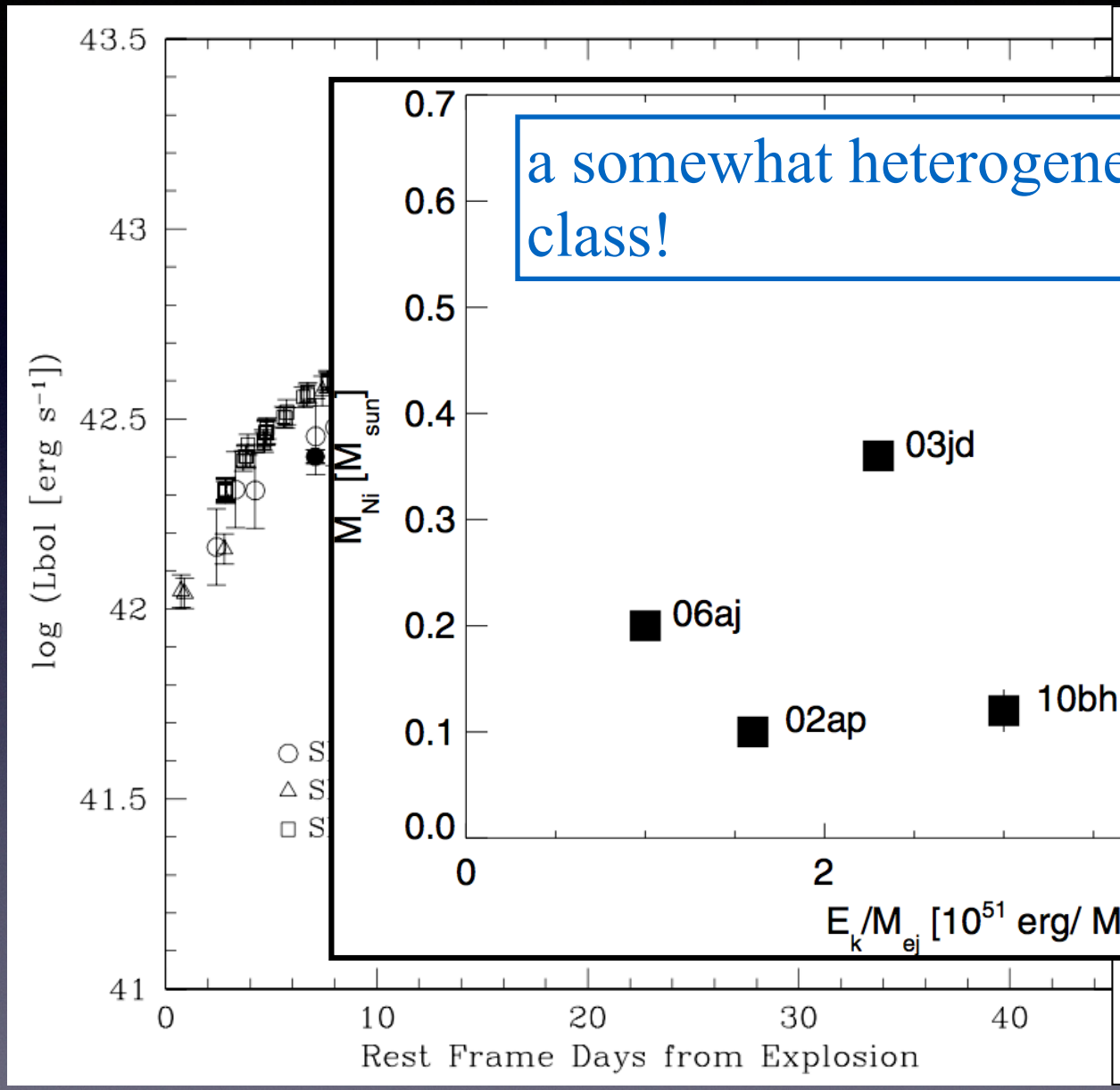


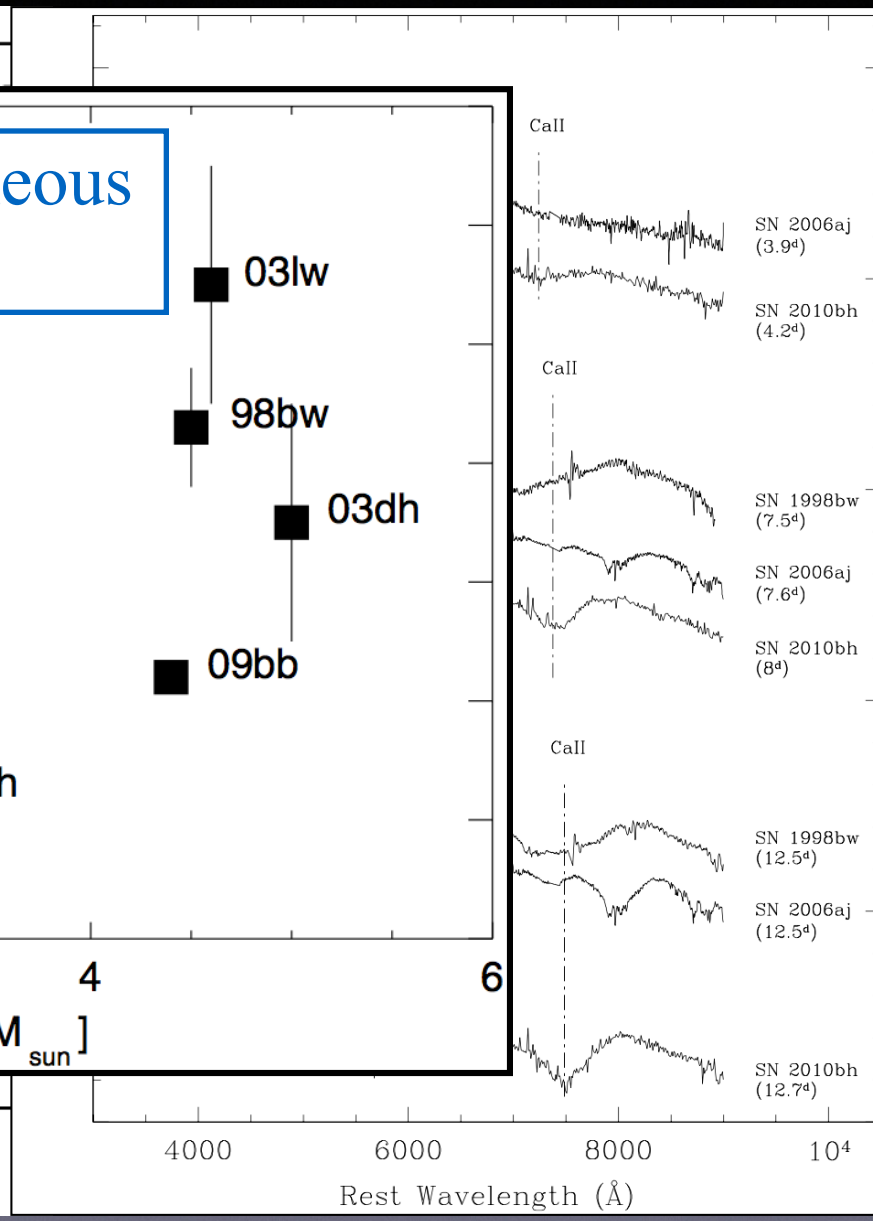
$\log(L/L_\odot)\sim5.1$; $T_{eff}=6000$ K

$M\lesssim15\ M_\odot$

Fraser+ 2010, ApJL

GRB-SN SN 2010bh/GRB 100316D





Bufano+ 2012, ApJ

LP: Conclusions

Followed ~60 transients, optical+NIR spectrophotometry

Papers: 32 on main journal, total citations ~1000 (ADS/Sep15)

~150 non refereed + telegrams (CBET+Atel)

Several still in prep. → goal ~45 papers (~1.5 papers/obs. run!)

SNe: a long history in EU & ESO