Peculiar Supernovae and their Progenitors

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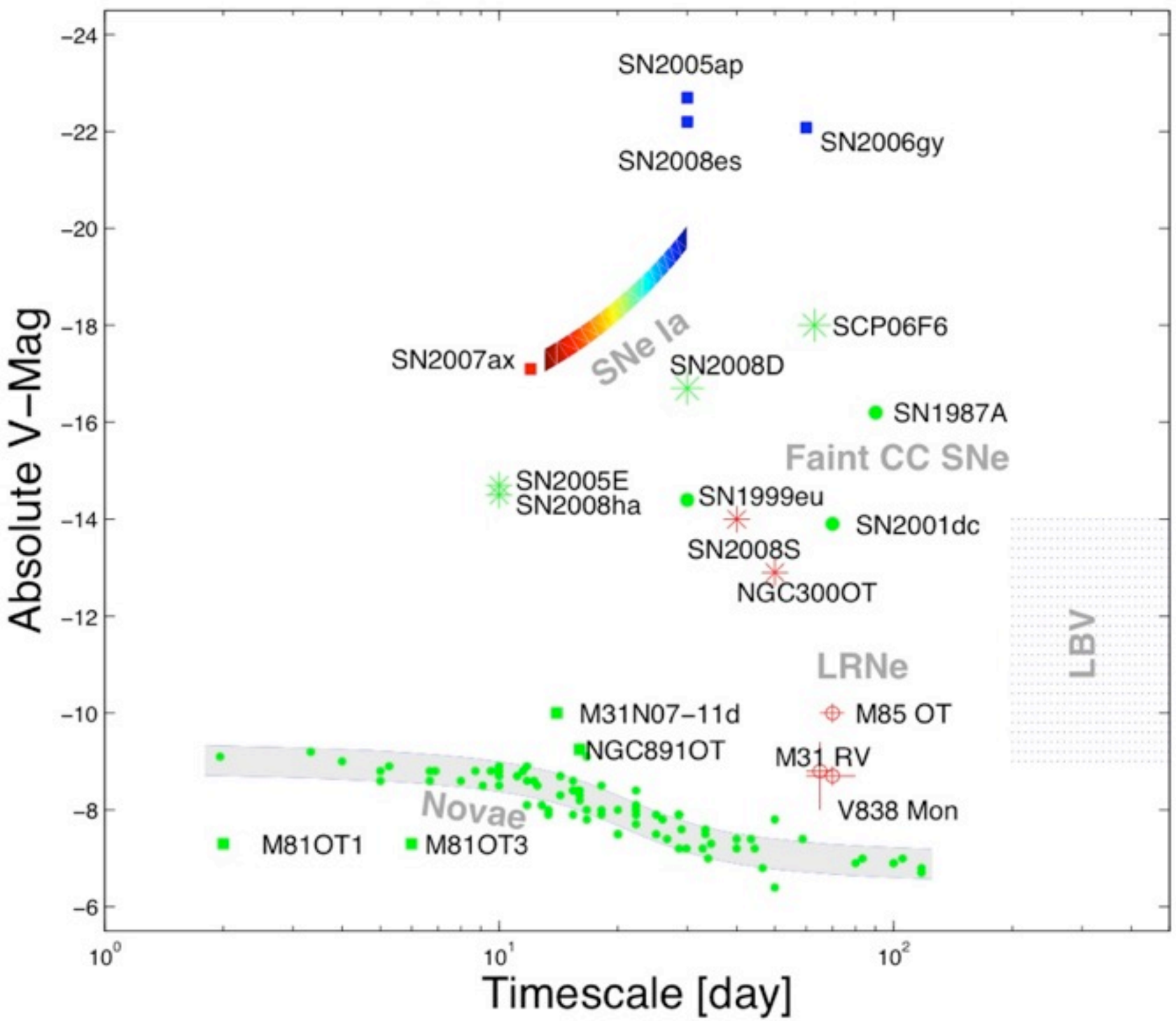
"Explosive Ideas about Massive Stars - from Observations to Modeling"

AlbaNova: 10-13 August, 2011

Outline

- Introduction: hyper-luminous supernovae and transients in the luminosity "gap"
- High luminosity supernovae:
  - SN 2006jc, SN 2010al & type Ibn SNe
  - SN 2010gx & hyper-luminous SNe Ic
- Sub-luminous supernovae:
  - Weak, H-rich core-collapse supernovae
  - The low-luminosity, 1987A-like SN 2009E
  - Sub-luminous stripped-envelope supernovae
- Faint supernovae IIn or supernova impostors?
- What's hell is (SN) 2010jp?
- Summary

New transients



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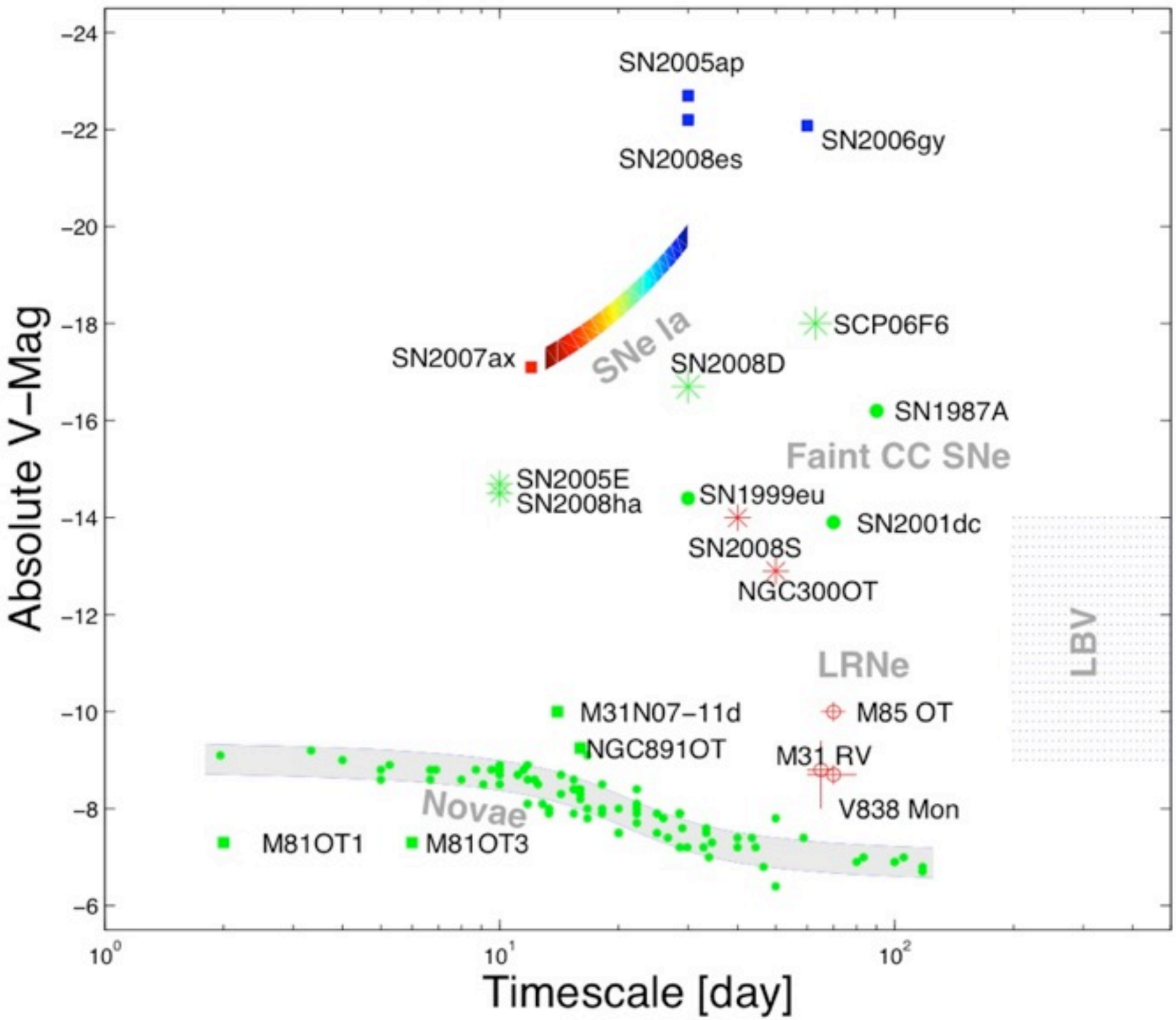
Kulkarni & Kasliwal 2009



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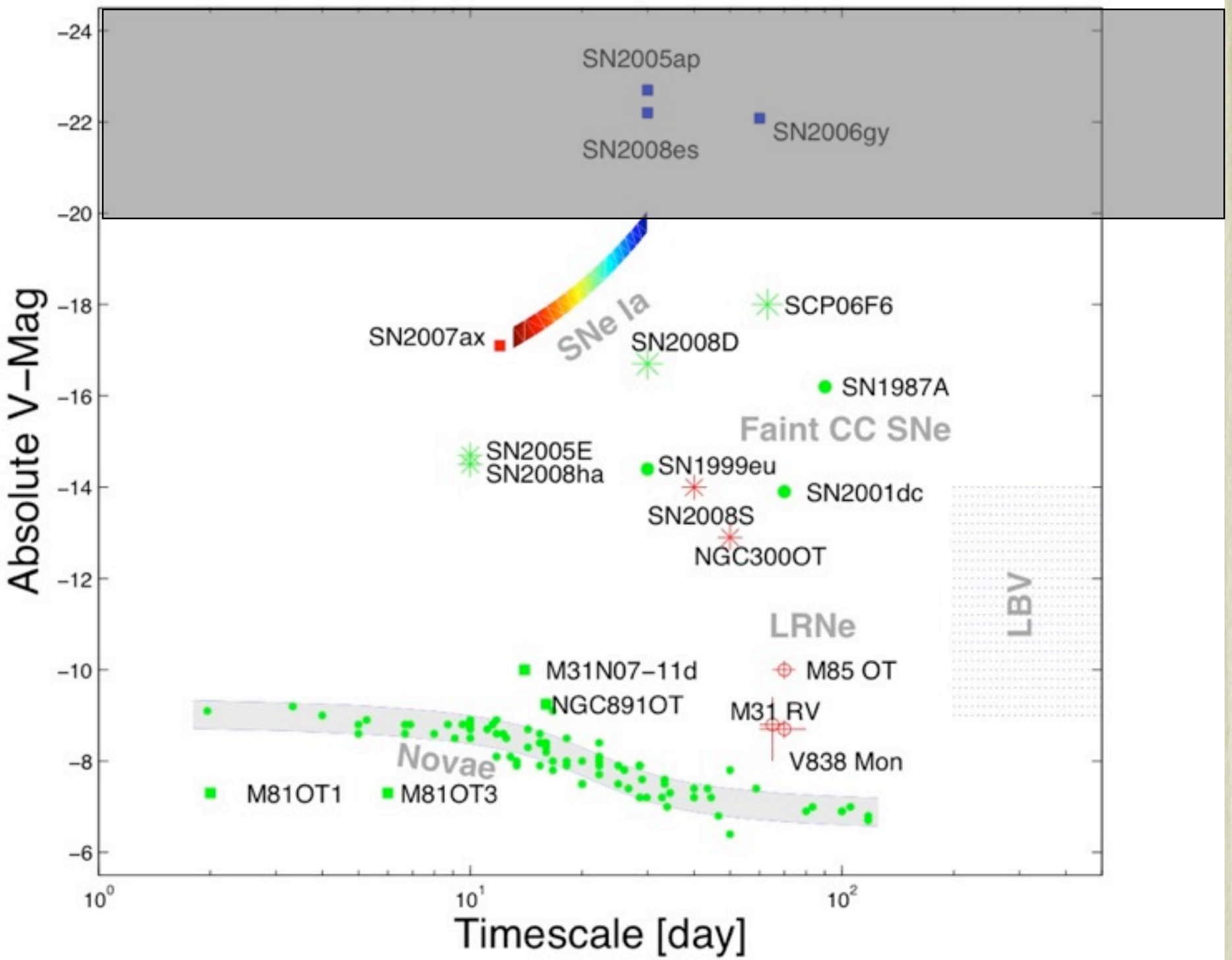

Ultra-bright Supernovae

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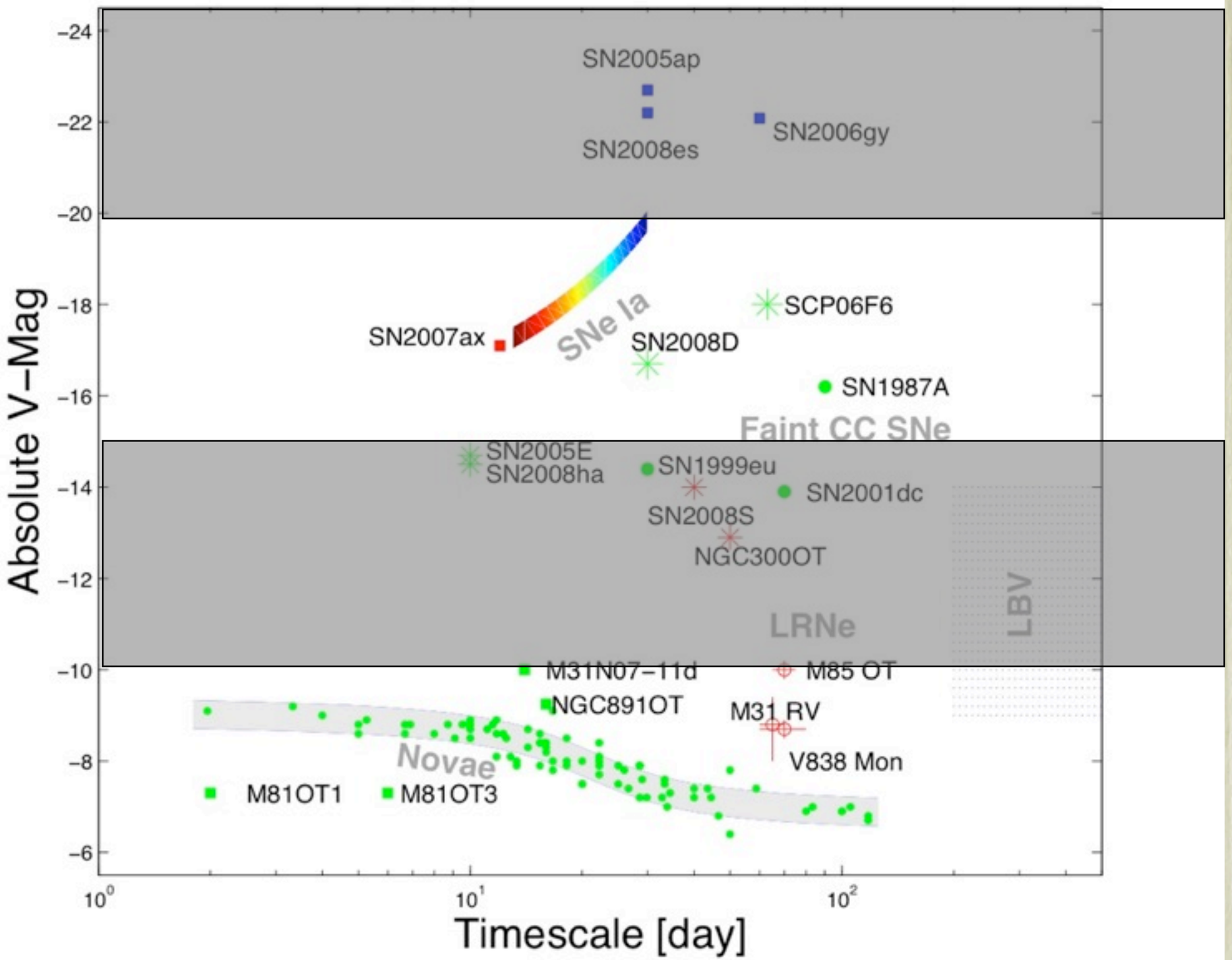

Ultra-bright Supernovae

Transients in the "gap"

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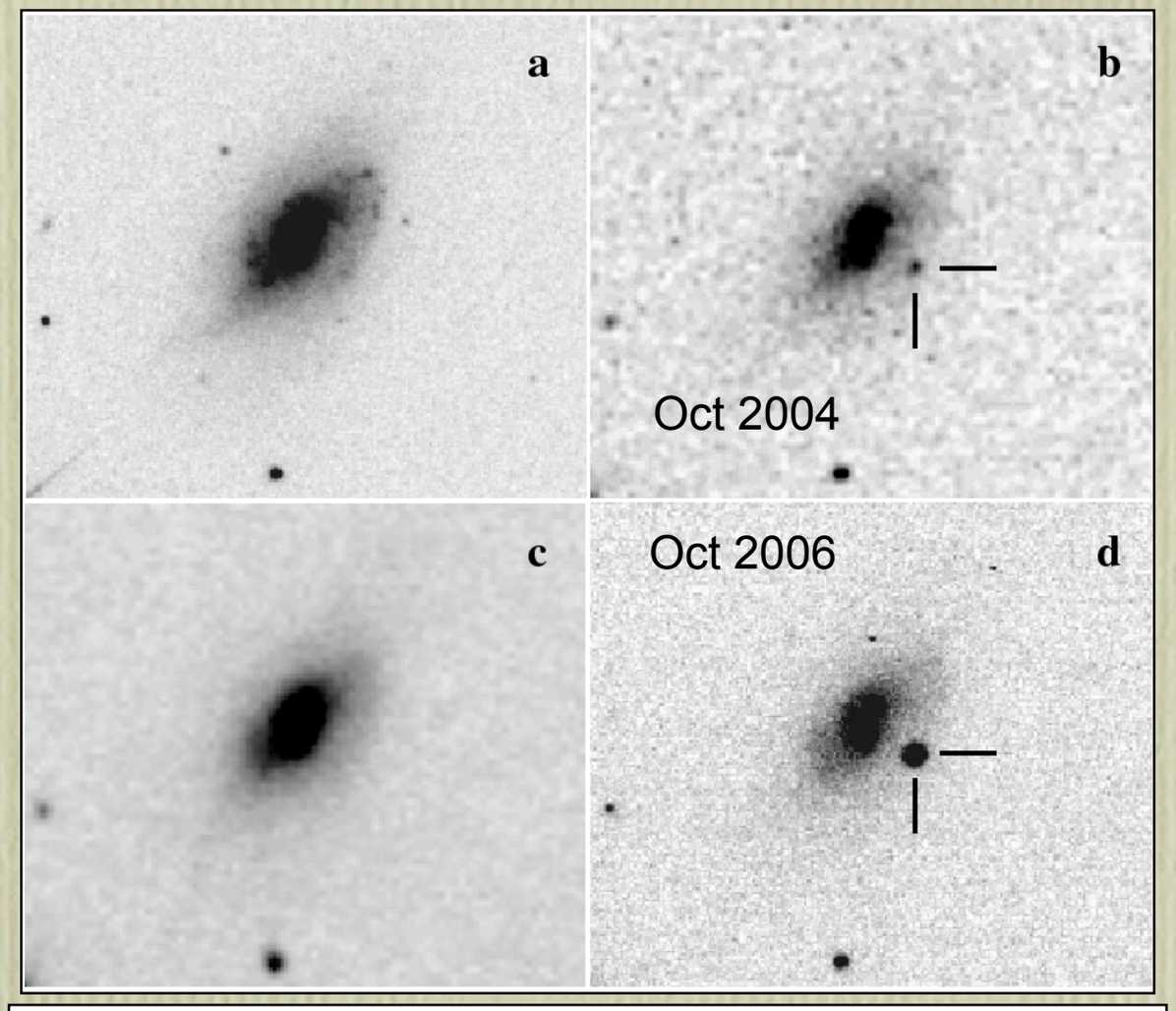

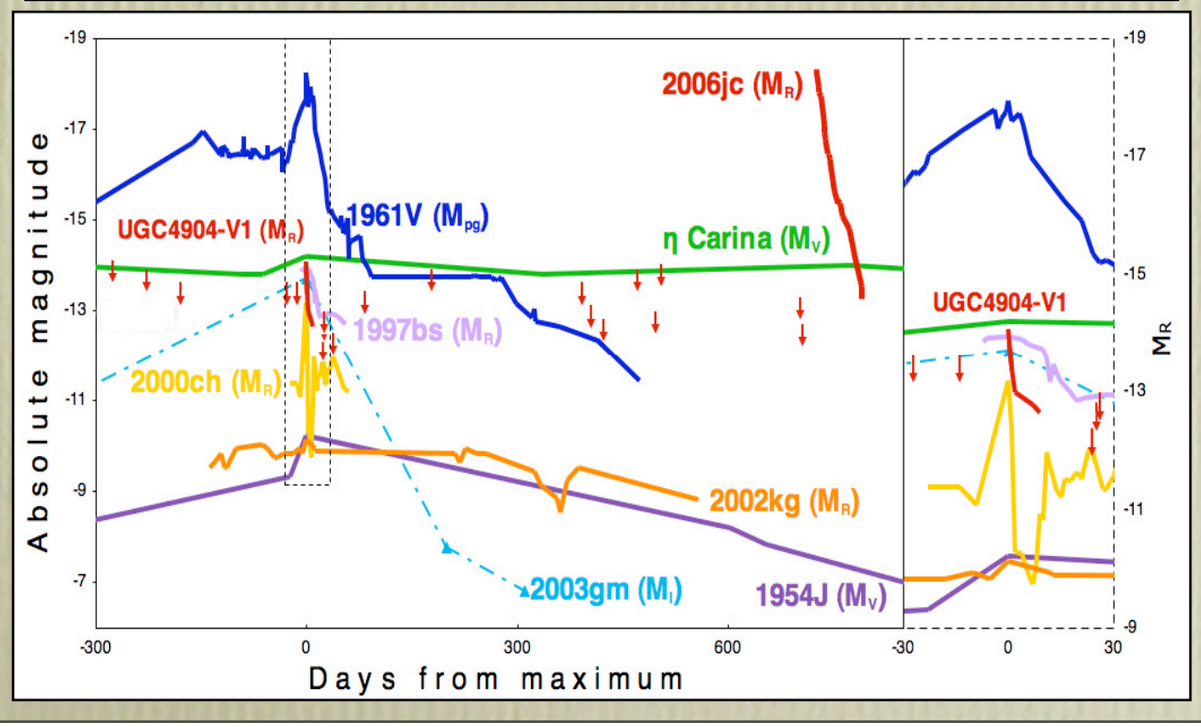

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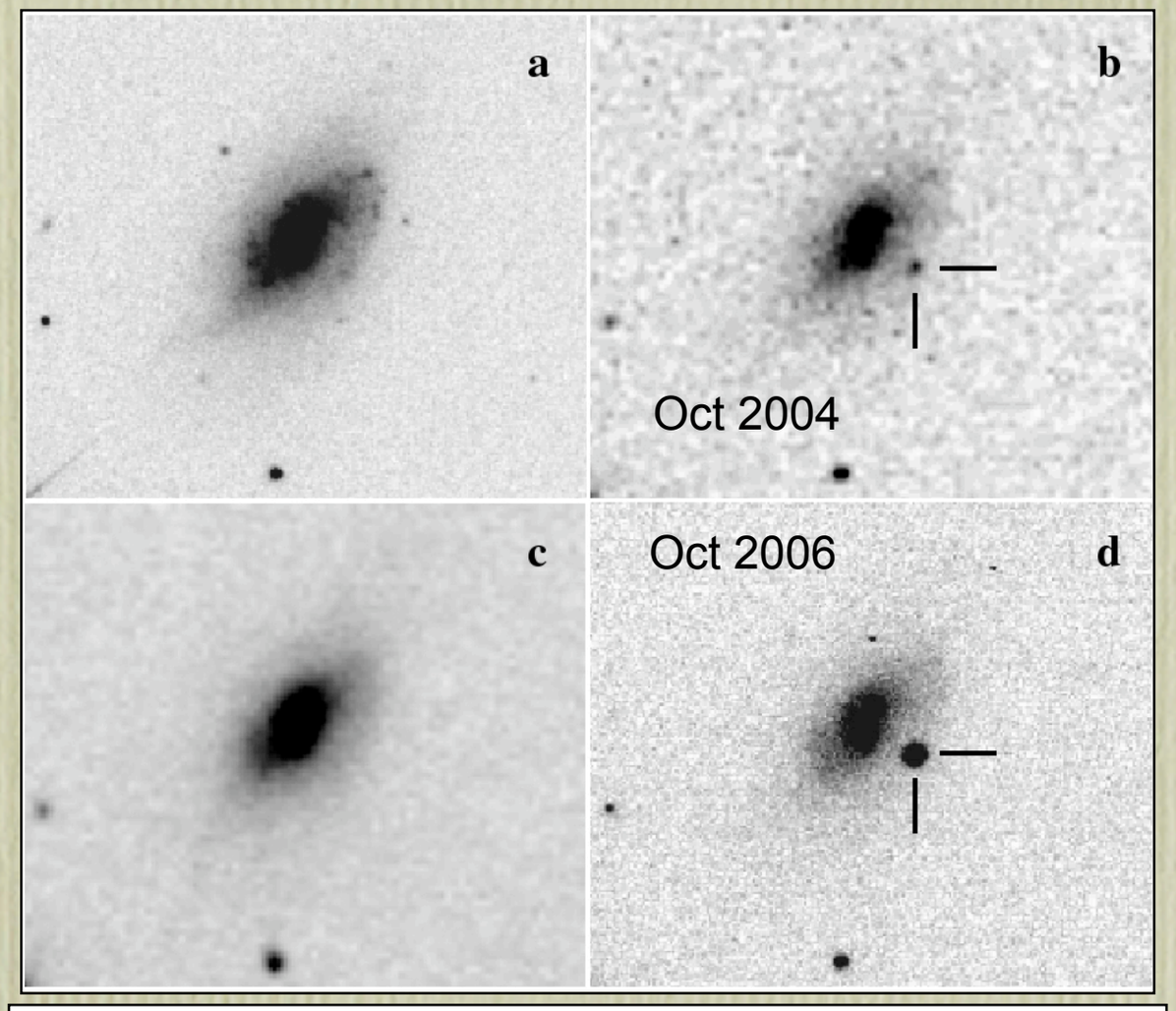

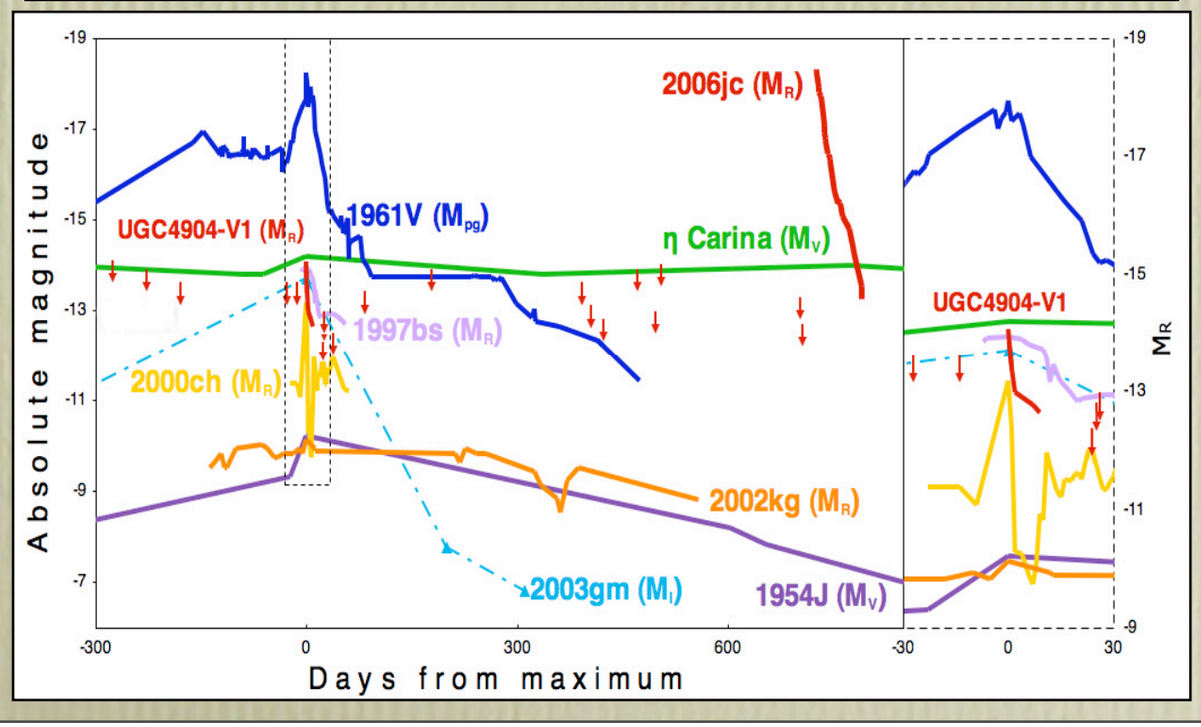

Pastorello et al. 2007

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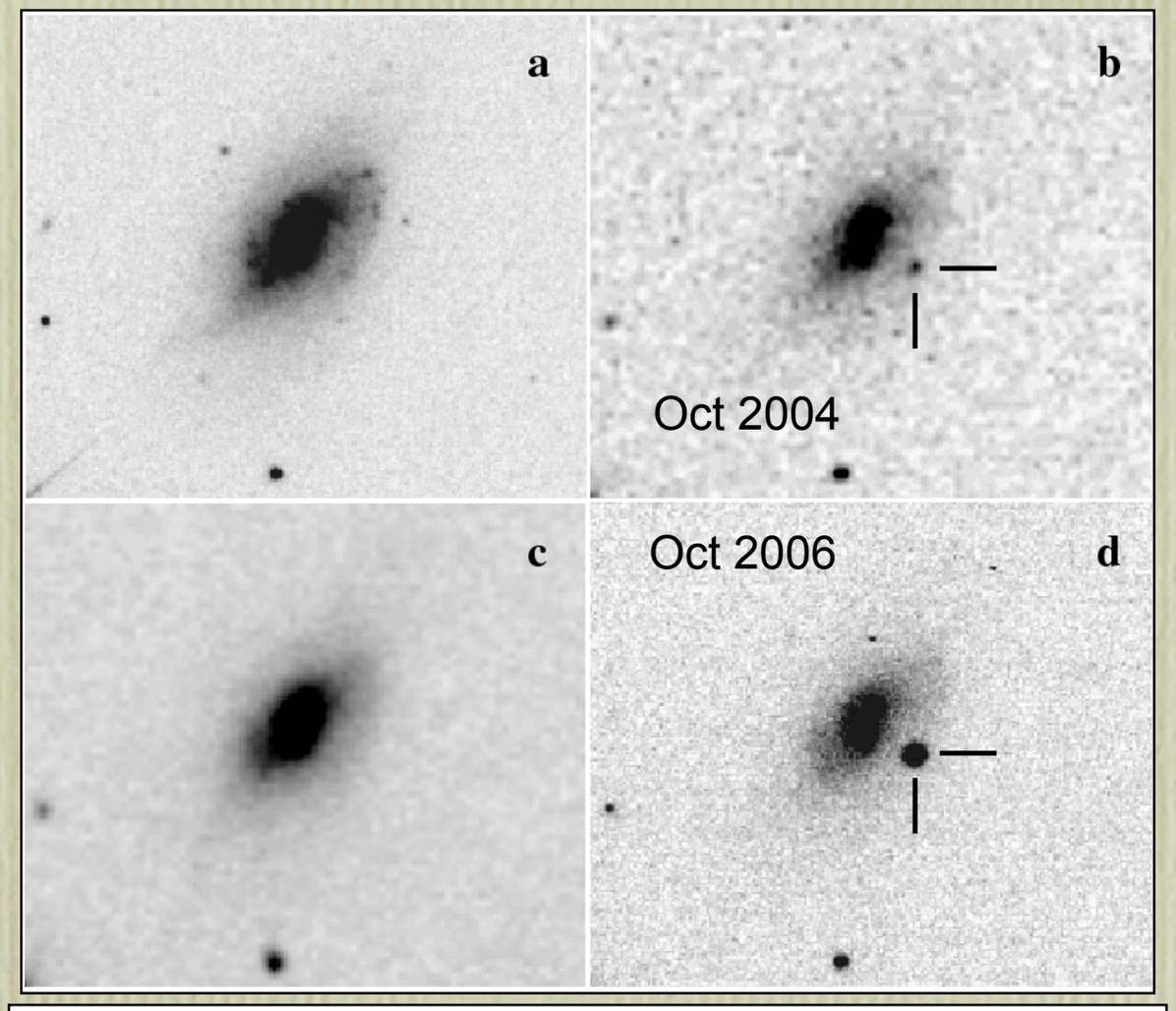

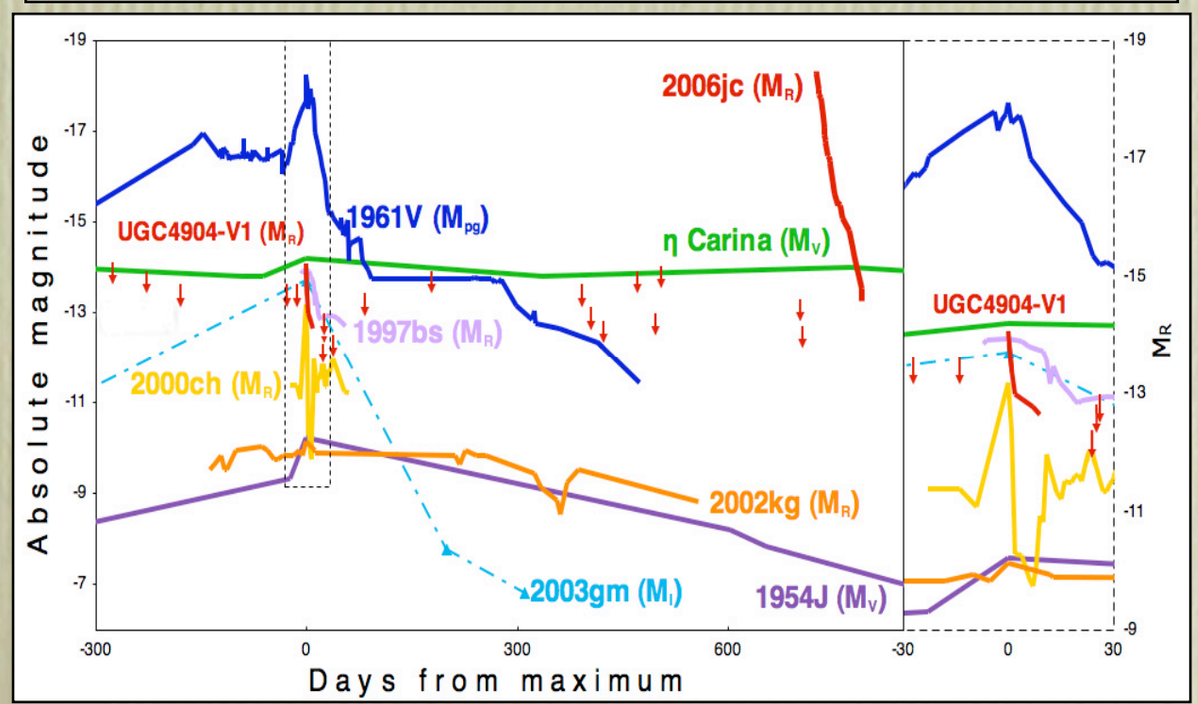

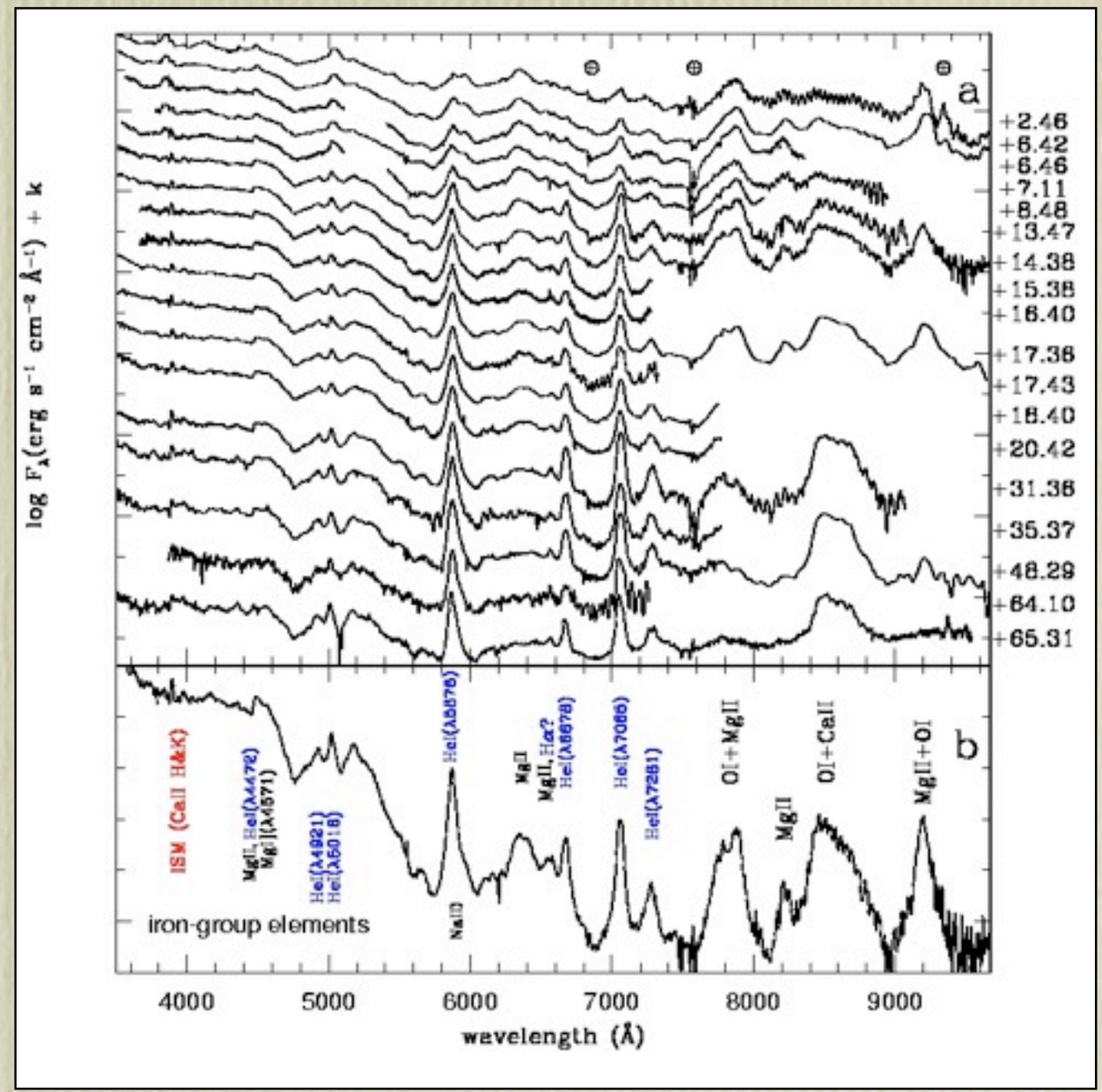

Pastorello et al. 2007

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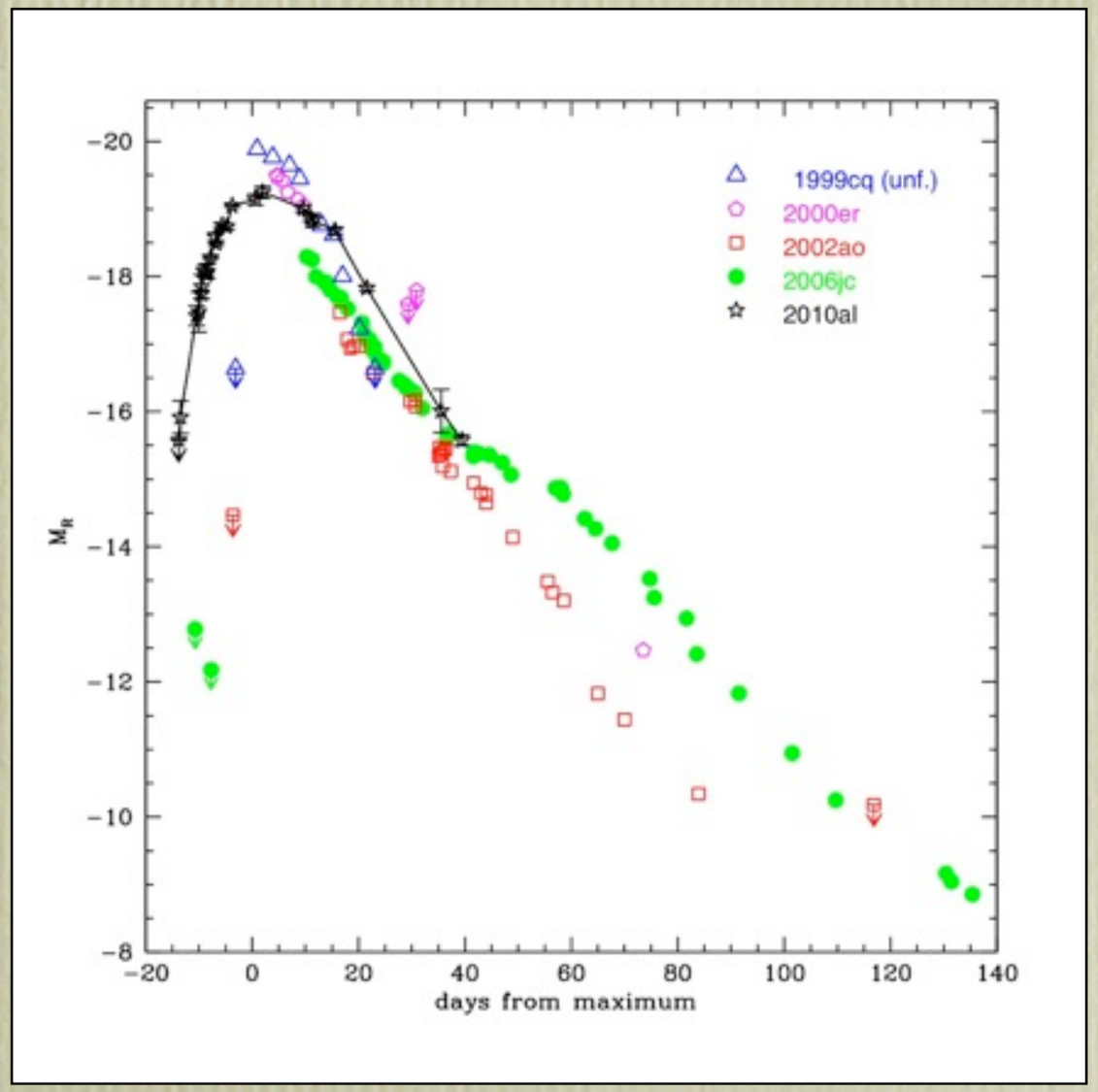

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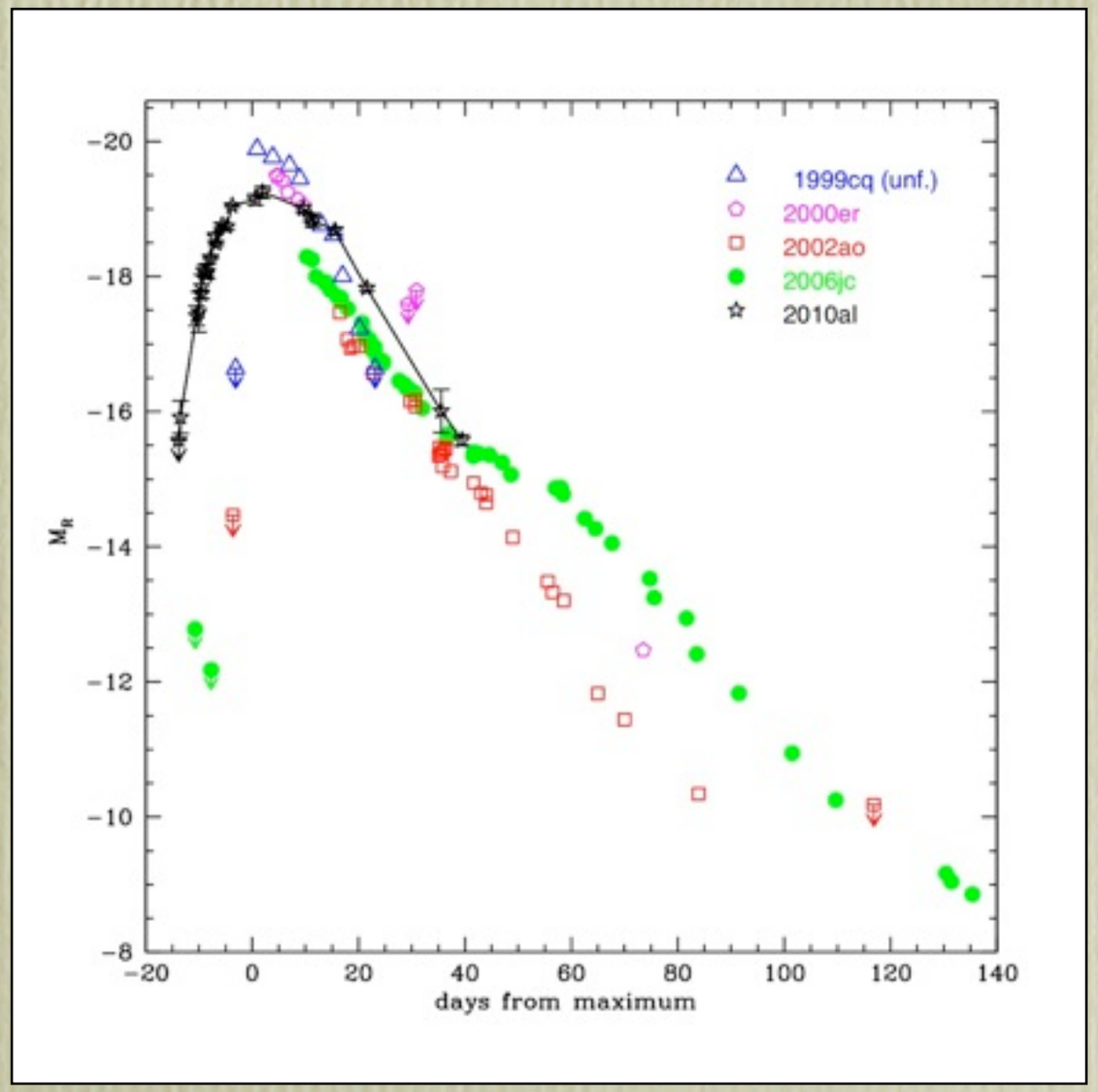

Pastorello et al. in preparation

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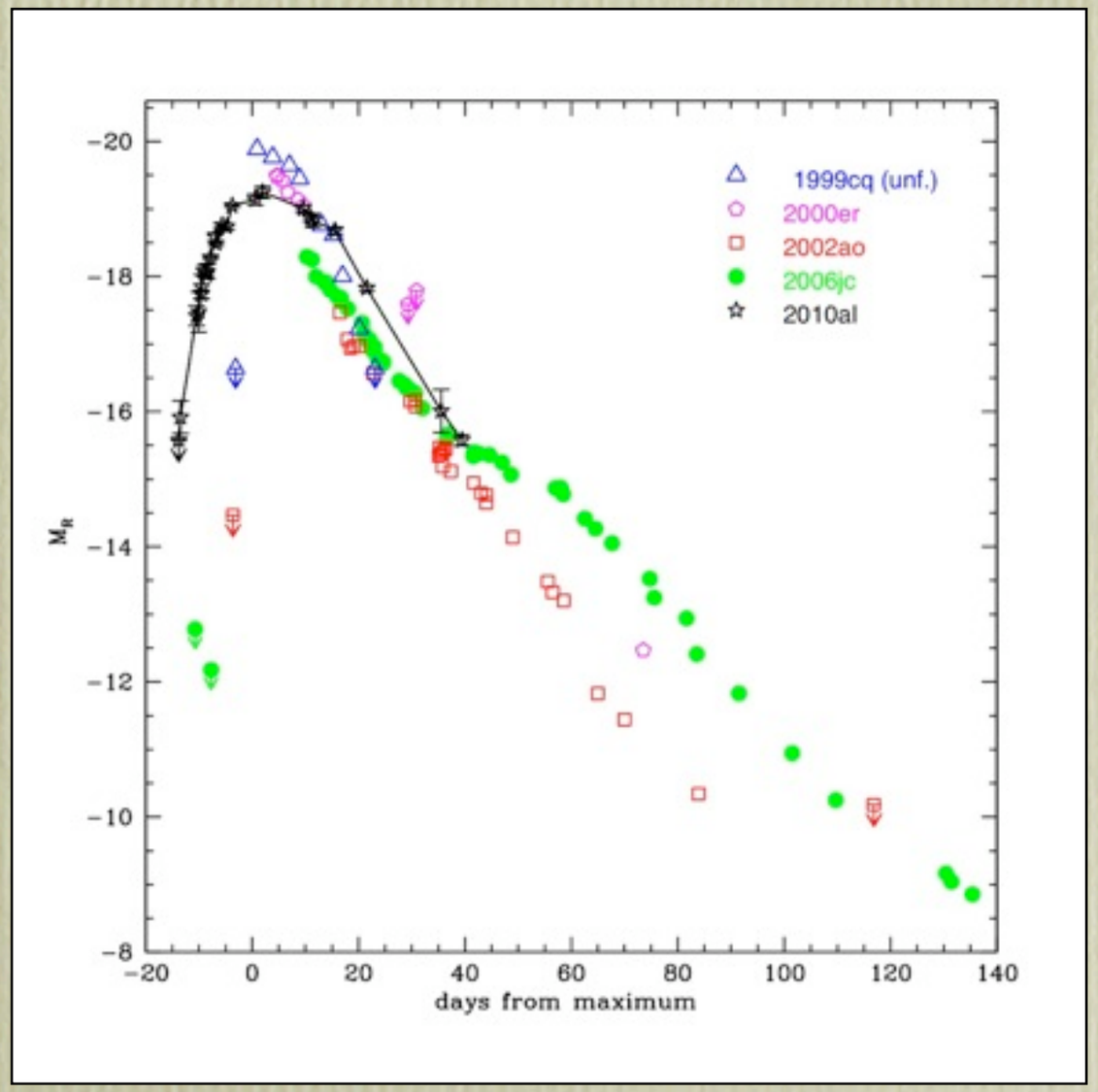

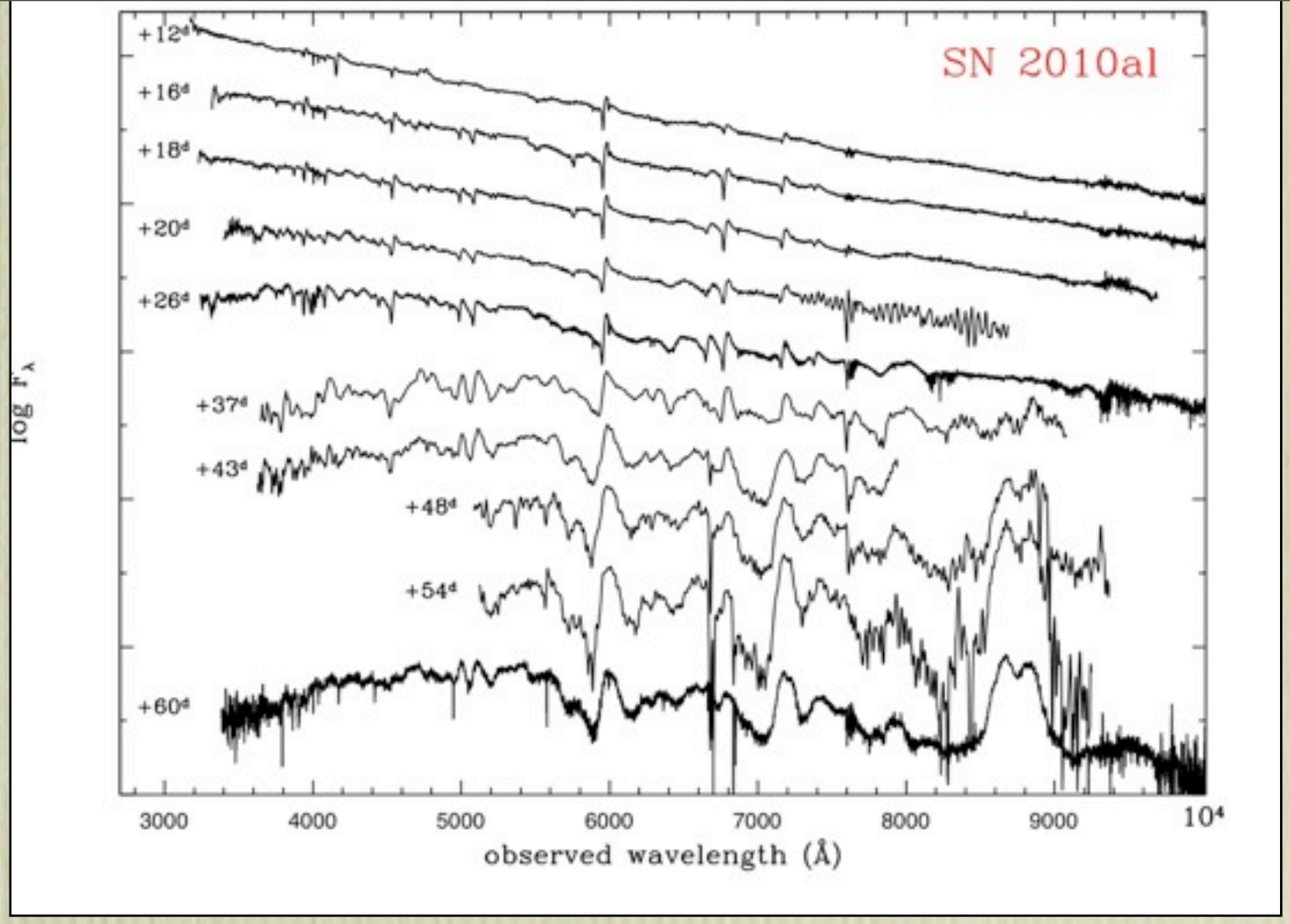

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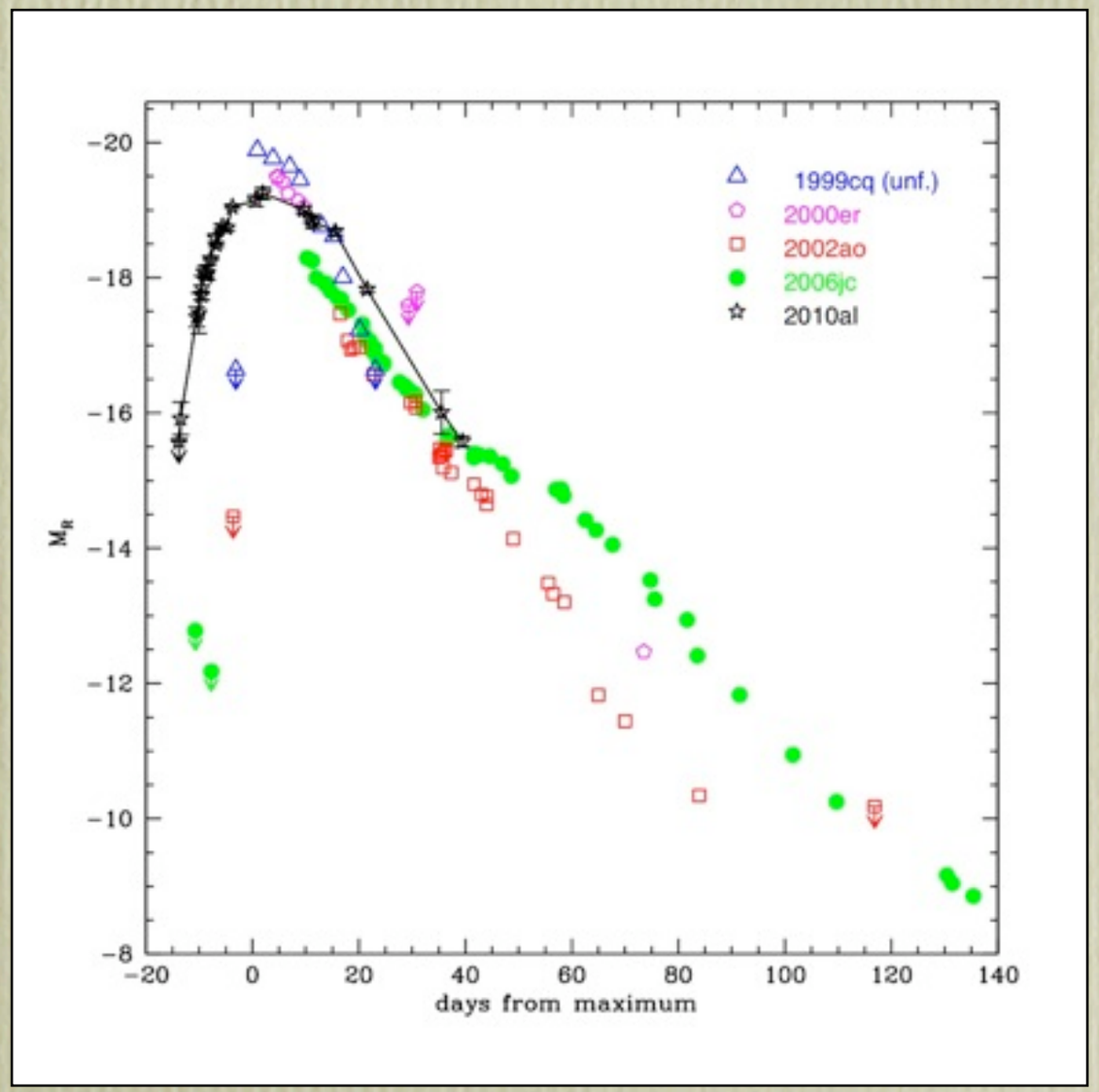
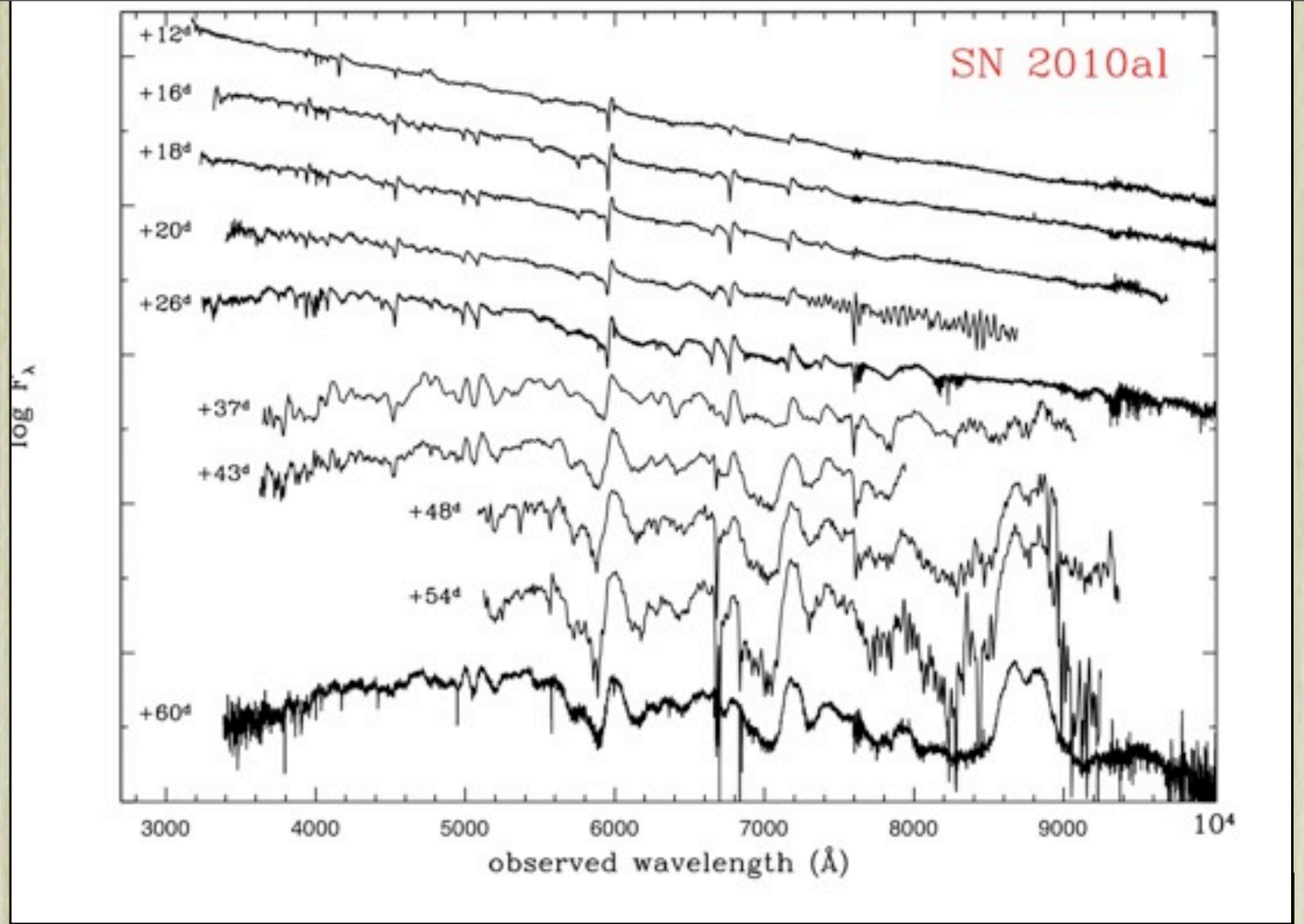
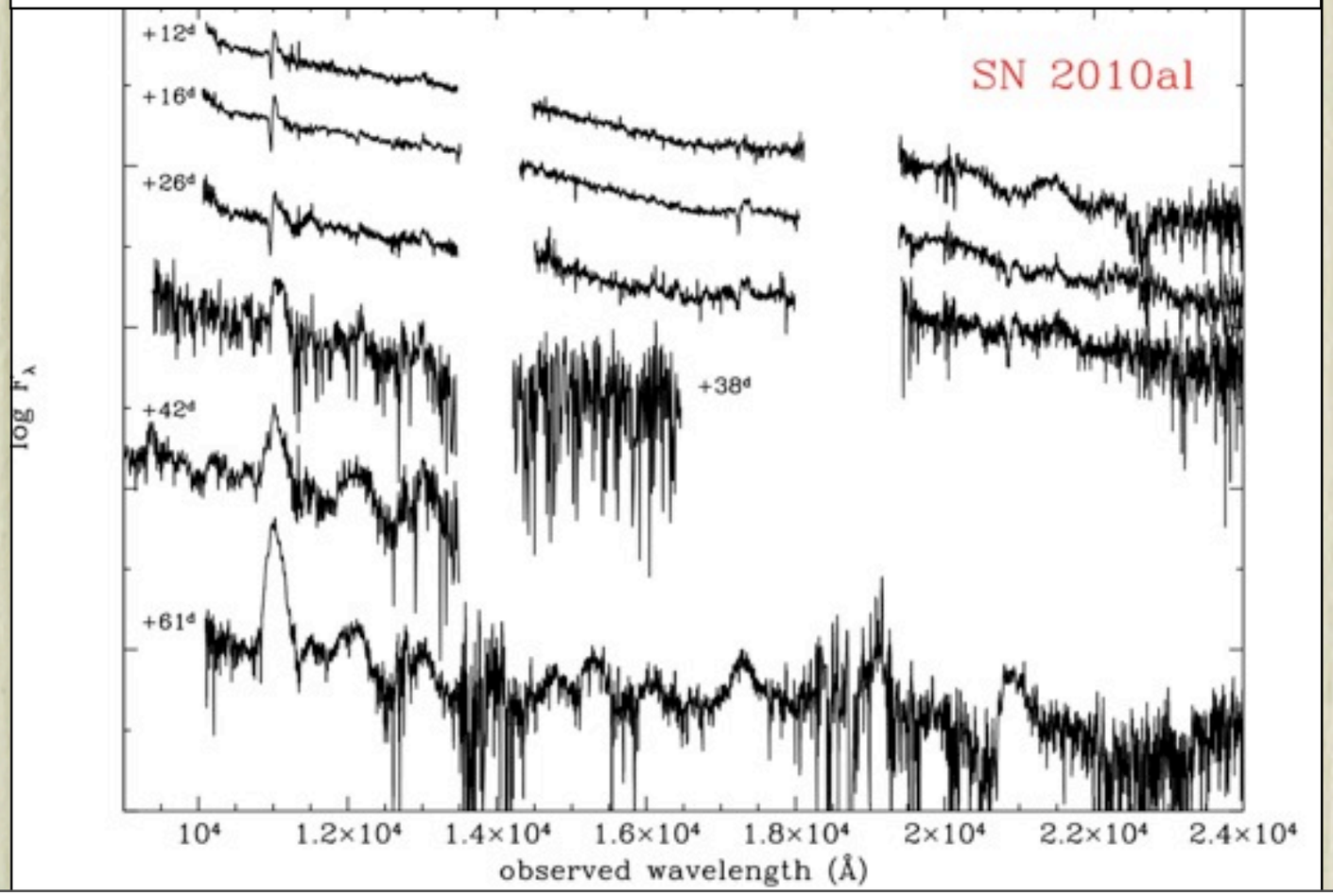


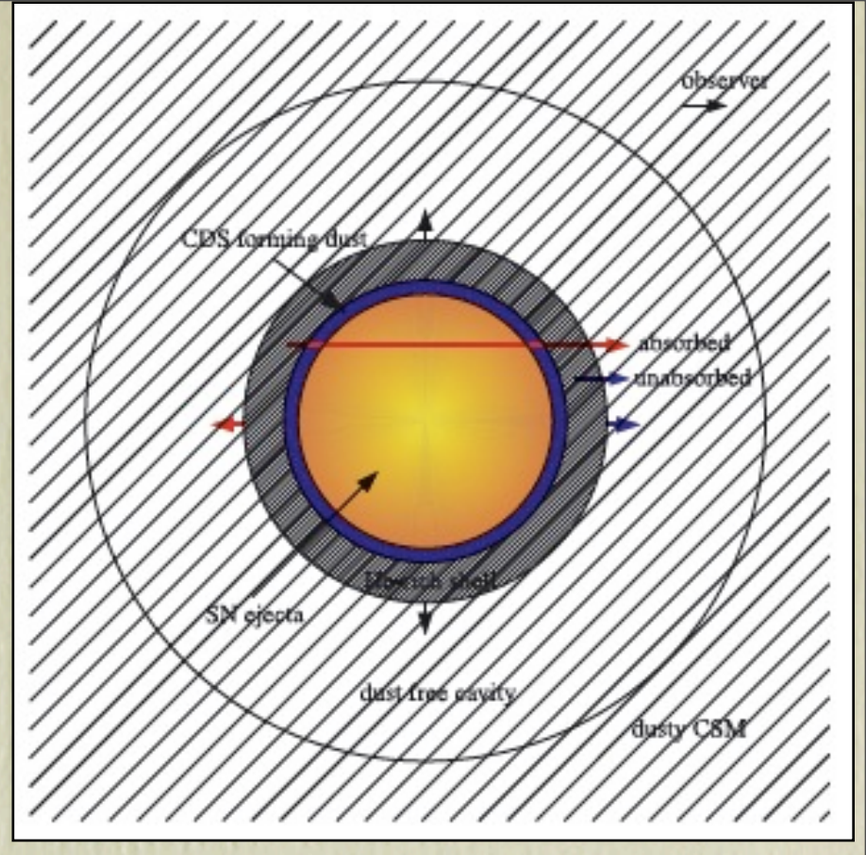




Pastorello et al. in preparation

Progenitors of SNe Ibn

- Type Ib/c SNe interacting with a He-rich CSM *(Foley et al. 2007; Pastorello et al. 2007,2008a,2009; Smith et al. 2008; Immer et al. 2008; Tominaga et al. 2008; Anupama et al. 2009; Chugai 2009; and others)*

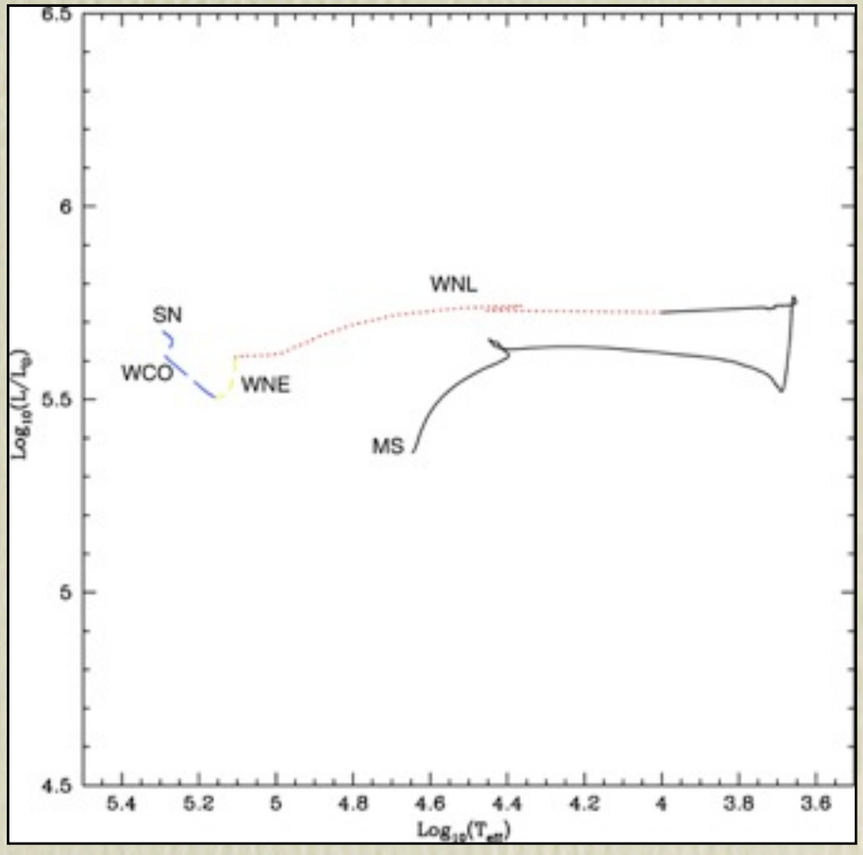


Mattila et al. 2008

- E ~ a few x 10^{51} erg; M_{ej} ~ $5M_{\odot}$; M_{Ni} <$0.3M_{\odot}$ *(Chugai 2009; Tominaga et al. 2008)*

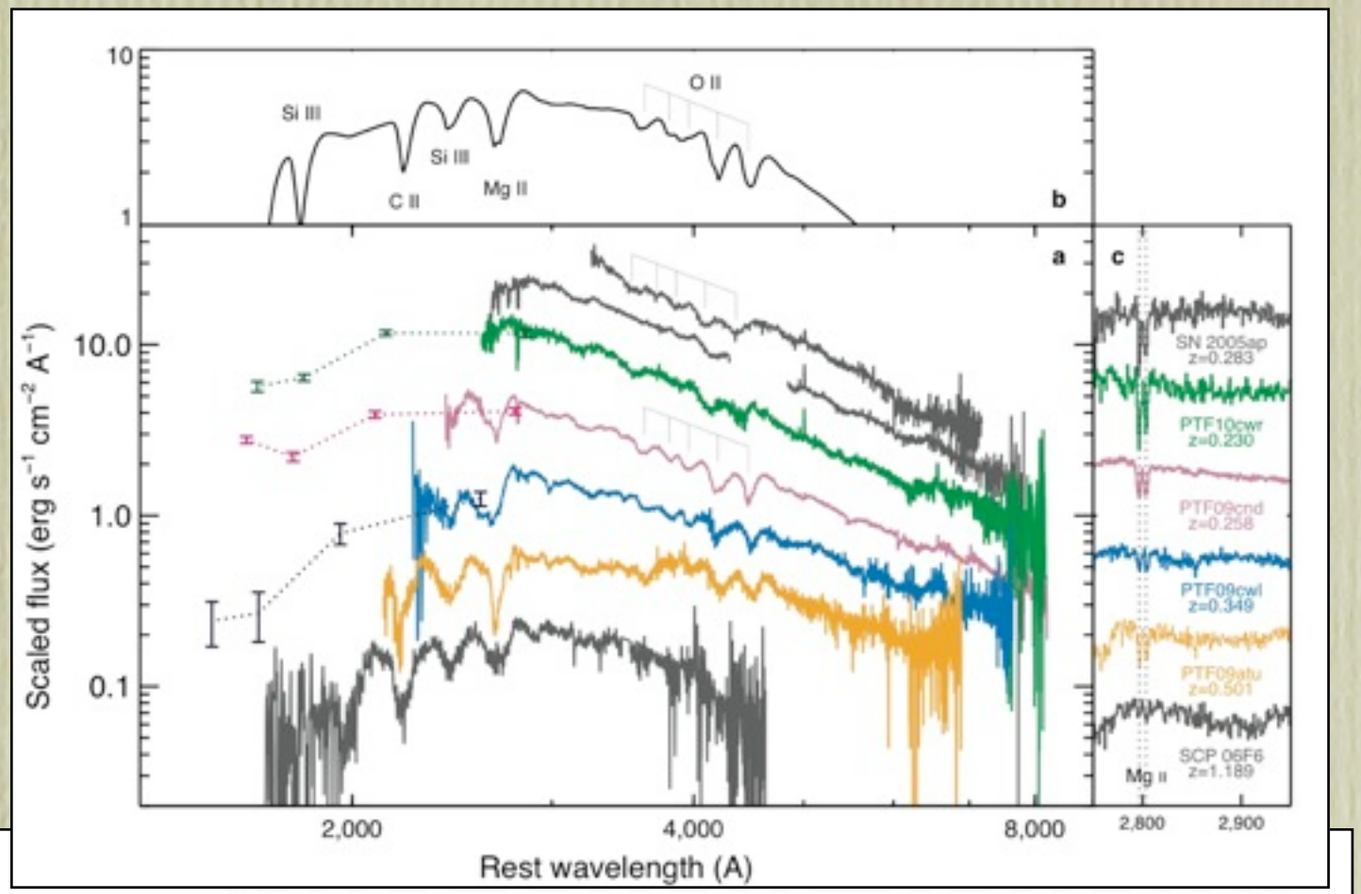
- WR star that expelled He-rich material before core-collapse

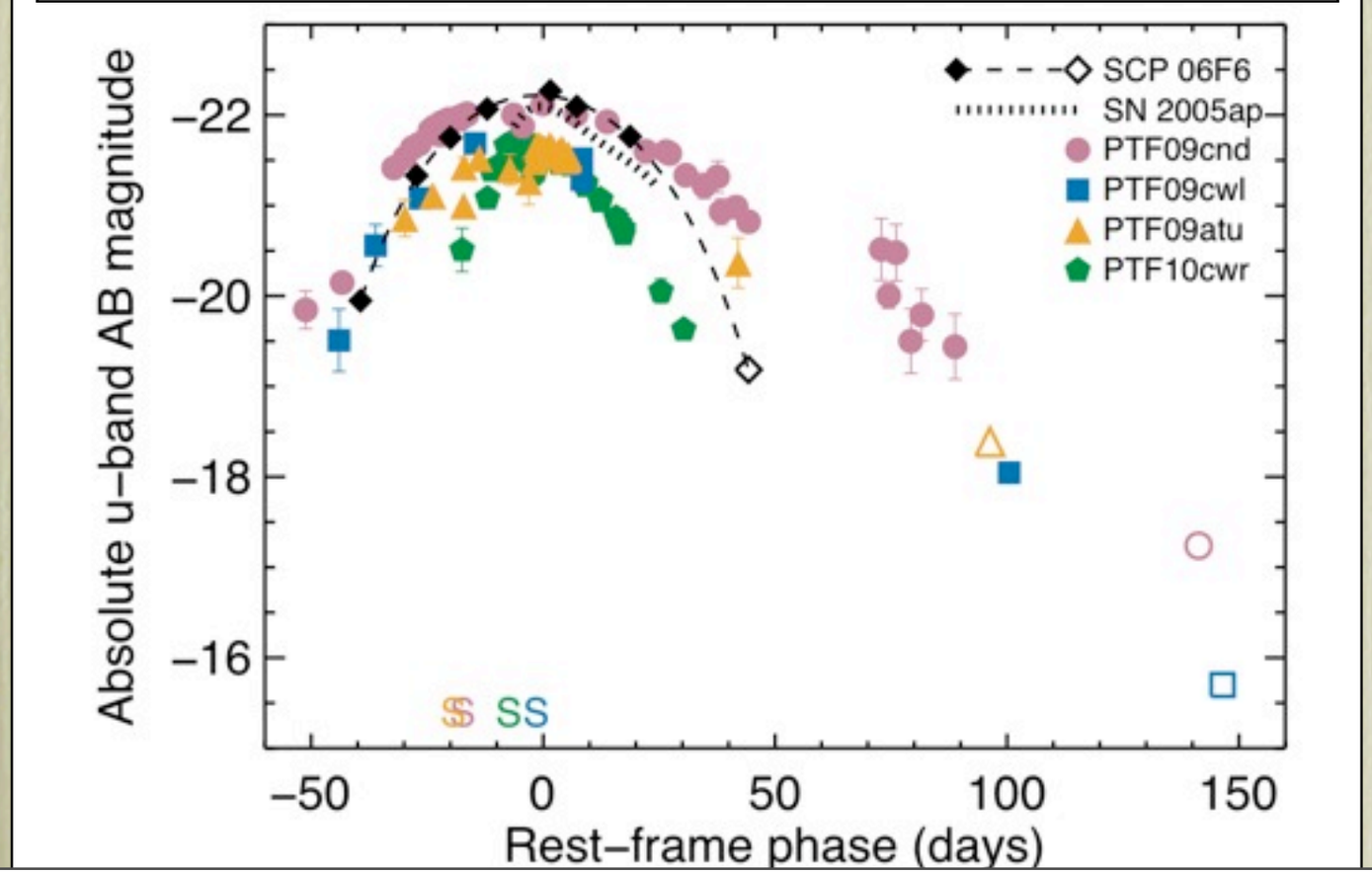
- Altervative for 2006jc: a binary system (erupting LBV + WR exploding as SN)

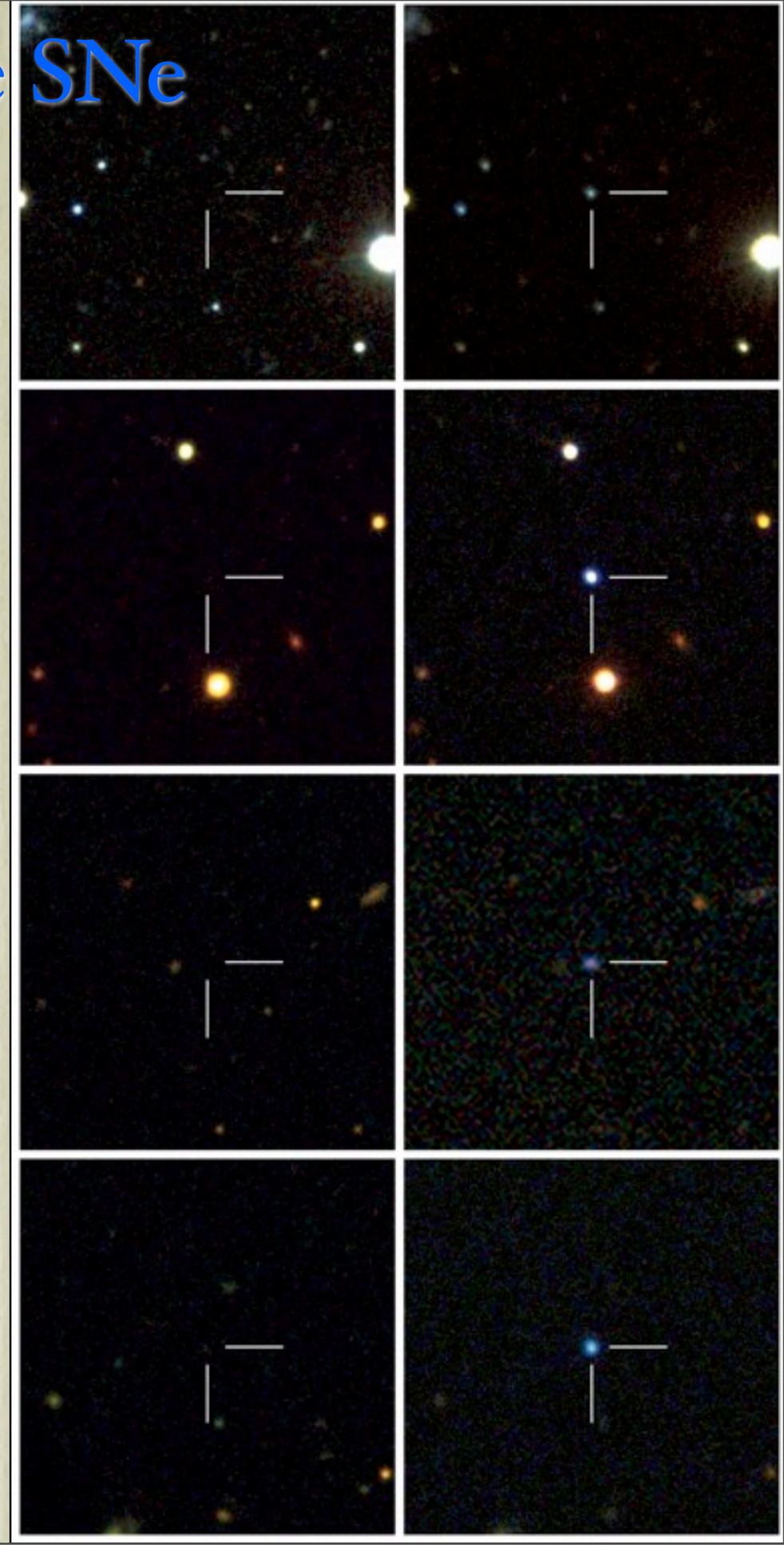


Tominaga et al. 2008

Ultra-bright stripped-envelope SNe







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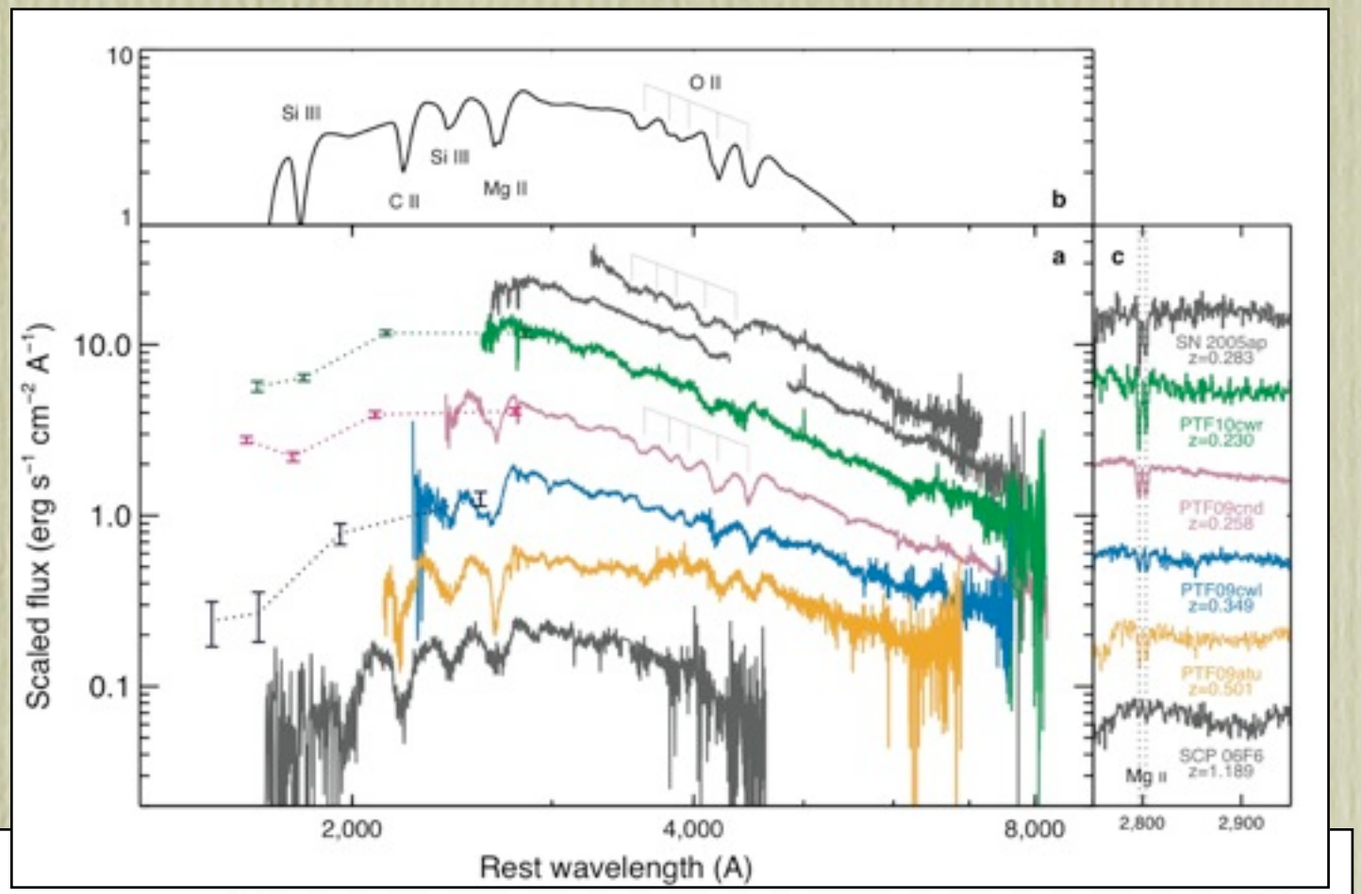
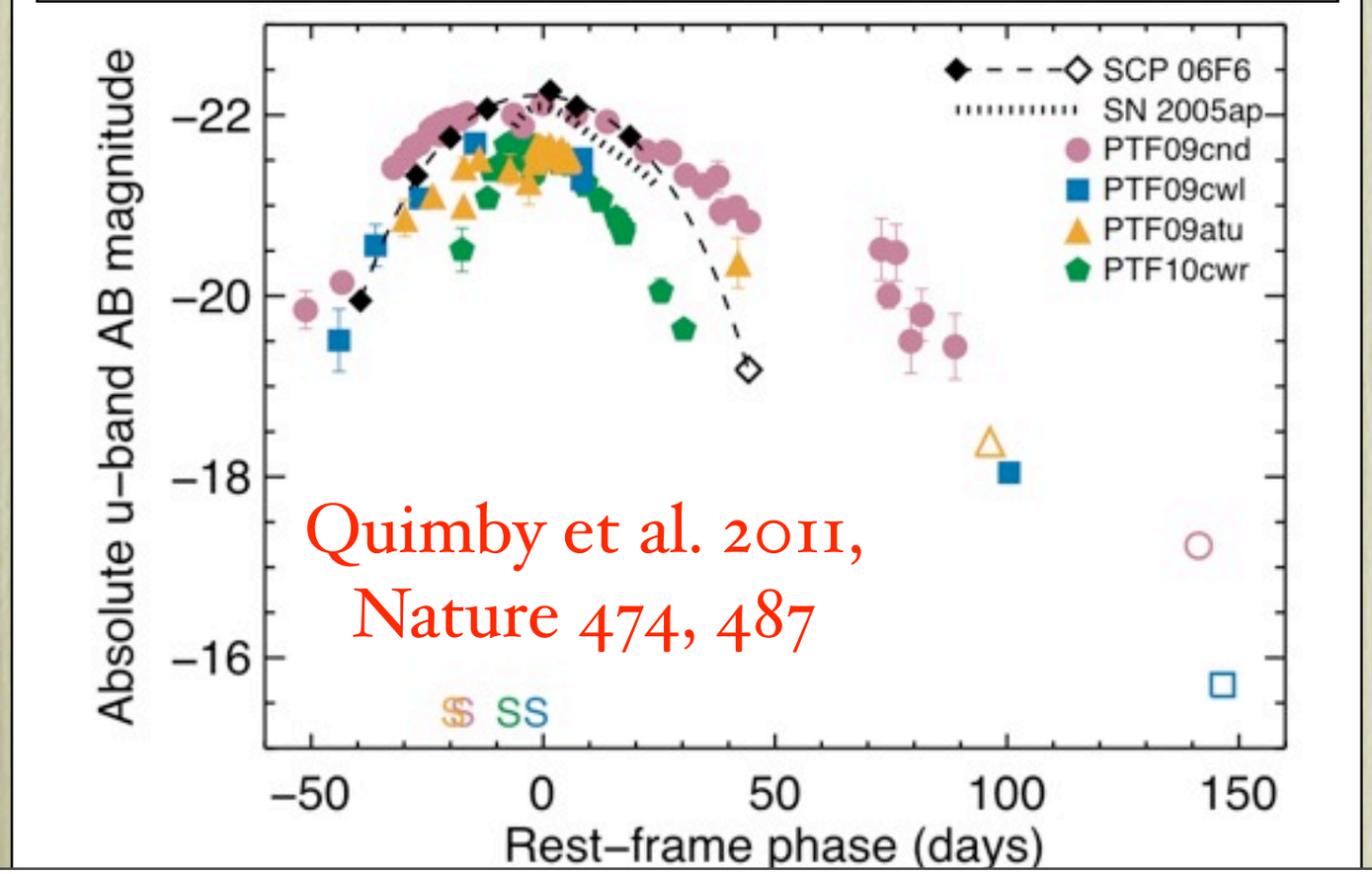
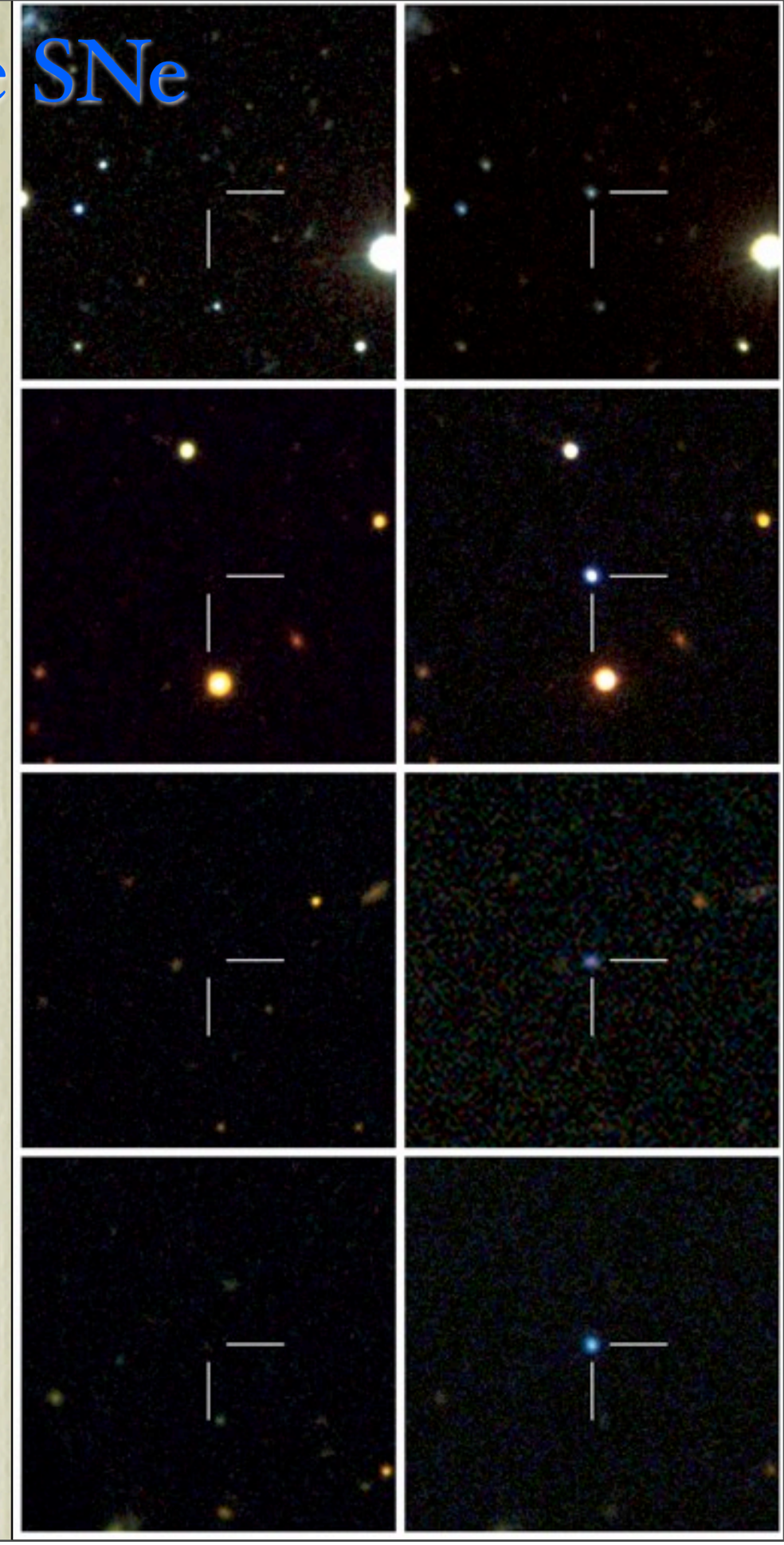
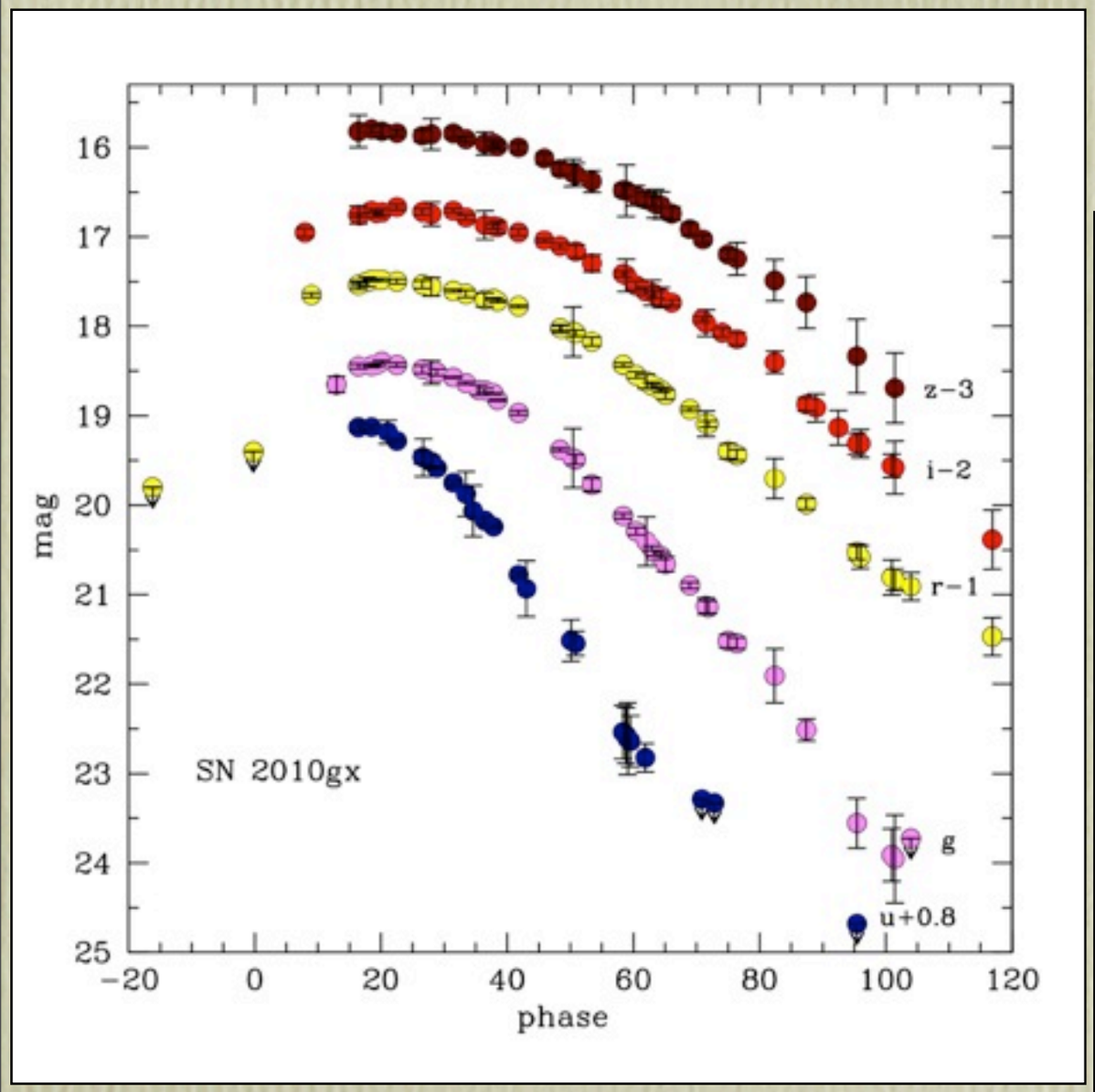


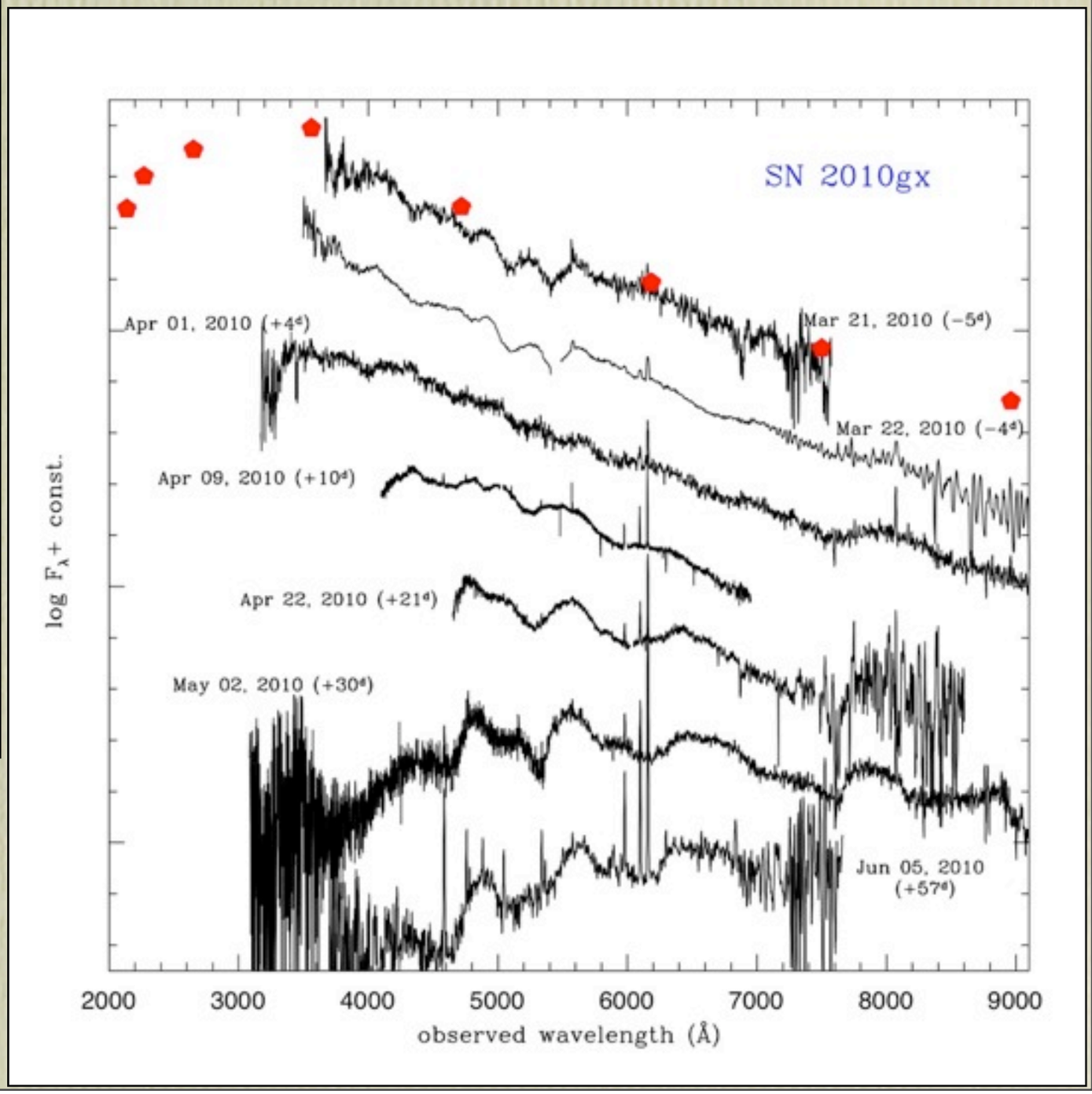


Quimby et al. 2011, Nature 474, 487



Ultra-bright stripped-envelope SNe: SN 2010gx





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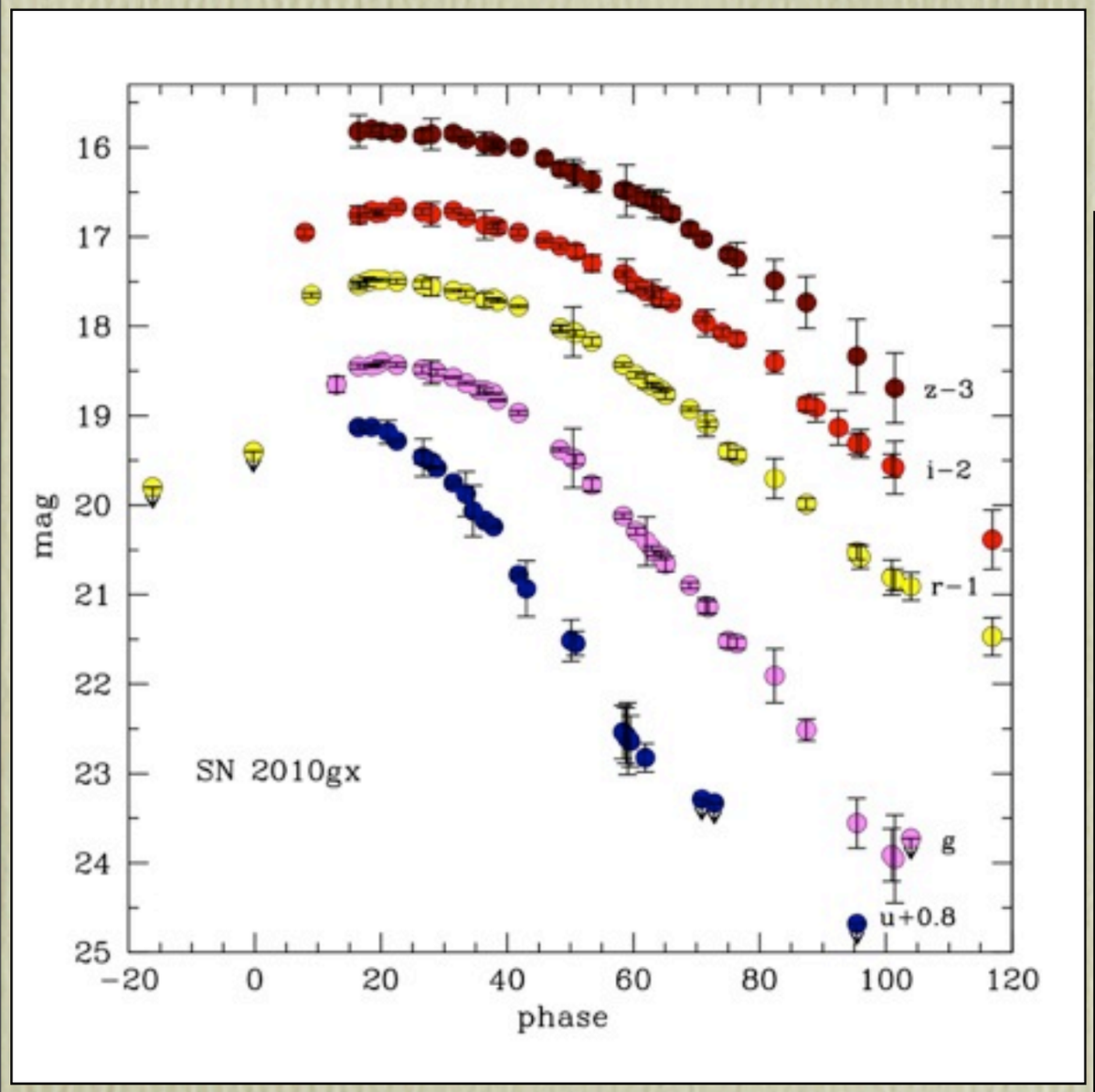

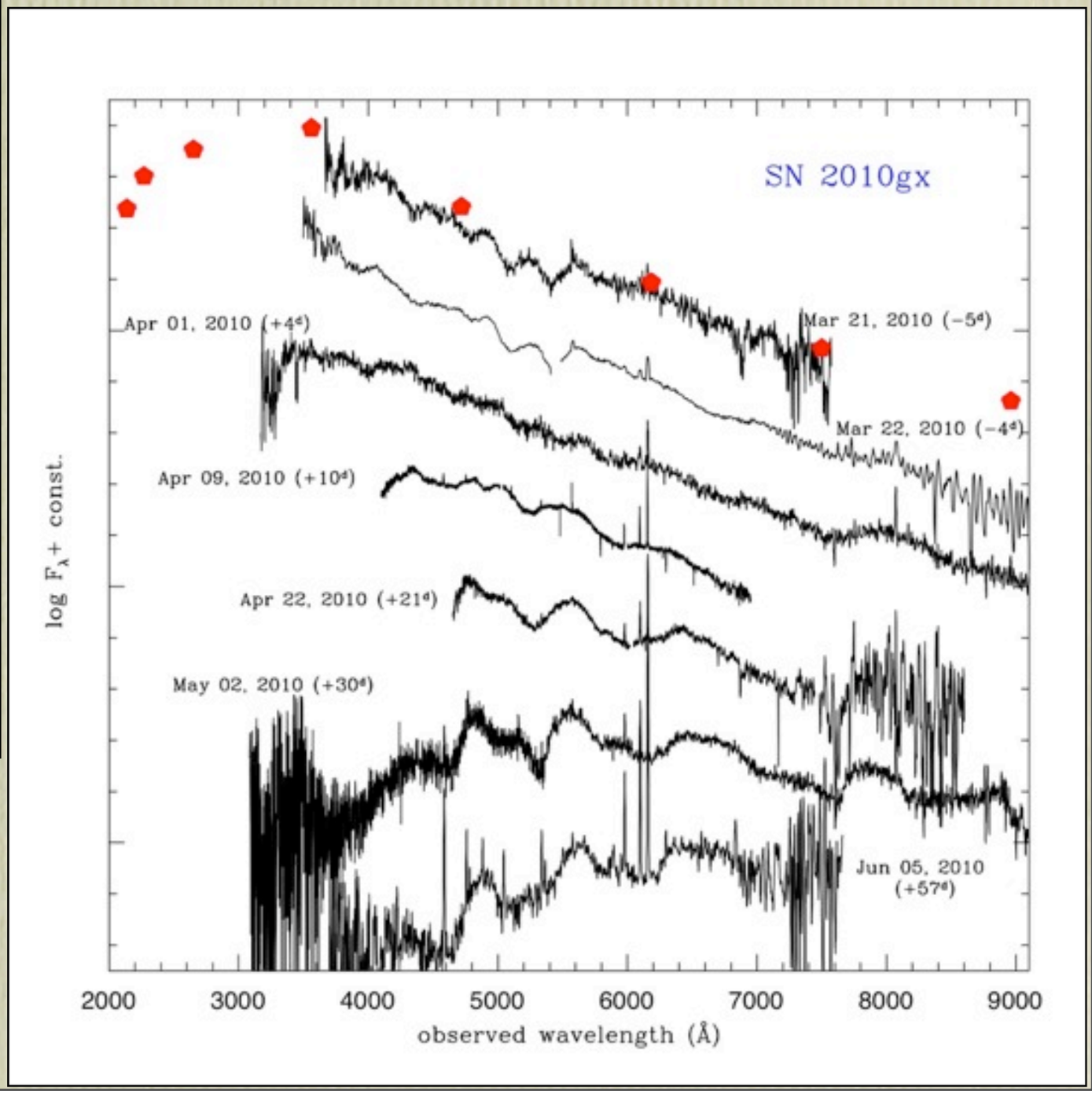

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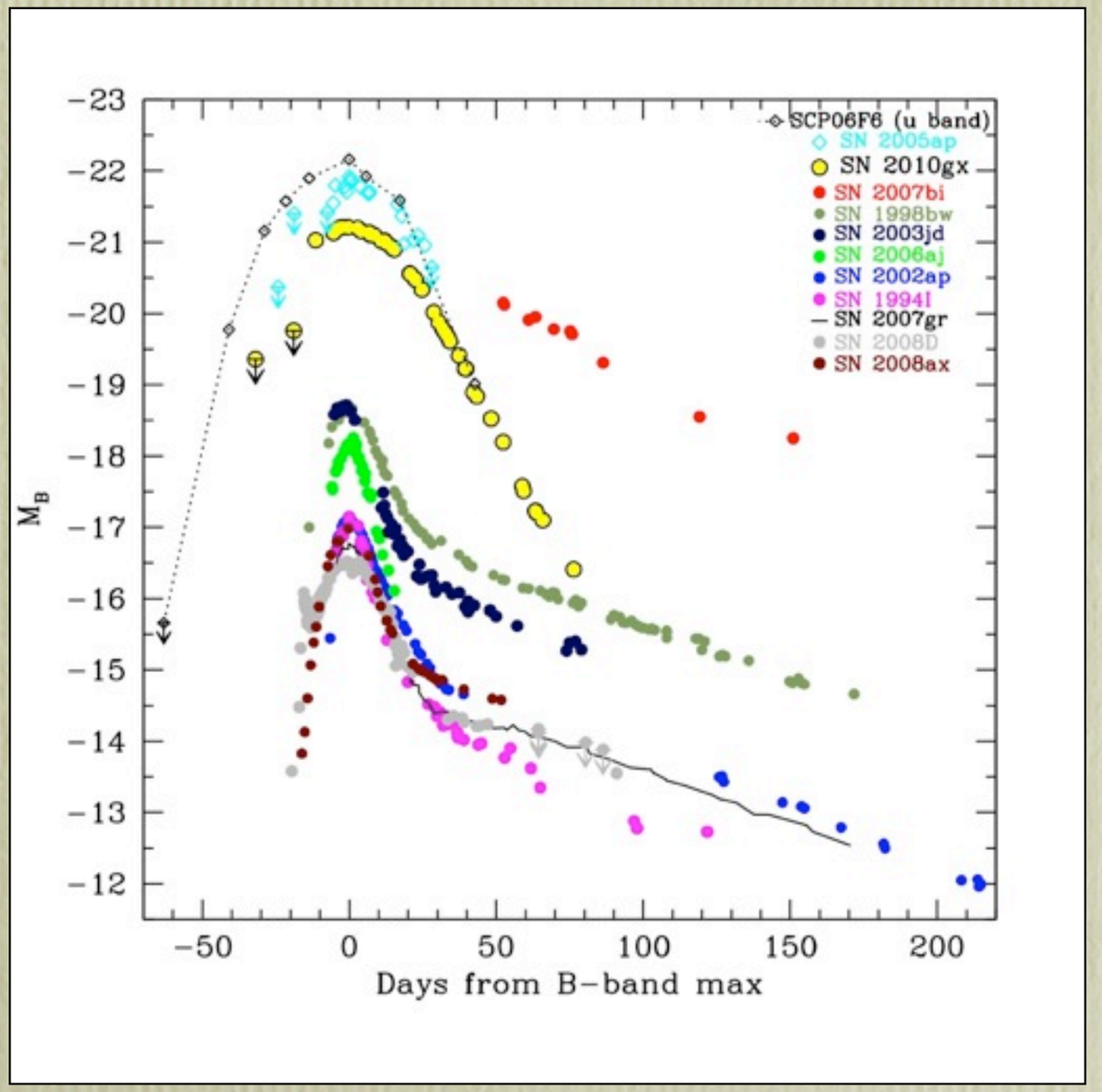

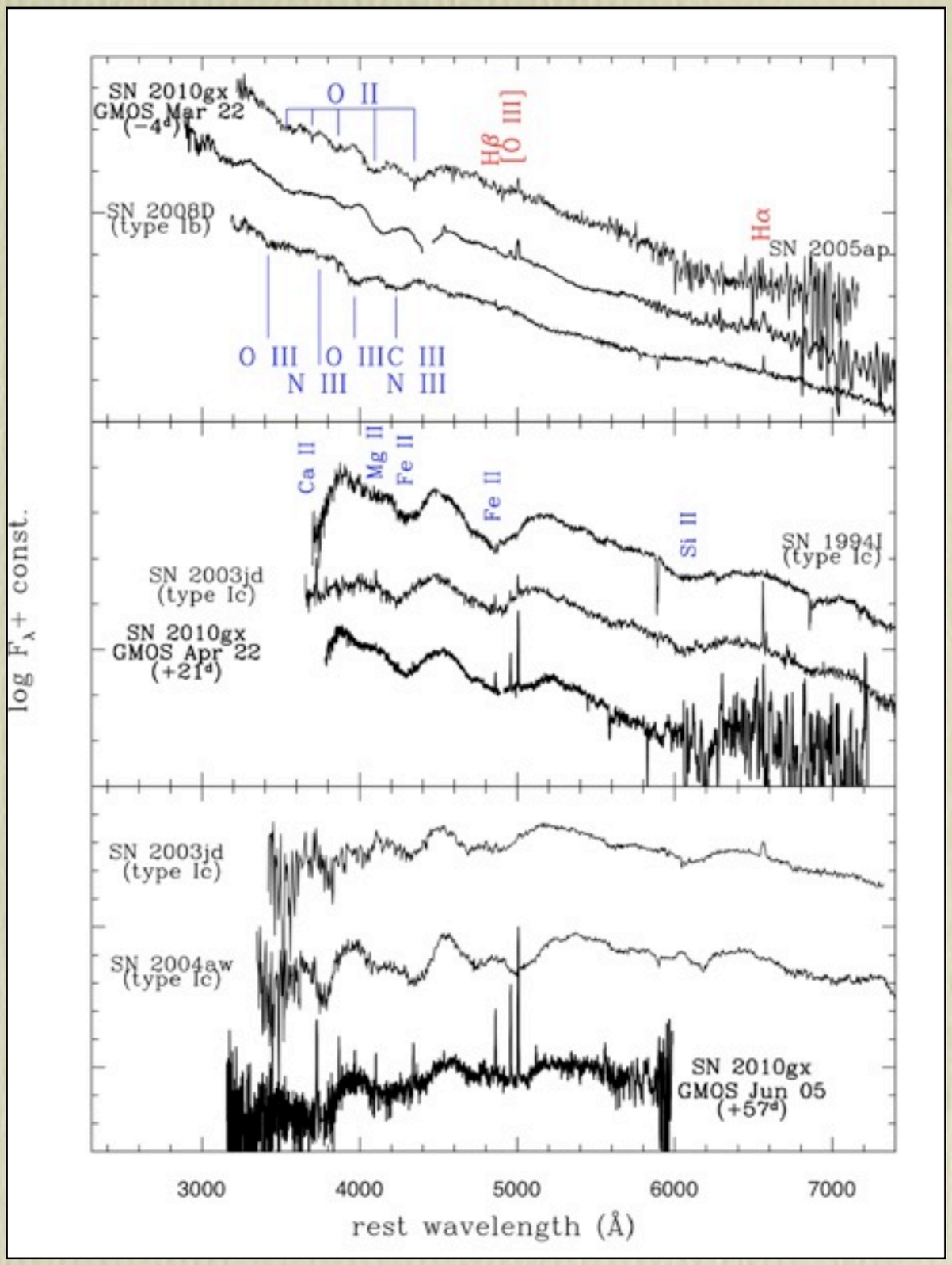

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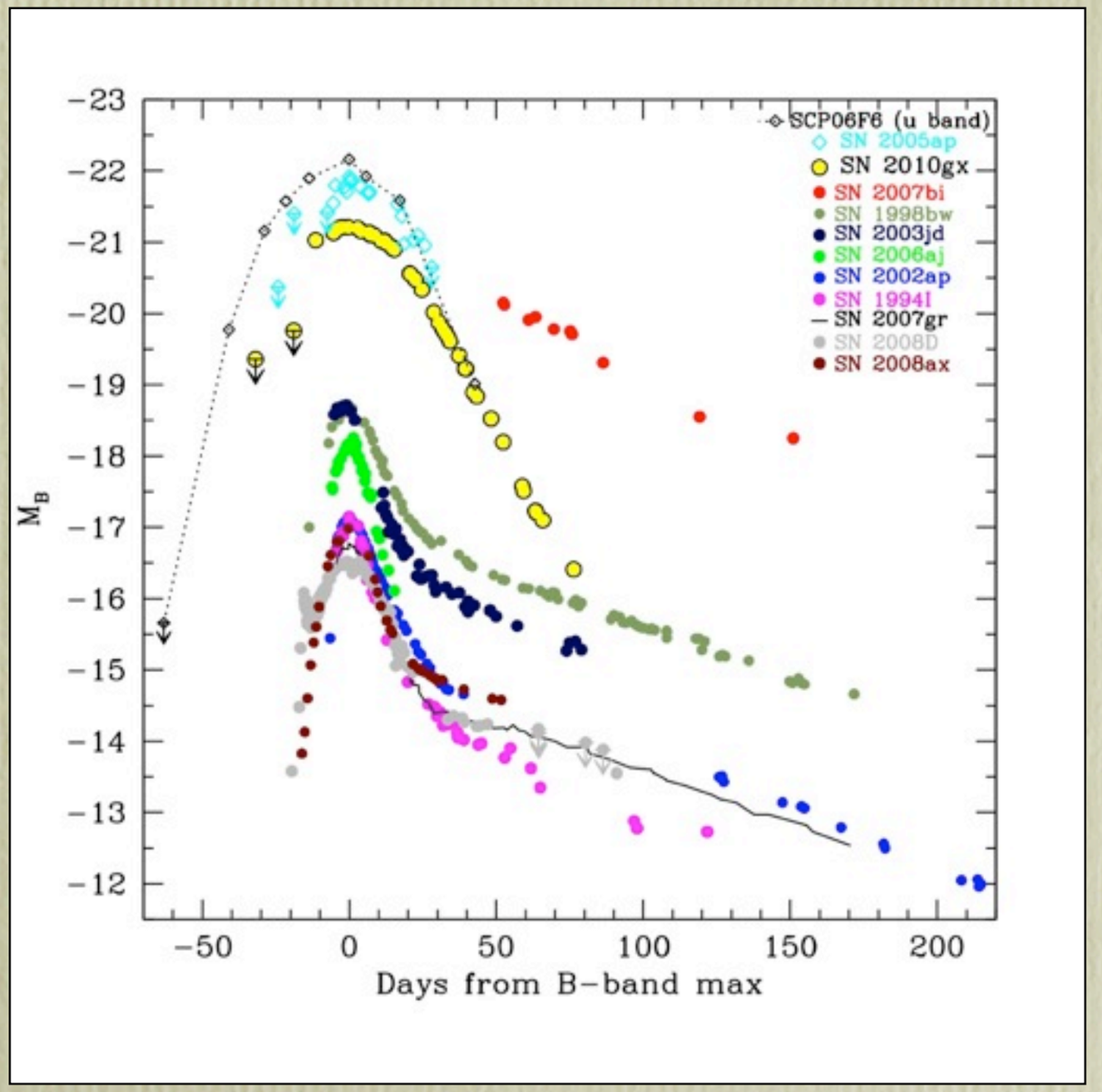

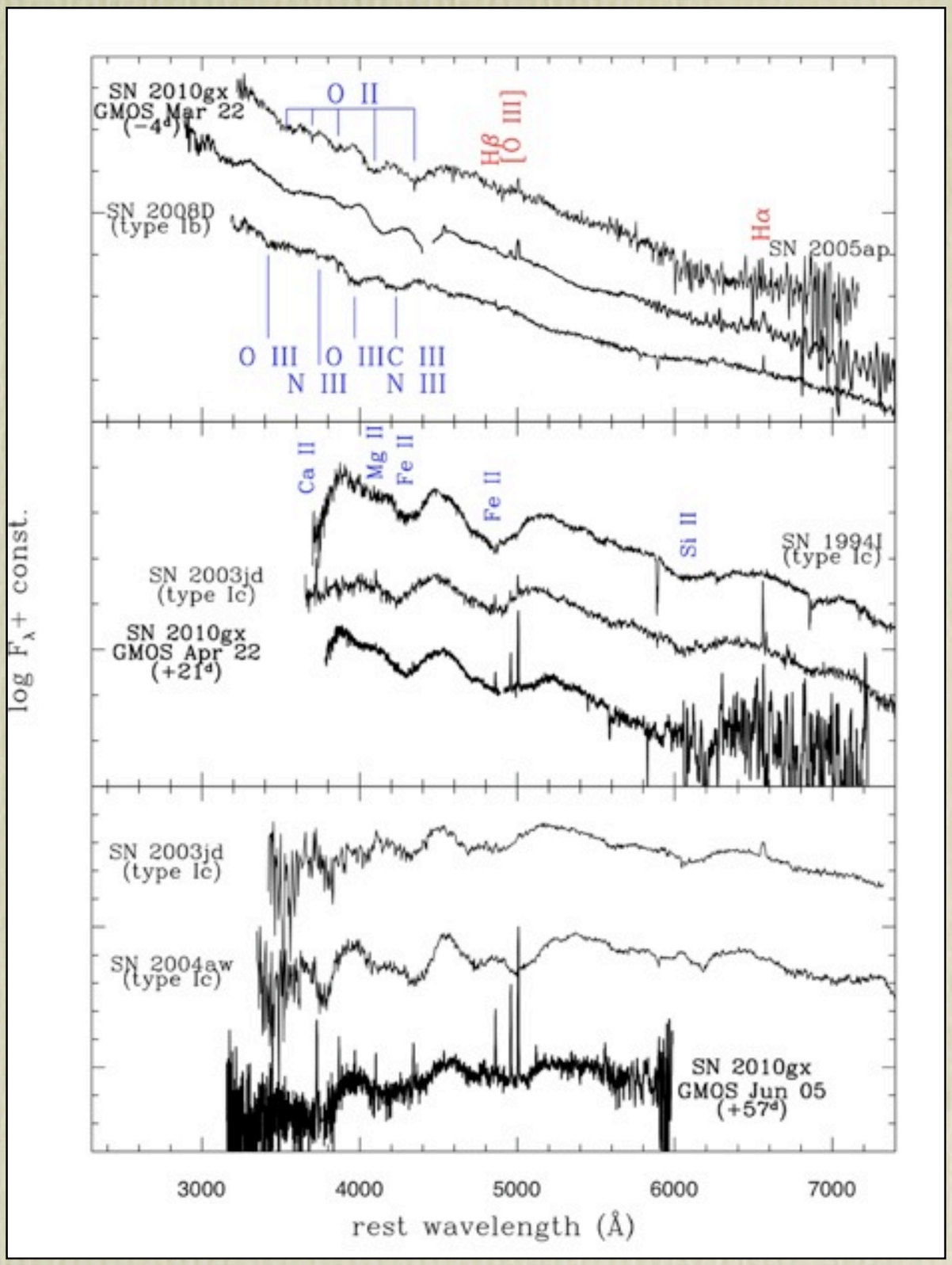

Pastorello et al. 2010

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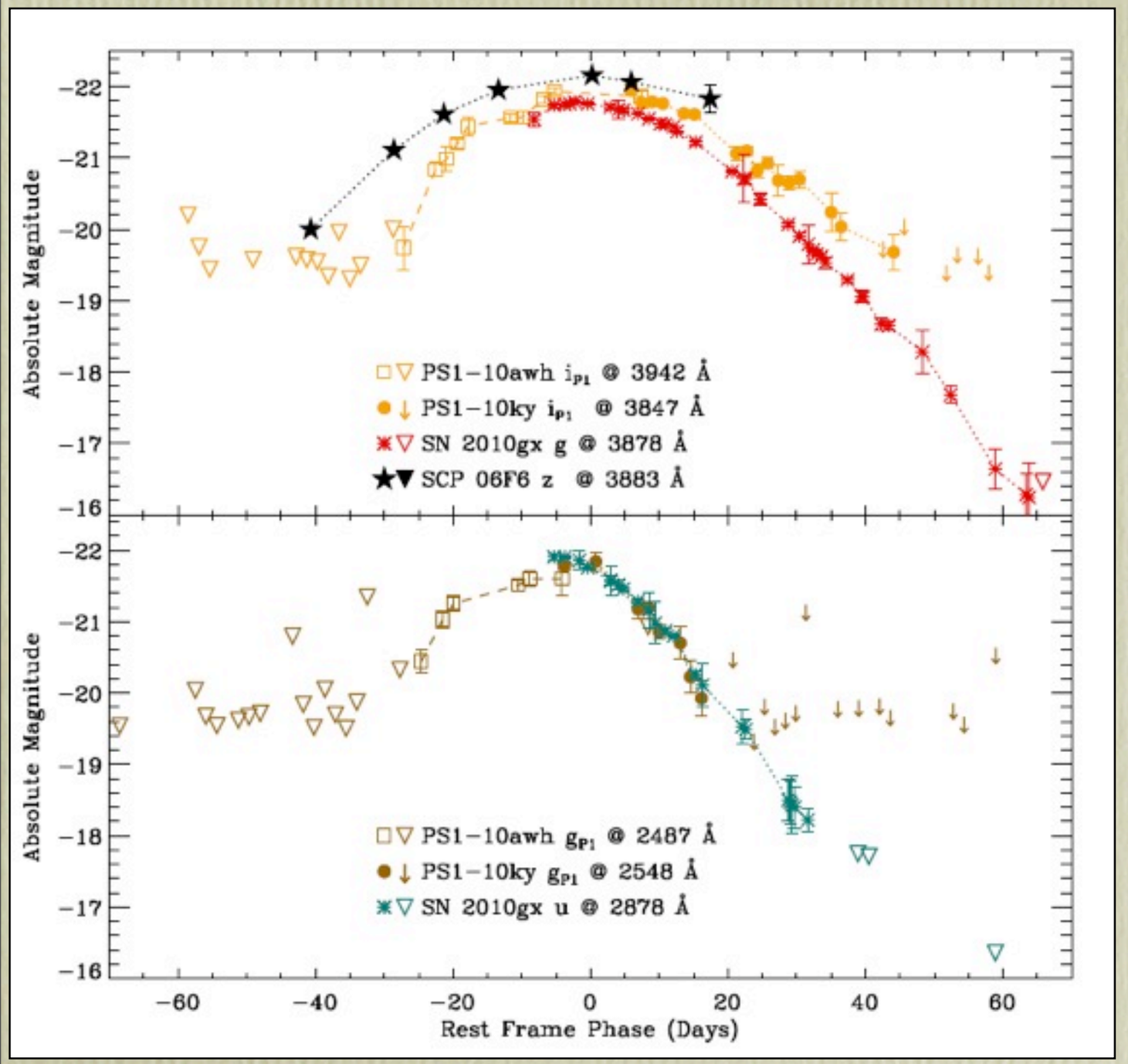
2 PS1 objects at z ≈ 0.9!



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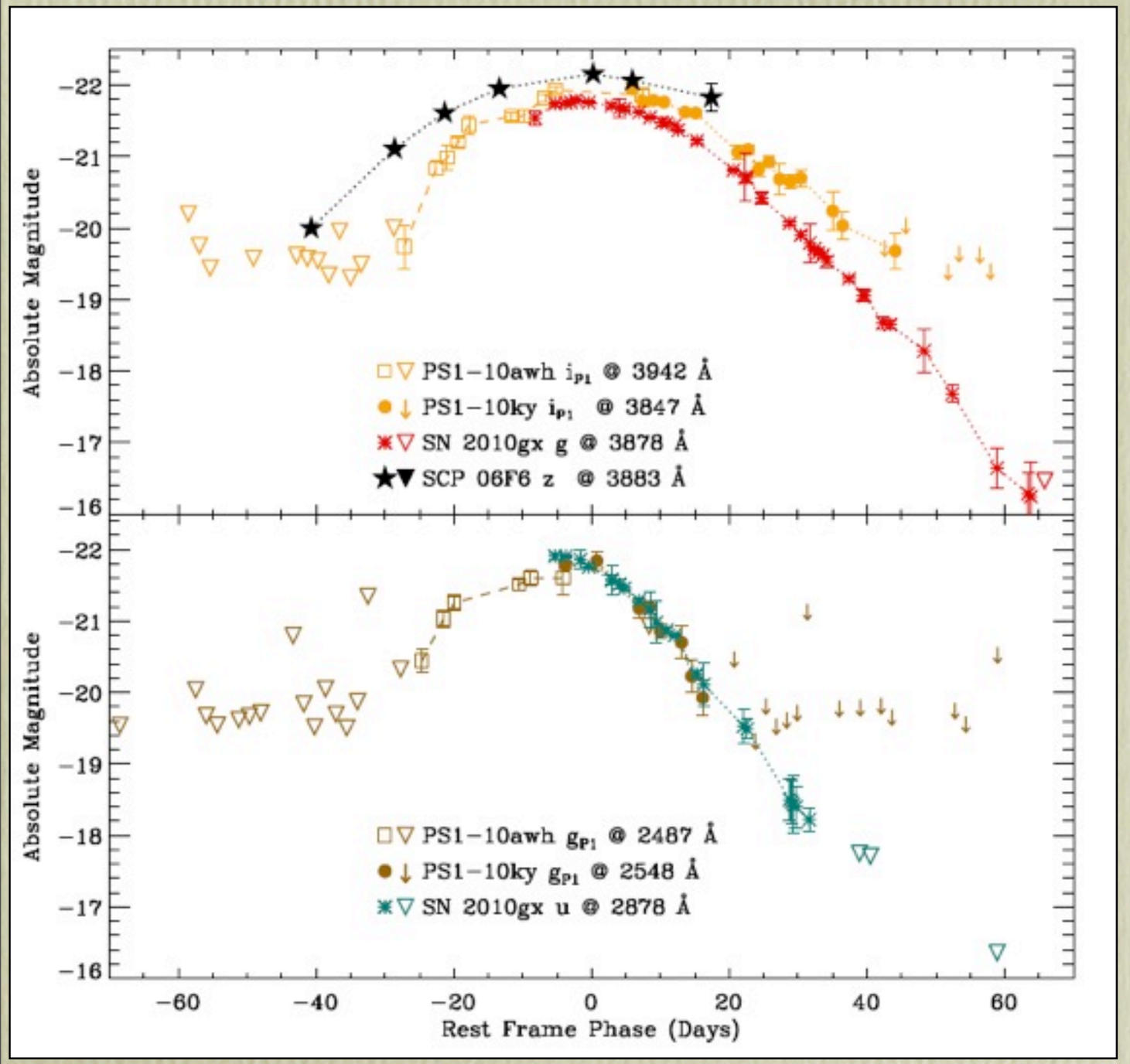

Chomiuk et al. 2011

see also Stephen Smartt's talk

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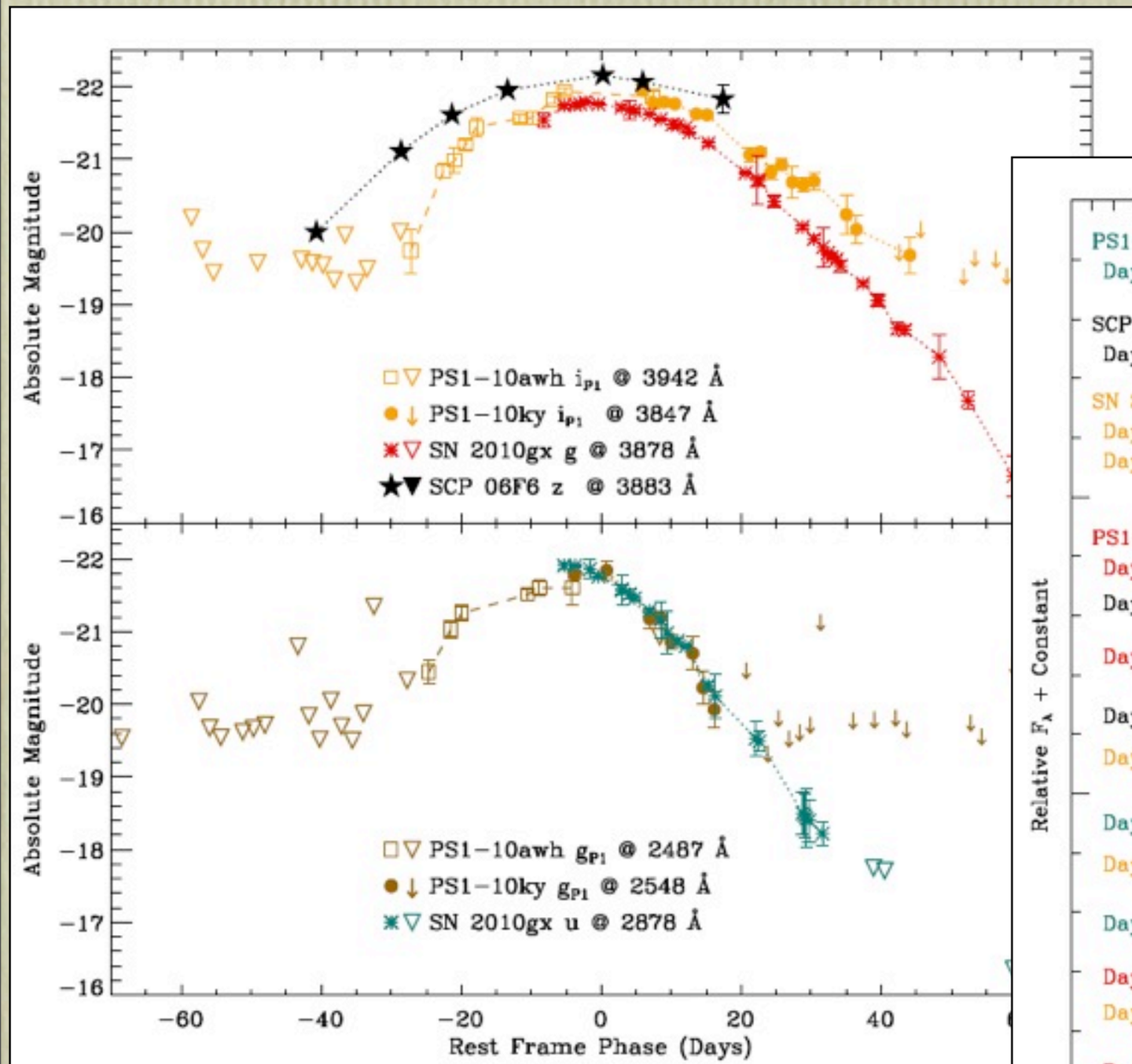

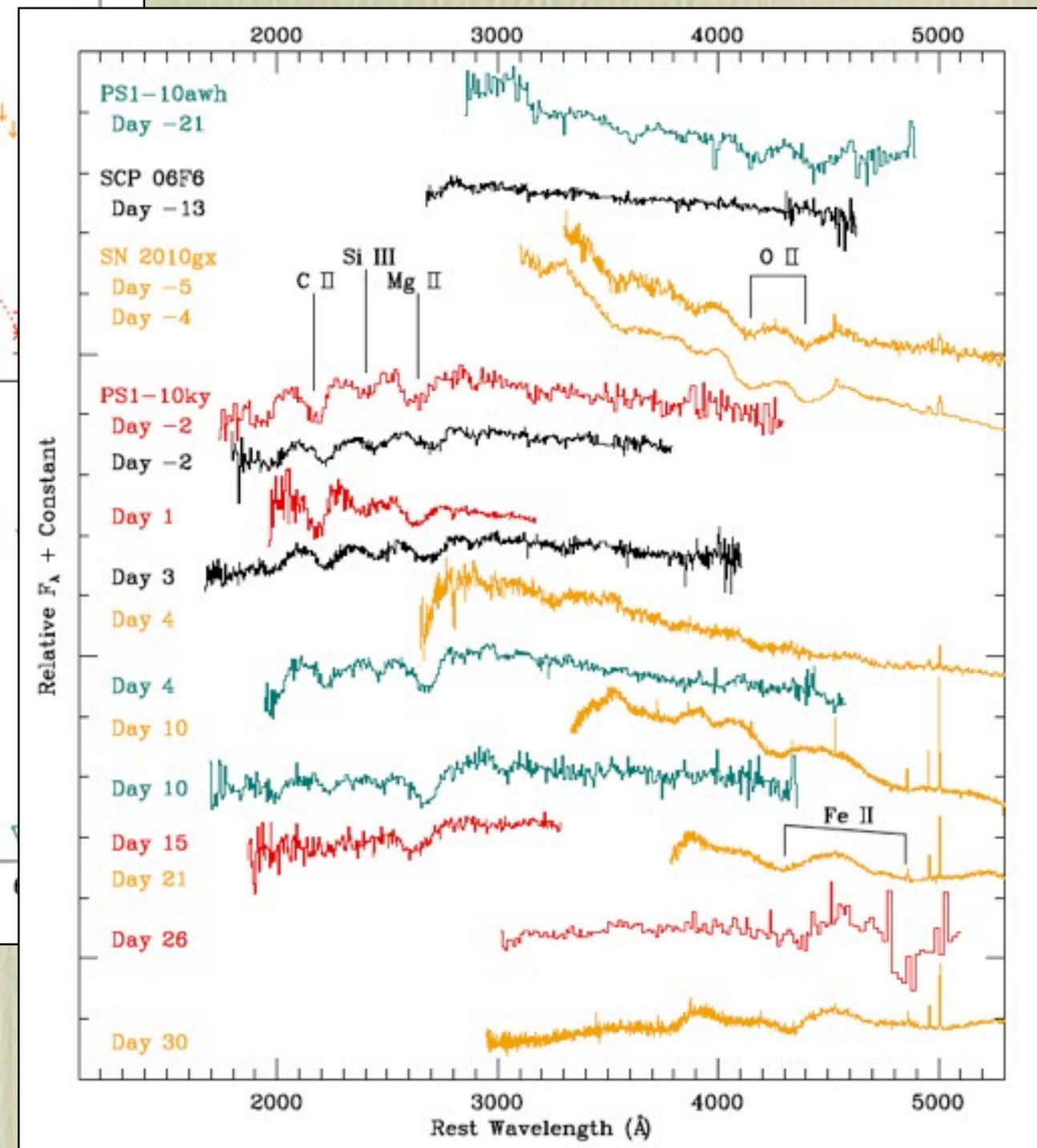

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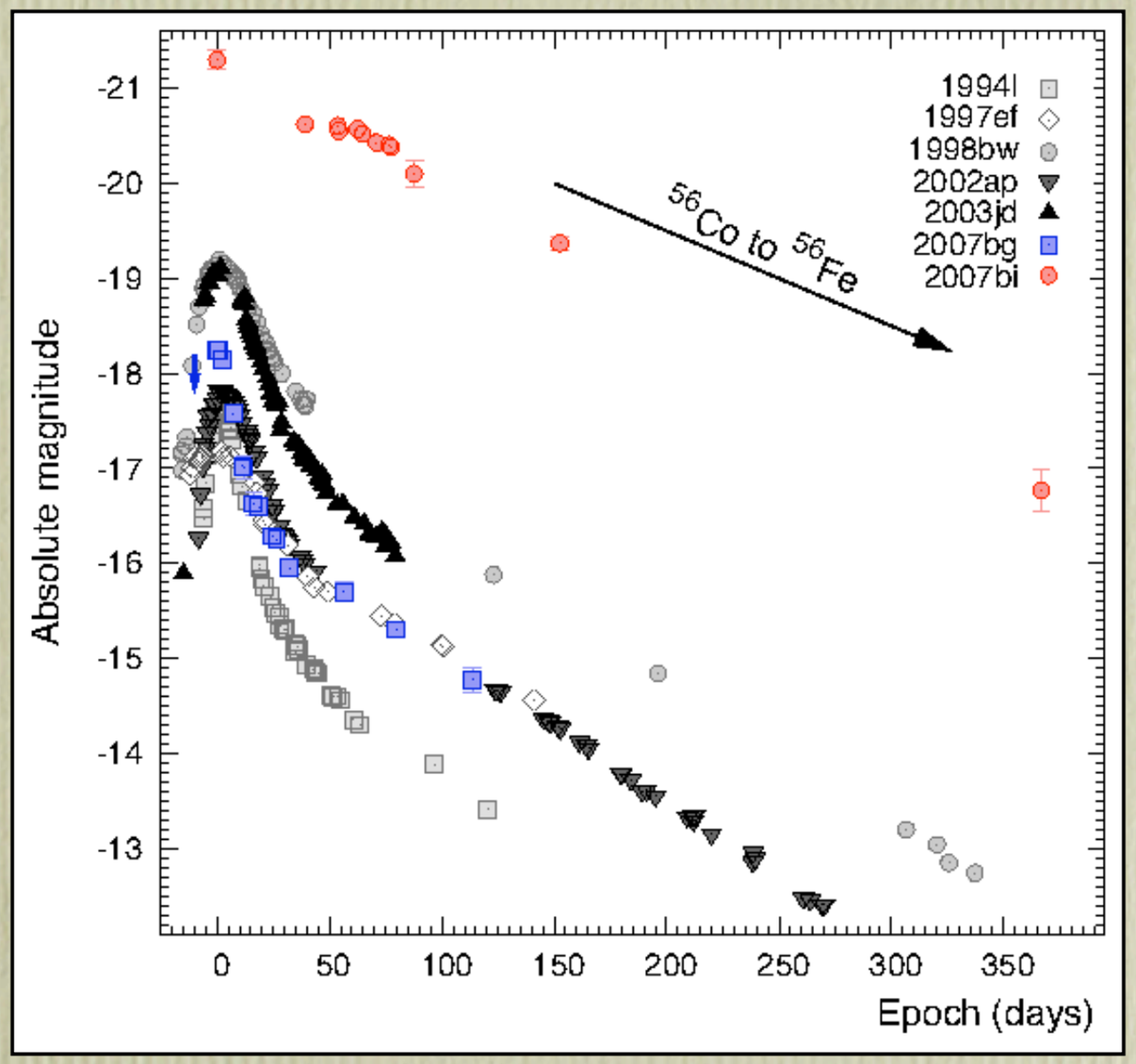
4) Magnetar-powered SN (CC+BH)
Maybe, but its lightcurve is fast-evolving compared with models (Woosley, 2010; Kasen & Bildsten 2010)

SN Ic 2007bi: the first pair-instability SN?



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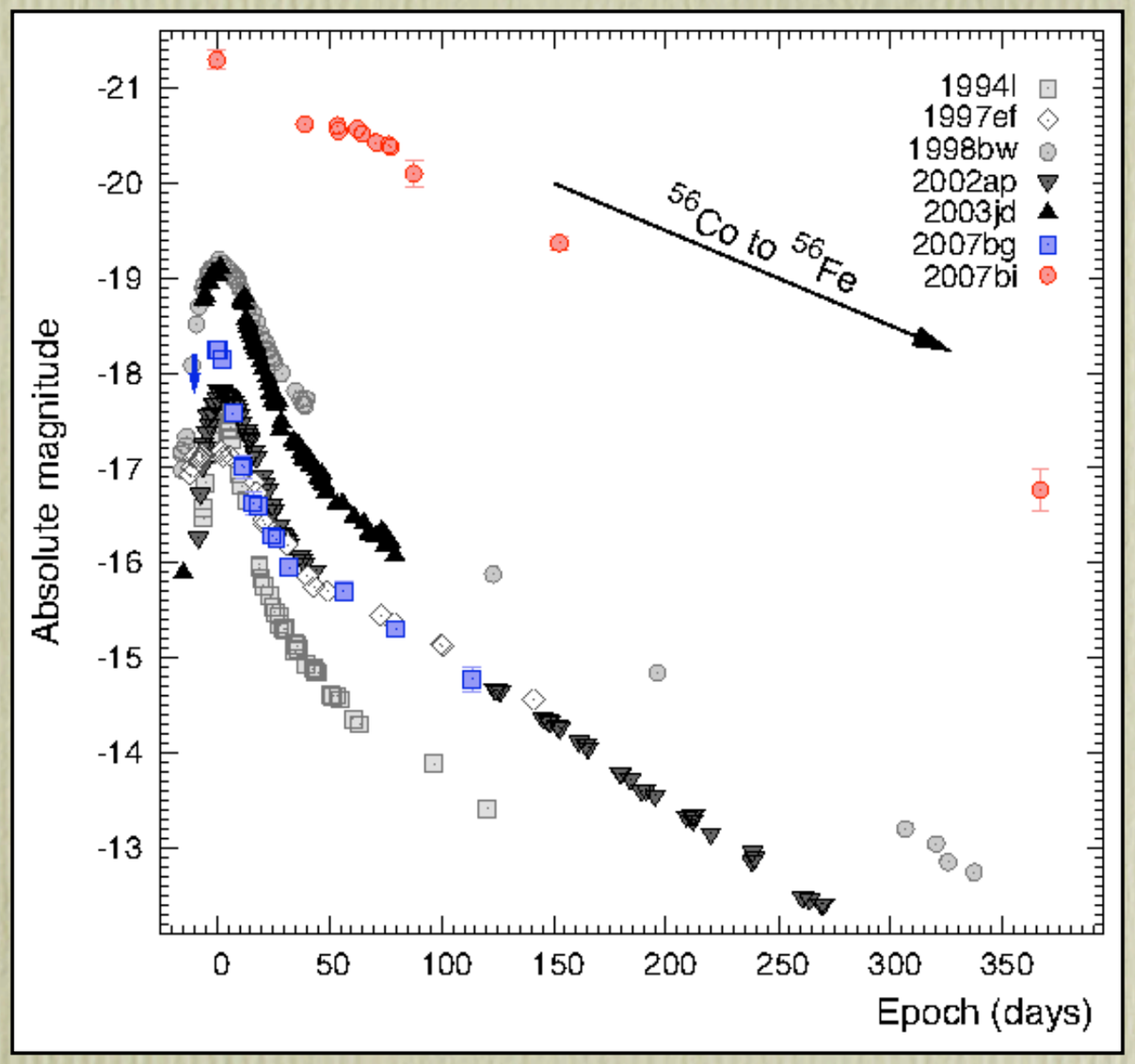

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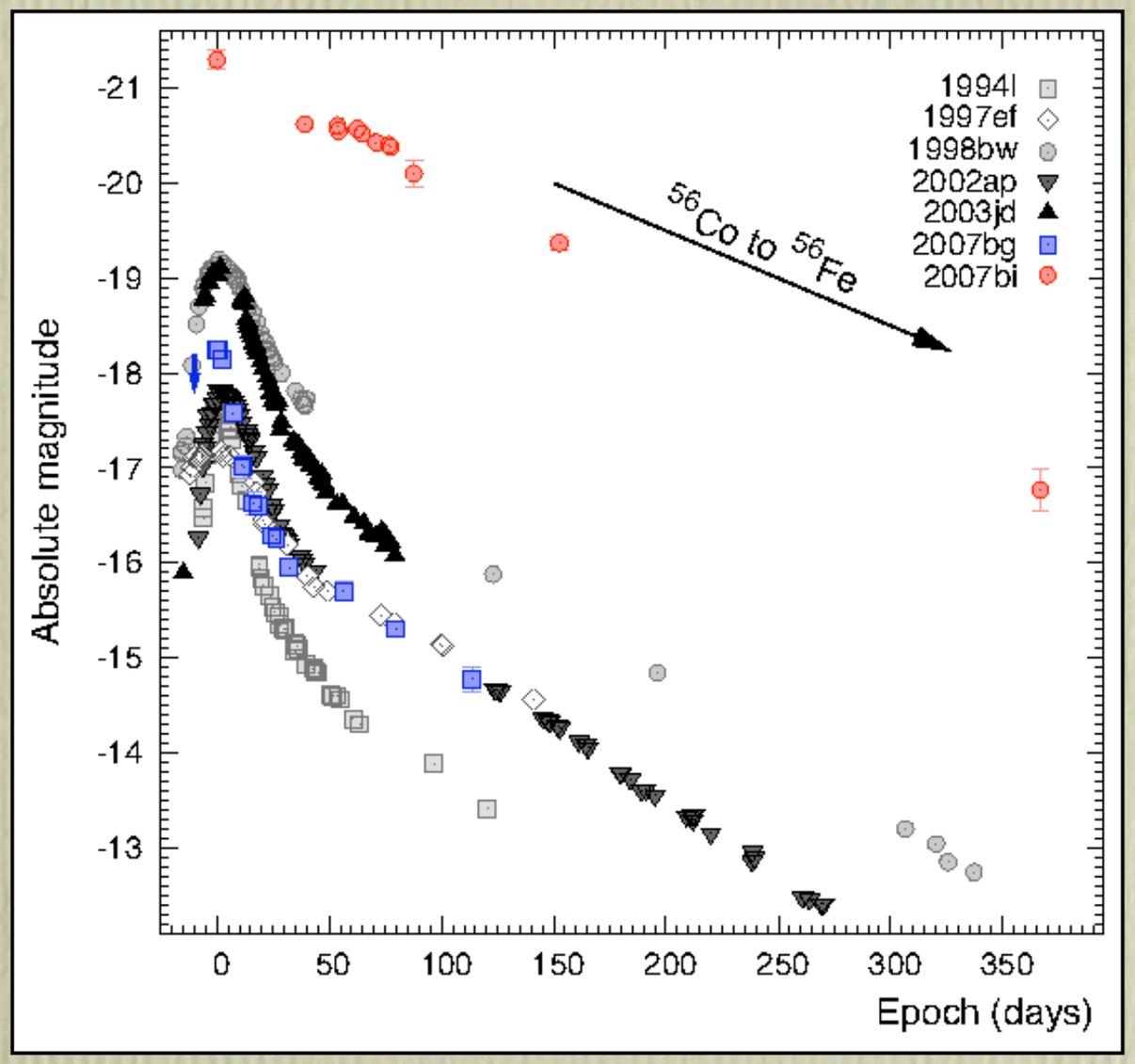

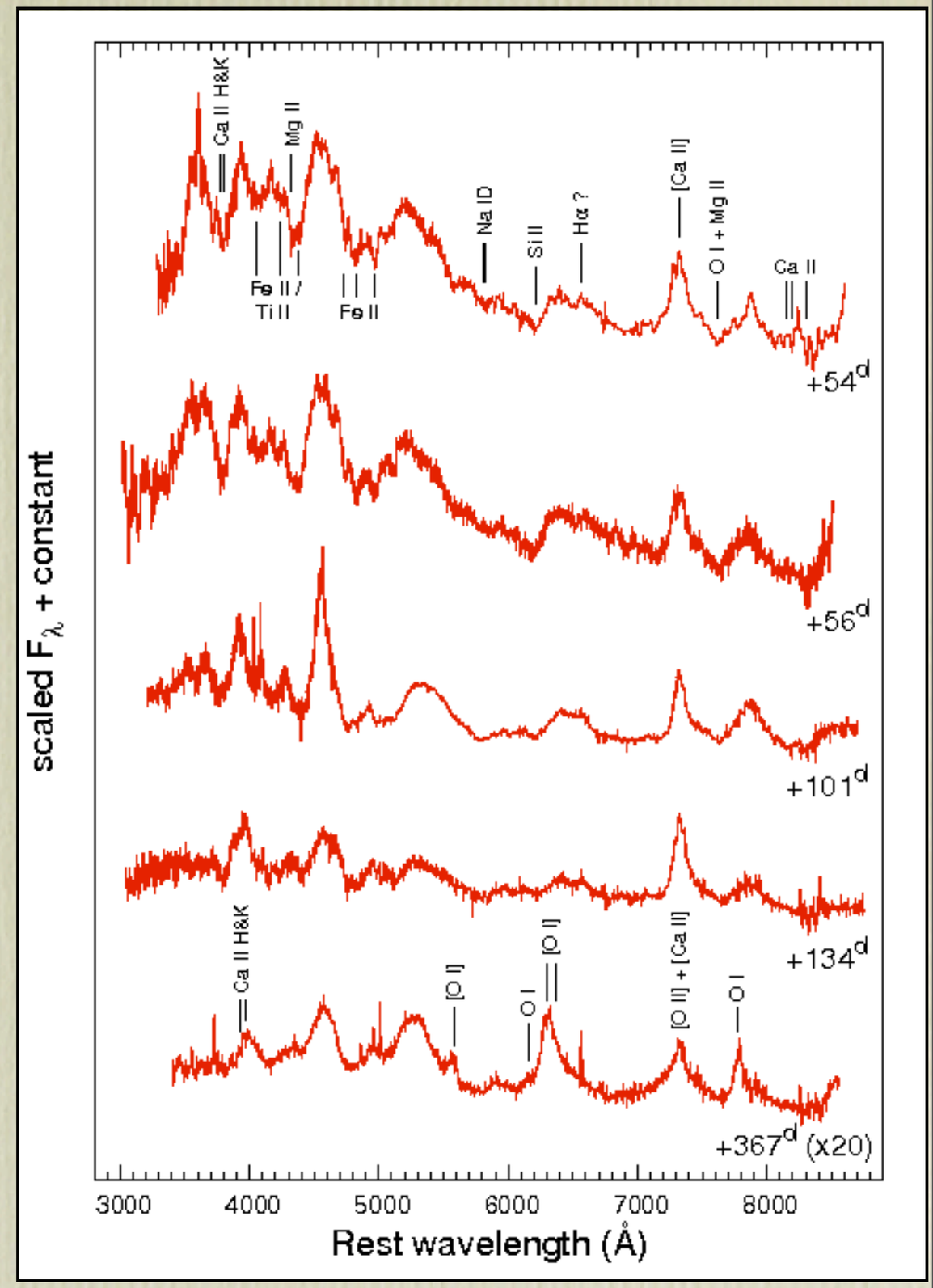

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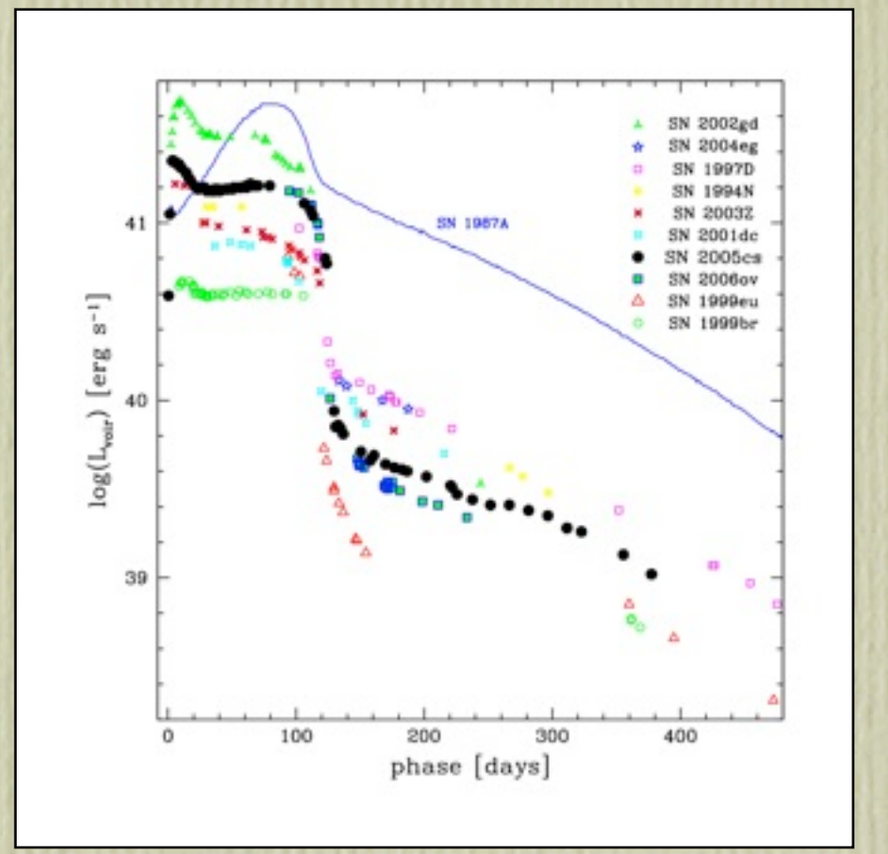
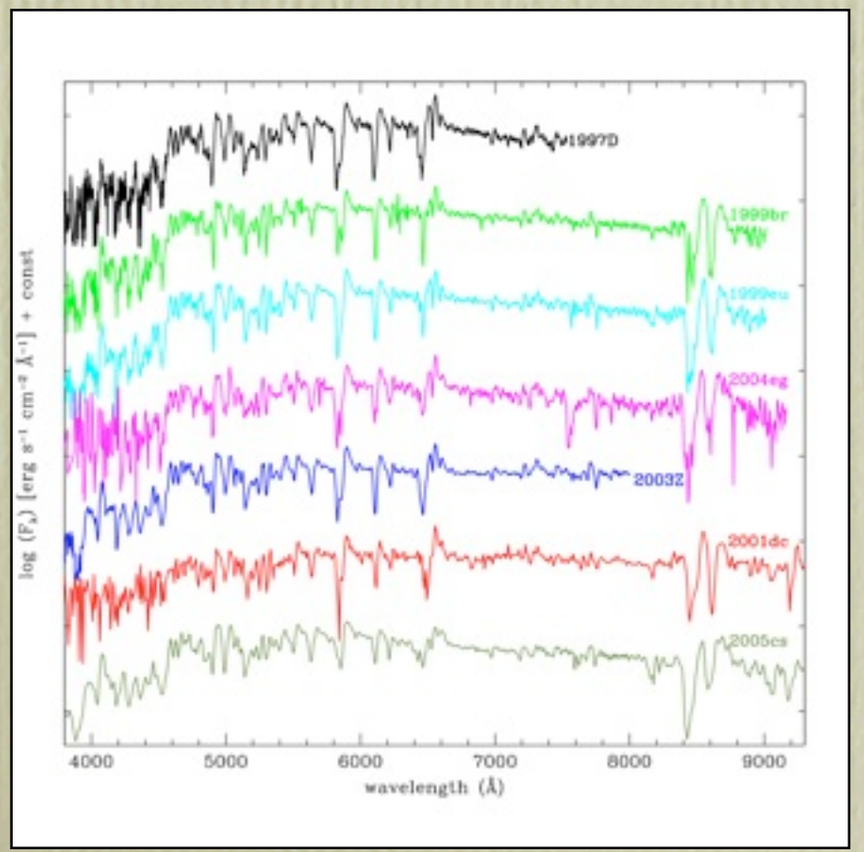
Sub-luminous type IIP SNe





- Faint plateaux (mag > -16)
- Long-duration plateau (100-120d)
- Red colours
- Faint LC radioactive tail (^{56}Ni mass << 10^{-2} Mo)
- Narrow spectral lines (v_{ph}=700-1200 km s^{-1})
- Prominent Ba II lines
- Fe- and O-poor nebular spectra

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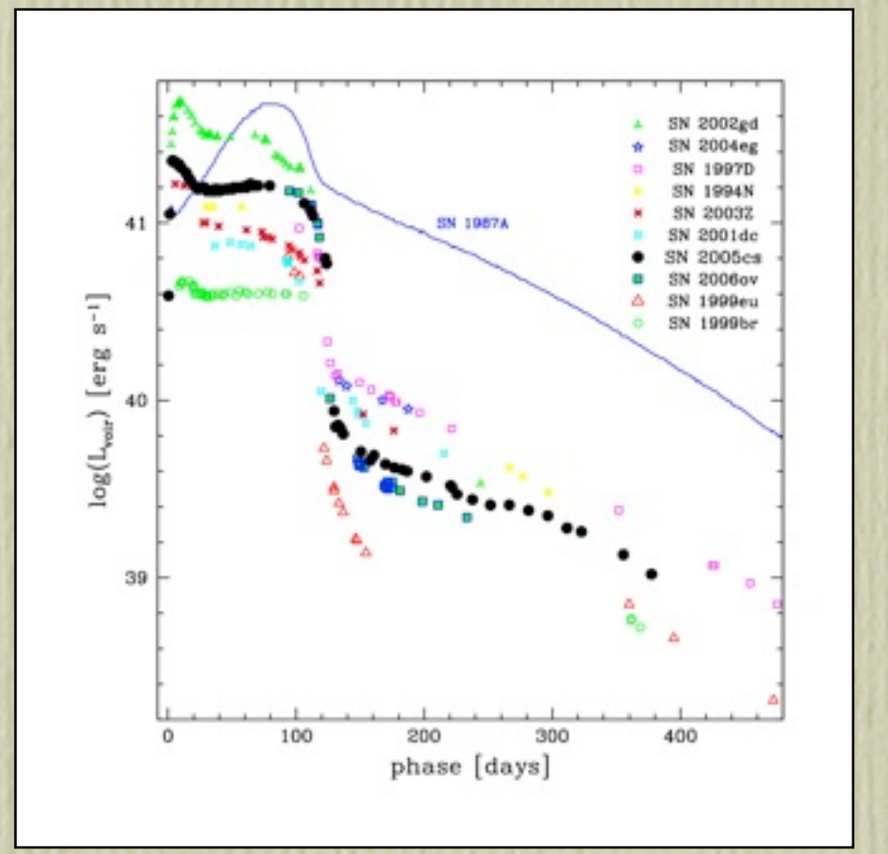

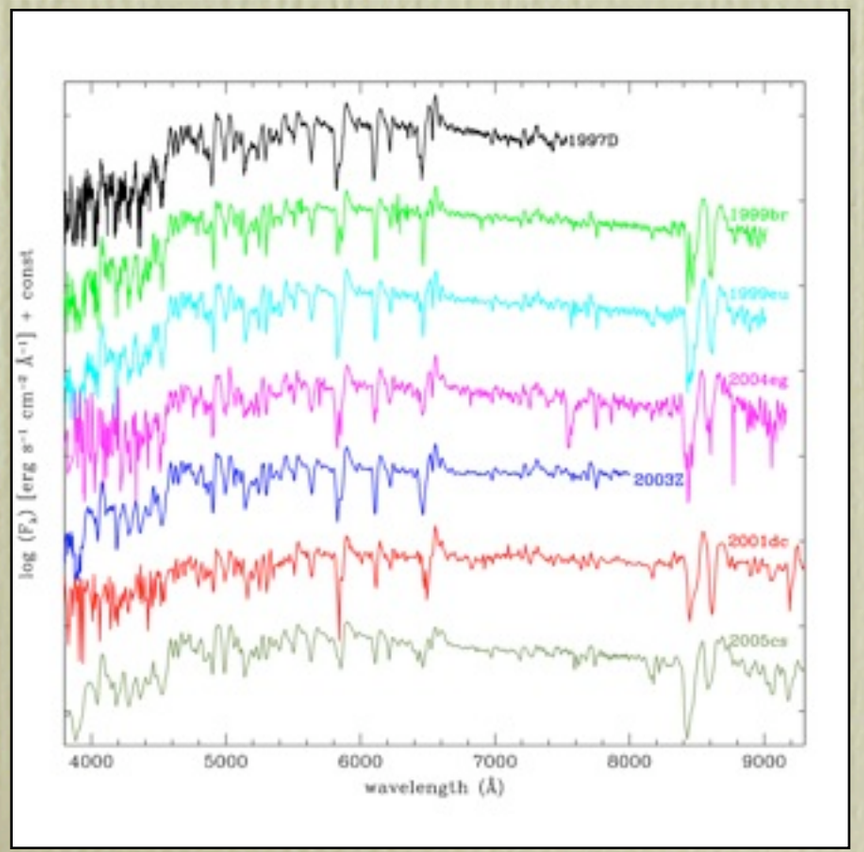

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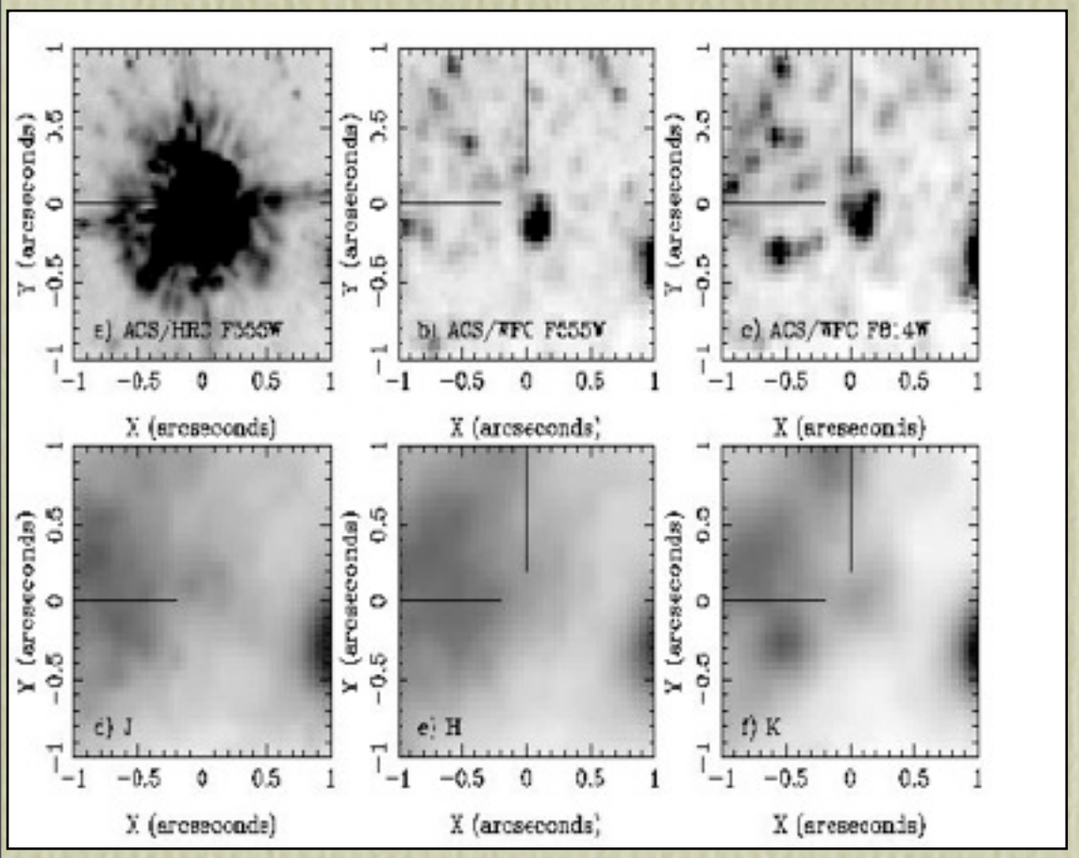
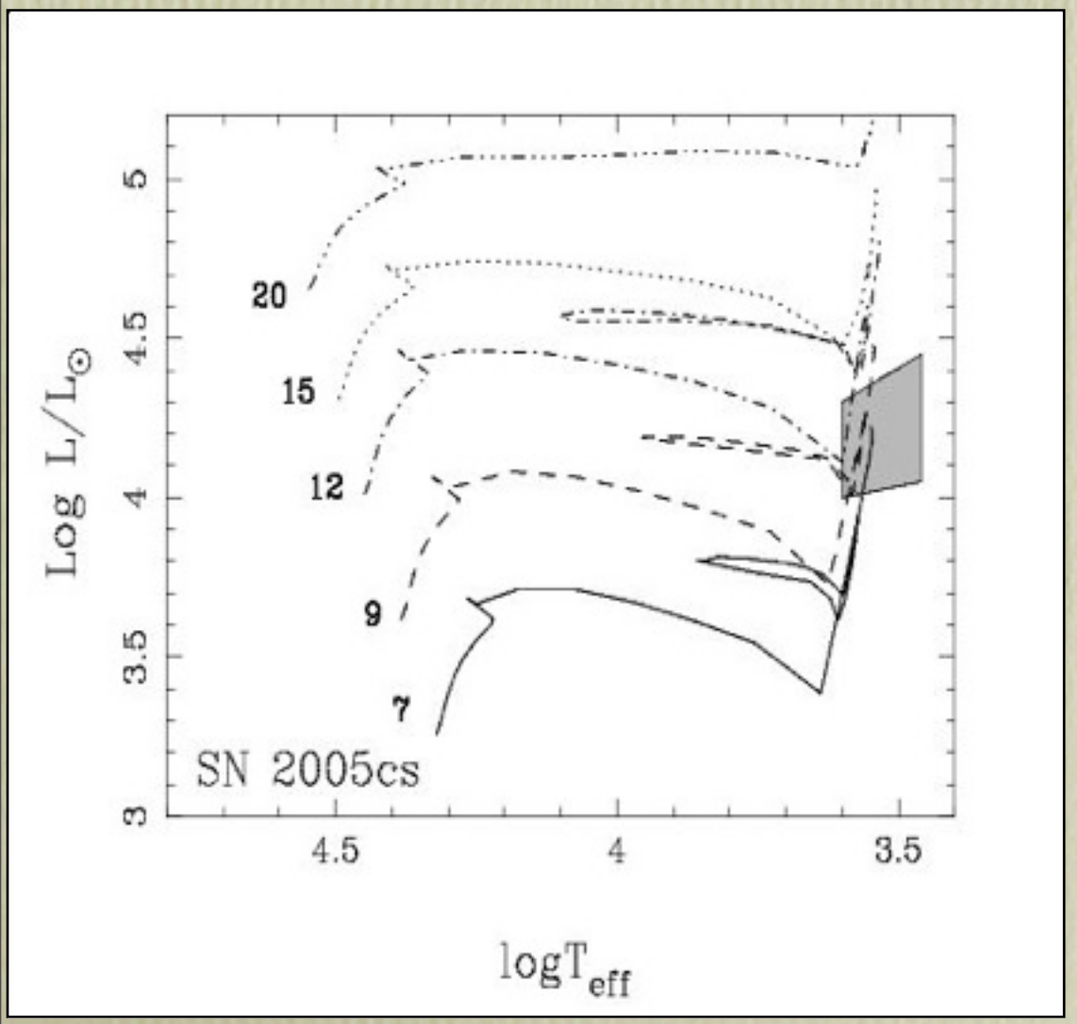
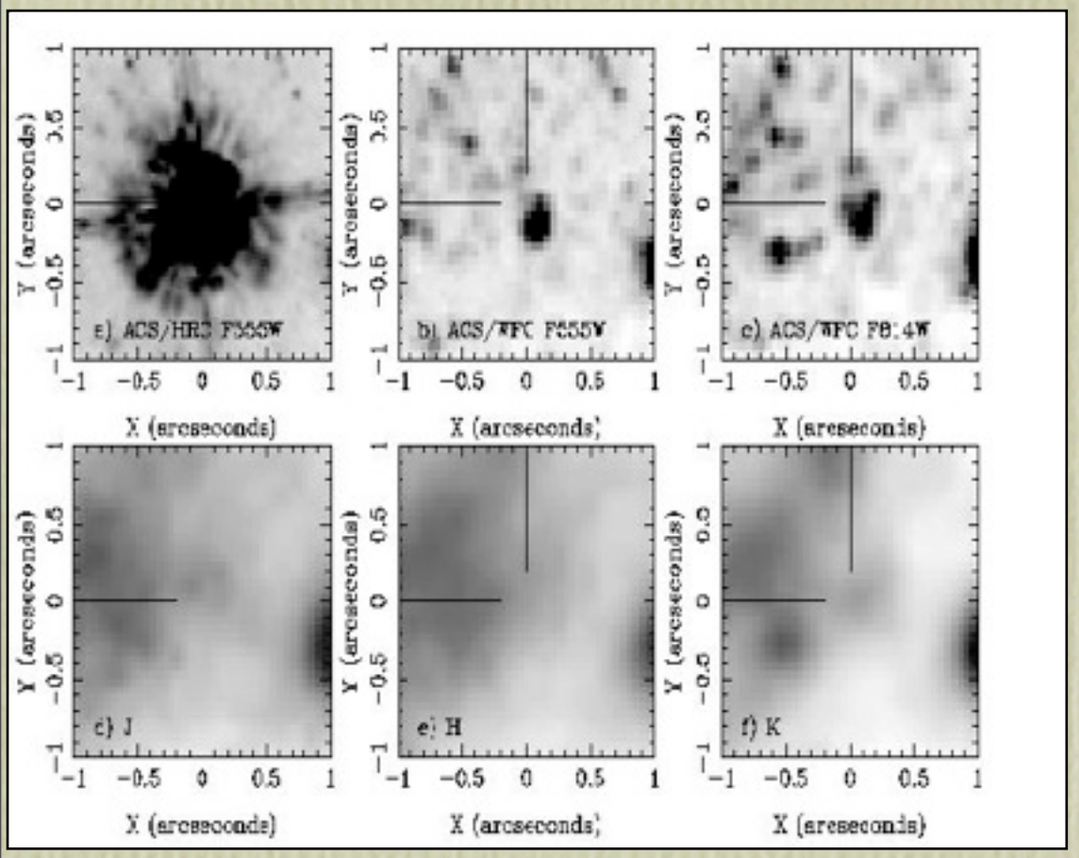
Turatto et al. 1998; Benetti et al. 2001; Zampieri et al. 2003;Pastorello et al. 2004, 2006, 2009

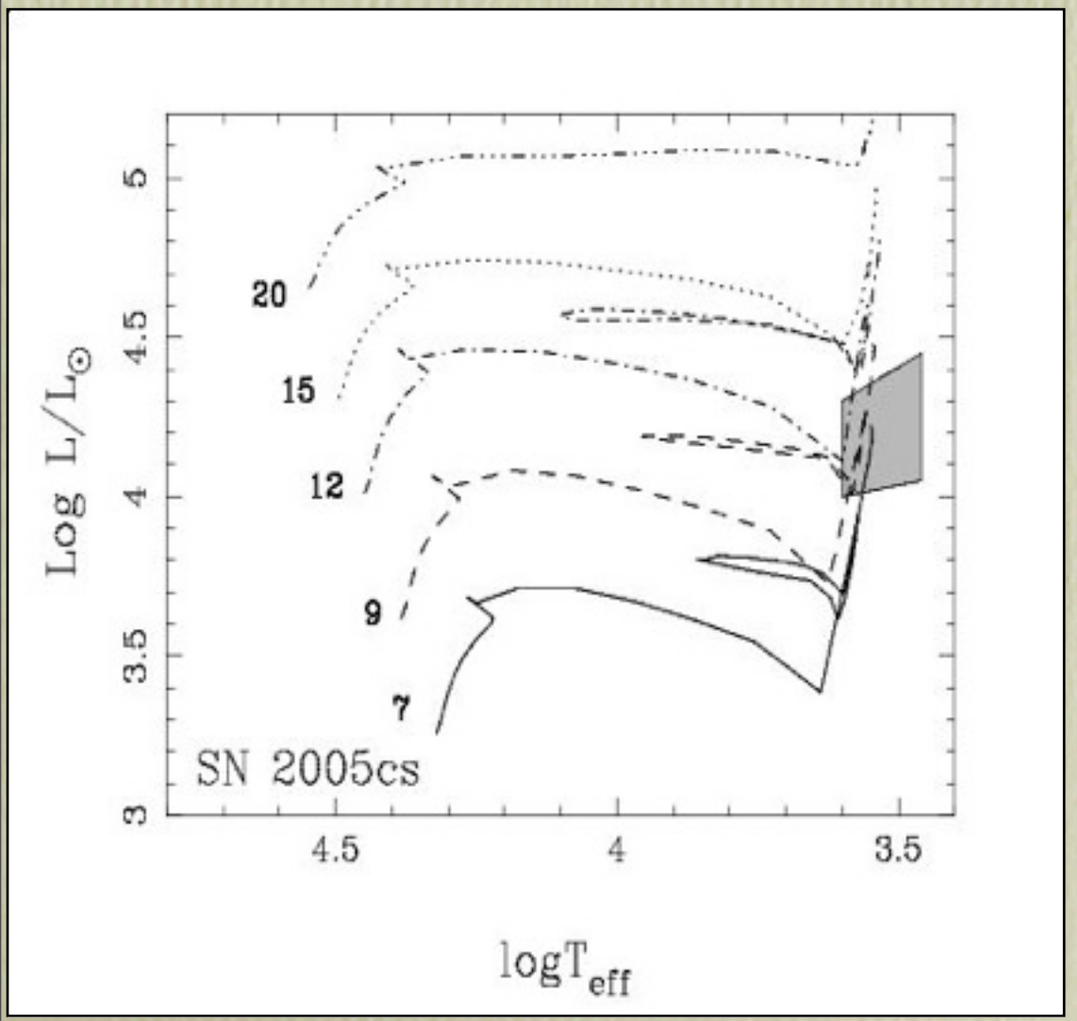
The progenitors:

the case of SN 2005cs









The progenitors:

the case of SN 2005cs

- <u>DIRECT DETECTION</u>
  - 8-10 $M_\odot$ *(Maund et al. 2005, Li et al. 2006)*
  - 6-8 $M_\odot$ *(Eldridge et al. 2007)*
  - 6-10 $M_\odot$ (Smartt et al. 2009)
- <u>SN DATA MODELING</u>
  - 17.3±1.0 $M_\odot$ *(Utrobin & Chugai 2008)*
  - 10-15$M_\odot$ *(Pastorello et al. 2009)*

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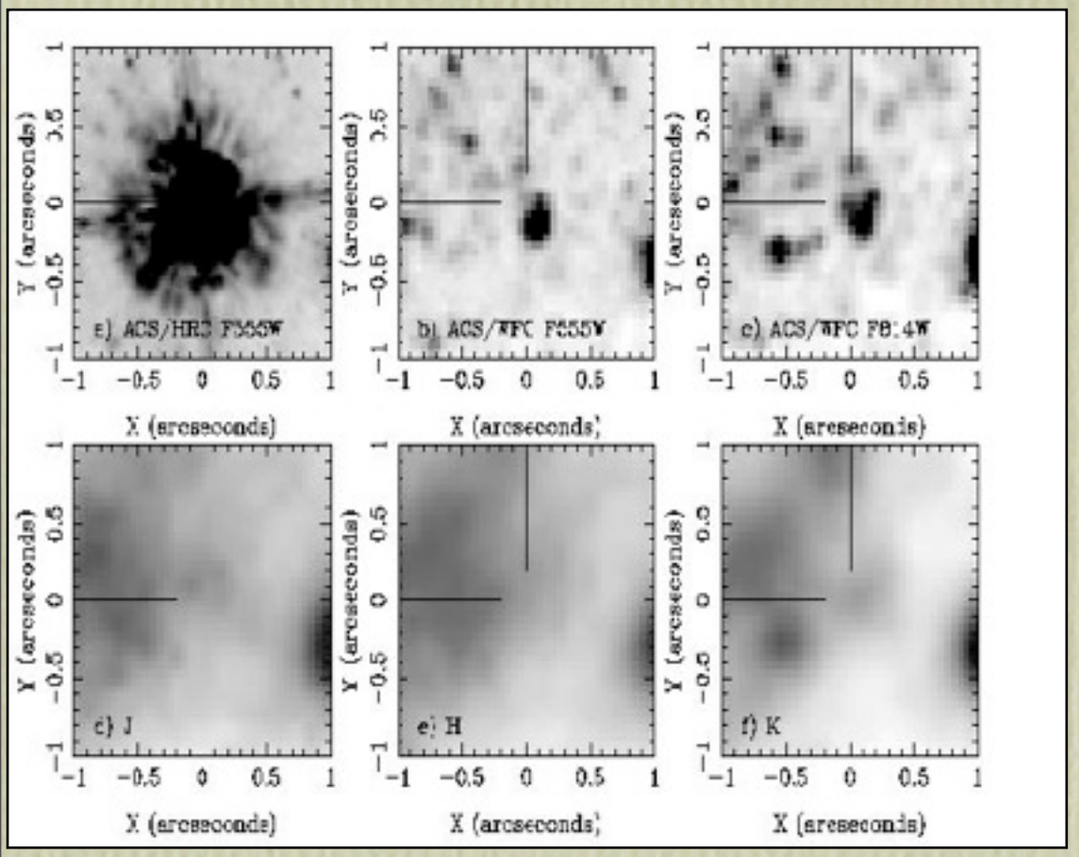

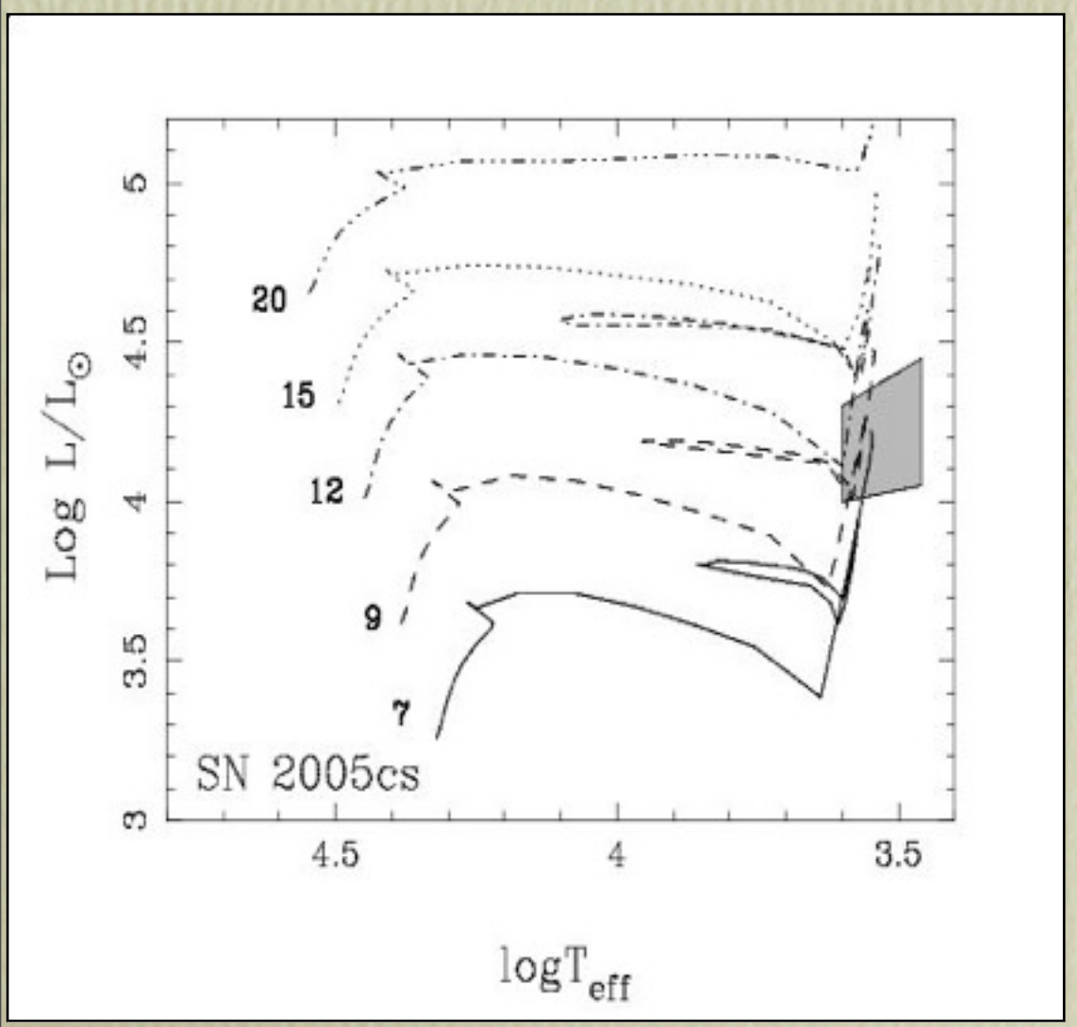

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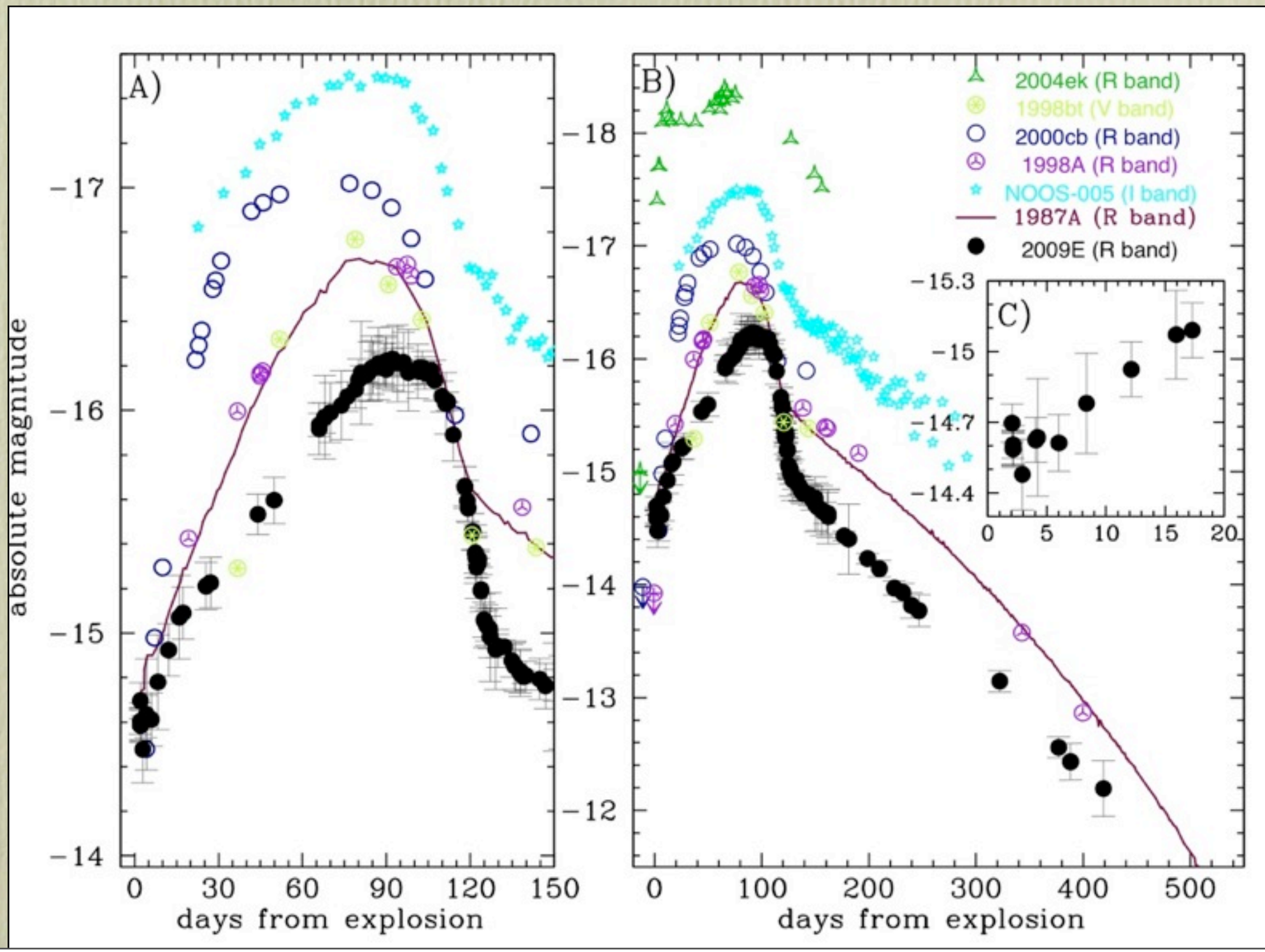
SOME DISCREPANCY

(see Morgan Fraser's talk!)

SN 2009E - a faint clone of SN 1987A



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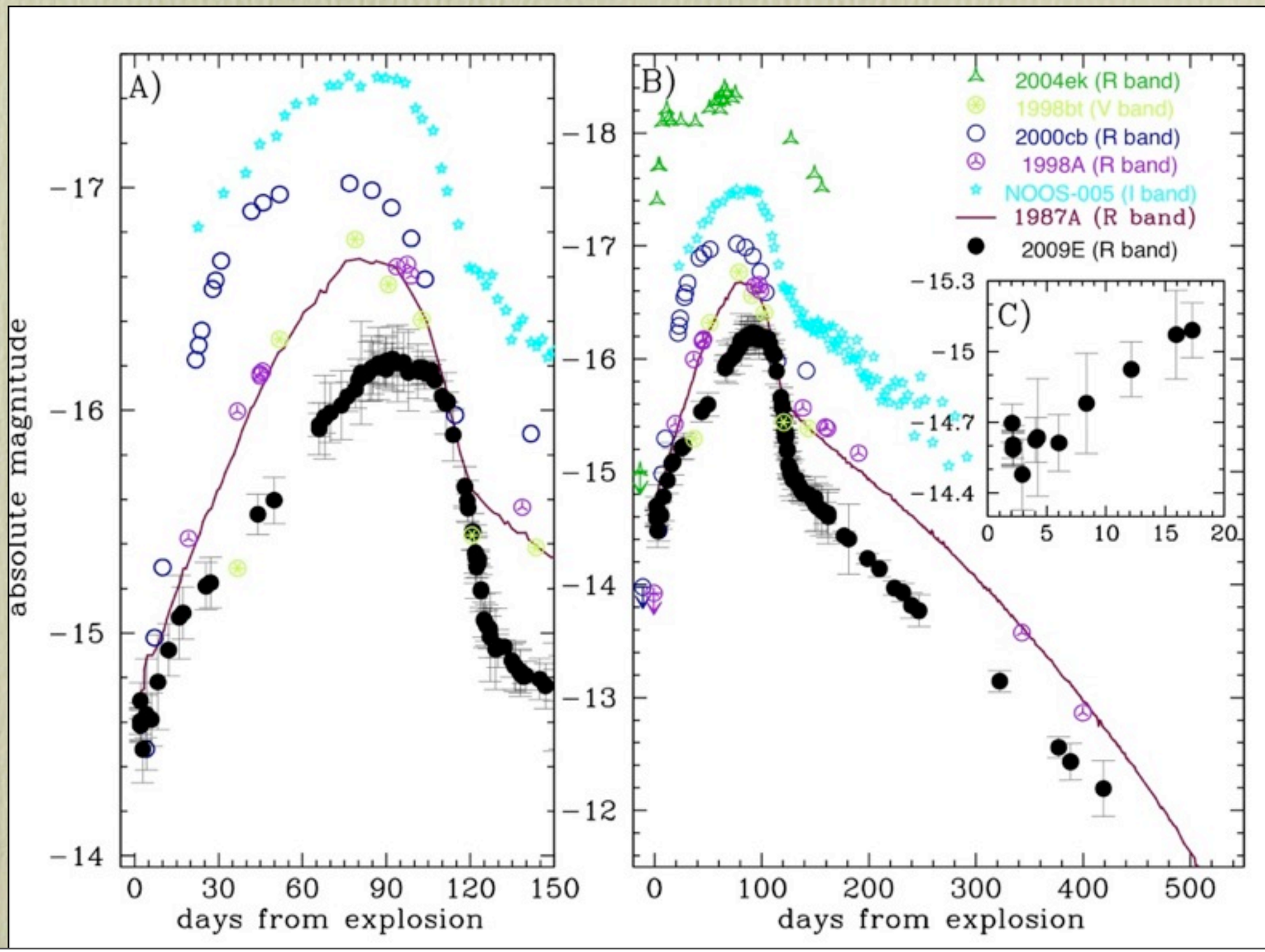

Pastorello et al.
(to be submitted)

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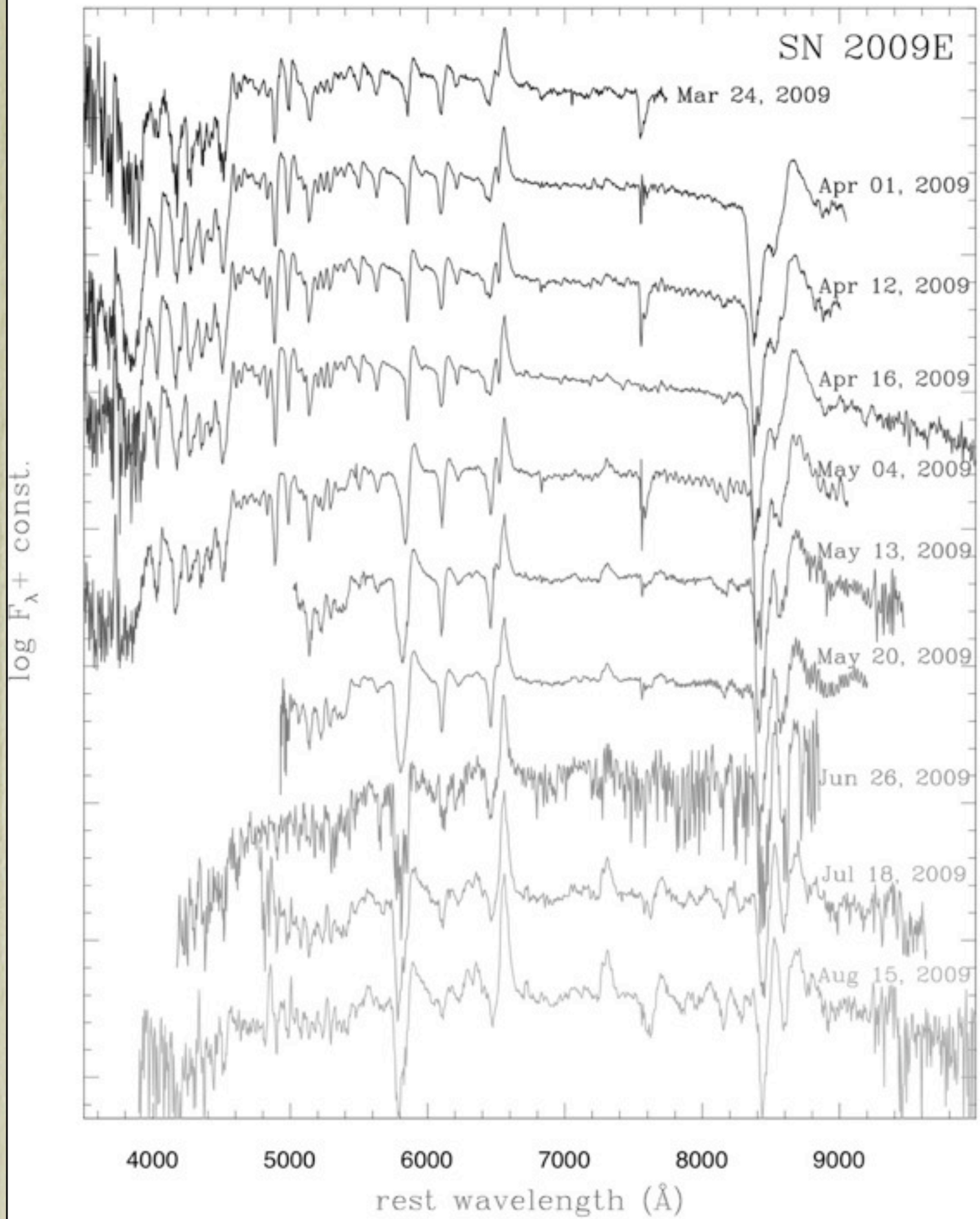

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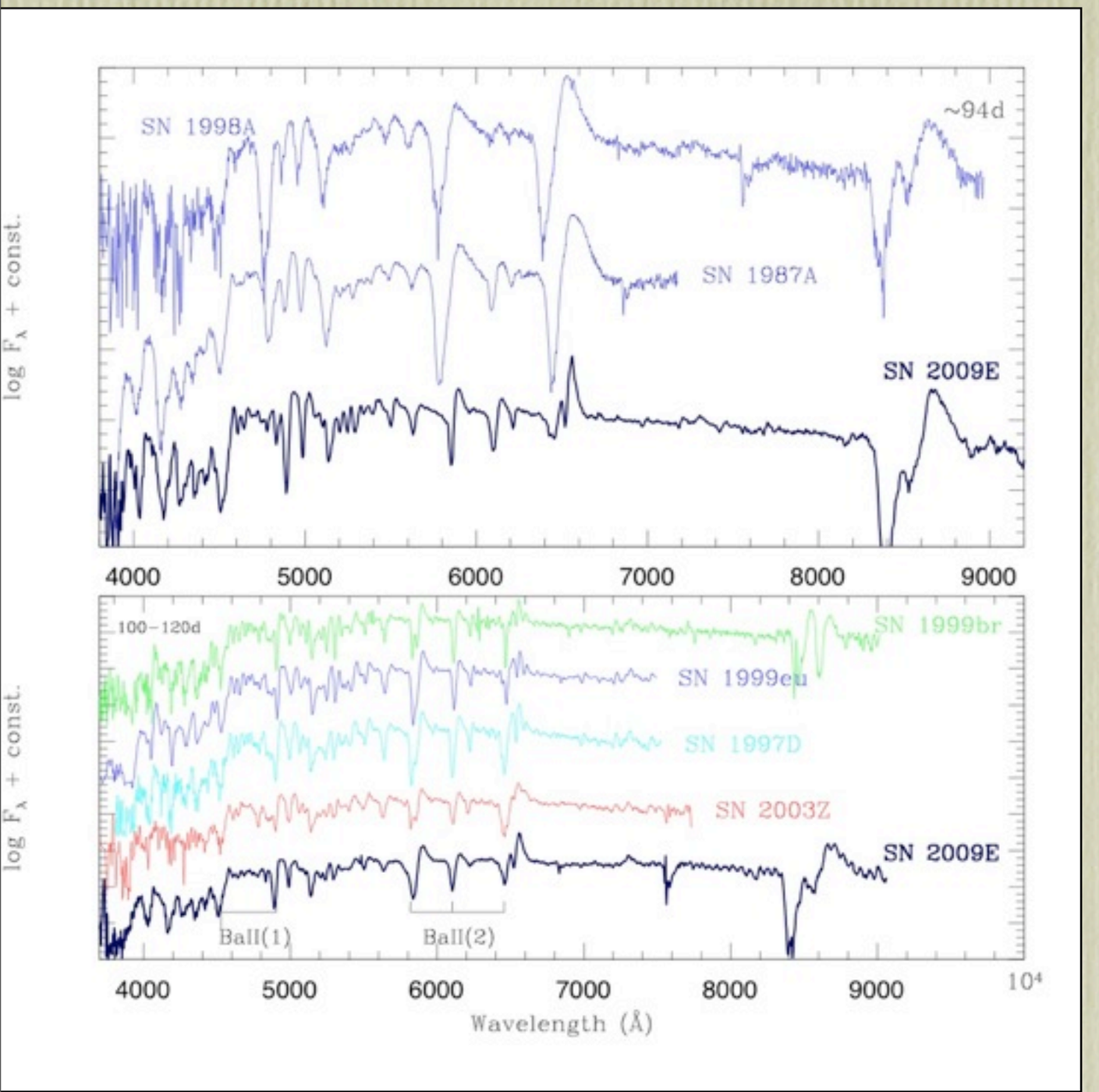

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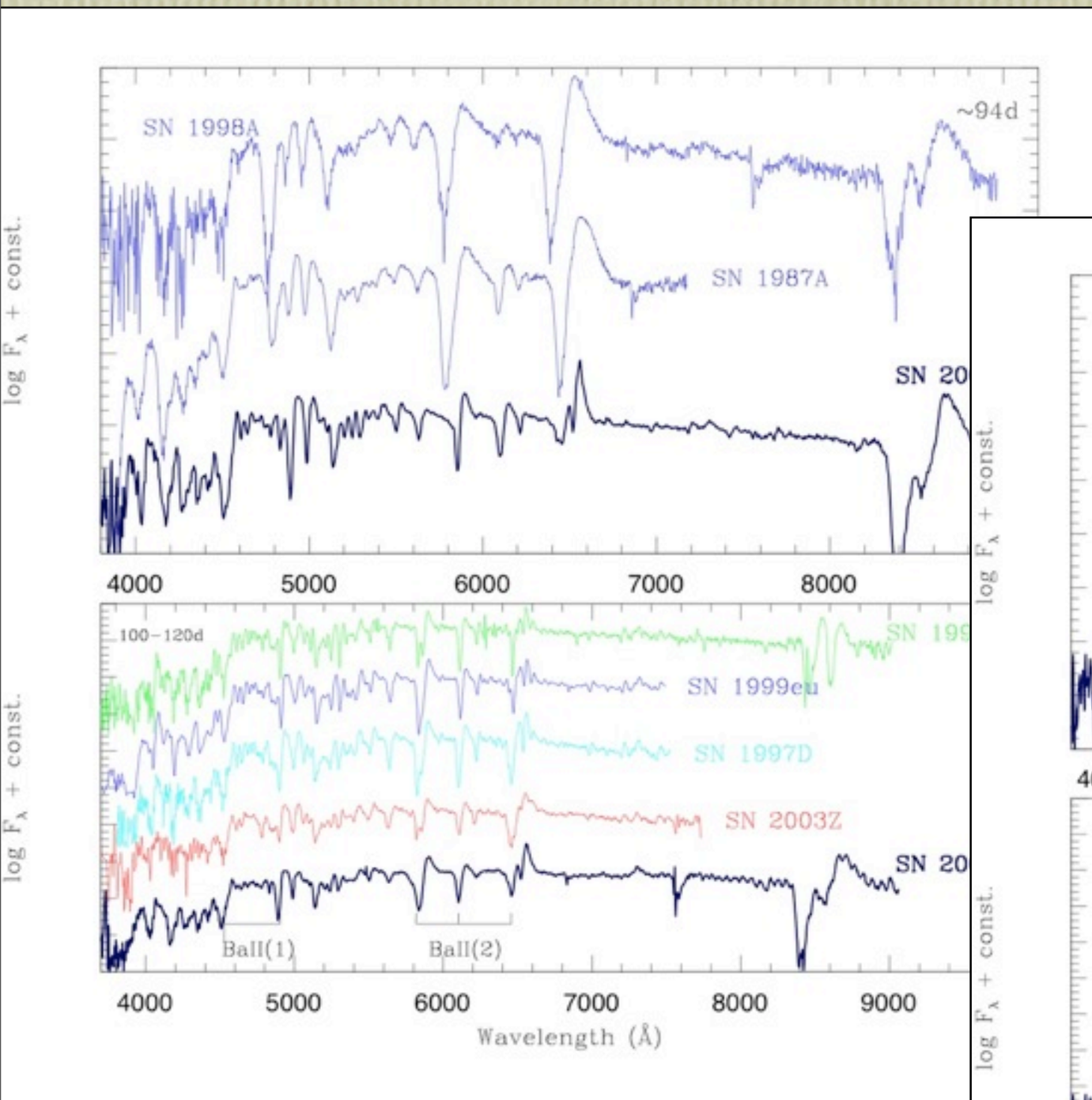

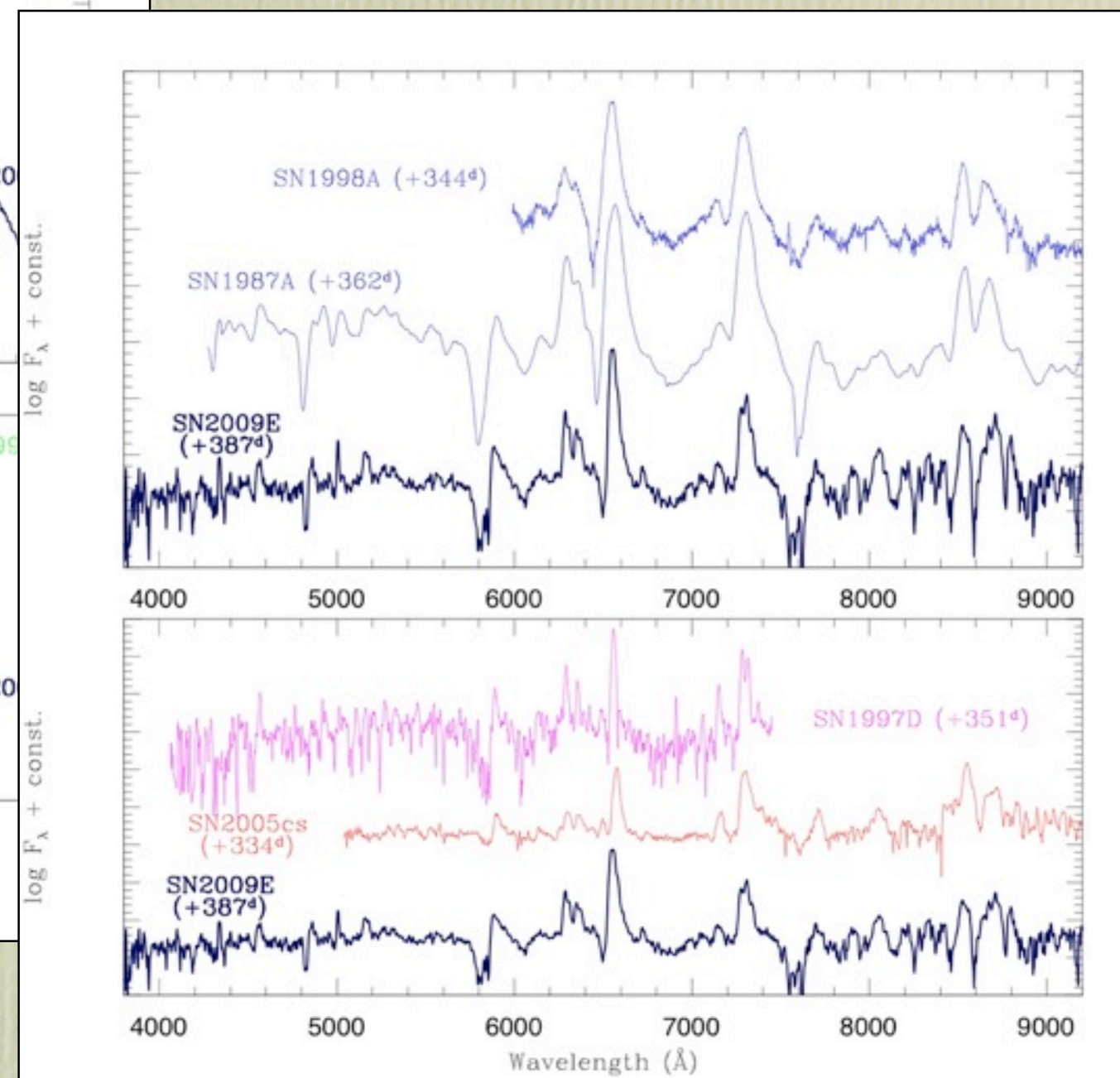

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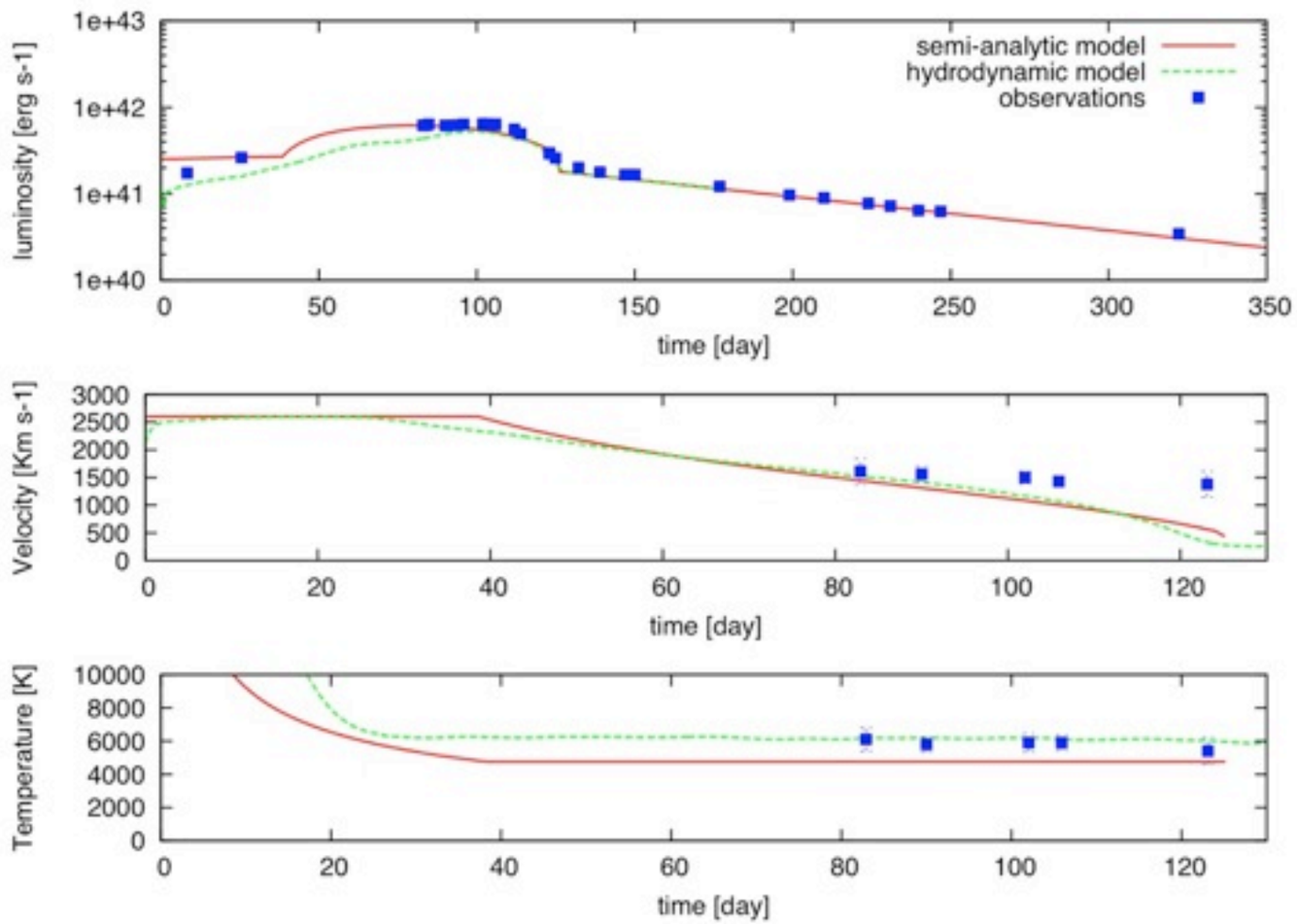

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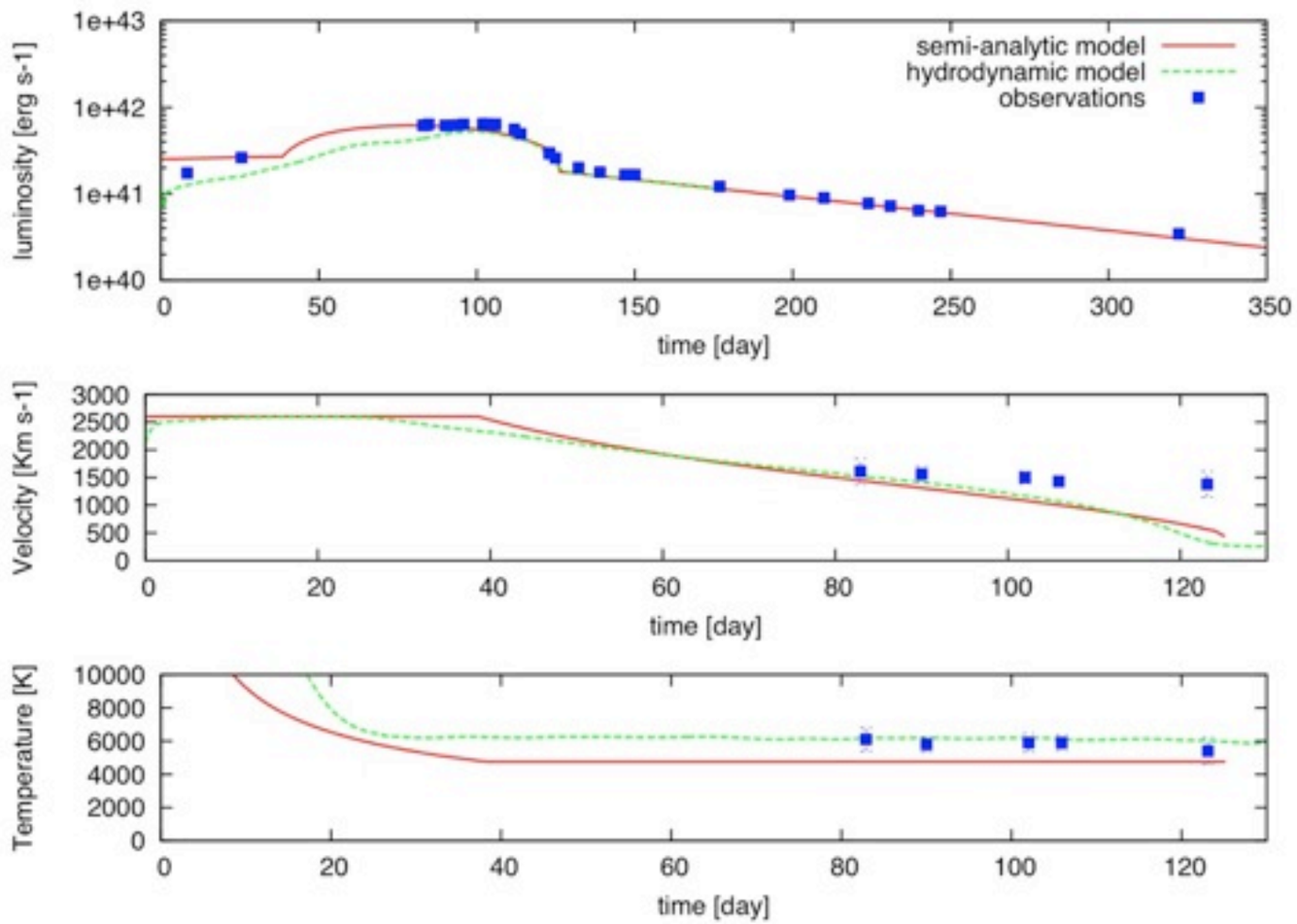

Pastorello et al. (to be submitted)

- Semi-analytic Model:
  - E_k = 1.3 foe
  - R_o = 6 x 10^{12} cm
  - M_{ej} = 26 M_o
  - $M(^{56}Ni)$ = 0.039 M_o

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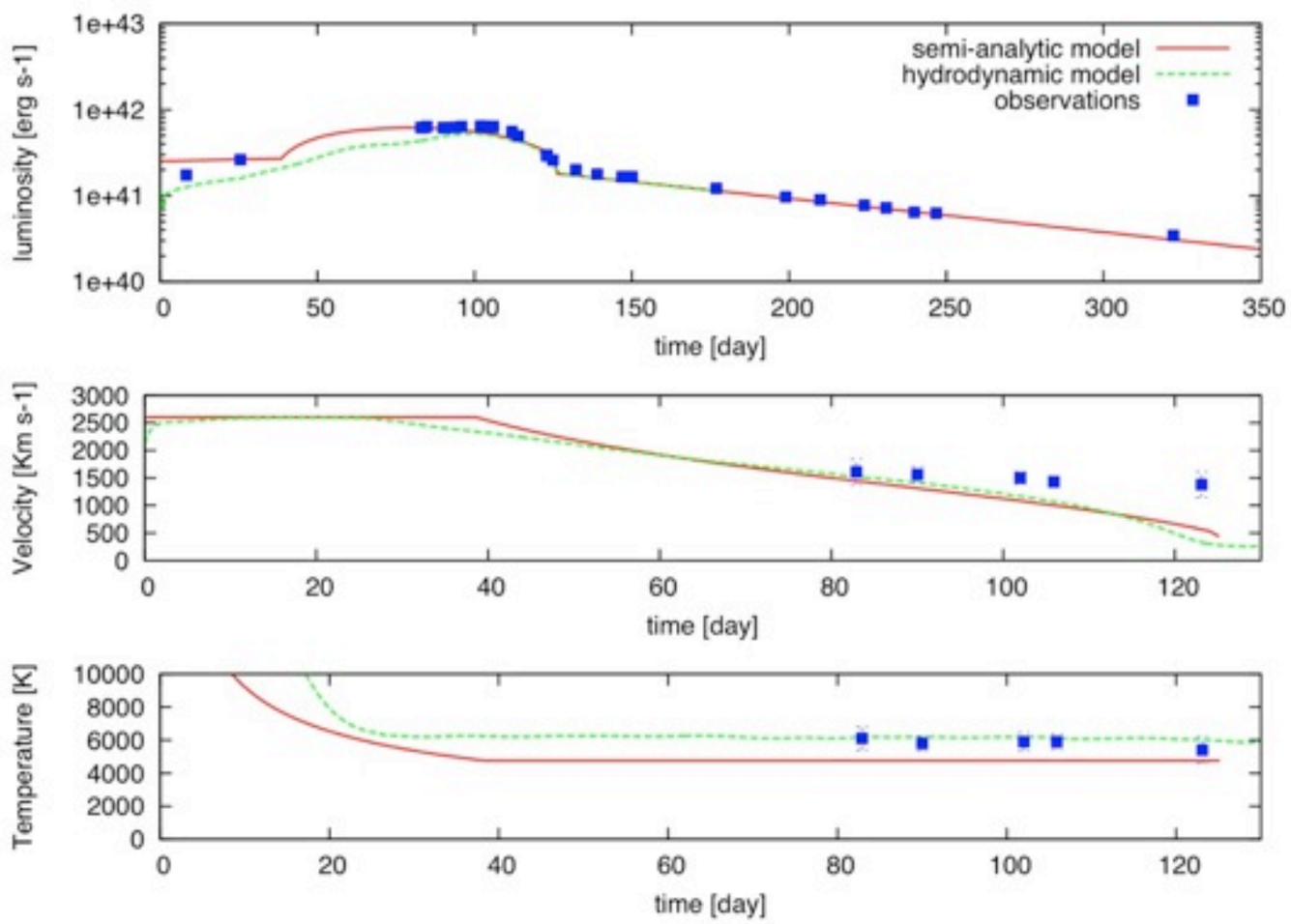

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- Hydrodynamic Model:
  - E_k = 0.6 foe
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  - $M(^{56}Ni)$ = 0.043 M_o

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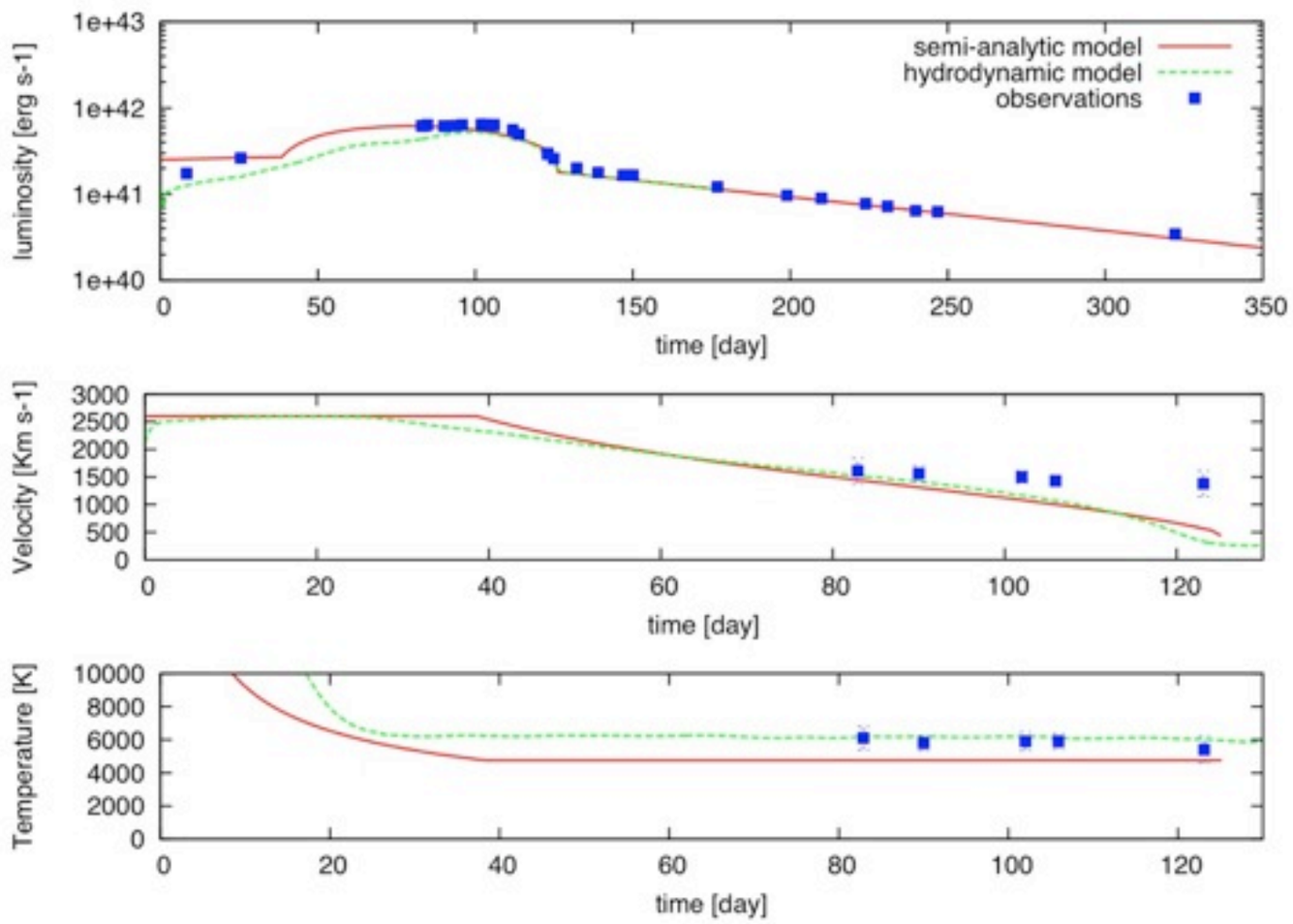

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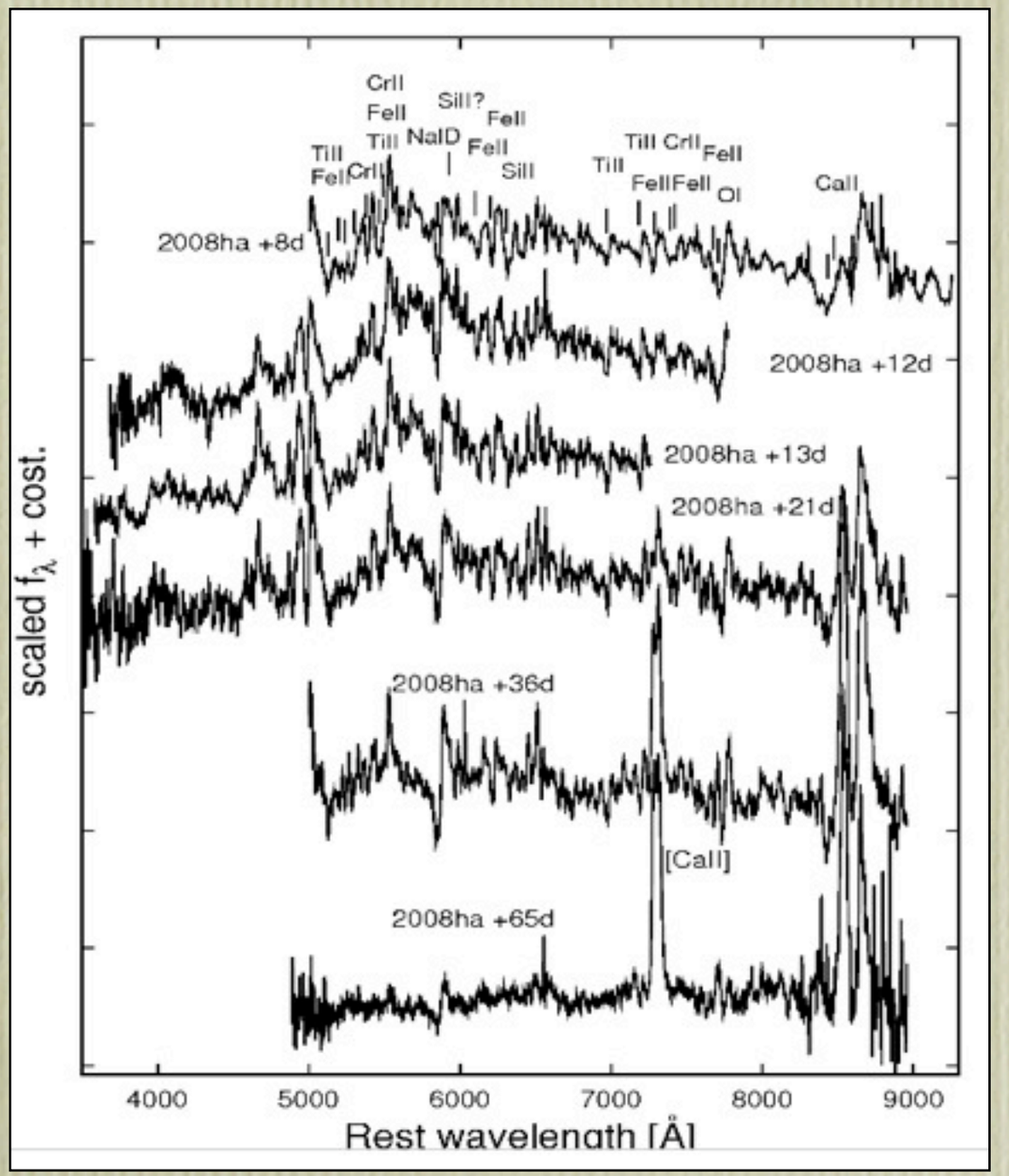
PARAMETERS SIMILAR TO THOSE OF 1987A!

(see posters of Io Kleiser and Francesco Taddia!)

Sub-luminous stripped-envelope SNe



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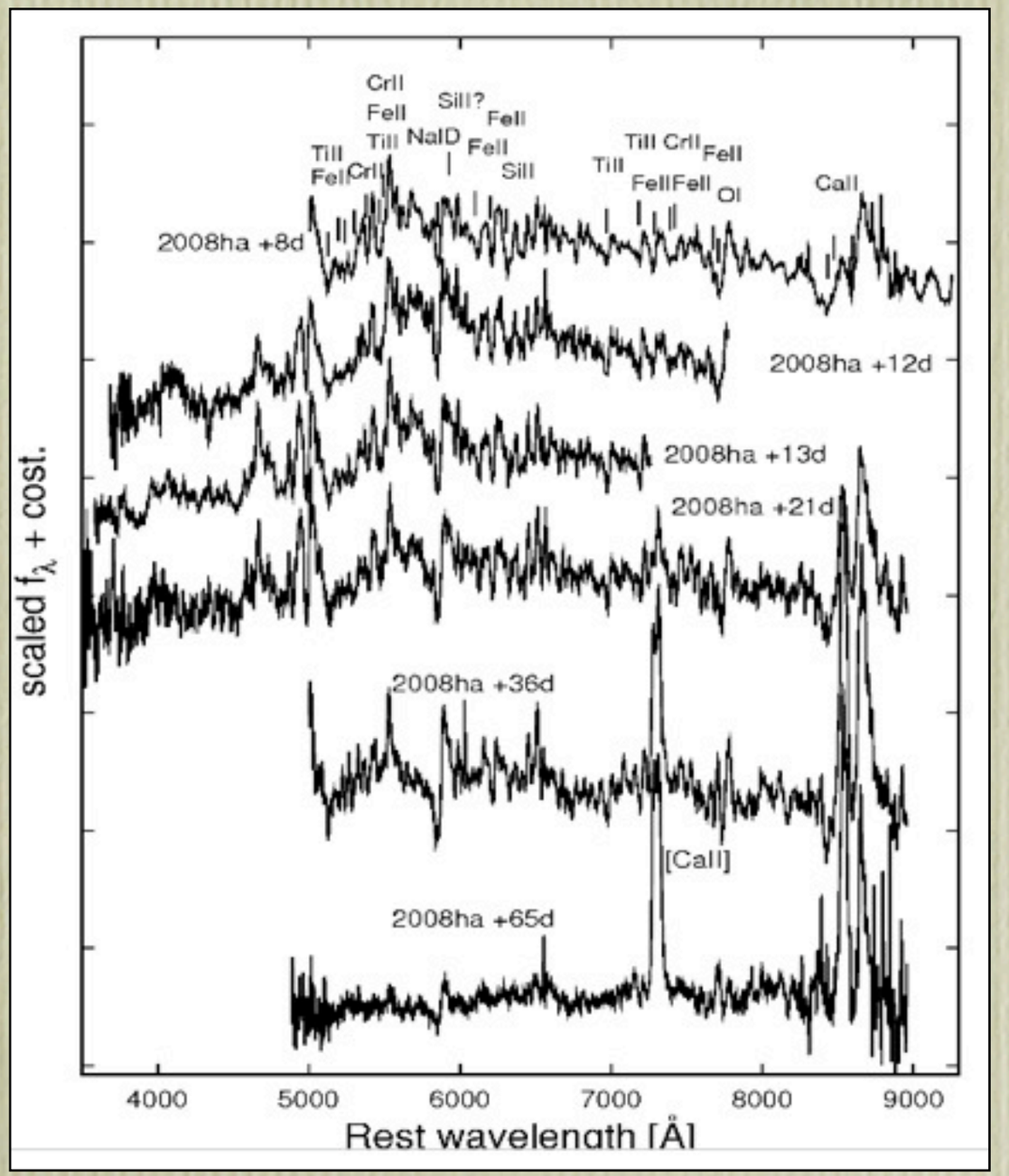
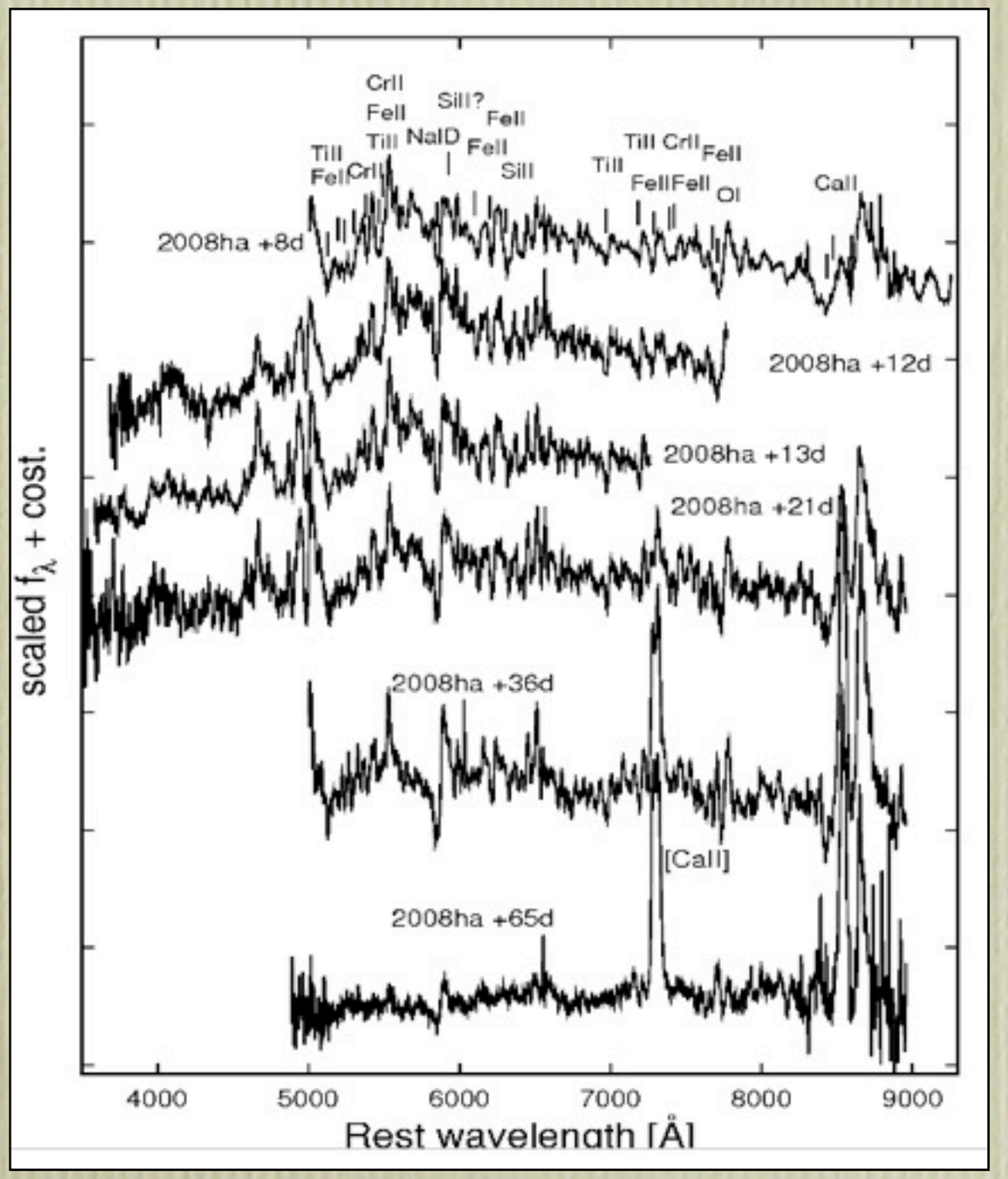
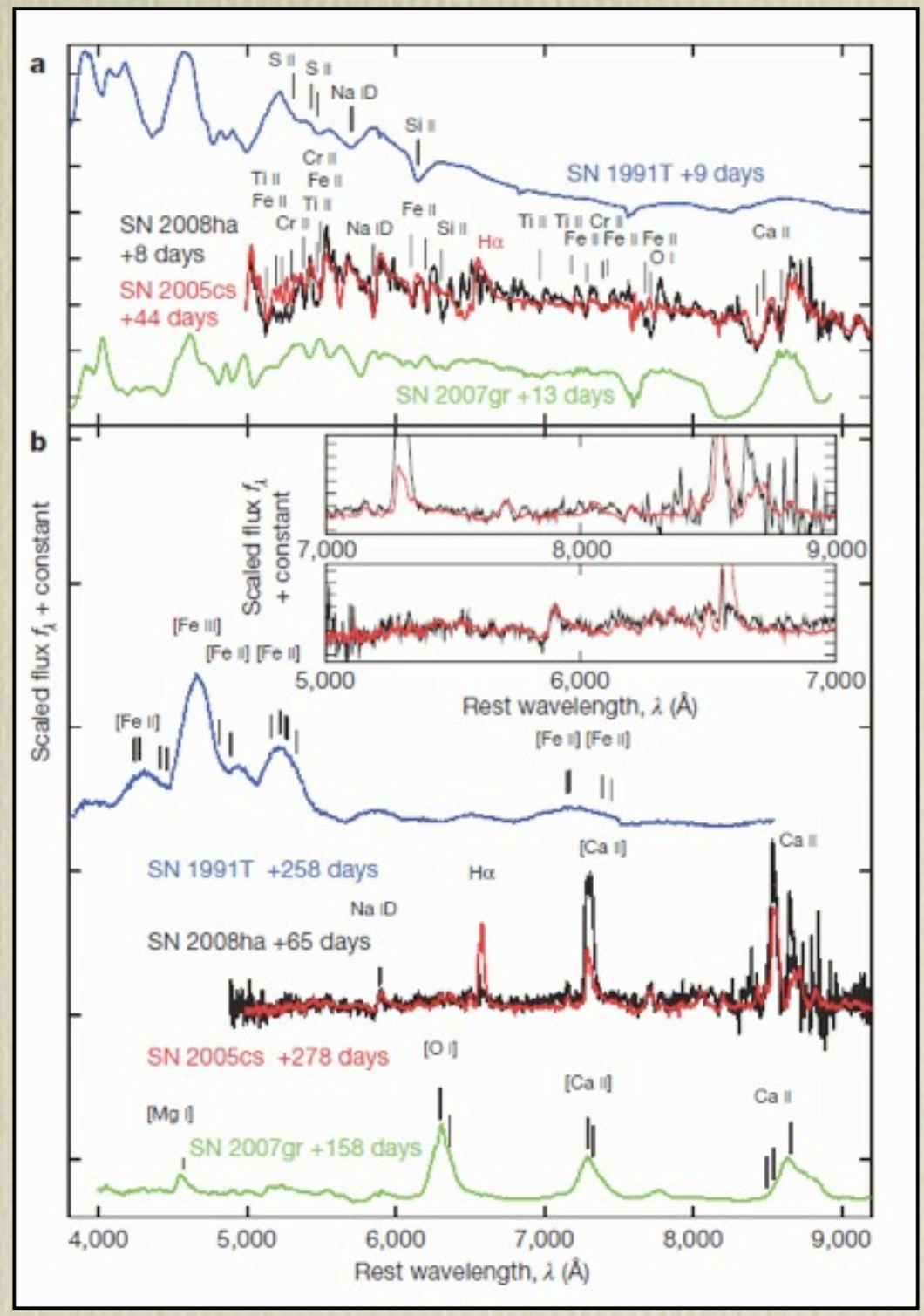


Valenti et al. 2009; also Foley at al. 2009, 1010
Narayan et al .2010; Kasliwal et a. 2010

Sub-luminous stripped-envelope SNe





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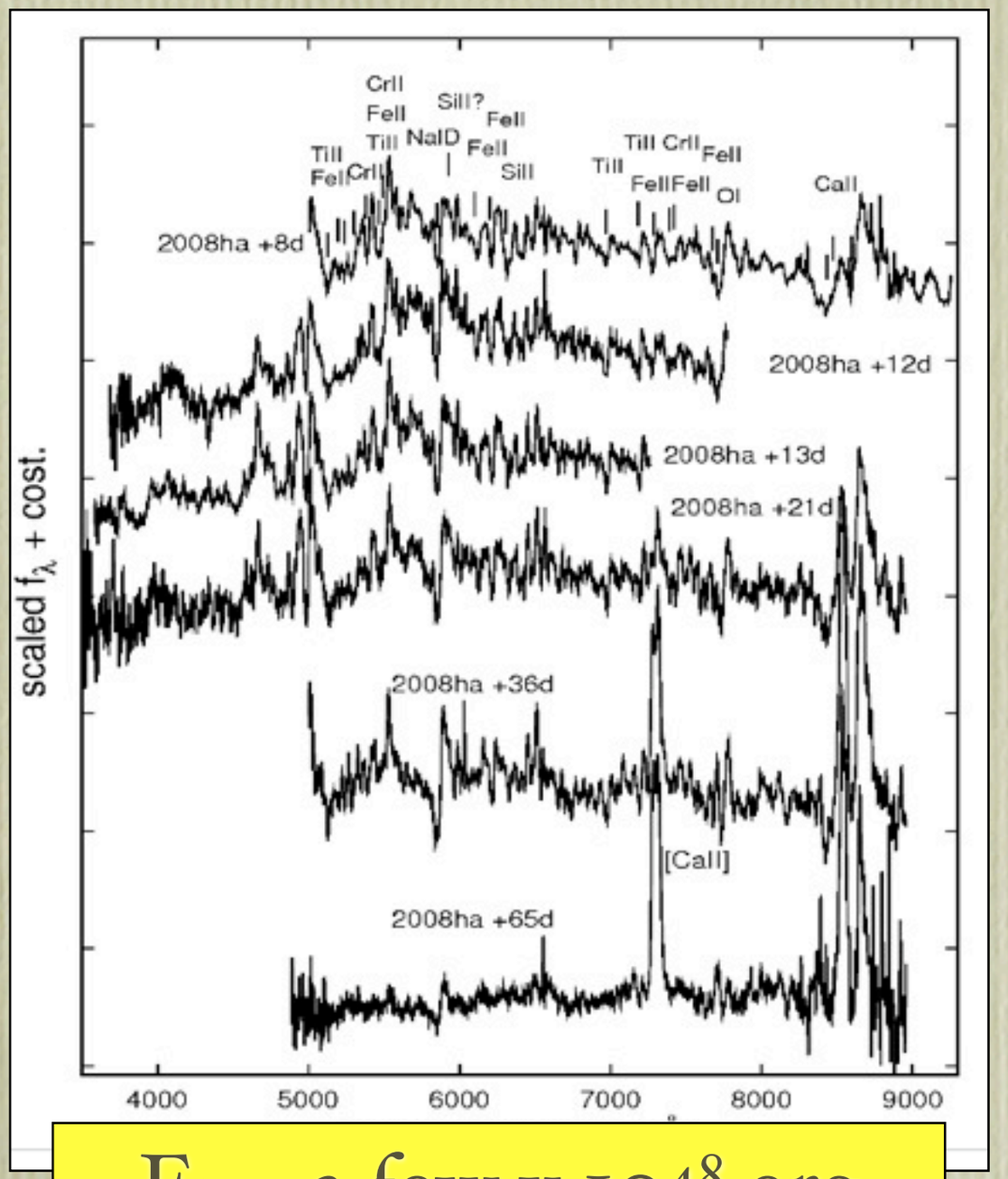

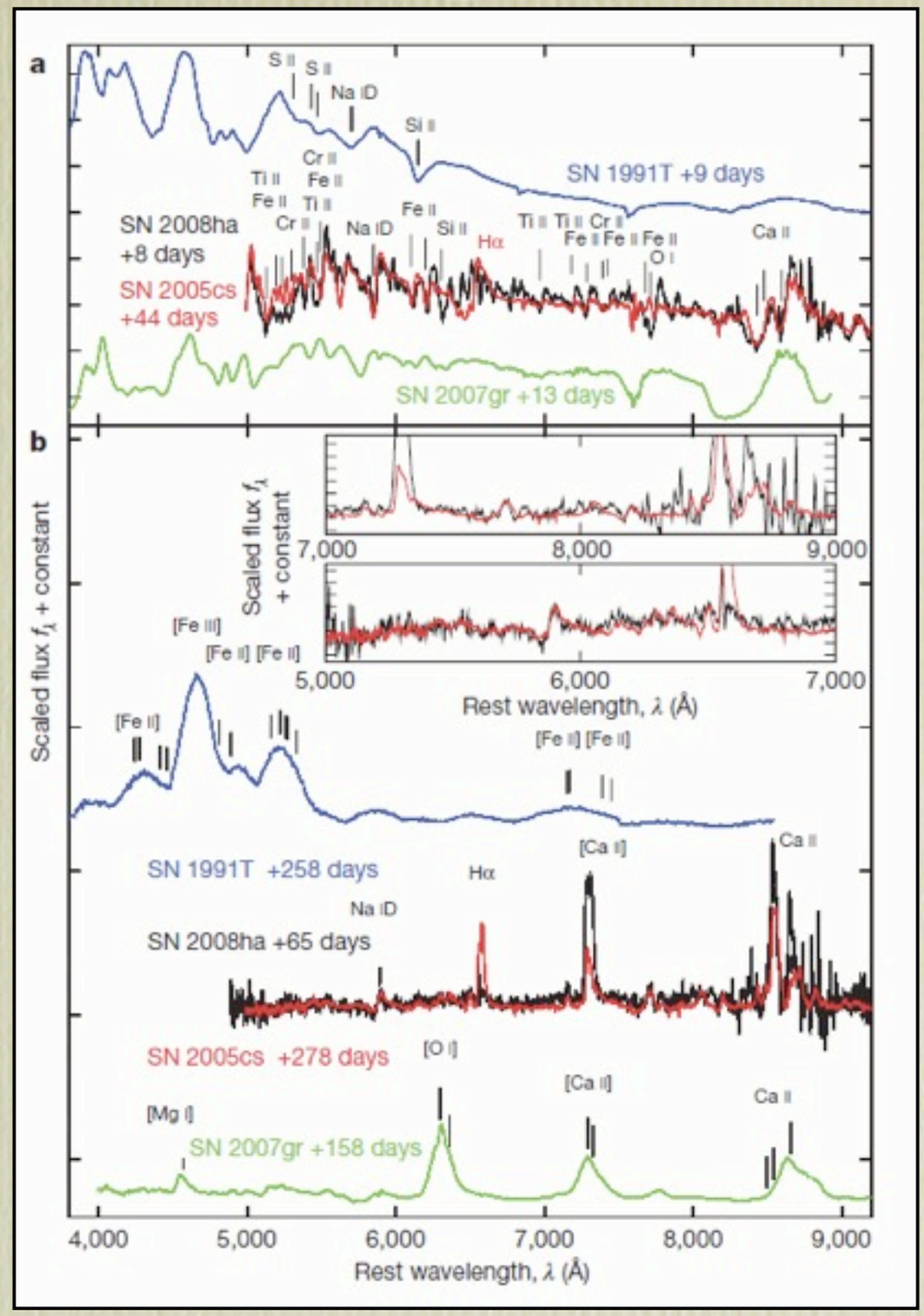

E_k = a few x 10^{48} erg

$M_{ej} \approx 0.07\text{-}0.15\ M_\odot$

$M(^{56}Ni) = 3\text{-}5\ 10^{-3}\ M_\odot$

Valenti et al. 2009; also Foley at al. 2009, 1010
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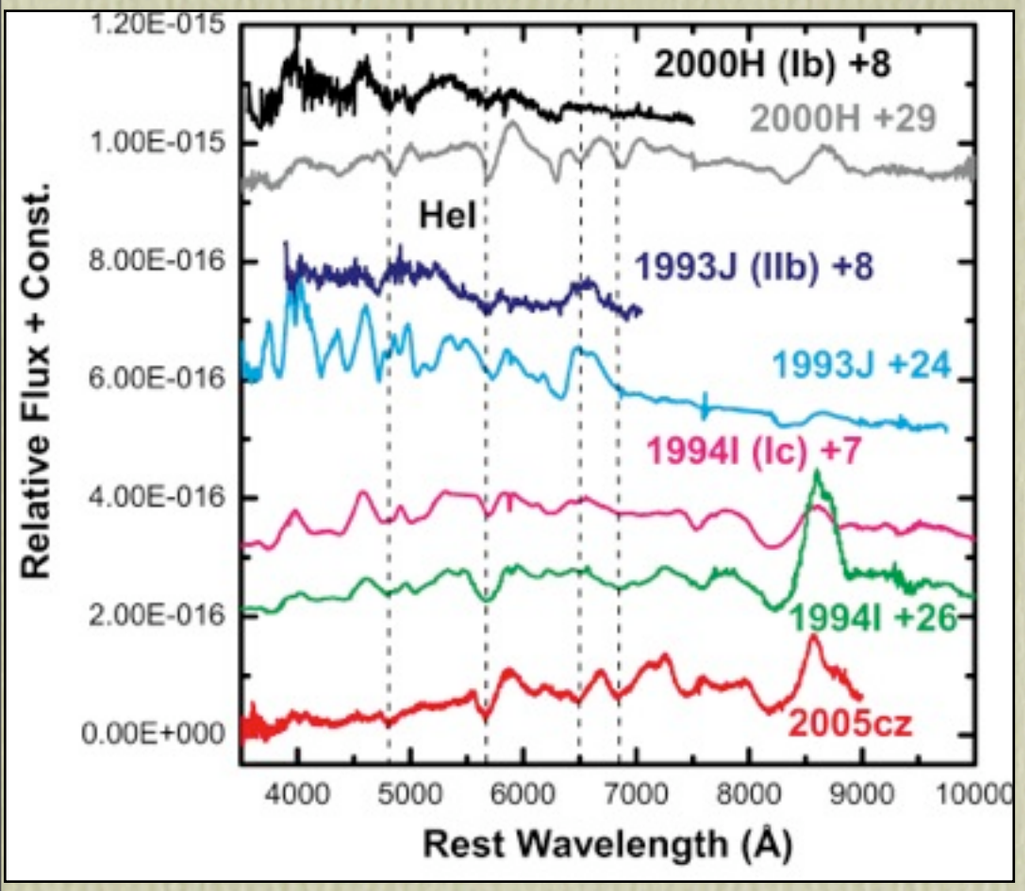

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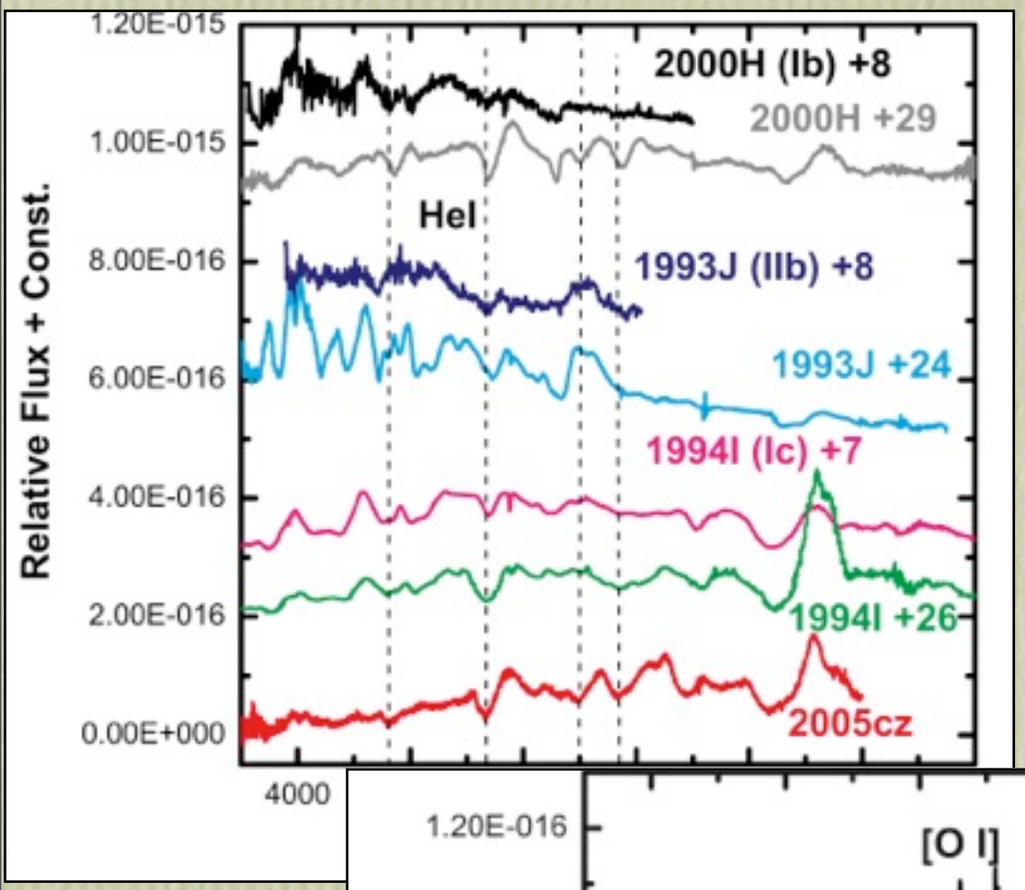

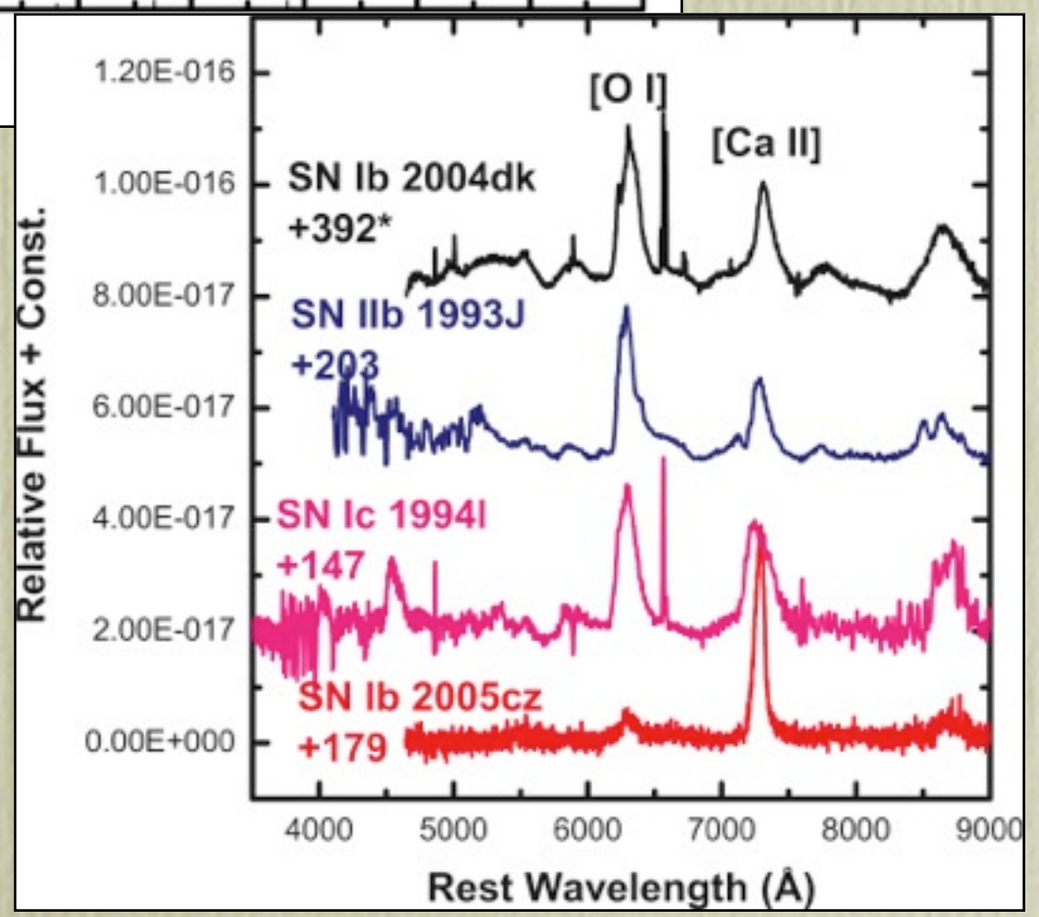

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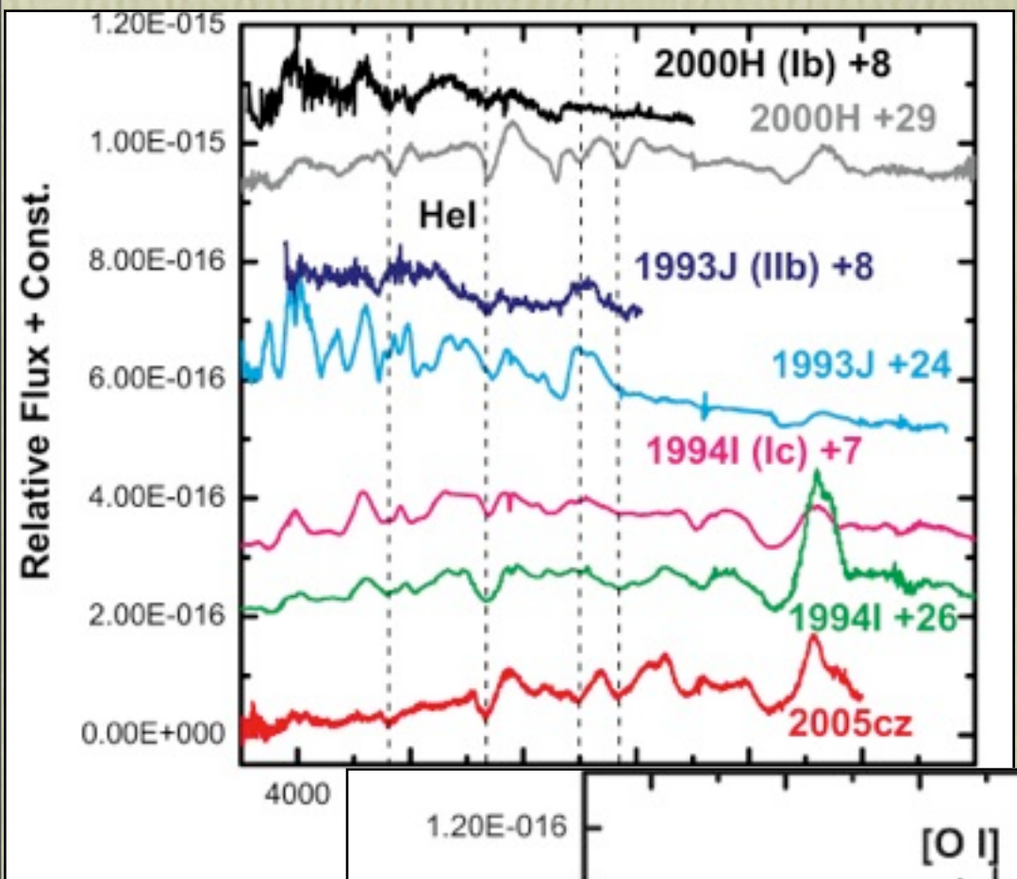
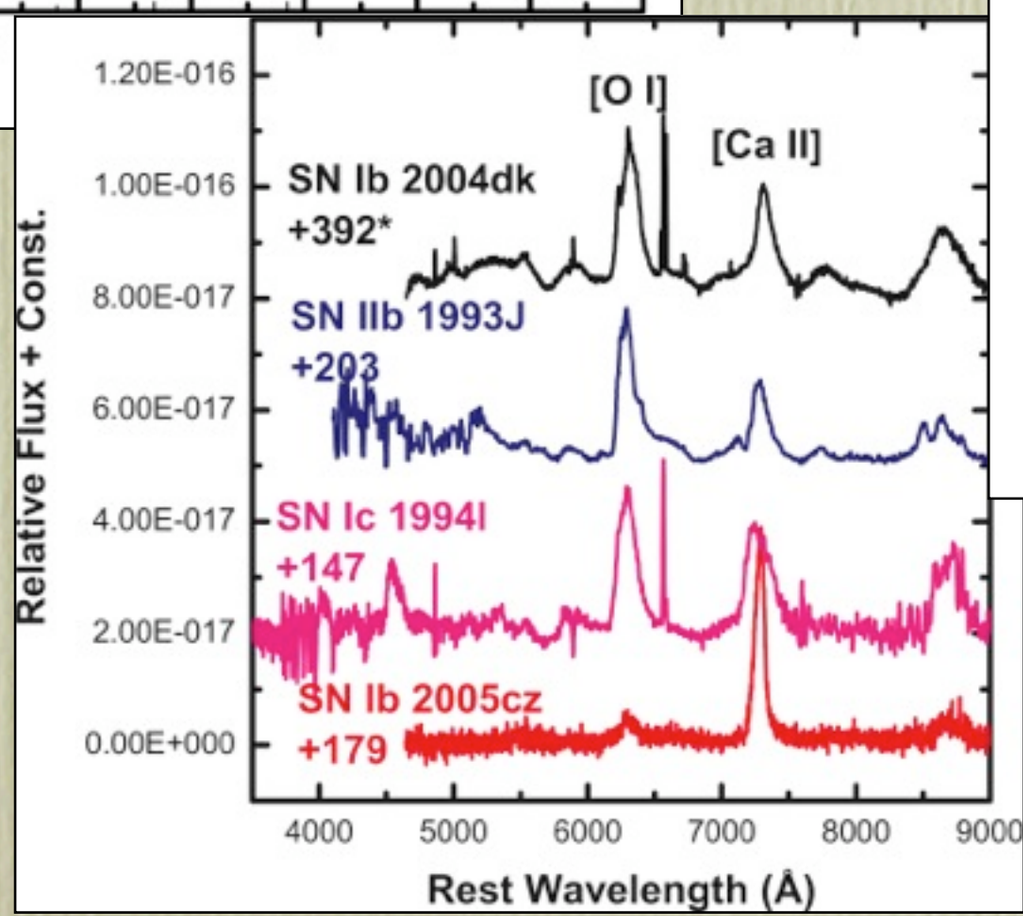
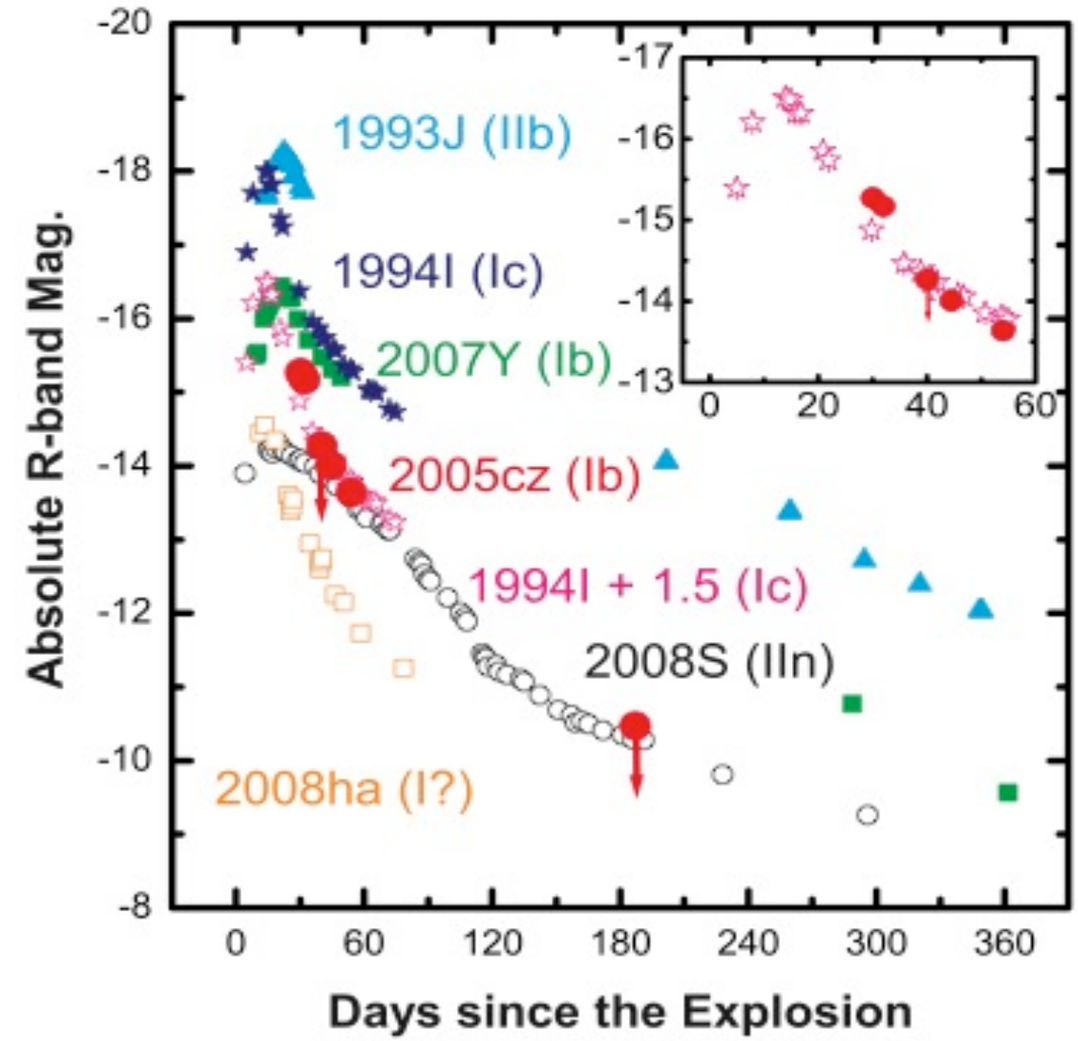
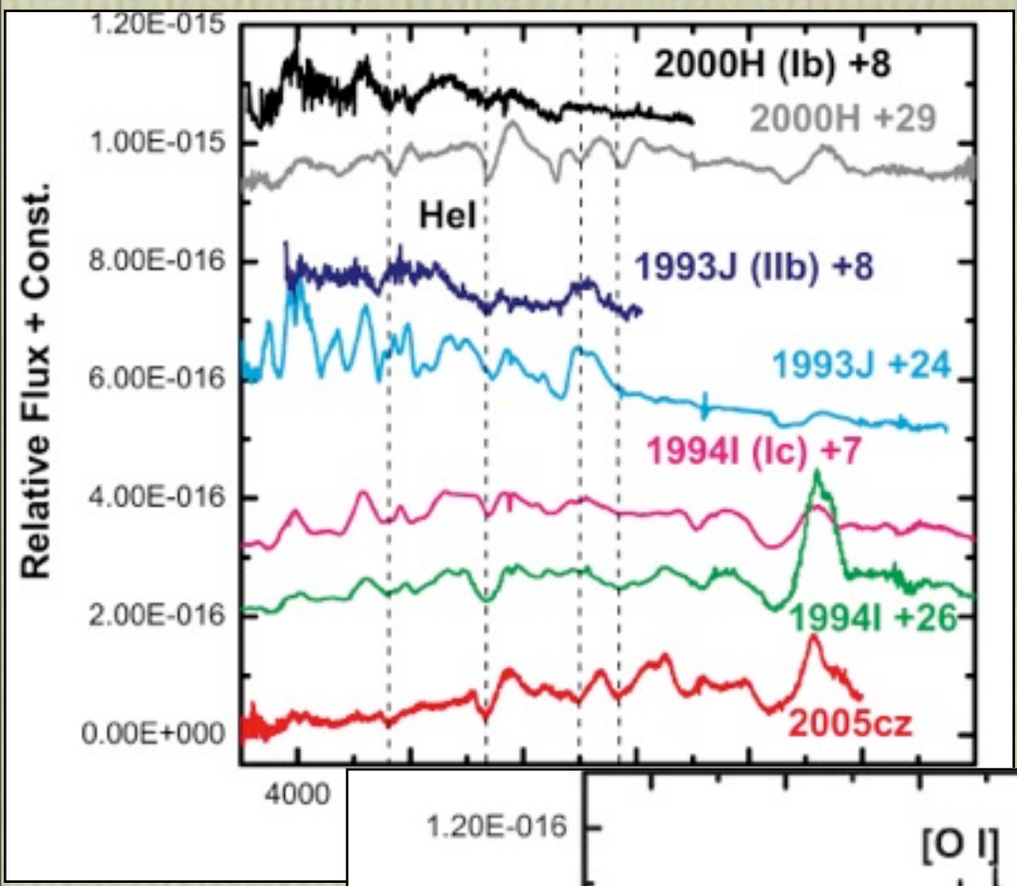


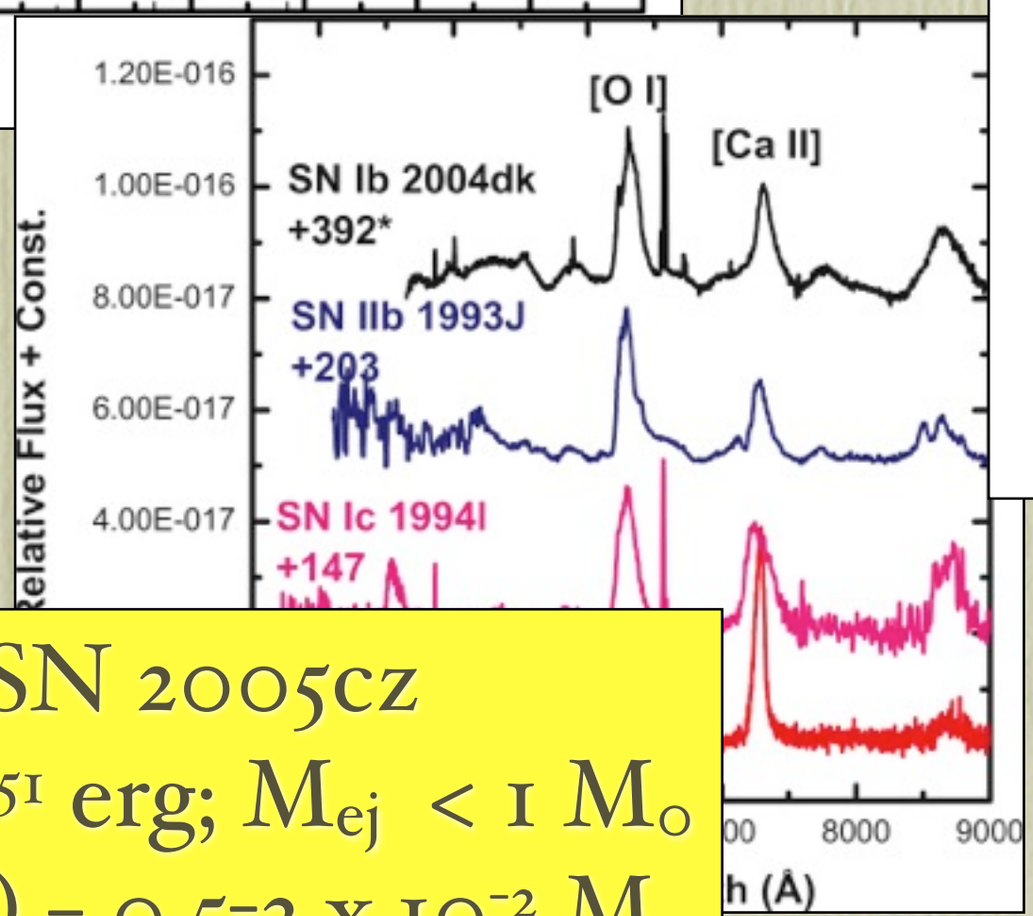


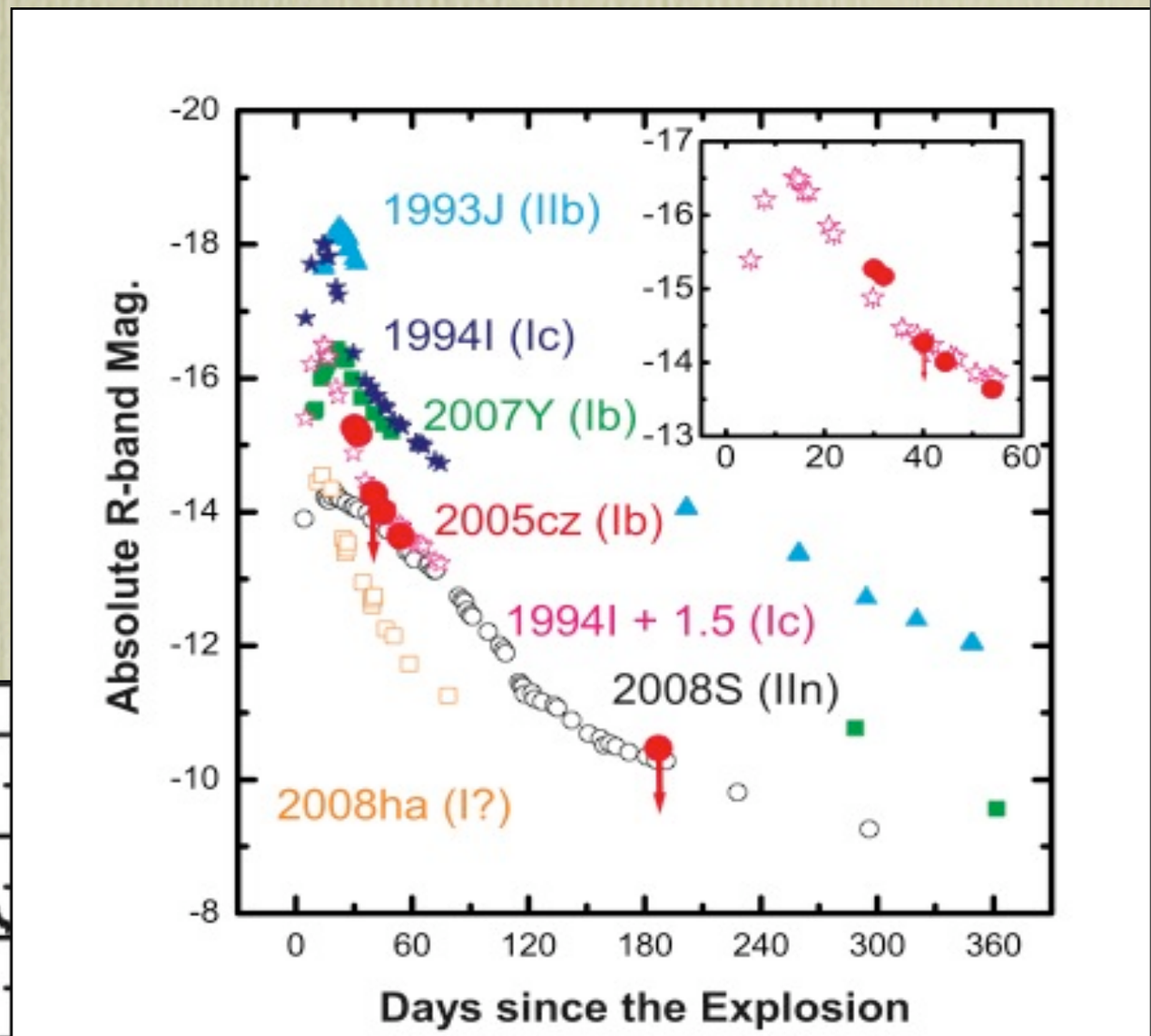


Kawabata et al. 2010, Nature 265, 326

Sub-luminous stripped-envelope SNe







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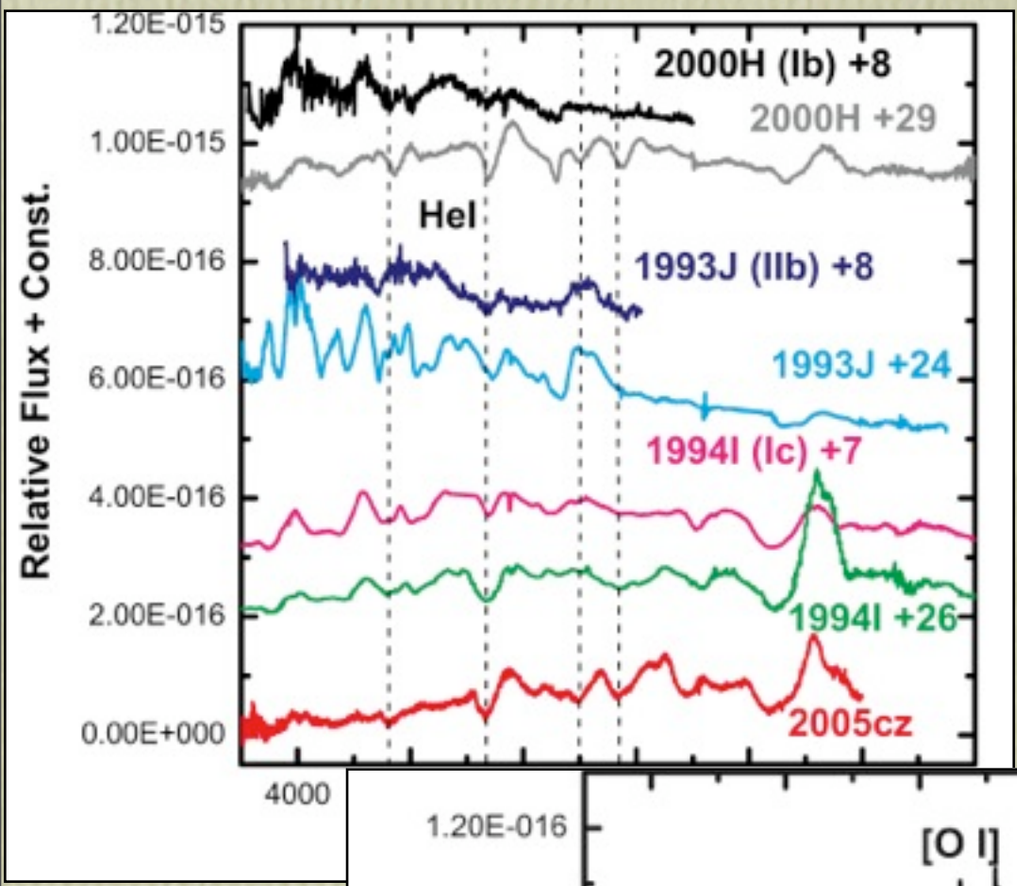
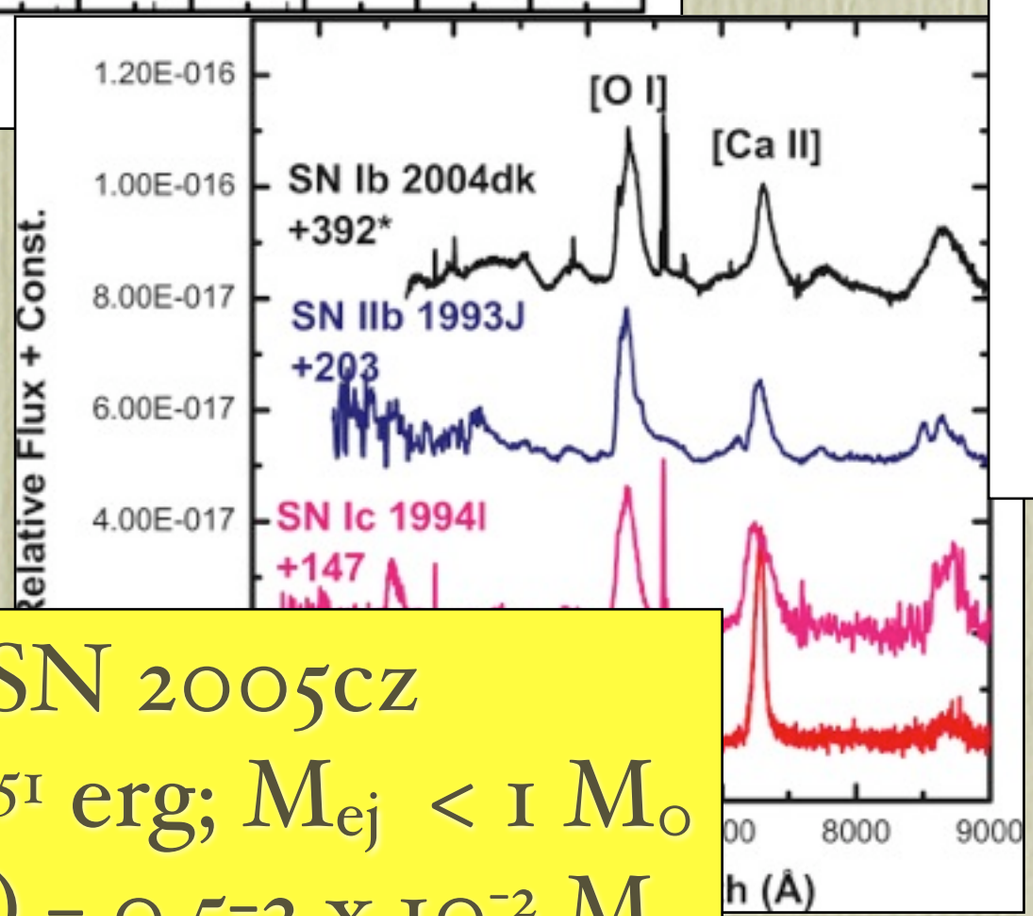
SN 2005cz

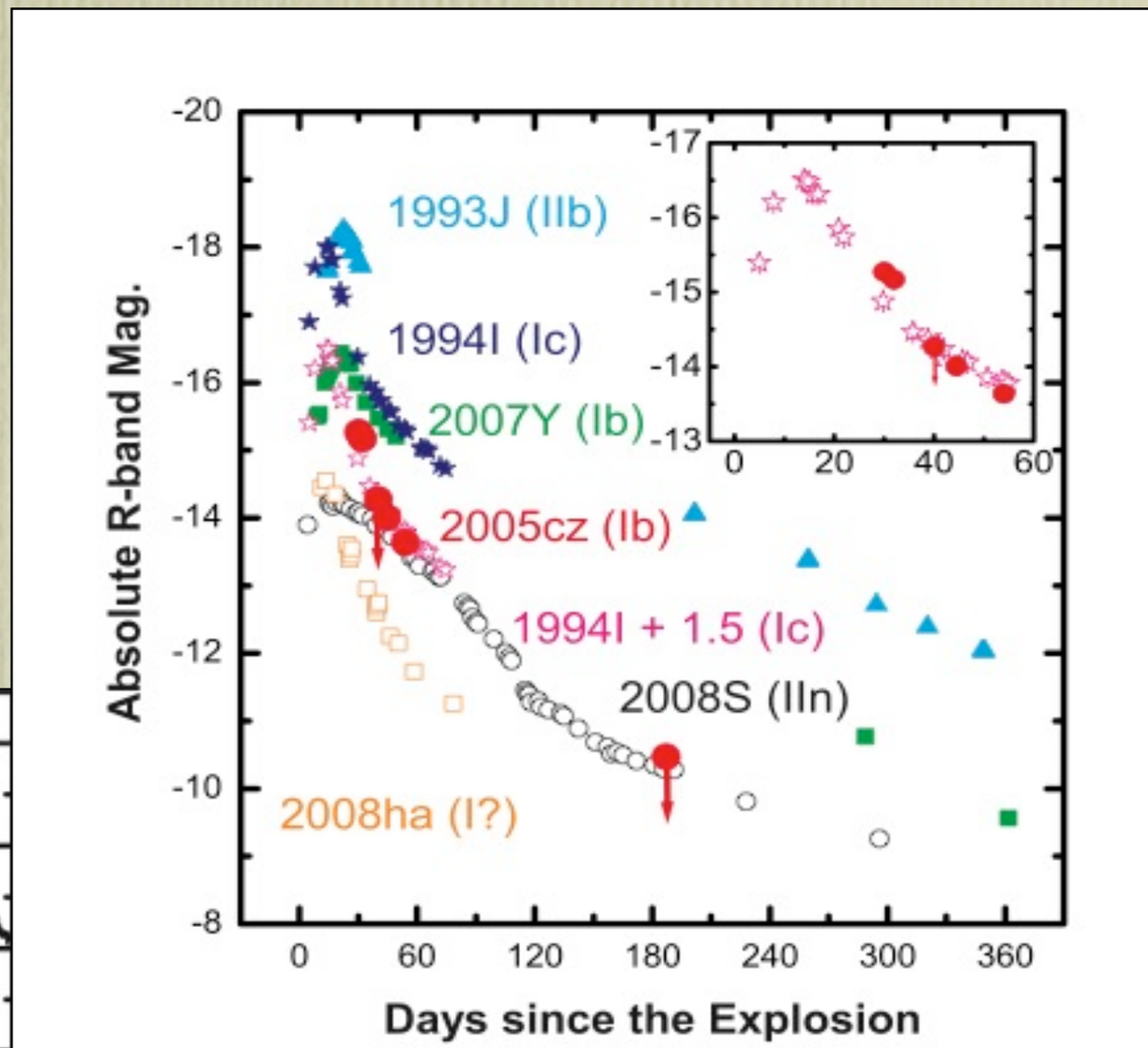
$E_k < 10^{51}$ erg; $M_{ej} < 1\ M_\odot$

$M(^{56}Ni) = 0.5\text{-}2 \times 10^{-2}\ M_\odot$

Sub-luminous stripped-envelope SNe







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SN 2005cz

$E_k < 10^{51}$ erg; $M_{ej} < 1\ M_\odot$

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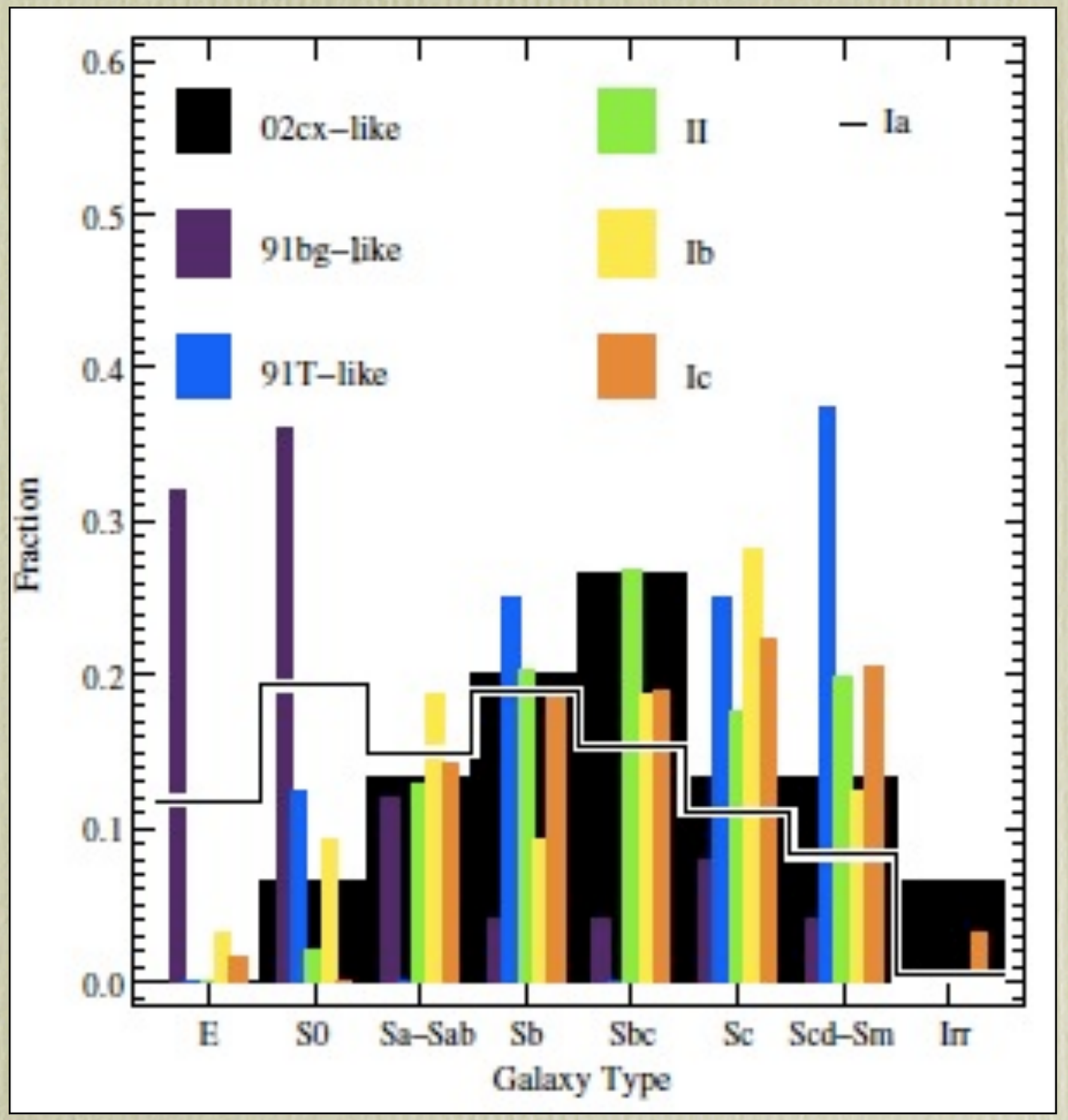
SN 2005E

(Peretz et al, 2010, Nature 265, 322)

$E_k \sim 5 \times 10^{50}$ erg; $M_{ej} \sim 0.3 M_\odot$

$M(^{56}Ni) = 3 \times 10^{-3}\ M_\odot$

Sub-luminous stripped-envelope SNe



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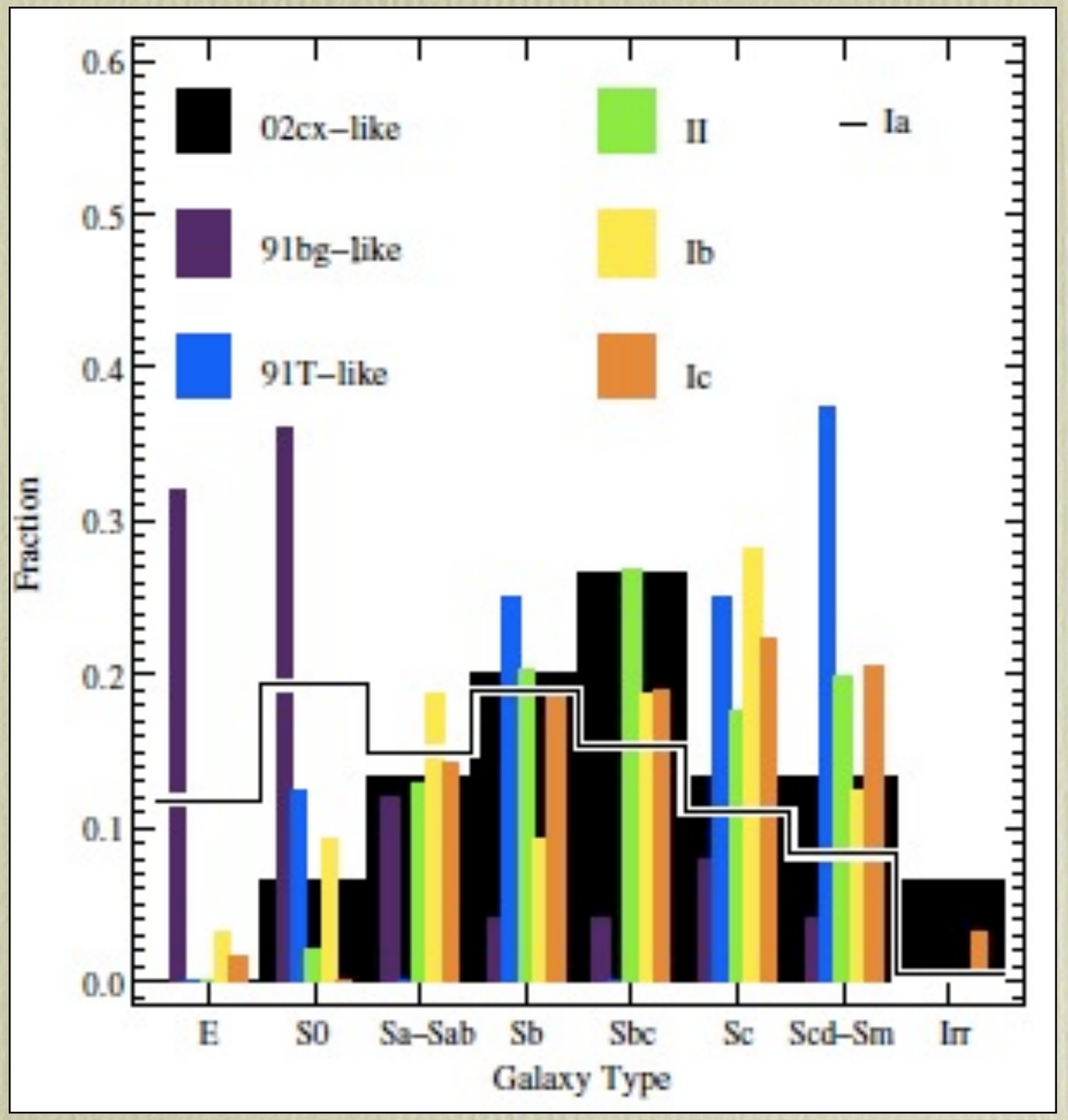

Foley et al, 2009

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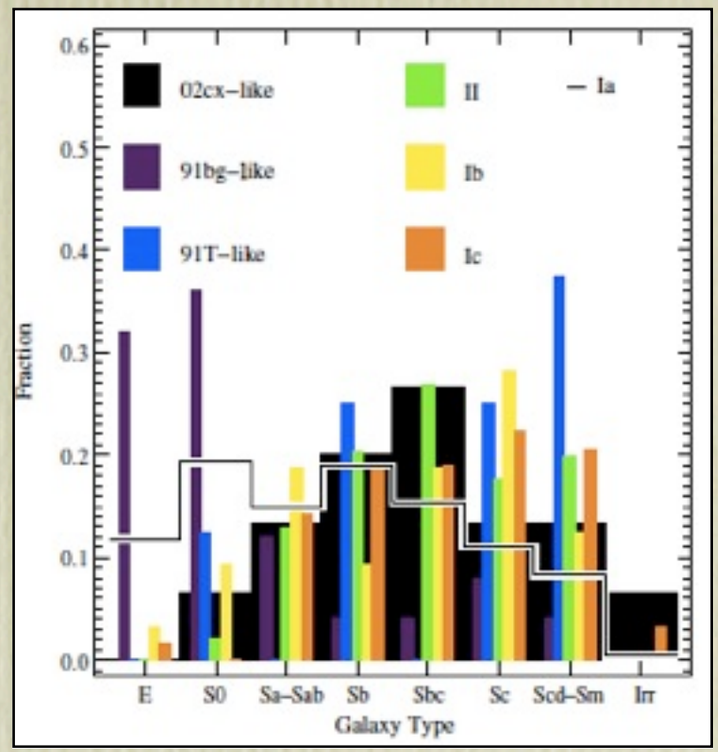

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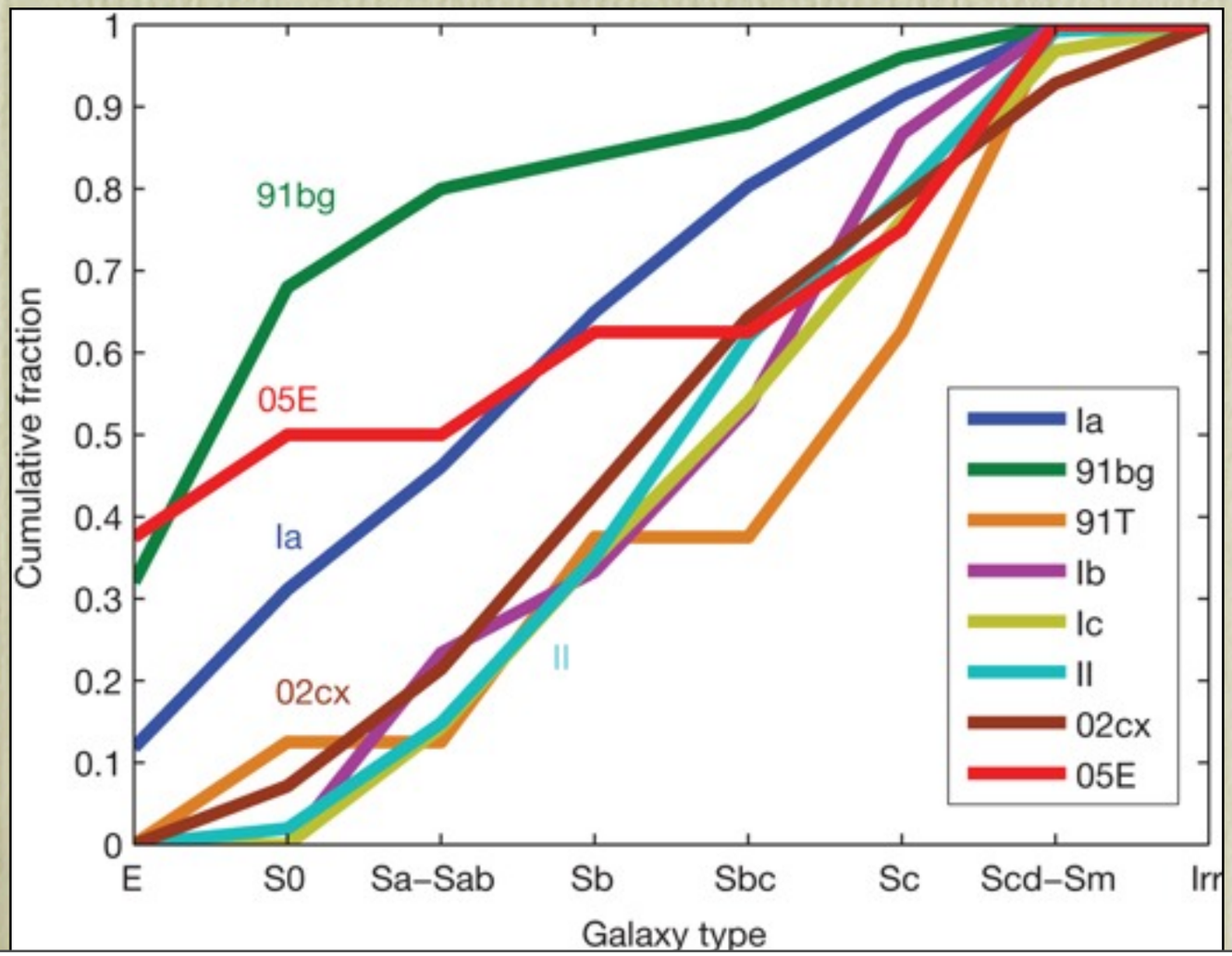
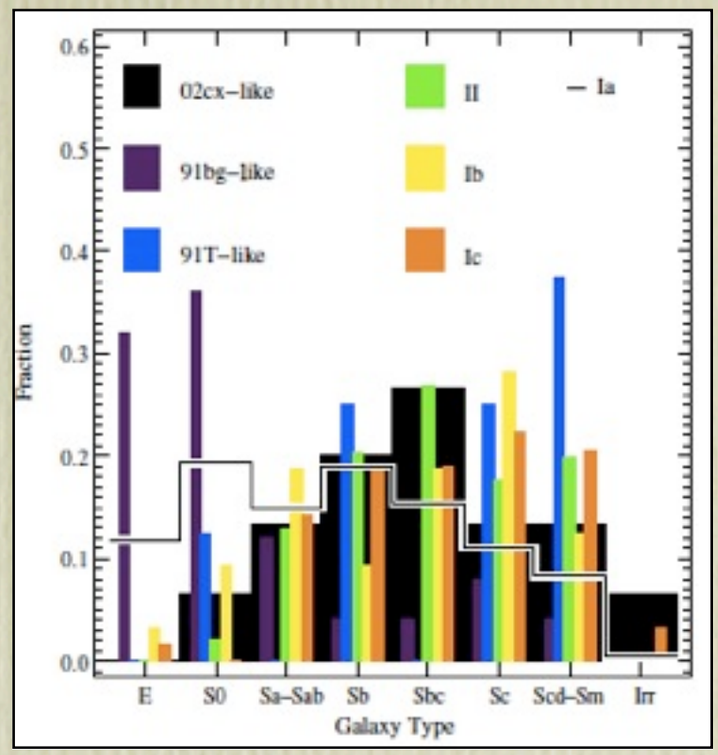


Peretz et al, 2010

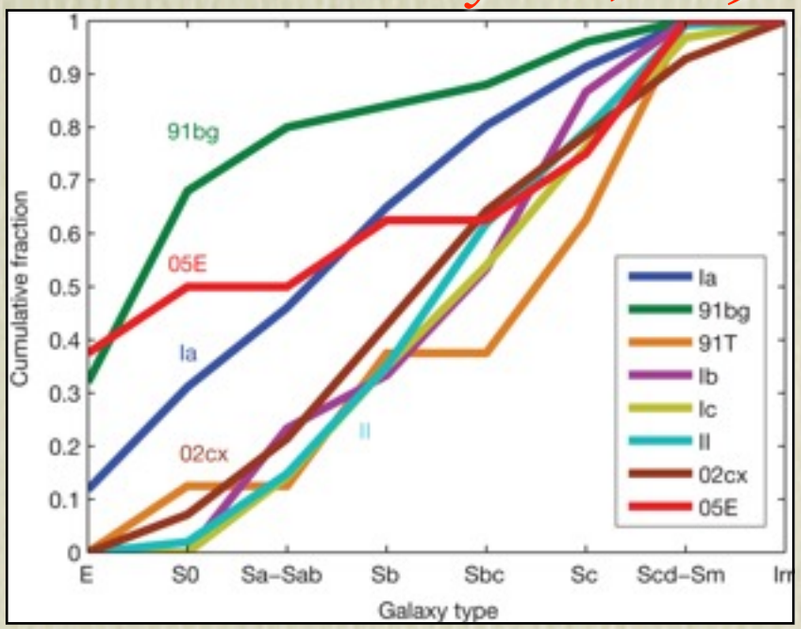
Sub-luminous stripped-envelope SNe

SN 2008ha (and other SE-SNe)

- Deflagration of sub-Chandrasekhar mass WDs *(e.g. Branch et al. 2004)*; a failed deflagration for SN 2008ha *(Foley et al. 2009)*
- He shells detonation in close WD binaries (.Ia SNe) - unburned He in the ejecta! *(Bildsten et al. 2007, Shen et al. 2010)*
- WD - NS/BH mergers *(Metzger 2011)*
- Accretion-induced collapses *(Darbha et al. 2010)*
- EC-SNe (Ibc-type) from ~9 M_o super-AGB stars *(Pumo et al. 2010)*
- Faint CC-SNe from > 20-25M_o stars + fall-back *(Moriya et al. 2011)*

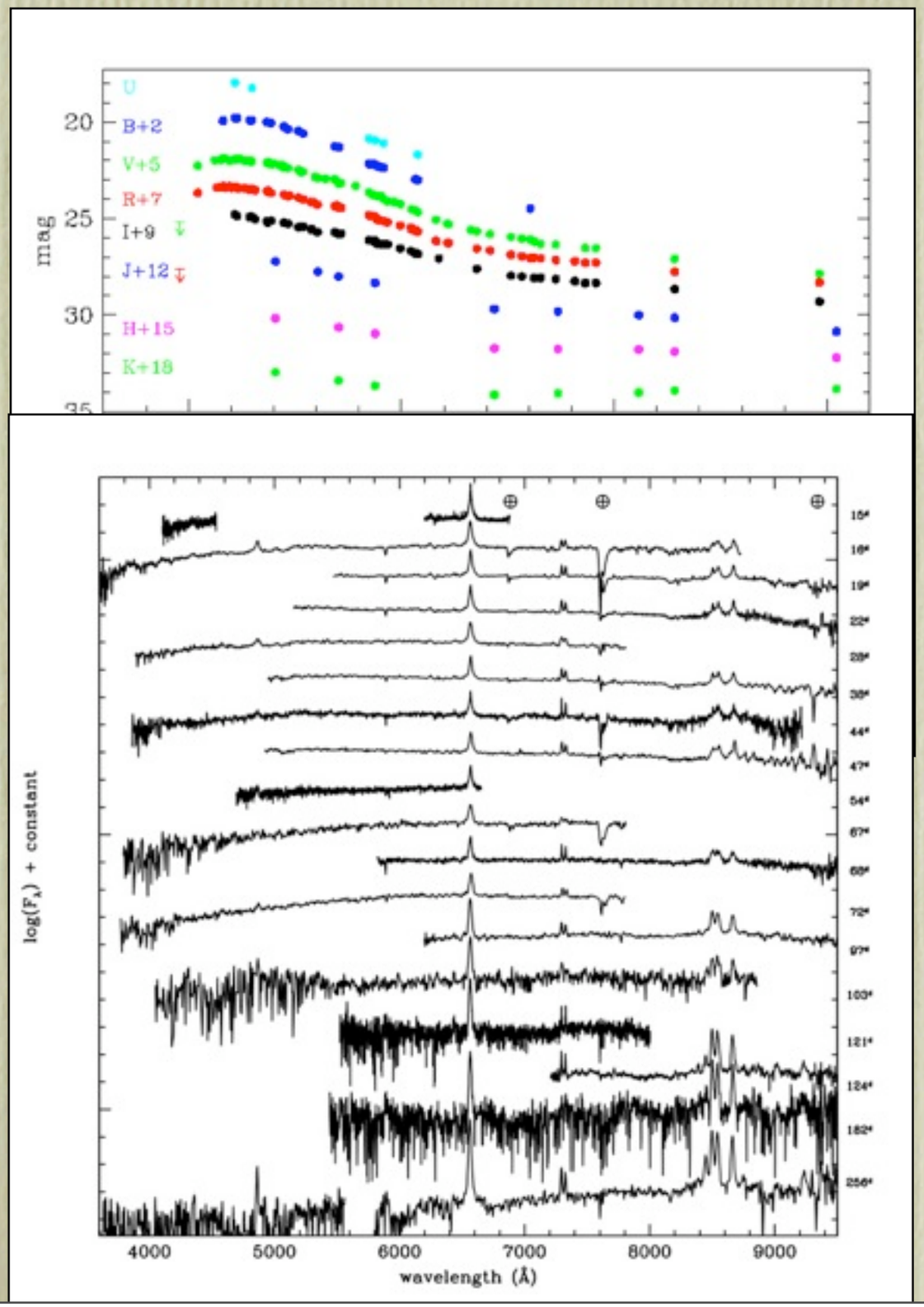


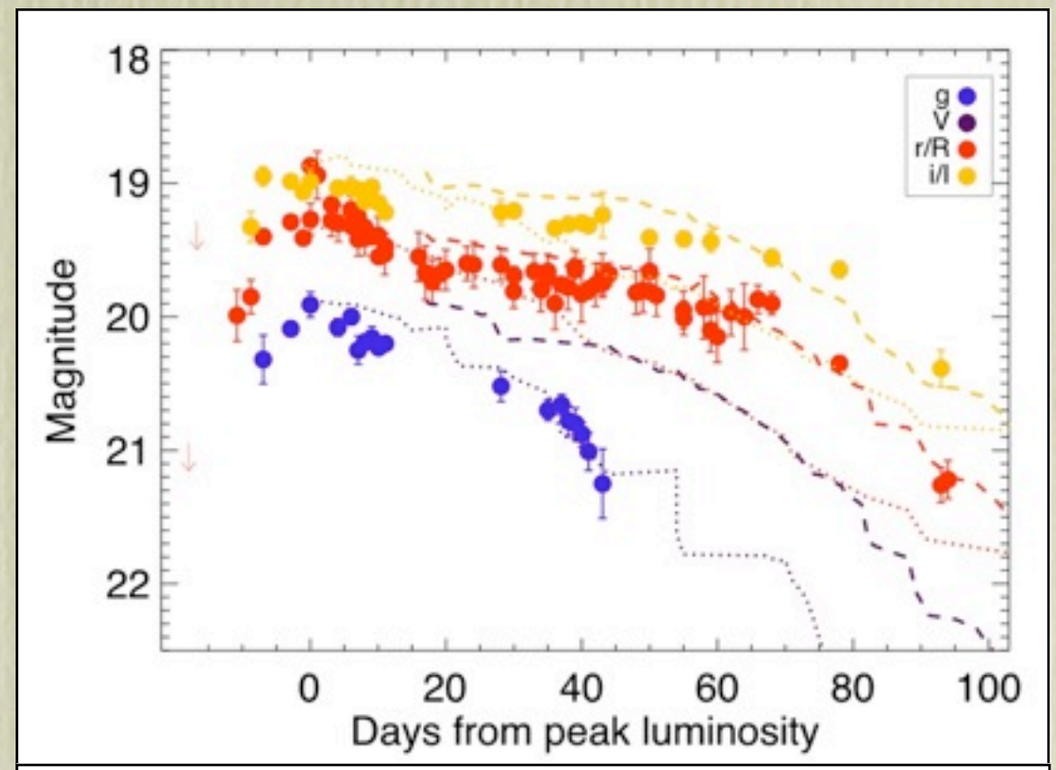
Foley et al, 2009

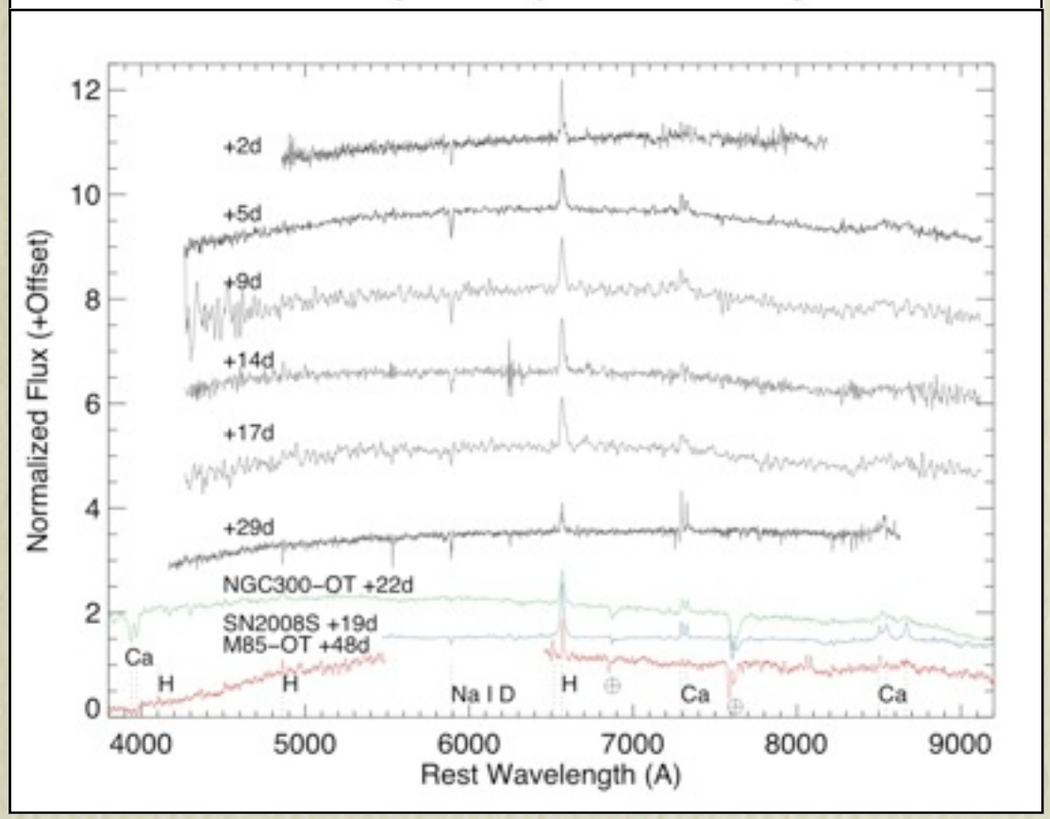


Peretz et al, 2010

SN impostors or ultrafaint SNe?
SN 2008S, PFT10fqs....

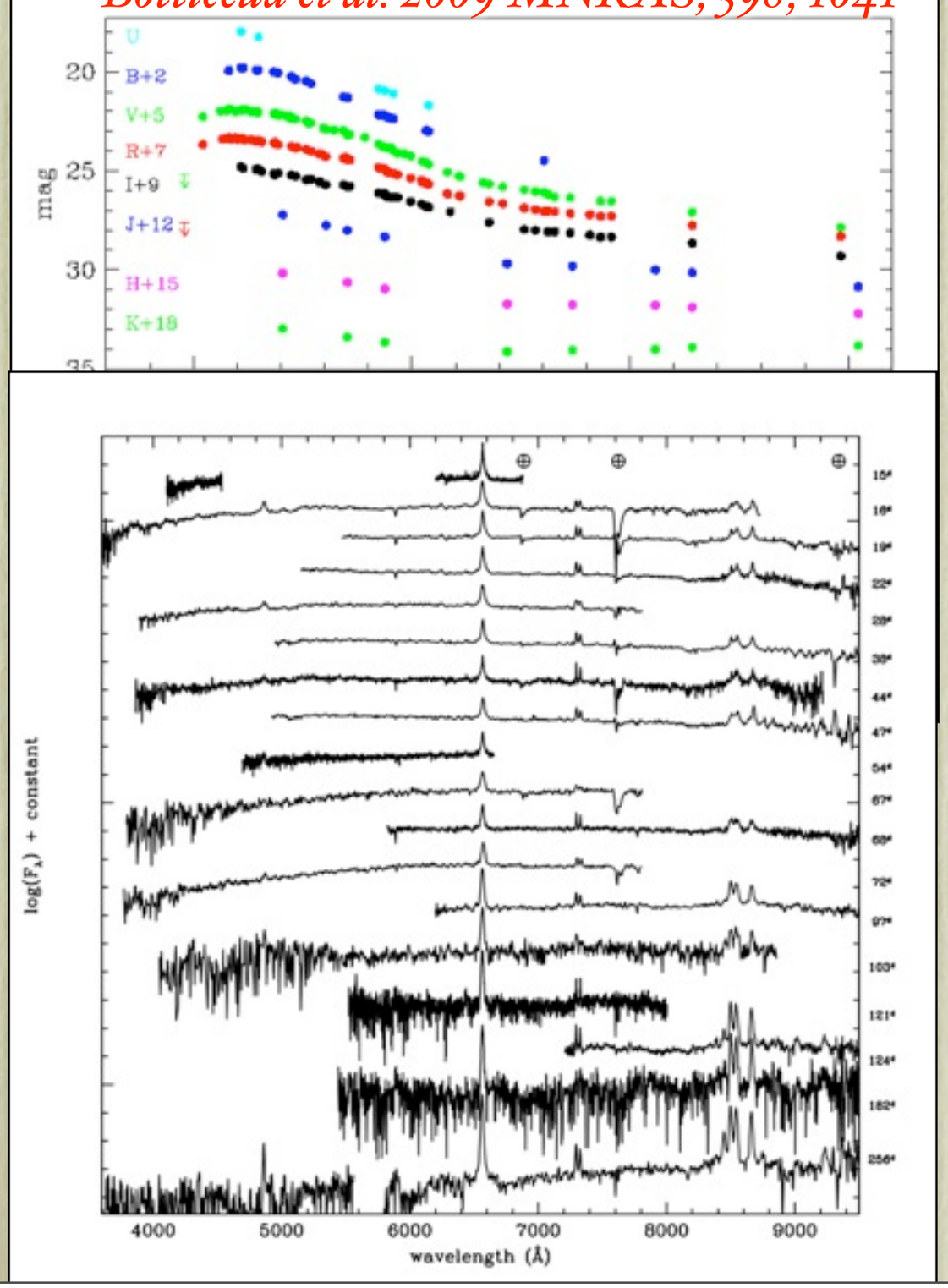


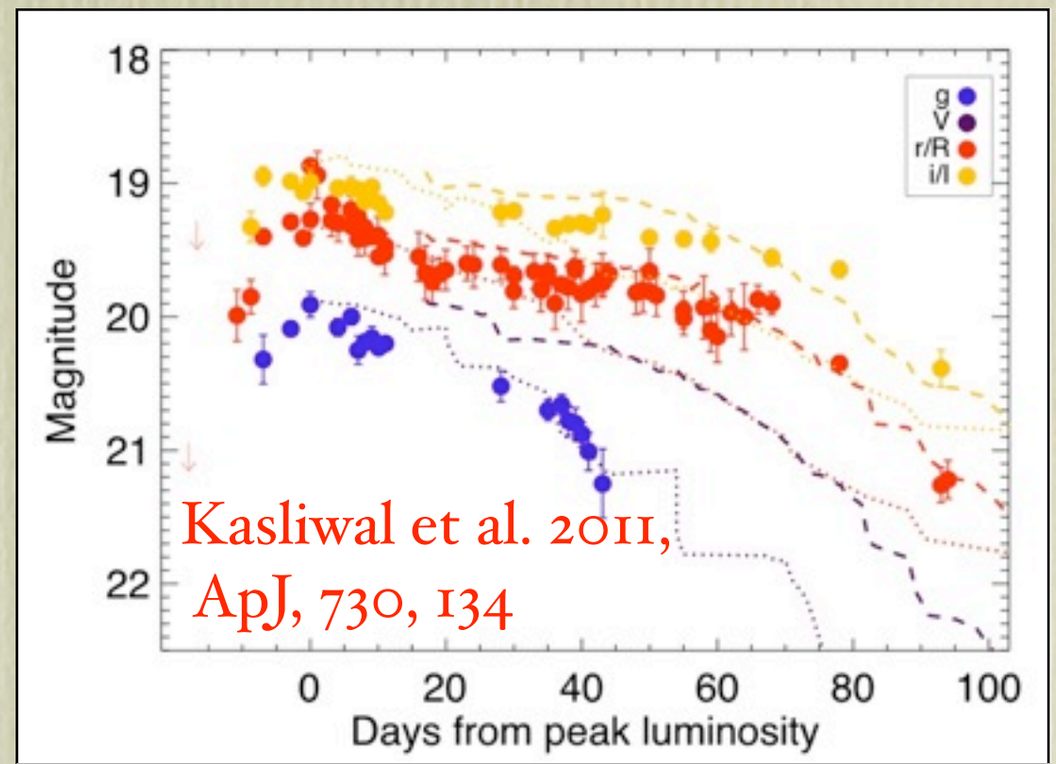




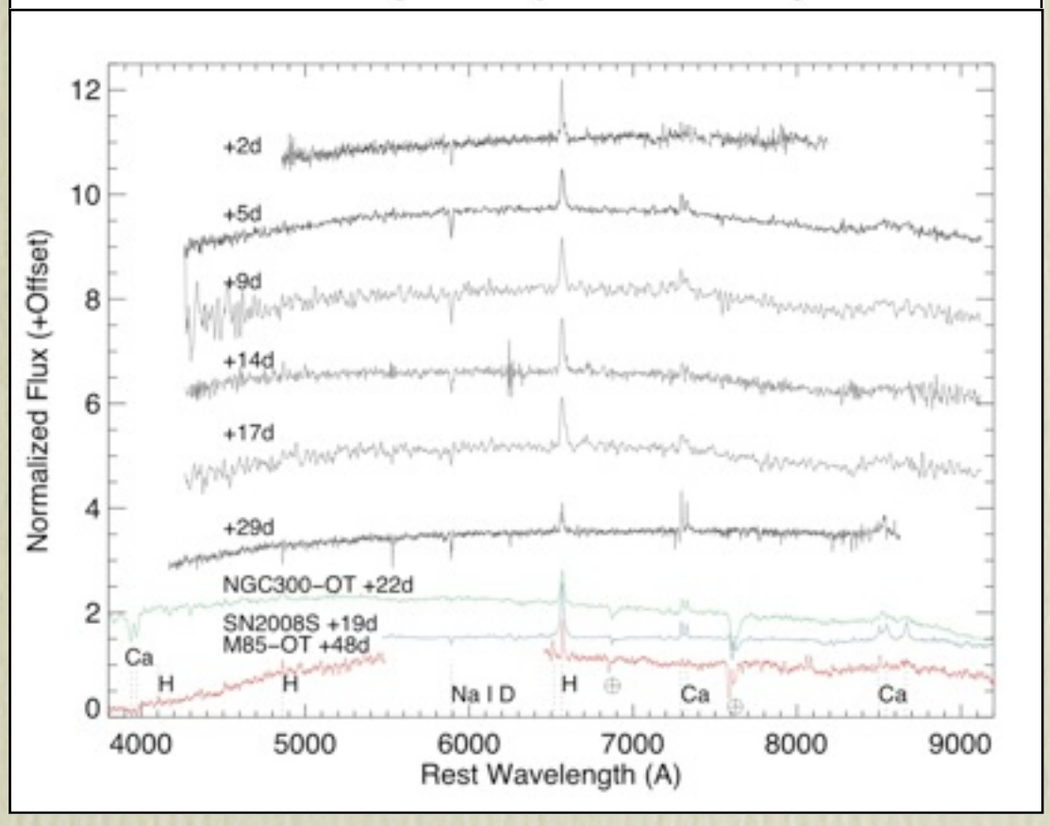
SN impostors or ultrafaint SNe?
SN 2008S, PFT10fqs....

Botticella et al. 2009 MNRAS, 398, 1041

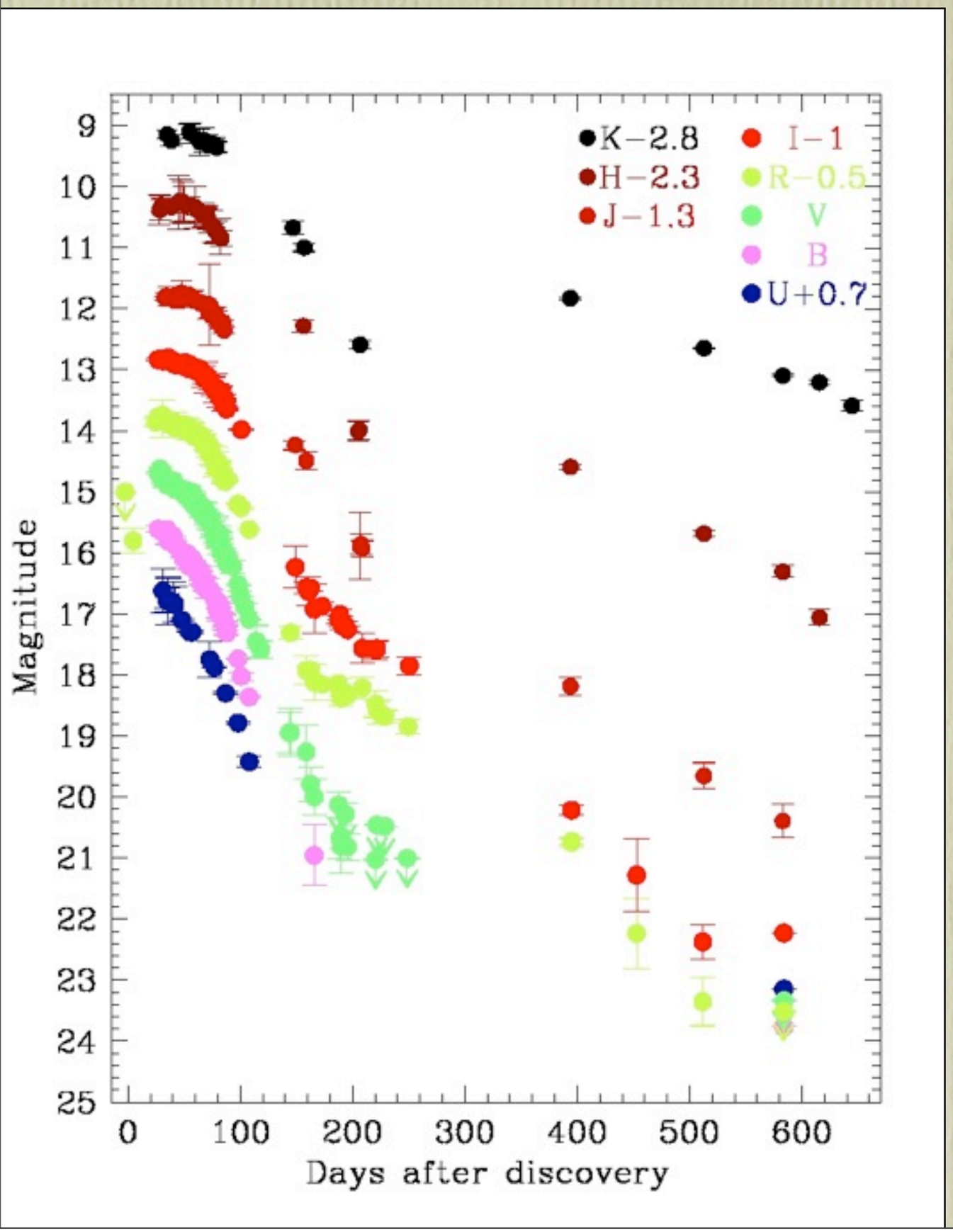




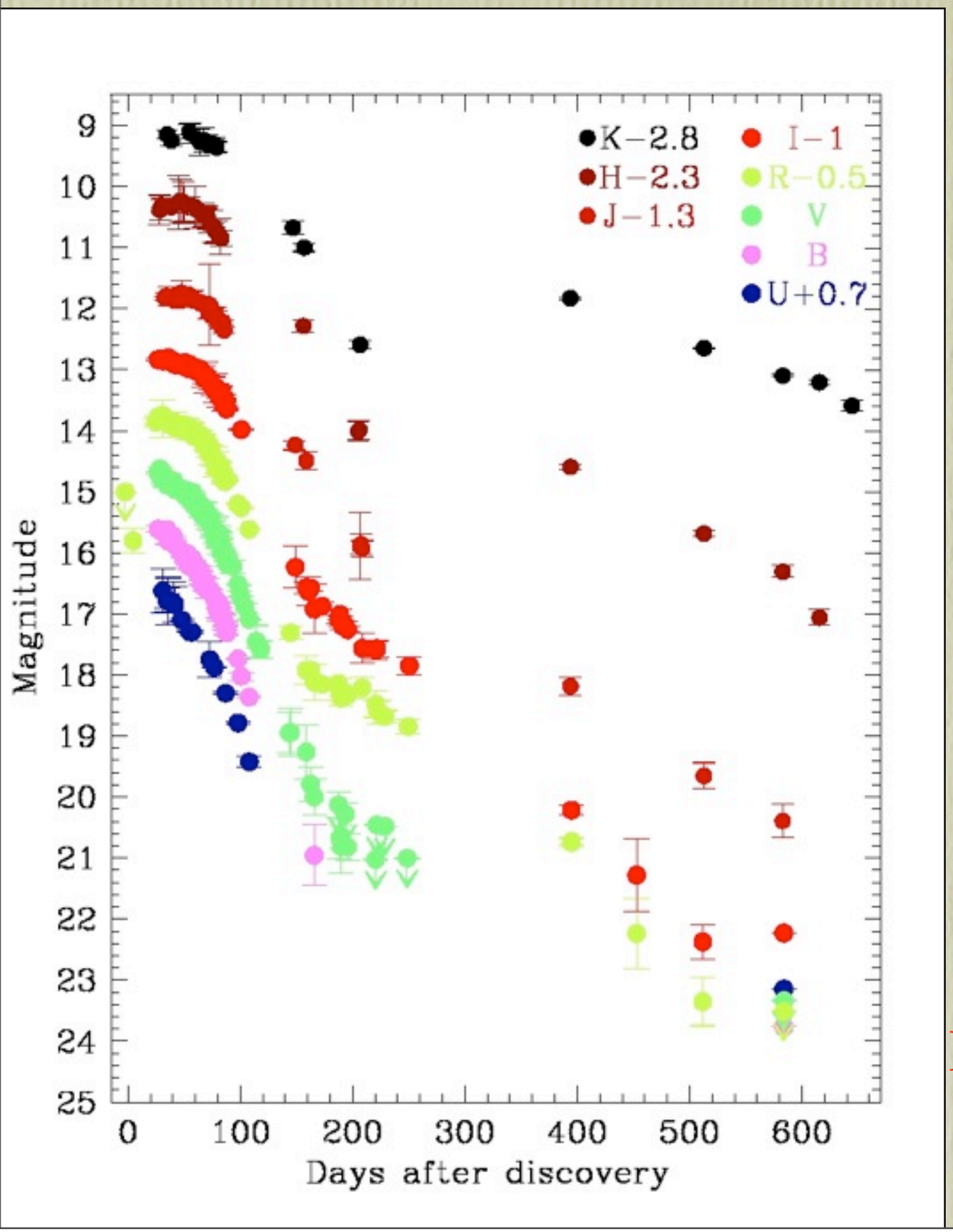
Kasliwal et al. 2011, ApJ, 730, 134



SN impostors or ultrafaint SNe? NGC300-2008OT

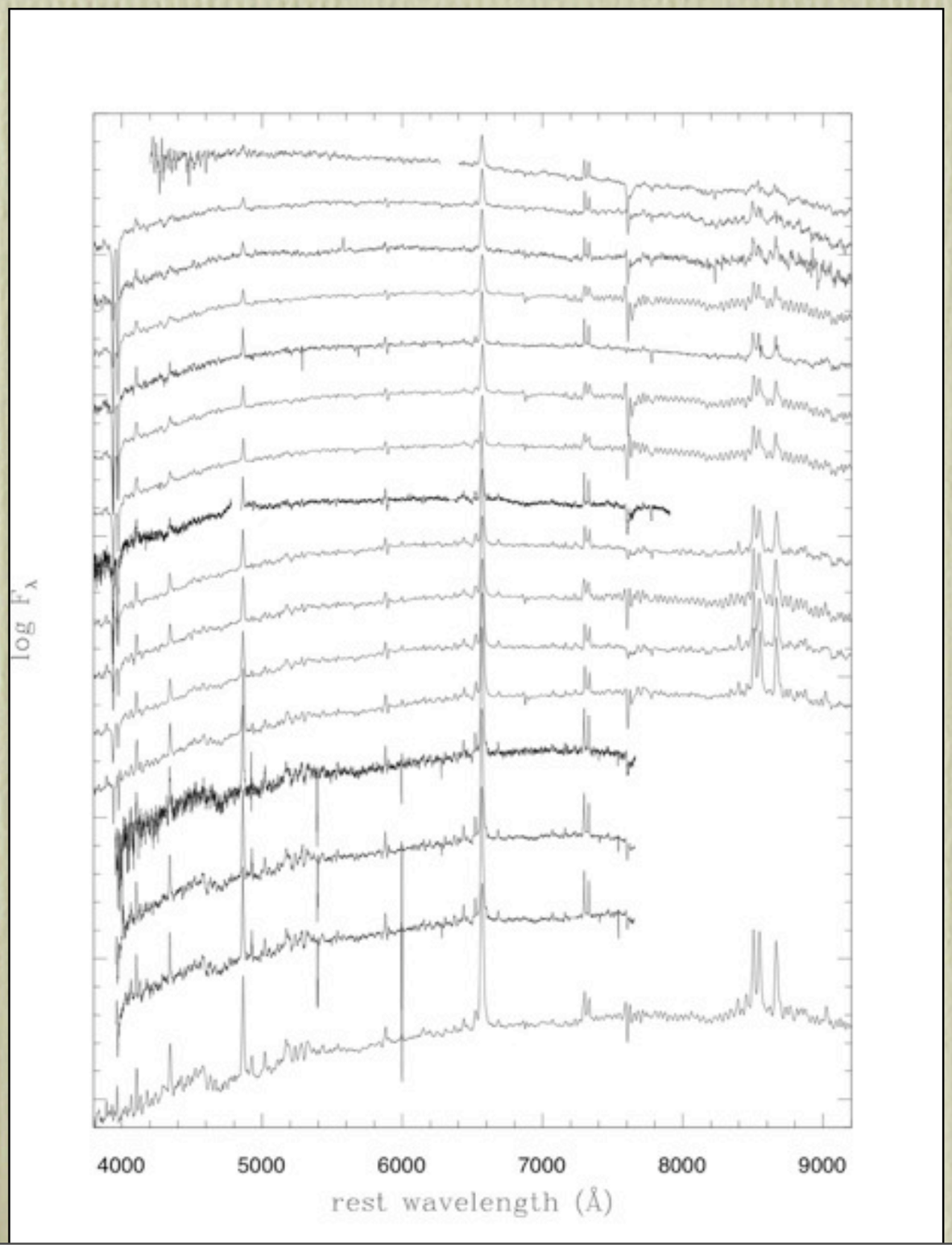


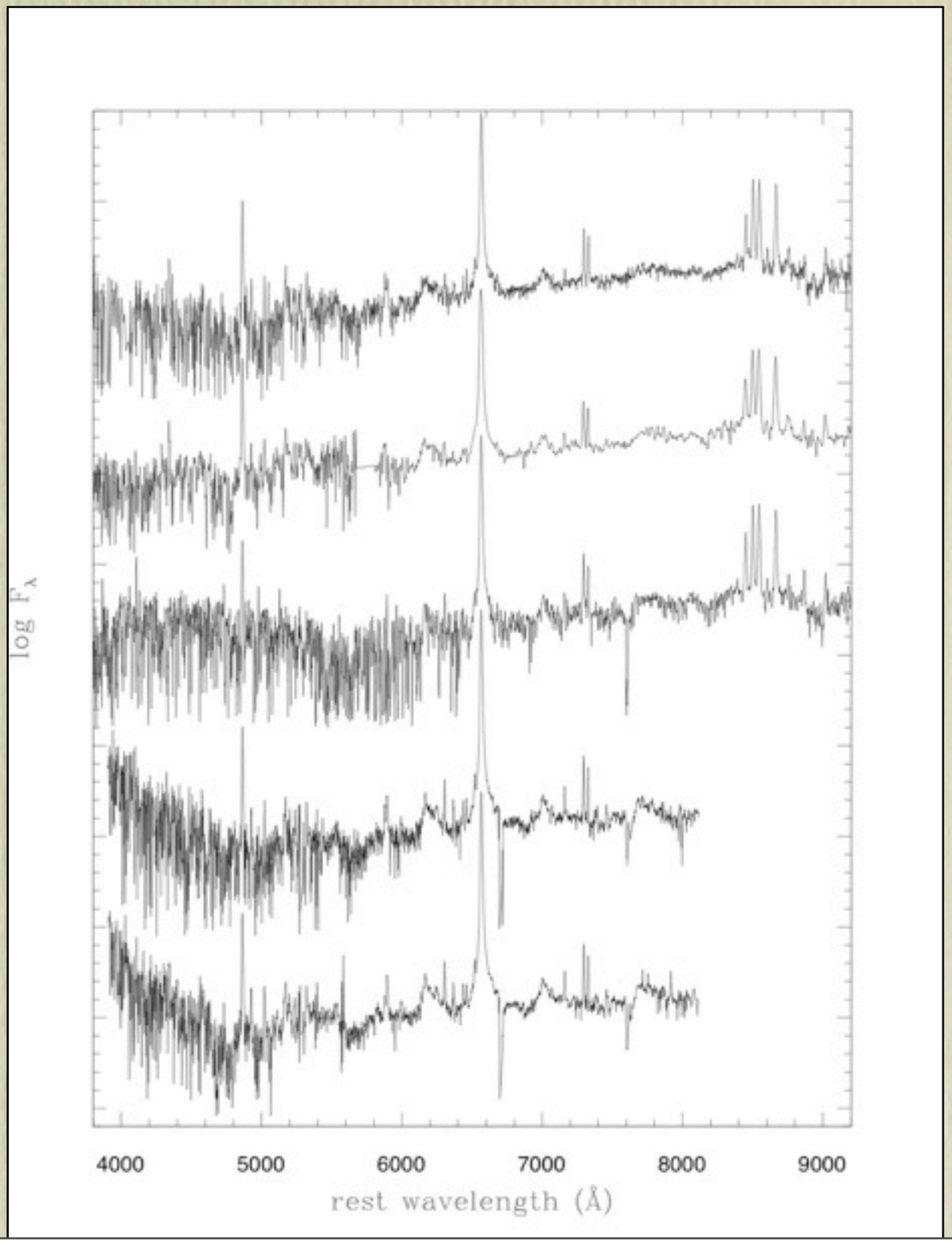
SN impostors or ultrafaint SNe? NGC300-2008OT



Pastorello et al. in prep. (see also Bond et al. 2008; Berger et al. 2008)

SN impostors or ultrafaint SNe? NGC300-2008OT



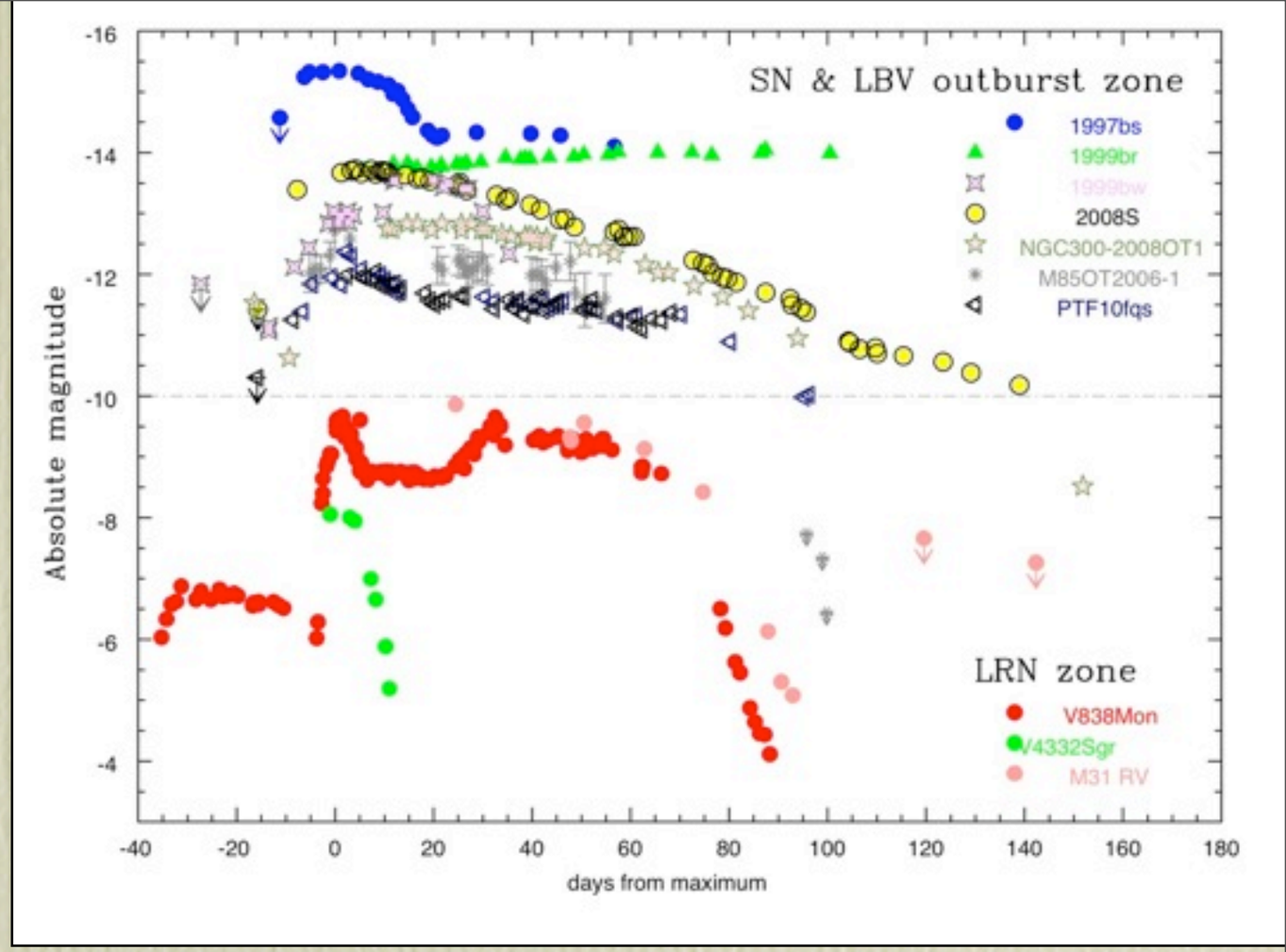


The family

SN1999bw, M85-2006OT,

SN2008S, NGC300-2008OT,

SN2010dn, PTF10fqs.



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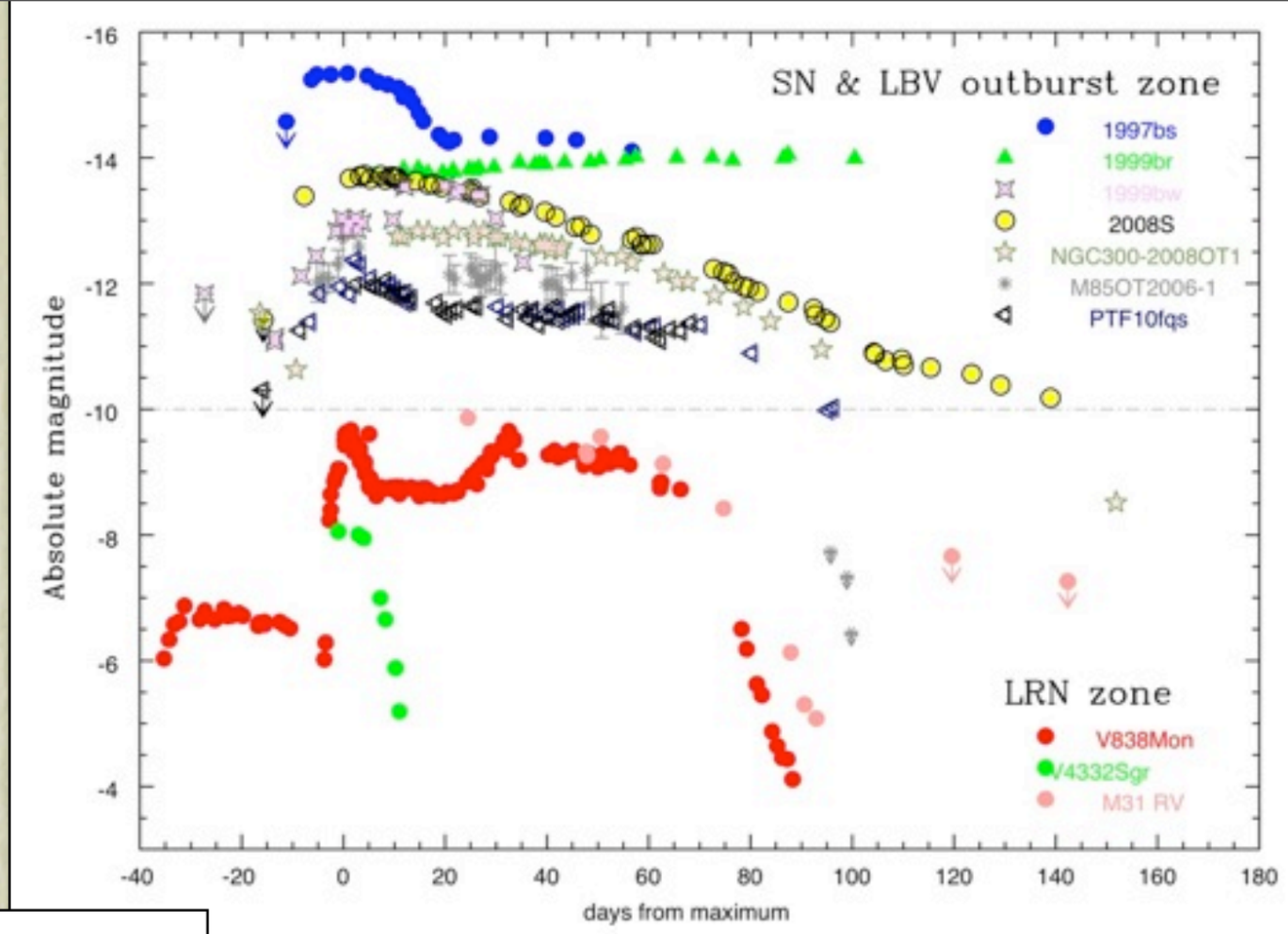
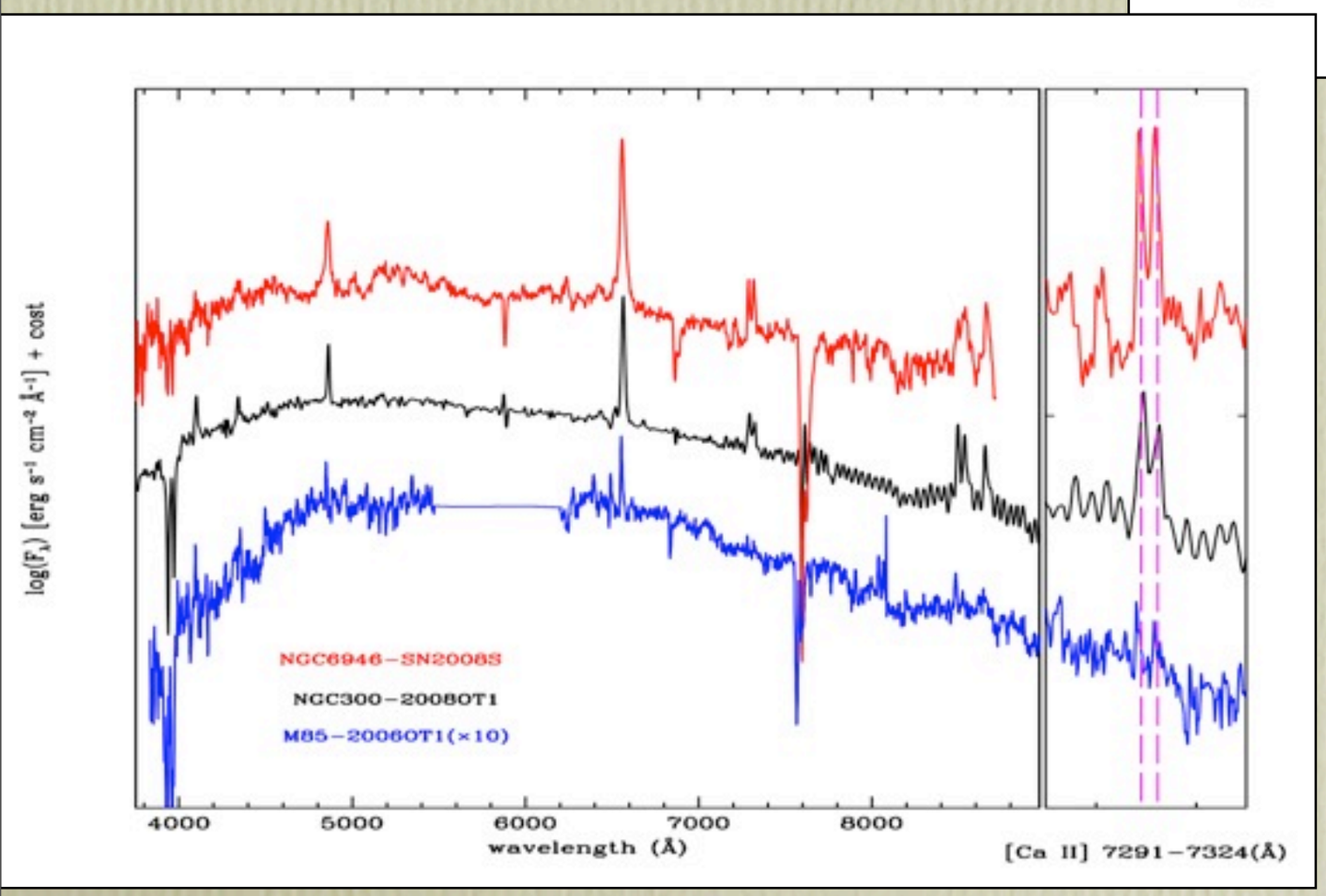
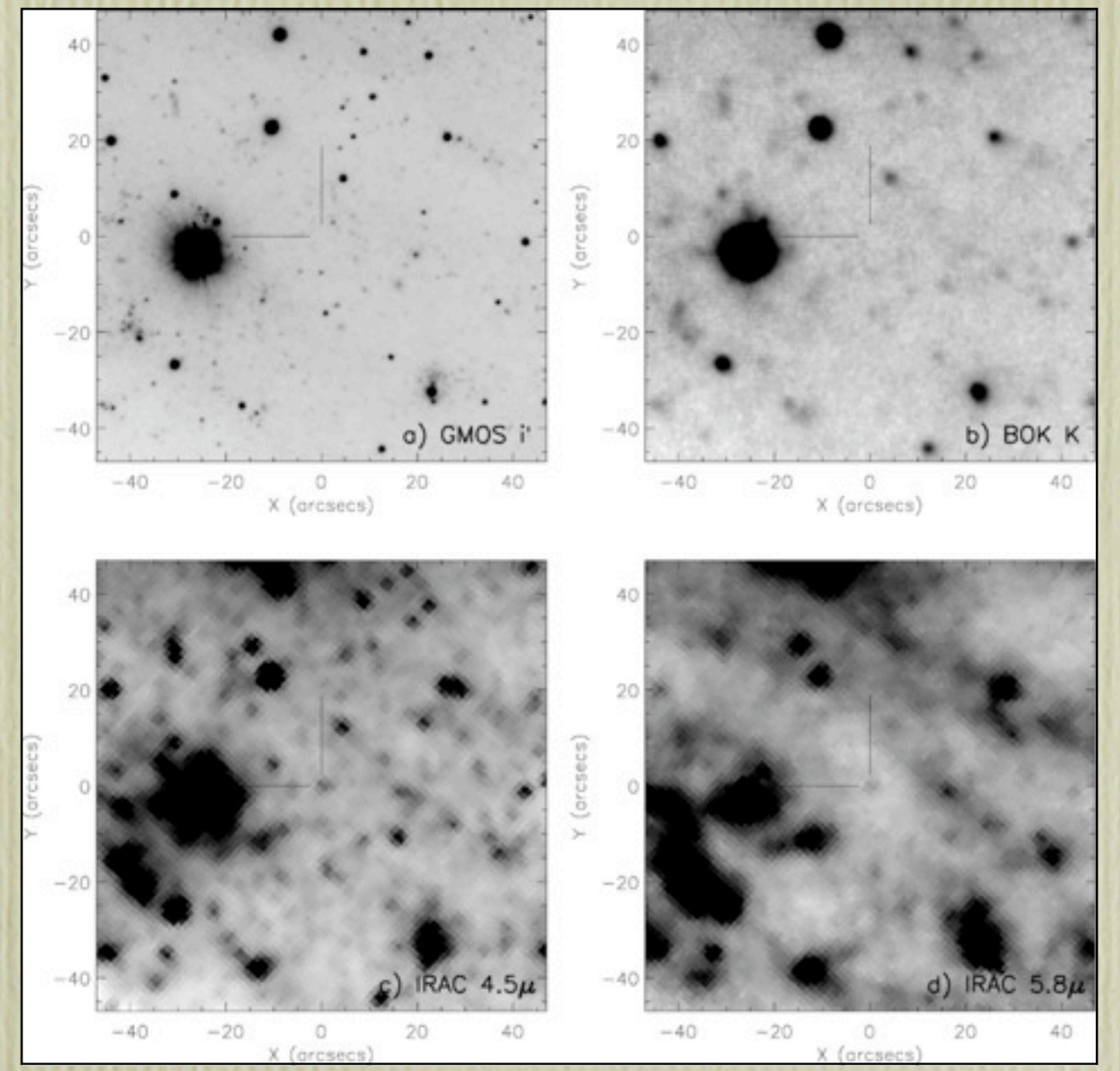




Detection of the progenitors



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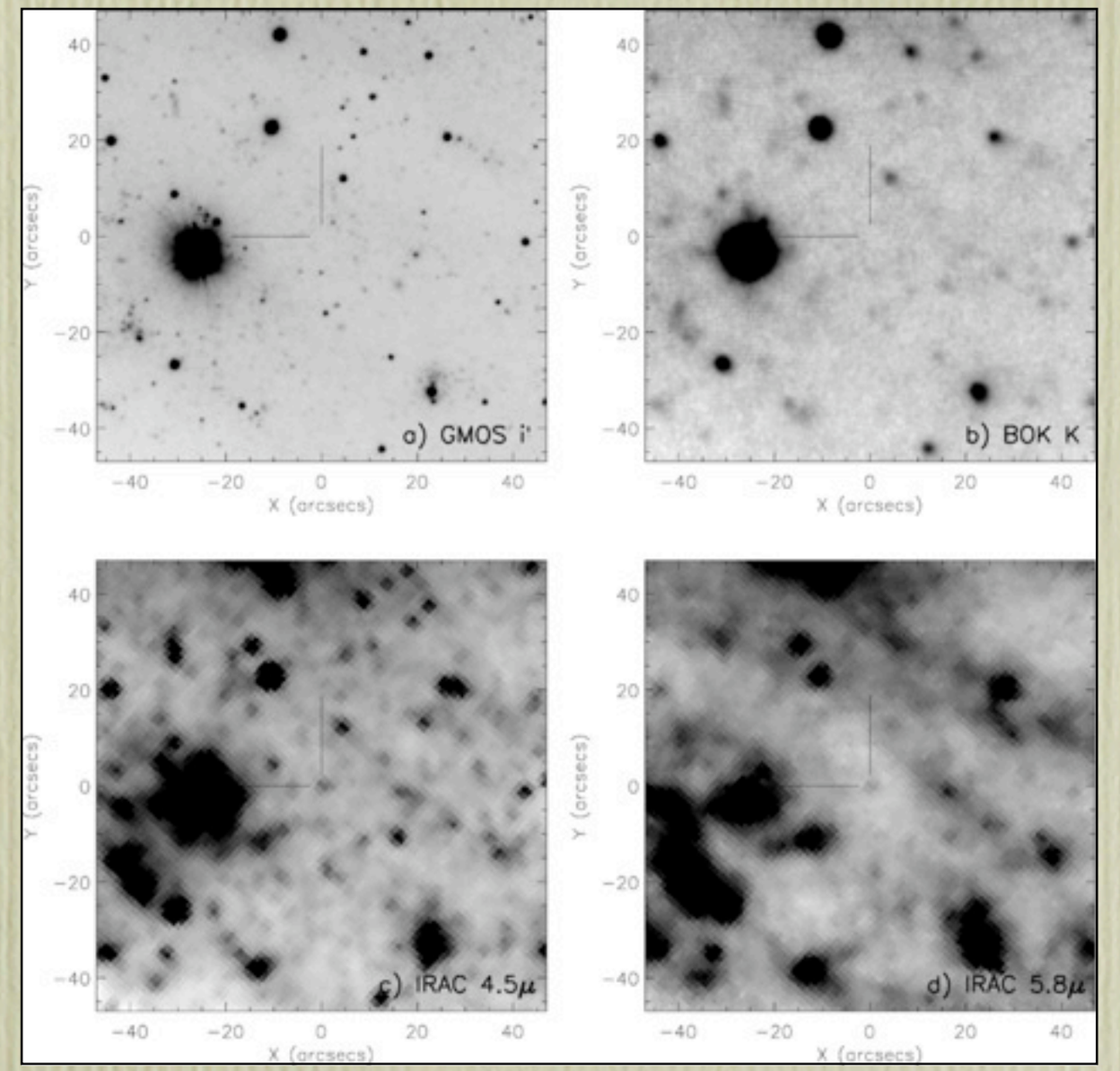

Thompson et al. 2009; see also Prieto et al. 2008; 2009, 2010; Smith et al. 2009; Bond et al. 2009; Botticella et al.2009; Gogarten et al. 2009; Berger et al. 2009, Khan et al. 2010; Bonanos et al. 2010; Wesson et al. 2010; Ohsawa et al. 2010

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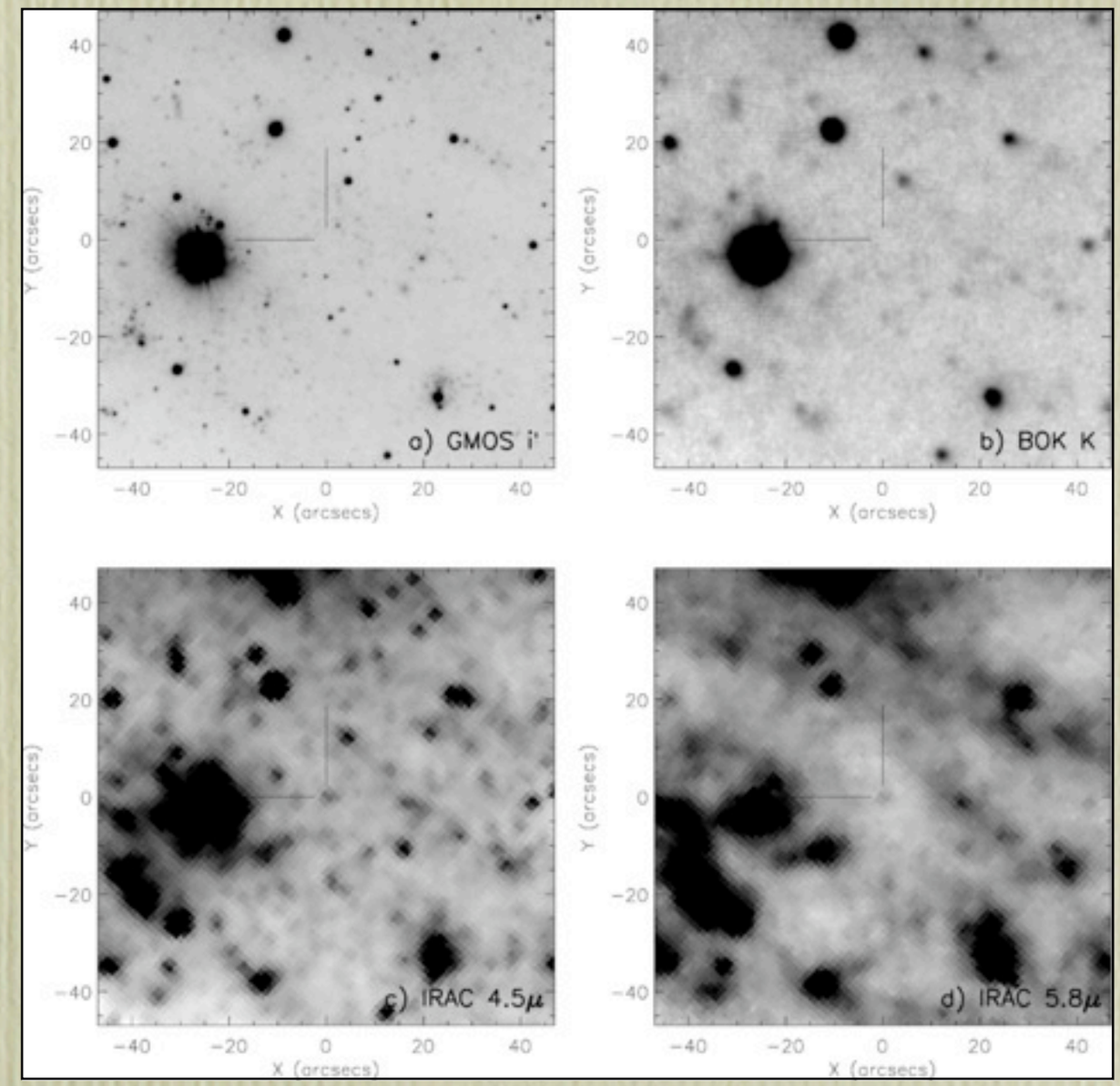

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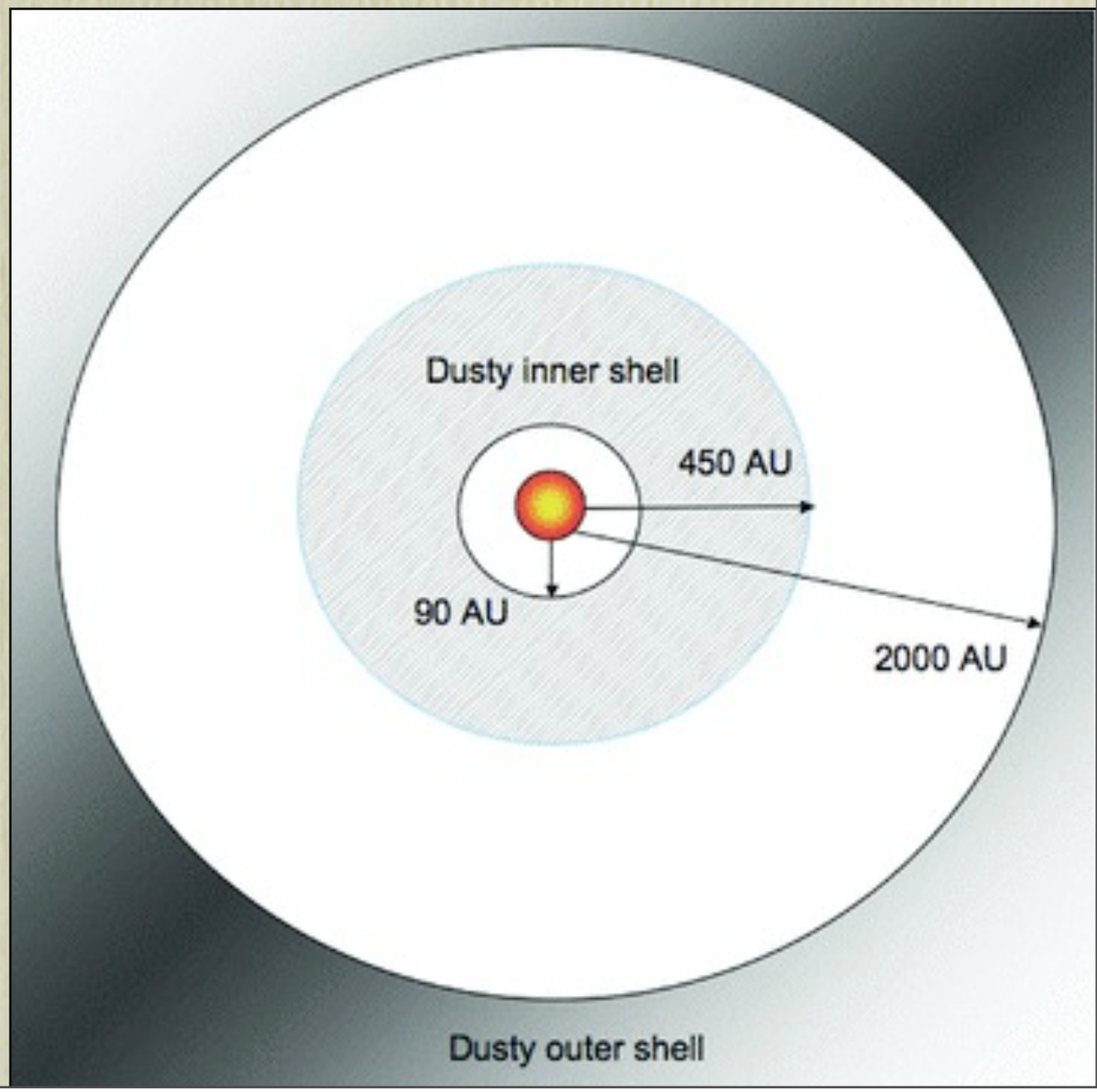

Botticella et al.2009

SN impostors or ultra-faint SNe?

- "Luminous red novae" from low-to-moderate mass mergers
- Eruptions triggered by mass transfer from an extreme-AGB to a main sequence companion
- Eruptive birth of a massive (6-8M_o) WD + planetary nebula
- Outbursts from moderate-mass LBVs (M~10-20 Mo) or B[e] hypergiants
- EC-SNe from ~9 M_o super-AGB stars (SNe IIL/IIn)
- Faint CC-SNe from 10-12M_o RSGs

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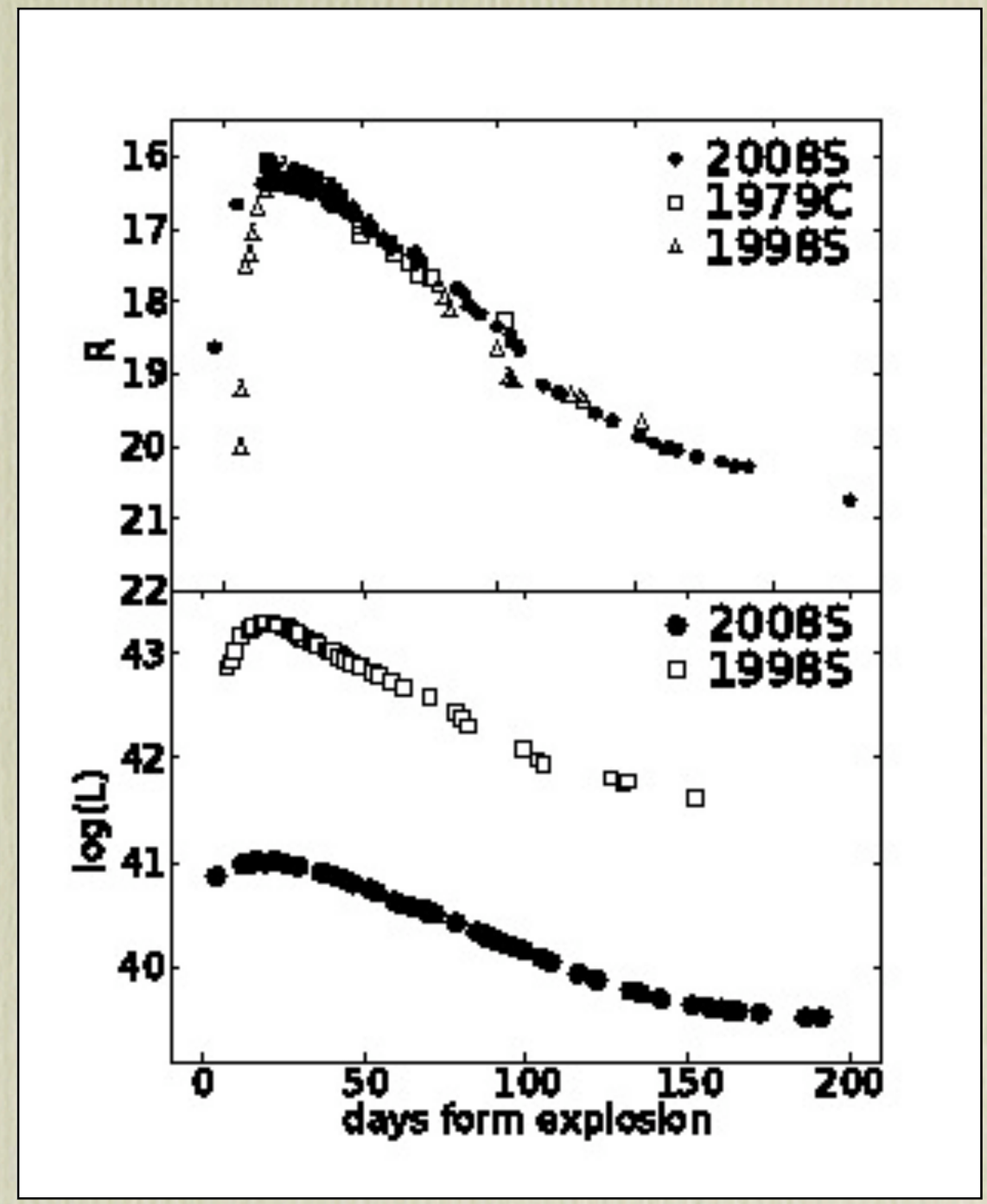
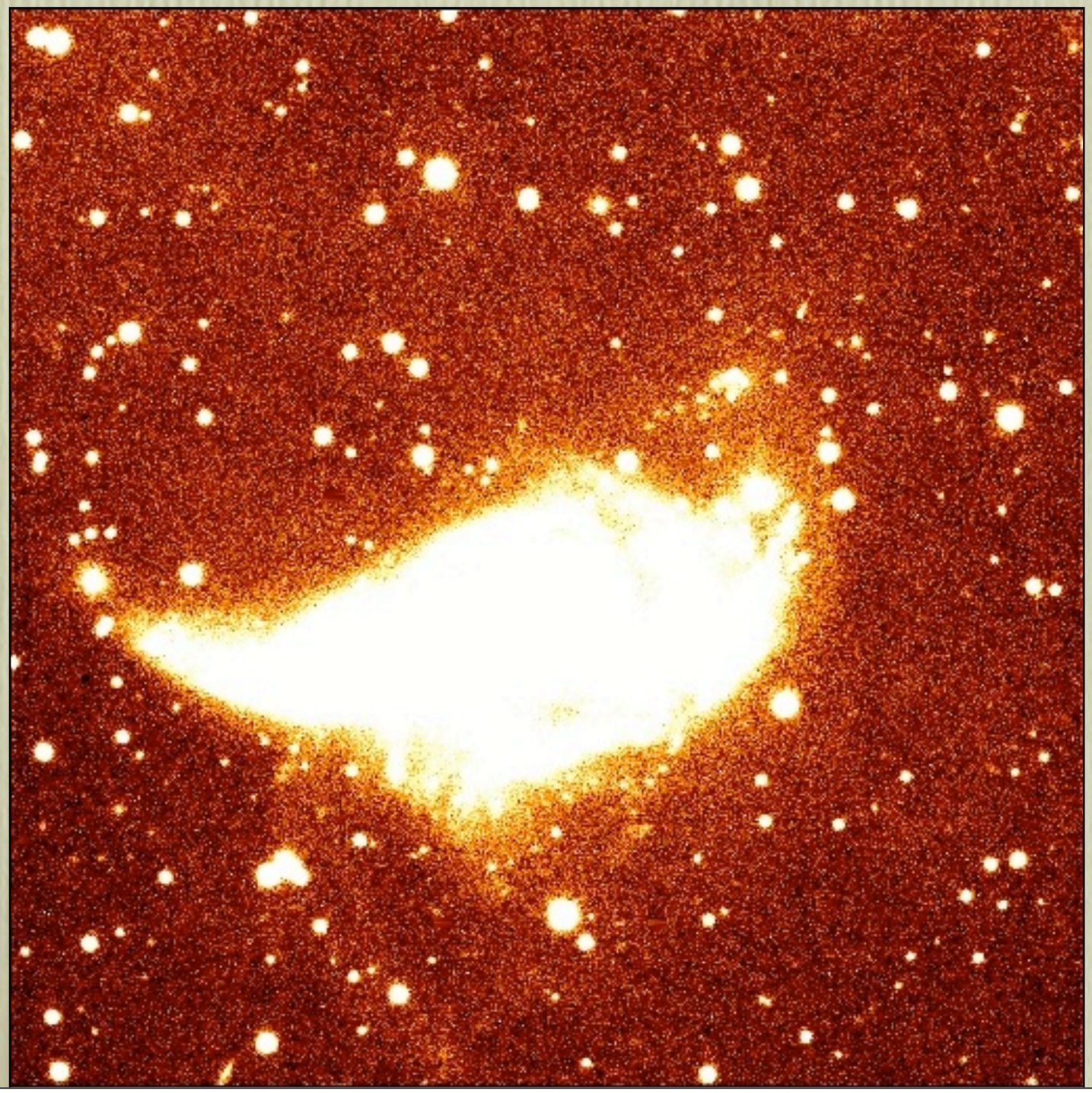


^{56}Ni masses in weak SN candidates

- LL SNe IIP: 2-8 x 10^{-3} $M_\odot$
  - SN 2005cs: 2-4 x 10^{-3} $M_\odot$
  - SNe 1999br, 2008bk: 2 x 10^{-3} $M_\odot$
- SN 1999ga (IIL): 10^{-2} $M_\odot$
- Ultrafaint SNe IIn?: $\leq 10^{-3}$ $M_\odot$
  - SN 2008S: 1-2 x 10^{-3} $M_\odot$
  - NGC300-OT: 8-10 x 10^{-4} $M_\odot$
  - M85-OT: $< 5 \times 10^{-4}$ $M_\odot$
- SN 2005cz & LL SNe Ib: 3-20x10^{-3} $M_\odot$
- SN 2008ha (Ia/c): 2-5 x 10^{-3} $M_\odot$
- SN 2002cx-like: a few x 10^{-2} $M_\odot$

SN 2010jp: supernova or super-impostor?



Host: interacting system
NGC2207+IC2163 @ 36 Mpc

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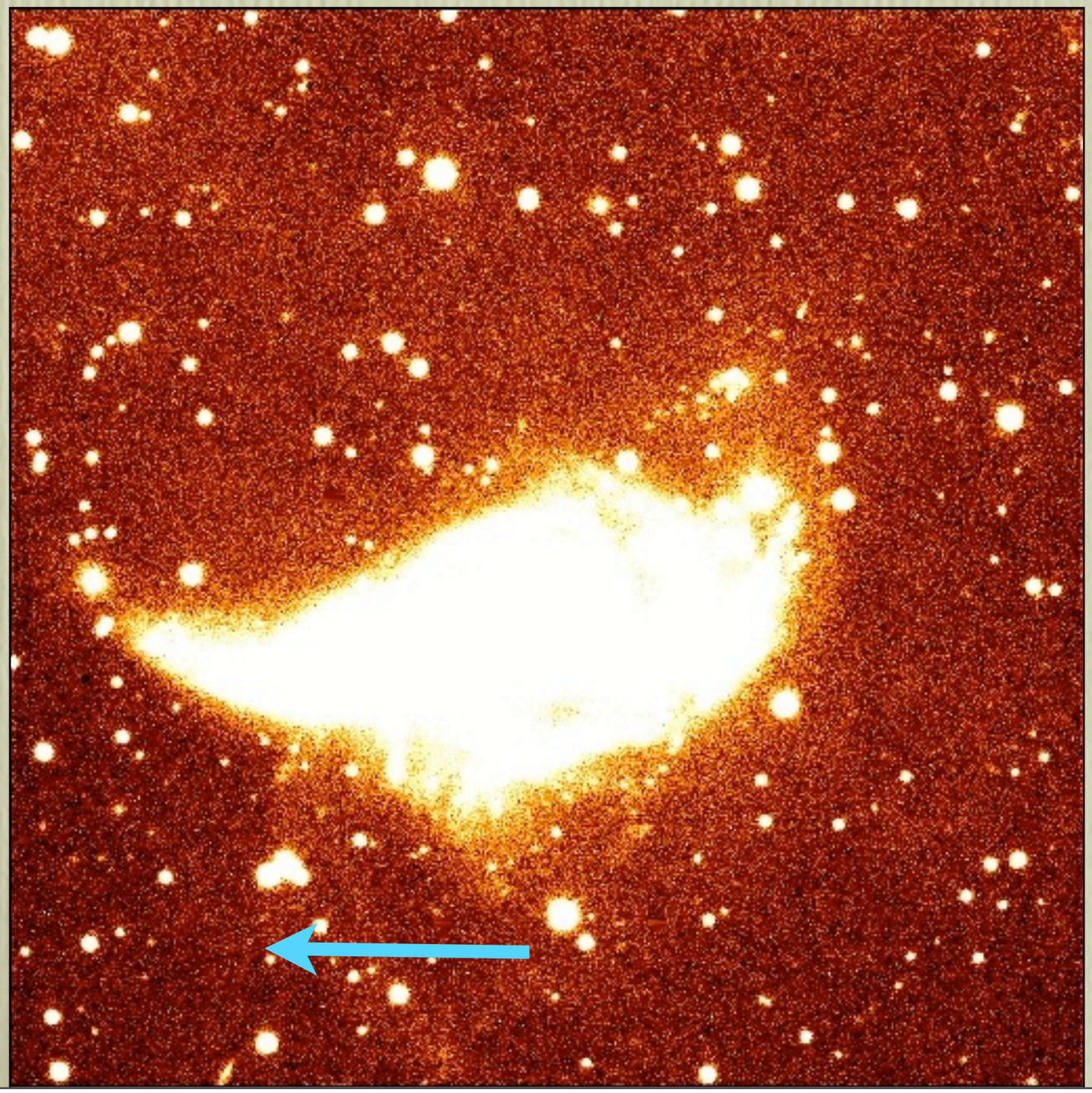

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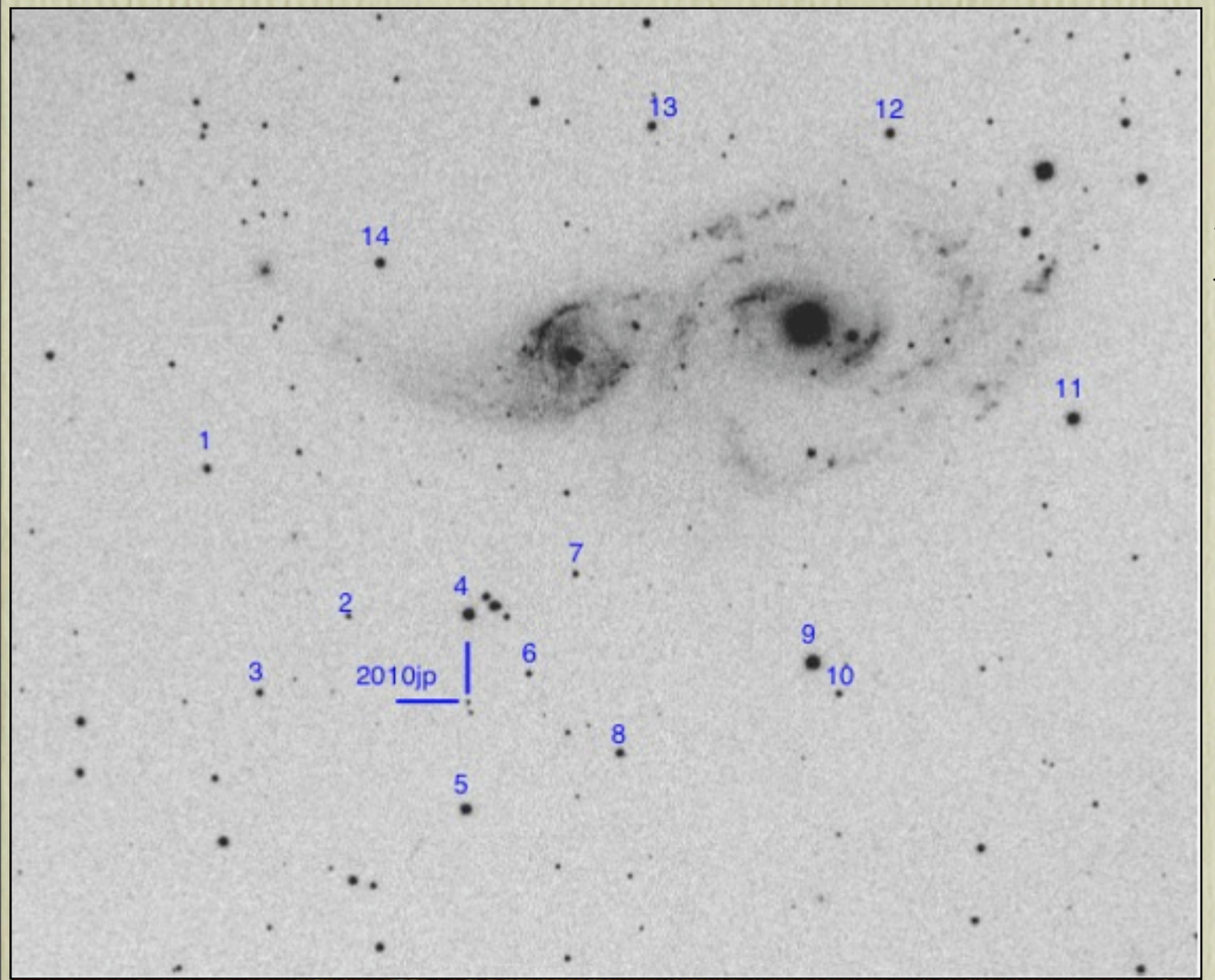

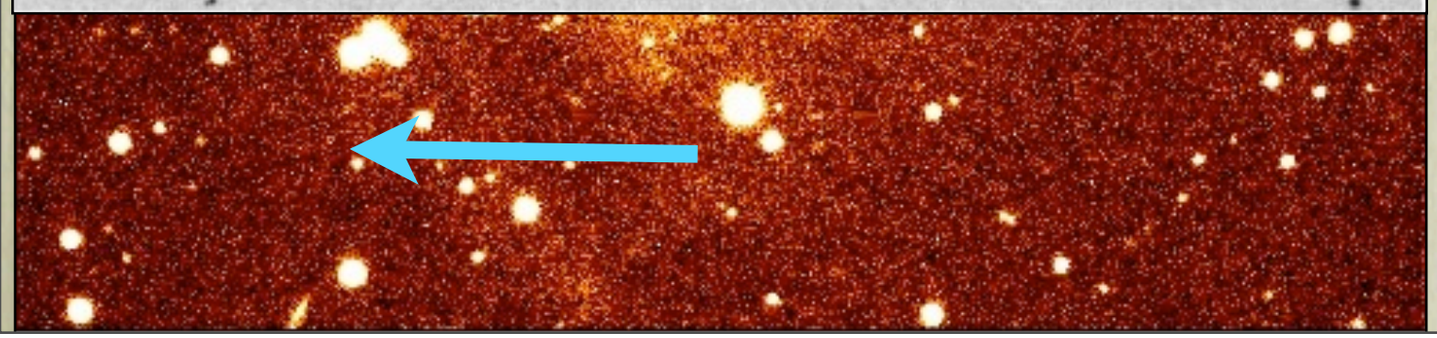

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Discovered by CHASE
R = 17.2 => $M_R \sim -15.8$

Classification:
type IIn SN
(Challis & Kirshner)

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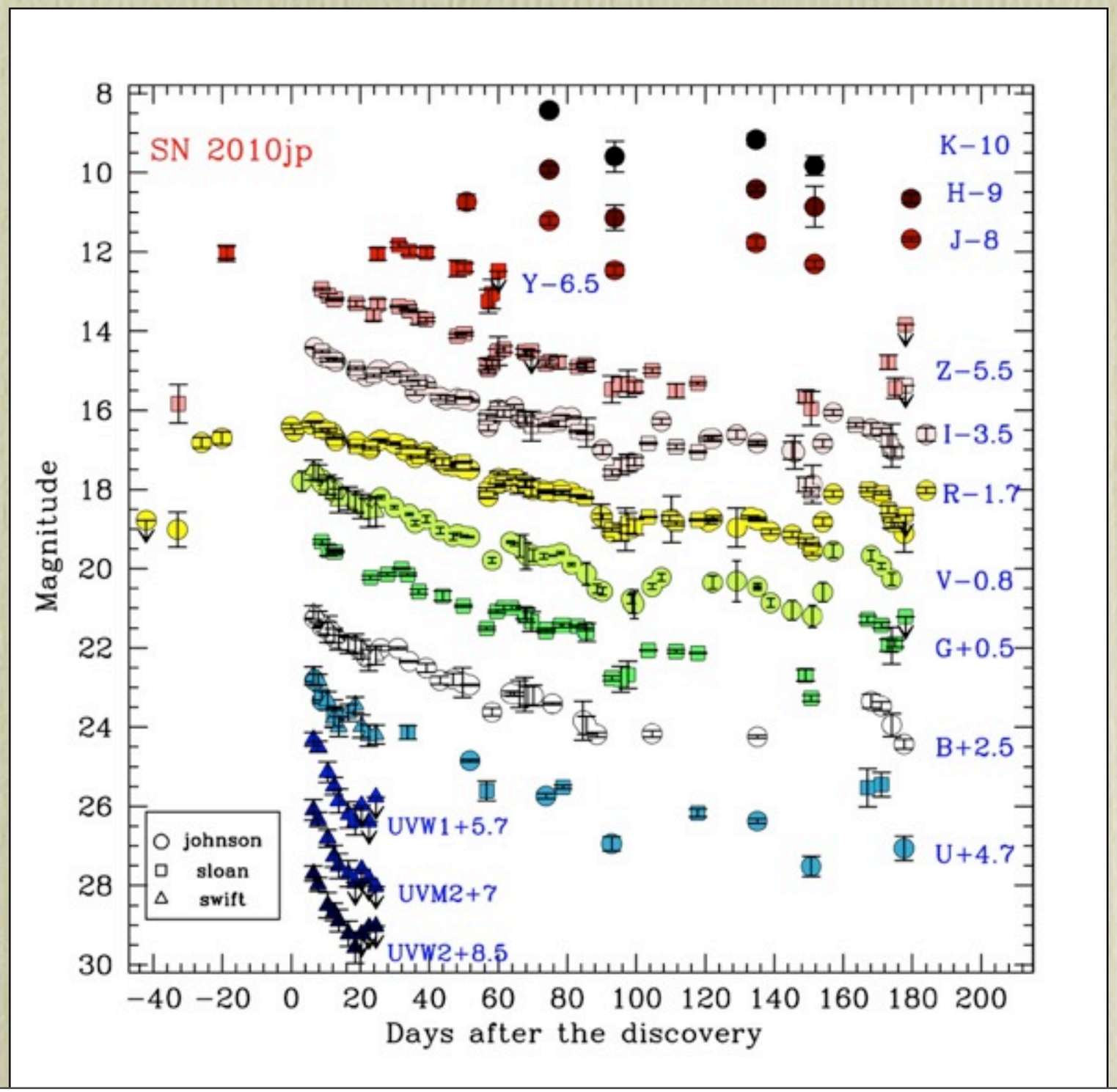

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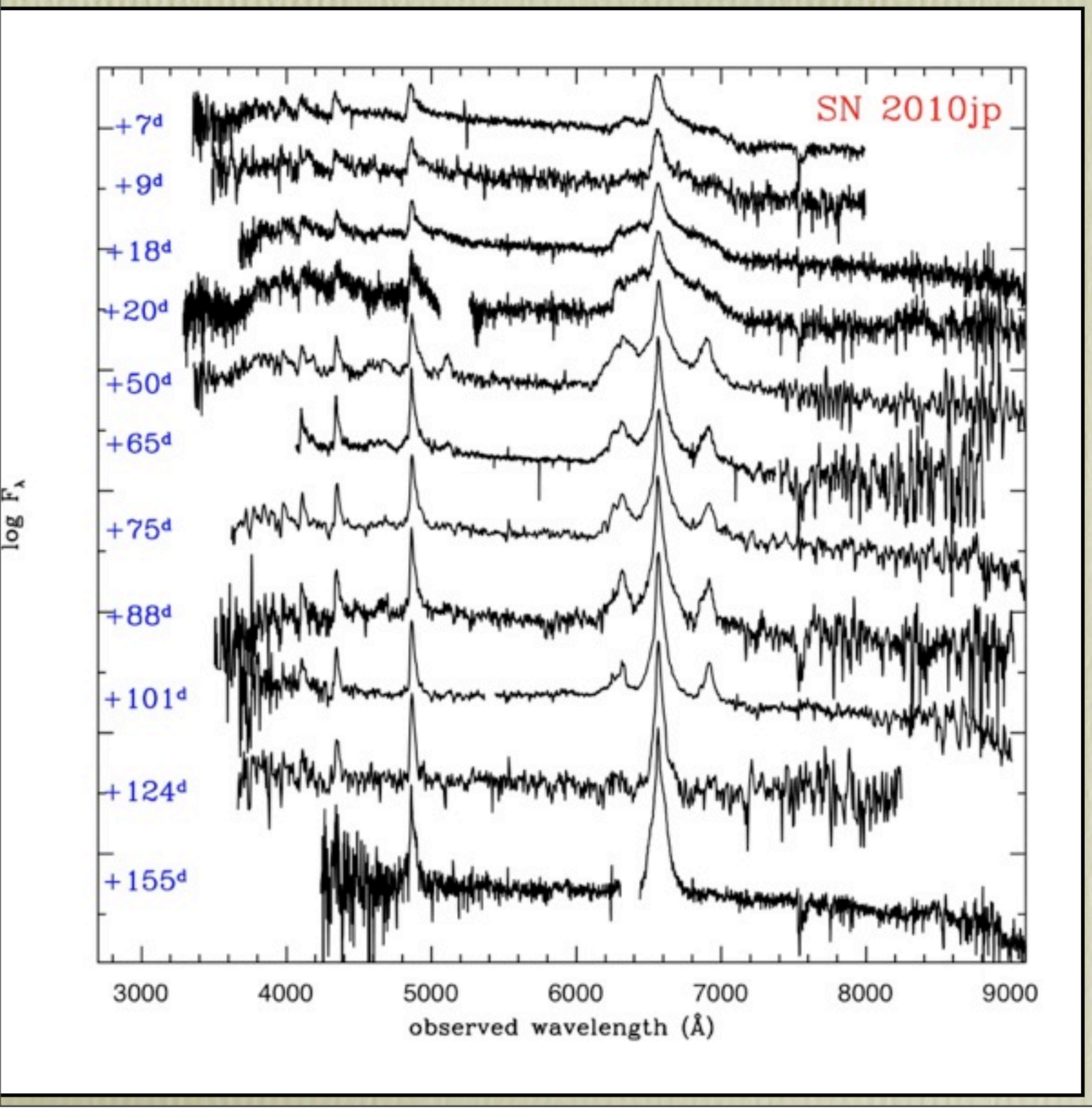

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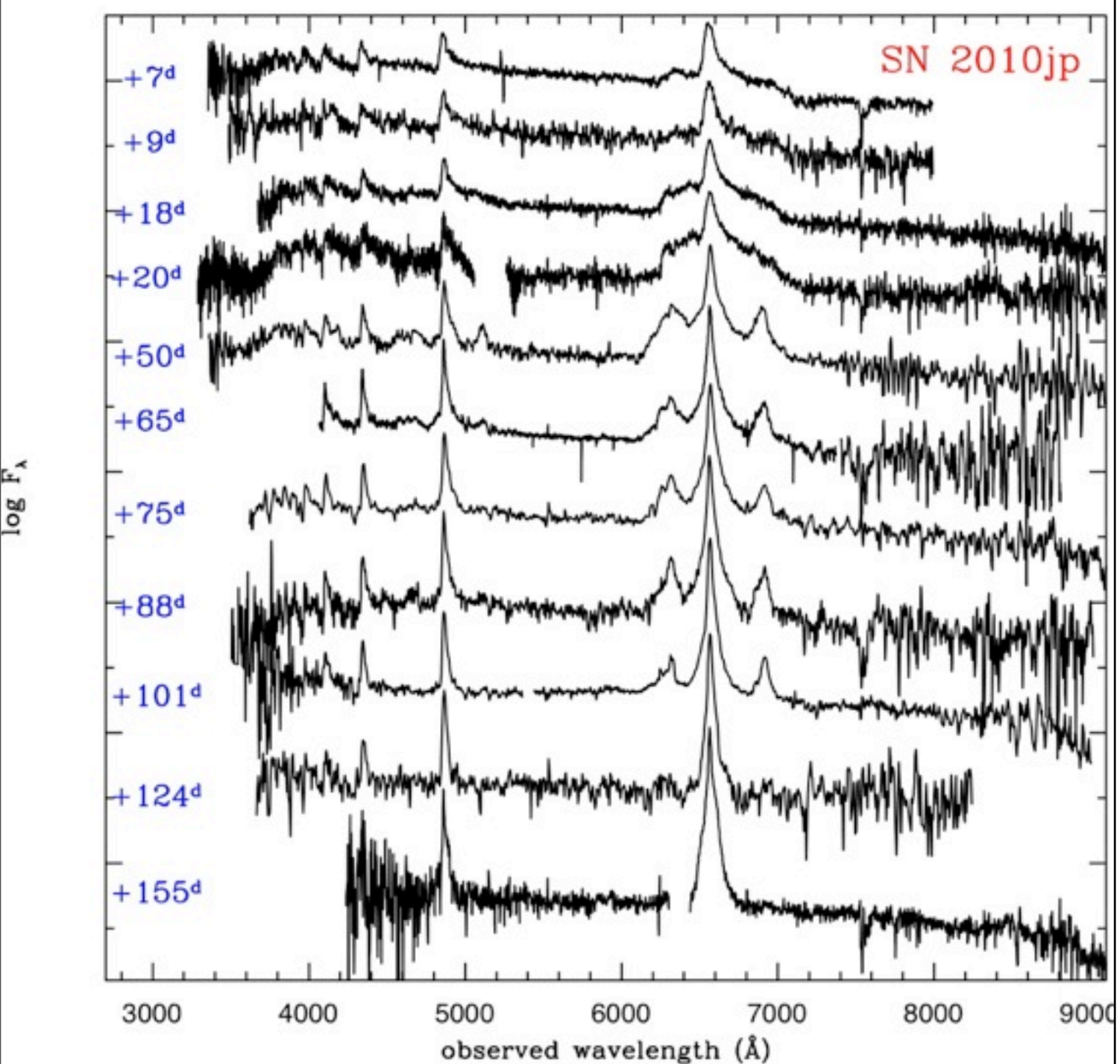
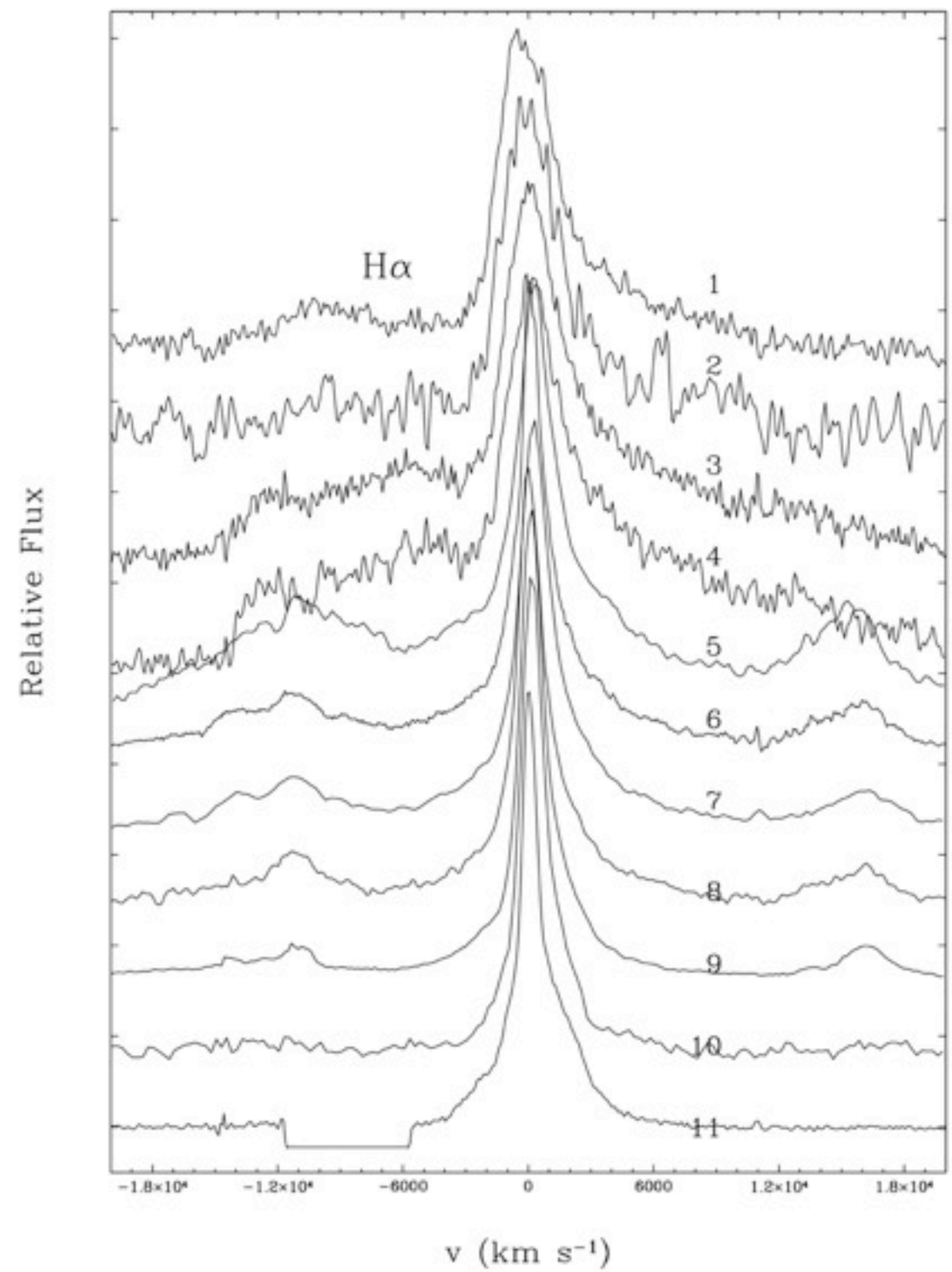


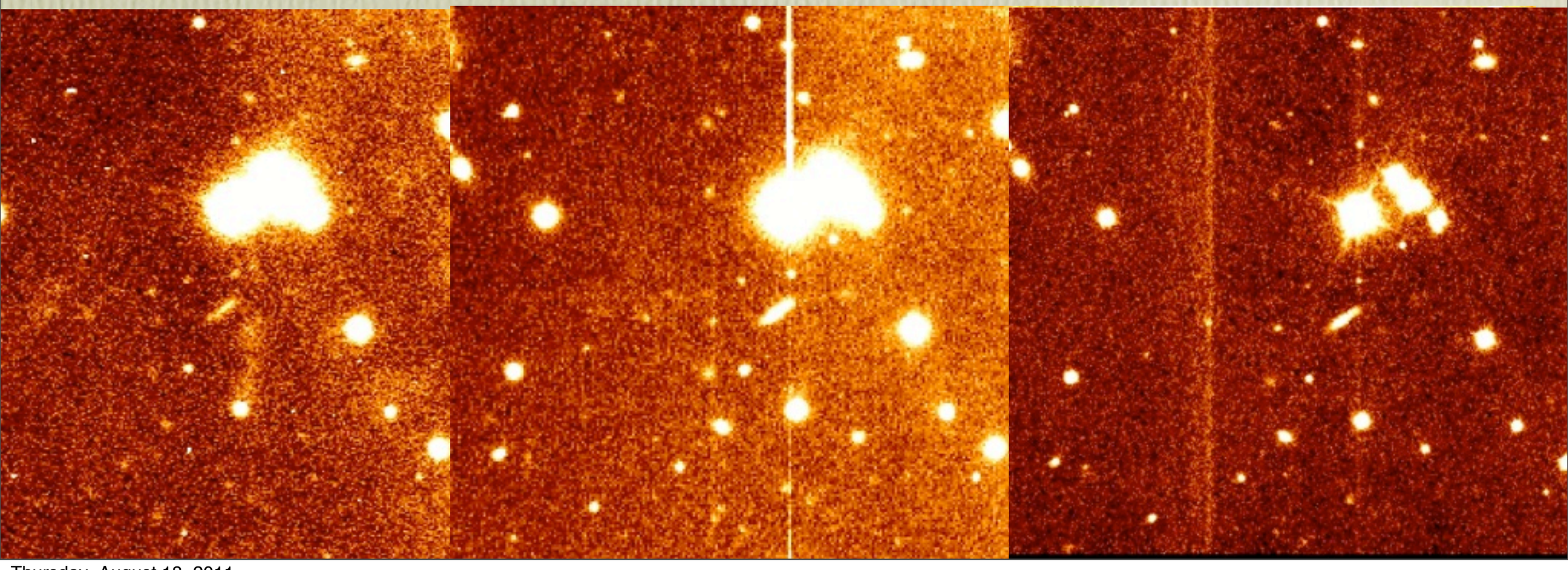


SN 2010jp: supernova or super-impostor?

No progenitor detection in optical and NIR archive images obtained in 1992, 2006, 2007, 2008 with limiting mags

B > 24.7, R> 23.5, I>23.1, J>22.0, H>21.1, K>20.7

=> M_B > -8.4, M_R> -9.5, M_J> -10.8, M_K > -12.1



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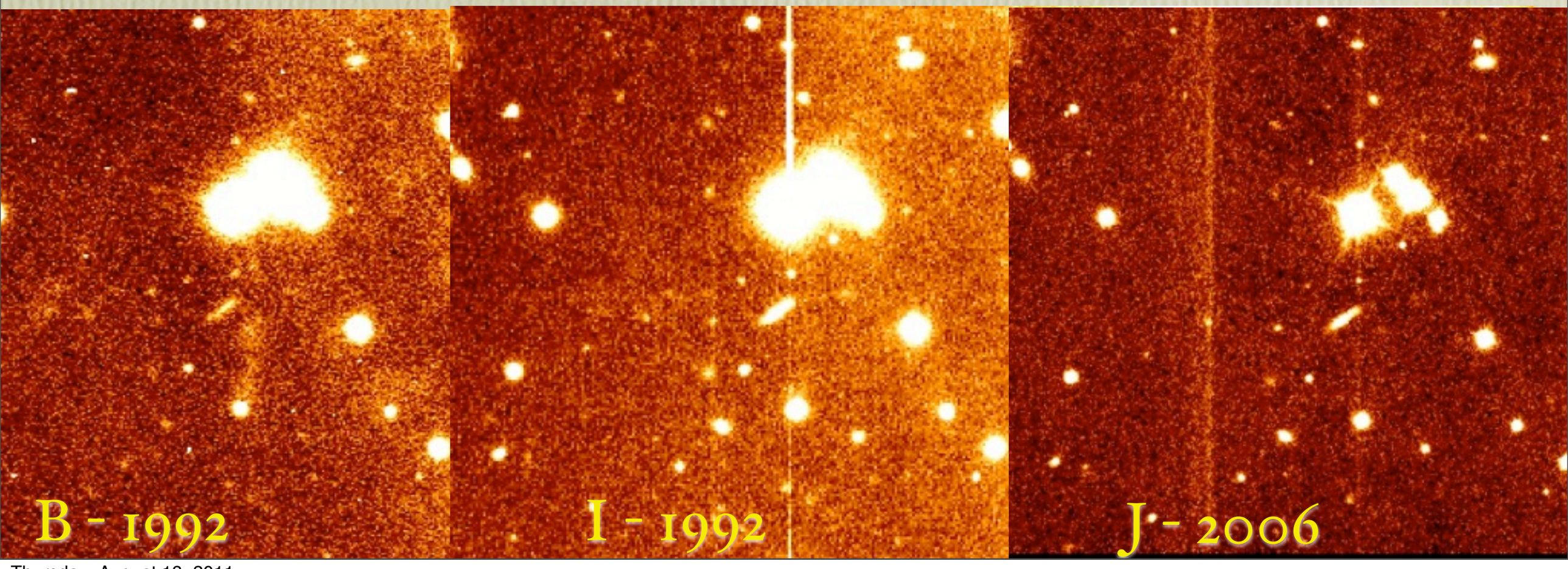

Summary

1) Recent surveys discovered new types of stellar explosions

2) Low- and high-luminosity tails probably exist in the luminosity distribution of all SN types!

3) CC-SNe may span 3-4 orders of mag in ^{56}Ni masses

4) Unusual progenitors for weird SNe?

5) New observational constraints. Now modelling is necessary!