Optical Studies of type IIb supernova SN 2011dh

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IIA CREST

SN 2011dh

Discovery - June 01.89 in the galaxy M51,

Detection on May 31.89

Non detection on May 30.1

PTF – detected on June 1.19 (PTF11eon)

Non detection on May 31.275

Classification - Spectrum taken on June 03 young type II SN (Silverman et al., Yamanaka et al. 2011).

Arcavi et al. (2011)- possibly IIb

Emergence of HeI features in the IR spectra - consistent with IIb.

Follow up studies

Radio – detected 3 days past discovery (CARMA)

Radio evolution - VLBI and EVLA

X-ray – detected by Swift XRT 3 days after explosion – followed with Swift and

Chandra.

Multi-wavelength study (Soderberg et al. 2012)

Optical follow up for first 50 days (Maund et al.)

Photometric data for ~ 300 days, preliminary light curve modeling (Tsvetkov et al. 2012).

Progenitor - HST/ACS – a luminous star at the SN location. Colour mid F-type supergiant but with higher luminosity and more extended radius.

Yellow supergiant M_{ZAMS} = 13± 3 M□(**Maund et al.)**

M_{ZAMS} = 17 - 19 M□(Van Dyk et al.)

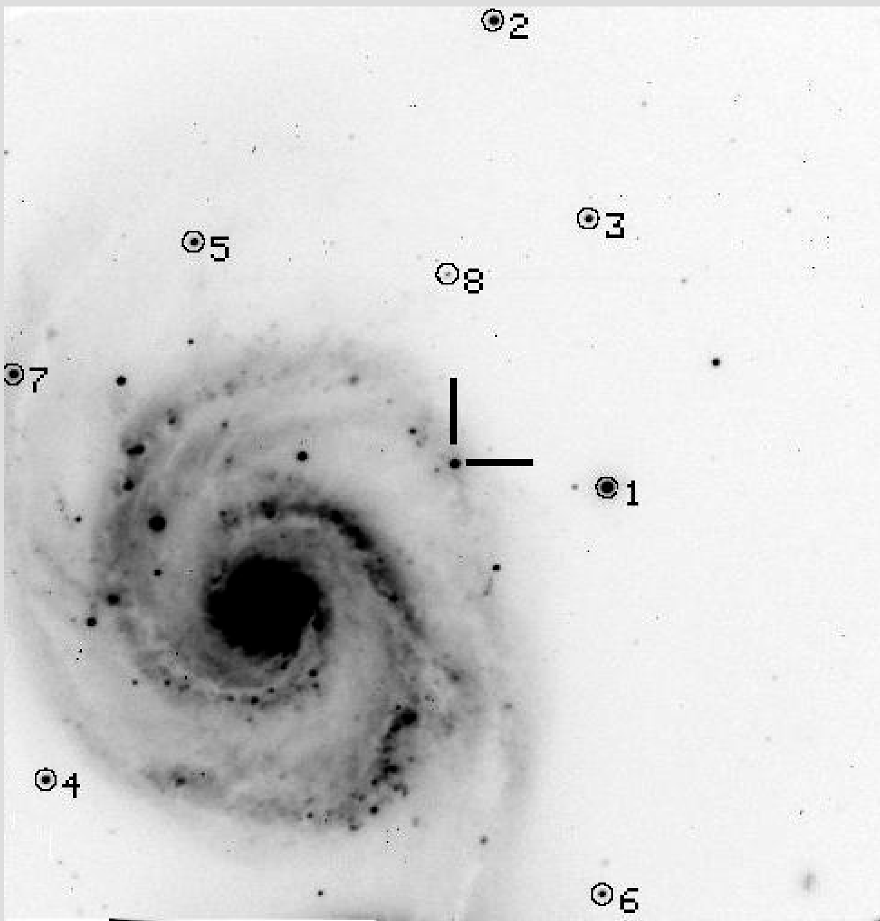
Soderberg et al. - a compact star progenitor

Bersten et al. - large progenitor with radius ~ 200 R□– **consistent with the yellow super giant detected in the pre-explosion image.**

Optical followup with HCT

Photometric and Spectroscopic monitoring ~3 days to 1 year after the explosion

Imaging Bessells UBVRI bands



troscopy -

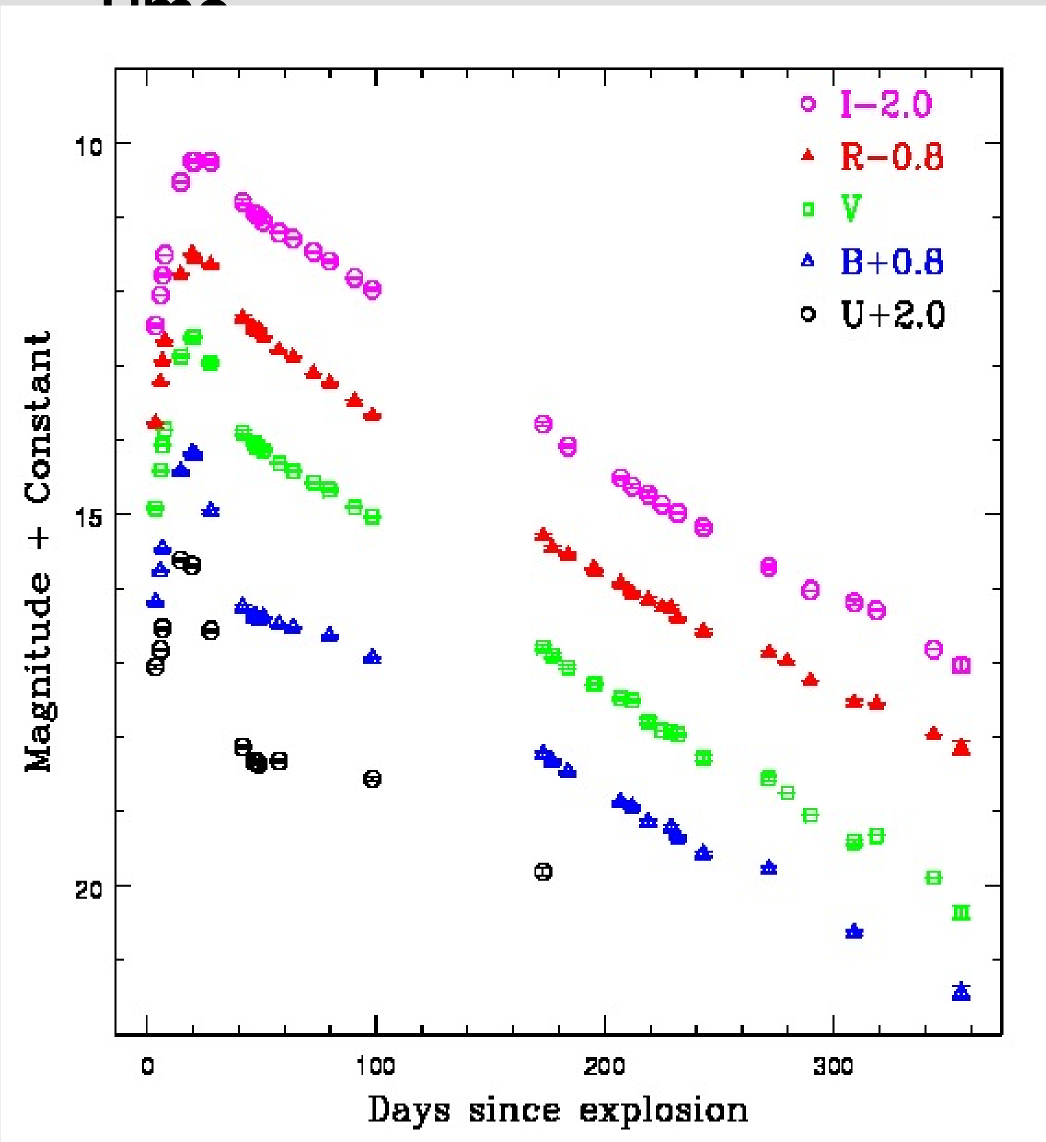
(3500 – 7800 A)

(5200 – 9250 A)

Results

Light Curve Time

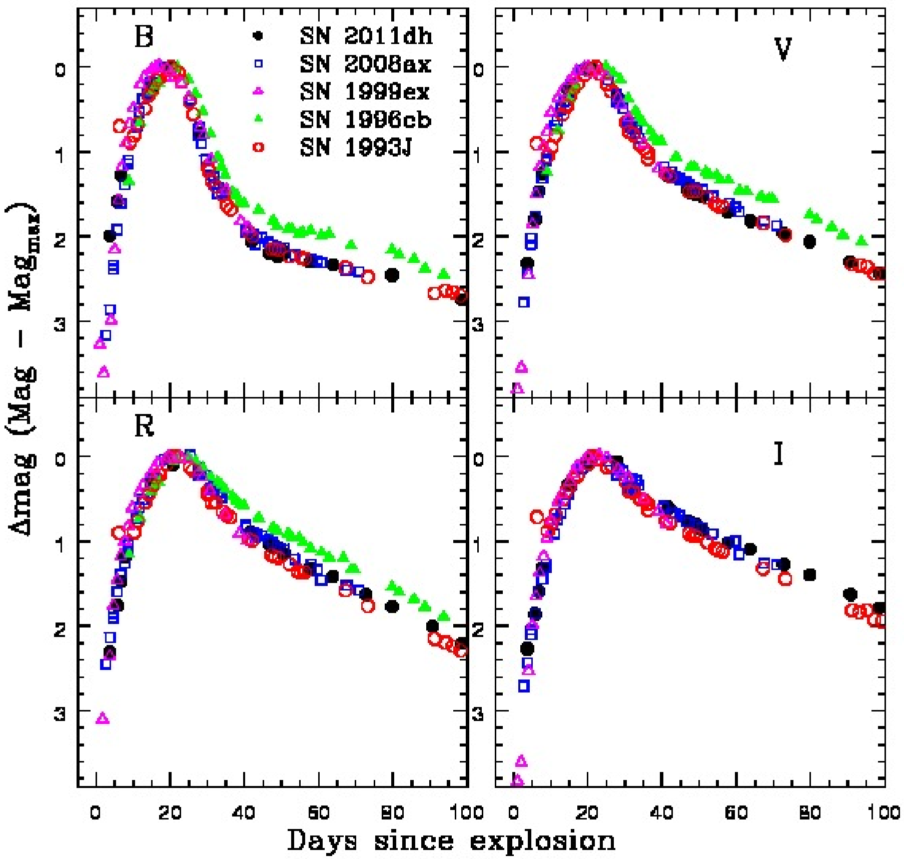
Band	Rise	Δm15
	15.8 d	
	19.6 d	1.75
	20.6 d	0.98
	21.3 d	0.64
	22.9 d	0.47

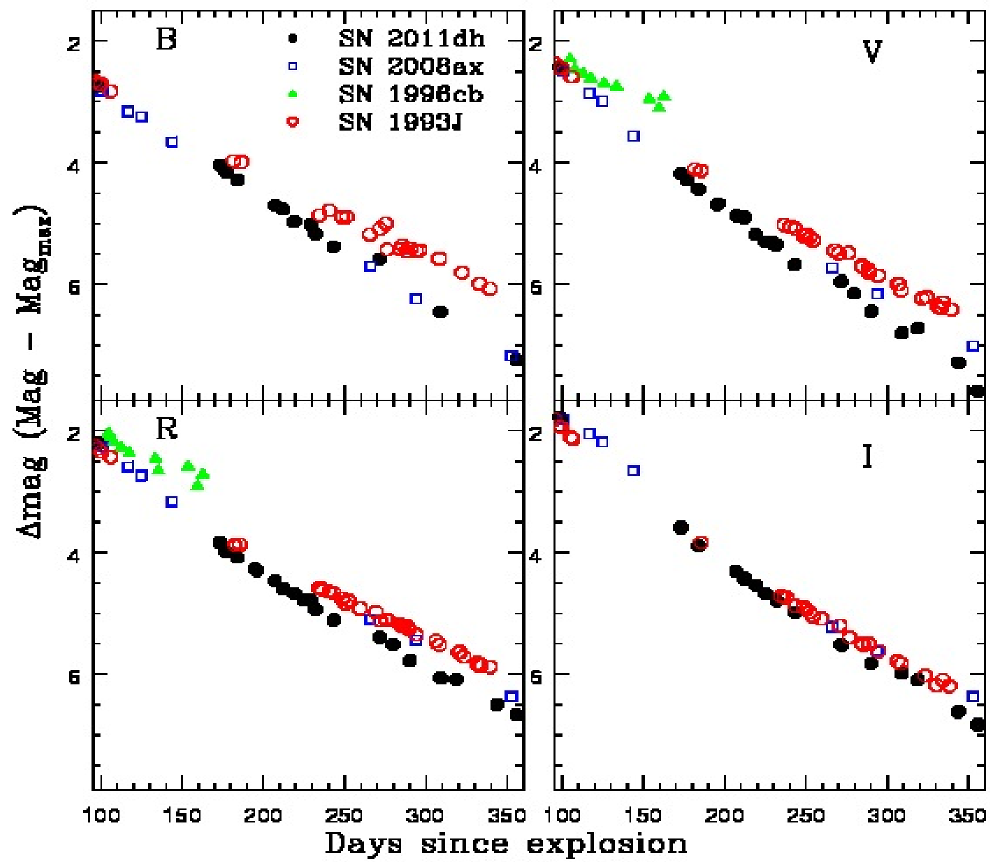


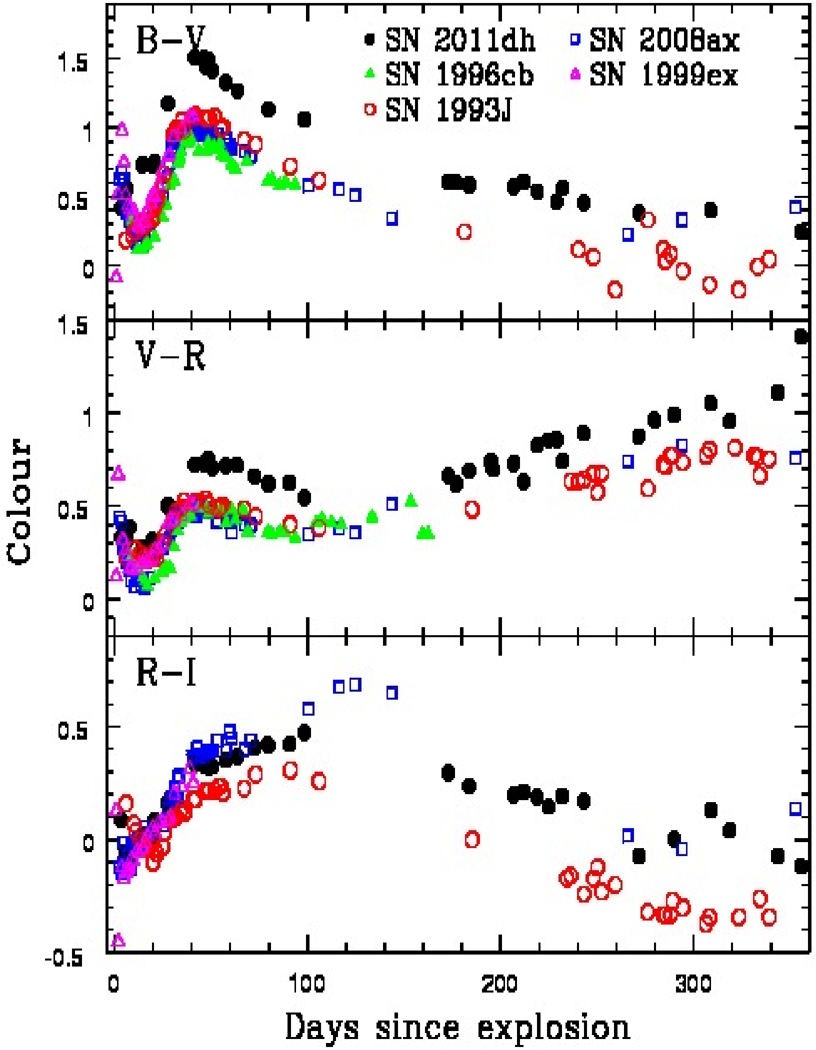
ning in B-band

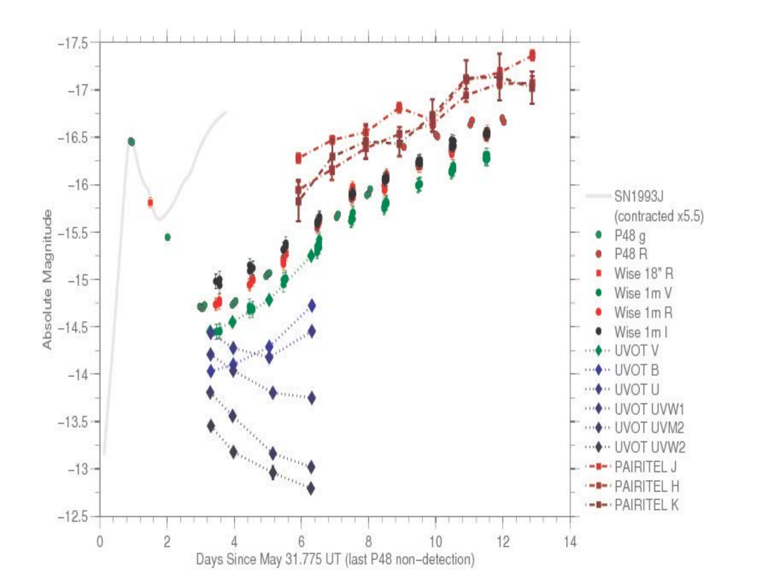
Flattening in

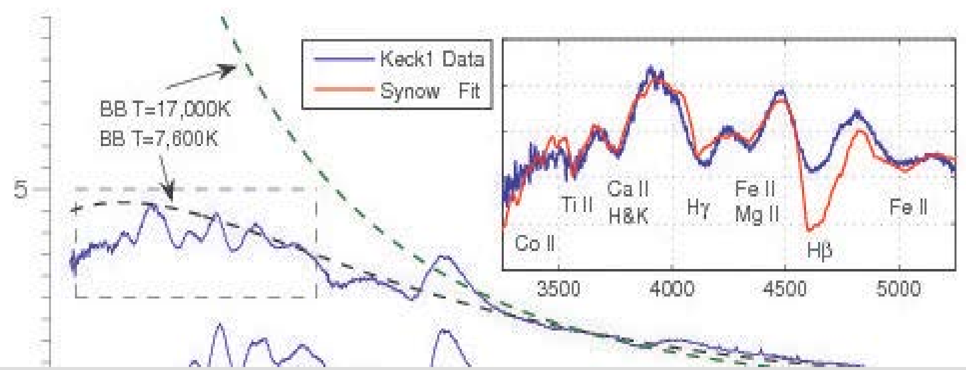
bands


B
V
R
I
SN 2011dh
SN 2008ax
SN 1999ex
SN 1996cb
SN 1993J
Δmag (Mag − Mag$_{max}$)
Days since explosion

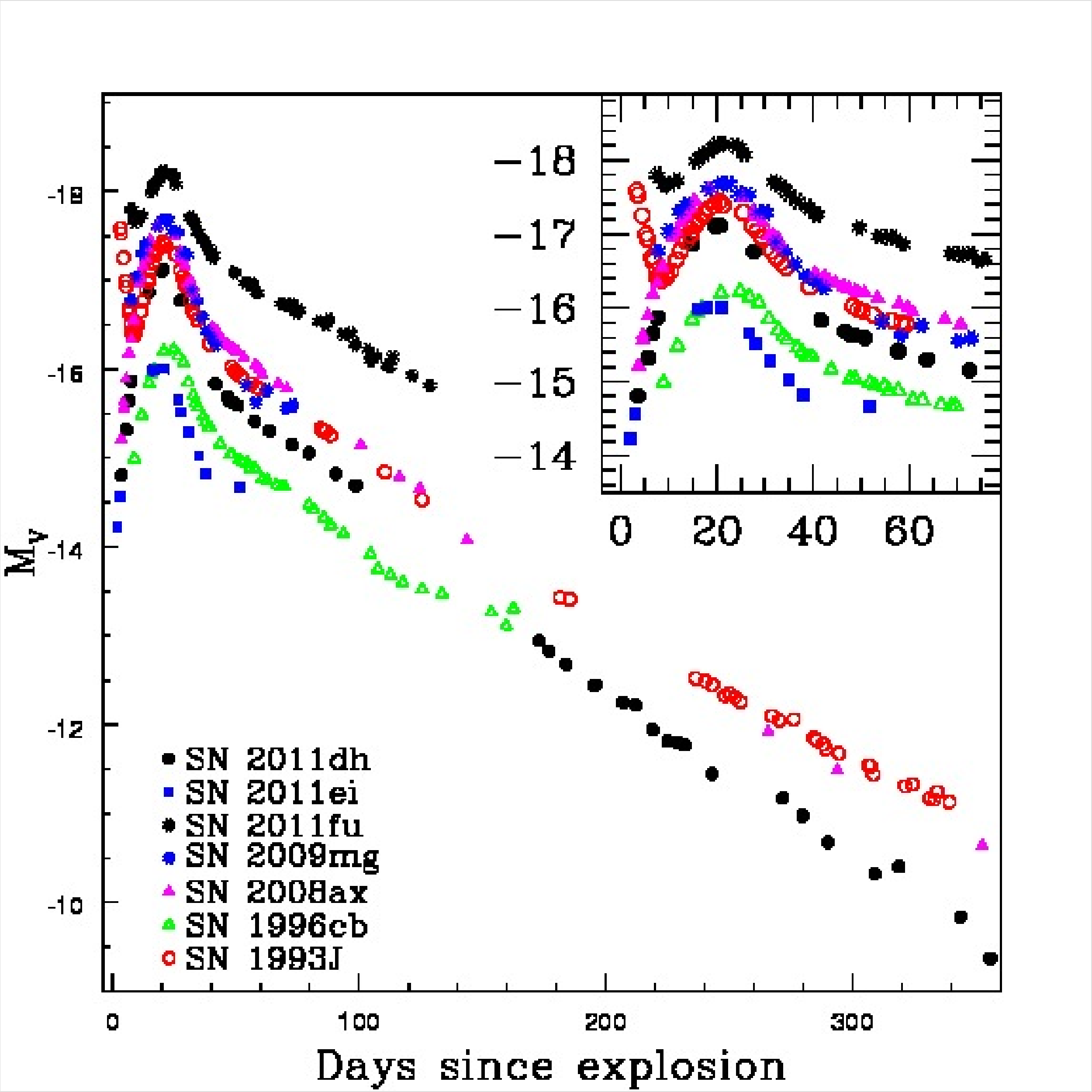

B
V
R
I
SN 2011dh
SN 2008ax
SN 1996cb
SN 1993J
Δmag (Mag − Mag$_{max}$)
Days since explosion


B−V
V−R
R−I
SN 2011dh
SN 2008ax
SN 1996cb
SN 1999ex
SN 1993J
Colour
Days since explosion
1.5
1
0.5
0
-0.5
0
100
200
300


Absolute Magnitude
Days Since May 31.775 UT (last P48 non-detection)
SN1993J
(contracted x5.5)
P48 g
P48 R
Wise 18" R
Wise 1m V
Wise 1m R
Wise 1m I
UVOT V
UVOT B
UVOT U
UVOT UVW1
UVOT UVM2
UVOT UVW2
PAIRITEL J
PAIRITEL H
PAIRITEL K


Keck1 Data
Synow Fit
BB T=17,000K
BB T=7,600K
5
Co II
Ti II
Ca II
H&K
Hγ
Fe II
Mg II
Hβ
Fe II
3500
4000
4500
5000

Absolute magnitude



B -16.38

17.43

~ 1 mag

than SE CCSNe

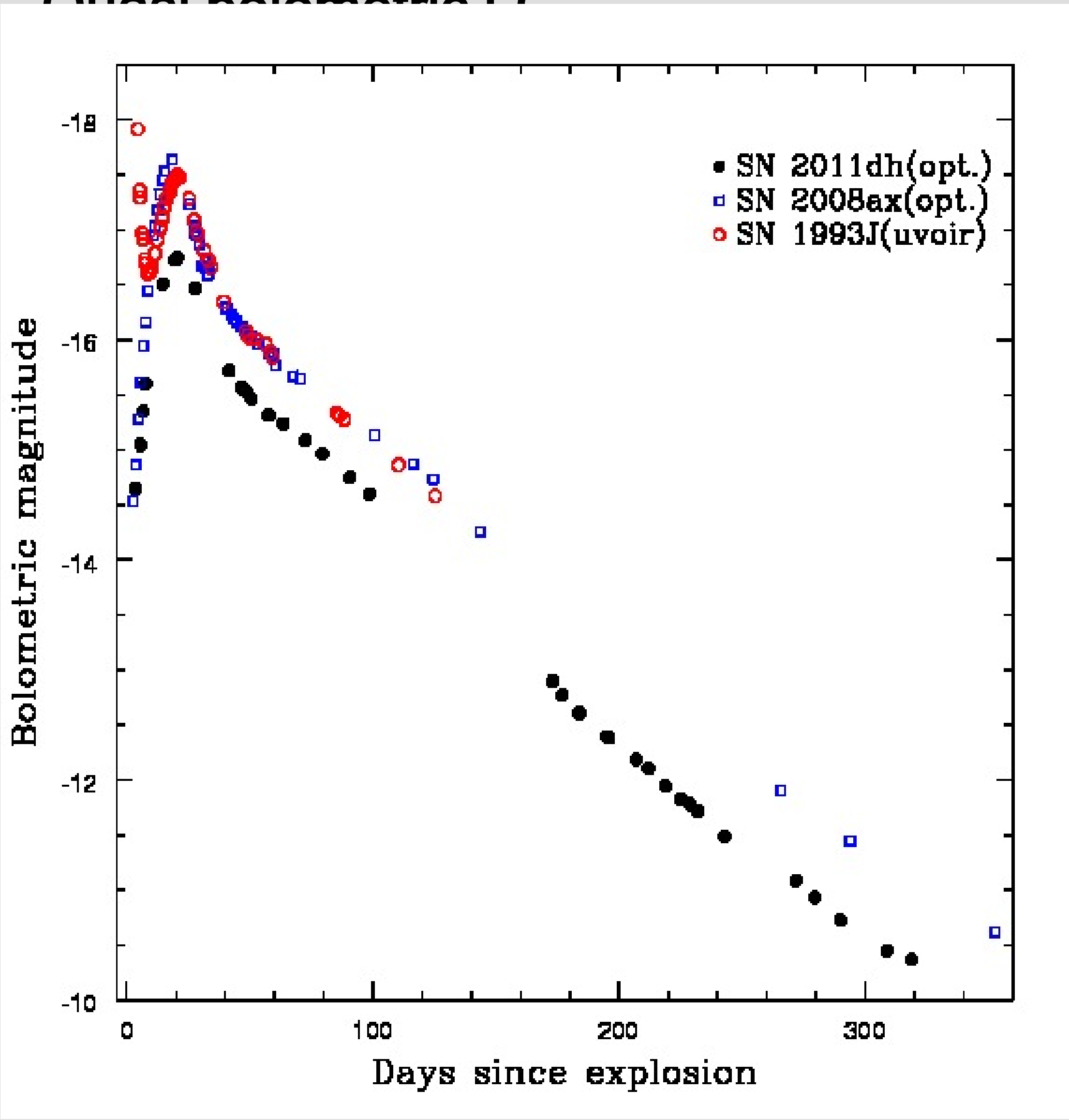
fainter

Bolometric light curve

Quasi bolometric LC

U B V R and

Fainter ~ 1 mag than SN2008ax



f ^{56}Ni

$_{bol}/\alpha S(t_R)$

on date is well

ned

Peak bol lum.

10^{42} erg sec^{-1}

M_{Ni} = 0.06 M☐

Missing UV and NIR bands

SN 1993J photospheric temperature close to maximum

~ 8200 K (Lewis+ 94)

At BB temp. ~ 8000 K, sum of UBVRI contains ~ 70% of total flux (Richmond+ 94)

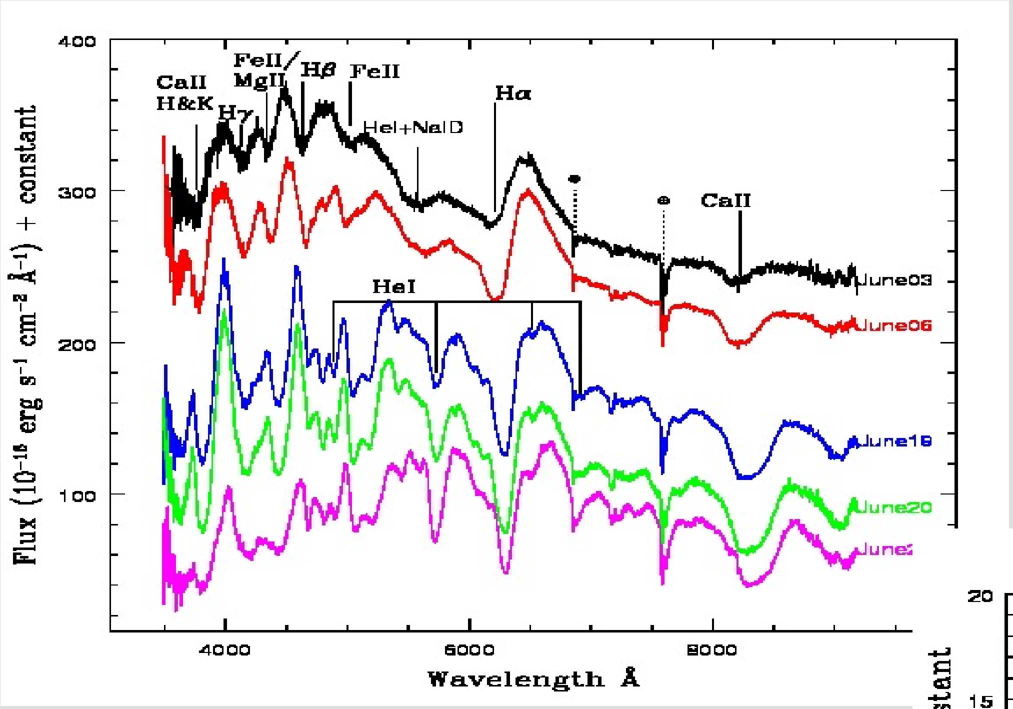
SN 2008ax – UV contribution always < 15% and at peak

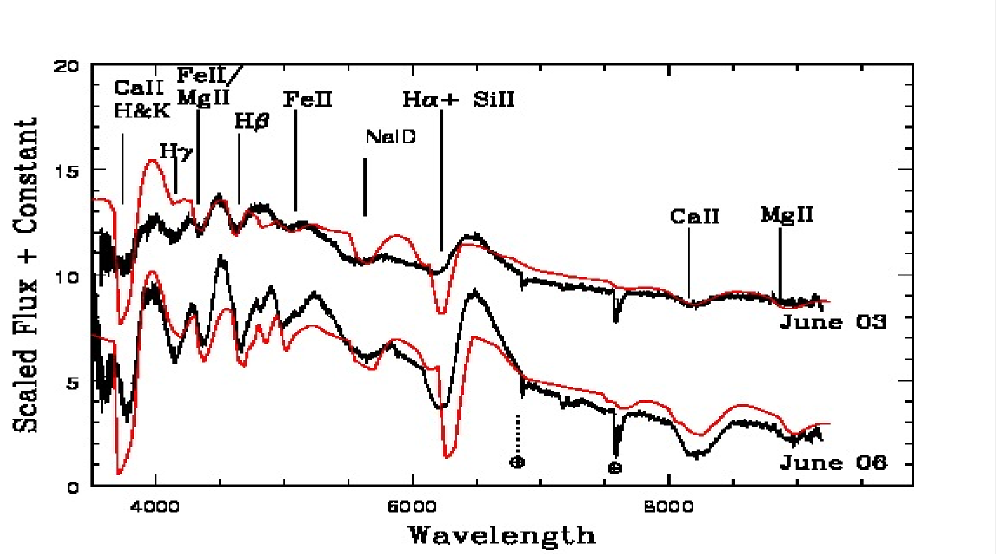
< 10% (Taubenberger+ 2011)

The peak bolometric flux of SN 2011dh

1.646×10^{42} erg sec^{-1} and M_{Ni} = 0.08 M☐

Spectroscopic results





lue to HeI

NIR spectrum

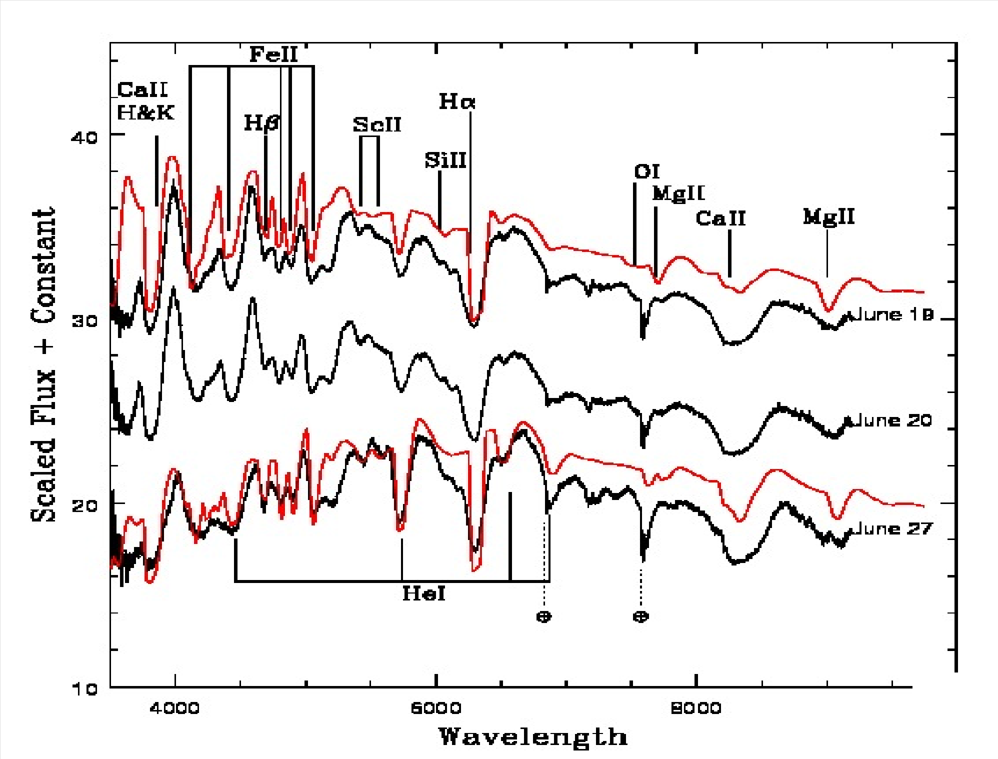
of He lines on June 14.

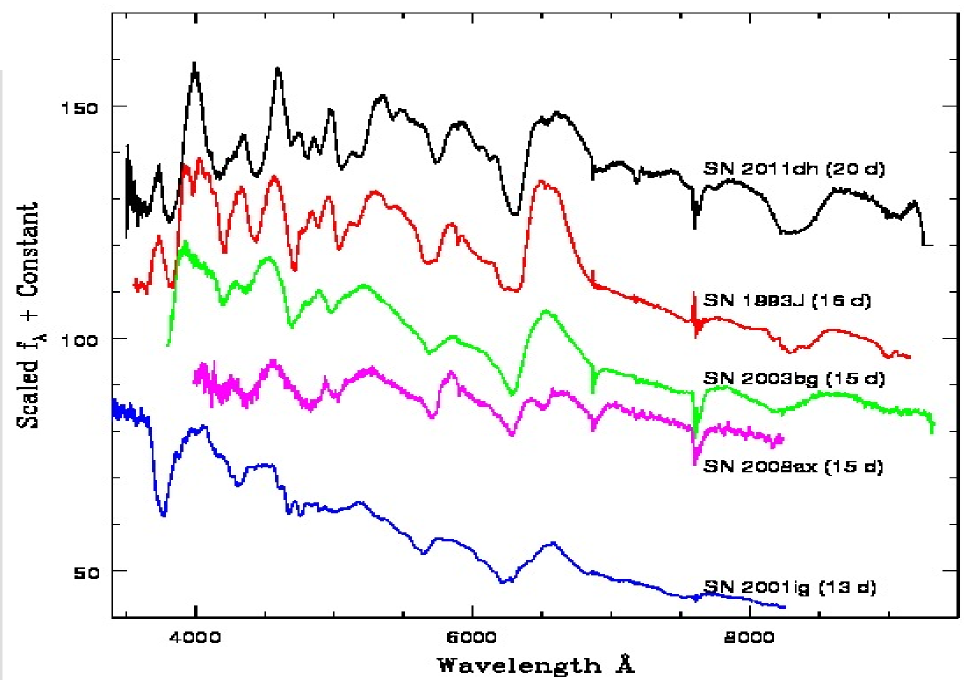
~ 13 days

(Marion + 2011)

T_{BB} = 6500 K

V_{min}(He) =





Transitional phase

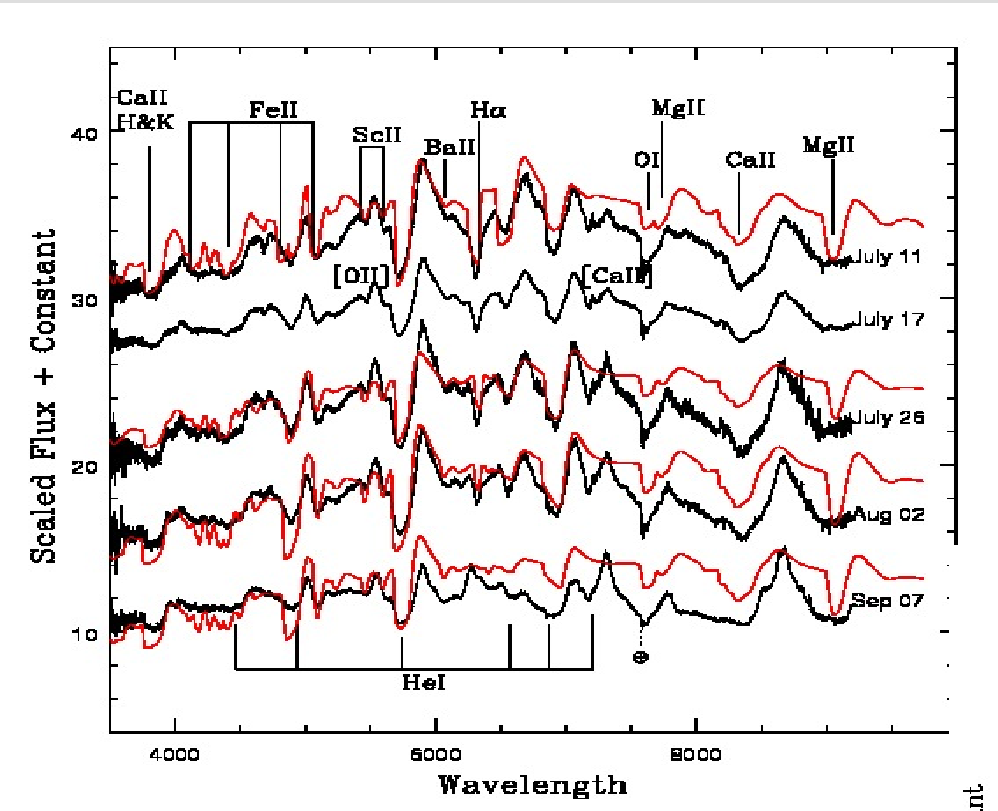
eks - ~2.5 months

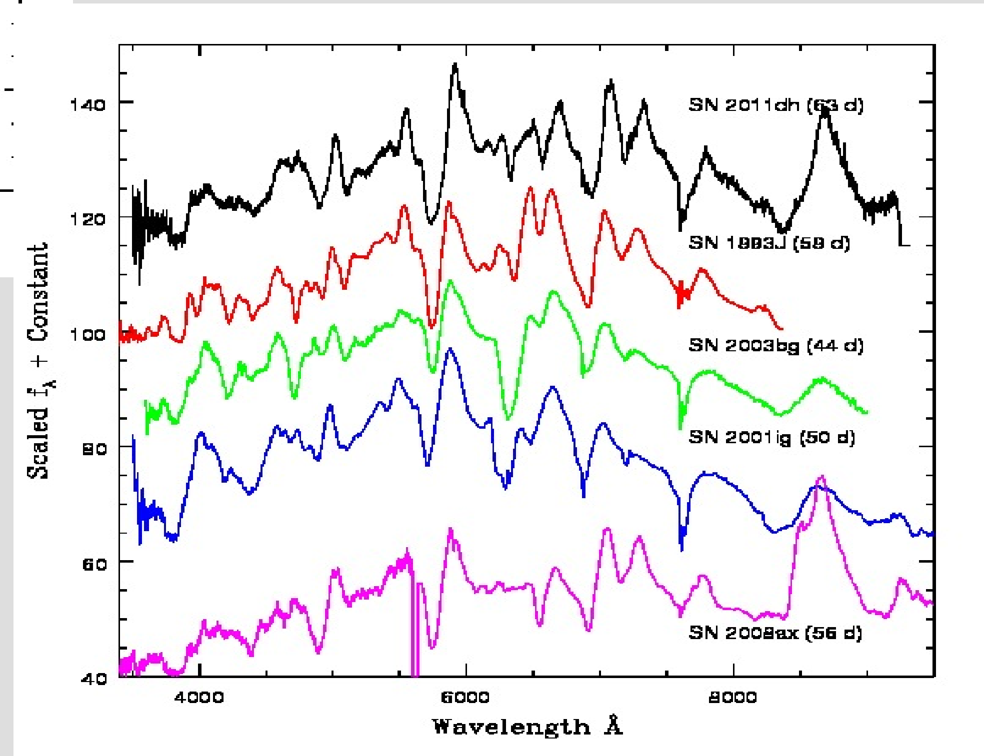
Type II-like to

T_{BB} = 6500 K

7000 km/sec

l) = 10000 km/sec





Exact amount of Hydrogen – differs significantly from

object to object.

LC of SN 1993J – explosion of red SG with H < 0.9 M□ (Shigeyama+ 1994). Woosley et al. (1994) mass of H 0.2 M□ Houck & Fransson (1996) mass of H ~ 0.3 M□

SN 2003bg: 0.05 M□(Mazzali+ 2009)

SN 2008ax: few x 0.01 M□(Chornock+ 2011)

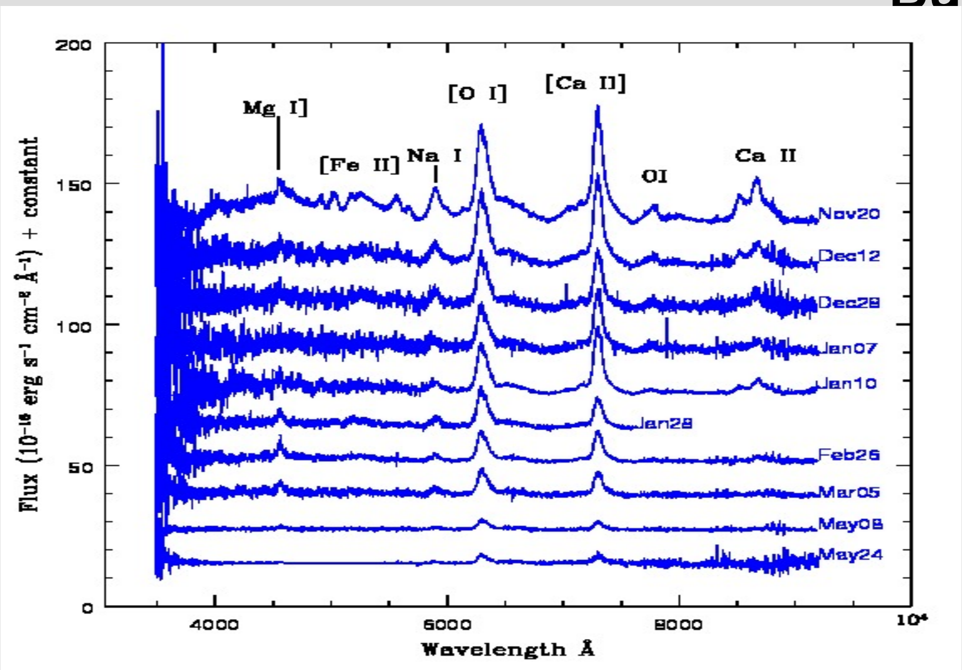
Mass of the H envelope in SN 2011dh may be similar to

SN 1993J.

Nebular phase

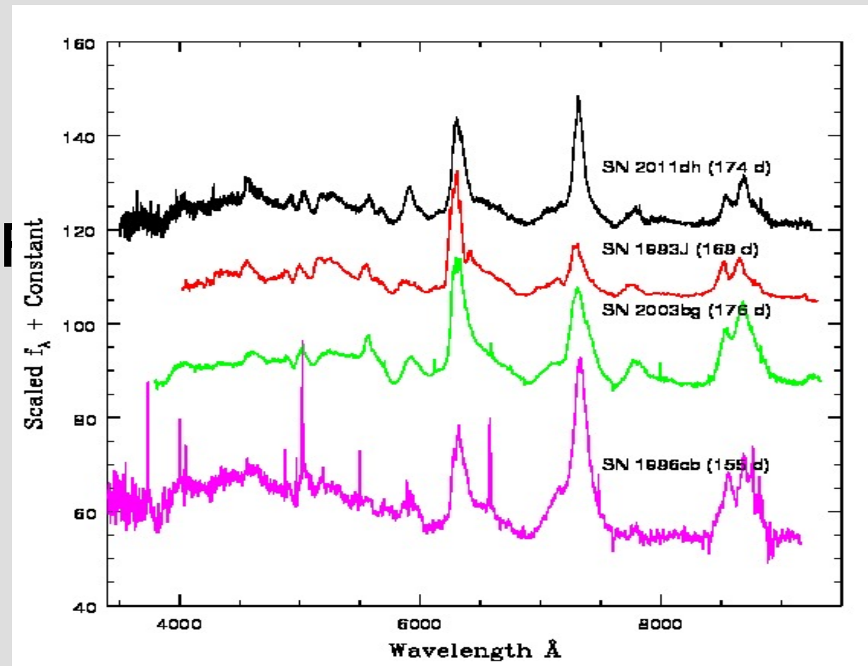
[CaII], blends of [FeII]

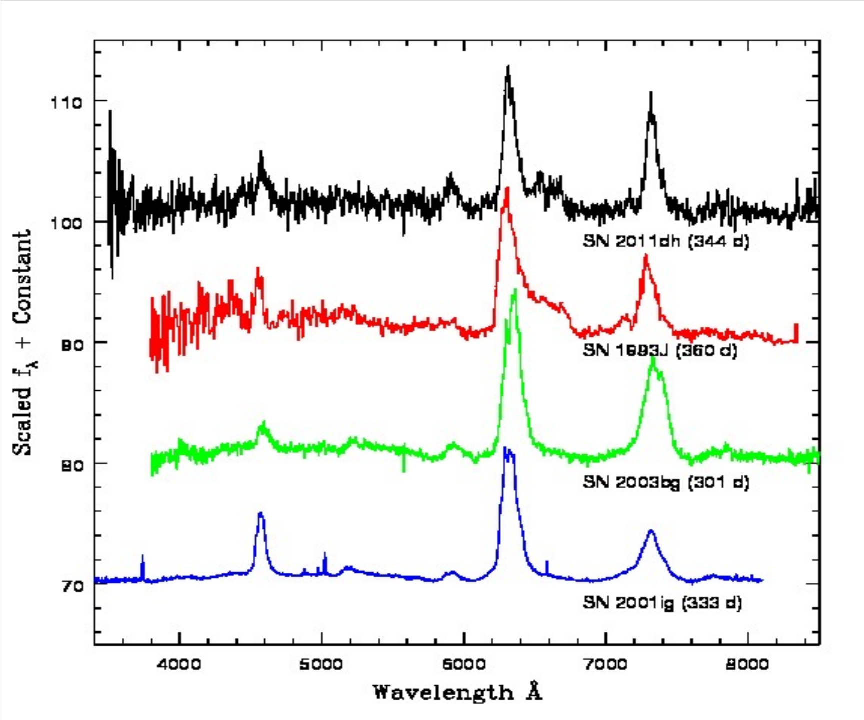
Bump redward of [OI]



[CoII] (Patat+ 95)

[I





ble mechanism for Hα

ionization of H by

radioactivity or

-rays emitted due to

993J – emission from a

by interaction

(Patat+ 95; Houck + 96)

SN 2007Y – late phase Hα **was due to** shock interaction (Stritzinger +09), CSM density is too weak (Chevalier+10)

SN 2008ax–shock-wave inter. faces serious problem

(Taubenberger+ 11)

Right combination of mixing and clumping of H and He ionized by radioactive energy deposition (Maurer+10)

SN 2011dh – detected radio in early stage.

Radio monitoring in late phase, time averaged expansion vel. of the forward shock ~ 21000 km/sec.

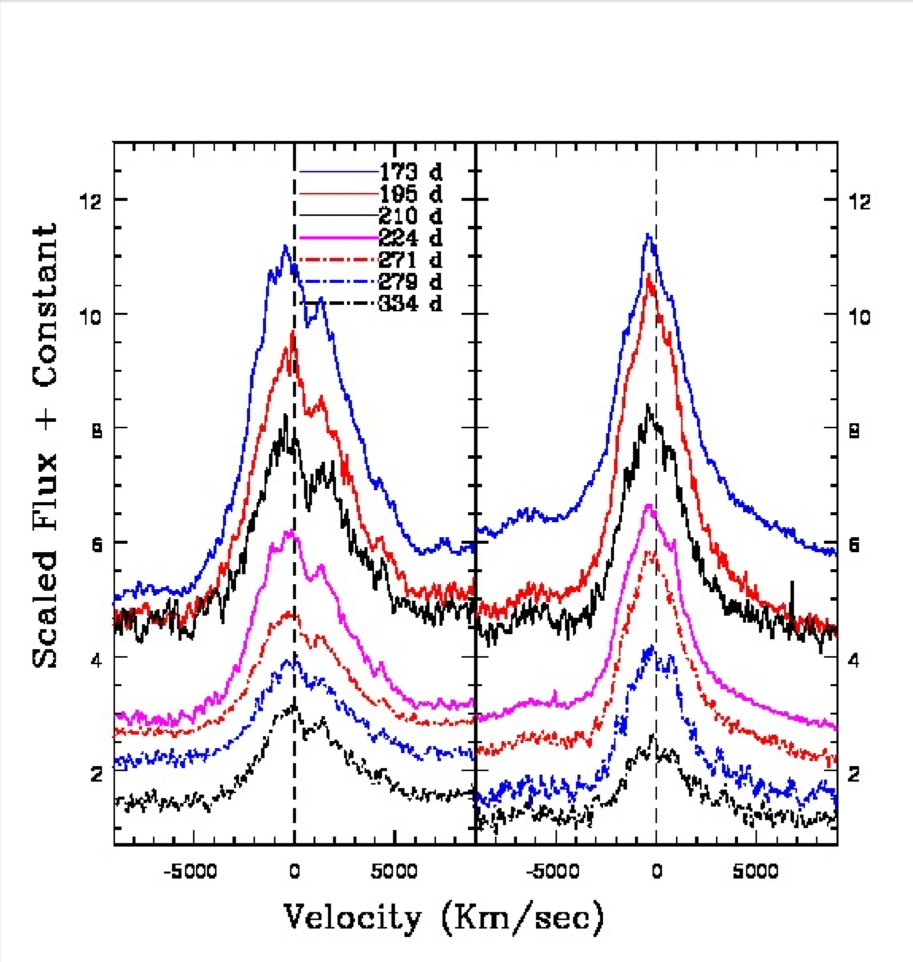
(Bietenholz + 2012)

X-ray emission – interaction of blast wave with its surrounding CSM (Campana & Immler 2012).

Presence of CSM, high expansion velocity of forward shock – shock wave interaction may be the most plausible mechanism for late phase Hα emission

Line profile of [OI] & [CaII]

Double peaked [OI]



ation ~ 3000 km/sec

asphericity in

with preferred viewing angle

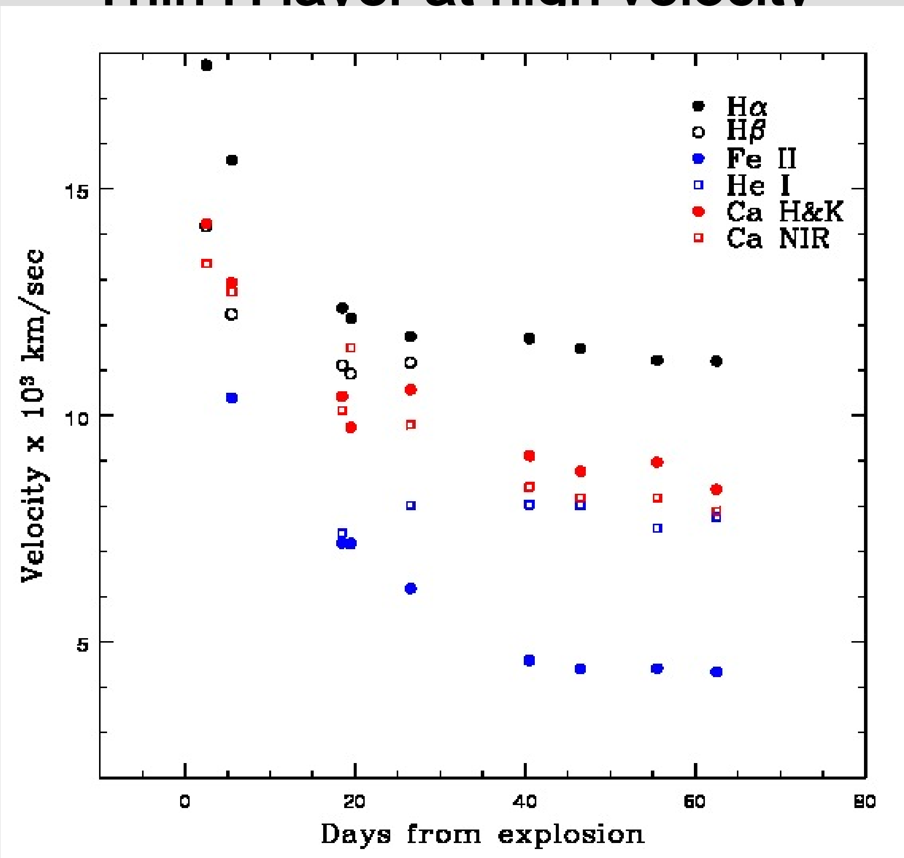
sorption (Maurer+ 10),

locity evolution looks

Velocity Evolution

Stratification of H and H layer.

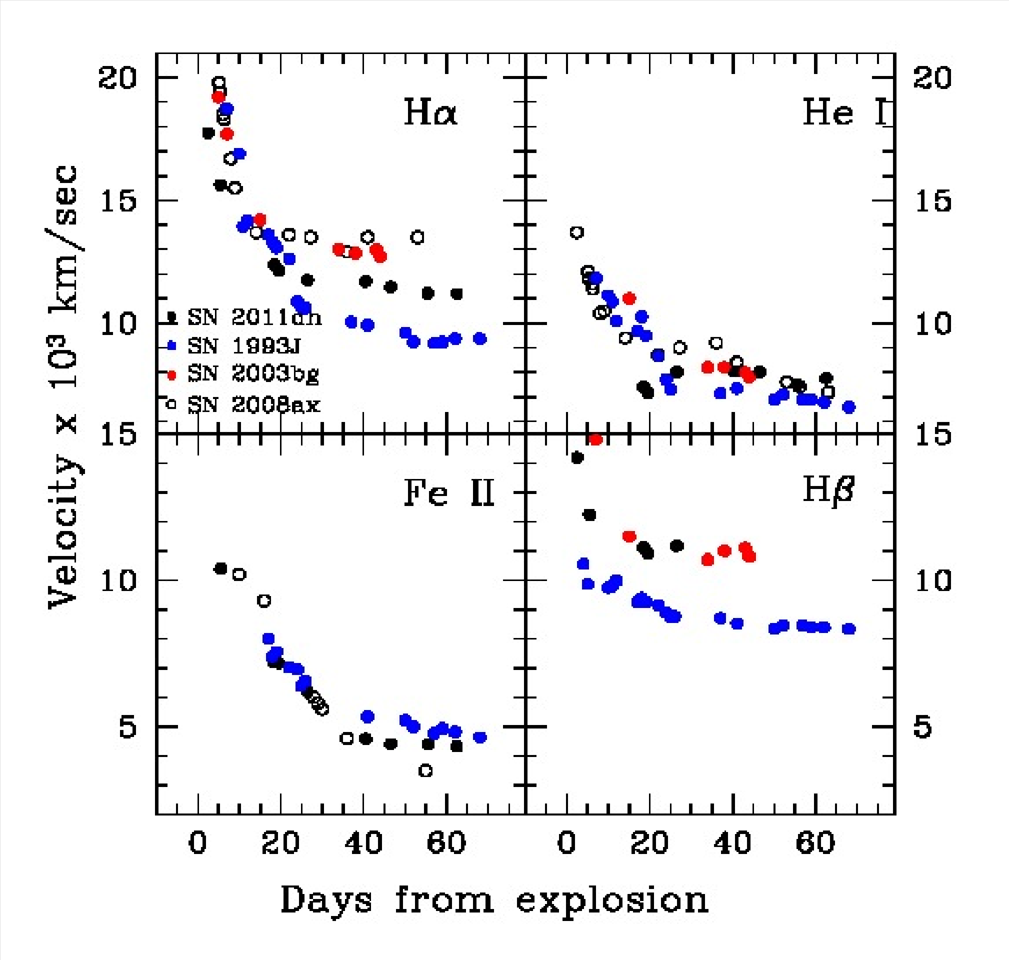
Thin H layer at high velocity



nediate layer He

core other

2003bg – spectral



um velocity of H in

on mass of H

(Iwamoto+ 1997).

past

velocity, between

& 03bg.

0.3 to 0.05

Oxygen mass and [CaII]/[OI] ratio

Uomoto (1986)

Mo = 10^8 x D^2 x F([OI]) x $\exp^{(2.28/T4)}$

[OI] flux 1.03 x 10^{-13} erg sec^{-1} cm^{-2}

Mass of oxygen 0.22 M☐

Explosive nucleosynthesis yields for CCSNe for 13-40 M☐

progenitor star or various metallicity (Nomoto et al. 06).

HII region #53, #54 and #55 of Bresolin et al. (2004)

O/H abundance is ~ few tenths of solar value.

Progenitor of SN 2011dh - low mass star of ~ 13 - 15M☐

[CaII]/[OI]

Weakly depends on the density and temp of the emitting region (Fransson & Chevalier 1989)

Good diagnostic of the of main-sequence mass of the progenitor.

Smaller value is expected for massive star (Nomoto+06)

Flux ratio at ~ 340 days after explosion ~ 0.7

Summary :

- UBVRI photometry and medium resolution spectroscopy ~ 3 days to 1 yr after explosion
- B-band rise time 19.6±0.6 days, M_B = -16.38; M_V = -17.12
- Late phase steepening in the B-band light curve
- Peak quasi-bolometric luminosity 1.267 x 10^{42} erg sec^{-1} mass of ^{56}Ni = 0.06 $M_\odot$
- Hα is seen till ~ 60 days after explosion.
- Nebular spectrum - double-peaked [OI] profile
- Box shaped emission in the red wing of [OI] line
- Mass of oxygen ~ 0.22 $M_\odot$ – less massive progenitor in a binary system.

Thank you