Optical and Near IR Observation of Bright Supernovae by Hiroshima 1.5-m and Other Domestic Telescopes in Japan

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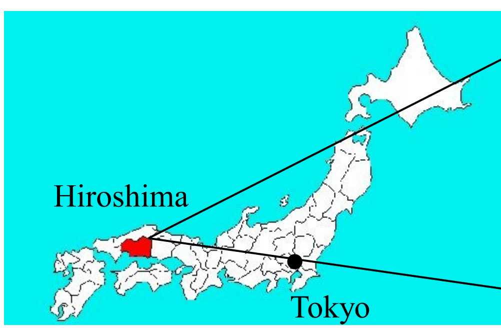
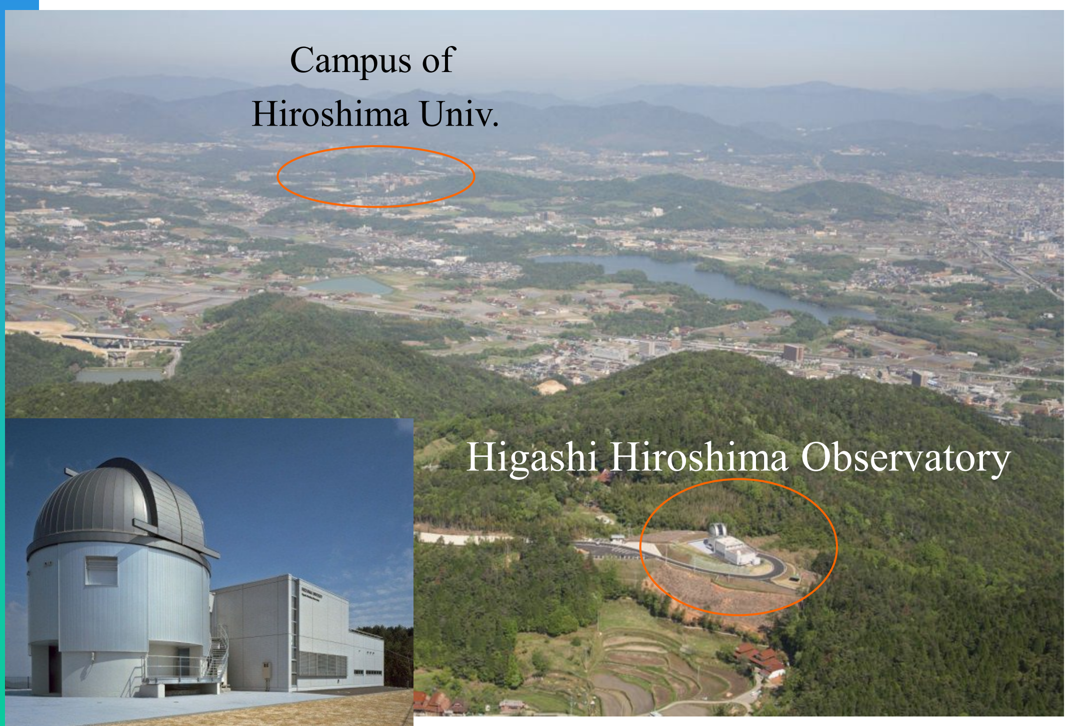
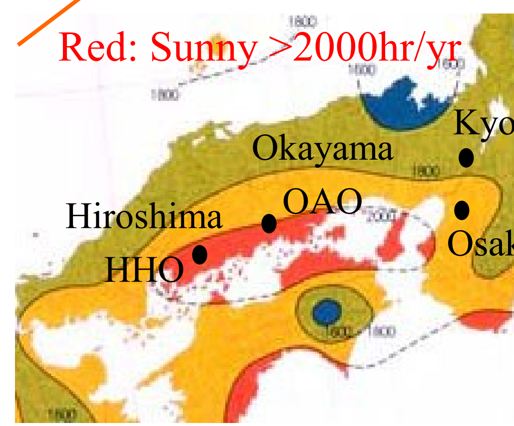


Higashi-Hiroshima Observatory (HHO)

- Found in 2006
- Only ~20 min by car from campus (503m above sea level)
- Better seeing relatively within Japan (FWHM ~1.1 arcsec by DIMM)
- Sky brightness R~19 mag/arcsec^2 in dark nights
- 1.5-m telescope, 0.3-m telescope, sky-monitor, etc.





Kanata 1.5-m telescope and instruments

<u>High-speed readout spectrograph:</u> 2008-

Optical Imaging spectrograph with high-speed readout camera FoV: 2.3’×2.3′

SITe EB CCD (30 frames/sec)

<u>HOWPol</u>: 2009-

Optical Imaging polarimeter with a low-res. spectrograph

FoV 15′ Φ

2 Hamamatsu CCDs

<u>HONIR</u>: 2012-

Simultaneous optical and NIR imager and spectrograph with polarimetric capability

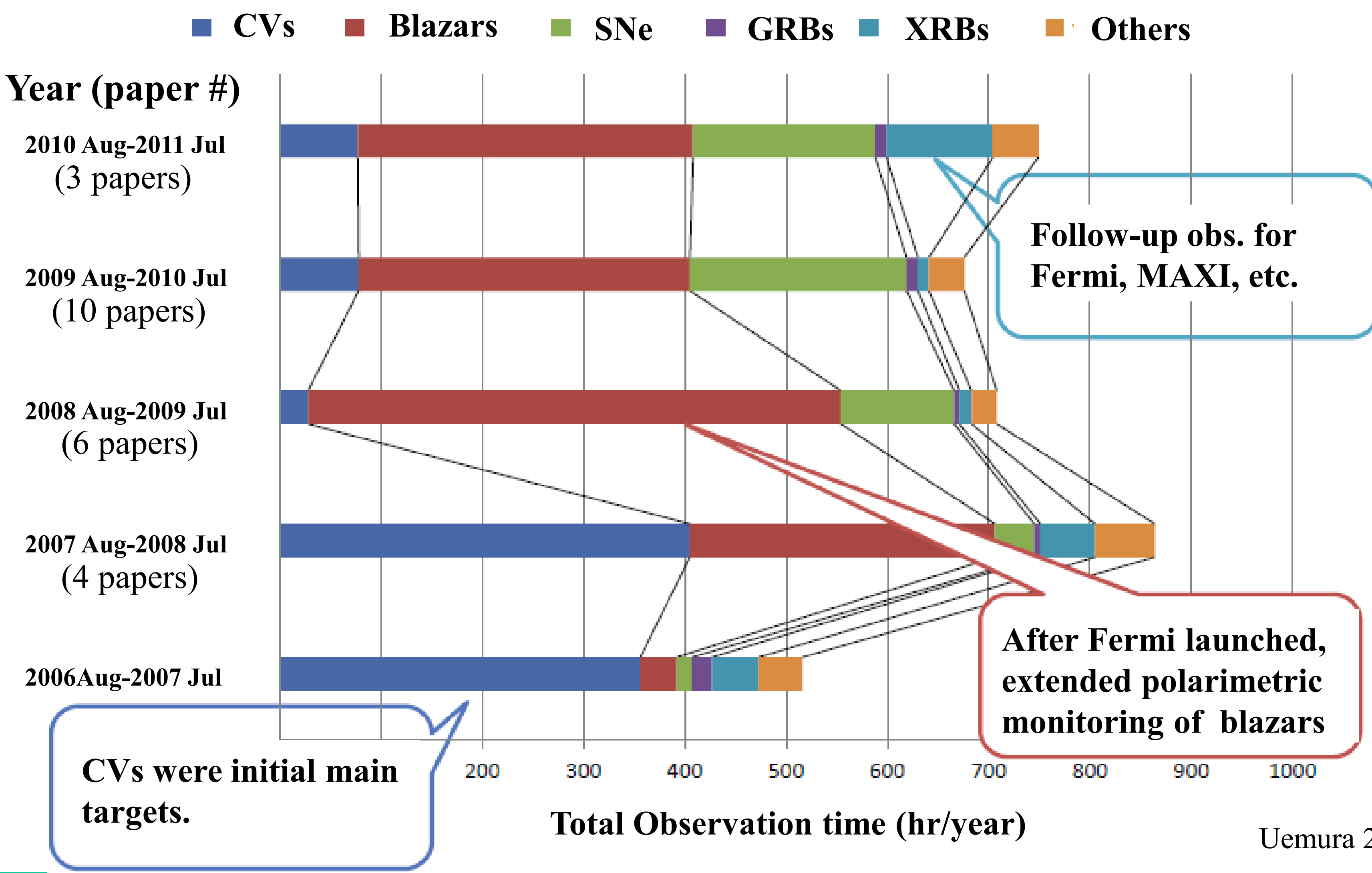
FoV 10′ × 10′(H)

Hamamatsu CCD + Raytheon HgCdTe array

Kanata Telescope

- 1.5mΦ main mirror
- High speed (5° /sec) azimuthal rotation

Observed Target in Kanata telescope



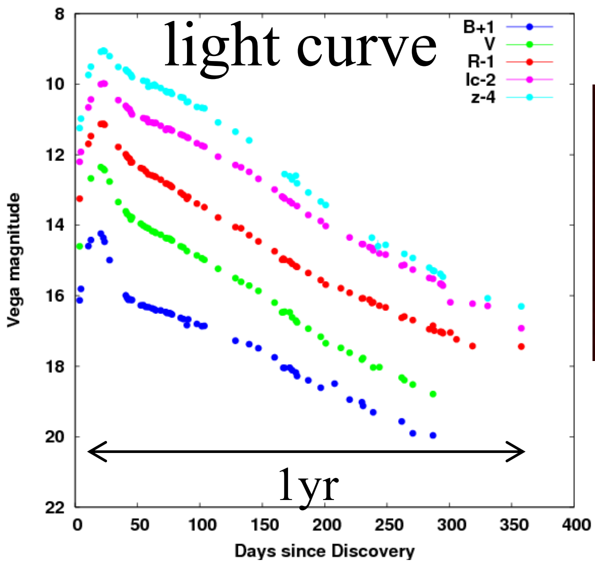
Uemura 2011

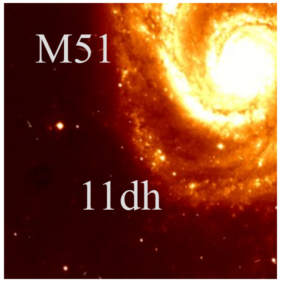
Inter University Cooperation Network: OISTER

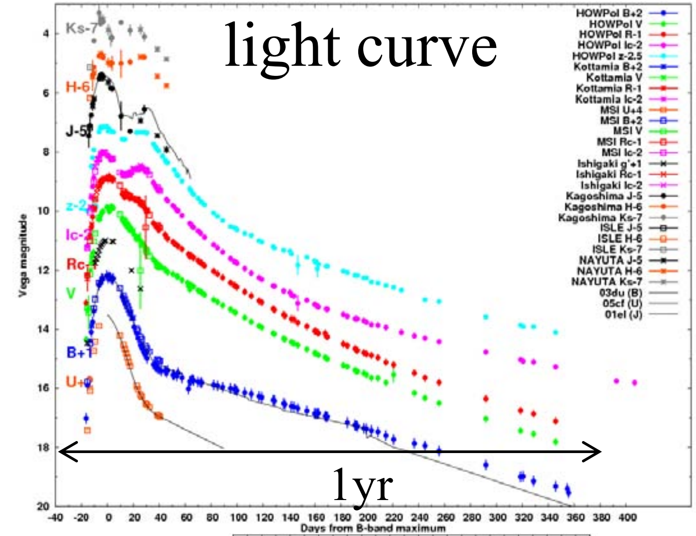
(Japan)	(Chile)	(South Africa)
16 tels.	1 tel.	1 tel.
0.5-2m	1m	1.4m

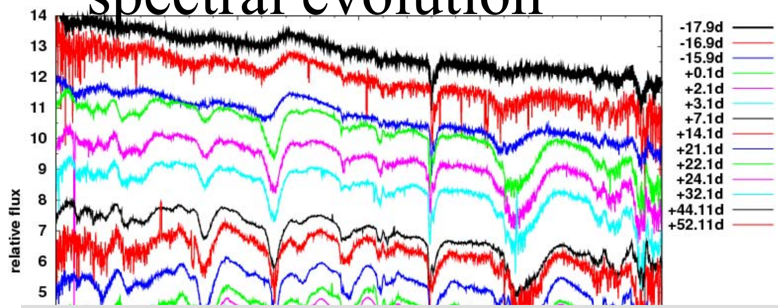
(Hawaii)
Subaru
8.2m

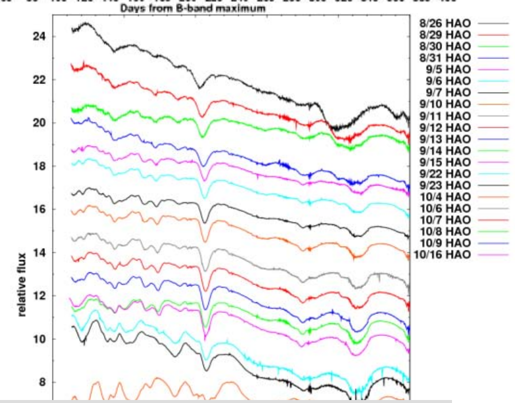
SN 2011dh (IIb)　　SN 2011fe (Ia)











With Japanese telescopes, detailed observation (Opt/IR photometry, spectroscopy) is now available for nearby SNe

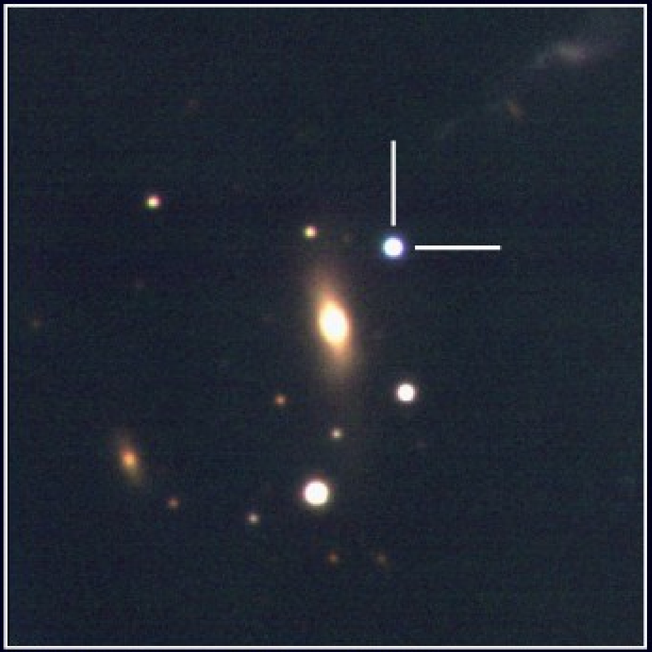
Yamanaka + in prep.

Topic: Diversity in SNe

- Extremely bright type Ia SN 2009dc (Yamanaka, KK+ 2009)
- SN 2012dn: Fainter version of SN 2009dc-like SNe? (Yamanaka in prep)
- Faint type Ia SN 2012Z (Yamanaka in prep)
- Bright type Ib SN 2012au (Takaki in prep)

Sorry, but most results are still preliminary

SN 2009dc: extremely bright SN Ia



SN 2009dc in UGC 10064
KANATA Telescope/HOWPol (B, V, R)

SN 2009dc was discovered at 16.5 mag in lenticular galaxy UGC 10064 (d~100 Mpc) on 2009 Apr 9.31 UT (CBET 1762).

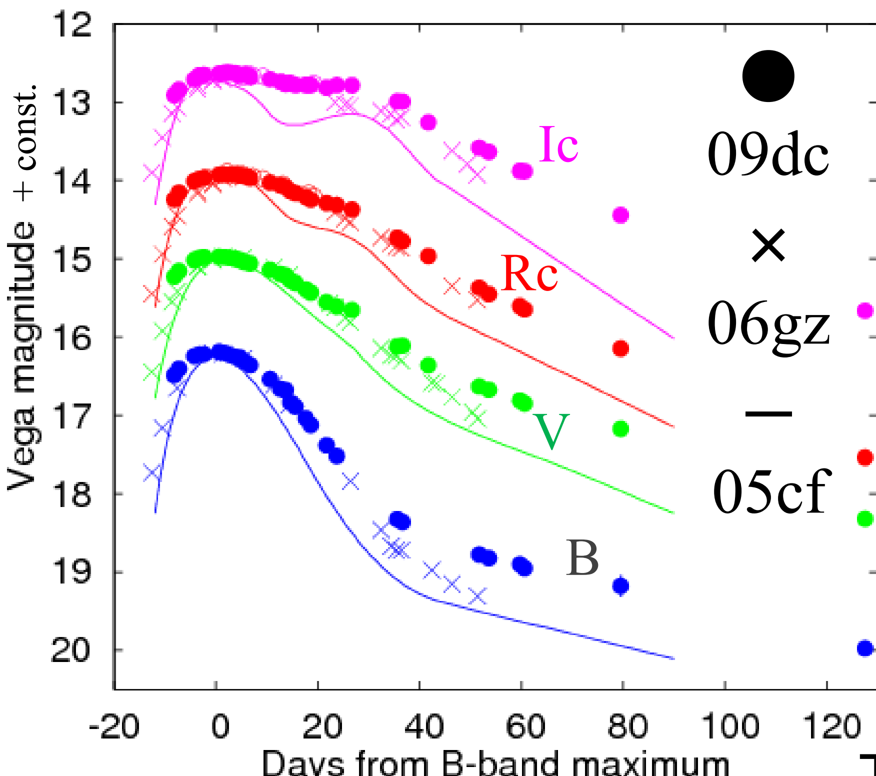
A follow-up observations revealed that the absorption line of C II exists, which has been seen in the **super-Chandrasekhar mass SN Ia SN 2006gz** (CBET 1768).

Super-Chandrasekhar mass type Ia SNe (2003fg, 2006gz)

Extremely bright → requires > ~1 $M_{\odot}$ ^{56}Ni → progenitor mass > 1.4 $M_{\odot}$

(e.g., Maeda+ 2007)

SN 2009dc : optical light curve

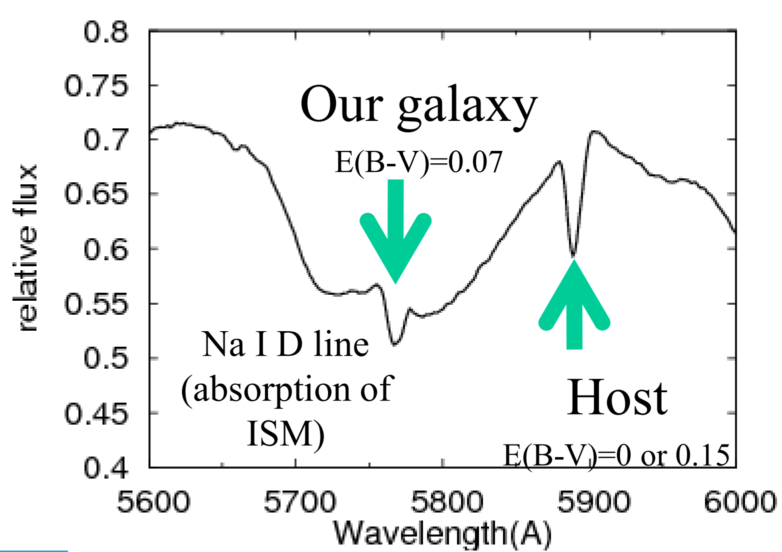


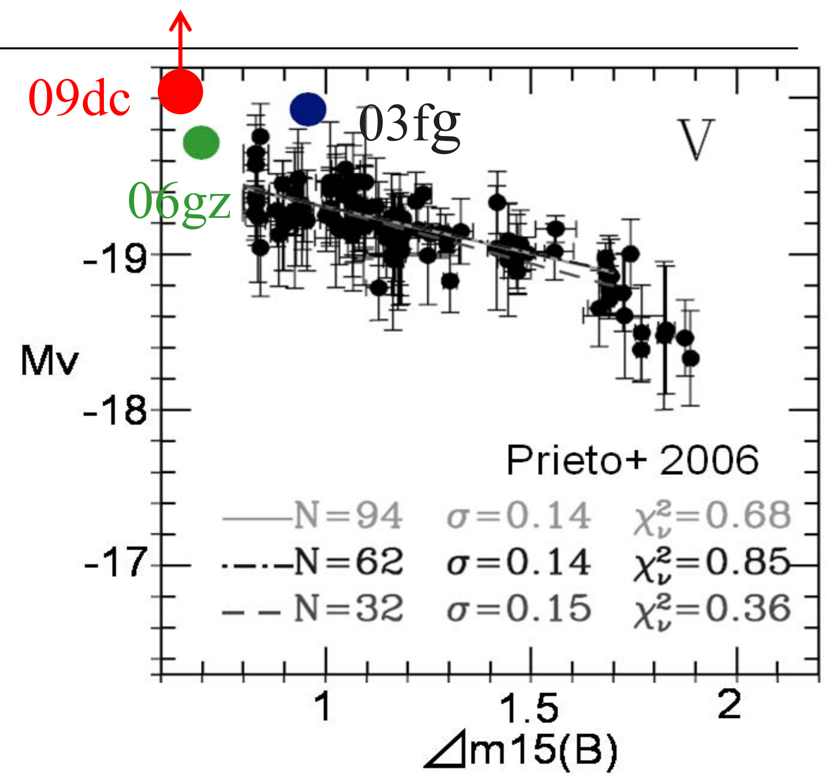
The decline rate of 09dc is very slow compared with that of a typical SN Ia ($\triangle m_{15}(B)$~1.1).

$\triangle$m15(B) of 2009dc is 0.65+/-0.03, comparable to 0.69+/-0.05 of 06gz.

The very slow light curve indicates that SN 2009dc is intrinsically luminous as SN 2006gz.

Correcting interstellar extinction (Gal. + host)





E(B−V)	Rv	Mv
0.07	3.1	−19.90+/−0.05
0.22	2.1	−20.19+/−0.19
0.22	3.1	−20.32+/−0.19

The absolute magnitude of −19.90+/−0.05 mag is estimated even if no extinction in the host galaxy is assumed.

Even if we neglect the extinction in the host, SN 2009dc is one of the most luminous Type Ia Supernovae.

Bolometric luminosity and ^{56}Ni mass

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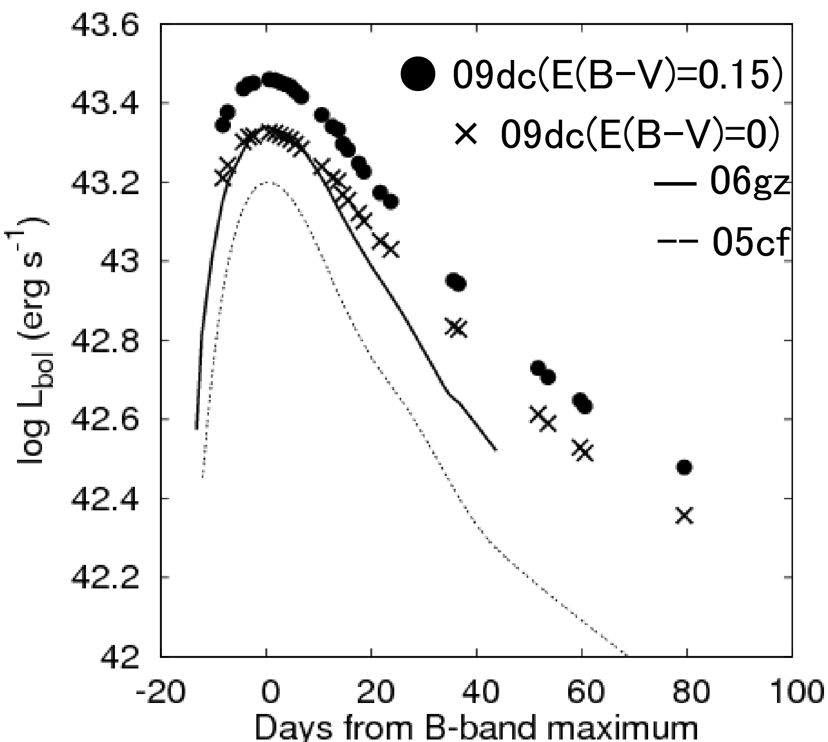


Assumption
60% from the optical regions.
rising time of 20 days

Even if we regrect the host extinction, the luminosity of 09dc is 1.5 times as that of typical 05cf.

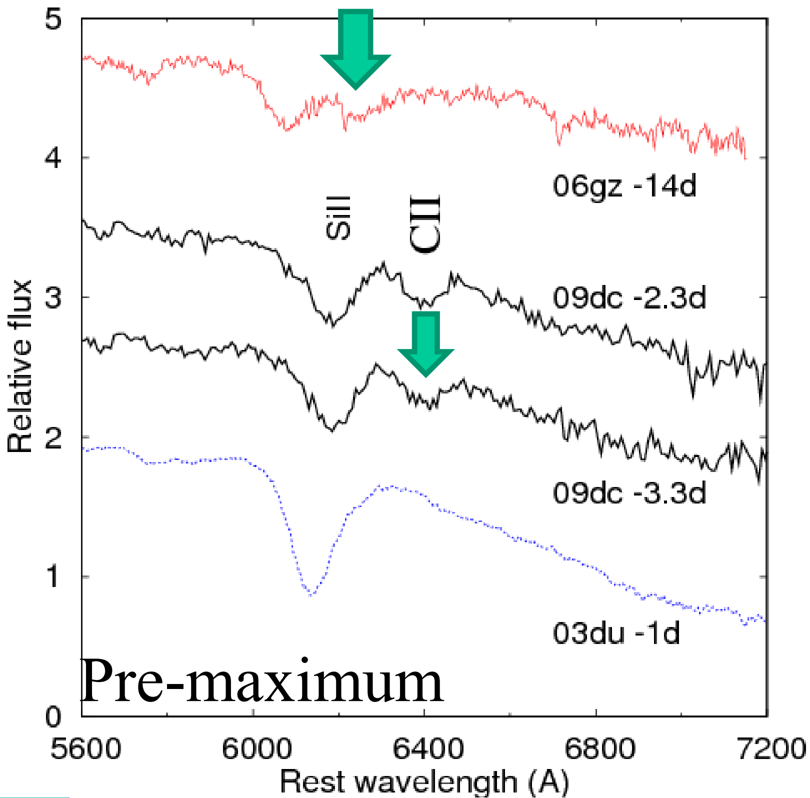
The peak luminosity is proportional to ^{56}Ni mass. SN 2009dc synthesized the one of the largest Ni mass.

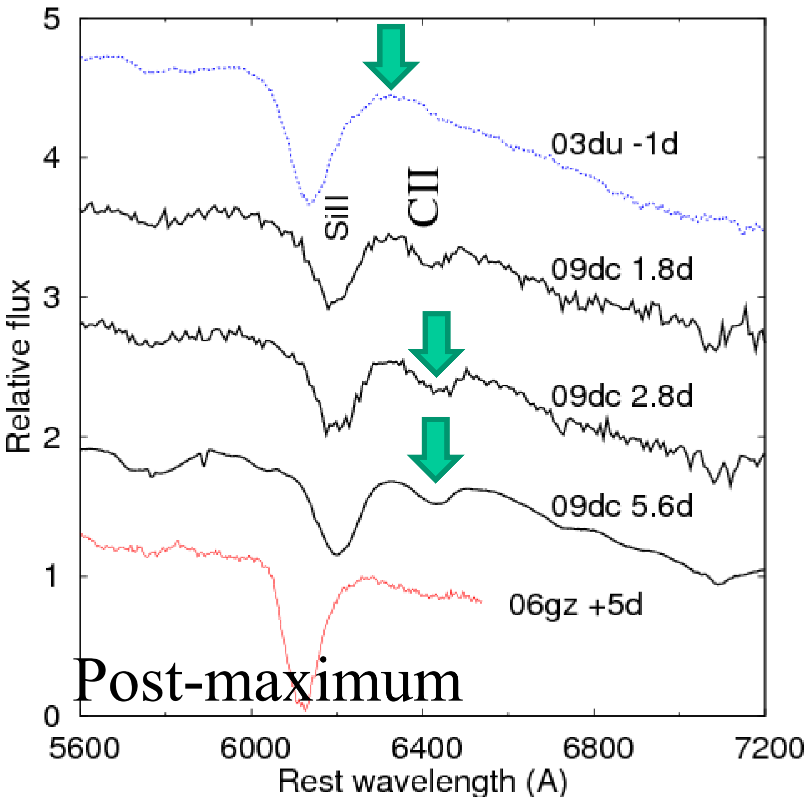
Considering the extinction in host, ^{56}Ni mass is much more.

We estimated 1.2 – 1.8 $M_\odot$ of total ^{56}Ni mass from the peak luminosity and the rising time. (1.2 $M_\odot$ for no extinct. in host gal., 1.8 $M_\odot$ for Av=0.43 in host gal.).

e.g.
Super Chandrasekhar
06gz : 1.2$M_\odot$
Typical SN Ia)
05cf : 0.8$M_\odot$

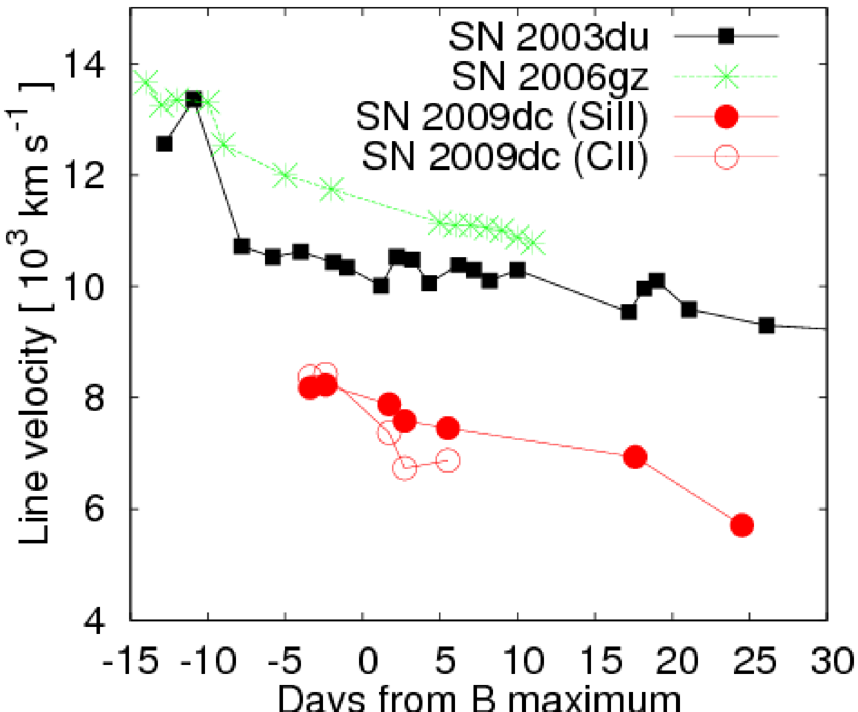
Spectral evolution





In normal SNe Ia, carbon features are not seen (or disappear earlier). But, the features are conspicuously seen in 06gz and 09dc in their early phase. Furthermore, in 09dc, absorption of CII λ 6580 is still seen in 09dc at the 5.6 days after maximum, while not in 06gz. This suggests that the outer unburned CO layer is thicker in 09dc comparing with that of 06gz.

Line velocity



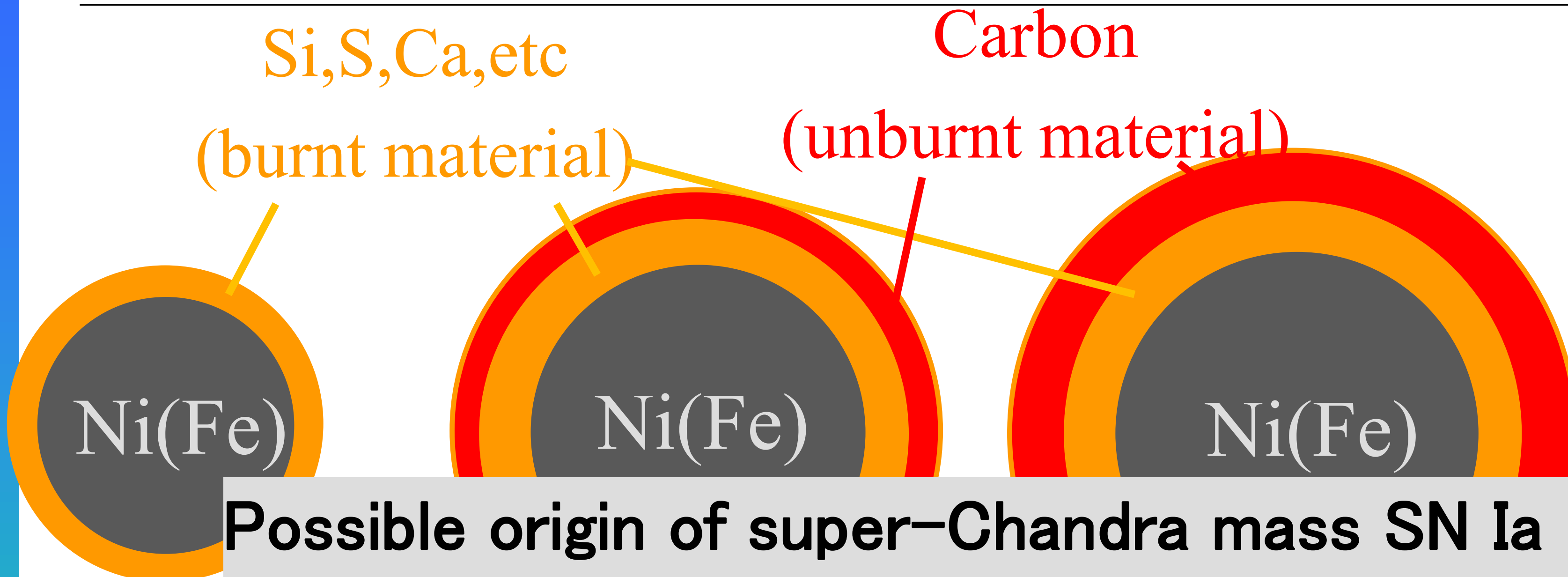
06gz : SiII 12000km/s

09dc : SiII,CII 8000km/s

(typical SN Ia : 12000km/s)

The line velocity of 09dc is much slower than SN 2006gz, suggesting a larger ejecta mass.

Pictures of explosion



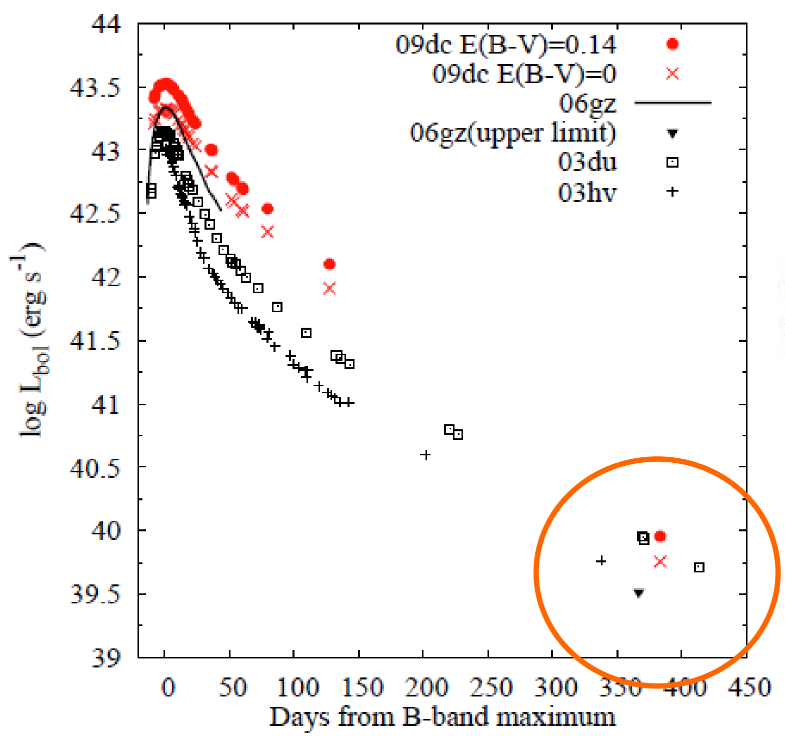
In a norr
burning
material
burning
remains

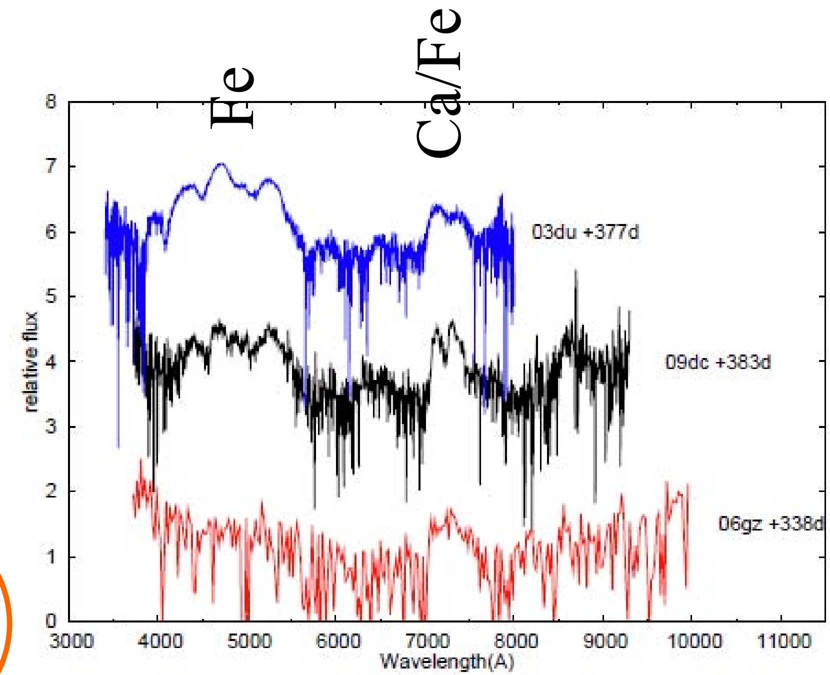
Possible origin of super-Chandra mass SN Ia progenitor

- Rapidly-rotating WD
  - Strong centrifugal force reduces the effective gravitational force → Ignition delays
  - A rapidly-rotating WD can be fat up to ~2 $M_{\odot}$.

  (e.g., Kamiya+ 2010; Hachisu+ 2011)
- Merger of some kinds of WDs?

SN 2009dc: Late-phase





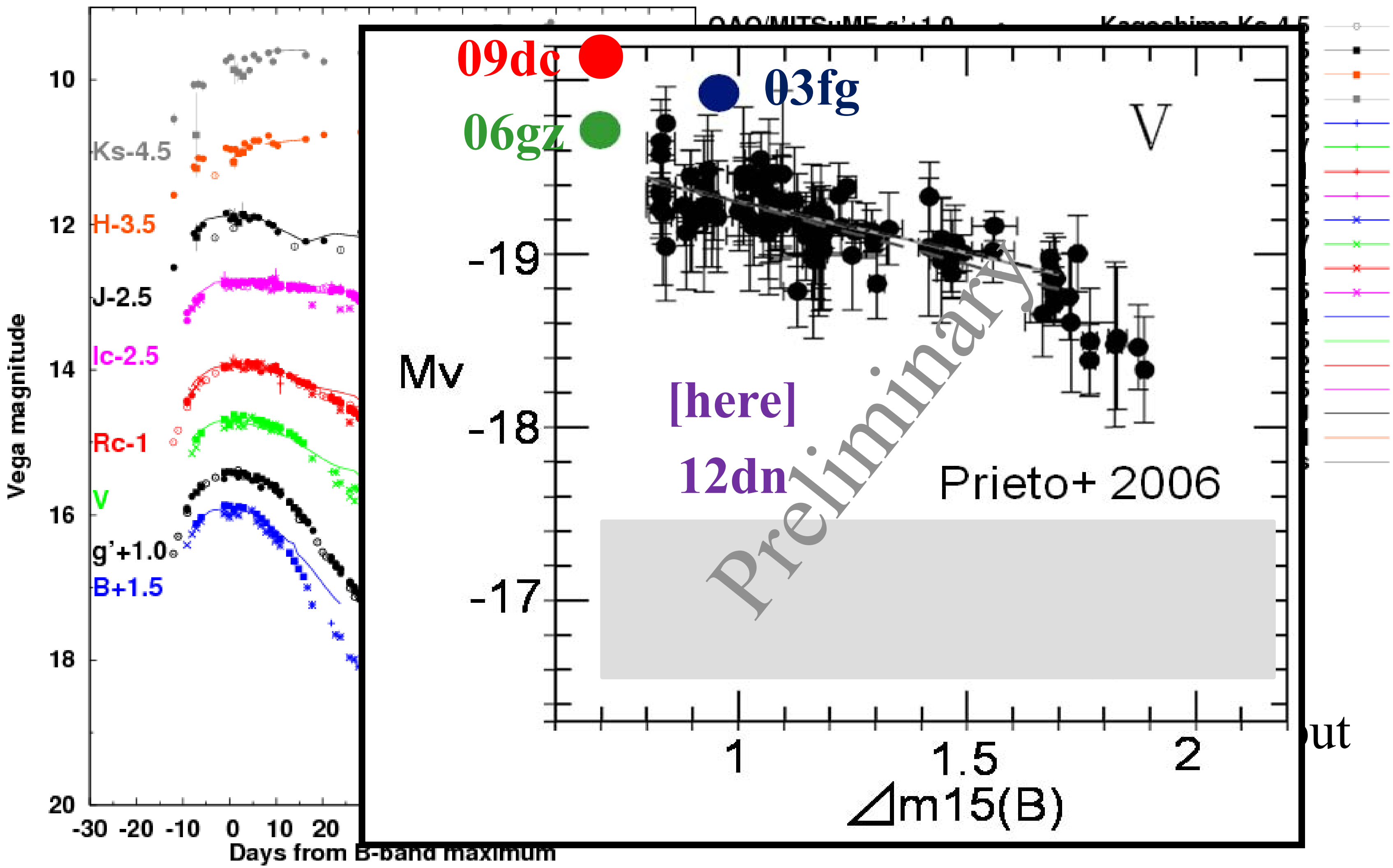
Yamanaka+, in prep.

- Not so bright
- Not so strong Fe emission lines (much $^{56}Ni \rightarrow {}^{56}Fe$)

Why?

Extinction by dust formed in ejecta?

SN 2012dn: 09dc-like LCs



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SN 2012dn: Spectra also similar to 06gz/09dc

Sorry, spectra coming soon！

May give a clue to questions for super-Chandrasekhar-mass SNe Ia

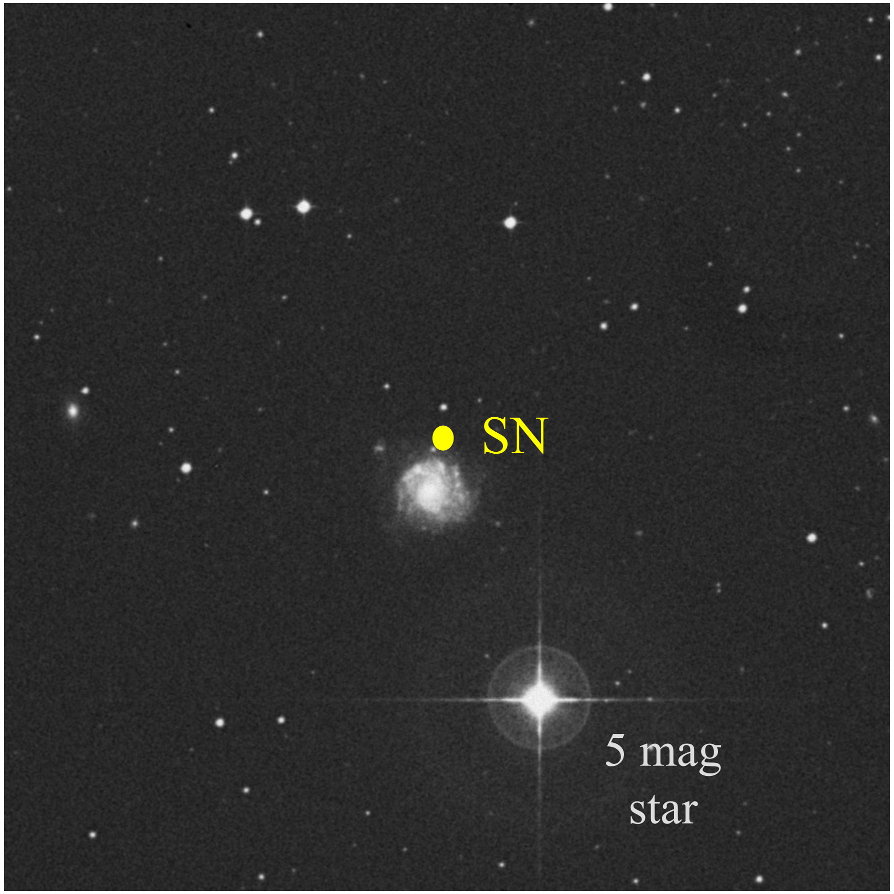
SN 2012Z in NGC 1309

(Peculiar Type Ia SN ; 02cx-like event)

Discovered by LOSS in NGC 1309 (d~20Mpc) at V~18.0 mag on 2012 Jan 29 (ATEL 3900)

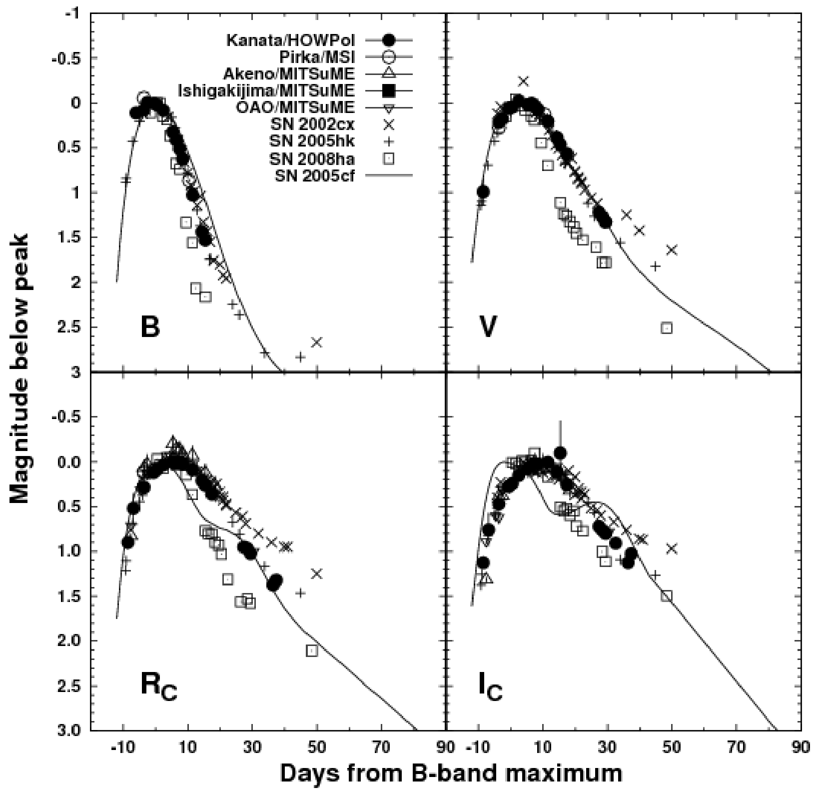
Similar to SN 2005hk, belonging to faint subclass of SNe Ia (02cx-like) (ATEL 3901)

Mechanism of SN 2002cx-like events is still in debate.



FOV 15' x 15' (Red in DSS)

Optical / NIR light curve



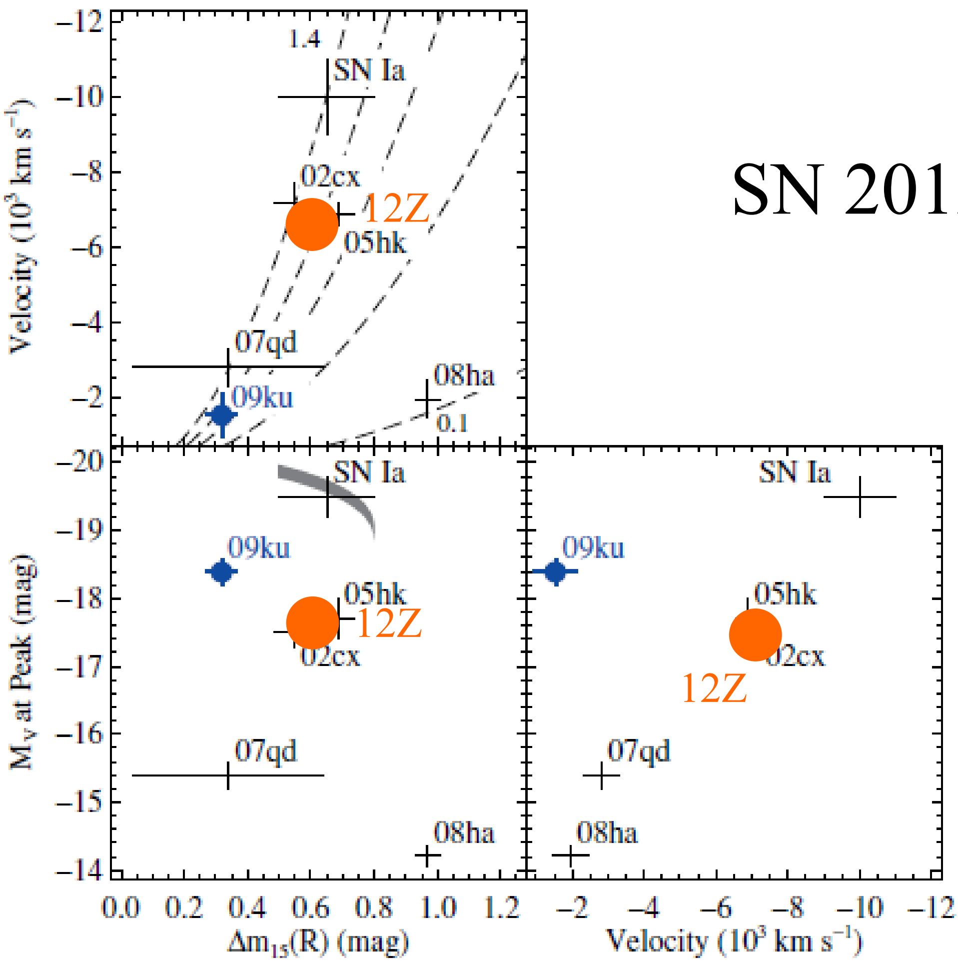
Sorry, NIR LC will come soon !

Observed -10d through +30d

No clear second peak in I band
Similar to SN 2005hk

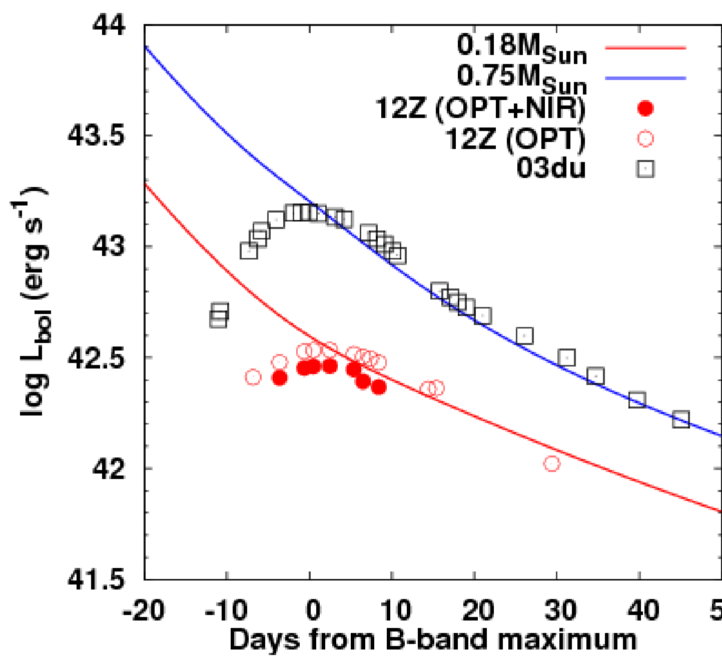
First K-band LC in 2002cx-like event

SN 2002cx-like type Ia SNe



Narayan et al. 2011

SN 2012Z is a twin SN 2005hk?

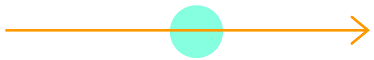


Late-phase photometry and spectroscopy

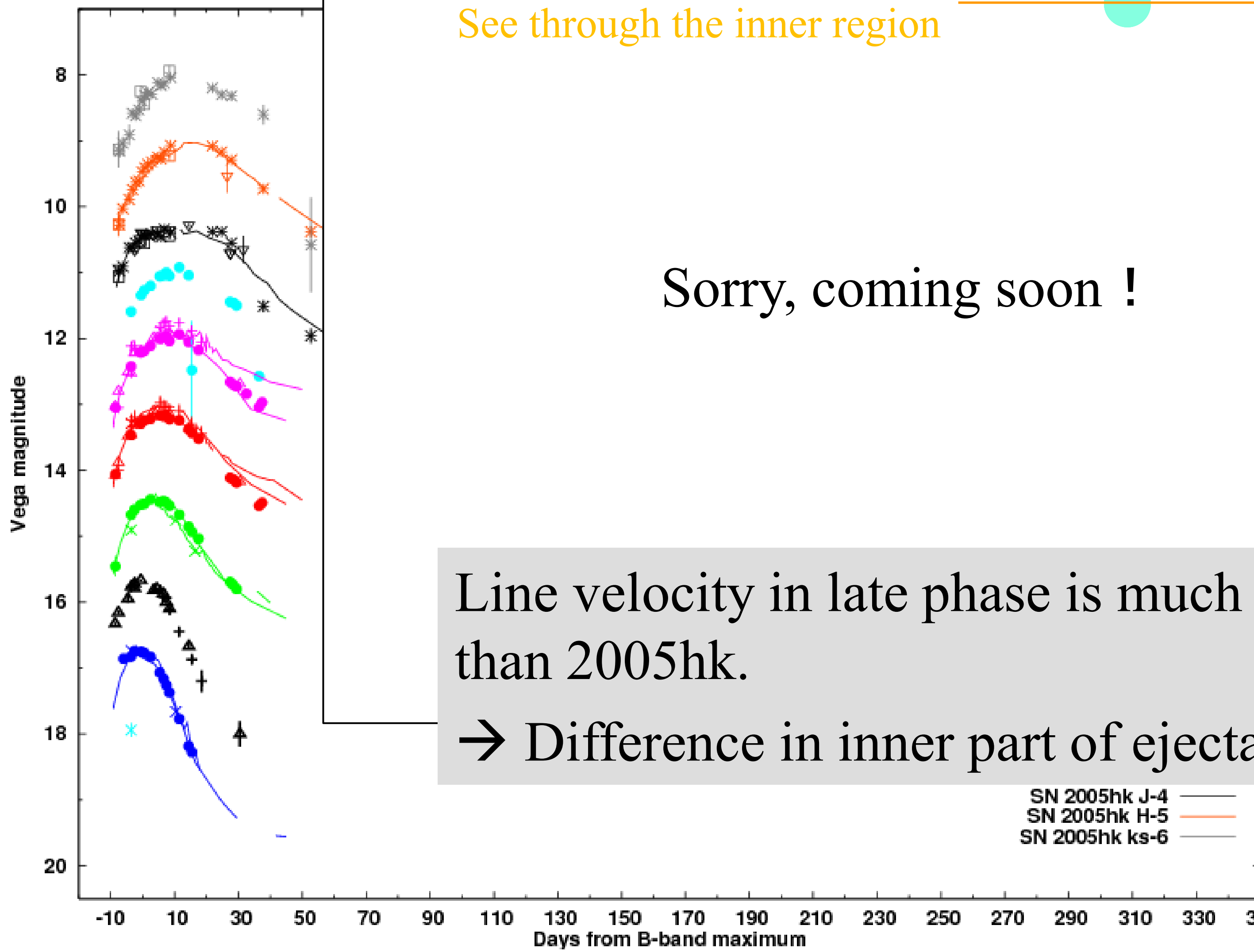
SN ejecta (no photosphere)

Late phase: Optically-thin

See through the inner region



Sorry, coming soon！



Line velocity in late phase is much higher than 2005hk.

→ Difference in inner part of ejecta

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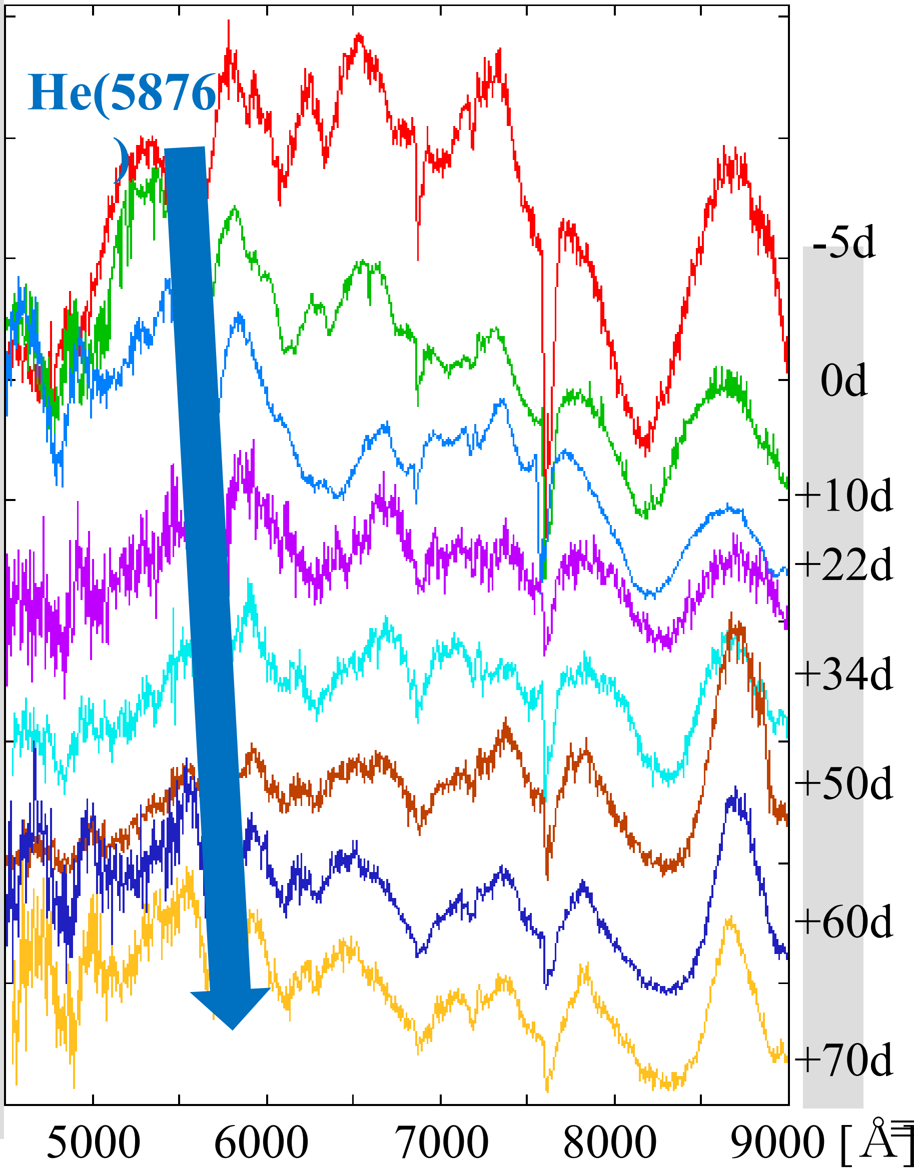
SN 2012au: Very bright type Ib: Spectra



Line velocity He I 5876

Sorry, coming soon！

Higher velocity of He layer than other type Ib

SN 2012au: Bolometric light curve

60% of total flux in B,V,R,I-banda (Tomita +03)

$L_{max} = 6.7 \times 10^{42}$ [erg/s]

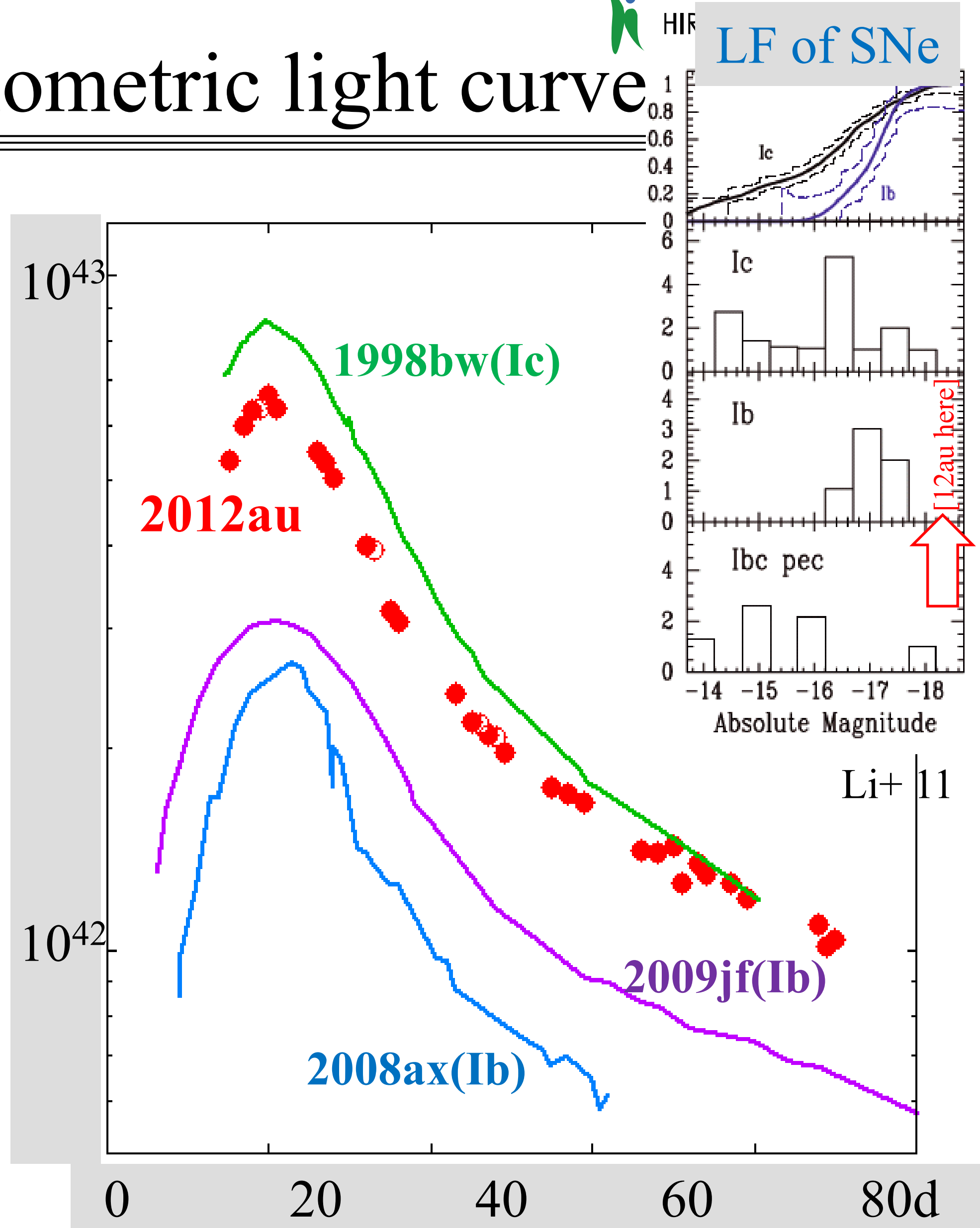
Very bright type Ib

$M(^{56}Ni) \sim 0.4 M_\odot$

c.f) 08ax : 0.1M⊙

c.f) 98bw : 0.4M⊙

$M_{ej} = 2\sim5 M_\odot$
$E_k = (1\sim7) \times 10^{51}$[erg]



c.f) 08ax $M_{ej} = 1\sim6 M_\odot$, $E_k = (1\sim6) \times 10^{51}$erg

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Summary

We promote optical/NIR observational studies for SNe with 1.5-m Kanata telescope in Hiroshima, together with OISTER inter university cooperation network.

One of the theme is exploring the diversity of SNe

SN 2009dc: super-Chandrasekhar mass type Ia SNe, most bright (largest ^{56}Ni mass) among ever found SNe Ia. Rapidly-rotating WD?

SN 2012dn: super-Chandrasekhar SN Ia-like spectra, but ~2mag fainter.

SN 2012Z: Similar to SN 2005hk, a faint subclass SN Ia, but late-phase spectra different

SN 2012au: Bright SN Ib

Observation/analyses still continue…