Follow-up Observations of a Peculiar Supernova with Domestic Telescopes
国内光学望遠鏡による特異なIa型超新星の追観測

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SNe & GBB meetings 2014.08.25-27 @Riken Wako Campus

Physics obtained by SNe Observations

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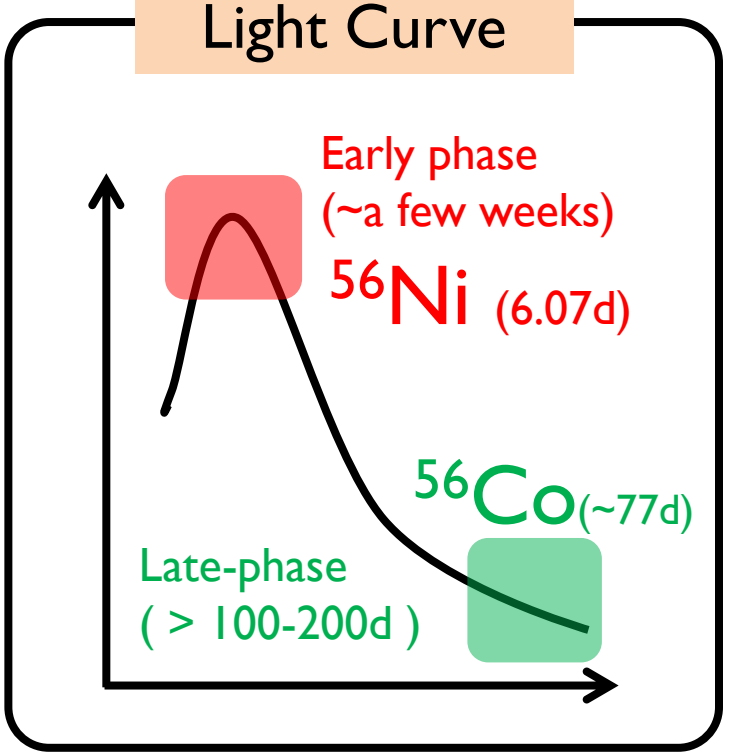
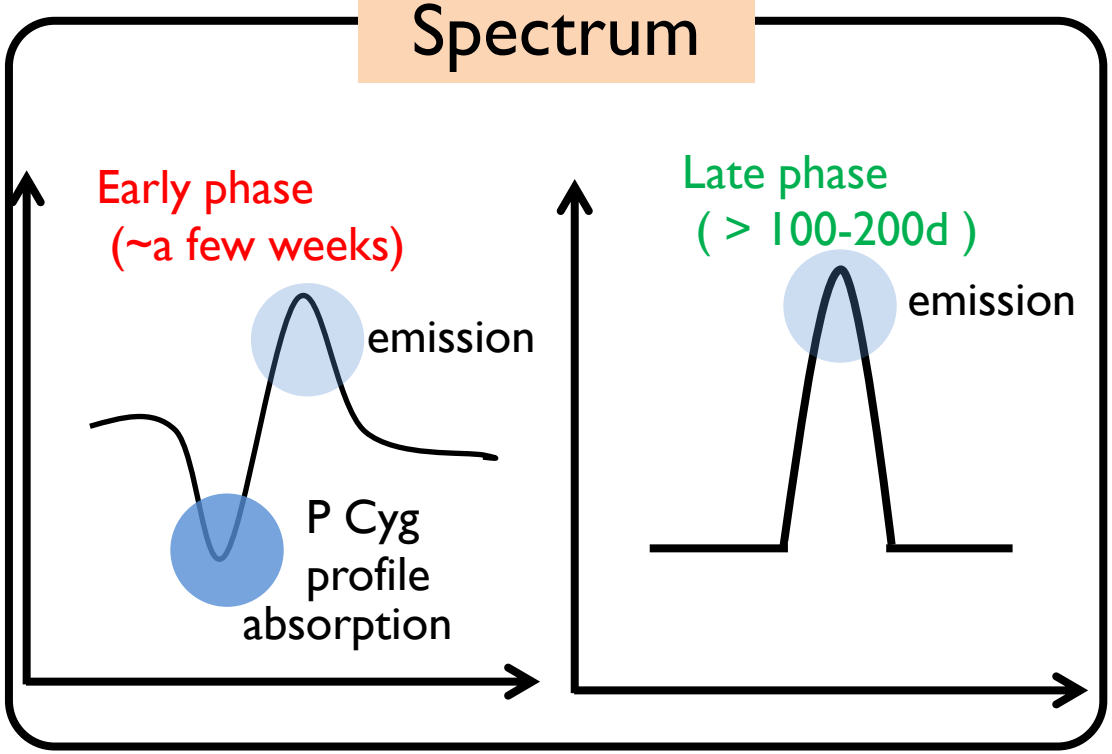
Light Curve



Spectrum



Early phase
(~a few weeks)
thin
thick

Outer layer
Si, S, Ca etc.
(for SNe Ia)

Presence of
unburnt material ?
(outermost)

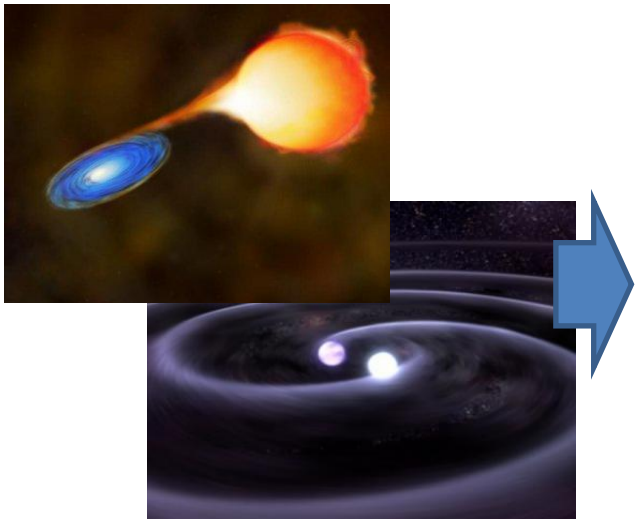
Late (> 100-200d)
Shrinkage of
photosphere

^{56}Ni → ^{56}Co → ^{56}Fe
γ γ

Light Curve (radiation)
~ ^{56}Ni or ^{56}Co decay
~ ^{56}Ni mass (progenitor)

Spectra → Line velocity
$v \propto r$ ∵ free expansion
→ **ejecta structure**
→ **explosion model**

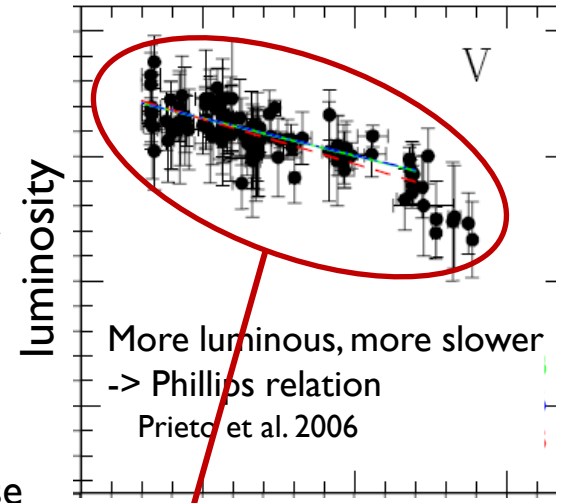
Today's topic : Peculiar Type Ia SNe

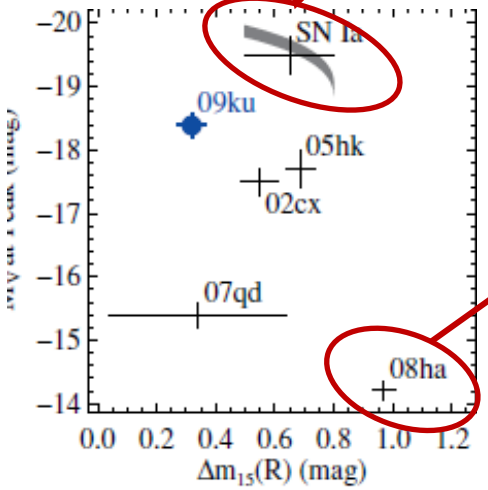


SNe Ia Progenitor : WD in the close binary system
-> Thermonuclear explosion
-> Similar properties :
distance indicator

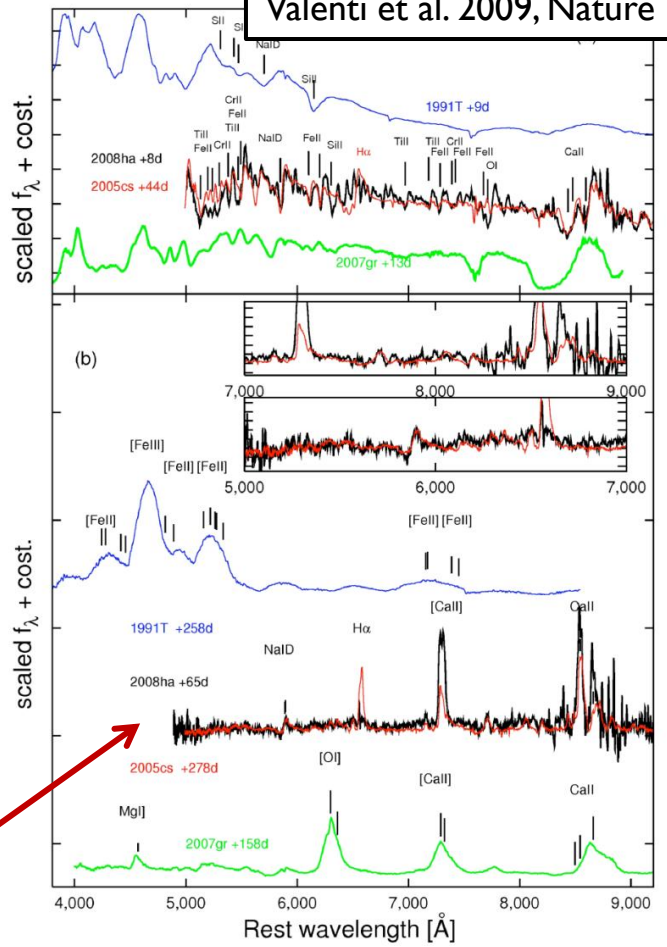
Please see Maeda-san's talk Tomorrow

However, some peculiar SNe Ia do not obey Phillips (width-luminosity) relation (discovered by Li+ 2003)





Valenti et al. 2009, Nature



The most faint peculiar SNe Ia was discovered in 2008. Its properties are rather similar to those of CC SNe.
-> Too faint to be reproduced by thermonuclear explosion?

SN 2012Z in NGC 1309

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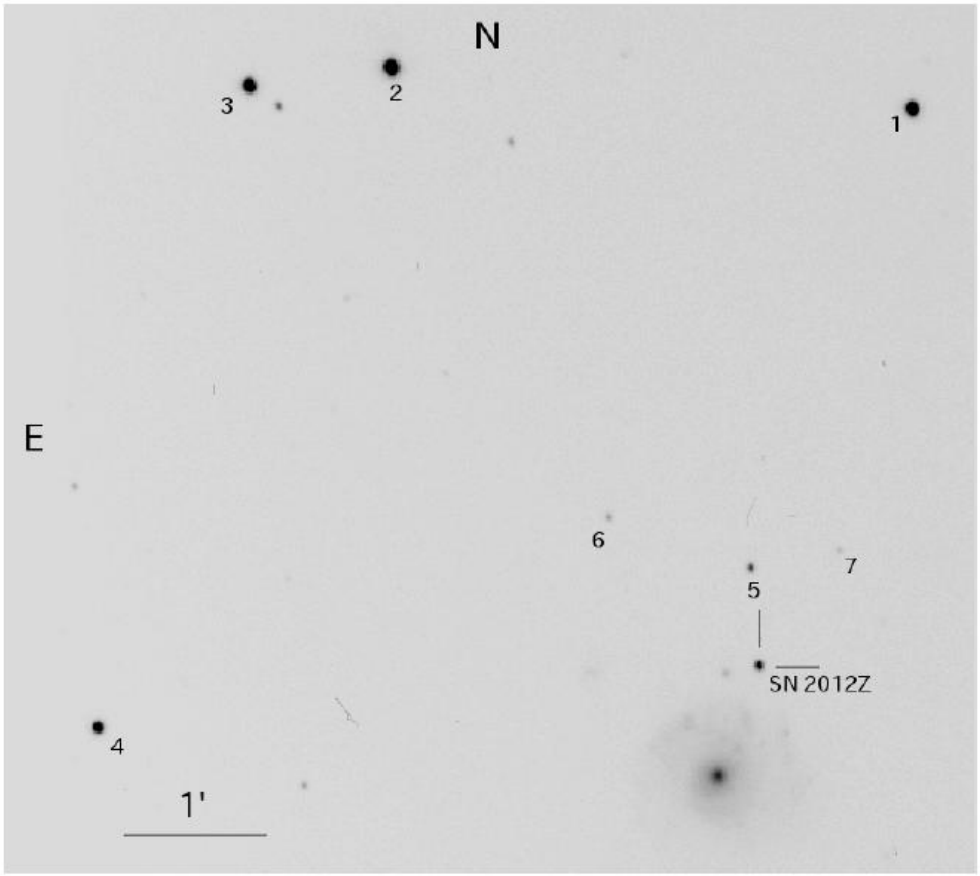
Coordinates (ATEL 3900)

R.A. 03:22:05.35,
Decl. -15:23:15.6

This SN was discovered at V~18 mag on Jan. 29 in the nearby galaxy NGC 1309 (D~20Mpc) by LOSS (ATEL 3900).

It is reported that the spectrum is similar to that of the prototype of the peculiar SN 2005hk at a week before maximum (ATEL 3901)

Swift/UVOT observations confirmed V~15.5 mag on Feb.2. It means that the 2.5 mag increase at very short time.
⇒**just after exploion** ! (ATEL 3909)



Request for ToO observations with "OISTER"

What is "OISTER" ?

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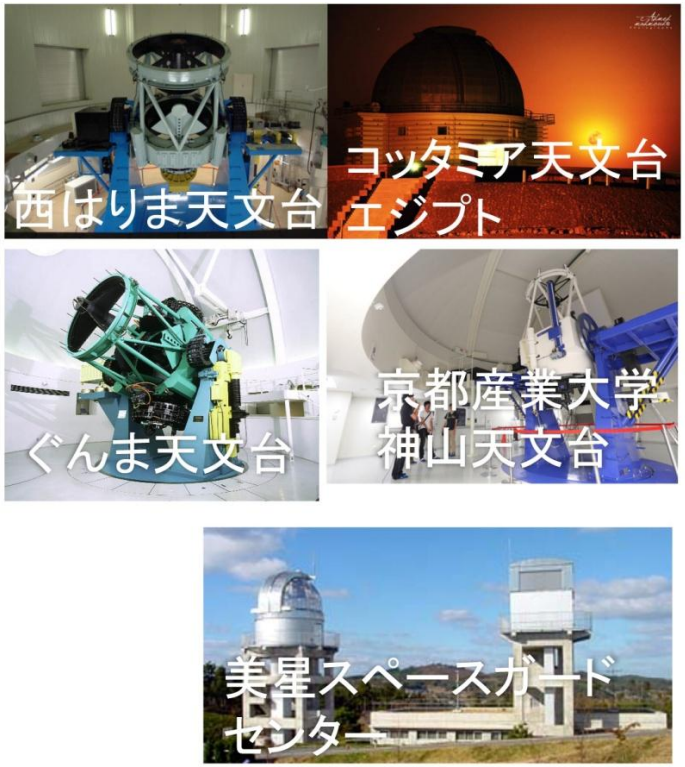
Optical and Infrared Synergetic Telescopes for Education and Research ("OISTER")
Domestic collaborations among Universities and NAOJ cooperated since 2011.



Two strong points for SNe observations
①Canceling out the bad-condition weather, ② multi-band observations in the limited time
-> Realized the high-cadence and multi-bands observations just after explosion date
Permit us get the high-quality and large data set as good as
those by other international collaborations

Observations Strategy with Kanata/OISTER

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Discovery

High-cadence survey

KISS

Amateur Astronomer

Tanaka-san's talk

There are 1500 SNe discovered in 2013

Nearby SNe: bright and just after explosion (m<16mag,D<50Mpc): N~10-20yr^{-1}

identification
Spectra(CBET,ATEL)
1,2 day delay

Follow up obs @ 120d

Hiroshima Univ.
1.5m "Kanata"
HOWPol,HONIR
Prompt reduction

Takaki-san
Kawabata-san

Osaka Kyoiku Univ.
51cm telescope

Nishi-Harima 2.0m "Nayuta"

Spectroscopy at fainter phase

moderate phase (120-170d) follow up

1.88m+KOOLS@OAO

Follow-up ToO Observations with OISTER

Light curves, color, spectra
-> diagnostics
-> peculiar? rare?
1-5 day delay

Light Curves and Spectra

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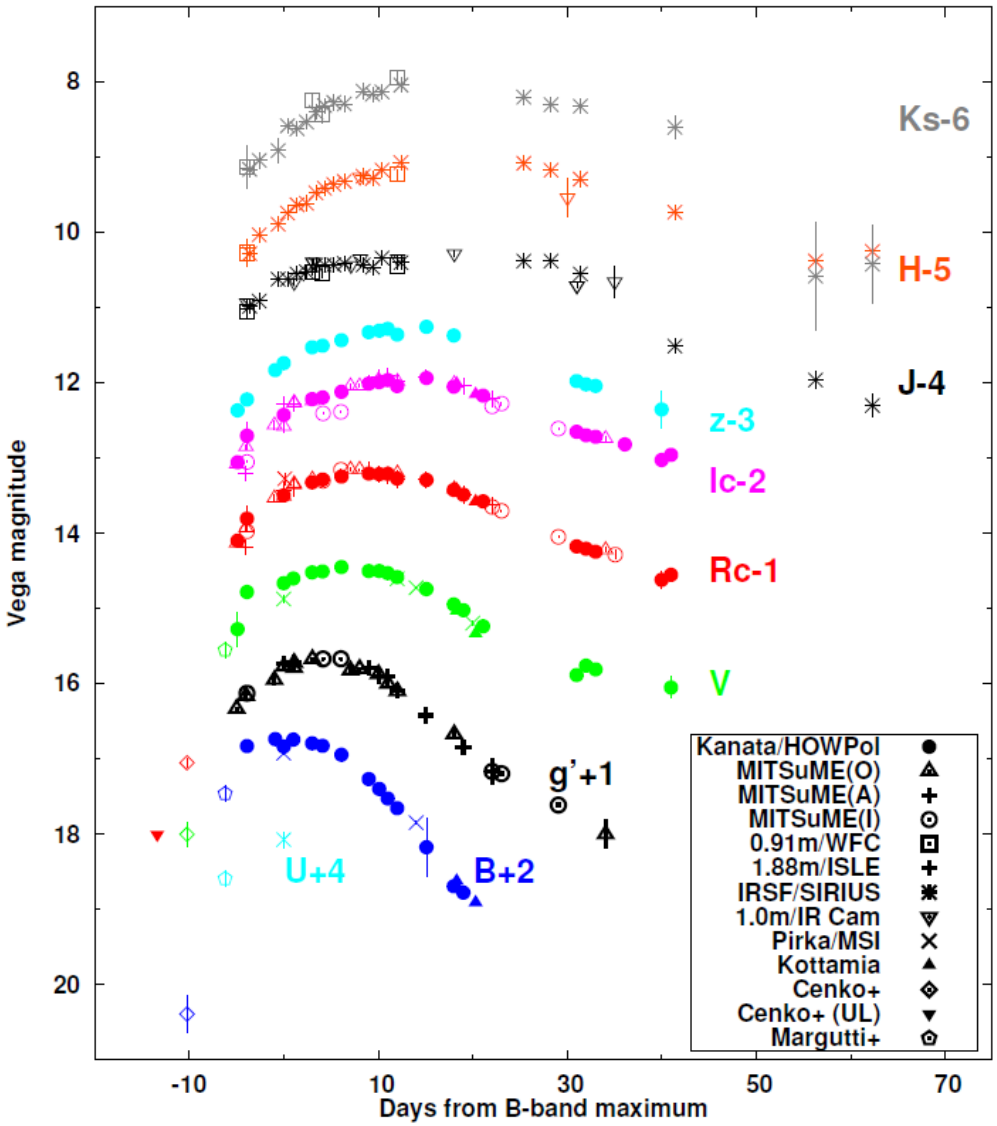
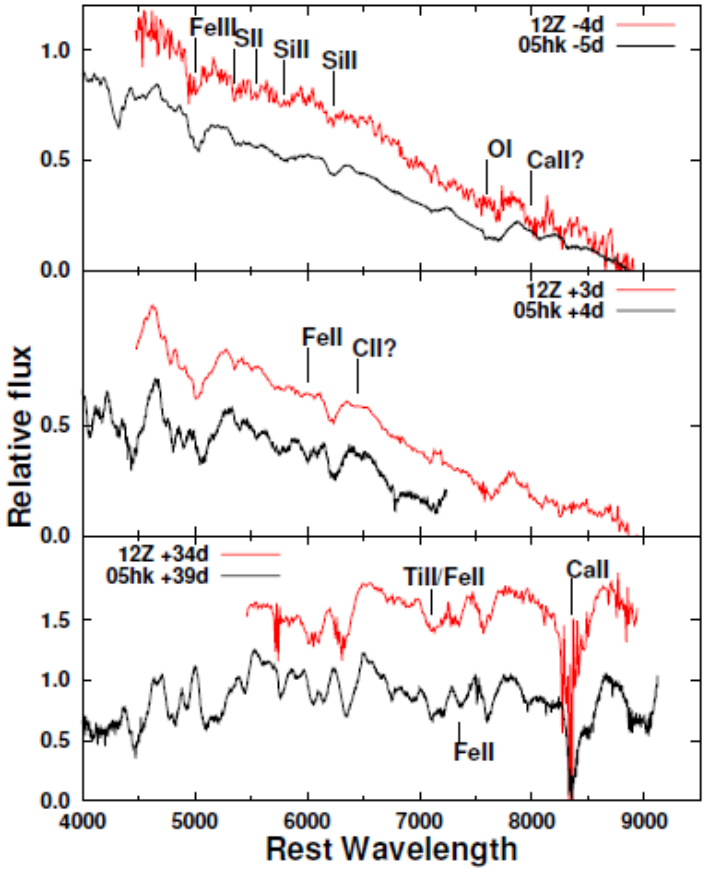
Ubg'VRIzJHKs light curves



Compared with 05hk



The line profile of SN 2012Z is very similar to those of Type Iax

BVRI(optical)+JHKs(near infrared) Light Curves

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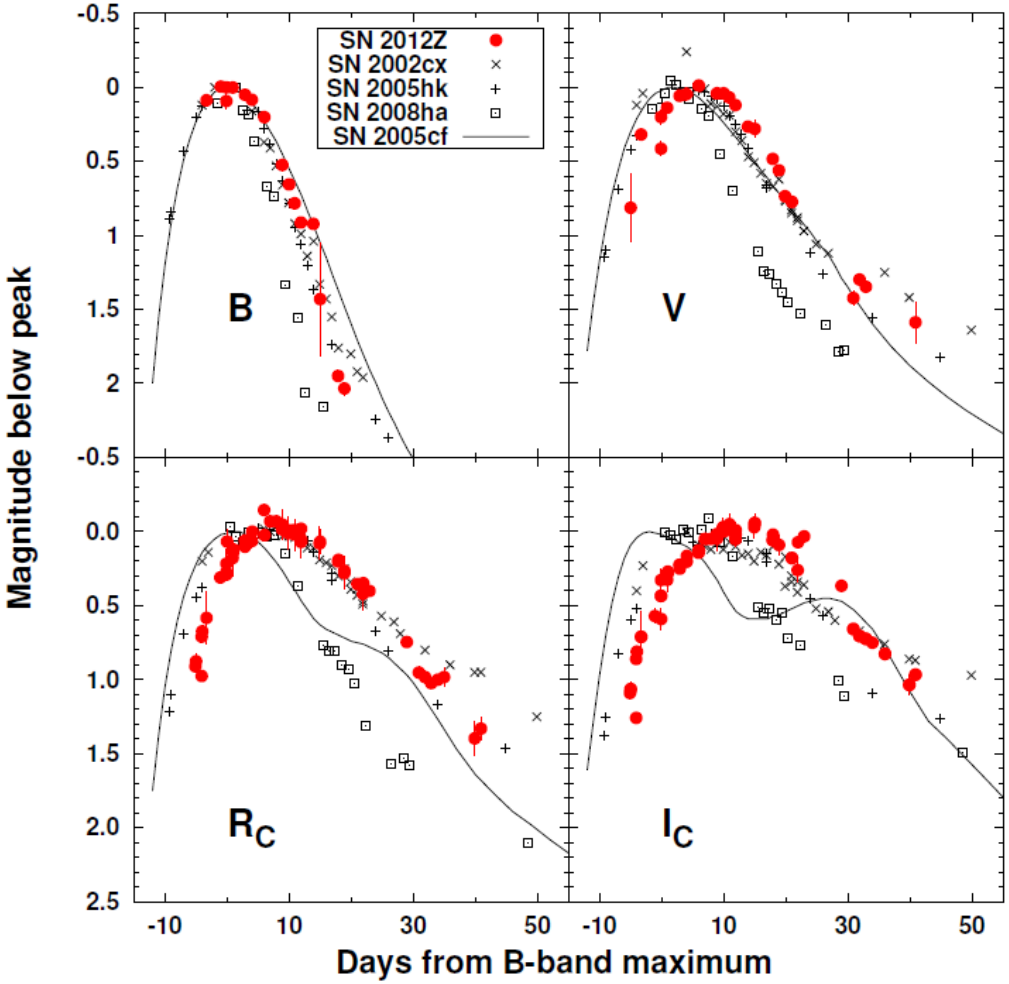
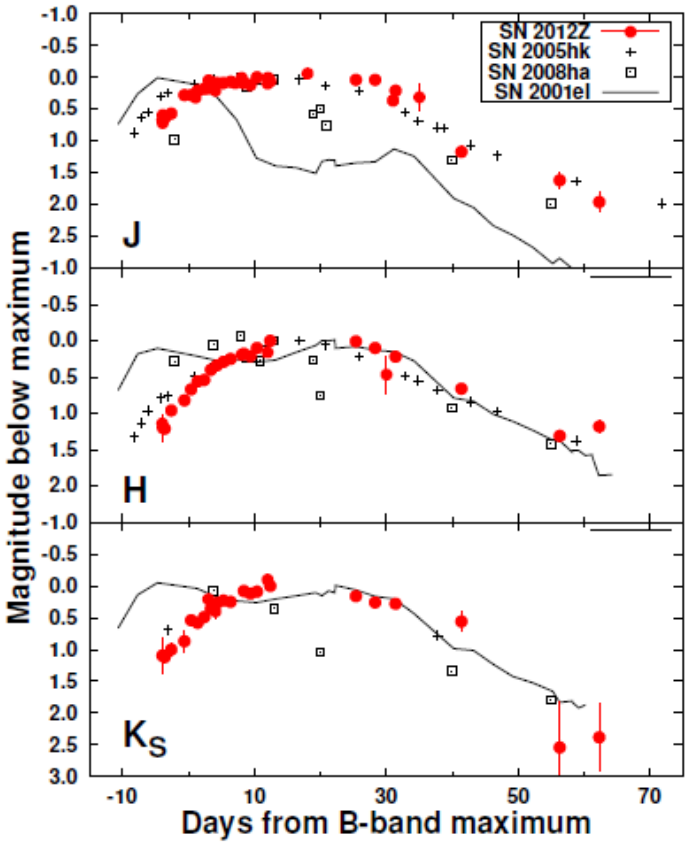
BVRI-bands light curves (optical)



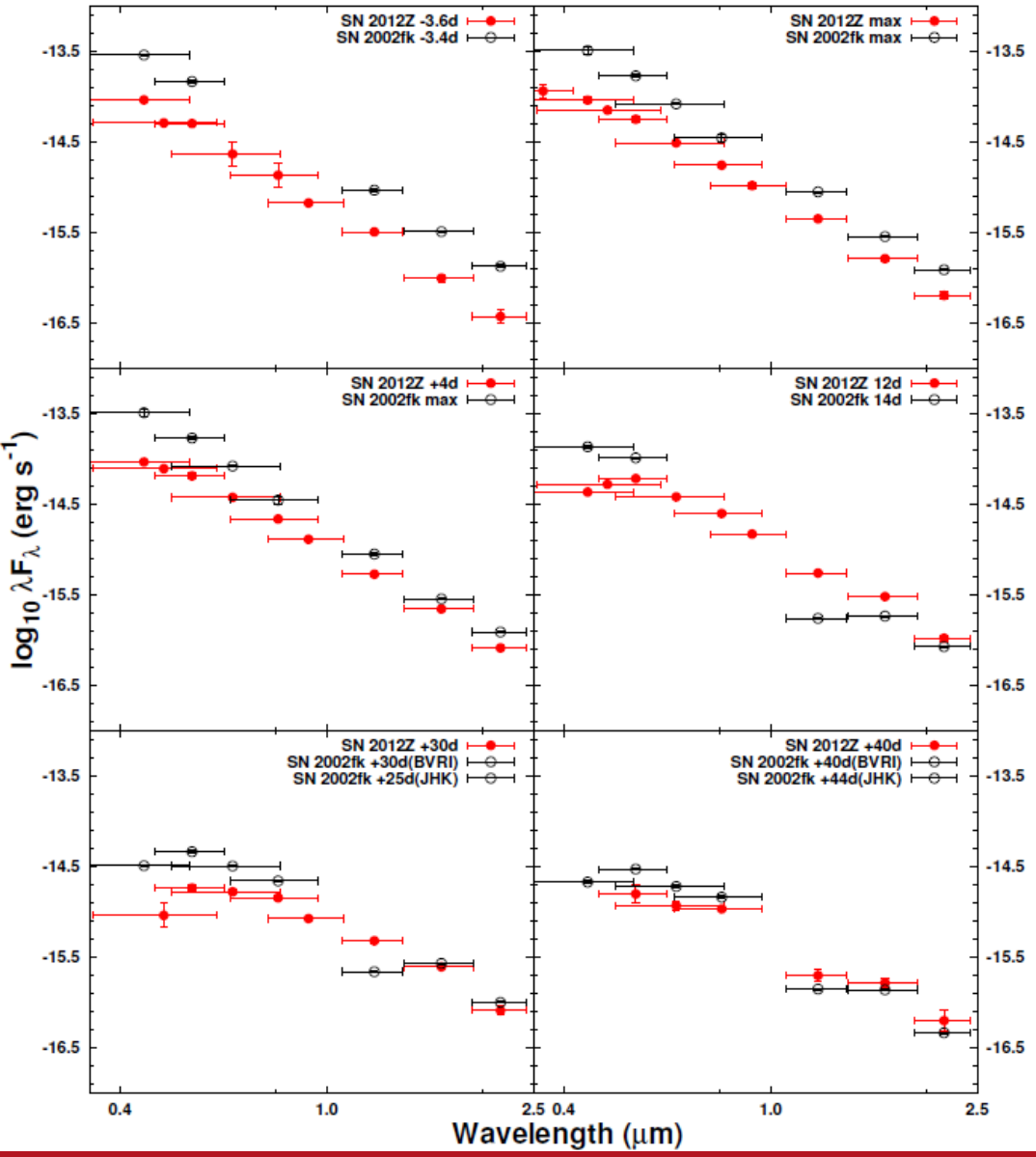
The BVRI-bands light curves are very similar to those of SN 2005hk. For I band, the 2nd peak is not seen for peculiar SNe Ia.

JHKs-bands light curves (NIR)



The J and H-bands light curve are very similar to those of SN 2005hk.
We got the high-cadence Ks-band light curve for this class for the first time.

Spectral Energy Distribution



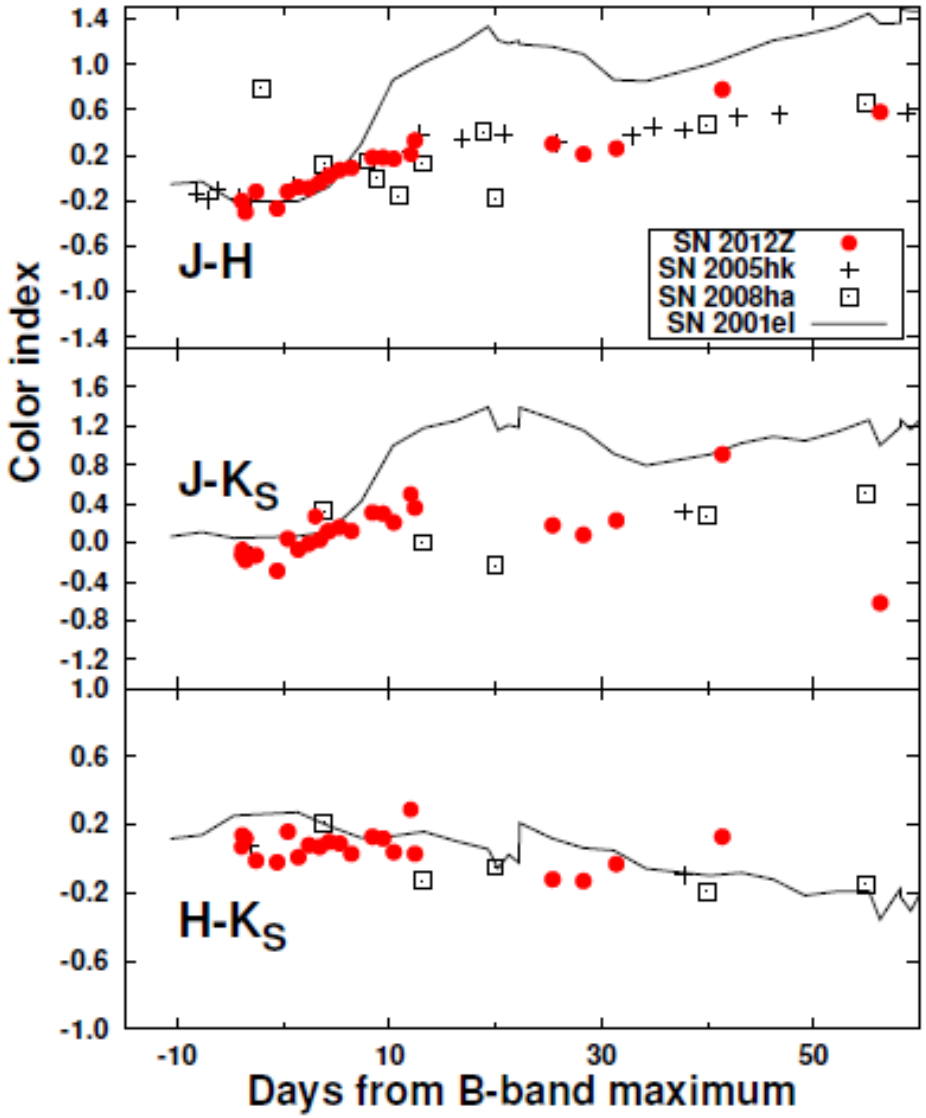
We constructed SED evolutions in optical and near-infrared regions. It is very dense for the wavelength.

They are compared with another Type Ia SN 2002fk occurred at same galaxy (The distance uncertainty is minimized)

For normal SN Ia, the gap is seen at 0.8-1.2 um at t=30d (corresponding to 2nd peak). On the other hand, SN 2012Z exhibits smoothed continuous SED.

However, such gap for SN 2012Z is seen at t=40d at 1.2um.
-> It may indicate the rather more-than-two component in the ejecta

J-H, J-Ks and H-Ks (NIR) Color Evolutions



J-H and J-K color evolutions significantly deviates from those of normal SN Ia.

Those color are very similar to those of Type Iax SNe despite of sparse data ever published.

On the other hand, H-Ks is even well similar to that of a normal SN Ia.
-> It may result in that such resemblance will affect the rest frame H-band photometric survey for distant SNe Ia for cosmology.

SN 2012Z in the width-luminosity relation

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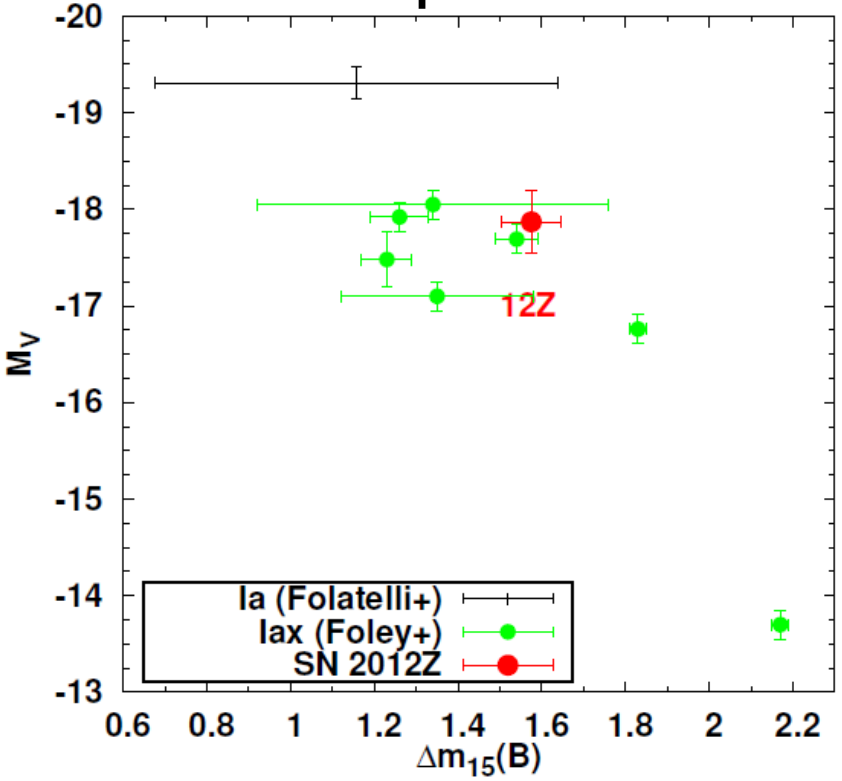
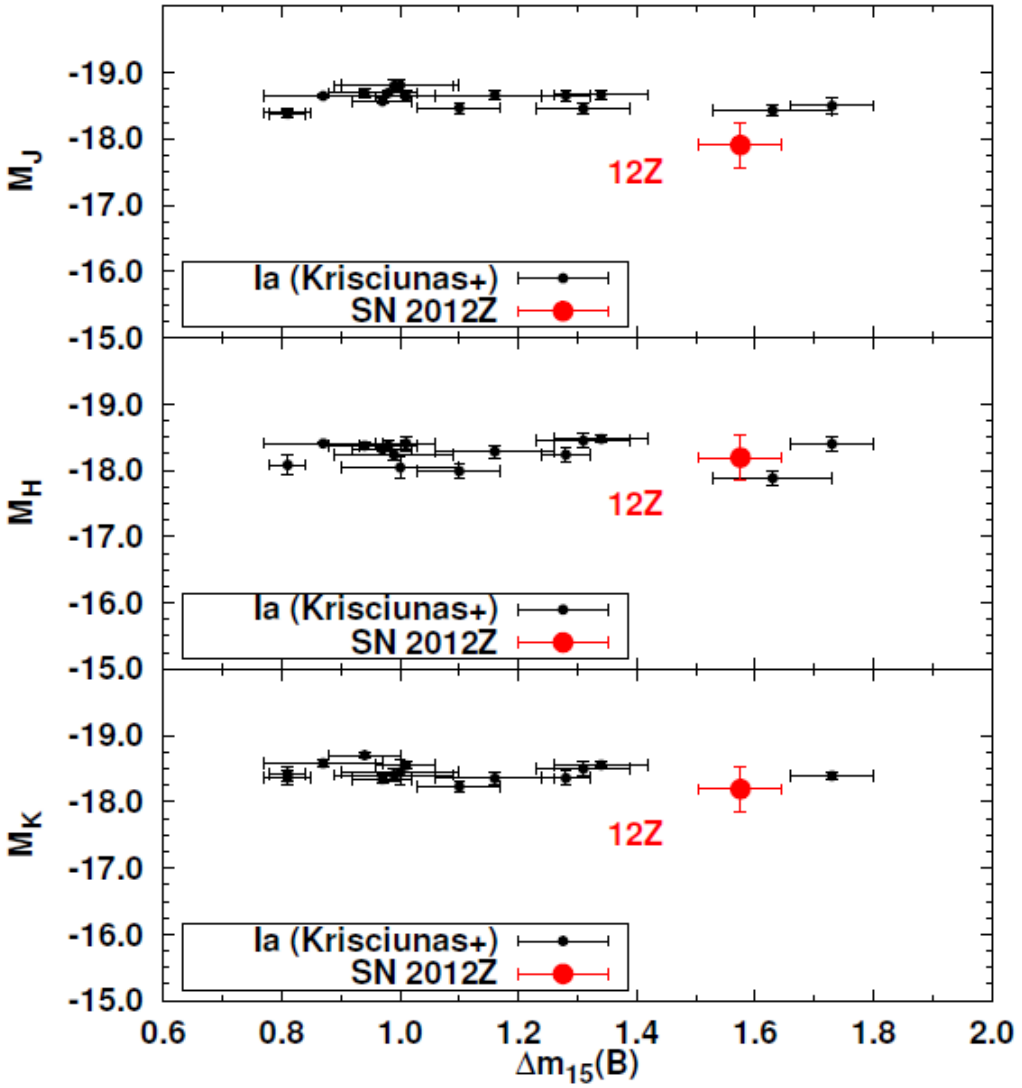
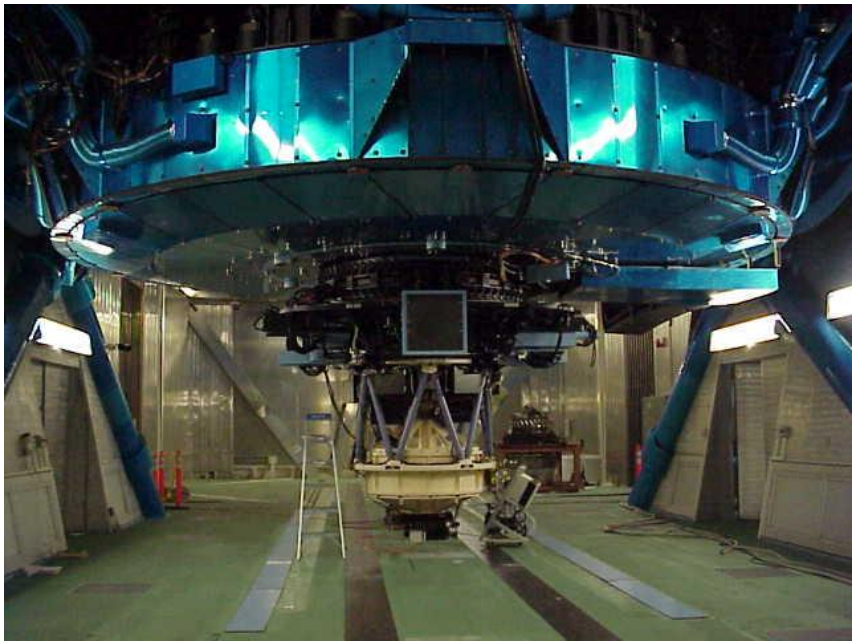
Optical

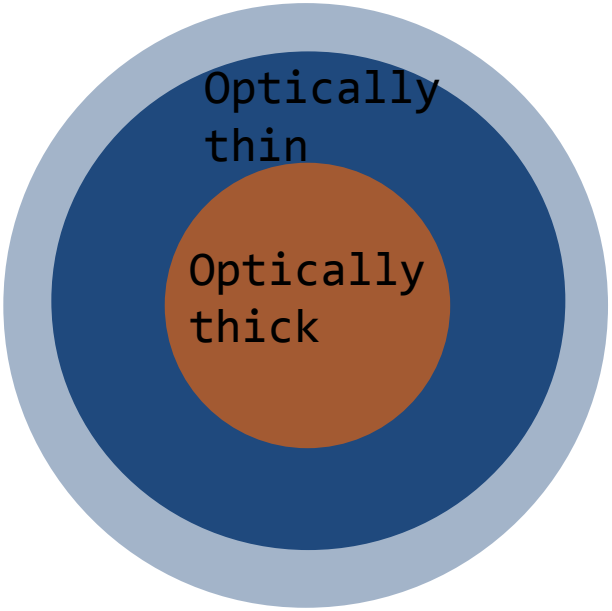


Near Infrared



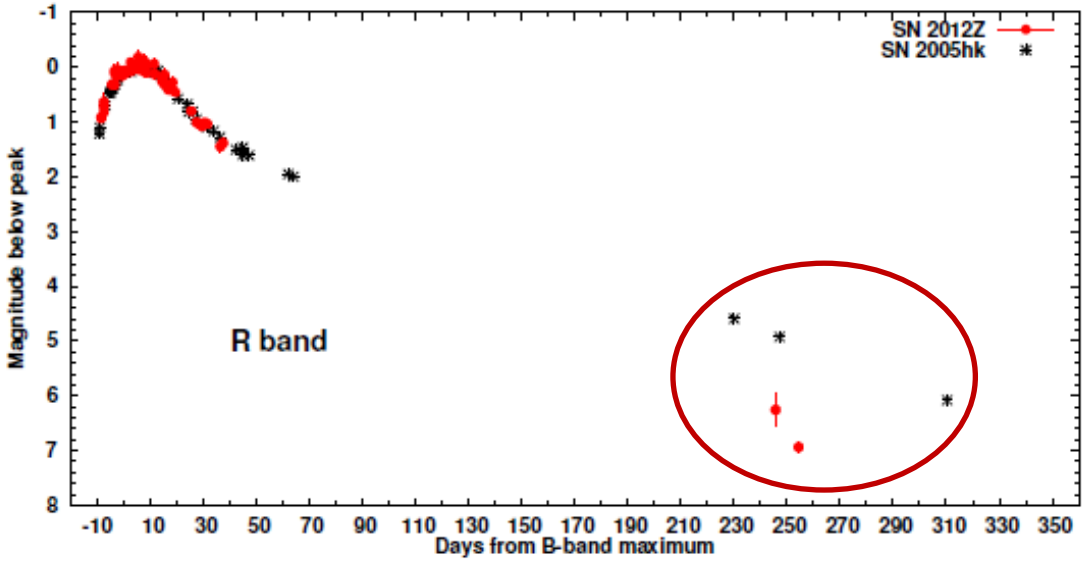
Observations at 250 days after maximum



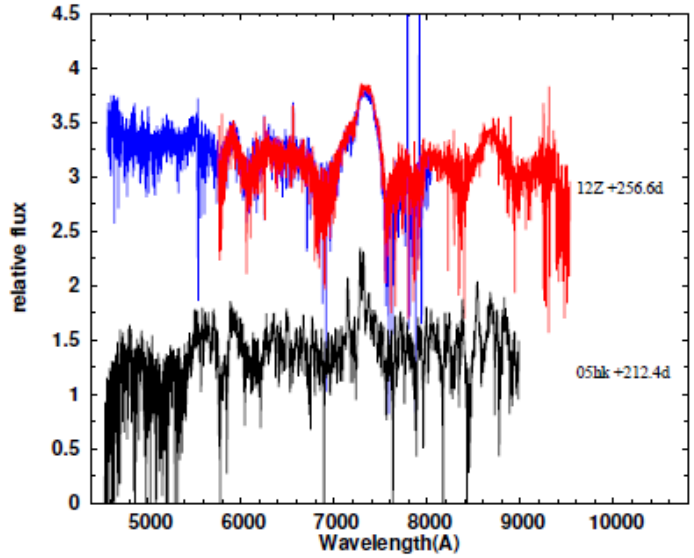


8.2m Subaru telescopes
With FOCAS

Late-phase photometry & spectroscopy



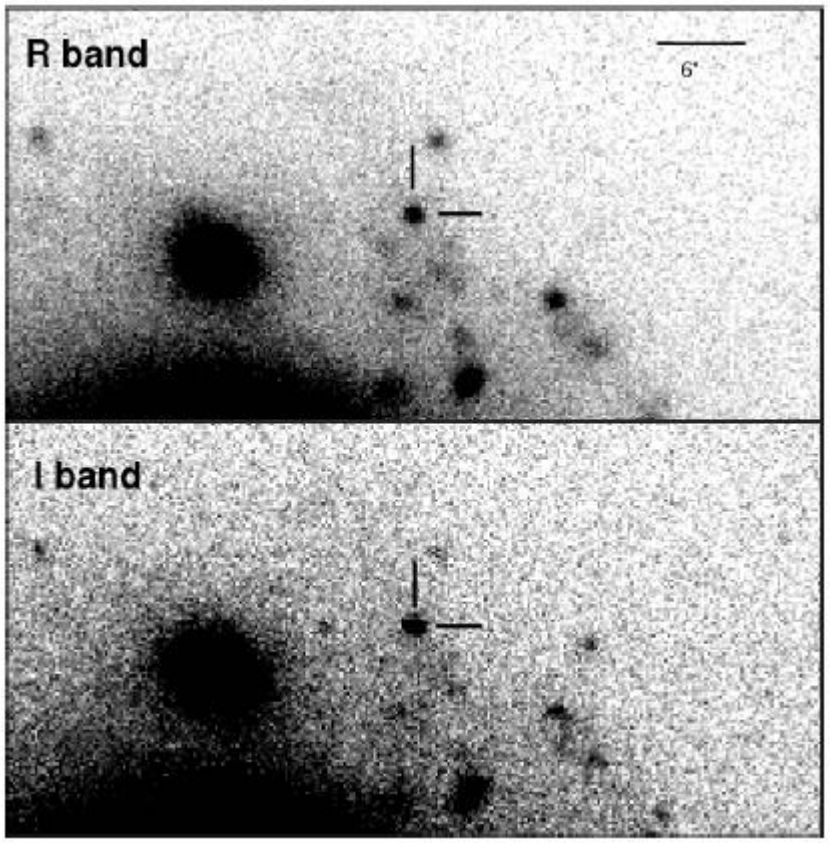
Unexpected fading is found at +220-250 d although the early-phase light curves is similar to that of SN 2005hk.



It is interpreted that E/M is much larger than that of SN 2005hk.

The line velocity width of Ca II IR triplet, [Ca II] and NaID are 6-7 times broader than those of 05hk.
-> fast expanding in inner ejecta

The metalicity and activity of host galaxy



The HII regions are confirmed in the deep Subaru/FOCAS image. The closest regons are ~50-100pc to SN locations

-> Previous studies indicate that the star-forming rate is similar to that of CC Type IIP SNe (Lyman et al. 2013)
-> Such "fast evolutions" of the progenitor is consistent with the scenario predicted by recent theoretical binary evolutions (WD+MS)

We also estimate the metalicity from the ratio of [O III]/Hbeta to [N II]/Halpha
12+log(O/H)=8.5+/-0.3
(Galaxy~ 8.8)

This is consistent with those of extremely faint Type Iax 08ha and 10ae.

Three papers appeared on this summer

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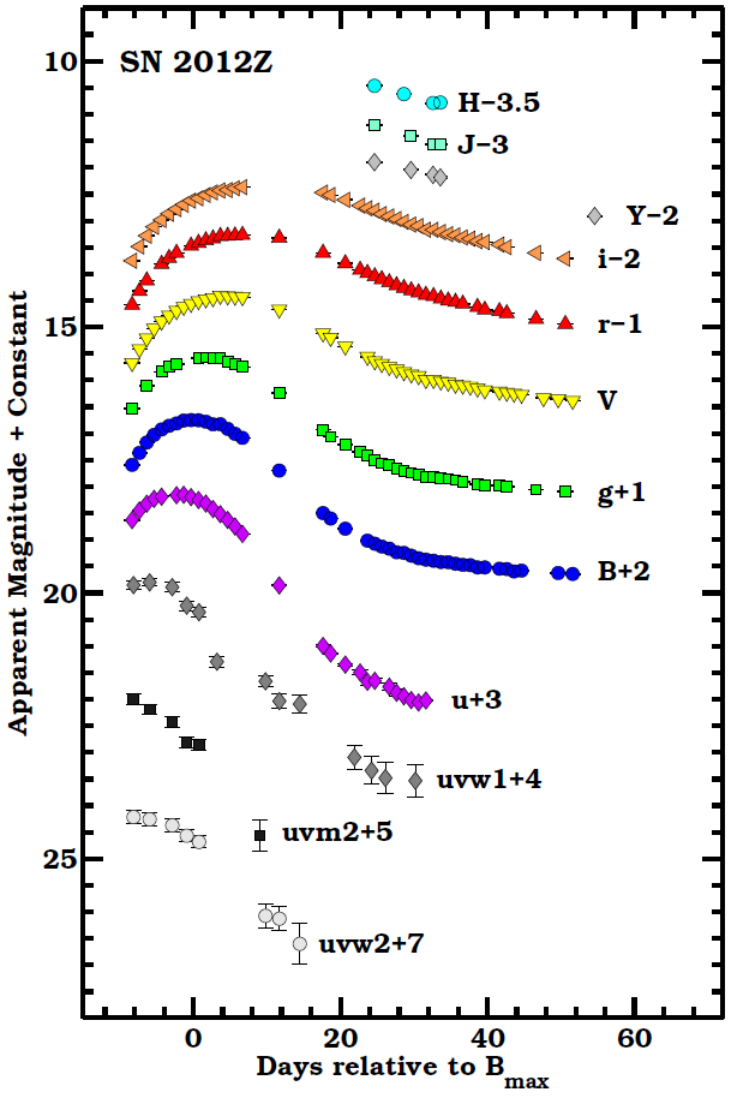
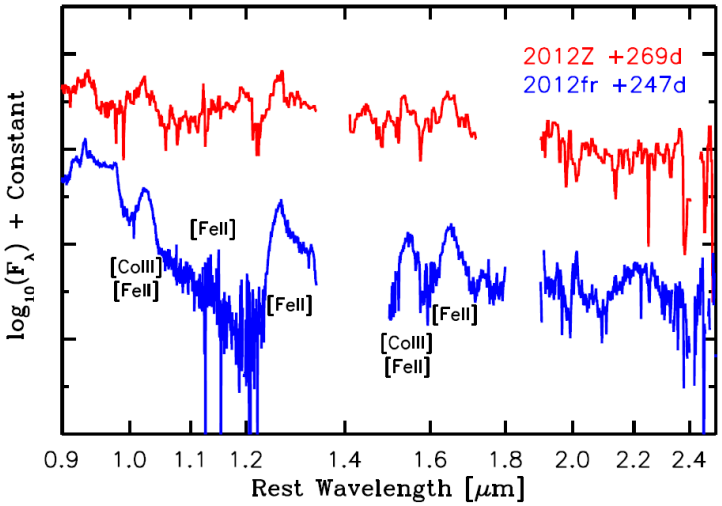
Stritzinger et al. 2014, submitted





Very dense light curves in optical and ultra violet regoins among 200 days

Very high-quality spectra are also gotten.

However, the near-infrared data is sparse relative to our results

McCully et al. 2014, accepted to *Nature*

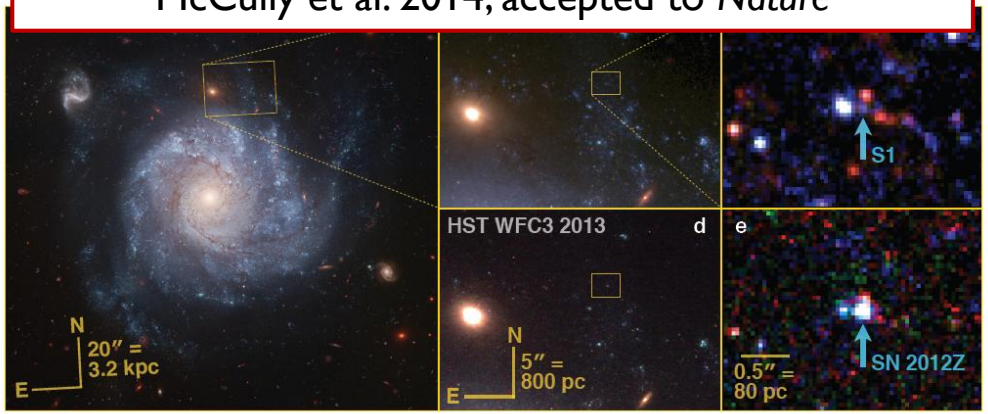


Figure 1 | *Hubble Space Telescope* colour images before and after supernova 2012Z. Panel **a** shows the Hubble Heritage image of NGC 1309 (http://heritage.stsci.edu/2006/07), with panels **b** and **c** zooming in on the progenitor system S1 in the deep, pre-explosion data. Lower panels **d** and **e** show the shallower post-explosion images of SN 2012Z on the same scale as the panels above.

SUMMARY

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- We obtained very high-cadence and dense-for-wavelength data set of Type Iax SN 2012Z.
- We found that early-phase (outer layer) properties are very similar to those of prototype SN 2005hk.
- SED exhibits more-than-two components.
- Unexpected fading is confirmed at 220-250 days (inner regions in ejecta)
- The metalicity of host galaxy is as low as other Type Iax SNe. It indicate that the progenitor may originate from similar populations, e.g., fast-evolving single degenerate systems

Relation of luminosity and decline rate (for `canonical` SN Ia)

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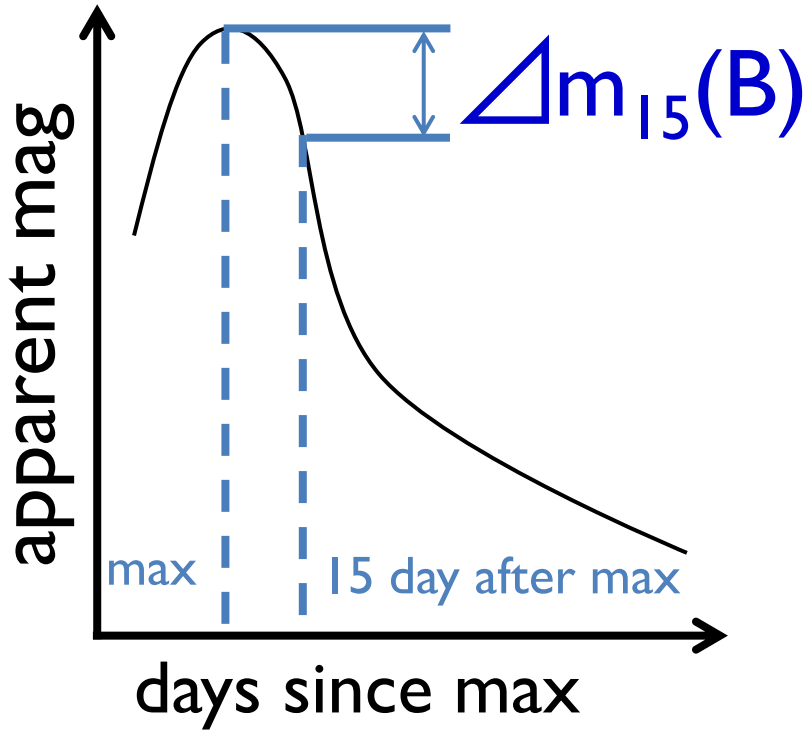
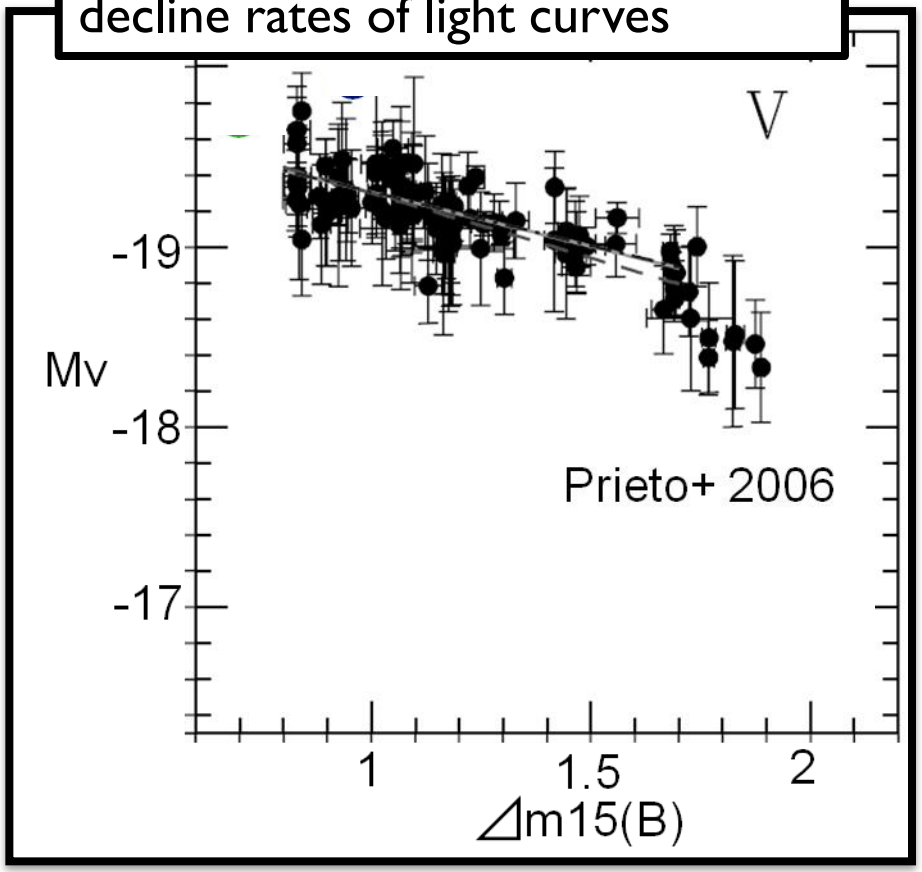
Please see Maeda-san's talk tomorrow

Light curve



Correlations of $\Delta m_{15}(B)$ and the decline rates of light curves



$\Delta m_{15}(B)$: the decline rate
Strongly-correlated with luminosity

Good indicators of distance

We can estimate the distance from the light curves
⇒ Distant SNe Ia
⇒ Constraints on dark energy