SN 2009js: connecting the subluminous and intermediate luminosity regimes

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Motivation for this work

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- Understand the diversity of Type II SN population
- Origin of mid-infrared emission in low-lum. SN

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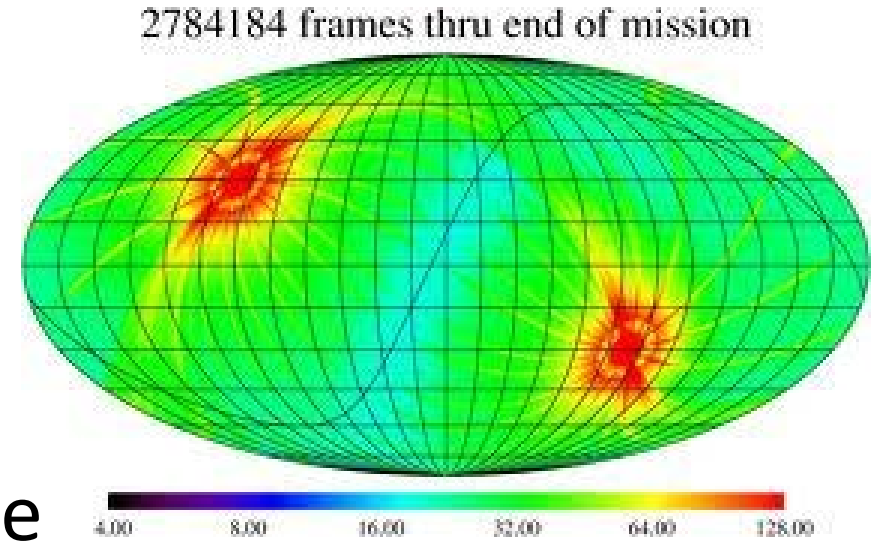
- Understand the diversity of Type II SN population

- Explore something different
  - find someone smart
  - someone who likes to talk
  - who is (apparently) never busy
  - someone who can explain things simply

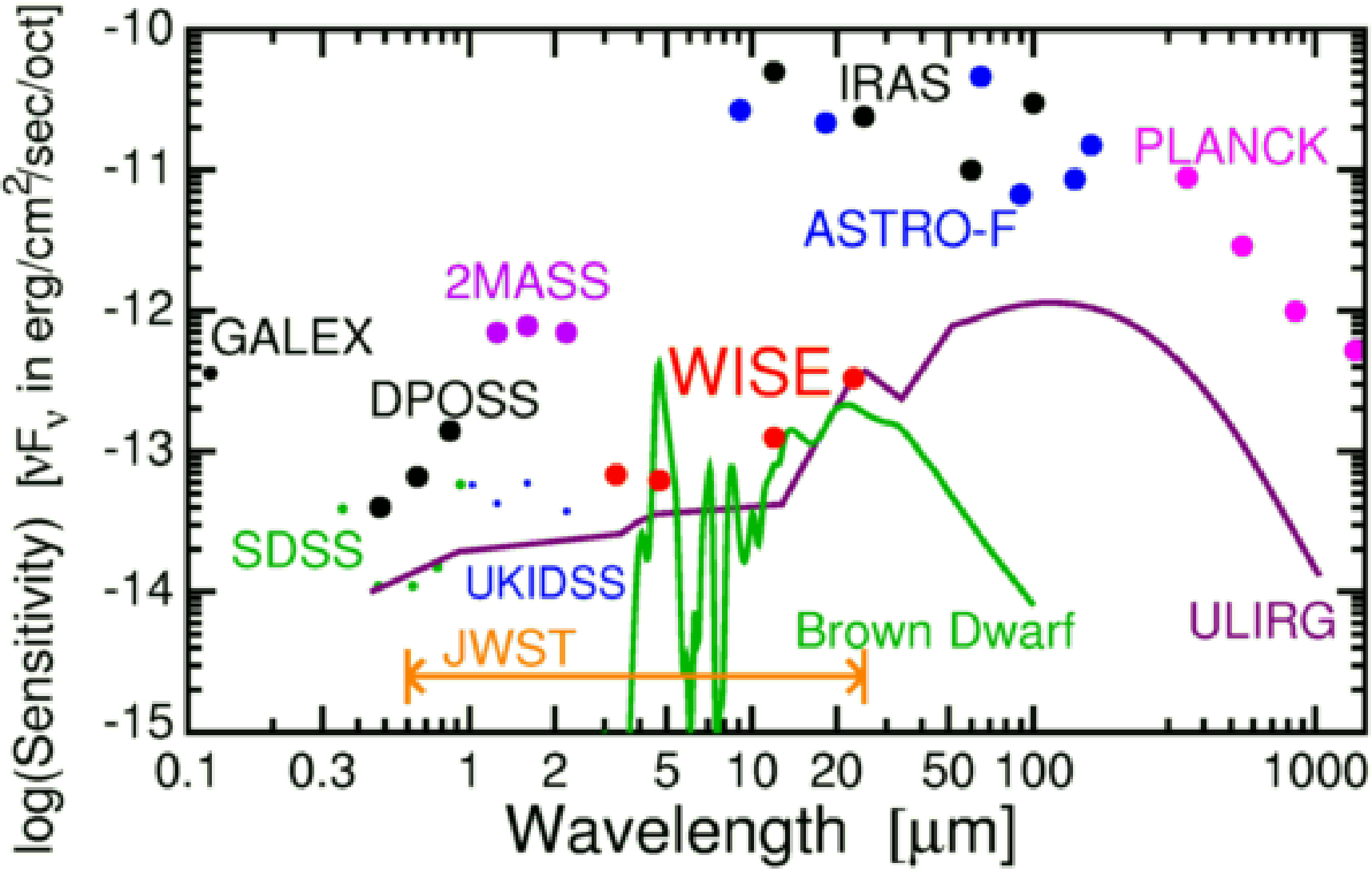
(Meeting in IPMU on 2011 Nov 16)

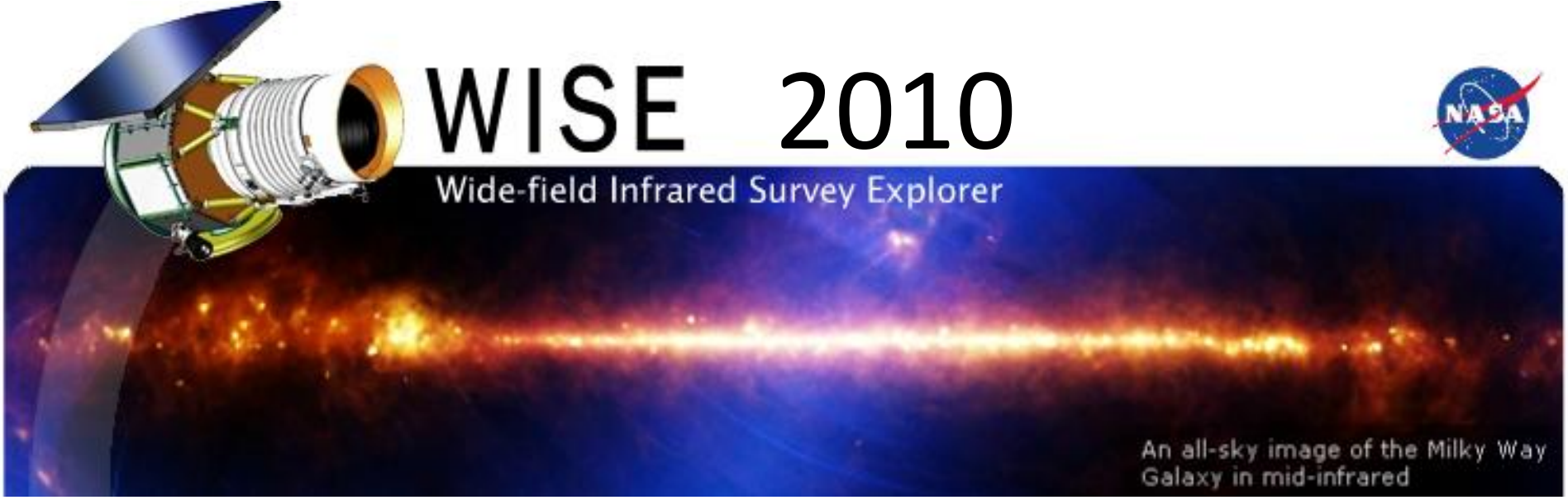
- Sensitive all sky surveys
- PSF ~ 6-9 arcsec
- 3, 4, 12, 12 μm cameras
- Two orders of magnitude deeper than IRAS.



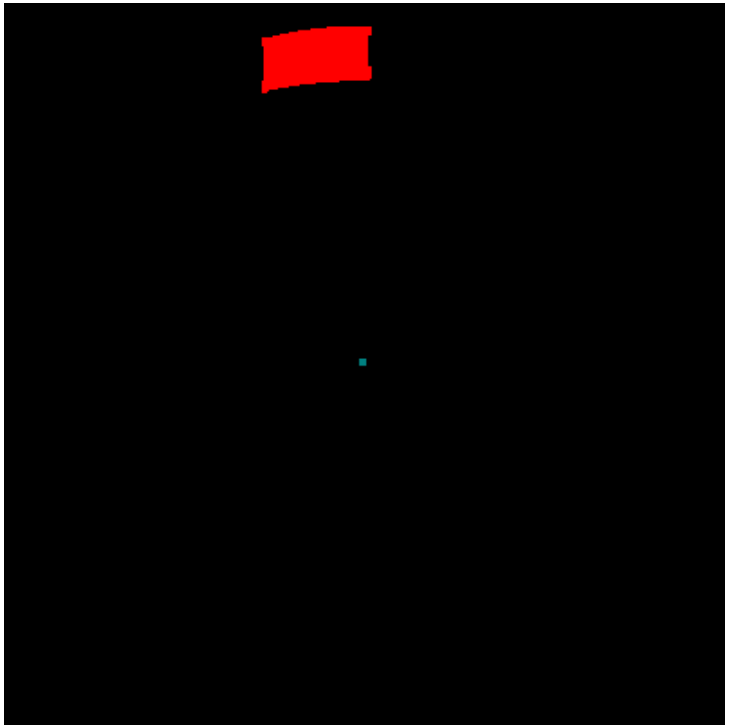
(Wright et al. 2010)

WISE : most sensitive mid-IR all sky survey to date





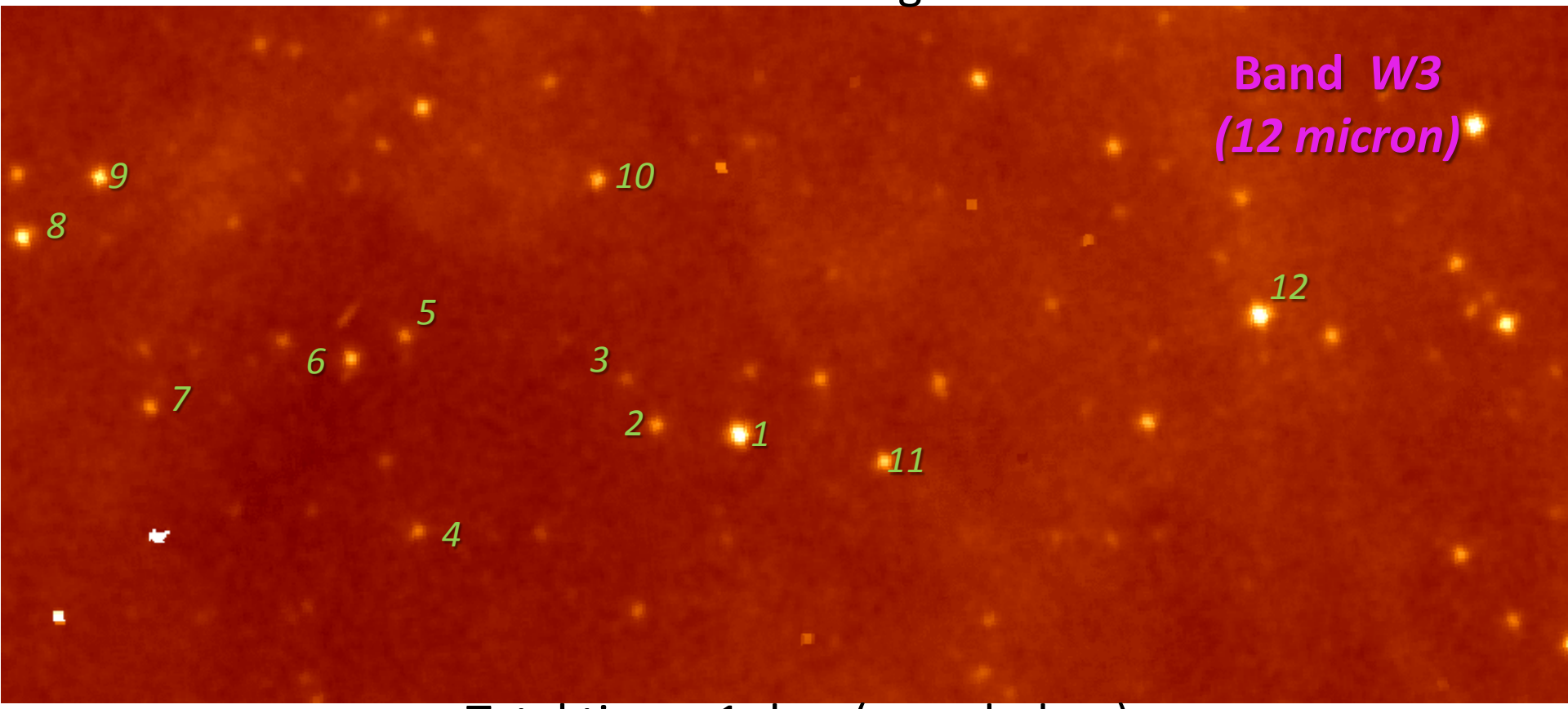
- Every position scanned multiple times in all bands
- 95 min. orbit
- 11s scan cycle time
- ~12 obs. per “epoch”
- Re-visited 6 months later



(Scan coverage)

Spot the black hole!

13 scan images

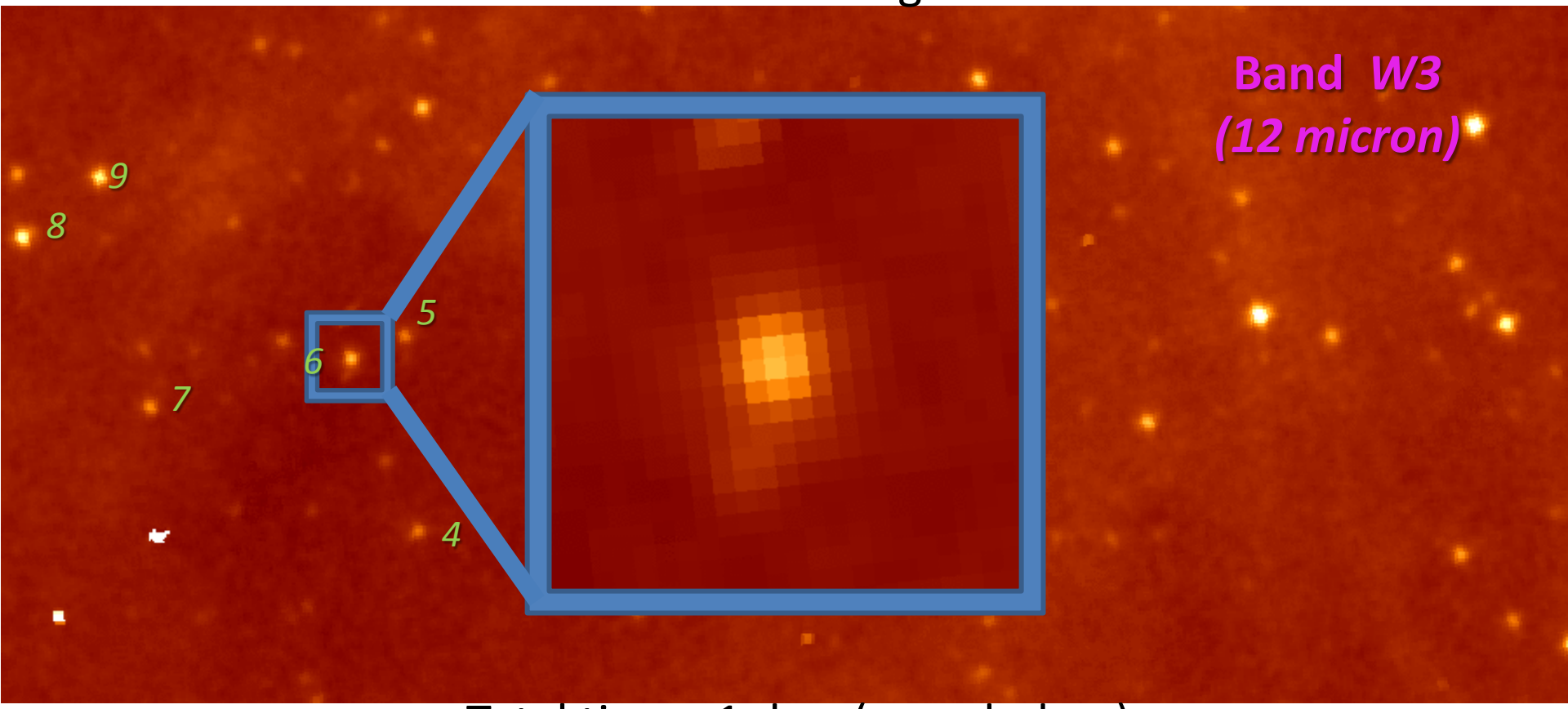


Total time ~1 day (speeded up)

GX 339-4: Gandhi+11

Spot the black hole!

13 scan images

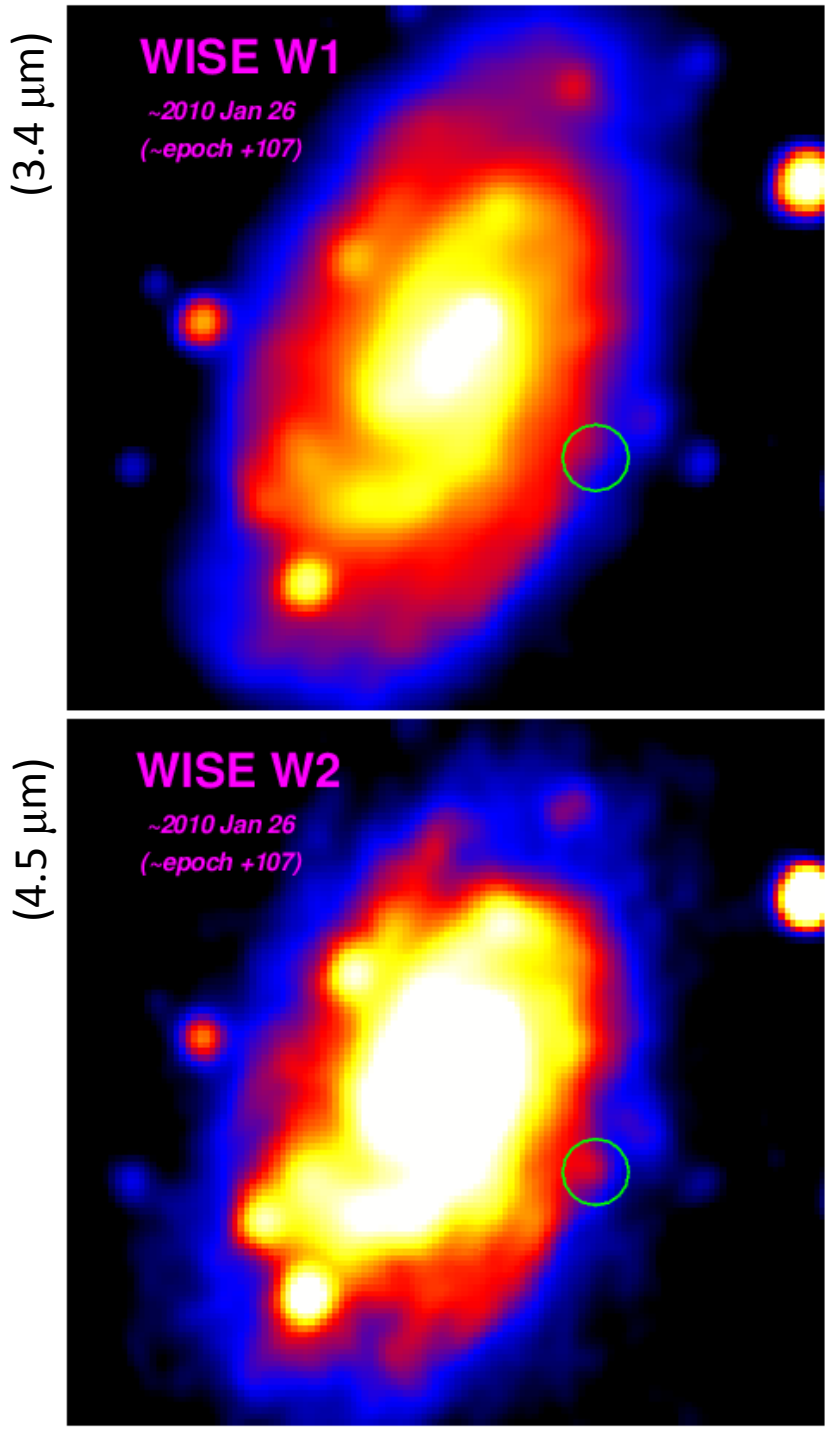


Total time ~1 day (speeded up)

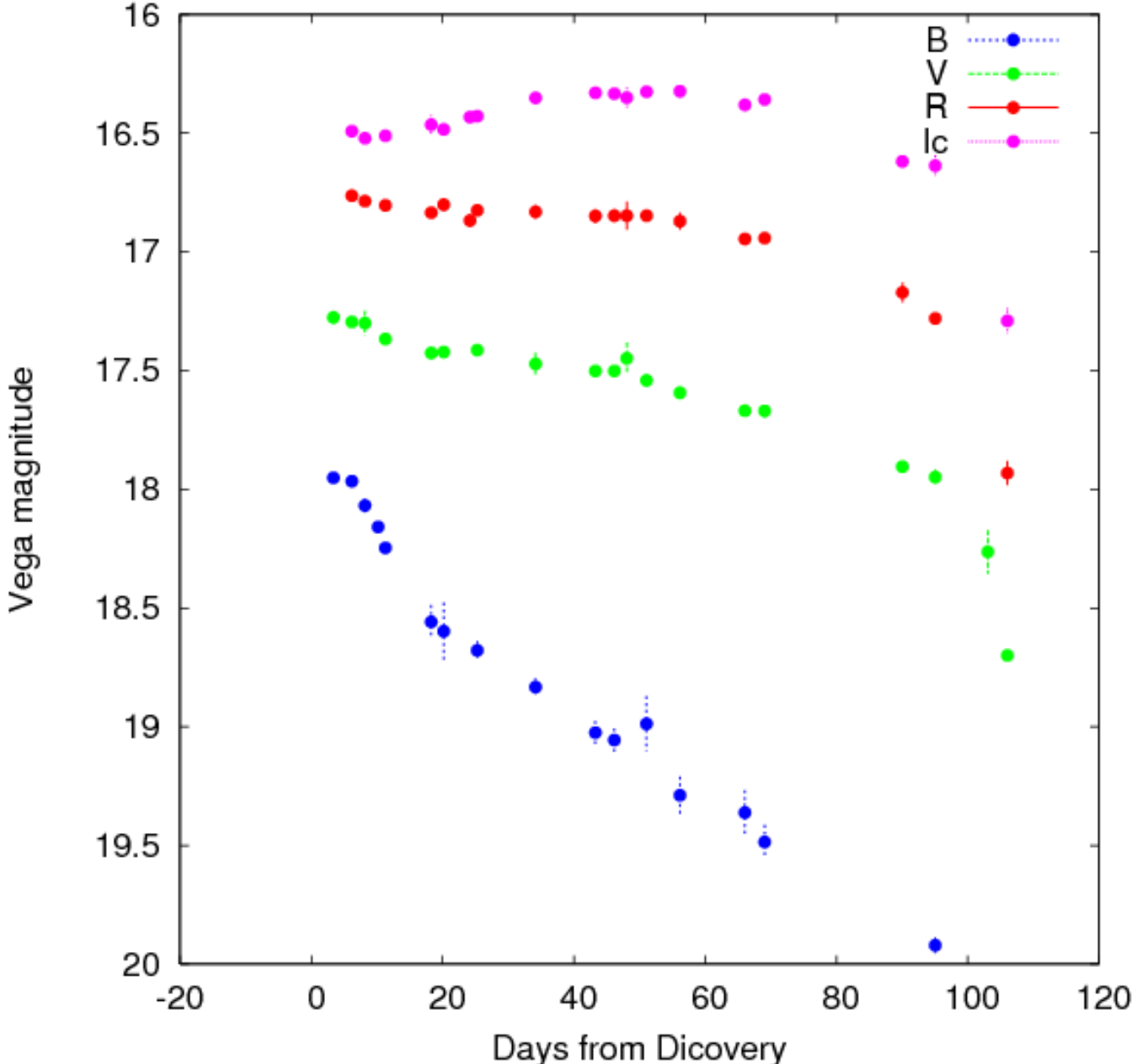
GX 339-4: Gandhi+11

SN 2009js in NGC 918 : serendipitous catch by-eye

(Nov 20 2011)



Kanata monitoring



Electronic Telegram No. 1969

Central Bureau for Astronomical Telegrams
INTERNATIONAL ASTRONOMICAL UNION
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IAUSUBS@CFA.HARVARD.EDU or FAX 617-495-7231 (subscriptions)
CBAT@CFA.HARVARD.EDU (science)
URL http://www.cfa.harvard.edu/iau/cbat.html

SUPERNOVA 2009js IN NGC 918

Independent discoveries of a supernova in NGC 918 have been received, first via S. Nakano, Sumoto, Japan, who reports the discovery by K. Itagaki (Teppo-cho, Yamagata) of an apparent supernova (mag 17.2) on ten or more 15-s unfiltered CCD frames (limiting mag 19.5) taken around Oct. 11.69 UT using a 0.60-m f/5.7 reflector, noting that nothing is visible at the new object's position (tabulated below) on the Digitized Sky Survey. Itagaki's discovery image is posted at website URL http://www.k-itagaki.jp/images/ngc918.jpg. Nakano also forwards confirming astrometry from T. Yusa (Osaki, Miyagi-ken, Japan), from five 120-s unfiltered CCD exposures (limiting magnitude 19.5) taken remotely using a 0.25-m f/3.4 reflector near Mayhill, NM, U.S.A., as tabulated below. An independent discovery of 2009js was then received by X. Parisky, S. B. Cenko, W. Li, and A. V. Filippenko, University of California, on unfiltered LOSS/KAIT images (cf. CBET 1963), as also tabulated below. Available astrometry and unfiltered CCD magnitudes for 2009js:

2009 UT	R.A. (2000.0)	Decl.	Mag.	Offset	Observer
Oct. 11.44	2 25 48.28	+18 29 25.8	17.2	35".5 W, 20".7 S	KAIT
11.689	2 25 48.30	+18 29 26.2	17.2	35" W, 20".5 S	Itagaki
12.172	2 25 48.30	+18 29 25.8	16.7		Yusa
12.527	2 25 48.29	+18 29 26.2	17.2		Itagaki

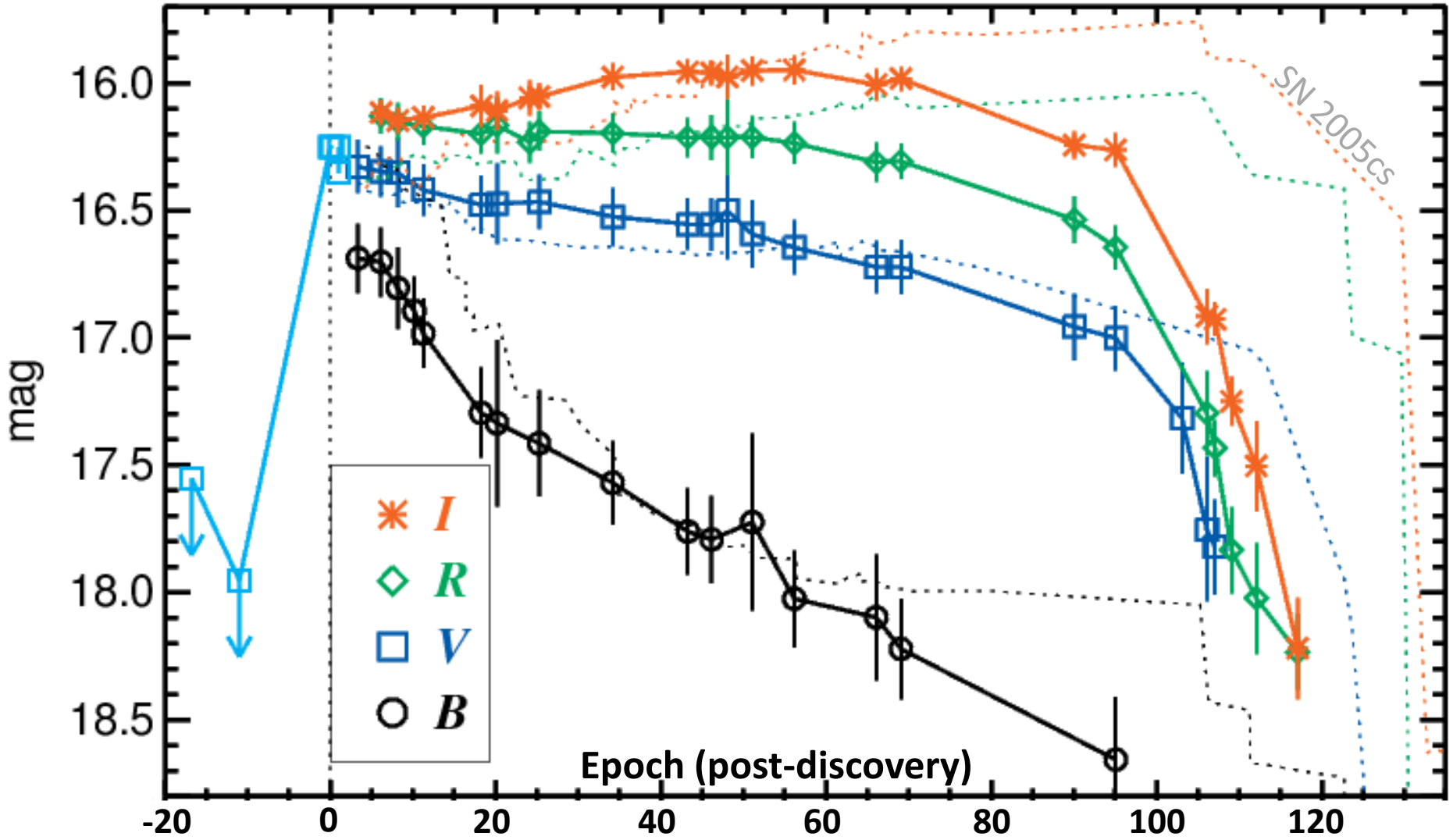
Additional unfiltered CCD magnitudes for 2009js (including limiting magnitudes from archival images): 2007 Aug. 23, [19.0 (Itagaki); 2009 Sept. 24.67, [18.5 (Itagaki); 30.44, [18.9 (KAIT); Oct. 12.44, 17.3.

J. M. Silverman, M. T. Kandrashoff, and A. V. Filippenko, University of California, Berkeley, report that inspection of CCD spectra (range 340-1000 nm), obtained on Oct. 12 UT with the 3-m Shane reflector (+ Kast) at Lick Observatory, shows that SN 2009js is a type-II supernova; cross-correlation with a library of supernova spectra using the "SuperNova IDentification" code (SNID; Blondin and Tonry 2007, Ap.J. 666, 1024) indicates that it is most similar to the type-IIP supernova 2005cs about two days after maximum brightness. After removal of the host-galaxy recession velocity of 1507 km/s (Rhee et al. 1996, A.Ap. Suppl. 115, 407), the H-alpha absorption (which is greatly dominated by the emission component) is found to be blueshifted by about 7200 km/s.

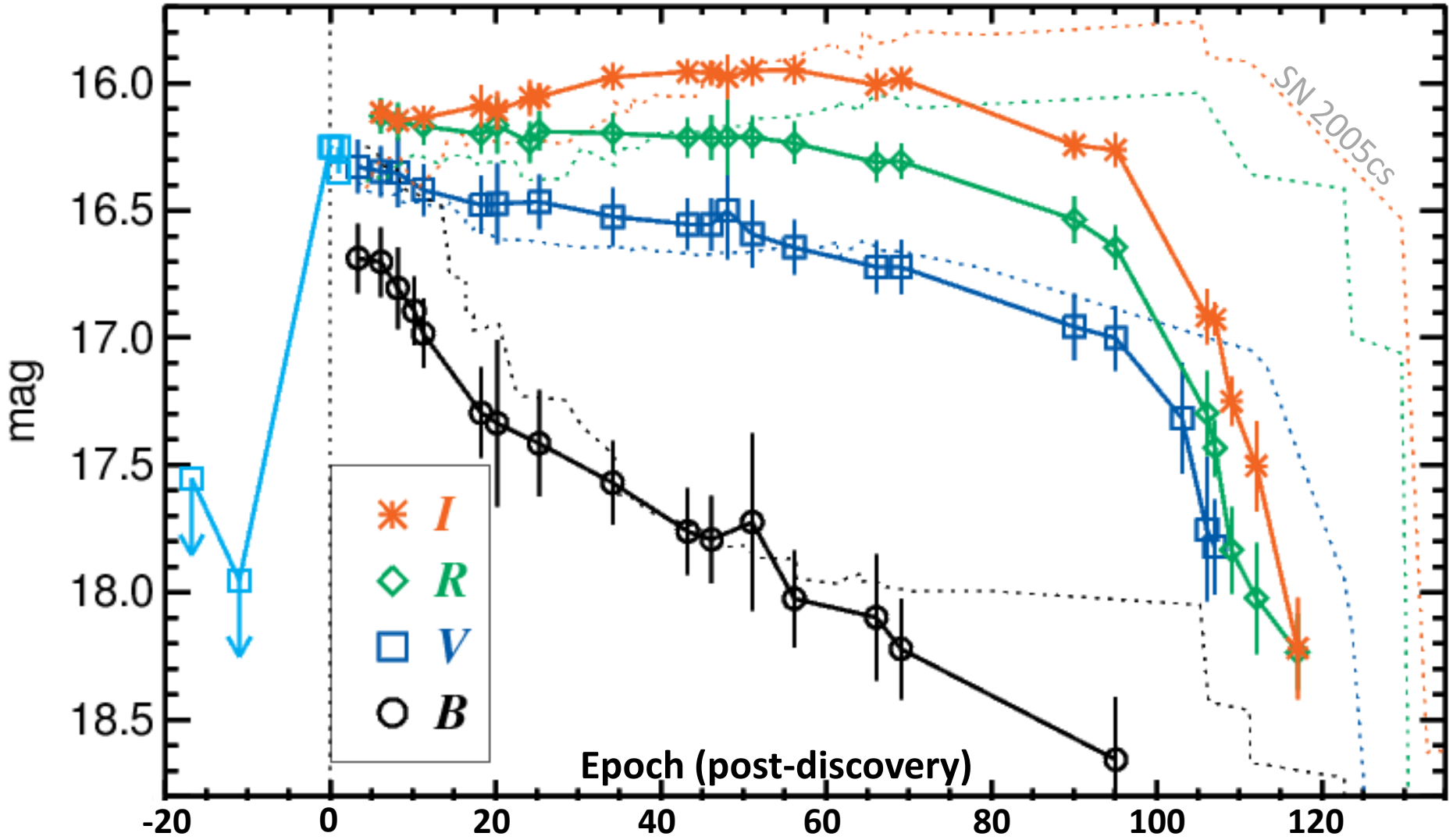
Discovery and initial classification

SN 2009js is similar to well-known subluminous SN 2005cs

Type IIP lightcurves



Explosion epoch uncertain to within 5.5 days

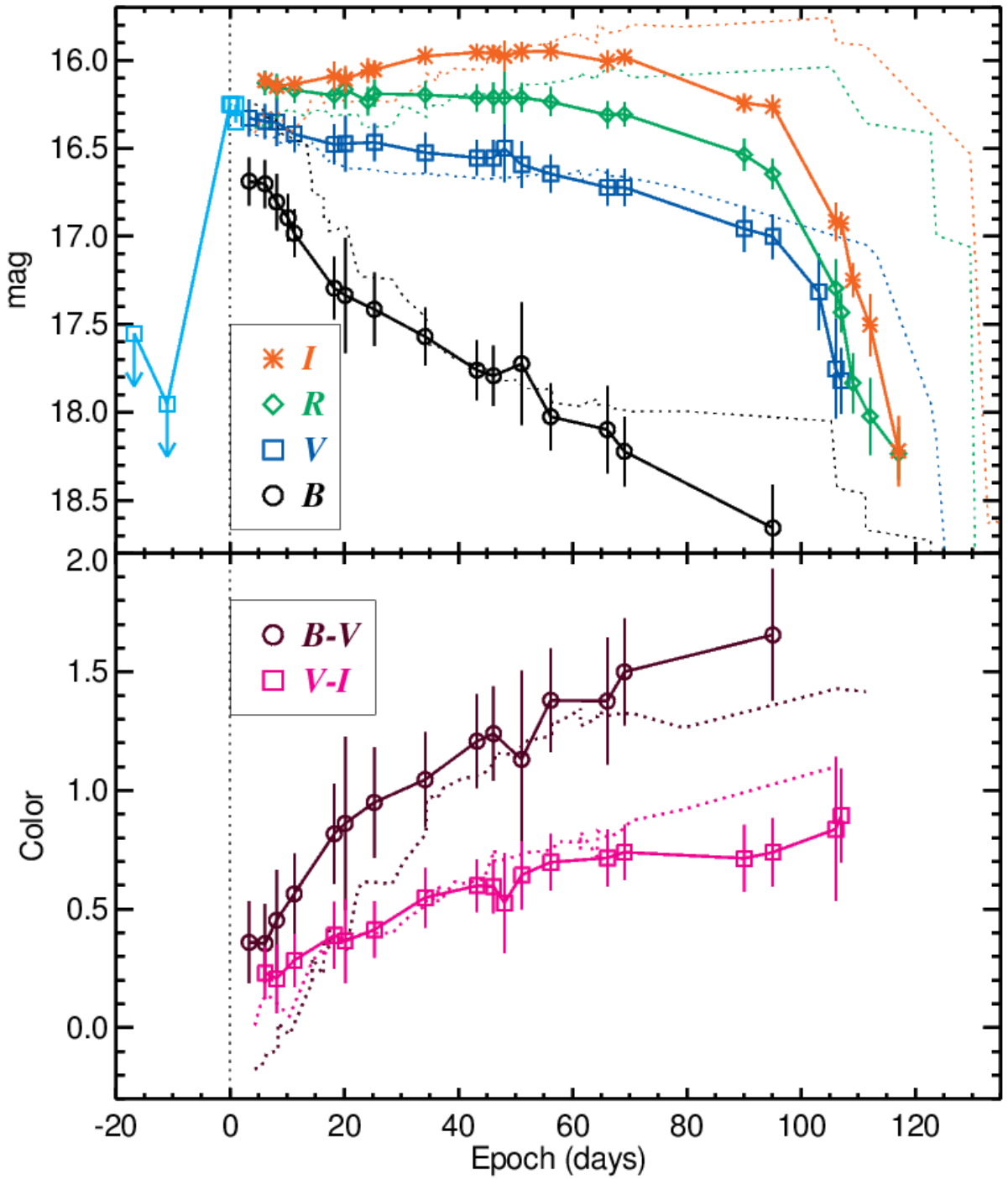


Reddening

A_V(Gal)= 0.95 mag
(Schlafly & Finkbeiner 2011)

A_V(host)=0.18±0.38

Based upon V-I color
(Olivares et al. 2010)

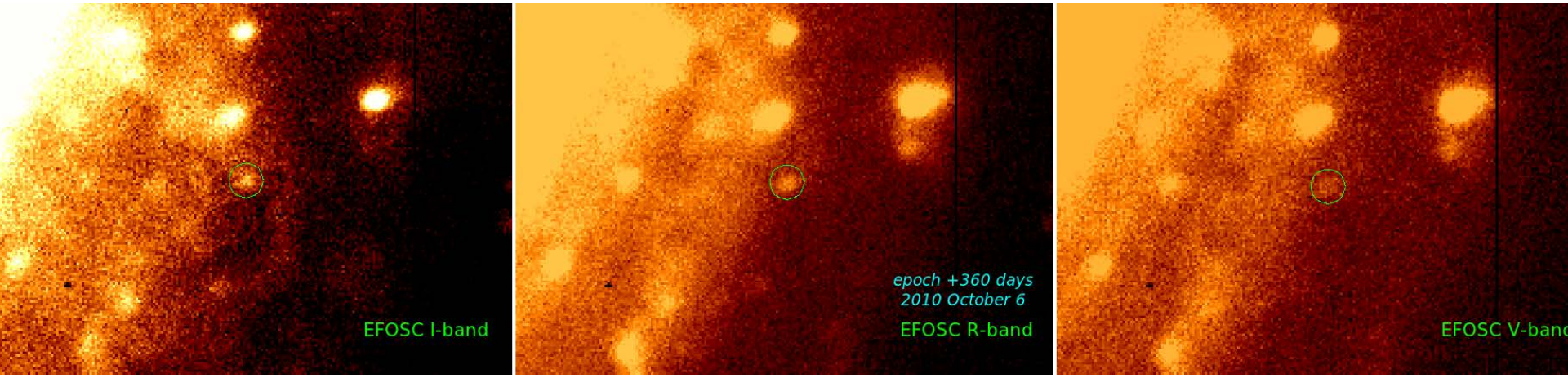


Late-time archival data


ESO/NTT

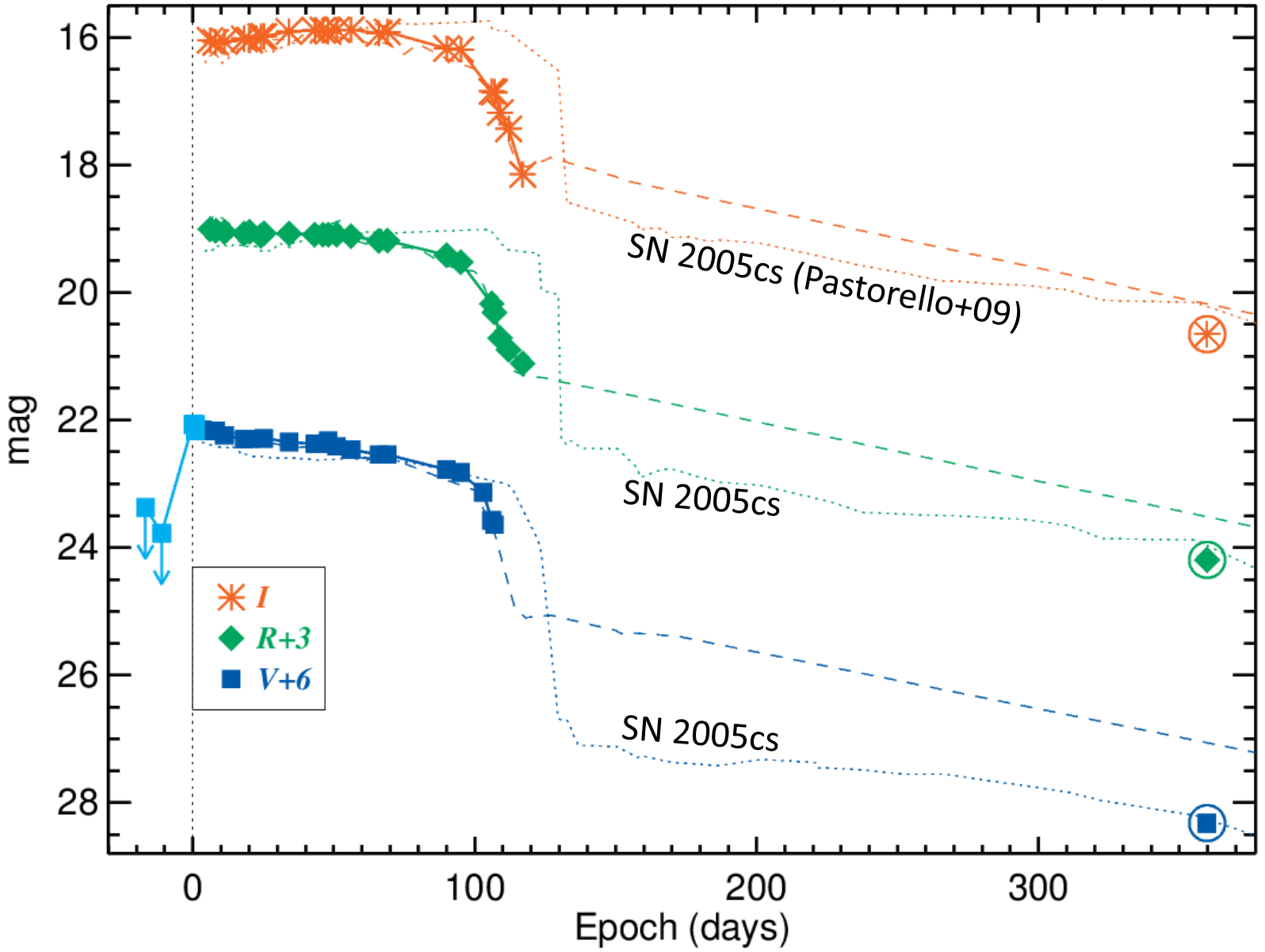
EFOSC I-band
2010 Oct 06
epoch +360

Late-time archival data



ESO archival data
ESO Large program
P.I. S. Benetti

Long-term optical evolution



Subaru spectroscopy

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irafterm

NOAO/IRAF V2.14.1 pg@note186.astro.isas.jaxa.jp Thu 15:31:41 13-Dec-2012
[sn09js.fits]: SN 2009js - Aperture 1 300. ap:1 beam:0

.500E-16
.400E-16
.300E-16
.200E-16
.100E-16
.000E-16

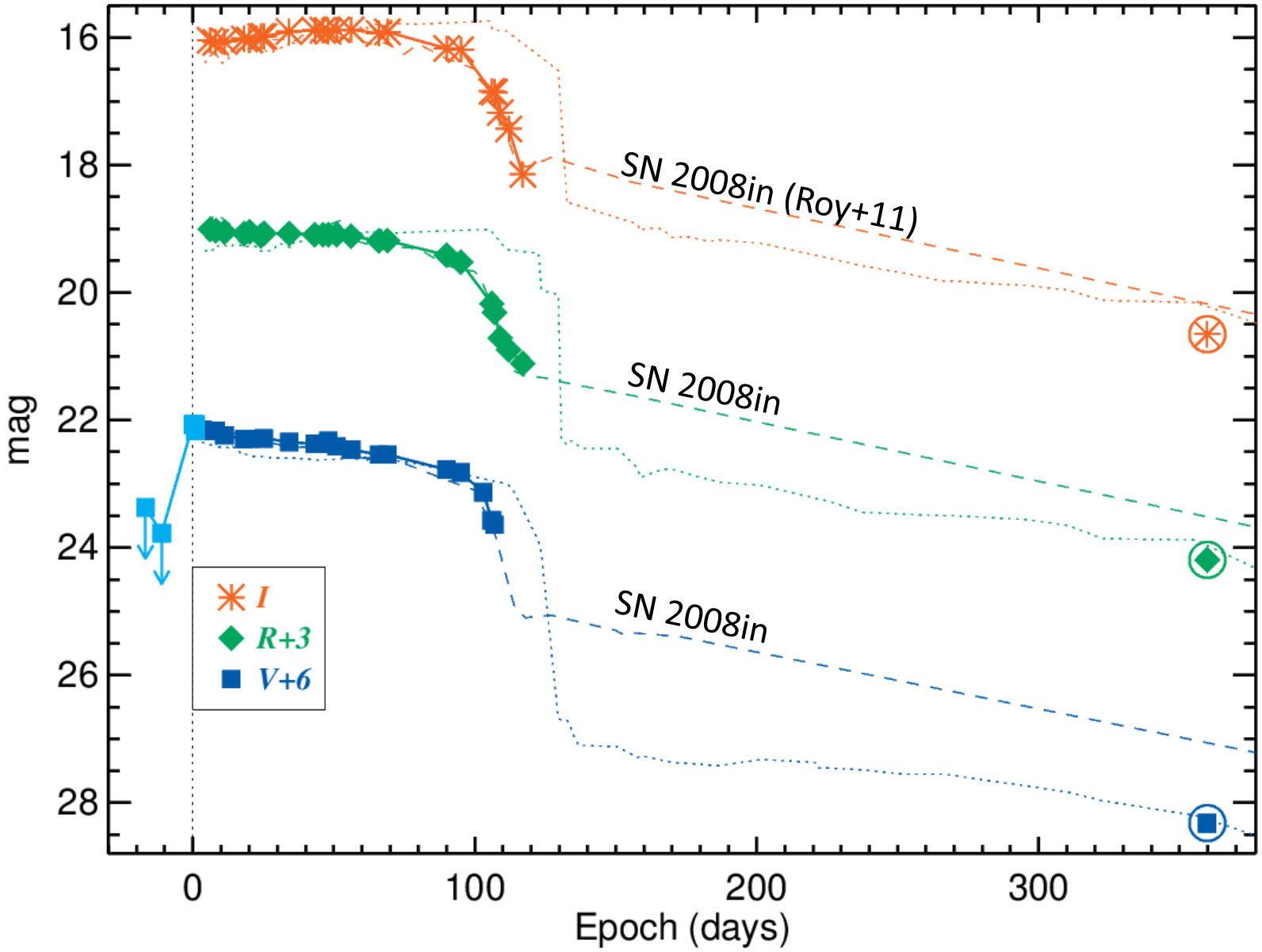
Na I 5891
(Gal)

Na I 5891
(z=0.005)

5825 5850 5875 5900 5925 5950

Wavelength (angstroms)

Long-term optical evolution



SN 2008in : intermediate luminosity SN

THE ASTROPHYSICAL JOURNAL, 736:76 (20pp), 2011 August 1 doi:10.1088/0004-637X/736/2/76

SN 2008in—BRIDGING THE GAP BETWEEN NORMAL AND FAINT SUPERNOVAE OF TYPE IIP

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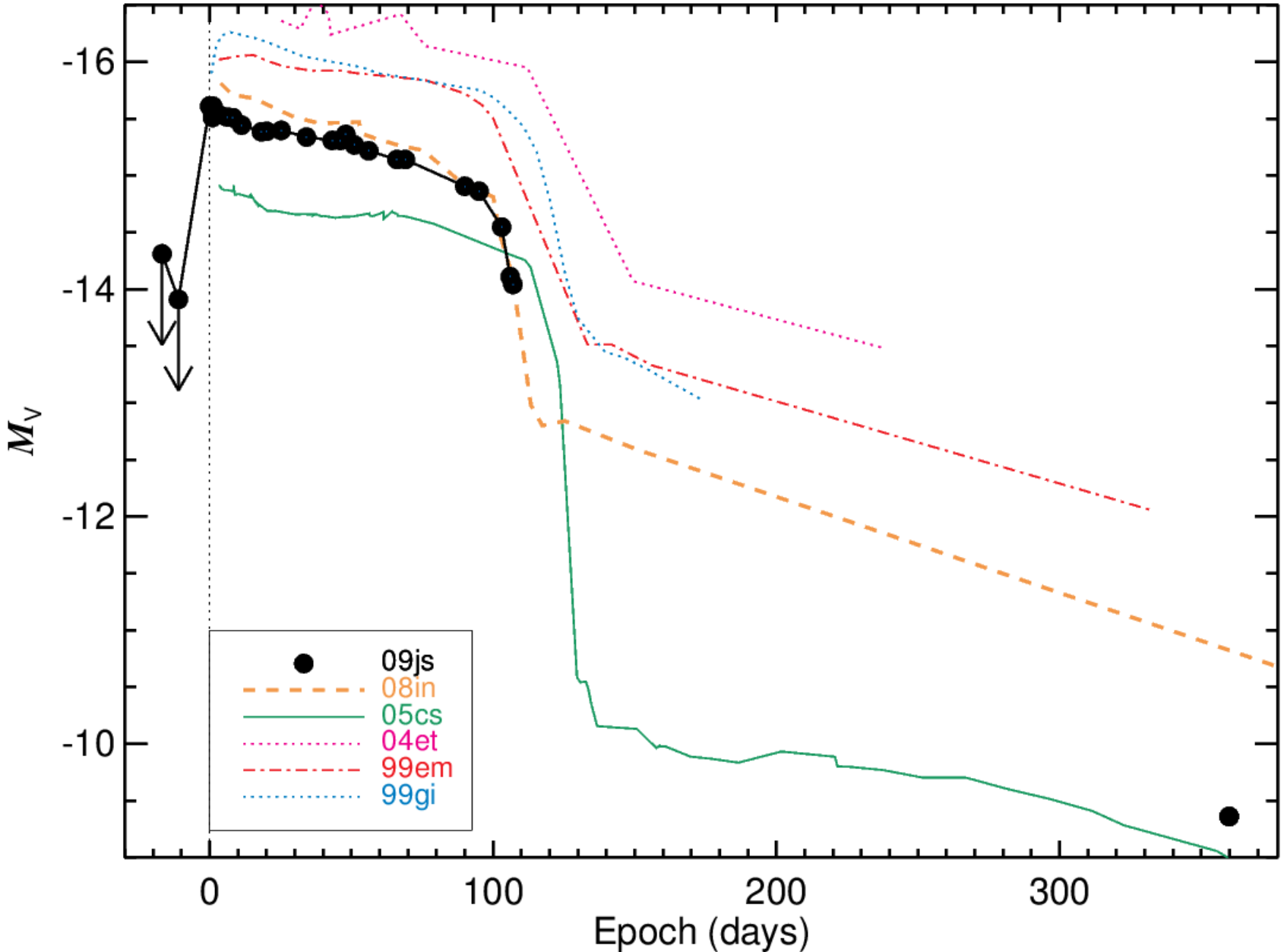
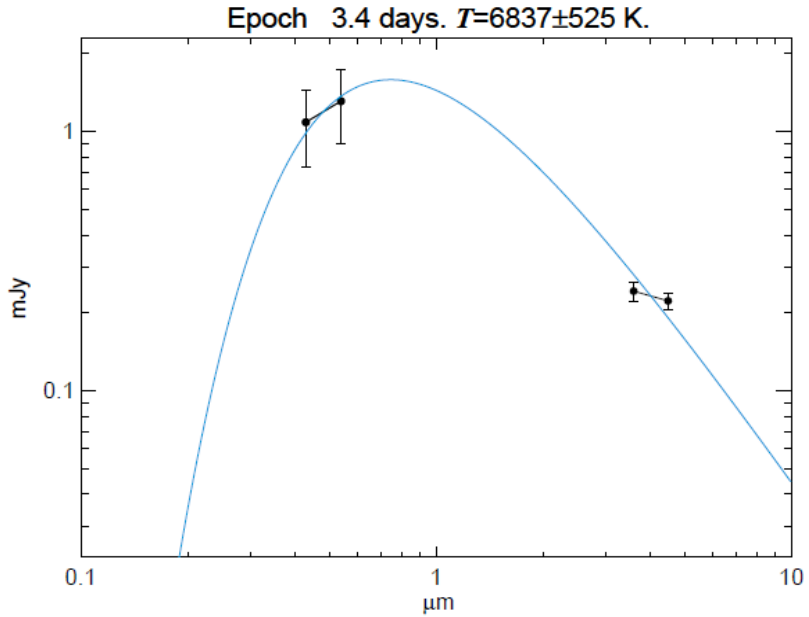
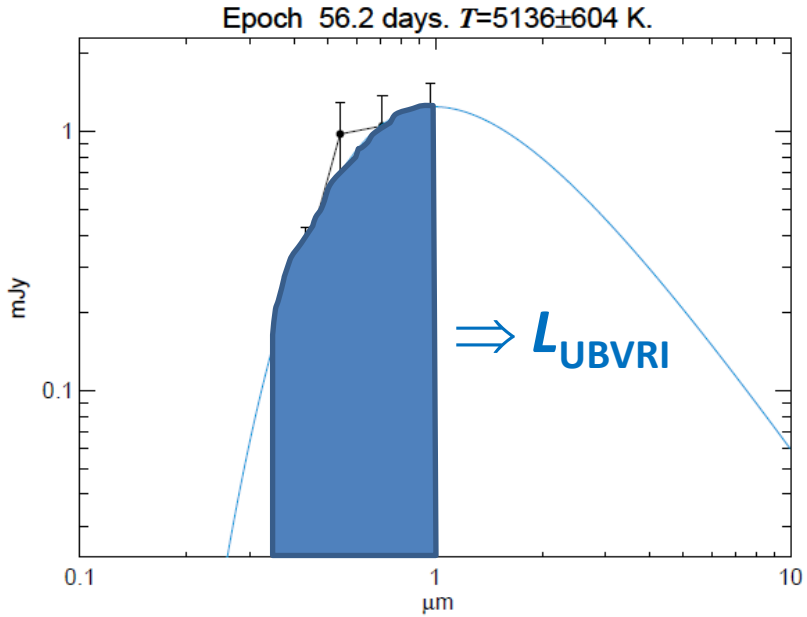
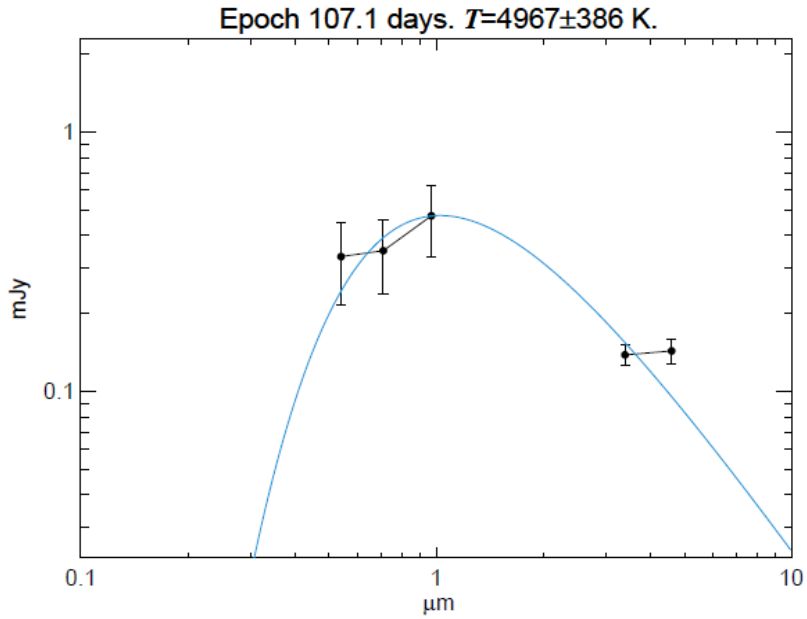
Similarity to SN 2008in



Quasi-bolometric luminosity







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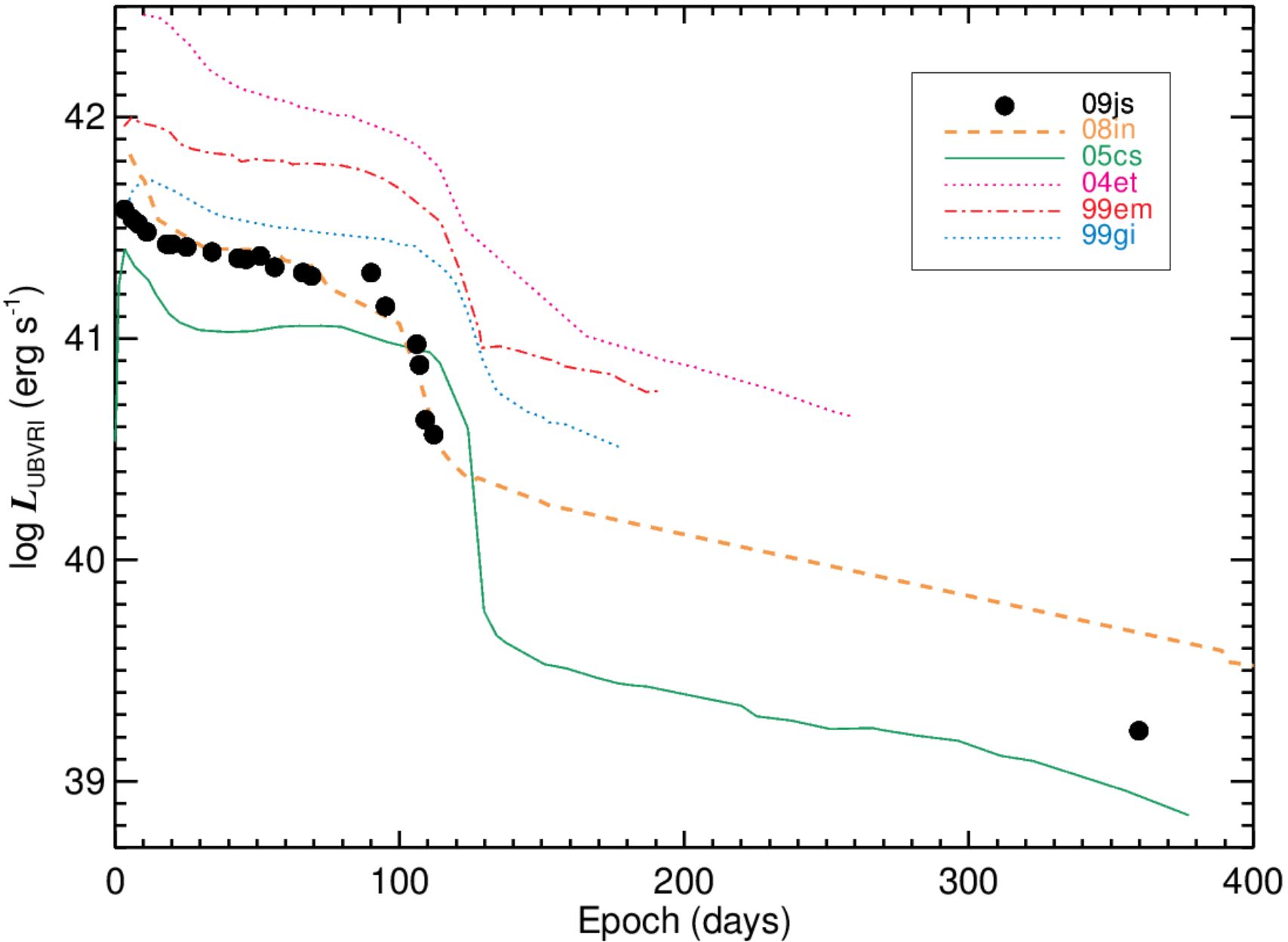


SN 2009js : classification

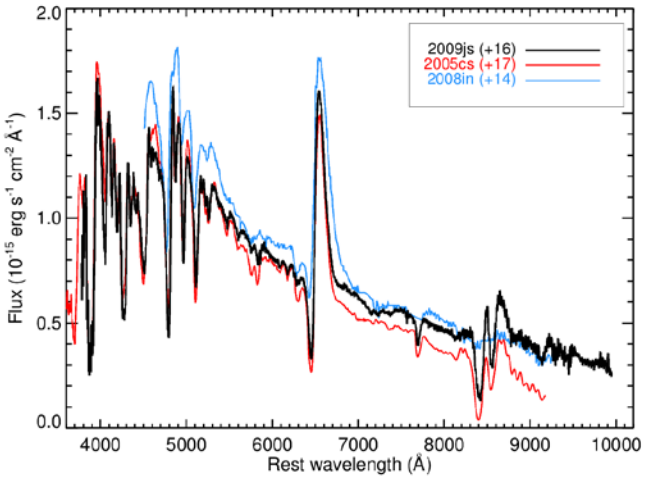
- Type IIP

SN 2005cs

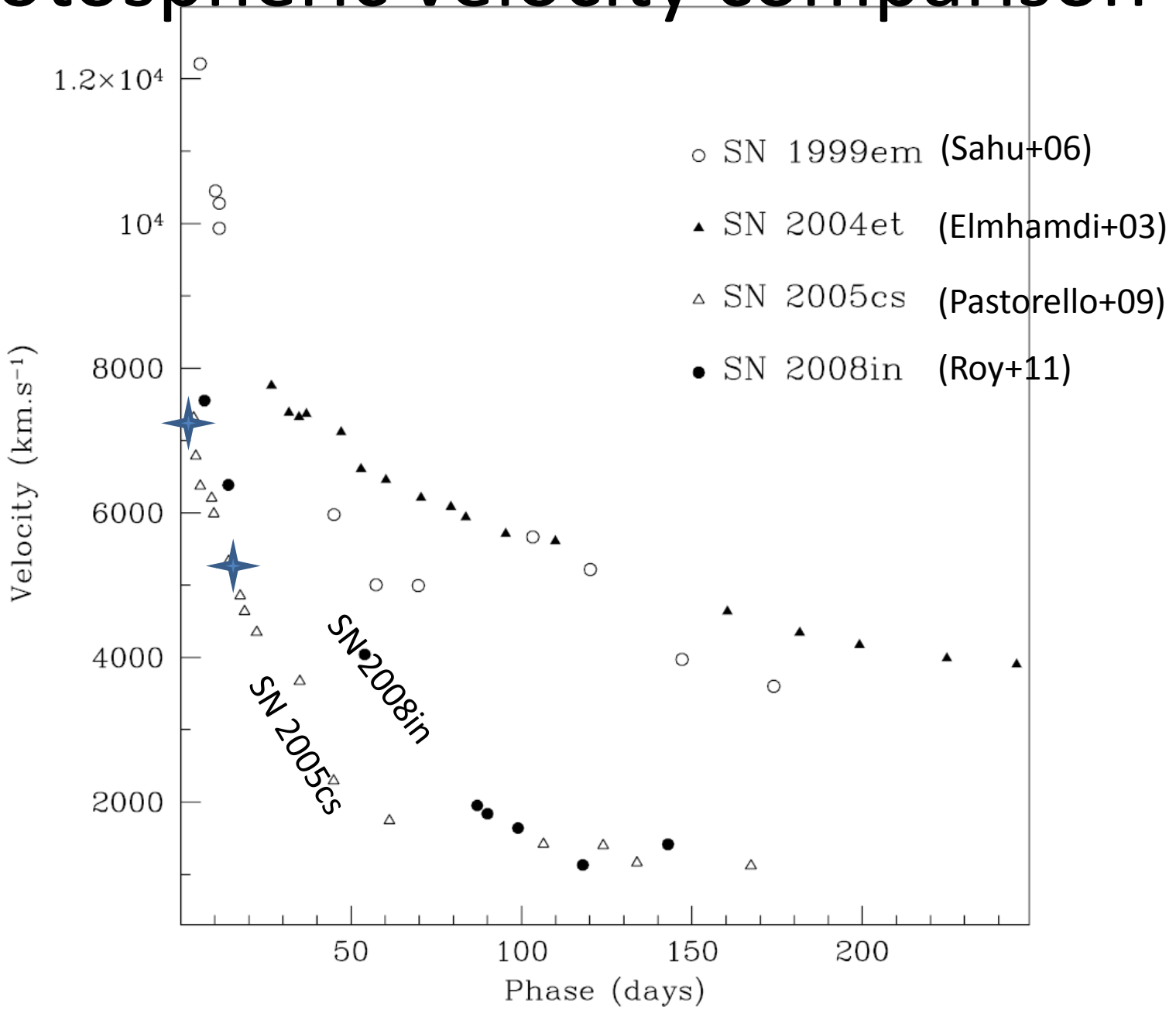
1) Spectra very similar
2) Long-term evolution similar

SN 2008in

1) Plateau luminosity closely matched
2) Plateau length matched



Photospheric velocity comparison



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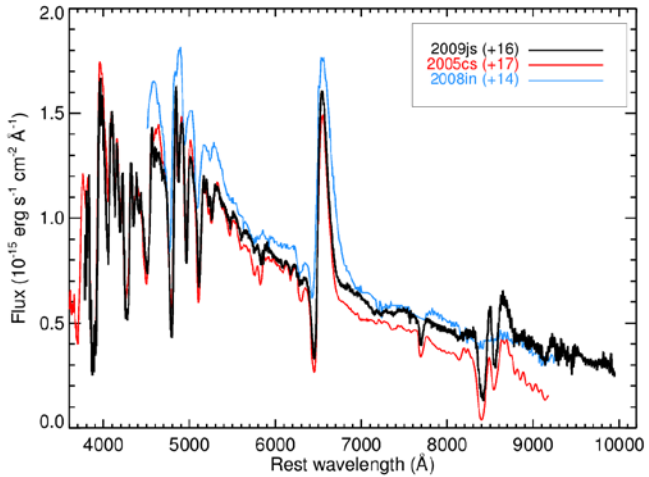

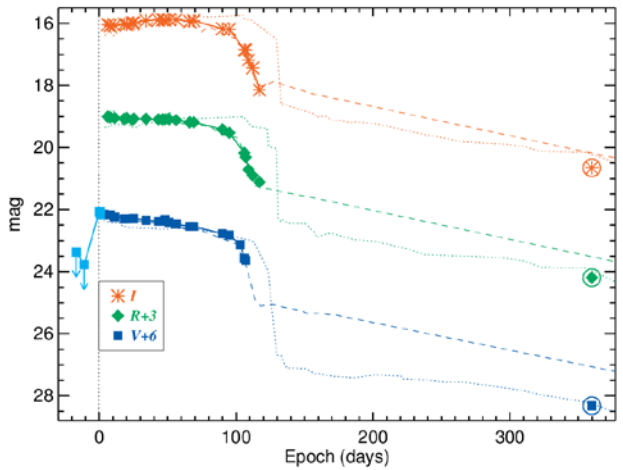

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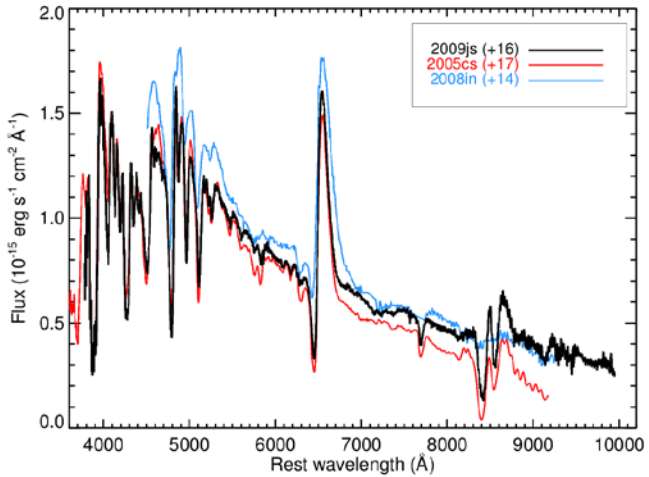
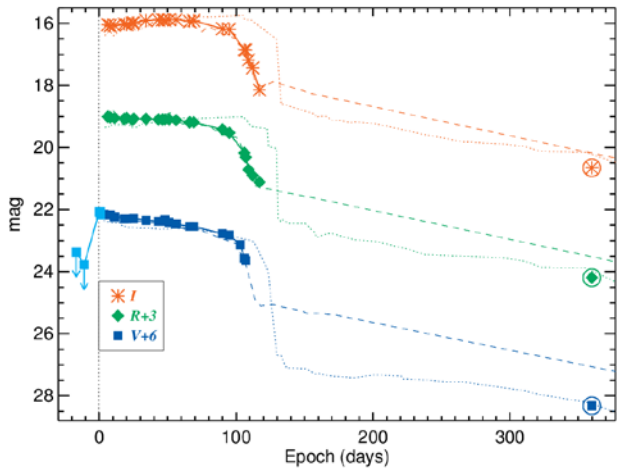
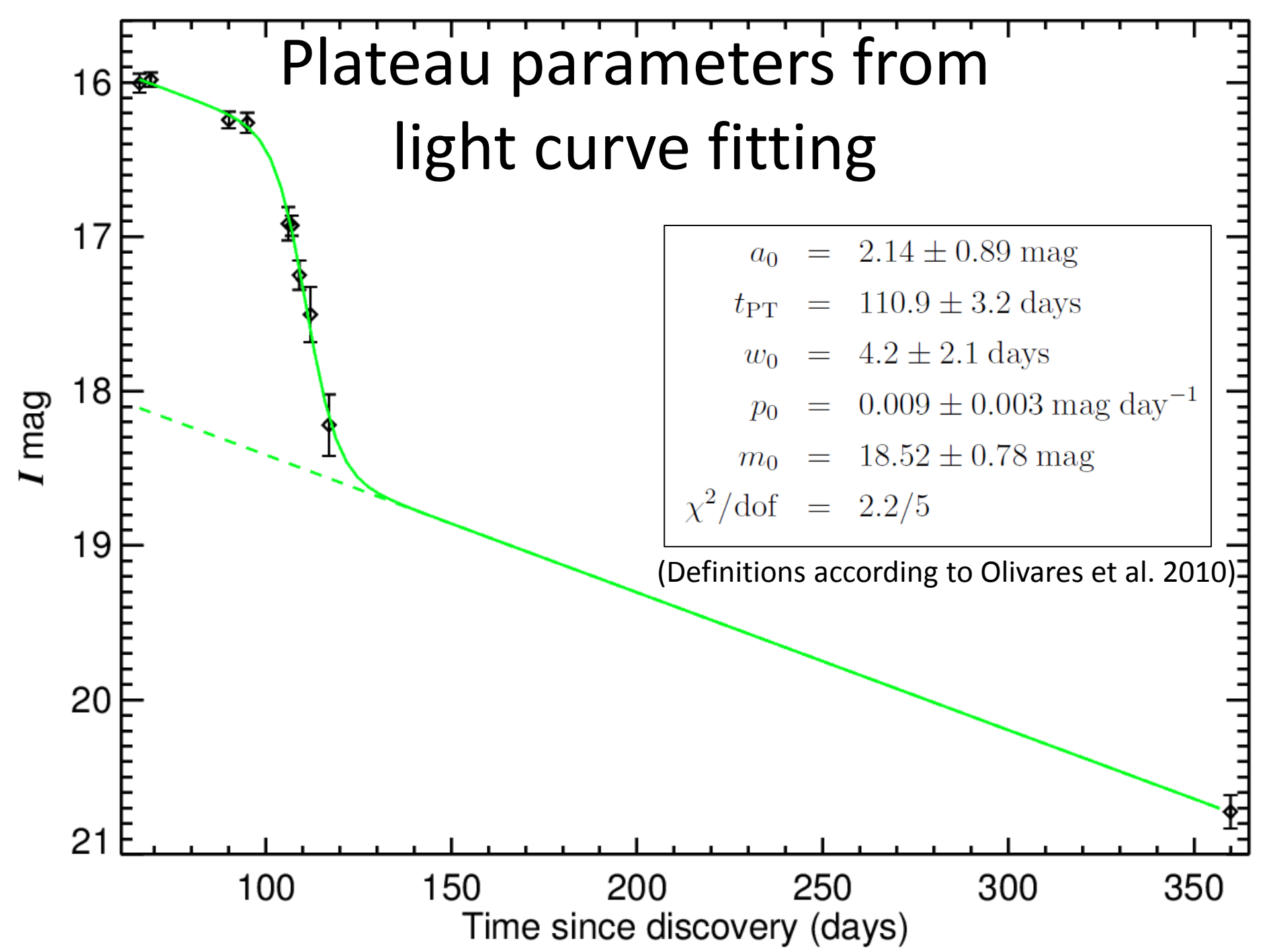




Plateau parameters from light curve fitting



(Definitions according to Olivares et al. 2010)

SN 2009js : classification

- Type IIP

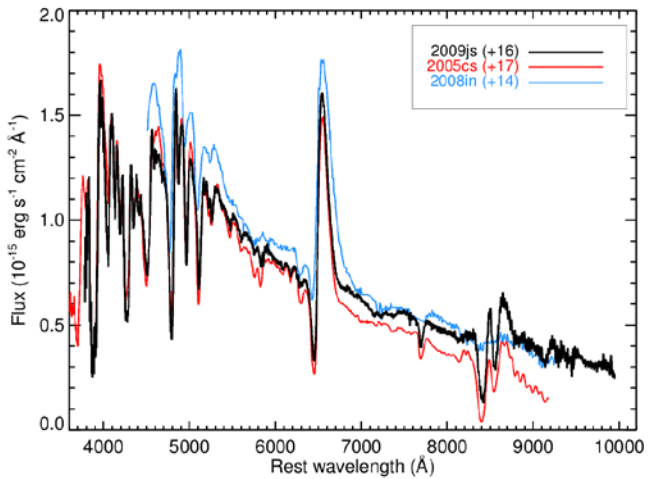
Shares characteristics with both subluminous and intermediate luminosity events

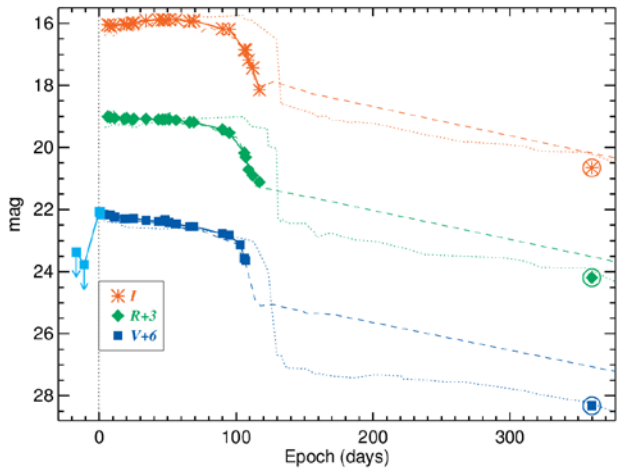
SN 2005cs

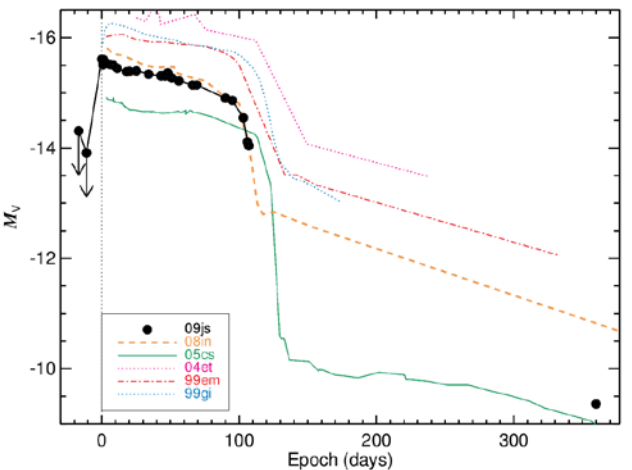
1) Spectra very similar
2) Long-term evolution similar

SN 2008in

1) Plateau length matched
2) Plateau luminosity closely matched







SN 2009js : properties

- M(^{56}Ni)=0.004-0.008 M_{sun}

(Pastorello+09)

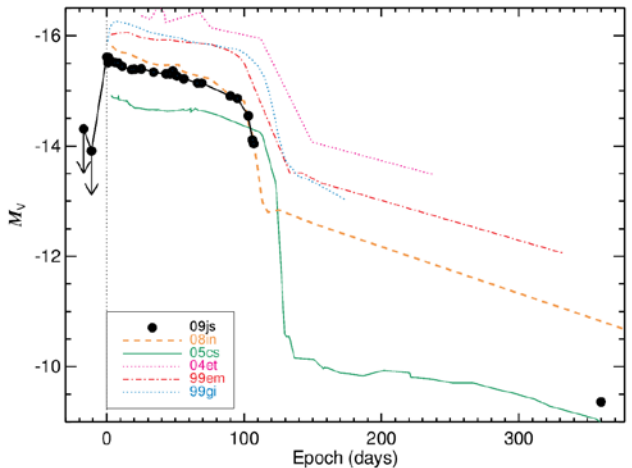
SN 2005cs

M(^{56}Ni)~0.003M_{sun}

SN 2008in

M(^{56}Ni)~0.015M_{sun}

(Roy +11)



SN 2009js : properties

- $M(^{56}Ni)=0.004\text{-}0.008\ M_{sun}$
- $E\sim0.14\pm0.1$ foe
- $M_{ej}=9\pm5\ M_{sun}$

(Litvinova & Nadezhin 1985, Popov 1993, but see Maguire et al. 2010)

SN 2005cs

(Pastorello+09)

$M(^{56}Ni)\sim0.003M_{sun}$

E~0.17 foe

$M_{ej}\sim8\text{-}16\ M_{sun}$

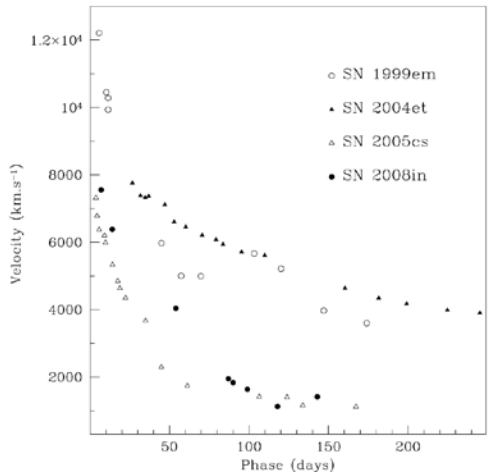
SN 2008in

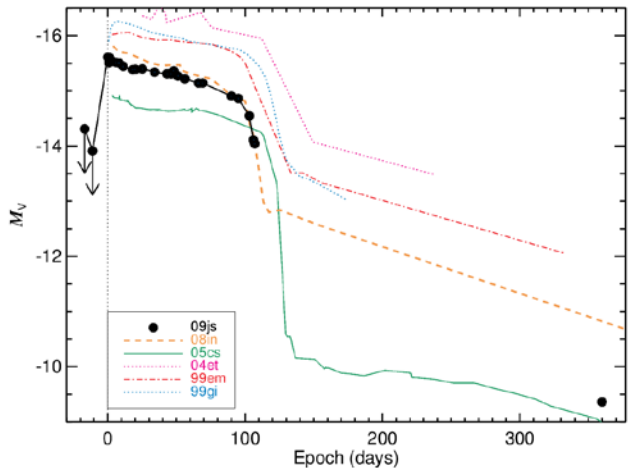
$M(^{56}Ni)\sim0.015M_{sun}$

E~0.5 foe

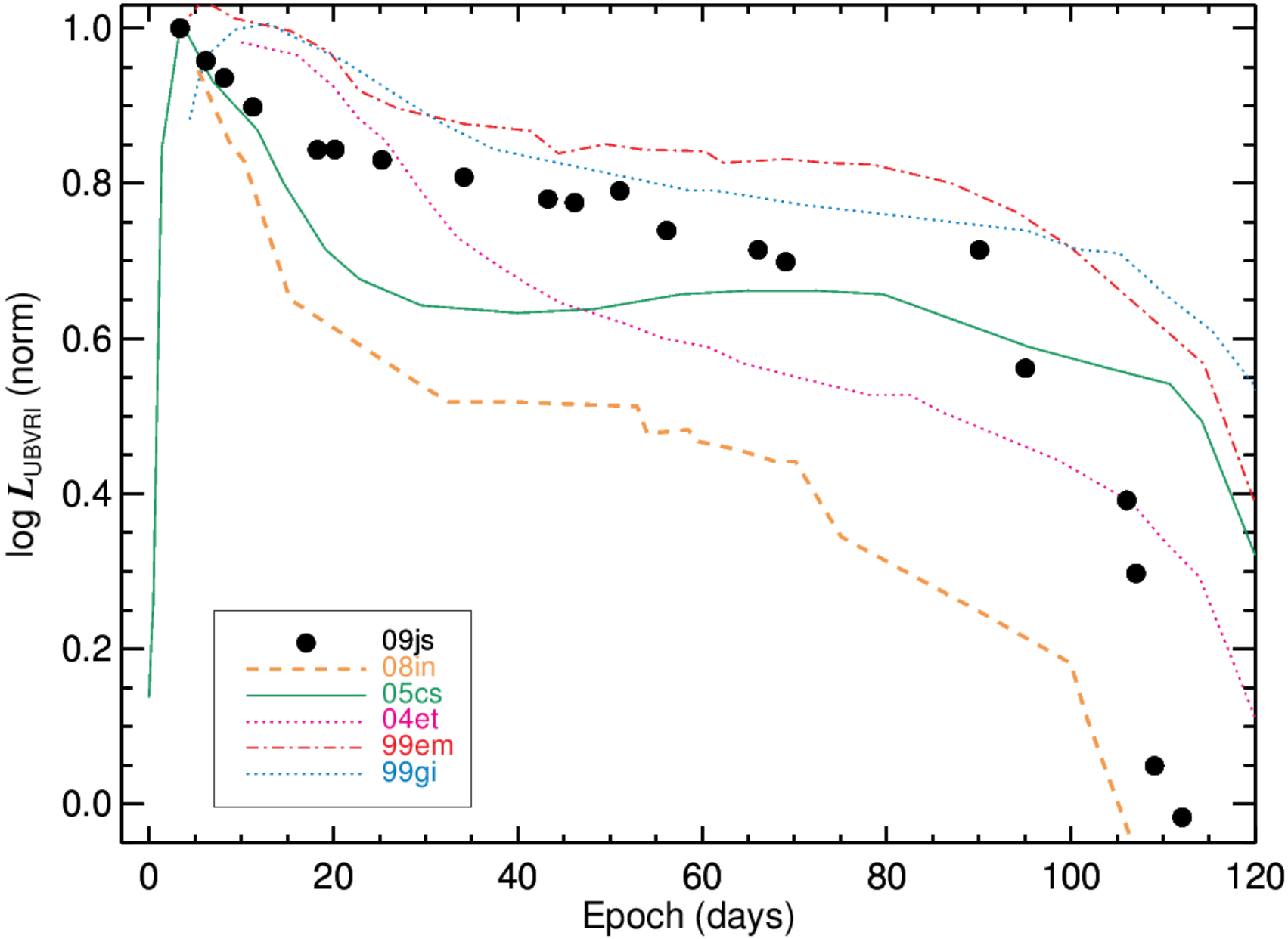
$M_{ej}<20\ M_{sun}$

(Roy +11)





SN 2009js : less adiabatic cooling



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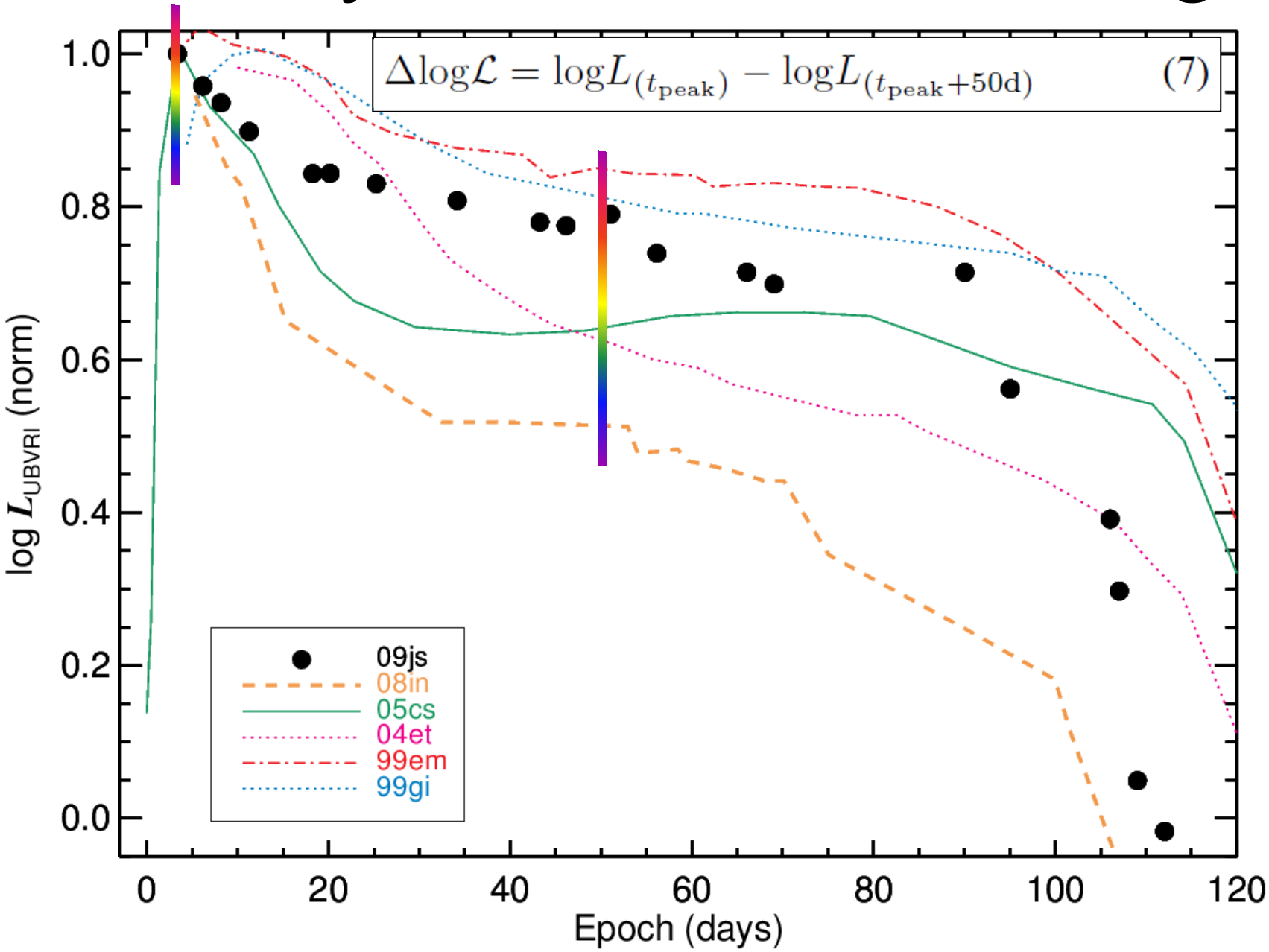
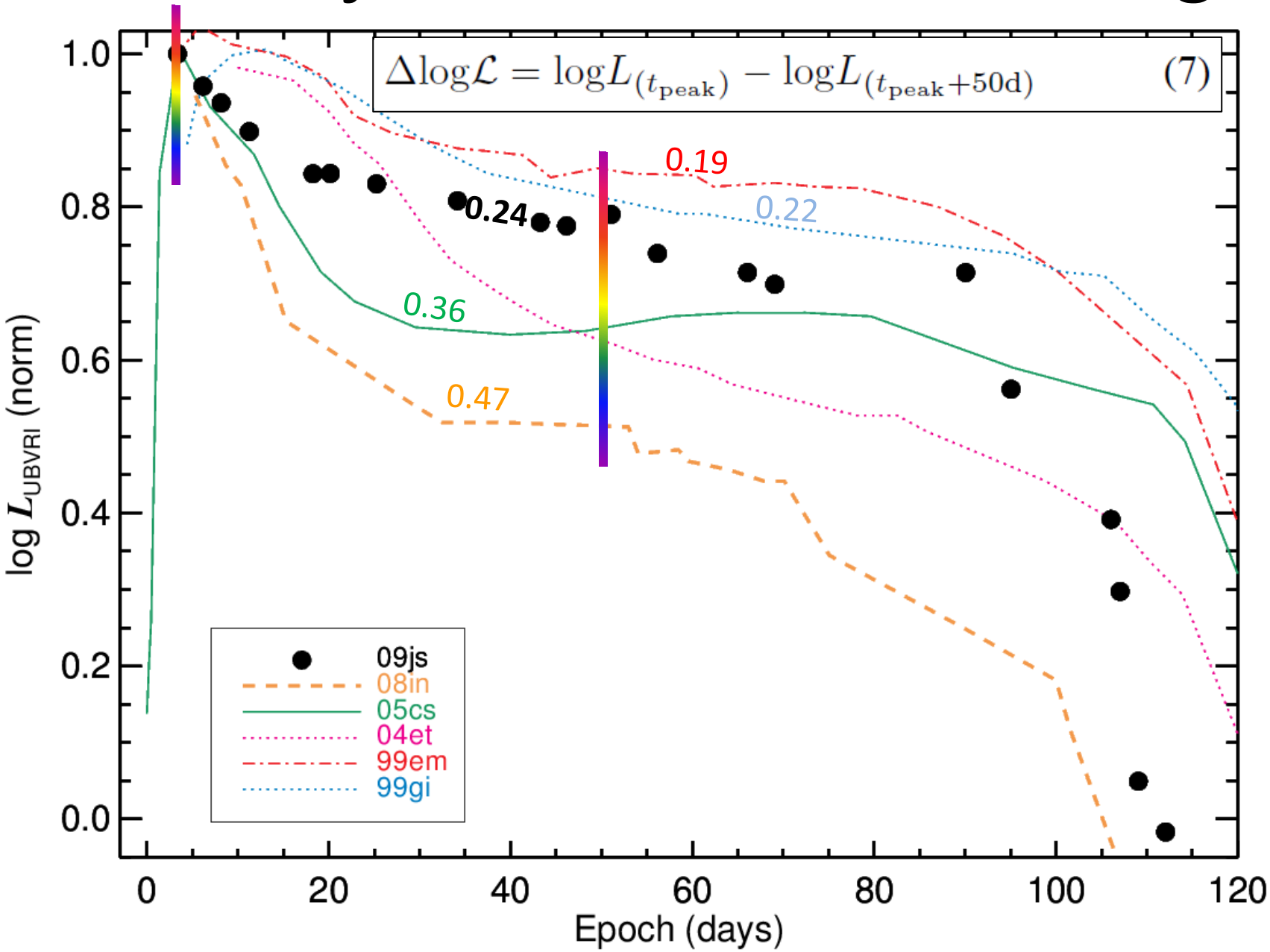
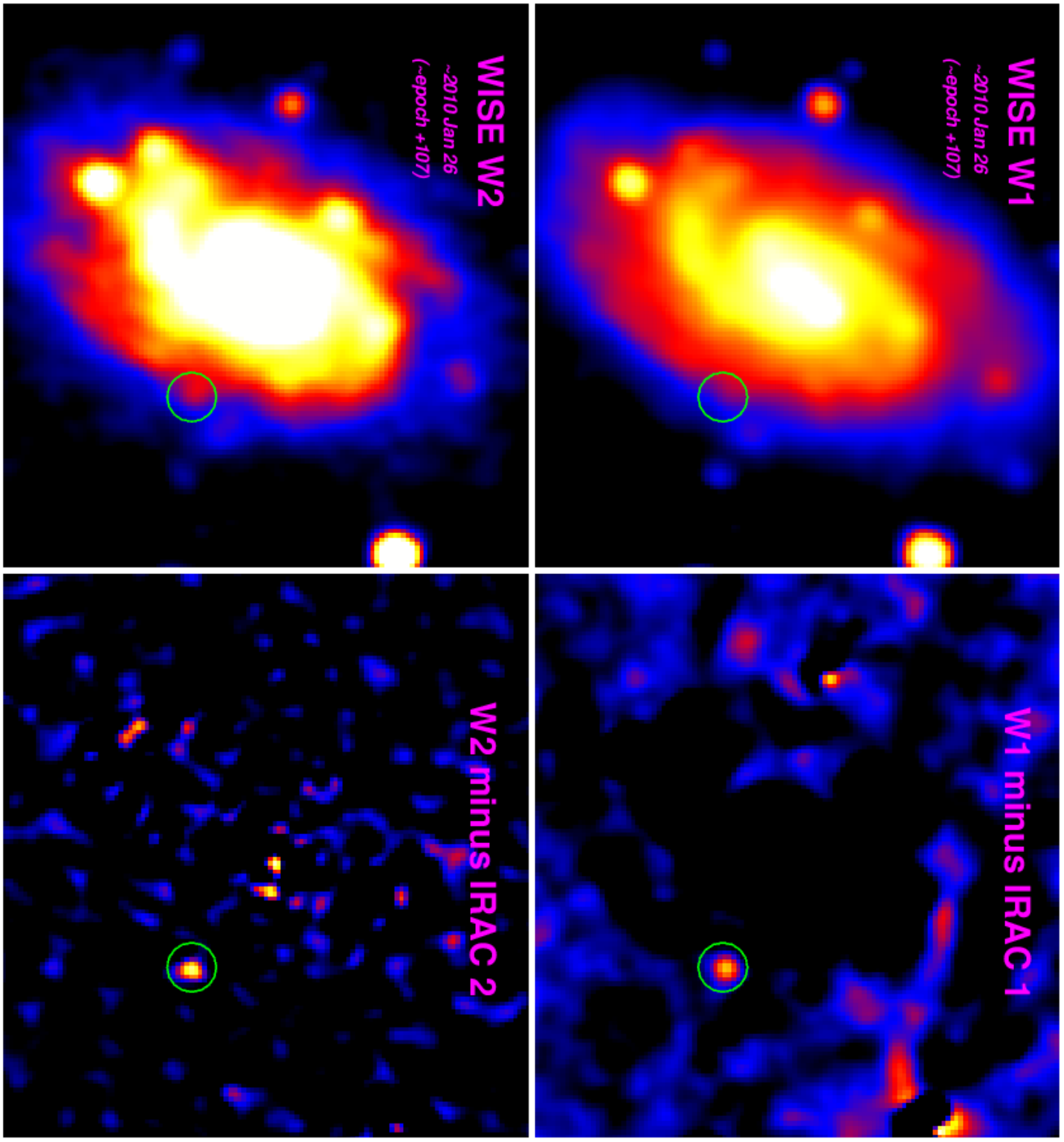


SN 2009js : less adiabatic cooling

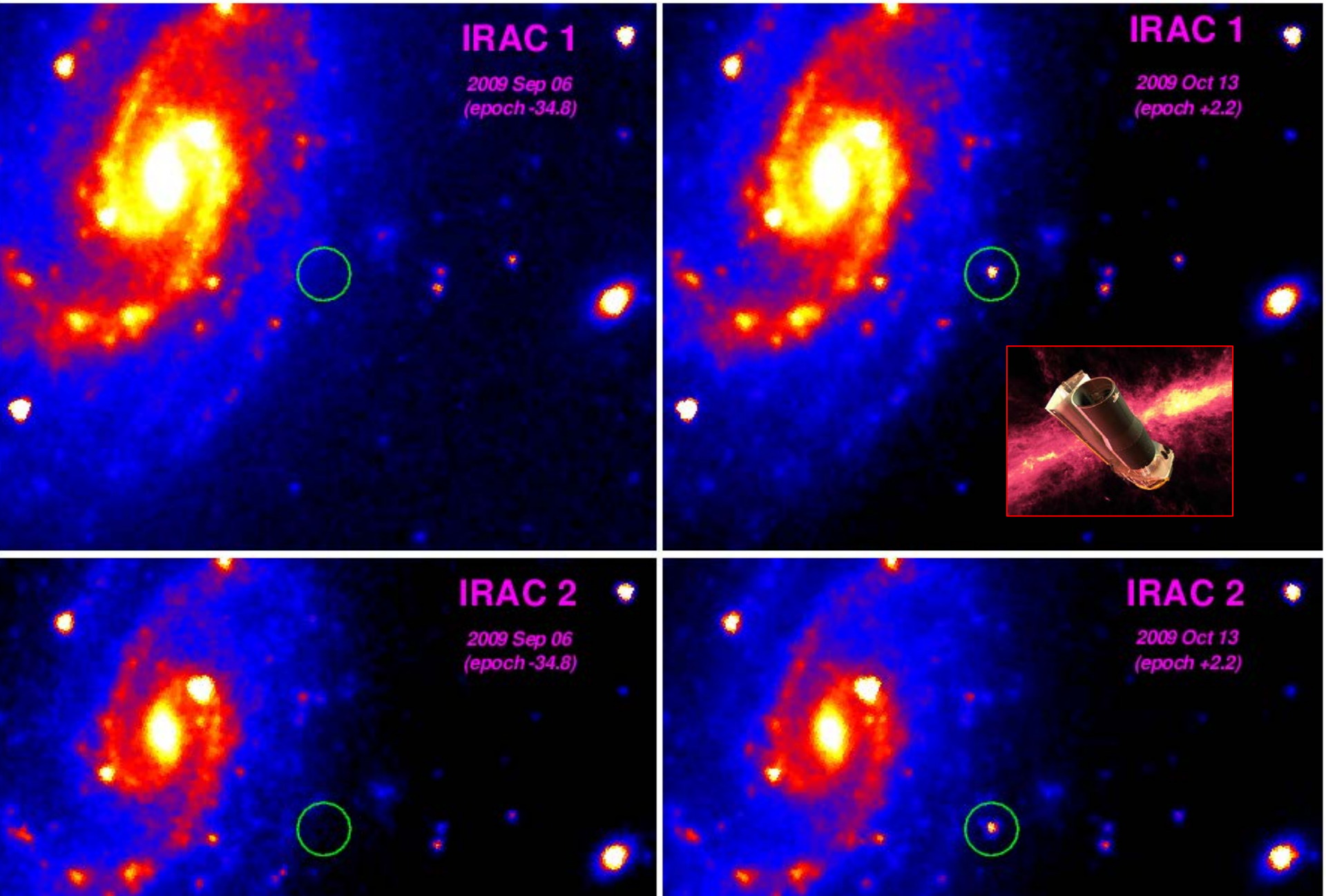




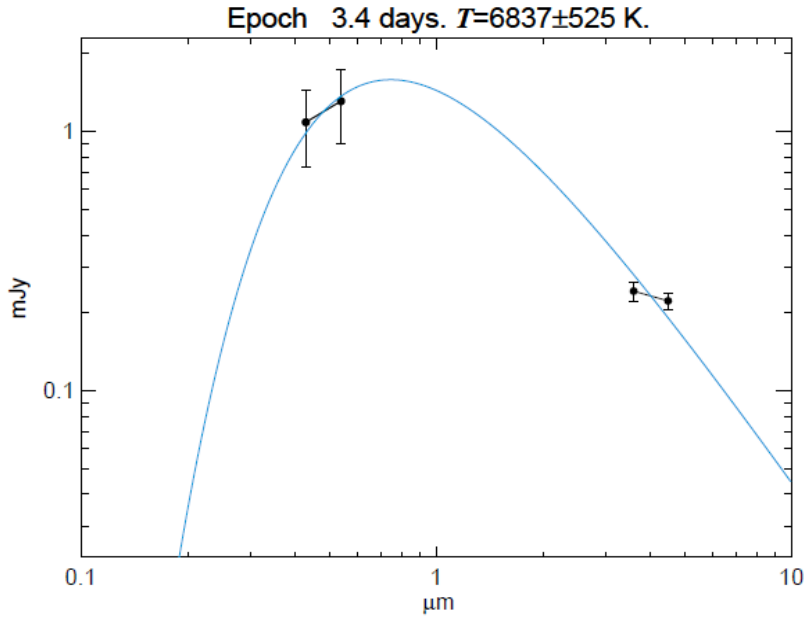
Mid-infrared

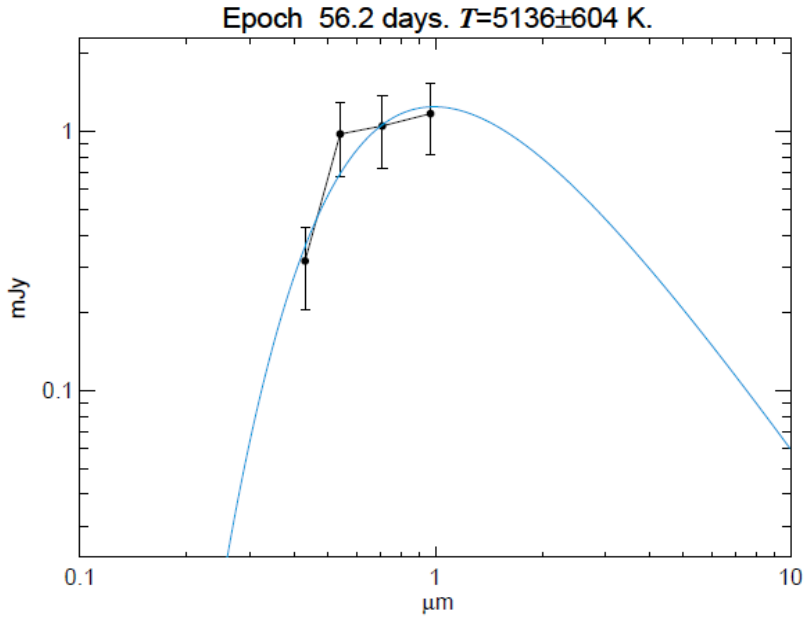
SN 2009js : serendipitous catch by-eye

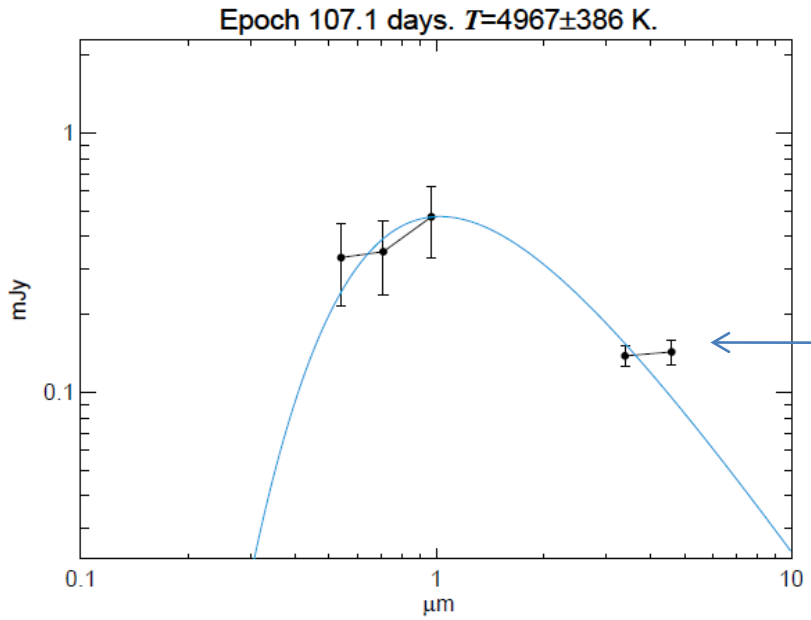
Serendipitous catch at early epoch



SN 2009js : first sublum. SN in mid-IR

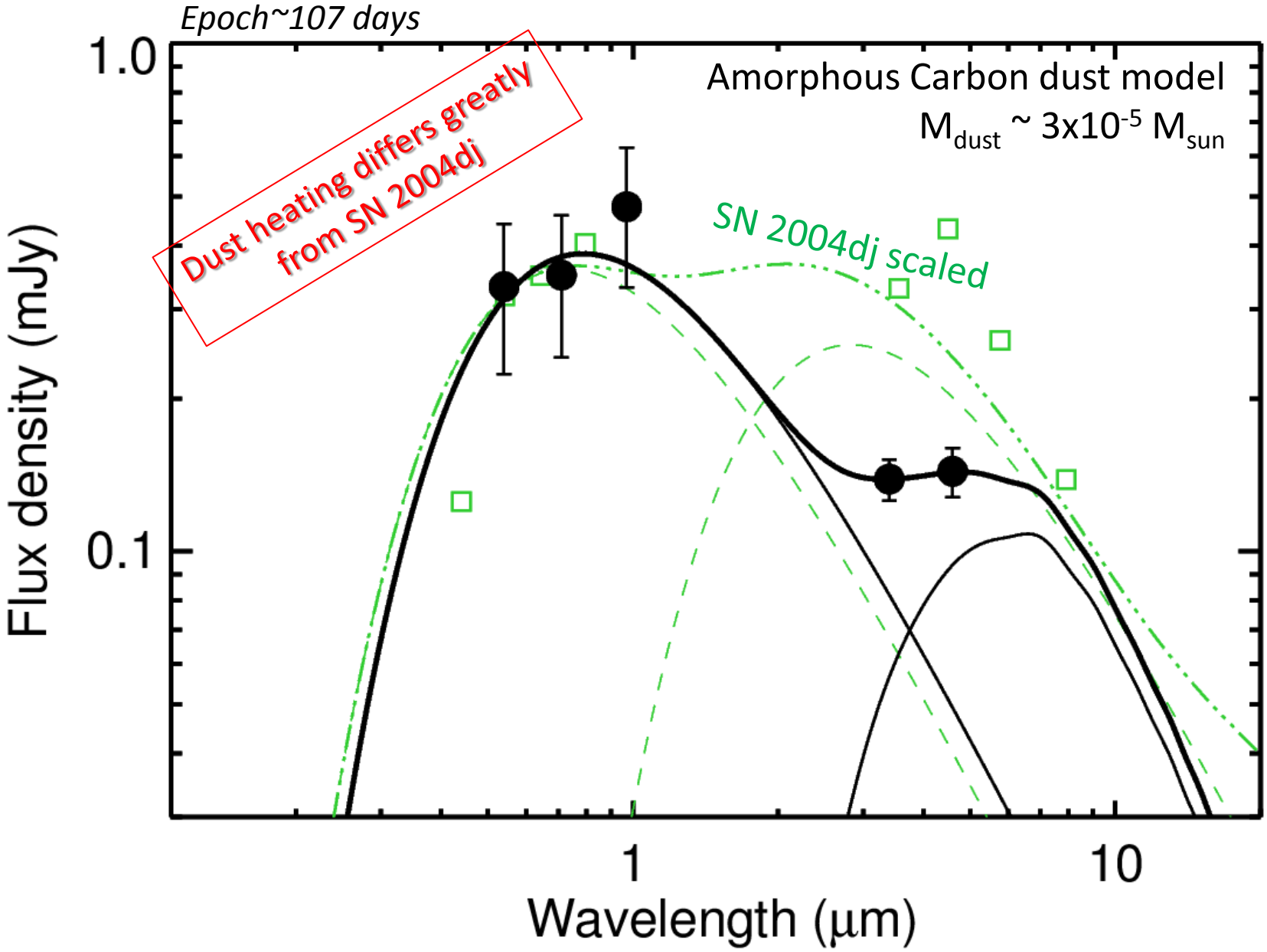






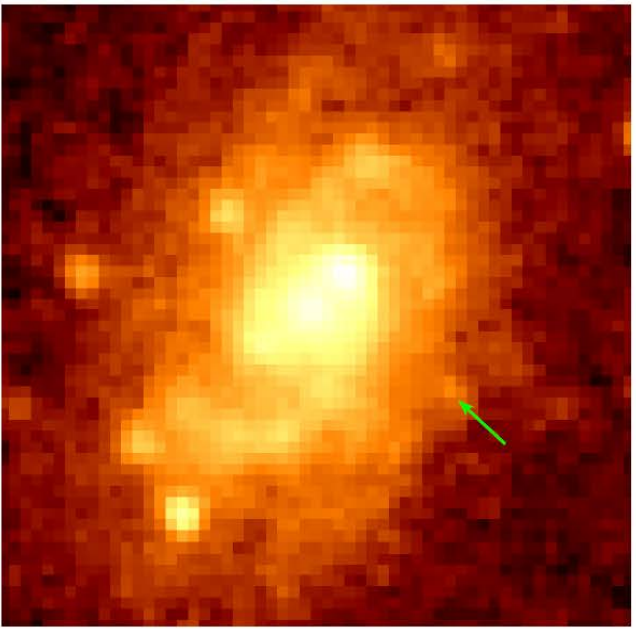
Apparent significant excess at 4.5 μm

If there is dust…

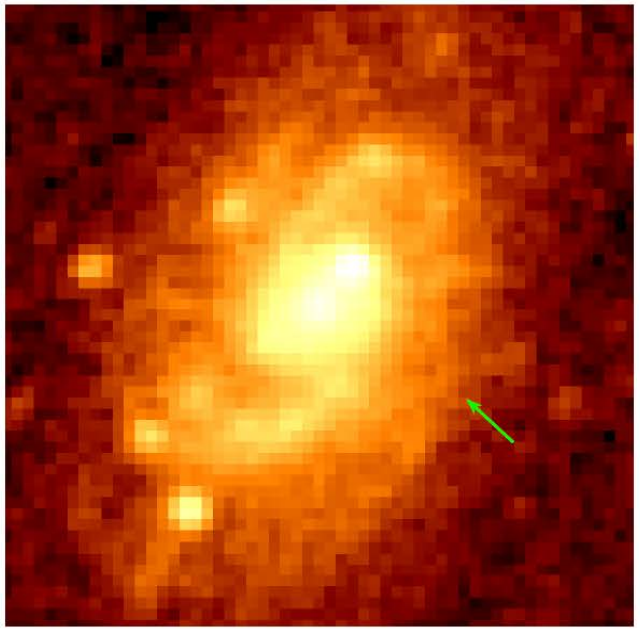


WISE epochs 6 months apart

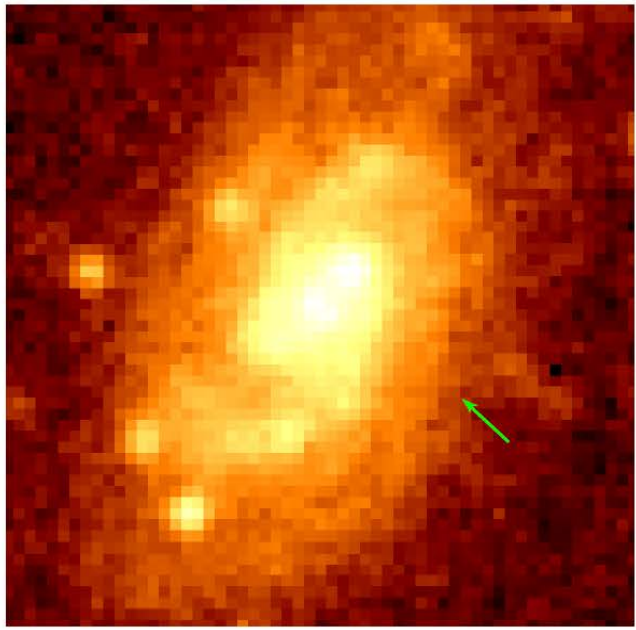
4.6 μm



+107 days



+295 days



+470 days

Summary

(Gandhi et al. 2012 submitted)

- Type IIP

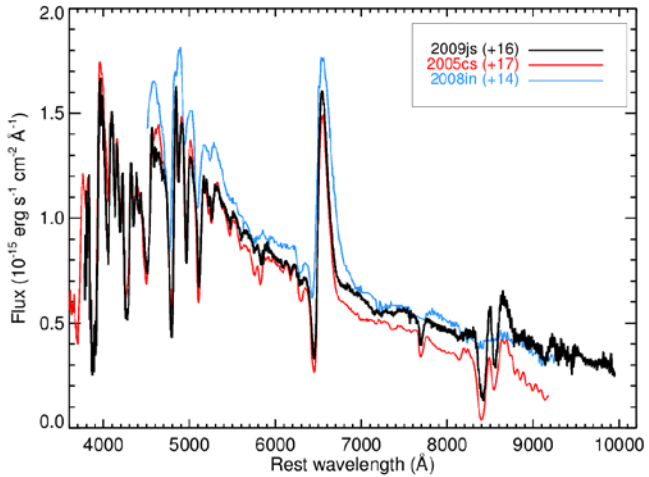
Shares characteristics with both subluminous and intermediate luminosity events

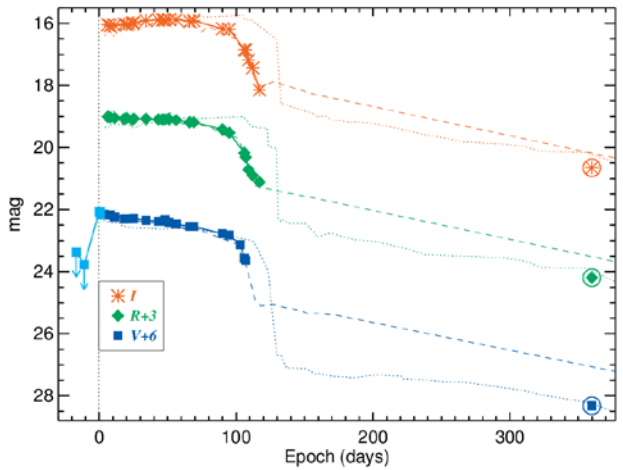
SN 2005cs

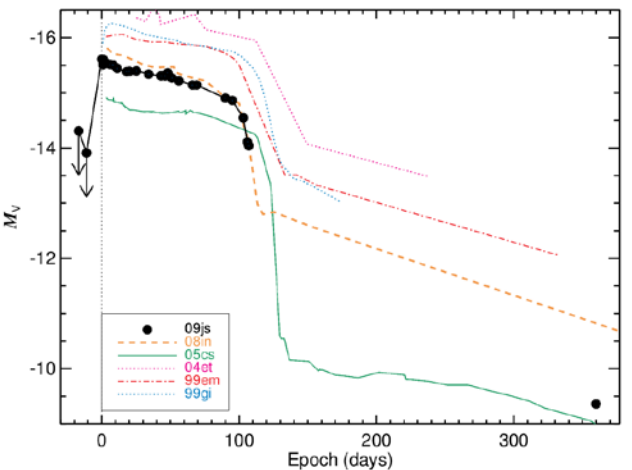
1) Spectra very similar
2) Long-term evolution similar

SN 2008in

1) Plateau length matched
2) Plateau luminosity closely matched







What next?

- There must be more SNe serendipitously detected by WISE (problem is PSF).

- Only ~10 subluminous events studied so far. None in mid-IR other than SN 2009js (SN2005cs is undetected, Szalai+12)

- Do subluminous SNe produce less dust? Bridge between normal SNe and AGB stars?

以上。
ありがとうございました。

END.

ありがとうございました。

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Ivo Saviane
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Masaomi Tanaka
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Similarity to SN 2008in