New clues about the progenitors of Type Ia Supernovae

Santiago González-Gaitán, Francisco Förster Burón, Joseph Anderson, Sebastián Marchi, Claudia Gutiérrez, Regis Cartier, Mario Hamuy, Giuliano Pignata

CSP, Pasadena, 28th October 2012

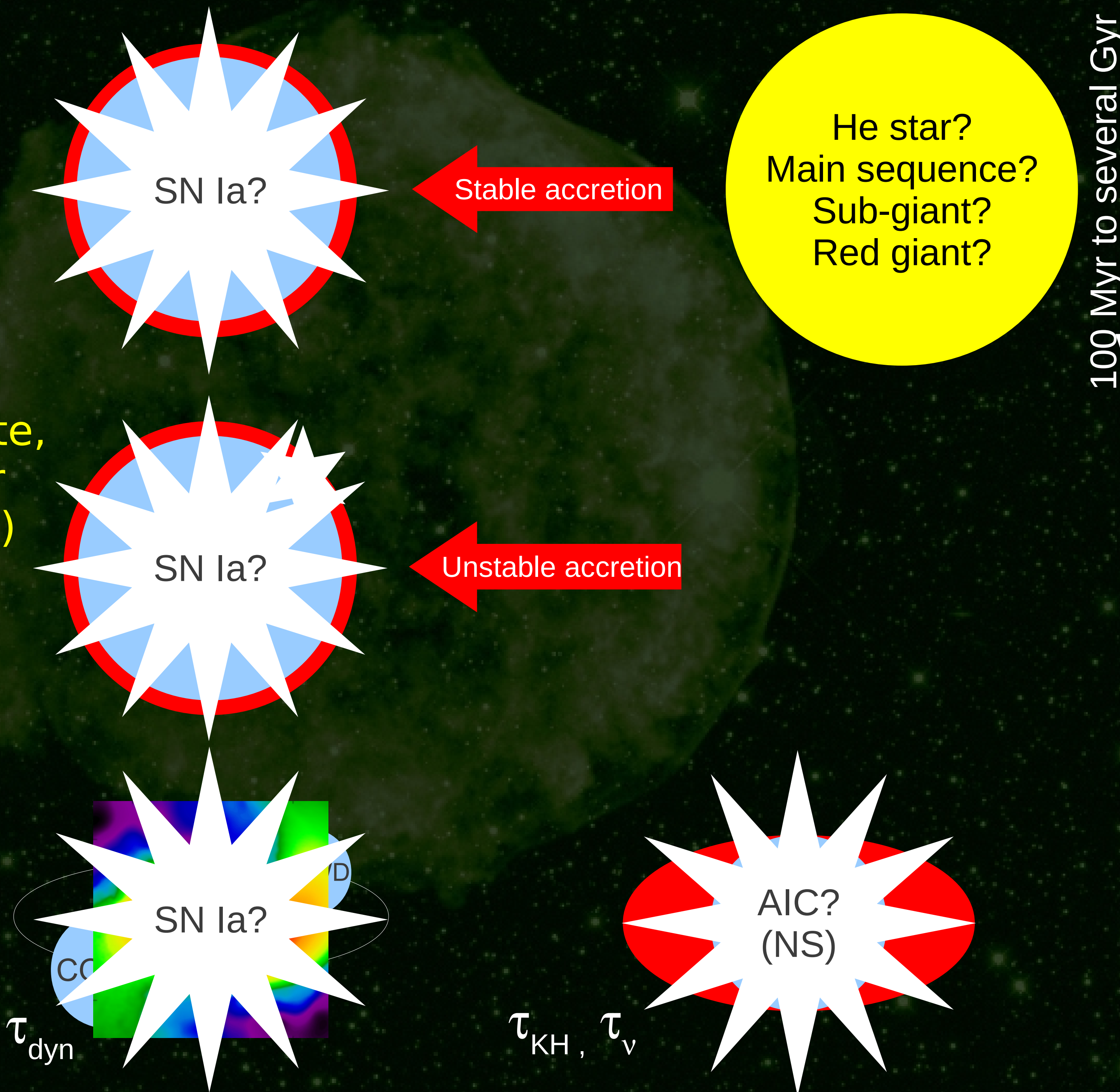
Type Ia Supernova progenitors candidates

1. Single degenerate, Chandrasekhar mass (SD – M_{Ch})
   M ⩽ MCh

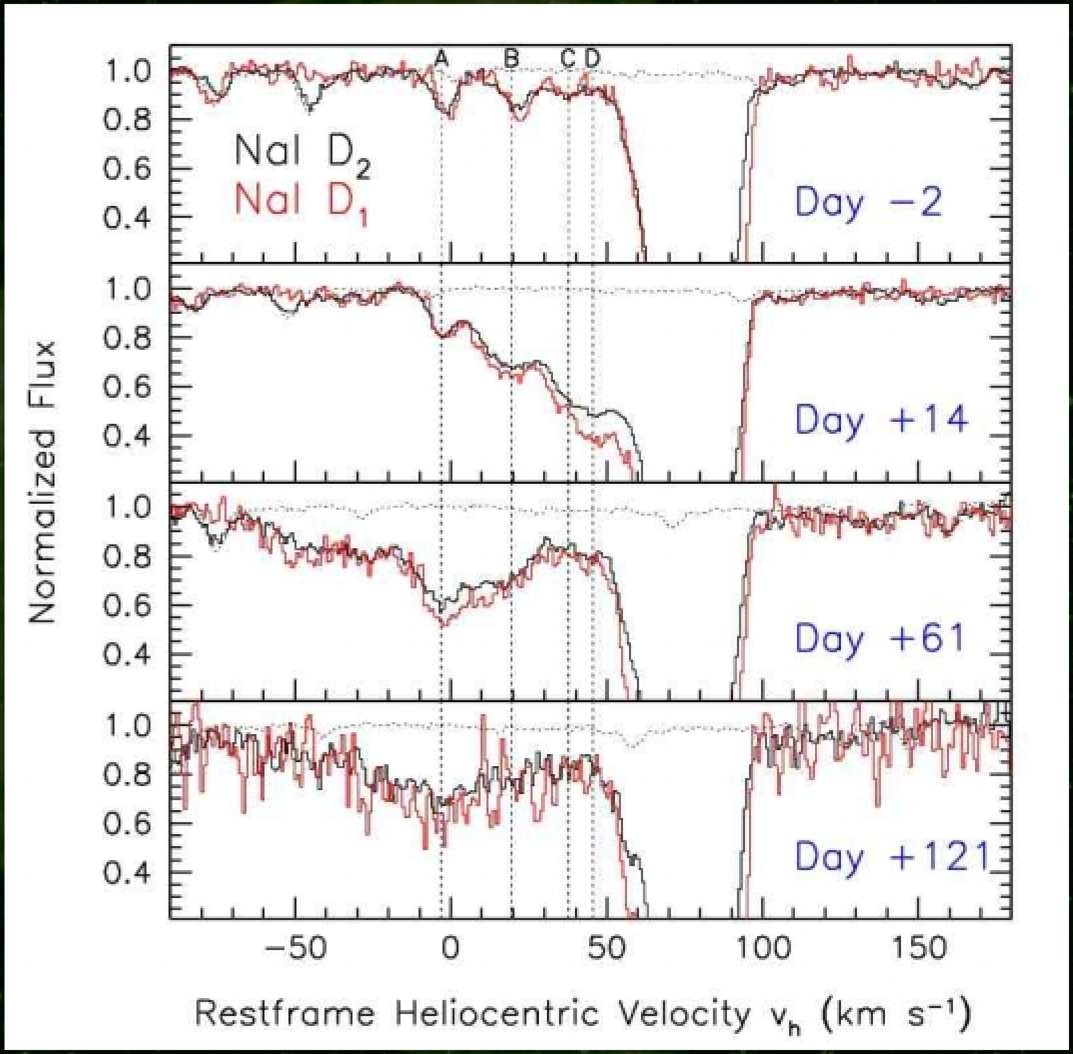
2. Single degenerate, sub-Chandrasekhar mass (SD – sub M_{Ch})

   M < MCh

3. Double degenerate merger (violent or slow DD mergers)

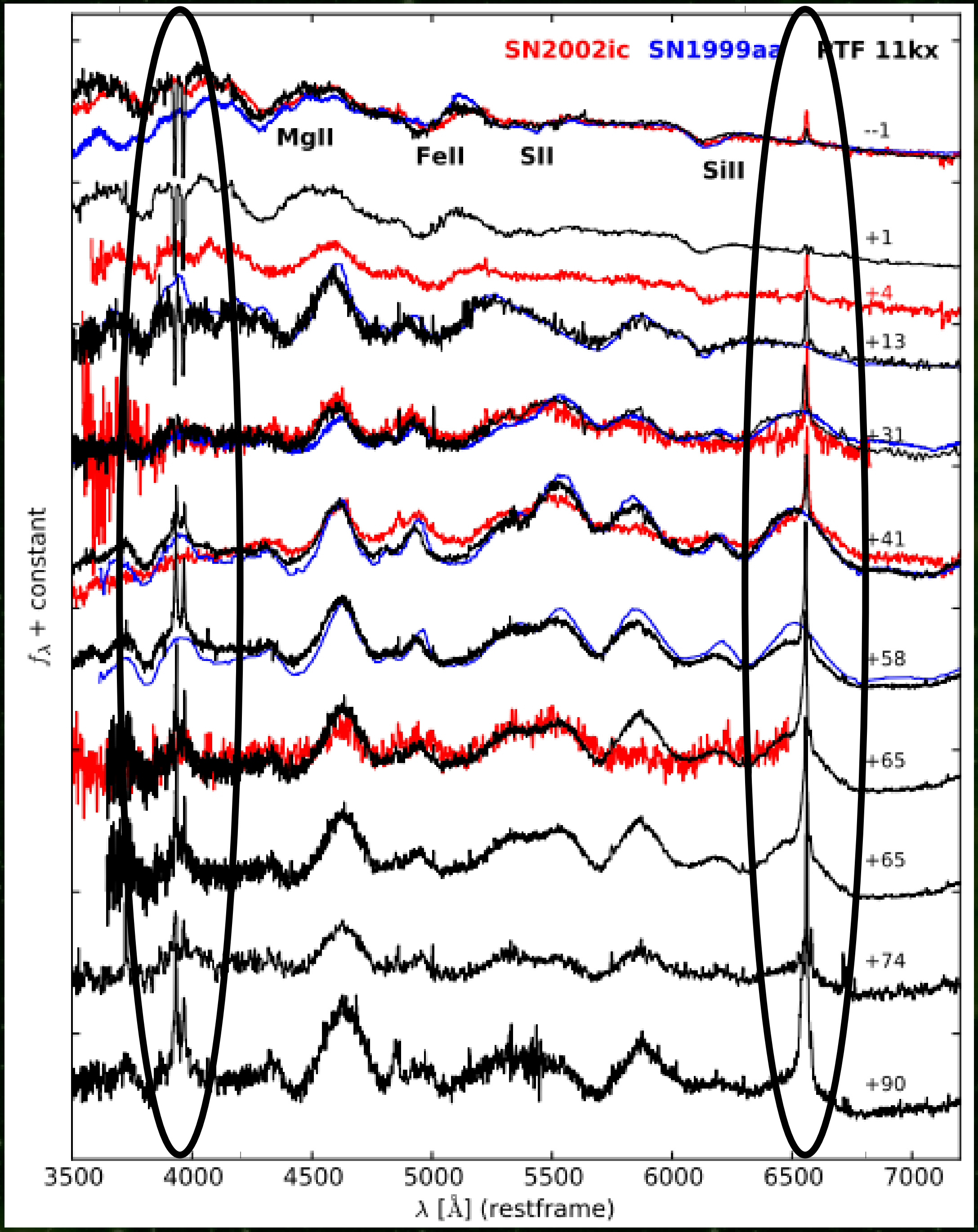


1. Evidence of CSM in SNe Ia: Time-variable narrow absorption lines



Time varying narrow absorption lines seen in SN2006X (Patat et al. 2007), SN 2007le (Simon et al. 2009) and SN1999cl (Blondin et al. 2009) argued to be evidence for material near SN Ia (CSM). Observed recombination scales suggests high electron densities, easier to obtain in novae shells.

2. Evidence of CSM in SNe Ia: PTF 2011kx

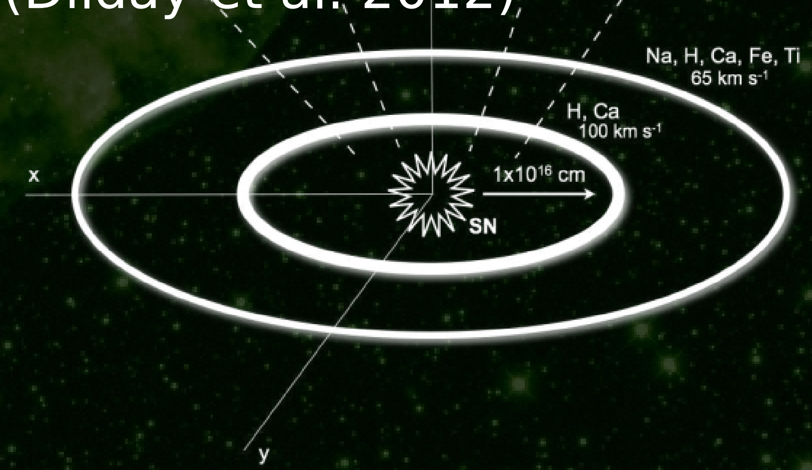


Narrow Ca H & K absorption lines detected, first in absorption and then in emission.

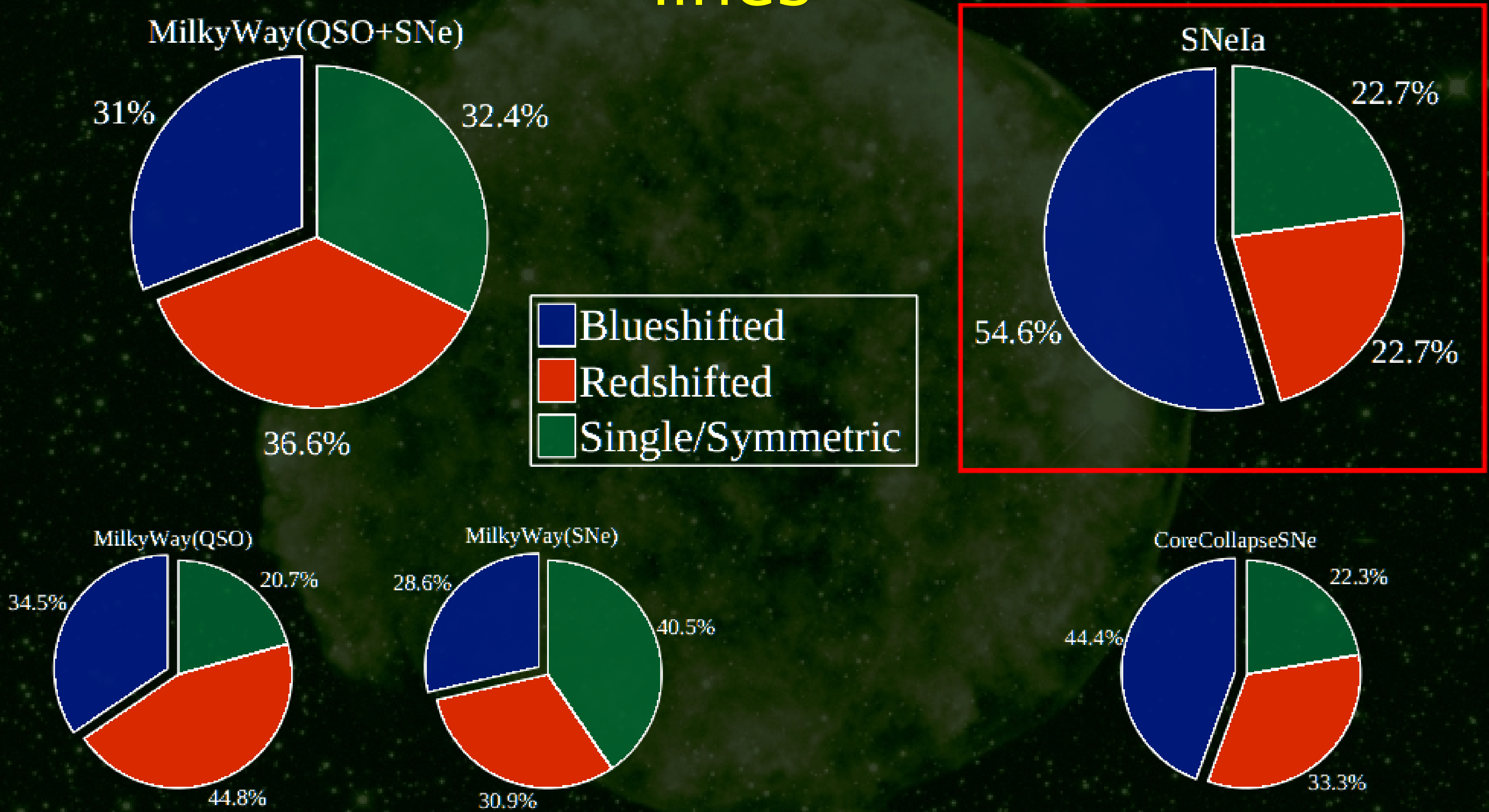
Hα emission detected at all times (shocked material)

Variable narrow absorption Na I D1 & D2 lines

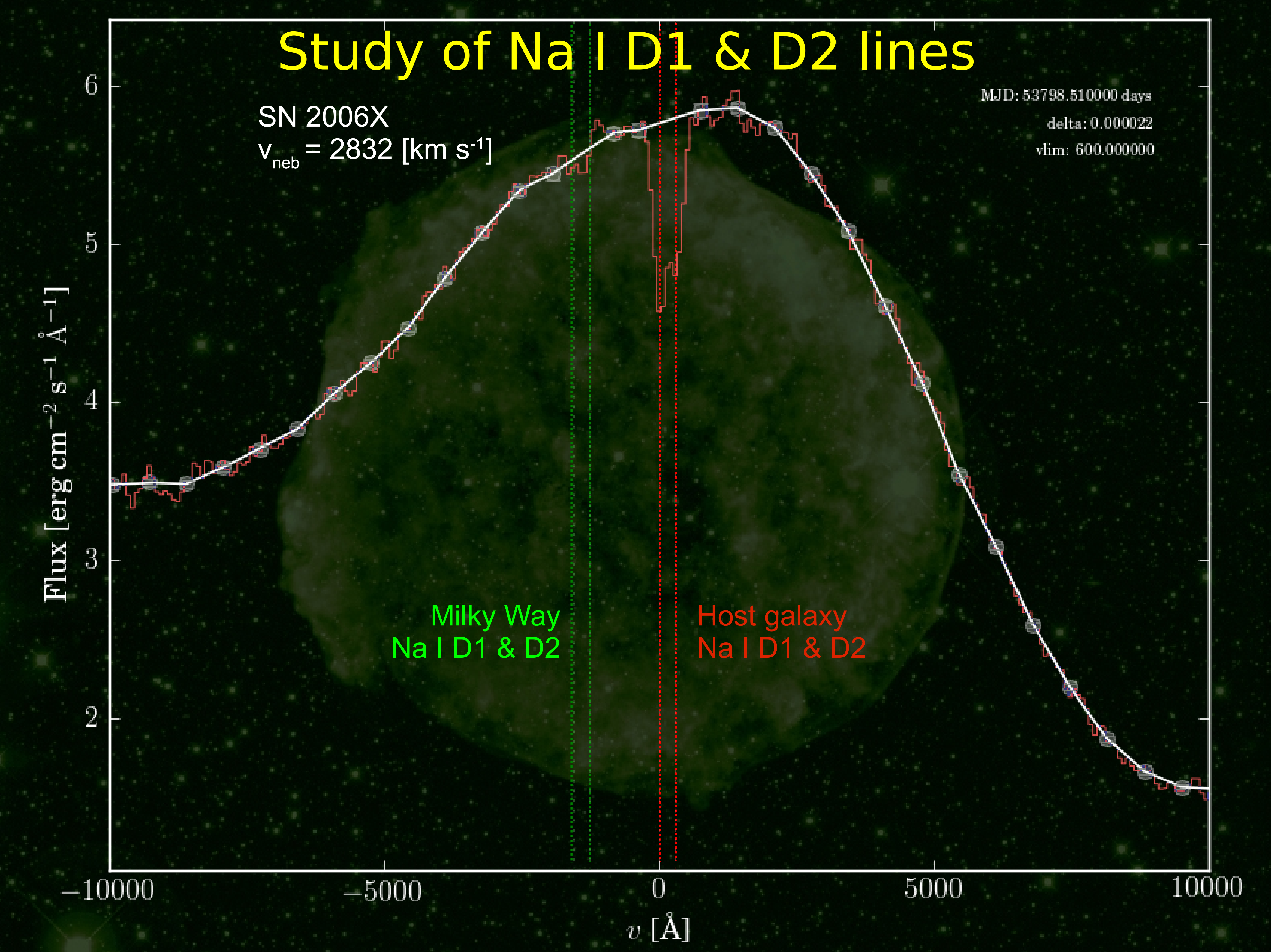
Evidence for narrow novae shells within a RG wind? (Dilday et al. 2012)

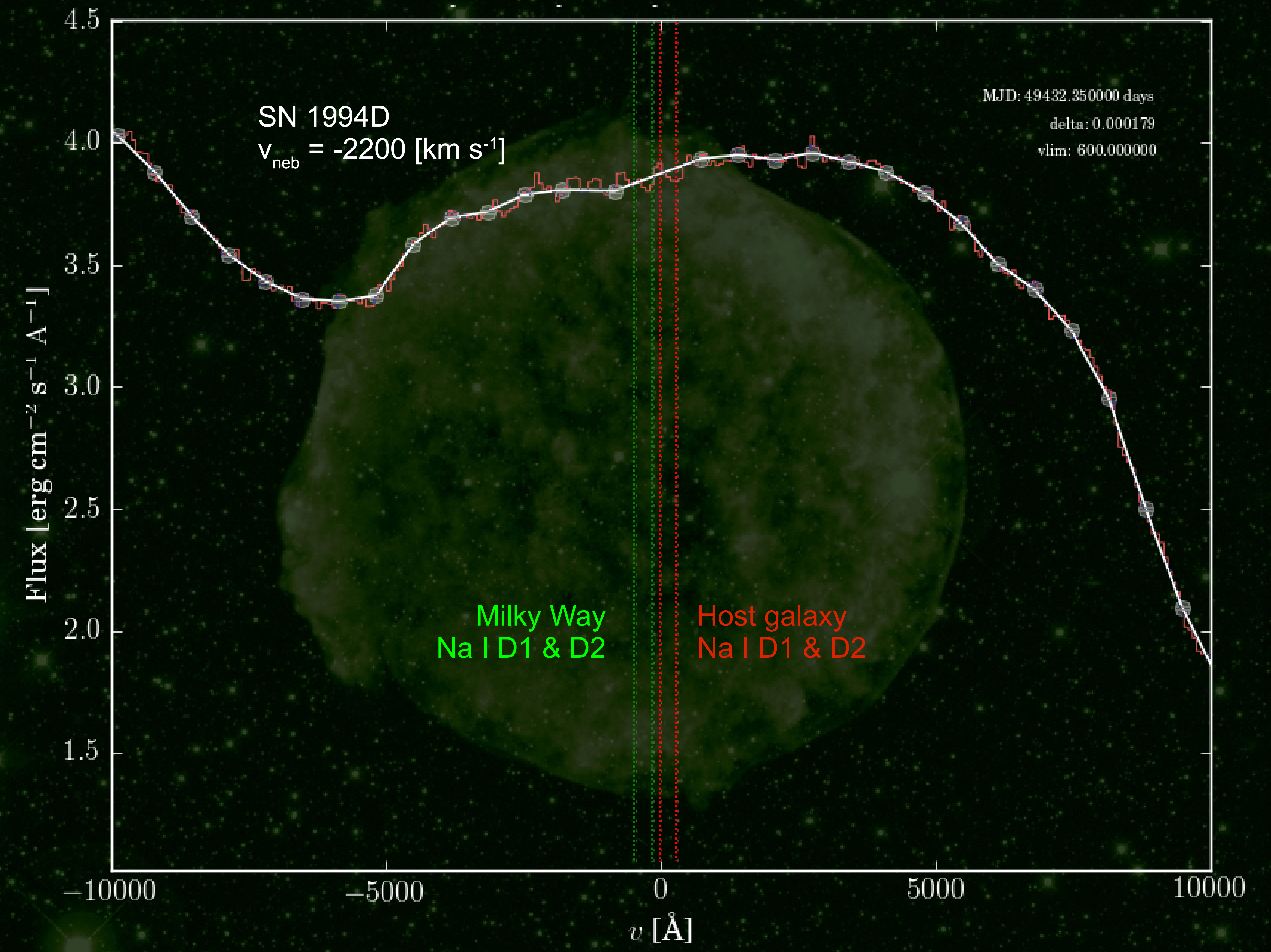


3. Evidence of CSM in SNe Ia: Excess of blueshifted narrow absorption lines



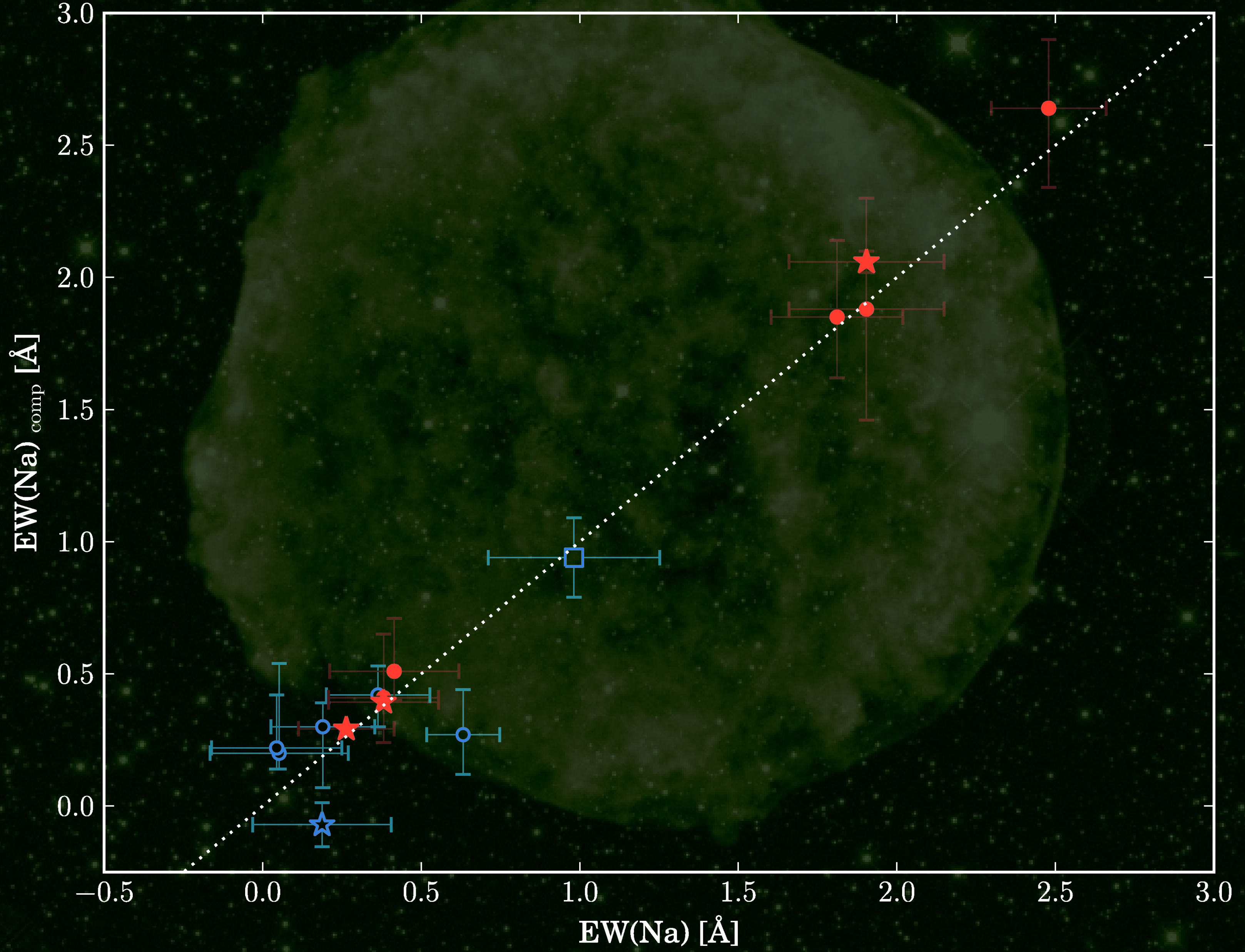
Significant excess of blueshifted Na I absorption only in SNe Ia, typical velocities of ~100 km s^{-1} (Sternberg et al. 2011)


Study of Na I D1 & D2 lines
SN 2006X
v_neb = 2832 [km s^-1]
MJD: 53798.510000 days
delta: 0.000022
vlim: 600.000000
Milky Way
Na I D1 & D2
Host galaxy
Na I D1 & D2
Flux [erg cm^-2 s^-1 Å^-1]
v [Å]
6
5
4
3
2
−10000
−5000
0
5000
10000

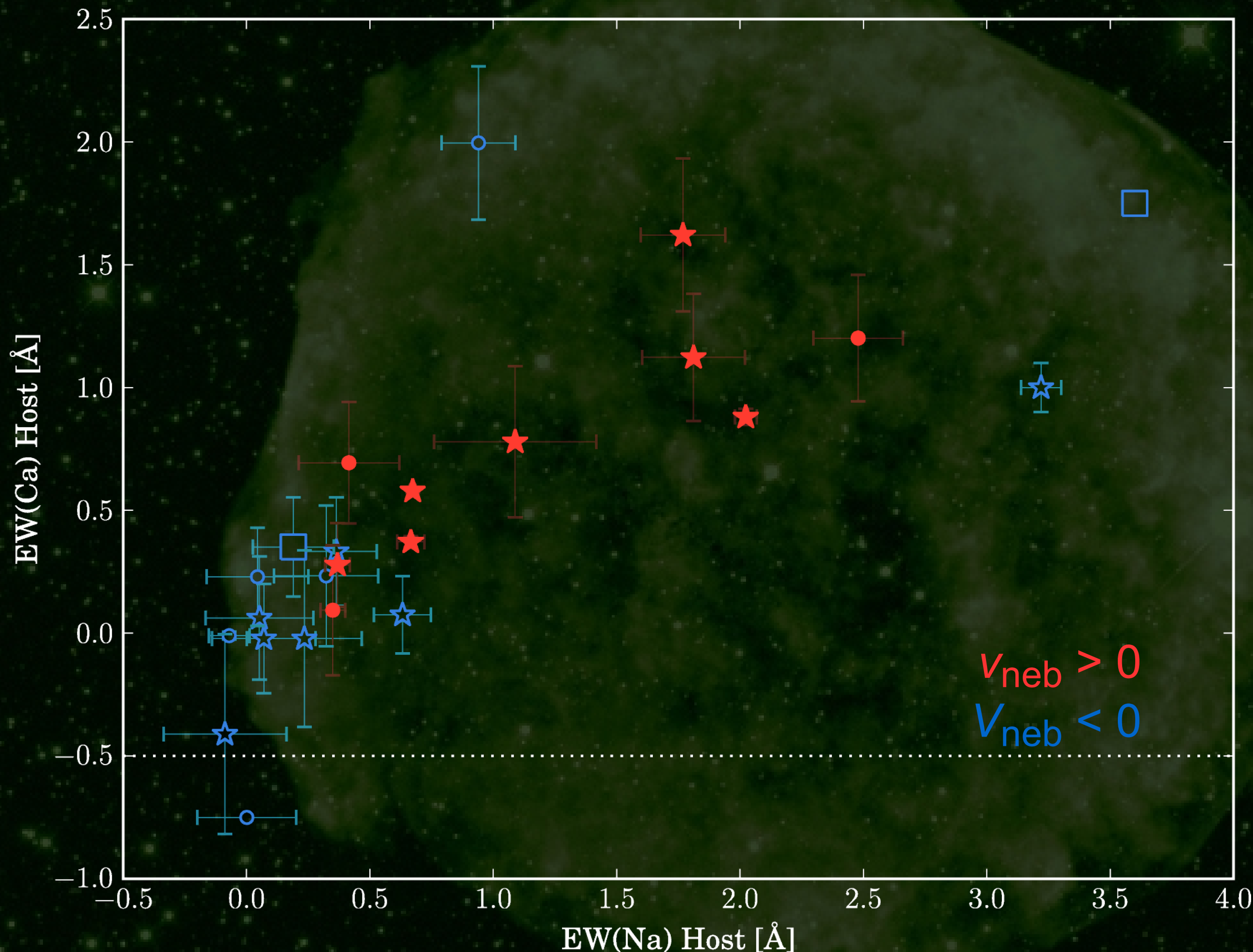


SN 1994D
v_{neb} = -2200 [km s^{-1}]
MJD: 49432.350000 days
delta: 0.000179
vlim: 600.000000
Milky Way
Na I D1 & D2
Host galaxy
Na I D1 & D2
Flux [erg cm^{-2} s^{-1} Å^{-1}]
v [Å]

Comparison with literature and high resolution spectra



4. Evidence for asymmetric CSM around Type Ia SNe



Förster et al. 2012 ApJ Letters

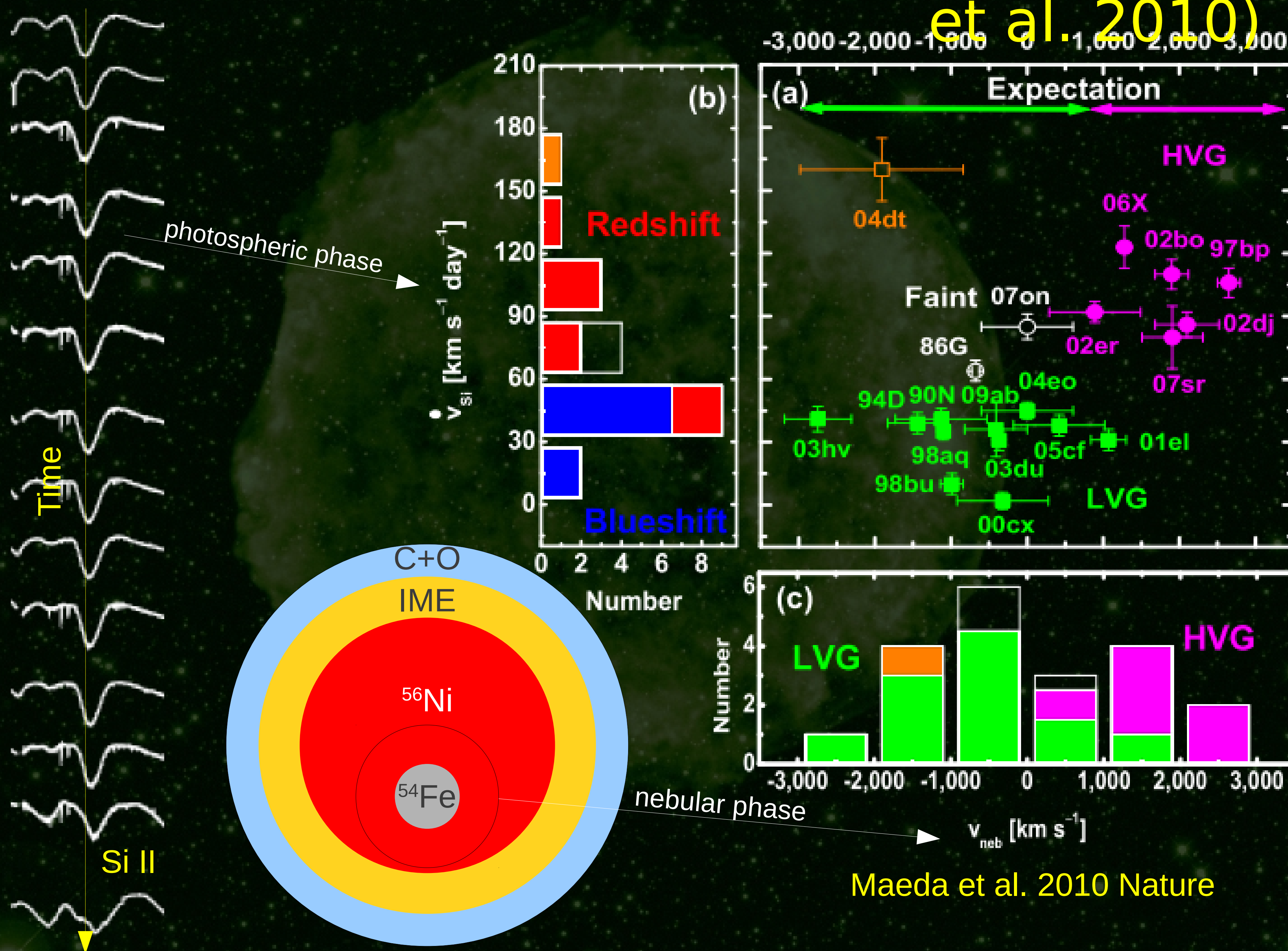
KS test	E(B-V)^{SNooPy}	(B-V)$^{SiFTO}_{B_{max}}$	MW Na	Host Na	MW Ca	Host Ca
p–value	0.006	0.002	0.268	0.013	0.402	0.030

Host galaxy differences?

KS test	Morphological type	Galaxy inclination	NCR_{NUV}	$NCR_{H\alpha}$
p–value	0.133	0.390	0.768	0.944

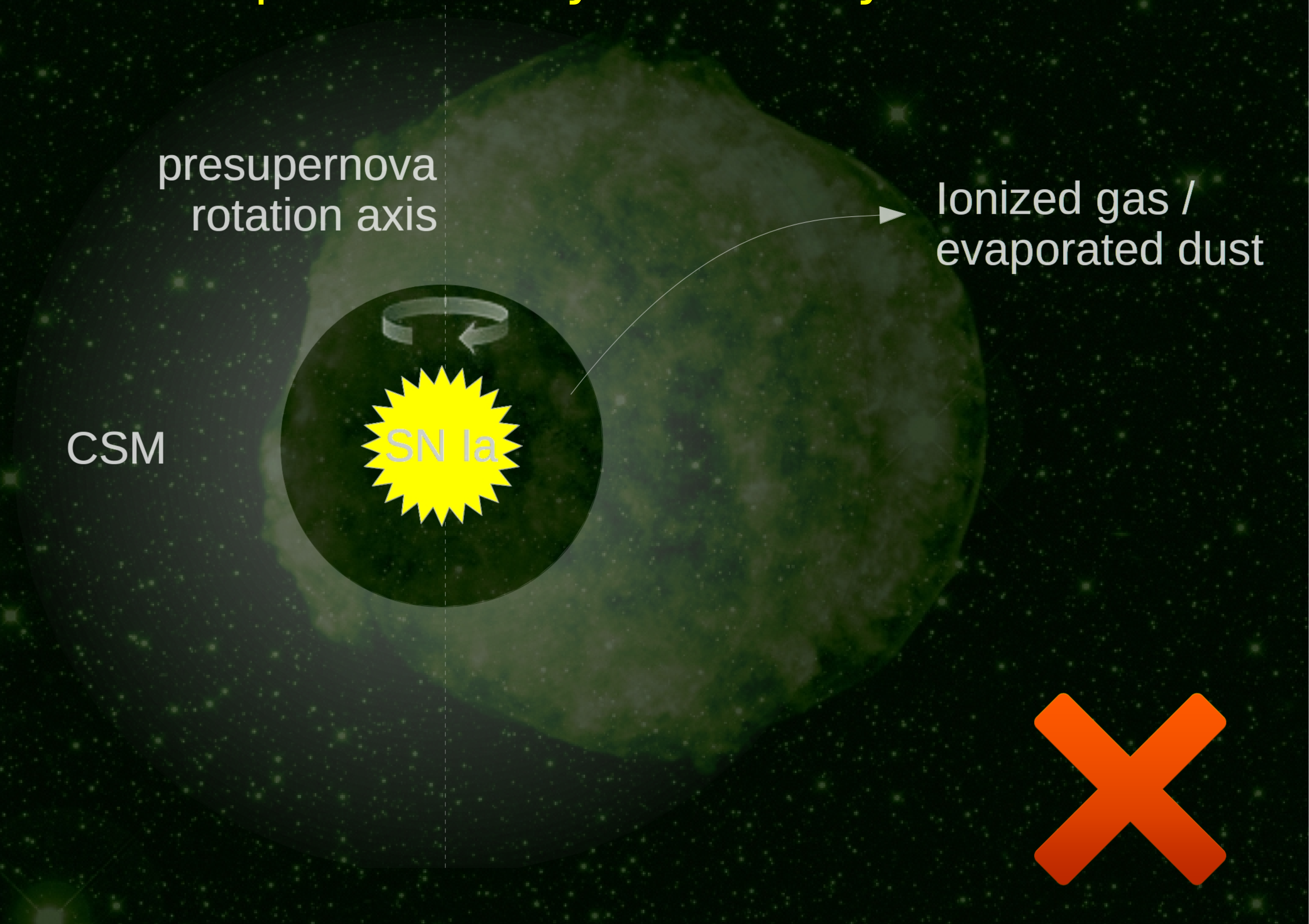
No relation found between nebular velocities and host galaxy properties

Asymmetries in the outer ejecta (Maeda et al. 2010)

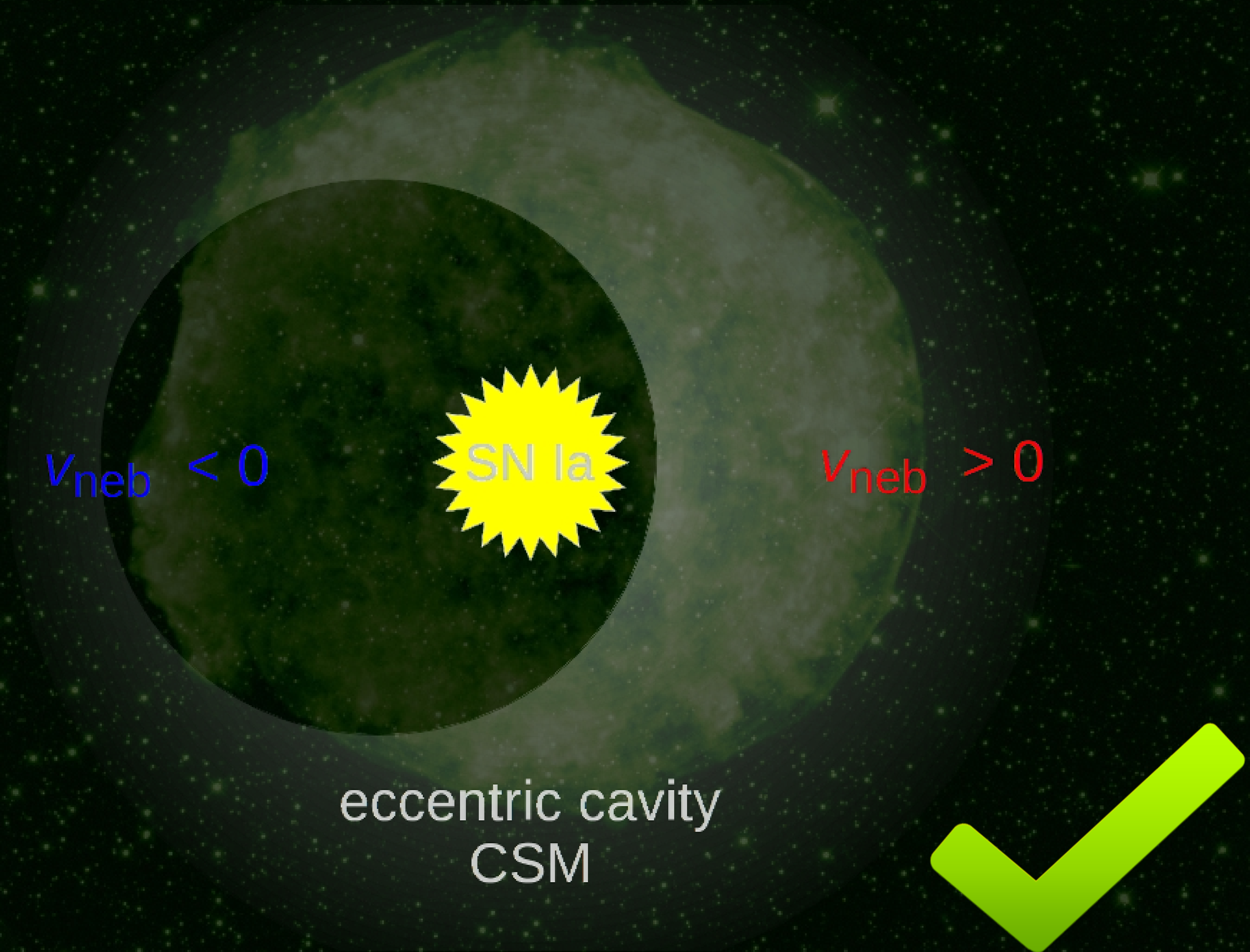


Maeda et al. 2010 Nature

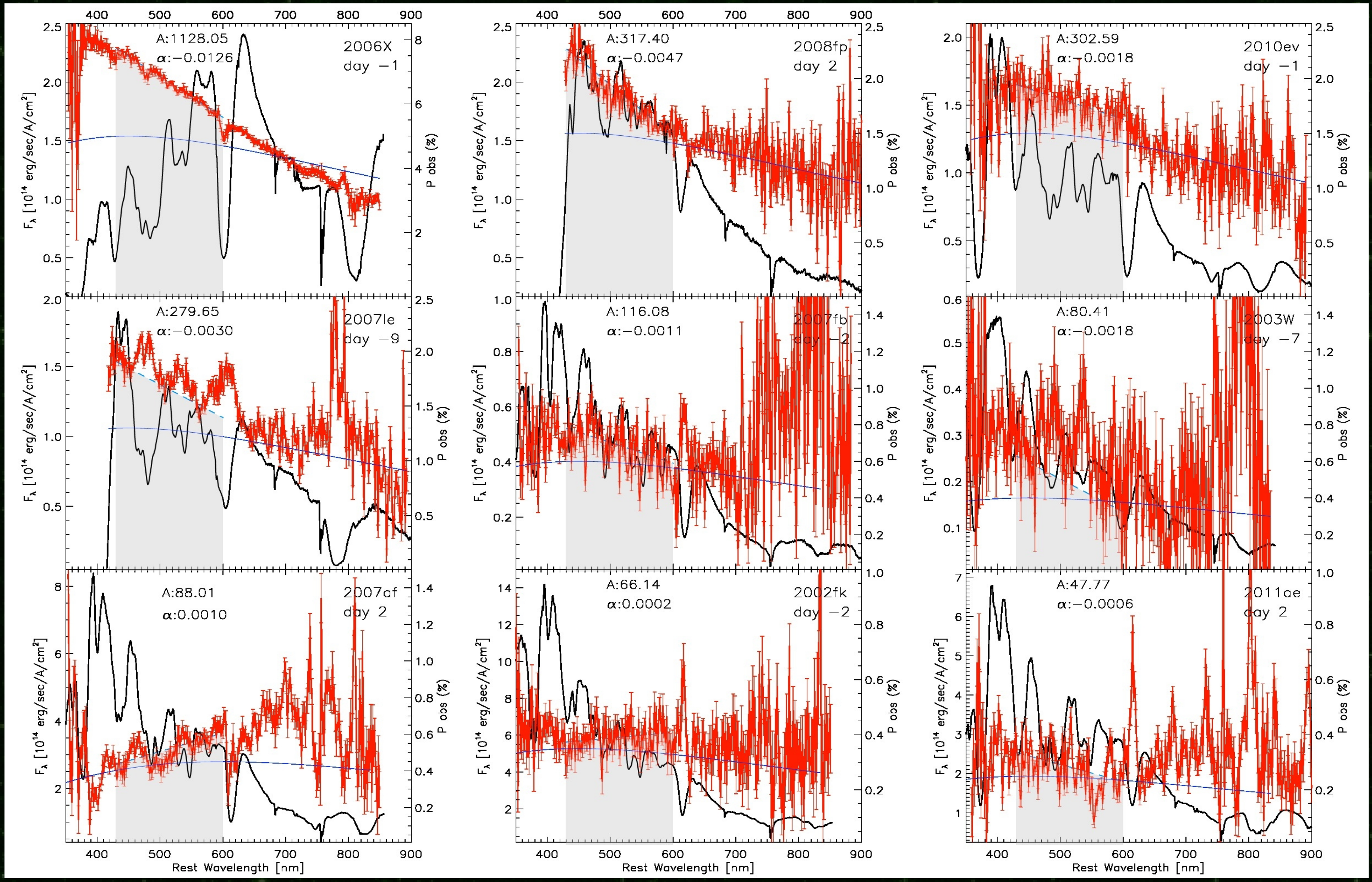
Interpretation: cylindrical symmetries?



Non-cylindrical symmetries?

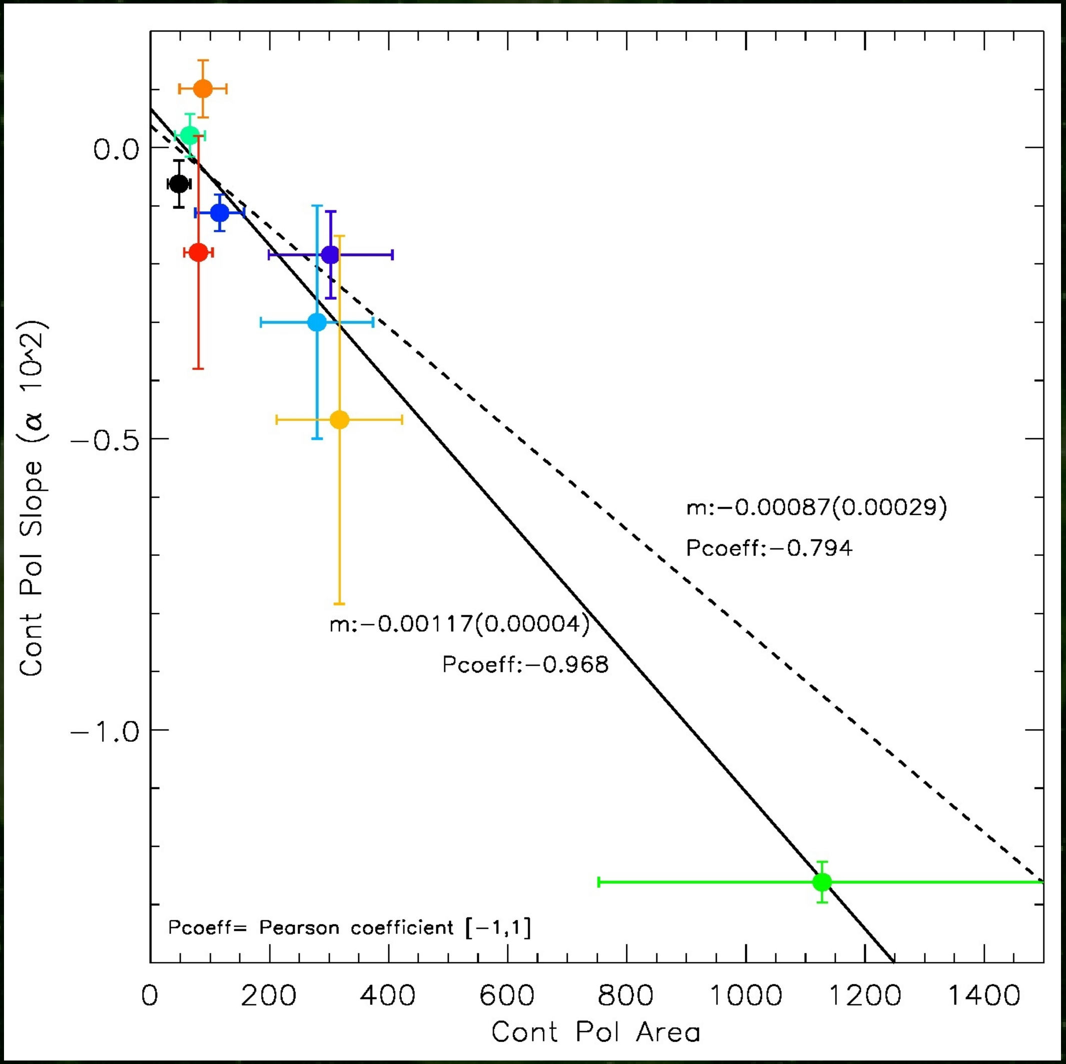


5. Continuum polarization: CSM?



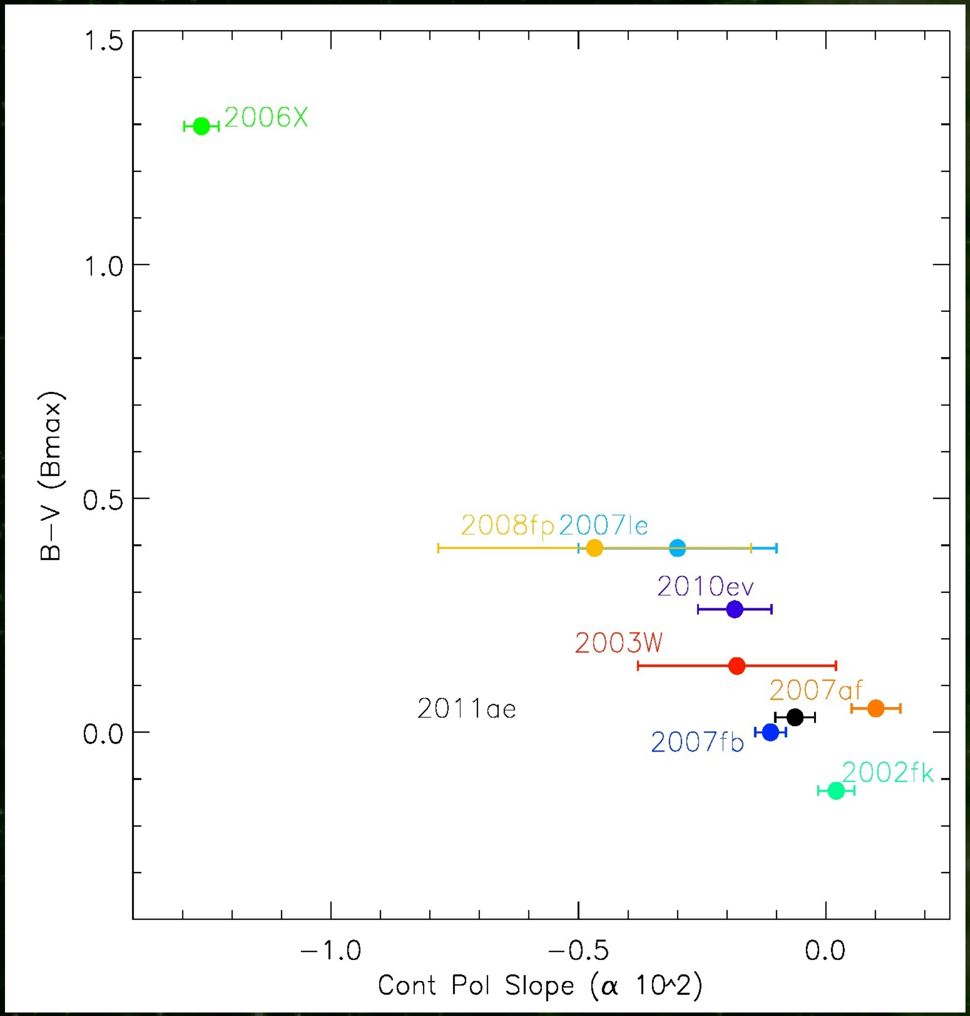
Paula Zelaya et al (in prep)

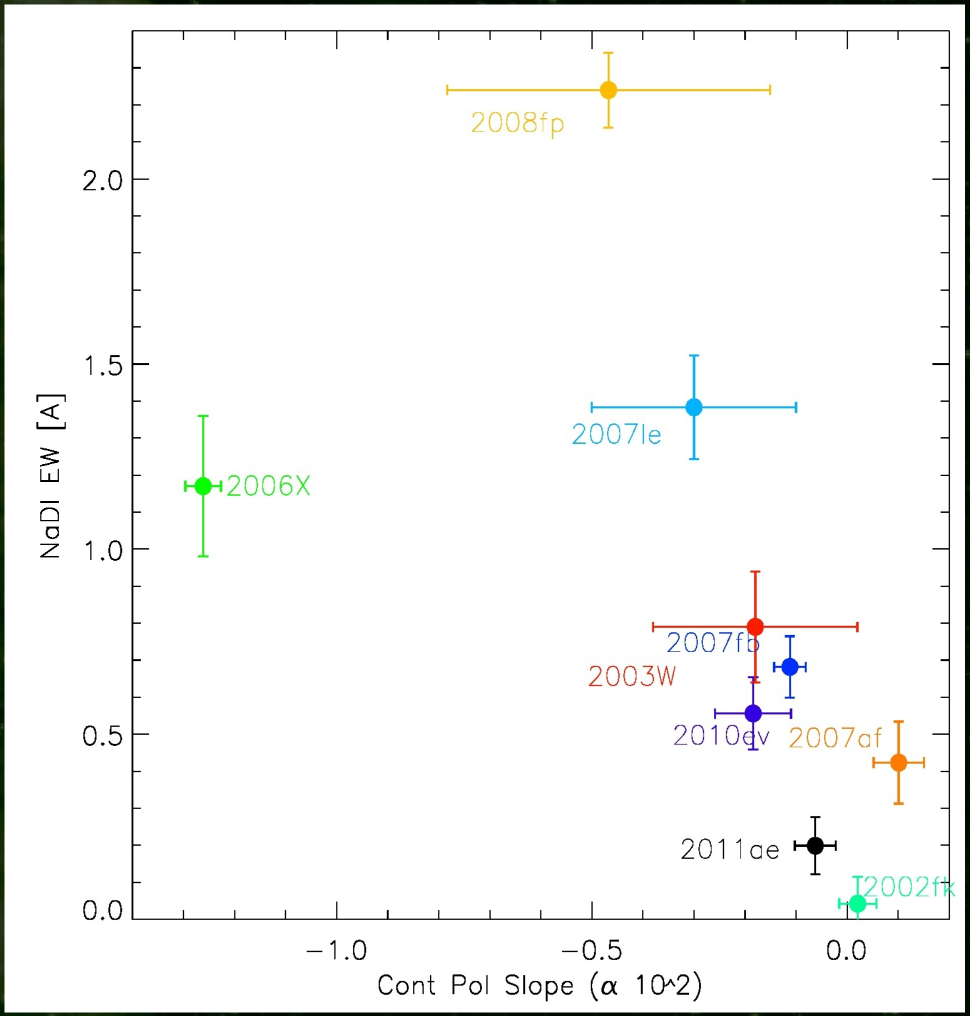
5. Continuum polarization



Paula Zelaya et al (in prep),

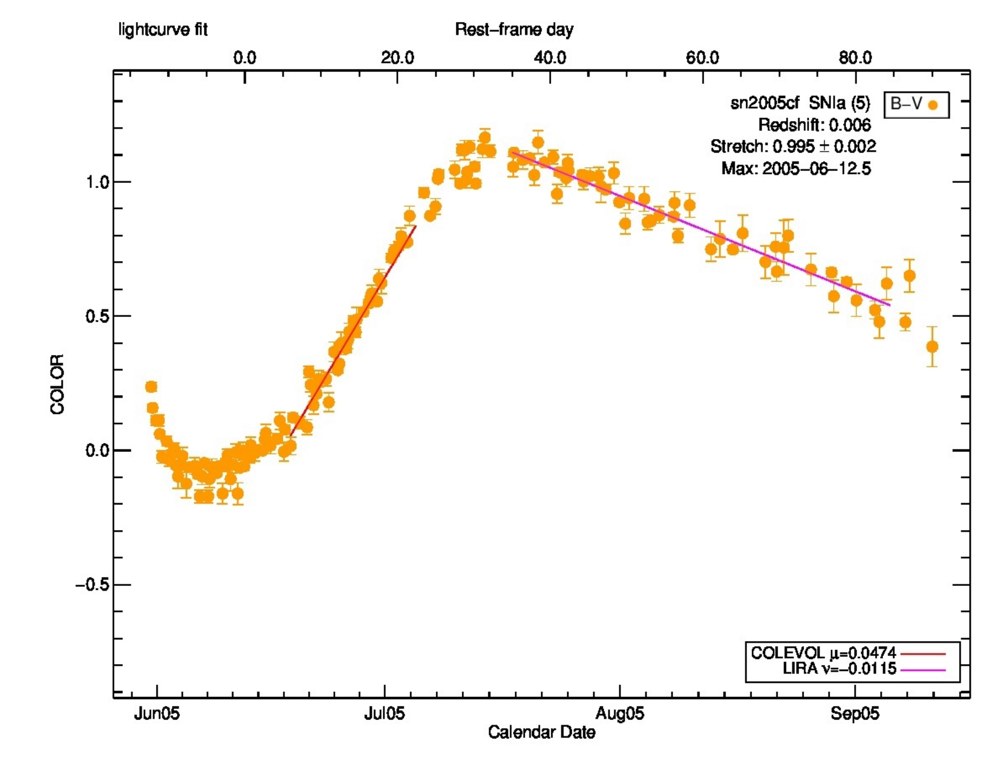
5. Continuum polarization

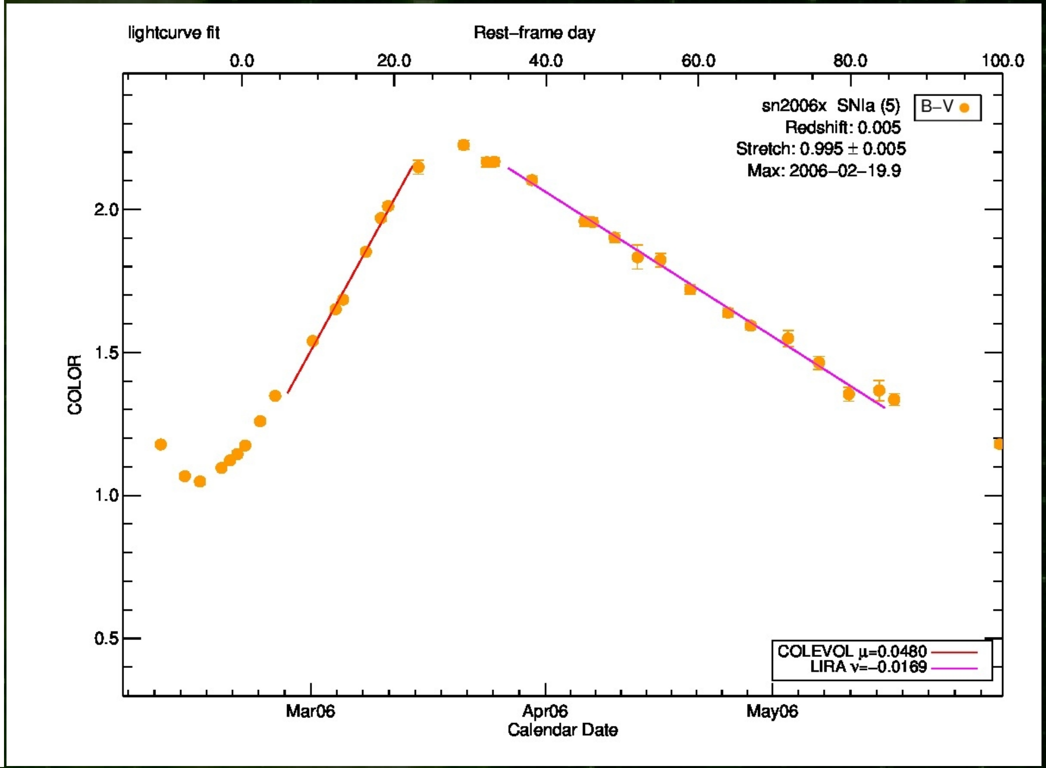




Paula Zelaya et al (in prep),

6. Light echoes?





DEFINING PHOTOMETRIC SUBLUMINOUS SNe Ia

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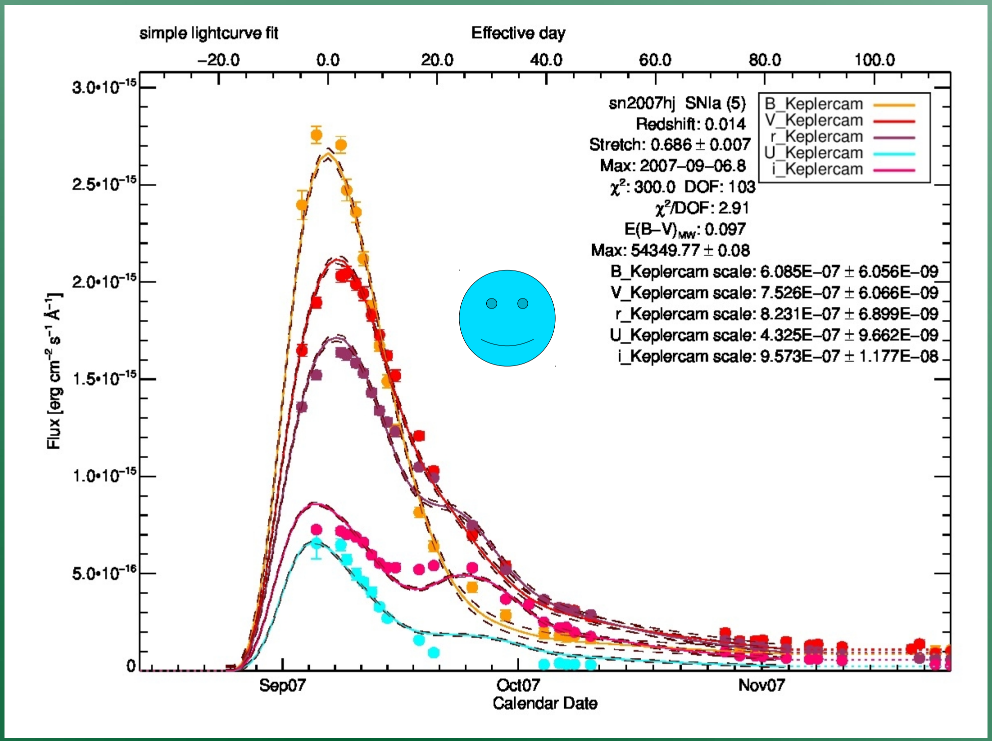
SiFTO fits to low-z SNe Ia with 2 templates

Fit with SiFTO (Conley et al. 2008) to low-z SNe Ia from literature with two templates:

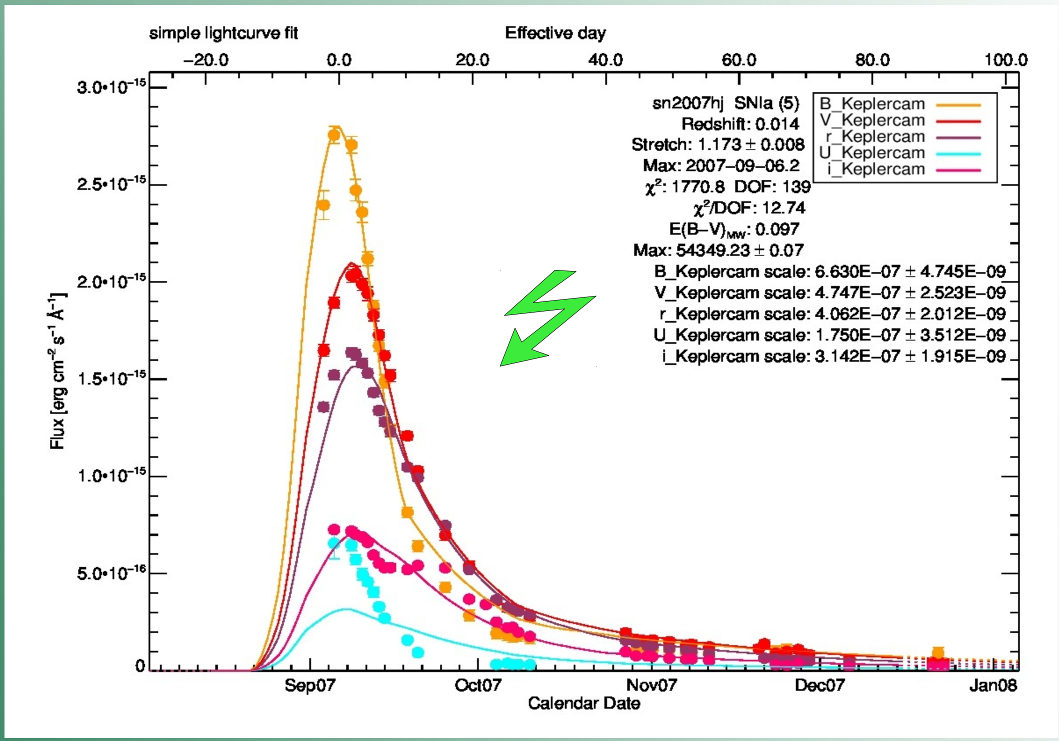
1) Normal Ia template from Hsiao et al. (2007)
2) Sublumionus Ia template from Nugent et al. (2002): http://supernova.lbl.gov/~nugent

SiFTO fits to low-z SNe Ia with 2 templates

NORMAL IA FIT

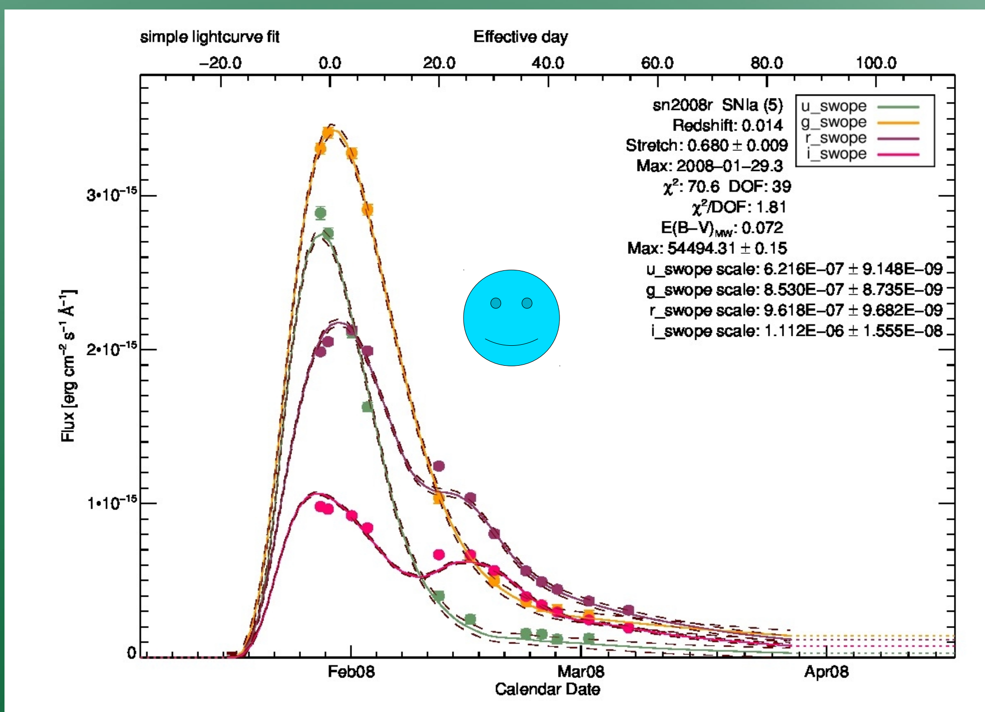


SUB IA FIT

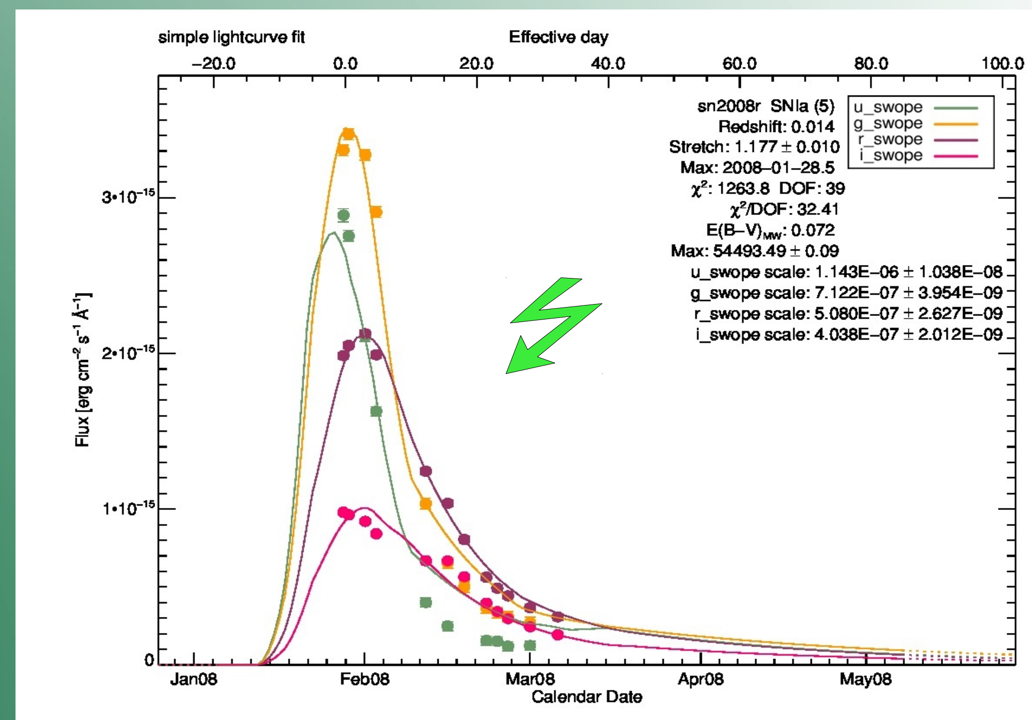


SiFTO fits to low-z SNe Ia with 2 templates

NORMAL IA FIT

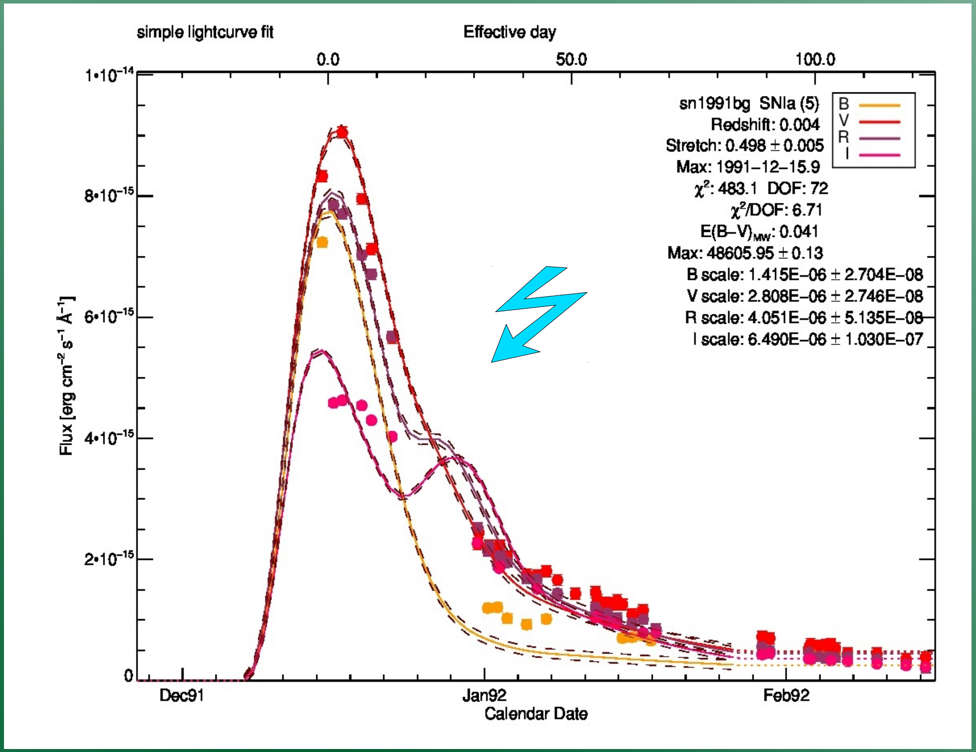


SUB IA FIT

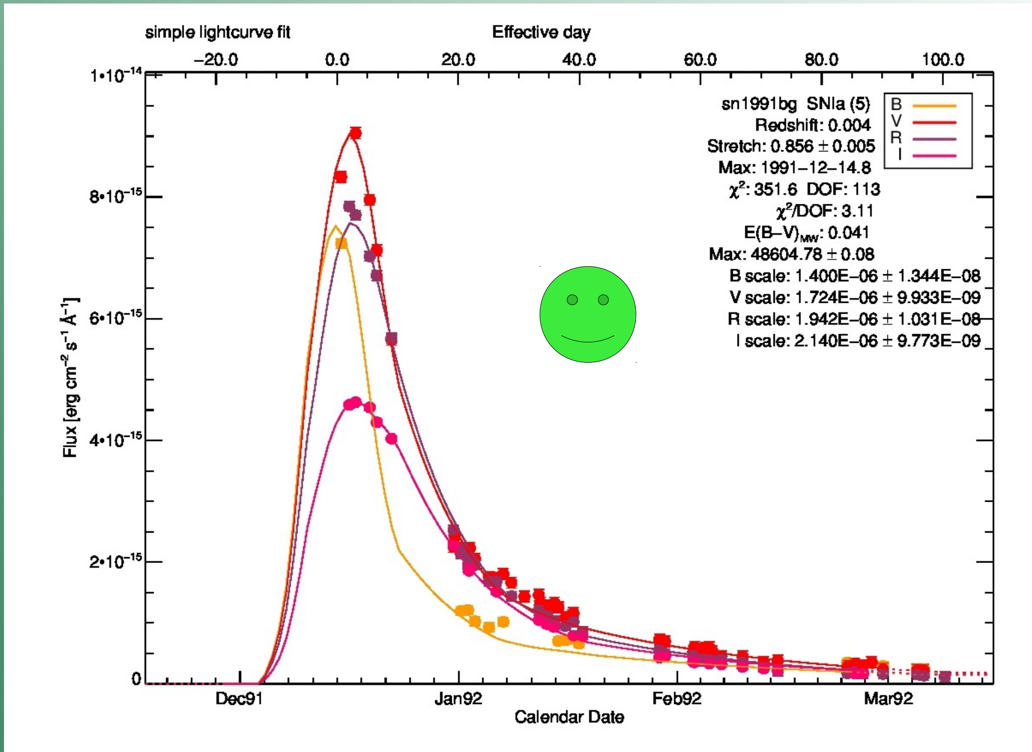


SiFTO fits to low-z SNe Ia with 2 templates

NORMAL IA FIT

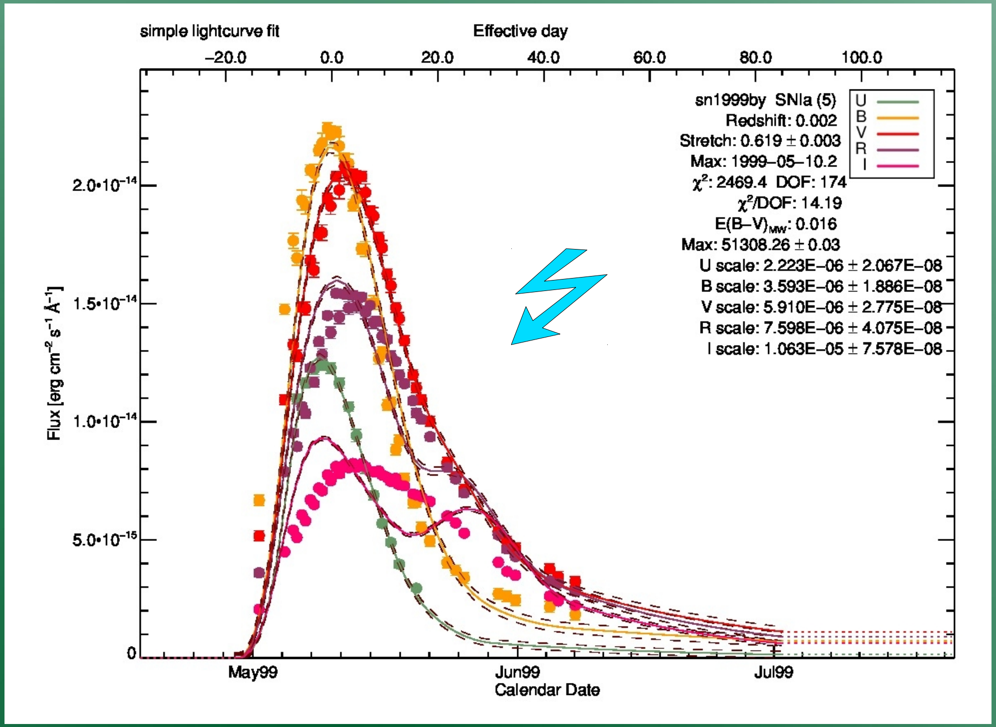


SUB IA FIT

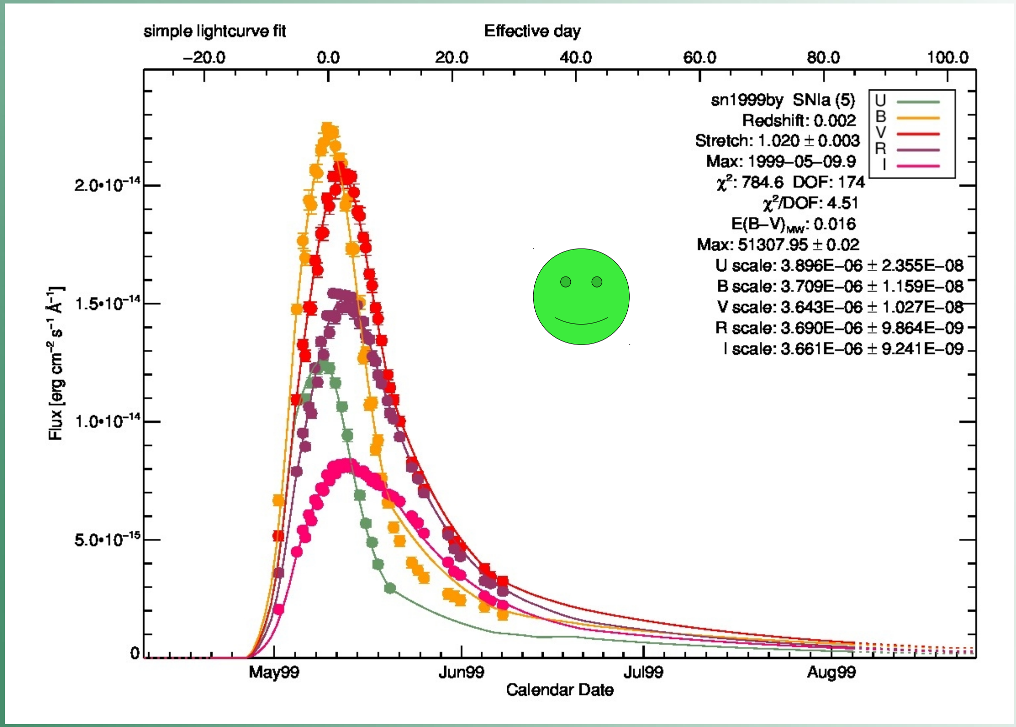


SiFTO fits to low-z SNe Ia with 2 templates

NORMAL IA FIT



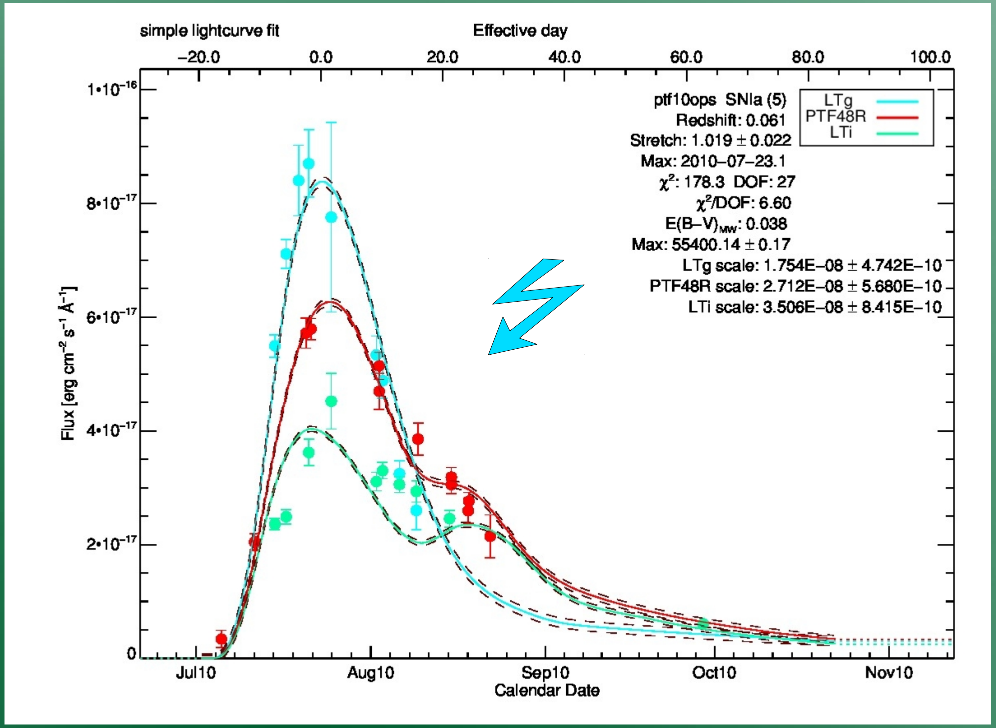
SUB IA FIT

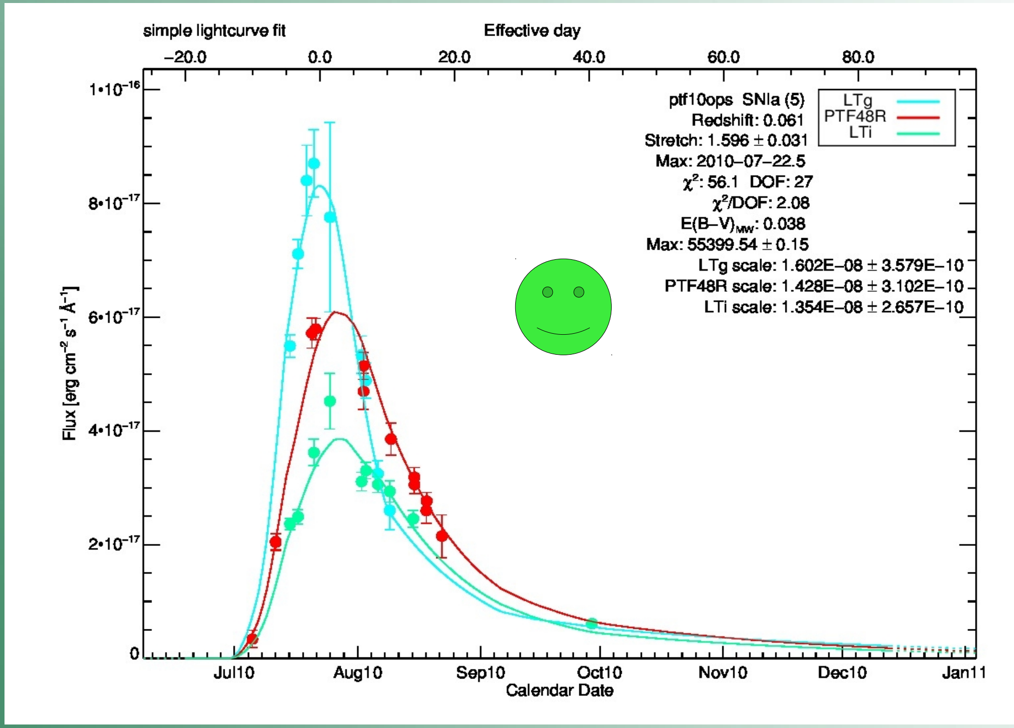


SiFTO fits to low-z SNe Ia with 2 templates

NORMAL IA FIT

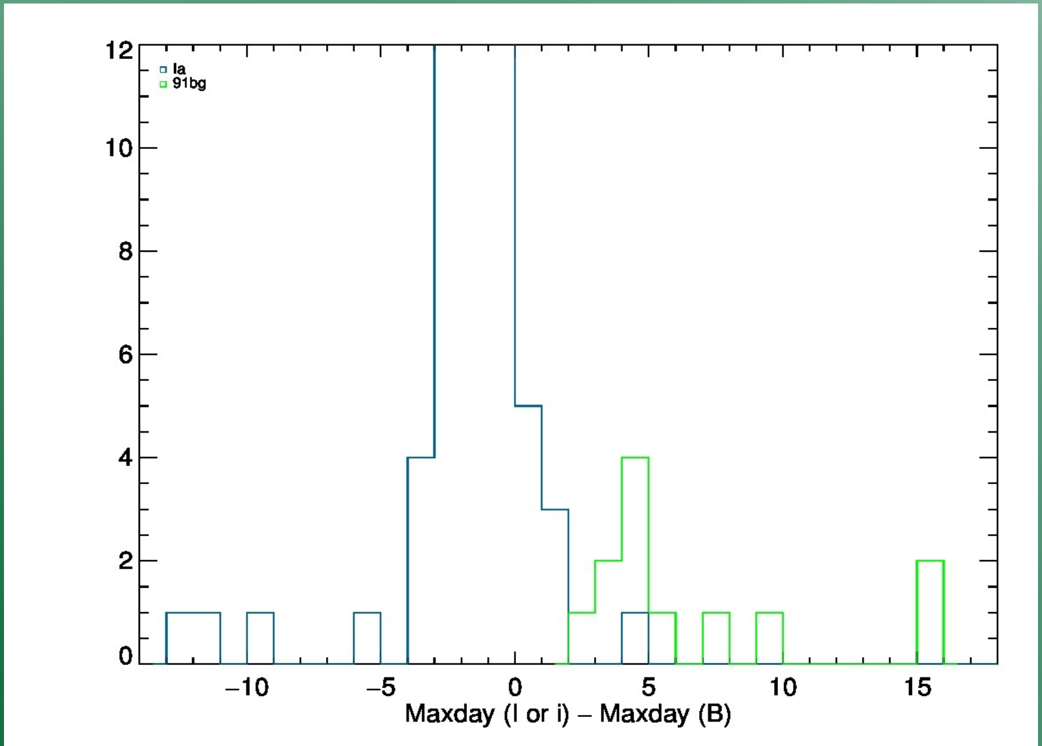
SUB IA FIT



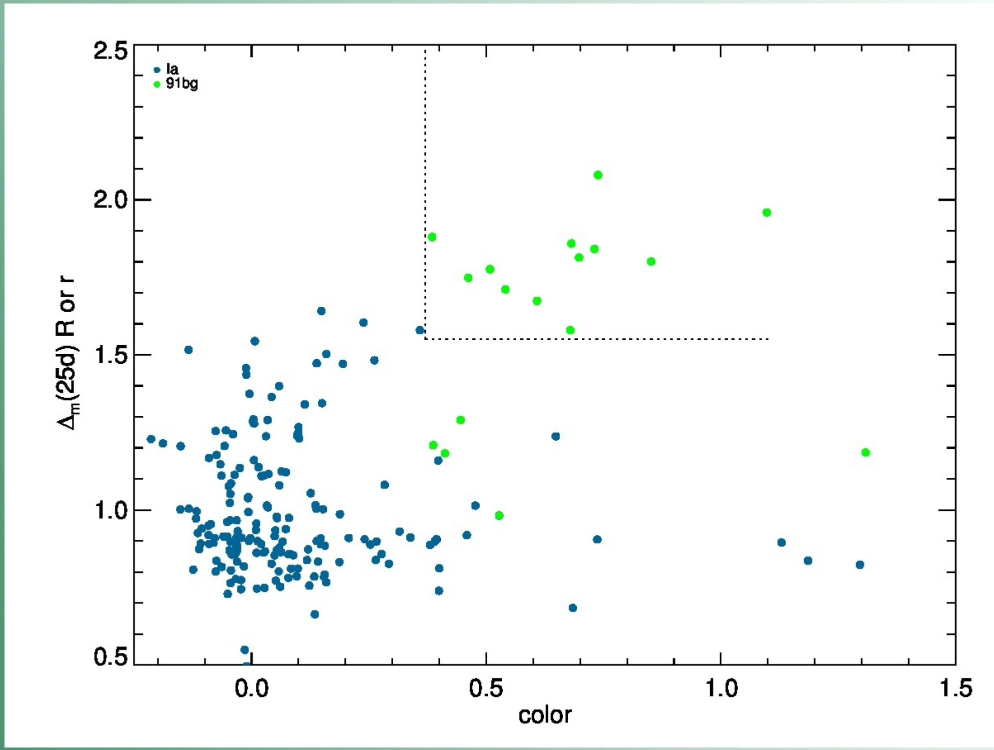


Maguire et al. 2011

Validation of the method trough other LC parameters

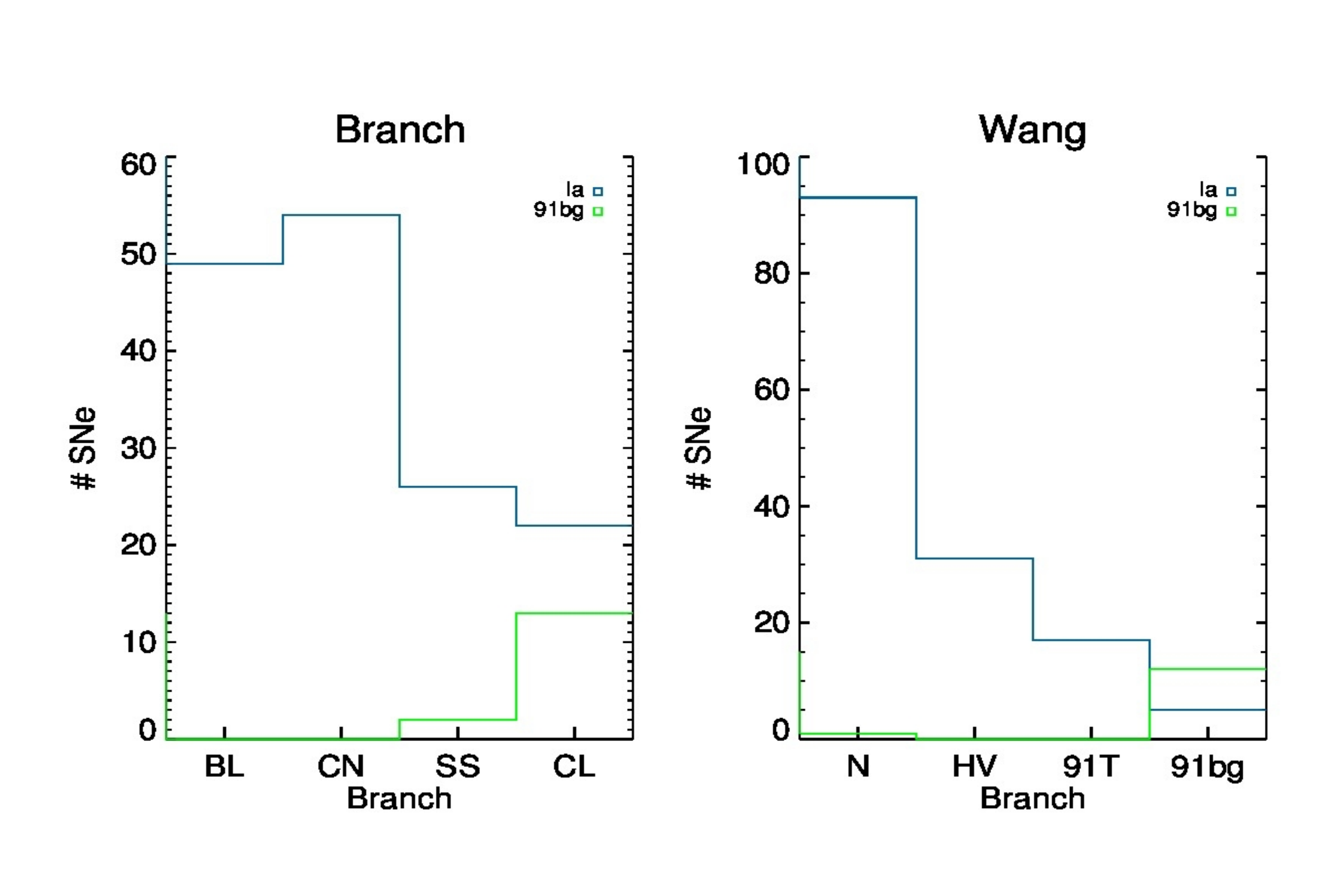


Polynomial fits to get maximum in different bands

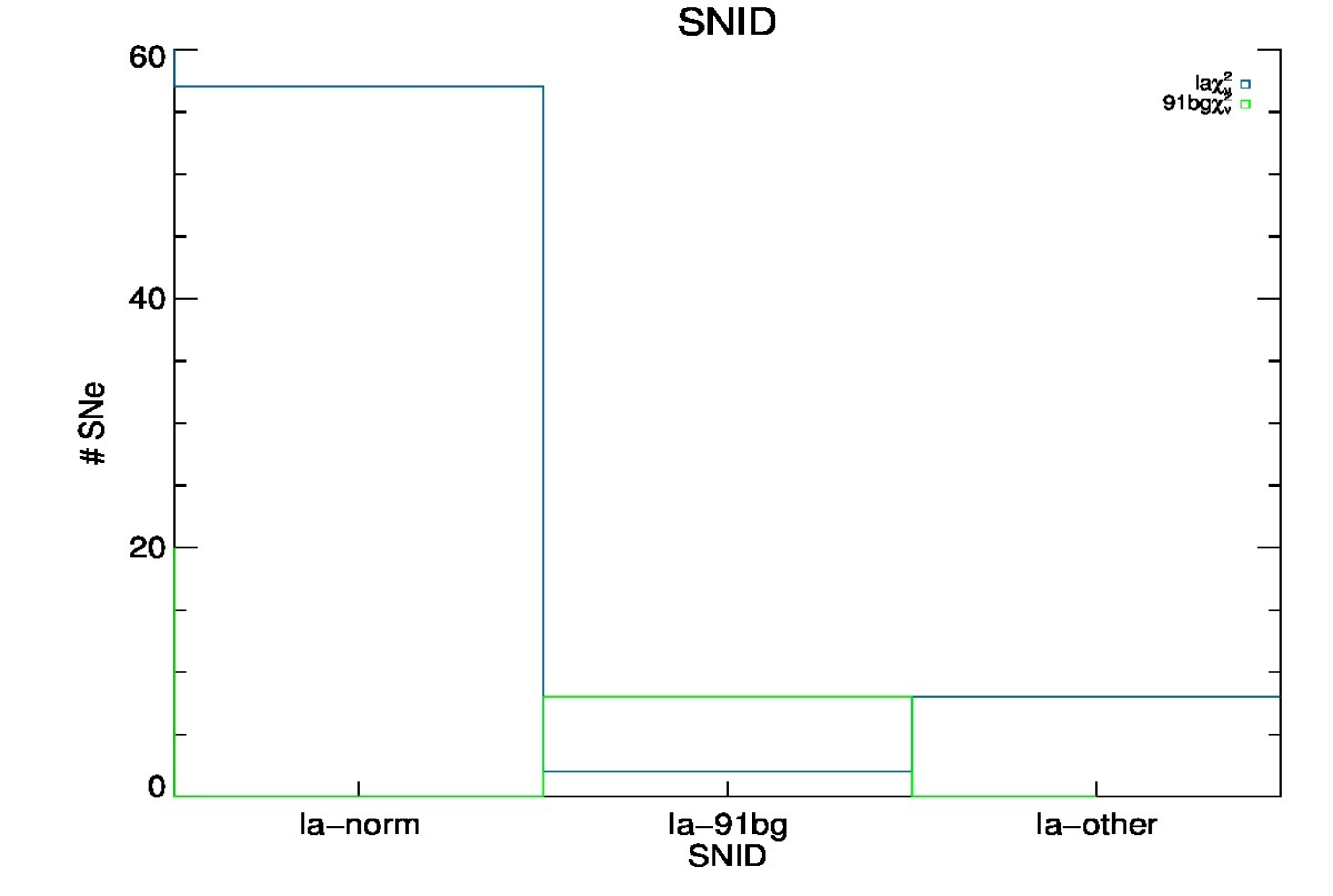


Dm25 = decline in mags after 25d in R/I

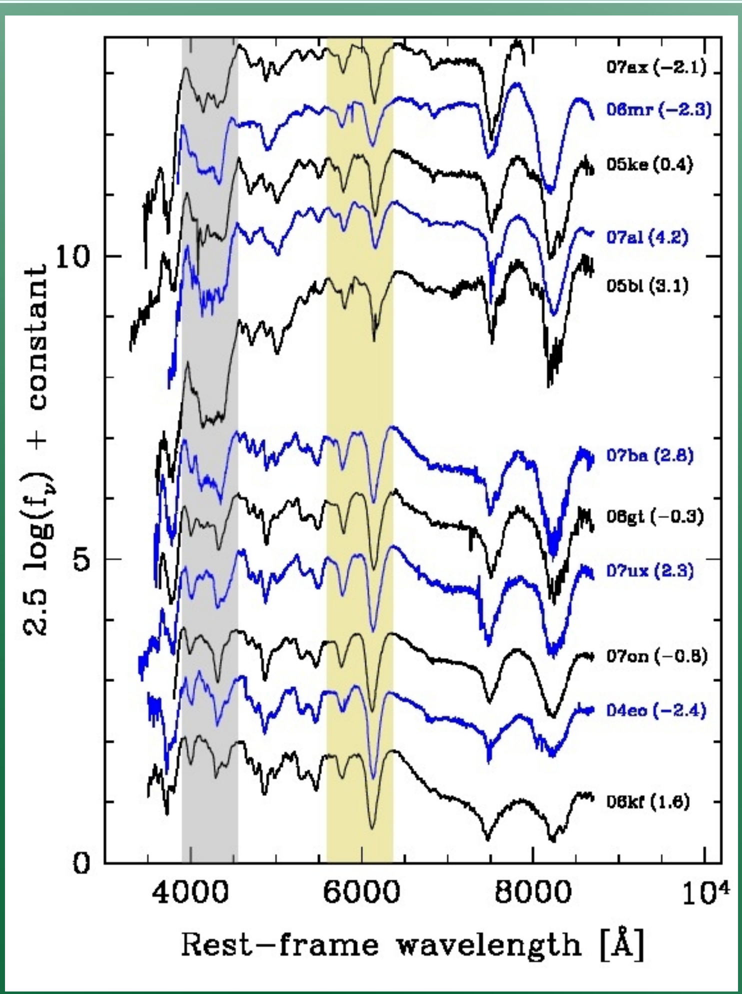
Spectral comparison

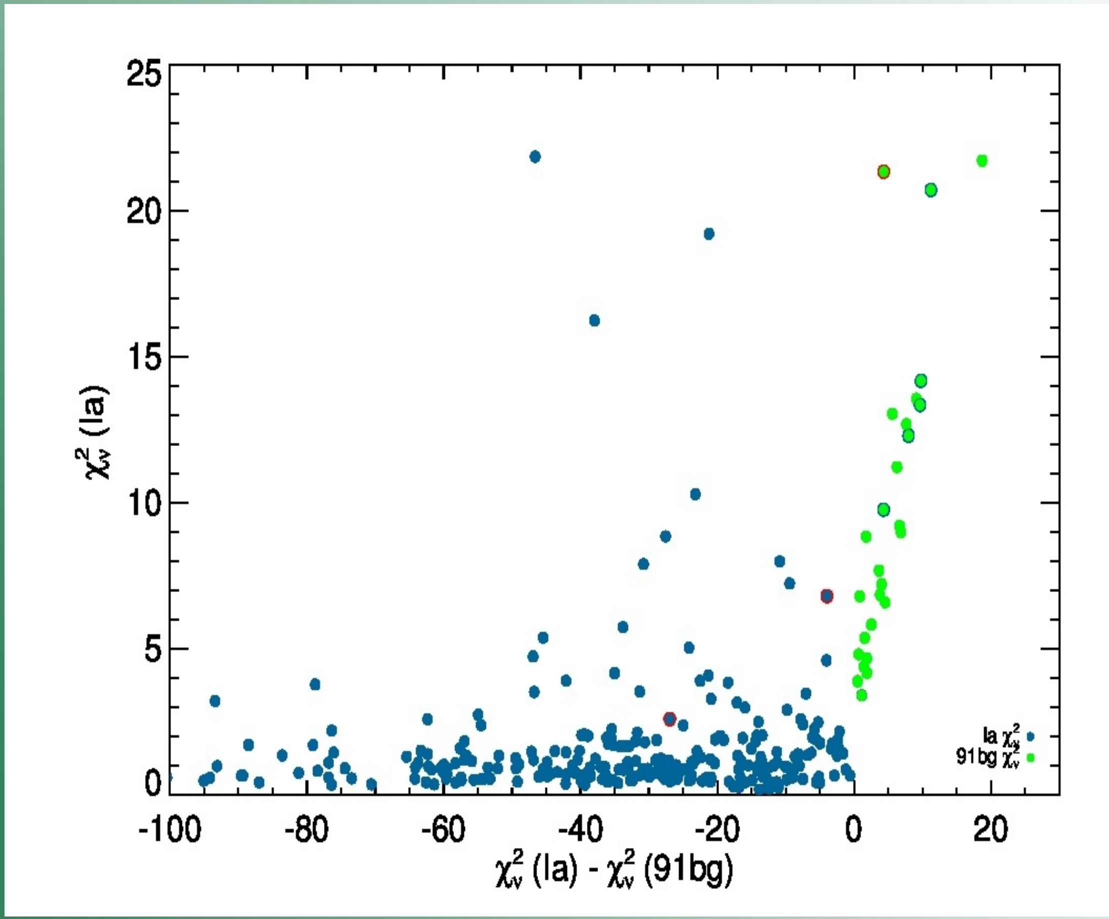


Spectral comparison



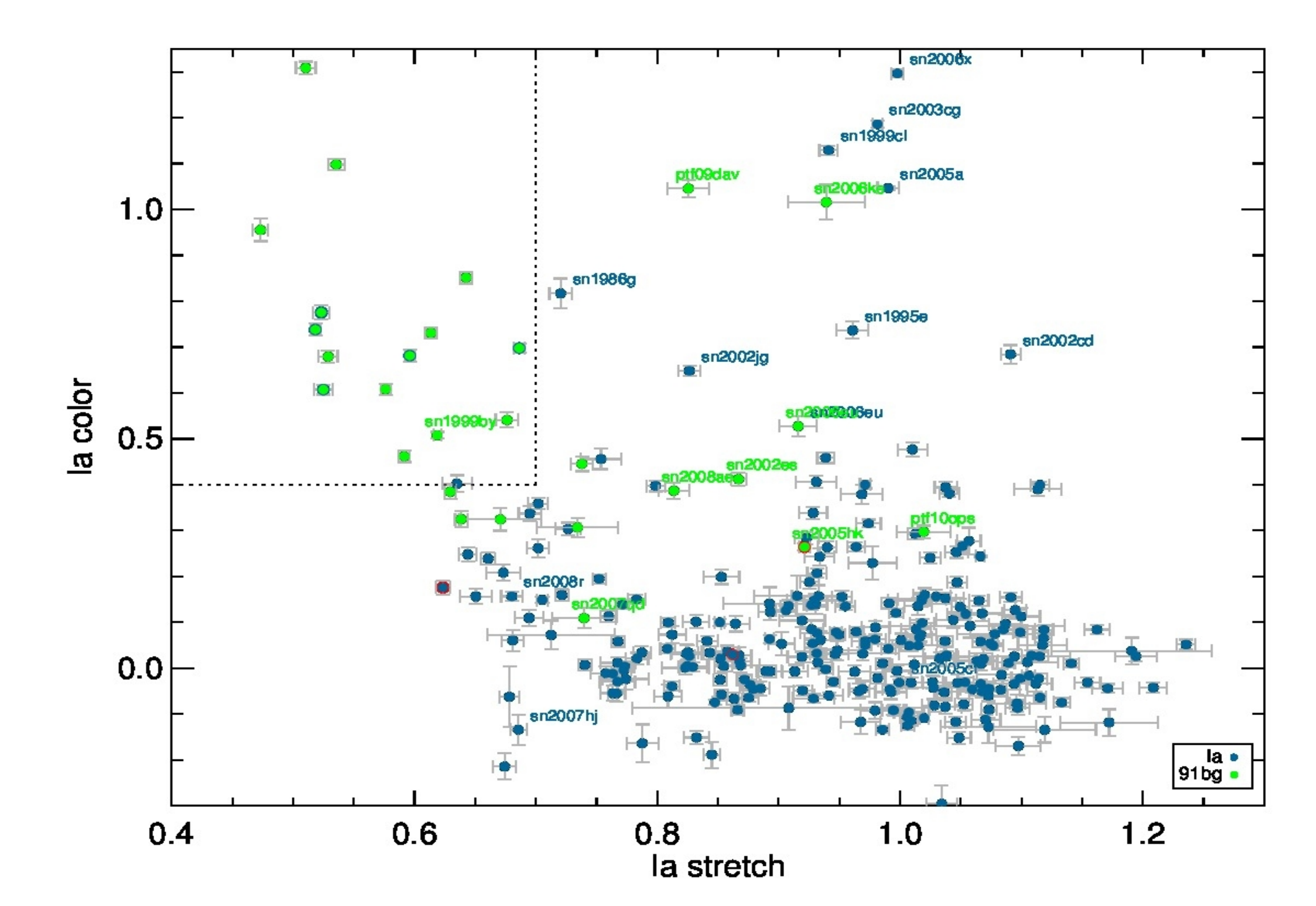
Spectra: cool and extreme cool



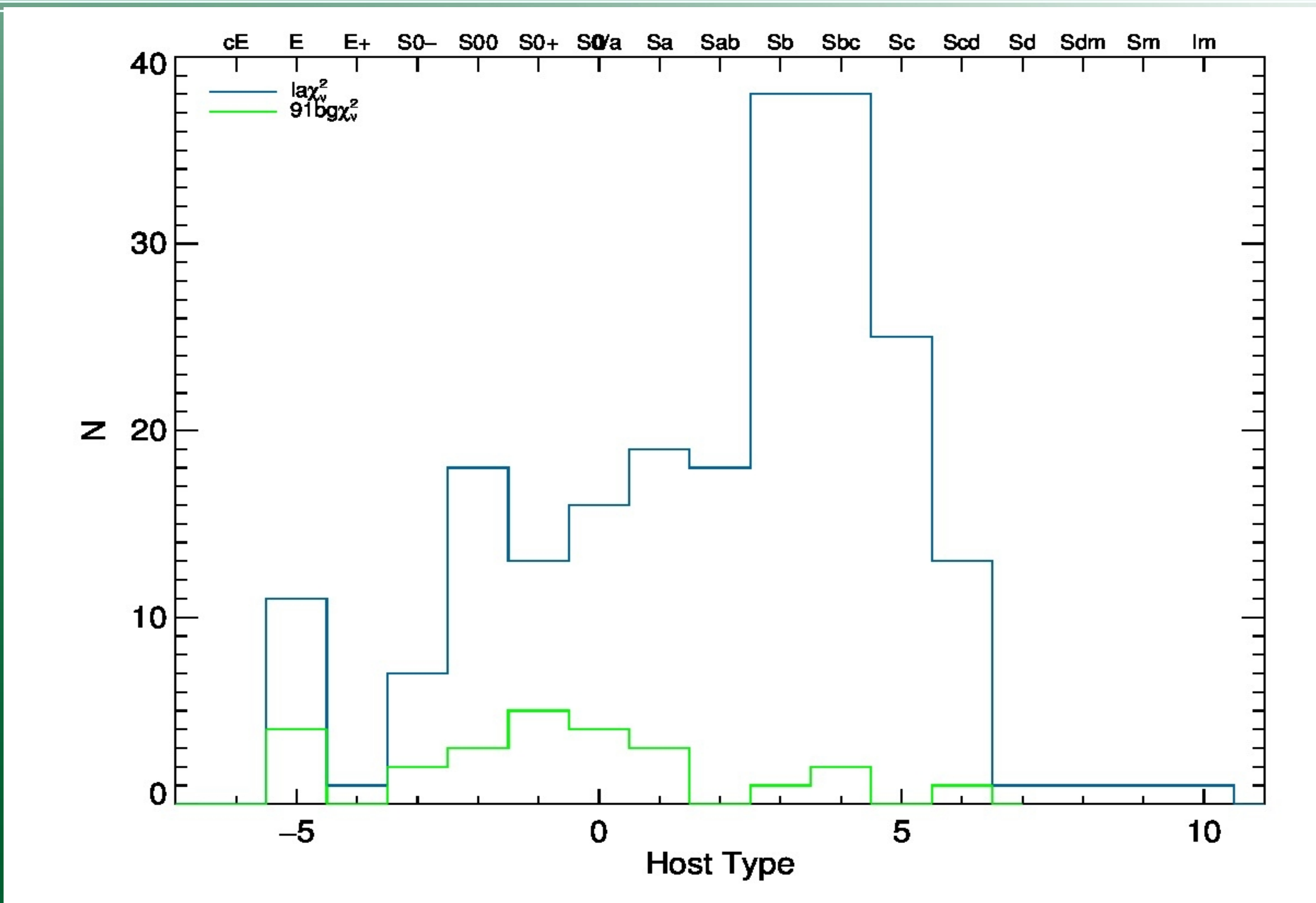


Folatelli et al.

Color vs stretch



Host properties



TYPE IA COSMOLOGY WITH CMAGIC

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CSP, Pasadena, 28th October 2012

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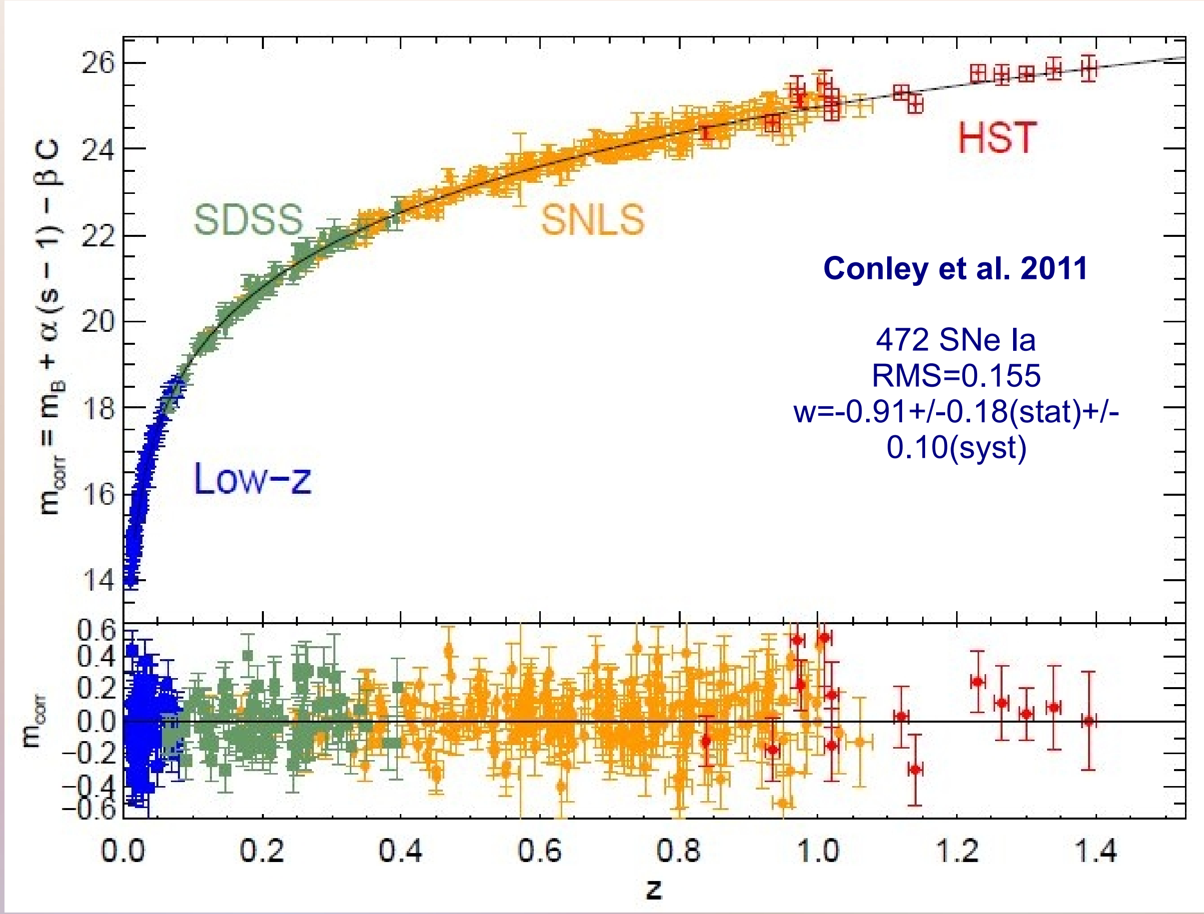
SNIa cosmology status



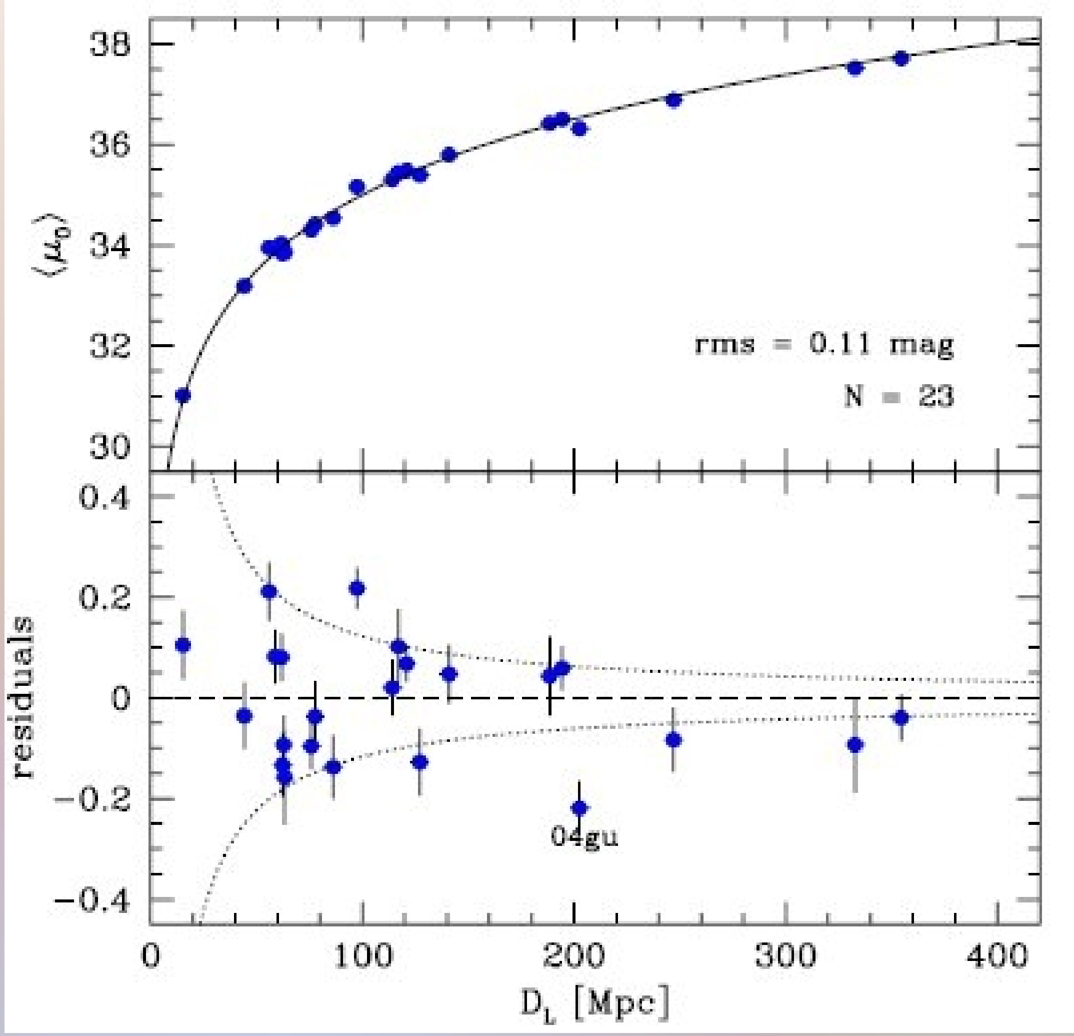
$$m_{\rm mod} = 5\log_{10}\mathcal{D}_L\left(z_{\rm hel}, z_{\rm cmb}, w, \Omega_m, \Omega_{DE}\right) - \alpha\left(s-1\right) + \beta\mathcal{C} + \mathcal{M}$$

Systematics

- Calibration
- Environment-properties
- Evolution/Dust
- LC fitter, Malmquist bias, peculiar velocities, MW correction, non-Ia, lensing

- Host environment corrections (Sullivan et al. 2010,Kelly et al. 2010,Lampeitl et al.2010)
- Spectral corrections (Bailey et al. 2009, Blondin et al. 2011, Silverman et al. 2012)

SNIa cosmology status



NIR

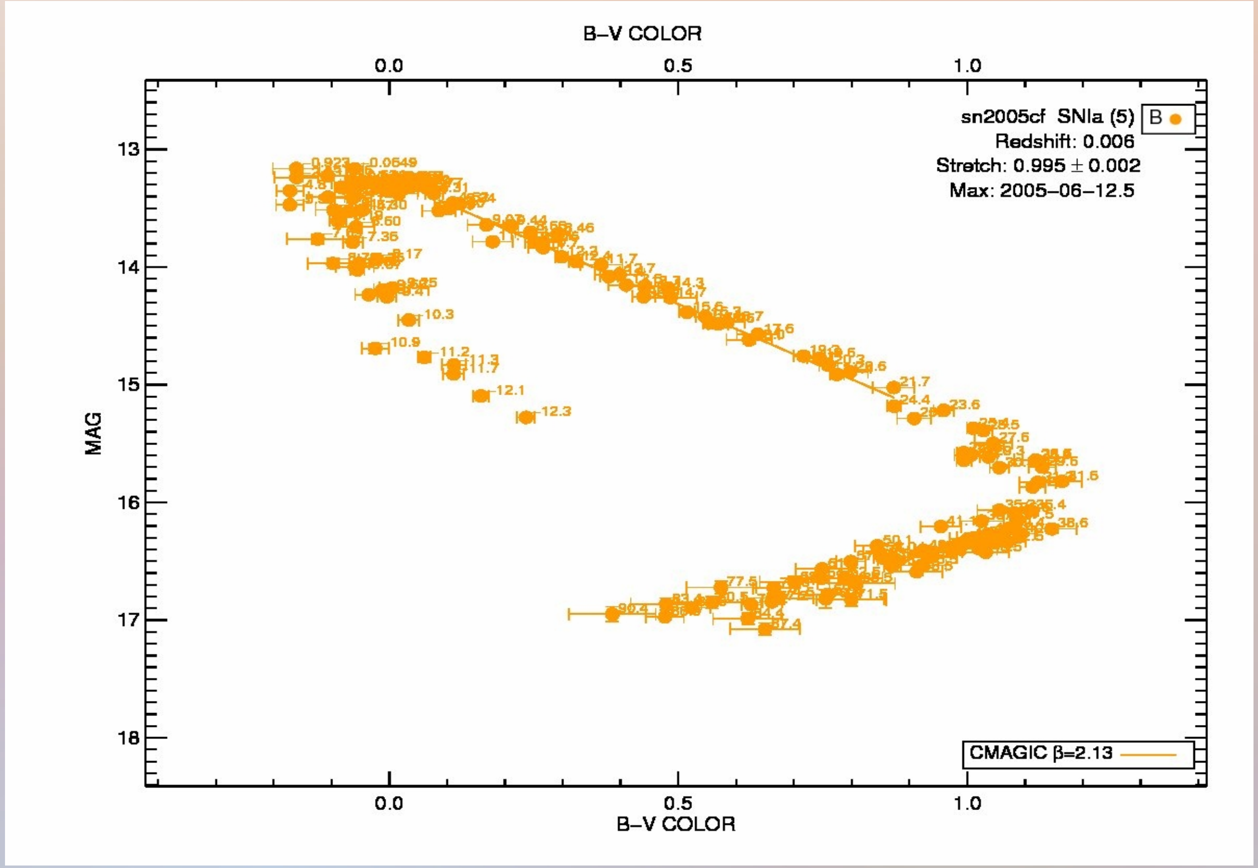
- Less dust extinction and scattering
- Shallow dependence on lightcurve shape

Folatelli et al. 2010

Y-band RMS=0.24
J-band RMS=0.18
H-band RMS=0.19
Ks-band RMS=0.27

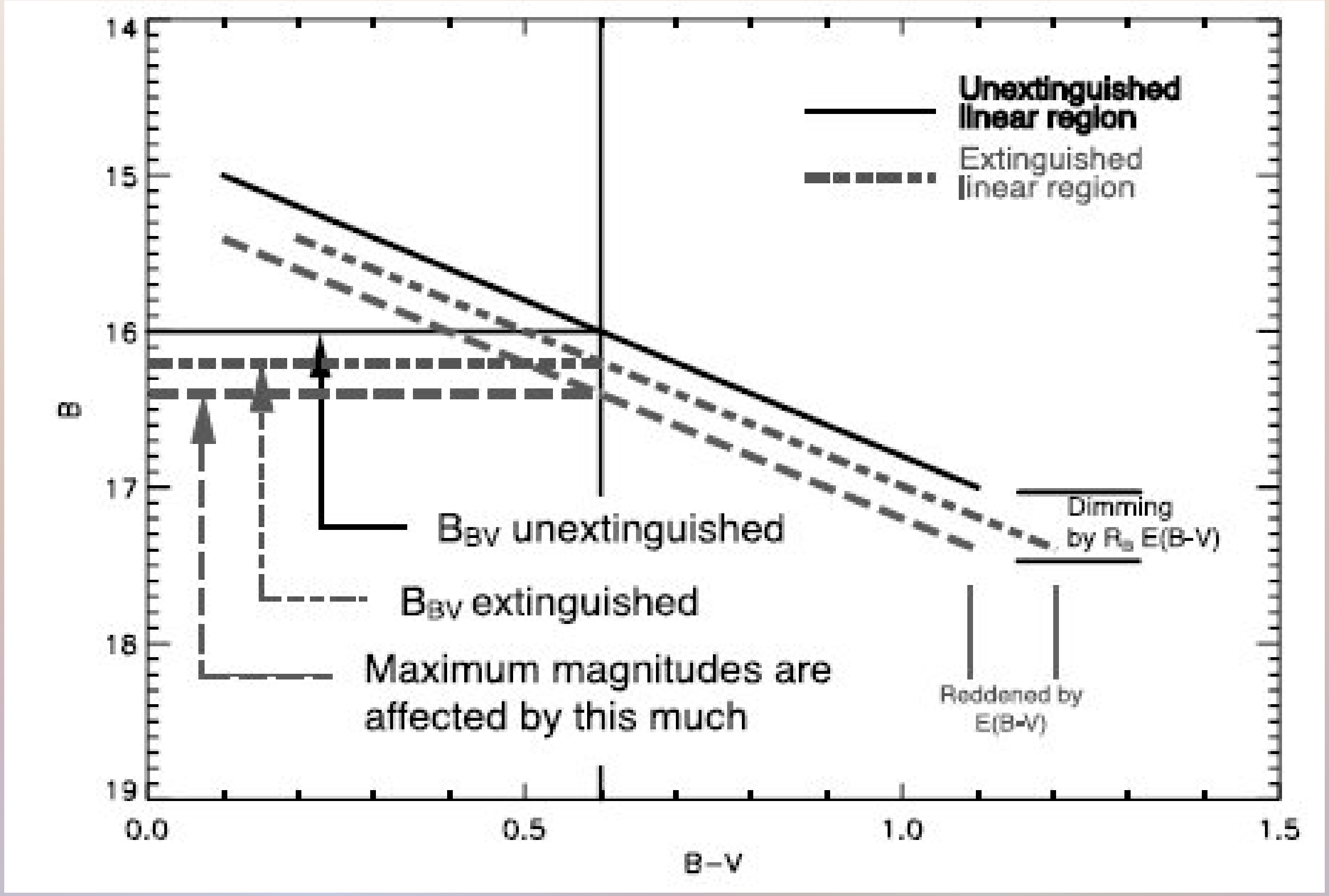
Different approach: CMAGIC

CMAGIC: Color-Magnitude Intercept Calibration (Wang et al. 2003, Conley et al. 2006)



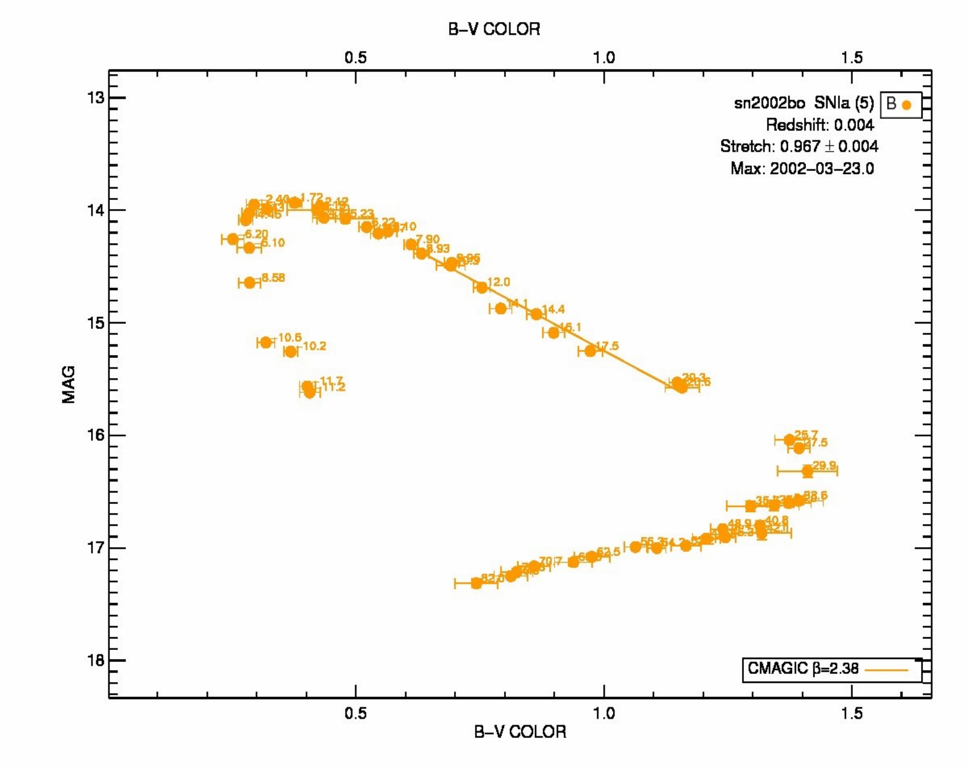
- Linear fit of mag vs color after maximum
- Intercept gives the magnitude of SNIa

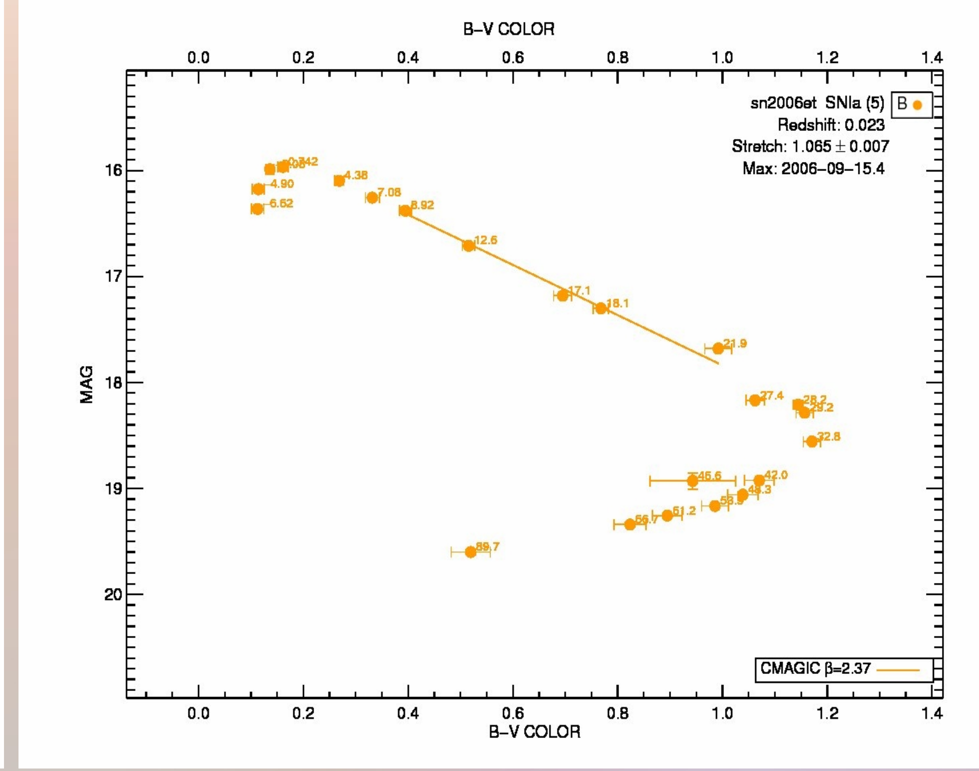
CMAGIC



- Magnitude always at same color
- Less uncertainty in extinction

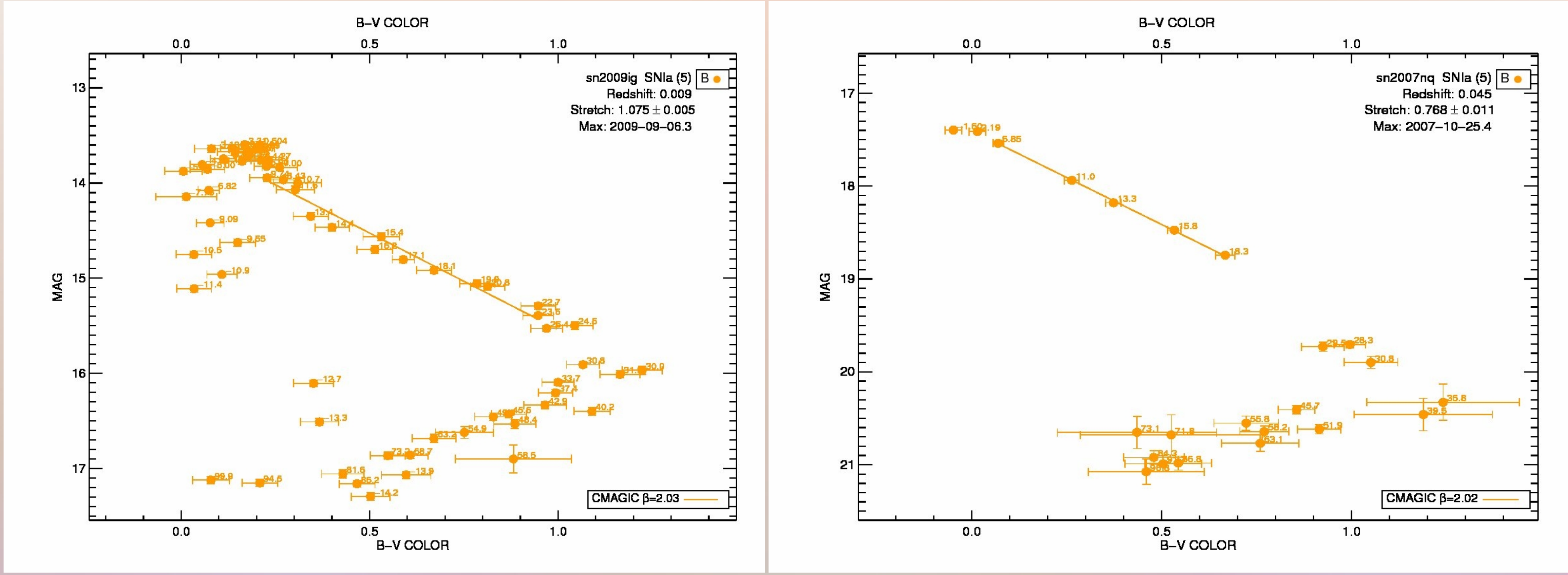
CMAGIC examples





Fit requirements: 3 points with +5d difference

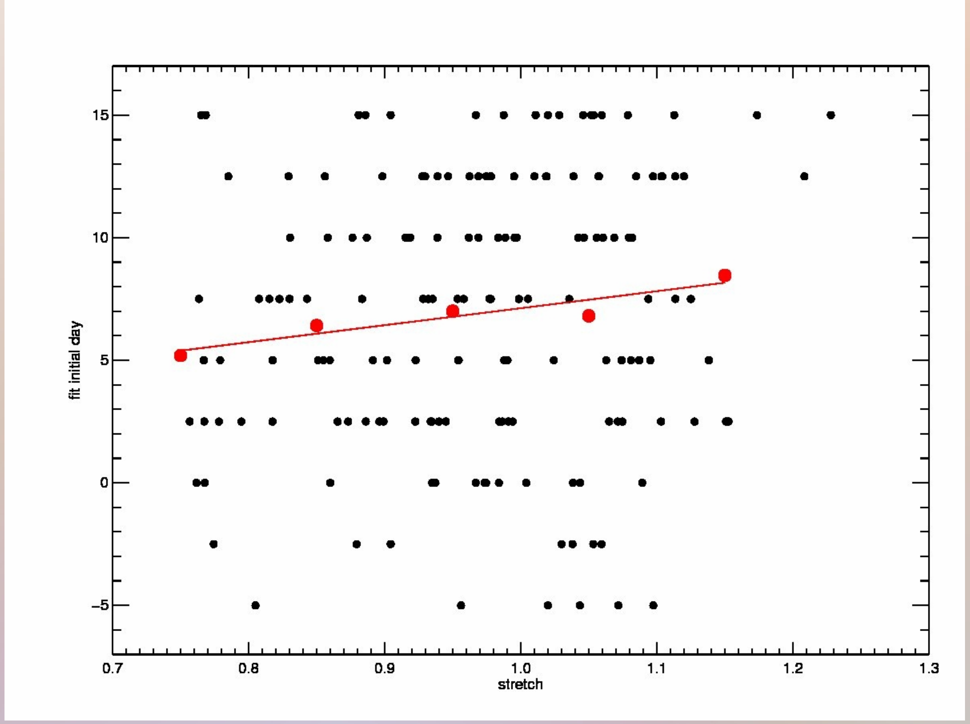
CMAGIC examples

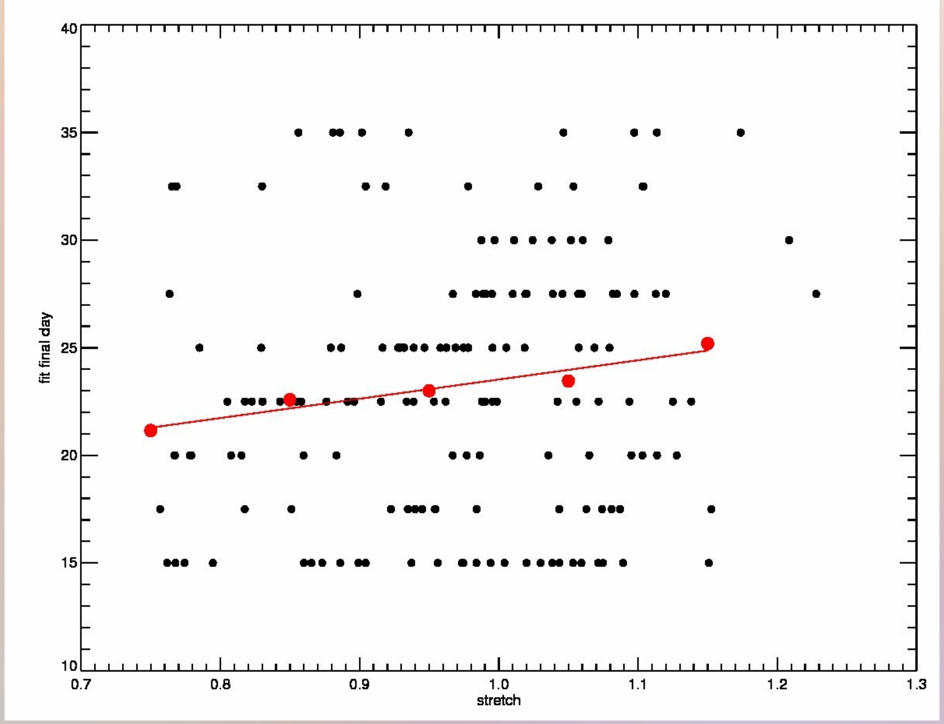


Works for different stretches but time range

Bump SNe Ia

CMAGIC fit duration

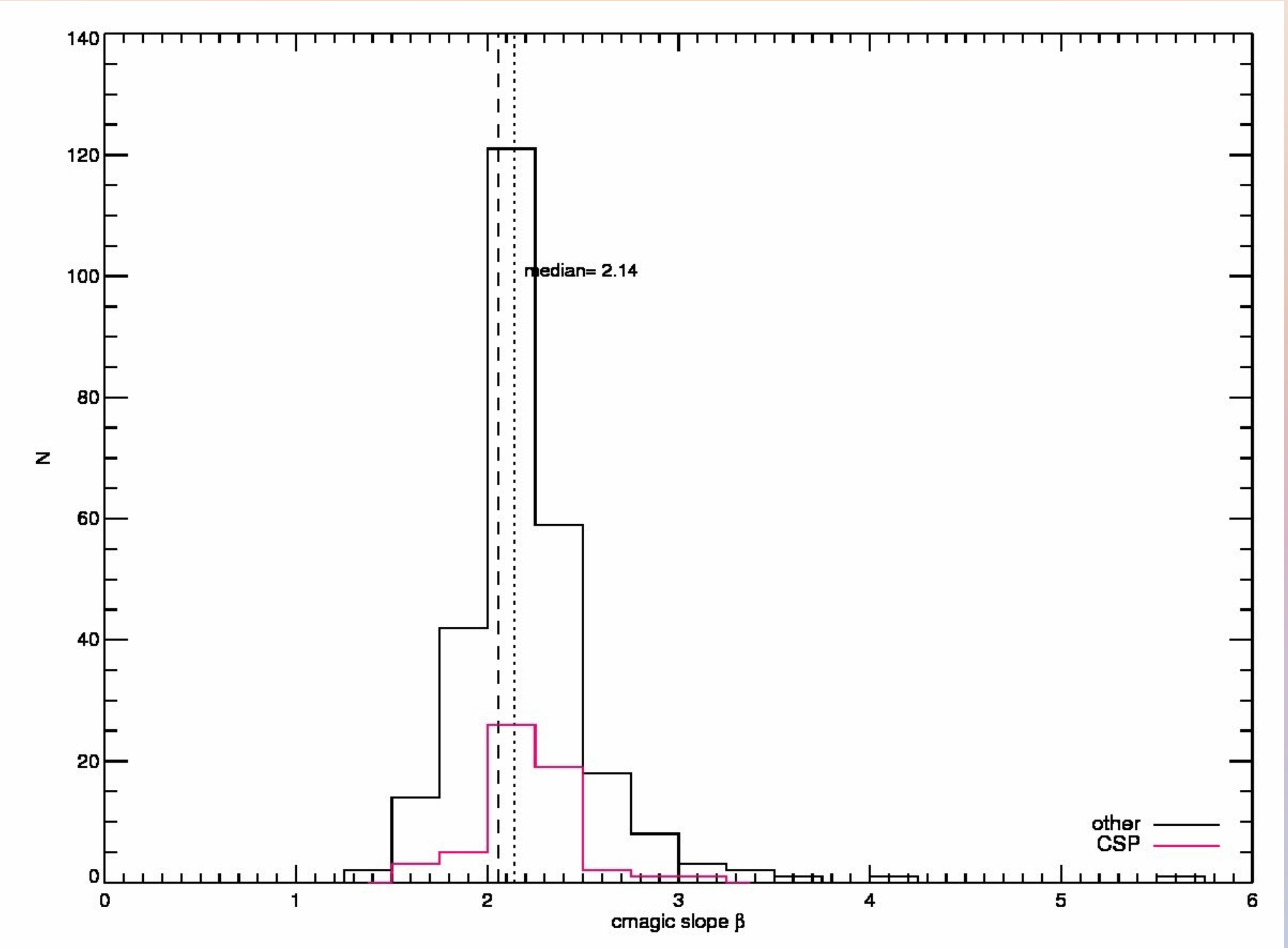




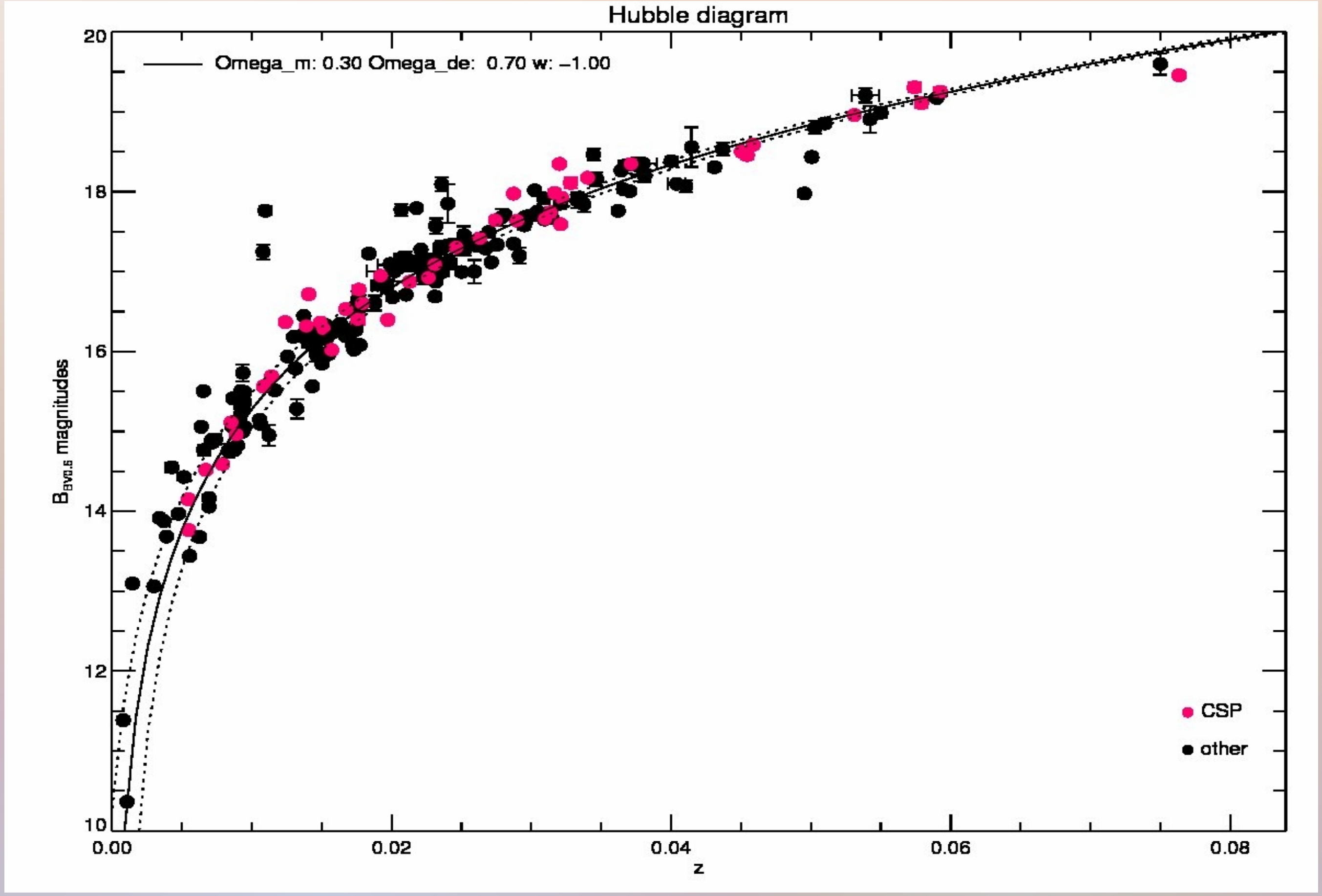
Fit duration depends on light-curve shape:

t_{ini}=0.2+6.9*st t_{fin}=15+9.0*st

CMAGIC slope



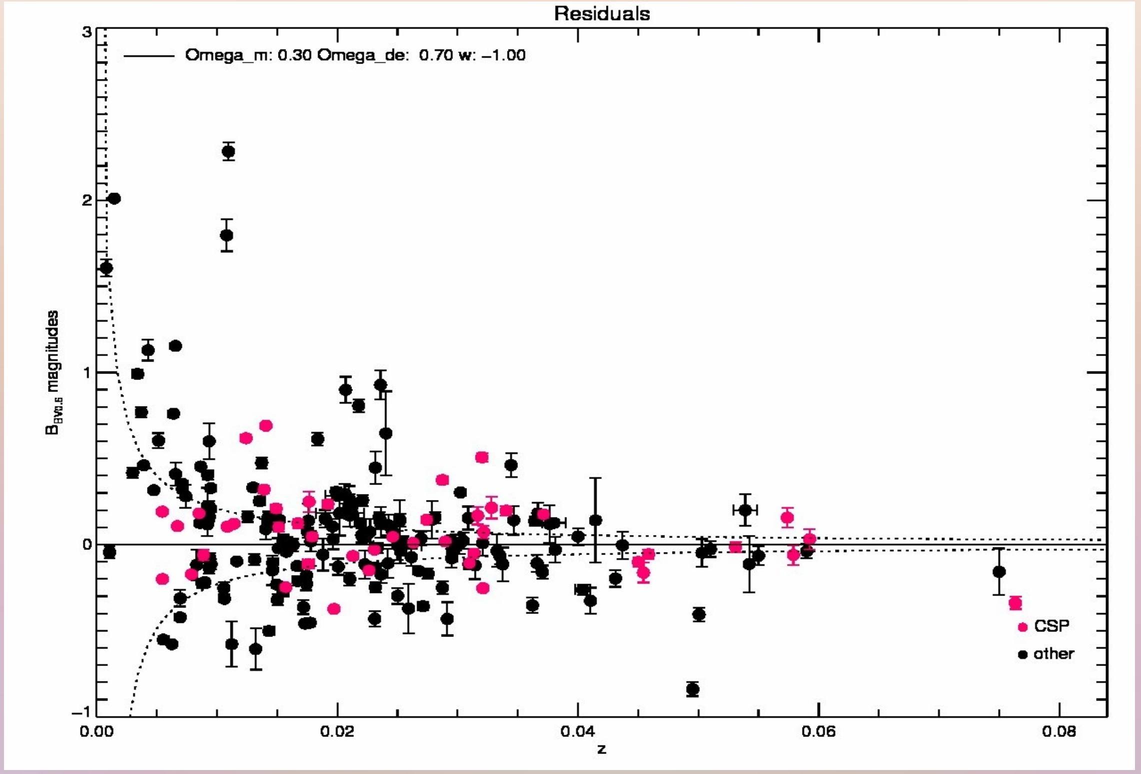
CMAGIC Hubble diagram



- 216 SNe Ia: RMS=0.34
  - stretch-corr: 0.33
- 45 CSP: RMS=0.23
  - stretch-corr: 0.22

$$m = 5\log_{10}[\mathcal{D}_L(z,\ \Omega_m,\ \Omega_\Lambda)] + \mathcal{M} - \alpha(s-1)$$

CMAGIC Hubble diagram



FUTURE

- Test other filter combinations
- Test other redshifts