CSP Observations of Stripped Core-Collapse SNe

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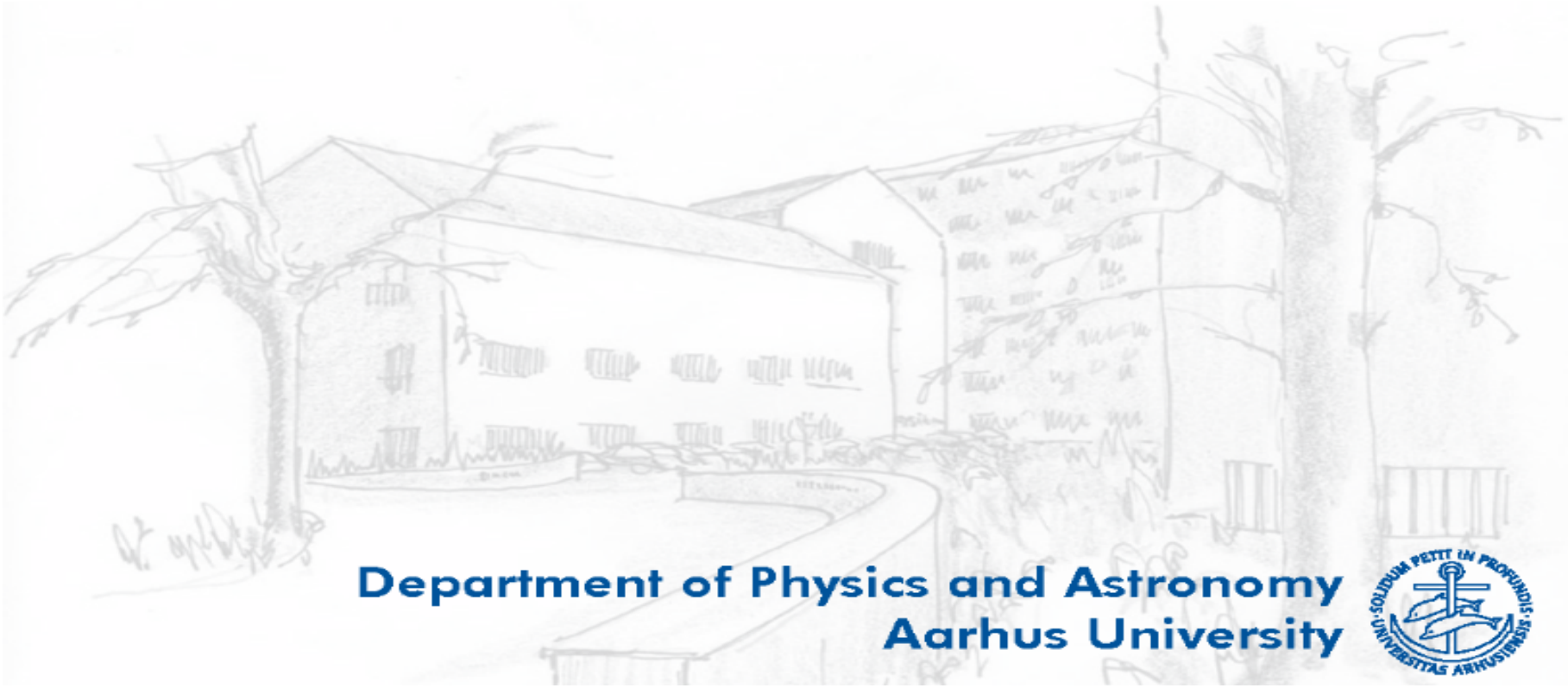

Department of Physics and Astronomy
Aarhus University

Aims of work on CSP SNe Ib/c sample

- Photometric analysis, LC properties, Colors, Templates
- Optical spectroscopy analysis, link with LC properties
- Improved methods to determine host extinction
- Bolometric properties and estimations of explosion parameters and test of methods

Previously CSP Related Publications

- Peculiar Type Ib SN 2005bf: Folatelli et al. (2006)
- Normal Faint Type Ib SN 2007Y: Stritzinger et al. (2009)
- Radio bright Type Ic SN 2009bb: Pignata et al. (2011)

Early-time light curves of Type Ib/c supernovae from the SDSS-II Supernova Survey

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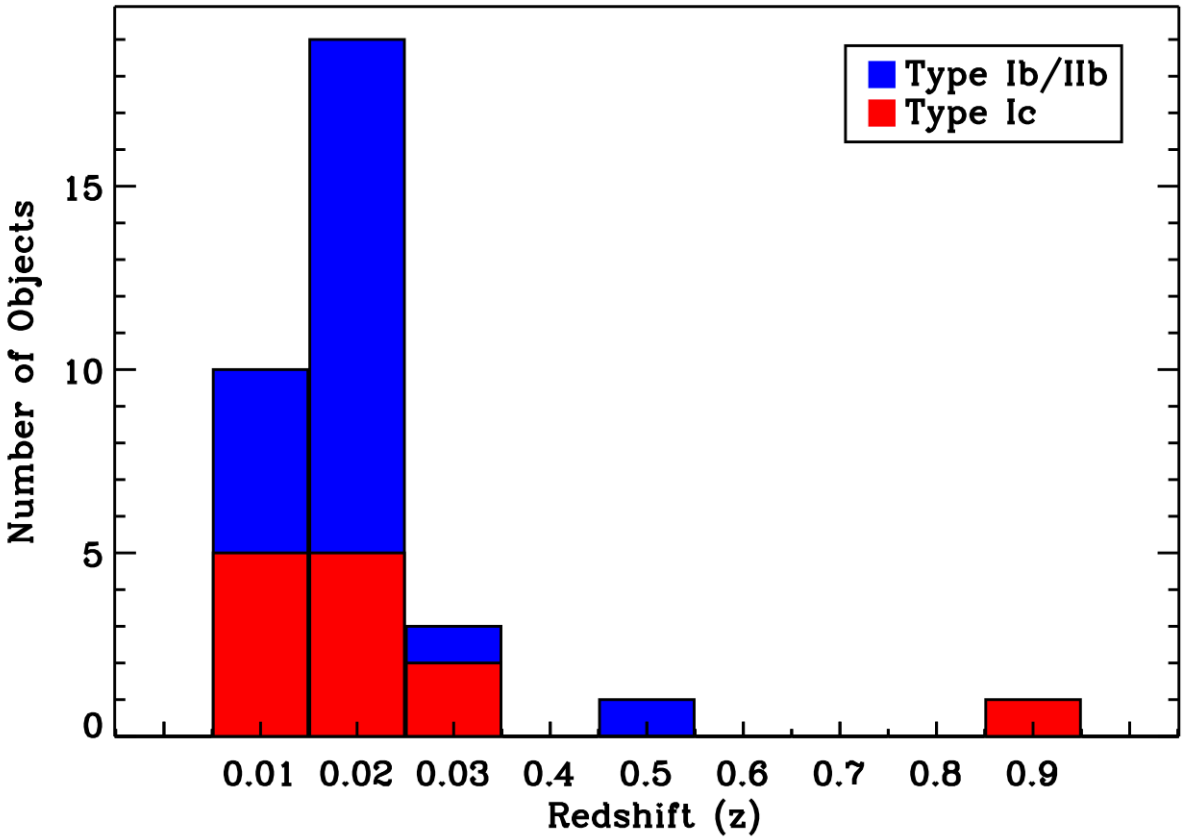
Abstract

Context. Type Ib/c supernovae (SNe Ib/c) are investigated in several single-object studies. However, there is a paucity of works concerning large, homogeneous samples of these hydrogen-poor transients, in particular regarding the pre-maximum phase of their light curves.
Aims. In this paper we present and analyse the early-time optical light curves (LCs, $ugriz$) of 20 SNe Ib/c from the Sloan Digital Sky Survey (SDSS) SN survey II, aiming to study their observational properties as well as to derive their progenitor parameters.
Methods. High-cadence, multi-band LCs are fitted with a functional model and the best-fit parameters are compared among the SN types. Bolometric LCs (BLCs) are constructed for the entire sample. We also computed temperature (T_{BB}) and photospheric radius (R_{ph}) evolution for each SN via black-body fit on the spectral energy distributions. In addition, the bolometric properties are compared to both hydrodynamical and analytical model expectations.
Results. Complementing our sample with literature data, we find that SNe Ic and Ic-BL (broad-line) have shorter rise times than those of SNe Ib and IIb. The decline rate parameter, Δm_{15}, is similar among the different sub-types, whereas the rise rate (Δm_{-10}) is larger for helium-poor SNe. SNe Ic appear brighter than SNe Ib, but this difference vanishes if we consider host galaxy extinction corrections based on colors. Templates for SN Ib/c LCs are presented. Our SNe have typical T_{BB} of 6000$-$10000 K at peak, and R_{ph} of $\sim10^{15}$ cm. Analysis of the BLCs of SNe Ib and Ic gives typical ejecta masses $M_{ej} \approx 2{-}5\ M_{\odot}$, energies $E_K \approx 2{\times}10^{51}$ erg, and M(^{56}Ni) $\approx 0.1{-}0.2\ M_{\odot}$. Higher values for all these properties are measured for SNe Ic-BL. For the majority of SNe Ic and Ic-BL we can put strong limits (<2$-$4 days) on the duration of the expected early-time plateau. Less stringent limits can be placed on the duration of the plateau for the sample of SNe Ib. In the single case of SN Ib 2006lc, a >5.9 days plateau is detected. The rising part of the BLCs is reproduced by power laws with index <2. For two events we find signatures of a possible shock break-out cooling tail. Compact progenitor radii (a few $R_{\odot}$) were derived for the SNe Ib/c with the earliest discoveries.
Conclusions. Based on the limits for the plateau length and on the slow rise of the BLCs, we find that in most of our SNe Ic and Ic-BL the ^{56}Ni is mixed up to the outer layers, suggesting that SN Ic progenitors are de facto helium poor. The derived progenitor parameters (E_K, M_{ej} and R) are consistent with previous works.

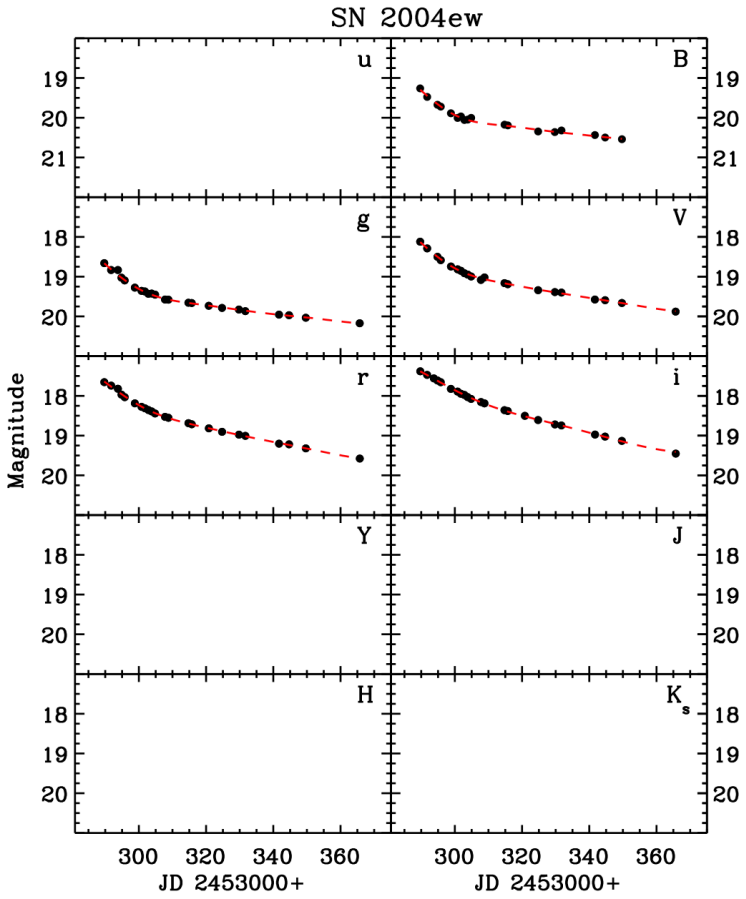
Key words. supernovae: general – supernovae

Sample of 34 objects (24 with NIR photometry)



Largely discovered by targeted SN search programs
→ Nearby, large host galaxies

Photometry


SN 2004ew
u
B
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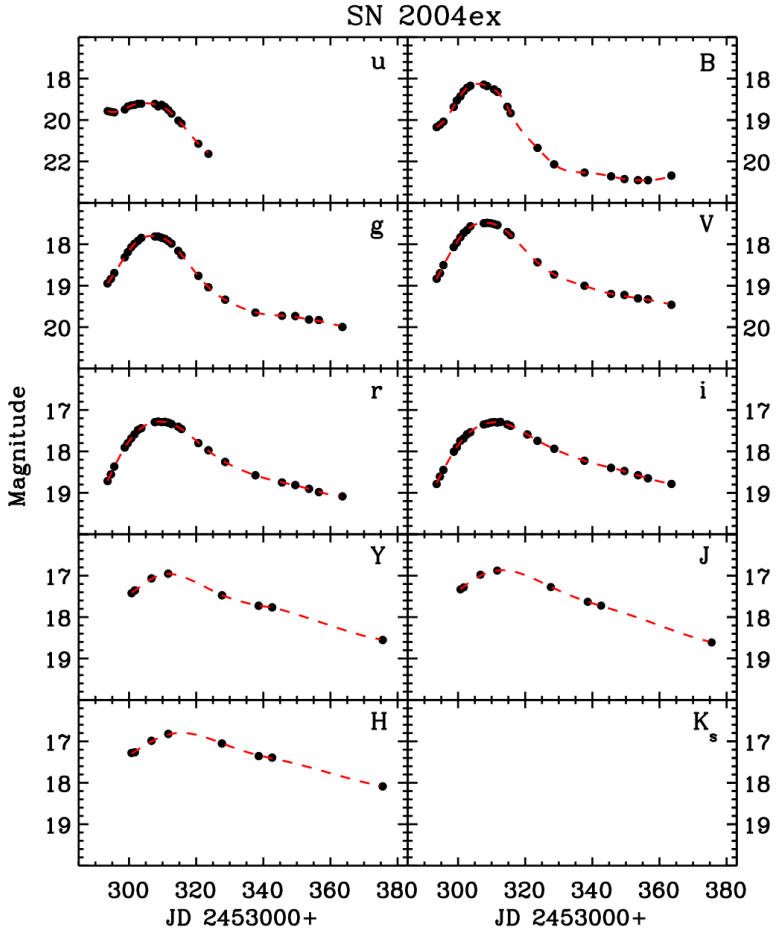
V
r
i
Y
J
H
K_s
Magnitude
JD 2453000+
JD 2453000+


SN 2004ex
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r
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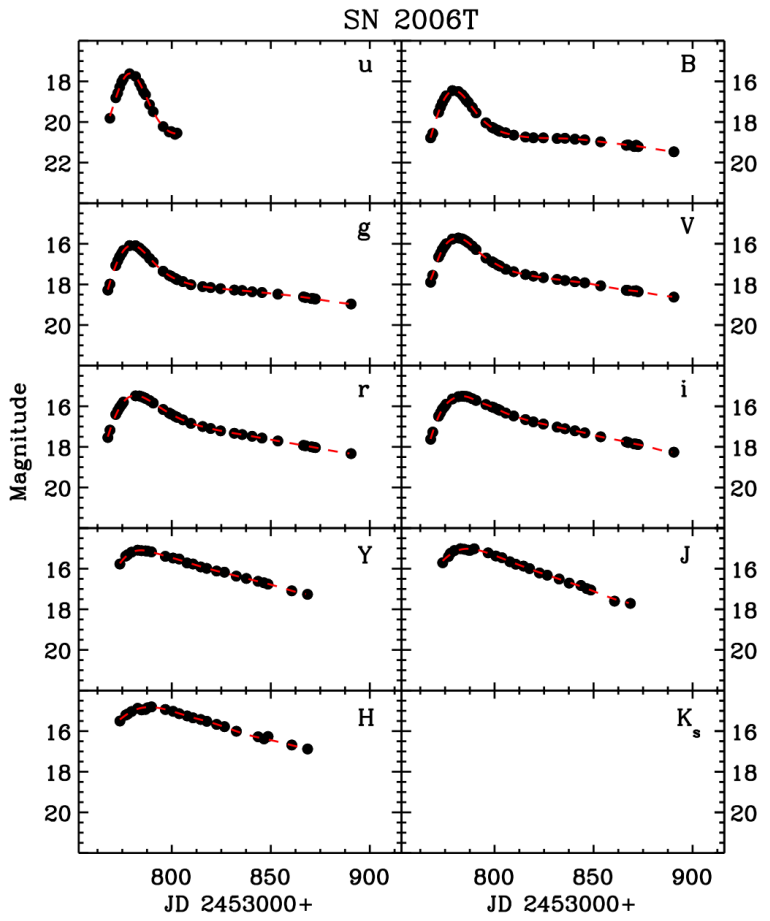
Y
J
H
K_s
Magnitude
JD 2453000+
JD 2453000+

Photometry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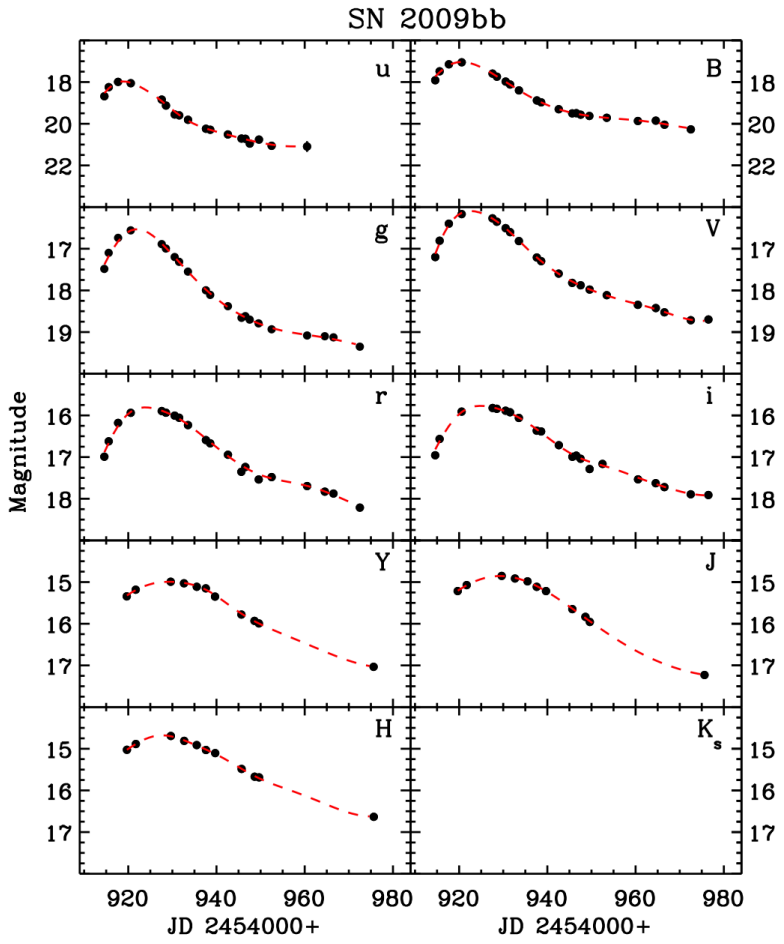
JD 2453000+


SN 2009bb
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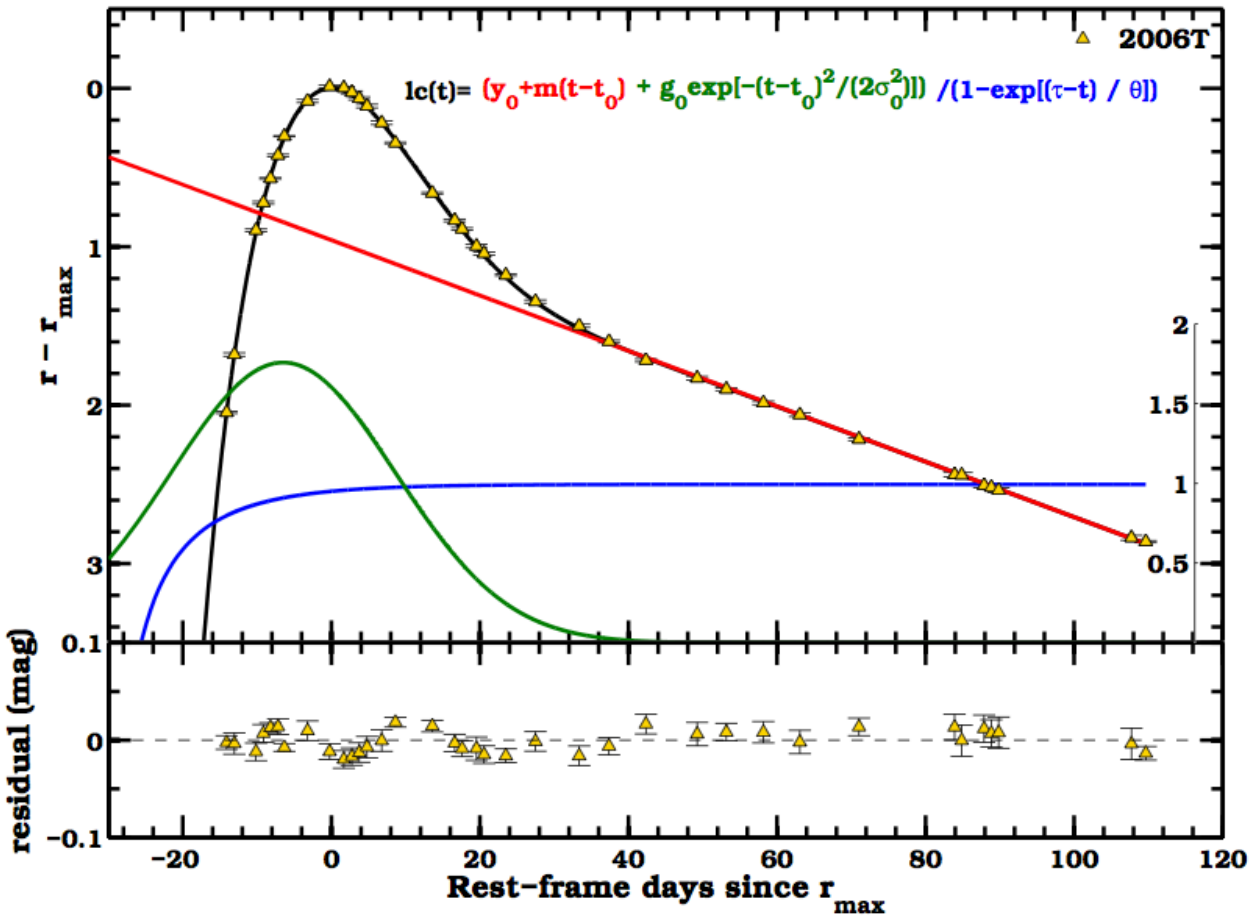
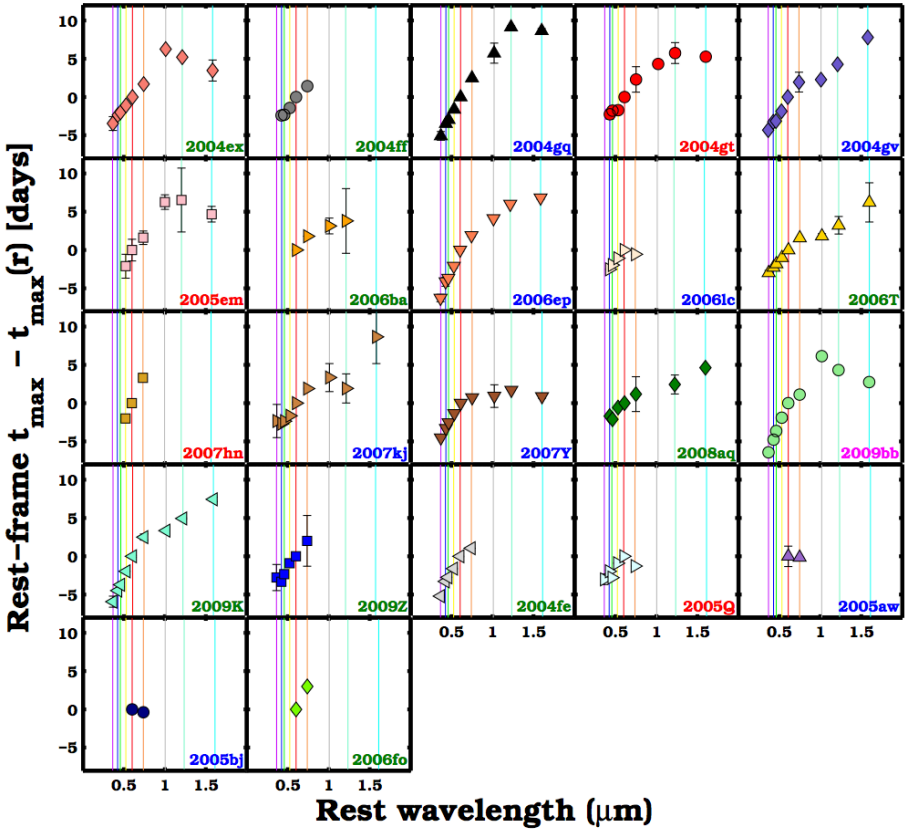
K_s
Magnitude
JD 2454000+
JD 2454000+

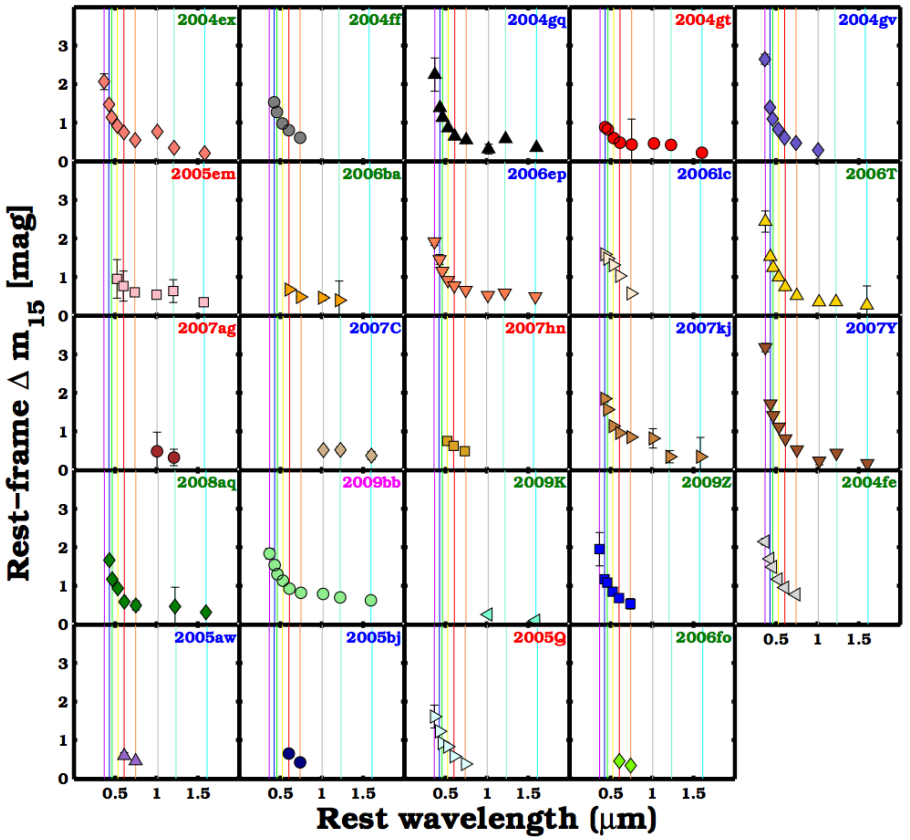
Light Curve Fits



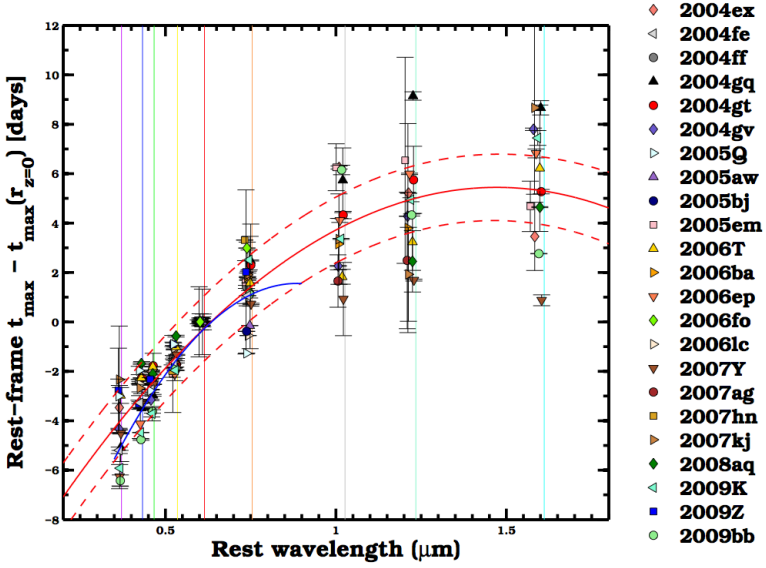
SNooPy fits give consistent parameter values

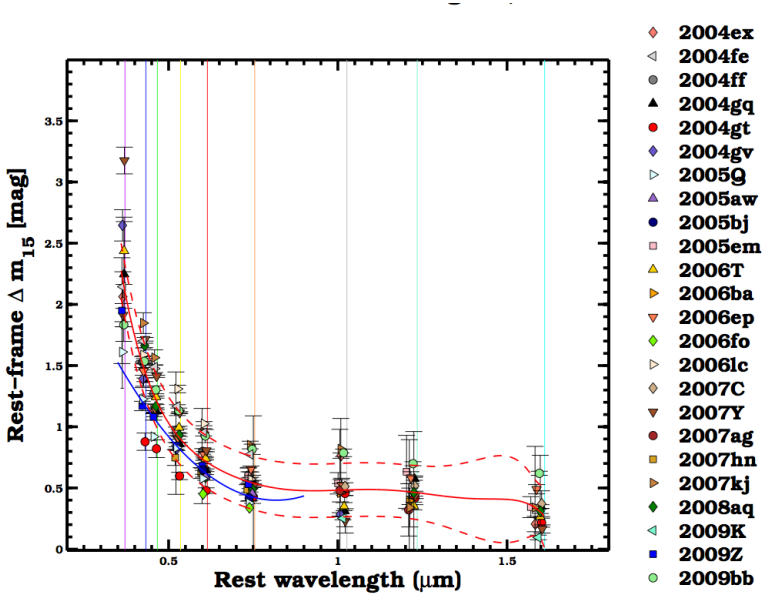
Light Curve Parameters



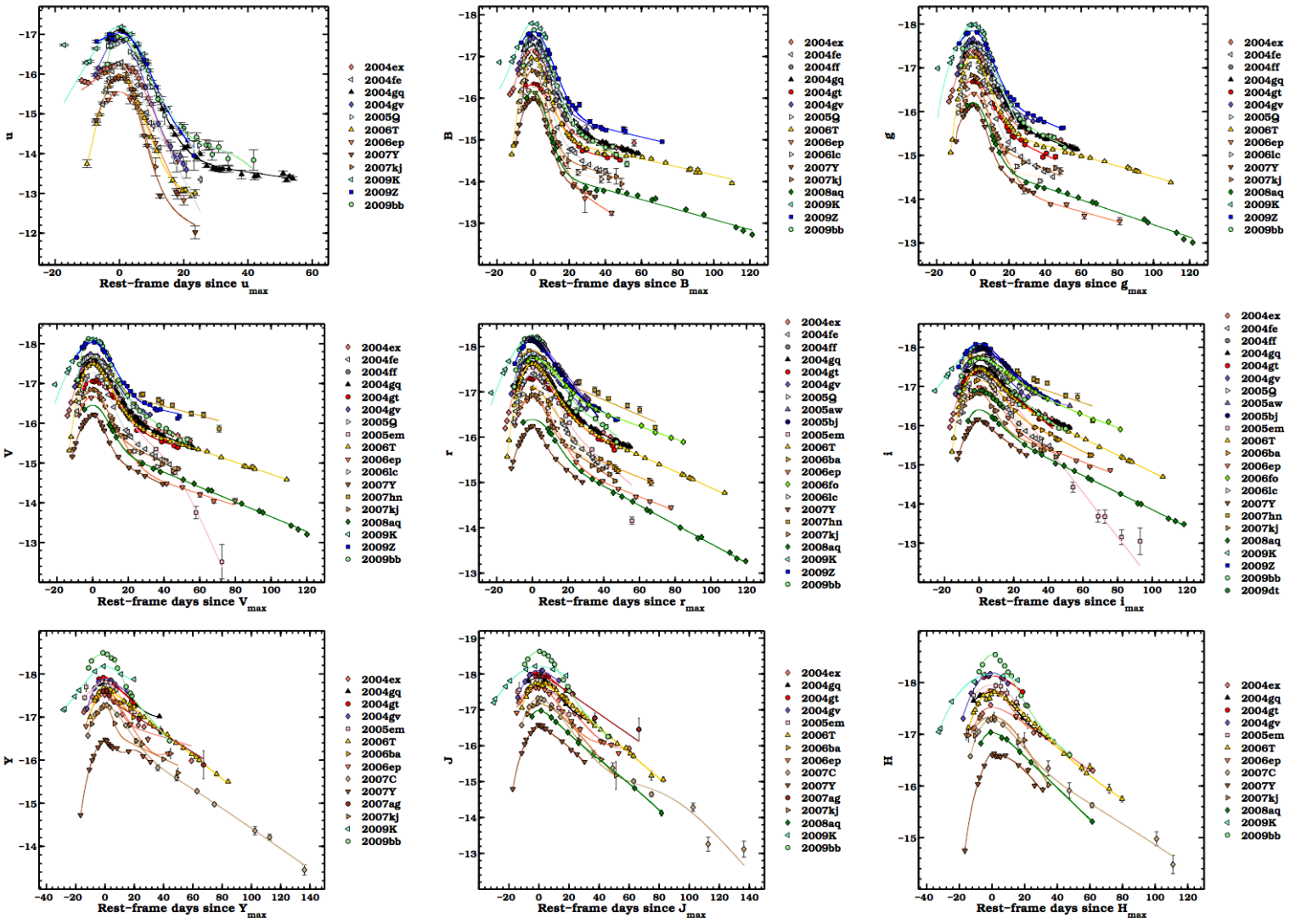


Trends Seen Within Light Curve Parameters

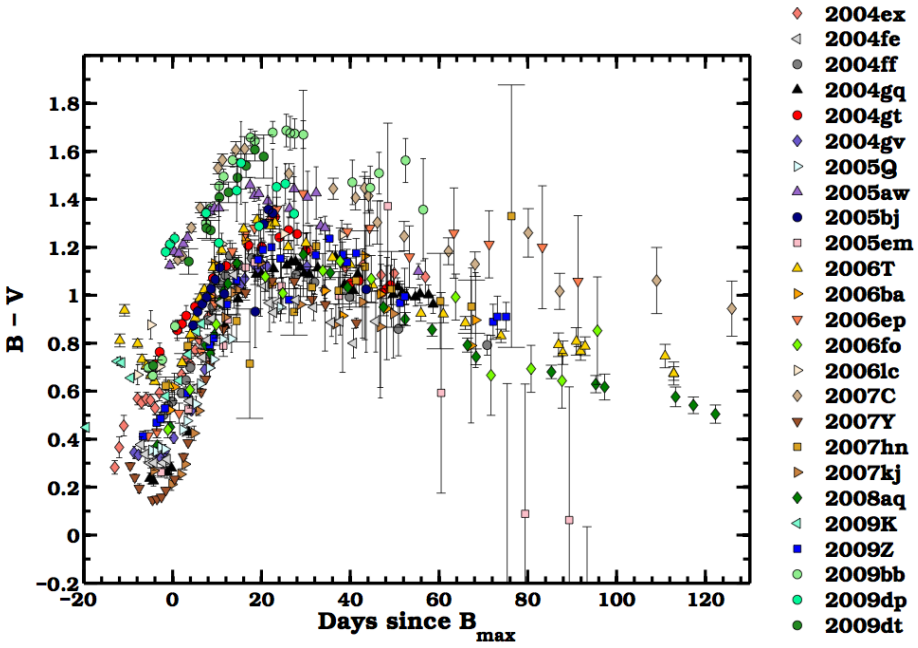


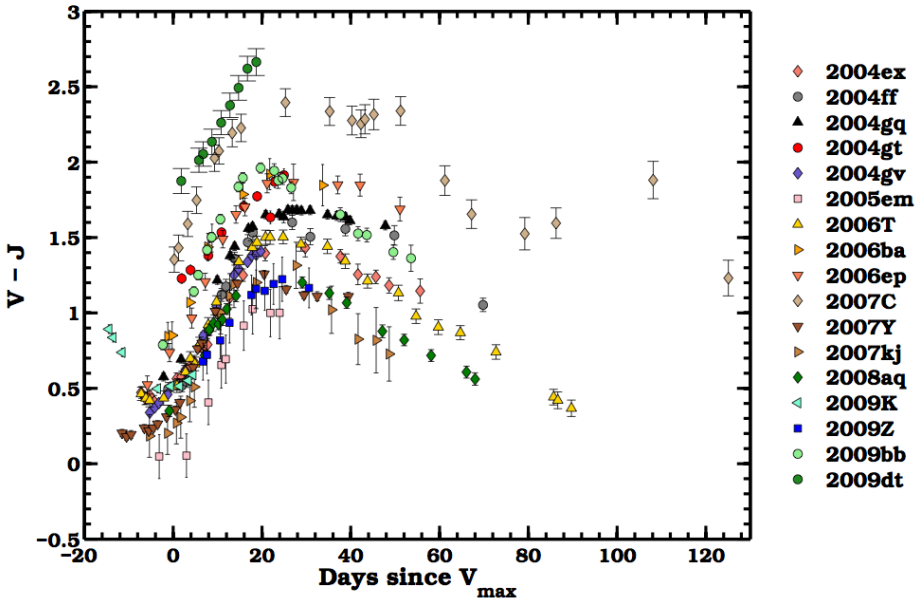


Absolute Magnitudes



Colors and Host Reddening

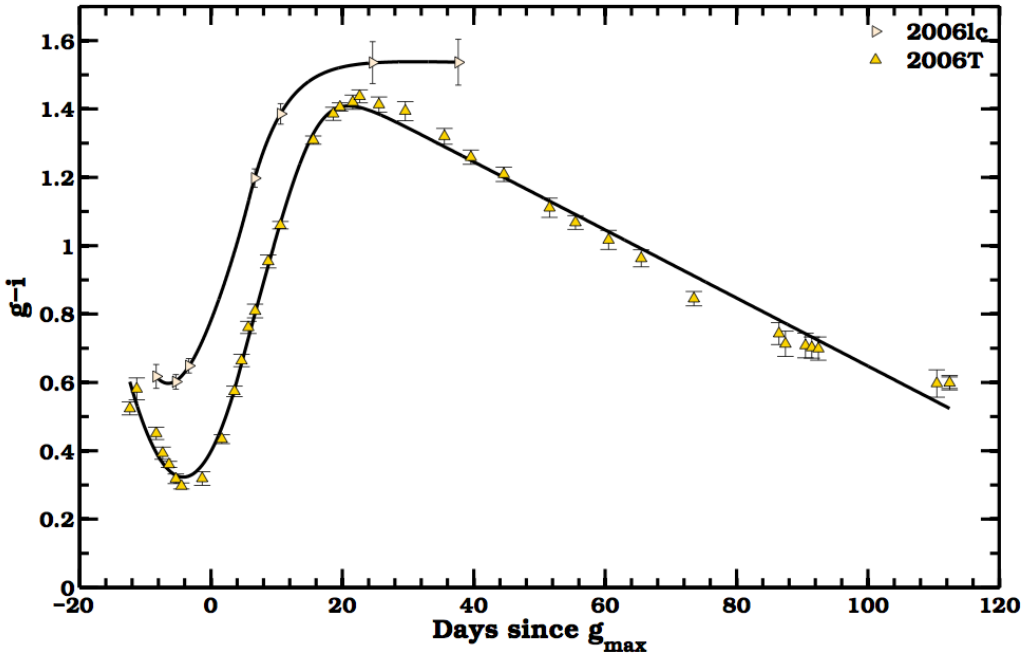




"The First Systematic Study of SNe Ib/c Multi-band Light Curves" (Drout et al. 2011), only V&R

→ With CSP sample we can look at many colors!

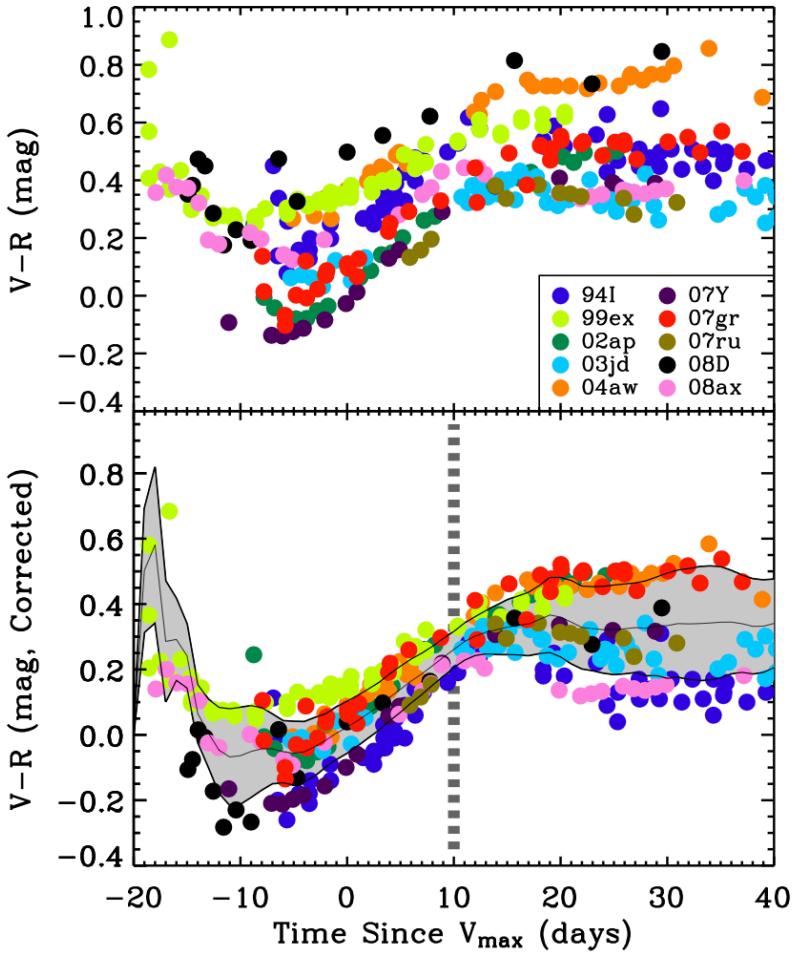
Color fit



$$color(t) = \frac{s_0 + s_1}{2} t + \frac{\tau_0}{2} (s_1 - s_0) \, ln \left[cosh \left(\frac{t - t_1}{\tau_0} \right) \right] + c + f_2(t) \tag{3}$$

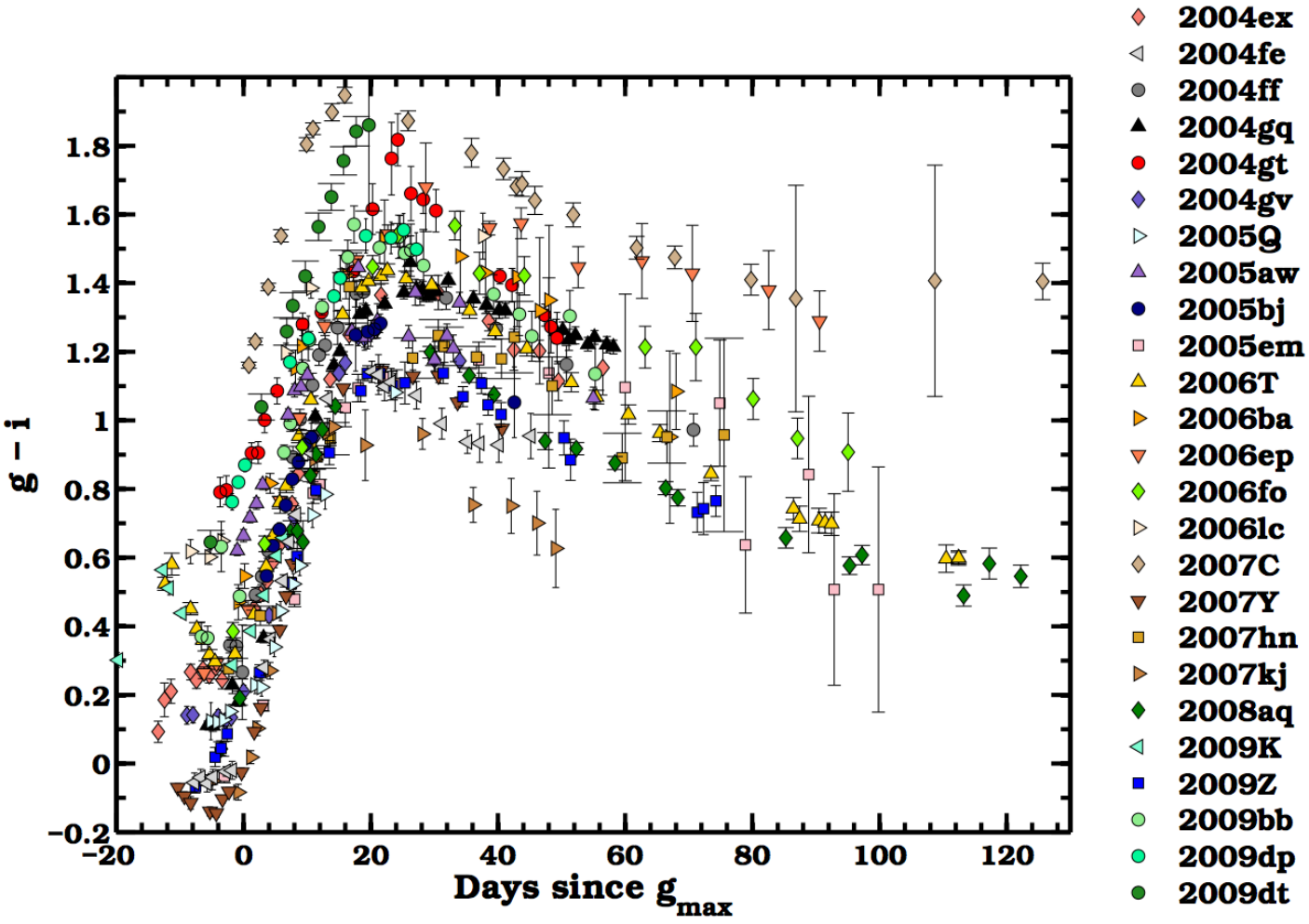
$$f_2(t) = \begin{cases} 0, & t > t_0 \\ d (t - t_0)^2, & t < t_0 \quad (C.\ Burns,\ SNe\ Ia) \end{cases} \tag{4}$$

Color excess and extinction (Drout et al. 2011)



- 10 SNe Ibc from literature
- $E(B-V)_{host}$ from Na I D
- $V-R$ color at 10 days is assumed as intrinsic color, after host extinction corrections
- The host extinction for each SN Ibc can be estimated from the color excess at 10 days

Color excess and extinction



First aim to identify an unreddened subsample

The selection of unreddened objects

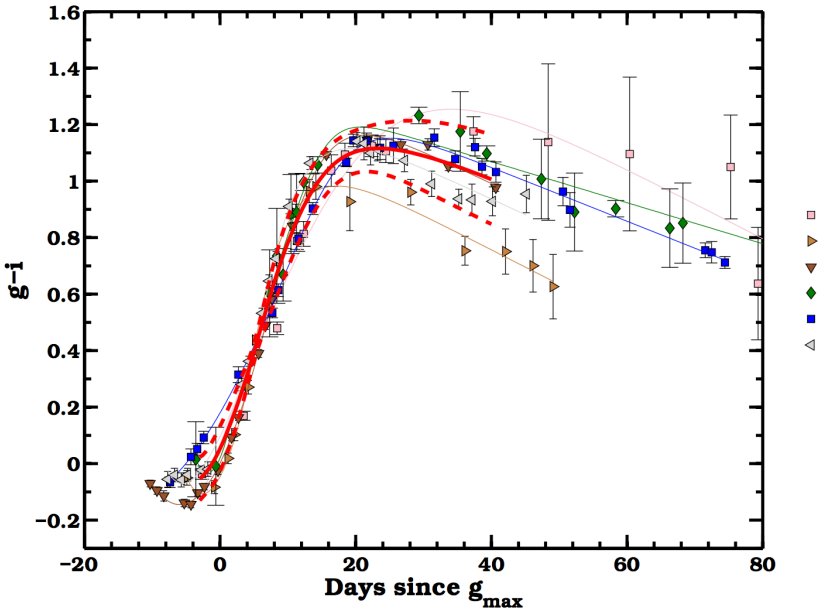
Criteria

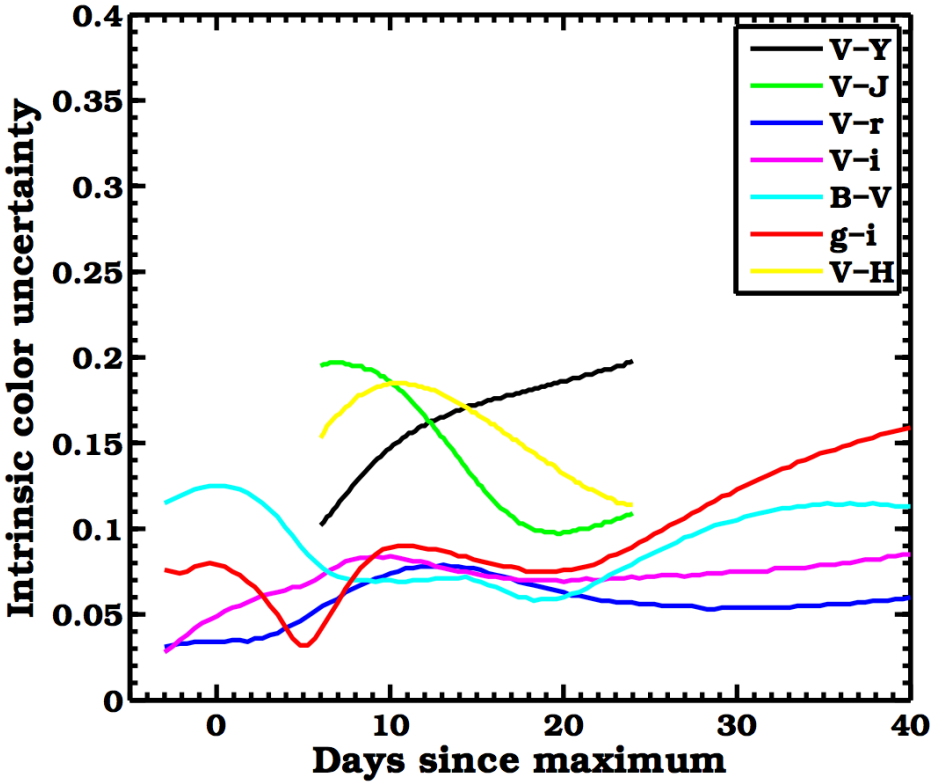
- No or negligible Na ID absorption
- Blue colors

Additional criteria

- Relatively large distance from the center of host
- Relatively small galaxy inclination

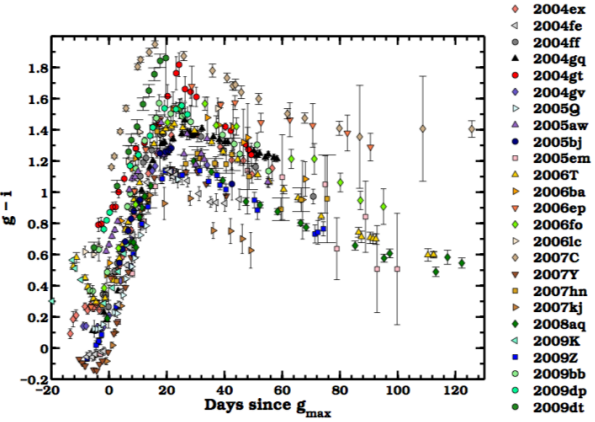
The selection of unreddened objects

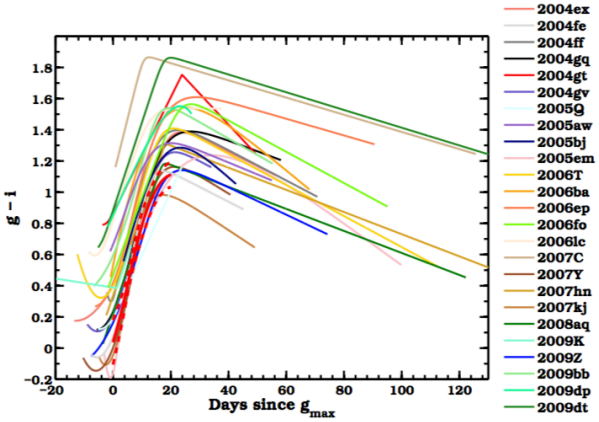


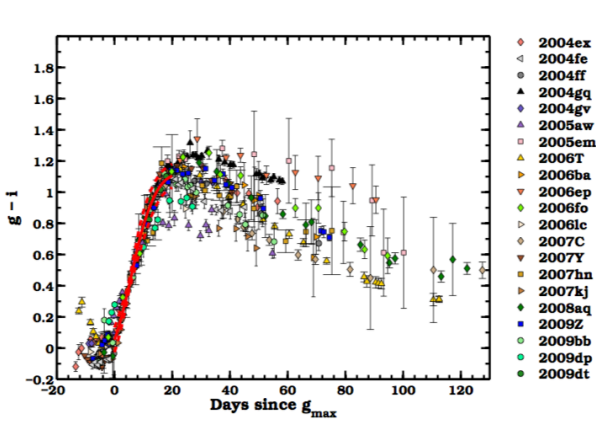


We identified 6 objects which likely suffer no to negligible extinction

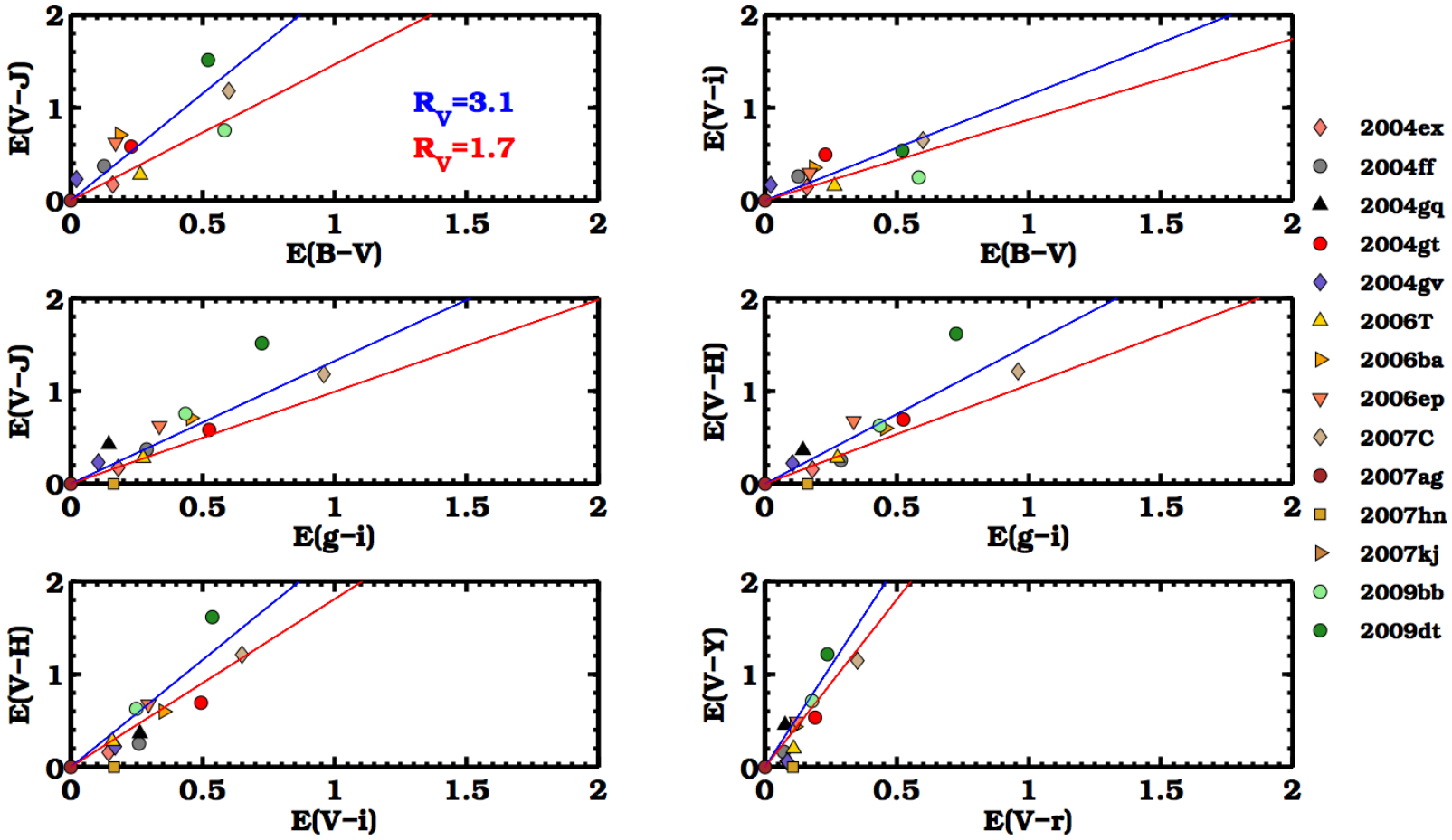
Computing Color Excesses



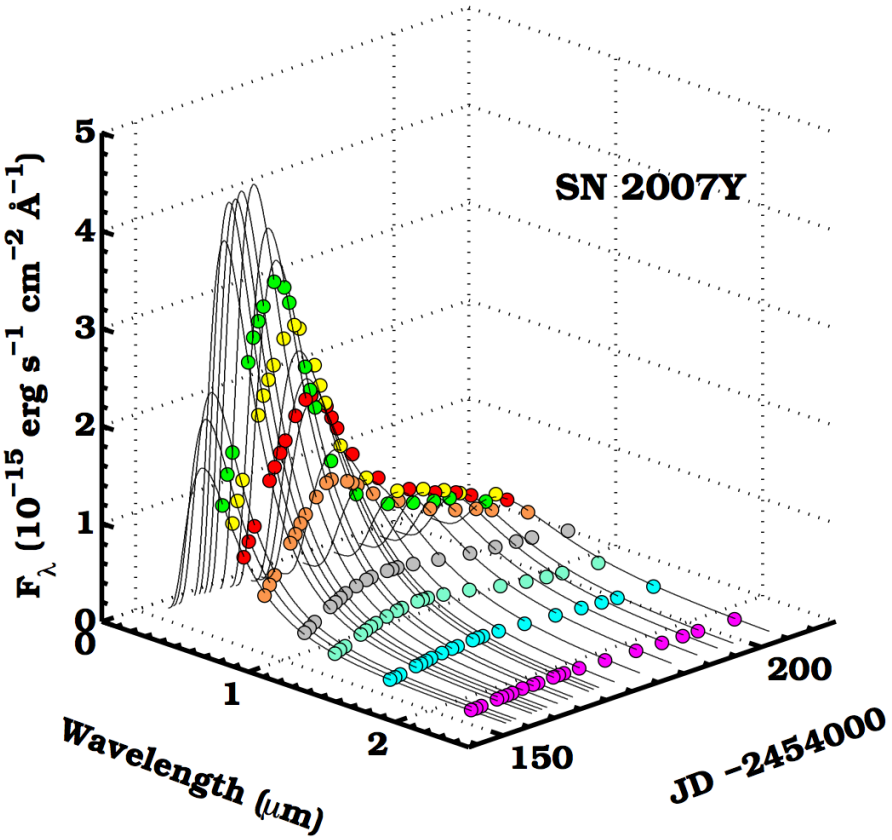


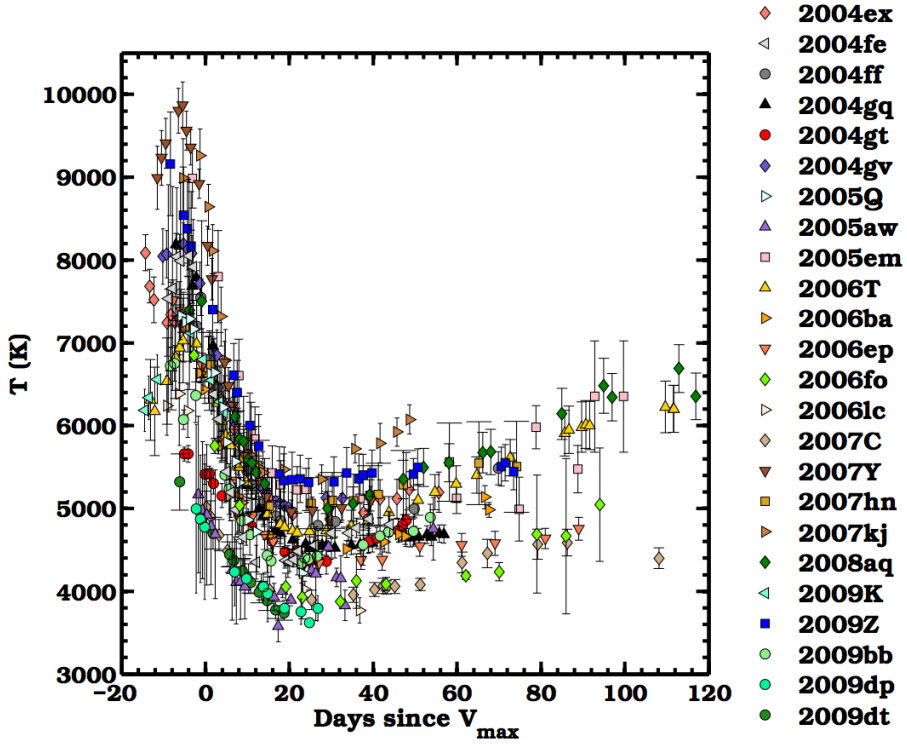


The Reddening Law

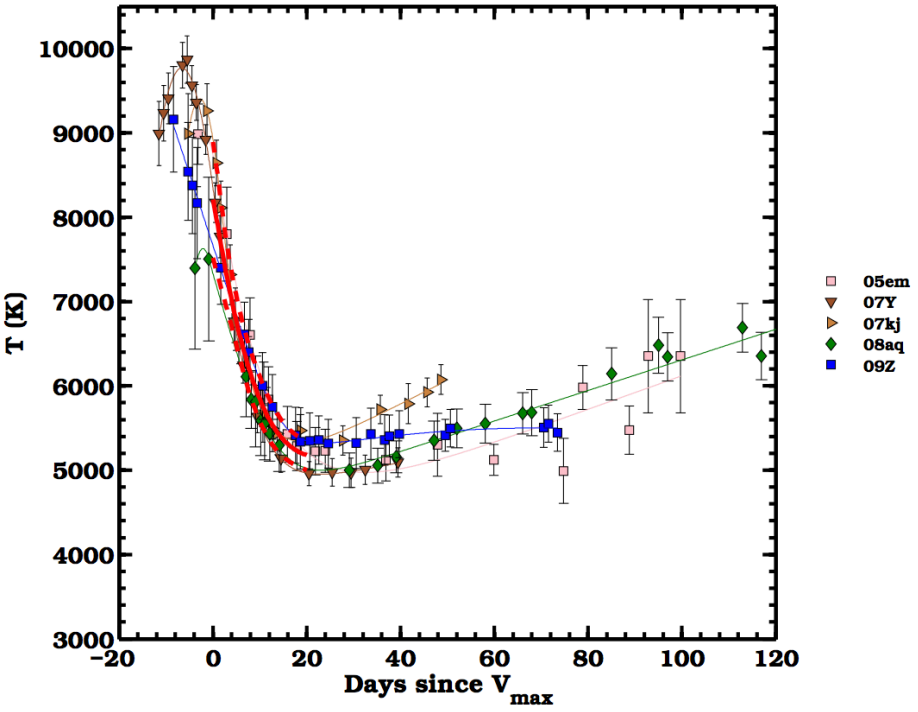


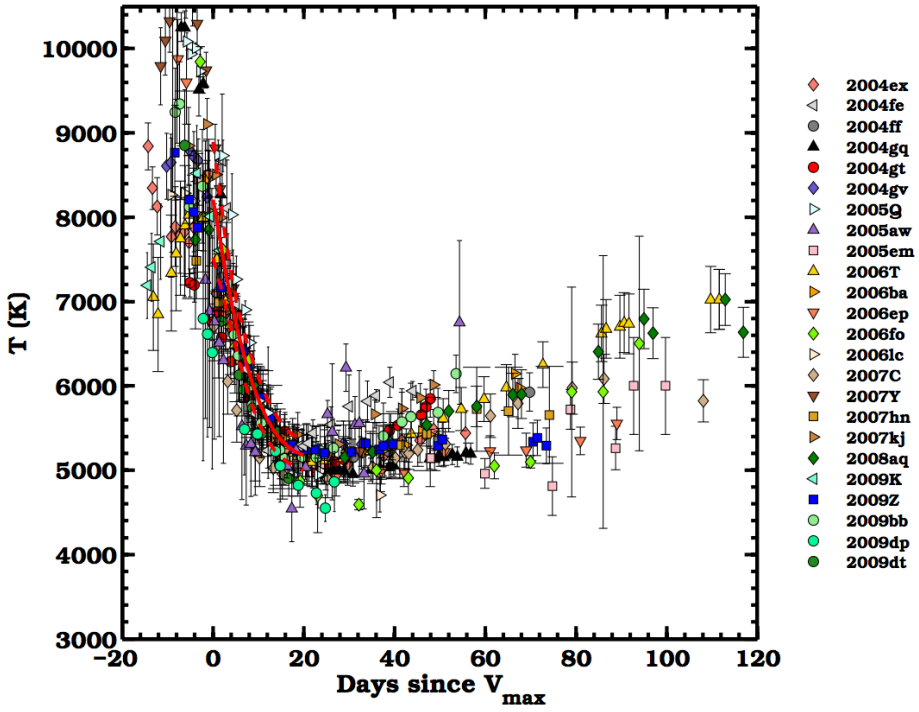
Temperature from BB fits to SEDs



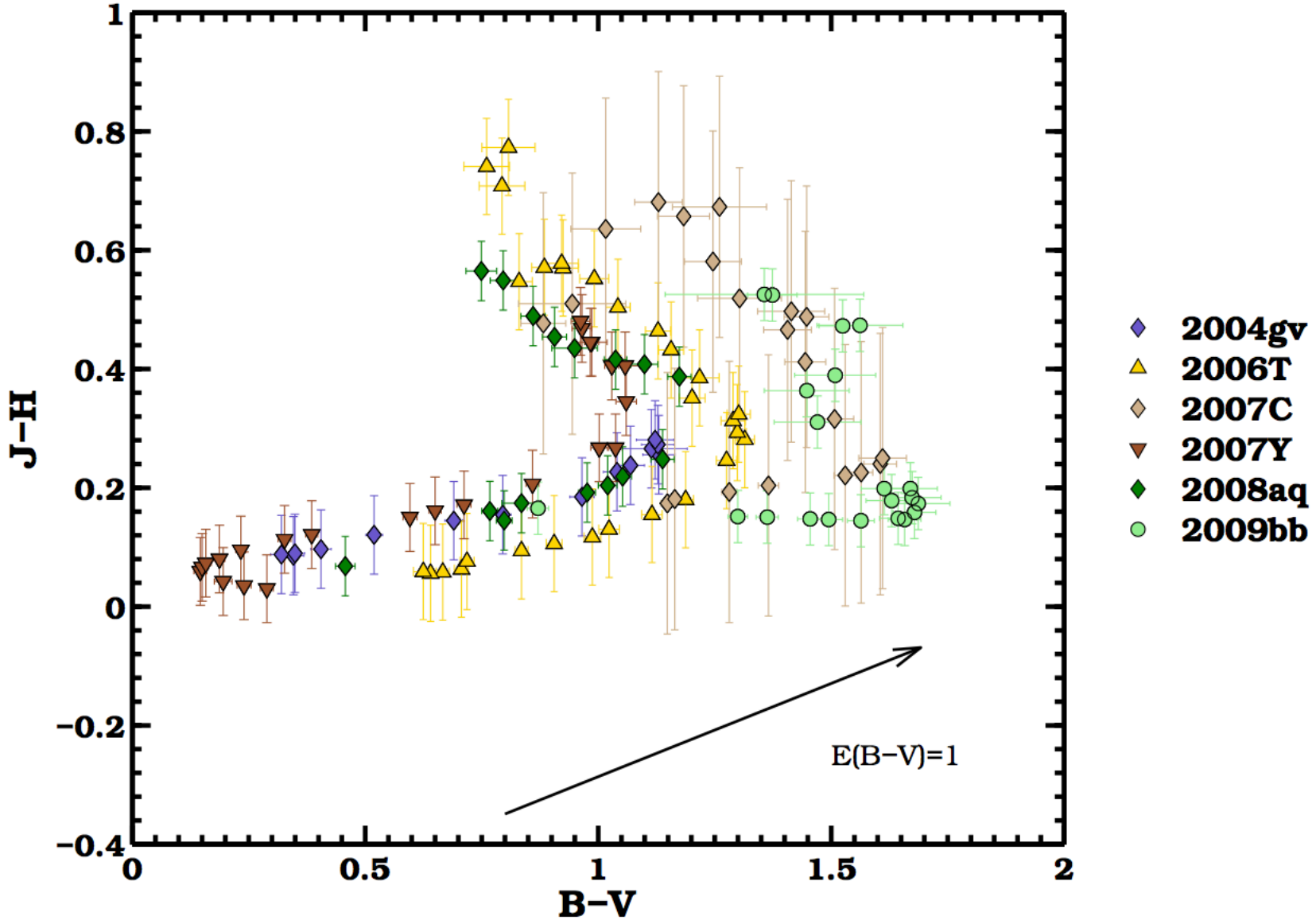


Extinction Estimates from the Temperature

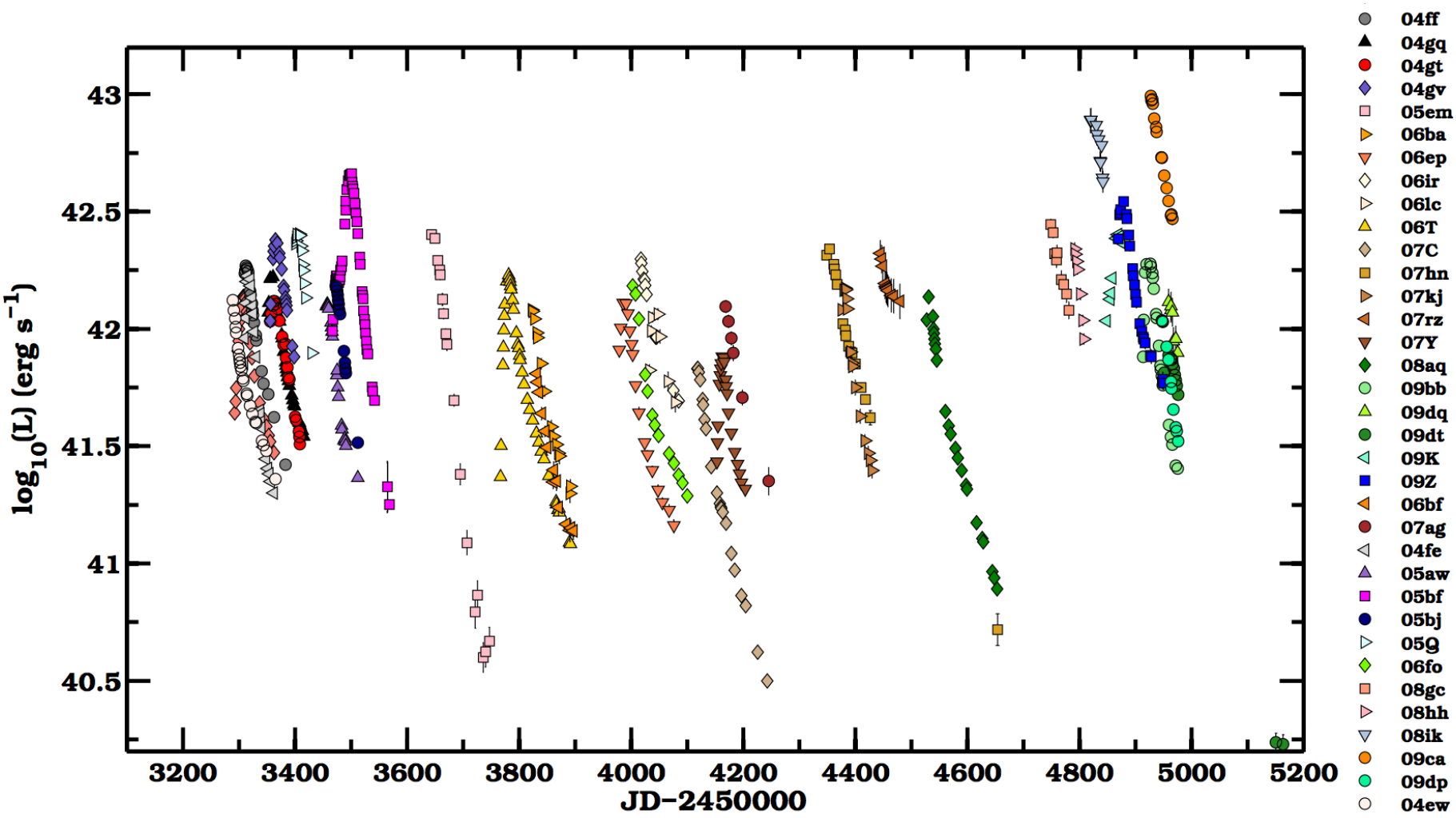




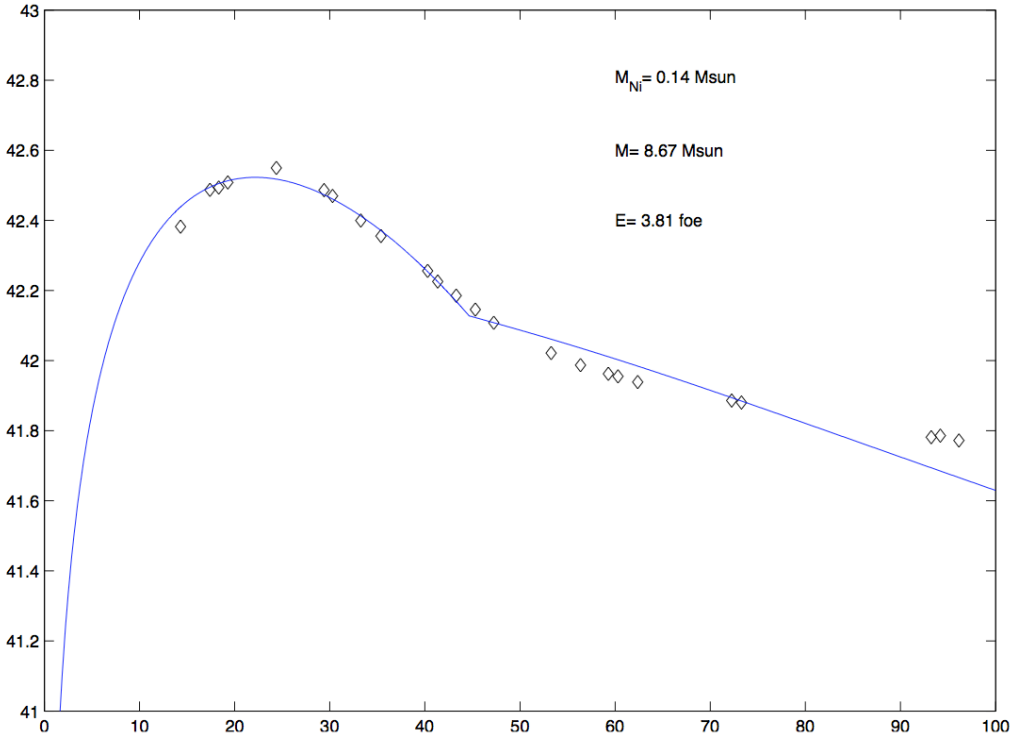
Color vs. Color Diagrams



Bolometric Light Curves

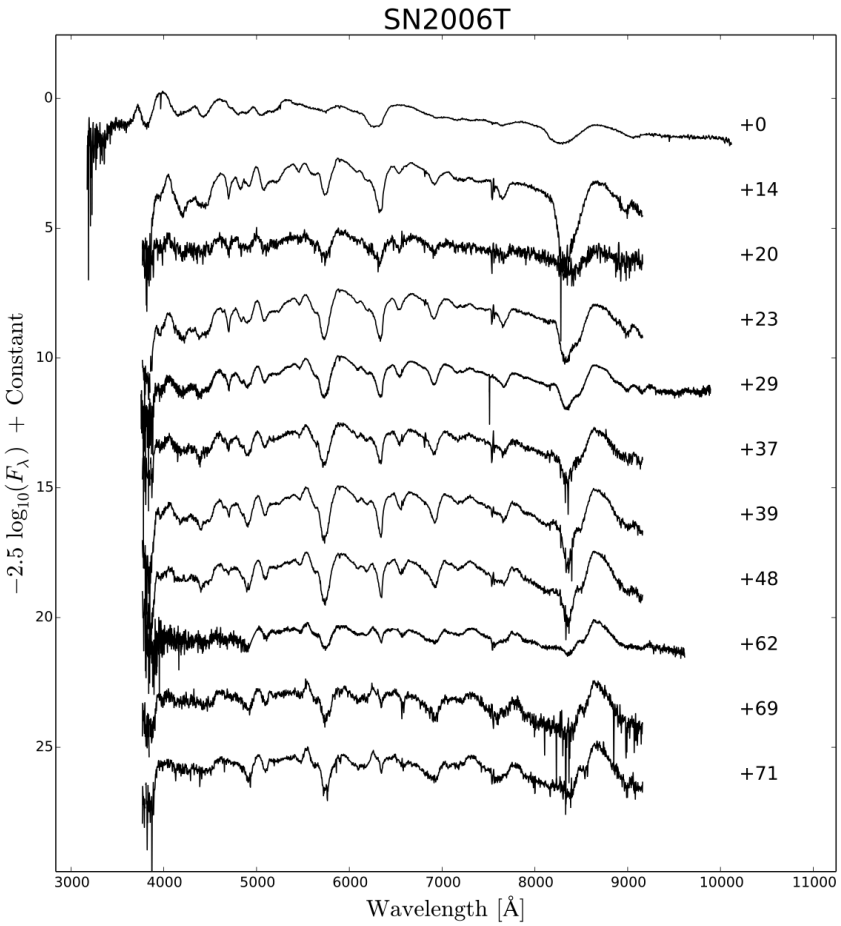


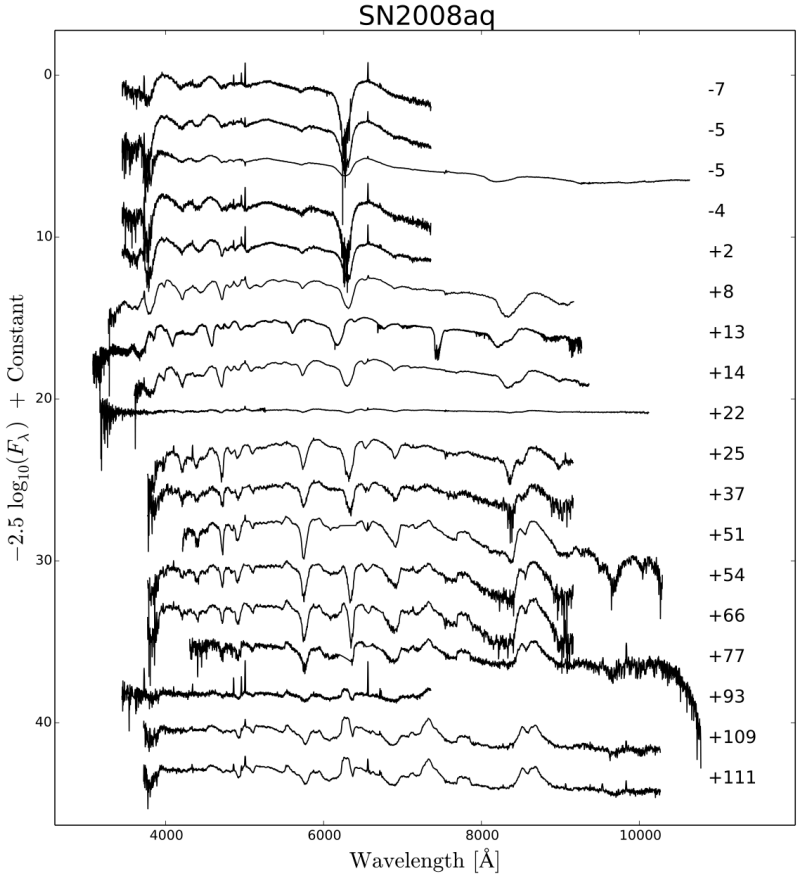
Estimate Explosion Parameters



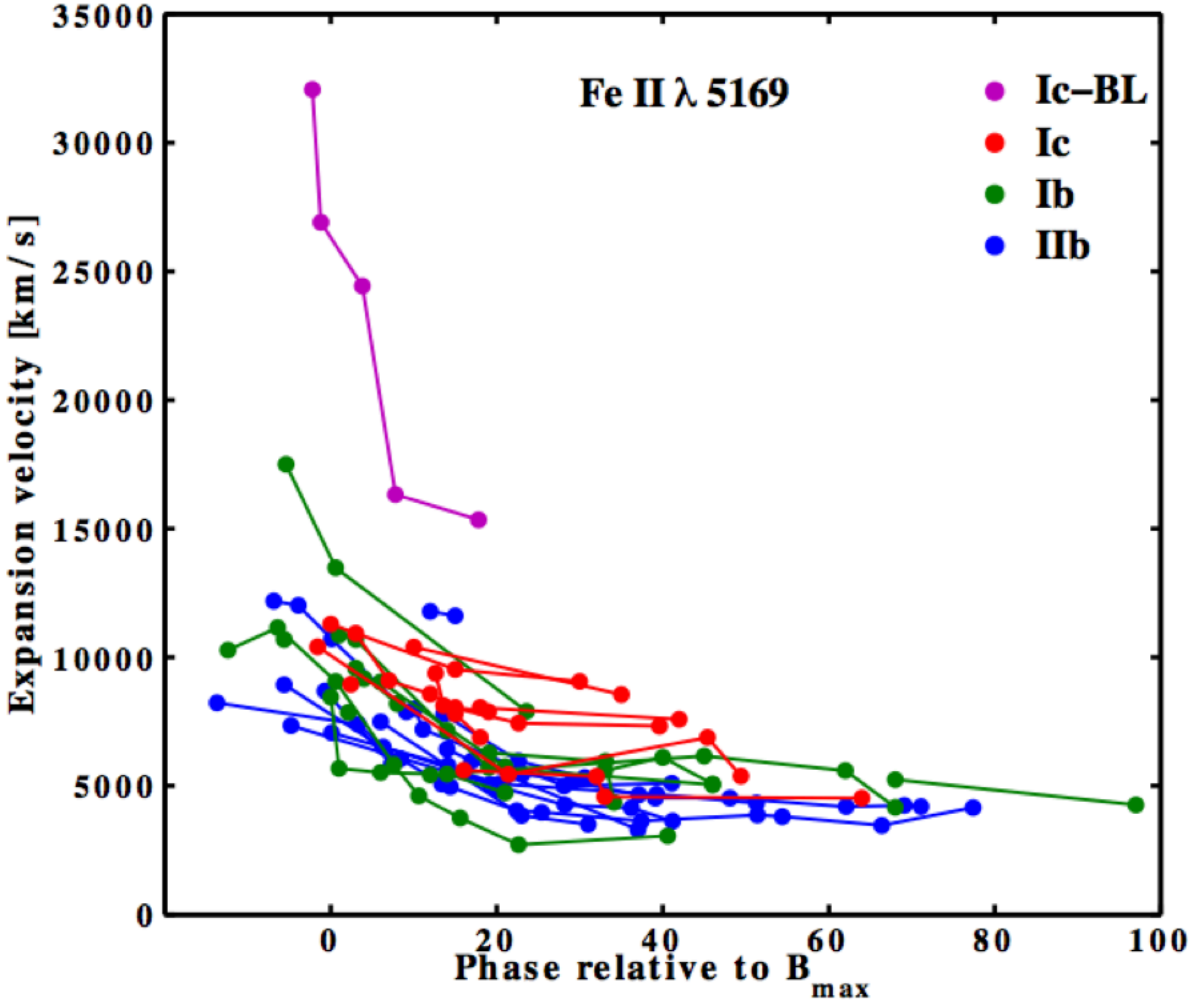
- Analytic model fits
- Hydro-code of Bersten
- Comparison of results

Visual-wavelength Spectroscopy

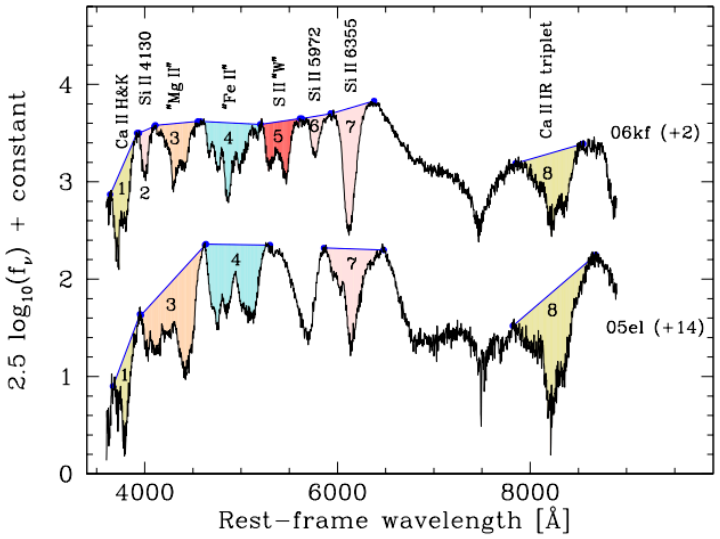


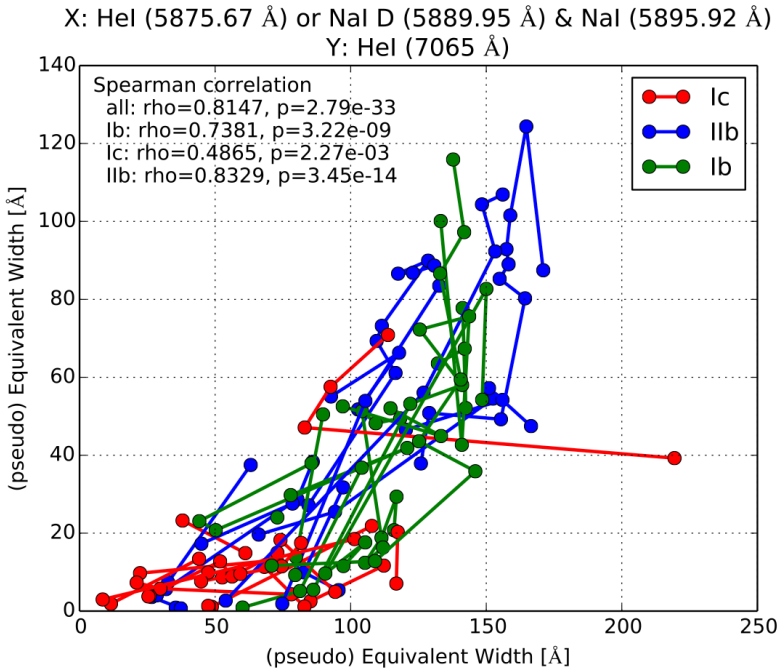


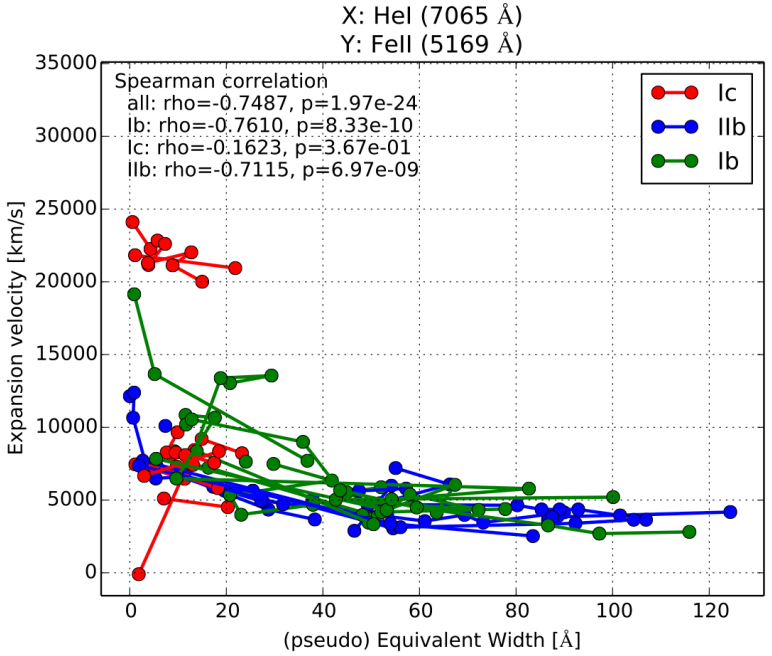
Expansion Velocities



Line width analysis



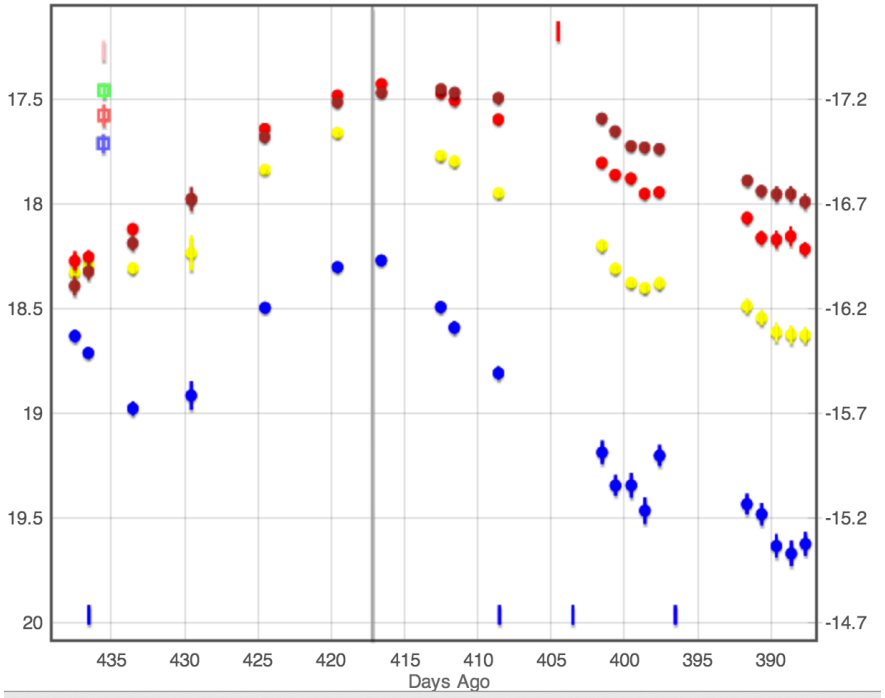


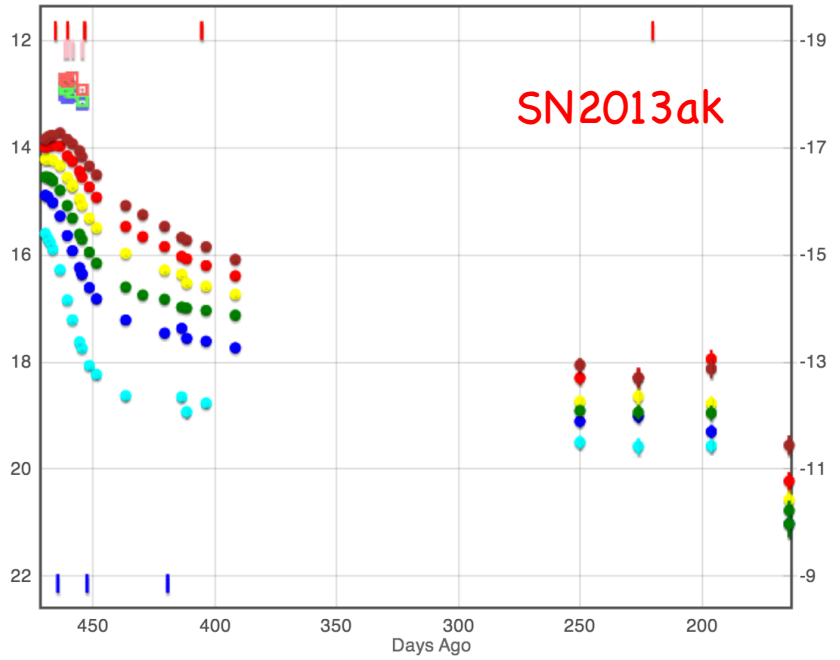


CSP-II SNe Ib/c

- Detailed optical and NIR followup (more of the former than latter) of about a dozen (SNe 11hs, 12ap, 12hf, 13ak, 13L, 14ad, 14ar, LSQ13abf, LSQ14akx, LSQ14bef)
- NIR spectroscopic followup of around half-dozen objects

- LSQ13abf as an interesting example






YURI
BELETSKY