CSPI and CSPII: Past and Future Optical and NIR Follow-up of Type Ia SNe

Chris Burns, OCIW
CSPI has finished

130 Type Ia SNe observed.

Photometry of 85 Ia’s published

Spectroscopy of 94 Ia’s any day now.
CSPI has finished

130 Type Ia SNe observed.

Photometry of 85 Ia’s published

Spectroscopy of 94 Ia’s any day now.
ugriBVYJH scanned

![Normalized Throughput vs Wavelength](image1)

![Relative Throughput](image2)
CSPII Starting its 2nd year

Number of SNe Ia vs. redshift

Number of SNe Ia vs. starting phase (d)
Lira Law
SN2005al

$t_0 = 21.03 \pm 1.82$

$t_{\text{max}} = 26.77 \pm 0.49$
The Problem with $\Delta m_{15}$
Only matters at Low-L?
A Little C-Magic

Define color stretch:

\[ s_{BV} = \frac{t [(B - V)_{\text{max}}]}{30 \text{ days}} \]
Hints in the Optical

The Carnegie Supernova Project

Mitchell Workshop, 2013
NIR Really shows it
$\Delta m_{15} > 1.7$
SNooPy2... Now with:

- GP-generated templates ($S_{BV}$ and $\Delta m_{15}$) instead of GLoEs
- Eric Hsiao seal of approval for K-corrections
- Easy-install bootstrap script for installing python environment.
- Bolometric light-curve generator.
- Soon: integration with SALT and others.
Unfortunately, sBV doesn’t fix the NIR bump.
Color Corrections

\[
\begin{align*}
R_J & = 0.97 \pm 0.00 \\
R_H & = 0.63 \pm 0.00 \\
R_I & = 2.27 \pm 0.00 \\
R_Y & = 1.31 \pm 0.00 \\
R_g & = 4.17 \pm 0.00 \\
R_r & = 2.96 \pm 0.00 \\
R_u & = 5.26 \pm 0.00 \\
R_B & = 4.51 \pm 0.00 
\end{align*}
\]
Intrinsic Colors vs. $s_{BV}$

$$R_V = \frac{A_V}{E(B-V)} \sim \frac{E(V-H)}{E(B-V)}$$

$$R_V - R_H \frac{A_V}{R_V}$$
NIR pins down $R_V$

$$E(B-V) / E(B-V) = 3$$

$$R_V = 3$$

$$R_V = 1$$
SN2007af optical + NIR

- $R_V$
- $E(B-V)$
- $A_V$
- $A_V$ vs $E(B-V)$
SN2004ef
CSP OBJECTS

The regression slope represents the population mean linear trend with \( \beta \), where \( \beta \) is the slope of the regression line. The intercept \( \alpha \) is uncertain because of the difference between individual SN and between samples, reflecting some scatter between individual SN. The intercept \( \alpha \) obtained from the MCMC samples is shown. The intercept \( \alpha \) is uncertain because of the difference between individual SN and between samples, reflecting some scatter between individual SN. In the top panel, we show the histogram of the modal \( \alpha \) values for each SN, so they can be individually distinguished. The regression slope \( \beta \) is uncertain, but consistent with the Milky Way average within 1 standard deviation. The marginal estimate of the slope is 2.9, the mode is 2.7, and the interval containing 68% of the highest probability density is [2.2, 3.6]. The marginal probability that \( \beta = 0 \) is 0.05 can be compared against the Milky Way average \( \beta = 0 \). The regression slope \( \beta \) represents the population mean linear trend with \( \beta \). The regression slope \( \beta \) is uncertain, but consistent with the Milky Way average within 1 standard deviation.
CSP OBJECTS

![Graph showing CSP objects with parameters $R_V$ and $E(B-V)$.](image_url)
Consistent $R_V$ for one host?
Polarization of SN1986G

Hough et al. 1987

\( \lambda_{\text{max}} = 0.47 \mu \)

Whittet et al. 1978

\( \lambda_{\text{max}} \) (microns) vs. \( R_V \)

\( \log_{10}[1/\lambda \text{ (microns)}] \)

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Now a few words from...

You don’t know $%^%$#
This paper
Sembach et al. (1993)

This paper
Welty & Hobbs (2001)
This paper
Friedman et al. (2008)

Milky Way

Host

Redshifted
Single/Symmetric

09ig
07sr
09le
07af
08fp
02bo
06X
86G
01el
10ev
10A
12cg

log N_{Na I} (cm^{-2})

This paper
NIR’s great, but...

✨ Reducing dispersion doesn’t get you very far. You need to reduce *systematics*
According to SNLS

**Table 3**
Detailed Summary of Systematic Uncertainties

<table>
<thead>
<tr>
<th>Source</th>
<th>$\Omega_m$</th>
<th>$w$</th>
<th>Relative Area$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statistical only</td>
<td>0.2763$^{+0.0163}_{-0.0132}$</td>
<td>$-1.0430^{+0.0543}_{-0.0546}$</td>
<td>1.0</td>
</tr>
<tr>
<td>All systematics</td>
<td>0.2736$^{+0.0186}_{-0.0145}$</td>
<td>$-1.0676^{+0.0799}_{-0.0821}$</td>
<td>1.693</td>
</tr>
<tr>
<td>All systematics, except calibration</td>
<td>0.2756$^{+0.0164}_{-0.0133}$</td>
<td>$-1.0481^{+0.0573}_{-0.0580}$</td>
<td>1.068</td>
</tr>
<tr>
<td>All systematics, except host term</td>
<td>0.2738$^{+0.0186}_{-0.0145}$</td>
<td>$-1.0644^{+0.0790}_{-0.0809}$</td>
<td>1.677</td>
</tr>
<tr>
<td>All systematics, fixing $\alpha$, $\beta^b$</td>
<td>0.2656$^{+0.0179}_{-0.0144}$</td>
<td>$-1.1168^{+0.0807}_{-0.0824}$</td>
<td>1.641</td>
</tr>
</tbody>
</table>

**Contribution of different systematics**

<table>
<thead>
<tr>
<th>Source</th>
<th>$\Omega_m$</th>
<th>$w$</th>
<th>Relative Area$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calibration</td>
<td>0.2750$^{+0.0185}_{-0.0150}$</td>
<td>$-1.0581^{+0.0774}_{-0.0791}$</td>
<td>1.614</td>
</tr>
<tr>
<td>SN Ia model</td>
<td>0.2767$^{+0.0163}_{-0.0132}$</td>
<td>$-1.0403^{+0.0543}_{-0.0547}$</td>
<td>1.013</td>
</tr>
<tr>
<td>Peculiar velocities</td>
<td>0.2761$^{+0.0162}_{-0.0132}$</td>
<td>$-1.0452^{+0.0548}_{-0.0548}$</td>
<td>1.002</td>
</tr>
<tr>
<td>Malmquist bias</td>
<td>0.2758$^{+0.0163}_{-0.0132}$</td>
<td>$-1.0474^{+0.0548}_{-0.0553}$</td>
<td>1.014</td>
</tr>
<tr>
<td>Non-SN Ia contamination</td>
<td>0.2763$^{+0.0163}_{-0.0132}$</td>
<td>$-1.0430^{+0.0543}_{-0.0546}$</td>
<td>1.000</td>
</tr>
<tr>
<td>Milky Way extinction</td>
<td>0.2762$^{+0.0164}_{-0.0133}$</td>
<td>$-1.0441^{+0.0553}_{-0.0557}$</td>
<td>1.023</td>
</tr>
<tr>
<td>SN redshift evolution</td>
<td>0.2763$^{+0.0163}_{-0.0132}$</td>
<td>$-1.0408^{+0.0544}_{-0.0547}$</td>
<td>1.017</td>
</tr>
<tr>
<td>Host galaxy term</td>
<td>0.2762$^{+0.0163}_{-0.0132}$</td>
<td>$-1.0453^{+0.0556}_{-0.0562}$</td>
<td>1.029</td>
</tr>
</tbody>
</table>

Sullivan et al., 2011

Mitchell Workshop, 2013
NIR’s great, but...

- Reducing dispersion doesn’t get you very far. You need to reduce *systematics*.
- Dust is not the biggest systematic; calibration is. But working in the NIR has a big payoff...
Effects of a zero-point offsets between low and high-z
How well can we calibrate ground-based NIR?

See Blake & Shaw (2011)