SNfactory: a spectrophotometric dataset for cosmology

E. Gangler
For the SNFactory

Type Ia Supernova

➢ Great standard candles
  ➢ Bright $M_B \approx -19.5$
  ➢ Low Intrinsic dispersion 0.40 mag
  ➢ Empiric standardization (SALT2/MLCS2k2)
    ➢ Intrinsic (stretch) 0.15
    ➢ Color (intrinsic or reddening ?) 0.35
    ➢ Residual 0.15
Why nearby SNe / Why Spectroscopy

- Anchoring hubble diagramm at low $z$
  - Measure of nuisance parameter $L_0 H_0^2$
- Addressing systematics
  - Reference Model
  - K- and S-corrections
  - Subclassing SNe
  - Homogeneous set: selection bias control
  - Intercalibration with high-z sample
- And also
  - SNIa physics constraints

$\textbf{SpectroPhotometry}$
Nearby Supernova Factory

1. Discover

- Palomar Nightly

2. Observe

- NERSC
  - Ref
  - New
  - New-Ref
  - \( \approx 10^{-7} \) of the area observed per night

3. Analyze

- SNIFS UH 2.2-m
  - Every 2-3 nights
  - Custom, unique spectrometer designed for nearby SN obs

Stephen Bailey

Moriond 2010
The sample so far

Palomar/QUEST search over in 2008
Run over in 2009
SNF2 starting 2010 (under discussion)

<table>
<thead>
<tr>
<th></th>
<th>SNfactory</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>All typed SN</td>
<td>624</td>
<td>71</td>
<td>695</td>
</tr>
<tr>
<td>SN Ia</td>
<td>396</td>
<td>50</td>
<td>446</td>
</tr>
<tr>
<td>Follow-up (&gt;5 spec)</td>
<td>147</td>
<td>38</td>
<td>190</td>
</tr>
<tr>
<td>Processed</td>
<td>62</td>
<td>12</td>
<td>74 (101)</td>
</tr>
<tr>
<td>Spec @ max</td>
<td>49</td>
<td>9</td>
<td>58</td>
</tr>
</tbody>
</table>
SNIFS instrument principle

Photometric channel

IFU : 15x15=225 spectra

MLA : 2 channels
0.32 – 0.54 µm @ 2.4 Å
0.54 – 1.0 µm @ 2.9 Å
6"x6" FOV @ 0.4"/spax

Sky + galaxy

SN + sky + galaxy

Sky

Reconstructed SN

Observations every 2-3 days : Spectral time series
## Calibration status

**Per-night atmospheric model**

Specific treatment of telluric lines

Per-object grey extinction

### Validation on faint Standard stars

<table>
<thead>
<tr>
<th>Color</th>
<th>U-B</th>
<th>B-V</th>
<th>V-R</th>
<th>R-I</th>
</tr>
</thead>
<tbody>
<tr>
<td>nMAD</td>
<td>1.9%</td>
<td>1.1%</td>
<td>0.6%</td>
<td>0.8%</td>
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</tbody>
</table>

### Ongoing work:

- Standard star network
- Intercalibration with SNLS tertiaries

### Photo, Non-photo, Total nMAD

<table>
<thead>
<tr>
<th>Photo</th>
<th>Non-photo</th>
<th>Total</th>
<th>U-band</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.7%</td>
<td>3.2%</td>
<td>2.5%</td>
<td>3.2%</td>
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</tbody>
</table>
Galactic subtraction

- Ongoing work: Galactic model & subtraction
- Current production: galactic background as tilted plane
  Validation / light curve fit

<table>
<thead>
<tr>
<th></th>
<th>Photo</th>
<th>Non-photo</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Std error</td>
<td>5.8 %</td>
<td>6.1 %</td>
<td>6.0%</td>
</tr>
</tbody>
</table>
Photometric-like analysis

Integration on custom Square filters:
Minimal loss of flux
No band overlap
Photometric-like analysis

Fit to SALT2 model (Guy 07): SN parameters $x_1$ & $c$

$X_1$ (intrinsic luminosity)

SNfactory preliminary vs. Hicken (09)
Hubble diagram residuals

\[ \mu = m^*_B - M + \alpha x1 - \beta c \]

We can do better:
• K-correction less analysis (ongoing work)

\begin{align*}
\sigma &= 0.41 \text{ mag} \\
\sigma &= 0.161 \text{ mag}
\end{align*}
New variable: $R_{642/443}$

Using flux ratios as standardization indicators

$$R_{x/y} = \frac{F_x}{F_y}$$

Find the ratio mostly correlated to Hubble diagramm residuals

- Search on training sample
- Confirmation on validation sample

Corrected by $R_{642/443}$

$\sigma = 0.128$ mag

Bailey et al. (09) A&A 500L 17B.
Determining dust/color properties!

\[ R_V = \frac{A_V}{E(B - V)} \]

Rv : parameter characterizing dust properties
E(B-V) : color excess/dust-free signal

From SALT2 (Guy 07): \( \beta=1.8 \) ('\( R_v=0.8 \)')
From MLCS2k2 (Hicken 09): \( R_v=1.7 \)
From Galaxy measurement : \( R_v=3.1 \)

Difficulties :
• SN intrinsic color
• Dust-free reference observations

➢ Determine intrinsic
➢ Determine absorption in B,V
➢ Fit for Rv
EW (Si II 4130) as an intrinsic luminosity indicator

\[ EW = \int_{\lambda_1}^{\lambda_2} \frac{F_C(\lambda) - F(\lambda)}{F_C(\lambda)} d\lambda \]

EW insensitive to dust

No correlation with color
Strong correlation with $x_1$ and with Hubble residuals

**Color cut**

<table>
<thead>
<tr>
<th>Correction</th>
<th>None</th>
<th>$c &amp; x_1$</th>
<th>$c &amp; EWSill 4000$</th>
<th>None</th>
<th>$c &amp; x_1$</th>
<th>$c &amp; EWSill 4000$</th>
</tr>
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<tbody>
<tr>
<td>RMS</td>
<td>0.406</td>
<td><strong>0.161</strong></td>
<td><strong>0.164</strong></td>
<td>0.217</td>
<td><strong>0.153</strong></td>
<td><strong>0.123</strong></td>
</tr>
<tr>
<td>nMAD</td>
<td>0.264</td>
<td>0.159</td>
<td>0.177</td>
<td>0.243</td>
<td>0.139</td>
<td>0.148</td>
</tr>
</tbody>
</table>

*Standard deviation and normalized median absolute deviation.*
Derivation of Cardelli parameter $R_V$

- **Model-independent $B', V', R'$**:
  - Synthetic filter
  - Interpolation at max (SALT2 shape)

- Compare Hubble residuals to intrinsic (EW)
  → Extract Reddening

\[
\delta A_B = \Delta M_B - I_B(\text{EW}) + \epsilon_B
\]
Testing the color effect on Hubble diagram

$\frac{\partial A_B}{\partial A_V}$ allows to determine $R_V \approx 3.0 \pm 0.4 \pm$ syst...

Additional color dispersion 0.04 mag

Robust on B, V, R bands
Robust vs. choice of intrinsic

Compatible with Galaxy value.
Compatible with Hubble residuals

Mag dispersion 0.17 mag
or
Color dispersion 0.05 mag
Conclusion

➢ A wealth of data ready for science analysis
➢ Hubble diagram dispersion already competitive
➢ 0.13 mag dispersion achieved
➢ Color measurement compatible with Rv=3.1
➢ Cosmology fit under way

Case study: SN2007if
Astro-ph 1003.2217
SN2007if

Super-chandrasekhar!

$$M = 2.4 \pm 0.2M_\odot$$