Cosmology with Unusually Bright Supernovae

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Absolute Magnitude Distributions of Supernovae

Data from LOSS (Li et al. 2011)
SN 2005ap

- Spectroscopic redshift \( z = 0.283 \)
- Peak absolute magnitude brighter than -22 (unfiltered)
SN 2006gy

- Peak absolute magnitude nearly -22
- Brighter than -21 mag for ~100 days
- Integrated light >10^{51} erg
SLSN Spectra

The graph compares the luminosity density of different types of supernovae (SLSN) relative to a Type Ia supernova at 2400 A. The x-axis represents the rest wavelength (Å), and the y-axis shows the luminosity density. The graph includes four lines:

- **SLSN-II (x10)**: A line representing SLSN-II, scaled by a factor of 10.
- **SLSN-I**: A line representing SLSN-I.
- **Type Ia**: A line representing Type Ia supernovae.
- **Type II**: A line representing Type II supernovae.

Vertical bars indicate differences in brightness, with one bar showing 1000 times brighter and another showing 100 times brighter.
SLSN Light Curves
unfiltered optical (ROTSE-IIIb) magnitudes
SLSNe Peak Magnitude Distributions (pseudo-absolute)
Local SLSN Rates

(based on ROTSE-IIIb sample)

**SLSN-I**

32\(^{+77}_{-26}\) events/Gpc\(^3\)/yr

(z~0.17)

**SLSN-II**

151\(^{+151}_{-82}\) events/Gpc\(^3\)/yr

(z~0.15)

All SLSN-like events

199\(^{+137}_{-86}\) events/Gpc\(^3\)/yr

(z~0.16)

Compare to CCSN: \(~10^5\) events/Gpc\(^3\)/yr and SNIa: \(~3\times10^4\) events/Gpc\(^3\)/yr
A novel approach, a Dense Shell Method, is proposed for measuring distances for cosmology. It is based on original Baade idea to relate absolute difference of photospheric radii with photospheric velocity. We demonstrate that this idea works: the new method does not rely on the Cosmic Distance Ladder and gives satisfactory results for the most luminous Type II In Supernovae. This allows one to make them good primary distance indicators for cosmology. Fixing correction factors for illustration, we obtain with this method the median distance of $68^{+19}_{-15}$ (68% CL) Mpc to SN 2006gy and median Hubble parameter $79^{+23}_{-17}$ (68% CL) km/(s Mpc).
Can SLSNe-I be Turned Into Standardizable Candles?

Hatano et al. (1999)
Other ways to use SLSNe as probes 1

SN 2005ap
$z = 0.238$

PS1-11bam
$z = 1.566$

Berger et al. (2012)
Other ways to use SLSNe as probes II

Cosmic SFR

CCSNe

SLSNe

\[ R_{SN}(z) = \rho_\ast(z) \frac{\int_{M_{\text{min}}}^{M_{\text{max}}} \psi(M) \, dM}{\int_{0.1}^{100} M \psi(M) \, dM} \]

see Masaomi Tanaka et al. (2012)
Contamination
PS1-10afx

Chornock et al. (2013)
PS1-10afx Spectra
Gold Standard

HST04Sas.................. 53,156.2 (+1) HST ACS 1.39\textsuperscript{a,b}

\begin{itemize}
  \item \textsuperscript{a} From cross-correlation with broad SN features.
  \item \textsuperscript{b} Classified as SN Ia with high confidence from spectrum.
\end{itemize}

Riess et al. (2007)
Rest Frame UV Light Curve

PS1-10afx

2011fe

Relative Brightness

Day
Multi Band Photometry
Gravitational Lensing
Lens Parameters
How Likely is Lensing?

Table 3. The expected number of detected lensed SNe (Type Ia and core collapse) in various time-domain surveys. We adopt the minimum image separation $\theta_{\text{min}} = (2/3)\theta_{\text{PSF}}$ for all surveys. The numbers of non-lensed sources detectable in the surveys are also shown for reference. Percentages in parentheses indicate the fraction of quad lenses. For lensed SNe, we adopt the peak magnitude limit of $i_{\text{peak,lim}} = i_{\text{lim}} - 0.7$ in actual calculations so that the light curves of lensed SN images can well be traced.

<table>
<thead>
<tr>
<th>Survey</th>
<th>$N_{\text{non-lens}}^{\text{SN (Ia)}}$</th>
<th>$N_{\text{lens}}^{\text{SN (Ia)}}$</th>
<th>$N_{\text{non-lens}}^{\text{SN (cc)}}$</th>
<th>$N_{\text{lens}}^{\text{SN (cc)}}$</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDSS-II</td>
<td>$4.34 \times 10^2$</td>
<td>0.003 (54 per cent)</td>
<td>$1.09 \times 10^3$</td>
<td>0.01 (40 per cent)</td>
<td></td>
</tr>
<tr>
<td>SNLS</td>
<td>$7.52 \times 10^2$</td>
<td>0.03 (24 per cent)</td>
<td>$1.44 \times 10^3$</td>
<td>0.05 (26 per cent)</td>
<td></td>
</tr>
<tr>
<td>PS1/3\pi</td>
<td>$3.34 \times 10^4$</td>
<td>0.28 (53 per cent)</td>
<td>$8.23 \times 10^4$</td>
<td>0.97 (39 per cent)</td>
<td></td>
</tr>
<tr>
<td>PS1/MDS</td>
<td>$2.93 \times 10^3$</td>
<td>0.09 (32 per cent)</td>
<td>$6.05 \times 10^3$</td>
<td>0.16 (30 per cent)</td>
<td></td>
</tr>
<tr>
<td>DES/wide</td>
<td>$8.30 \times 10^4$</td>
<td>2.7 (29 per cent)</td>
<td>$1.62 \times 10^5$</td>
<td>4.9 (29 per cent)</td>
<td>Detections only</td>
</tr>
<tr>
<td>DES/deep</td>
<td>$8.95 \times 10^2$</td>
<td>0.04 (22 per cent)</td>
<td>$1.80 \times 10^3$</td>
<td>0.07 (24 per cent)</td>
<td>Detections only</td>
</tr>
<tr>
<td>HSC/deep</td>
<td>$1.10 \times 10^3$</td>
<td>0.06 (18 per cent)</td>
<td>$2.56 \times 10^3$</td>
<td>0.13 (21 per cent)</td>
<td></td>
</tr>
<tr>
<td>JDEM/SNAPa</td>
<td>$1.36 \times 10^4$</td>
<td>2.9 (13 per cent)</td>
<td>$5.39 \times 10^4$</td>
<td>12.0 (18 per cent)</td>
<td></td>
</tr>
<tr>
<td>LSST</td>
<td>$1.39 \times 10^6$</td>
<td>45.7 (32 per cent)</td>
<td>$2.88 \times 10^6$</td>
<td>83.9 (30 per cent)</td>
<td></td>
</tr>
</tbody>
</table>

$a$Instead of the $i$ band, we adopt an $H$-band magnitude limit of $H_{\text{lim}} = 26.8$ to predicted the number of (lensed) SNe since in practice the detection in space will be done in the near-infrared to optimize the number of high-redshift SN sources.
Measuring $H_0$ with Lensed SNIa

Oguri & Kawano 2003