Supernova Rates from the Lick Observatory Supernova Search

Weidong Li
Department of Astronomy
University of California, Berkeley

(Main collaborators: J. Leaman, A. Filippenko, M. Ganeshalingam)
KAIT, the Katzman Automatic Imaging Telescope; 0.76 m mirror.

Lick Observatory, near San Jose, CA
Scientific motivation of LOSS

- Monitor a well-defined galaxy sample
- Find lots of young SNe (search engine)
- Photometric follow-up obs. (database)
- Detailed log files (SN rate, statistics)
- GRB follow-up observations
The KAIT SN Search at Lick Obs.

- **1997**: 1 (SN 1997bs)
- **1998**: 20 (world record)
- **1999**: 40 (world record)
- **2000**: 38 (including SN 2000A)
- **2001**: 68 (world record; SN 2001A)
- **2002**: 82 (world record)
- **2003**: 95 (world record)
- **2004**: 83
- **2005**: 82
- **2006**: 84

http://astron.berkeley.edu/~bait/kait.html
LOSS SNe, m < 19 mag when discovered
Template subtraction; SN photometry

(Automatic pipeline: Mohan Ganeshalingam)
SN Ia

SN 2002eb

SN 2002er

SN 2002cs

SN 2003fa
Supernova Rates

Benchmark for $z = 0$ SN rate:

Cappellaro et al. 1999 (C99 hereafter)
* 5 surveys (1 visual, 4 photographic plates)
* 137 SNe in about $10^4$ galaxies
* B-band luminosity normalization
* SN rate as a function of SN type (Ia, Ib/c, II) and host morphology (E/S0, Sa/b, Sbc/d, Irr)

Mannucci et al. 2005 (M05 hereafter)
* Same database as C99
* K-band luminosity normalization
* SNr versus galaxy color (B-K)
**LOSS results (1998-2006):**
Leaman, Li, & AVF (2007, in prep.)

- 844 SNe observed (600 LOSS discoveries & 240 independent confirmations)
- SNe used* in the SN rate calculation for a given normalization technique and SN type:

<table>
<thead>
<tr>
<th>Filter</th>
<th>Ia</th>
<th>Ib/c</th>
<th>II</th>
<th>?</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>247</td>
<td>97</td>
<td>284</td>
<td>14</td>
<td>642</td>
</tr>
<tr>
<td>K</td>
<td>235</td>
<td>93</td>
<td>274</td>
<td>13</td>
<td>615</td>
</tr>
<tr>
<td>B&amp;K</td>
<td>227</td>
<td>87</td>
<td>265</td>
<td>12</td>
<td>591</td>
</tr>
</tbody>
</table>

*Only SNe for which we have all host galaxy information were included
SN rate = \frac{\text{No. of Supernovae}}{\text{Total } L \times \text{Total monitoring time}}
d = 100 Mpc
Mag limit = 19

Could see SN Ia for 125 d, SN Ib/c for 30 d, SN II-P for 130 d.
Control time (multi epochs)

Observation interval (days)

<table>
<thead>
<tr>
<th>t1</th>
<th>t2</th>
<th>t3</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT=130d</td>
<td>130d</td>
<td>130d</td>
</tr>
</tbody>
</table>

Total ct = 130d + 7d + 14d

Obs intervals

2001–2003 After June 2004

For SN Ia, 92% of the observations use the obs interval for the control time ~ a nearly continuous coverage!
Choice of light curves

• Very important; major source of uncertainty (especially for SNe Ib/c, II).
• Different from C99 light curves (our curves are broader, so SN rate decreases).
• In the process of determining more accurately.
• Extinction, luminosity scatter are not considered yet.
Detailed log files; data comparisons

• The limiting magnitude was calculated for every single observation over the course of the survey.

• (Not done for previous nearby SN rate calculations.)
a) No clear inclination effect (maybe inverse!)

b) Negligible missed SNe in the galaxy nuclei.
Units

• $1 \text{ SNe} = 1 \text{ SN} / (100 \text{ yr}) / (10^{10} L_{\odot})$
  (SNeB, SNeK for B and K bands)

• $1 \text{ SNeM} = 1 \text{ SN} / (100 \text{ yr}) / (10^{10} M_{\odot})$

PRELIMINARY

Not to be used or quoted without permission.
Not much fluctuation in the SN Ia rate from early to late-type galaxies

Biggest change: SN Ib/c rate in late-type spirals
An increasing trend for SN Ia rate from early to late-type galaxies
M05 values in irregular galaxies are too large
SN rate in more galaxy bins

solid: Ia SNe
preliminary

---: CC SNe
Volume SN Ia rate versus redshift

\[
\text{log}_{10} (\text{SN Ia yr}^{-1} \text{ Mpc}^{-3}) = \text{SN delay function} \times \text{cosmic SFH}
\]

\[(\text{Dahlen et al. 2004; Strolger et al. 2004})\]

Point : this work
Triangle: Cappellaro et al. 1999
Conclusions, I

Uncertainties are significantly reduced
- Increased number of SNe (~140 vs. ~600)
- No inclination correction factor
- CCD camera and image subtraction
- Limiting magnitude calculated for every obs
- Nearly continuous search

Type Ia SN rate:
- B-band: Independent of host morphology
- K-band: increasing from early to late type galaxies
- Mass: prompt and tardy components
Conclusions, II

Type Ib/c & II SN rate:
- B & K-band: increasing from early to late type galaxies
- Mass: follows SFR
- SN Ibc rate higher and SN II rate slightly lower than C99/M05 (choice of light curves is important).

Future refinements:
- More representative light curves
- More SN bins (e.g., IIn, II-P, II-L)
- Consider extinction, L scatter
Lmag = Lmag(intensity, FWHM, sky)
Radial distribution of LOSS SNe

![Graph showing the radial distribution of LOSS SNe with data points and error bars, indicating the log surface density (SN arcsec$^{-2}$) vs. SN radial offset divided by the Galaxy radius. The graph has two data sets, one for distances greater than 1.25' and another for distances less than 1.25', indicated by black and red symbols, respectively.](image-url)
Dependence of SN (Ia) rate on environment
(work in progress)

a) Cluster versus field

Cluster (z=0.1) = 0.36 (+0.24-0.16) SNuB (Sharon et al. 2007)

E/S0 (z=0) = 0.16 (0.05) SNuB (C99)
E (z=0) = 0.182 (0.036) SNuB (LOSS)
S0 (z=0) = 0.188 (0.032) SNuB (LOSS)

b) Radio properties

E+S0 SNR_{Ia}(z=0)=0.038^{+0.014}_{-0.012} SNuM (Mannucci et al. 2005)

0.071 SNuM in clusters (14 SNe)
0.029 SNuM in field (8 SNe)

(Mannucci et al. In prep)

0.131 SNuM in clusters + radio-loud (6 SNe)
0.018 SNuM in field + radio quiet (4 SNe)

c) Galaxy activities (AGN)
Dependence of SN Ia rate on light curve shape (work in progress)

- Light curve shape is correlated with L.
- Different SNe Ia like different hosts.

SN Ia rate (E-Sc-Ir, $\Delta m_{15}$)

Things need to do:

a) Determine control time for different L/light curve shape
b) Put all SNe Ia into different bins (from monitoring history)