Supernova Rates from the Lick Observatory Supernova Search

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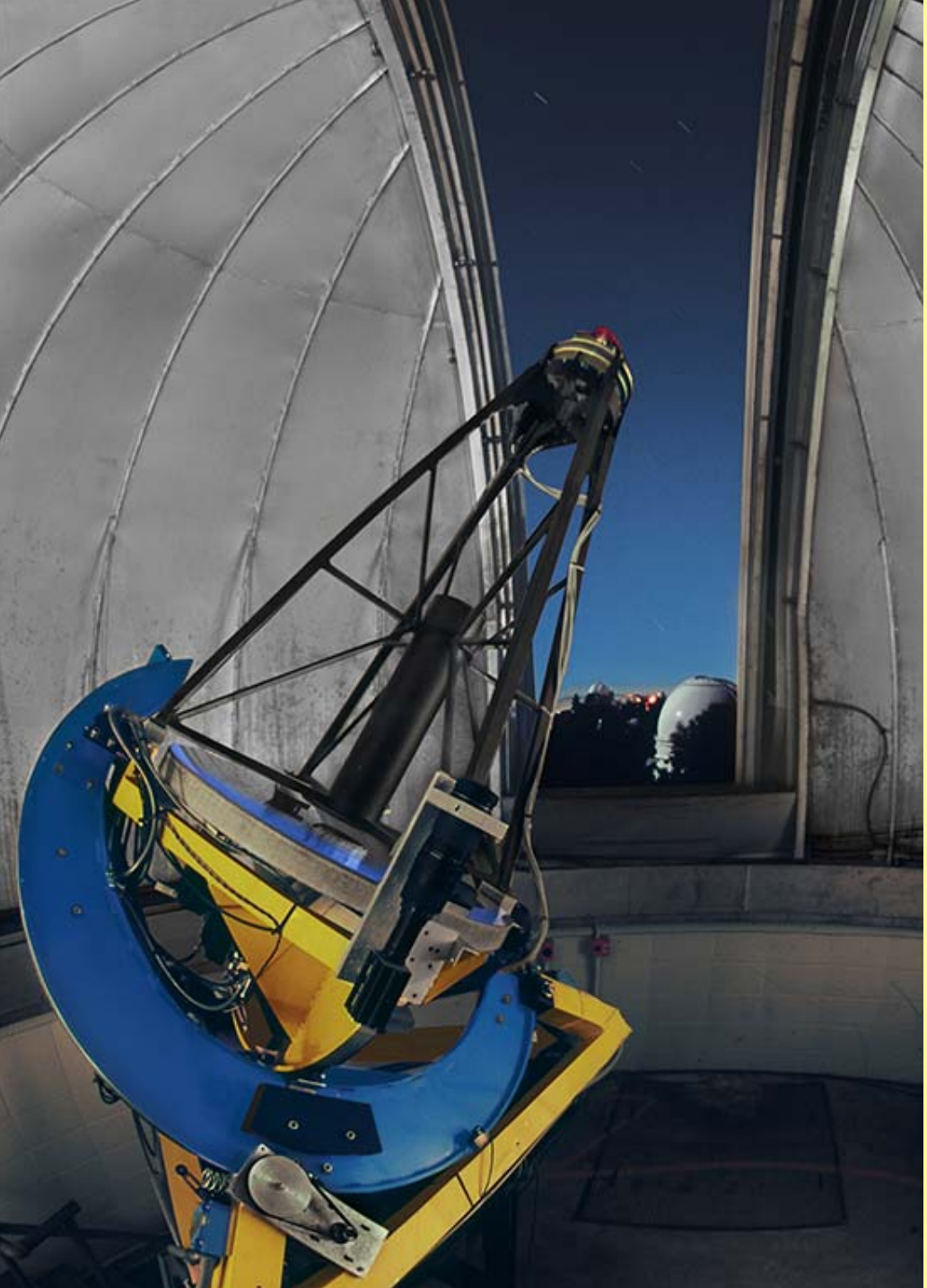
Jesse
Leaman



KAIT,

the Katzman Automatic Imaging Telescope; 0.76 m mirror.

Lick Observatory, near San Jose, CA

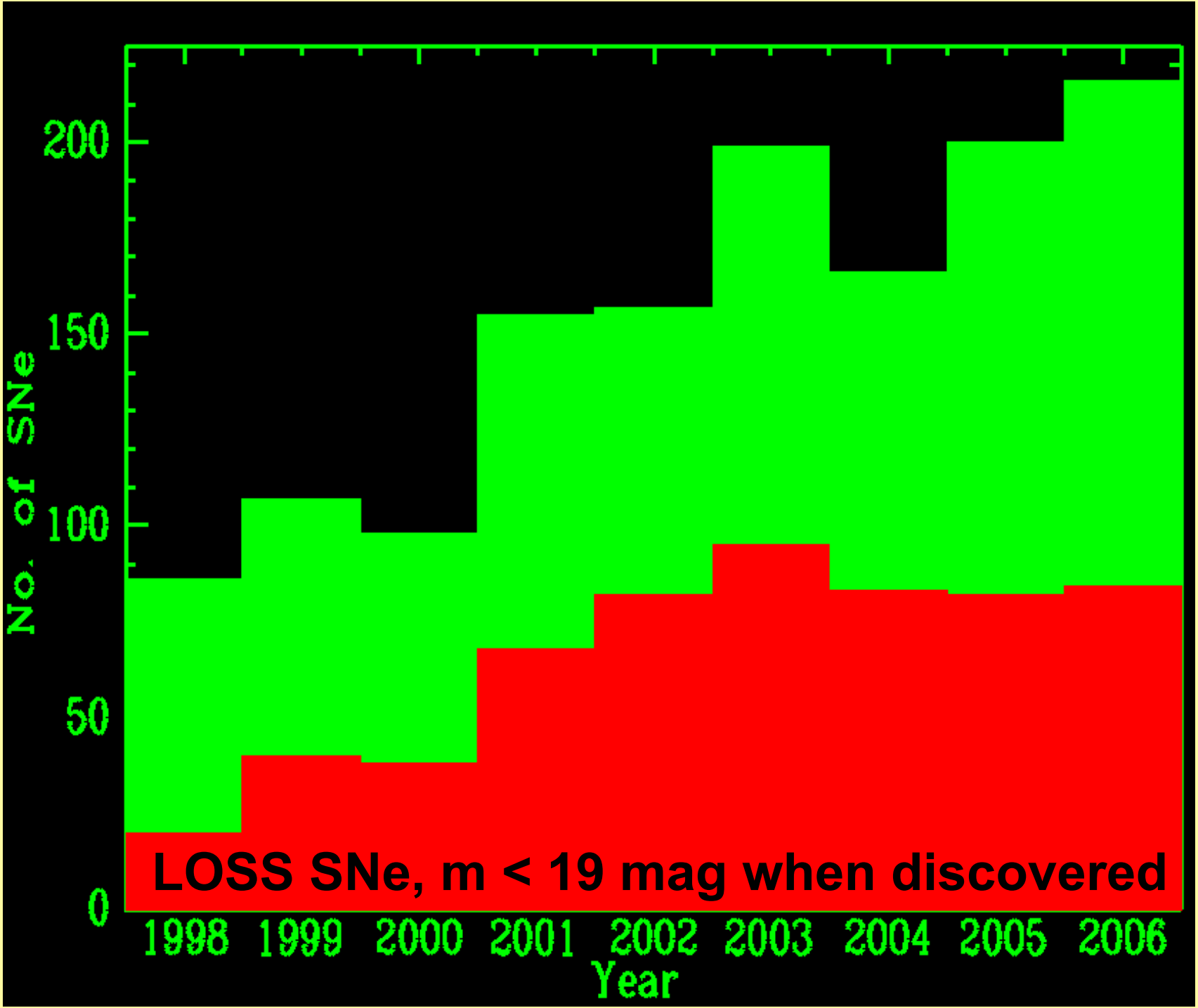
Scientific motivation of LOSS

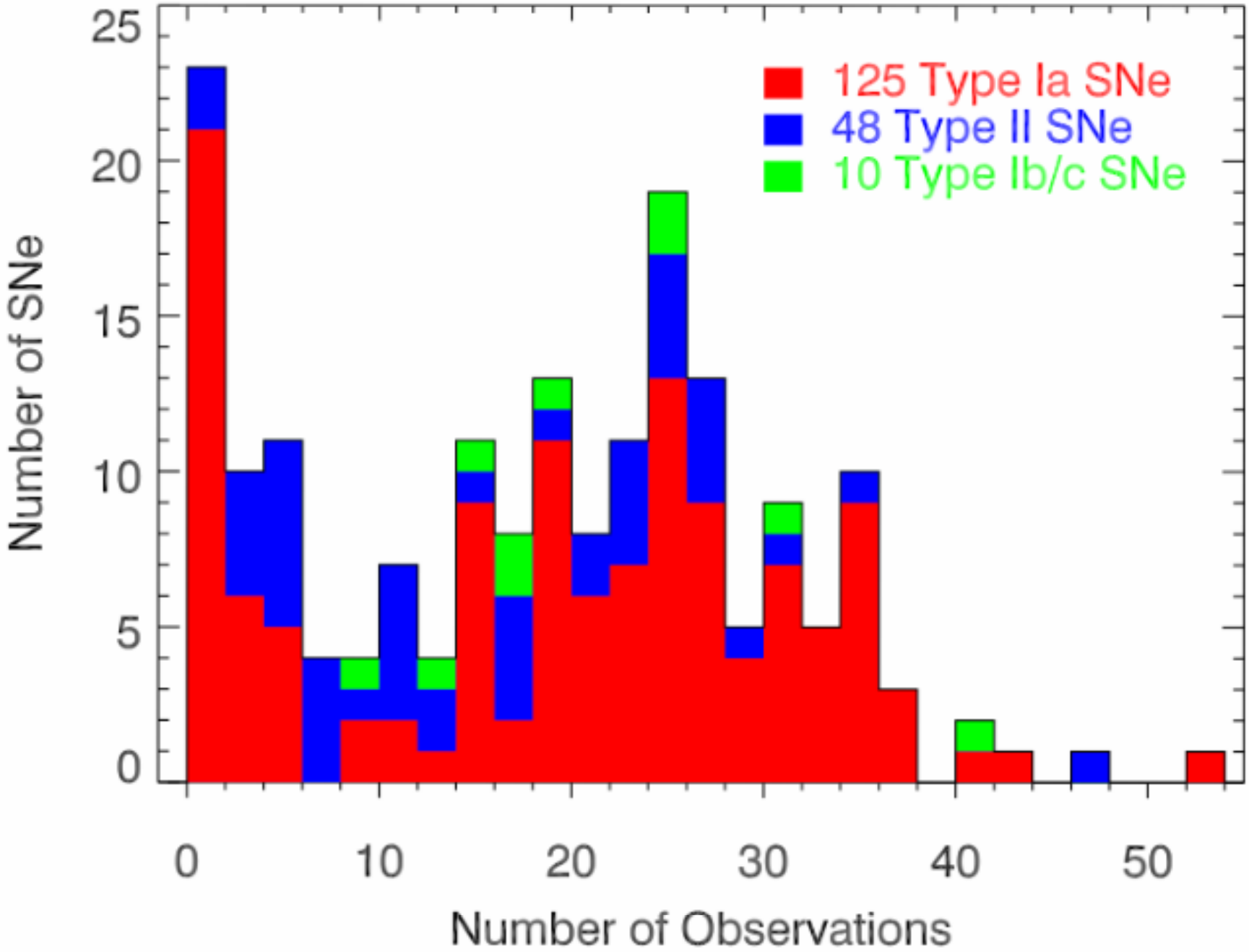
- Monitor a well-defined galaxy sample
- Find lots of young SNe (search engine)
- Photometric follow-up obs. (database)
- Detailed log files (SN rate, statistics)
- GRB follow-up observations

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

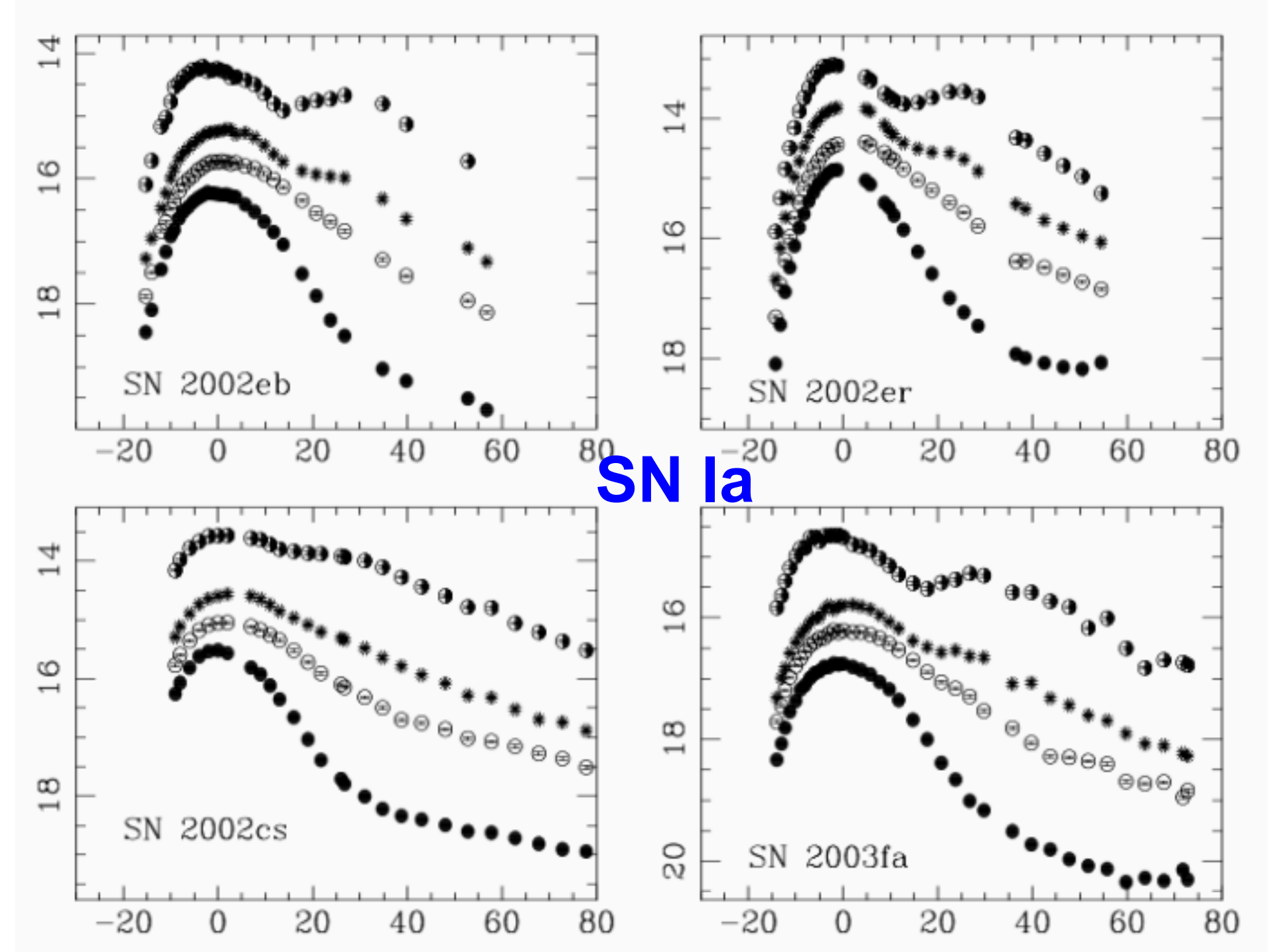

No. of SNe
0
50
100
150
200
1998
1999
2000
2001
2002
2003
2004
2005
2006
Year
LOSS SNe, m < 19 mag when discovered

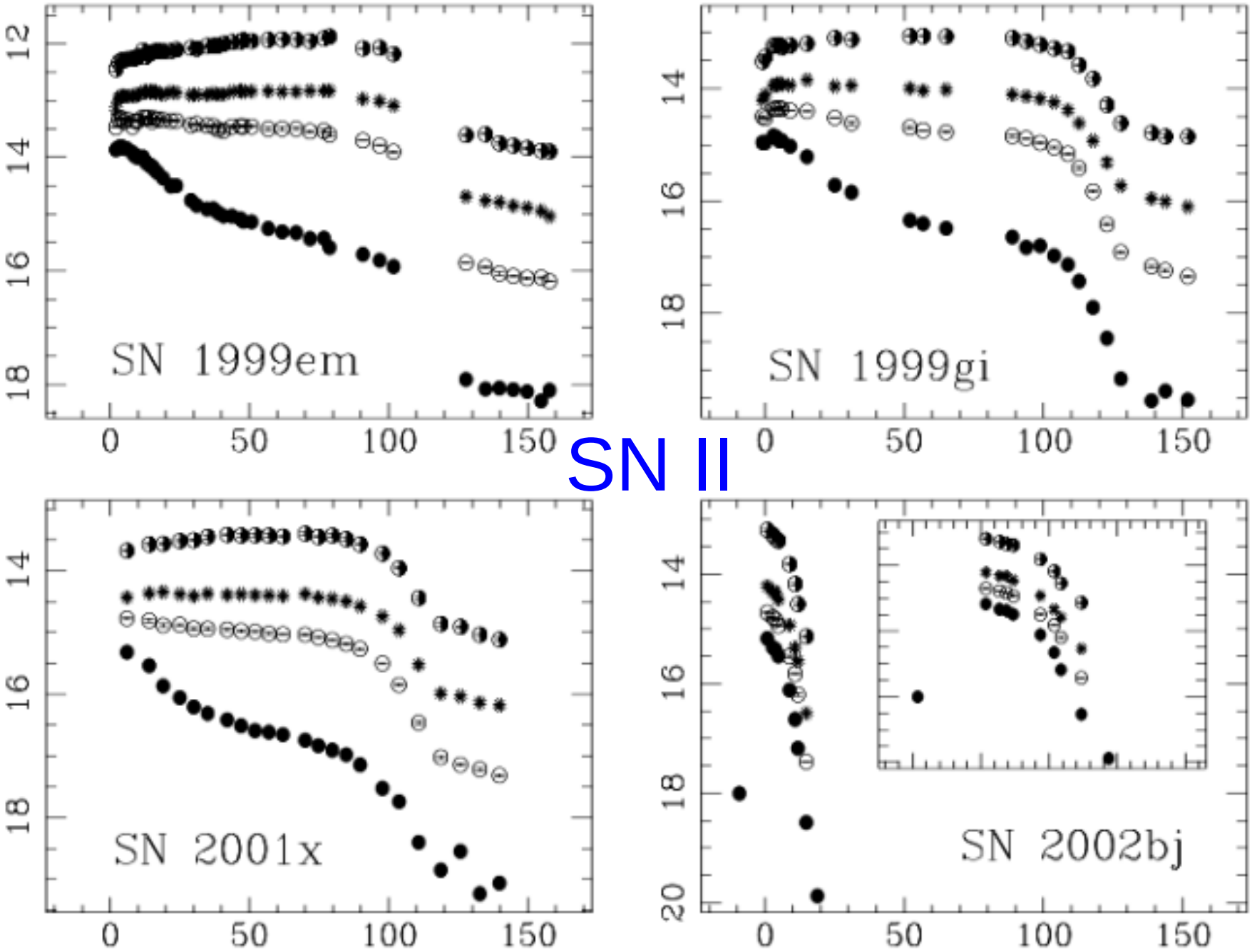

125 Type Ia SNe
48 Type II SNe
10 Type Ib/c SNe
Number of SNe
0
5
10
15
20
25
0
10
20
30
40
50
Number of Observations


Mohan
Ganeshalingam

Template subtraction; SN photometry

(Automatic pipeline: Mohan Ganeshalingam)


SN 2002eb
SN 2002er
SN Ia
SN 2002cs
SN 2003fa


SN II
SN 1999em
SN 1999gi
SN 2001x
SN 2002bj

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)

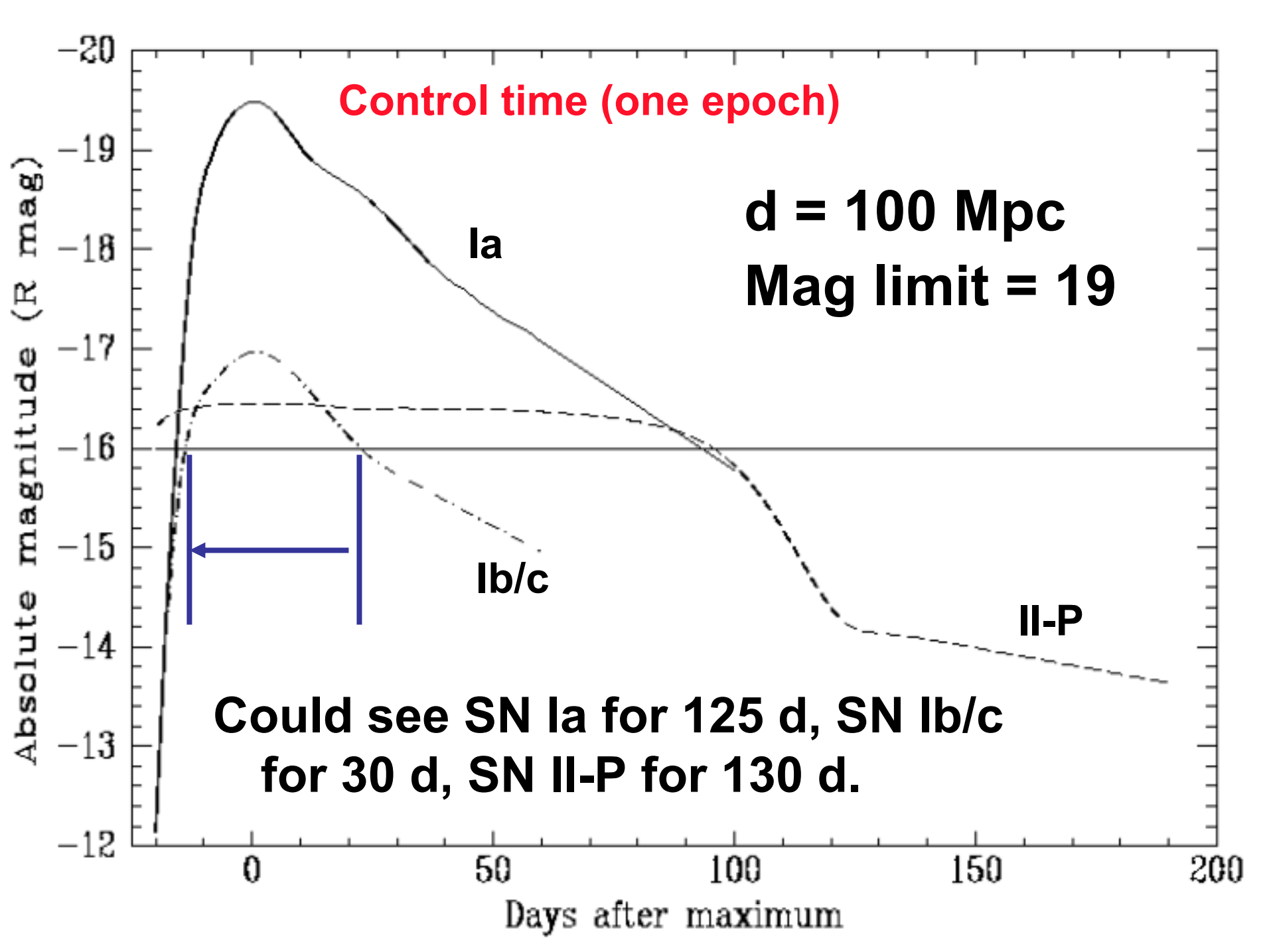
LOSS results (1998-2006):
Leaman, Li, & AVF (2007, in prep.)

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

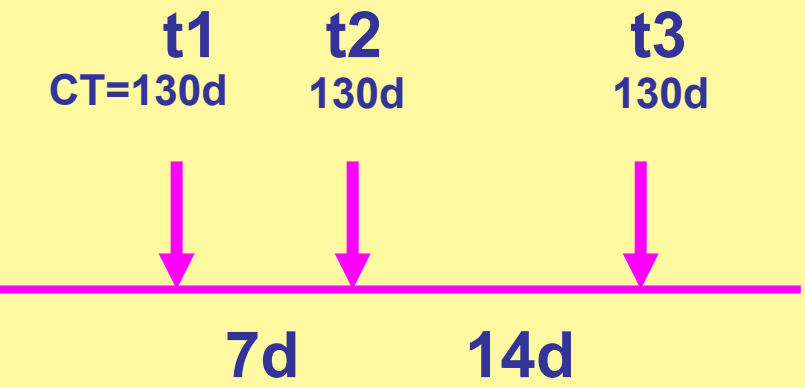
Filter	Ia	Ib/c	II	?	Total
B	247	97	284	14	642
K	235	93	274	13	615
B&K	227	87	265	12	591

***Only SNe for which we have all host galaxy information were included**

$$\text{SN rate} = \frac{\text{No. of Supernovae}}{\text{Total L} \times \text{Total monitoring time}}$$


Control time (one epoch)
d = 100 Mpc
Mag limit = 19
Ia
Ib/c
II-P
Could see SN Ia for 125 d, SN Ib/c for 30 d, SN II-P for 130 d.
Absolute magnitude (R mag)
Days after maximum
−20
−19
−18
−17
−16
−15
−14
−13
−12
0
50
100
150
200

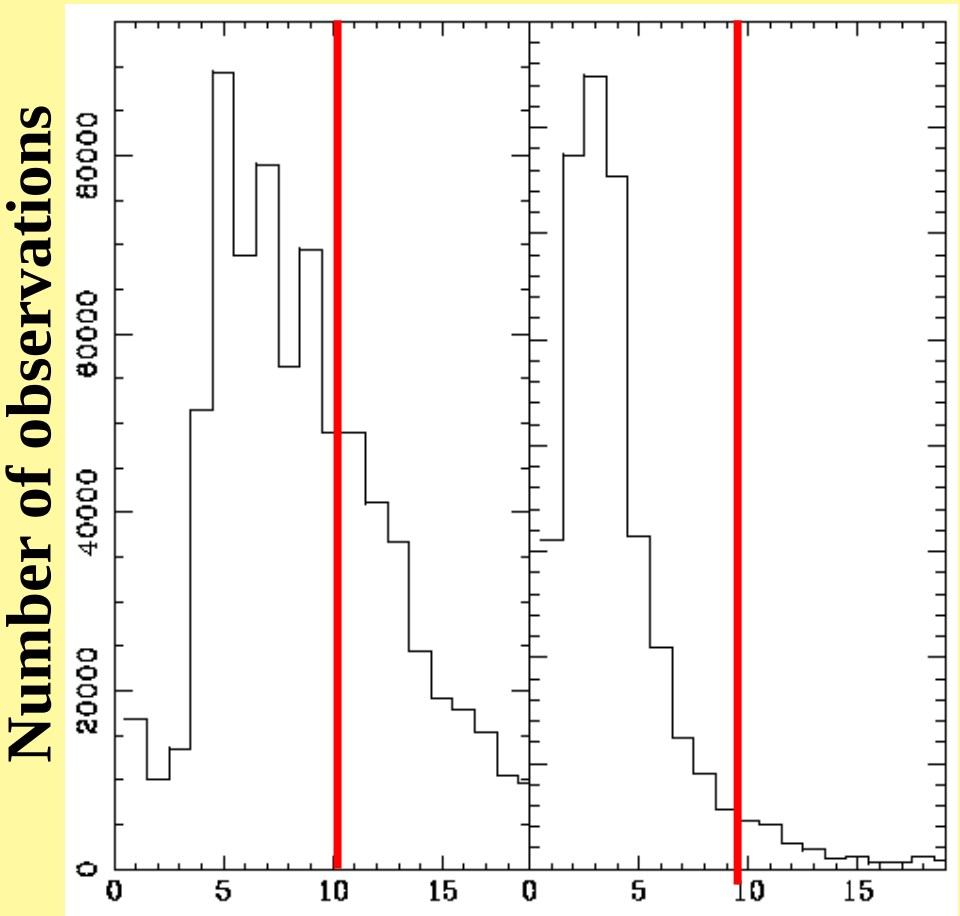
Control time (multi epochs)



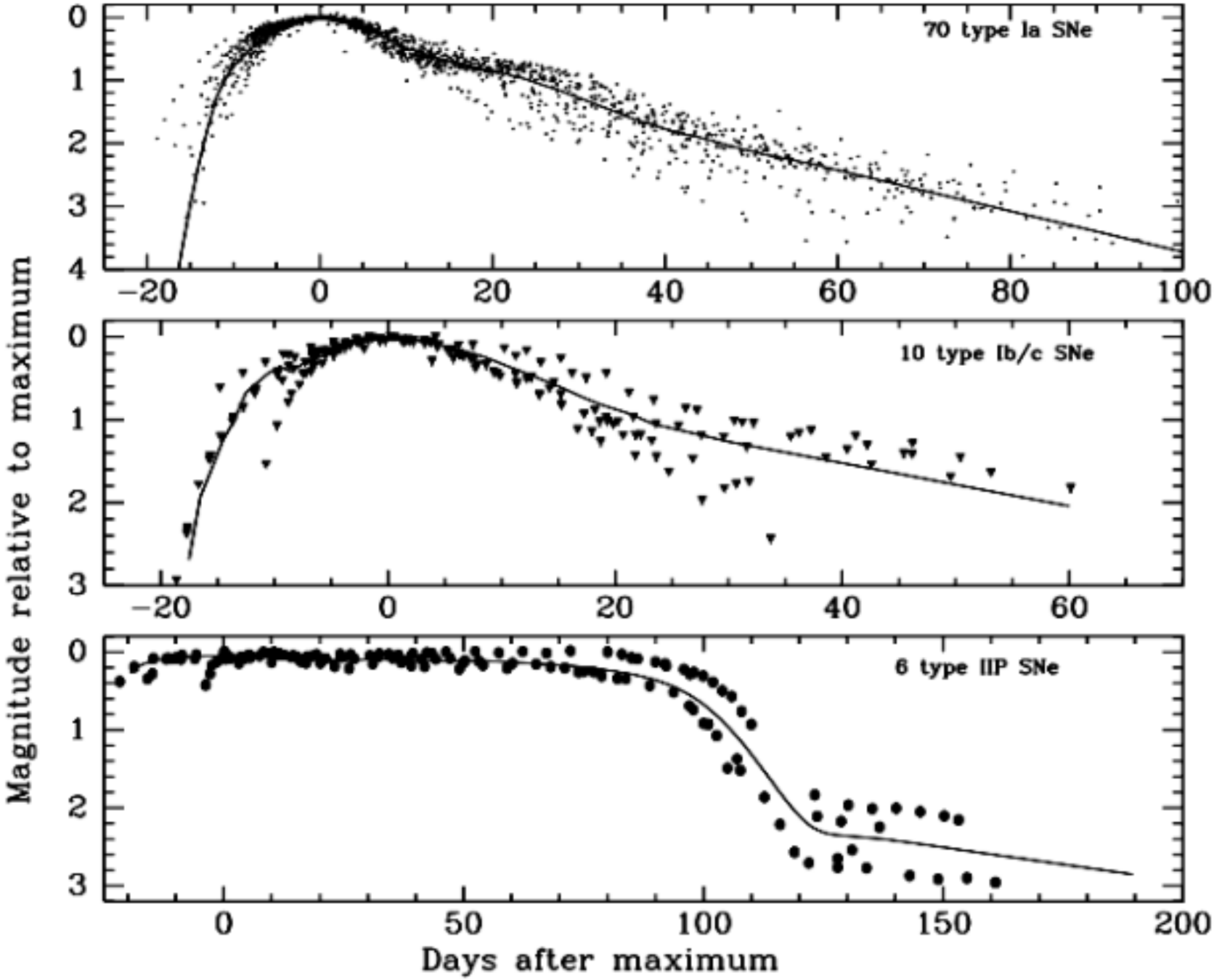
Total ct = 130d + 7d +14d

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!


70 type Ia SNe
10 type Ib/c SNe
6 type IIP SNe
Magnitude relative to maximum
Days after maximum
0
1
2
3
4
−20
0
20
40
60
80
100
50
150
200

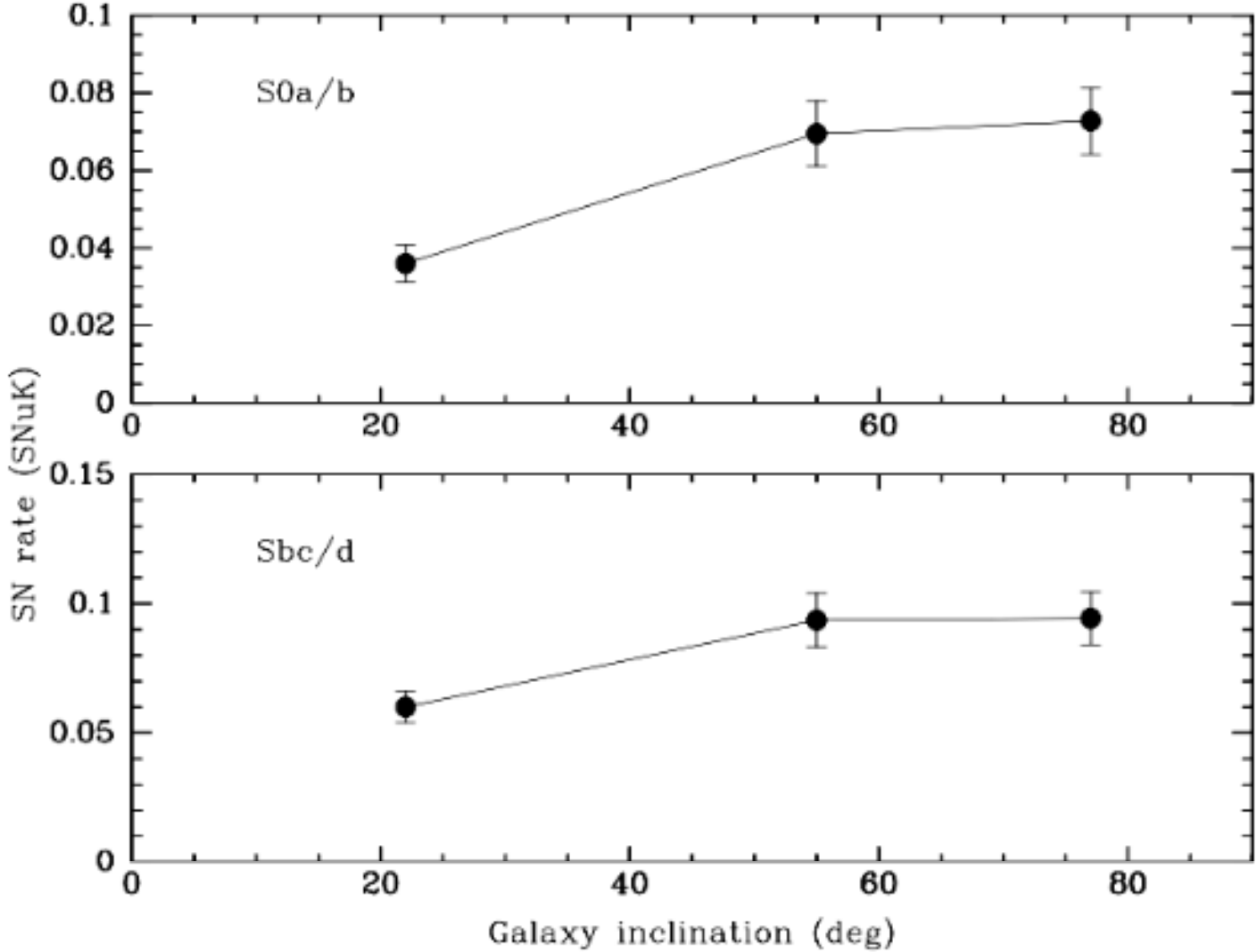
Choice of light curves

- **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

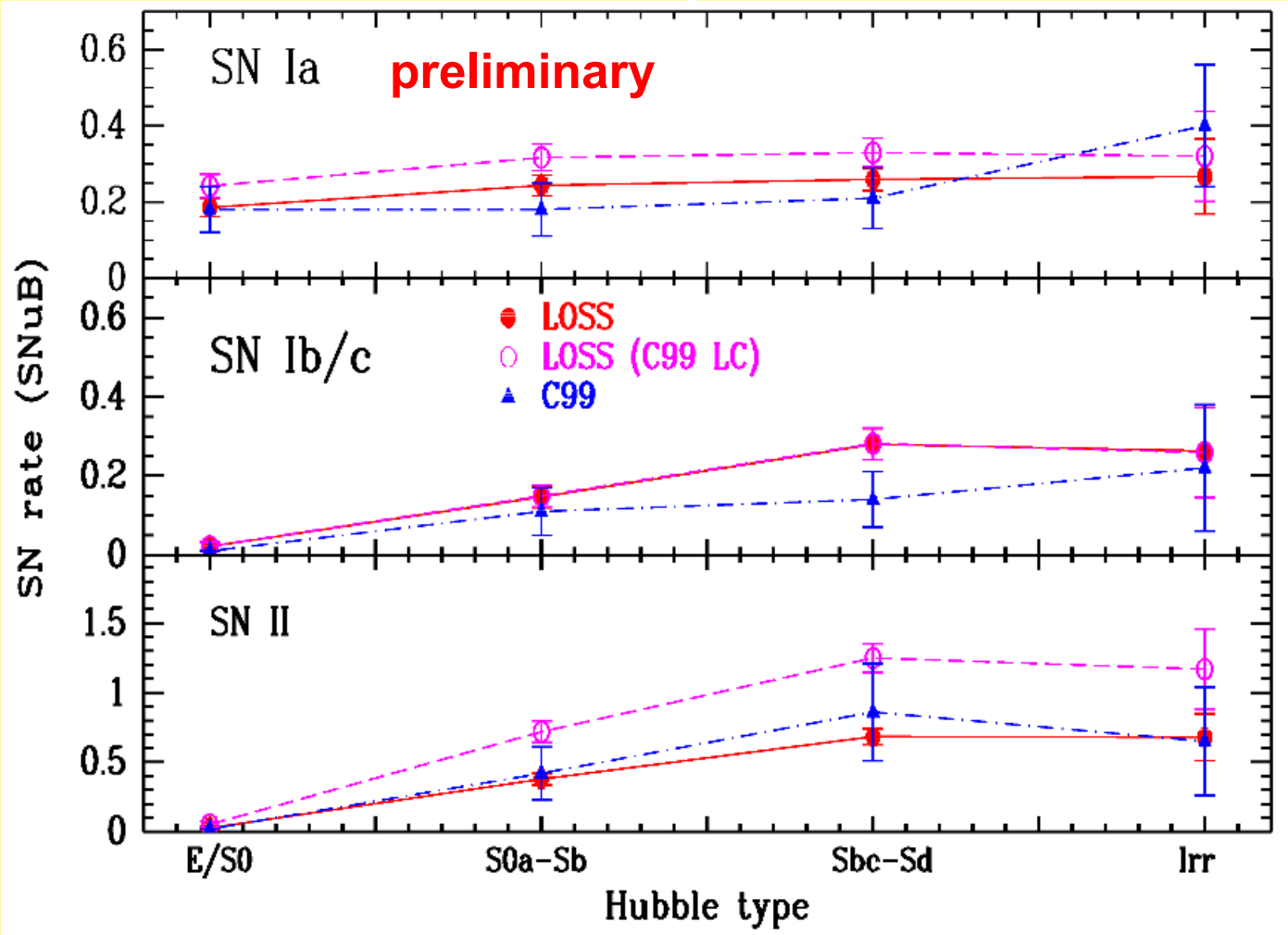
- **1 SNu = 1 SN / (100 yr) / (10^{10} L_{Sun})**
  (SNuB, SNuK for B and K bands)
- **1 SNuM = 1 SN / (100 yr) / (10^{10} M_{Sun})**

PRELIMINARY

Not to be used or
Quoted without permission.

SN rate vs. Hubble type

B-band luminosity normalization

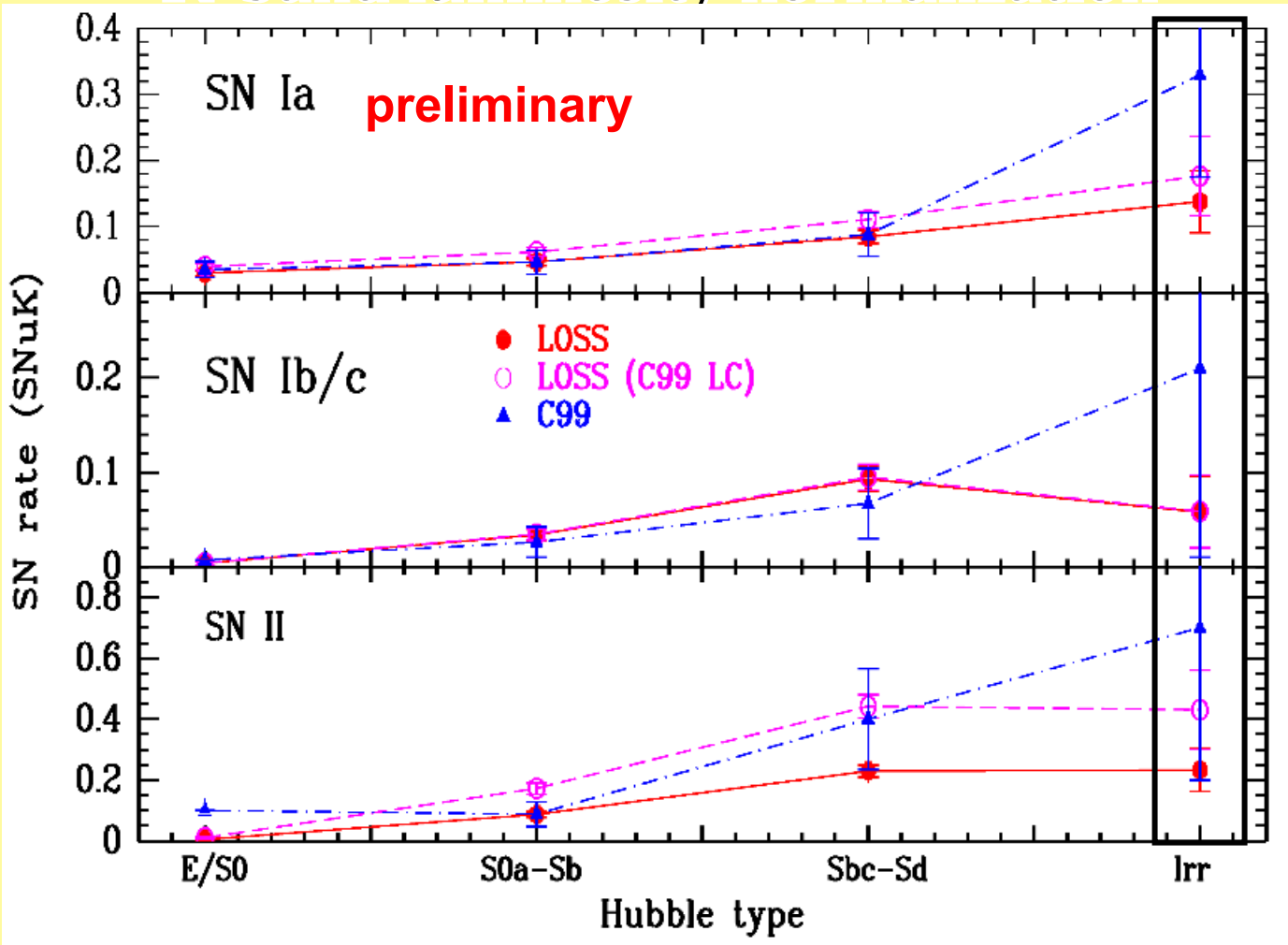


Not much fluctuation in the SN Ia rate from early to late-type galaxies

Biggest change: SN Ib/c rate in late-type spirals

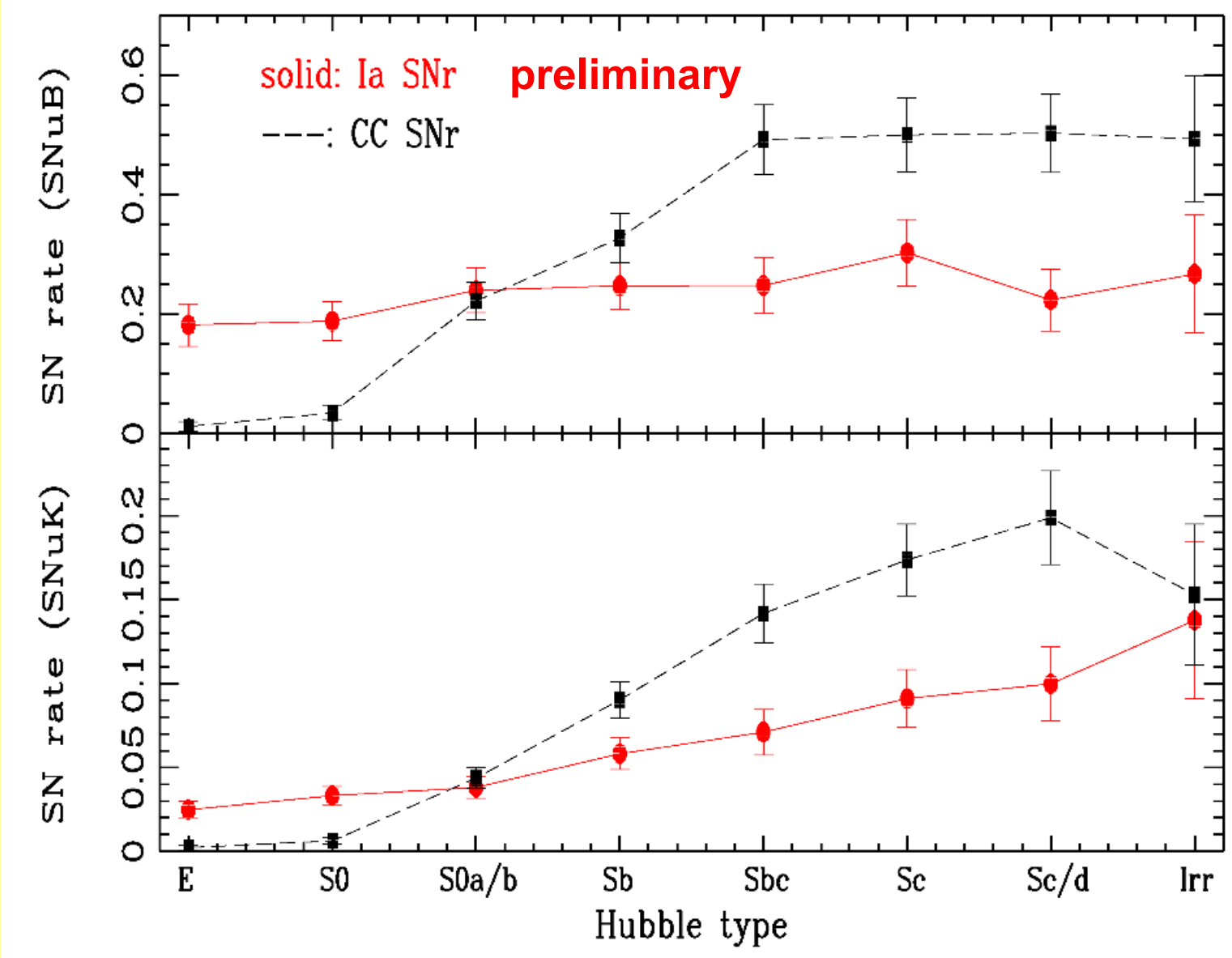
SN rate vs. Hubble type

K-band luminosity normalization

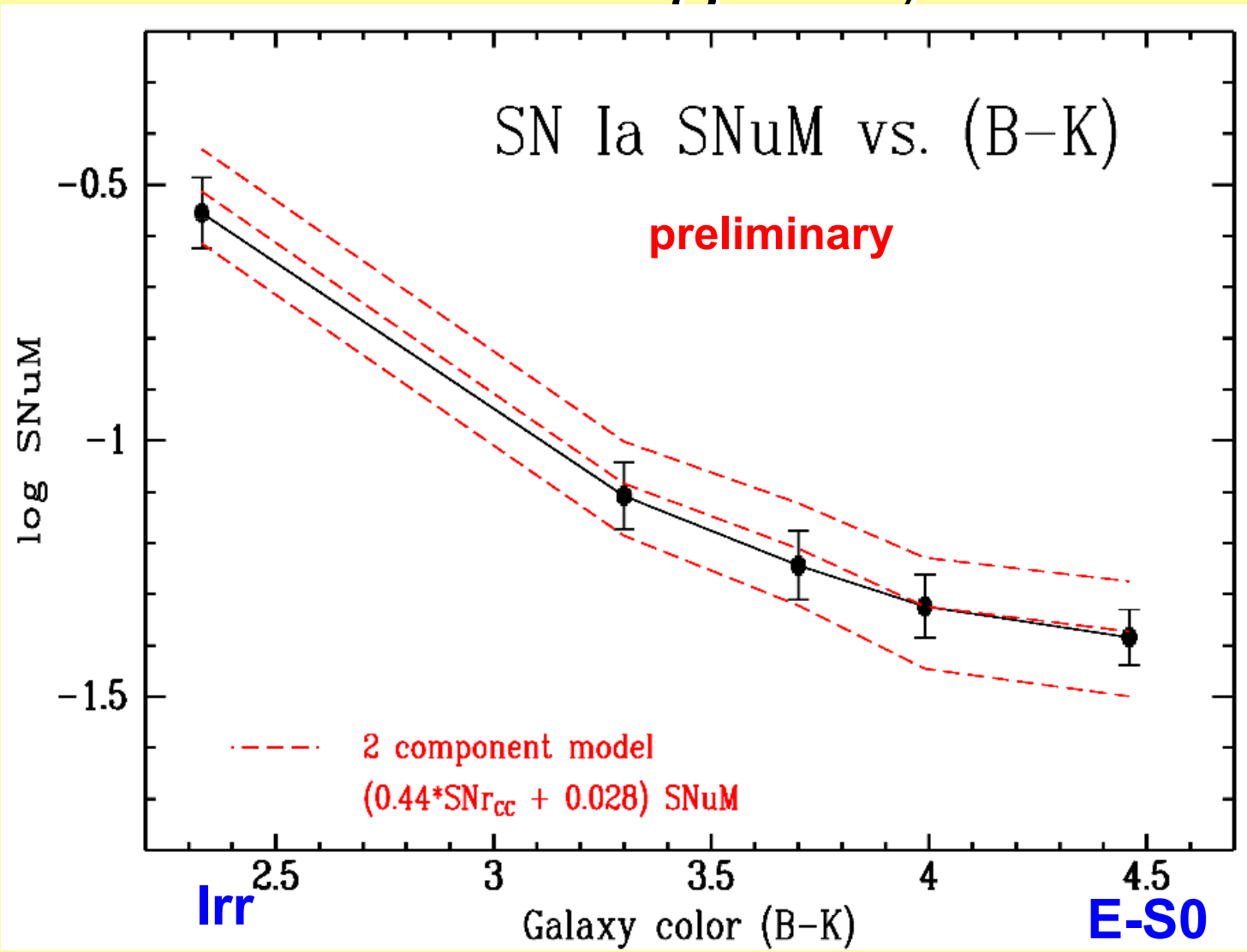


An increasing trend for SN Ia rate from early to late-type galaxies
M05 values in irregular galaxies are too large

SN rate in more galaxy bins

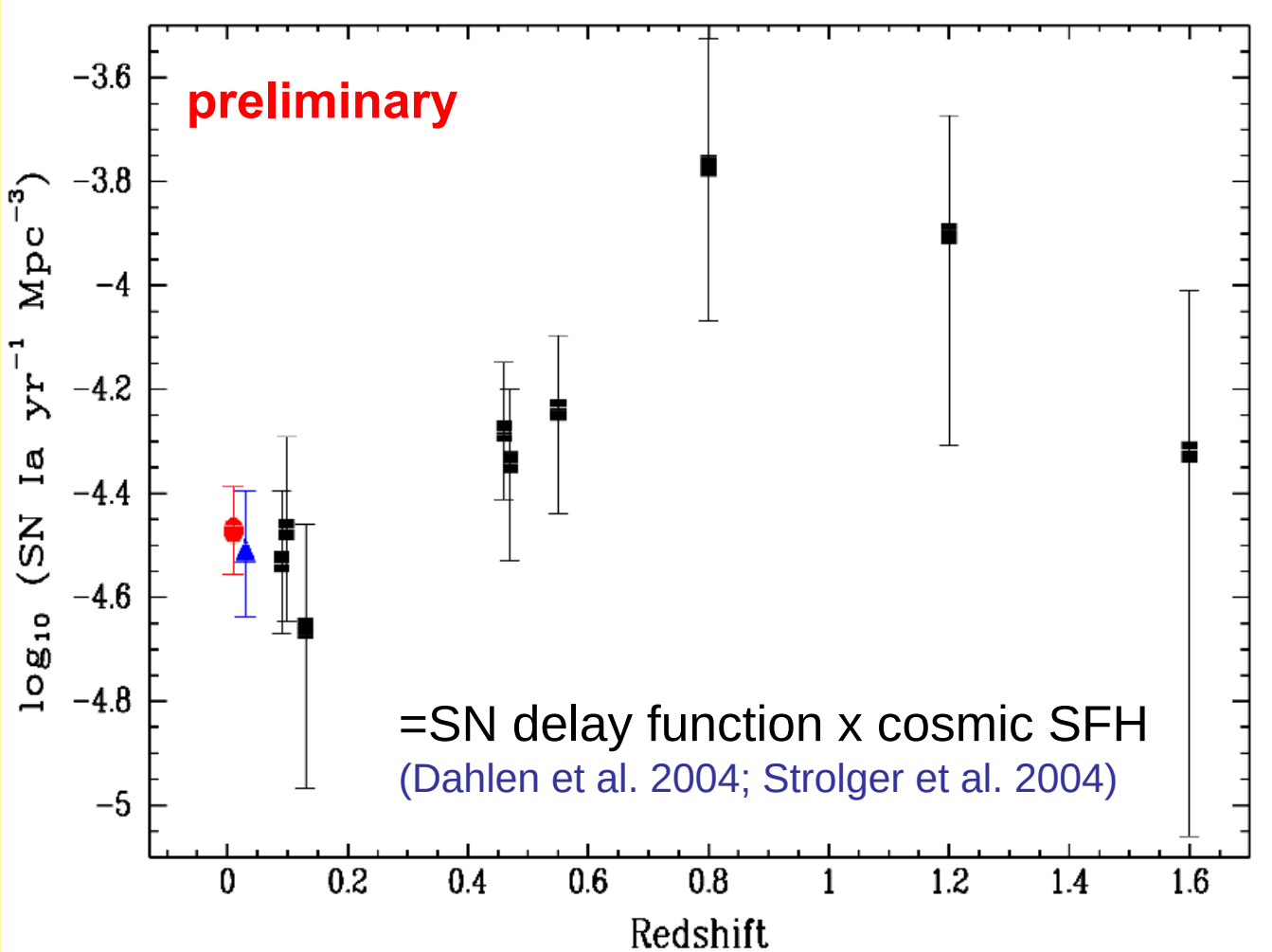


SN Ia rate vs. galaxy color



SN Ia rate proportional to (1) SFR [prompt] and (2) galaxy mass [tardy] (confirms Mannucci et al. 2004, 2005, Scannapieco & Bildsten 2005, Niel et al. 2006, Sullivan et al. 2006)

Volume SN Ia rate versus redshift



Point : this work
Triangle: Cappellaro et al. 1999
Squares: SDSS 2006, Madgwick et al. 2003, Blanc et al. 2004, Hardin et al. 2000
Neill et al. 2006, Pain et al. 2002, and the last three are from Dahlen et al. 2004

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

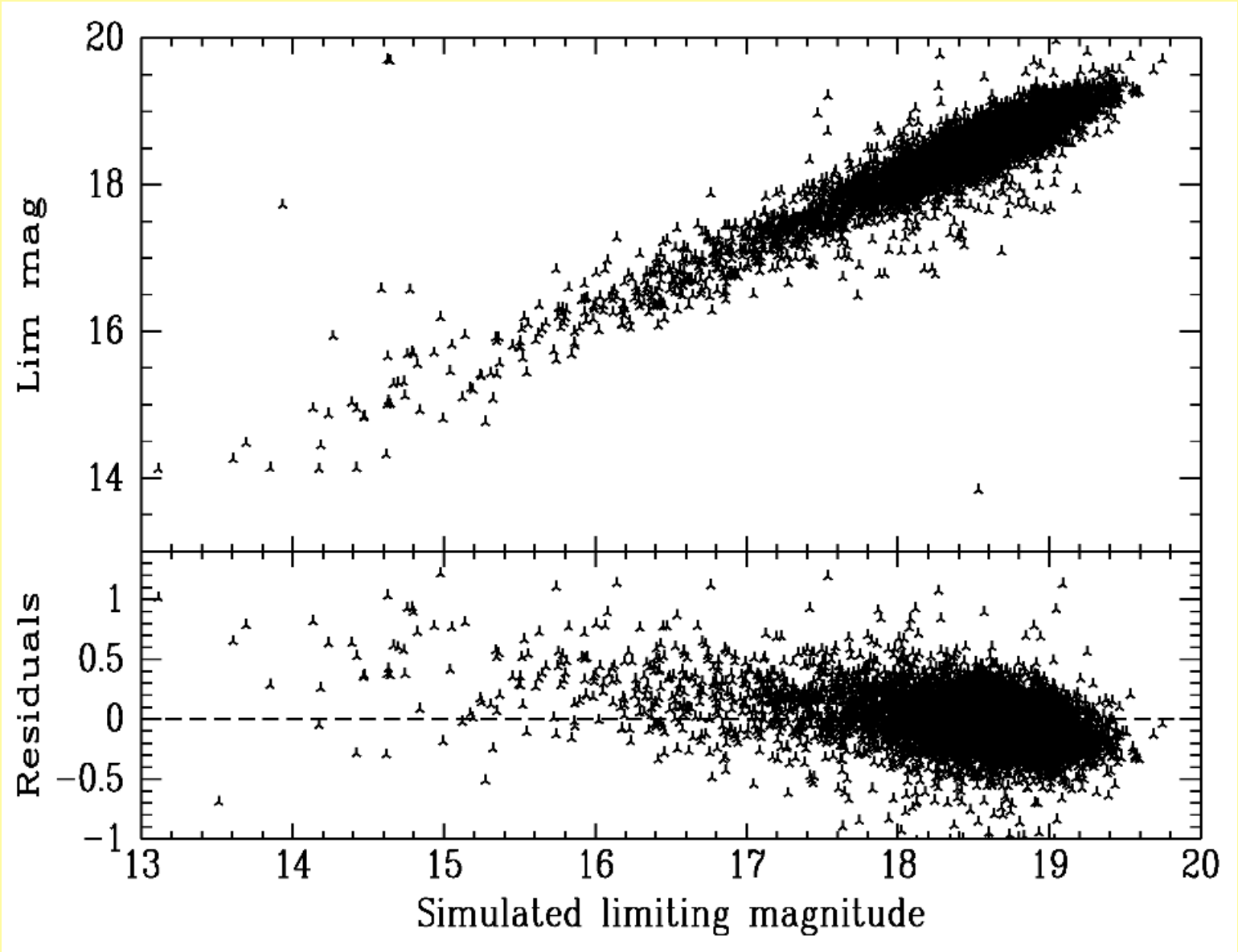
Type Ib/c & II SN rate:

- 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).

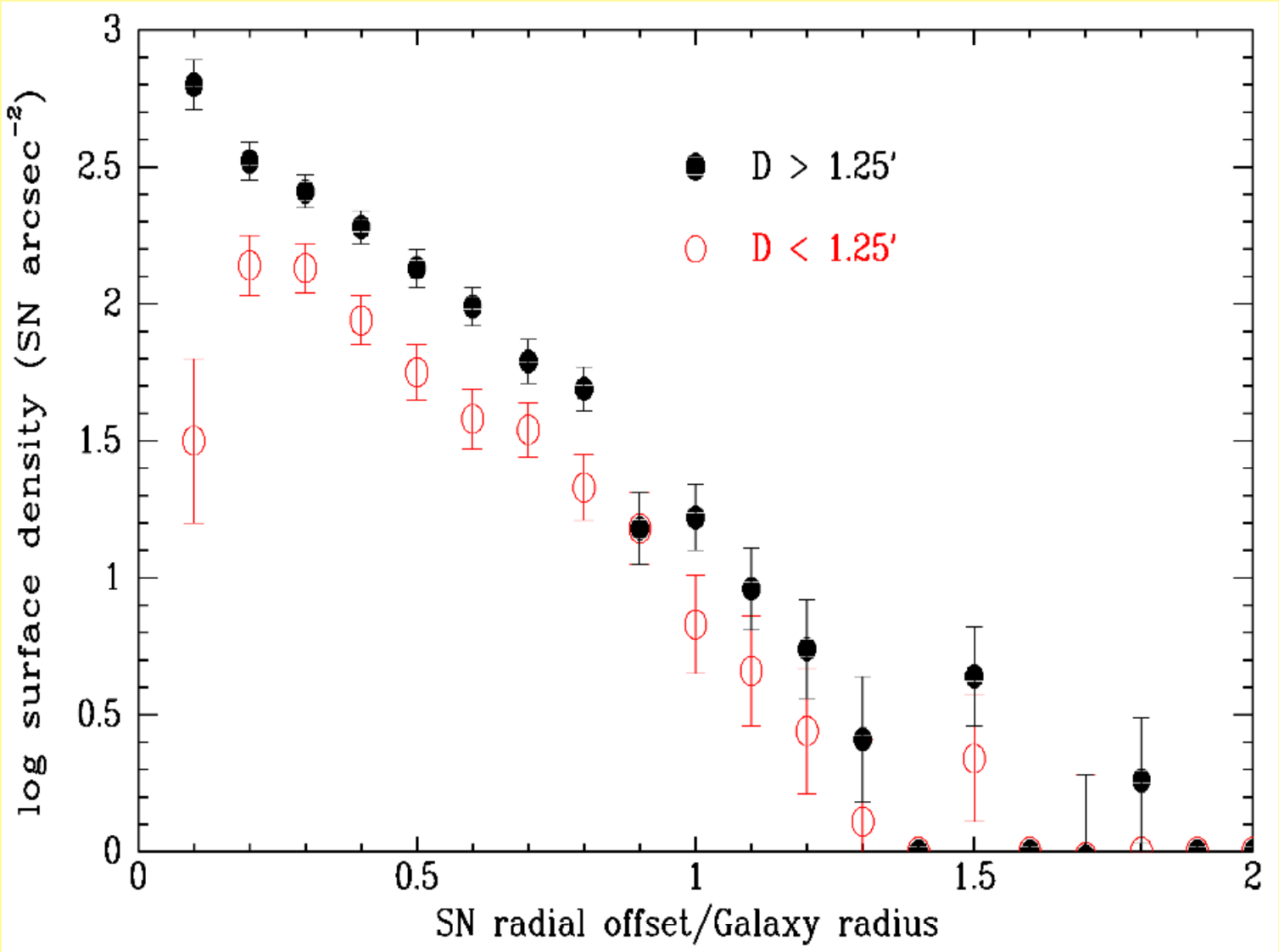
Future refinements:

- 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



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)

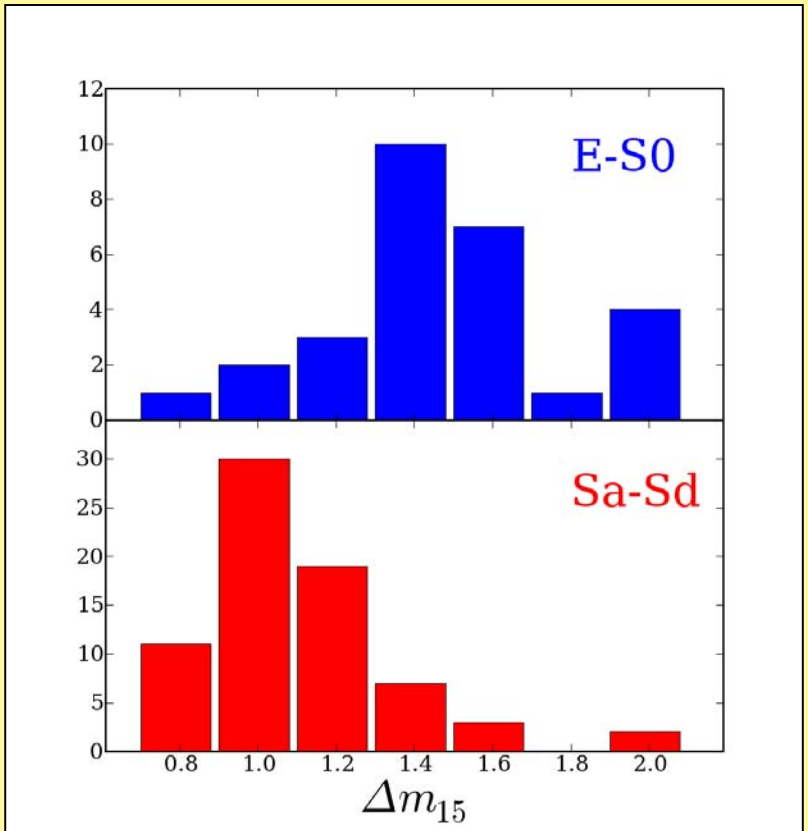
0.131 SNuM in clusters +radio-loud (6 SNe)

(Mannucci et al. In prep) 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, Δm15)

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)