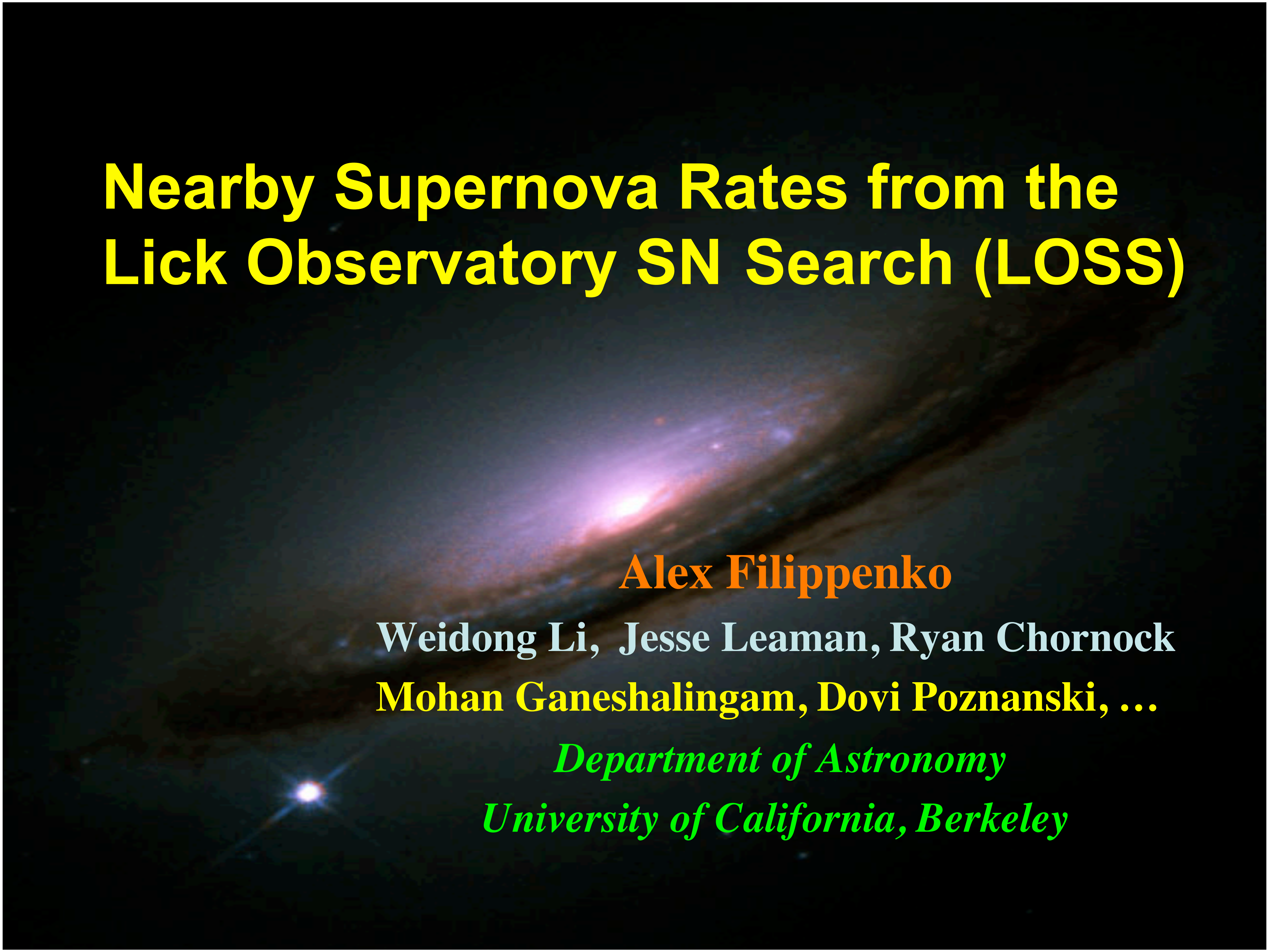


Nearby Supernova Rates from the Lick Observatory SN Search (LOSS)

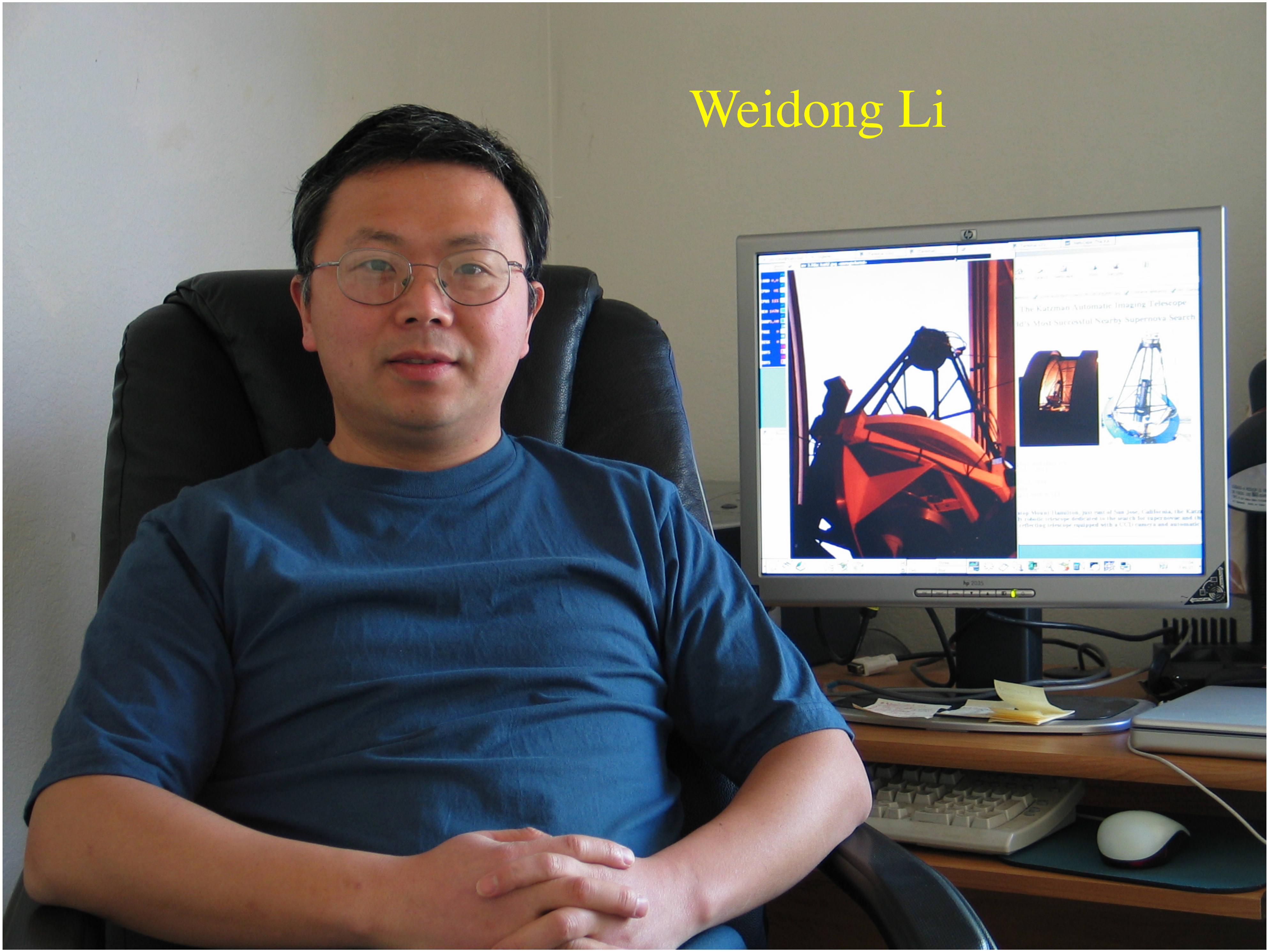
Alex Filippenko

Weidong Li, Jesse Leaman, Ryan Chornock

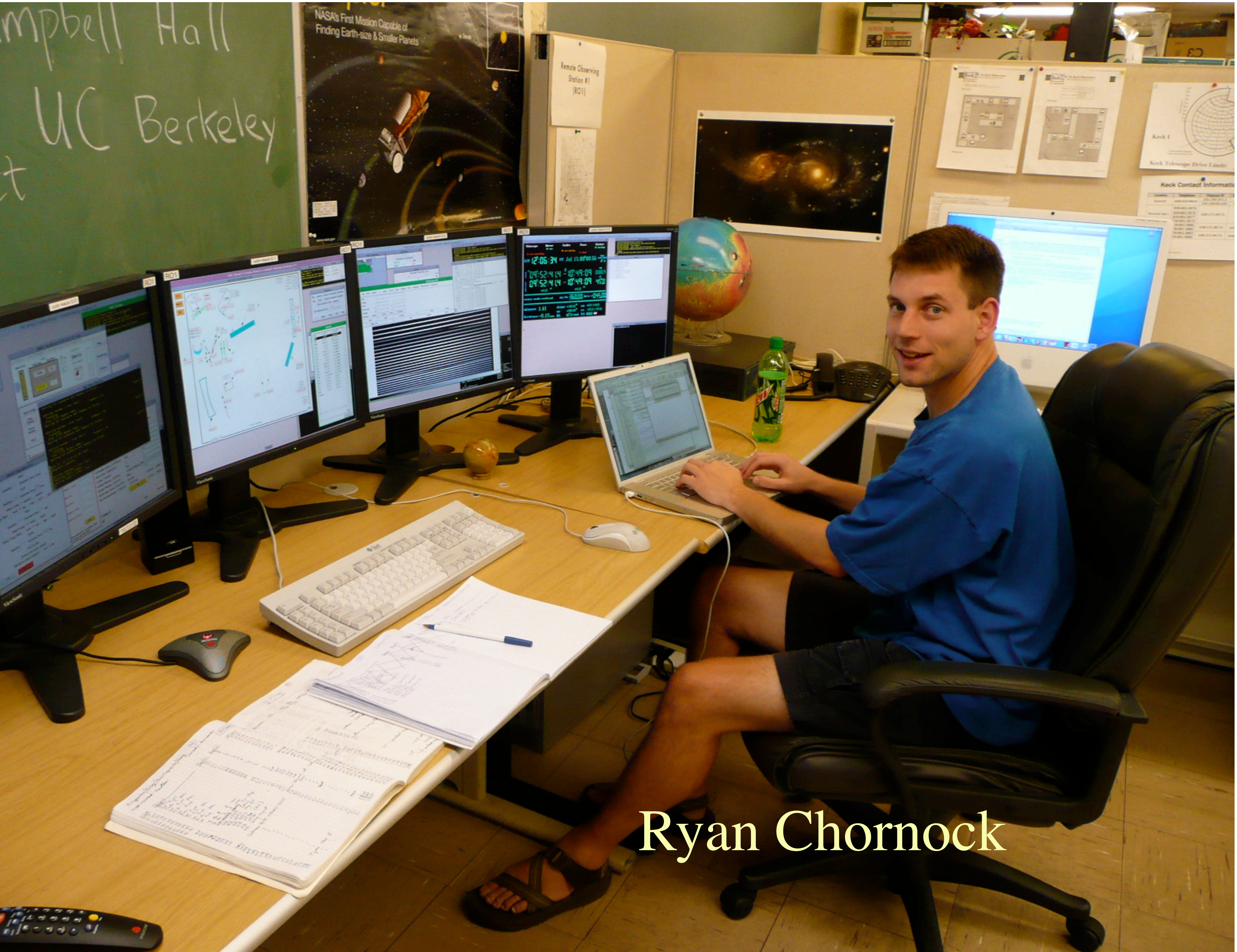
Mohan Ganeshalingam, Dovi Poznanski, …

Department of Astronomy

University of California, Berkeley


Weidong Li
The Katzman Automatic Imaging Telescope

Jesse Leaman

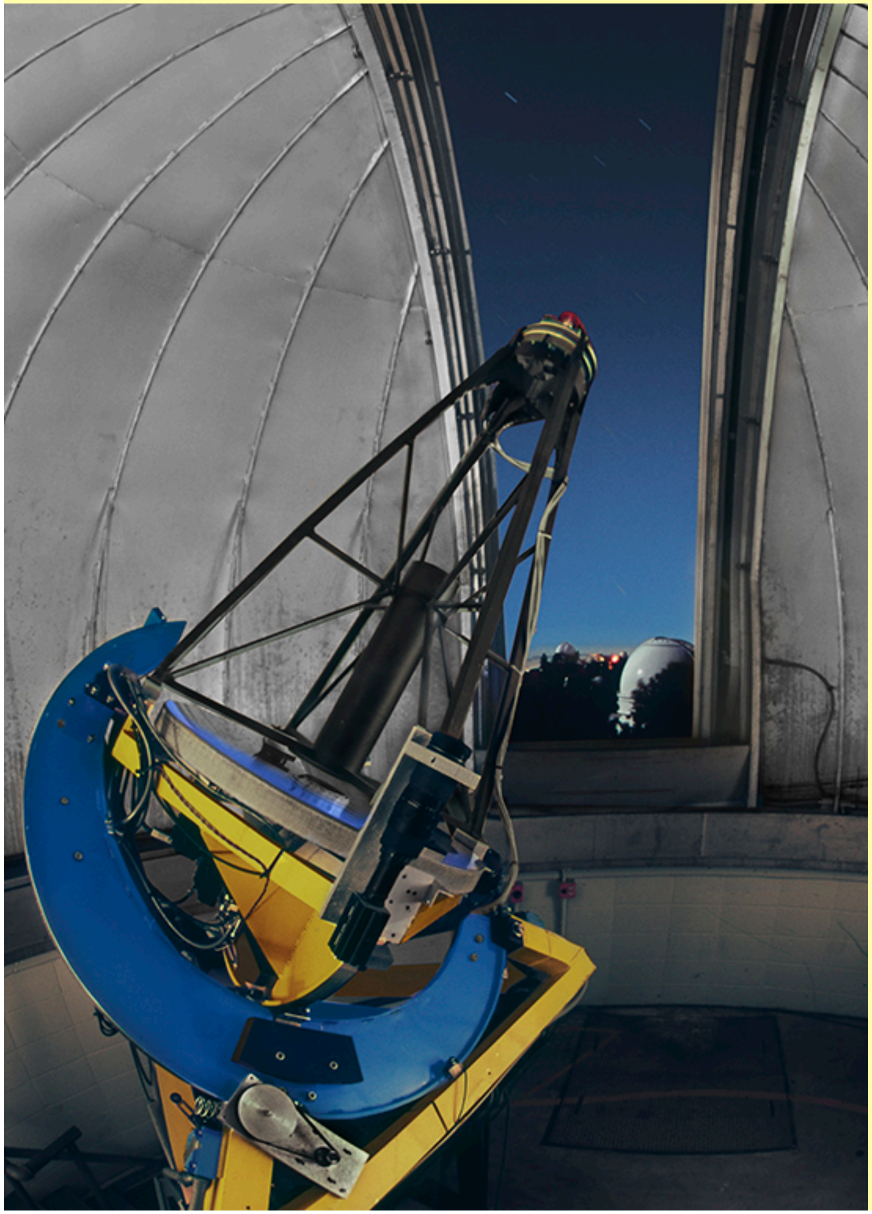


Ryan Chornock


great

How many astronomers does it take to change a flat tire?

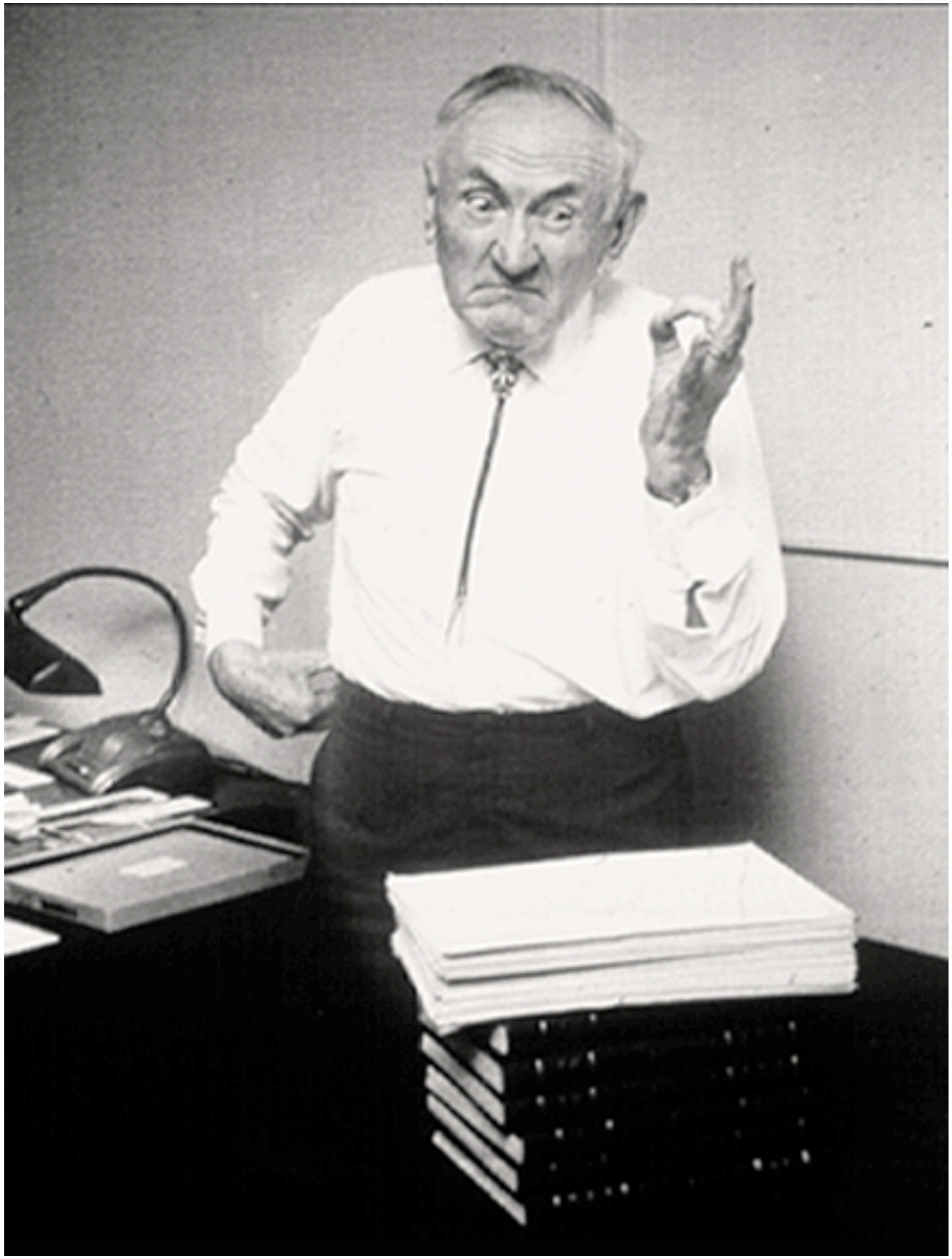
Katzman Automatic Imaging Telescope (KAIT) at Lick Observatory: 0.76 m, 6.7' x 6.7' FoV

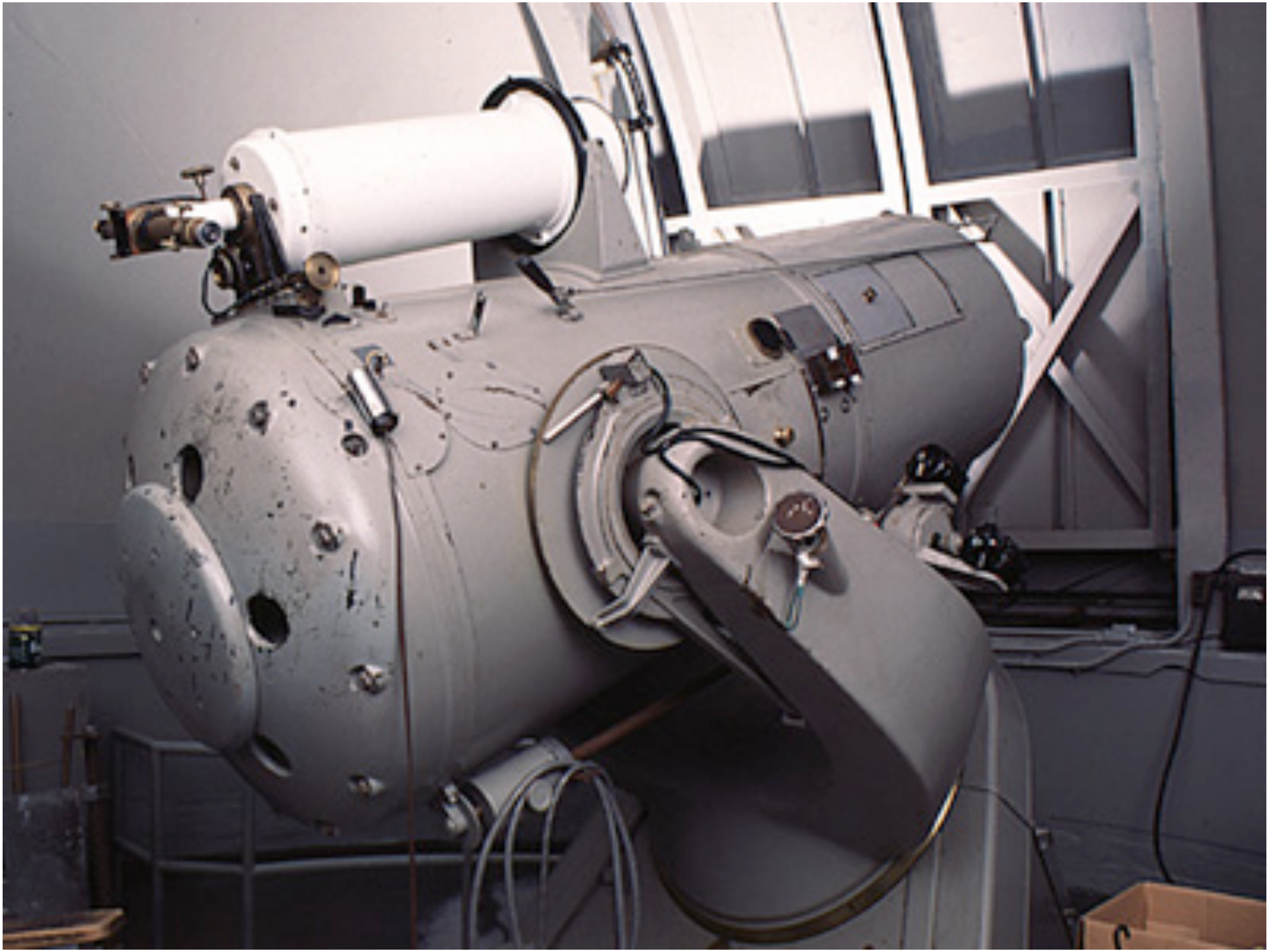


Main project: LOSS

Goals

- **Discover a lot of SNe**
  720 SNe in the past decade,
  40% of all nearby (z < 0.05) SNe
- **Monitor a lot of SNe**
  ~300 observed so far.
  Light curves, physics,
  distances, cosmology
- **Provide statistics on SNe**
  Luminosity function, *RATES*





Abastumani Observatory, Georgia


GTA


diet
coke
ROBERTKIRSHNER


DOG SUNNY

Nearby Supernova Rates
(AVF et al., Leaman et al., 2 x Li et al.)

- **Previous benchmark:**

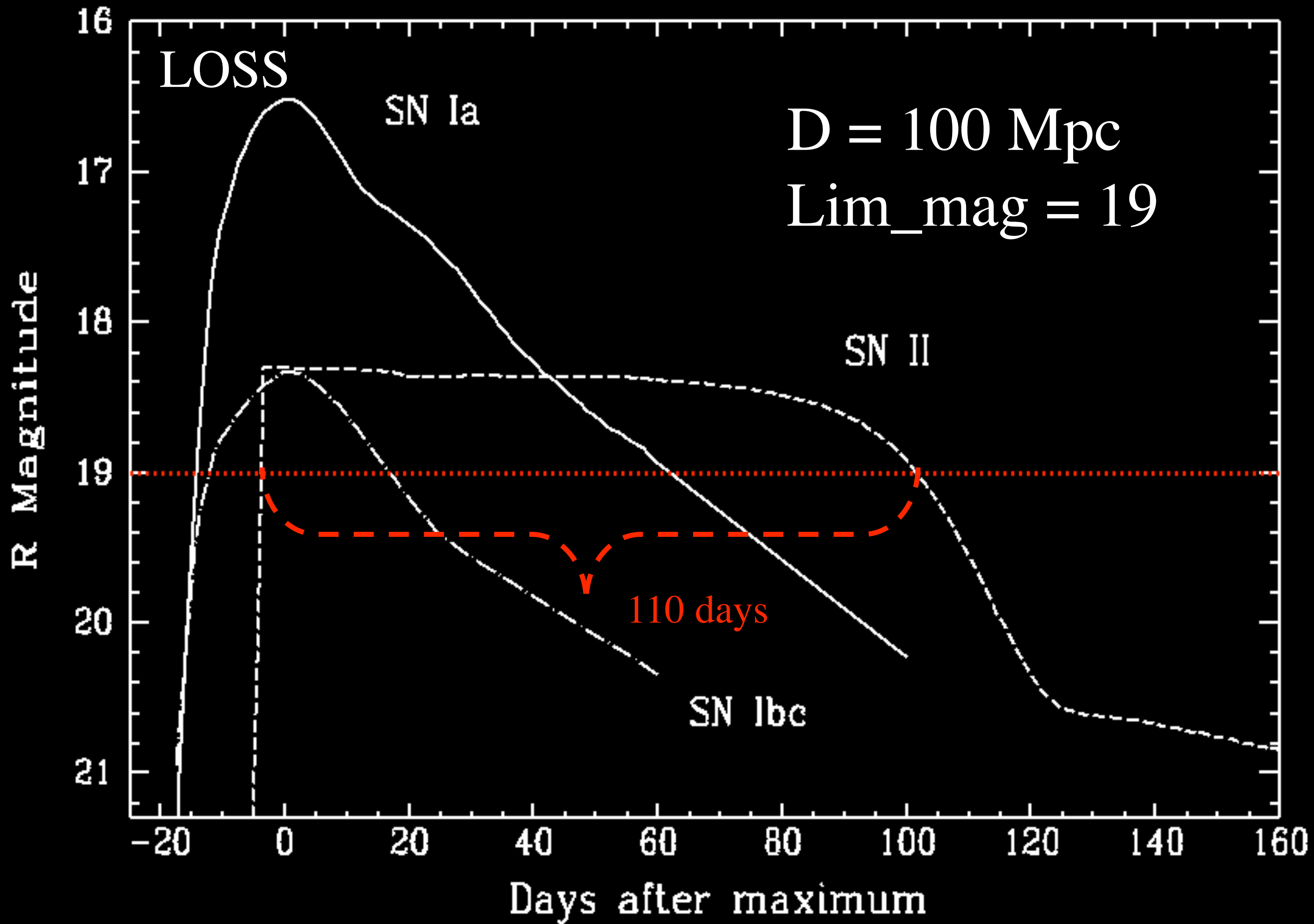
Cappellaro et al. 1999 (C99)
Mannucci et al. 2005 (M05)

* 137 SNe in about 10,000 galaxies
* 5 surveys (1 visual, 4 photographic plates)
* SN rate as a function of SN type (Ia, Ib/c, II) and host morphology, color (B-K), environment

- **LOSS rate (this talk):**

* 931 SNe in 15,000 galaxies, 728 SNe used
* One systematic CCD imaging survey
* Improved control-time (Zwicky) calculation

Control time (one epoch)



Could see SN Ia for 80 days, SN Ib/c for 35 days, SN II-P for 110 days

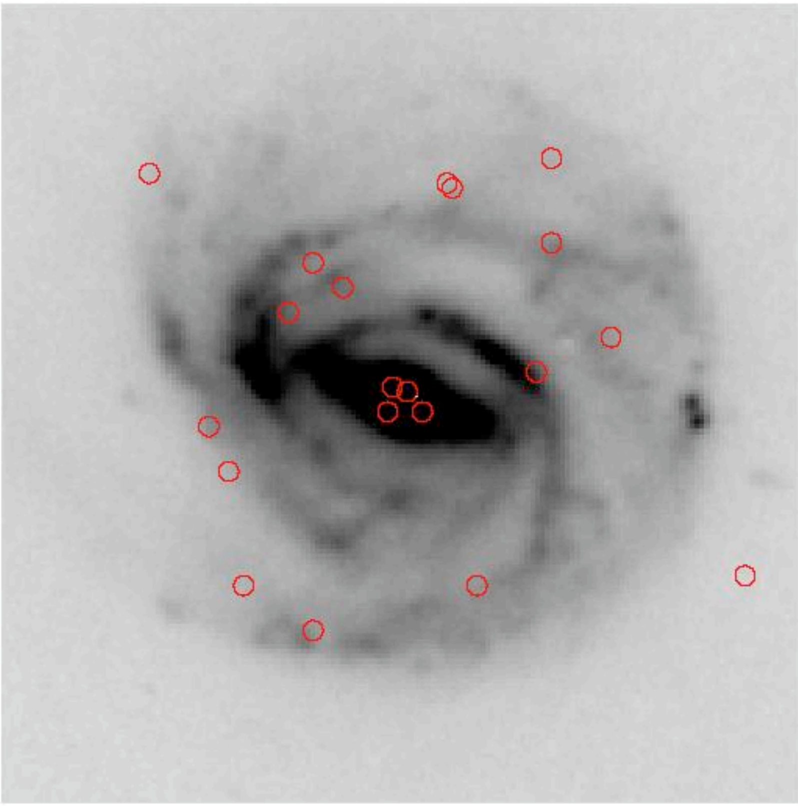
Improved Control-Time Calculation

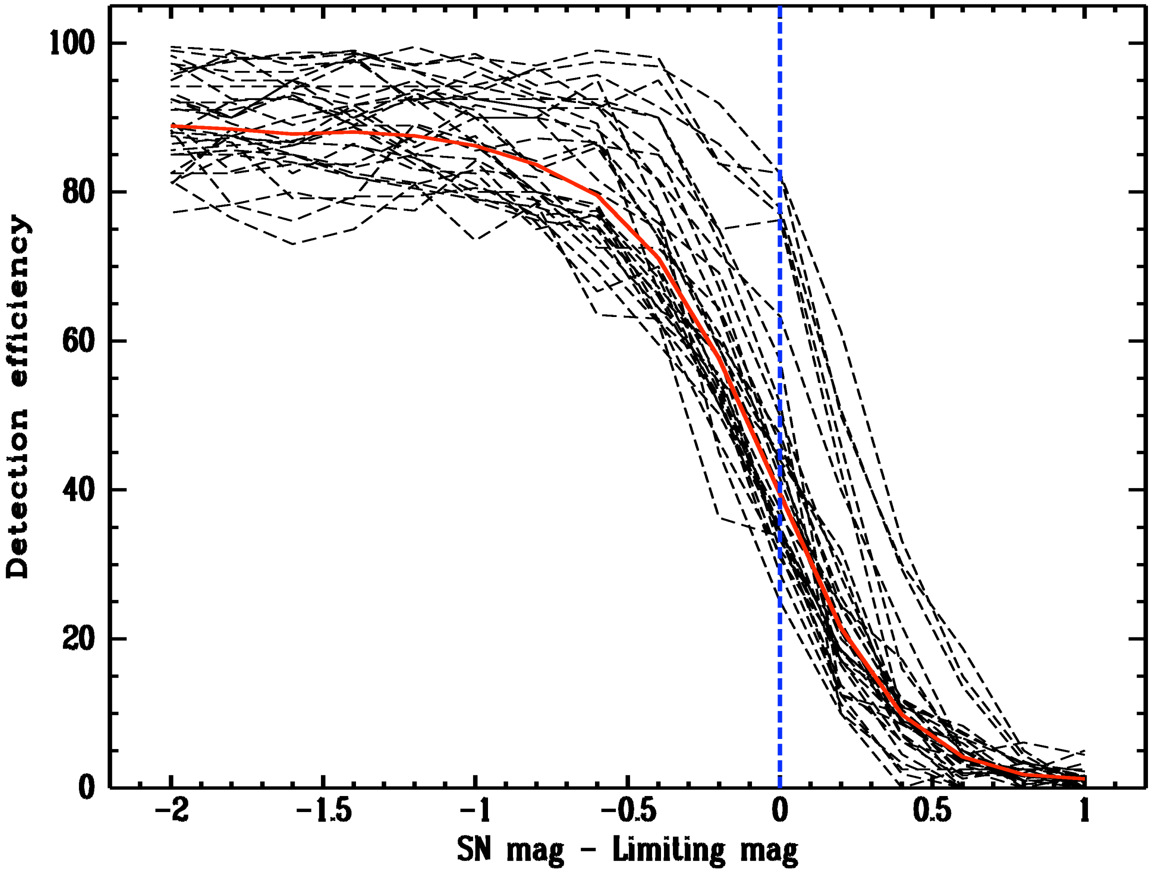
$$\text{SN rate} = \frac{\text{Number of Supernovae}}{\sum_{i=1}^{15000} L_i \times \text{Total\_Control\_Time}_i}$$

- **Monitoring history**
  - Detailed log files, limiting mag for each image
- **Detection efficiency**
  - Monte Carlo simulation
- **SN light curve, peak magnitude, reddening**
  - Construction of a complete SN sample

Detection efficiency simulation

- **Fake SNe follow the galaxy light.**
- **Images processed by the SN search pipeline.**
- **Efficiency is a function of galaxy type, size, and inclination.**





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  - Monte Carlo simulation
- **SN light curve, peak magnitude, reddening**
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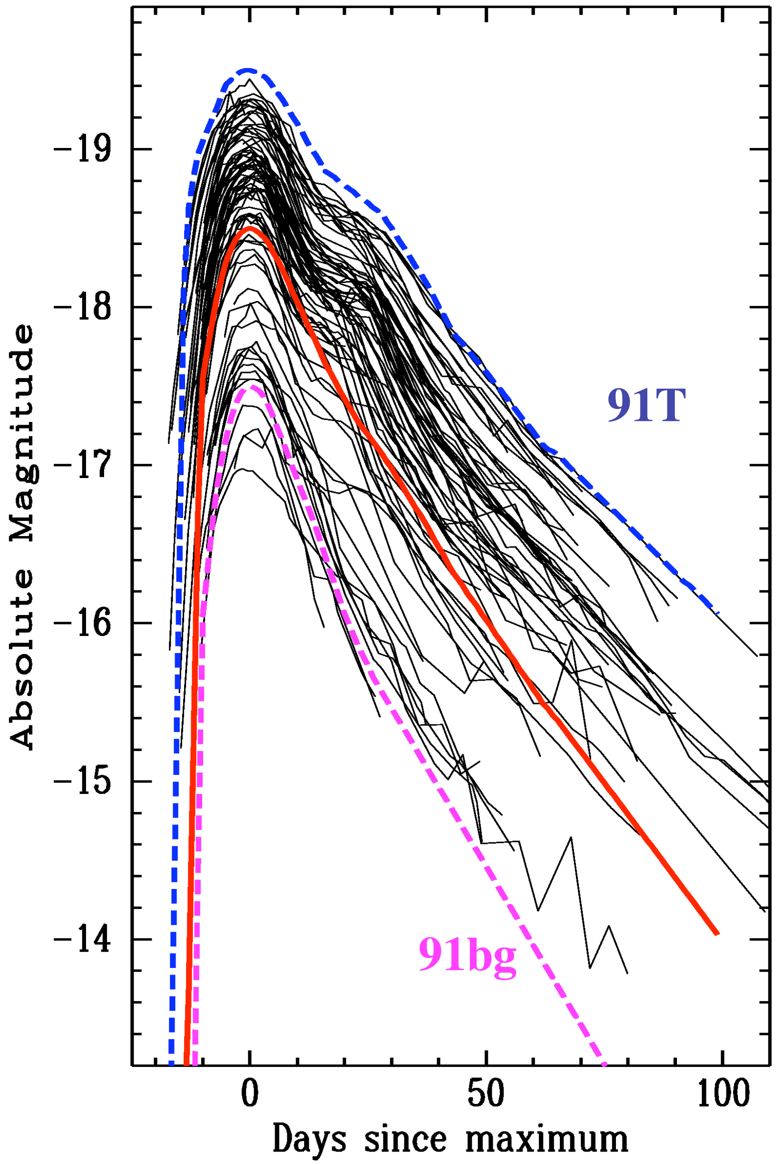
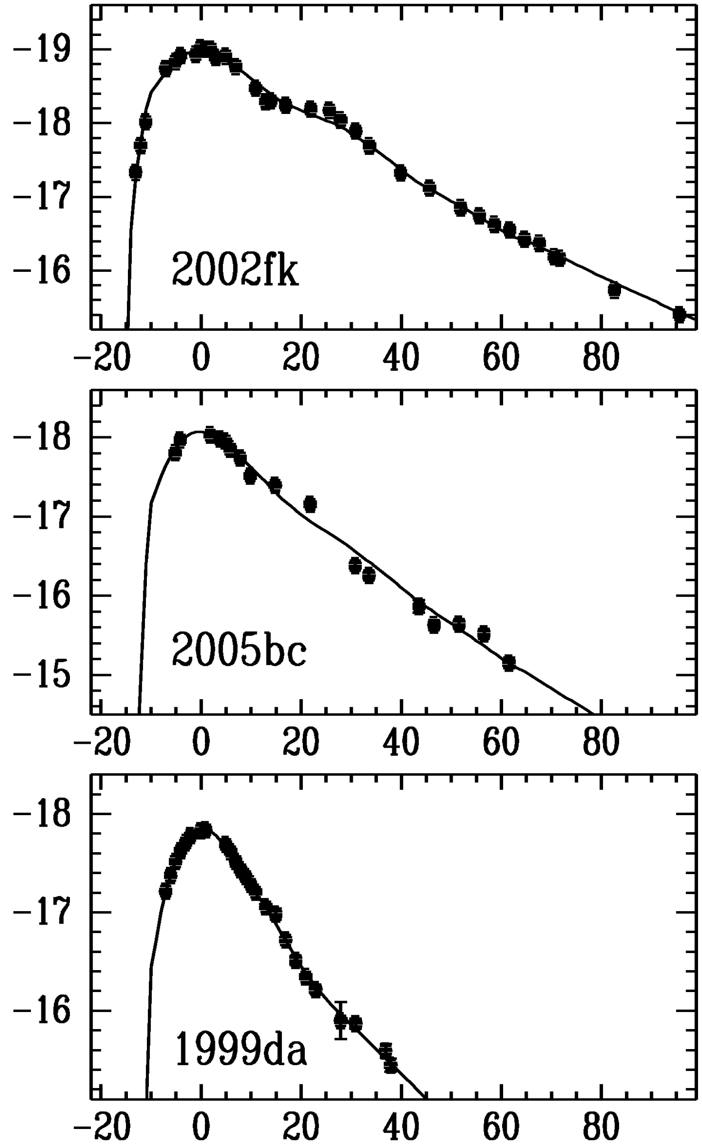
The Construction of a Complete SN Sample
(complete to $M_R \approx -16$ mag, d < 60 Mpc)

- Select a distance-limited KAIT SN sample (total = 137 SNe)
  - SN Ia (<80 Mpc): 56 objects
  - SN Ibc (<60 Mpc): 23 objects
  - SN II (<60 Mpc): 58 objects
- Collect photometry for every SN
  - R-band follow-up photometry (42%)
  - Unfiltered search monitoring data (58%)
- Fit a family of light curves to each SN type
  - Light-curve shape, peak magnitude
- Study the completeness of each SN

A family of 21 light-curve shapes

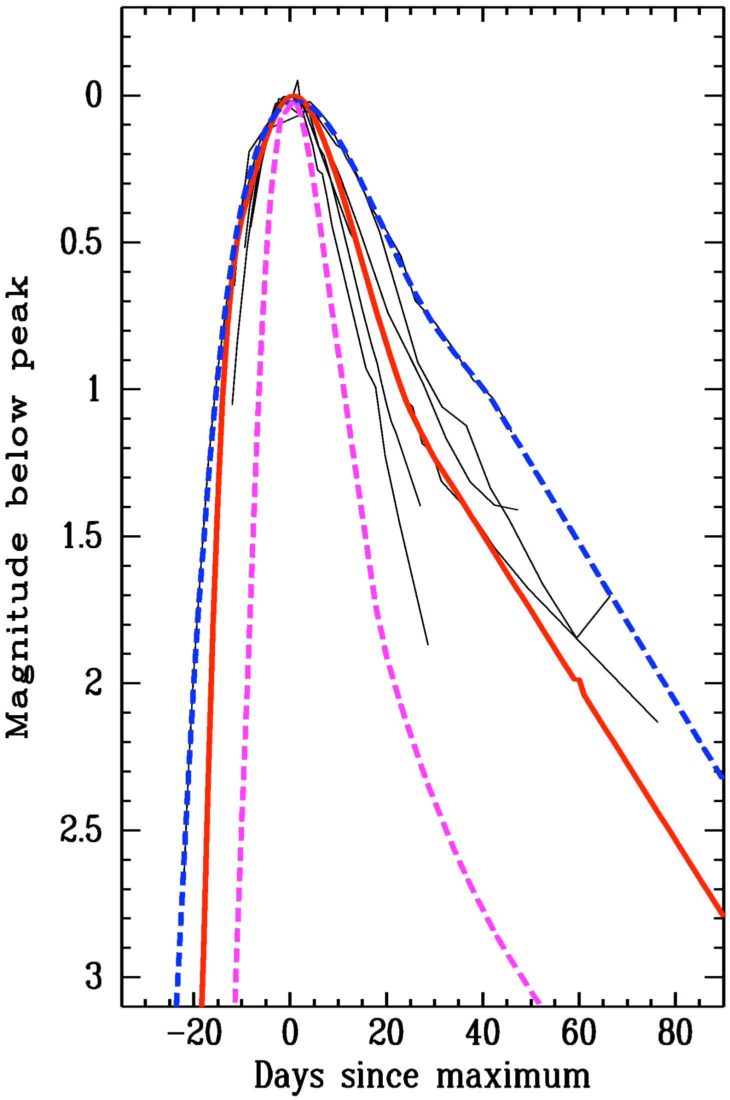


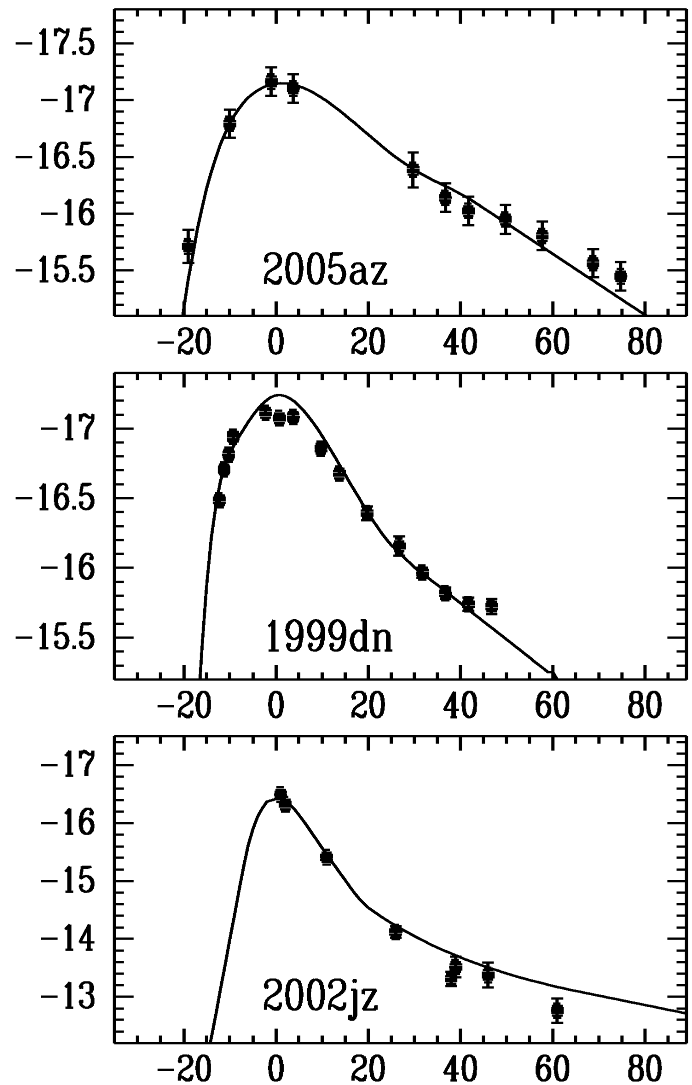
Fits to all 56 SNe Ia



- Slow (04dk)
- Average
- Fast (94I)

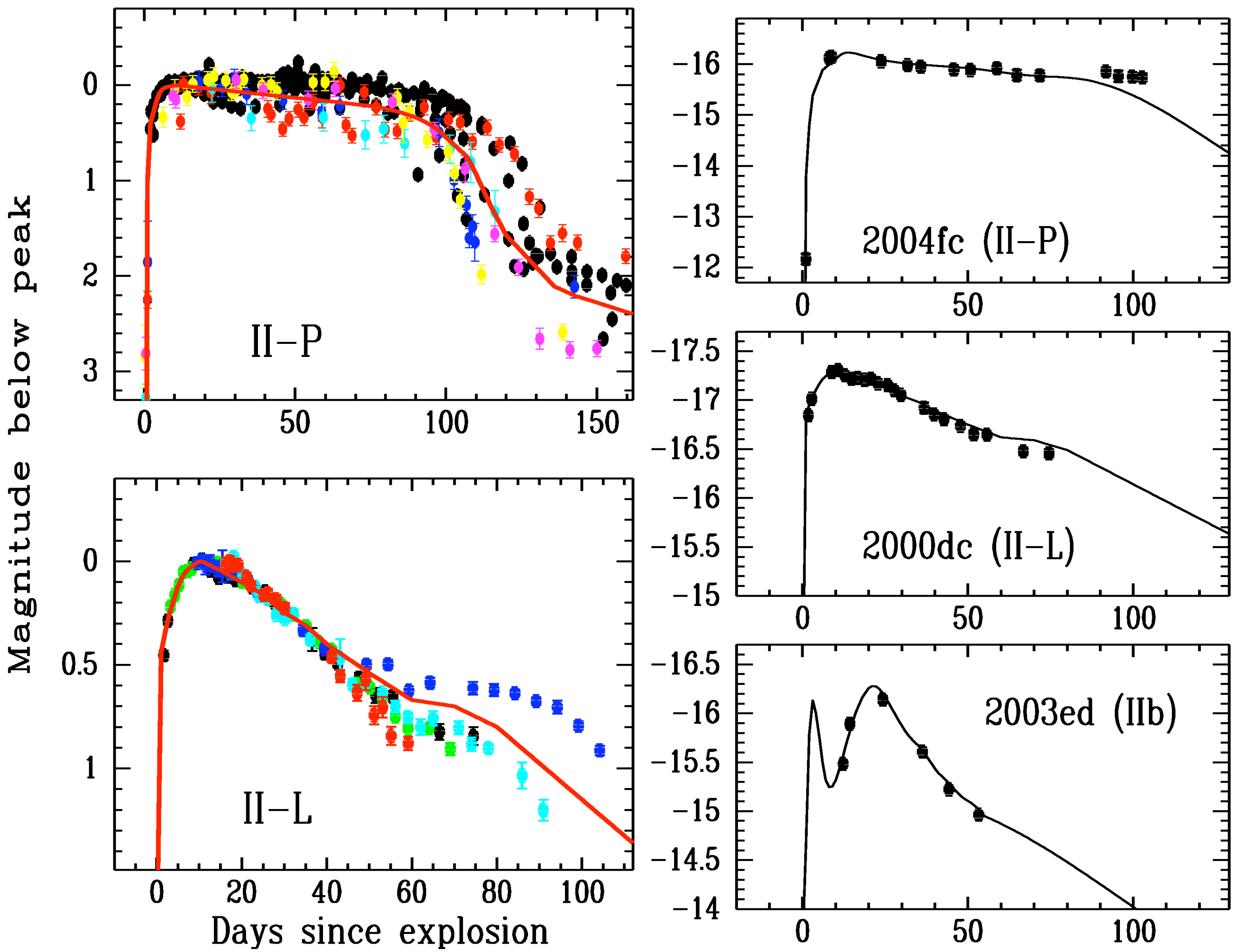
Fits to all 23 SNe Ibc





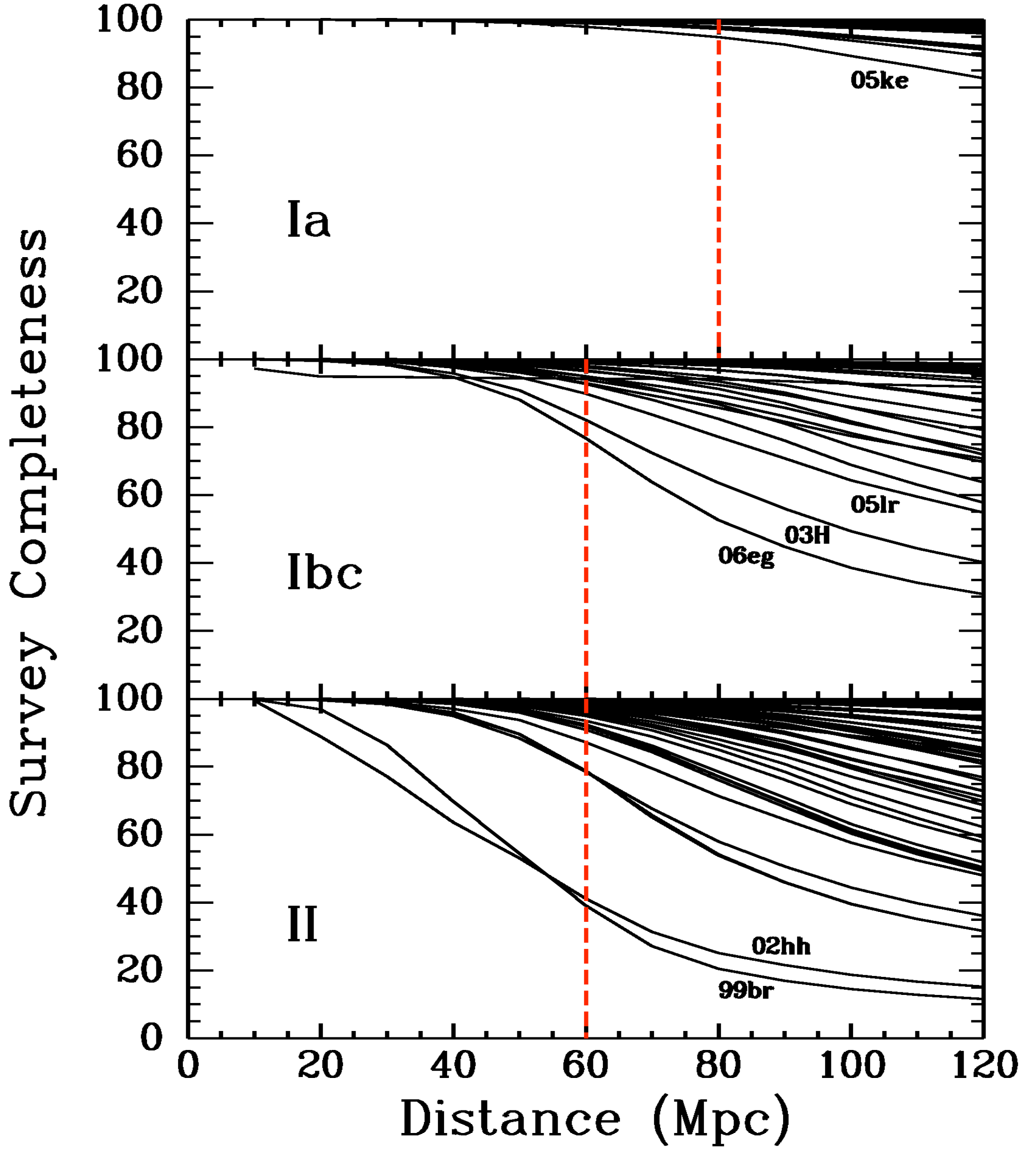
- Average II-P
- Average II-L
- Average IIb (93J)

Fits to all 58 SNe II

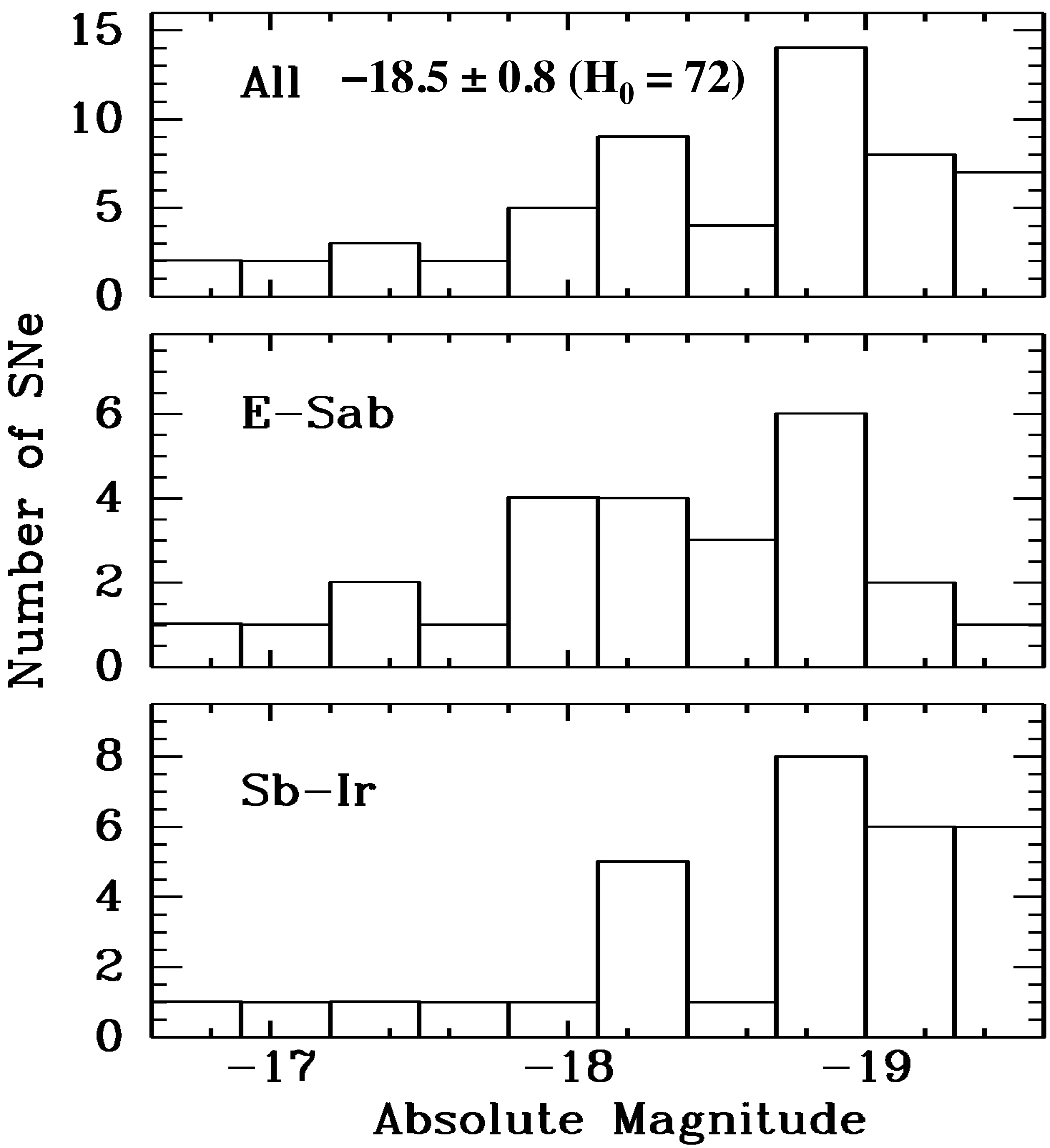


- **Completeness study for every SN**

Completeness = control time / season time



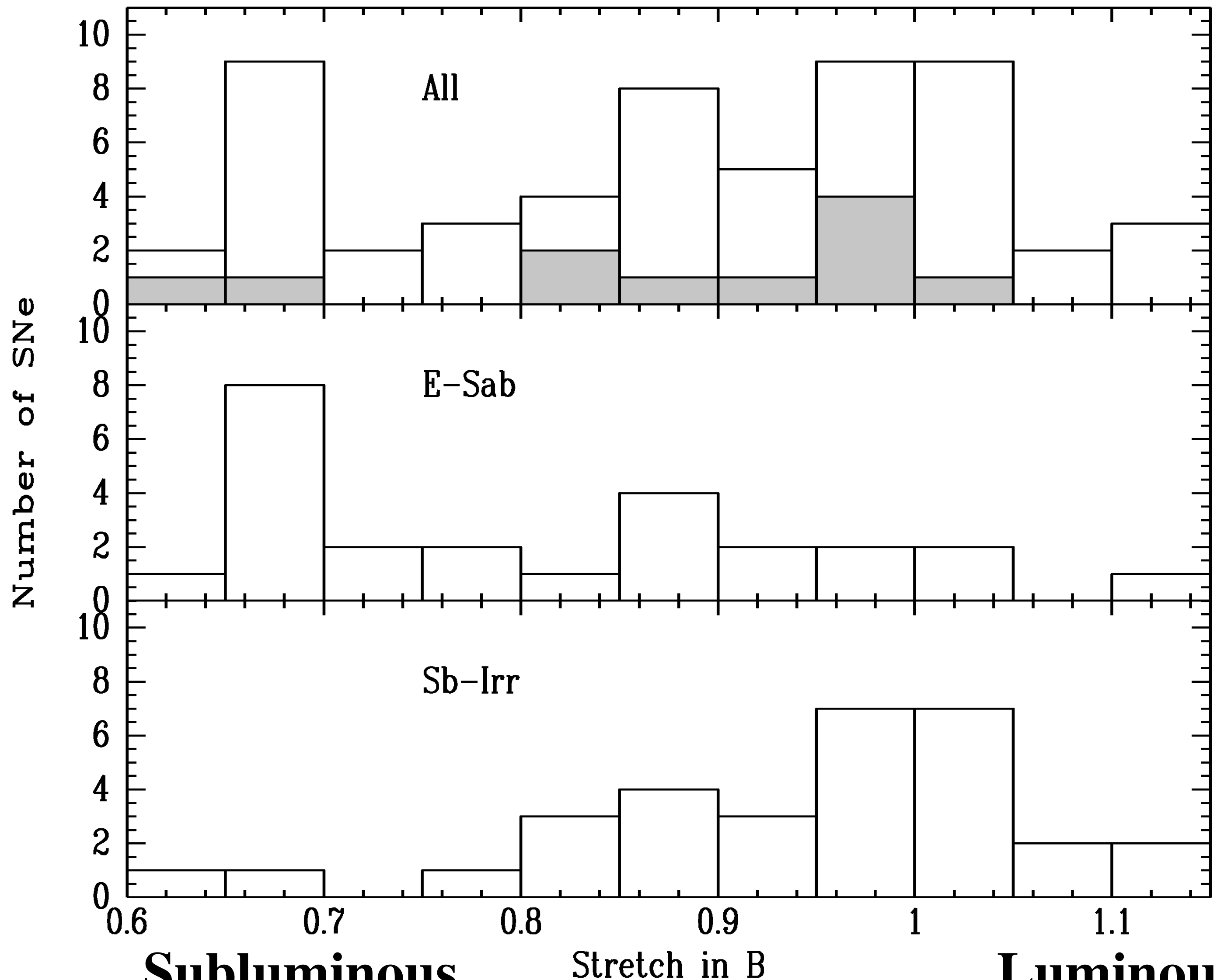
The Observed SN Ia Luminosity Function (56.5 SNe) (R band)



Input = 56 SNe

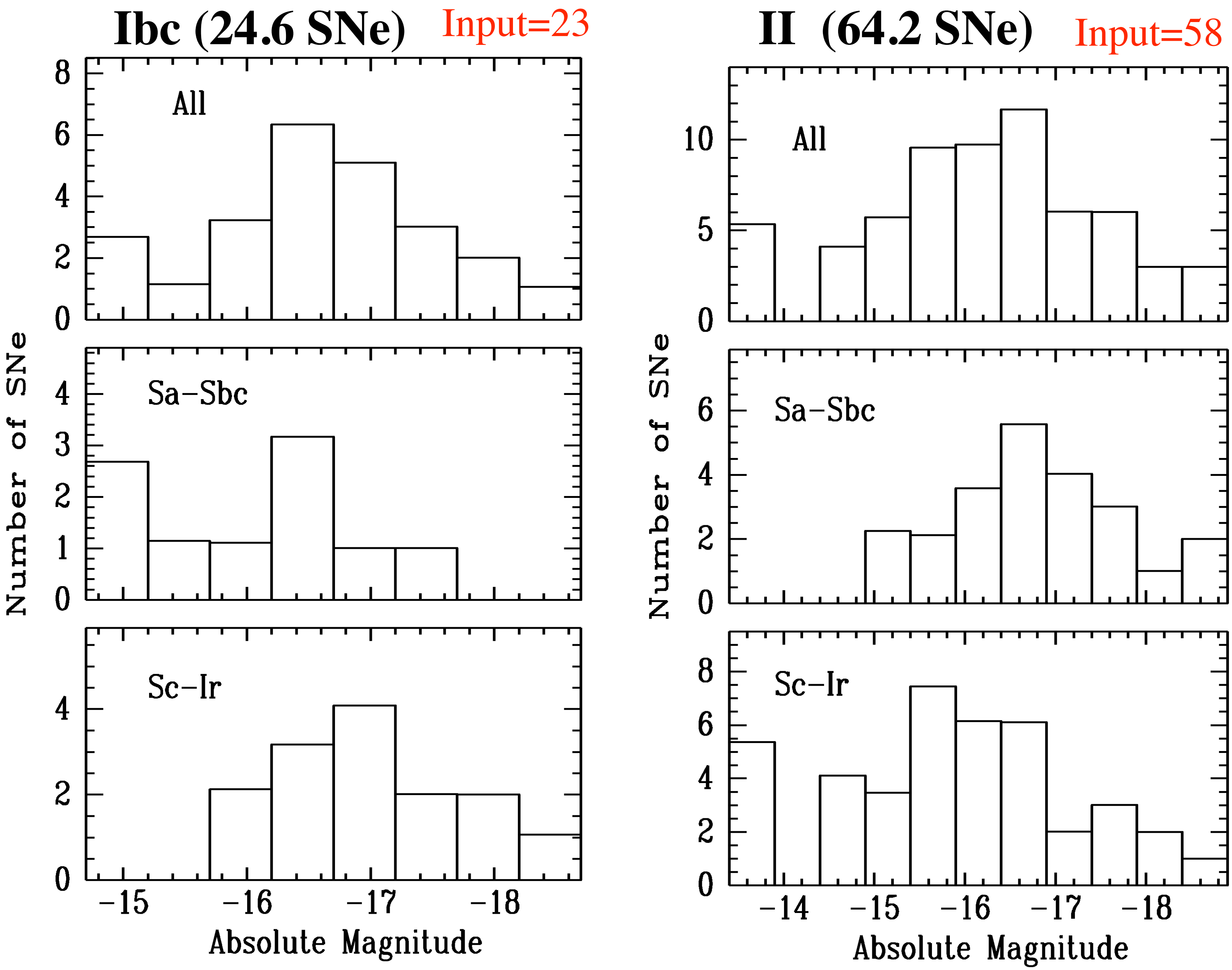
Intrinsic Volume-Limited LF of SNe Ia

Bimodal distribution

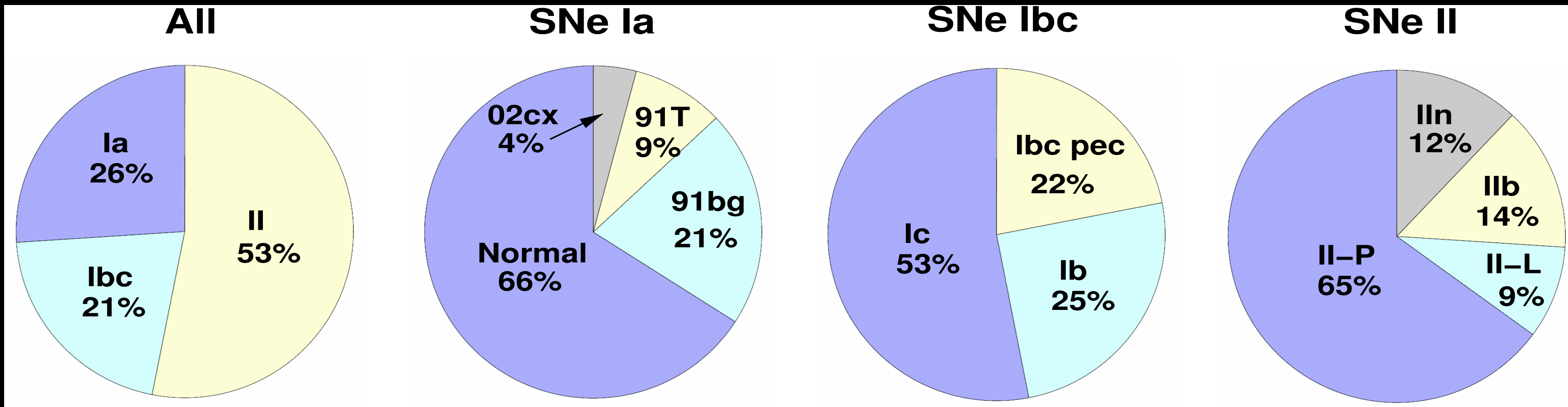


Subluminous **Luminous**

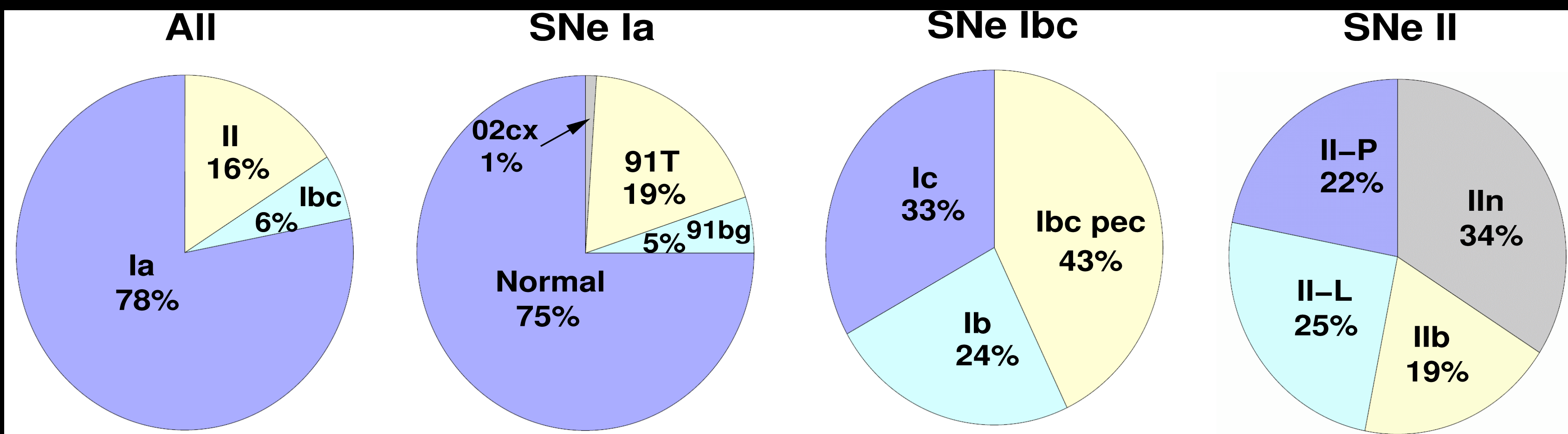
LFs of Core-Collapse SNe (R band)



Subtype distribution (volume-limited)

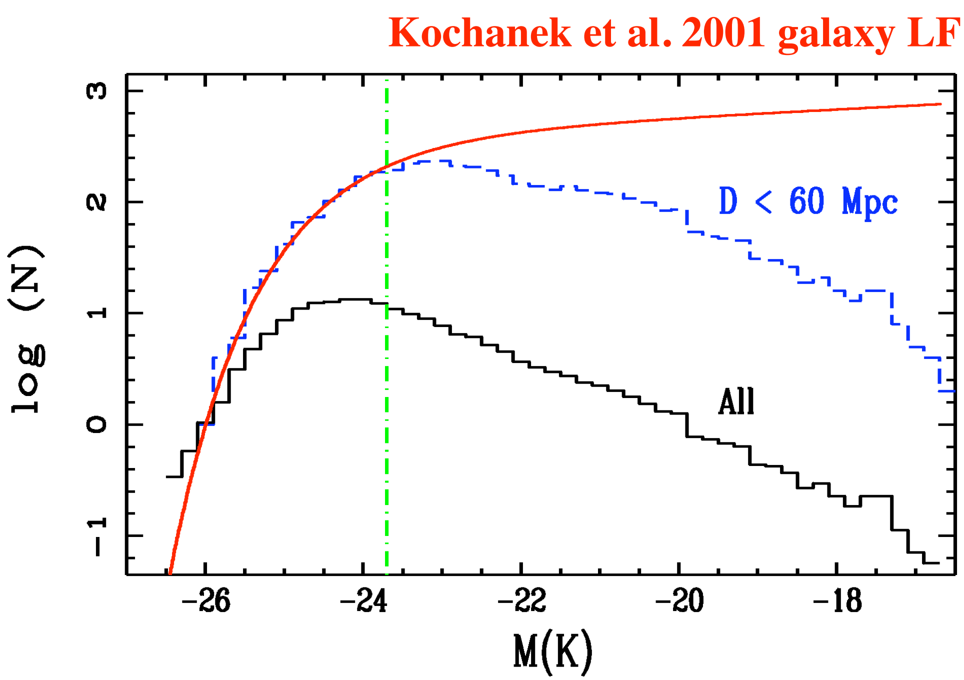


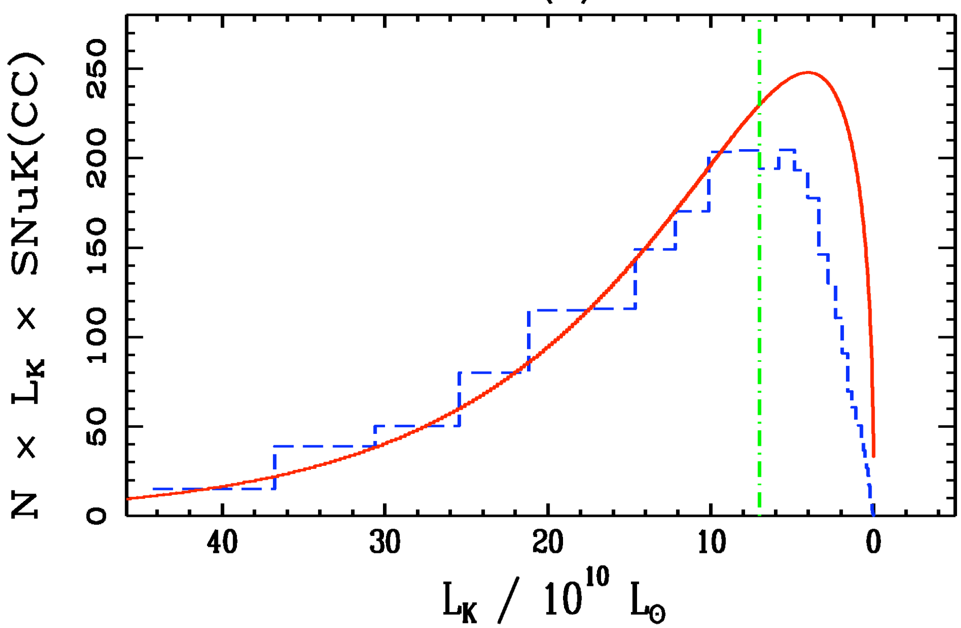
Subtype distribution (magnitude-limited)



- KAIT background SNe: 46 SNe; 74% Ia, 9% Ibc, 17% II
- Recent PTF: 29 SNe; 72% Ia, 4% Ibc, 24% II.

LOSS Galaxy Sample: not just luminous galaxies





Within 60 Mpc:

C-C SNe: missing 15%

SNe Ia : missing 10%

The SN Rate Unit (SNu)

$$\text{SN rate} = \frac{\text{Number of Supernovae}}{\sum_{i=1}^{15000} L_i \times \text{Total\_Control\_Time}_i}$$

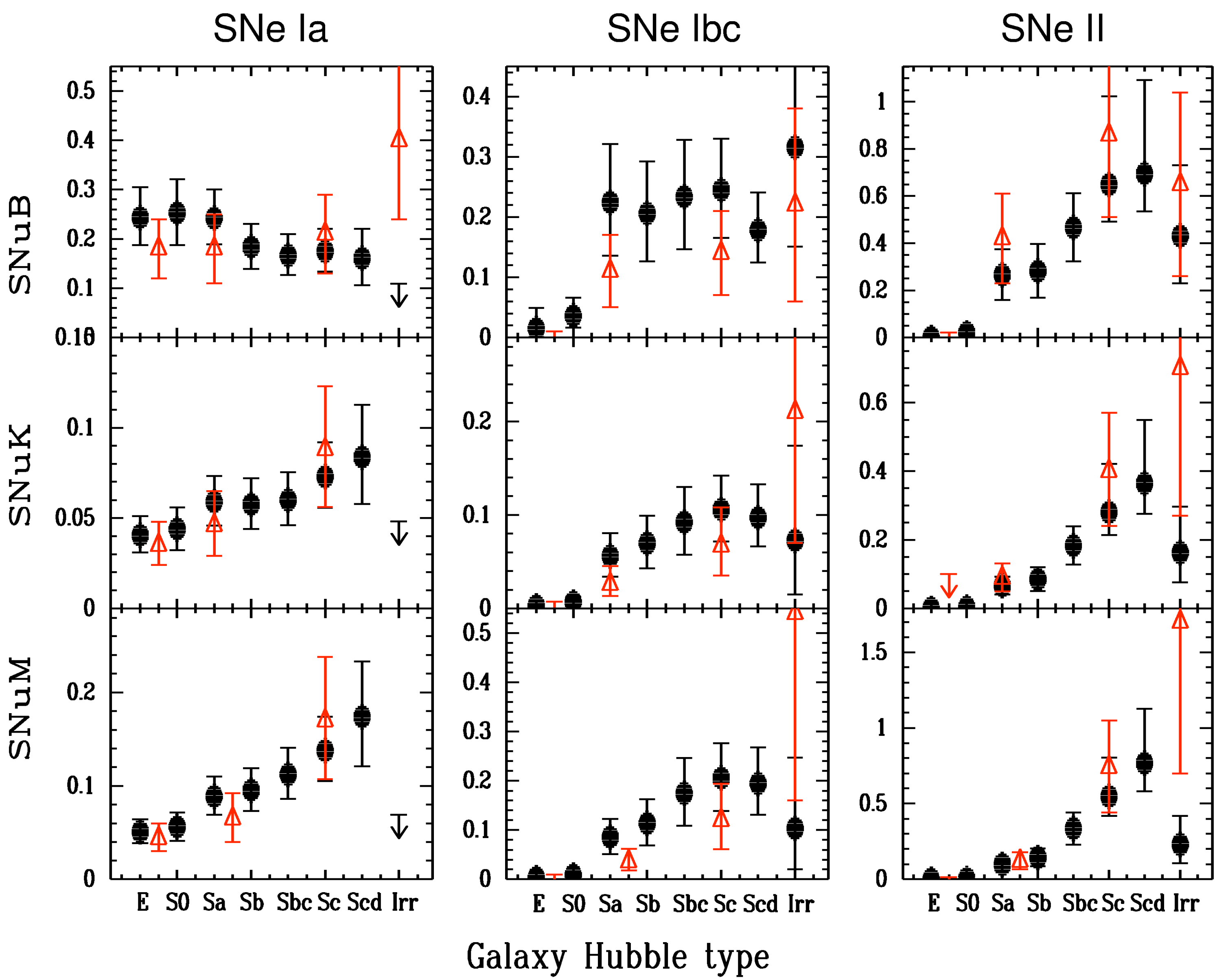
SNuB 1 SN per $10^{10}\ L_{\odot}(B)$ per 100 yr

SNuK 1 SN per $10^{10}\ L_{\odot}(K)$ per 100 yr

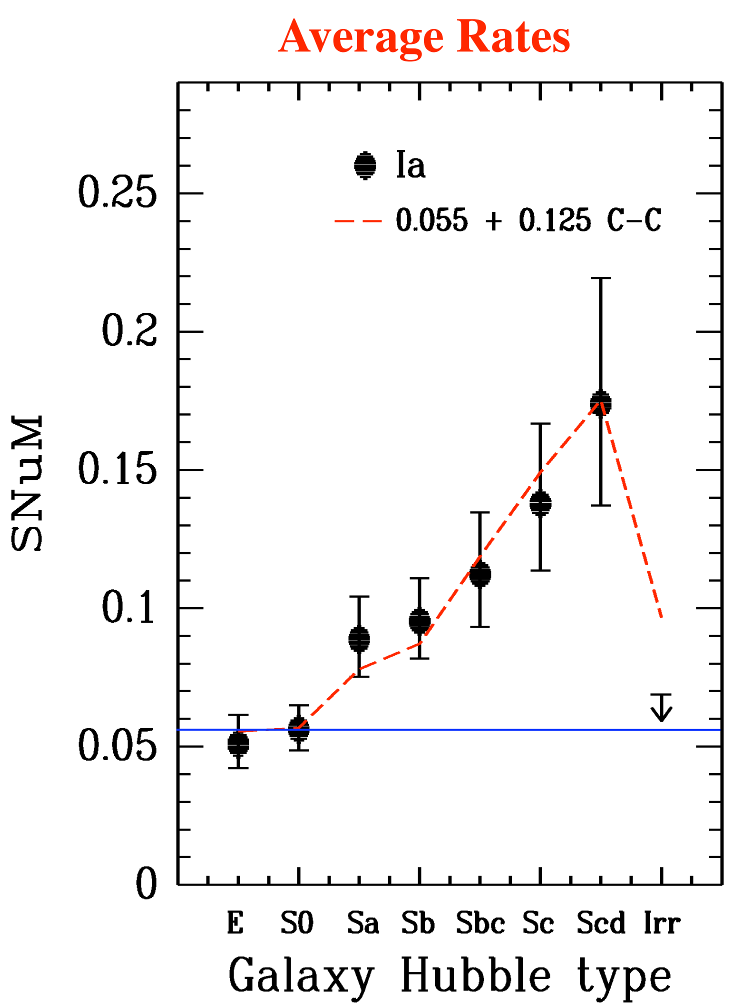
SNuM 1 SN per $10^{10}\ M_{\odot}$ per 100 yr

(Note: $M \approx L(K) + \exp[0.212(B-K) - 0.959]$)

LOSS rates compared with previous best nearby rates: Cappellaro et al. 1999, Mannucci et al. 2005

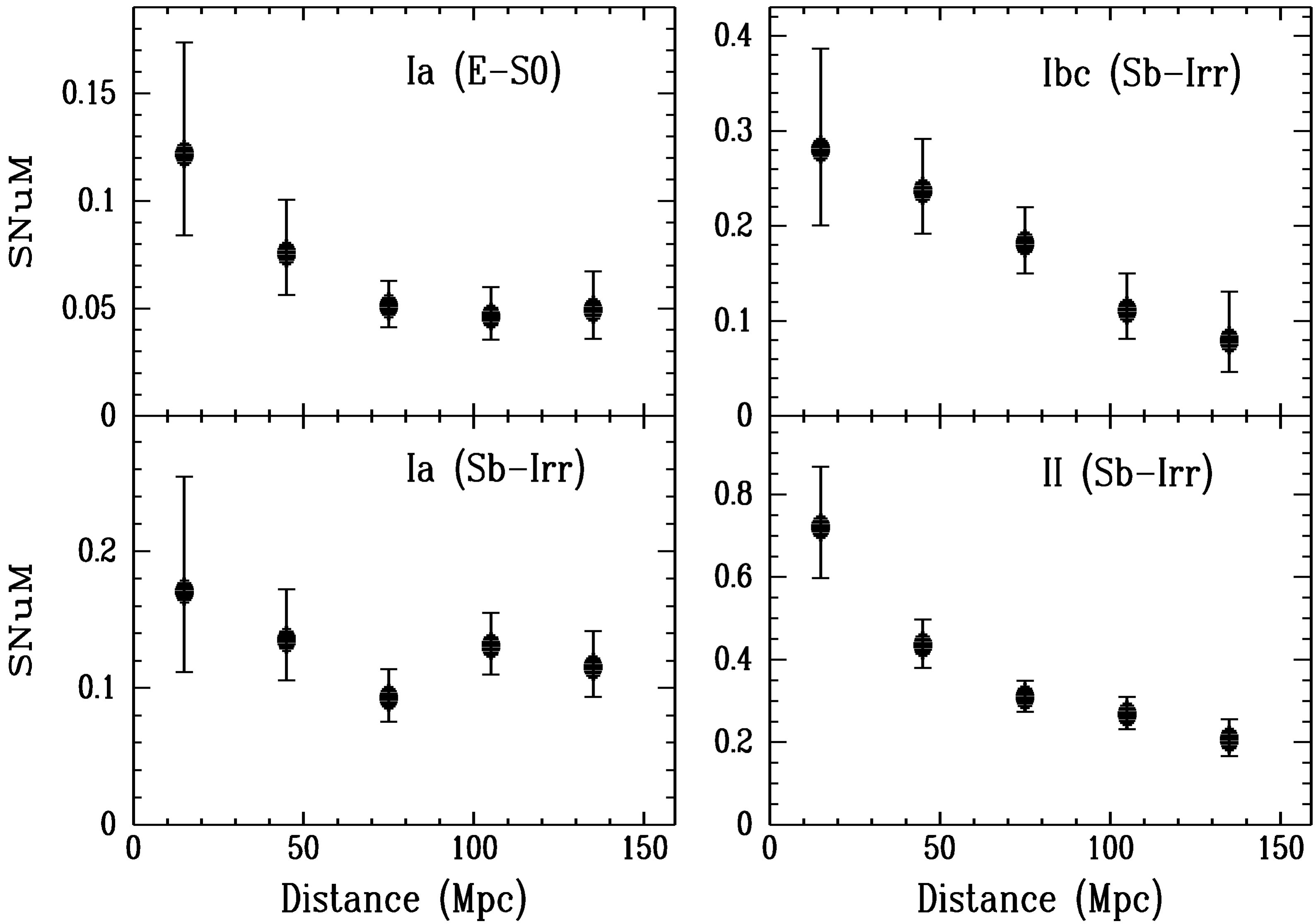


A Two-Component Fit to SN Ia Rates

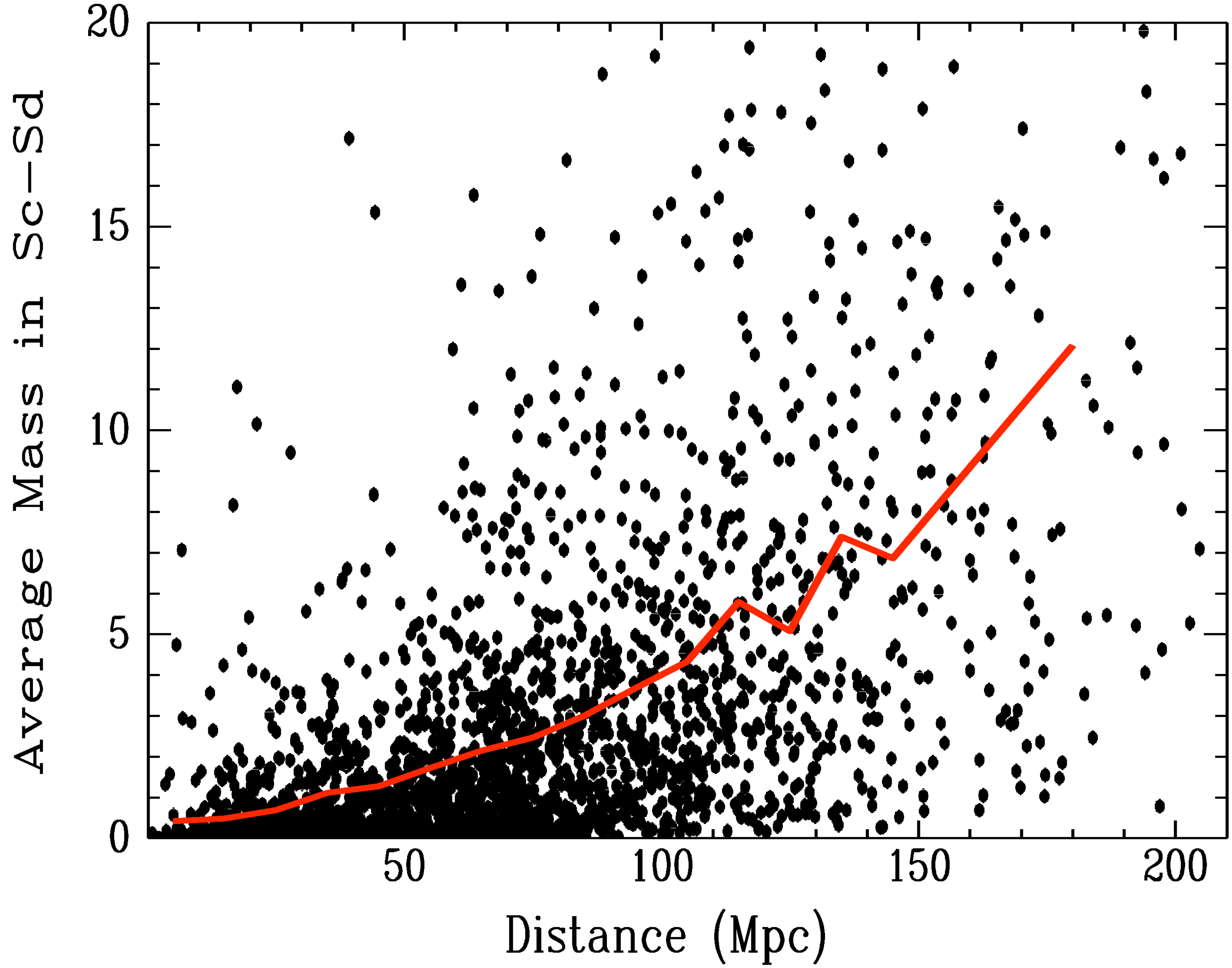


SN Ia rate proportional to (1) SFR [prompt] and (2) galaxy mass [tardy] (confirms Mannucci et al. 2004, 2005, Scannapieco & Bildsten 2005, Neill et al. 2006, Sullivan et al. 2006, Pritchet et al. 2008)

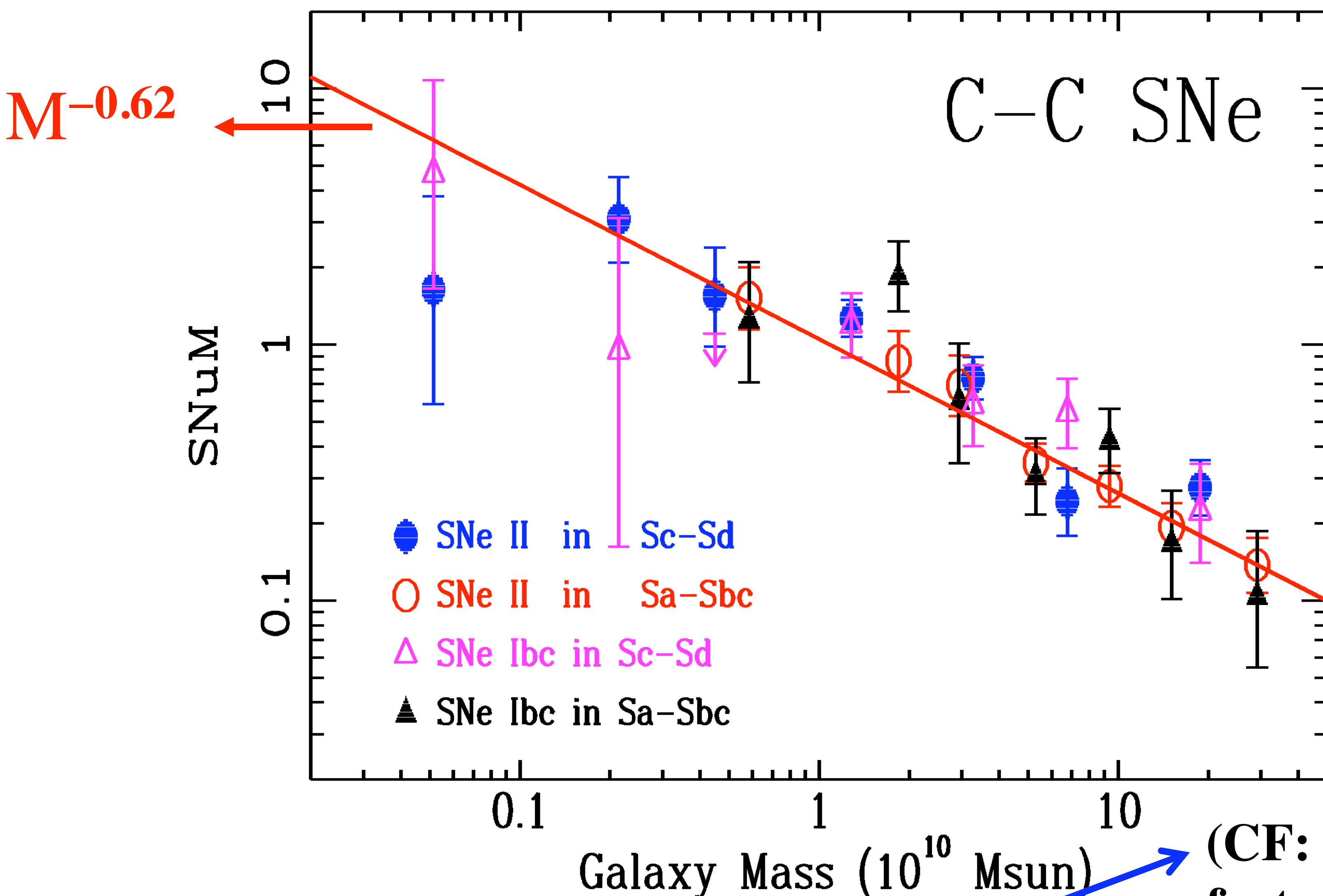
A "Nasty" Trend: Rates in Different Distance Bins



A Clue from the Average Mass in Distance Bins



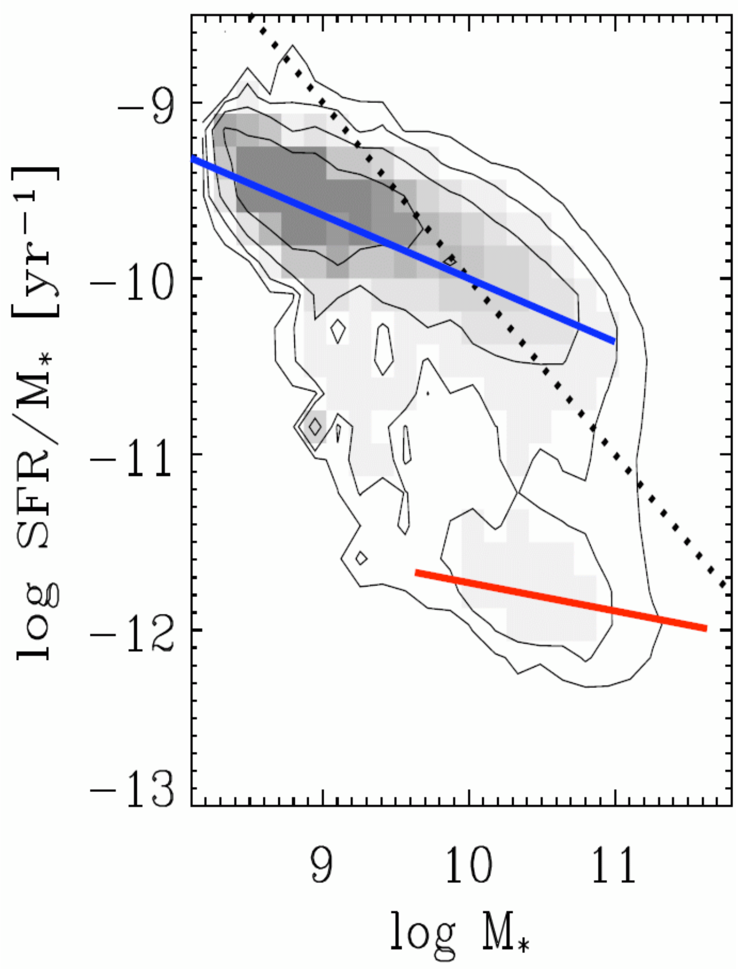
A correlation between C-C SN rate and galaxy mass



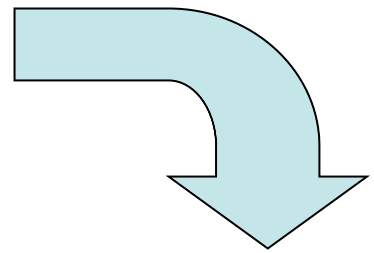
(CF: correction factor)

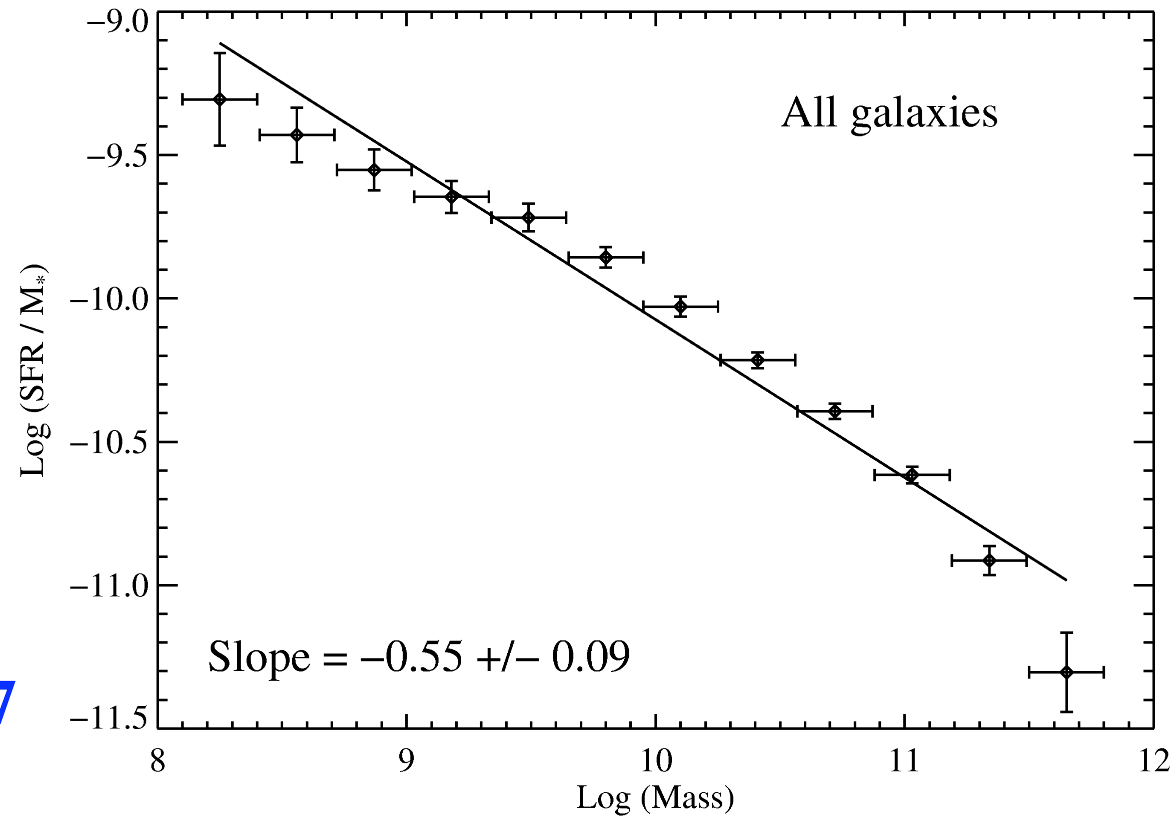
$$\text{Rate/mass} = \text{SNuM}(M_0) \left(\frac{M}{M_0}\right)^{-0.62} \text{; total rate} \propto M^{0.38}$$

Probable connection to specific star formation rate



Schiminovich et al. 2007
(using data from SDSS)





The rate-mass relation

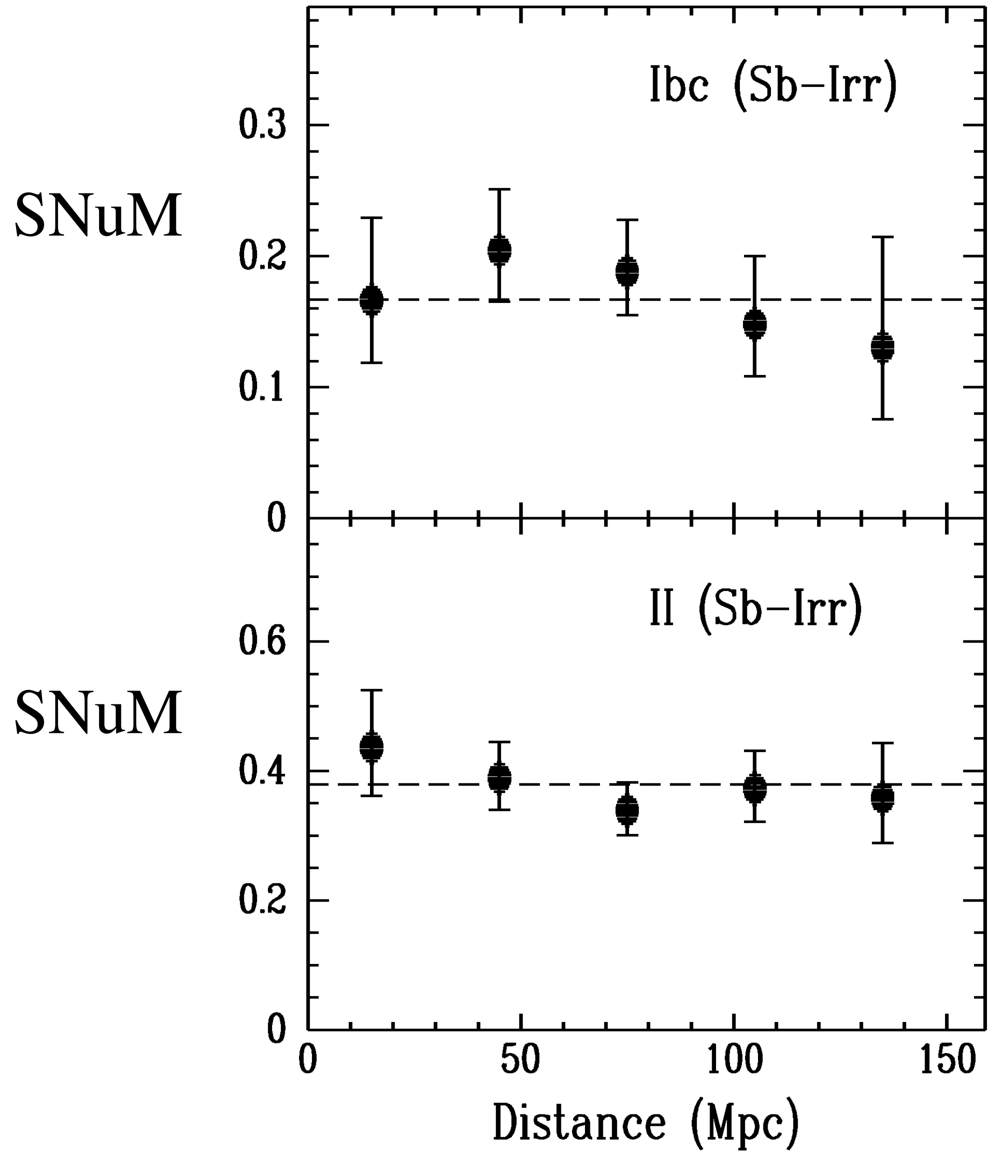
1. $$\text{Rate/mass} = \text{SNuM}(M_0)\left(\frac{M}{M_0}\right)^{-Y}$$

M_0: nominal mass

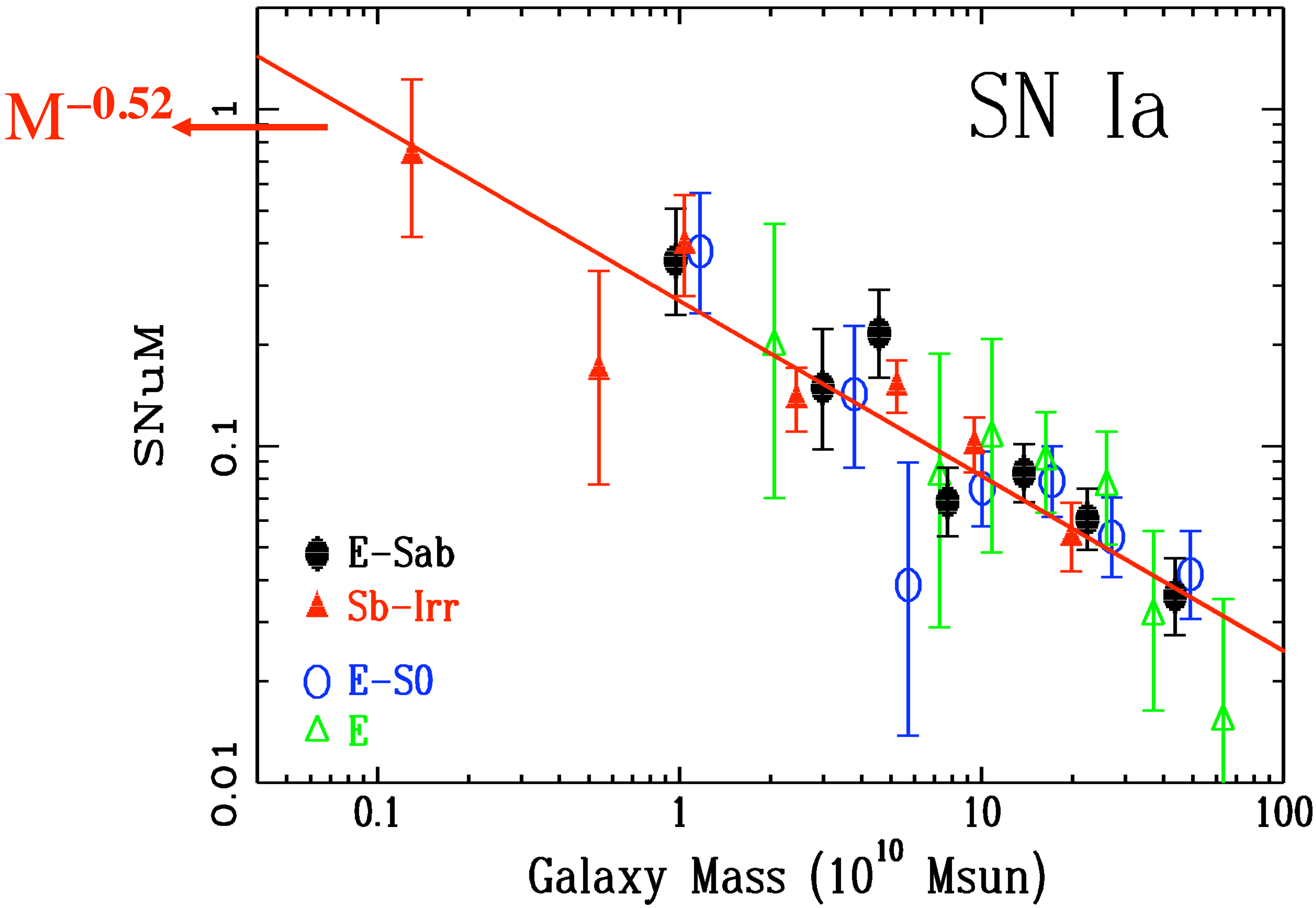
Y: mass correction factor (CF)

2. Total SN per year $\propto$ mass$^{(1-Y)}$

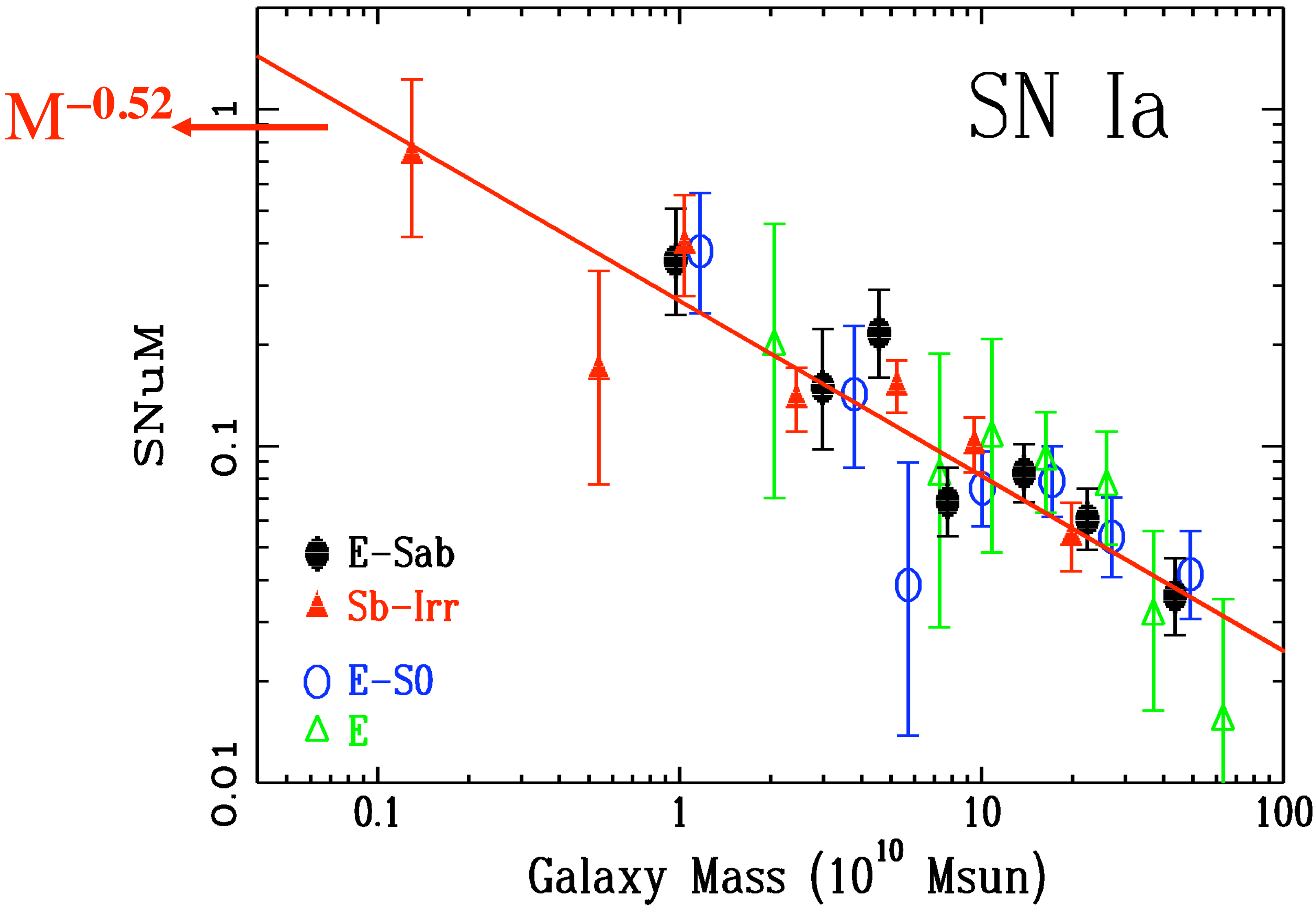
Rates in different distance bins ($M_0 = 4.0 \times 10^{10} M_\odot$).
The "nasty trend" is gone now… good!



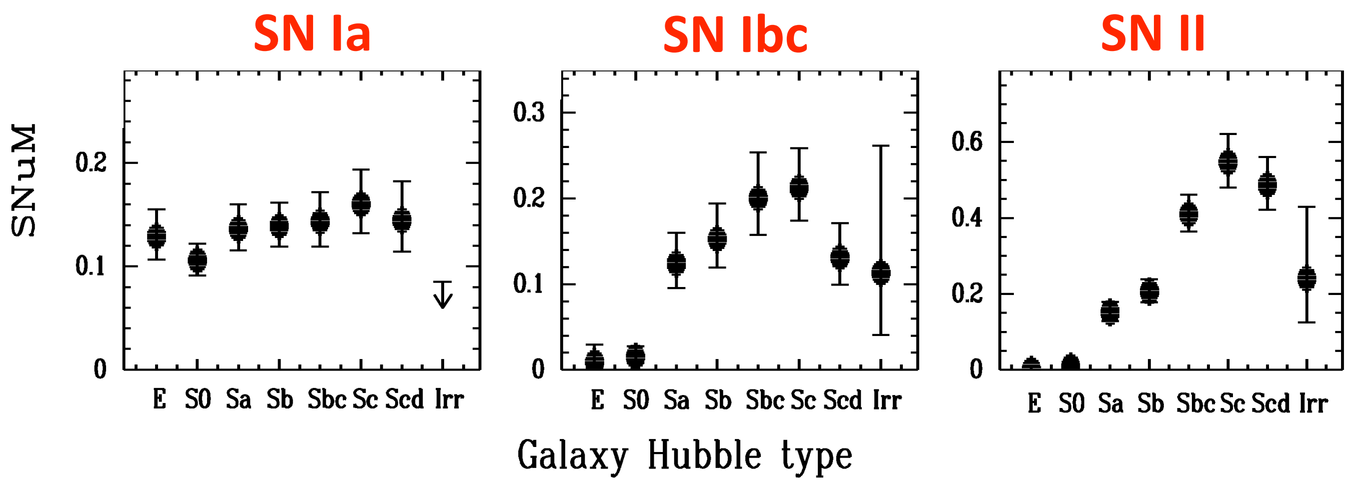
A similar correlation between SN Ia rate and galaxy mass!
(Already seen by Sullivan et al. 2006, for star-forming galaxies.)



BUT, the SN Ia rate-mass correlation holds even for passive (E/S0) galaxies! (Contrary to conclusion of Sullivan et al. 2006)

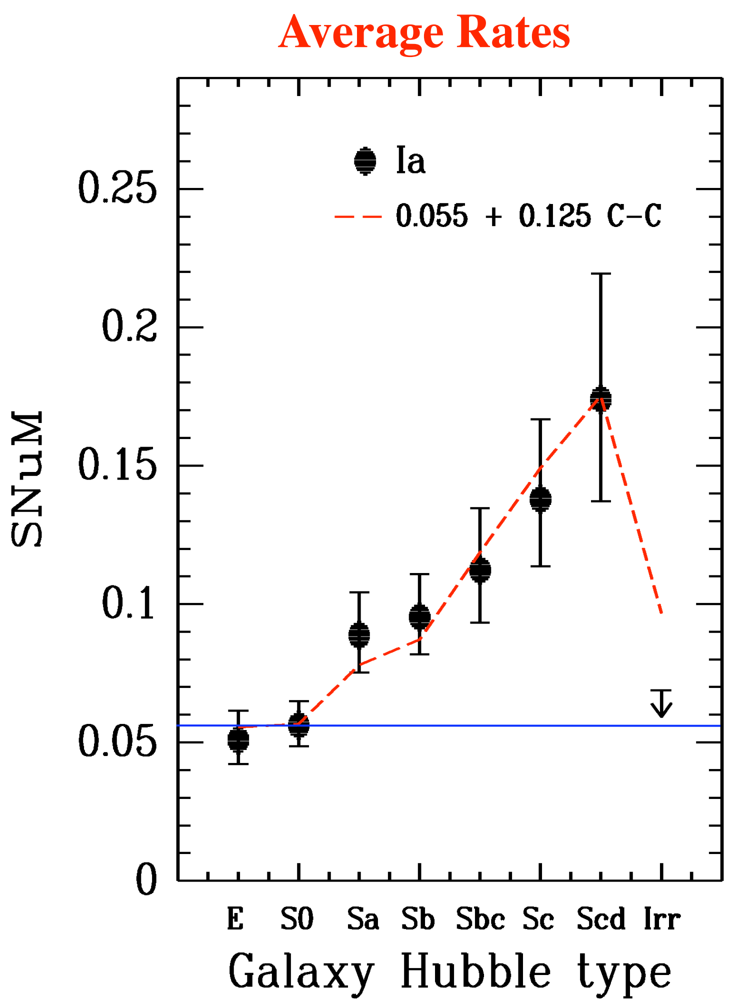


LOSS Rates for a Nominal Galaxy (M_0 = 4.0 x 10^{10} $M_\odot$)



“Prompt” component (SFR) not so important for SNe Ia?

A Two-Component Fit to SN Ia Rates



SN Ia rate proportional to (1) SFR [prompt] and (2) galaxy mass [tardy] (confirms Mannucci et al. 2004, 2005, Scannapieco & Bildsten 2005, Neill et al. 2006, Sullivan et al. 2006, Pritchet et al. 2008)

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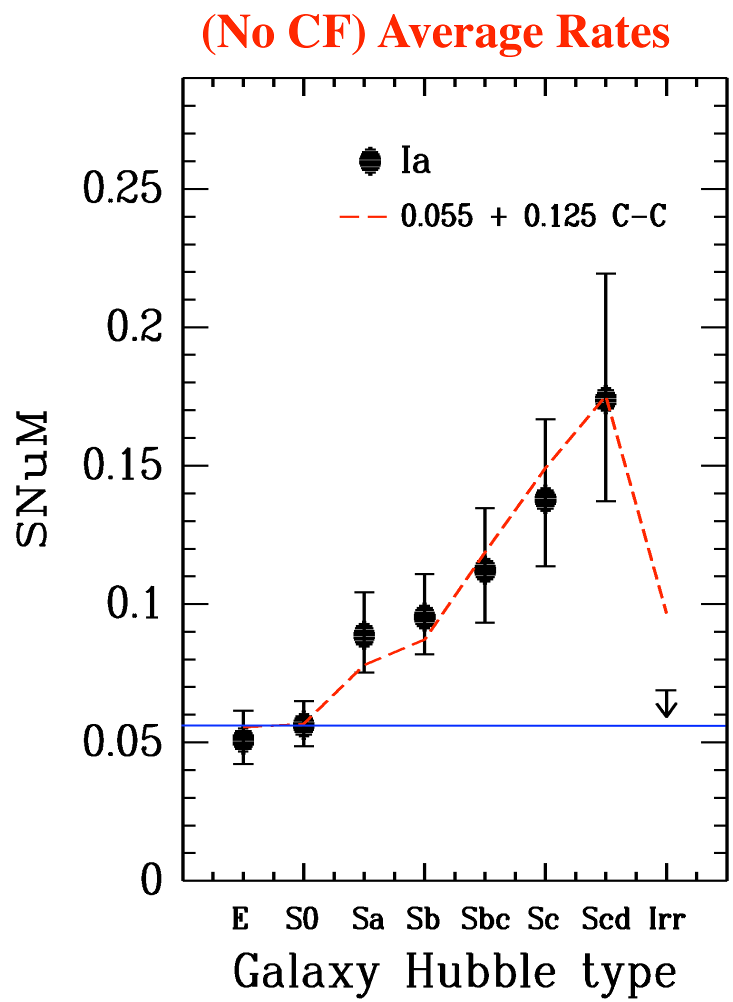

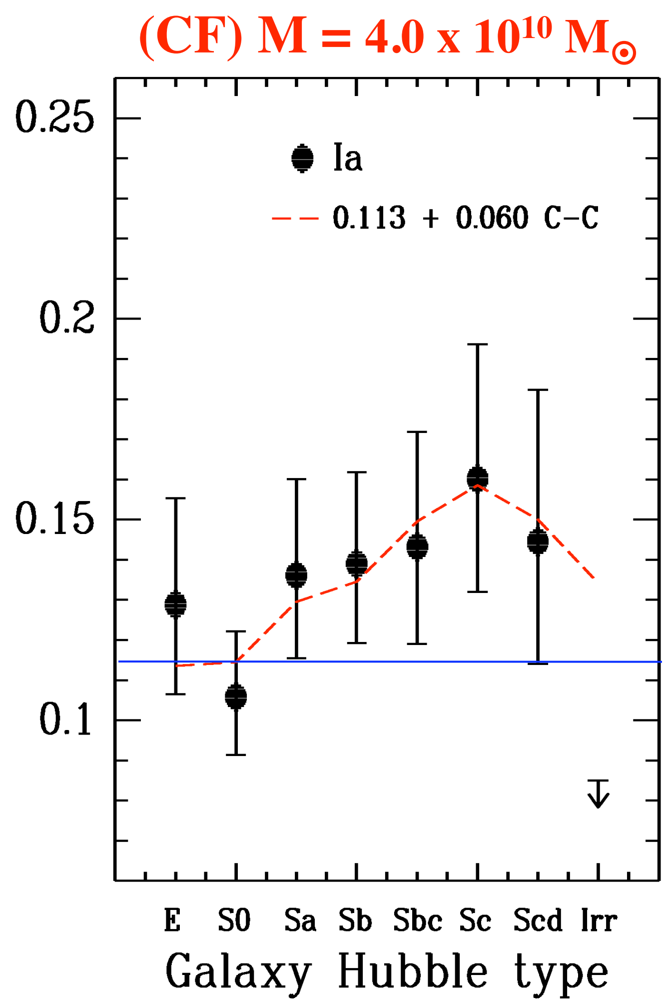

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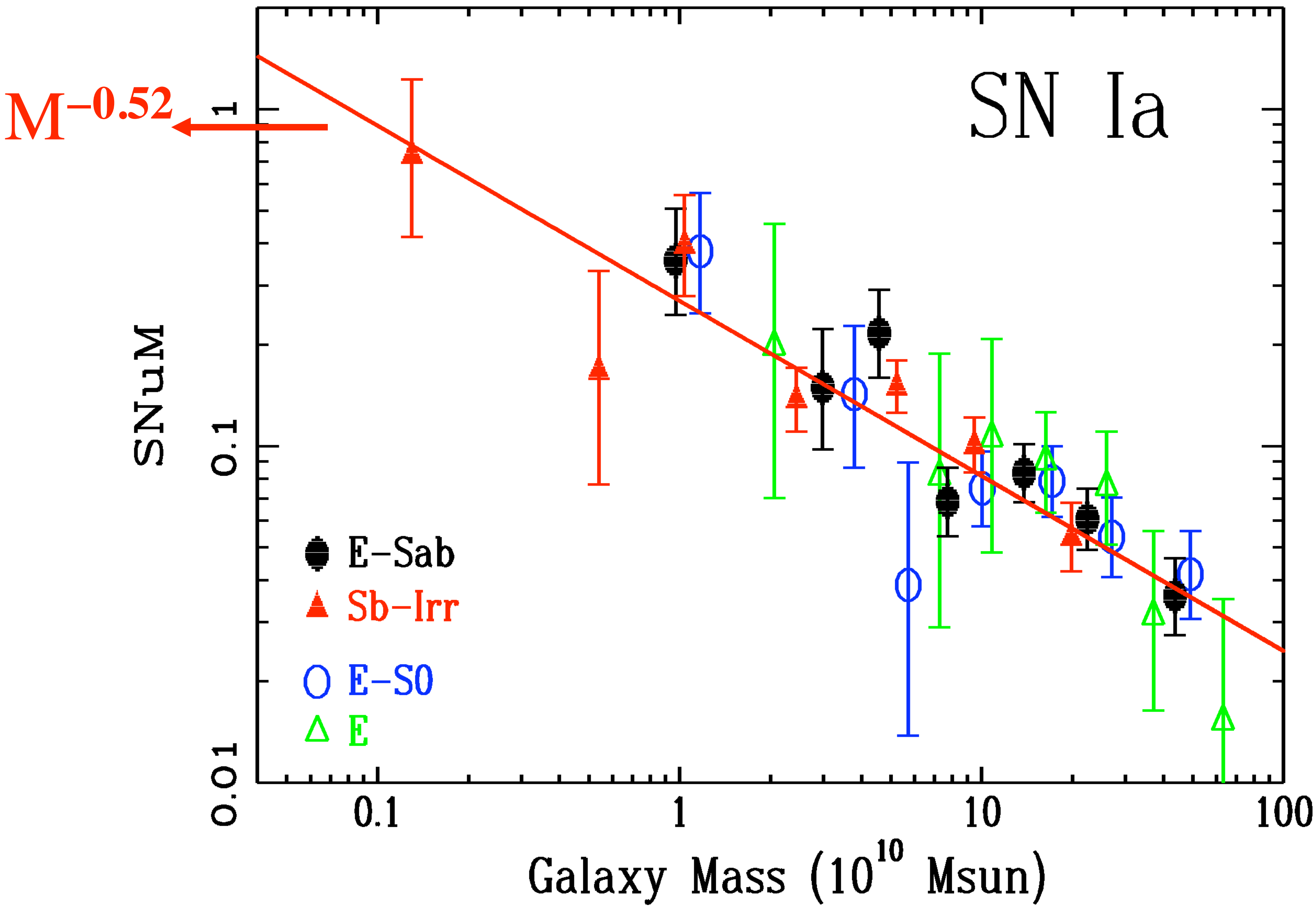
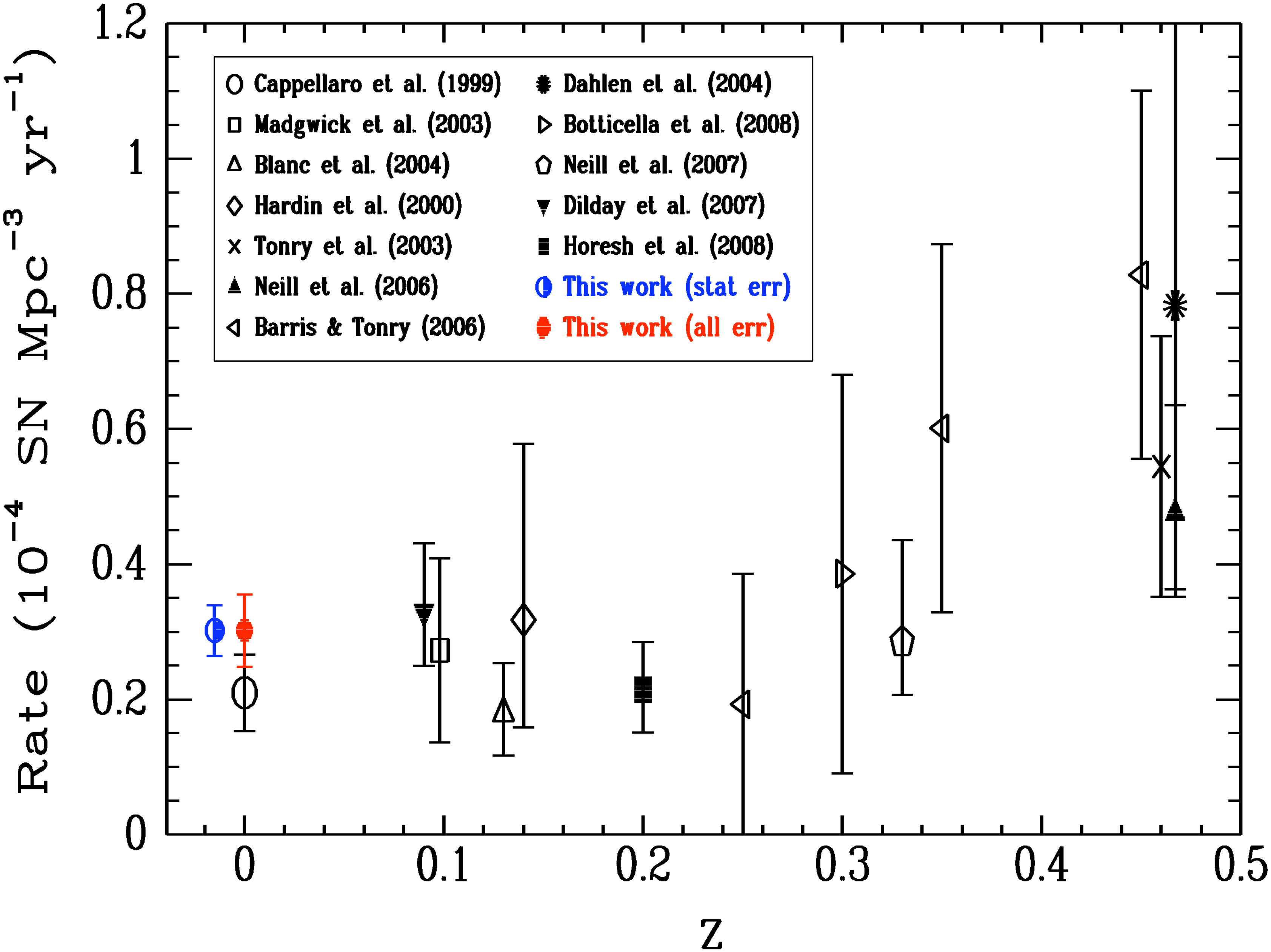
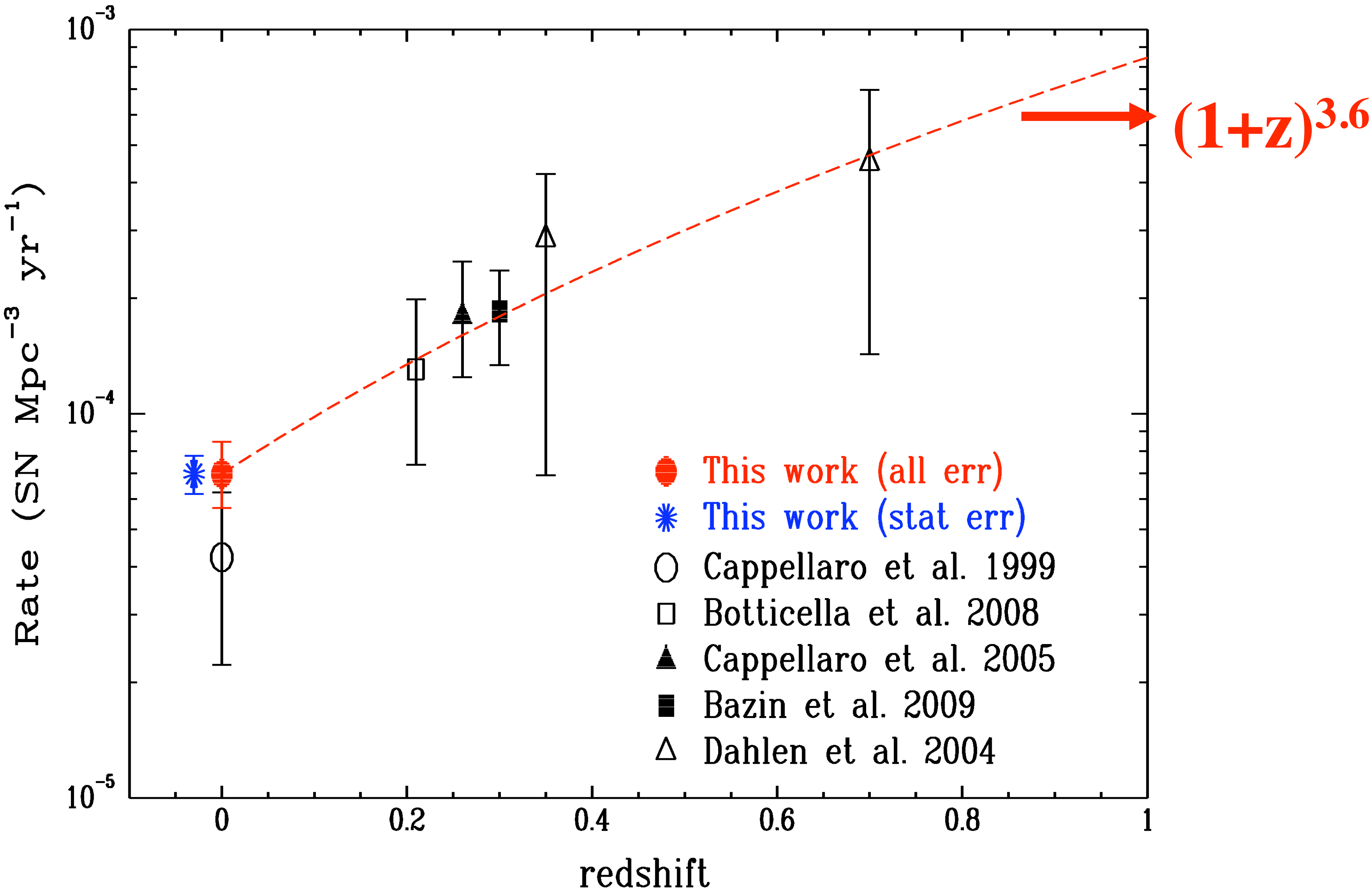
Instead of SFR, possibly an effect caused by stellar age and a declining delay-time distribution. Or something else?



Volumetric SN Ia rate versus redshift



Volumetric C-C SN rate versus redshift



Main Conclusions

1. For the first time, the observed luminosity function in the R band and subclass fractions are derived from a complete SN sample.
2. The nearby SN rate is updated, with significant improvement in the data homogeneity, sample size, and calculation method.
3. A strong correlation between the SN rate and the galaxy physical size (mass) is found. Smaller galaxies have higher SN rates. For C-C SNe, probably related to specific SFR.
4. The two-component model of the SN Ia rates is affected by the rate-mass relation; the "prompt" component is not very obvious after mass correction.