Science Thoughts at -17 and Fainter

1. Sub-luminous 1991bg SN.
2. .Ia's from AMCVn binaries
3. Born Again Stars (birth of DB WDs), WD-WD Mergers and Turn-on of RCrB stars

Lars Bildsten, KITP

KITP Extragalactic Transients, Dec 13, 2007

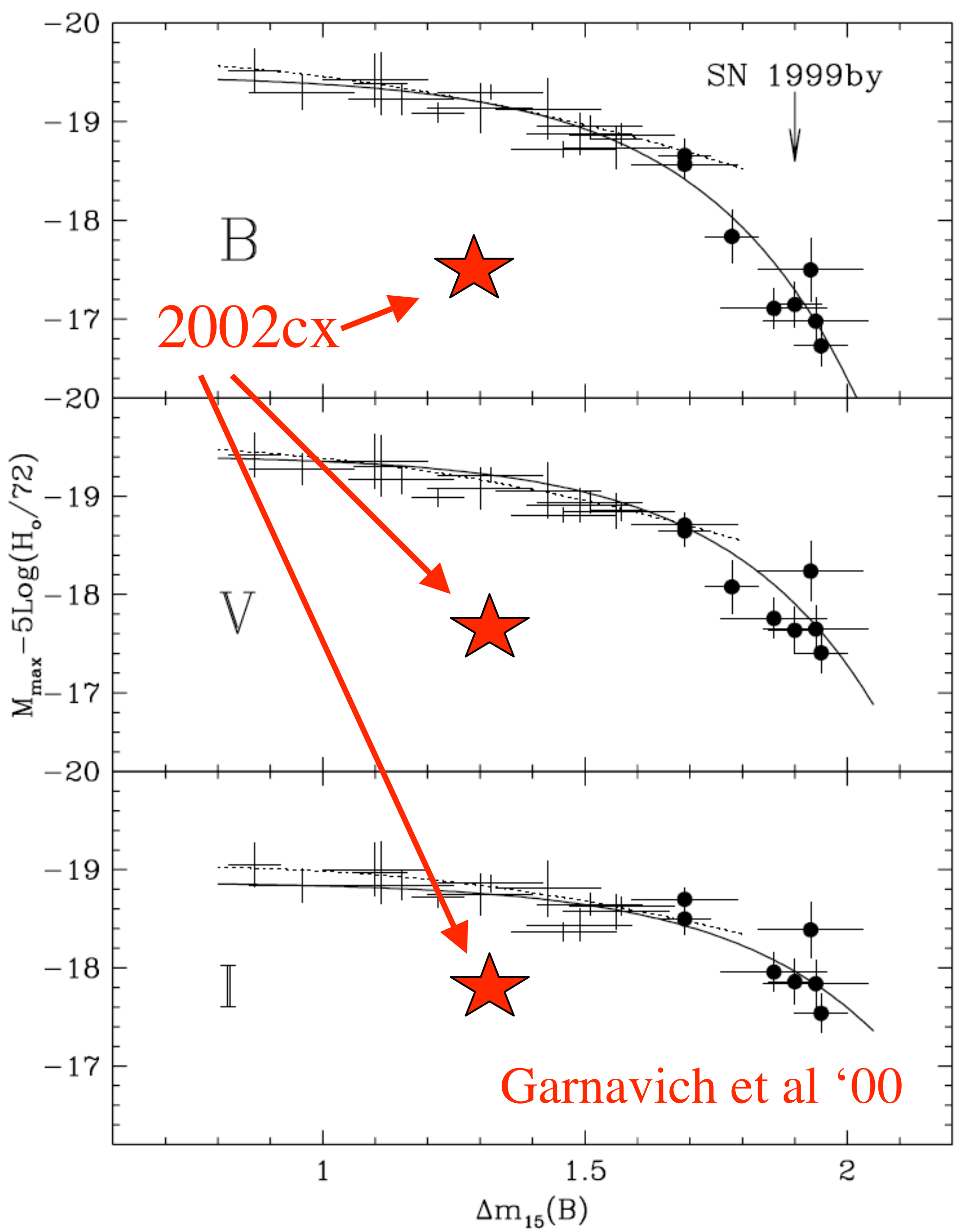


FIG. 17.—Absolute magnitudes of SNe Ia vs. $\Delta m_{15}(B)$ from Phillips et al. (1999), with so-called peculiar SNe added (*filled points*). The dotted line is the quadratic fit derived by Phillips et al. for $\Delta m_{15}(B) < 1.7$. The solid line is an exponential fit that attempts to fit all the objects represented.

- The sub-luminous Ia's fit within the continuum of the Phillip's relation, extending down by nearly 2.5 mags, all share the Ti II excesses
- Most prevalent in E/S0 galaxies (Howell '01, van den Bergh et al '03)
- Still other odd ducks (2002cx)!

TABLE 4

GALAXY CLASSIFICATION AND SN TYPE: ALL

Galaxy Type	Ia	Ia-pec	Ibc[c]	II	IIn
E	21.5	10.5	0	2	1
E/Sa	8	3	1	0	0
Sa	13	5	4	10	2
Sab	9	4	4	11	0
Sb	35.5	3	9.5	36	4
Sbc	11	3	13	18	2
Sc	17	1	15	40	6
Ir	2	0	0	2	0.5

Sub Luminous Rise Times

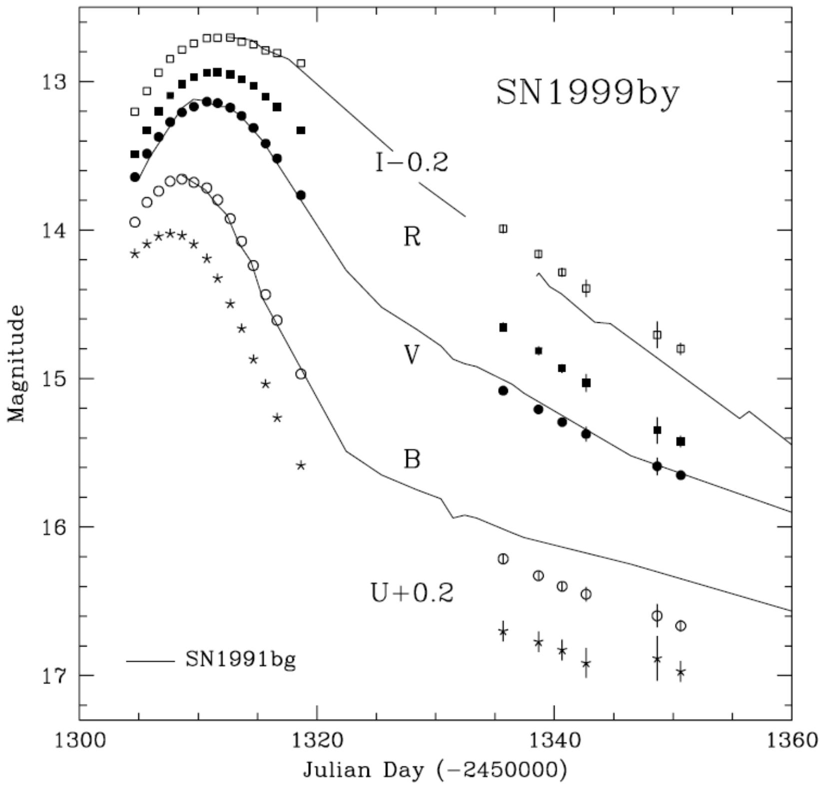


FIG. 2.—Light curves of SN 1999by in the *U*, *B*, *V*, *R*, and *I* filters, showing the light curves of SN 1991bg from Leibundgut et al. (1993; *solid lines*), with the curves shifted in magnitude and time to match the light curves of SN 1999by at maximum. For the data near maximum, the uncertainties of the photometry are on the order of the size of the points.

Taubenberger et al. 2007

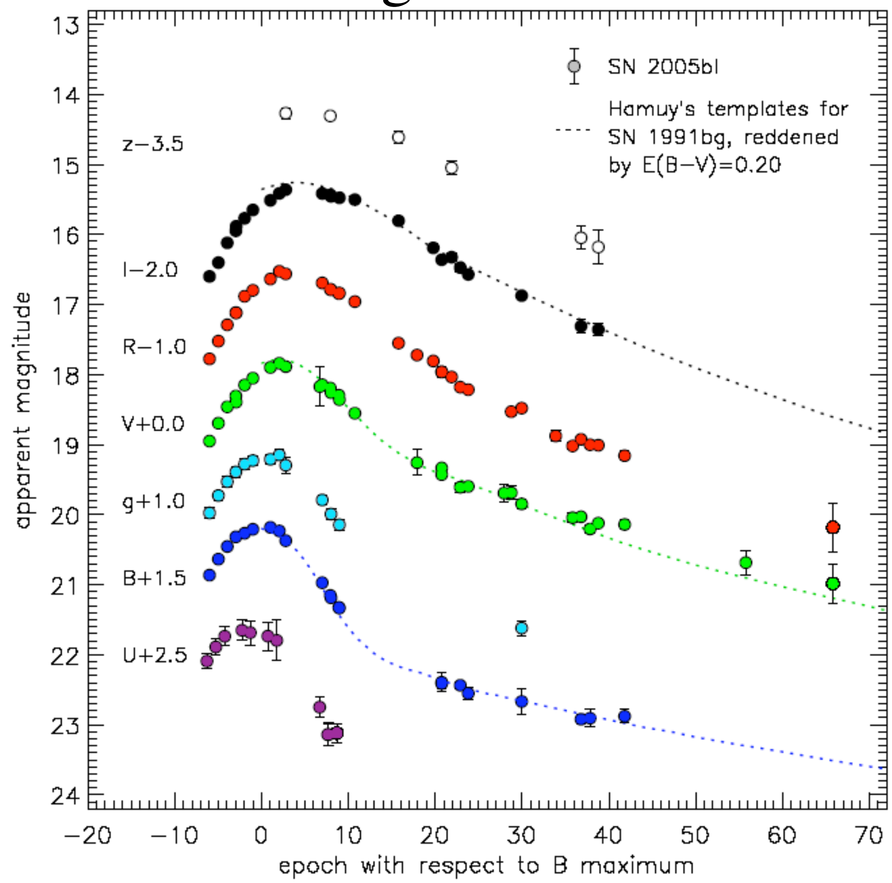


Figure 5. *UBVRI* Bessell and *gz* Sloan light curves of SN 2005bl. The *BVRI* data (Table 3) are *S*- and *K*-corrected except for the latest phases, while the *U*, *g* and *z* data (Tables 3, 5 and Contreras et al. in prep.) are not. Hamuy et al.'s (1996c) templates for SN 1991bg are shown for comparison (dotted lines).

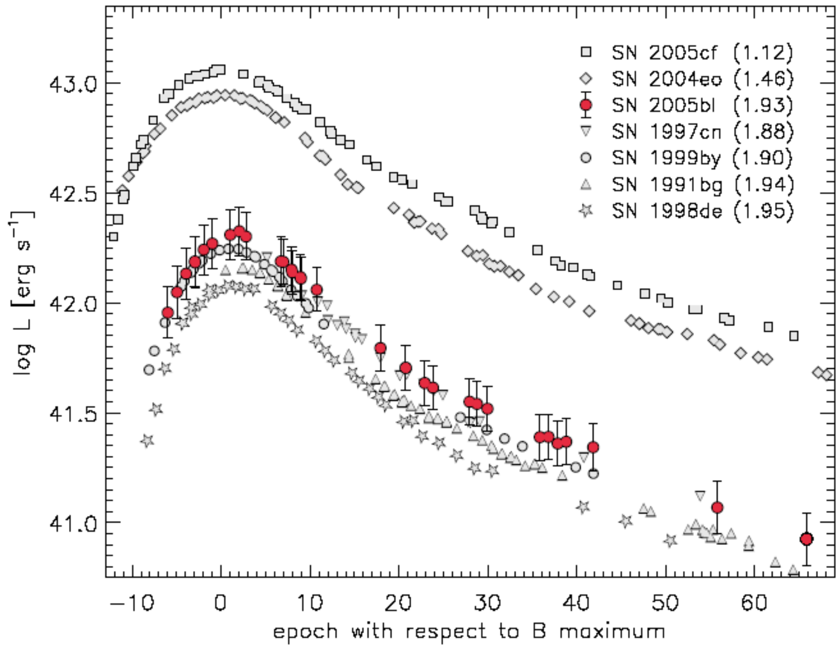


Figure 6. Quasi-bolometric light curves of SNe 2005bl, 1991bg, 1997cn, 1998de, 1999by, 2004eo and 2005cf, obtained by integrating the U-through-I-band fluxes (for the adopted distance and extinction parameters see Table 8 and Pastorello et al. 2007a,b). Error bars are shown for SN 2005bl only, and account for uncertainties in the photometric calibration, distance and extinction estimates. The $\Delta m_{15}(B)_{\rm true}$ of the SNe is given in parentheses.

What makes these direct measurements so demanding is the need for high-quality early-time photometry, preferentially before day −10 (Riess et al. 1999), which to date is not available for any 91bg-like SN, including 2005bl. In order to constrain the rise times of this class of objects, it may be useful to consider the two 91bg-like SNe Ia with the earliest photometric data, SNe 1998de and 1999by. Both

Taubenberger et al. 2007

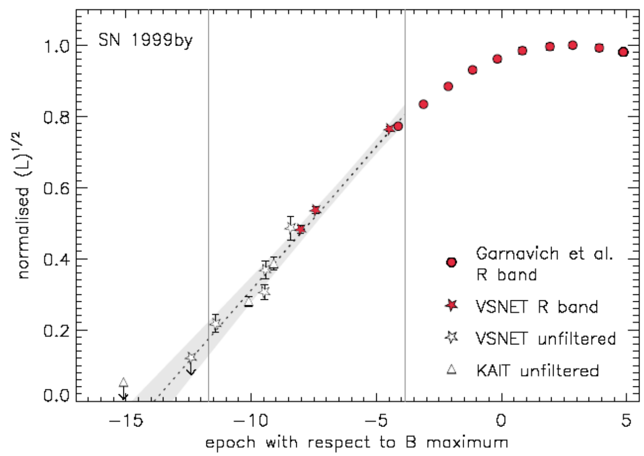
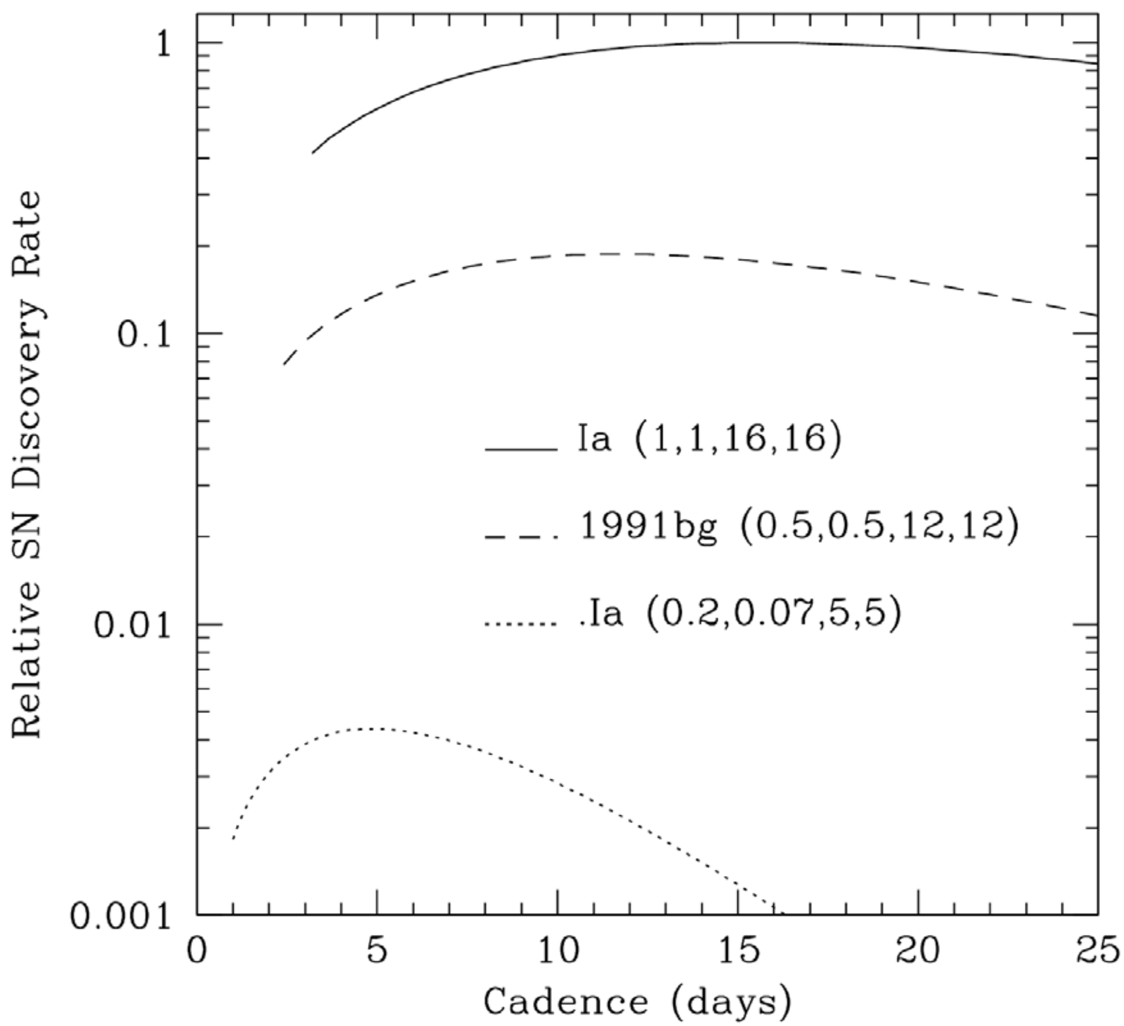


Figure 18. R-band / unfiltered early-time light curve of SN 1999by, plotted as $L^{1/2}$ vs. $t - t_{B_{\rm max}}$, and linear fit (dotted line) to the data up to day −4 (between the two thin vertical lines). Assuming $L \propto t^2$, the instance of explosion would be given by the intersection of the fit with $L^{1/2} = 0$ at −13.9 d. The grey-shaded region marks the 3-σ confidence bands of the linear fit. Caveats are discussed in the text.

Rise time between 14 and 22 days. Typical Ia's are 16-18, Matters for 56Ni masses, as well as TOTAL mass. Would force the issue of total mass maybe being less than Chandra

Optimal Cadences and Relative Discovery Rates



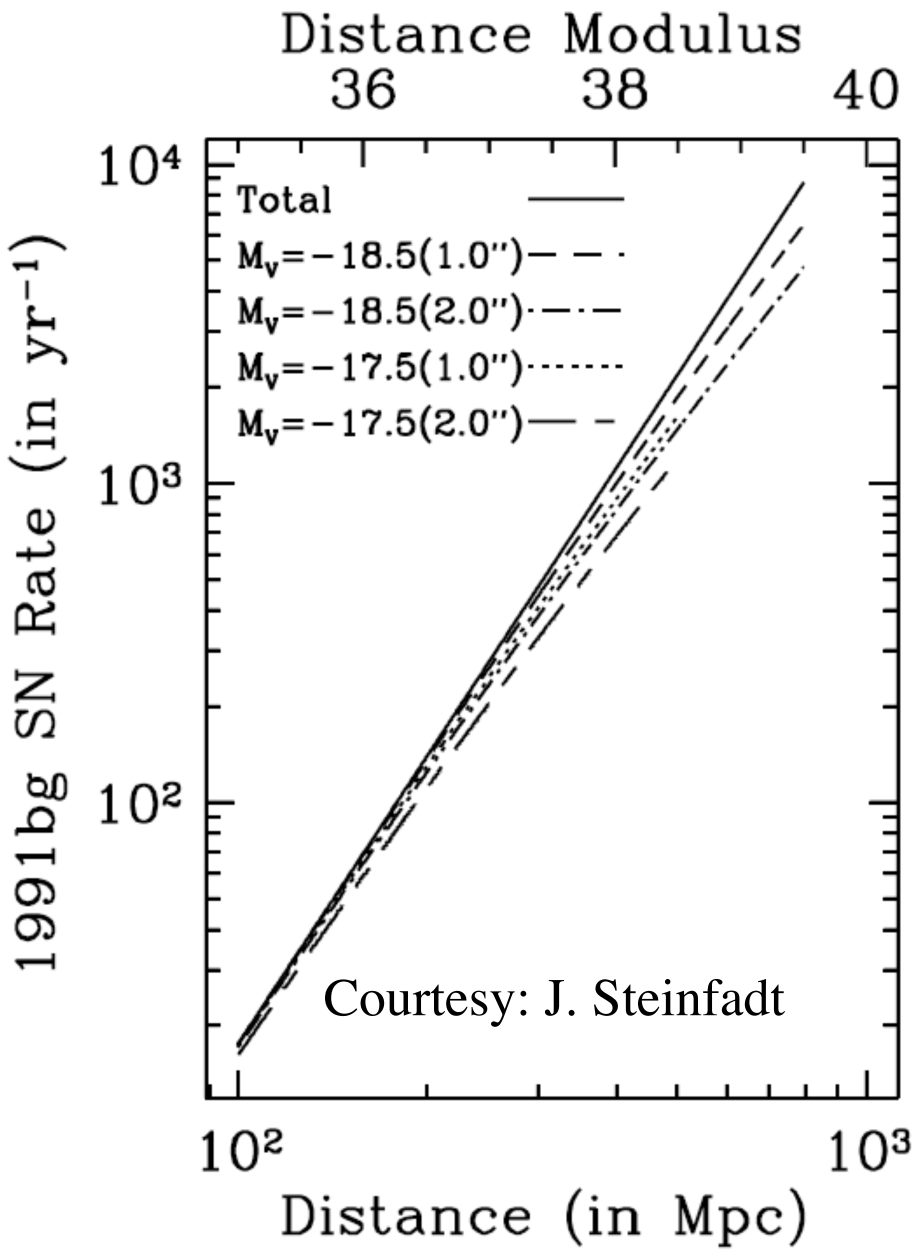
- This plot shows the relative discovery rates (defined here as seeing it TWICE) of three kinds of thermonuclear events: Ia's, 1991bg's and .Ia's.

- We characterize a SN by four parameters, L (relative to 'typical' Ia), Volume Rate (relative to Ia), rise time (days), e-folding decay time (days)

- Loss in host galaxy light for 1991bg's and Ia's is neglected for now

A 5 day cadence could discover one .Ia for every 200 Ia's (including loss in host)

1991bg-like SN with PTF (V=21)

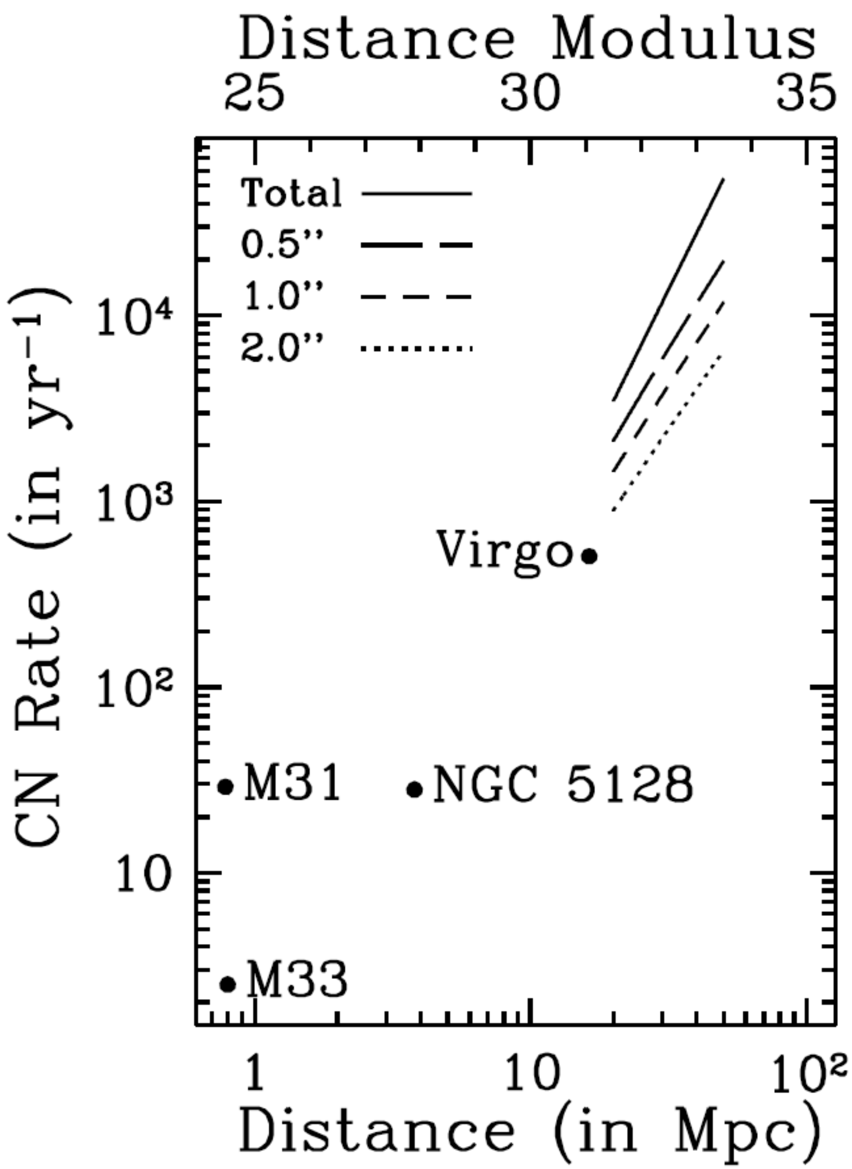


- Assume the rate is 20% of local volume rate of Ia's==> 4e-6

- At V=21. Then 100 per year in the 3 day cadence (800 deg^2), and 300 per year in the 9 day cadence (2500 deg^2)!!!

- We should do a careful calculation for a one day cadence and get discovery rate far below peak light!

Unusual Classical Novae??



- This plot shows the 'global' classical novae rate assuming an absolute magnitude of -8
- Clearly enough events that careful monitoring might well find something different
- Really need to go to Virgo (18 Mpc, DM=31.3) to make the numbers interesting.

Specific White Dwarf Birth Rate

Buzzoni et al, MNRAS, 368, 877 (2006)

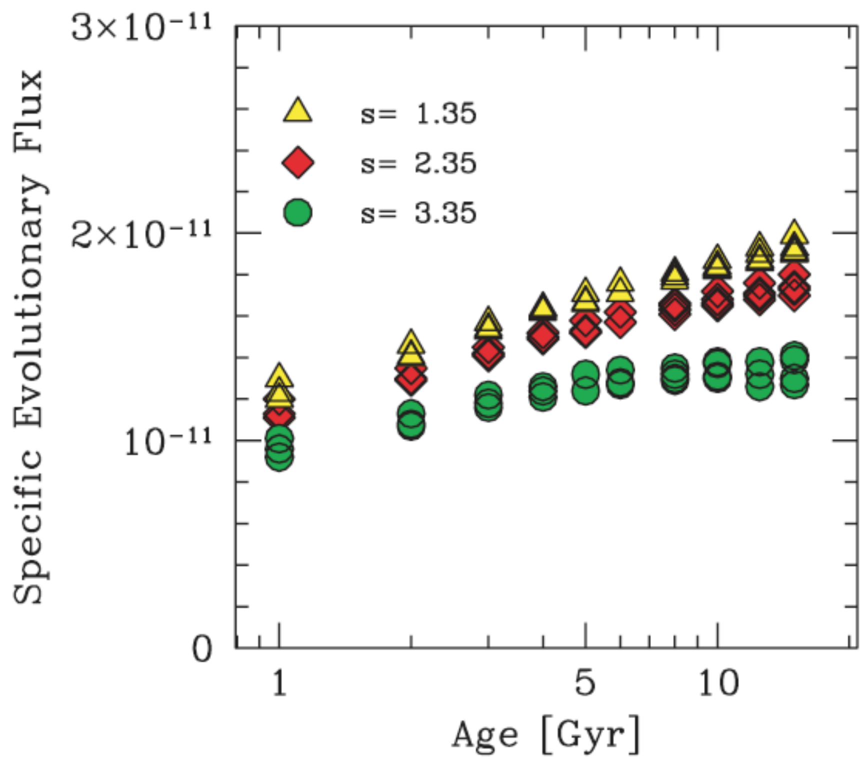


Figure 1. Specific evolutionary flux B, from equation (4), for B89 SSP models. Different metallicity sets (between $Z \sim 1/20$ and $2\,Z_\odot$) are over-plotted. In addition to the Salpeter case ($s = 2.35$), other IMF power-law coefficients are explored, as labelled on the plot. The value of B is given in units of $L^{-1}_\odot\,yr^{-1}$.

Many events are likely to have rates that scale with the WD formation rate, such as:

- 10% doing late He flashes, reaching M_V-8
- 1 % WD-WD merger rates making RCrB stars, also reaching -8 ?
- Stars leaving the tip of the RGB, .. But those are at -4.

Working thru the minimum detectable fraction in UNITS of the WD formation rate would guide nearby surveys!

Three Events

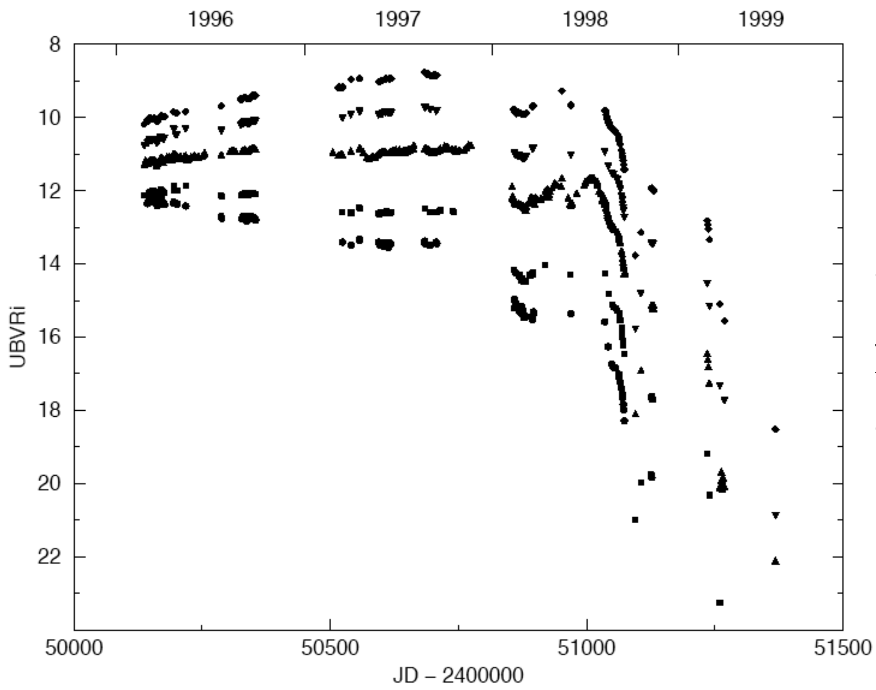


FIG. 3.—*UBVRi* light curve of V4334 Sgr. This curve includes only the observations made at the Dutch 0.91 m telescope and the Reñaca 0.2 m telescope, plus some observations at late stages made by Jacoby, Jacoby & De Marco and Benetti. *Bottom to top*: *U*, *B*, *V*, *R*, *i* light curves.

- Typically up to -5 to -8, lasts for many years, evolves to red..
- Dust is formed..

FG Sge (1894)
V605 Aql (1917) (-5)
V4334 Sgr (1992, Sakurai)

Duerbeck et al. AJ, 119, 2360 (2000)

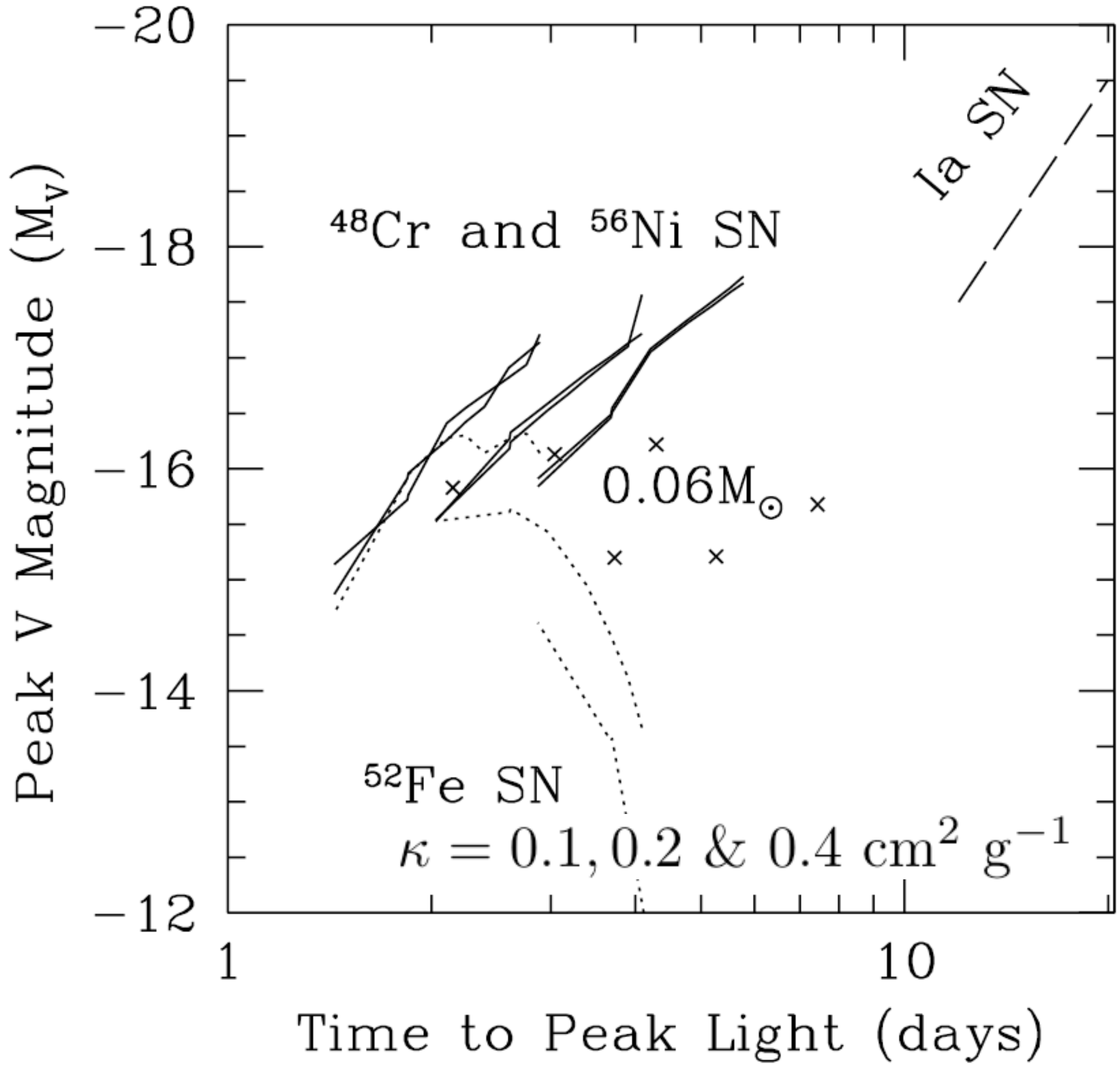
TABLE 5

EVENTS IN THE EVOLUTION OF FG SAGITTAE, V605 AQUILAE, AND V4334 SAGITTARII

Parameter	FG Sge	V605 Aql	V4334 Sge
Brightness increase (spectrum)	1894–1975 [B–G2 I]	1917.7–1918	1994.8–1995
Time of brightness maximum in *B* (spectrum)......	1968 [A3 I]	1919.6	B 1996.3 [F0]
Spectrum at later stage................................	G–K0 I in 1980s	C2, 2 in 1921.7	C2, 2 in 1997.3
Onset of dust formation	1992	1922.6 (?)	1998.4
Dramatic decline (“disappearance”).................	?	1924	1999.2

.Ia Supernovae

L. B., Shen, Weinberg & Nelemans ‘07

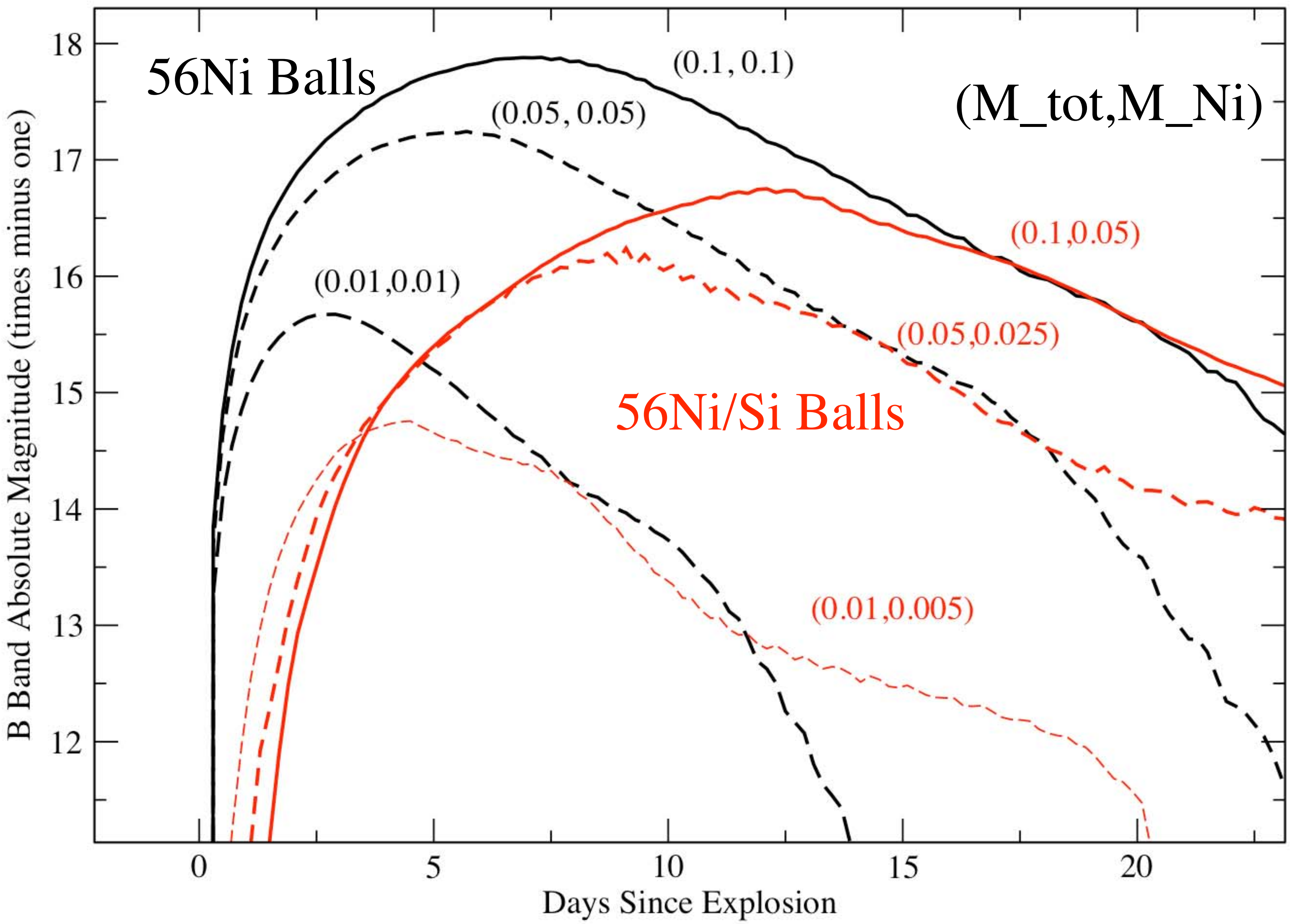


- Our small Helium ignition masses (0.02-0.1) only detonate helium, which leaves the WD at 10,000 km/sec, leading to rapid rise times.

$$\tau_m = \left(\frac{\kappa M_e}{7cv}\right)^{1/2} \approx 3-5\ \mathrm{d}$$

- The radioactive decays of the fresh 48Cr (1.3 days), 52Fe (0.5 d) and 56Ni (8.8 days) will provide power on this rapid timescale!!

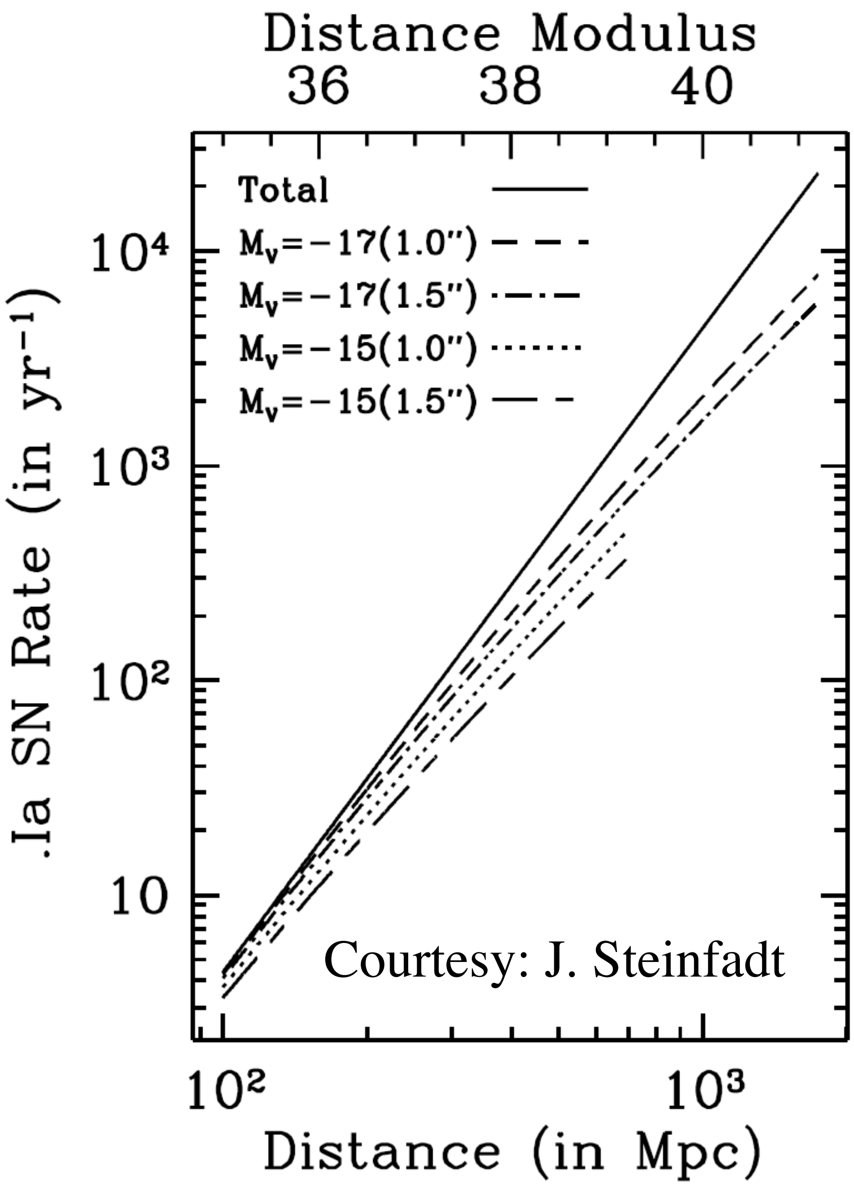
.Ia Lightcurves courtesy of Daniel Kasen (JHU)



Delta M_15(B)>3, and sometimes 4 (typical Ia's have 2 at most)

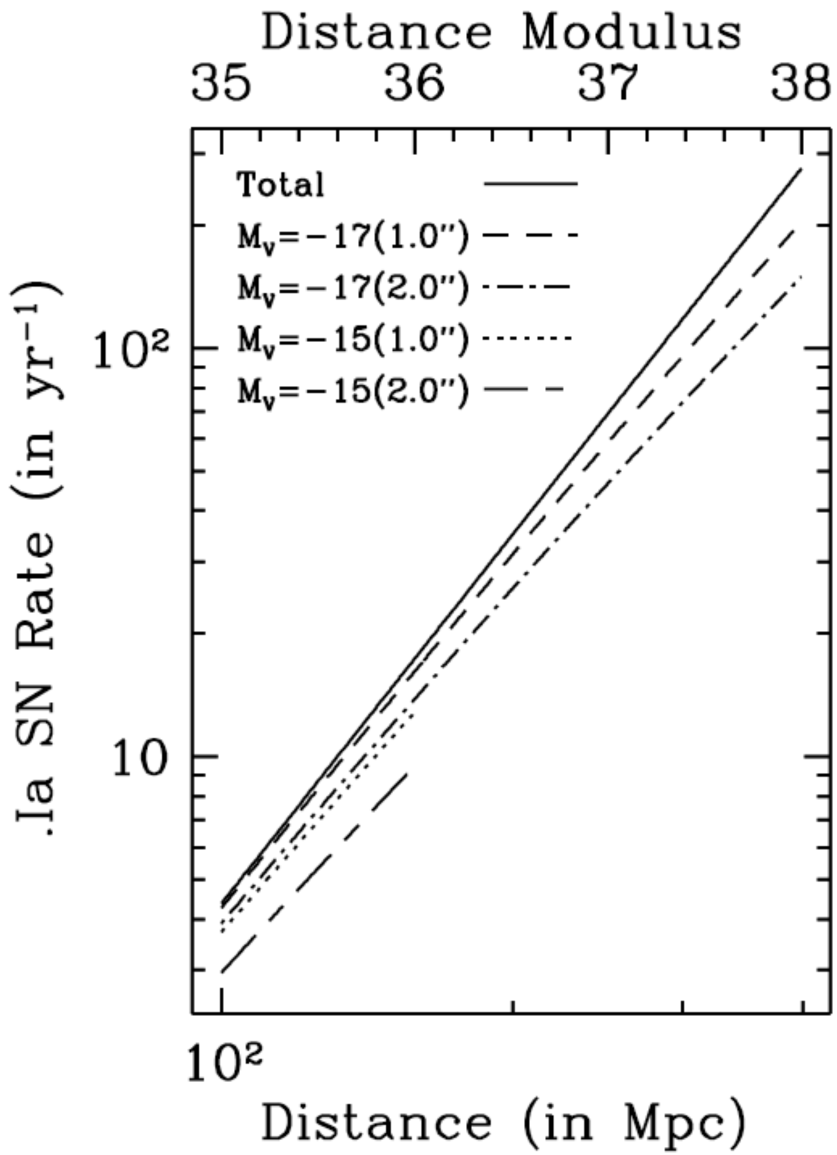
.Ia SN Rates

L. B., Shen, Weinberg & Nelemans '07



- Solid line shows number per year if .Ia's have a volume rate of 1e-6 .Ia's/yr Mpc^3 (5% of the Ia rate)
- Some events are lost in the light of the Elliptical host, which depends on .Ia brightness (-15,-17 shown)
- Lines show resulting all-sky detection rate assuming all ellipticals are L* and V=24.
- PS1 medium deep survey at V=24, 50 deg^2 (grizy every 4 days) with 1 arc-sec seeing gets 10 per year at -17, and 1 per year at -15
- SDSS SN is V=22.5, 280 deg^2, every 2 day (1.5 arc-sec) gives 7

.Ia's for PTF



Courtesy: J. Steinfadt

- Solid line shows number per year if .Ia's have a volume rate of 1e-6 .Ia's/yr Mpc^3 (5% of the Ia rate)
- Some events are lost in the light of the Elliptical host, which depends on .Ia brightness (-15,-17 shown)
- Lines show resulting all-sky detection rate assuming all ellipticals are L* and survey depth of V=21

==> For PTF (V=21, at -17), about 200 per year all sky, so IF they can be found in the 9 day cadence, 12 per year at 1 arc-sec.