SN Ia Rates from z=0.2 - 0.6 With SNLS

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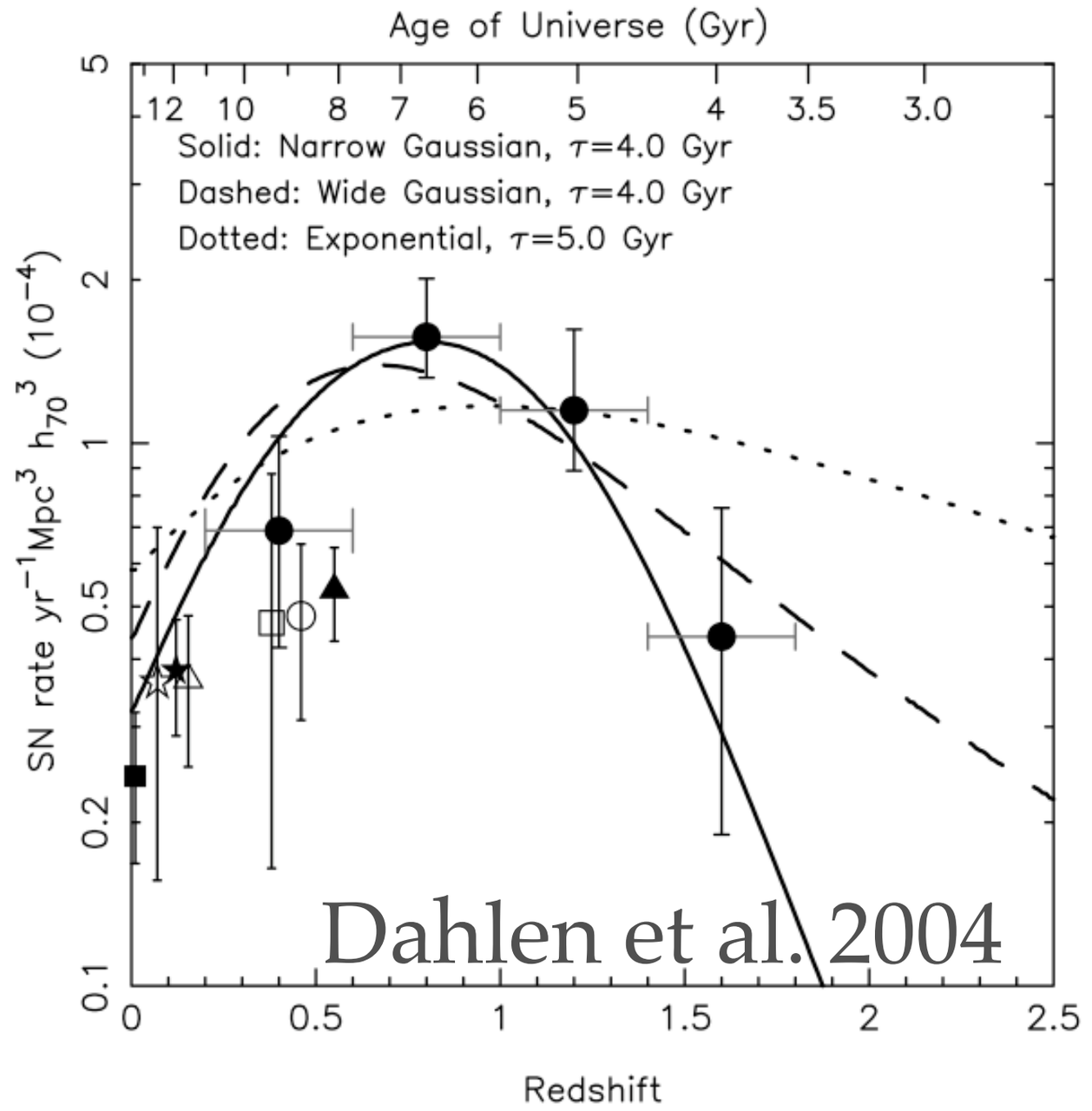
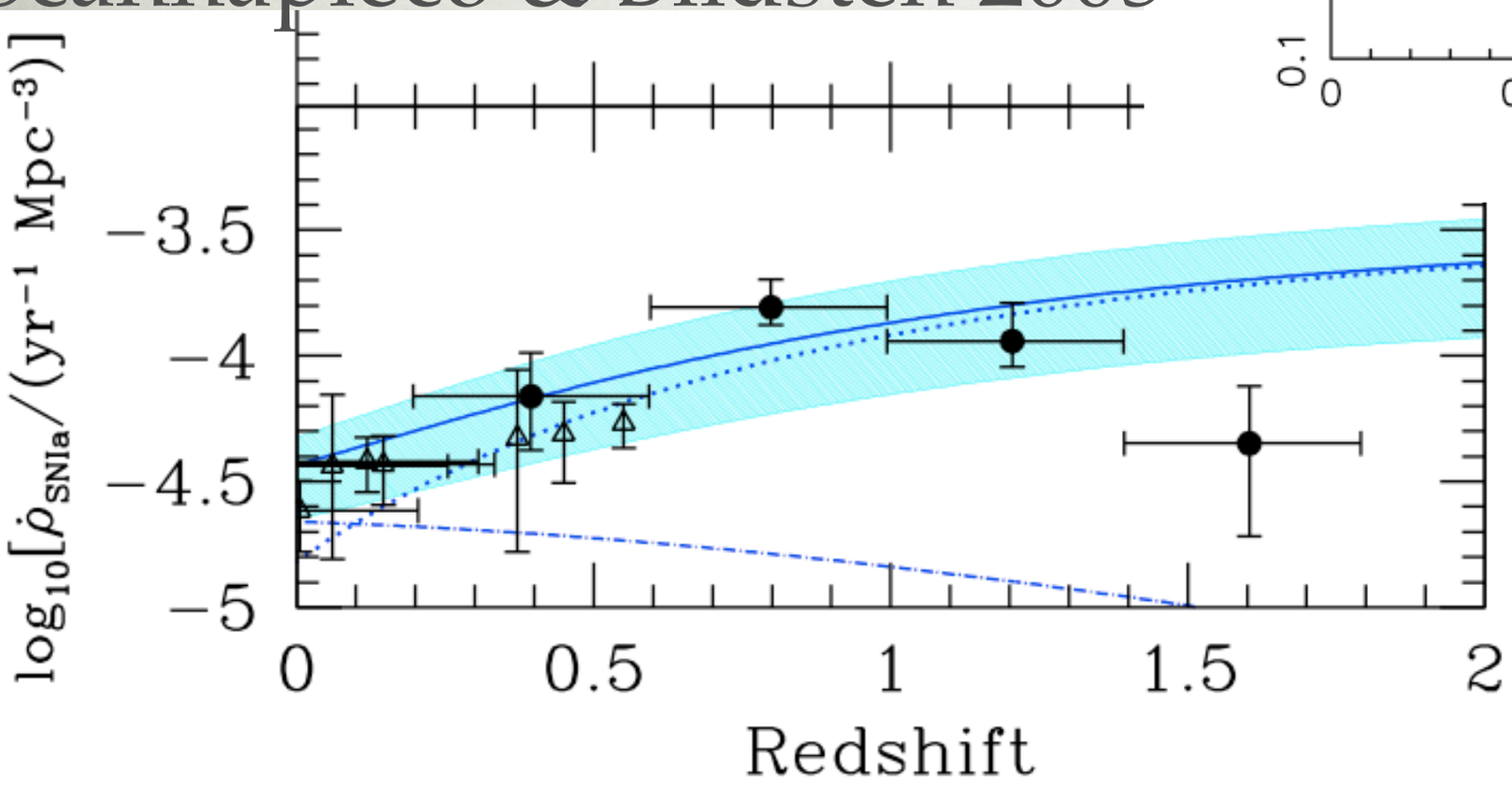
What's happening
at z = 0.5?
Are systematics
driving the models?

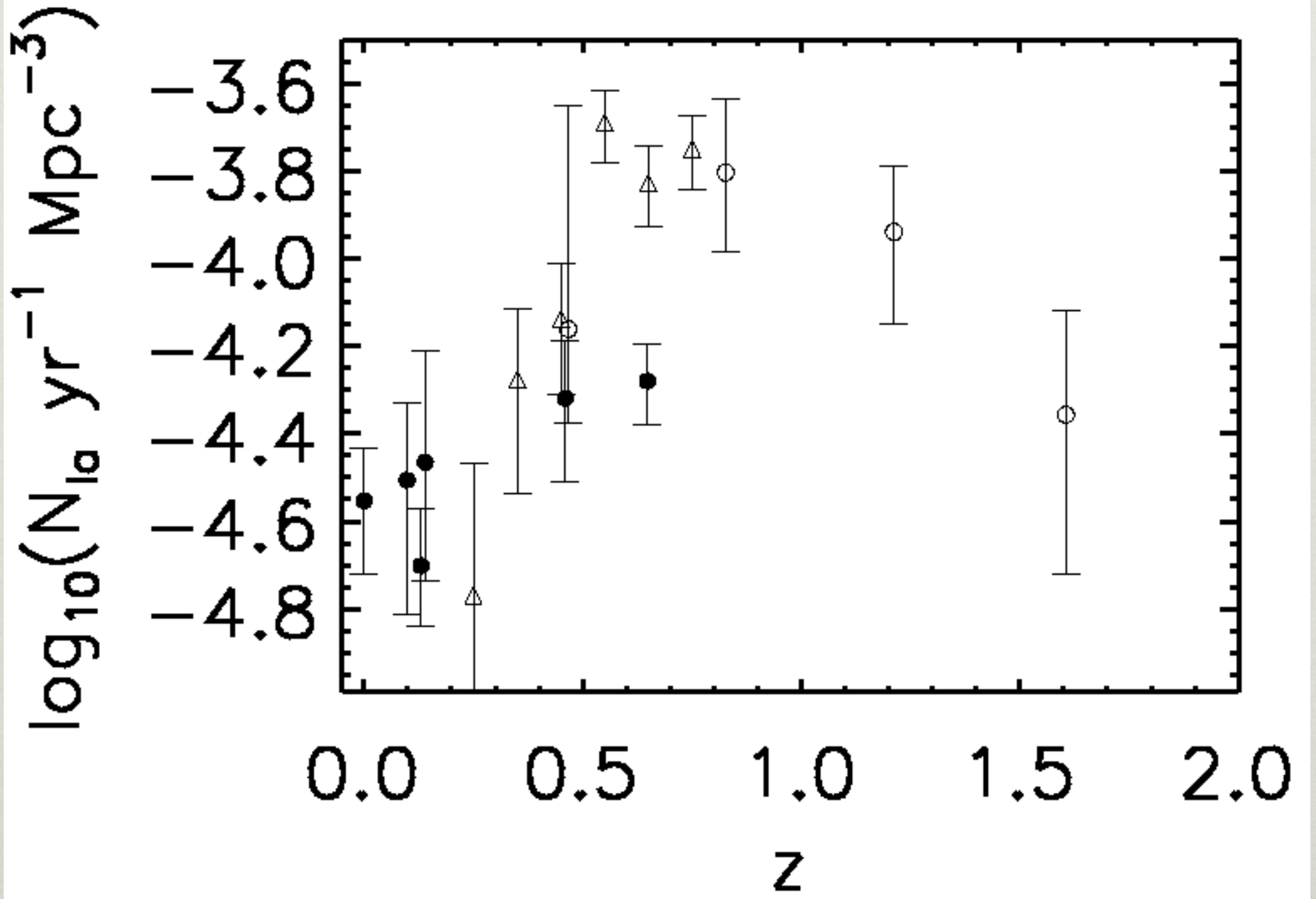


Dahlen et al. 2004

Scannapieco & Bildsten 2005



SNLS Rate
at z = 0.5
could be
revealing!



open triangles from Barris & Tonry (2005)

Rates from SNLS: Method Outline

- Identify control sample
- Analyze all candidates for missed SNe
- Identify larger full sample
- Derive SN detectability equation
- Monte Carlo simulate SN Ia population
- Observe with detectability equation
- Compare results with samples

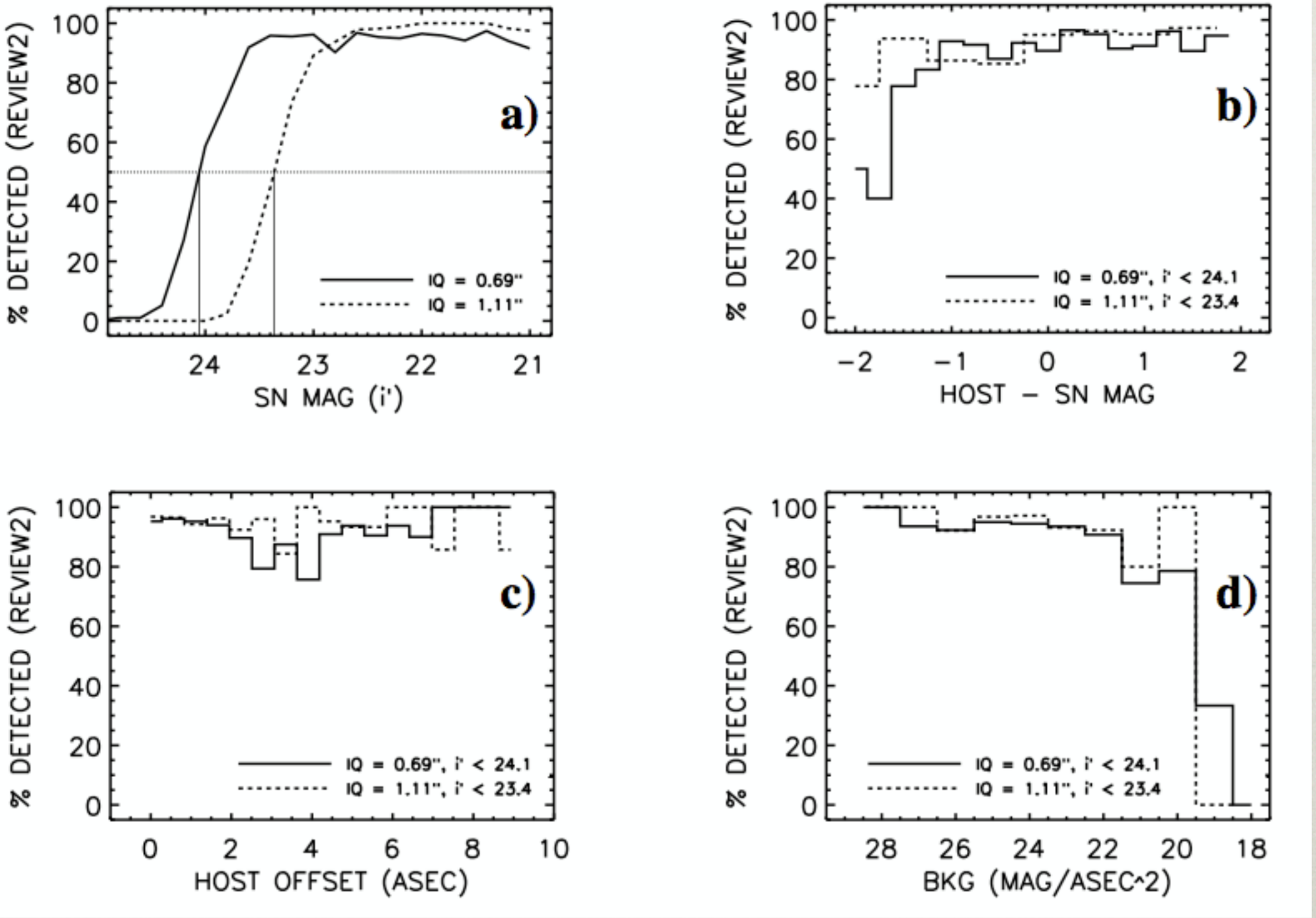
SN Ia SAMPLES

Table 2. SNLS SN Ia Samples: $0.2 < z < 0.6$

	Control Sample	Full Sample		
		ALL	Year 1	Year 2
Field	(N_{SN})	(N_{SN})	(N_{SN})	(N_{SN})
D1	9	15	6	9
D2	4	17	5	12
D3	6	8	8	...
D4	6	11	5	6
ALL	25	51	24	27

Spectroscopically Confirmed

SN Detectability



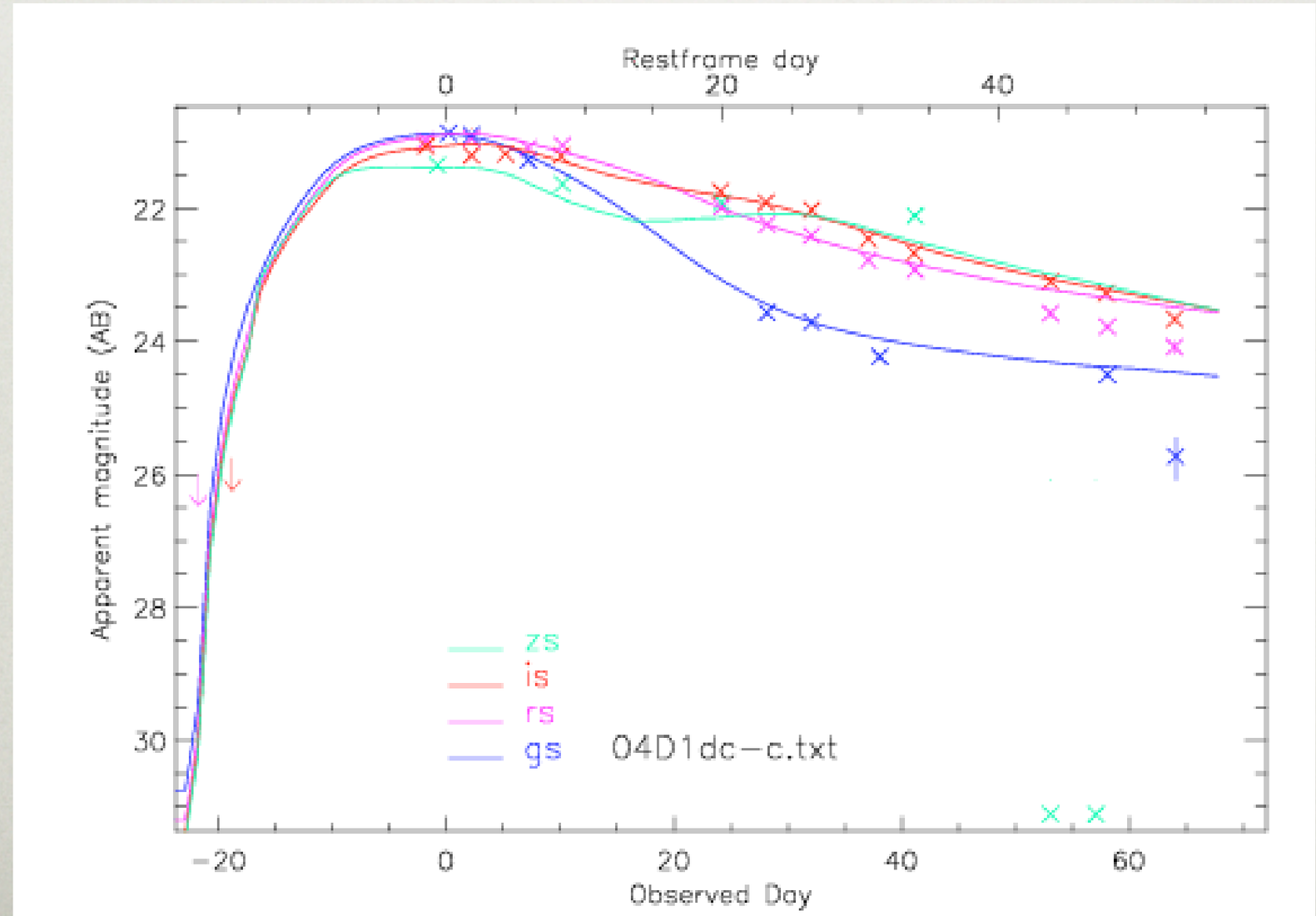
$$L_e = L_{f,0.5} - \alpha_f(IQ_e - 0.5) + 2.5\log(E_e/E_{f,r}) - 2.5\log(T_e)$$

SN Detectability

- Two real SNLS epochs at two IQ
- SExtractor runs to identify stars, hosts
- Fake SNe generated from real stars
- Flux-weighted host selection
- Flux-weighted host offset
- Need i'-detection, g'r'-early colors
- Fluxscales measure transparency
- Derive SN detectability equation

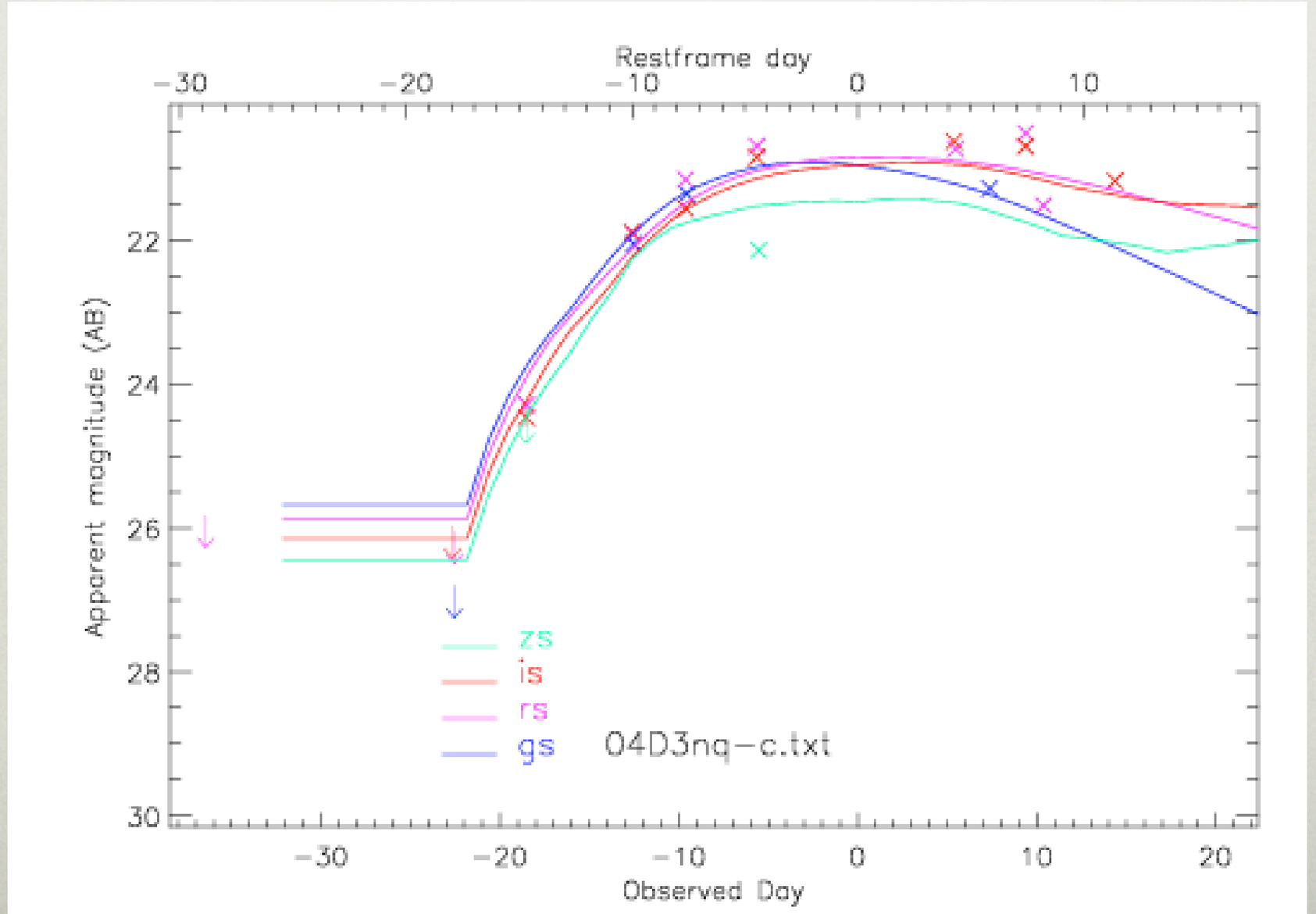
Spectral Followup Criteria

- Observe twice in i′ up to day -1.5
- Early color from either g′ or r′



Spectral Followup Criteria

- Determine stretch (decline rate) from g′r′i′ observation > 11 days after max



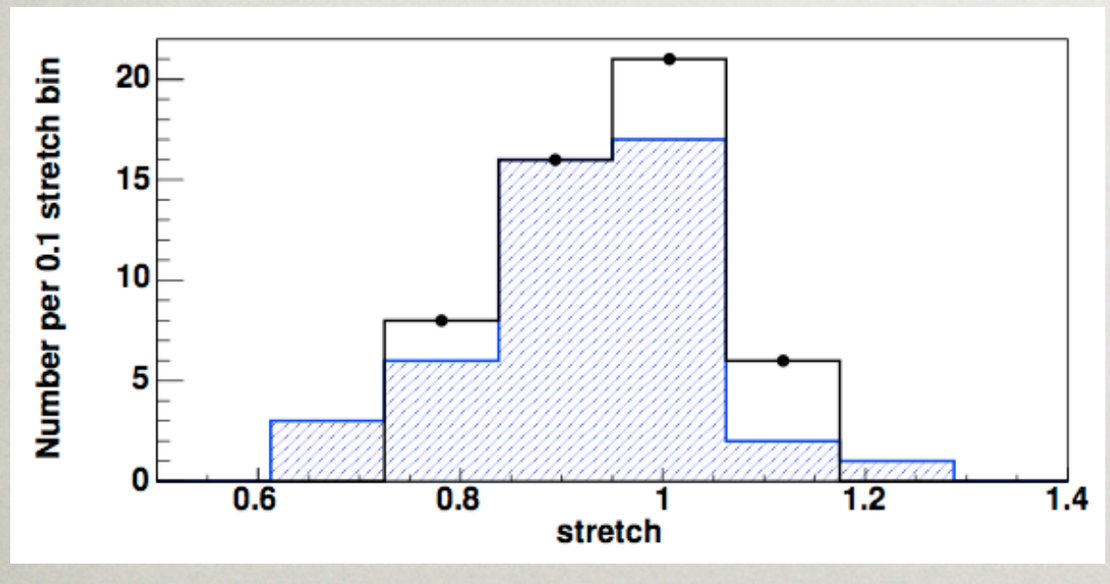
Possible Missed SNe Ia

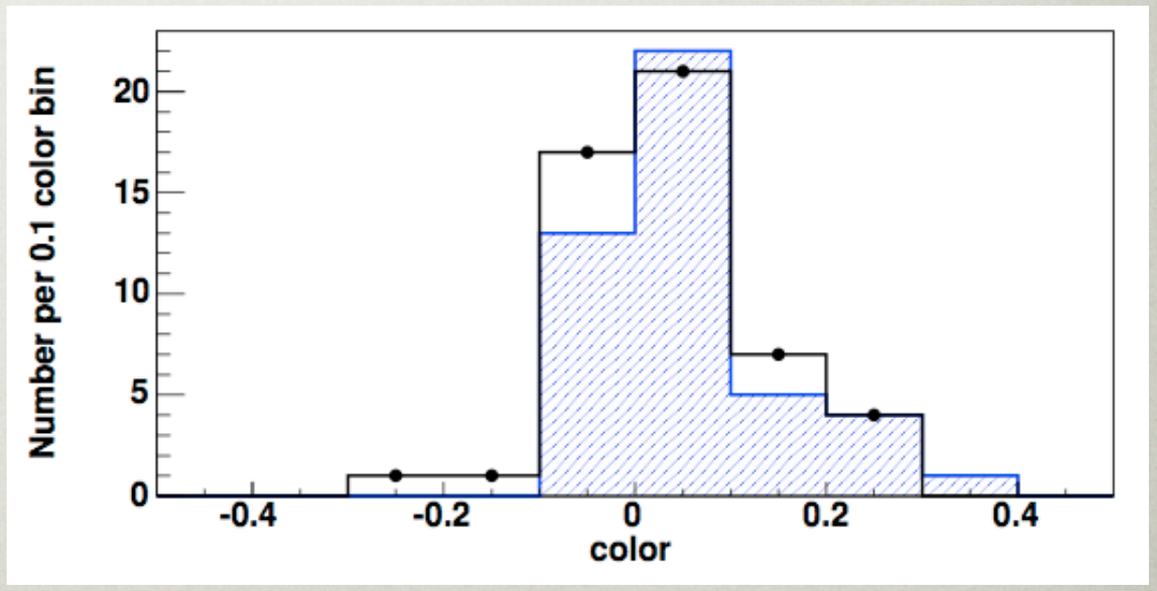
Table 4. Control Sample Spectroscopic Completeness

Field	Confirmed	Missed?	% Complete
D1	9	4	82^{+18}_{-13}
D2	4	0	100
D3	6	3	80^{+20}_{-13}
D4	6	3	80^{+20}_{-13}
ALL	25	10	83^{+17}_{-12}

Simulated SN Ia Population

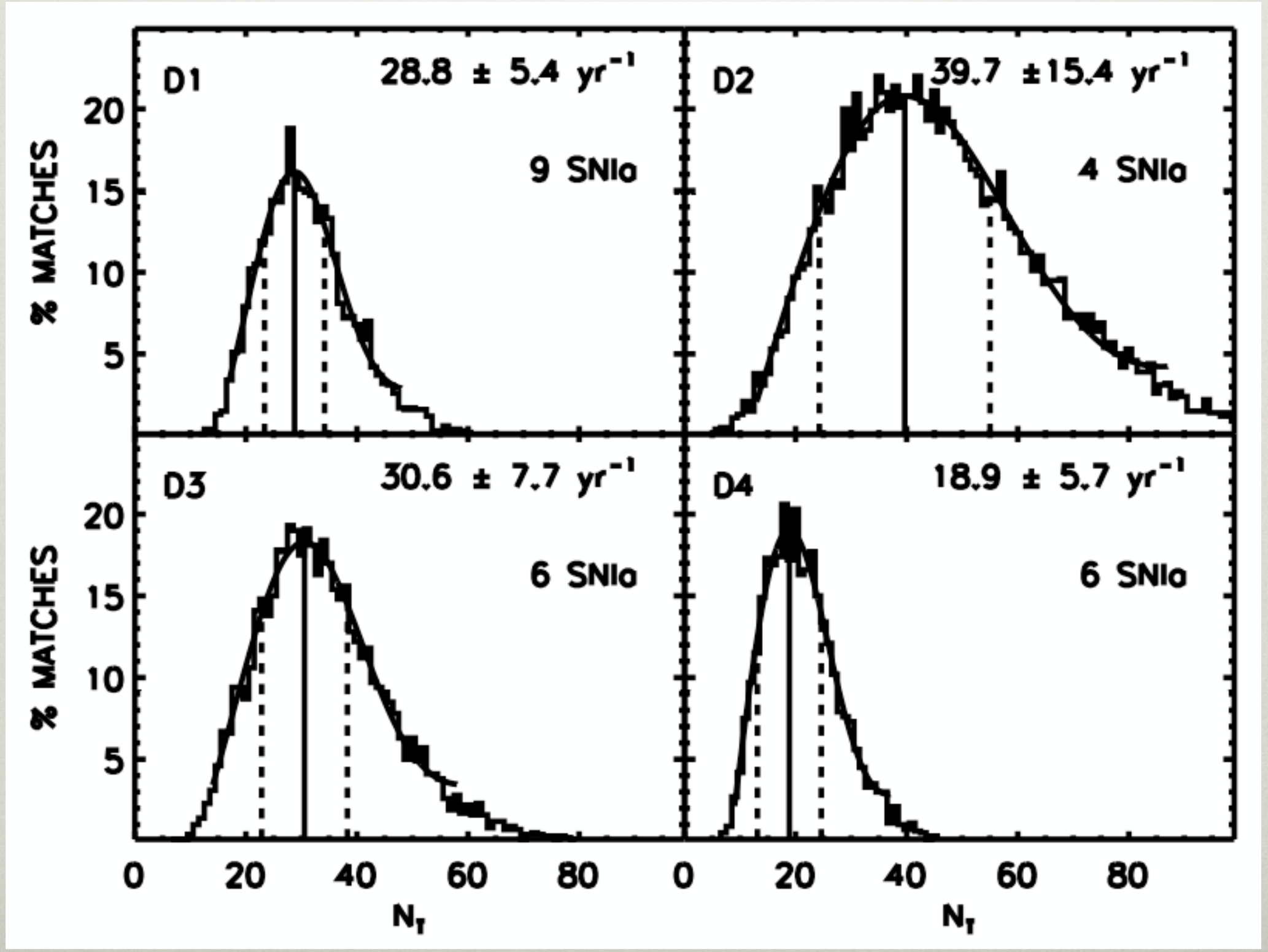
- $0.2 < z < 0.6$, volume weighted
- stretch: $\sigma = 0.25$, $\mu = 1.0$, $0.6 < str < 1.4$
- E(B-V)h: $\sigma = 0.2$, $\mu = 0.0$, $E(B\text{-}V)h > 0.0$
- Bmax: $\sigma = 0.17$, $\mu = 0.0$ Hamuy et al. 1996





Astier et al. 2005

Monte Carlo Results



SN Ia Rate Density

- Spectroscopic incompleteness
- Time dilation: 1+<z>vol
- Survey volume

Field	r_{MC} [a b] (yr^{-1})	r_{spec} (yr^{-1})	r_{1+z} (yr^{-1})	Ω degrees^2	V $\times 10^4$ Mpc^3	r_V ($\times 10^{-4}$ yr^{-1} Mpc^{-3})
D1	27.1 ± 5.7	33.0 ± 7.0	48.5 ± 10.2	1.024	101.6	0.48 ± 0.10
D2	38.2 ± 6.9	38.2 ± 6.9	56.1 ± 10.1	1.026	101.8	0.55 ± 0.10
D3	30.0 ± 8.1	37.5 ± 10.1	55.1 ± 14.9	1.029	102.1	0.54 ± 0.15
D4	18.7 ± 6.4	23.4 ± 8.0	34.3 ± 11.8	1.027	101.9	0.34 ± 0.12
SUM	114.0 ± 13.7	132.1 ± 16.2	194.0 ± 23.8	4.106	407.4	1.90 ± 0.23
AVG[c]	27.9 ± 3.3	33.1 ± 3.9	48.6 ± 5.7	1.026	101.8	0.48 ± 0.06[d]

Luminosity Specific SN Ia Rate

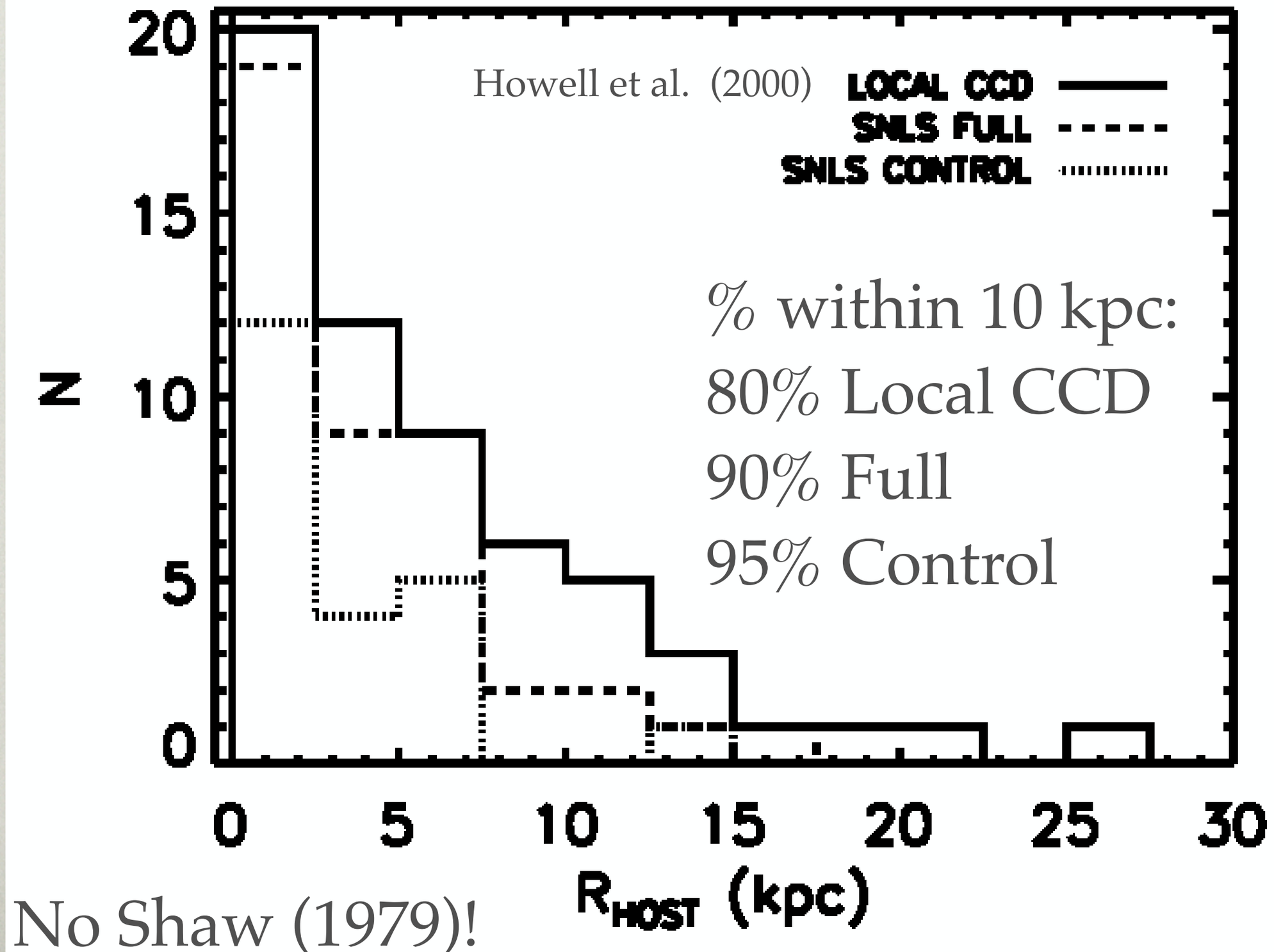
- VIMOS-VLT Deep Survey (Ilbert et al. 2005)
- 2,178 galaxies in $0.2 < z < 0.6$ (no evolution)
- Integrate Schechter fn -> luminosity density

$$r_L = 0.175^{+0.041}_{-0.032} \text{ SNu (statistical error only)}$$

Error Summary

Source	δr_V [a]	δr_L [b]
Monte Carlo + Poisson	± 0.06	± 0.020
Luminosity Estimate	...	$^{+0.038}_{-0.026}$
Spec. Completeness	$^{+0.09}_{-0.07}$	$^{+0.033}_{-0.027}$
Host Extinction	$+0.05$	$+0.018$
Frame Limits	± 0.08	± 0.029
Total Statistical	± 0.06	$^{+0.043}_{-0.033}$
Total Systematic	$^{+0.13}_{-0.11}$	$^{+0.048}_{-0.040}$

Host Offset



No Shaw (1979)!

Literature Comparison

$$r_V(\langle z\rangle_V = 0.47) = 0.48^{+0.13}_{-0.11}(syst) \pm 0.06(stat) \times 10^{-4} yr^{-1} Mpc^{-3}$$

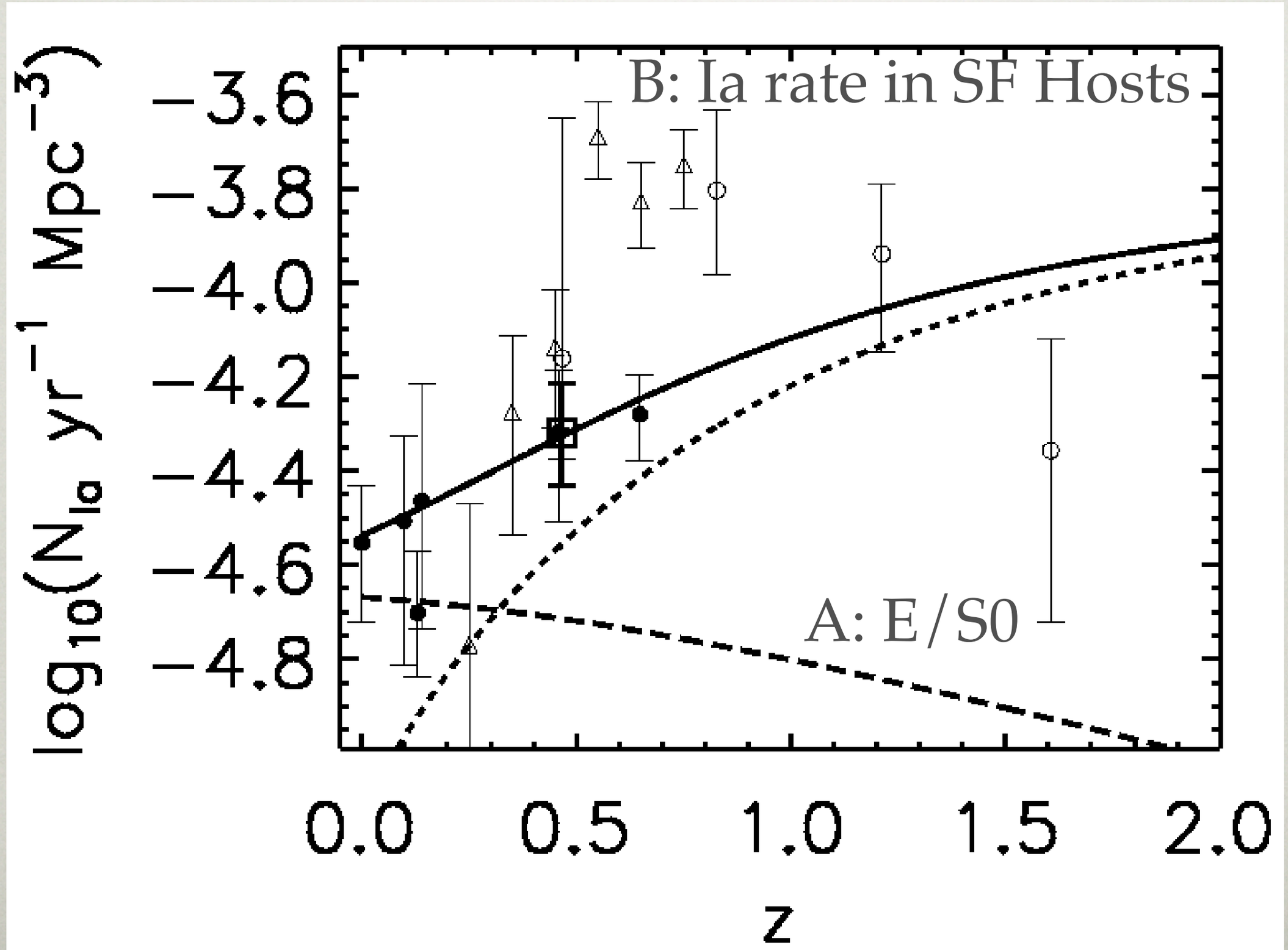
- 0.48 ± 0.17, z = 0.46, Tonry et al. 2003
- 0.525 ± 0.1, z = 0.65, Pain et al. 2002
- 2.04 ± 0.38, z = 0.55, Barris & Tonry ‘05 !
- No evidence for systematically low rates near z = 0.5

Also compare: Cappellaro et al. (1999), Madgwick et al. (2003), Blanc et al. (2004), and Hardin et al. (2000)

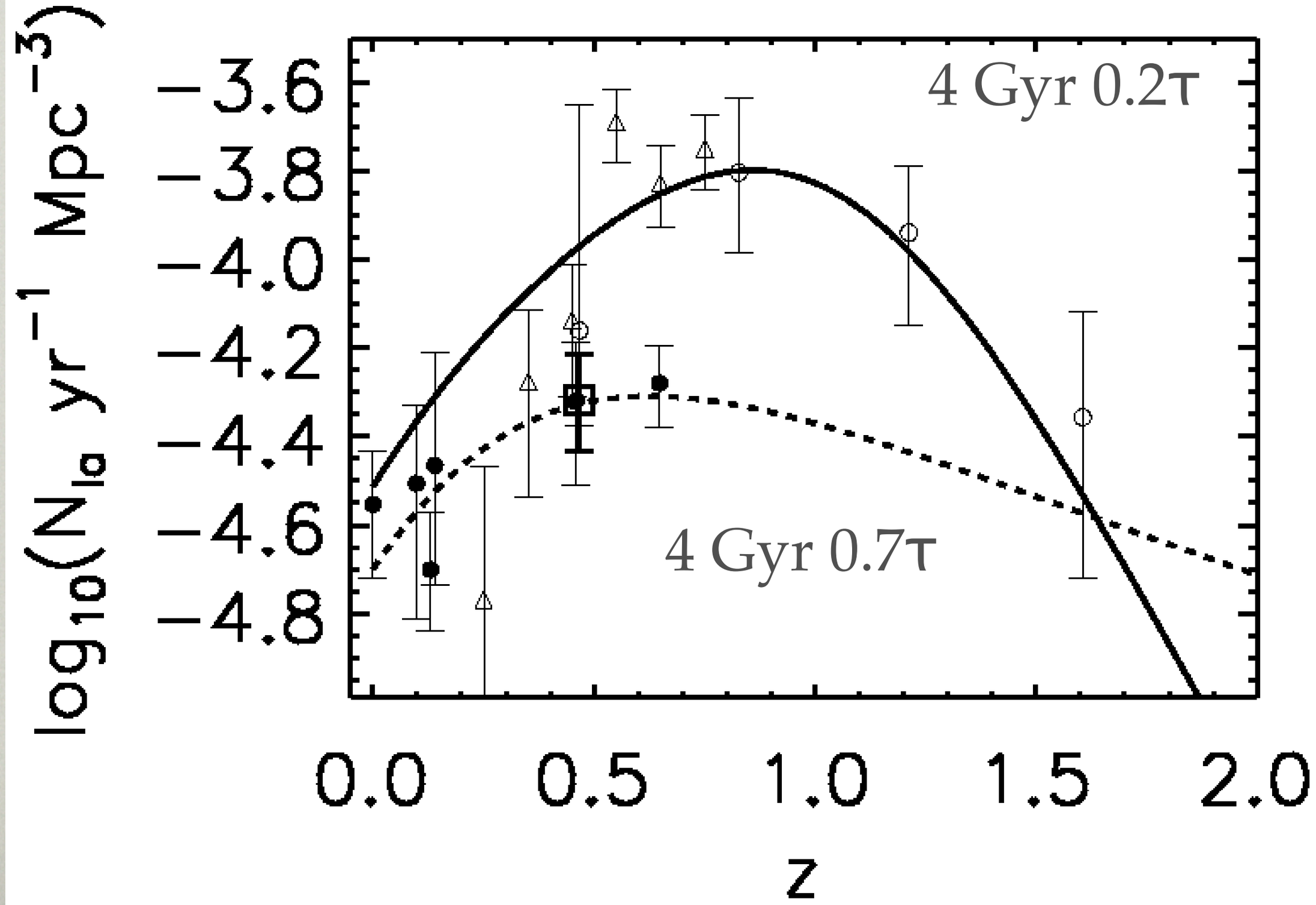
Star Formation History

- SN Ia rate is a mapping from SFH
- Gaussian delay time distribution:
  - τ in Gyr, $\sigma = f \times \tau$ ($f = 0.2, 0.5, 0.7$)
- Two-component model:
  - prompt: direct SFH (0.7 Gyr delay)
  - extended: total mass

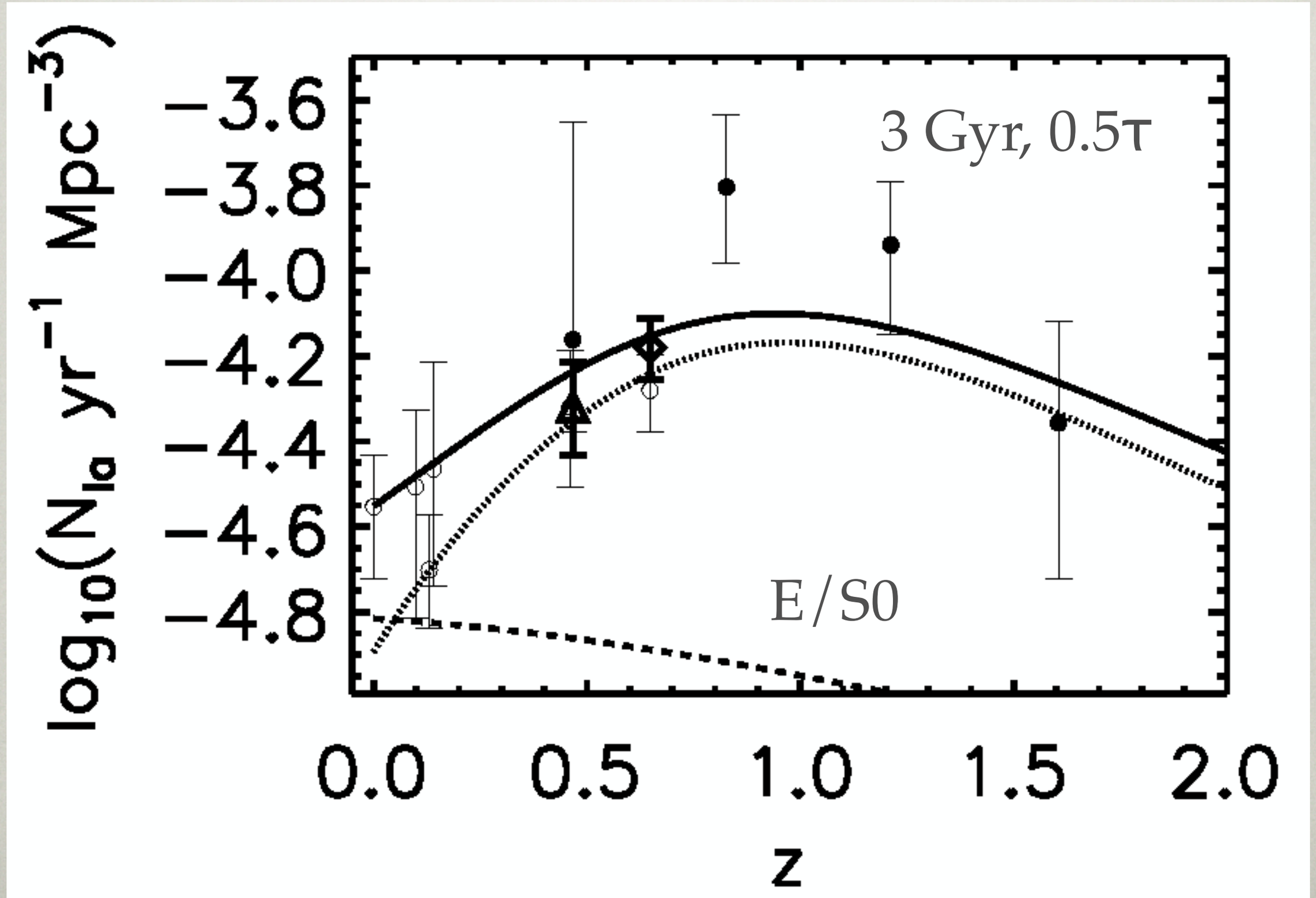
Two-Component Model



Delay Time Model



Hybrid Model



SFH Model Results

- 2-comp model fits ground based rates with prompt normalization from Ia rates in star-forming hosts
- Best delay-time model for ground based rates has $\tau = 4$ Gyr, $\sigma = 0.7\tau$
- Hybrid of extended plus delayed with $\tau = 3$ Gyr, $\sigma = 0.5\tau$ fits all but $z \approx 0.8$
- 0.5 - 3 Gyr for SD, ~0.3 Gyr for DD

(Lapente & Canal 1998; Hachisu et al. 1999)

Summary

- No evidence for systematics at $z = 0.5$
- No models fit all observed rates
- Contamination may be bigger systematic than missed SNe
- SNLS produces good rates with only 2 years of data (5 will be better!)