Cosmology & SN Ia Rates with the SNLS

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Outline

1. What is SNLS?
2. Cosmology results
3. SN Ia rates

the SuperNova Legacy Survey (SNLS)

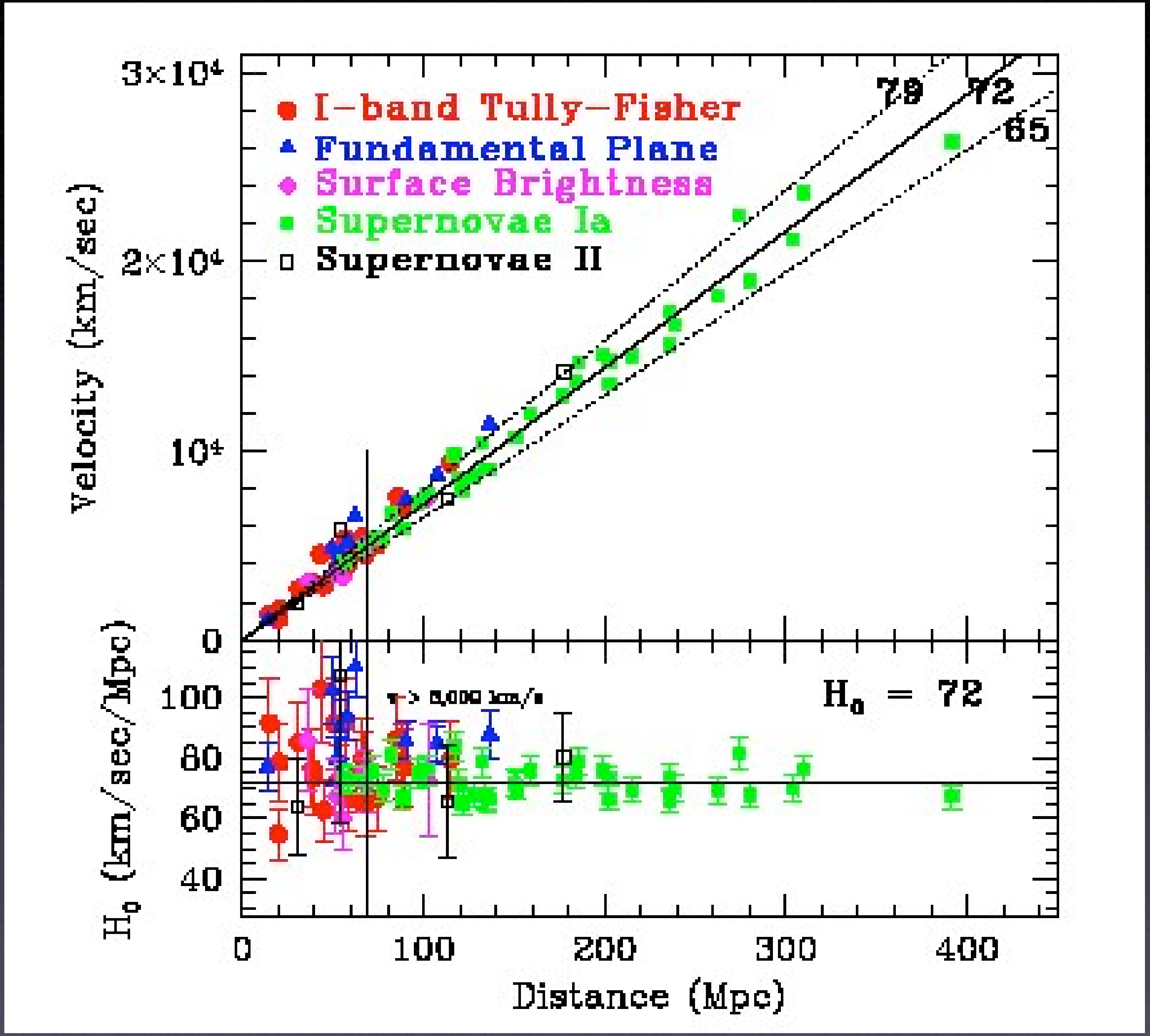
- 5 year program
- Goal: constrain w to ± 0.07 (± 0.04!)
- CFHT MegaCam/MegaPrime
- Four one square degree fields: D1-4
- Filters: g′r′i′z′ (and u* - hosts)
- Cadence ~ 3 restframe days
- RTA - produce good candidates in 6-hr!
- Spectral followup on 8m class scopes

The Supernova Legacy Survey: Measurement of Ω_M, Ω_Λ and w from the First Year Data Set ⋆

P. Astier[1], J. Guy[1], N. Regnault[1], R. Pain[1], E. Aubourg[2,3], D. Balam[4], S. Basa[5], R.G. Carlberg[6], S. Fabbro[7], D. Fouchez[8], I.M. Hook[9], D.A. Howell[6], H. Lafoux[3], J.D. Neill[4], N. Palanque-Delabrouille[3], K. Perrett[6], C.J. Pritchet[4], J. Rich[3], M. Sullivan[6], R. Taillet[1,10], G. Aldering[11], P. Antilogus[1], V. Arsenijevic[7], C. Balland[1,2], S. Baumont[1,12], J. Bronder[9], H. Courtois[13], R.S. Ellis[14], M. Filiol[5], A.C. Gonçalves[15], A. Goobar[16], D. Guide[1], D. Hardin[1], V. Lusset[3], C. Lidman[12], R. McMahon[17], M. Mouchet[15,2], A. Mourao[7], S. Perlmutter[11,18], P. Ripoche[8], C. Tao[8], N. Walton[17]

- Accepted, A&A: astro-ph/0510447
- 71 distant SNe Ia (SNLS)
- 44 nearby SNe Ia (Literature)
- 42 Authors (< 2 SNLS SNe/ Author!)
- Canada, France, USA, UK, Portugal, Chile, Sweden

Cosmology with SNe Ia



- Hubble (1929) noticed that the farther away a galaxy was, the faster it was receding

Equation Of State

$$p = w\rho \Rightarrow \rho \propto R^{-3(1+w)}$$

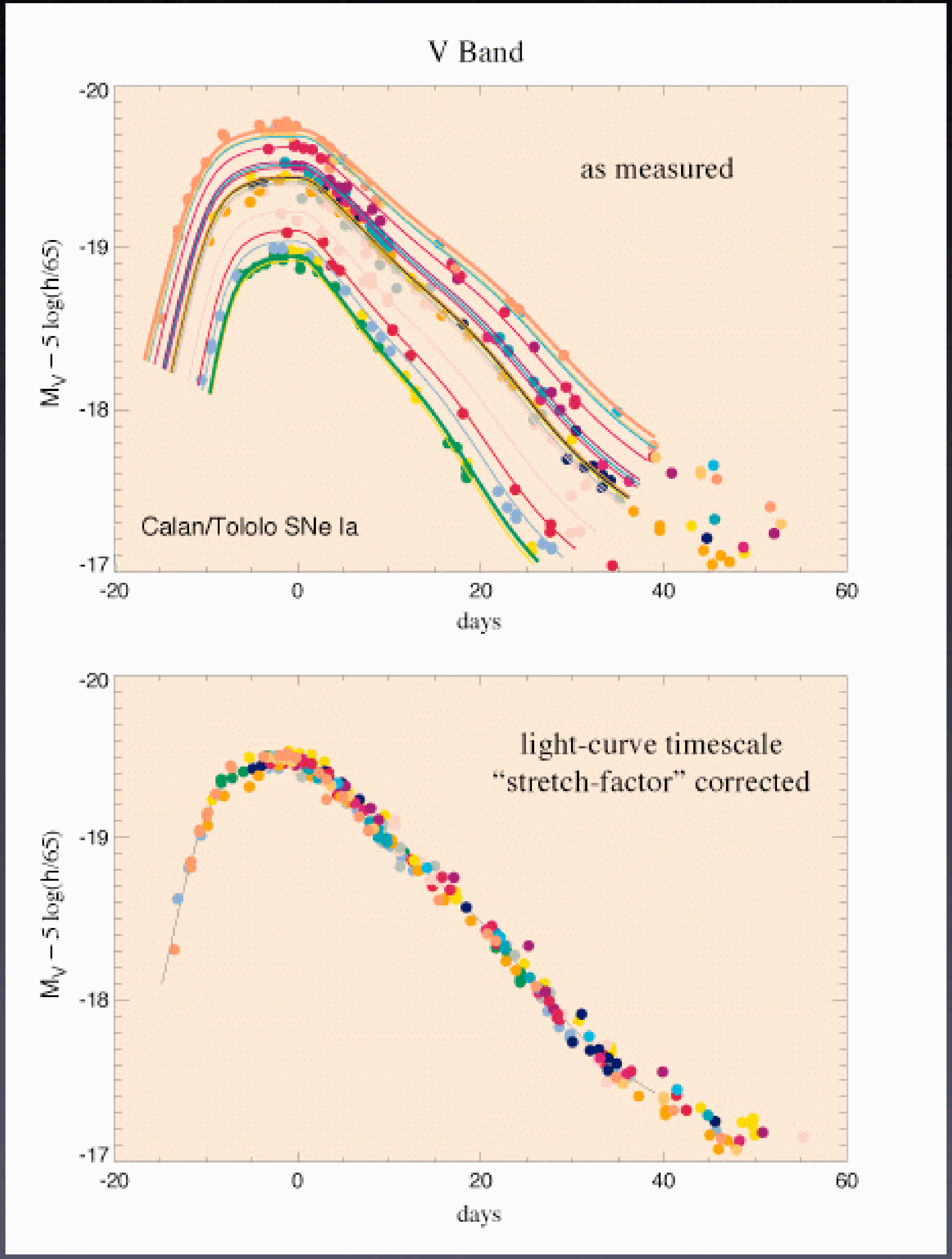
- w = 0, pressure-less matter: normal dilution with expansion (EdS Universe)
- w = -1, ρ independent of scale factor: vacuum energy (Cosmological Constant)

Cosmology with SNe Ia

Supernovae are visible across a large fraction of the Universe

Velocity from spectroscopic redshift

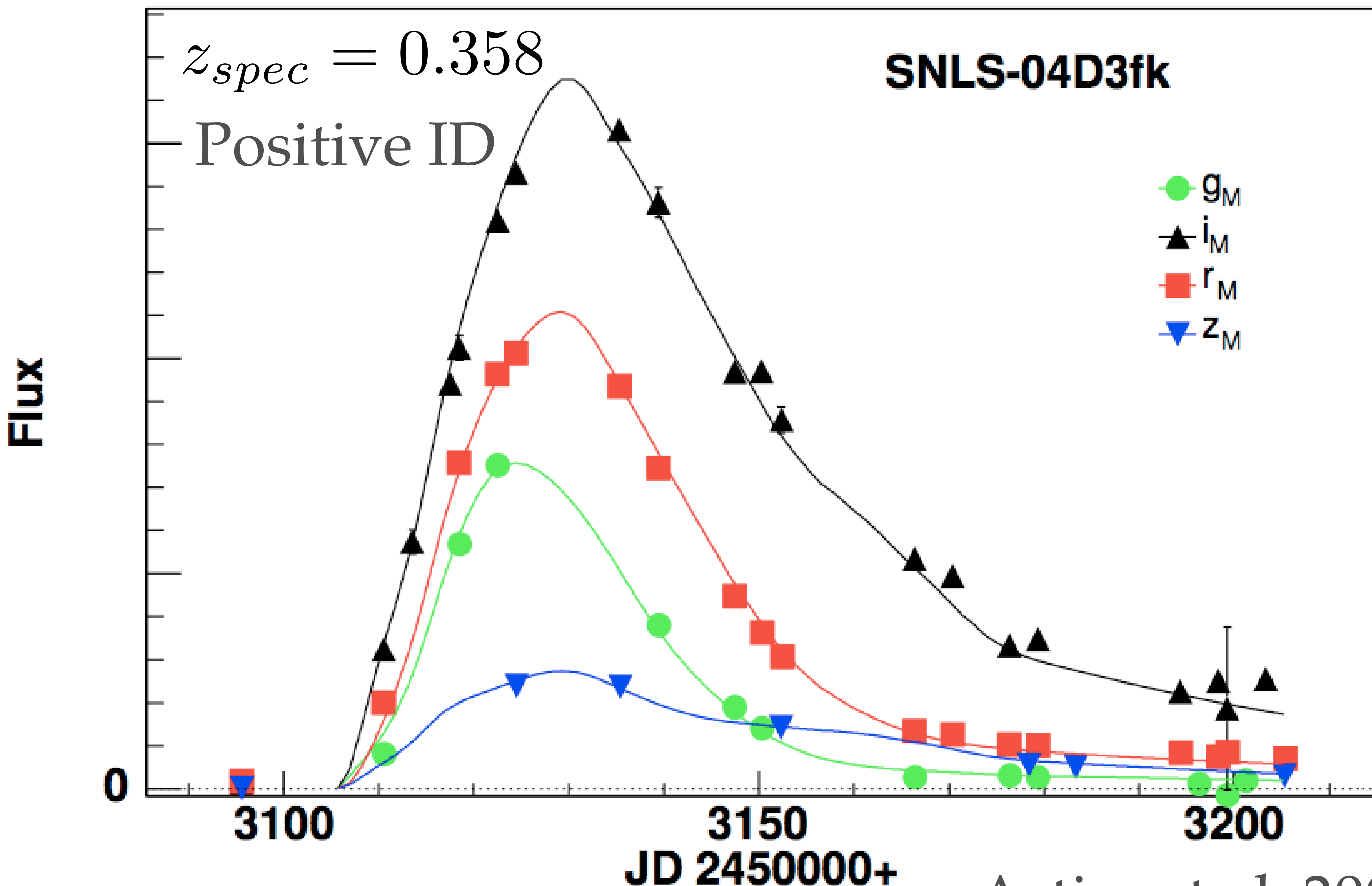
Distance from known intrinsic brightness



$M_{B,MAX}$ from SALT, (Guy et al. 2005)

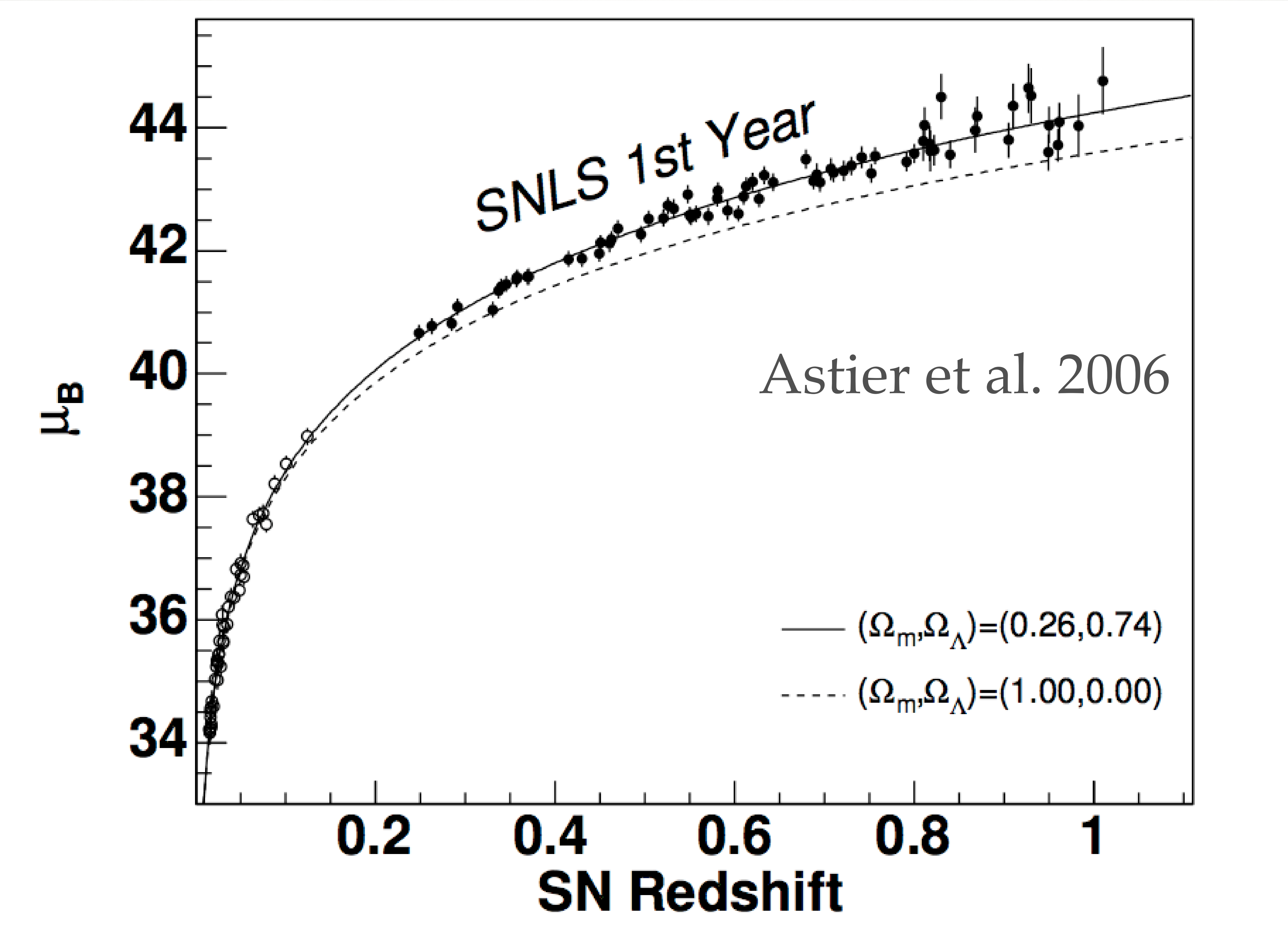
$z_{spec} = 0.358$

Positive ID



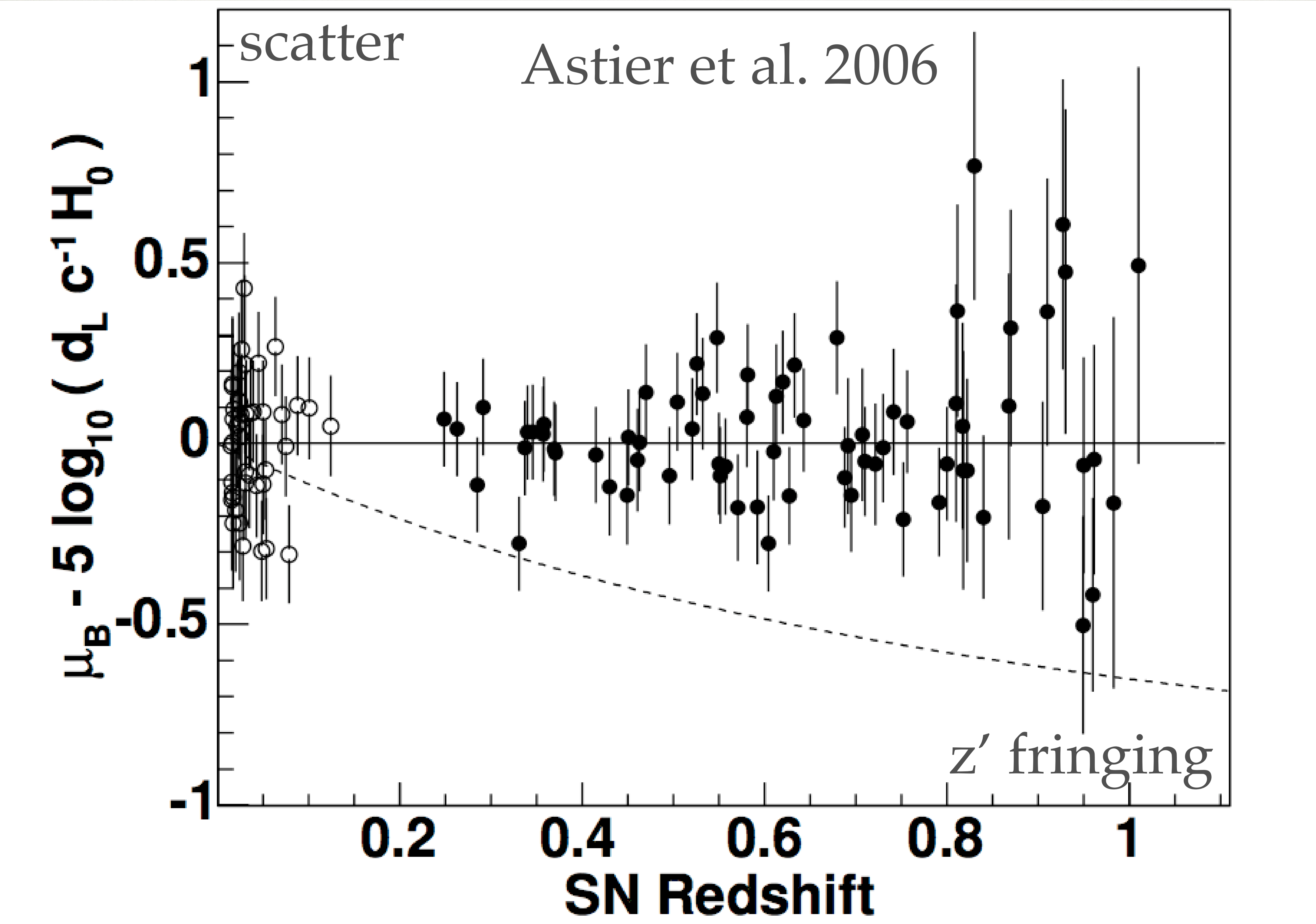
Astier et al. 2005

Multi-colour LC: stretch, host extinction



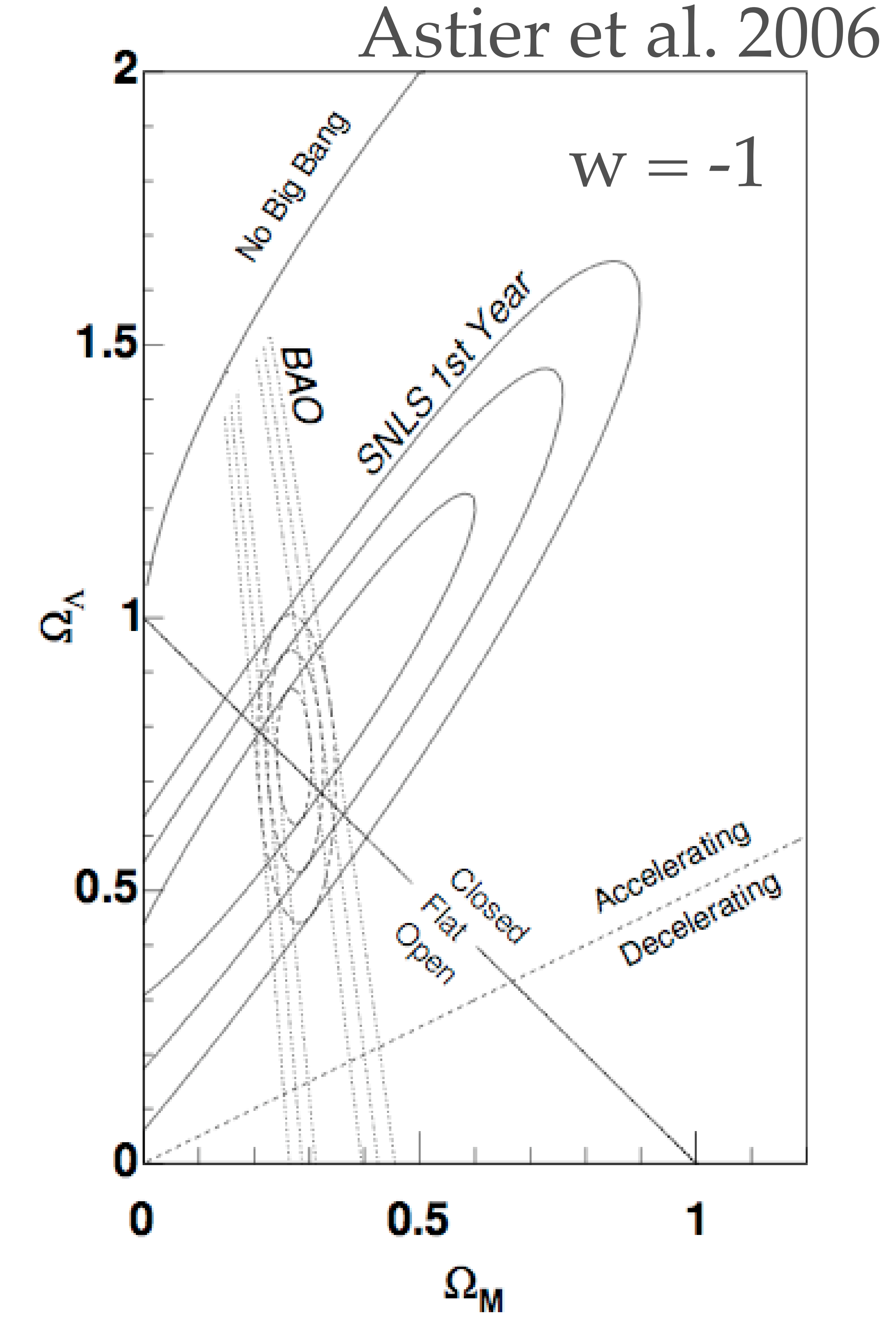
SNLS 1st Year
Astier et al. 2006
$(\Omega_m,\Omega_\Lambda)=(0.26,0.74)$
$(\Omega_m,\Omega_\Lambda)=(1.00,0.00)$
μ_B
34
36
38
40
42
44
0.2
0.4
0.6
0.8
1
SN Redshift

Local sample



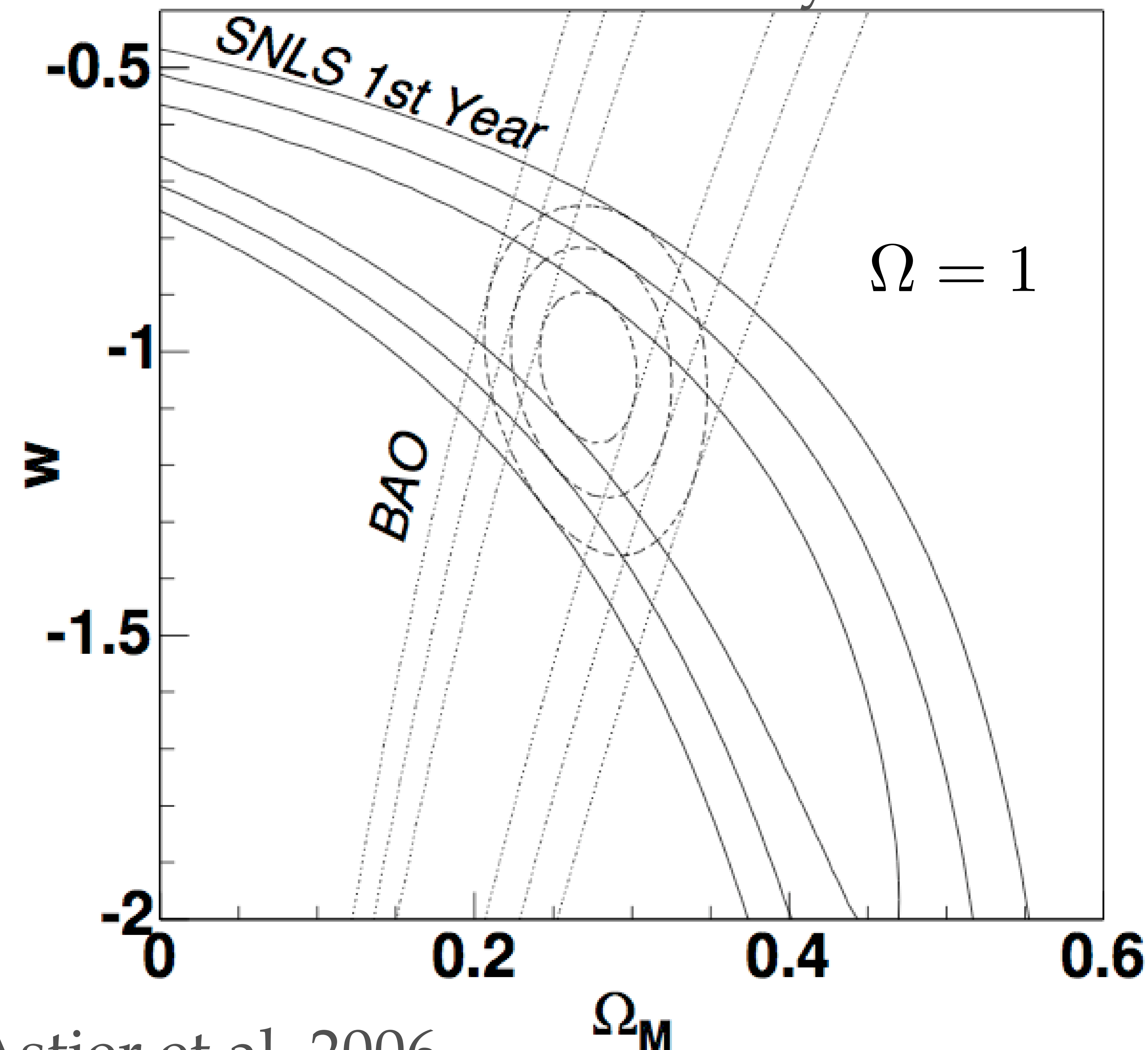
$$\Omega_M = 0.271 \pm 0.021(stat) \pm 0.007(sys)$$

Baryon Acoustic Oscillations (BAO) from SDSS (Eisenstein et al. 2005)



$$w = -1.023 \pm 0.090(stat) \pm 0.054(sys)$$

Best measurement yet!



Astier et al. 2006

Future Work

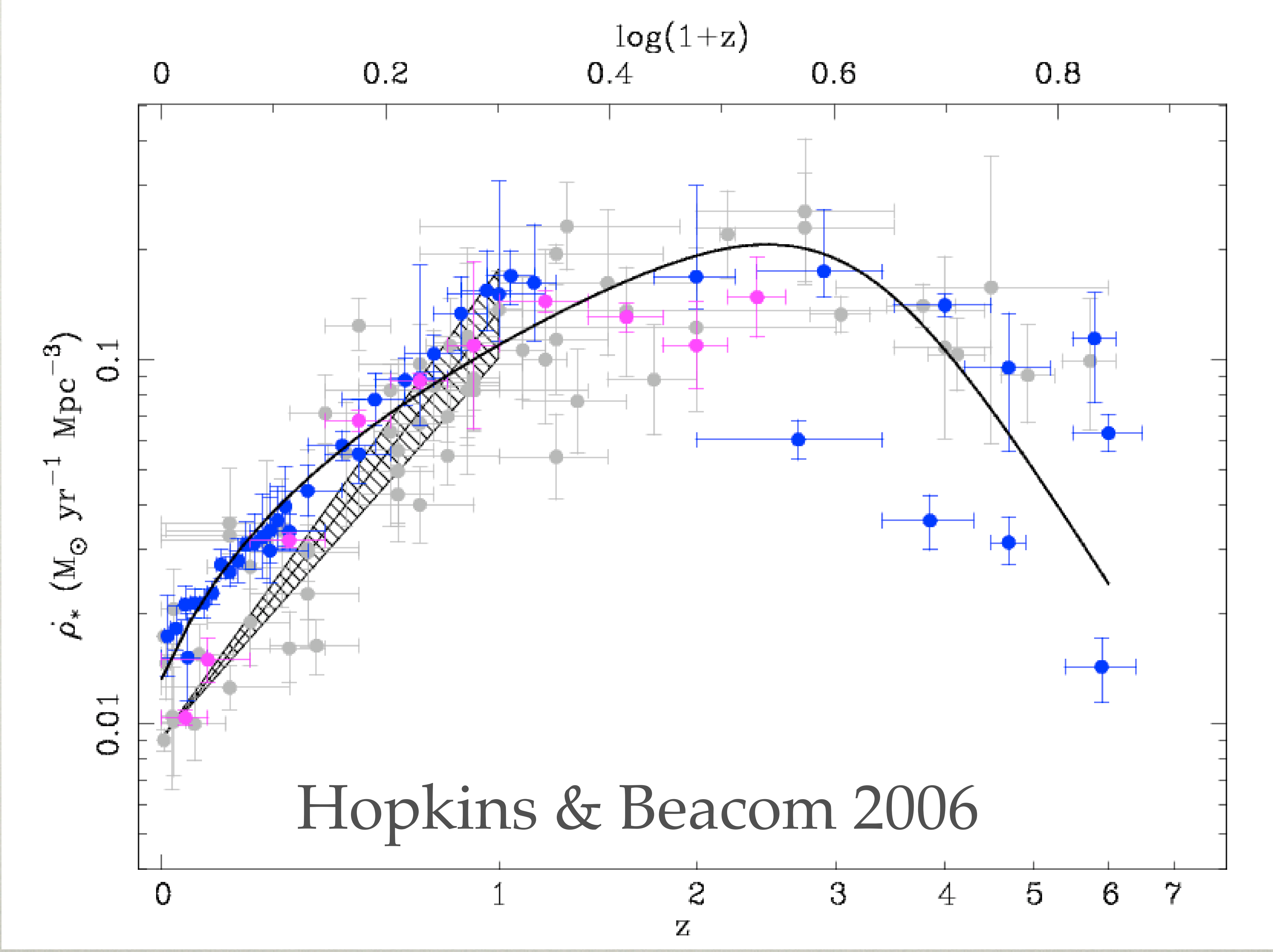
- Sample will grow (goal of ~700 SNe Ia)
- Re-observe local SN fields w/MegaCam
- Increase local sample
- Improve z′ de-fringing for $z > 0.8$ SNe
- Better understanding of systematics

SN Ia Rates from z=0.2 - 0.6 With SNLS

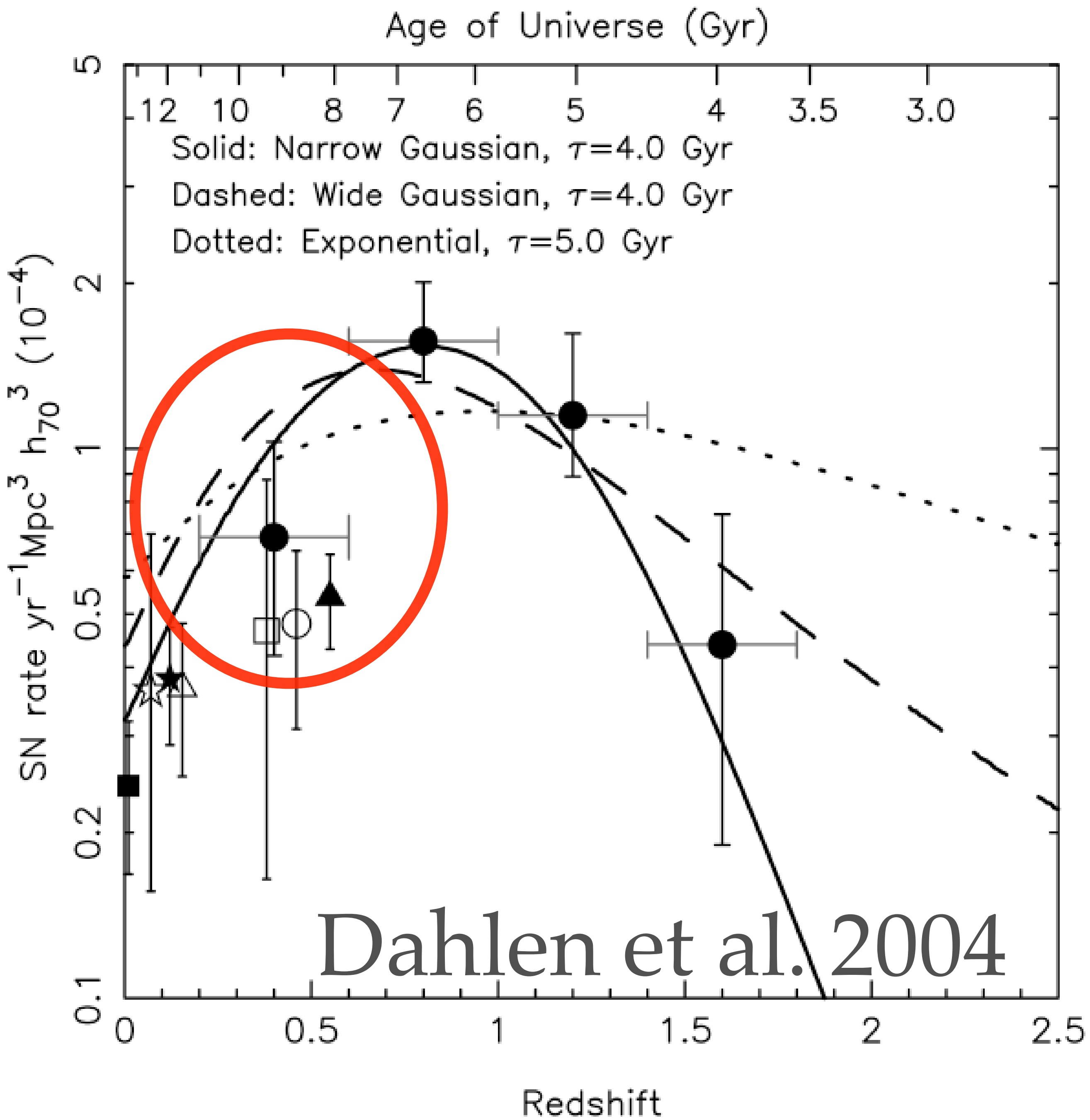
Motivation

- What is a Type Ia Supernova?
  - SD - White Dwarf + Ordinary Star
  - DD - Two White Dwarfs
- Why is this candle standard?
- Rate evolution + Star Formation History
  - Delay form constrains SN Ia process

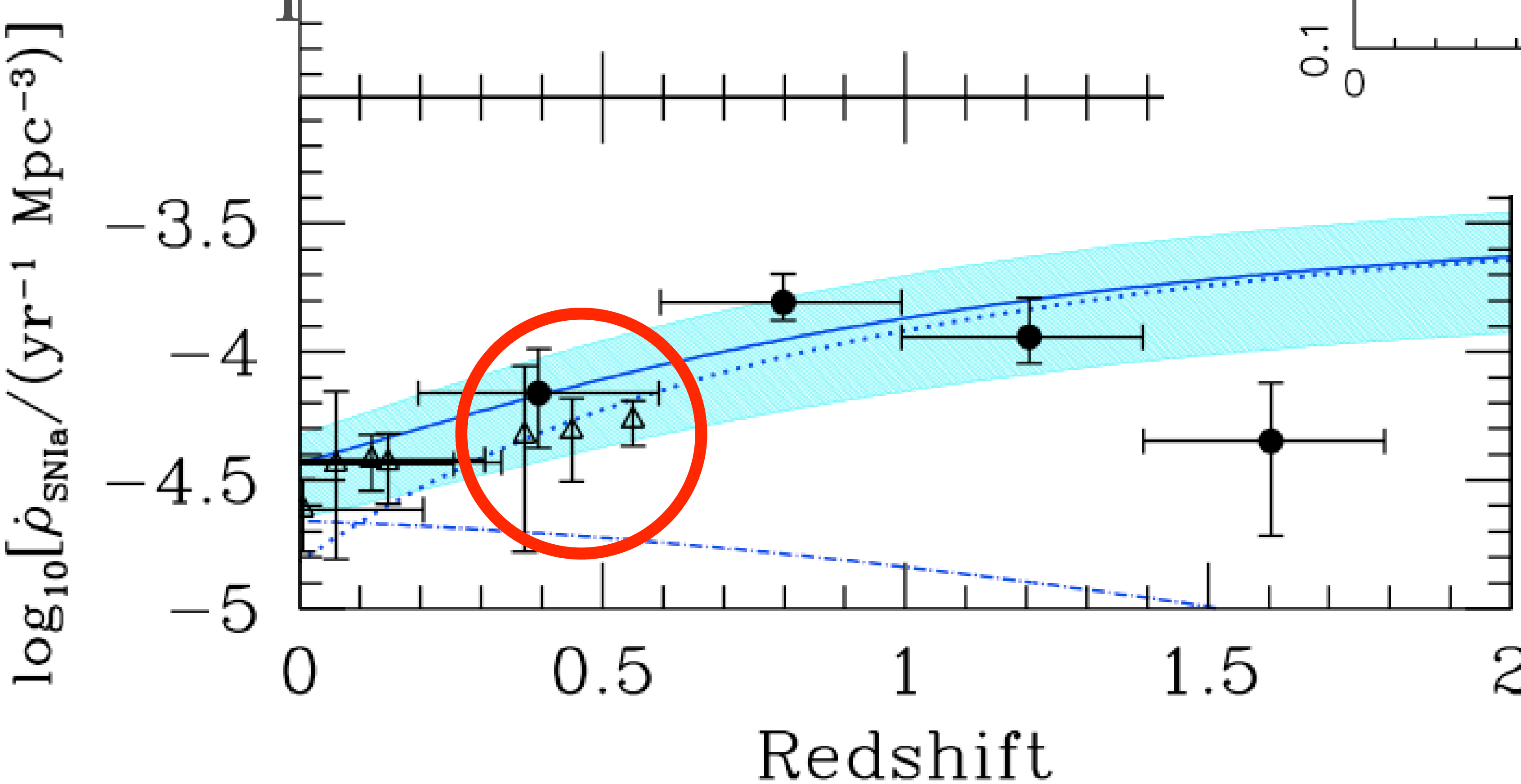
Star Formation History



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

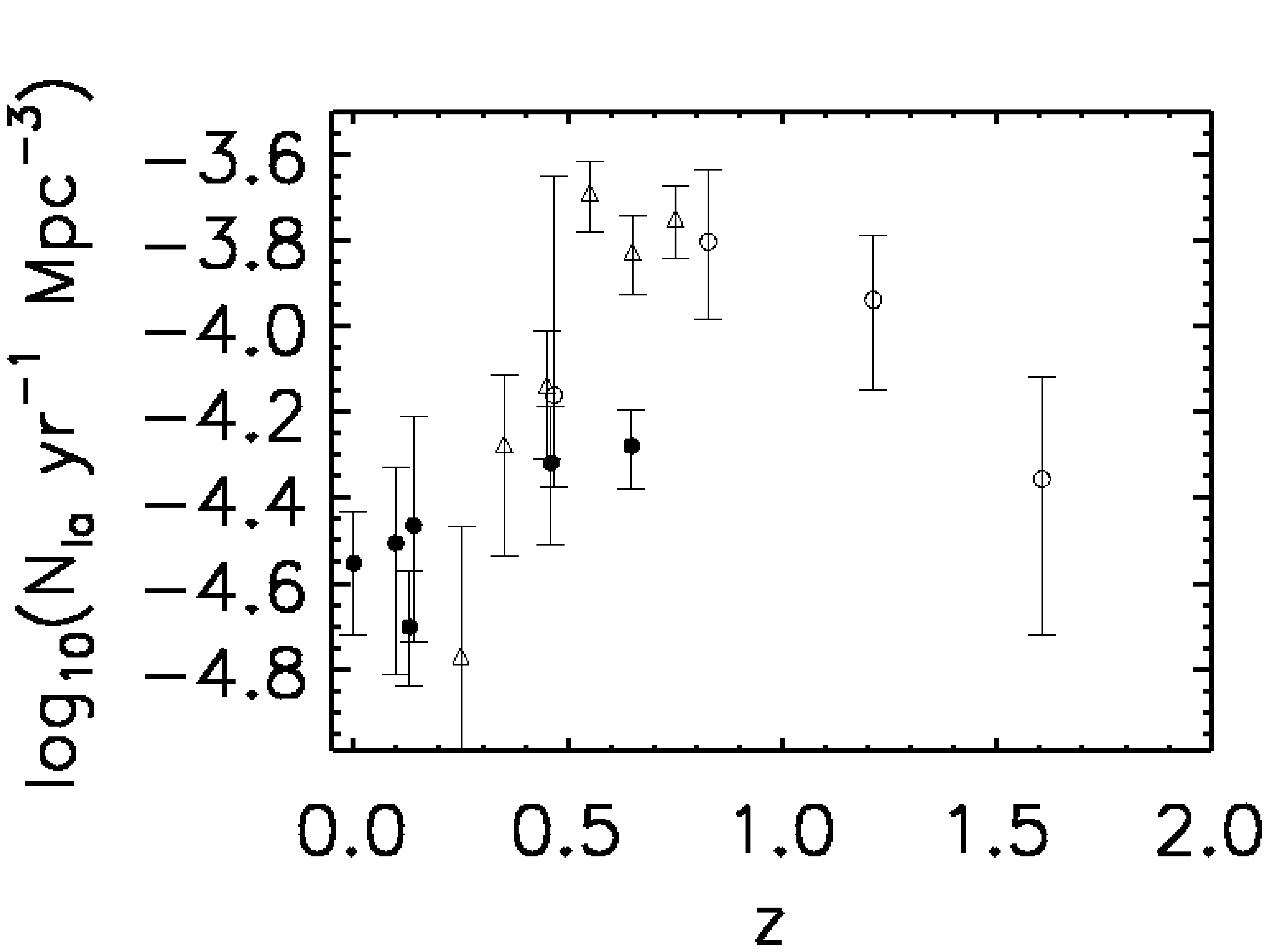


Scannapieco & Bildsten 2005



SNLS Rate at z = 0.5 could be revealing!

filled circles - spectroscopic confirmation



open triangles from Barris & Tonry (2005)

Rates from SNLS: Method Outline

- Careful selection of spectroscopically confirmed samples
- Artificial star experiments determine variable epoch limits
- Monte Carlo simulation to determine survey efficiencies
- Compare results with samples to derive volumetric rate

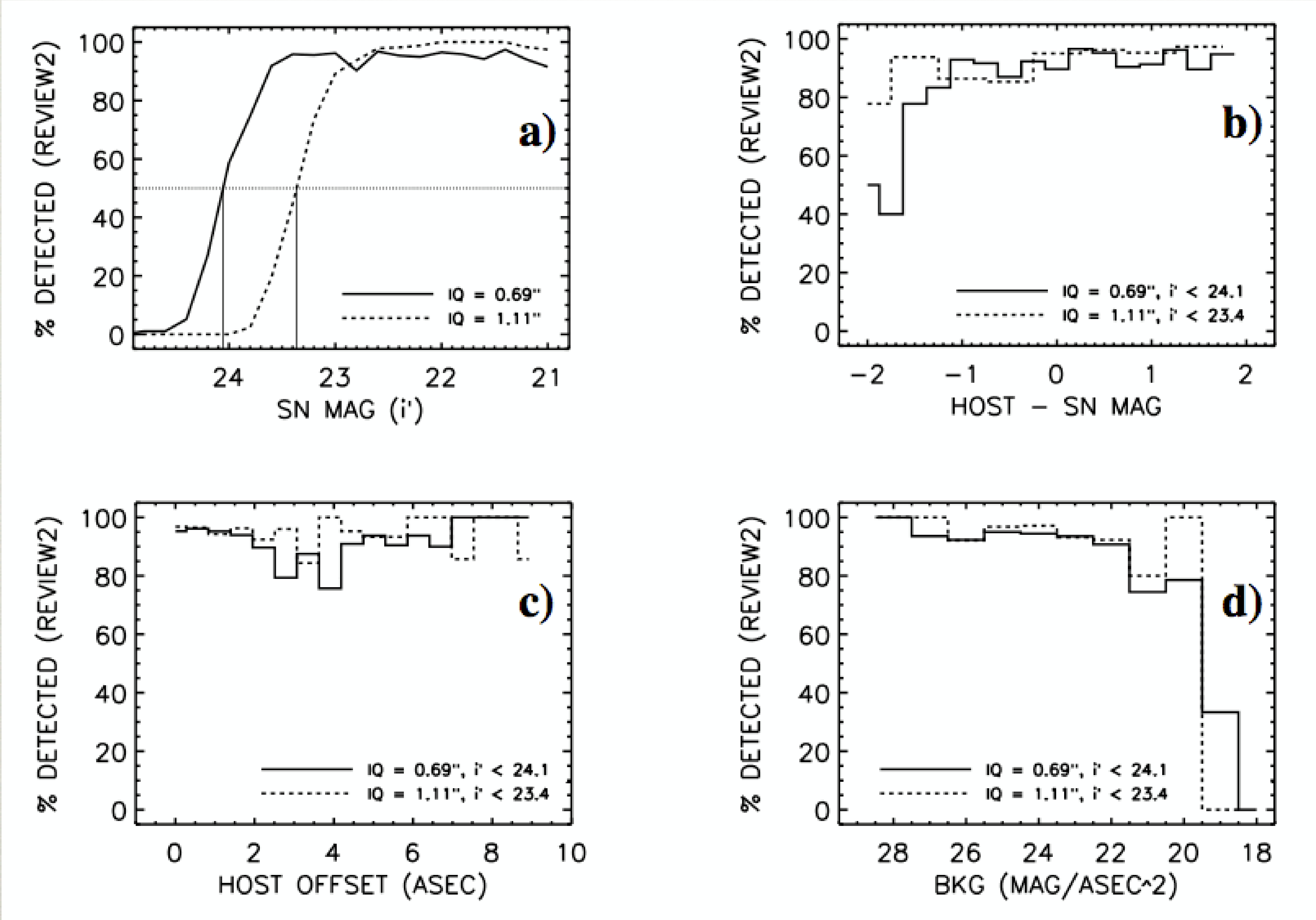
SN Ia SAMPLES

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

	Control Sample	Full Sample
Field	(N_{SN})	(N_{SN})
D1	9	15
D2	4	17
D3	6	8
D4	6	11
ALL	25	51

Spectroscopically Confirmed

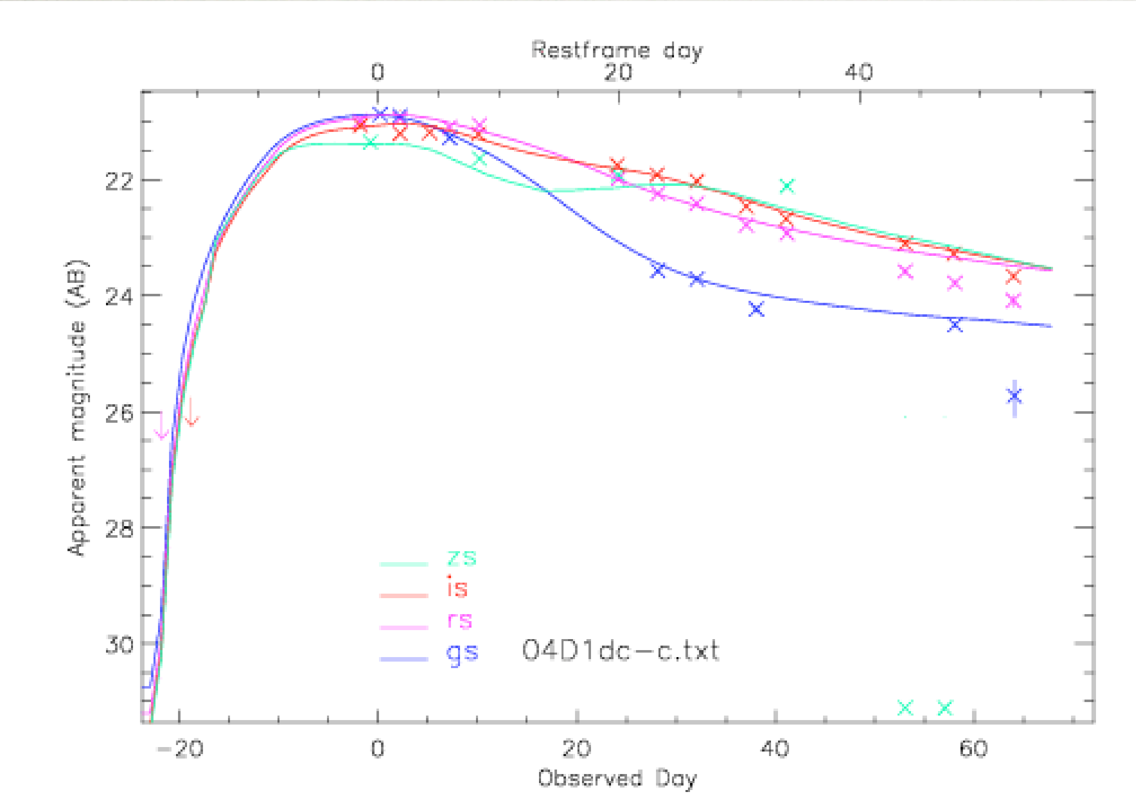
SN Detectability

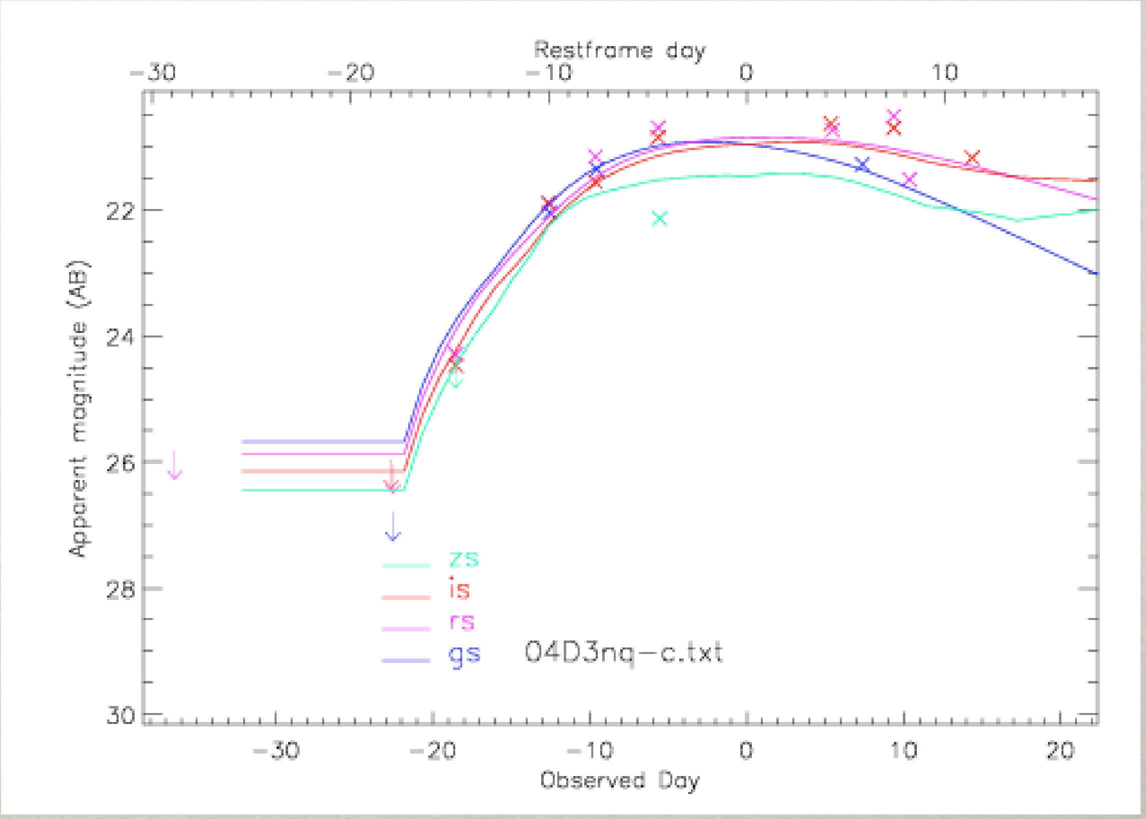


$$L_e = L_{f,0.5} - \alpha_f(IQ_e - 0.5) + 2.5\log(E_e/E_{f,ref}) - 2.5\log(T_e) - 2.5\log(S_e/S_{f,ref}),$$

Spectral Followup Criteria

- Observe twice in i′ up to day -1.5
- Early color from either g′ or r′
- Determine stretch (decline rate) from g′r′i′ observation > 11 days after max



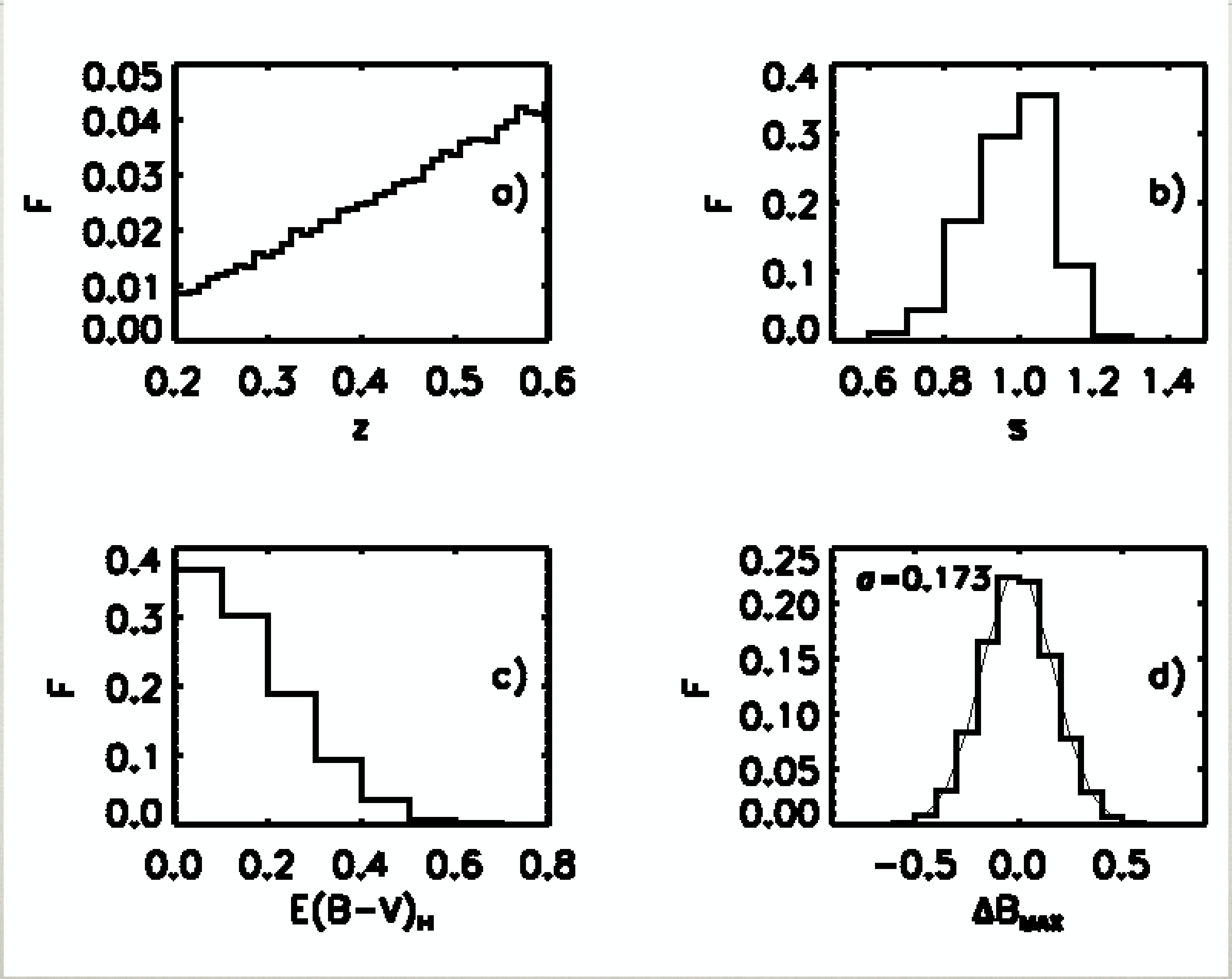


Possible Missed SNe Ia

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



Monte Carlo Results

Table 6. Monte Carlo Efficiencies and Rates

Field	Control Sample		Full Sample	
	(yr^{-1})	r_{RAW} (yr^{-1})	(yr^{-1})	r_{RAW} (yr^{-1})
D1	0.303	29.7 ± 9.9	0.267	28.0 ± 7.2
D2	0.102	39.2 ± 19.6	0.212	40.2 ± 9.7
D3	0.175	34.2 ± 14.0	0.235	34.1 ± 12.0
D4	0.314	19.1 ± 7.8	0.273	20.1 ± 6.1

SN Ia Rate Density

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

Field	r_{RAW} [a] (yr^{-1})	r_{spec} [b] (yr^{-1})	r_{1+z} [c] (yr^{-1})	Ω degrees^2	V $\times 10^4$ Mpc^3	r_V ($\times 10^{-4}$ yr^{-1} Mpc^{-3})
D1	28.0 ± 7.2	34.1 ± 8.8	50.1 ± 12.9	1.024	106.0	0.47 ± 0.12
D2	40.2 ± 9.7	40.2 ± 9.7	59.0 ± 14.2	1.026	106.2	0.56 ± 0.13
D3	34.1 ± 12.0	42.6 ± 15.0	62.5 ± 22.0	1.029	106.5	0.59 ± 0.21
D4	20.1 ± 6.1	25.1 ± 7.6	36.9 ± 11.2	1.027	106.3	0.35 ± 0.11
AVG[d]	27.4 ± 4.0	33.0 ± 4.7	48.4 ± 6.9	1.026	106.2	0.46 ± 0.06[e]

Errors & Results

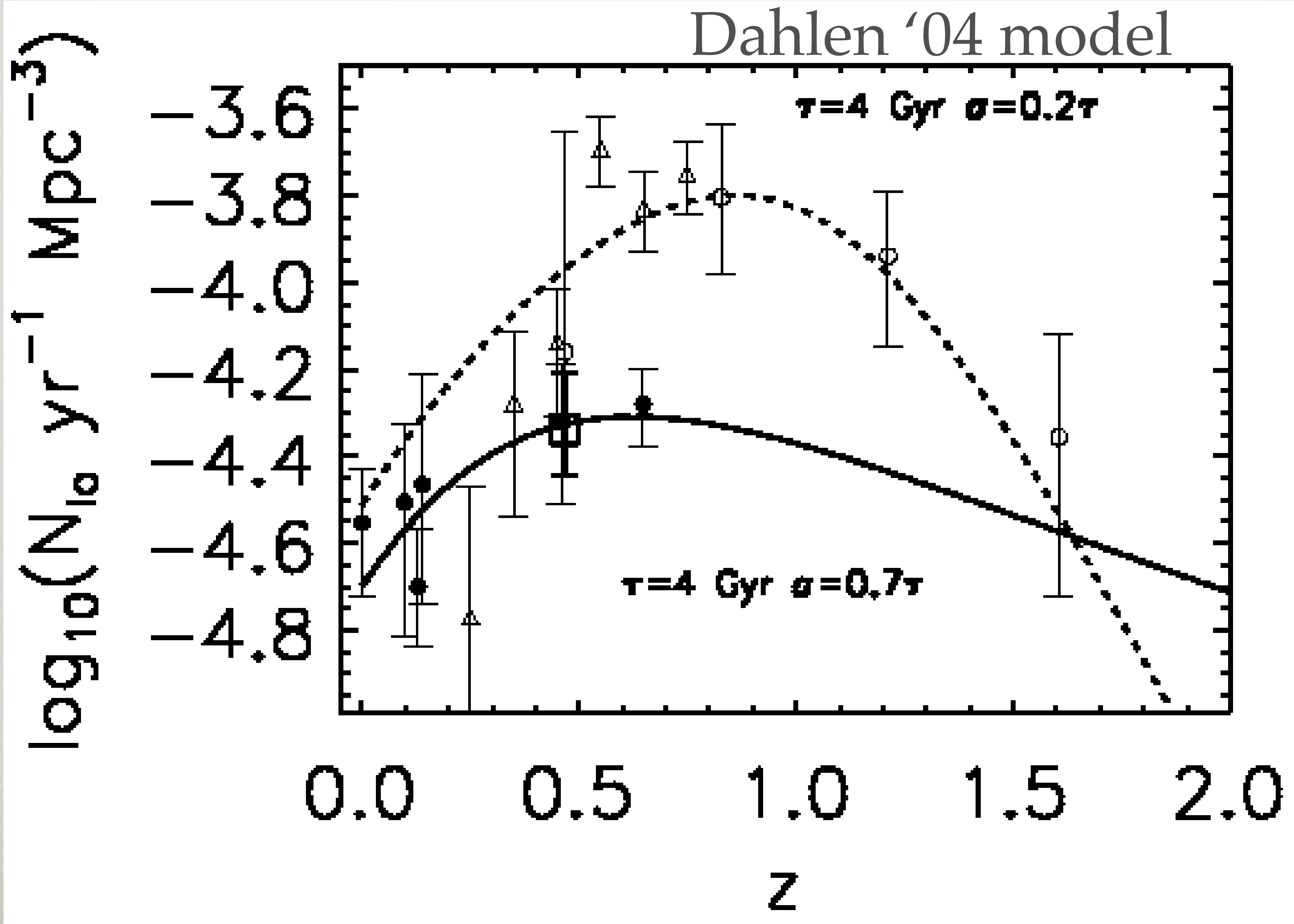
Source	δr_V [a]
Poisson	± 0.06
Spec. Completeness	$^{+0.08}_{-0.08}$
Host Extinction	$+0.13$
Frame Limits	± 0.06
Total Statistical	± 0.06
Total Systematic	$^{+0.16}_{-0.10}$

$$r_V(\langle z\rangle_V = 0.47) = 0.46^{+0.16}_{-0.10}(syst) \pm 0.06(stat) \times 10^{-4} yr^{-1} Mpc^{-3}$$

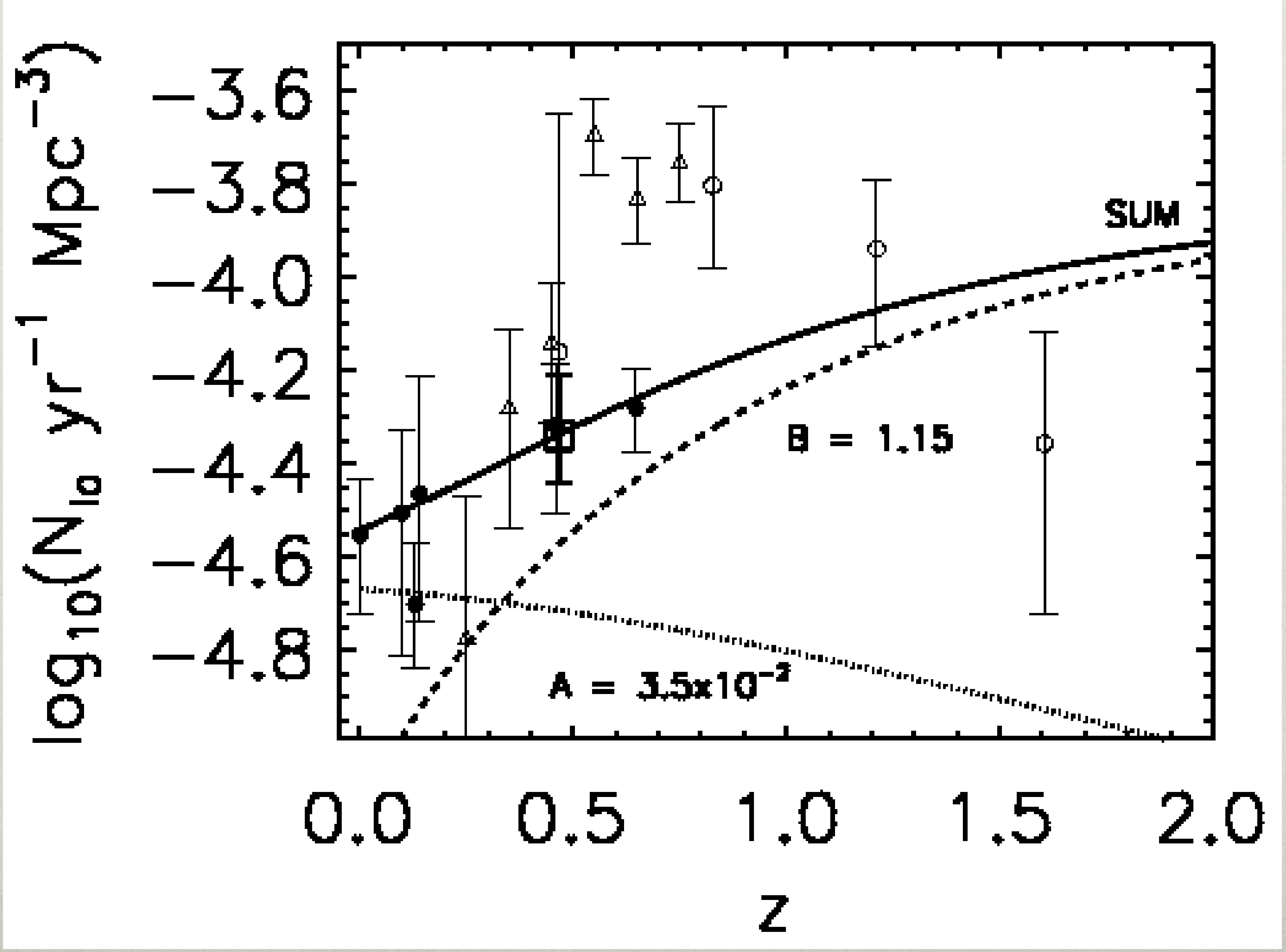
Star Formation History Mappings

- Gaussian delay time distribution:
  - τ in Gyr, $\sigma = f \times \tau$ (f = 0.2, 0.5, 0.7)
- Two-component model:
  - A - extended: total mass
  - B - prompt: direct SFH (0.7 Gyr delay)
  - Mannucci et al. 2005, Scannapieco & Bildsten 2005

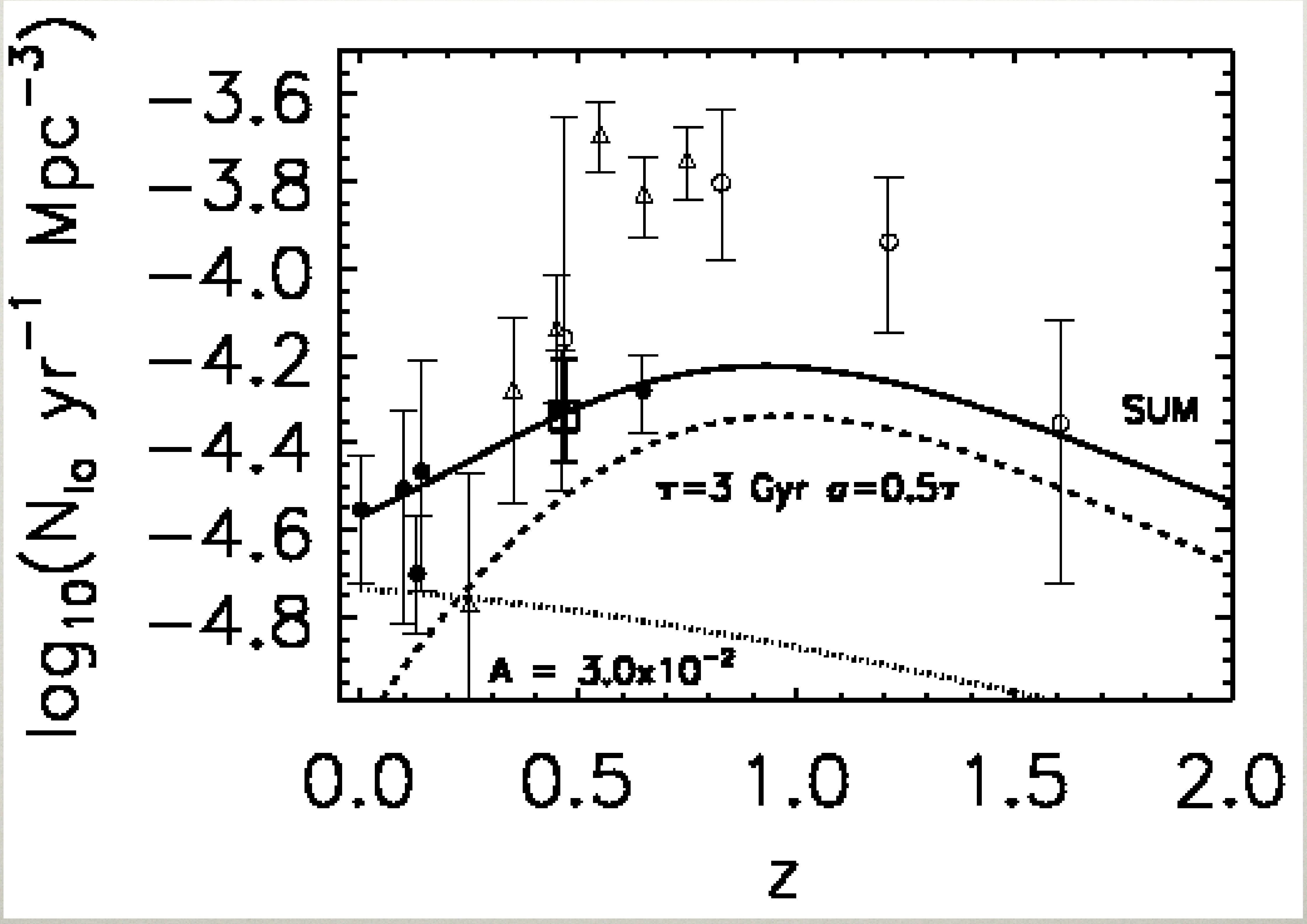
Delay Time Model



Two-Component Model



Hybrid Model



Summary

- No evidence for missing Ia's near z=0.5
- Models predict very different rates beyond z = 1 with impact on SNAP yield and SN weak lensing studies
- Two-component model fits spectroscopically confirmed rates well
- Must be wary of contamination in photometrically-typed samples

Future Directions

- Bin rates and extend to z = 0.75
- Rate as a function of host properties:
  - M. Sullivan, A. Howell, C. Pritchet
- Proper training of photometric typing
  - Account for wide range of CC SNe