New SDSS Results on Rates and Populations

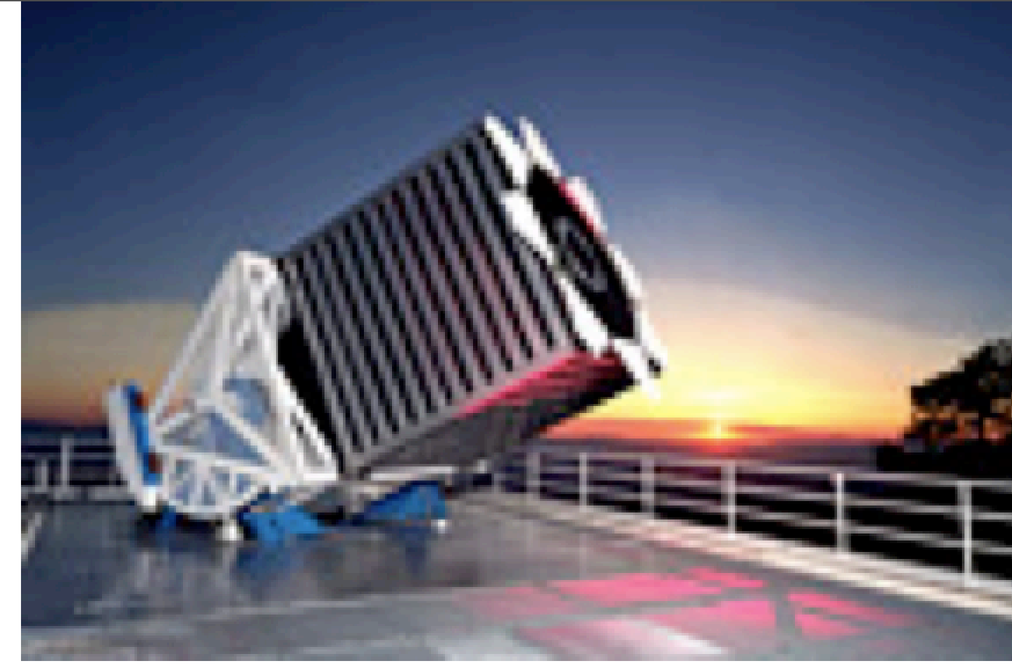
Ben Dilday
Rutgers University
KITP:Stellar Death and Supernovae
August 18, 2009

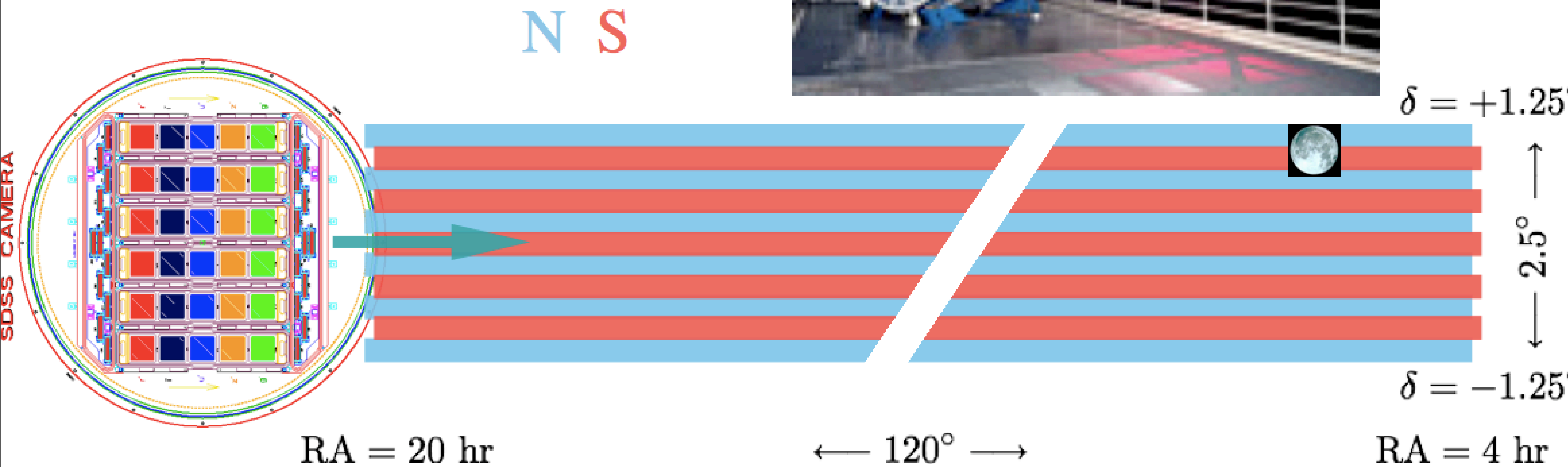
Outline

SN Ia rate...

- as a function of redshift for z<0.3
- in galaxy clusters
- as a function of host-galaxy stellar mass/ star formation (Mat Smith)

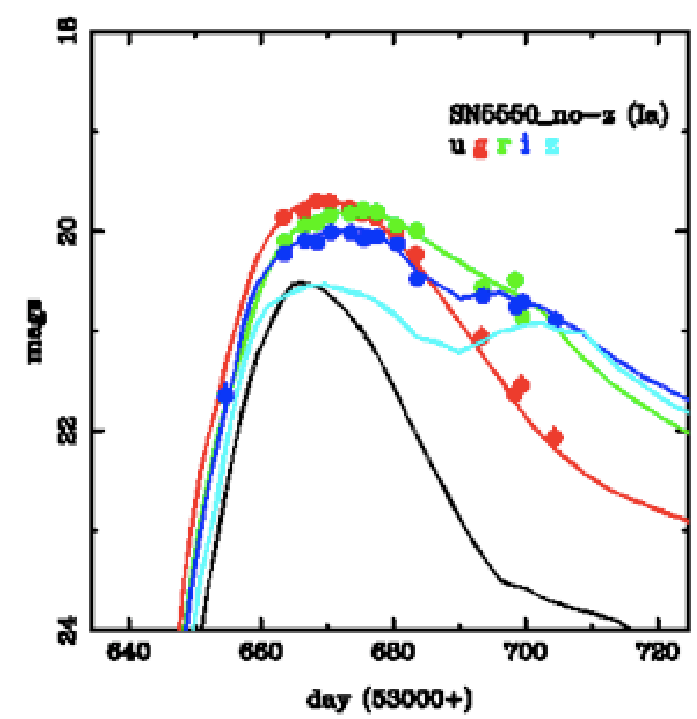
SDSS-II SN Survey





SDSS 2.5m telescope

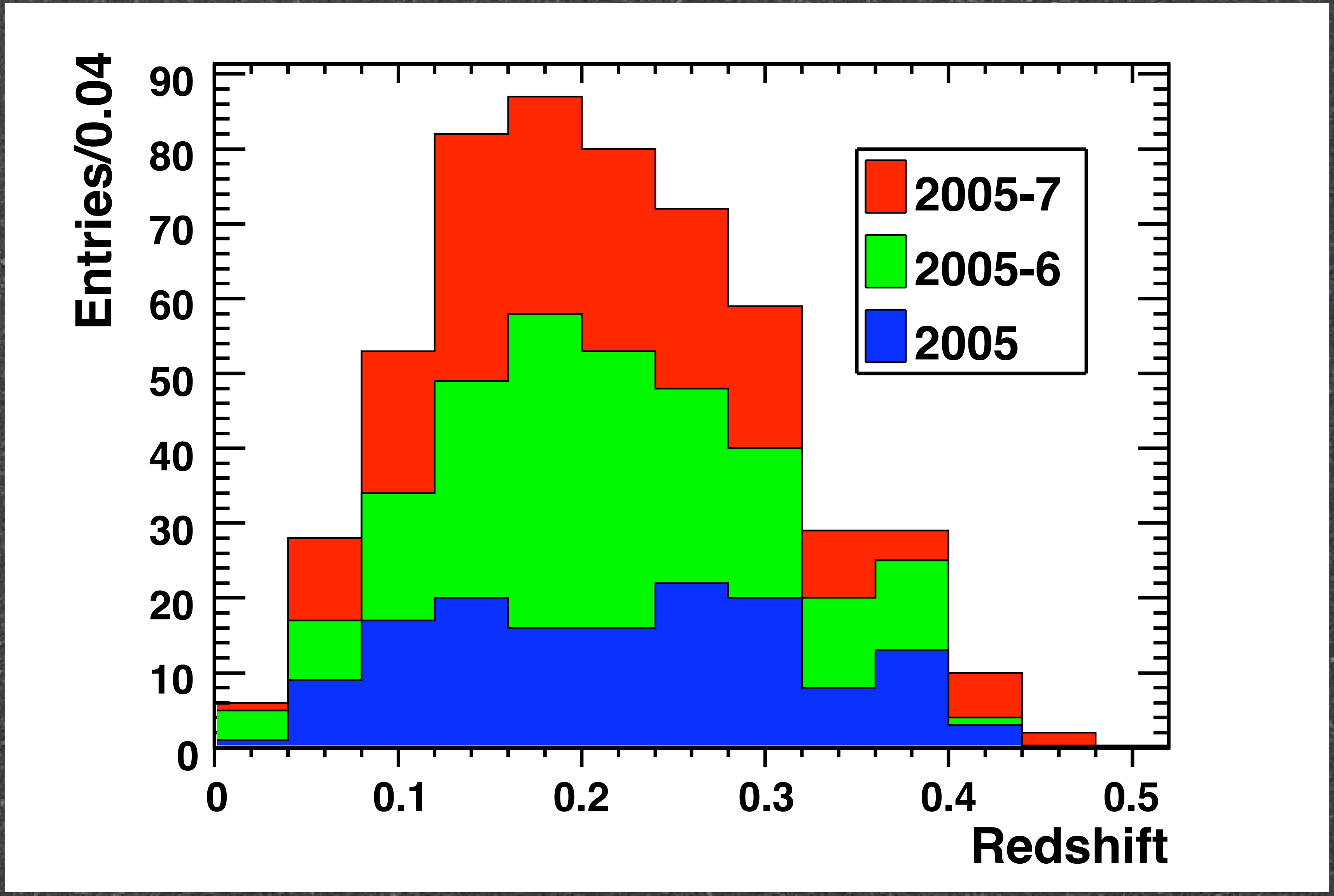
- September 1 - November 30 of 2005-2007
- Scan 300 square degrees every 2 days
- Obtain densely sampled multi-color light curves




~520 confirmed
SNe Ia

~15% of all SNe Ia discovered since 1885

~520 spectroscopically confirmed SNe Ia



~40 probable Type Ia

~20 Type Ib/c

~70 Type II

~300 SNe Ia candidates with host galaxy redshifts

SDSS-III:
4000 redshifts!

SN Sample Selection

- premax observation (-2 days)
- postmax observation (+10 days)

➡well constrained time of maximum

- at least 5 total observations
- 1 high S/N observation in *gri*

➡authentic astrophysical transient

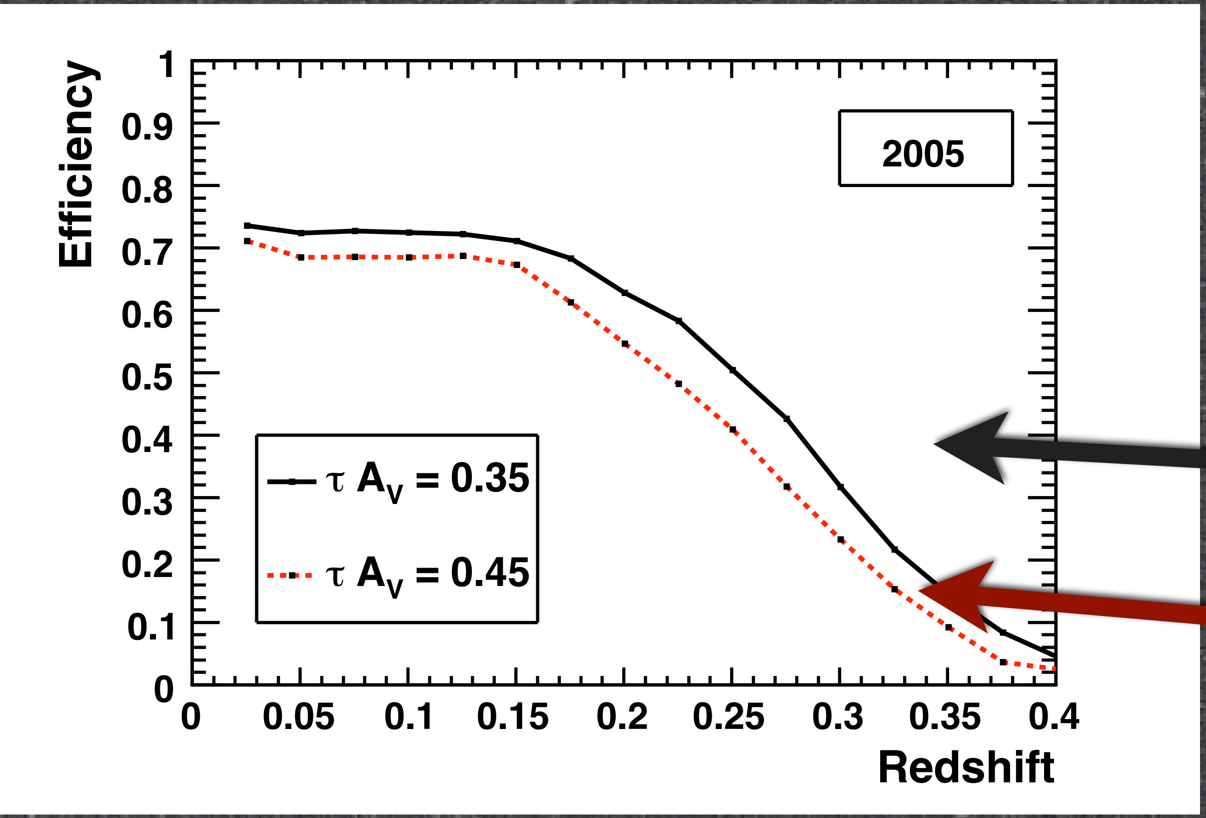
- fit probability > 0.001, Δ > -0.4
- bayesian probability for Ia > 0.45

➡reject non-Ias and peculiar Ias

SN MC described in
Dilday et al 08, Kessler et al 09a, 09b

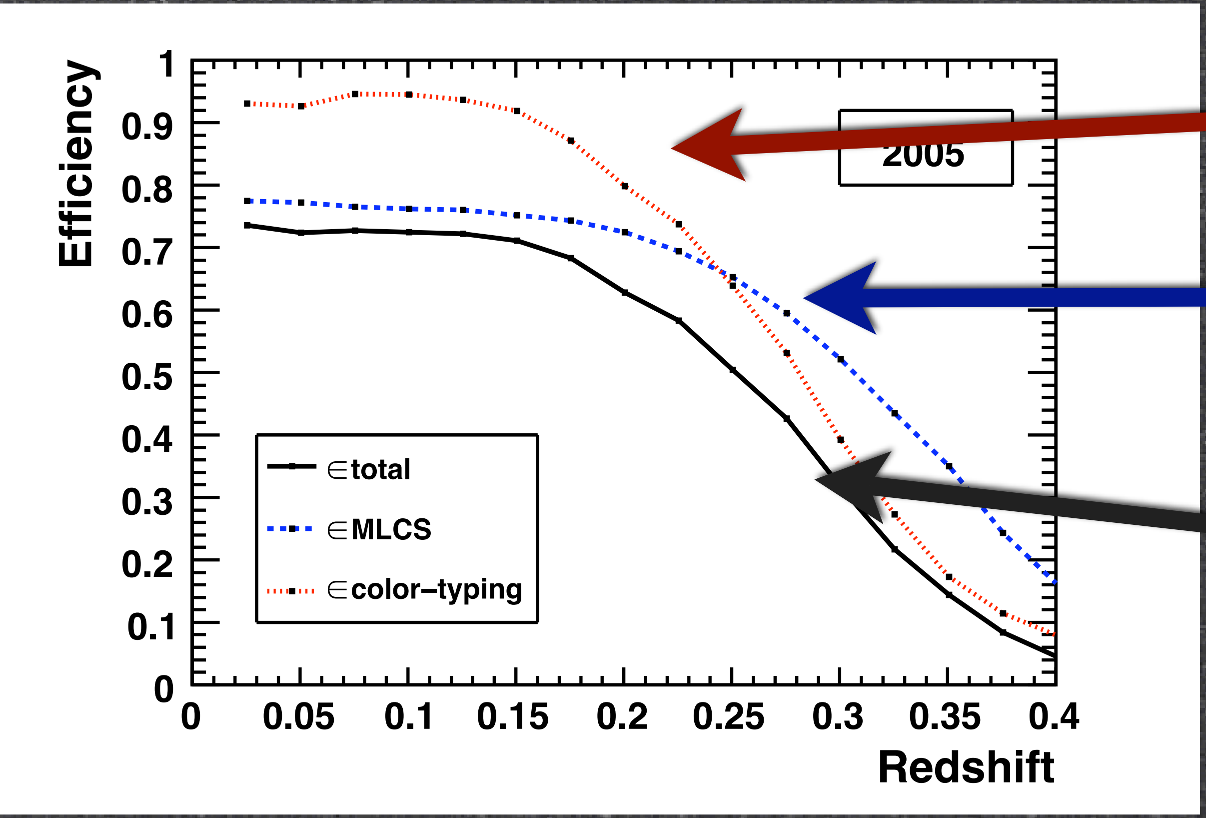
SN discovery efficiency

Monte Carlo simulations
1000 simulated SNe in
17 redshift bins



fiducial

larger mean Av



bayesian probability

light curve sampling,
S/N

total

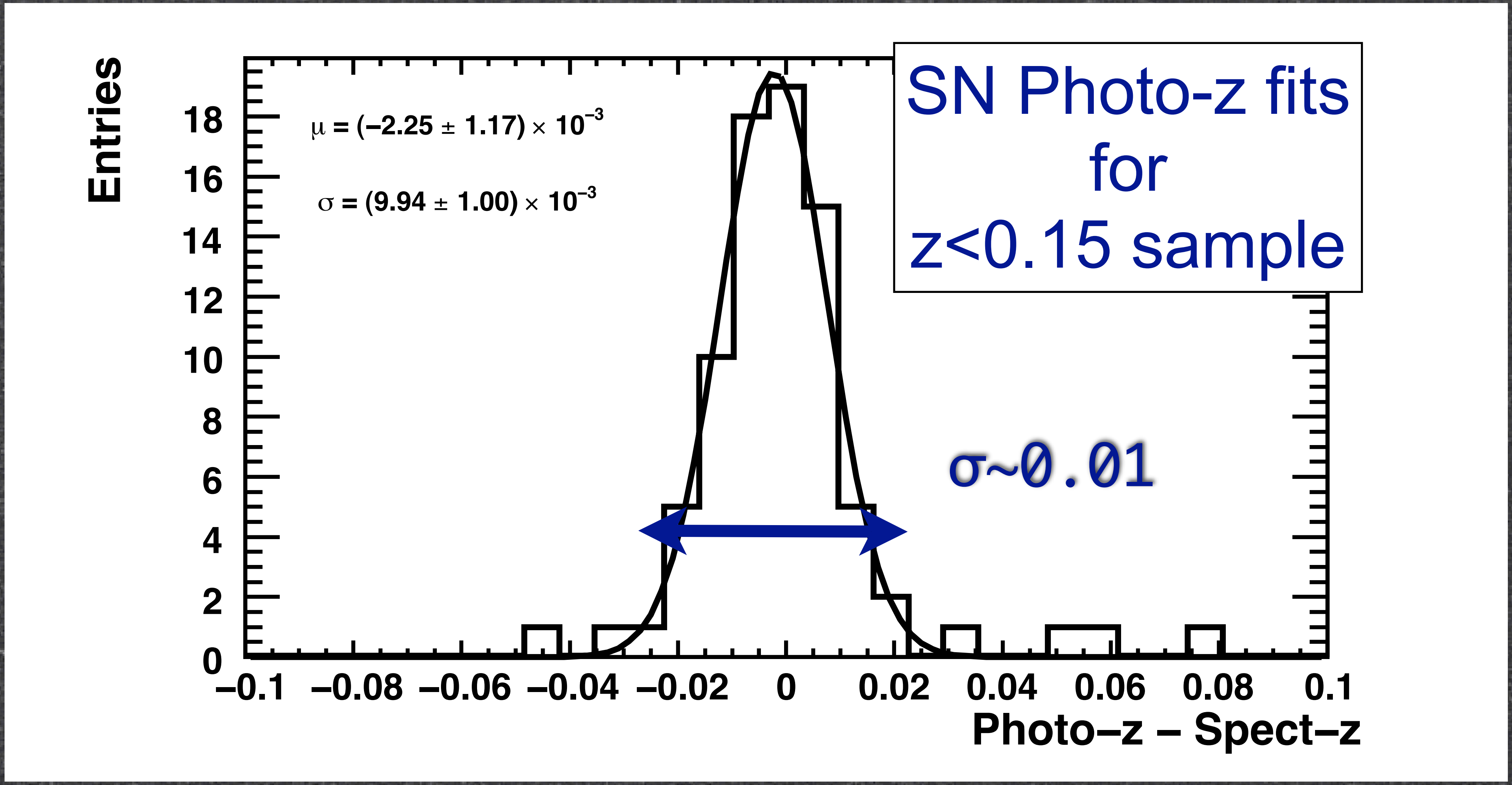
photometric SNe

<u>Host-galaxy redshift</u>

Fix redshift
fit SN for distance

<u>No host-galaxy redshift</u>

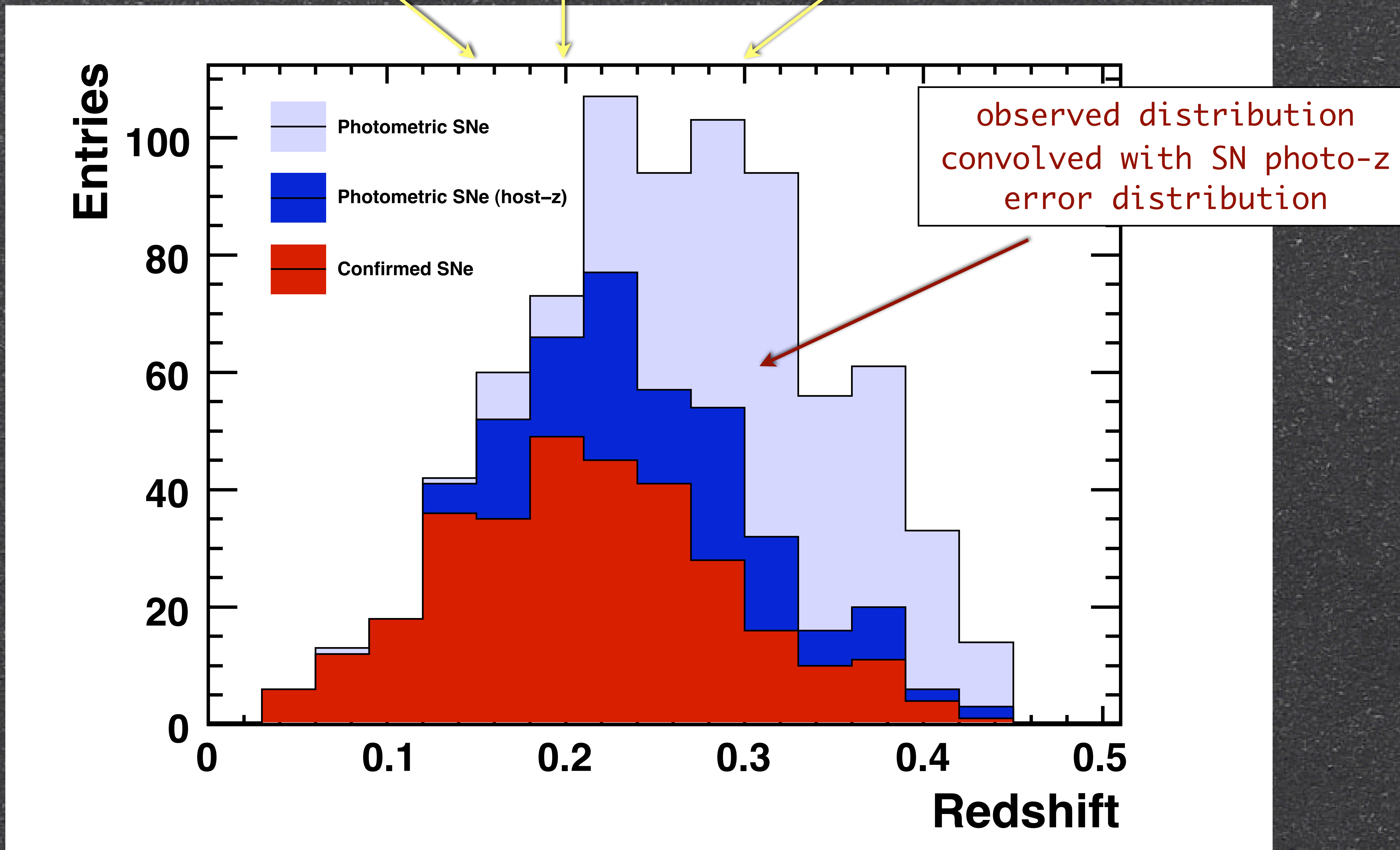
Assume distance vs redshift
fit SN for redshift



79 SNe Ia
(72 confirmed)
z=0.15

190 SNe Ia
(140 confirmed)
z=0.20

516 SNe Ia
(270 confirmed)
z=0.30



potential for bias due to use of photo-zs

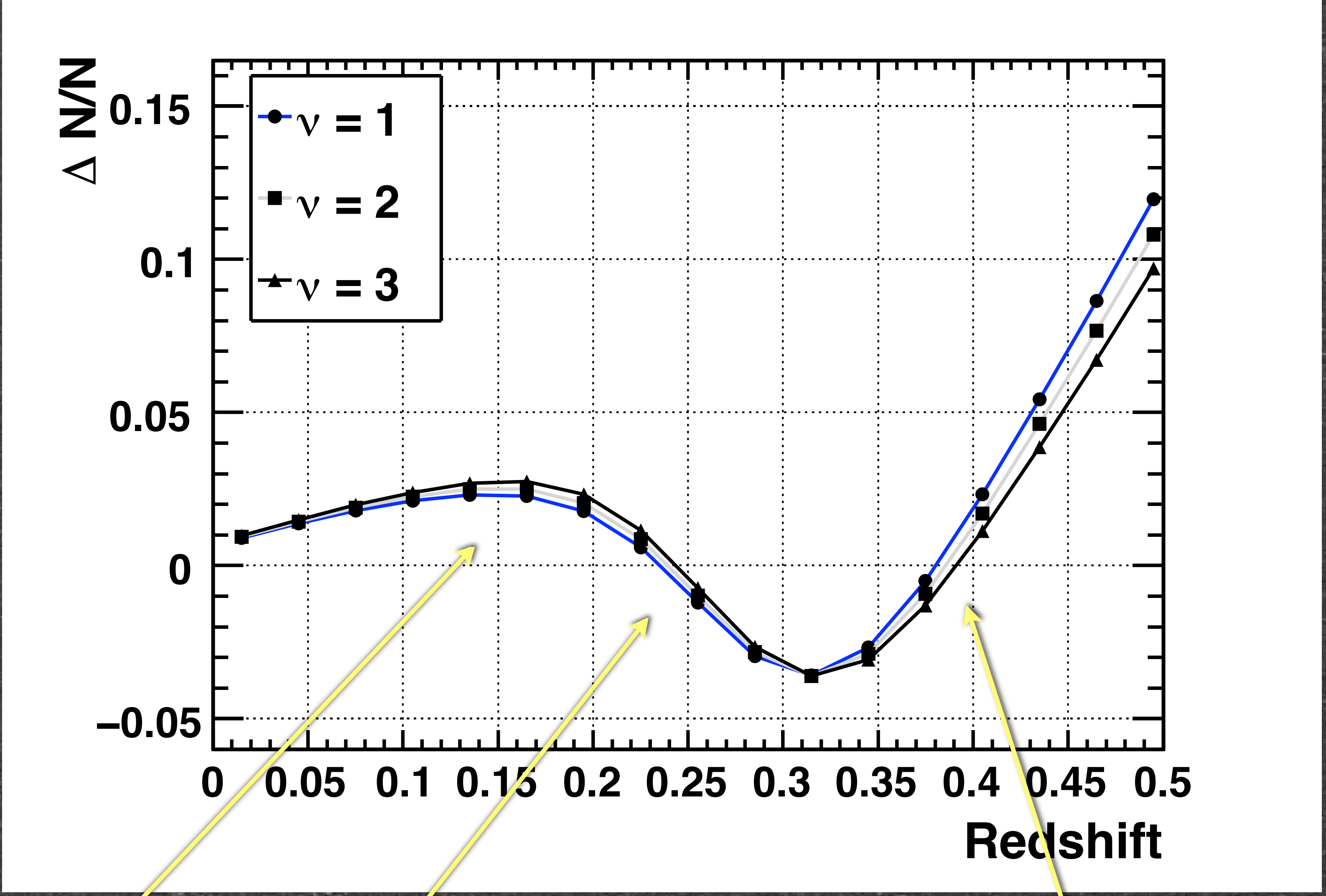
$$\eta_0(z)\, dz \propto \frac{r_V(z)\ \epsilon(z)}{1+z}\ \frac{dV}{dz}\ dz,$$

$$\eta(z) = \int_{-\infty}^{\infty} \eta_0(z')\ p(z|z')\ dz',$$

however,

<1% effect

assume all SNe are photometric...



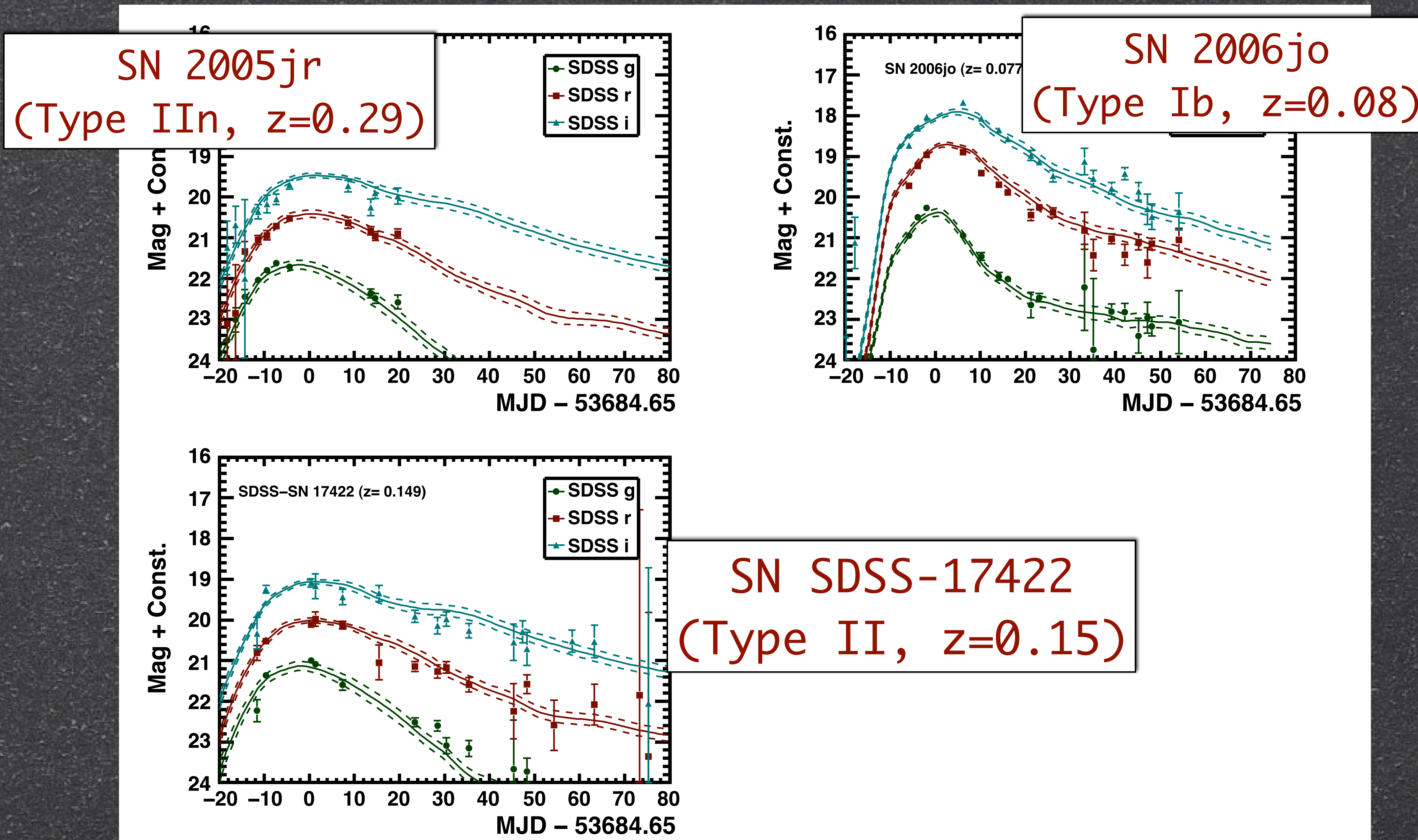
high spectroscopic completeness

flat distribution

low discovery efficiency

potential for contamination from non-Ia SNe

3/87 (~3.5%) non-Ia SNe pass selection criteria



Ia/non-Ia rate

$$\frac{N_{\rm CC}}{N_{\rm Ia}} = \frac{r_{\rm CC}}{r_{\rm Ia}} \frac{\epsilon^q_{\rm CC}}{\epsilon^q_{\rm Ia}} \frac{\epsilon^D_{\rm CC}}{\epsilon^D_{\rm Ia}},$$

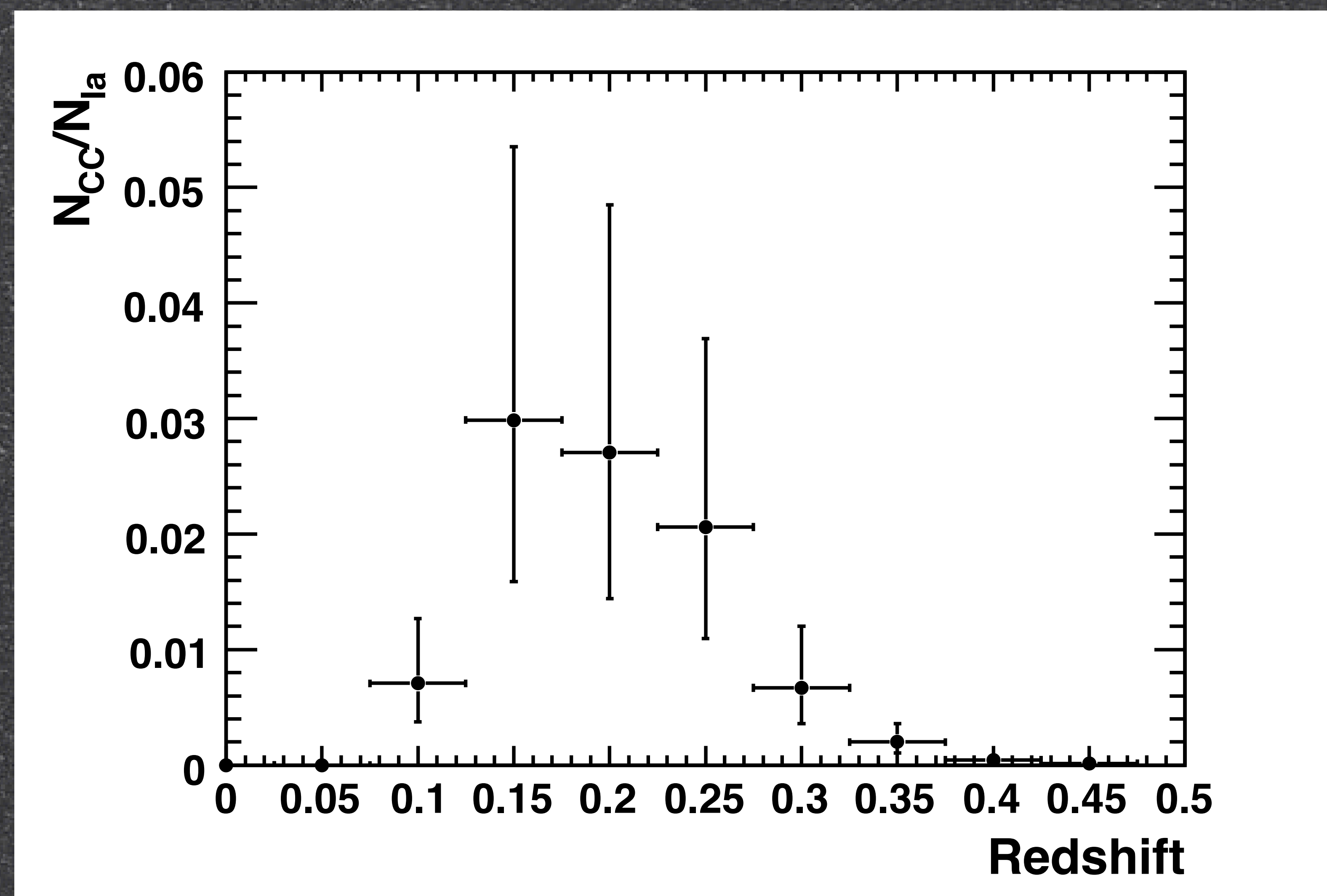
3/87

eye of newt

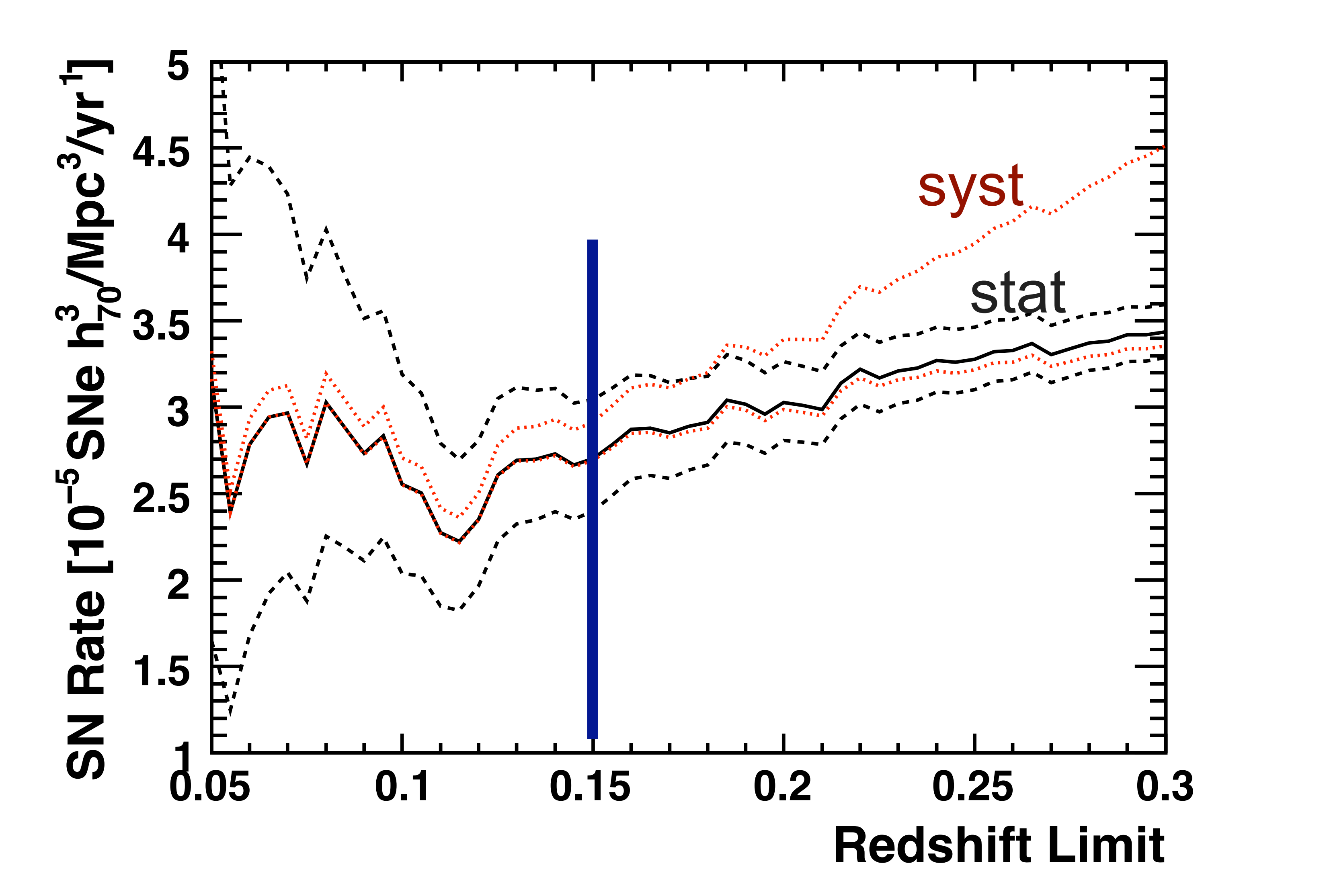
detection eff.
vs peak-mag

weight for SNe in
maximum likelihood fit

non-Ia contamination
fraction vs redshift



assume a constant SN rate...



e.g., $z \leq 0.15$

$$r_V = (2.69^{+0.47}_{-0.39}) \times 10^{-5}\ \text{SNe Mpc}^{-3}\ \text{yr}^{-1}\ h_{70}^{3}$$

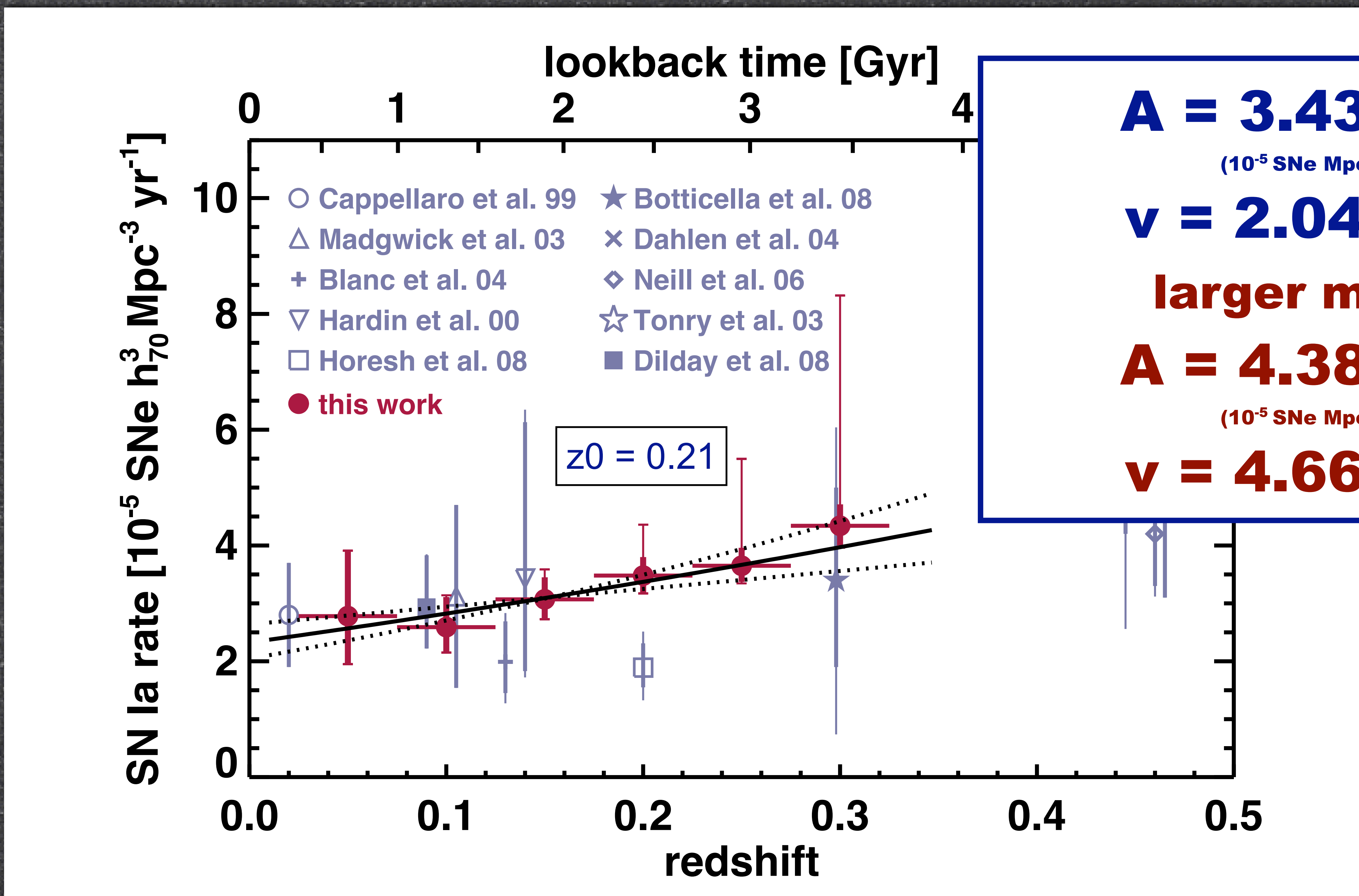
power-law SN rate model

$r = A \times [(1+z)/(1+z0)]^{\nu}$

unbinned maximum likelihood method

$$p_z^i = \langle N \rangle^{-1}\, \Theta\, T_{\oplus} \int_{-\infty}^{\infty} \epsilon(z')\, r_V(z')\, d(VT/\Theta)/dz'\, \rho(z'|z^i)\, dz',$$

$$L = \frac{\langle N \rangle^{N_{\rm SNe}}\, e^{-\langle N \rangle}}{(N_{\rm SNe})!}\, \Pi_{i=1}^{i=N_{\rm SNe}}\, p_z^i.$$



A = 3.43 ± 0.15

(10^{-5} SNe Mpc^{-3} yr^{-1} h_{70}^{3})

v = 2.04 ± 0.90

larger mean Av

A = 4.38 ± 0.20

(10^{-5} SNe Mpc^{-3} yr^{-1} h_{70}^{3})

v = 4.66 ± 0.93

galaxy cluster SN Ia rate

- simpler SFH
- enrichment of intra-cluster medium

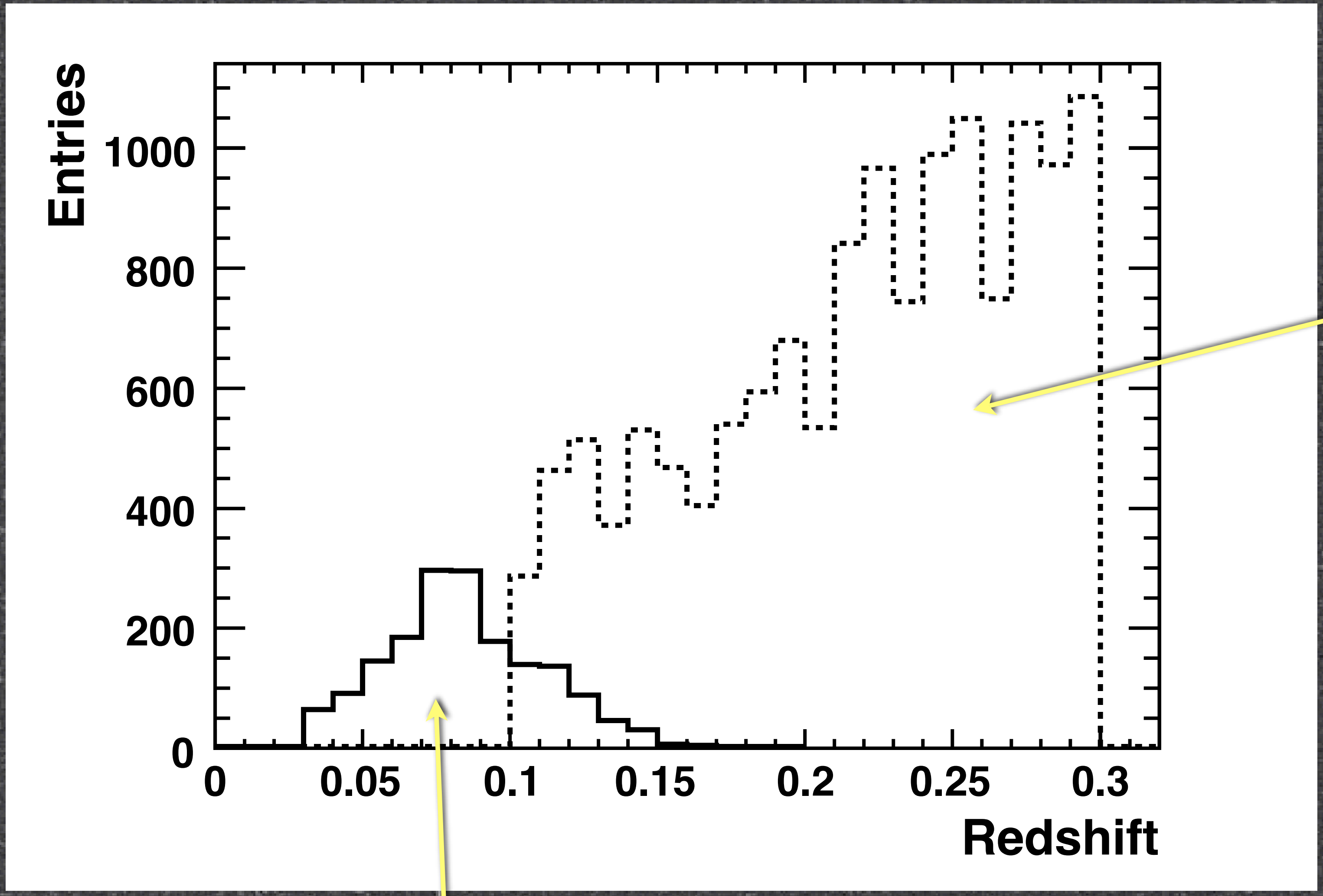
cluster SNe are rare
measurements based on few SNe

<u>SDSS galaxy clusters</u>

C4 clusters
(Miller et al. 2005)
71 clusters
$z < 0.17$

maxBCG clusters
(Koester et al. 2007)
492 clusters
$0.10 < z < 0.30$

Author	Redshift	N SNe
Mannucci	0 - 0.04	12.5
Sharon	0.06 - 0.19	6
Gal-Yam	≈0.25	1
Graham	≈0.45	3
Gal-Yam	≈0.90	2



maxBCG clusters
photometrically
selected
1.22 x 10^{14} Lsun (r) h^{-2}

27 SNe

C4 clusters
spectroscopically
selected
4.99 x 10^{13} Lsun (r) h^{-2}

9 SNe

<u>SNe belongs to cluster</u>

1 Mpc projected distance from cluster

Redshift consistency

C4 clusters
(z = 0.08)

$0.123^{+0.056}_{-0.040}$ SNuM

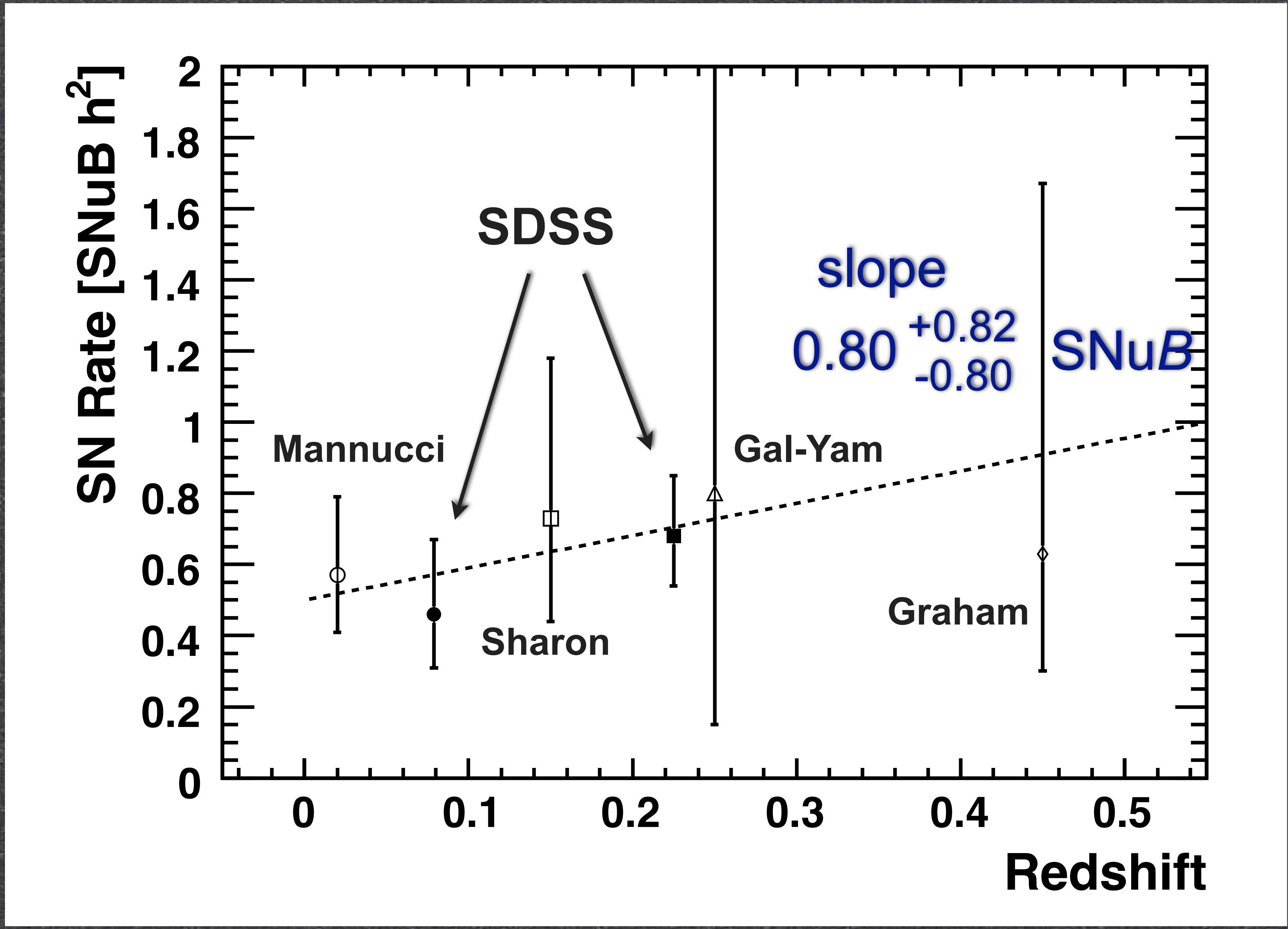
$0.37^{+0.17}_{-0.12}$ SNu*r*

maxBCG clusters
(z = 0.23)

$0.18^{+0.044}_{-0.036}$ SNuM

$0.55^{+0.13}_{-0.11}$ SNu*r*

*(H_0 = 100 km s^{-1} Mpc^{-1})



cluster rate vs. field rate

cluster elliptical galaxies	field elliptical galaxies (Dilday et al 2008)
C4 clusters: $0.31^{+0.18}_{-0.12}$ SNu*r*	$0.16^{+0.06}_{-0.04}$ SNu*r*
maxBCG clusters: $0.49^{+0.15}_{-0.11}$ SNu*r*	

ratio

C4 $1.94^{+1.31}_{-0.91}$

maxBCG $3.02^{+1.31}_{-1.03}$

hostless SNe

intra-cluster stellar population

~3 hostless SNe → $(9.4^{+8.3}_{-5.1})\%$

caveat: based on physical separation, not redshift

2/7 in Gal-Yam et al.

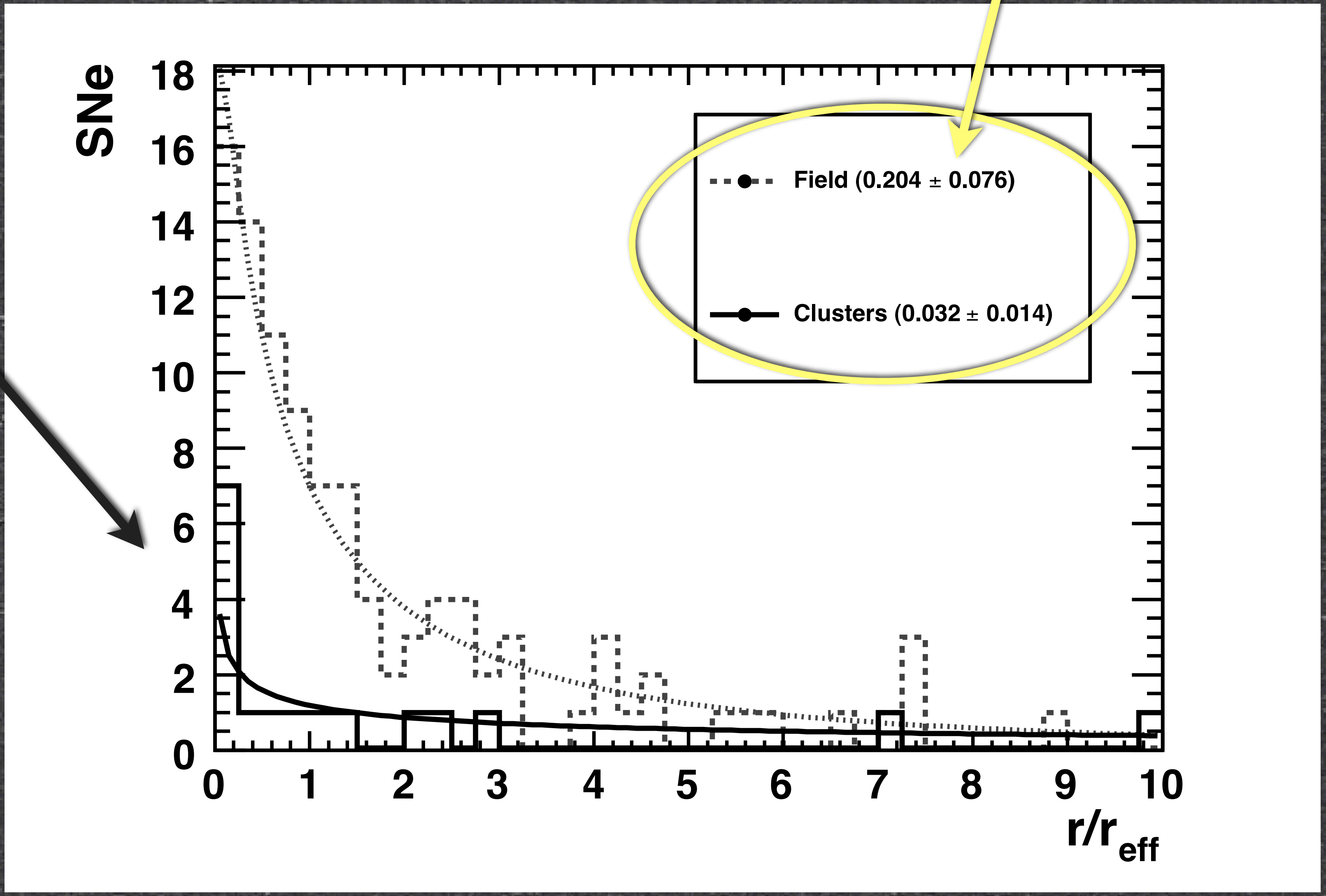
radial distribution of SNe

SNe in cluster ellipticals are concentrated in the center

residual star formation?

KS test
30% probability to be drawn from same distribution

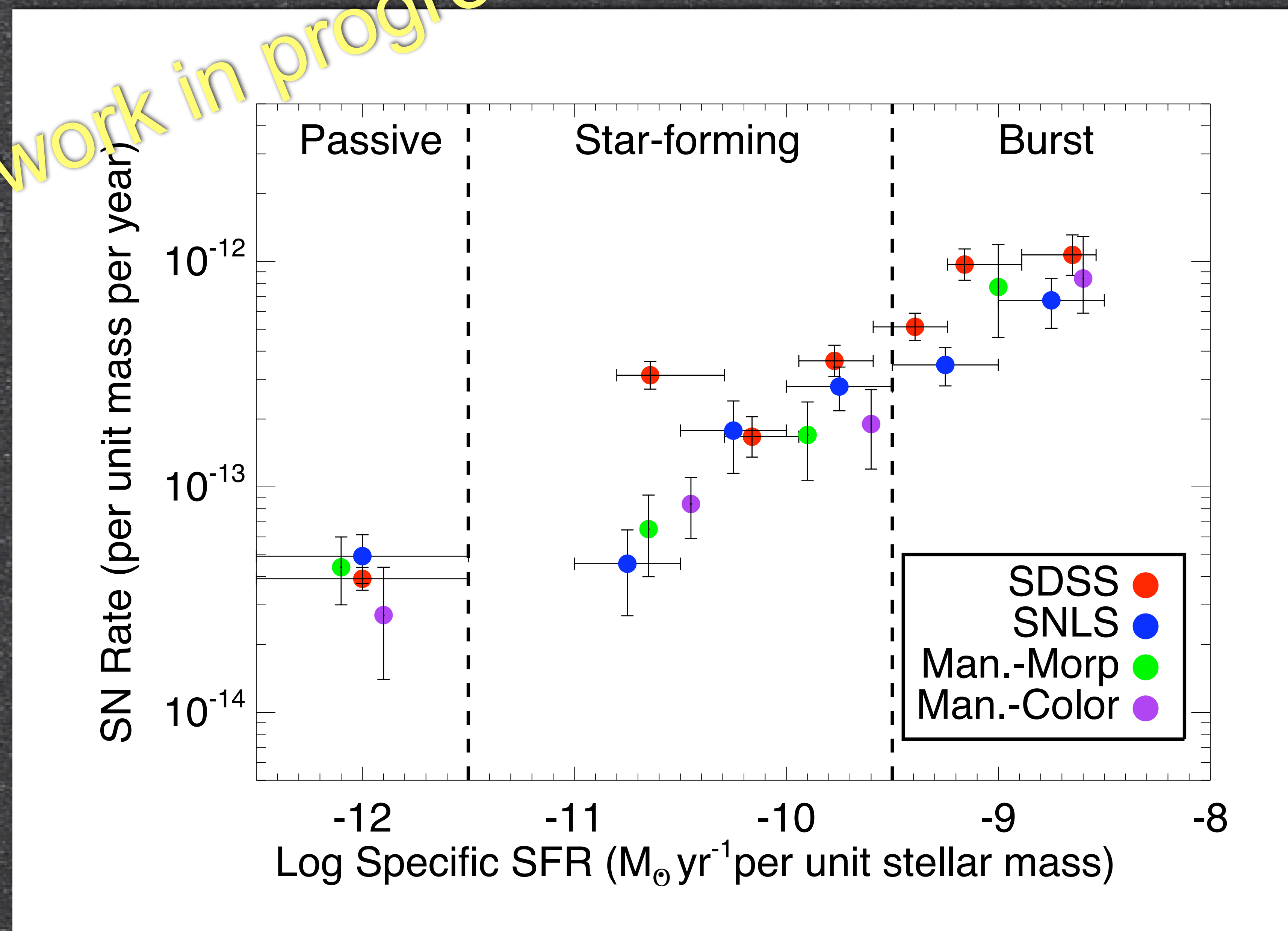
fit a Sersic profile
field ellipticals: consistent with deVaucouleurs
cluster ellipticals: not consistent with deVaucouleurs



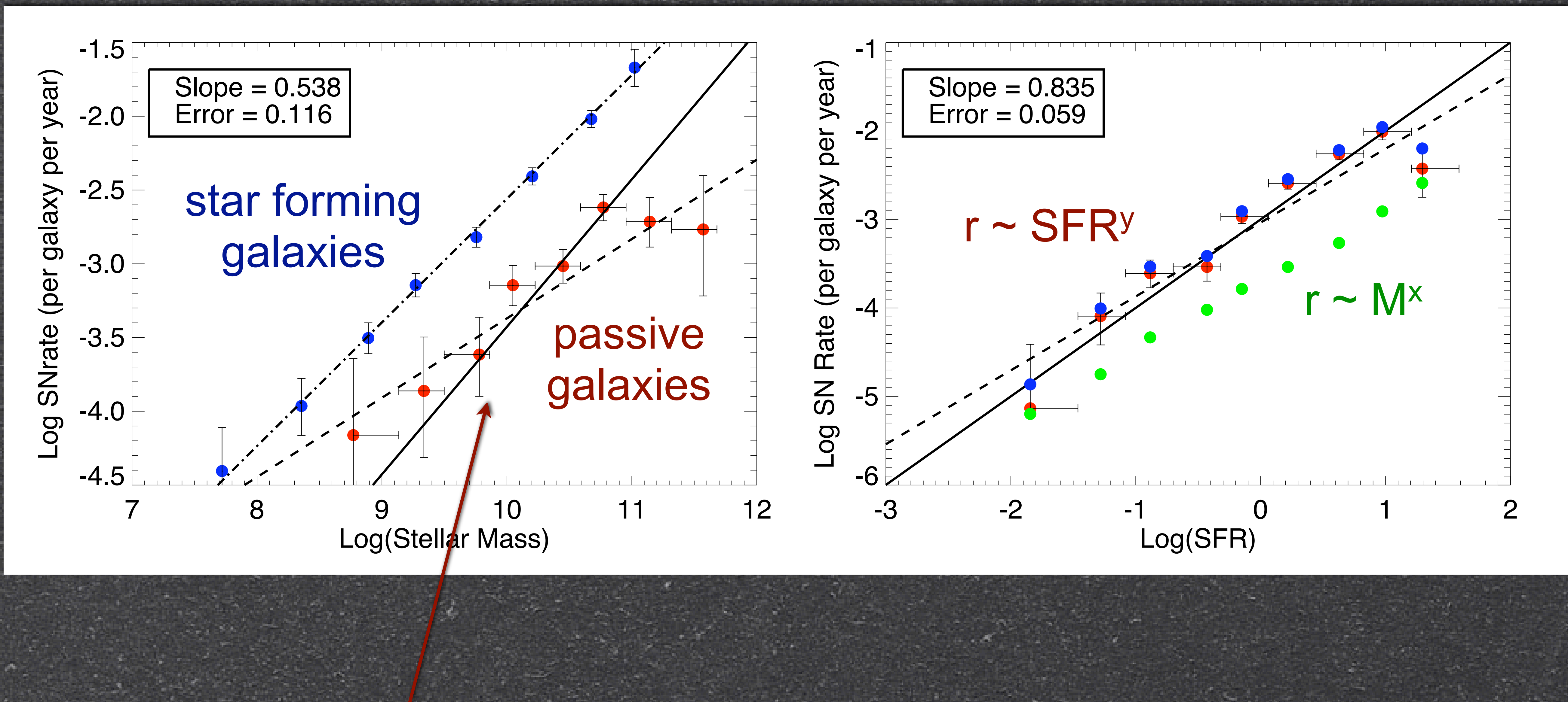
SN Ia rate vs host stellar mass/ star formation (Mat Smith)

derive mass/ SFR using PEGASE SED fits to 1.5 × 10^6 galaxies from coadded images

work in progress



rate vs mass　　　　rate vs SFR



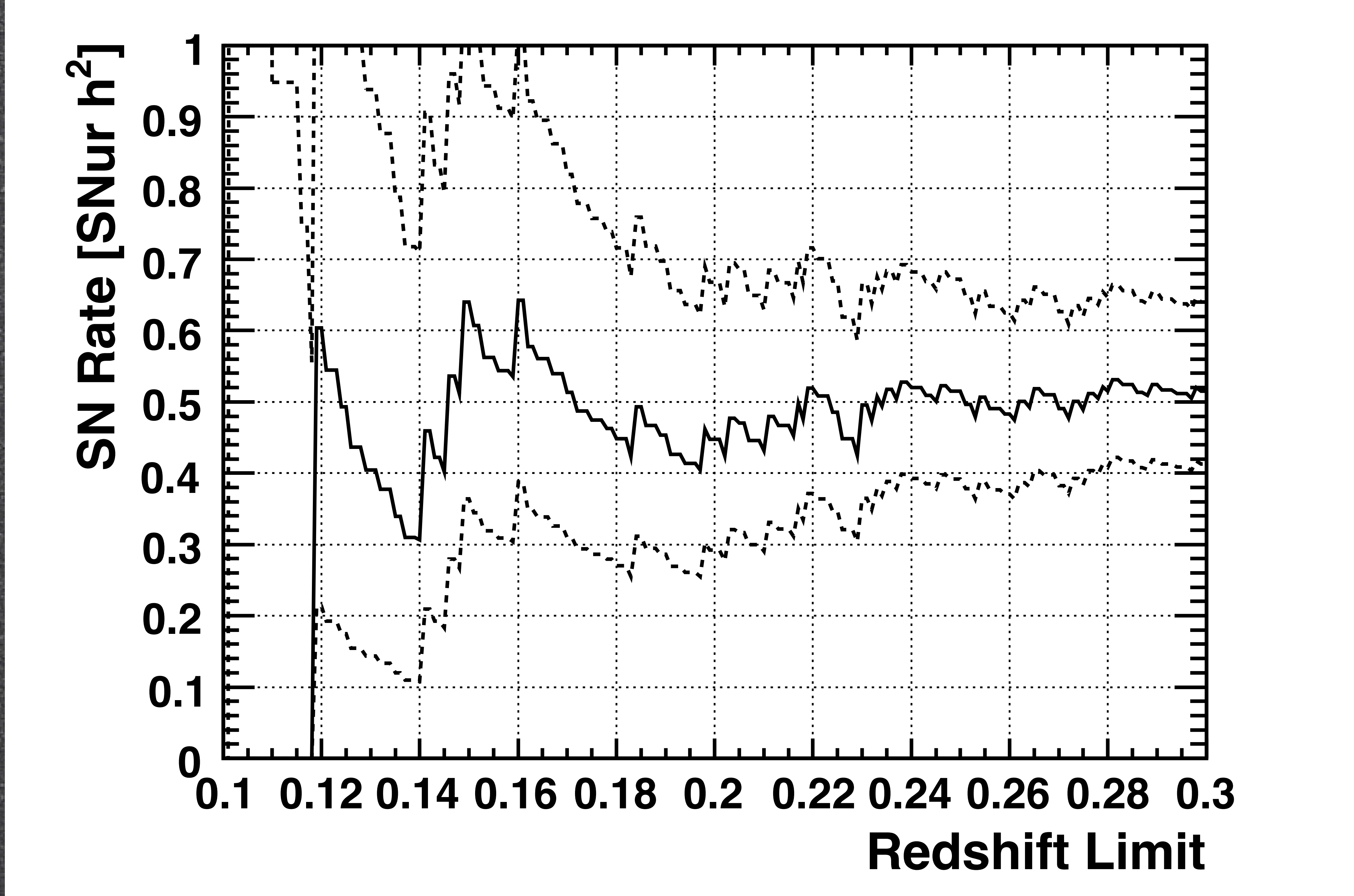
fit passive galaxies for
r ~ M^x component

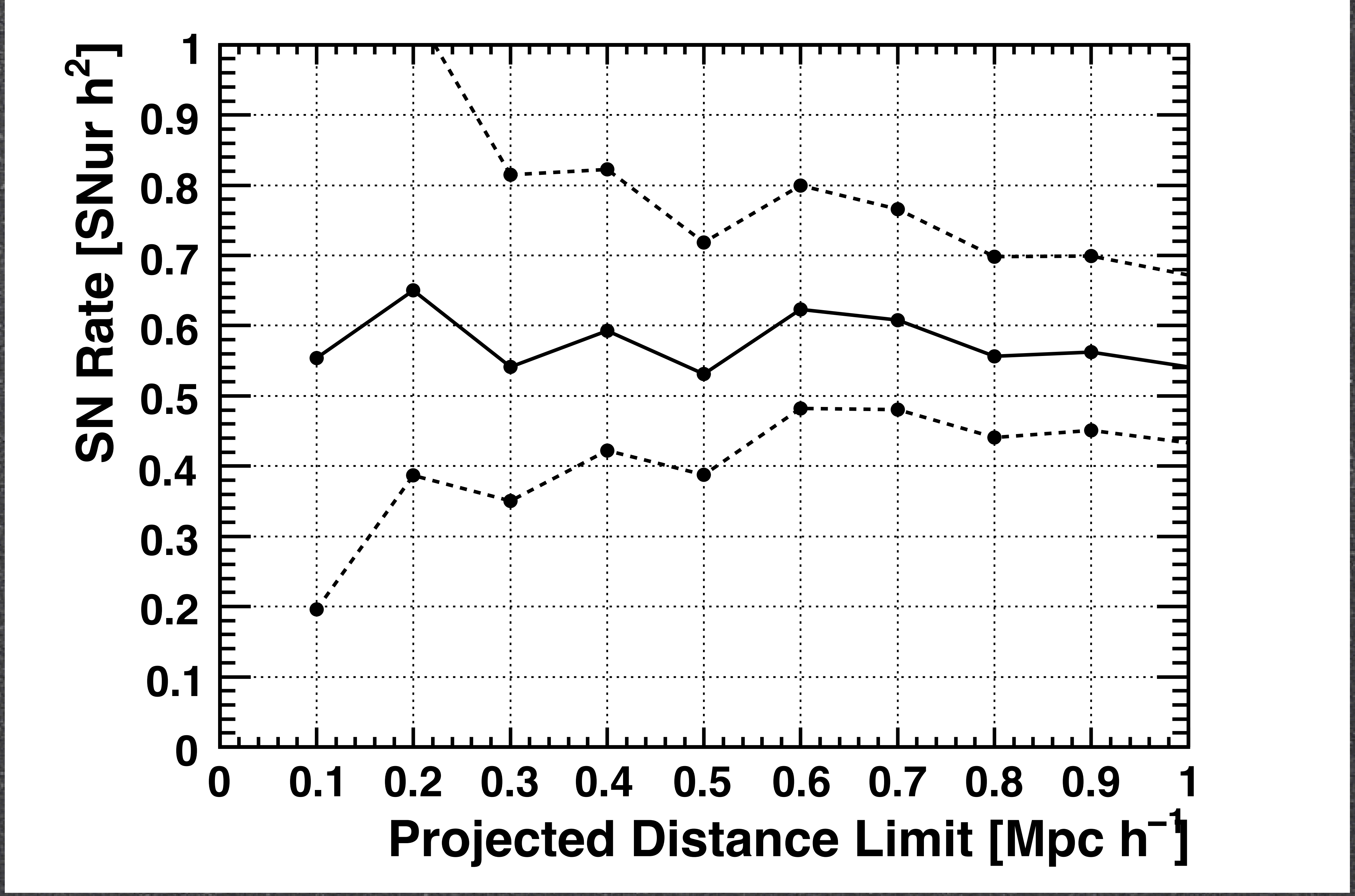
$$r = A \cdot M^{0.54} + B \cdot SFR^{0.84}$$

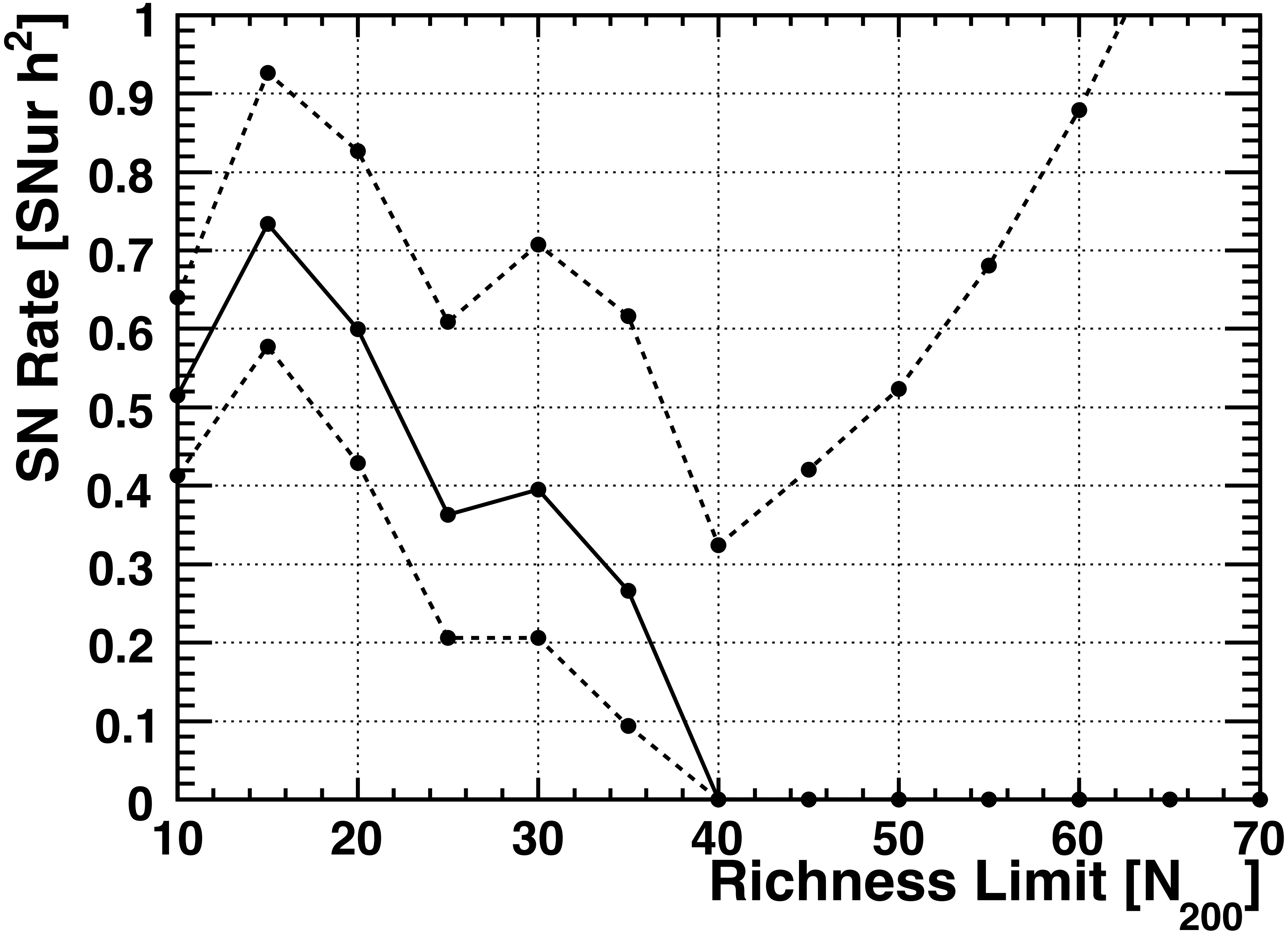
summary

- SN Ia rate at $z<0.3$ using ~500 SNe Ia
- cluster SN Ia rate with 27 total SNe
- cluster SNe Ia may occur preferentially in cores of cluster ellipticals
- SN Ia rate = $A \cdot M^{0.54} + B \cdot SFR^{0.84}$

Extra Slides


SN Rate [SNur h^2]
Redshift Limit
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.1
0.12
0.14
0.16
0.18
0.2
0.22
0.24
0.26
0.28
0.3


SN Rate [SNur h^2]
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
Projected Distance Limit [Mpc h^{-1}]



SN Rate [SNur h^2]
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10
20
30
40
50
60
70
Richness Limit [N_{200}]

rate in BCGs

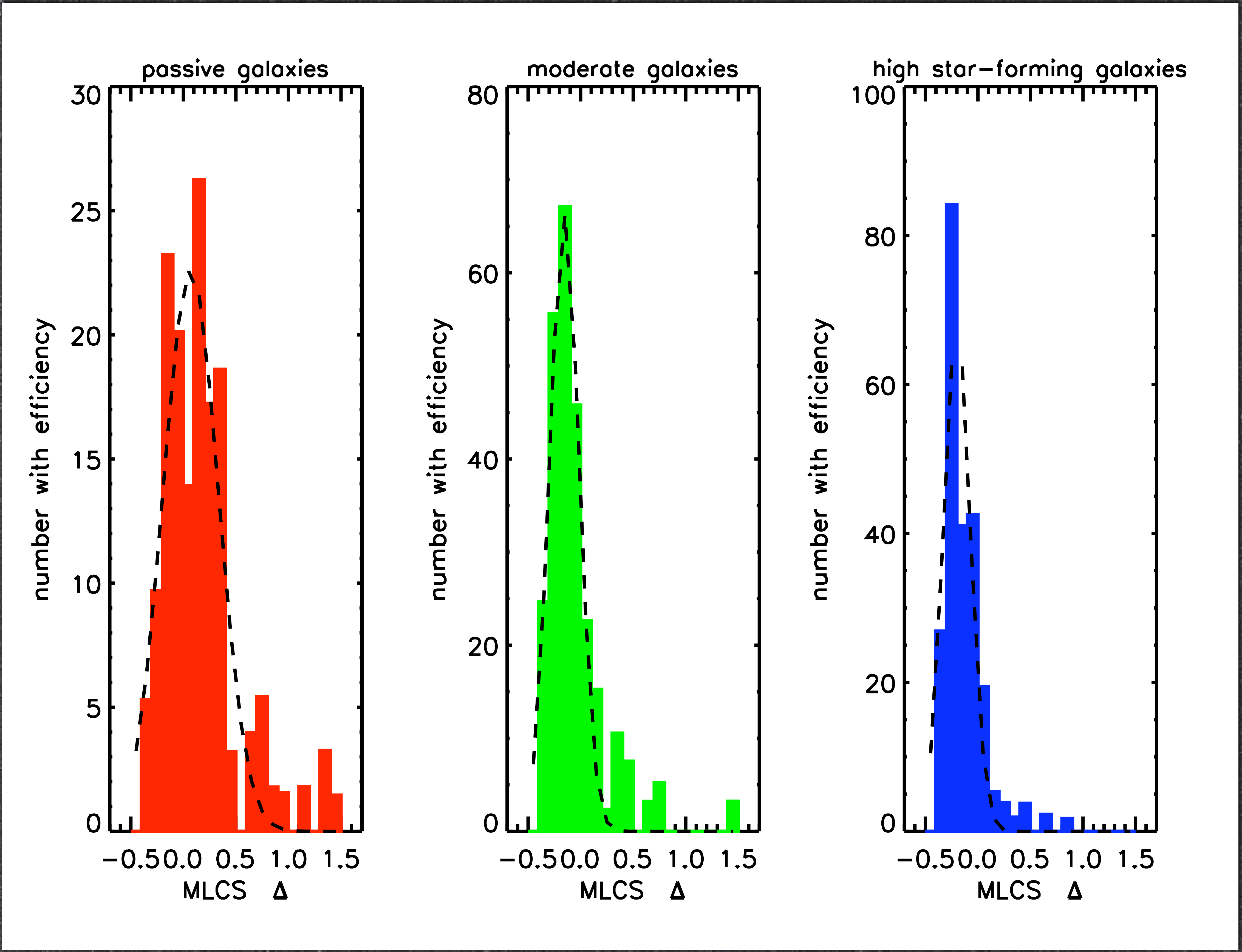
6% of cluster luminosity in brightest cluster galaxies

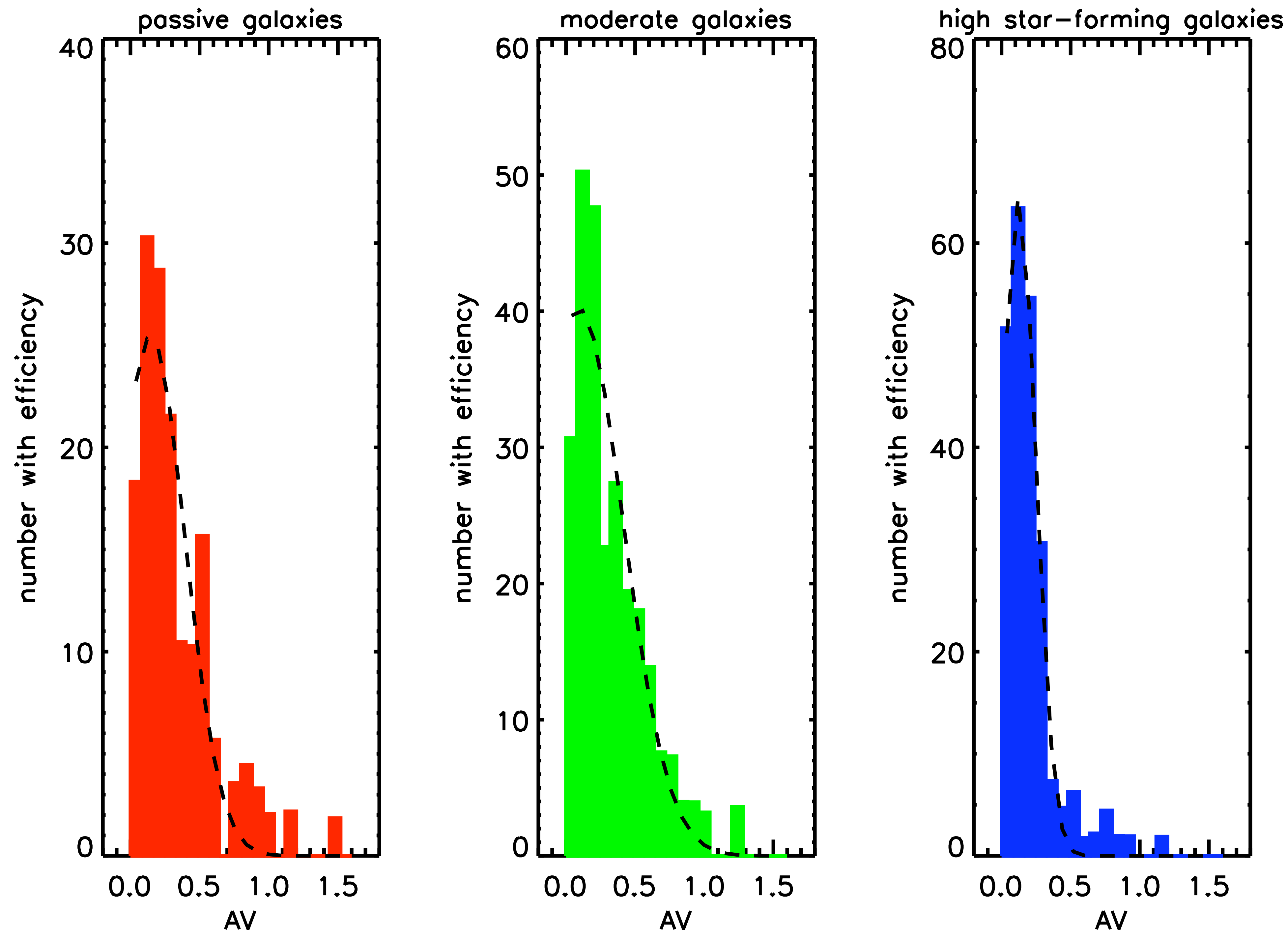
C4 clusters

$2.04^{+1.99}_{-1.11}$ SNu*r*

maxBCG clusters

$0.36^{+0.84}_{-0.30}$ SNu*r*


passive galaxies
moderate galaxies
high star−forming galaxies
number with efficiency
MLCS Δ
30
25
20
15
10
5
0
80
60
40
20
100
−0.5
0.0
0.5
1.0
1.5


passive galaxies
moderate galaxies
high star−forming galaxies
number with efficiency
AV
0.0 0.5 1.0 1.5
0 10 20 30 40
0 10 20 30 40 50 60
0 20 40 60 80