SNAP Photometric Redshifts and Simulations

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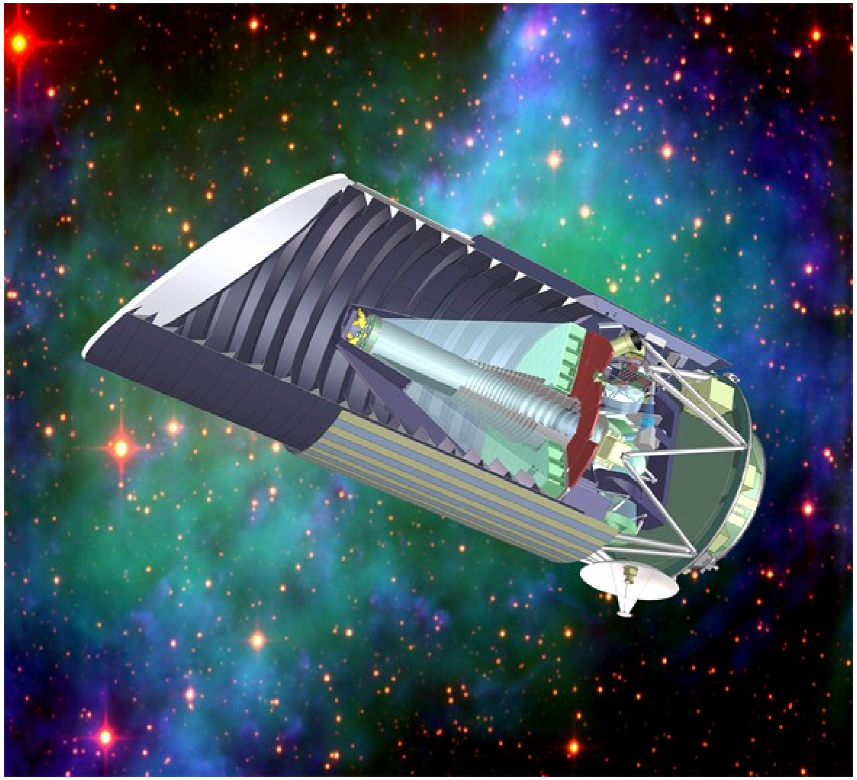
Investigating the SNAP Photo-z

Dahlen, Mobasher, Kneib, Jouvel, Ilbert, Arnouts



SNAP collaboration meeting – Berkeley Jan 19, 2007

Plan of the Talk

- Photometric Redshift technique- the SNAP code
- Accuracy of phot-z's compared to spec-z's
- Comparison between different phot-z techniques
- The simulated photometric catalog
- Phot-z simulations with SNAP filters
- Accuracy of the phot-z's
- Sensitivity to photometric errors
- Sensitivity to magnitude limits
- Advise for the choice of filters and wavelength coverage

The SNAP Phot-z Code

B. Mobasher & T. Dahlen

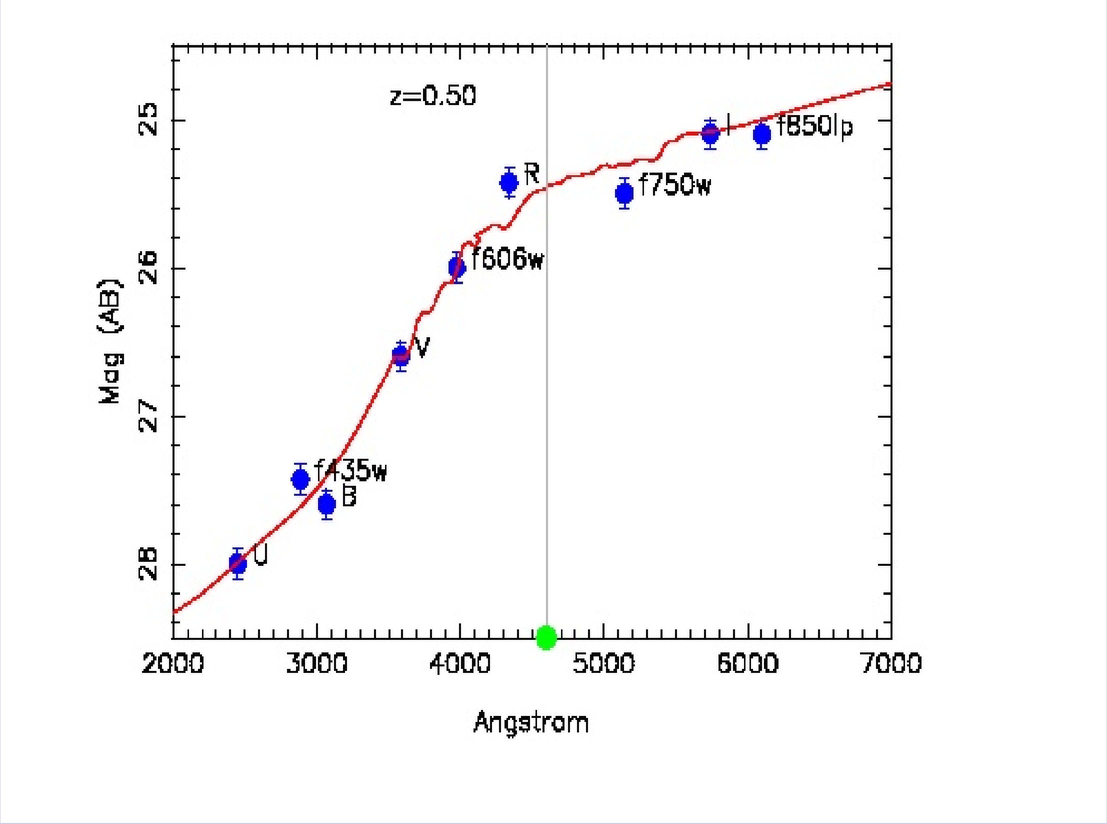
- six templates used
- Luminosity function used as prior
- Cosmic opacity from Madau et al.
- Extinction allowed as a free parameter, estimating E(B-V) for each galaxy
- Interpolates the spectral types
- Easily extended to other bands (ie IRAC, GALEX etc)

Input: Galaxy magnitudes, magnitude errors, templates, filter response functions

Output: z(phot), spectral types, redshift probability distribution, conventional and prior-based redshifts, extinction

Rest-frame absolute magnitudes

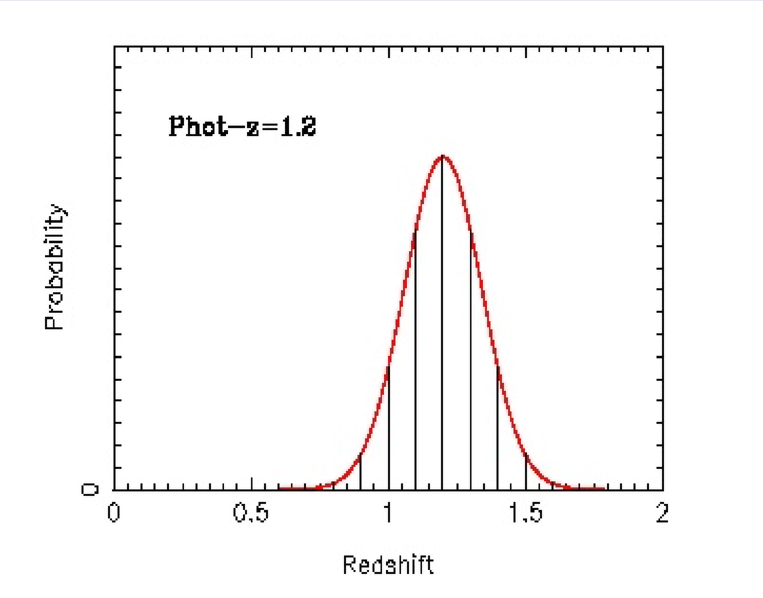
M(B)=m + K-correction -Distance modulus(z)



Luminosity functions are calculated using
* 1/Vmax method
* Maximum likelihood method

Traditionally (ideally):
each galaxy has one redshift
-> one absolute magnitude
-> one galaxy added to magnitude bin in LF

Using phot-z's:
Phot-z's have relatively large errors
Each galaxy is represented by a redshift distribution



1. Real Photometric Data with Spectroscopic Redshifts

Photometric Catalog

i-band selected photometric catalog

with available spectroscopic redshifts in CDF-S (680) and COSMOS (820)

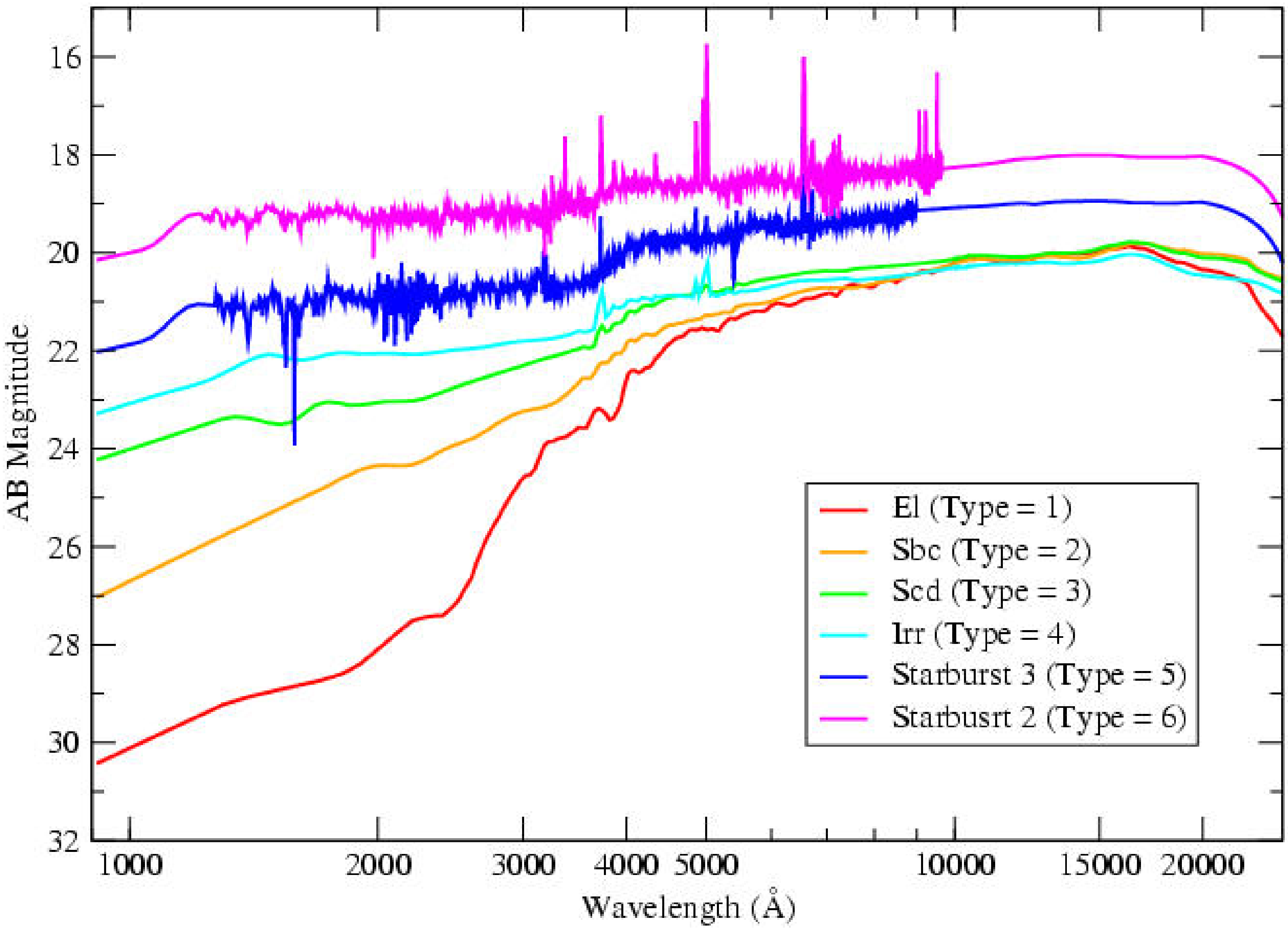
Photometry: U(CTIO), BVRI (WFI),

RI (FORS), JHK (SOFI, ISAAC),

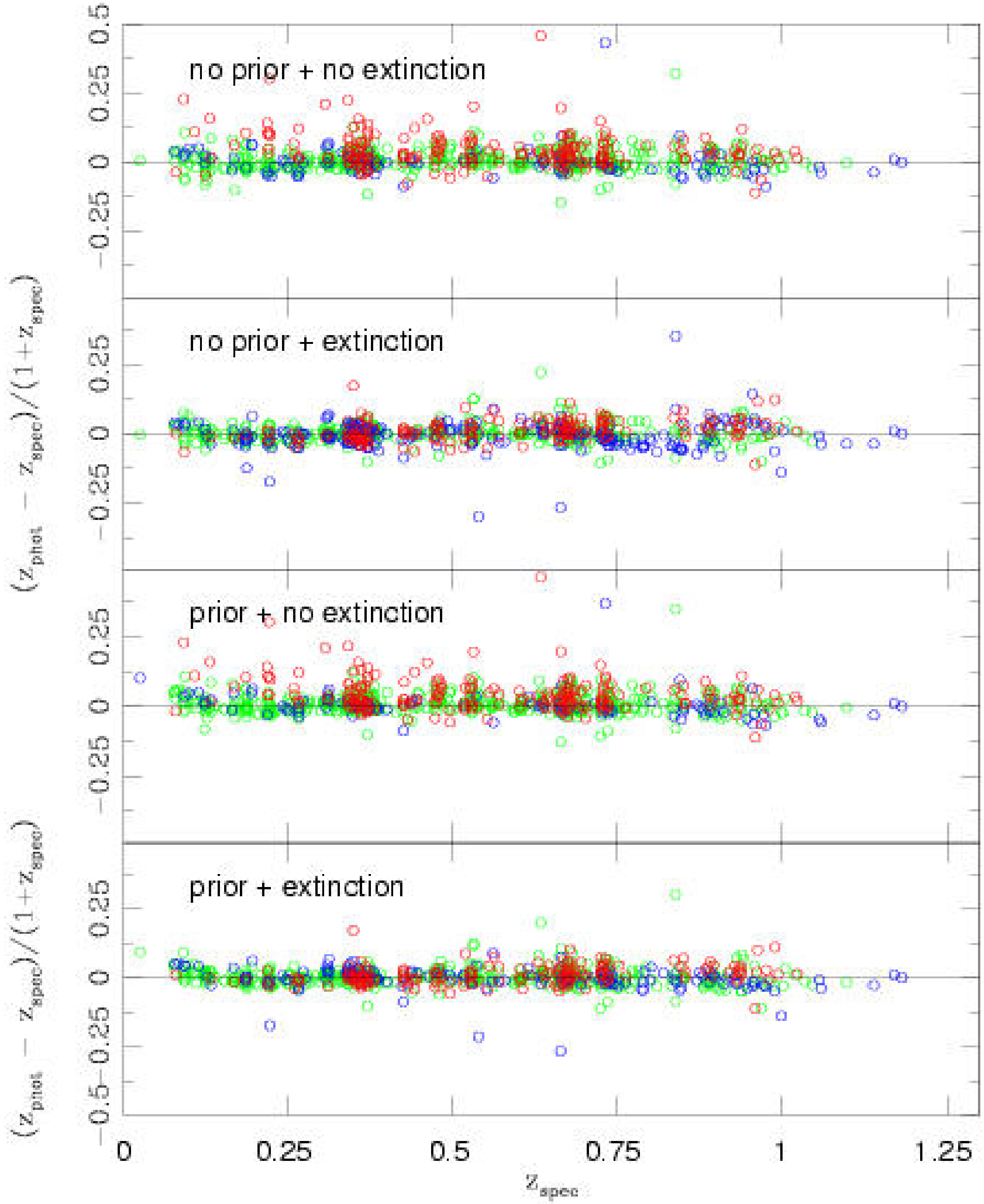
Bviz (ACS)

18 bands

Photometry accurate to ~ 0.04 mag



16
18
20
22
24
26
28
30
32
AB Magnitude
1000
2000
3000
4000
5000
10000
15000
20000
Wavelength (Å)
El (Type = 1)
Sbc (Type = 2)
Scd (Type = 3)
Irr (Type = 4)
Starburst 3 (Type = 5)
Starbusrt 2 (Type = 6)



no prior + no extinction
no prior + extinction
prior + no extinction
prior + extinction
$(z_{phot} - z_{spec})/(1+z_{spec})$
z_{spec}
0
0.25
0.5
0.75
1
1.25
−0.5
−0.25
0.25
0.5

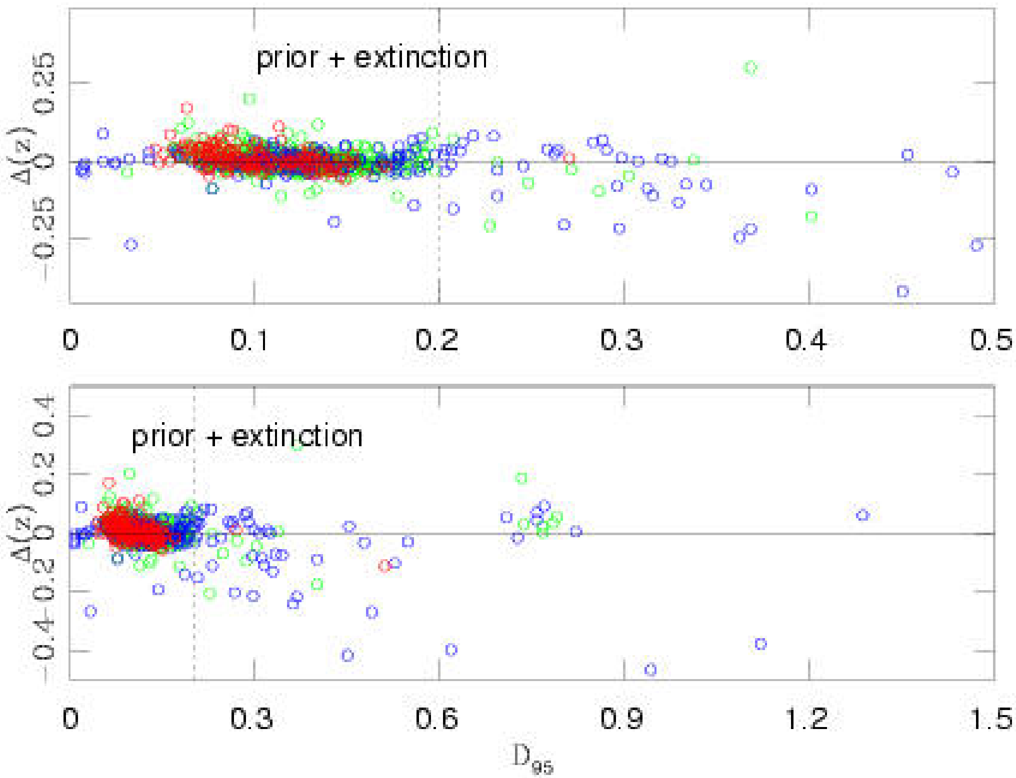
Phot-z Accuracy Parameters

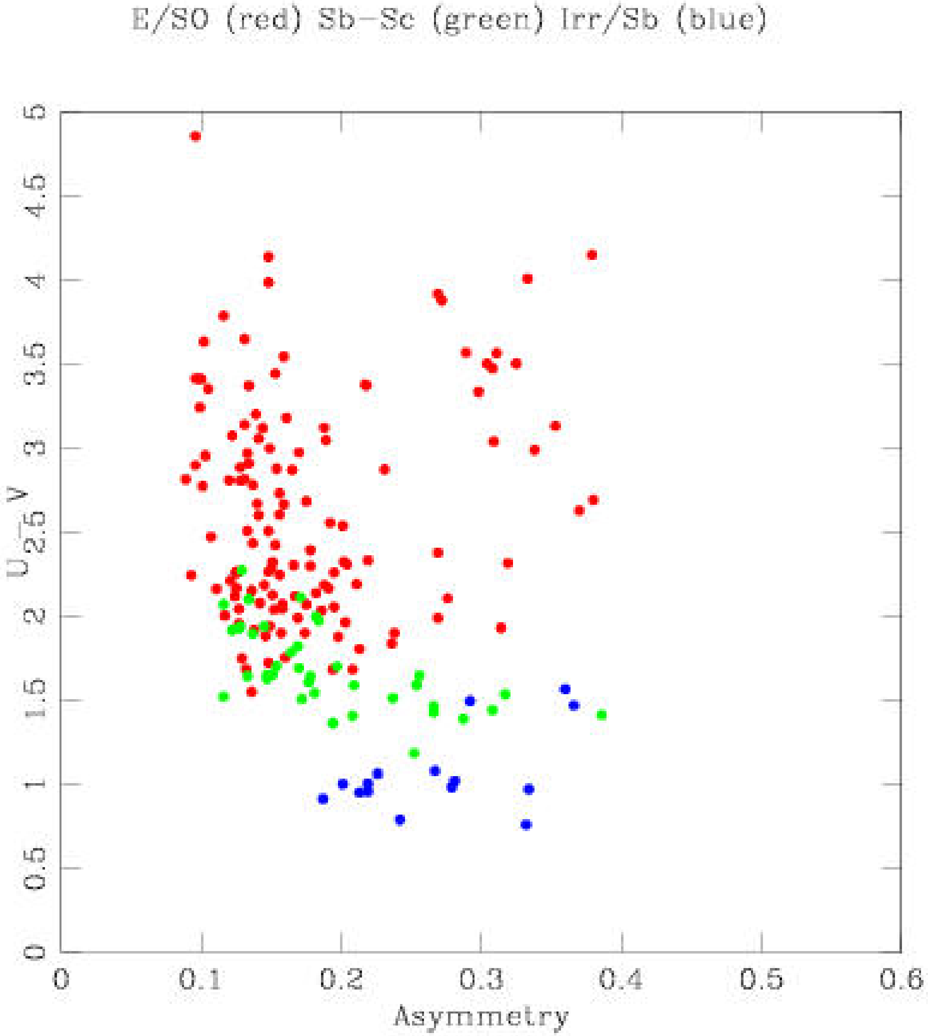
$$\delta z = (z_{phot} - z_{spec})/(1+z_{spec})$$

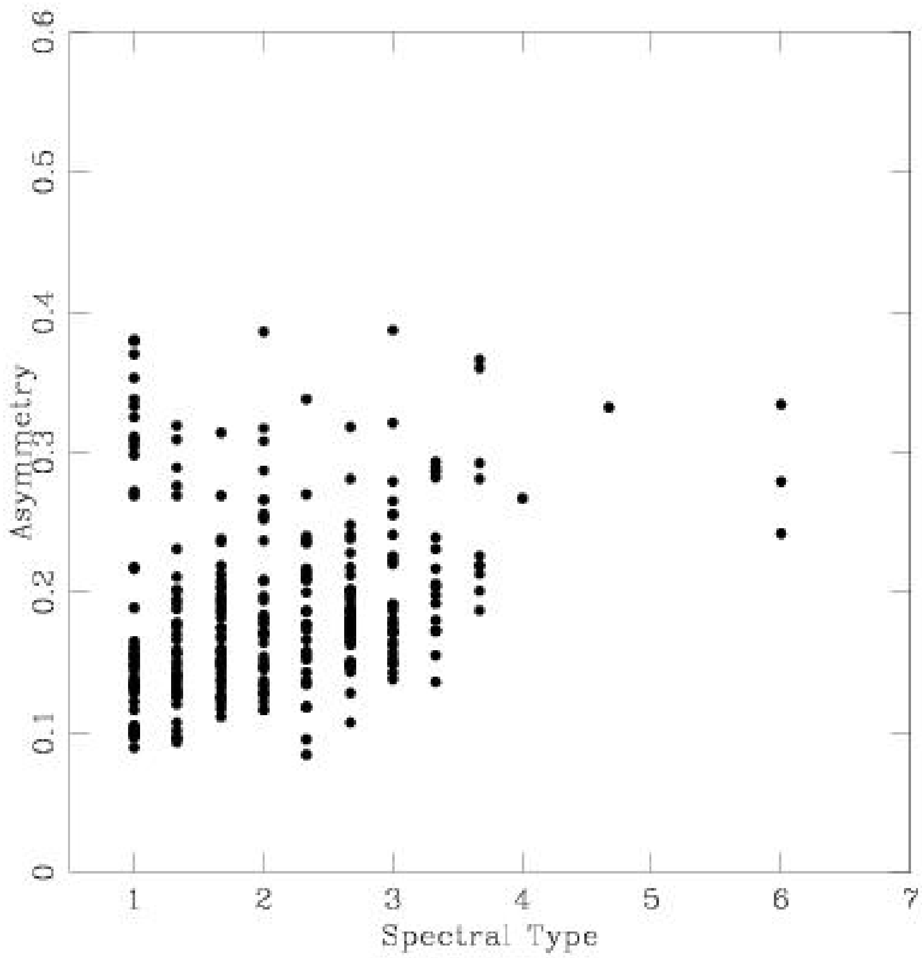
Outliers defined as objects with

$$\delta z > 0.3$$

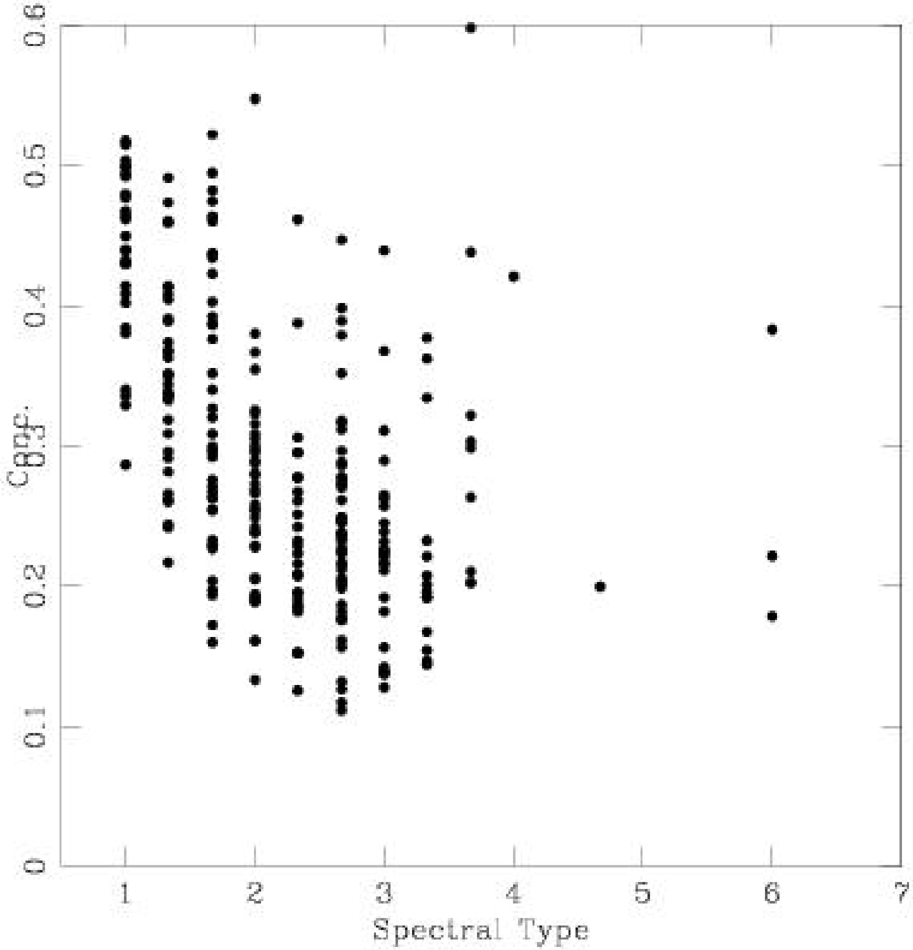
D_{95} = 95% conf. Int. width/$(1+z_{phot})$


prior + extinction
Δ(z)
0.25
0
−0.25
0
0.1
0.2
0.3
0.4
0.5
prior + extinction
Δ(z)
0.4
0.2
0
−0.2
−0.4
0
0.3
0.6
0.9
1.2
1.5
D95


E/SO (red) Sb−Sc (green) Irr/Sb (blue)
U−V
Asymmetry
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
0.1
0.2
0.3
0.4
0.5
0.6

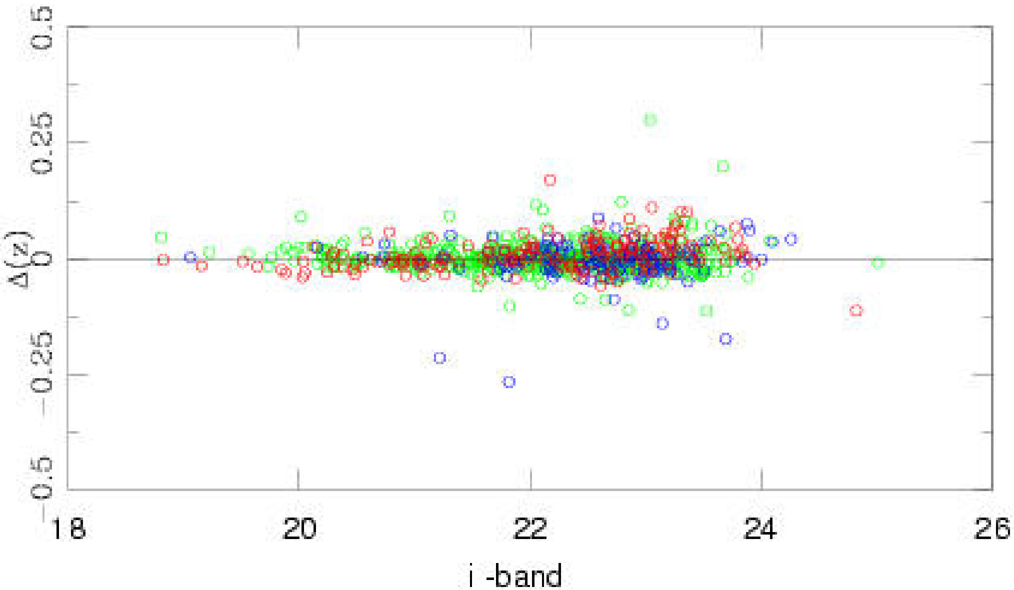


Asymmetry
Spectral Type
0
0.1
0.2
0.3
0.4
0.5
0.6
1
2
3
4
5
6
7



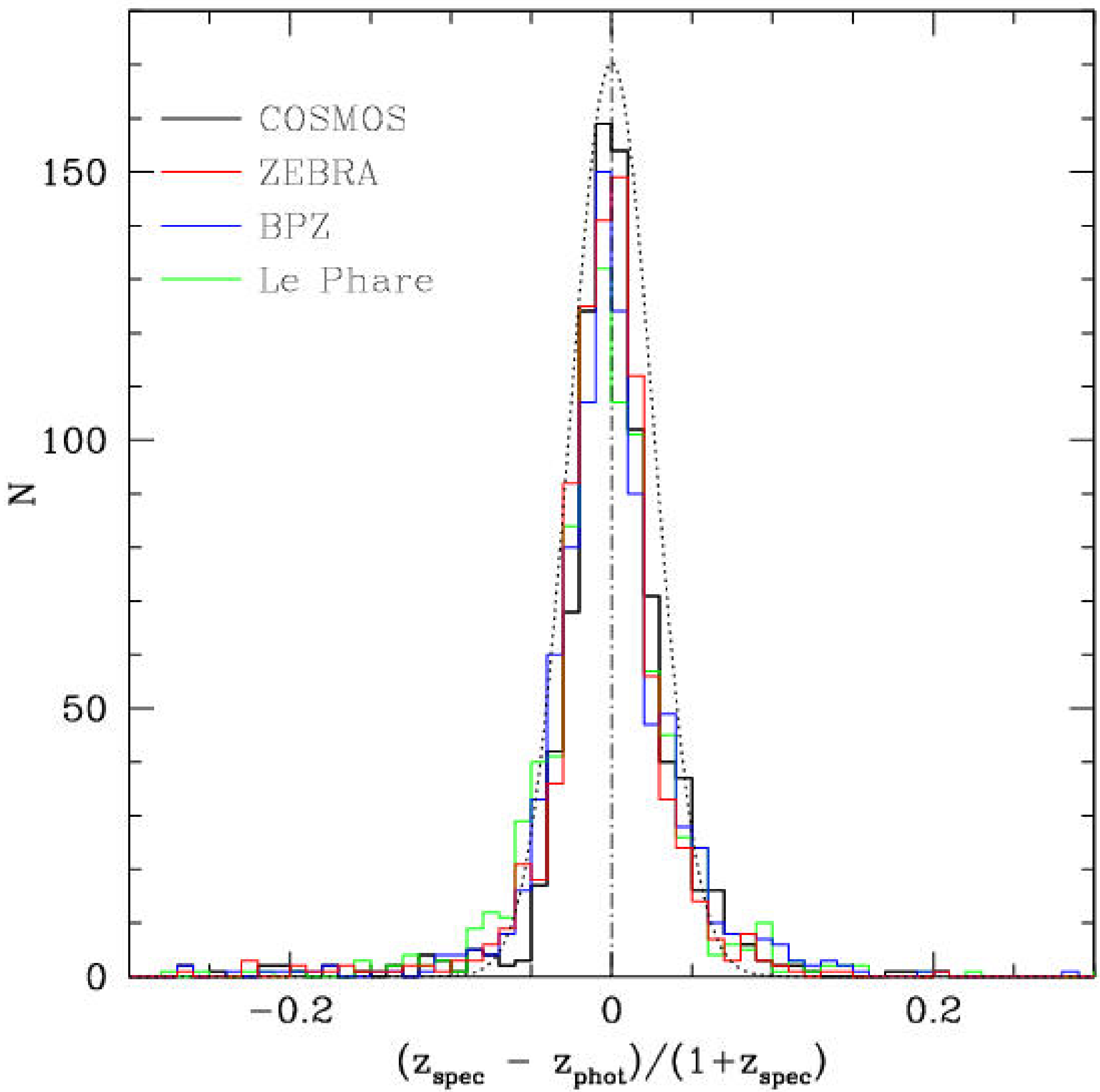
$C_{opc.}$
Spectral Type
0
0.1
0.2
0.3
0.4
0.5
0.6
1
2
3
4
5
6
7

Dependence of phot-*z*'s on magnitude limits



0.5
0.25
0
−0.25
−0.5
Δ(z)
18
20
22
24
26
i -band

Comparison between different phot-z techniques



COSMOS
ZEBRA
BPZ
Le Phare
N
0
50
100
150
−0.2
0
0.2
$(z_{spec} - z_{phot})/(1+z_{spec})$

Results

- The SNAP phot-z code fits redshift, spectral type and extinction for individual galaxies, all at the same time
- We estimate phot-z's to an accuracy of $\delta(z)=(z_{phot} - z_{spec})/(1+z_{phot})$ = 0.03 using broad-band *UBVrizK* band data
- We introduce a new parameter, D_{95}, to measure uncertainties in the phot-z's
- Using Intermediate Band data, we have been able to increase the accuracy in our phot-z measurement to 0.01

2. Simulated Photometric Data

Simulated Photometric Catalog

Use luminosity function to generate absolute mag (M_B) distribution

Assign random redshifts to each M_B, taking into account the volume effect

Estimate k-corr for each galaxy using SNAP filter functions and 6 templates (E,Sa,Sc,Irr,SB)

Measure magnitudes in different bands, using k-corr

More Details…

- Use rest-frame B-band luminosity function (Dahlen & Mobasher 2005) to $z \sim 2$ to generate M_B distribution
- A spectral type is assigned to each galaxy according to type specific LF
- Nine SNAP filters are considered
- Redshift range $0 < z < 6$
- Absolute magnitude range $-24 < M_B < -15$
- K-corrections are estimated by convolving filter response functions with redshifted SEDs
- An area of 1000 arcmin^2 is considered for the mock catalog

Simulated photometric catalog

type-dependent LF → M_B, Spectral type

z, SED, filter → color, k-corr

M_B, z, K-corr → m_B

m_B, color → m_i

m_i (i=1,9), z, Sp. Type, phot error

Simulation…

Calculate apparent magnitudes in different bands from (M,z,k-corr)

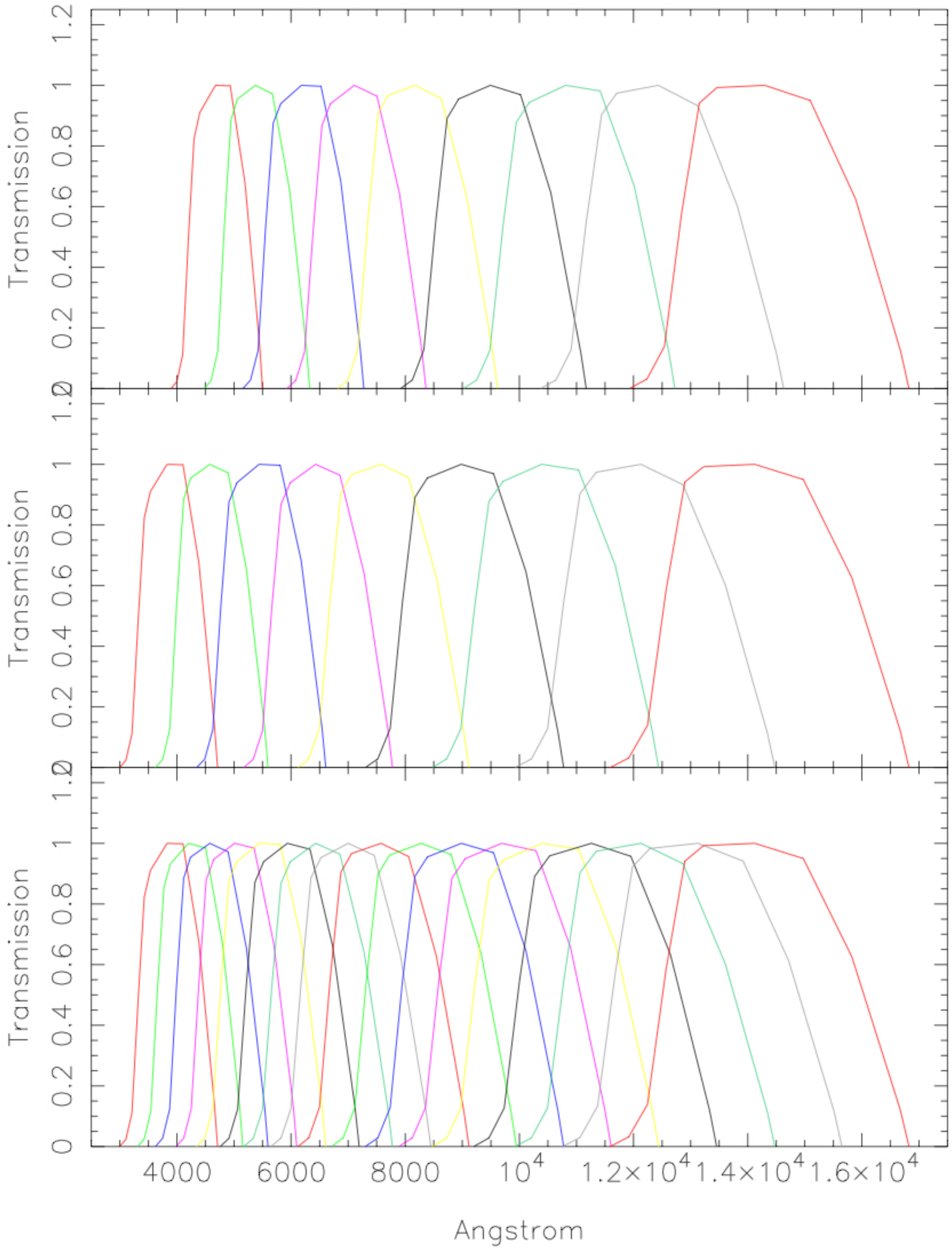
Assign random errors to apparent magnitudes

Produce the simulated catalog, containing [m1…m9,z,type]

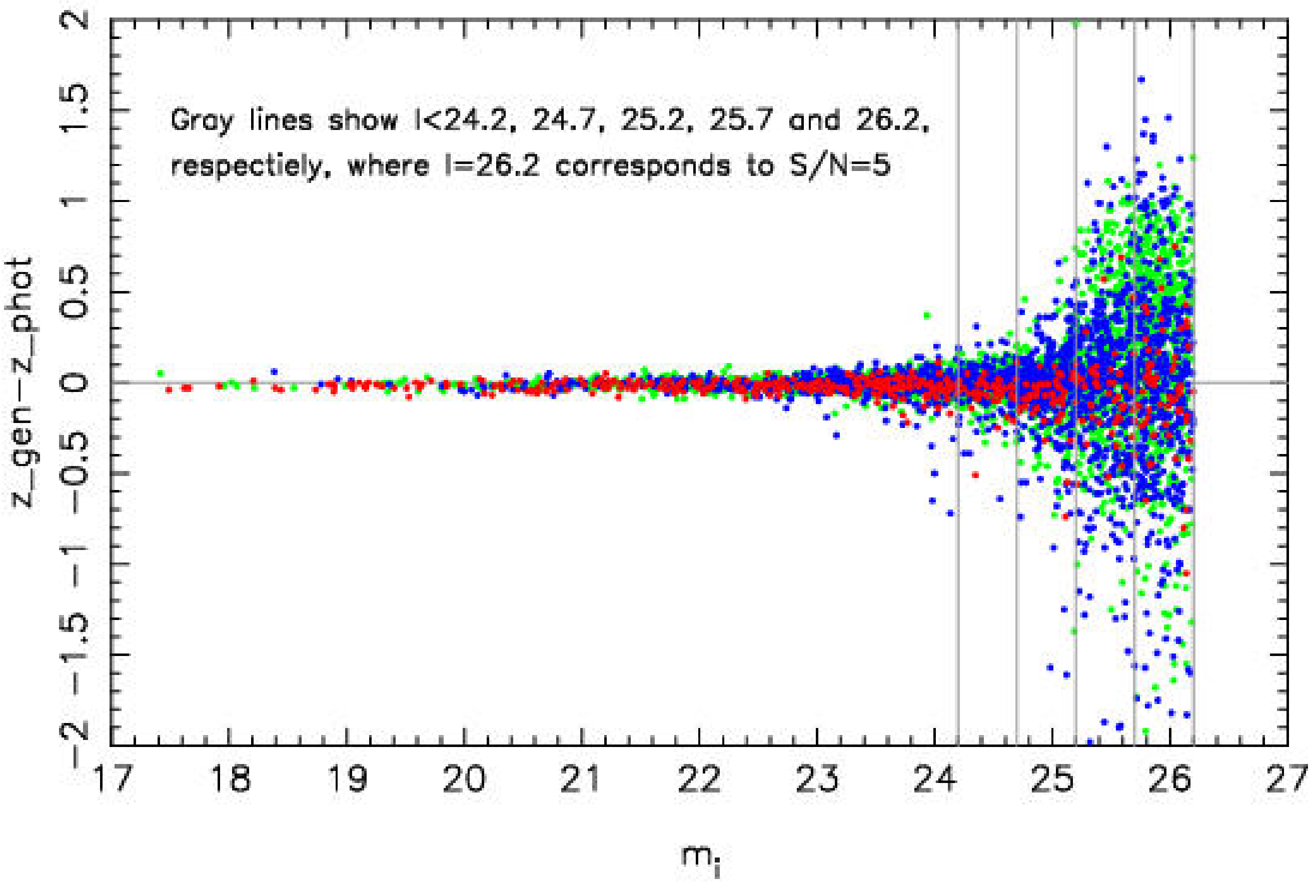
Include random extinction to magnitudes and colors

Run phot-z code on the mock catalog

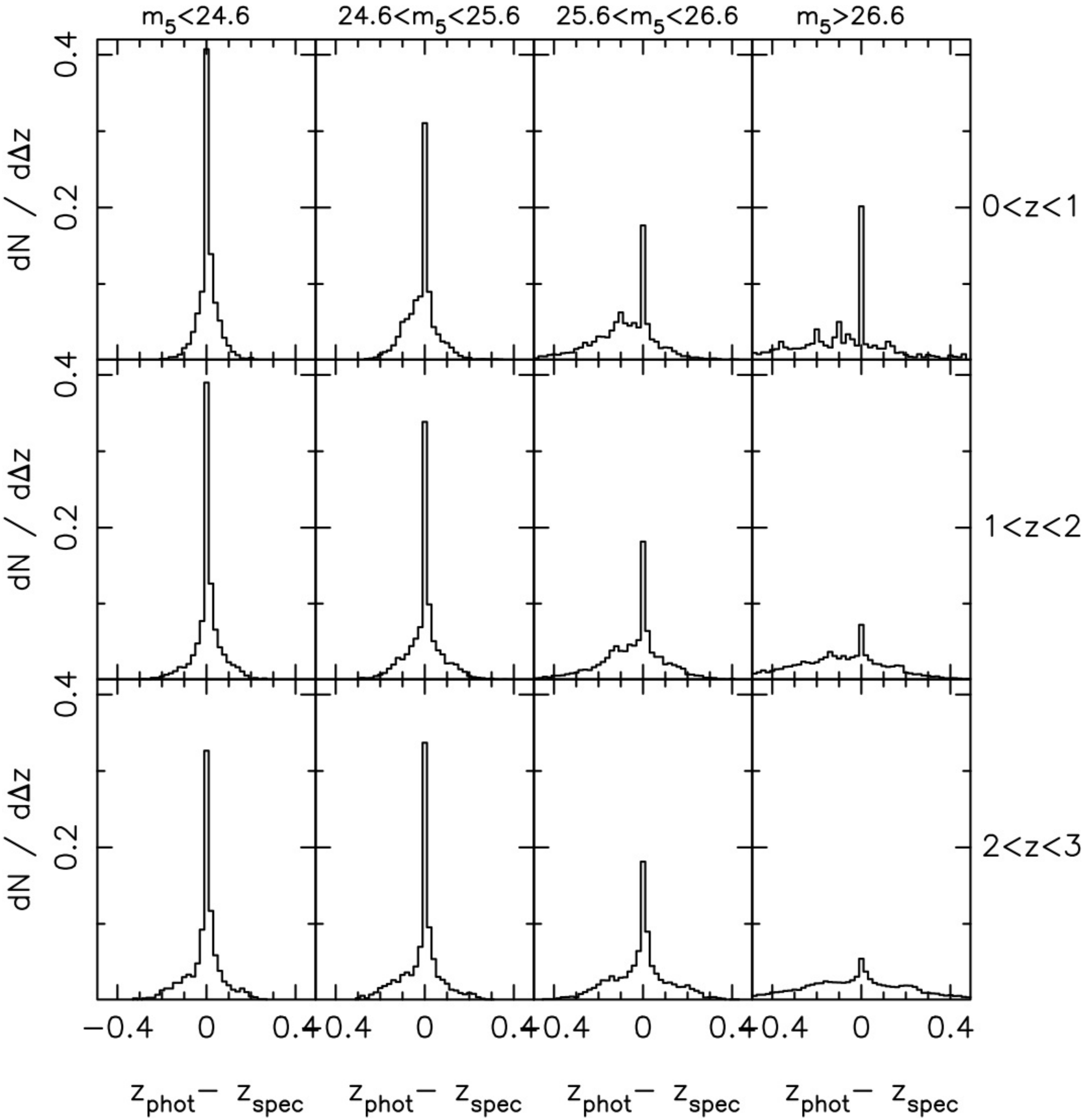
Compare the input vs output redshifts



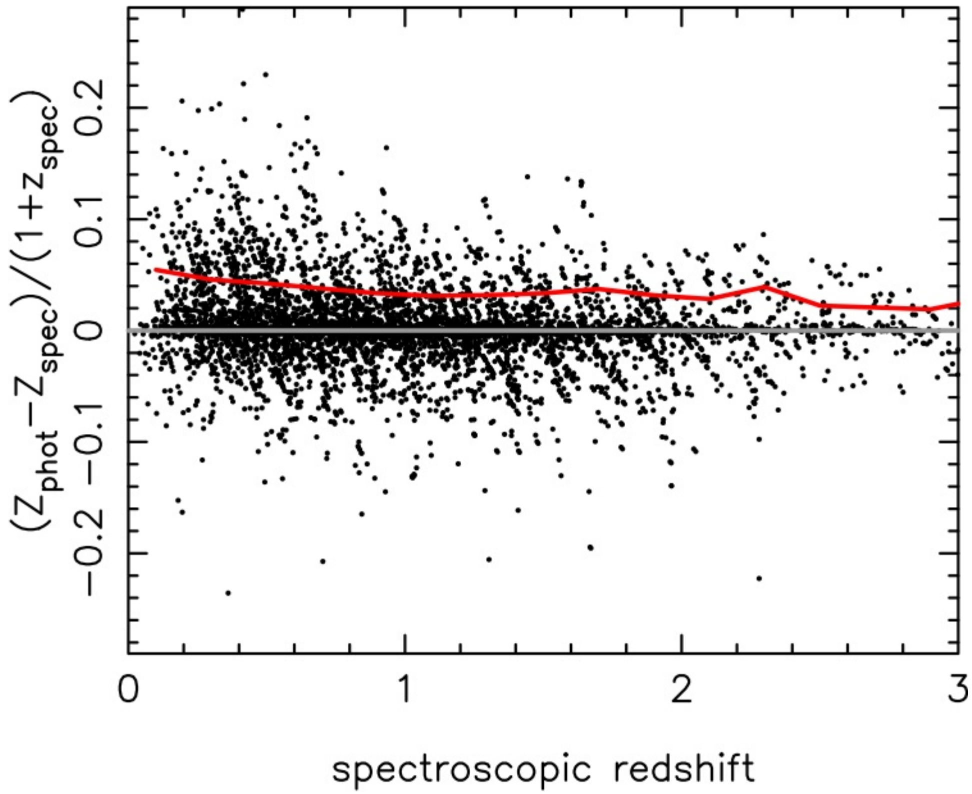
Transmission
Transmission
Transmission
1.2
1
0.8
0.6
0.4
0.2
0
4000
6000
8000
10^4
1.2×10^4
1.4×10^4
1.6×10^4
Angstrom



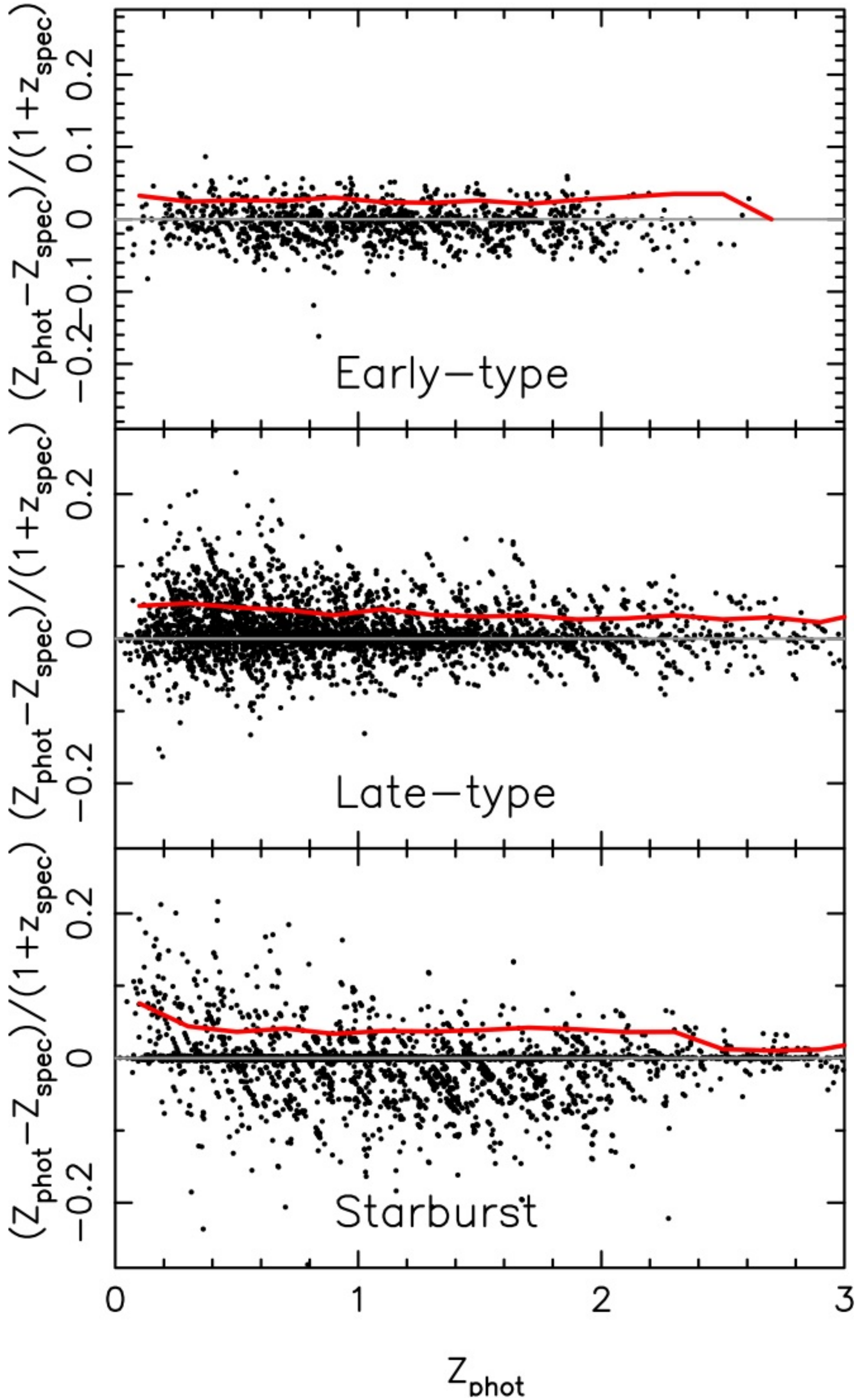
Gray lines show I<24.2, 24.7, 25.2, 25.7 and 26.2,
respectiely, where I=26.2 corresponds to S/N=5
z_gen−z_phot
m_i



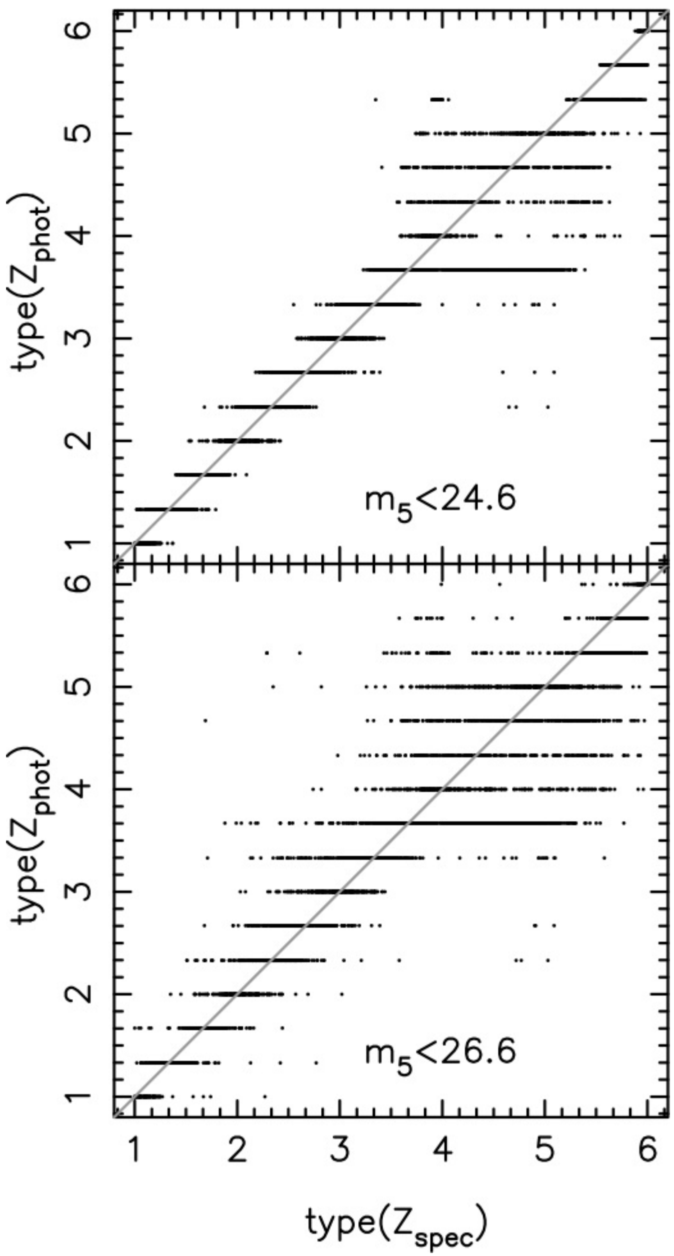
m5<24.6
24.6<m5<25.6
25.6<m5<26.6
m5>26.6
0<z<1
1<z<2
2<z<3
dN / dΔz
0.4
0.2
−0.4
0
0.4
zphot− zspec



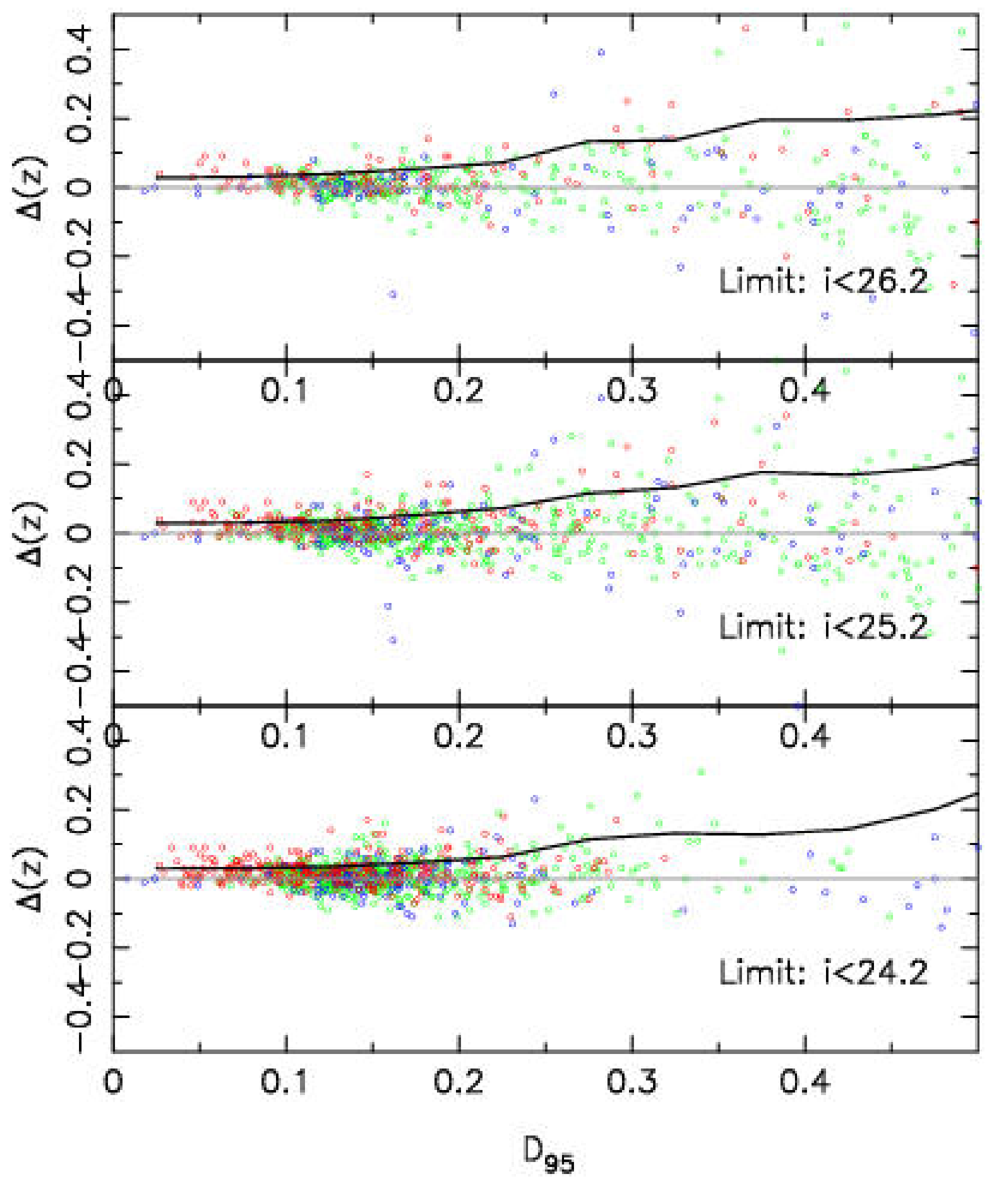
$(z_{phot} - z_{spec})/(1+z_{spec})$
0.2
0.1
0
−0.1
−0.2
0
1
2
3
spectroscopic redshift



$(z_{phot}-z_{spec})/(1+z_{spec})$
0.2
0.1
0
−0.1
−0.2
Early−type
0.2
0
−0.2
Late−type
0.2
0
−0.2
Starburst
0
1
2
3
z_{phot}



type(Z_{phot})
m$_5$<24.6
m$_5$<26.6
type(Z_{spec})
1
2
3
4
5
6



0.4
0.2
0
−0.2
−0.4
Δ(z)
Limit: i<26.2
Limit: i<25.2
Limit: i<24.2
0
0.1
0.2
0.3
0.4
D95

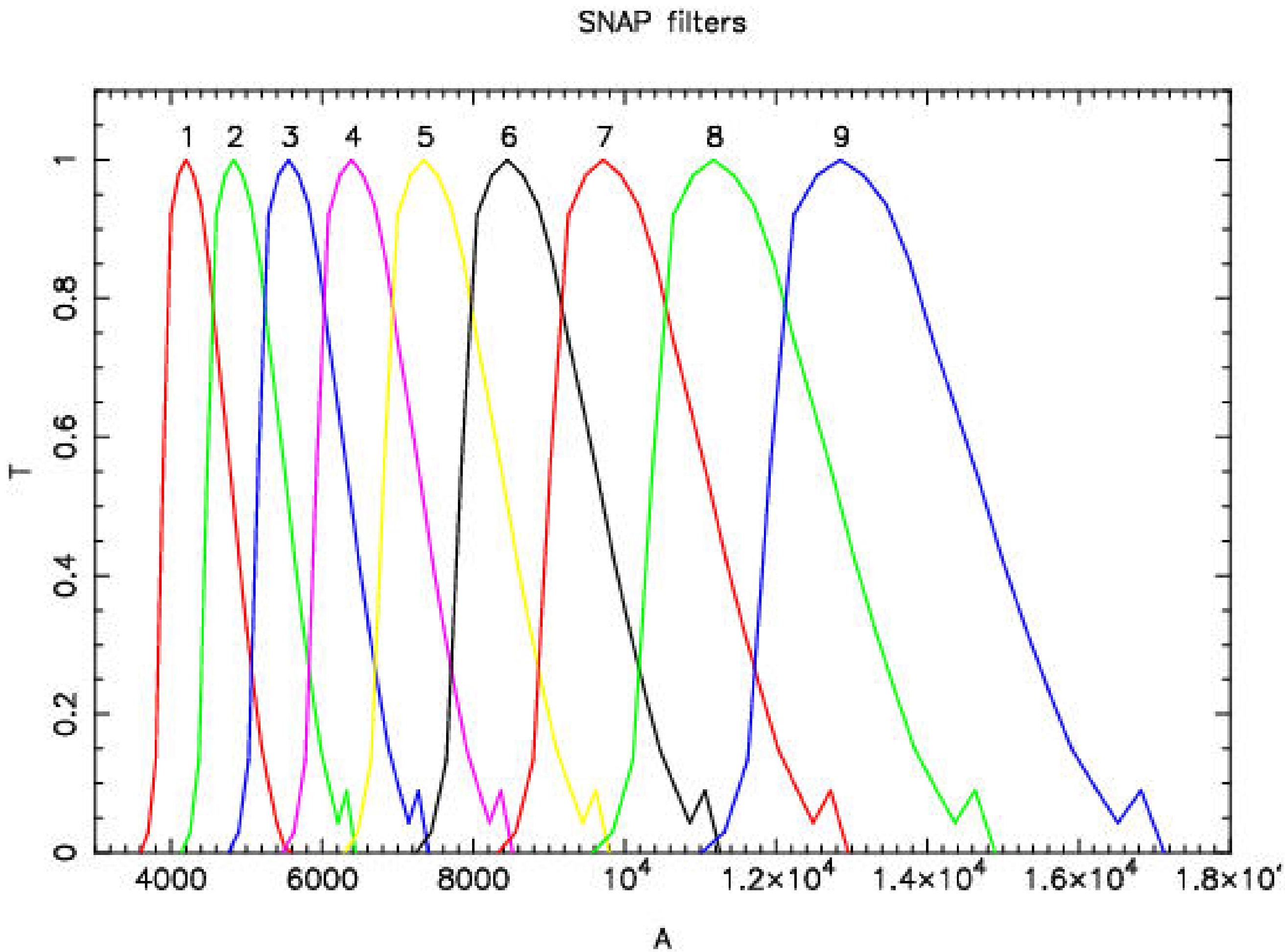
	Dz	OL %	Dz w/o OL
m_{lim}	0.179	2.16	0.057
m_{lim}-0.5	0.158	1.03	0.045
m_{lim}-1.5	0.087	0.21	0.030
m_{lim}-2.5	0.045	0.07	0.023
Early	0.055	0.10	0.054
Late	0.072	0.55	0.051
Starburst	0.293	5.52	0.068

Conclusions

- Better phot-z’s and reduced outlier fraction with brighter magnitudes
- Brighter magnitude cuts significantly reduces the number of objects
- Better phot-z’s for earlier types

Sensitivity to the choice of filters

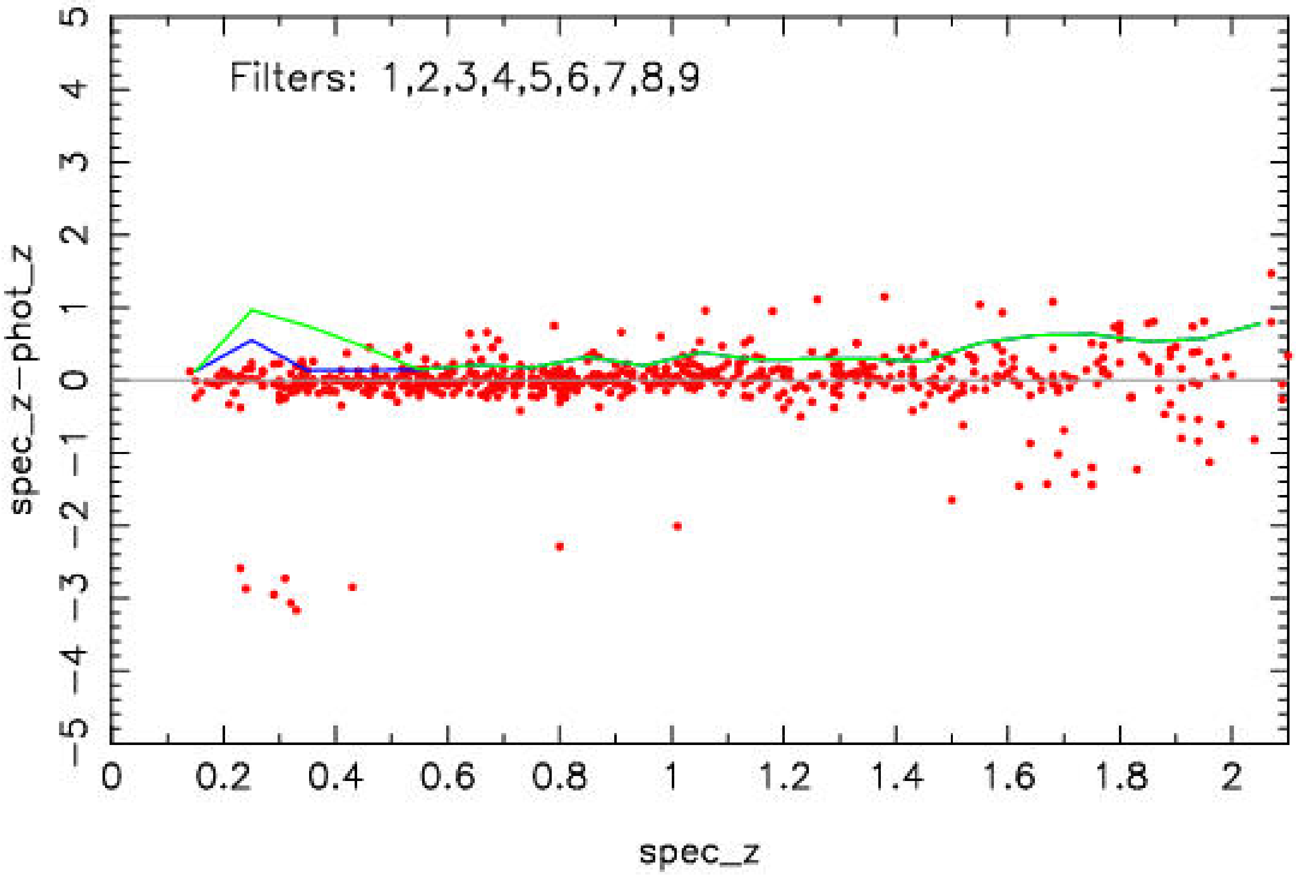
- Use 10 different filter sets
- Wavelength range 3600-17000 A
- Number of filters included varies between 6 to 13
- Filters have square shapes
- Each filter is redshifted version of the first filter
- Observing time available for each filter is assumed to be inversly proportional to the number of filters in each set



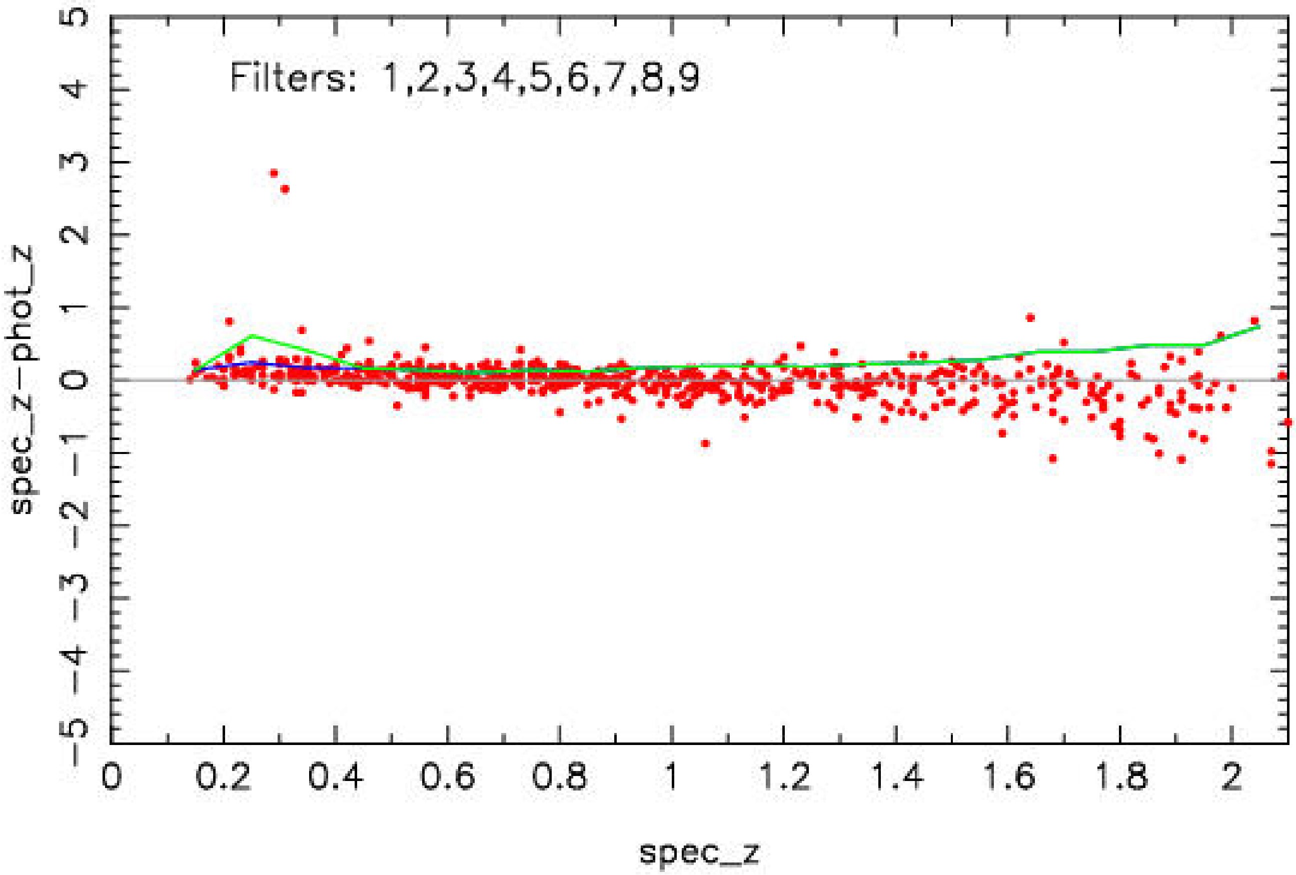
SNAP filters
1
2
3
4
5
6
7
8
9
T
0
0.2
0.4
0.6
0.8
1
4000
6000
8000
10^4
1.2×10^4
1.4×10^4
1.6×10^4
1.8×10^4
A

1. Filter combination 2. dz 3.dz w/o OL 4. % of outliers

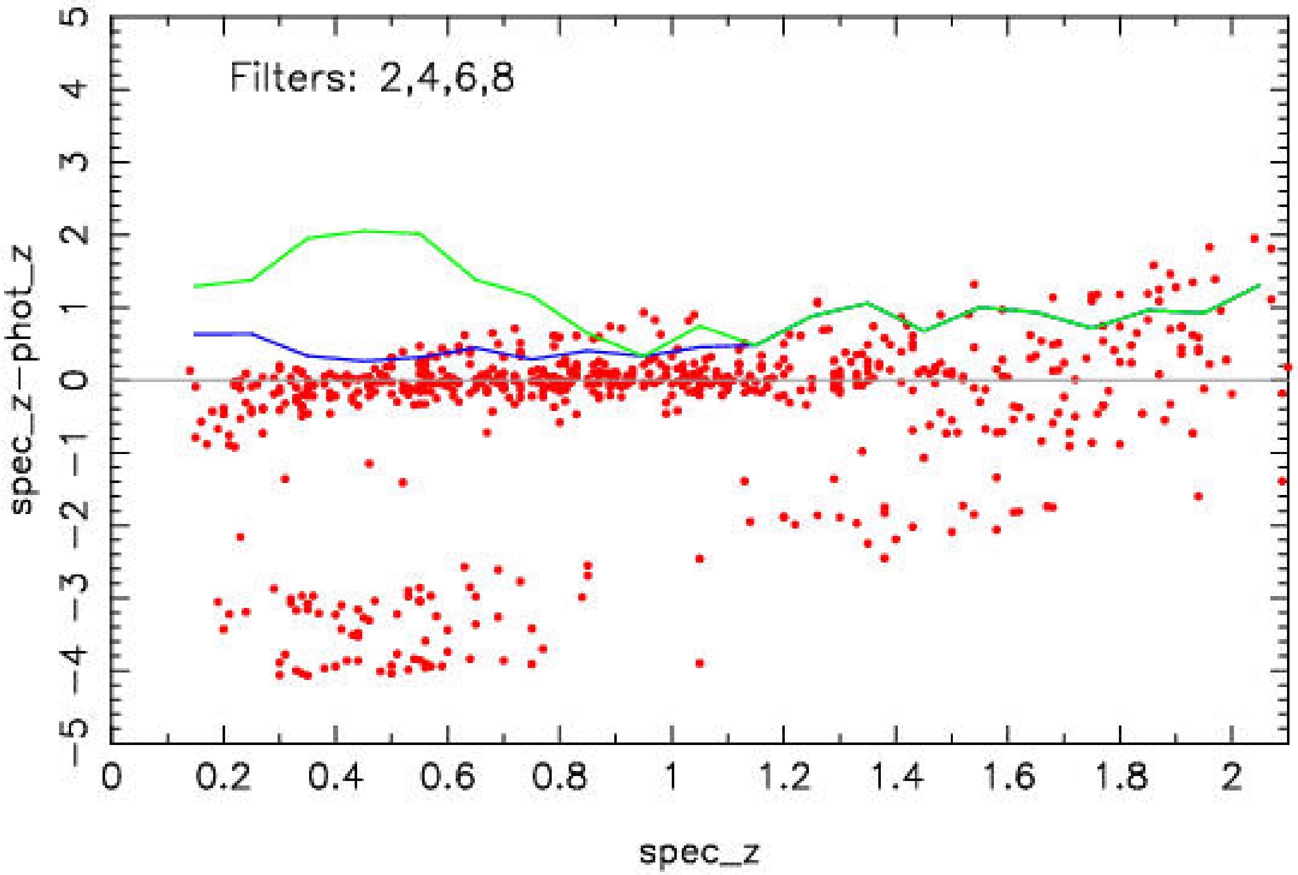
3-3	0.532	0.075	9.6	0.222	0.067	6.6
4-3	0.378	0.063	6.0	0.156	0.054	3.8
5-3	0.282	0.056	4.2	0.116	0.045	2.3
6-3	0.174	0.048	2.7	0.103	0.038	1.4
6-4	0.152	0.042	1.9	0.078	0.032	1.0
7-4	0.100	0.043	1.8	0.070	0.030	0.9
7-5	0.080	0.034	1.1	0.048	0.024	0.30
8-5	0.072	0.033	1.0	0.039	0.012	0.30
6-3	0.237	0.055	3.7	0.108	0.044	2.0

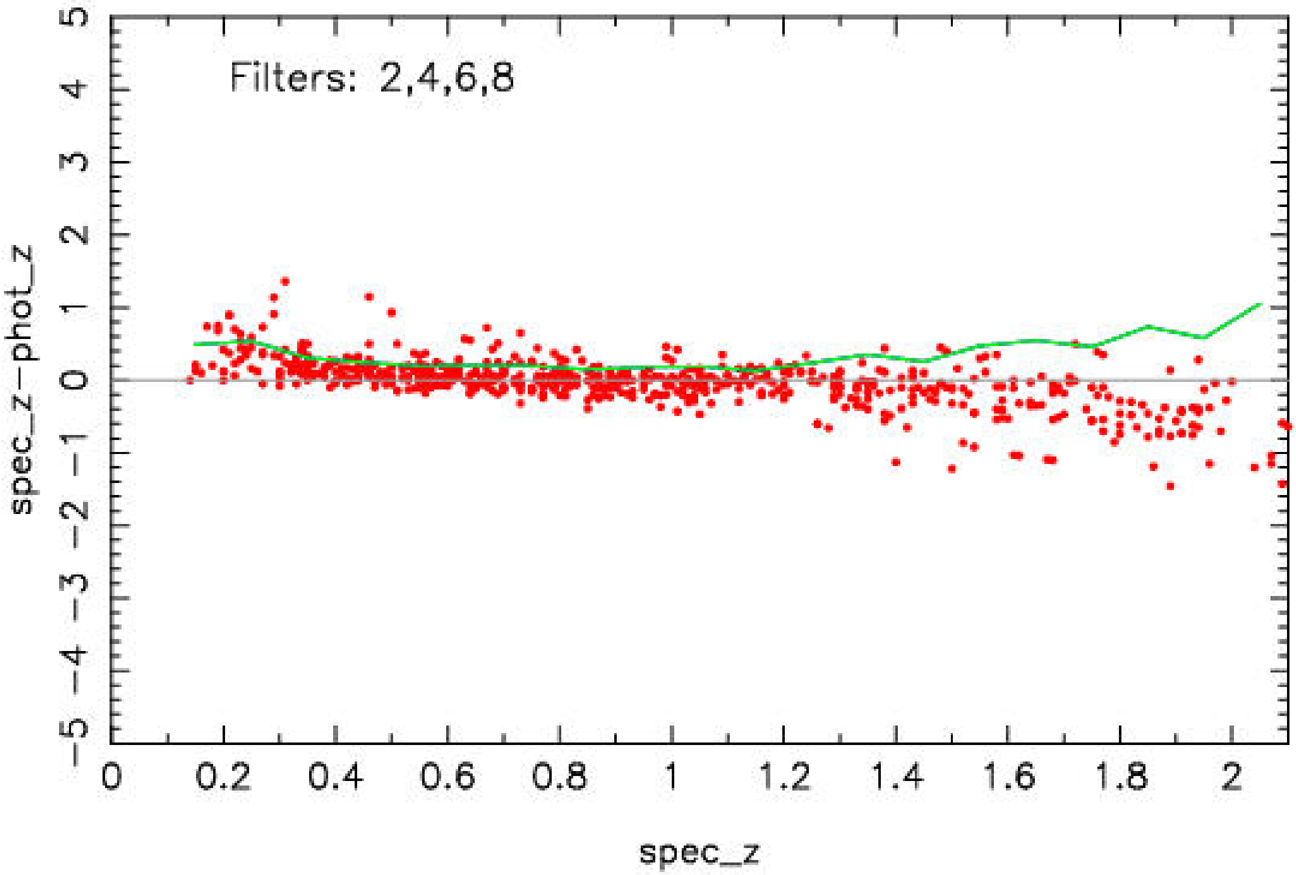


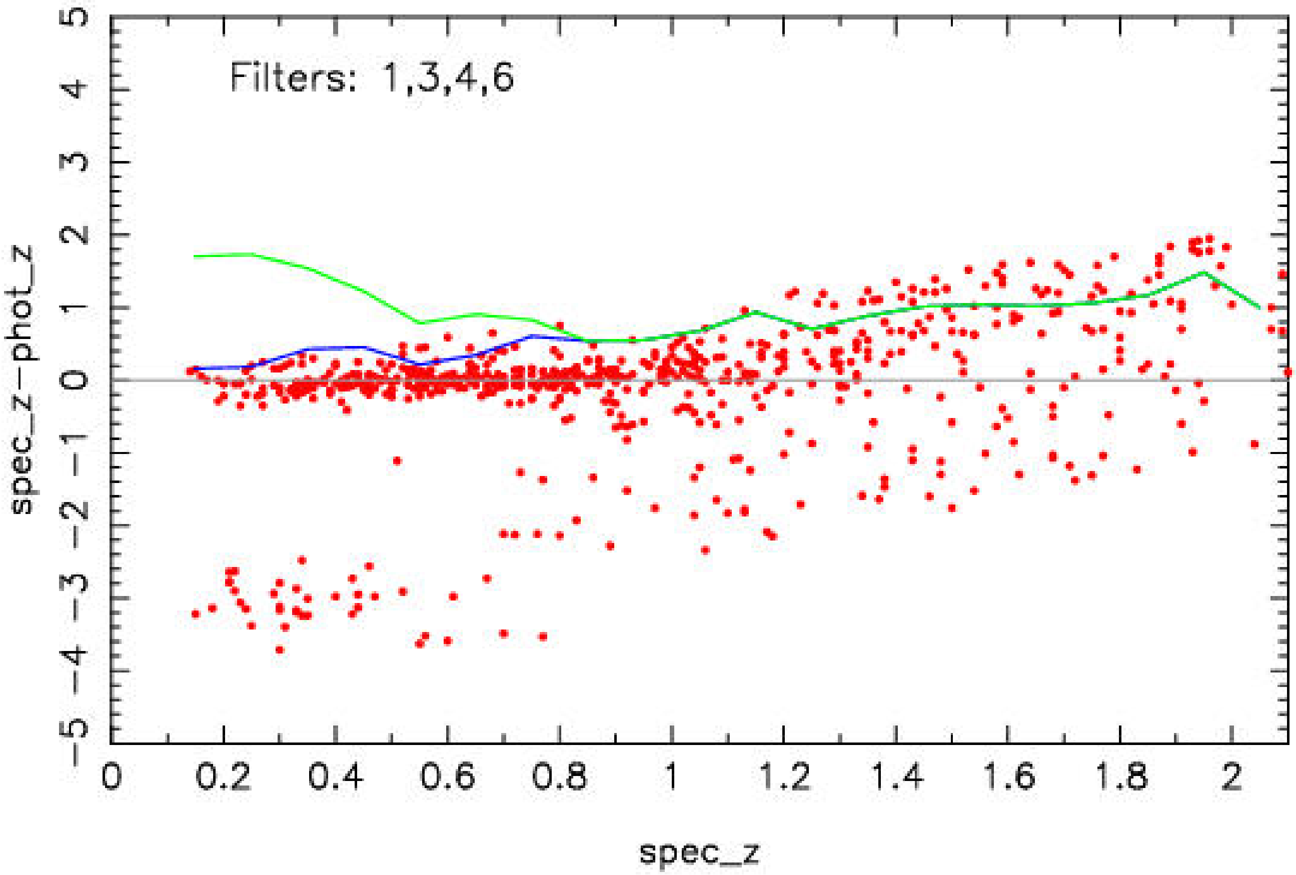
Filters: 1,2,3,4,5,6,7,8,9
spec_z−phot_z
spec_z
5
4
3
2
1
0
−1
−2
−3
−4
−5
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

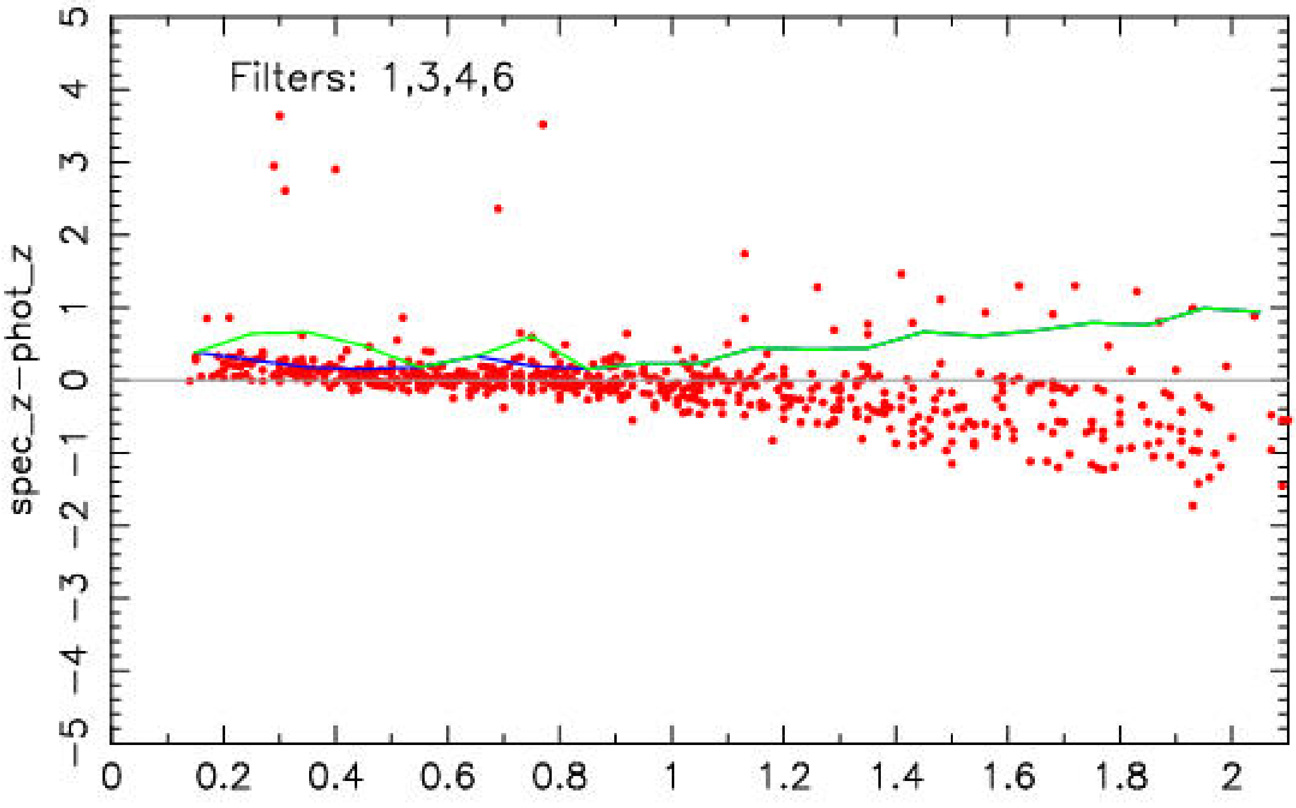


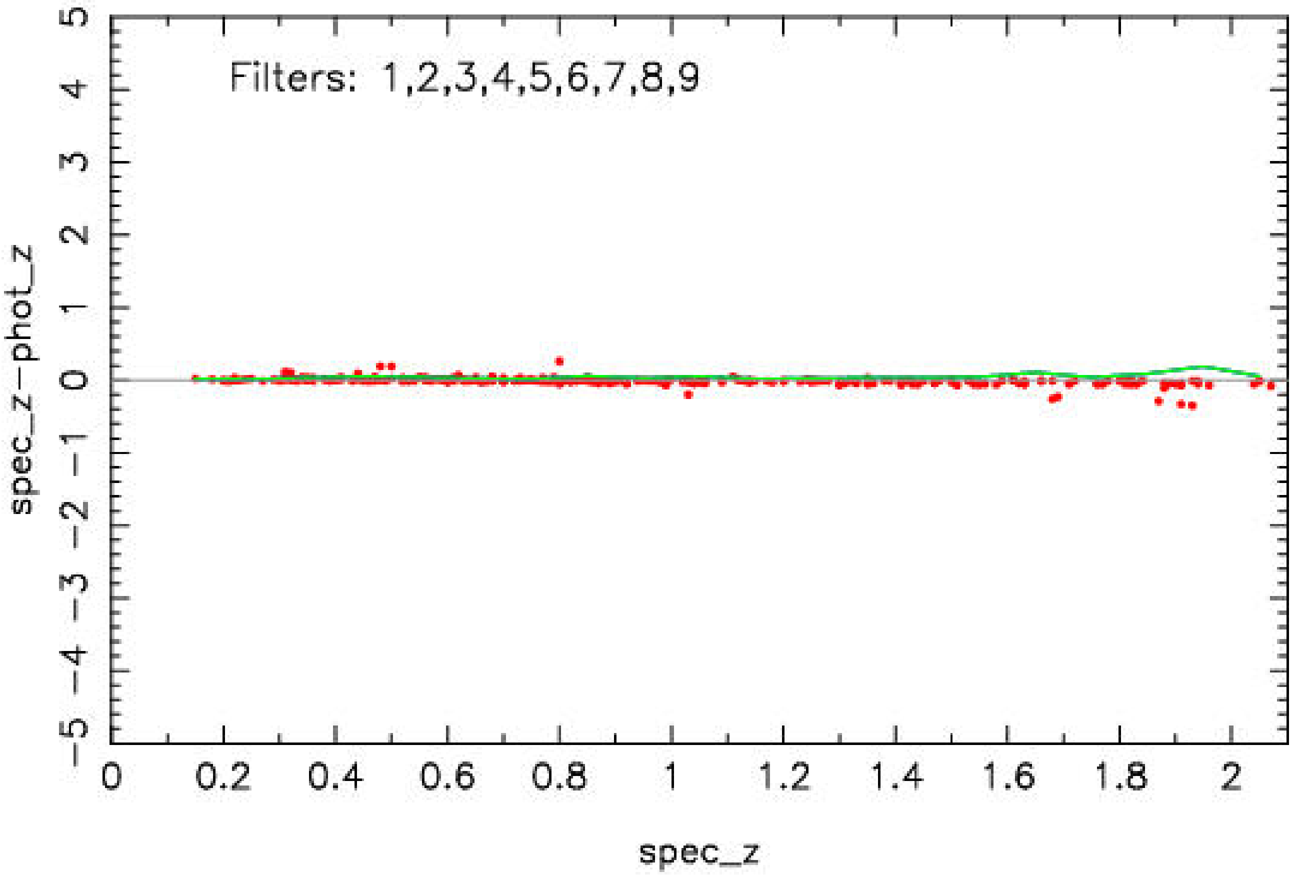
Filters: 1,2,3,4,5,6,7,8,9
spec_z−phot_z
spec_z
5
4
3
2
1
0
−1
−2
−3
−4
−5
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2


Filters: 2,4,6,8
spec_z−phot_z
spec_z
5
4
3
2
1
0
−1
−2
−3
−4
−5
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2


Filters: 2,4,6,8
spec_z−phot_z
spec_z
5
4
3
2
1
0
−1
−2
−3
−4
−5
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2


Filters: 1,3,4,6
spec_z−phot_z
spec_z
5
4
3
2
1
0
−1
−2
−3
−4
−5
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2


Filters: 1,3,4,6
spec_z−phot_z
spec_z
5
4
3
2
1
0
−1
−2
−3
−4
−5
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2



Filters: 1,2,3,4,5,6,7,8,9
spec_z−phot_z
spec_z
−5
−4
−3
−2
−1
0
1
2
3
4
5
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

Conclusions

- Accurate phot-z's and reduced outliers achieved with brighter magnitude cut
- Phot-z accuracy increases with more accurate photometry (i.e. zero-point) and better calibration
- Phot-z accuracy increases with the number of filters. Specially near-infrared bands will help

Filters

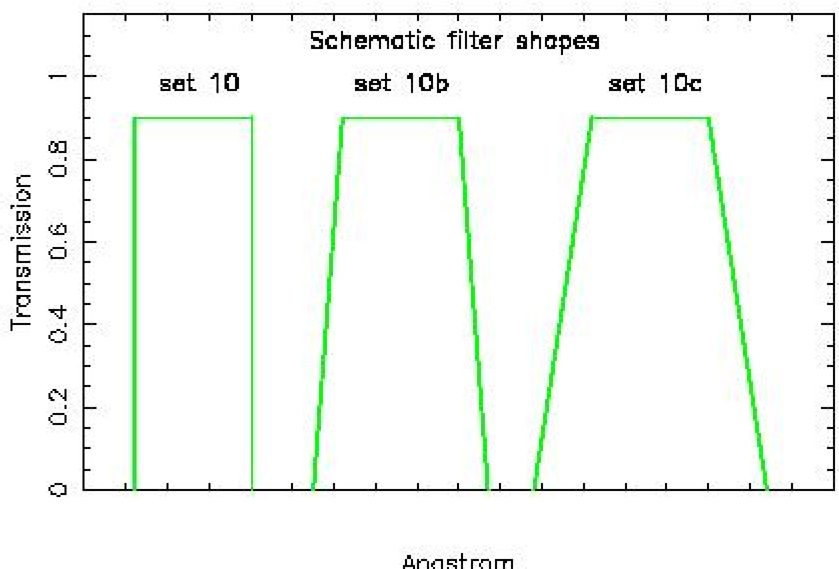
Phot-z's are found using redshifted 4000 A break. Accuracy of the phot-z's depend on photometric accuracy. In selecting optimal set of filters there are two competing requirements:

Using a number of narrow-band filters will significantly help but this would also lower the counting statistics, resulting in larger photometric errors.

Filters - Conclusions

However, dividing the limited observing time between large number of filters reduces the S/N per band.

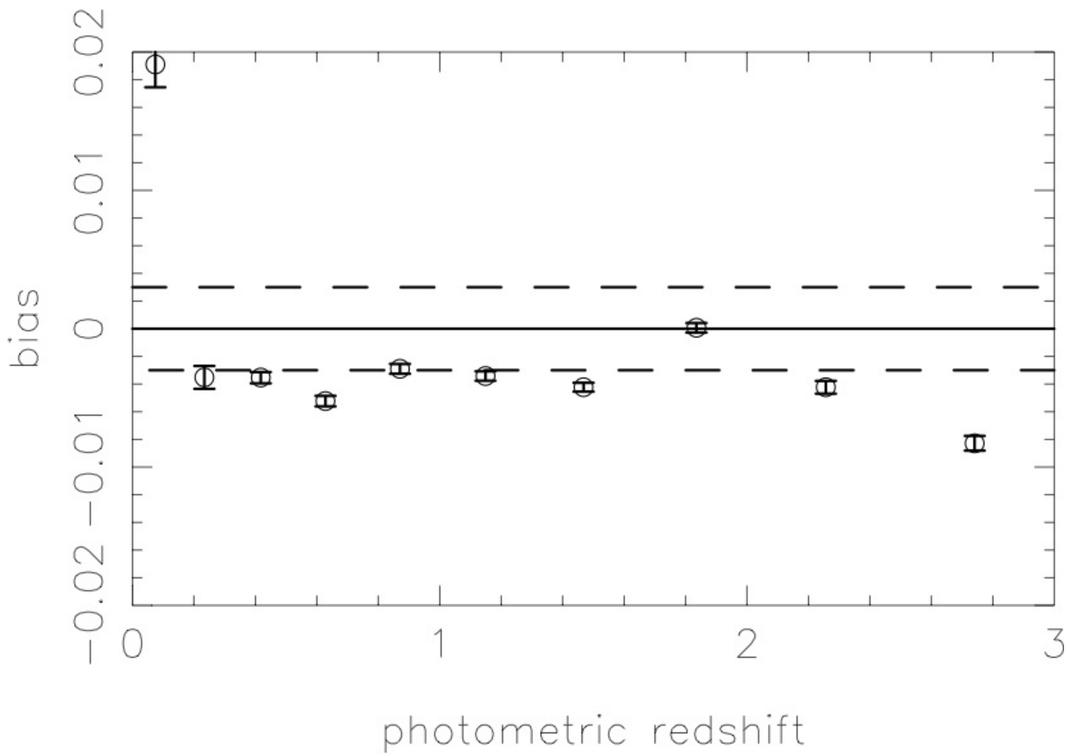
We use our simulations to study if there is some optimal choice for the filters for measuring phot-z's. We adopt the filter set in Davis et al astro-ph 0511017.



Schematic filter shapes
set 10
set 10b
set 10c
Transmission
0
0.2
0.4
0.6
0.8
1
Angstrom

To increase the accuracy of photo-z's we need:

- Good photometric calibration (~0.03 mag)
- Large training set of spectroscopic redshifts (~10^4)
- Sufficient number of filters
- High photometric S/N
- Near-Infrared photometric data



bias
0.02
0.01
0
−0.01
−0.02
0
1
2
3
photometric redshift