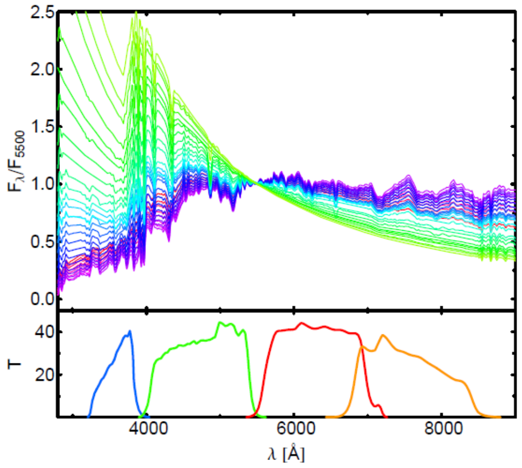
Photometric redshift measurement of CSS-OS

Liping FU

ISSI Program: Weak Gravitational Lensing Studies from Space Missions, Beijing, Nov 4-8, 2019

Two families of methods to evaluate photo-z:

- **SED fitting methods**



$$\chi^2(z,T,A)=\sum_{i=1}^{N_f}\left(\frac{F^f_{\rm obs}-A\times F^f_{\rm pred}(z,T)}{\sigma^f_{obs}}\right)^2$$

$$PDF(z)\propto exp\left(-\frac{\chi^2(z)-\chi^2_{min}}{2}\right)$$

- **Pros:** the estimates of photo-z, the spectral type, **PDF**
- **Cons:** a priori theoretical knowledge required

- **Machine Learning (ML) methods:**

1. Supervised

spectroscopic redshift

multi-band photometry

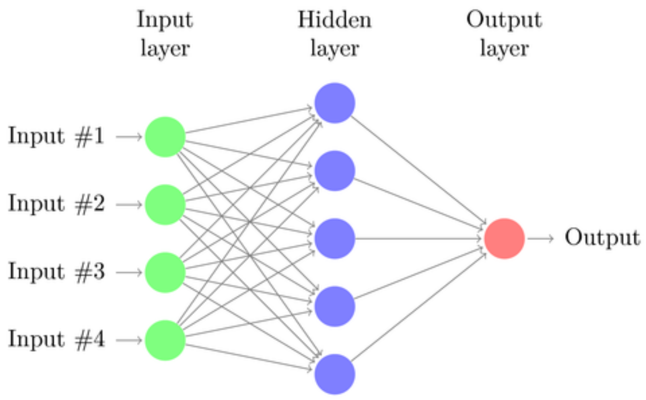


photo-z

-- a ground truth or
a knowledge base (**KB**) required .

2. Unsupervised: the spectroscopic info is not used in the training phase, until the validation of the process occurs

Pros: no priori theoretical information needed. Add information to photometry very easily

Cons: incapability of extrapolating information outside the training data

MNRAS **480**, 2178–2190 (2018)
Advance Access publication 2018 July 25
doi:10.1093/mnras/sty1980

Testing photometric redshift measurements with filter definition of the Chinese Space Station Optical Survey (CSS-OS)

Ye Cao,[1,2]★ Yan Gong,[1]★ Xian-Min Meng,[3] Cong K. Xu,[4,5] Xuelei Chen,[1,2,6] Qi Guo,[1] Ran Li,[1,2] Dezi Liu,[7] Yongquan Xue,[8,9] Li Cao,[3] Xiyang Fu,[3] Xin Zhang,[3] Shen Wang[3] and Hu Zhan[3]★

Motivation:

The current filter definition can provide accurate photo-z to achieve the science requirement -- $\sigma_z < 0.05$ (at least) $\sigma_z < 0.02$ (goal) [Zhan 2006; Abell et al 2009]

What we do:

1. Make a mock galaxy catalog (mock flux)
2. Compare three different photo-z fitting process
3. Photo-z dependence on each band, +J+H of Euclid

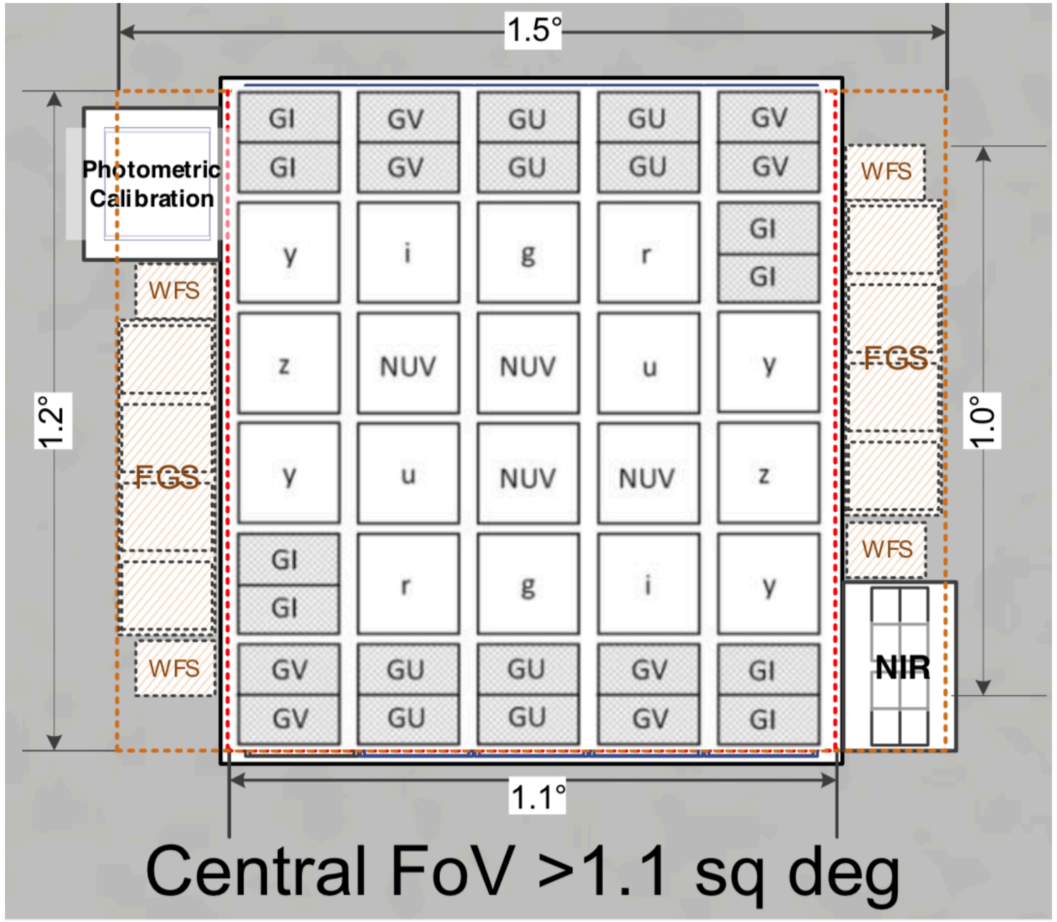
Conclusion:

1. CSS-OS along → good photo-z: $\sigma_z \sim 0.02$, outlier ~3%
2. CSS-OS + Euclid (JH) → better photo-z: : $\sigma_z < 0.02$, outlier ~0.22%

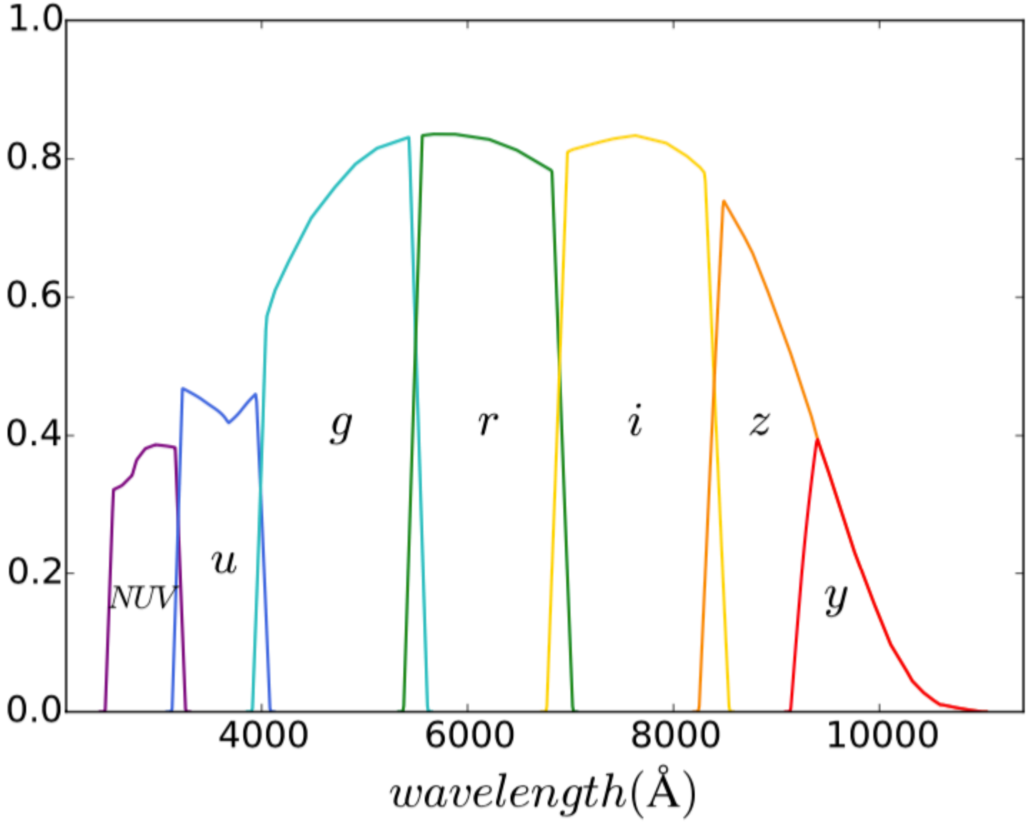
Overview of CSS-OS

Credit Hu Zhan

Project	Orbit /Site	Launch/op	FoV	R_{EE80}	Num pixels	Area	Wavelength	Num filters	spectr um
			deg^2	″	10^9	deg^2	nm		
CSS-OS 2m	**LEO**	**~2024**	**1.1**	**0.15**	**2.5**	**17500**	**255—1000**	**7**	**Y**
Euclid 1.2m	L2	2022	0.56 0.55	>0.2 pix lmt	0.6 0.07	15000	550—920 1000—2000	1 3	N Y
WFIRST 2.4m	L2	～2024	0.28	>0.2	0.3	2400	927—2000	4	Y
LSST 8.4m	Chile	2022	9.6	~0.7	3.2	18000	320—1050	6	N



Total transmission
(detector quantum efficiency considered)



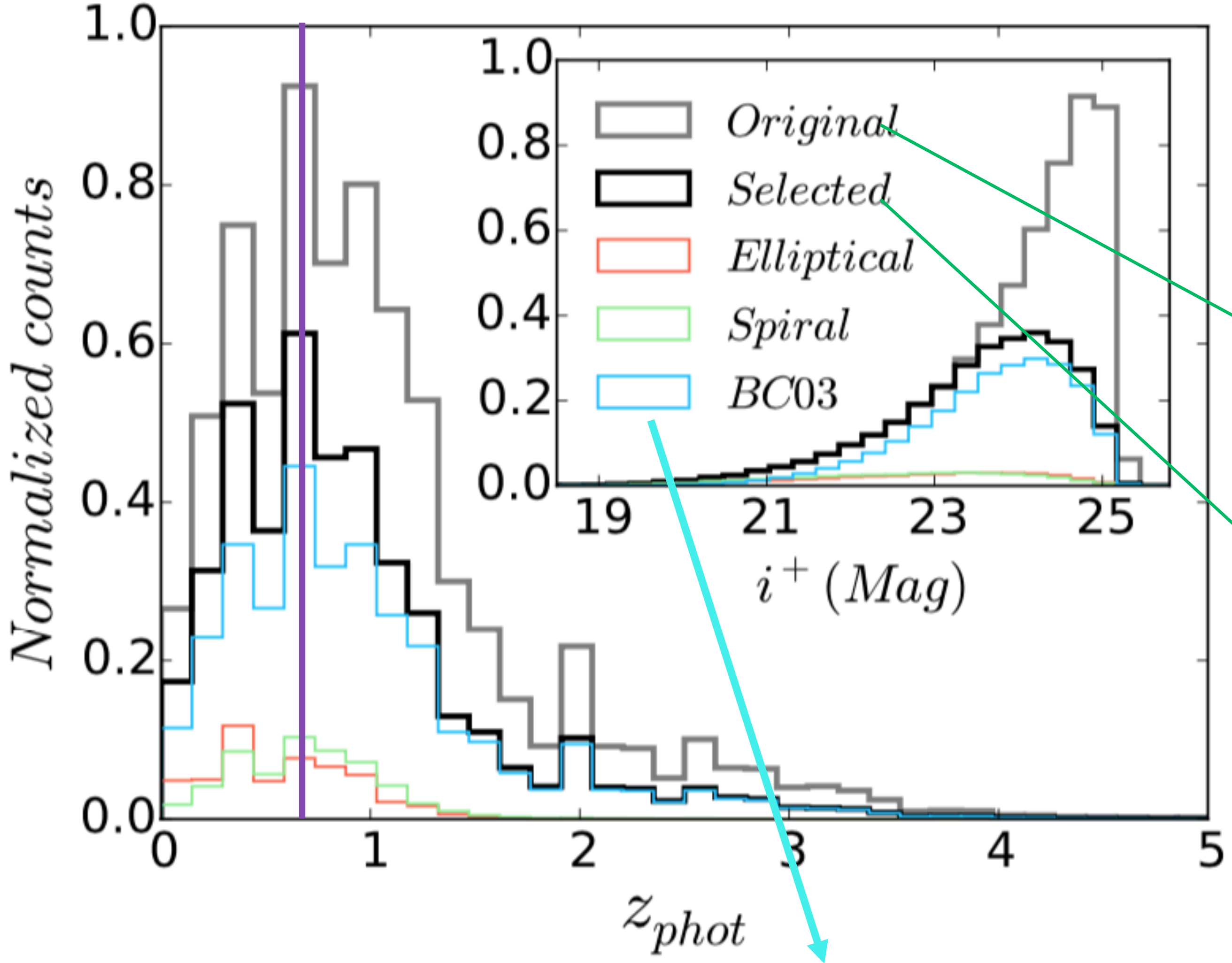
Limit mag for point sources:

NUV	u	g	r	i	z	y
25.4	25.5	26.2	26.0	25.8	25.7	25.5

1. Mock galaxy catalog

1) galaxy sample selection

Zpeak ~0.7



Young blue star forming
Dominant in the select sample

Use Cosmos galaxy catalog:

Original (~219,000):

- $i^+ < 25.2$
- Remove stars, mask sources, x-ray

Selected

- SNR >= 10 (g or i) (~126,000)
- Similar redshift & mag distributions as CSS-OS

- Random select 10,000 galaxies for the photoz test

2) Mock Flux

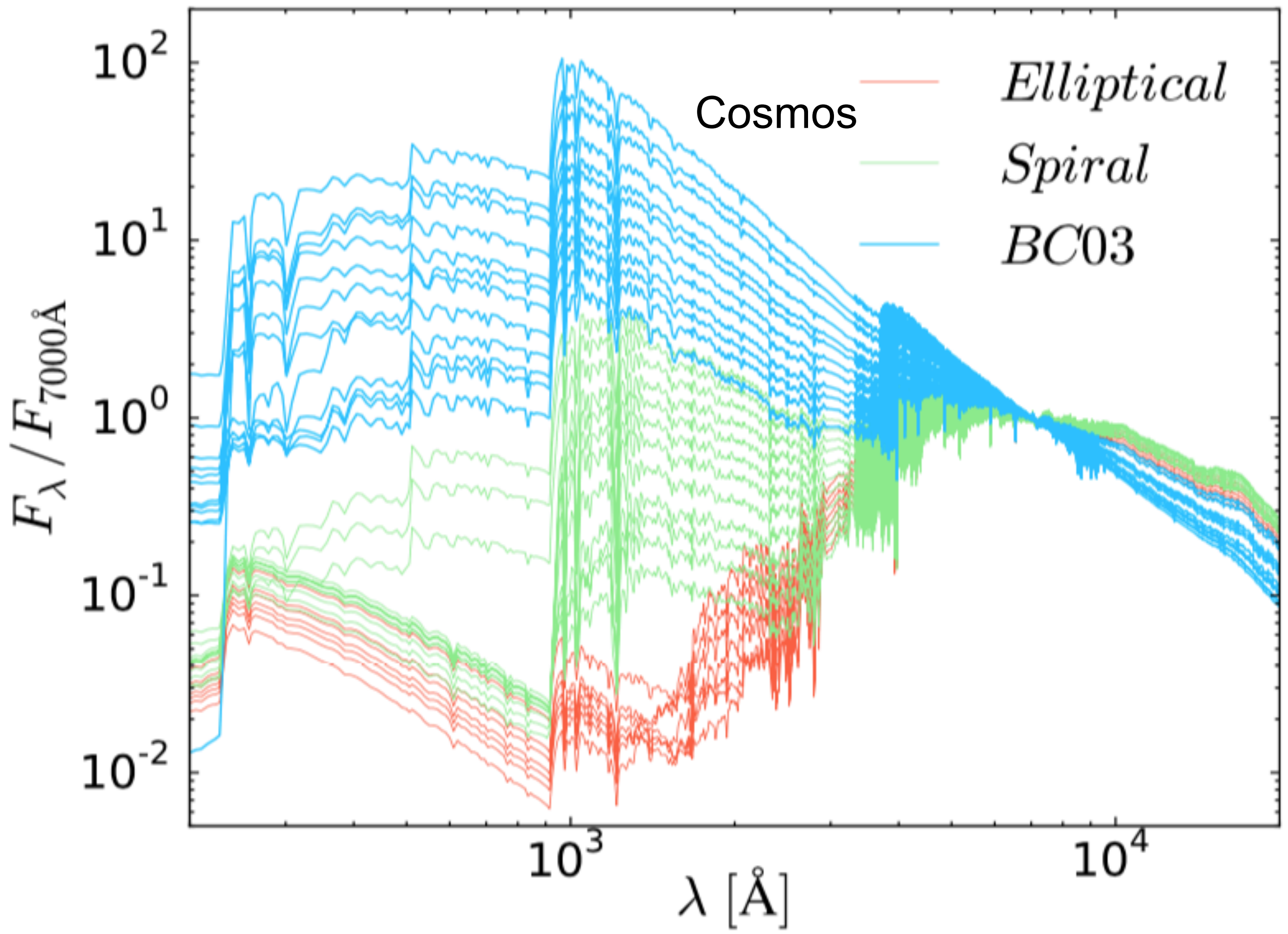
Response function

$$F_x^{\text{mock}} = \int S_{\text{model}}(\lambda) T_x(\lambda) \mathrm{d}\lambda.$$

SED model

- To avoid SED overfitting: linear combining SED templates with adjacent galaxy's
- Dust extinction included

Intrinsic SED templates



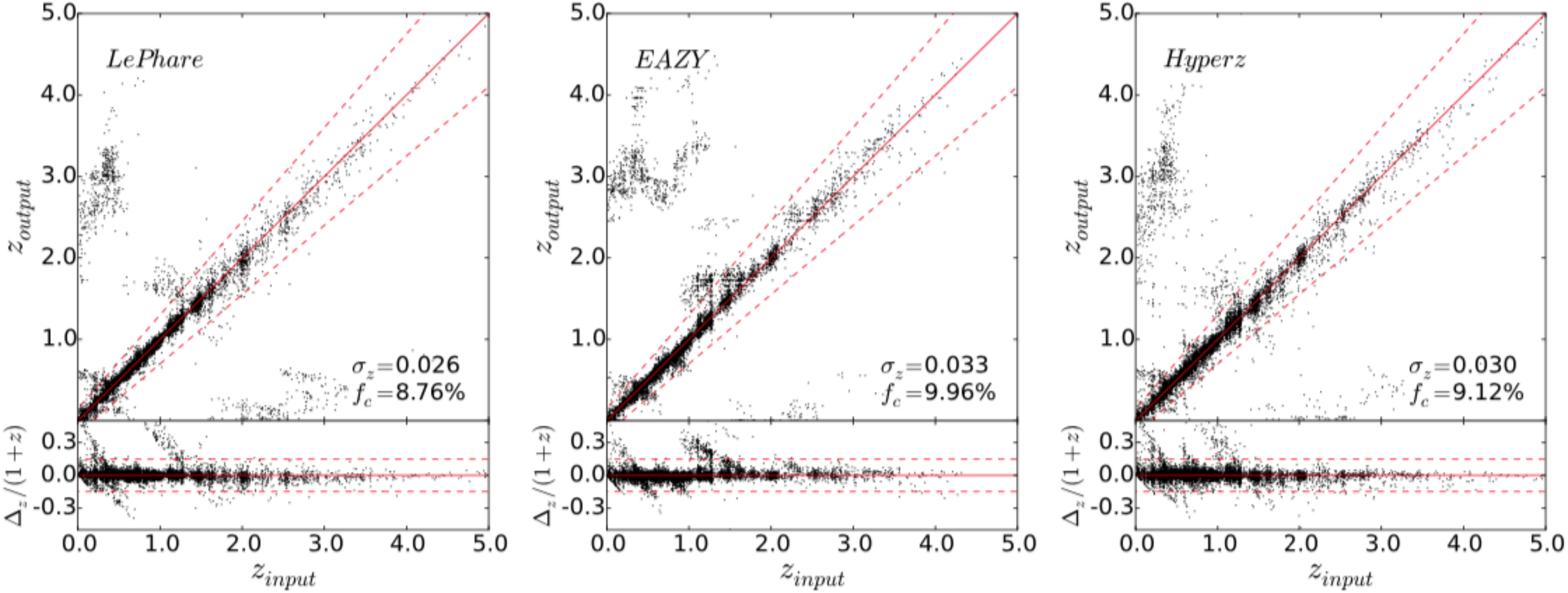
From Cosmos & BC03 template lib

2. Photo-z code comparison

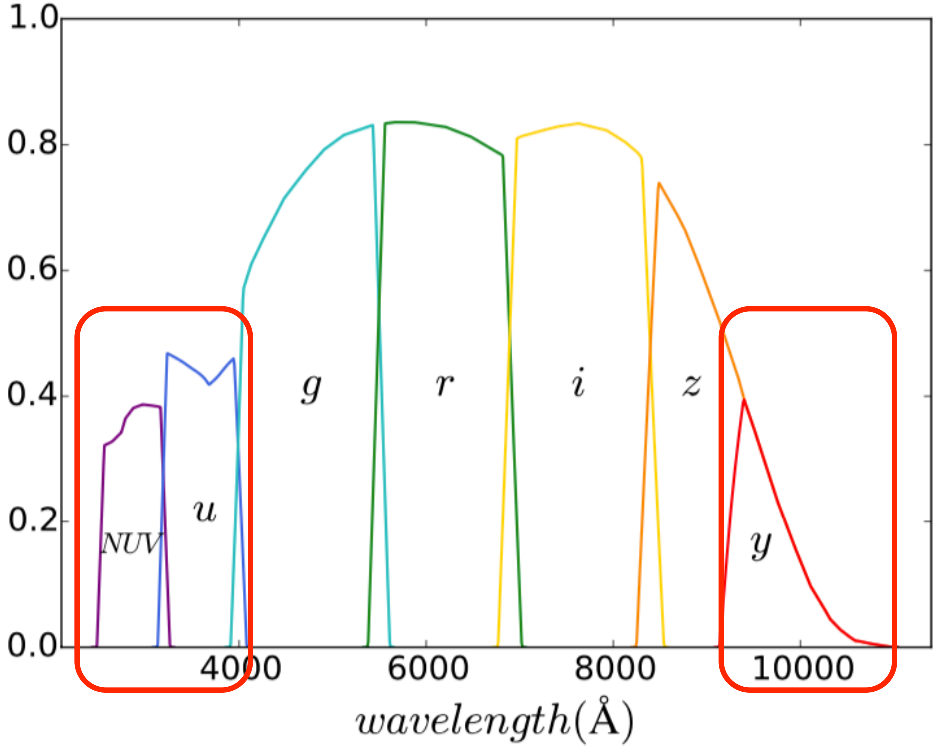
SNR >= 3

1) LePhare shows better results

	LePhare	EAZY	Hyperz
σ_z (NMAD)	0.026	0.033	0.030
$f_{catastrophic}$	8.76%	9.96%	9.12%



2) Modified chi-square of LEPHARE to exploit information in upper limits



Isobe, Feigelson & Nelson (1986); Lyu, Rieke & Alberts (2016)

$$\chi^2_{\rm tot} = \chi^2_N + \sum_j^M w_j \tag{10}$$

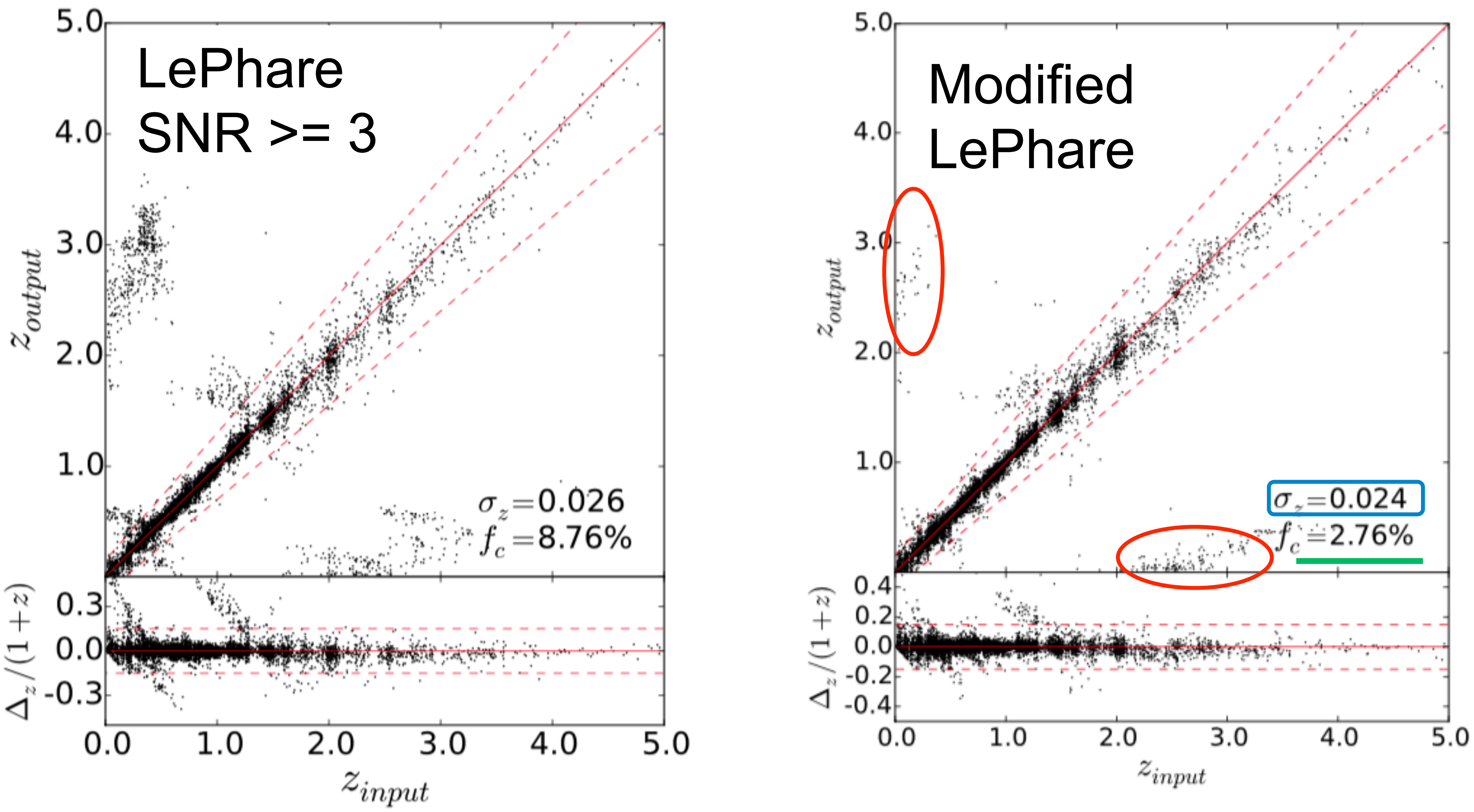
where χ^2_N is for the data with SNR≥3 as shown in equation (8), M is the number of the bands with upper limits, and $w_j = -2\log P_j$. Here P_j is given by

$$P_j = \frac{1}{\sqrt{2\pi}\sigma_j}\int_{F_{\rm l}}^{F_{\rm u}} \exp\left[-\frac{(f - F_j^{\rm th})^2}{2\sigma_j^2}\right] {\rm d}f, \tag{11}$$

where f is the flux variable, $F_j^{\rm th}$ is the flux calculated by the photo-z code for band j, σ_j is the flux error of band j, $F_{\rm l}$ and $F_{\rm u}$ are the flux lower and upper limits, and we take $F_{\rm l} = 0$ and $F_{\rm u} = 3\sigma_j$.

- Include the information in upper limits
- Suppress the catastrophic redshift fraction

2) Modified chi-square of LEPHARE to exploit information in upper limits

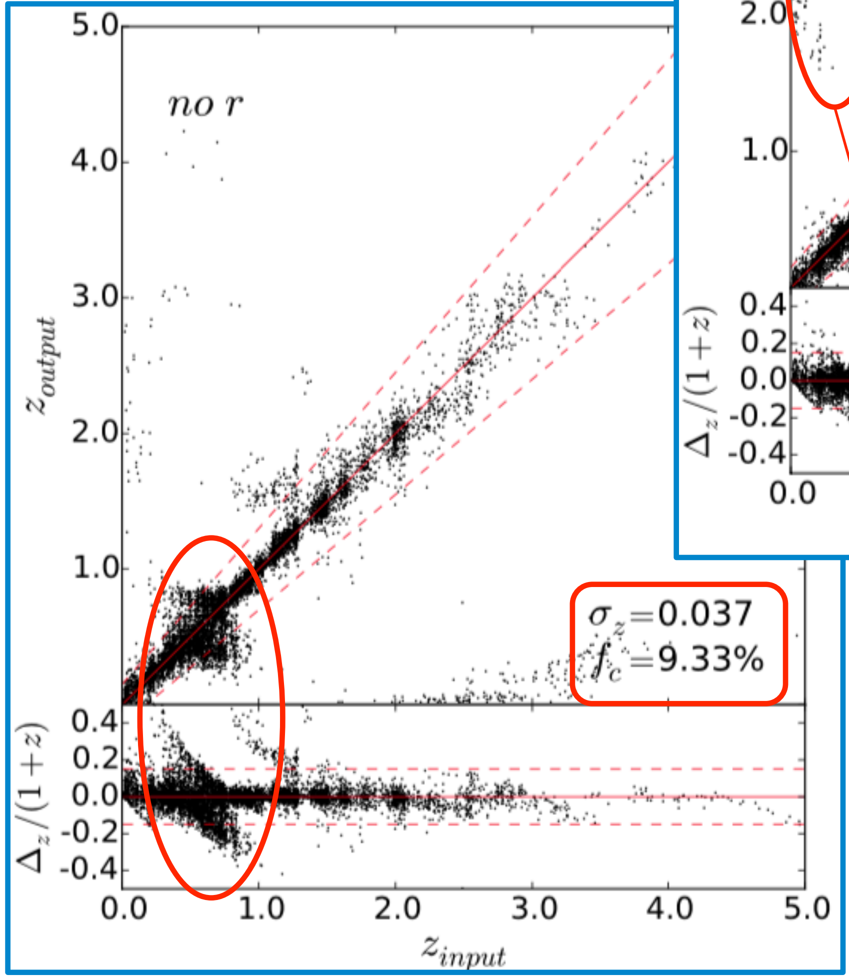


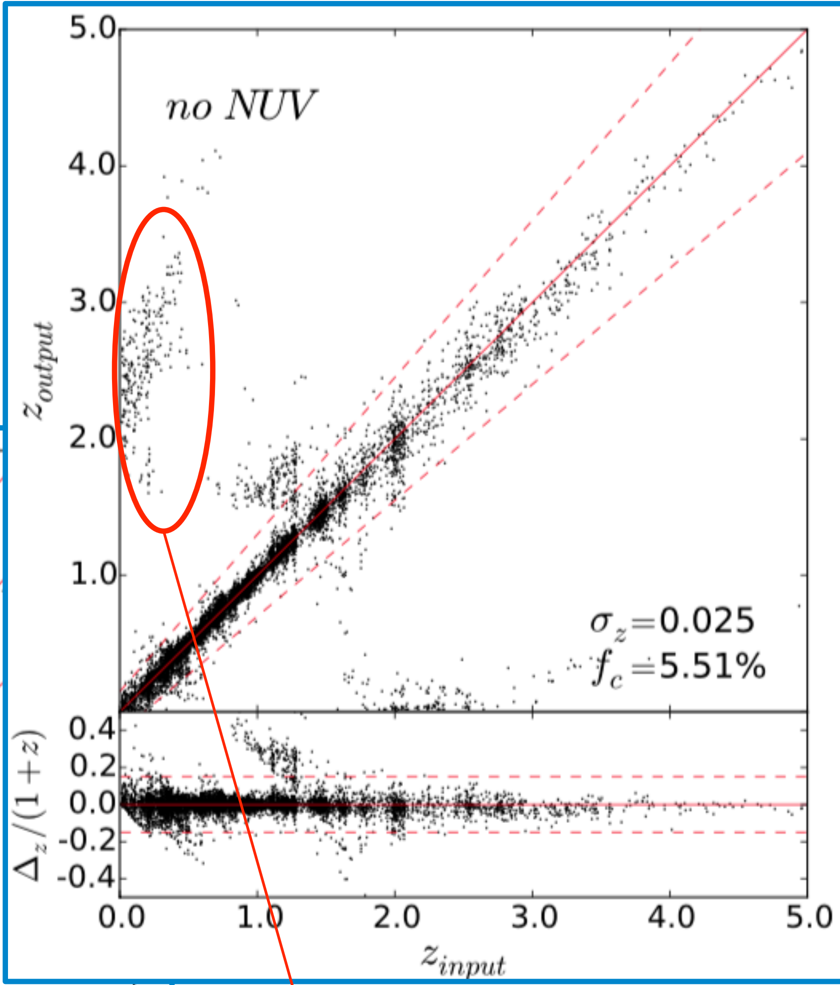
3. Photo-z dependence

1) Dependence on each band

Filter set	Real det. eff. σ_z	$f_c(\%)$	100% det. eff. σ_z	$f_c(\%)$
All	0.024	2.76	0.021	0.82
−*NUV*	0.025	5.51	0.022	3.07
−*u*	0.026	3.99	0.022	1.44
−*g*	0.033	7.53	0.028	4.26
−*r*	0.037	9.33	0.030	4.60
−*i*	0.036	5.69	0.030	2.96
−*z*	0.028	3.44	0.023	1.65
−*y*	0.027	3.49	0.023	1.32
+*J*	–	–	0.017	0.43
+*J* + *H*	–	–	0.017	0.22

Can't identify the Balmer/ 4000 A break



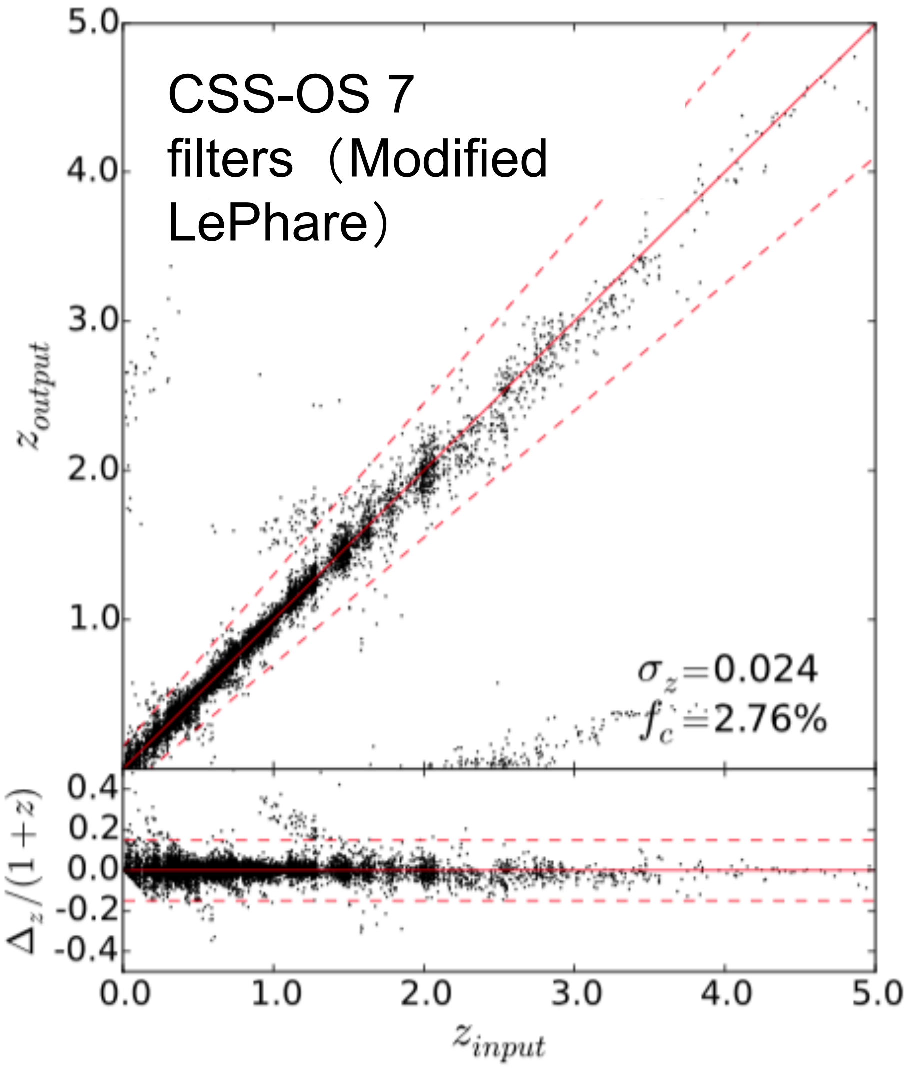


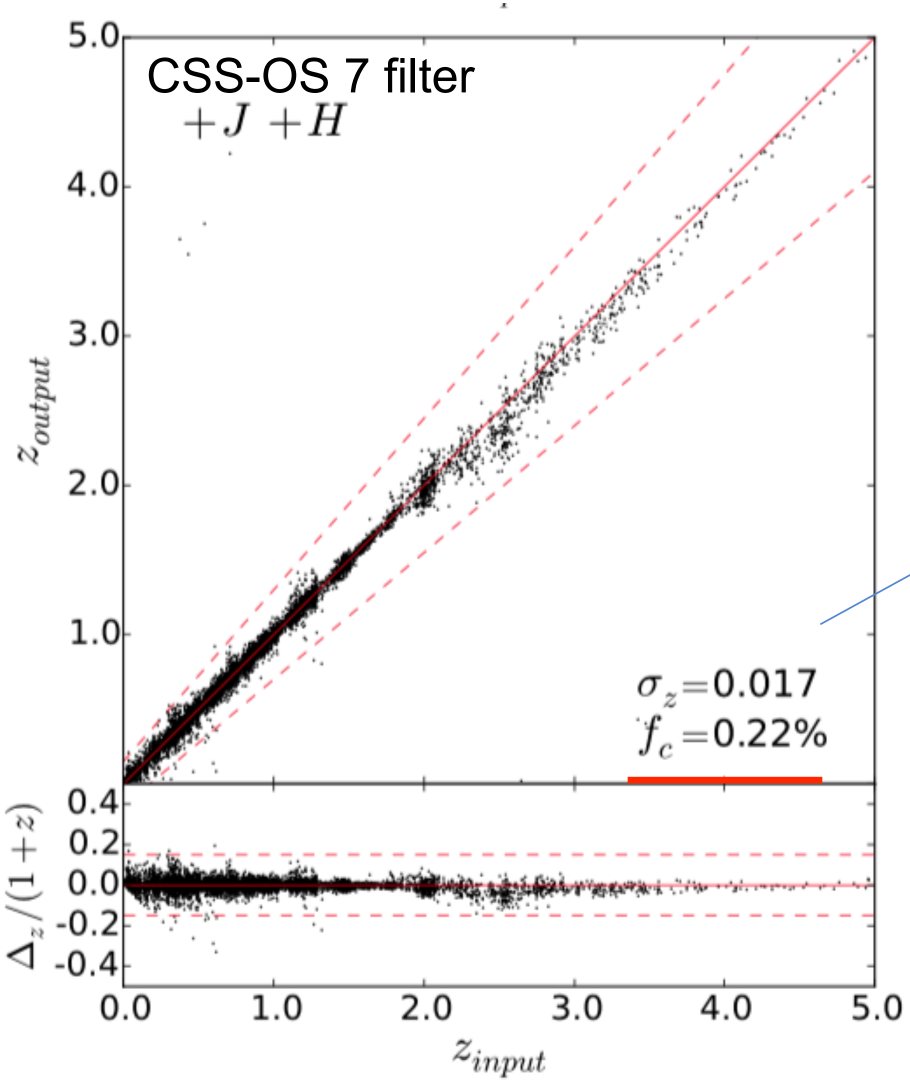
Misidentify continuum break at 2640 A as Layman break

2) +J +H band from Euclid

Conclusion:

1. CSS-OS along → good photo-z
2. CSS-OS + Euclid (JH) → better photo-z





goal achieved

10 times smaller

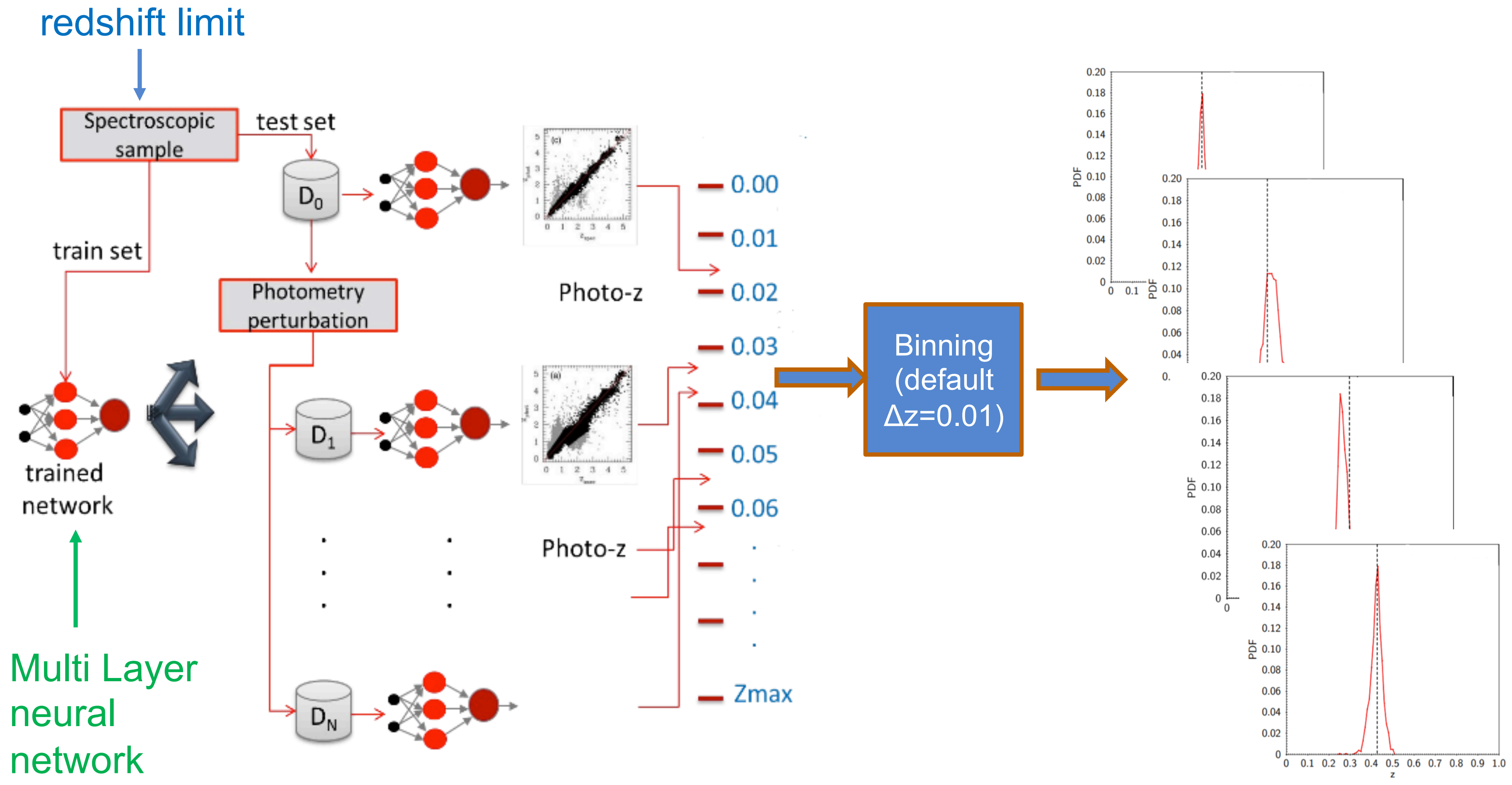
Machine-learning Estimation Tool for Accurate PHOtometric Redshifts (METAPHOR)

Naples group: M. Brescia, M. Salvato, S. Cavuoti, Valeria Amaro, T. T. Ananna, G. Riccio, S. M. LaMassa, C. M. Urry & G. Longo

Research Assistant of
Sun Yat-sen University@Zhuhai

METAPHOR Machine-learning Estimation Tool for Accurate Photometric Redshifts

Cavuoti+ 2017



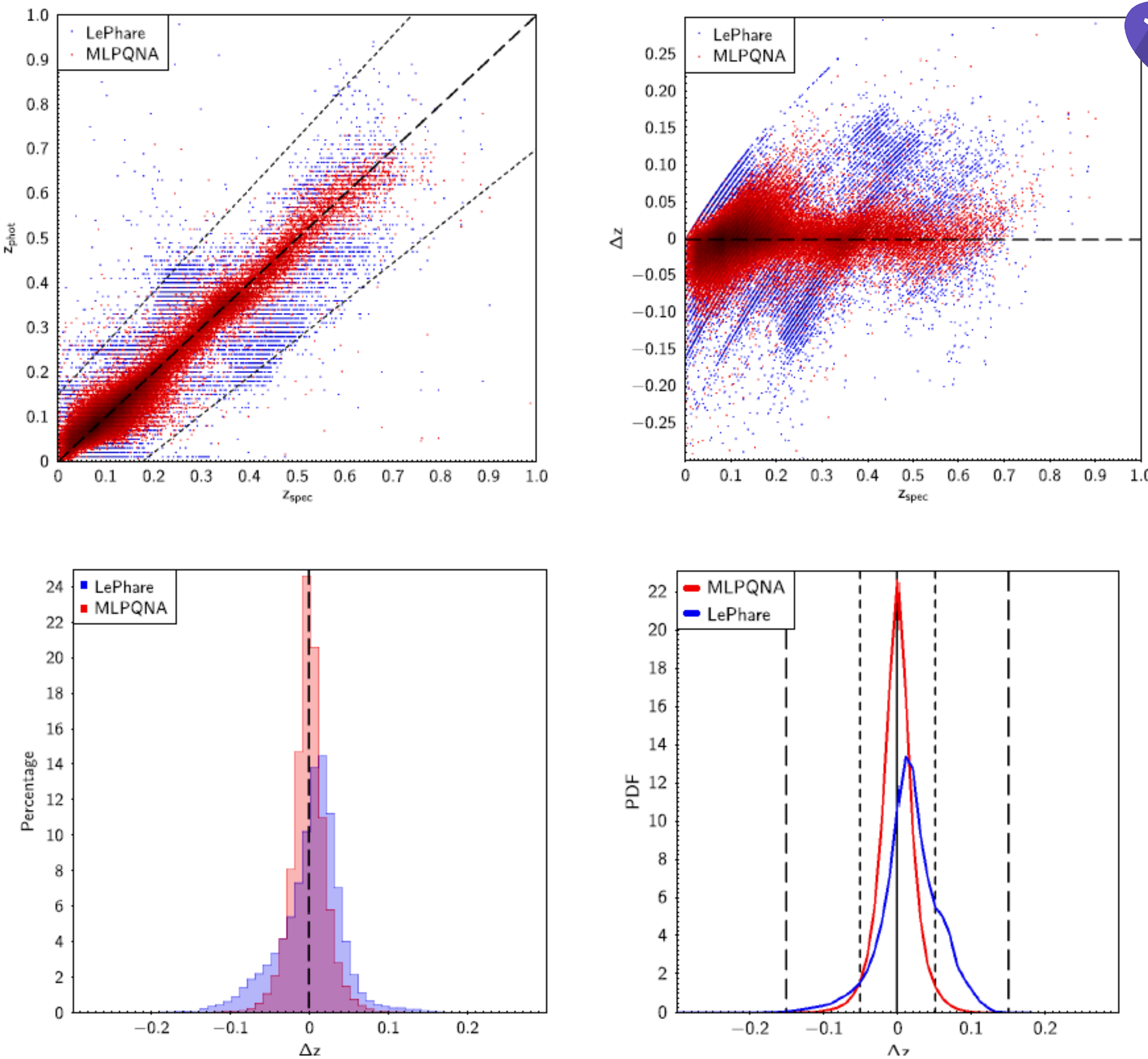
METAPHOR in Euclid OU-PHZ Data Challenge #2

Courtesy J. Coupon and EUCLID OU-PHZ Team

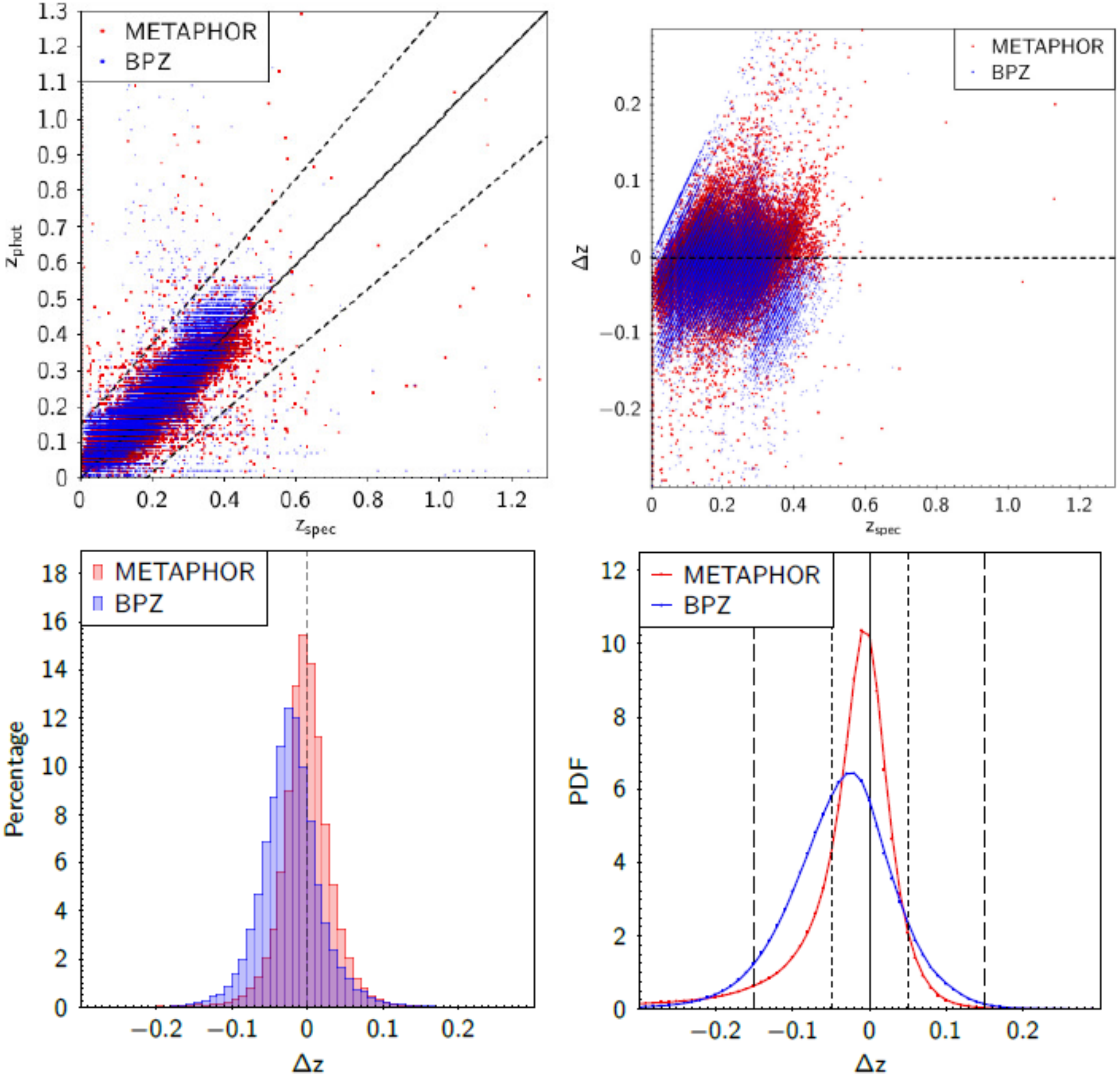
Code Name	σ	Outlier Fraction (%)	Relative Fraction
MLPQNA	0.057	11.99	0.60
ML	0.068	21.97	1.0
LePhare	0.070	17.49	0.85
ANNz	0.077	21.77	0.94
SOM+RF	0.064	18.92	0.78
LePhare+ColorPrior	0.057	15.6	0.94
LePhare	0.084	22.47	0.90

- Best precision
- No method matches all the Euclid requirements for photo-z measurements

METAPHOR vs Le Phare



METAPHOR vs BPZ



Conclusion:

1. General speaking, machine learning method (METAPHOR) provide high precision than SED model fitting method.
2. The completeness of the photoz is the most shortcoming of machine learning method due to the limit of training sample (z_{spec})
3. Brescia et al (2018), Delli Veneri et al (2019), optimsed METAPHOR by add the feature selection process (mag, color, galaxy shape……)

METAPHOR possible on CSS-OS in the future ?