上海师范大学
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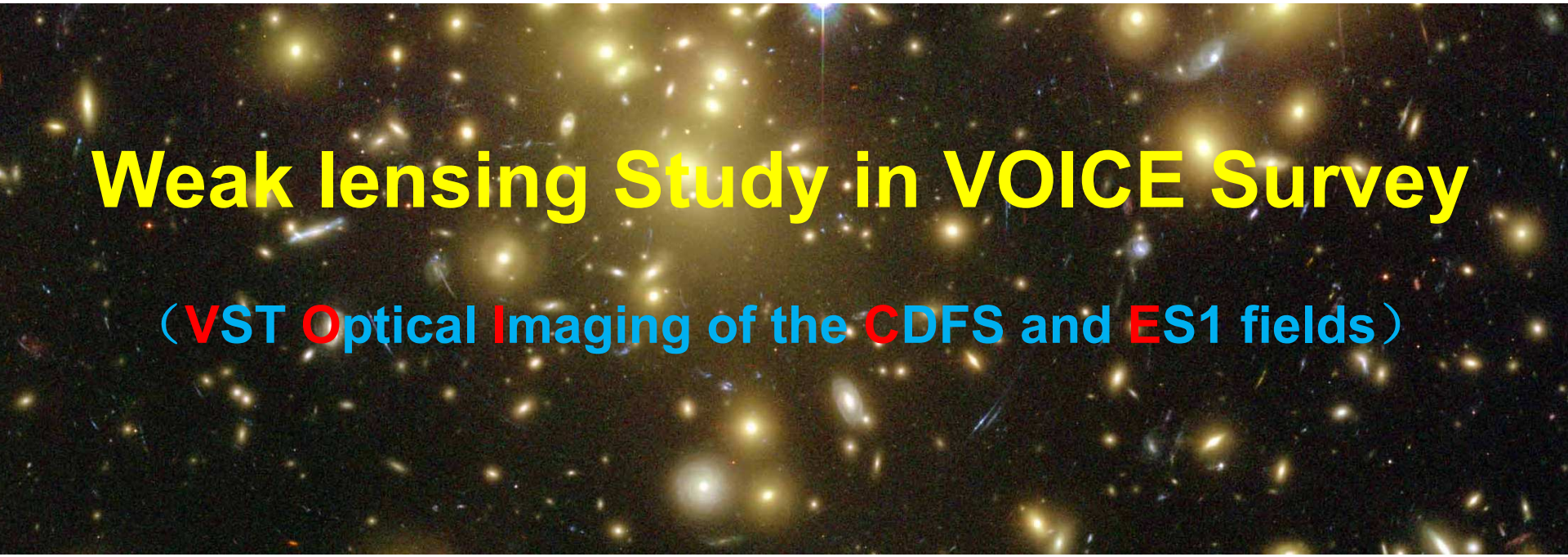
SHANGHAI Key Lab for Astrophysics



# Weak lensing Study in VOICE Survey

## （VST Optical Imaging of the CDFS and ES1 fields）


**Liping Fu**

**Shanghai Normal University**

Collaborated with:

-- Zuhui FAN (PKU&YNU), Dezi LIU (YNU), Xiangkun LIU (YNU), Chuzhong PAN (PKU);

-- Giovanni Covone (Univ. Napoli Federico II), Mattia Vaccari (Univ. Western Cap), Mario Radovich (INAF-Padova)

Alino Grado (INAF-Napoli), Lance Miller (Univ. Oxford) + VOICE-SUDARE team


Oct 5, 2018, CEA, Paris

## I. VOICE shear catalog (Fu+ 2018)

- ✓ Data selections
- ✓ Shear measurement
- ✓ Systematic checking
- ✓ Cosmological application

## II. VOICE imaging simulation (Liu, Fu+ 2018)

- ✓ Simulation build
- ✓ Shear bias calibration

## III. Voice photometric redshift estimation (Amaro+ in preparation)

- ✓ BPZ
- ✓ METAPHOR (Machine-learning Estimation Tool for Accurate Photometric Redshifts)

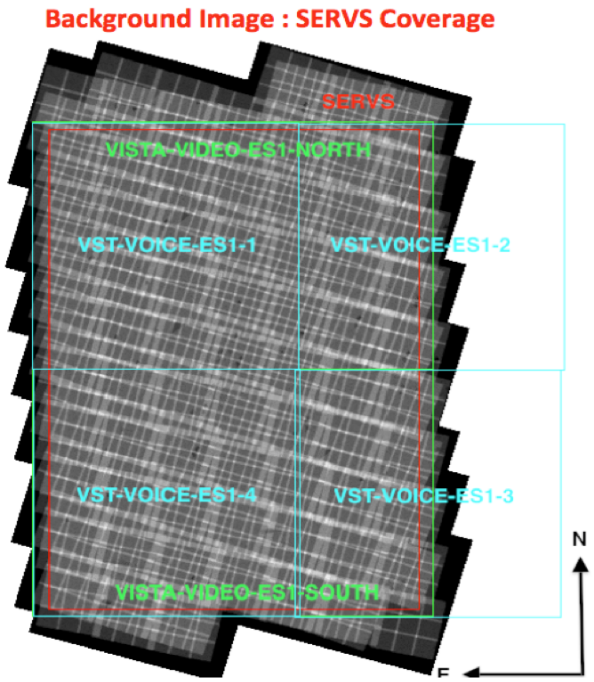
# I. VOICE（VST Optical Imaging of the CDFS and ES1 fields）

-- GTO program of VST;  co-PIs: Giovanni Covone & Mattia Vaccari

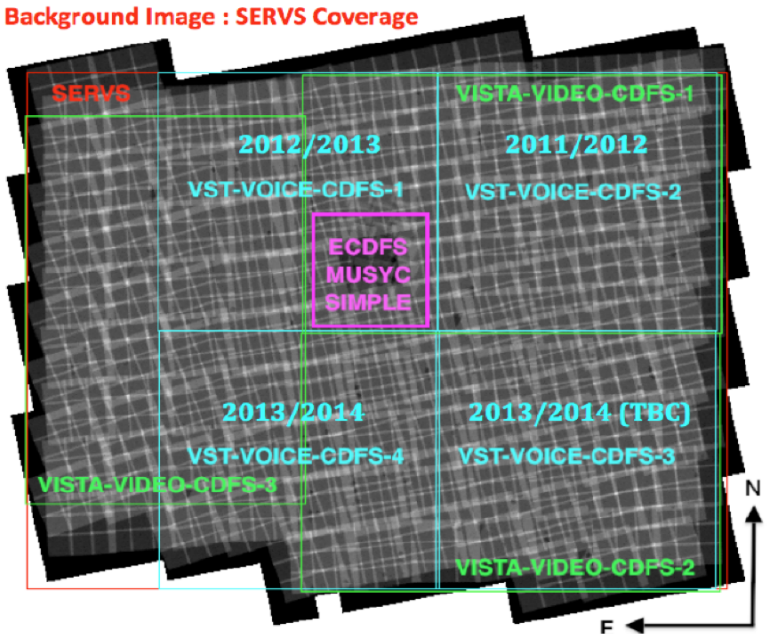
-- +SUDARE→ uniform & deep optical coverage：CDFS (4deg$^2$) & ES1 (4deg$^2$);

Spitzer SWIRE (IR), VISTA-VIDEO (NIR),Spitzer-SERVS (MIR), Herschel-HerME (FIR), GALEX (UV) and ATLAS(radio).

ES1




CDFS



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## VOICE vs KiDS

-- Kilo Degree Survey @ VST (VLT survey telescope): 1500 deg2, $r_{lim}$ = 24.9

-- Same instrument (u, g, r, i)

-- KiDS: each pointing, one epoch (5  consecutive exposures);

-- VOICE: multiple-epoch observations ( > 100 exposures, r band);

-- $r_{lim}$ = 26.1  (point source, 5σ)  →  ~ 1.2 magnitude deeper than KiDS.

# Shear catalog

## Weak lensing Study in VOICE Survey I: Shear Measurement

Liping Fu[1⋆], Dezi Liu[2,3,1], Mario Radovich[4], Xiangkun Liu[3], Chuzhong Pan[2]
Zuhui Fan[3,2], Giovanni Covone[5,6,7], Mattia Vaccari[8,9] , Maria Teresa Botticella[7],
Massimo Capaccioli[5], Enrico Cappellaro[4], Demetra De Cicco[5], Aniello Grado[7],
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[5]*Dipartimento di Fisica "E. Pancini", Università degli Studi Federico II, Napoli 80126, Italy*
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[8]*Department of Physics & Astronomy, University of the Western Cape, Robert Sobukwe Road, 7535 Bellville, Cape Town, South Africa*
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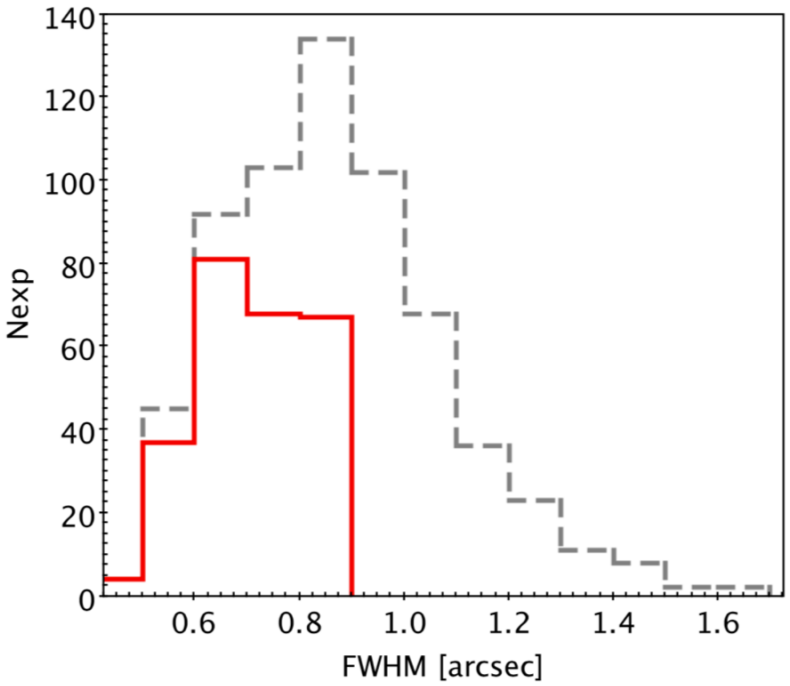
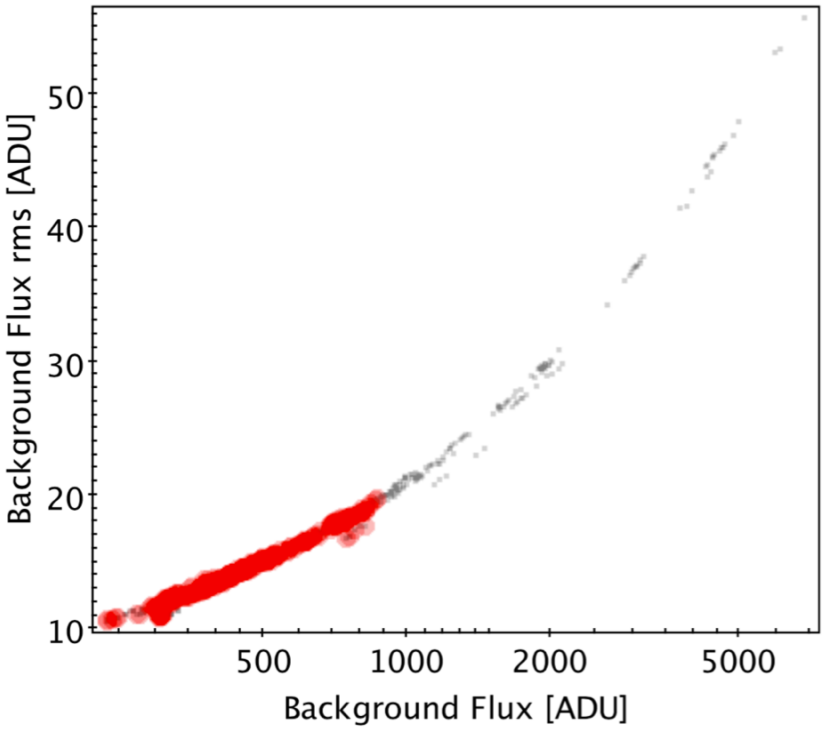
# Weak lensing selection criteria

Seeing < 0.9”




BG Flux rms < 20 ; BG Flux <900

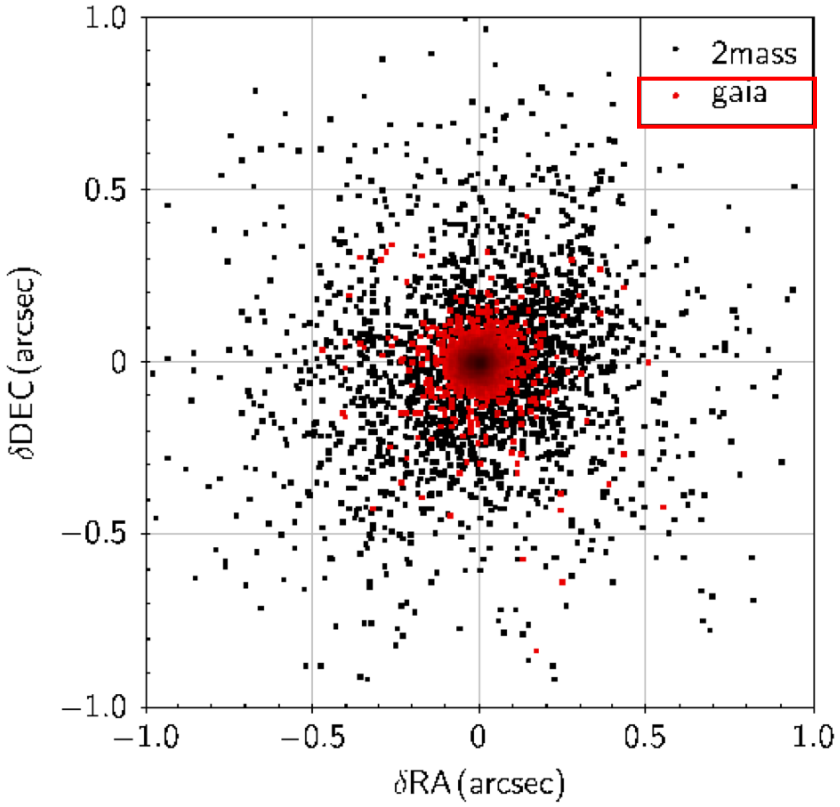



| r | $N_{exp}$ observed | $N_{exp}$ selected |
|---|---|---|
| CDFS1 | 209 | 62 |
| CDFS2 | 153 | 54 |
| CDFS3 | 206 | 79 |
| CDFS4 | 185 | 62 |

$r_{lim}$ = 26.1 (point source, 5σ)

~ 1.2 magnitude deeper than KiDS.

# Astrometric calibration




$\delta_{gaia}$ = 0.056”  $\delta_{2mass}$ = 0.19”

-- GAIA

- smaller intrinsic astrometric uncertainties
- higher matched number of stars with respect to 2MASS.

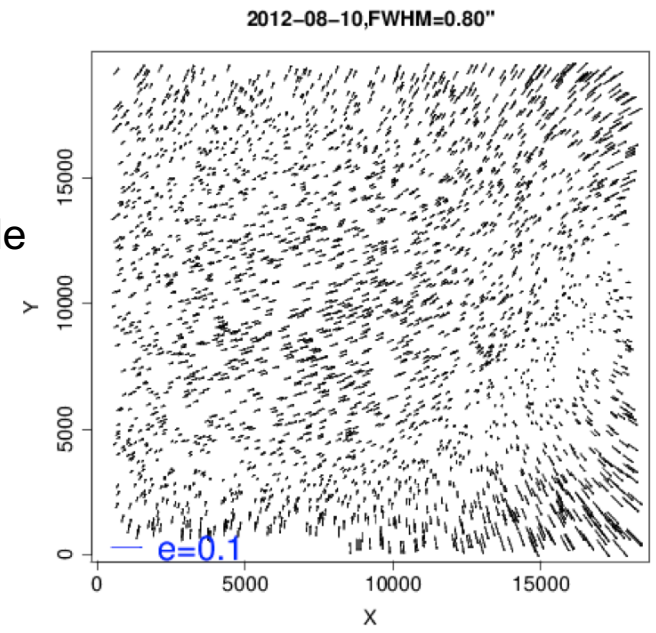
# PSF example

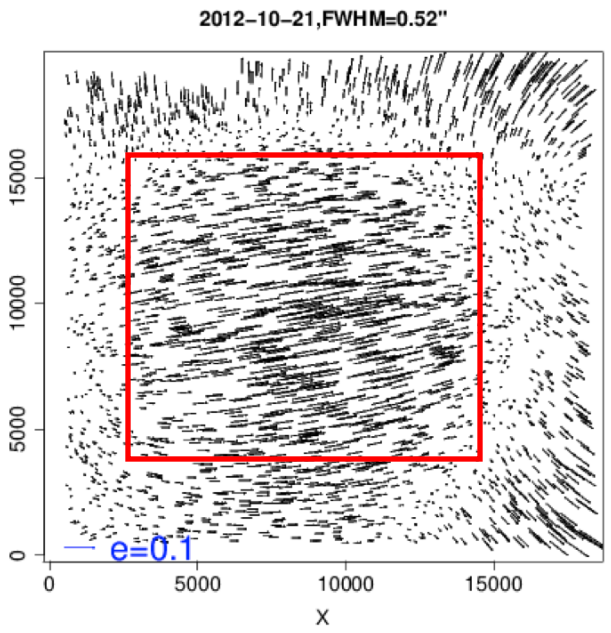
-- CDFS1, different epochs

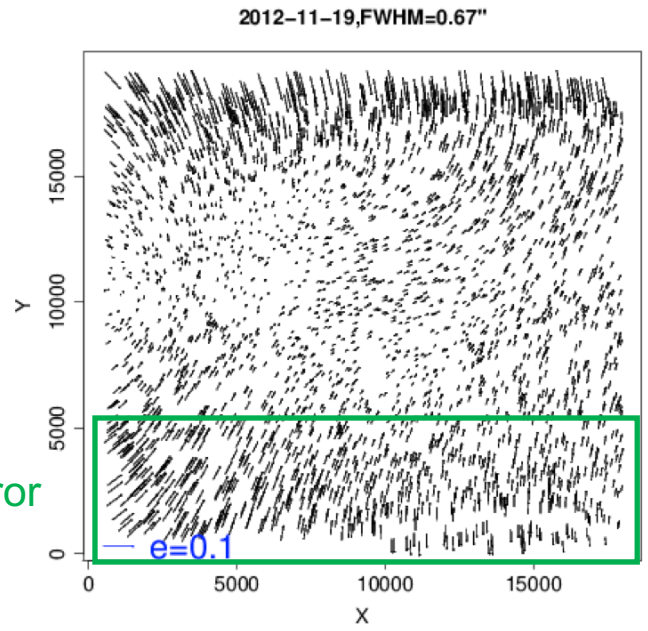
-- PSF model fitting on single exposures

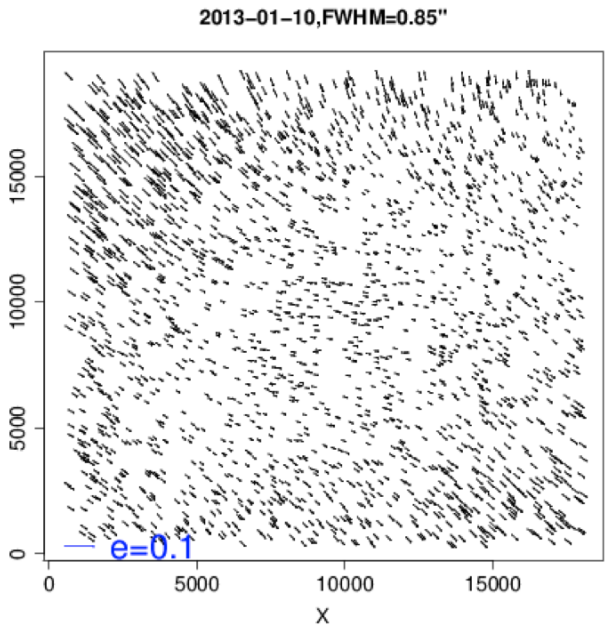
-- The primary mirror astigmatism of the curved focal plane

-- a tilt of the secondary mirror



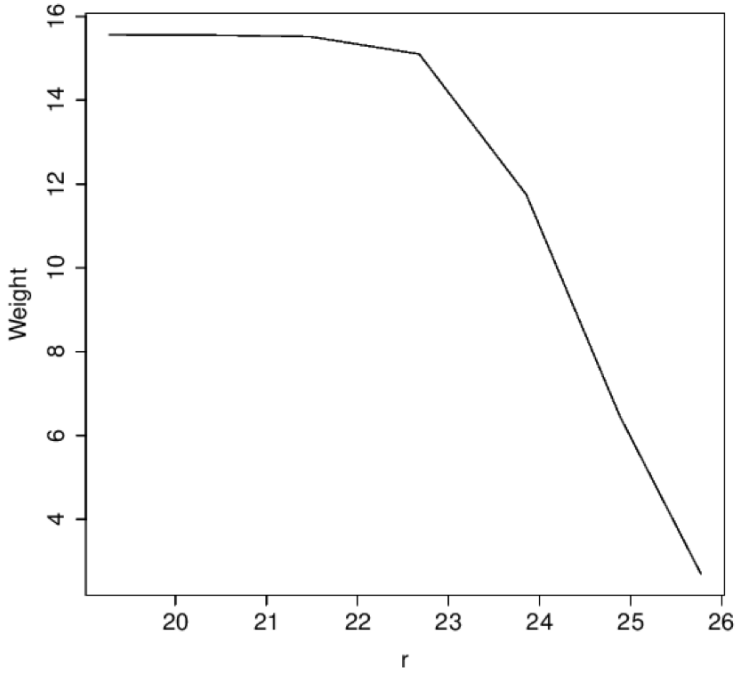



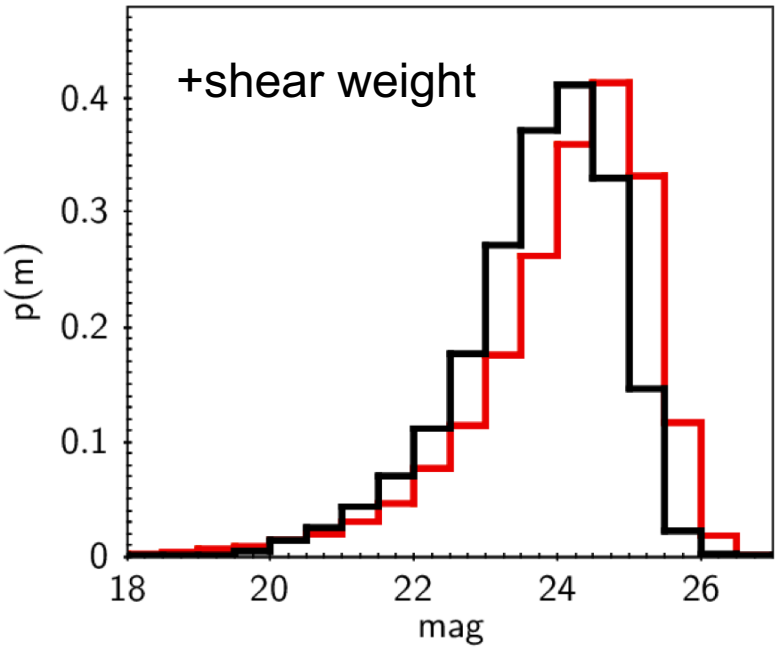
# Shear measurement: Lensfit (CFHTLenS, KiDS, Miller+ 13)

- Lensfit first time applied on few tens exposures ← calibrated from VOICE imaging simulation.

- PSF and galaxy model on single exposure;
- Multiple exposures joint fit → Likelihoods of each galaxy;

- 300,000 galaxy (weight > 0) → $n_{eff}$=16.35 gal/arcmin$^2$ ~ twice of KiDS';



# Photometric redshift catalog

-- VOICE ugri + VIDEO YJHKs ~~Z~~

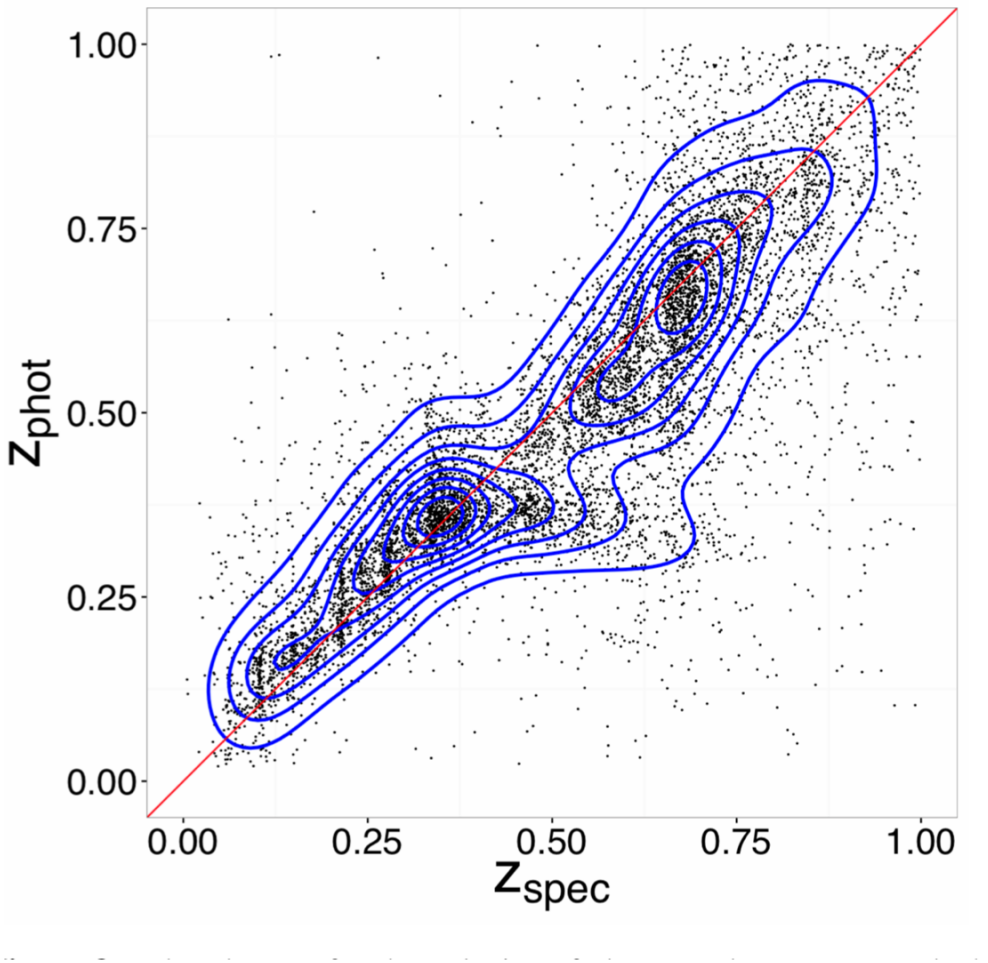
| | $u$ | $g$ | $r$ | $i$ |
|---|---|---|---|---|
| CDFS1 | 5.20 | 5.64 | 20.90 | 8.41 |
| CDFS2 | 6.50 | 4.83 | 15.30 | 4.38 |
| CDFS3 | 0.83 | 6.94 | 20.60 | 9.47 |
| CDFS4 | 0.83 | 5.43 | 18.50 | 8.51 |

-- BPZ

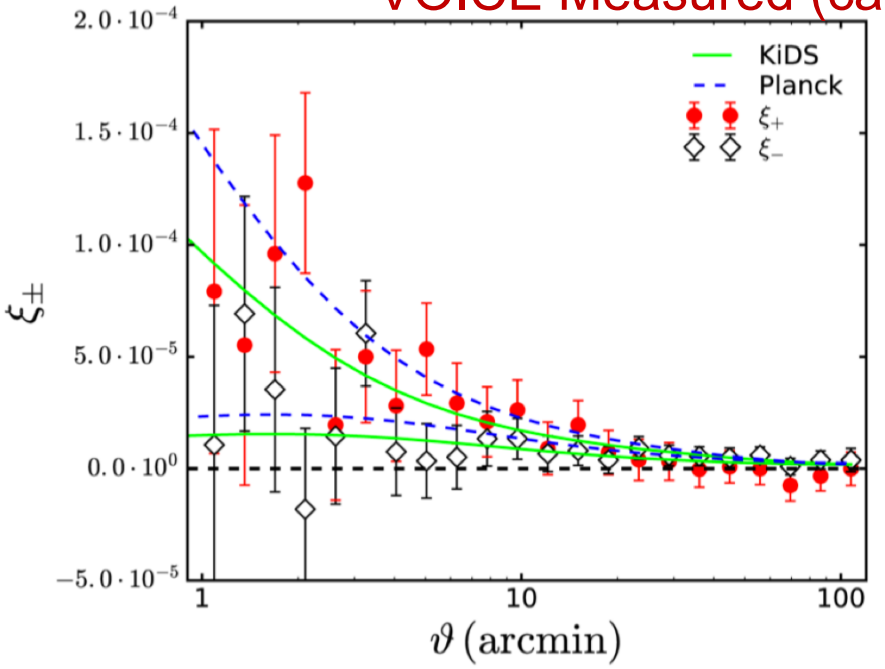
-- Shear catalog: <z> = 0.87; $z_{median}$=0.83

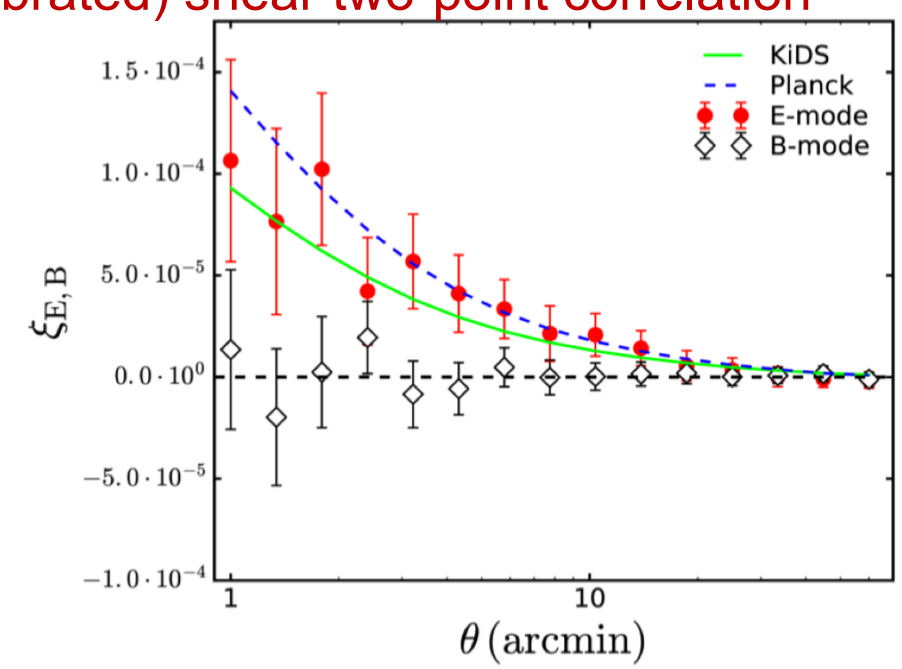
-- Z_spec: 23638

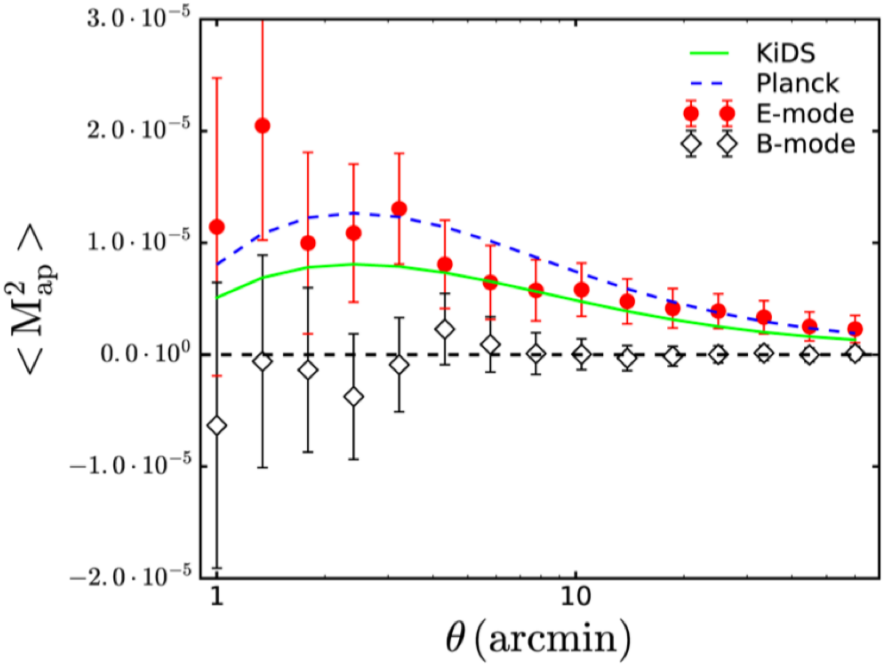
-- δz = (Photo-z–Spec-z) / (1+Spec-z)
= -0.008

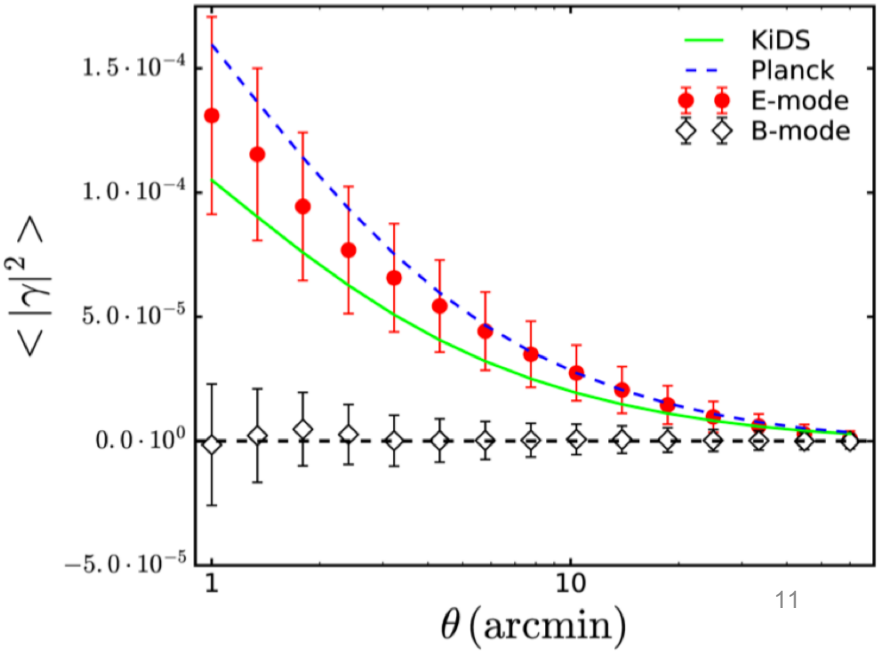


# VOICE Measured (calibrated) shear two-point correlation



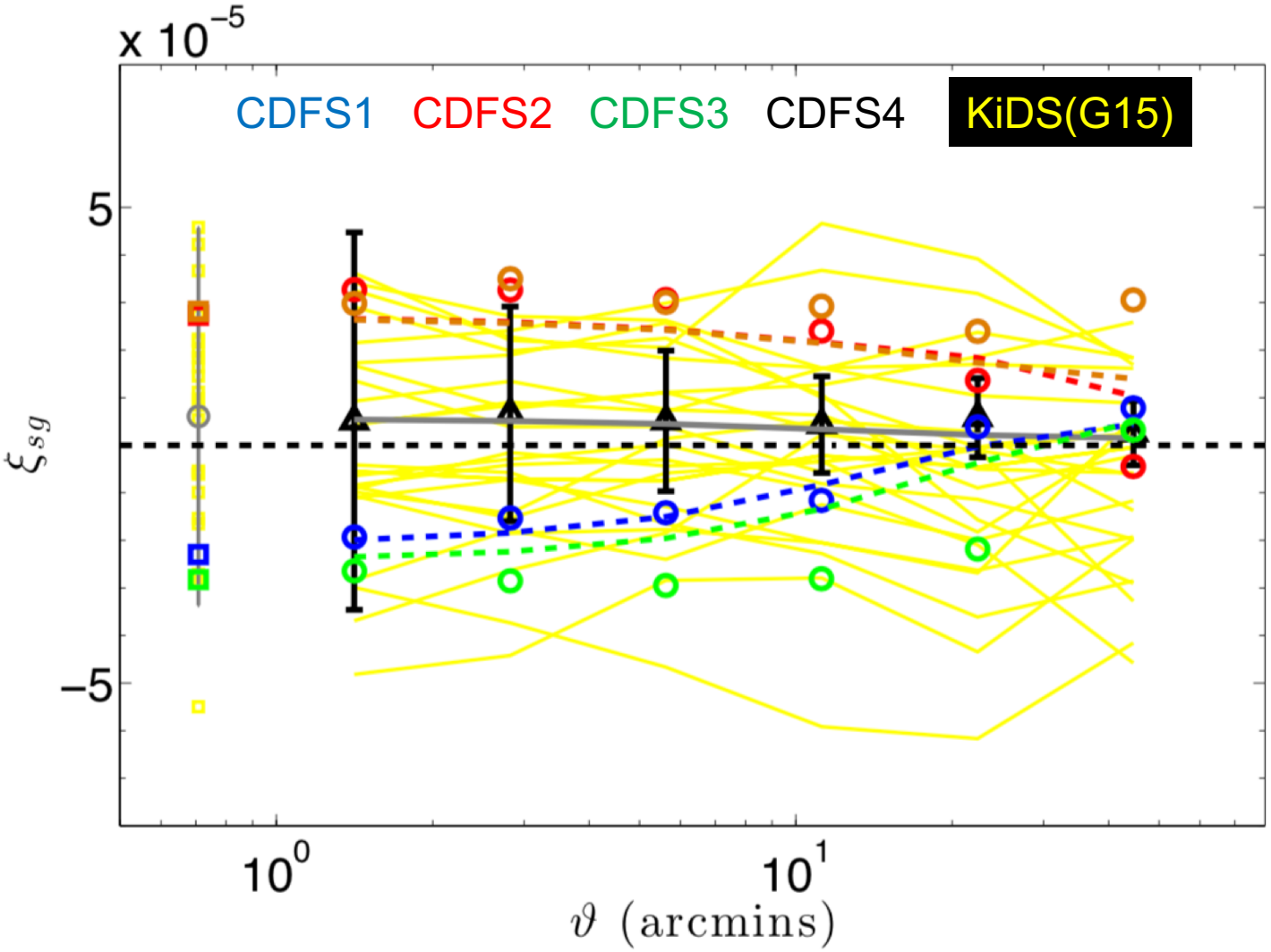



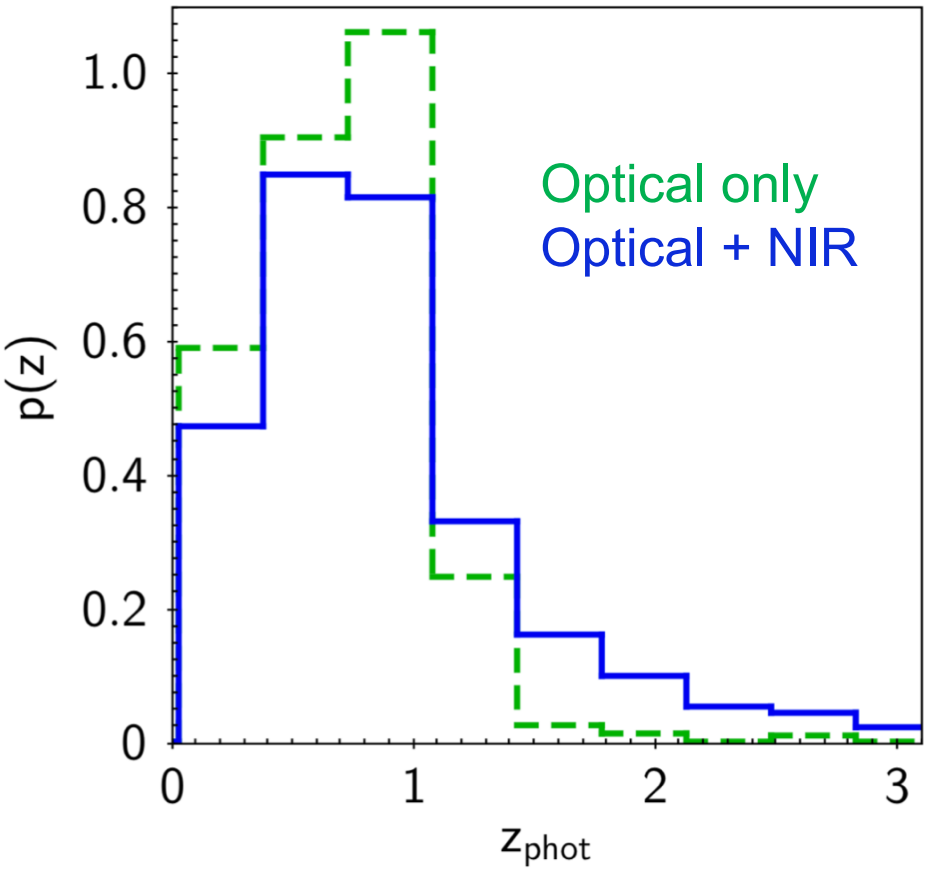
# Sanity checks

1. Star-galaxy correlations → check PSF correction



## 2. Photo-z using optical bands only (ugri)

| | | Ngal | $\delta z$ |
|---|---|---|---|
| 8-band photo-$z$ | all | 23638 | $-0.008$ |
| | low-$z$ | 19389 | $-0.012$ |
| | high-$z$ | 4069 | 0.022 |
| 4-band photo-$z$ | all | 23638 | $-0.010$ |
| | low-$z$ | 20168 | $-0.015$ |
| | high-$z$ | 3300 | 0.063 |

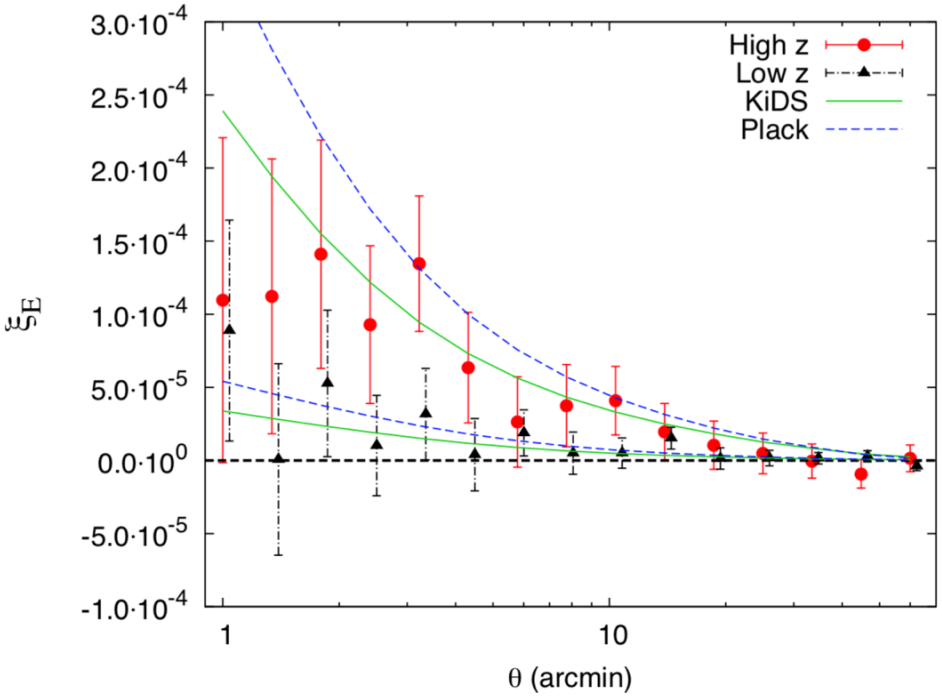


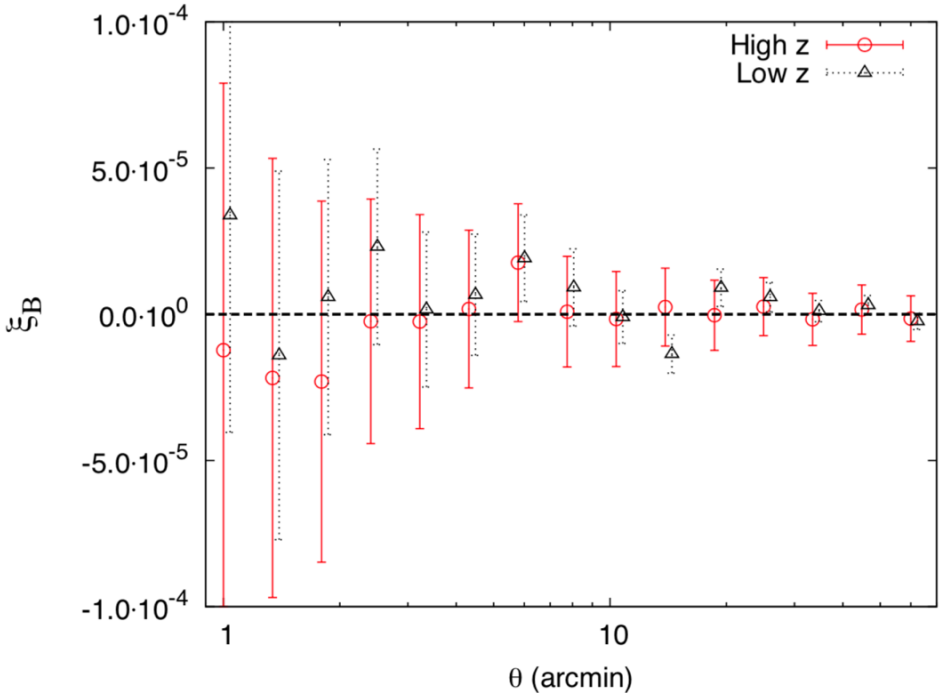
# 3.Tomography check

| | | Ngal | $\delta z$ |
|---|---|---|---|
| 8-band photo-$z$ | all | 23638 | −0.008 |
| | low-$z$ | 19389 | −0.012 |
| | high-$z$ | 4069 | 0.022 |

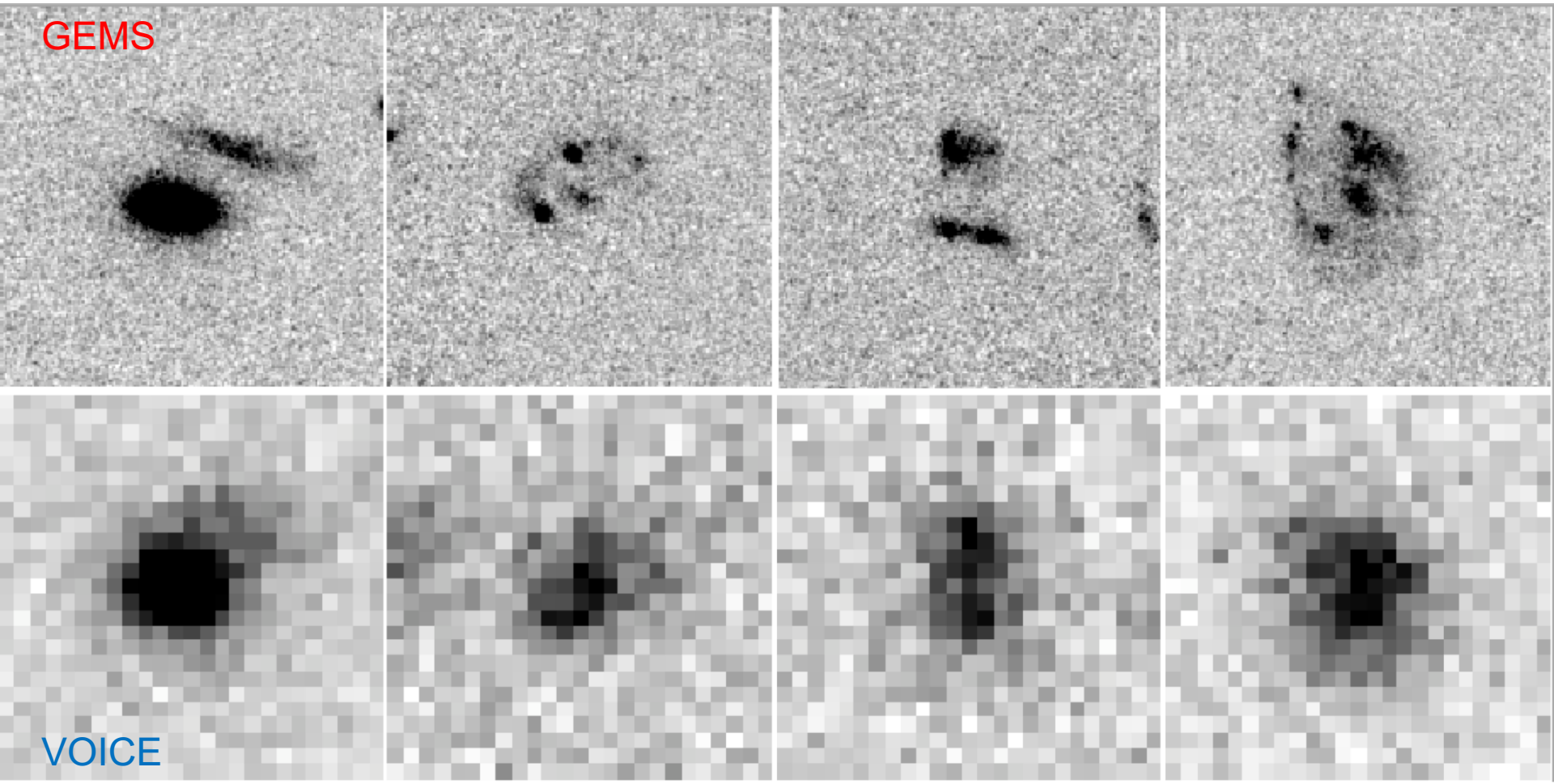
High-z: $z >= z_{median}$ (0.83);

Low-z : $z < z_{median}$ (0.83);



# 4. Blending check

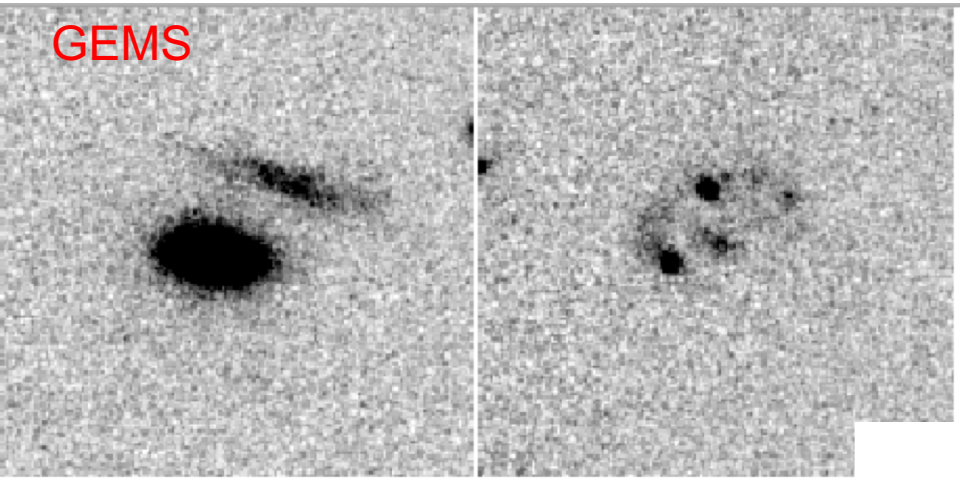


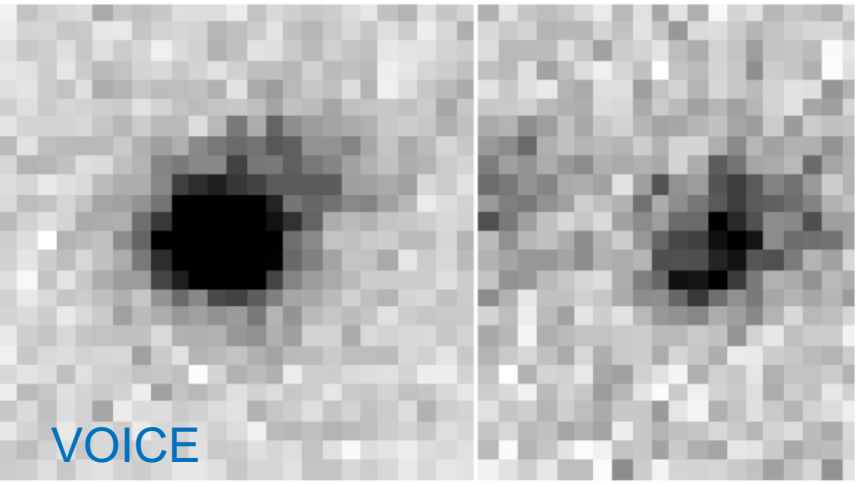

Blender: separation < 3”

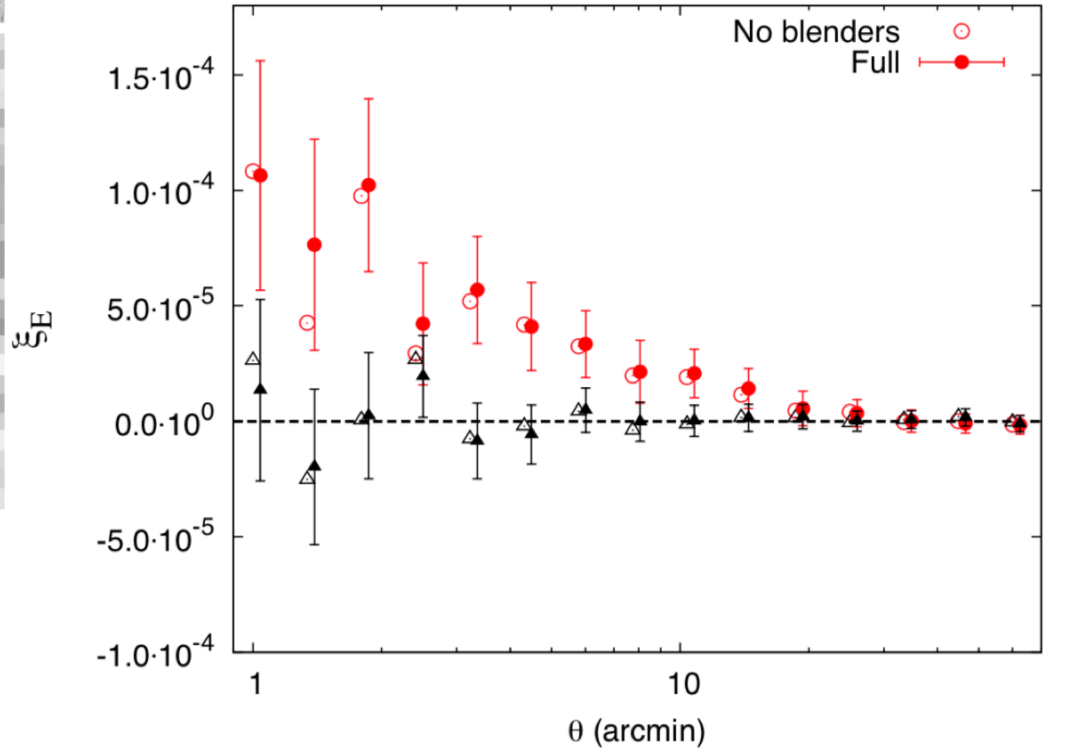
-- 8% of shear catalog (weight > 0)

# 4. Blending check

5 arcsec




Blender: separation < 3”

-- 8% of shear catalog (weight > 0)

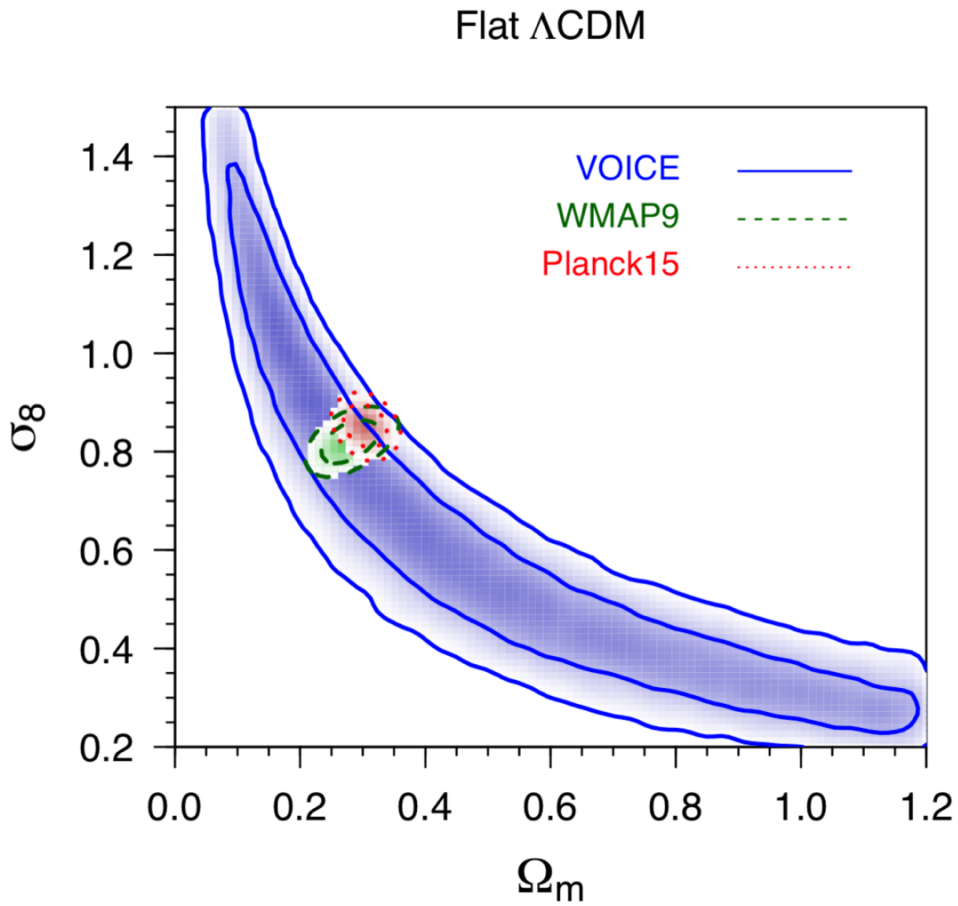
-- Minor effects on two-point correlations

# Cosmological application using $\langle M_{\rm ap}^2 \rangle$

-- No-systematics (no baryons, no photo-z err., no Intrinsic Alignment)

-- Weak lensing most sensitive to:

Small-scale density-fluctuations amplitude $\sigma_8$
Total matter density $\Omega_m$



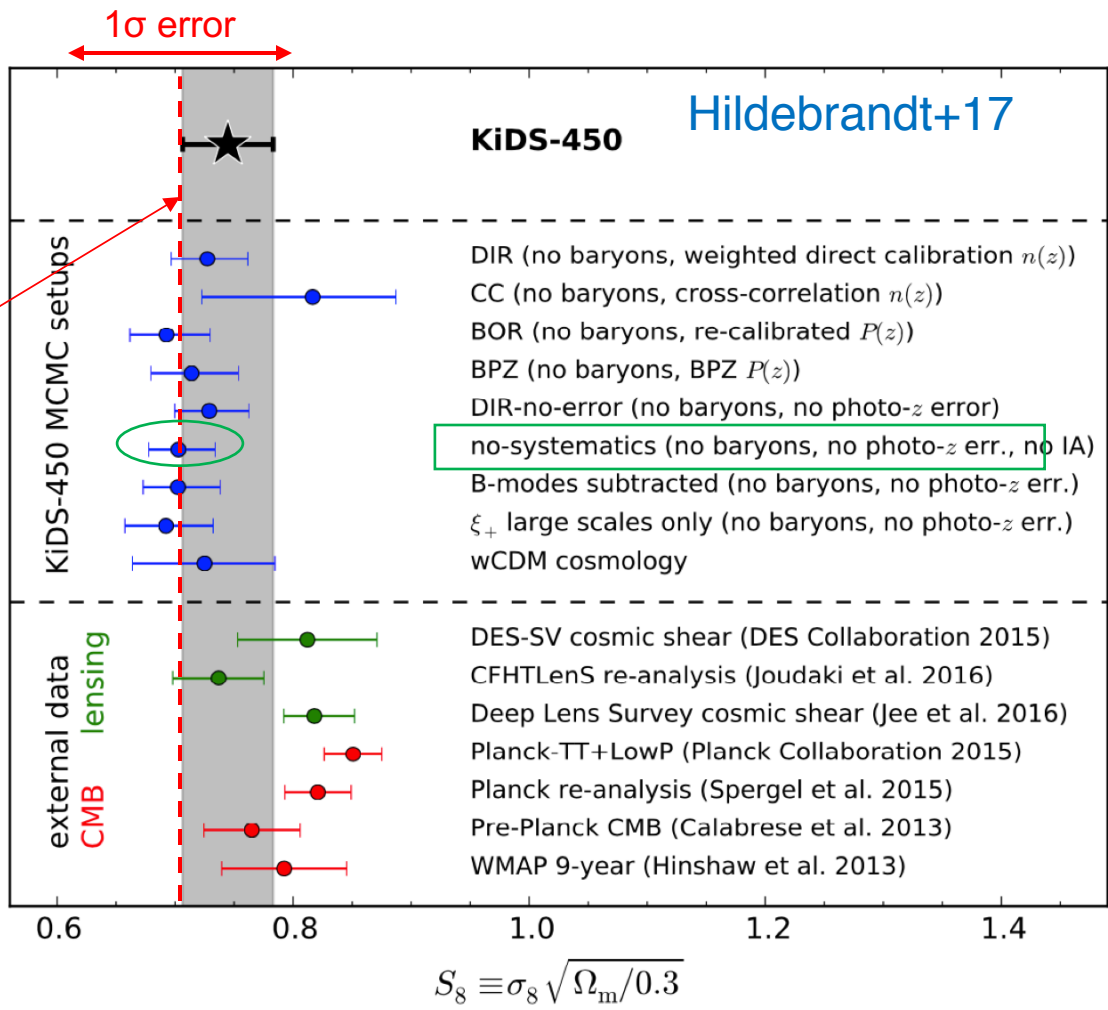
# Cosmological application using $\langle M_{\rm ap}^2 \rangle$

-- No-systematics (no baryons, no photo-z err., no Intrinsic Alignment)

VOICE

$$\Sigma_8 = \sigma_8(\Omega_{\rm m}/0.3)^{\alpha}$$

| Parameter | flat ΛCDM | flat $w$CDM | curved ΛCDM |
|---|---|---|---|
| $\Sigma_8$ | $0.704^{+0.111}_{-0.121}$ | $0.691^{+0.135}_{-0.129}$ | $0.688^{+0.148}_{-0.138}$ |
| $\alpha$ | $0.637 \pm 0.016$ | $0.65 \pm 0.04$ | $0.739 \pm 0.009$ |



# II. VOICE-like imaging simulation

## Weak Lensing Study in VOICE Survey II: Shear Bias Calibrations


Dezi Liu[1,2,3]★, Liping Fu[2]†, Xiangkun Liu[3], Mario Radovich[4], Chao Wang[1], Chuzhong Pan[1], Zuhui Fan[1]‡, Giovanni Covone[5,6,7], Mattia Vaccari[8,9], Maria Teresa Botticella[7], Massimo Capaccioli[5], Enrico Cappellaro[4], Demetra De Cicco[5], Aniello Grado[7], Lance Miller[10], Nicola Napolitano[7], Maurizio Paolillo[5], Giuliano Pignata[11]

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## Goal

- Build “realistic” simulation for Deep image: deblanding, dithering, complex PSF
- Optimize parameters of Lensfit
- Estimate and calibrate shear bias
- Impact of blending galaxies
- Impact of galaxies below detection limit

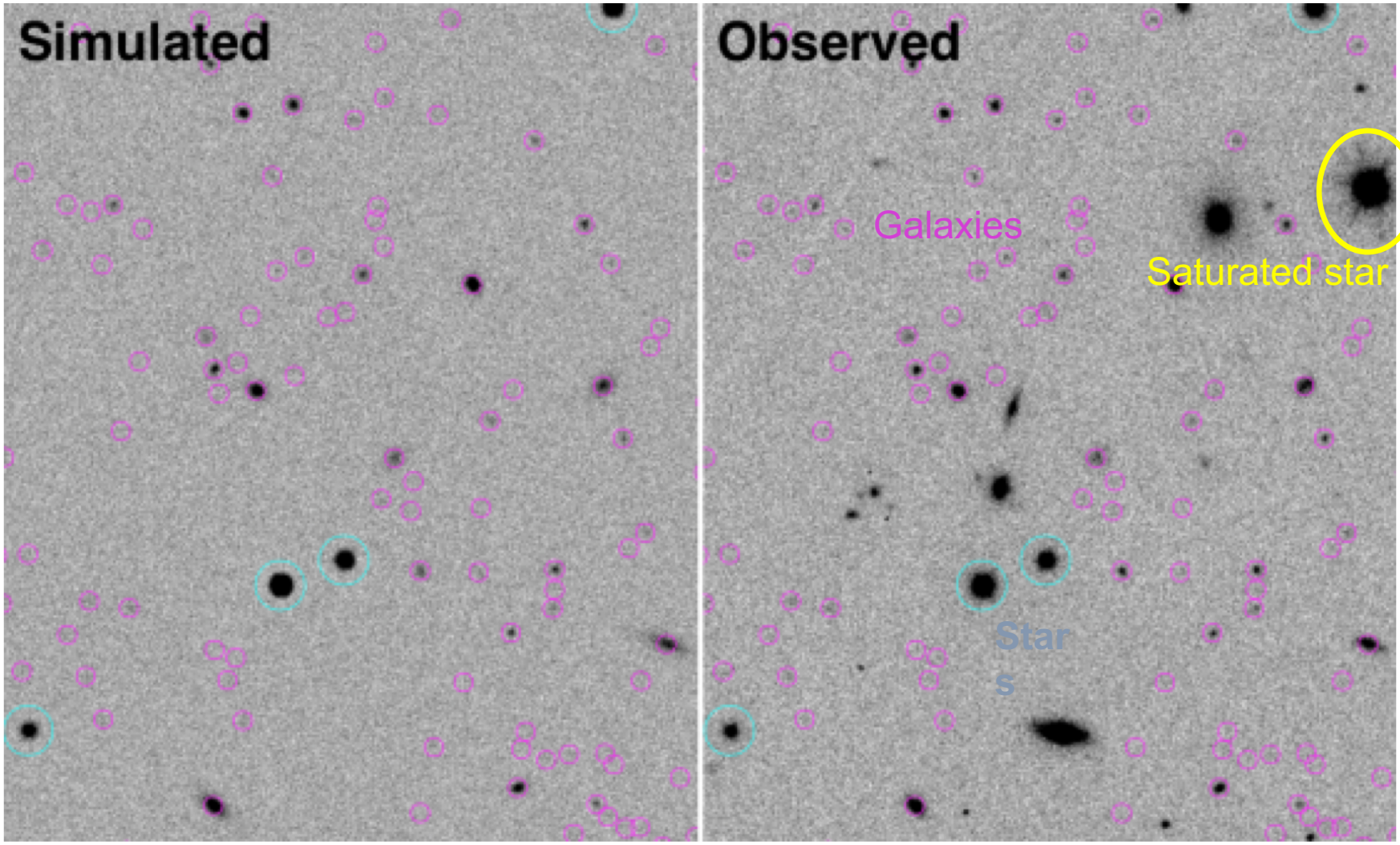
→ minor

### Simulation toolkit: Galsim (Rowe et al, 2015)

- S/G catalog: from observation (numbers, positions)
- Star (PSF) model: spatially varied PSF from observation (PSFEx )
- Galaxy model: exponential disc + De Vaucouleurs bulge

- Assign scale-length, ellipticity and shear components to every individual galaxy
- Weak lensing signal predicted by power spectrum
- Apply Gaussian noise with observed sigma of individual CCD

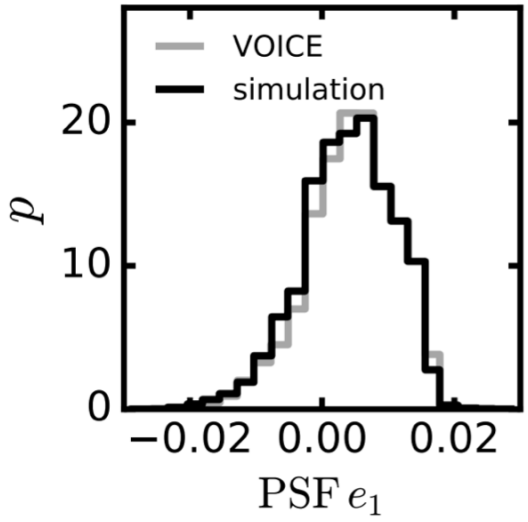
- Simulate for each individual exposure of VOICE

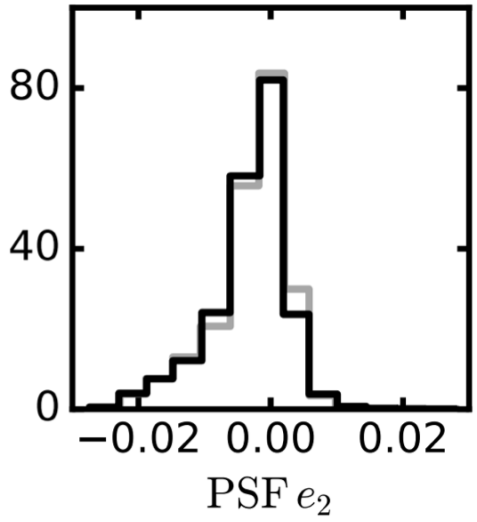



- Real S/G position
- Real PSF
- Same noise level

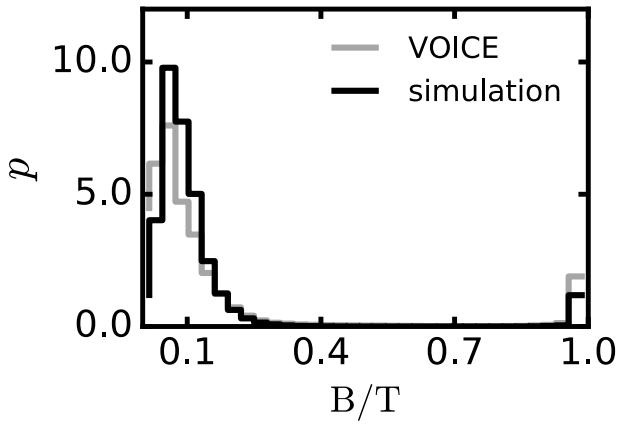
# Distributions

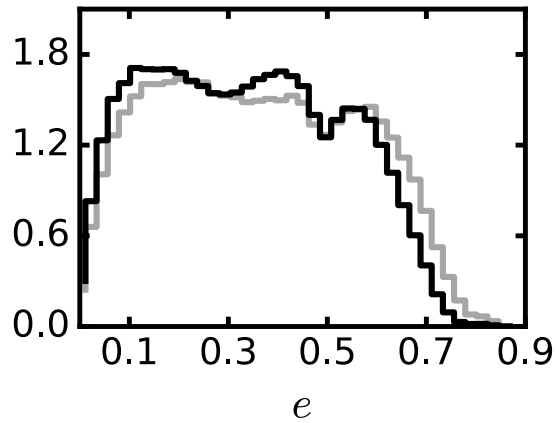
## Stars

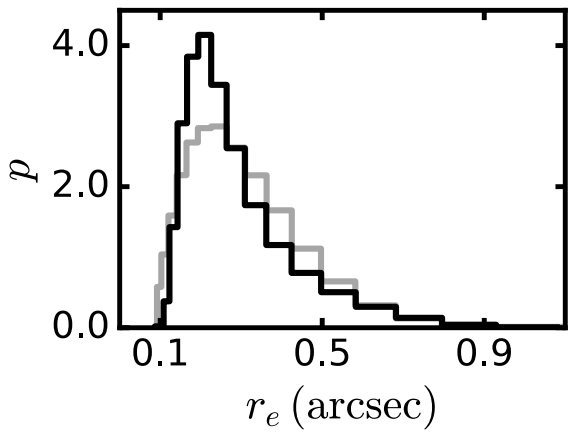


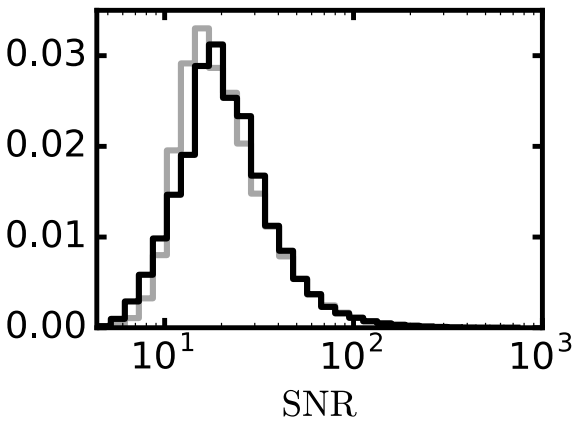




## Galaxies



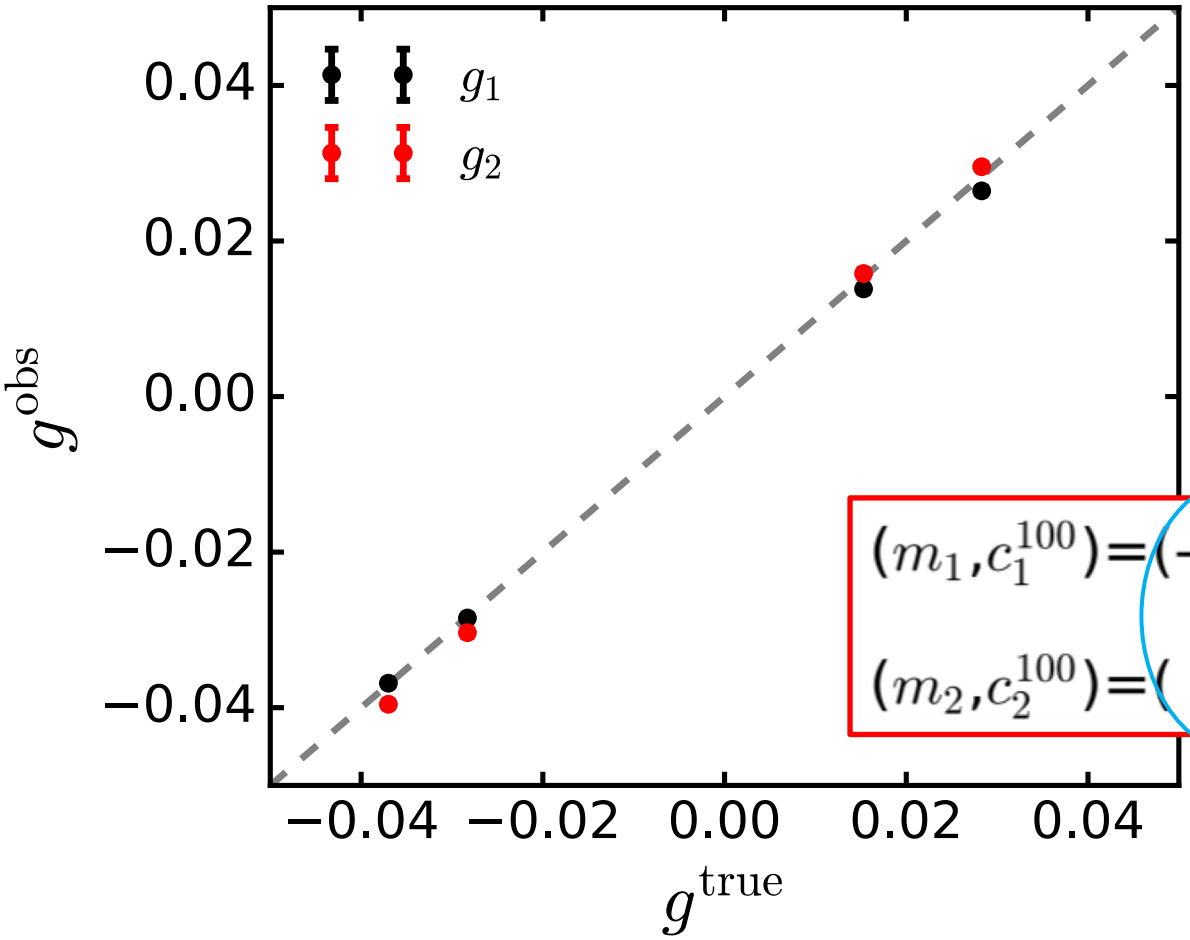



# Two sets of images with orthogonal ellipticity;

$g$ = 0.04;

$(g1,\ g2)$ = $(\pm 0.0283,\ \pm 0.0283)$; (+0.0153, −0.0370); (−0.0370, +0.0153)




$\boldsymbol{g}^{\rm obs} = (1+\boldsymbol{m}) \times \boldsymbol{g}^{\rm true} + \boldsymbol{c}$

$(m_1, c_1^{100})$=(-0.03±0.01,-0.10±0.02)

*10$^{-2}$

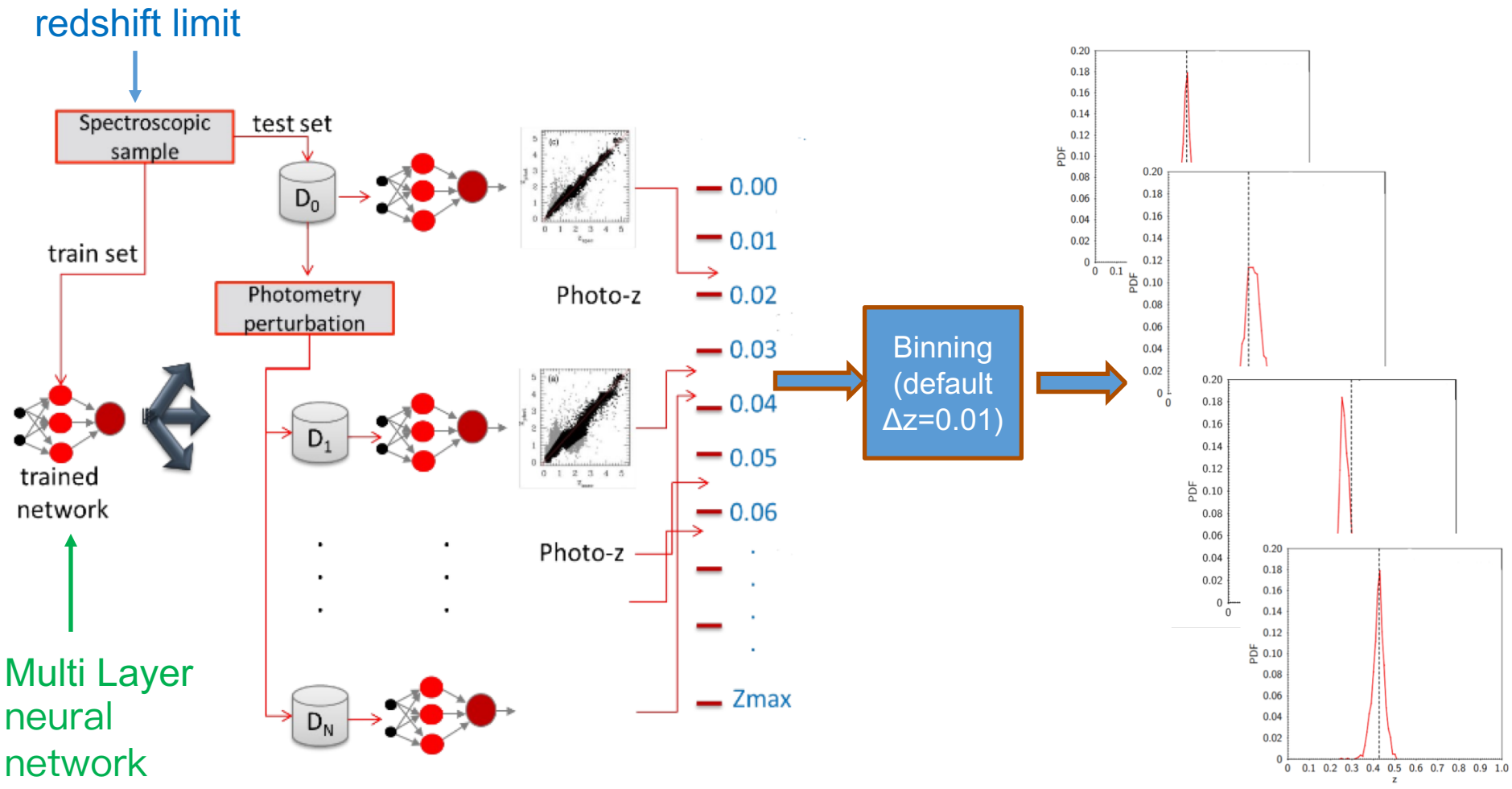
$(m_2, c_2^{100})$=( 0.06±0.01,-0.04±0.02)

# III. VOICE photo-z estimation

**+Collaboration with: V. Amaro, S. Cavuoti, M. Brescia, C. Vellucci, G. Longo**

# METAPHOR Machine-learning Estimation Tool for Accurate Photometric Redshifts

*Cavuoti+ 2017*



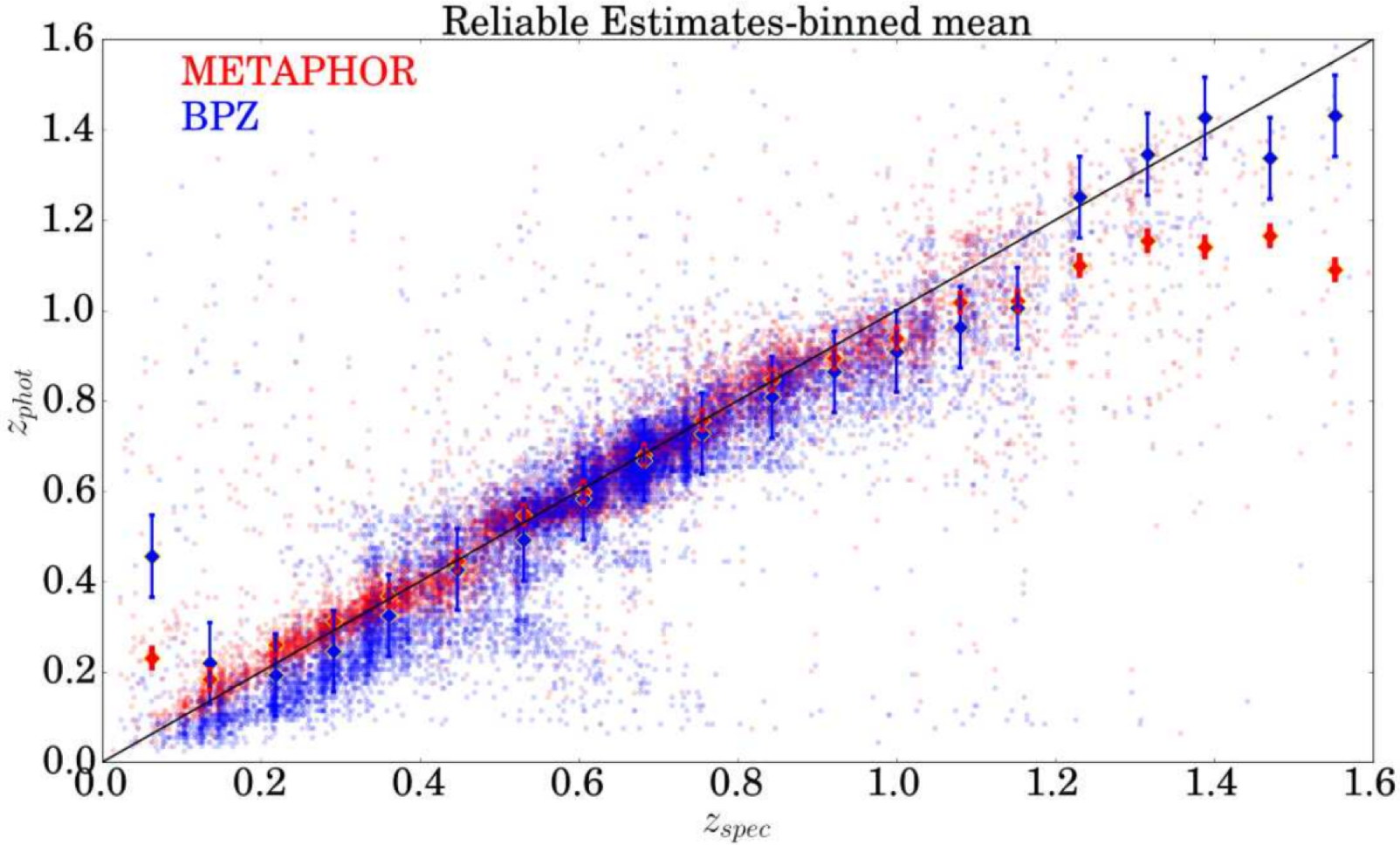
# VOICE: photo-z vs spec-z

-- ~23000 spec-z, up to 1.6

-- BPZ, shear cat & spec-z matching: 1 arcs → ~13000 objects

-- METAPHOR:

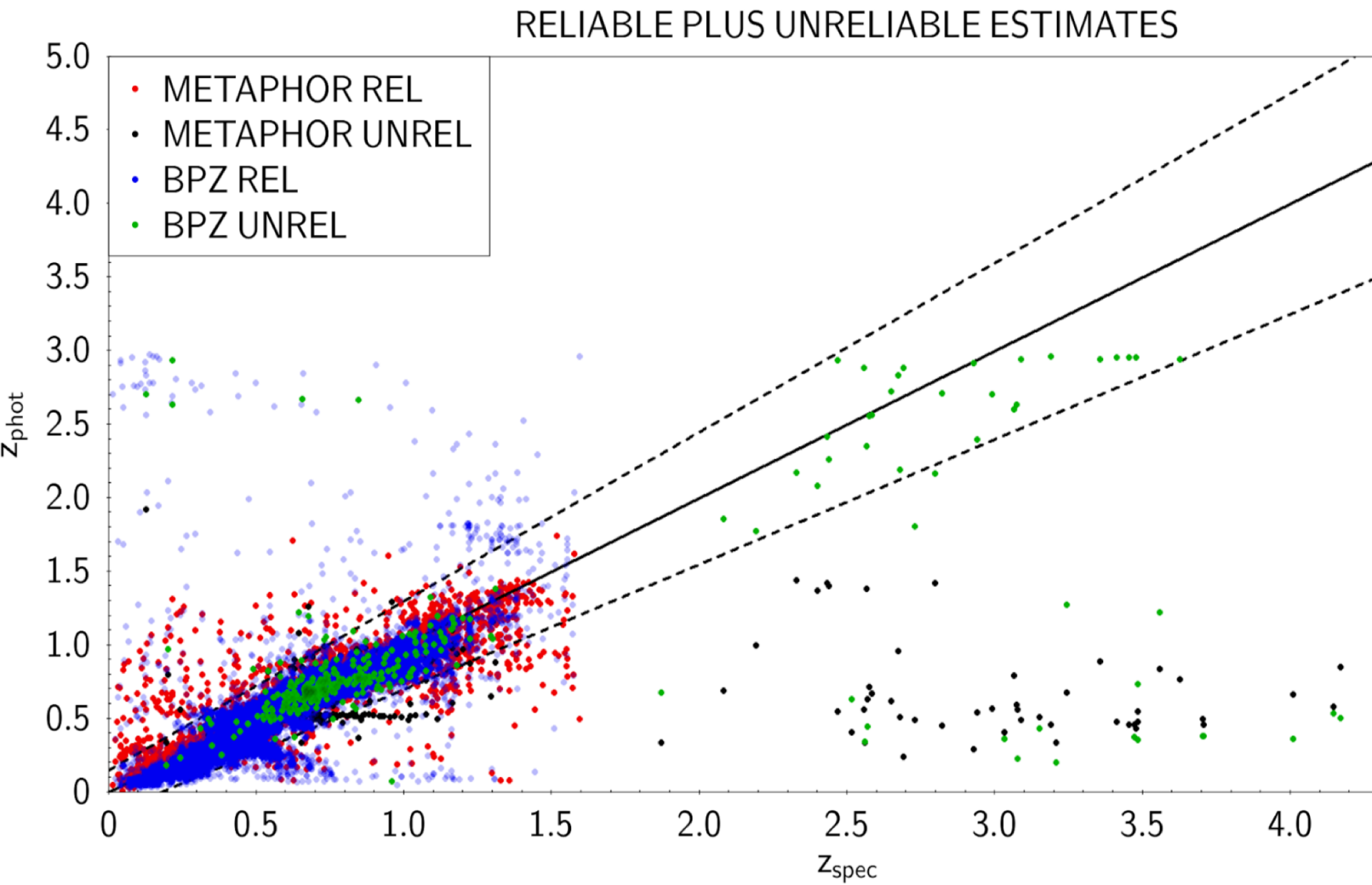
- feature selection: optimize of parameter space (photometry, colors, morphology);
- require all bands detection



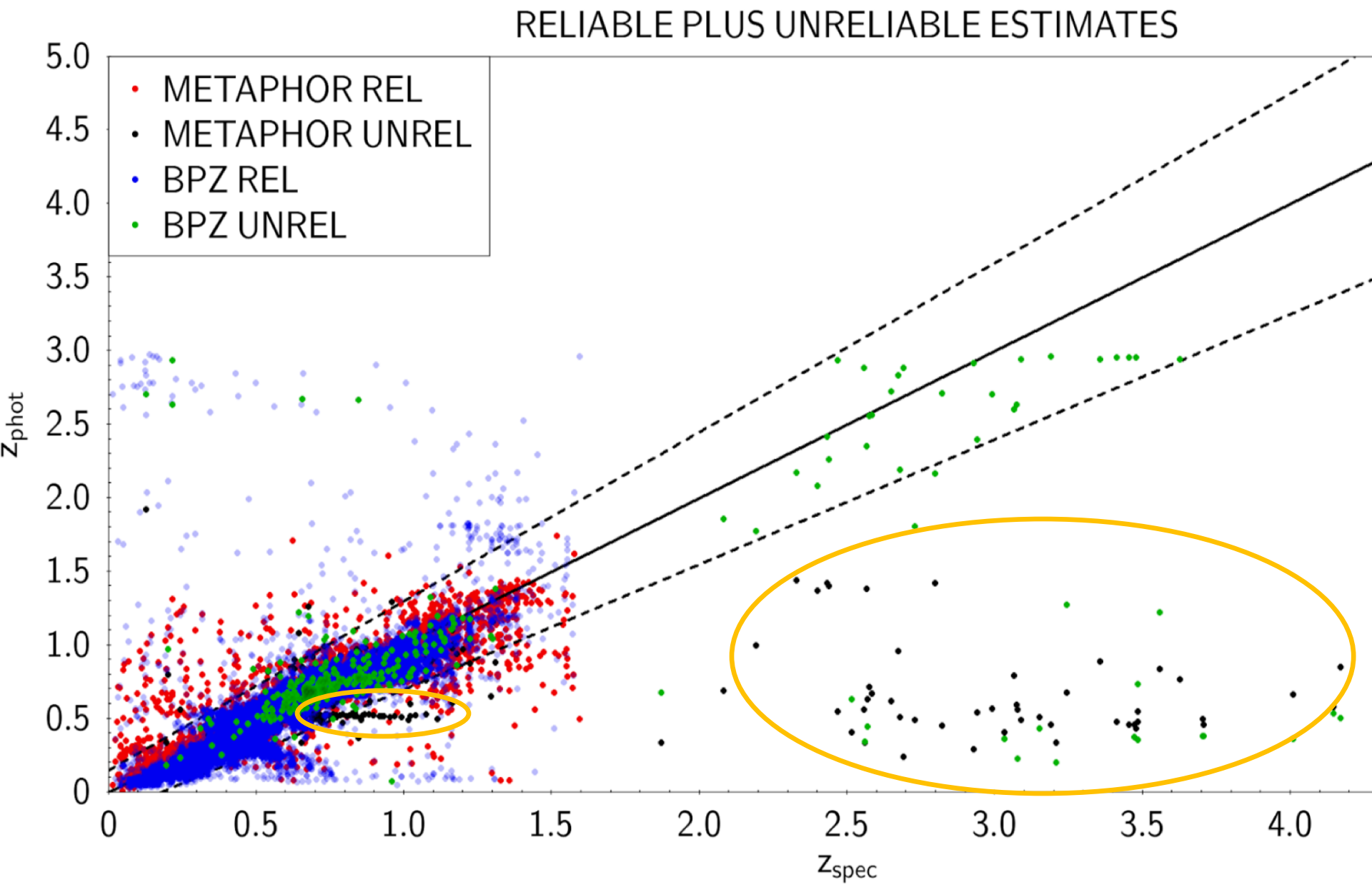
# METAPHOR vs BPZ

| Estimator | Reliable (#11,997) zspec<=1.6 | | unreliable (#286) zspec<=1.6 | | unreliable (#48) zspec>1.6 | |
|---|---|---|---|---|---|---|
| | METAPHOR | BPZ | METAPHOR | BPZ | METAPHOR | BPZ |
| \|bias\| | 0.001 | 0.015 | 0.030 | 0.025 | 0.570 | 0.275 |
| sigma | 0.065 | 0.154 | 0.136 | 0.253 | 0.118 | 0.083 |
| NMAD | 0.027 | 0.053 | 0.075 | 0.047 | 0.083 | 0.189 |
| Skew | -3.7 | -9.9 | -6.3 | -7.1 | -1.3 | 0.5 |
| Kurtosis | 44.5 | 142.1 | 71.8 | 55.3 | 0.6 | -1.5 |
| out_norm>0.15 | 2.8 % | 6.4% | 14.3% | 5.6% | 100% | 41.7% |

# METAPHOR unreliable objects



# METAPHOR unreliable objects



# METAPHOR next steps

- Missing bands of photometry → losing objects

  -- down weight (=0) of missing bands?

- For VOICE deep survey,

  -- METAPHOR (z < zspect & reliable) + BPZ (z > zspect & unreliable)

  -- How to combine them? Systematics?

# Summary

- Cosmic shear is measured using VOICE deep survey (CDFS 4 $deg^2$),

  $n_{eff}$=16.35/$arcmin^2$, $r_{lim}$=26.08, 3x$10^5$ galaxies with shear + photo-z;

- The shear signal has been calibrated using simulations;

- The shear two-point correlations have passed a few nulling systematic checks.

- Next step:

✓ machine learning photoz

✓ cosmological analysis + systematics + intrinsic alignment;

✓ cluster searching: color-photoz;

✓ lensing mass map;

✓ tomographic lensing;

✓ peak statistics…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