Cosmological constraints from the 100 square degree weak lensing survey

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Project overview

- Perform a weak lensing analysis of 4 of the largest data sets currently available:

	CFHTLS-Wide	GaBoDS	RCS	VIRMOS-DESCART
Area (deg^2)	22.0	13.0	53	8.5
$\mathrm{N_{fields}}$	2	52	13	4
Magnitude Range	$21.5 < i' < 24.5$	$21.5 < R < 24.5$	$22 < R_C < 24$	$21 < I_{AB} < 24.5$
$< z_{\mathrm{source}} >$	0.81	0.78	0.6	0.92
z_{median}	0.71	0.58	0.58	0.84
Previous Analysis	Hoekstra et al. (2006)	Hetterscheidt et al. (2006)	Hoekstra et al. (2002a)	Van Waerbeke et al. (2005)
σ_8 ($\Omega_m = 0.24$)	0.99 ± 0.07	0.92 ± 0.13	0.98 ± 0.16	0.96 ± 0.08
Statistic	$\xi_{E,B}(\theta)$	$\langle M_{ap}^2 \rangle(\theta)$	$\langle M_{ap}^2 \rangle(\theta)$	$\langle \gamma_{E,B}^2 \rangle(\theta)$

- Update the analysis in three key aspects:

1) Marginalize over shear bias as measured from simulated data (STEP)
2) Improve n(z) estimation by using the best photo-z catalogue (Ilbert et al. 2006)
3) Non-Gaussian contributions to the shear covariance matrix (Semboloni et al. 2007)

- Measure parameter likelihoods in the Ω_m - σ_8 plane
  - A flat ΛCDM cosmology is assumed throughout

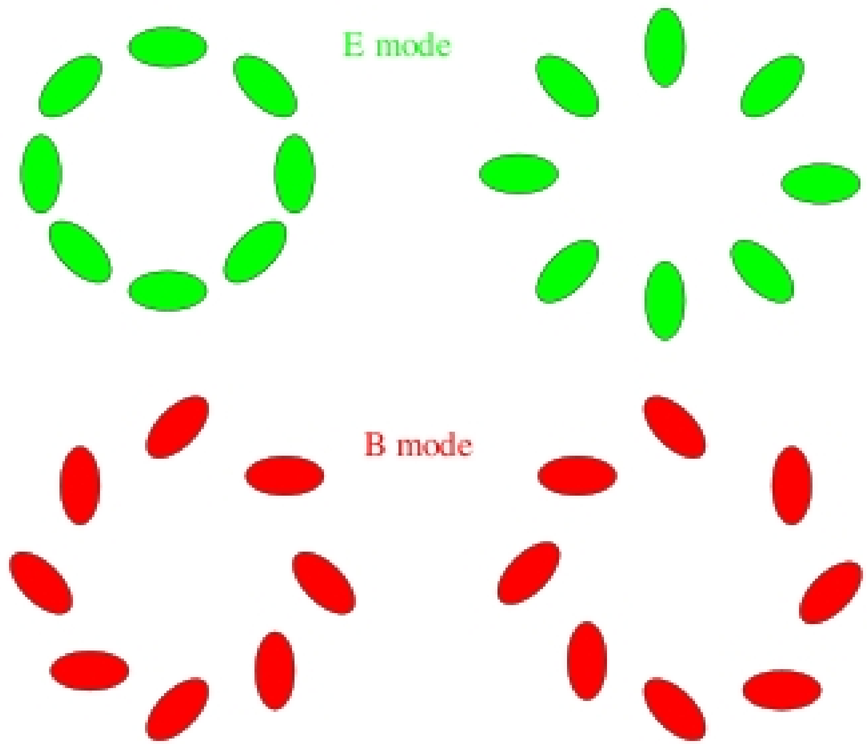
Choice of statistic

- E-mode: signal
- B-mode: systematics

$$\xi_+(r) = \langle\gamma_t(\theta)\gamma_t(\theta+r)\rangle + \langle\gamma_r(\theta)\gamma_r(\theta+r)\rangle$$
$$\xi_-(r) = \langle\gamma_t(\theta)\gamma_t(\theta+r)\rangle - \langle\gamma_r(\theta)\gamma_r(\theta+r)\rangle$$

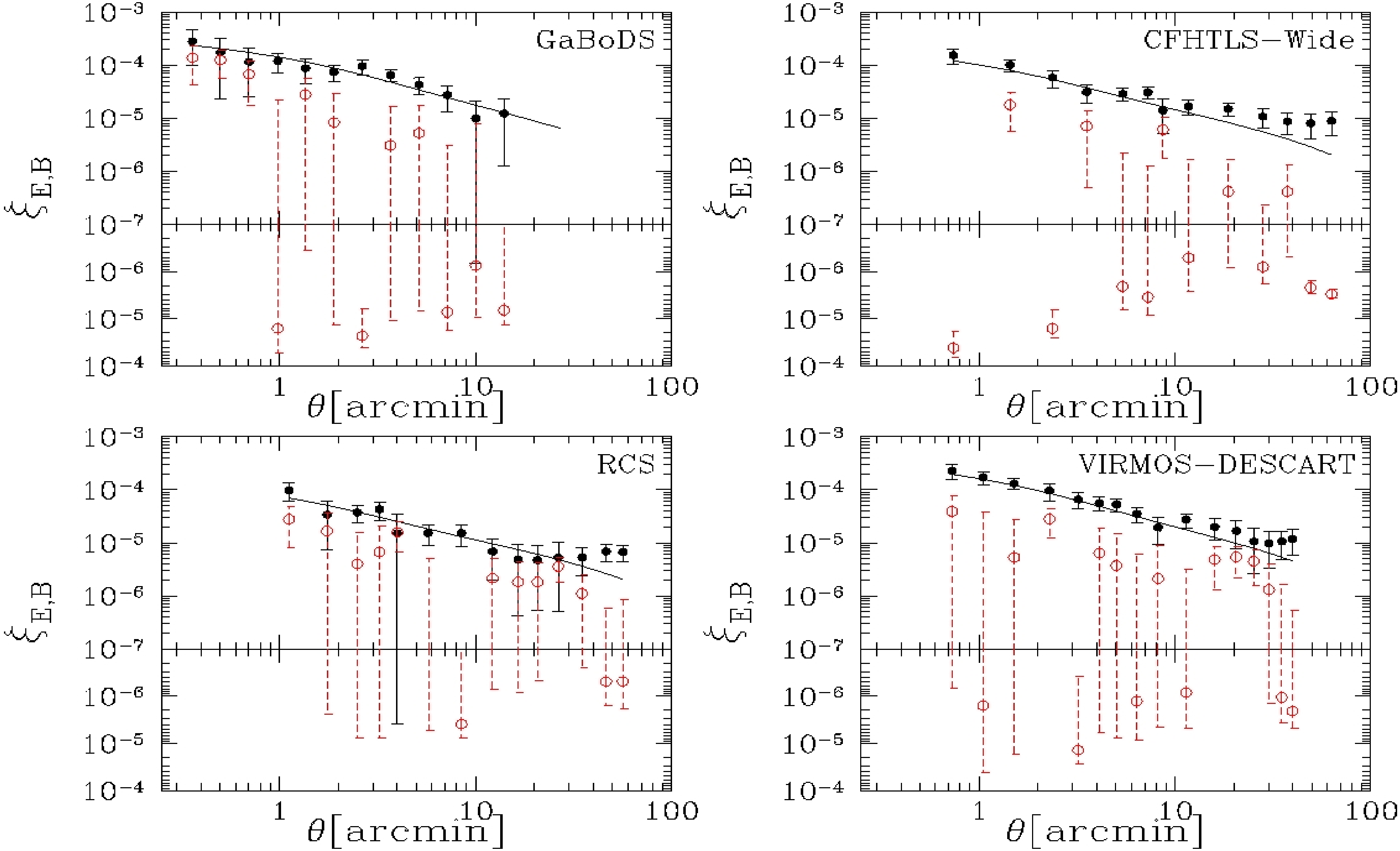
$$\xi^E(r) = \frac{\xi_+(r)+\xi'(r)}{2} \qquad \xi^B(r) = \frac{\xi_+(r)-\xi'(r)}{2}.$$

$$P_\kappa(k) = \frac{9}{4}\Omega_0^2 \int_0^{w_H} \frac{\mathrm{d}w}{a^2(w)} P_{3D}\left(\frac{k}{f_K(w)}; w\right) \times \left[\int_w^{w_H} \mathrm{d}w' n(w') \frac{f_K(w'-w)}{f_K(w')}\right]^2,$$



Shear signal

Removing all scales with non zero B-modes from the analysis changes the resulting σ_8 by ~0.01



1- Calibration bias

- The Shear TEsting Program (STEP) has used simulated data to test shear measurement methods.
- Deviations from perfect shear recovery are quantified by a bias (m) and an offset (c)

$$\gamma_{\rm meas} - \gamma_{\rm true} = m\gamma_{\rm true} + c$$

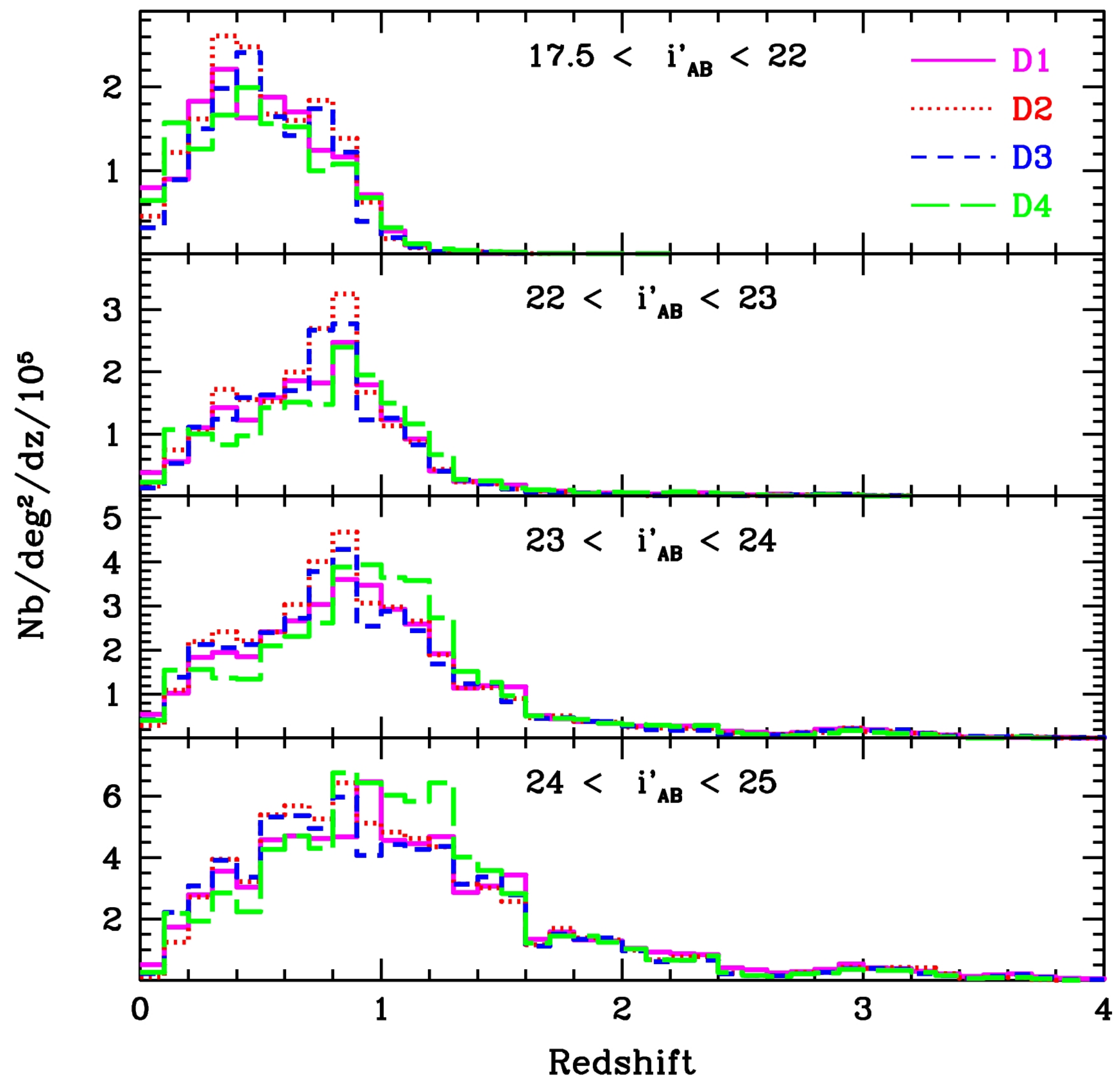
- The offset is small and dependent on the PSF strength and should appear in the B-modes which we conservatively add to the error budget
  - therefore taking c=0 is reasonable
- Since ξ_E is a second order shear statistic we are left with:

$$\xi_E^{\rm true} = \xi_E^{\rm meas}(m+1)^{-2}$$

  - where m=-0.0017±0.0088 for CFHTLS-Wide, RCS, and VIRMOS
  - and m=0.038±0.026 for GaBoDS
- We marginalize over m when calculating likelihood contours

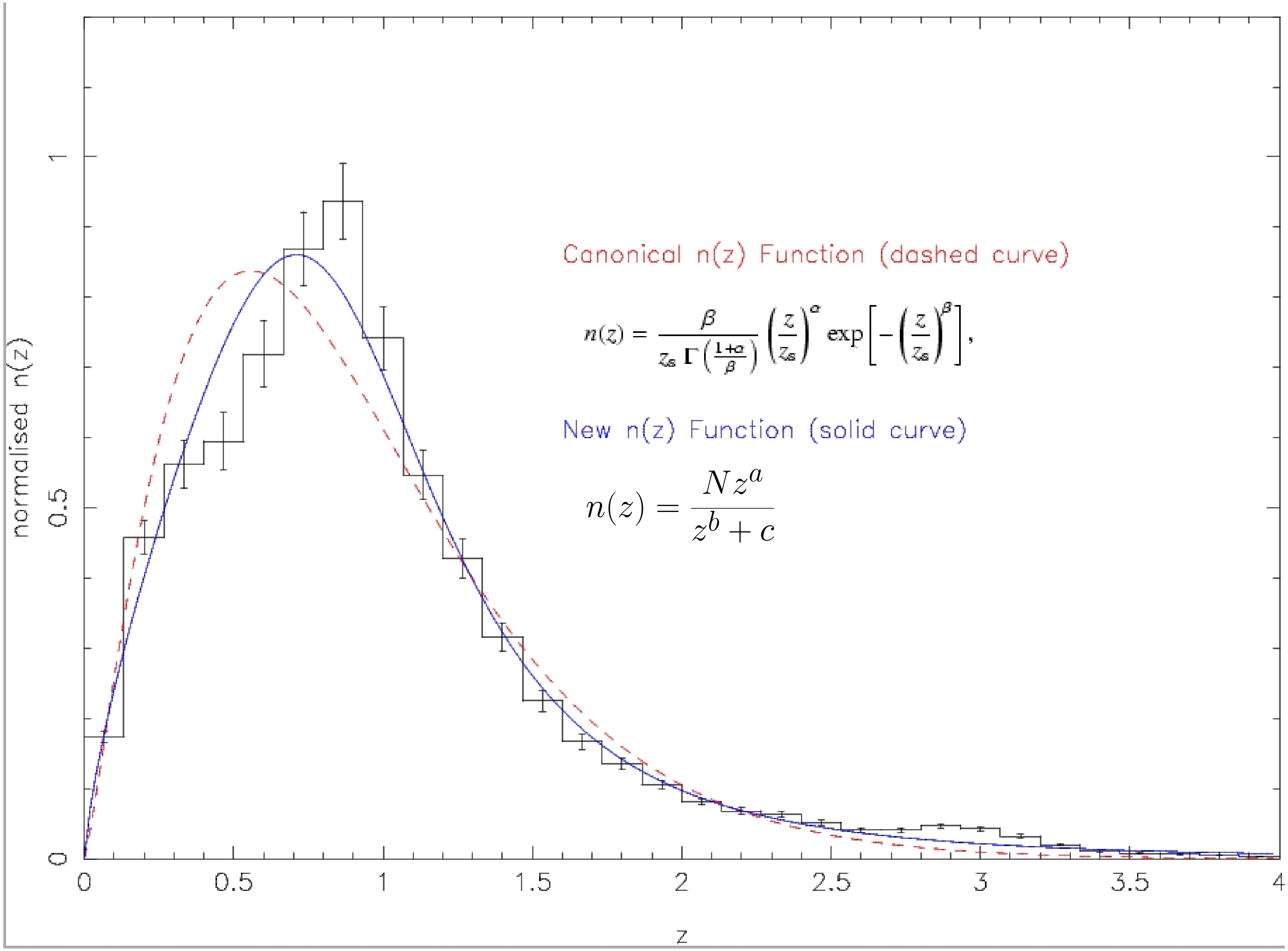
2 - Redshift distribution

- Ilbert et al. (2006) photometric redshift catalogue from the CFHTLS-Deep data
- Over $5x10^5$ galaxies, calibrated with over 3000 spectroscopic redshifts from VVDS
  - $0.0 < z_p < 4.0$
- High confidence redshifts
  - $0.2 < z < 1.5$
- Hubble Deep Fields, used in previous WL studies have only $1x10^3$ photometric redshifts



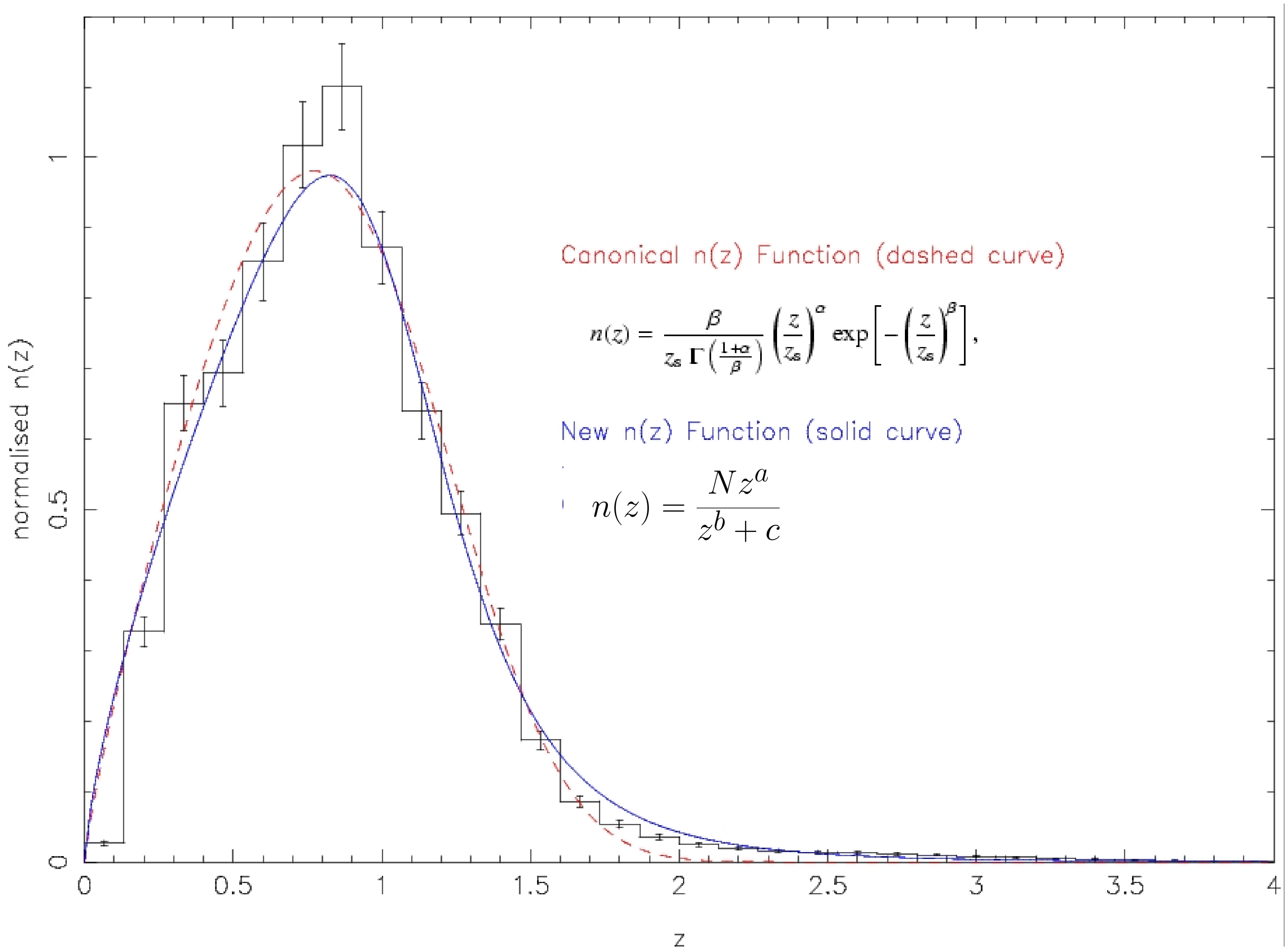
2 - CFHTLS-Wide: 0.0 < z < 4.0

- Note the high-z tail, which is poorly fit by the standard n(z)



2 - CFHTLS-Wide: 0.2 < z < 1.5

- Both functions fit the distribution well

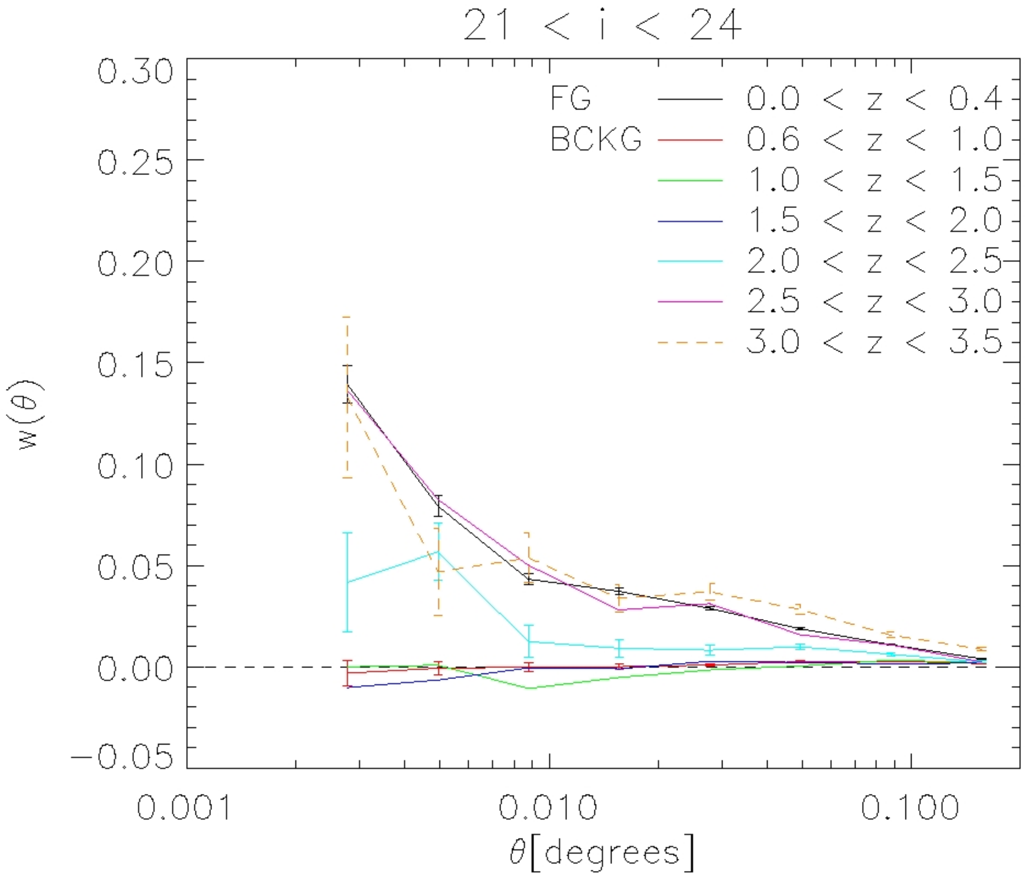


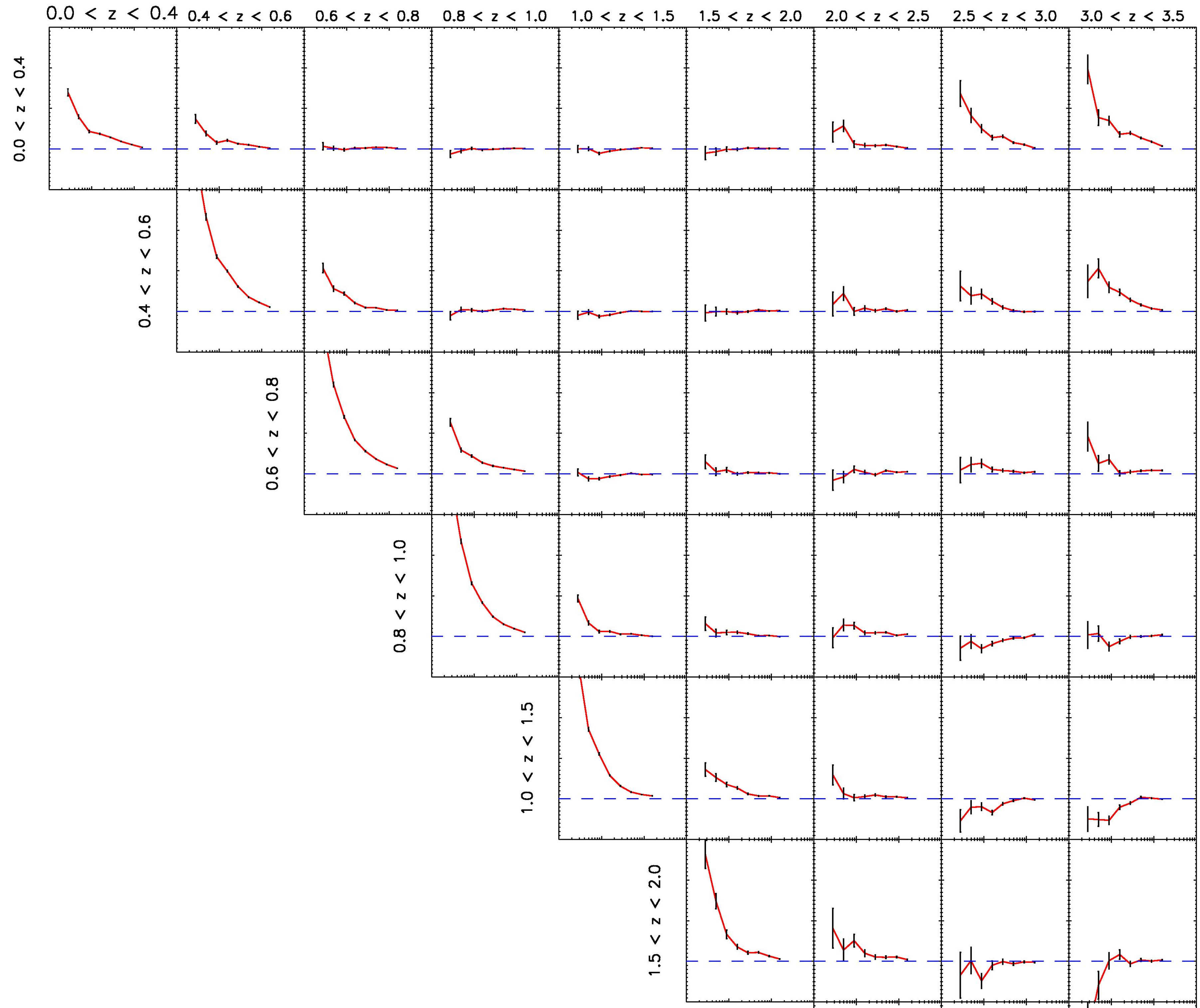
* Testing the photo-z catalogue

- The angular cross-correlation between redshift slices can be used to assess the level of contamination
  - We use the estimator from Landy & Szalay (1993)

$$w(\theta) = \frac{(D_1 - R)(D_2 - R)}{RR}$$

- We find that the low-z pop (z < 0.4) is highly correlated with the high-z pop (z>2.0)





0.0 < z < 0.4
0.4 < z < 0.6
0.6 < z < 0.8
0.8 < z < 1.0
1.0 < z < 1.5
1.5 < z < 2.0
2.0 < z < 2.5
2.5 < z < 3.0
3.0 < z < 3.5
0.0 < z < 0.4
0.4 < z < 0.6
0.6 < z < 0.8
0.8 < z < 1.0
1.0 < z < 1.5
1.5 < z < 2.0

Parameter estimation

- The shear signal is fit by a model that depends on Ω_m, σ_8, h, and n(z)
  - we assume a flat geometry $\Omega_m + \Omega_\Lambda = 1$
- The likelihood function is defined as:

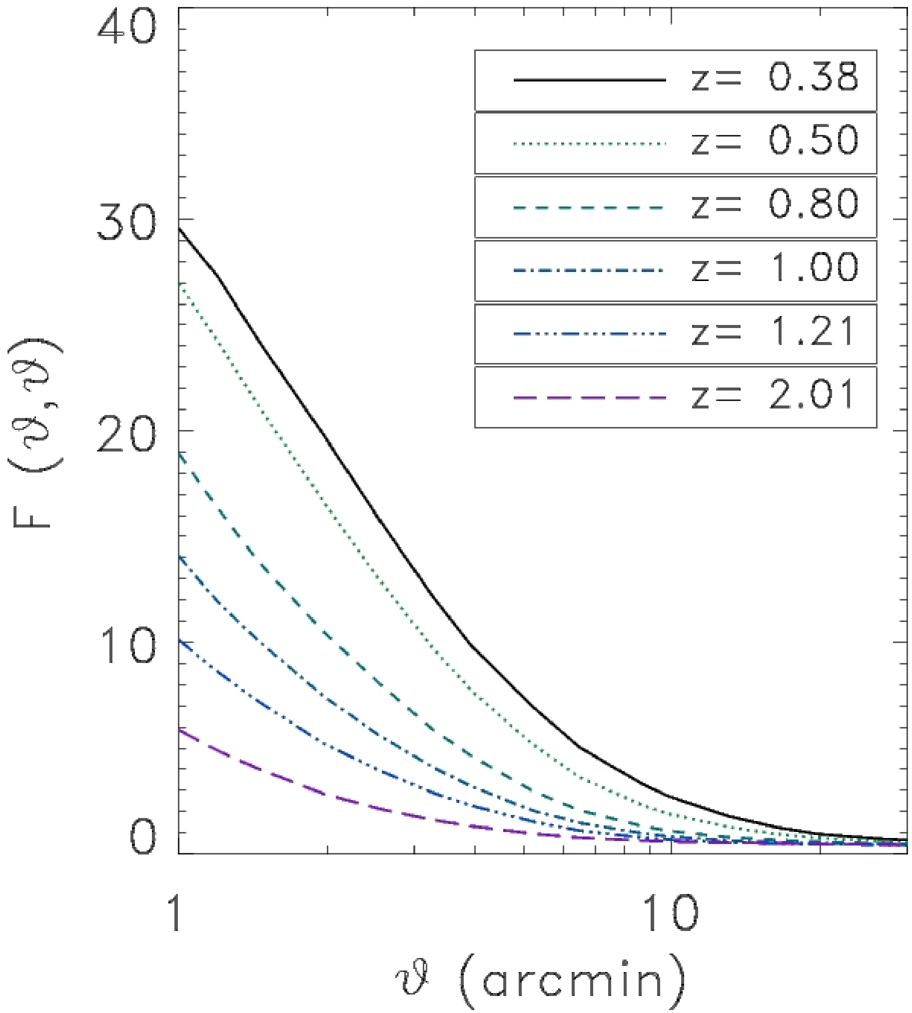
$$\mathcal{L} = \frac{1}{\sqrt{(2\pi)^n|\mathbf{C}|}} \exp\left[-\frac{1}{2}(\boldsymbol{\xi} - \mathbf{m})\mathbf{C}^{-1}(\boldsymbol{\xi} - \mathbf{m})^T\right]$$

$$\mathbf{C} = \mathbf{C}_n + \mathbf{C}_B + \mathbf{C}_s$$

- We marginalize over h=[0.64,0.80], and calibration bias (m) with flat priors and n(z) with Gaussian priors
- The likelihood contours of all 4 surveys are combined

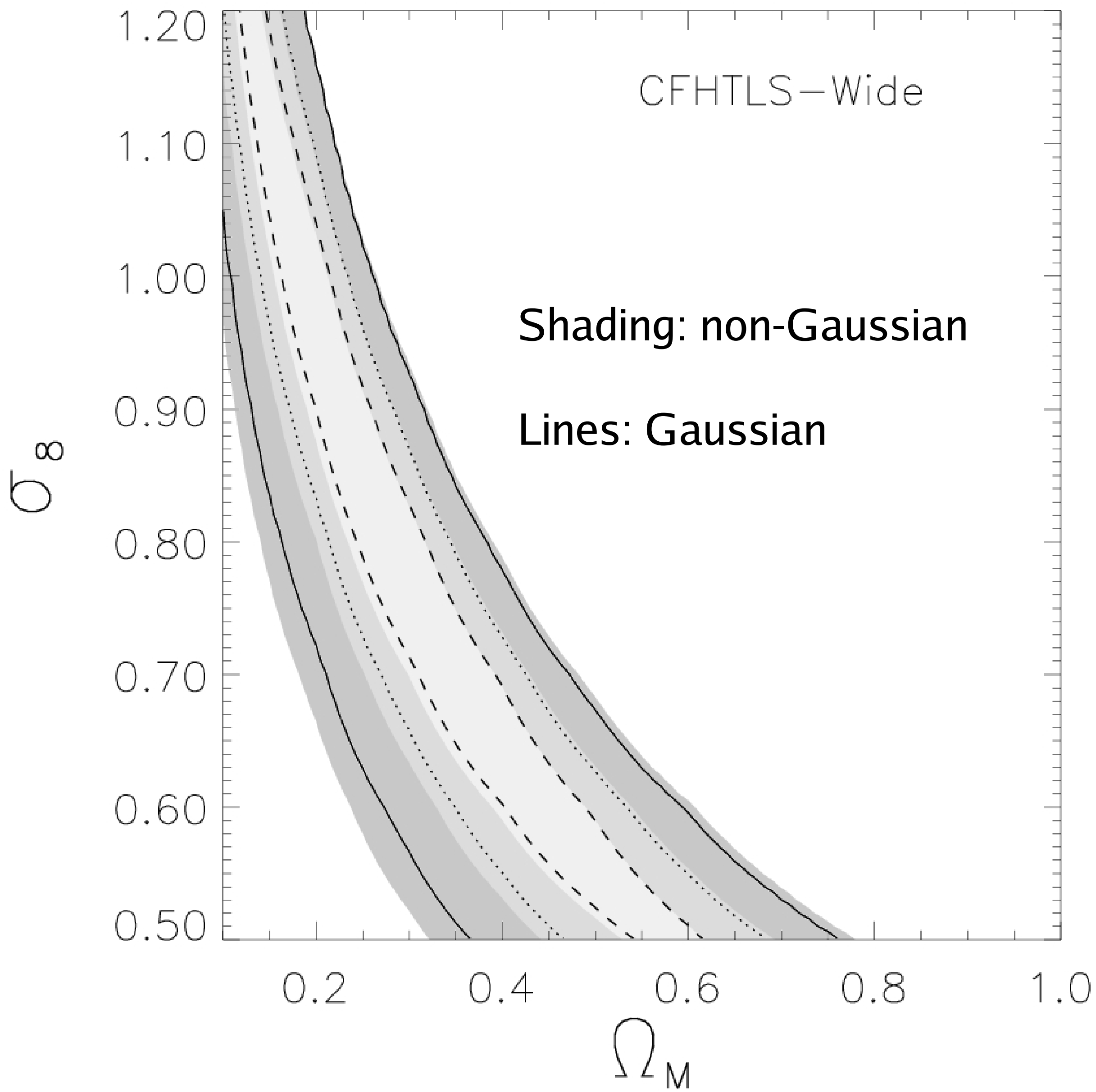
3 - Sample variance in the non-linear regime

- Gaussian statistics break down on small scales
  - the analytic formalism of Schneider et al. (2002) is used to find the Gaussian contribution
- The shear covariance as predicted by Gaussian statistics is too small
  - we calibrate the Gaussian covariance using scaling relations found by Semboloni et al. (2006) from simulations
- $F(\theta,\theta) \equiv Cov_{non\text{-}gass}/Cov_{gauss}$
- Comparing our covariance to that found from the GaBoDS data we find a median diff. along the diagonal of ~±15%



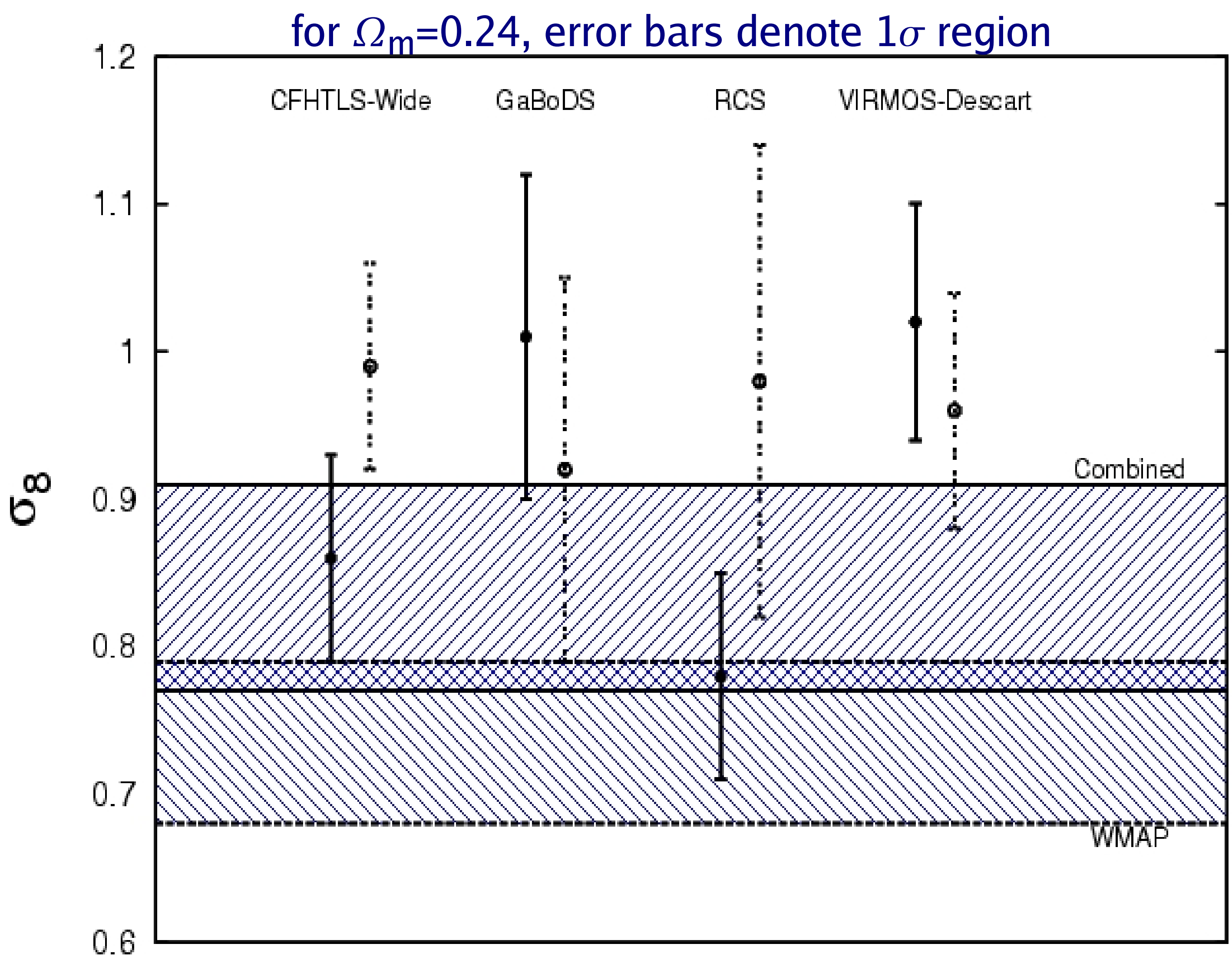
Semboloni et al. (2006)

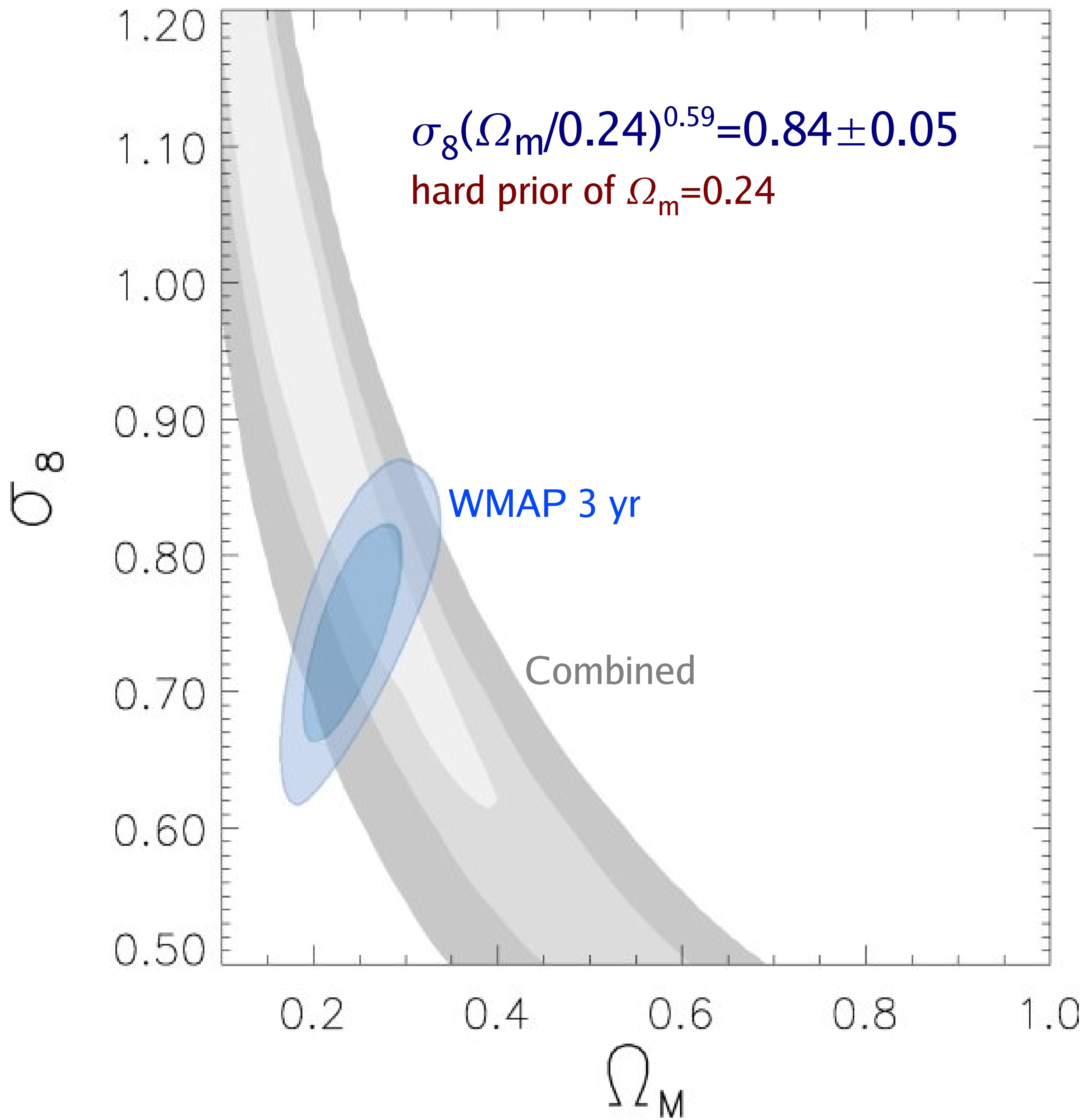
3 - Non-Gaussian contribution



Survey results

- Dashed: literature values
- Solid: our results
- Changes are almost entirely due to the updated n(z)



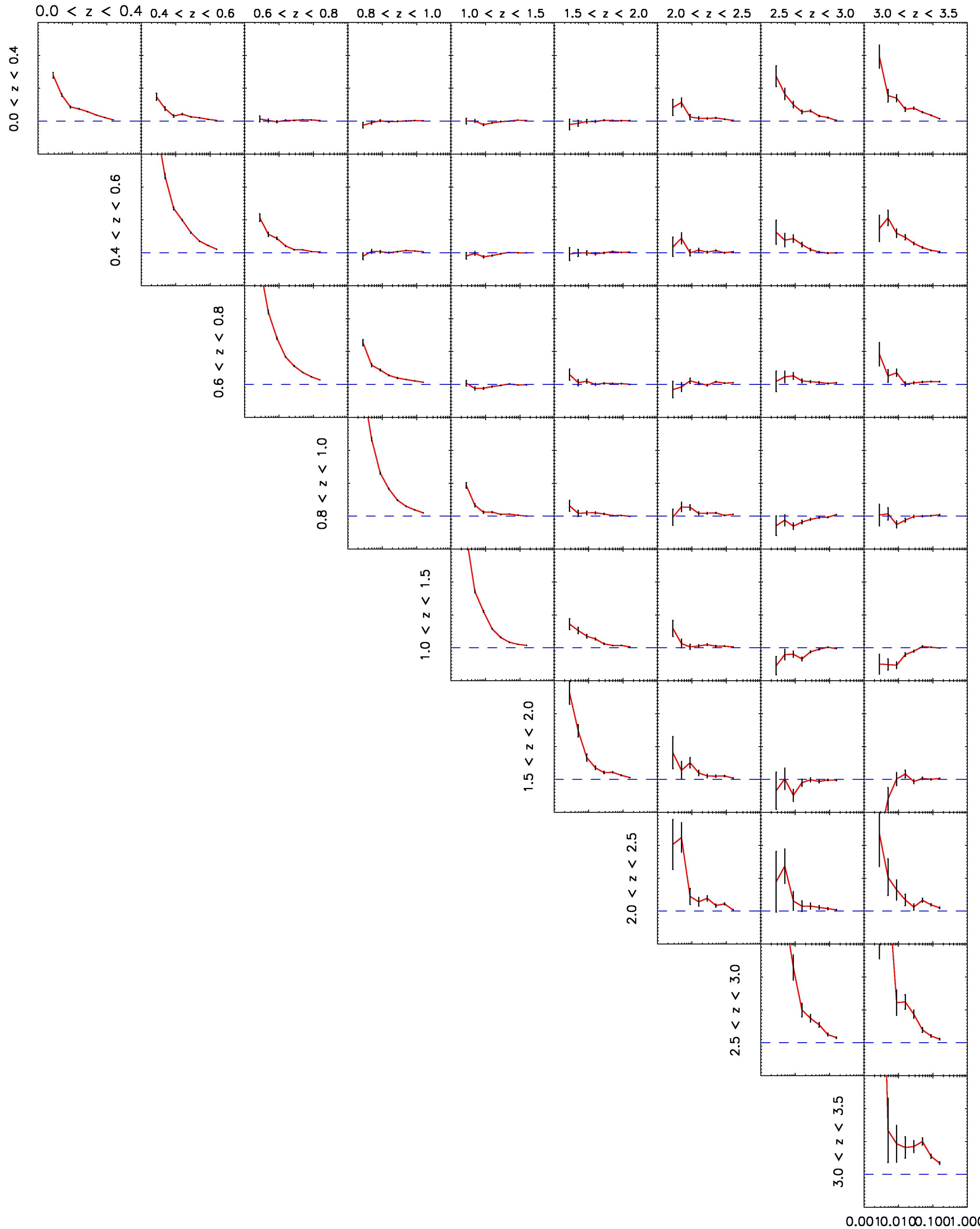


$\sigma_8(\Omega_m/0.24)^{0.59}$=0.84±0.05
hard prior of Ω_m=0.24
WMAP 3 yr
Combined
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
σ_8
0.2
0.4
0.6
0.8
1.0
Ω_M

Conclusions

- Properly accounting for non-gaussian cosmic variance is important
  - Ideally we would have enough independent fields of view that the covariance matrix can be measured accurately from the data
- The redshift dist. has significant effects on the measured cosmology
  - The angular correlation function is an excellent tool for assessing a reliable redshift range from photo-z catalogues
  - Since we must use photometric redshifts we should strive to include the near IR
- Weak lensing remains an excellent probe of cosmology
  - Degeneracies in the $\Omega_m - \sigma_8$ plane complement constraints from WMAP

- Survey Results can be found in Benjamin et al. astro-ph/0703570
- A publication concerning the angular cross-correlation function is in preparation


0.0 < z < 0.4
0.4 < z < 0.6
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0.8 < z < 1.0
1.0 < z < 1.5
1.5 < z < 2.0
2.0 < z < 2.5
2.5 < z < 3.0
3.0 < z < 3.5
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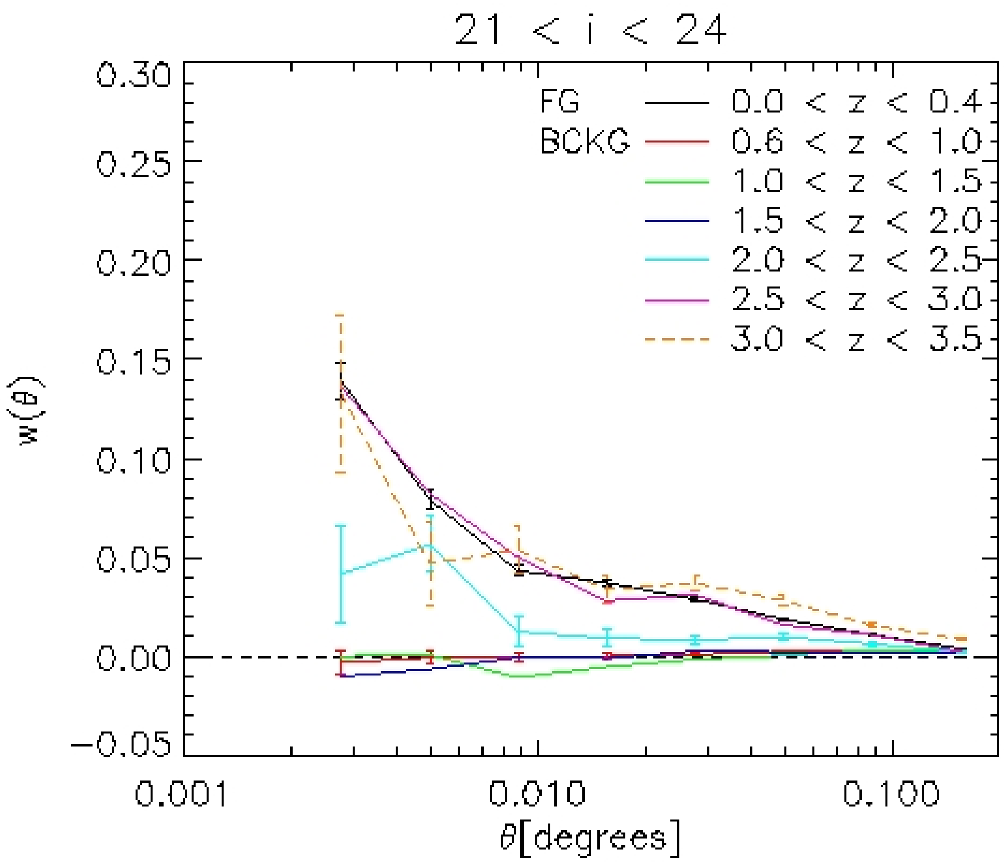
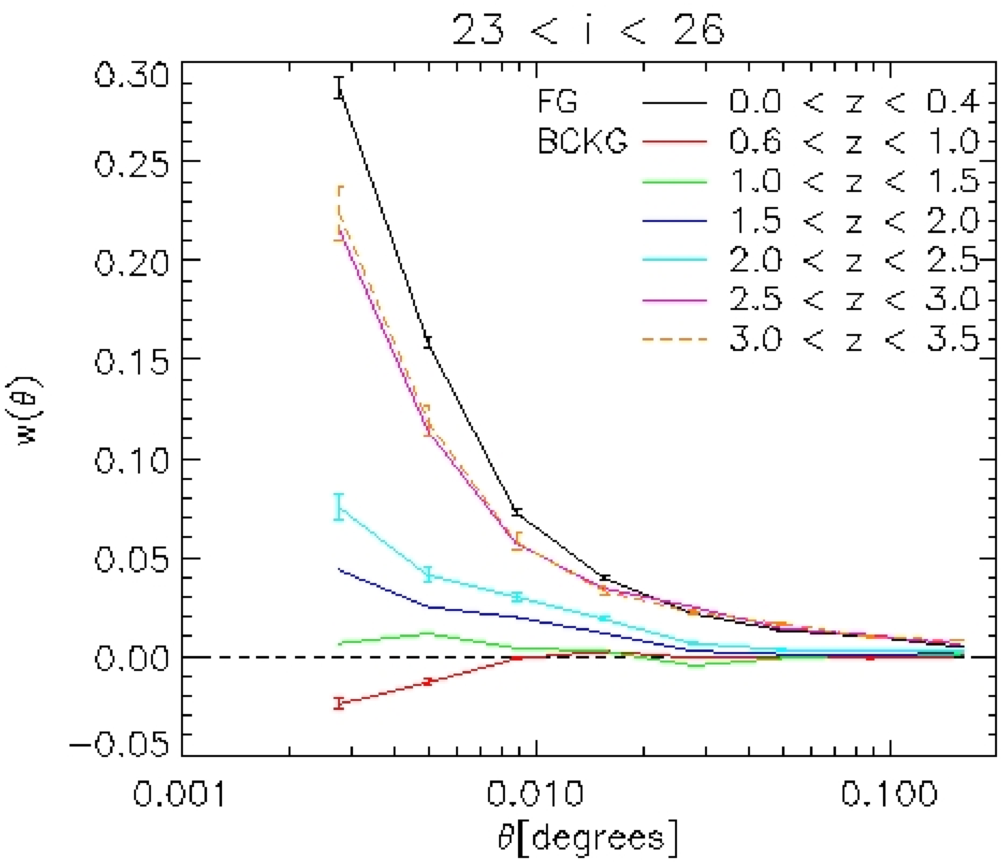
* Magnitude dependence

- There is more cross-talk at fainter magnitudes, photo-z errors increase



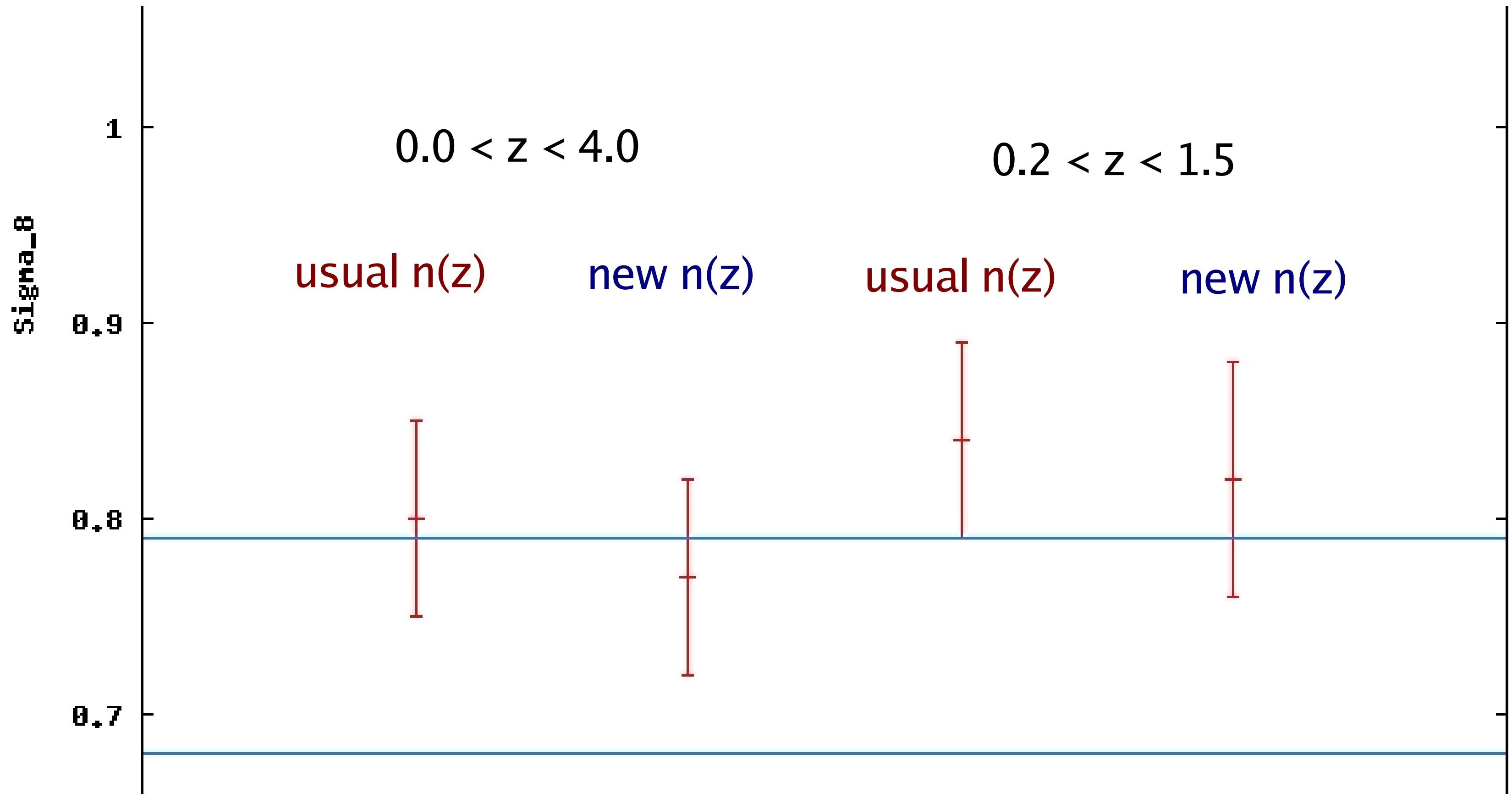


Combined results

usual n(z): $n(z) = \frac{\beta}{z_s\,\Gamma\left(\frac{1+\alpha}{\beta}\right)}\left(\frac{z}{z_s}\right)^{\alpha}\exp\left[-\left(\frac{z}{z_s}\right)^{\beta}\right],$

new n(z): $n(z) = \frac{Nz^a}{z^b + c}$

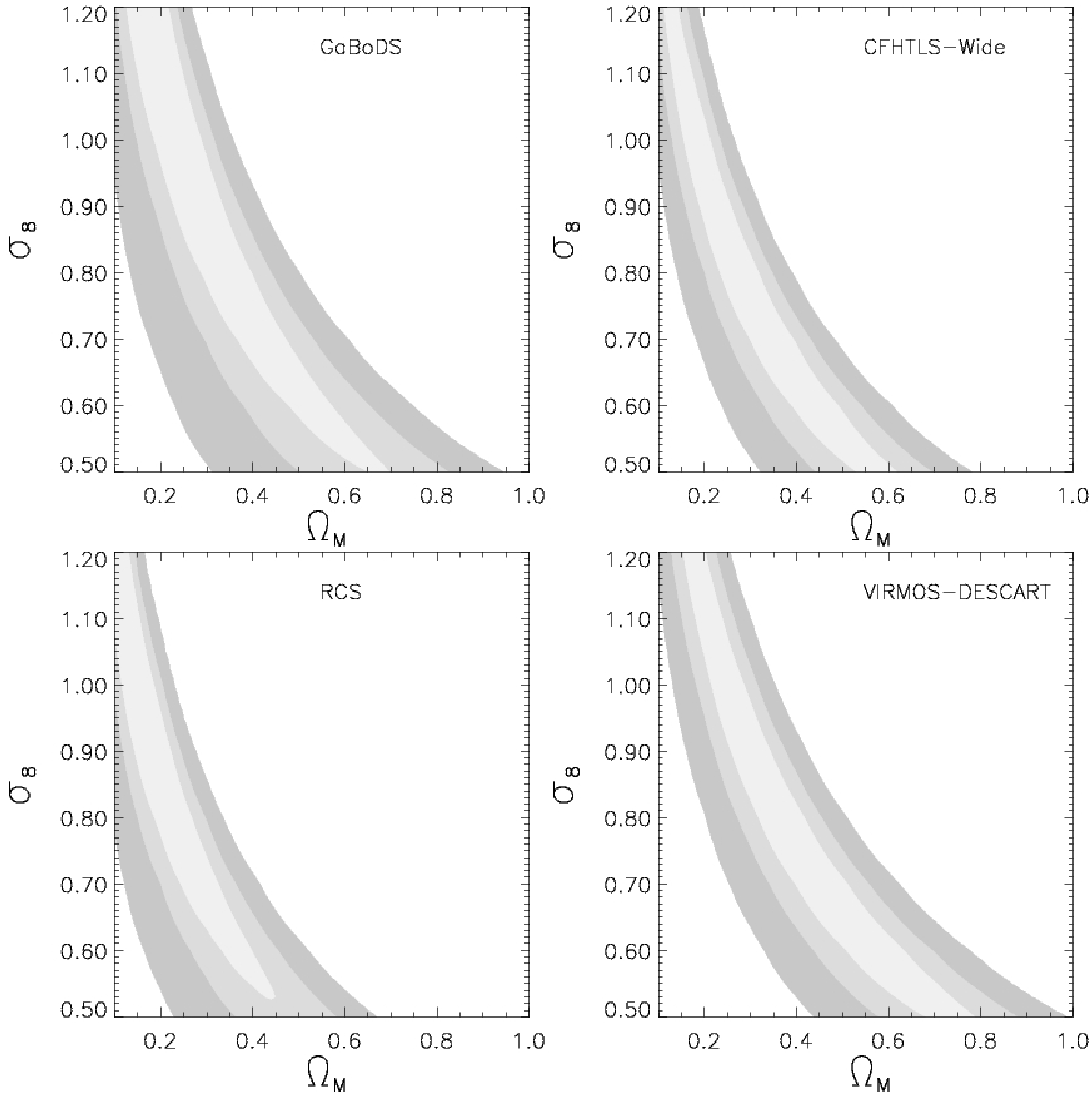
for a hard prior of Ω_m=0.24



Survey Results

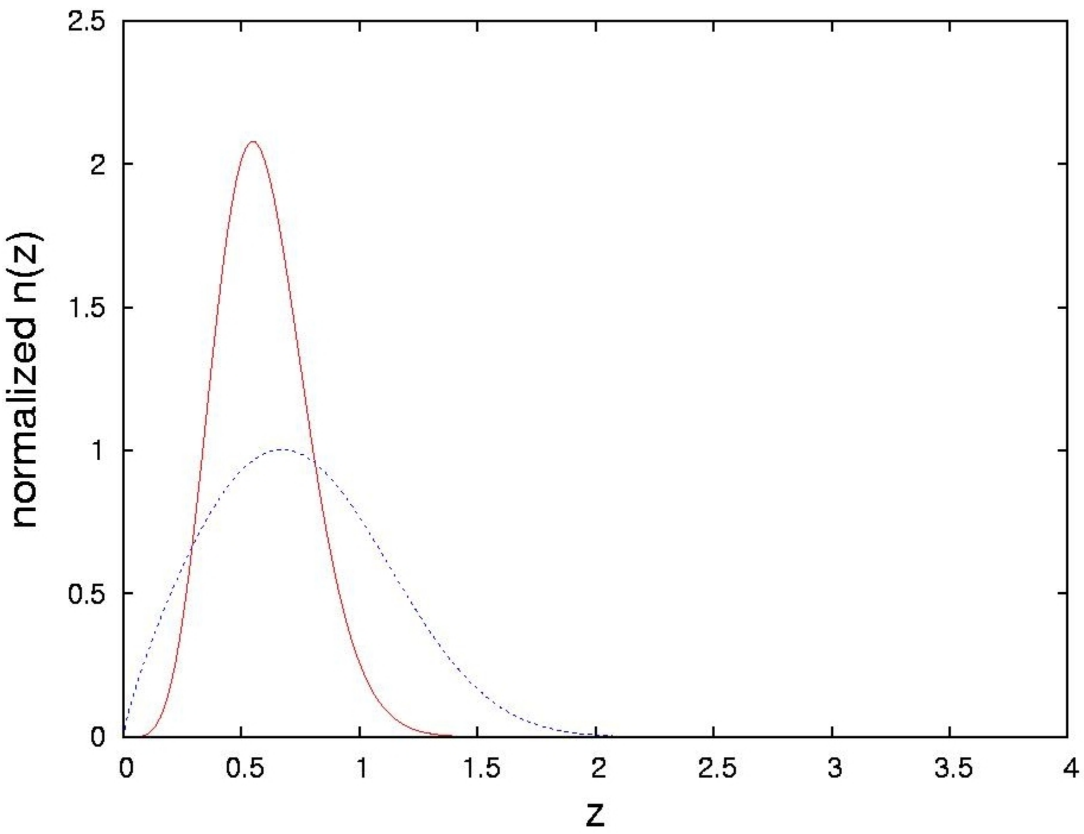
- For a hard prior of Ω_m=0.24
  - Note how sigma8 changes with average redshift
  - New results are consistent with the old for the canonical model (Eq.11, 0.2<z<1.5), except for RCS which changes due to updated n(z)

	$0.0 \leqslant z_p \leqslant 4.0$				$0.2 \leqslant z_p \leqslant 1.5$			
	Eq.(10)		Eq.(11)		Eq.(10)		Eq.(11)	
	β	α	β	α	β	α	β	α
CFHTLS-Wide	0.84 ± 0.06	0.55	0.81 ± 0.07	0.54	0.86 ± 0.06	0.56	0.84 ± 0.06	0.55
GaBoDS	0.93 ± 0.08	0.60	0.89 ± 0.09	0.59	1.01 ± 0.09	0.66	0.98 ± 0.10	0.63
RCS	0.75 ± 0.07	0.55	0.73 ± 0.08	0.55	0.78 ± 0.07	0.57	0.76 ± 0.07	0.56
VIRMOS-DESCART	0.99 ± 0.08	0.59	0.95 ± 0.07	0.58	1.02 ± 0.07	0.60	1.00 ± 0.08	0.59
Combined	0.80 ± 0.05	0.57	0.77 ± 0.05	0.56	0.84 ± 0.05	0.59	0.82 ± 0.06	0.58


GaBoDS
CFHTLS−Wide
RCS
VIRMOS−DESCART
σ_8
Ω_M
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.2
0.4
0.6
0.8
1.0

Redshift Distribution

- RCS's redshift distribution is changed dramatically
- The red (solid) line shows the previous best fit n(z), the blue (dashed) line shows our updated n(z)
  - this has a large effect on the measured σ_8, large z_{avg} => small σ_8
  - for an Ω_m of 0.3 the best fit red σ_8 decreased from 0.86 to 0.72 (error ~0.05 for both)



Redshift Distribution

- Eq.(11) $$n(z) = \frac{\beta}{z_s \, \Gamma\left(\frac{1+\alpha}{\beta}\right)} \left(\frac{z}{z_s}\right)^{\alpha} \exp\left[-\left(\frac{z}{z_s}\right)^{\beta}\right],$$
- Eq.(12) $$n(z) = \frac{N z^a}{z^b + c}$$

		Eq.(11)					Eq.(12)					
		α	β	z_0	$\langle z \rangle$	χ^2_ν	a	b	c	N	$\langle z \rangle$	χ^2_ν
$0.2 \leqslant z_p \leqslant 1.5$	Wide	0.836	3.425	1.171	0.802	1.63	0.723	6.772	2.282	2.860	0.848	1.65
	RCS	0.811	2.798	1.048	0.752	1.20	0.622	6.200	1.382	1.837	0.792	1.64
	VIRMOS	0.819	3.289	1.152	0.793	1.79	0.697	6.618	2.065	2.607	0.838	1.95
	GaBoDS	0.739	2.598	1.061	0.764	1.88	0.514	5.926	1.650	1.972	0.802	3.43
$0.0 \leqslant z_p \leqslant 4.0$	Wide	1.197	1.193	0.555	0.894	8.94	0.740	4.563	1.089	1.440	0.945	2.41
	RCS	1.793	0.764	0.153	0.872	4.00	0.810	4.067	0.557	0.938	0.921	1.40
	VIRMOS	1.165	1.186	0.548	0.879	9.45	0.711	4.525	1.019	1.365	0.927	2.49
	GaBoDS	1.518	0.780	0.198	0.926	4.65	0.740	3.629	0.575	0.895	0.981	1.87