MULTIWAVELENGTH COSMIC SHEAR TO MITIGATE INSTRUMENTAL AND OBSERVATIONAL SYSTEMATICS

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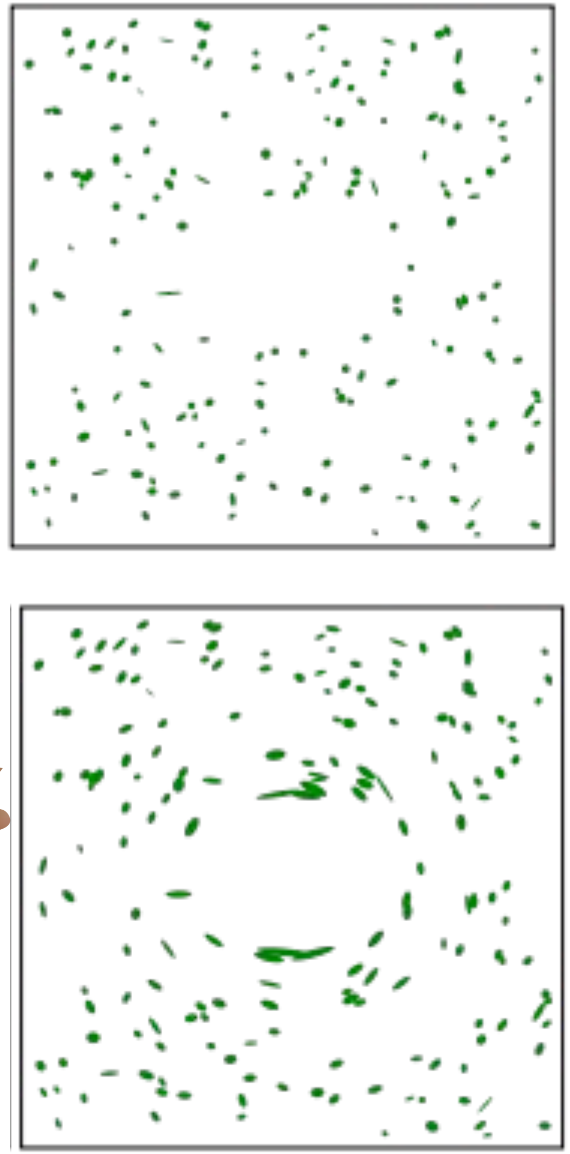
WEAK GRAVITATIONAL LENSING AND MULTIWAVELEGHT

The basic idea of this work is to search for synergies between Radio and Optic Weak Lensing analysis. In particular, proceeding from SKA Weak Lensing III: Added Value of Multi-Wavelength Synergies for the Mitigation of Systematics (Camera et al. 2018), we address for the issue of multiplicative type systematic in the shear angular power spectrum.

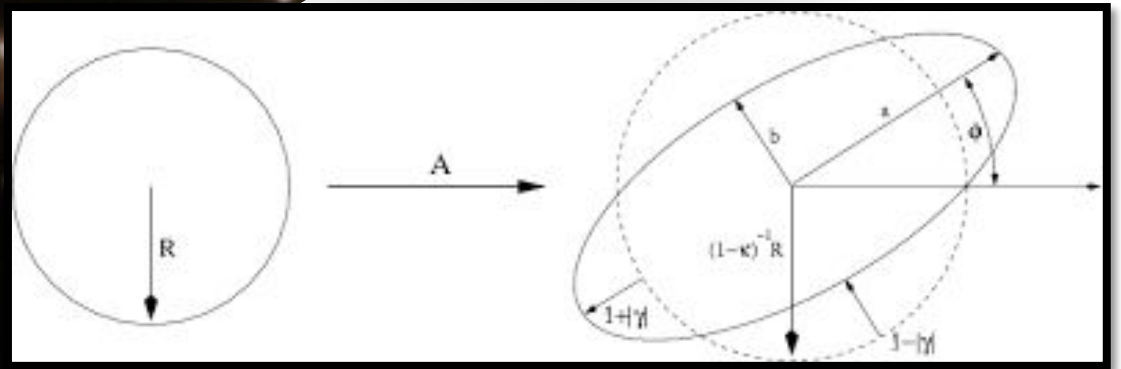


Cosmic Shear

The total effect of the weak lensing distortion can be taken into account by the Amplification Matrix:

$$\mathcal{A} = \frac{\partial \vec{\theta}_S}{\partial \vec{\theta}_I} = \mathbf{Id} + \begin{pmatrix} -\boldsymbol{\kappa} - \gamma_1 & -\gamma_2 \\ -\gamma_2 & -\boldsymbol{\kappa} + \gamma_1 \end{pmatrix}$$

which defines the convergence κ and the complex shear $\gamma = \gamma_1 + i\gamma_2$



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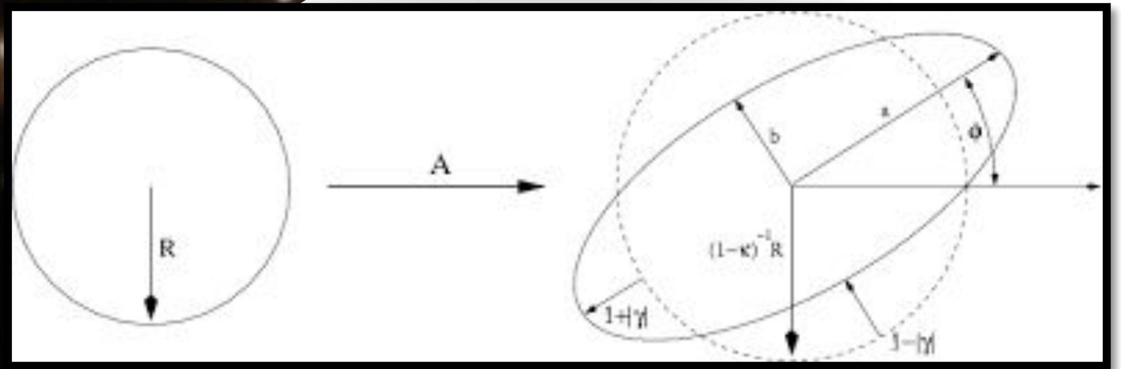


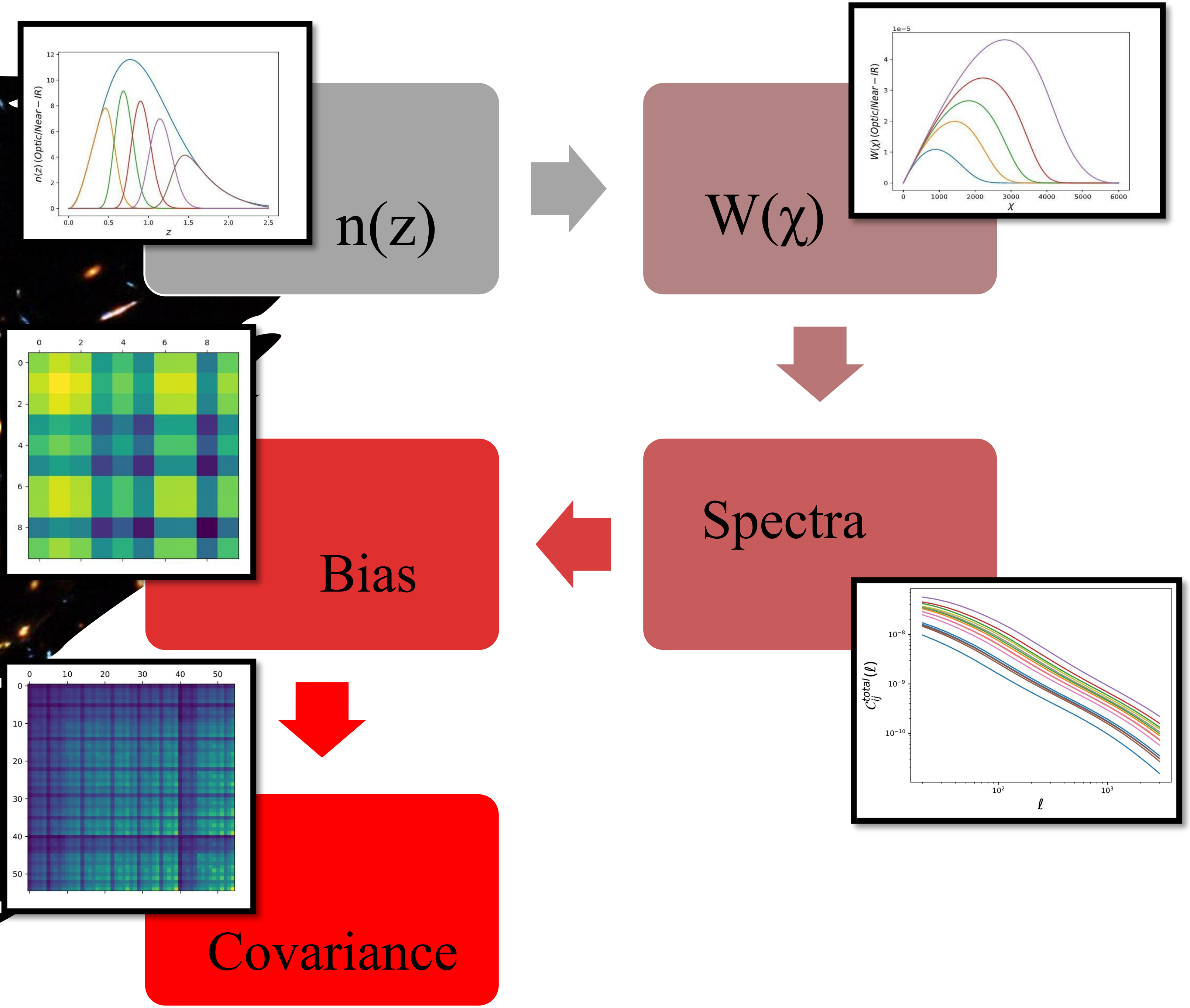
Systematics

The starting point of the work is the article SKA Weak Lensing III: Added Value of Multi-Wavelength Synergies for the Mitigation of Systematics (Camera et al. 2018).

$$C_\ell^{sys} = \mathcal{M}_{ij} C_\ell^{E_i S_j} + C_\ell^{add}$$

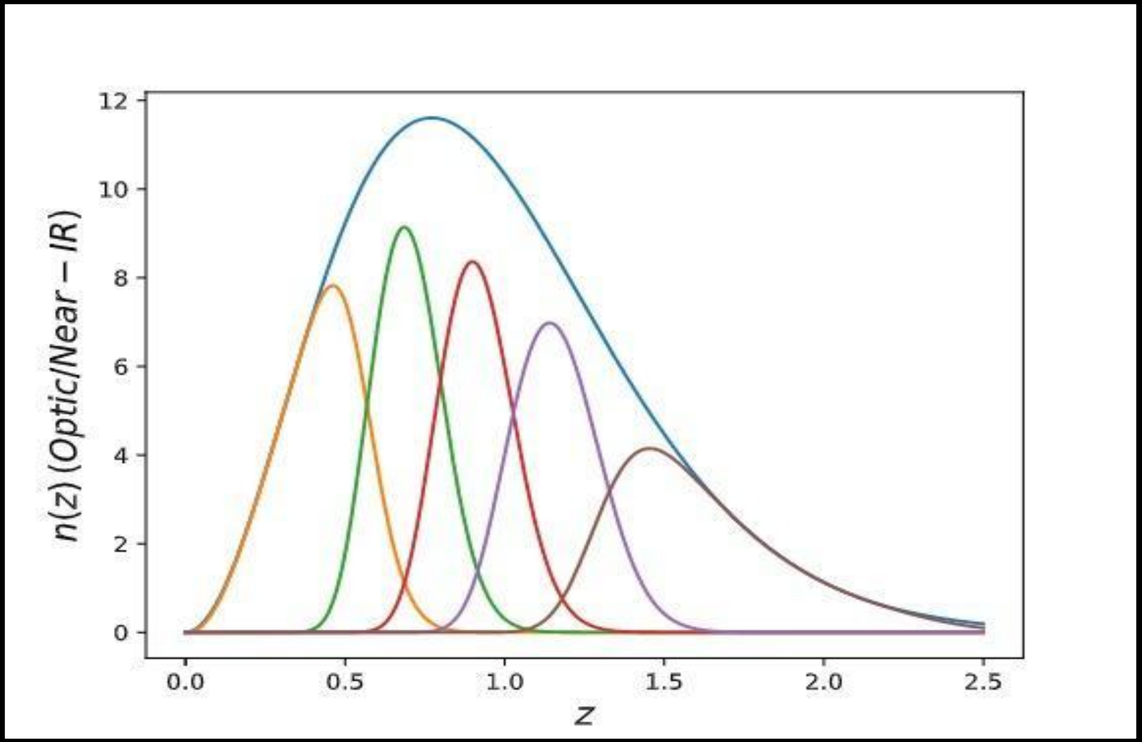
They explored only the effects of additive systematics on the weak lensing angular power spectrum and a possible mitigation strategy through a combined Optic-Radio analysis.

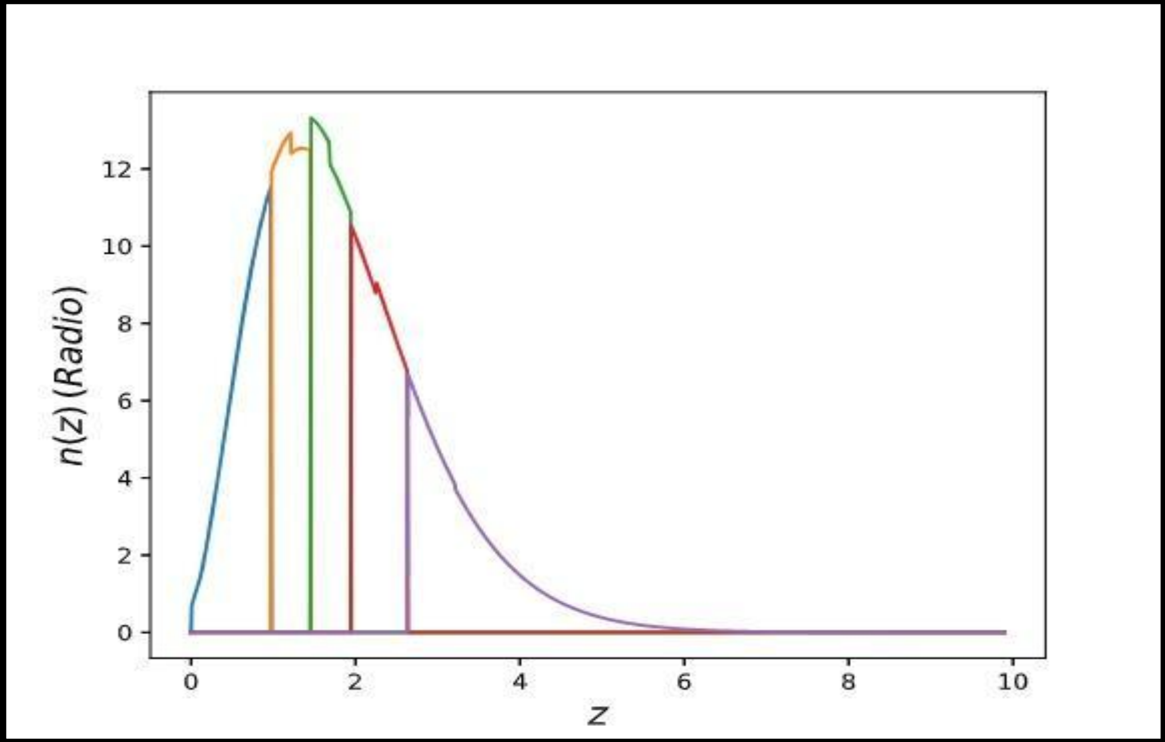
Here we have a schematic of our procedure to remove effects due to residual multiplicative systematics in Cosmic Shear based cosmological forecasts. This procedure aims to obtain a more accurate reconstruction of cosmological parameters confidence regions taking advantage of multiwalegth measuremets in Radio and Optical that will be performed by the Euclid Space Telescope and SKA Observatory.



From the galaxies to the spectra

The first ingredient in our procedure are the galaxy redshift distribution for the two experiments

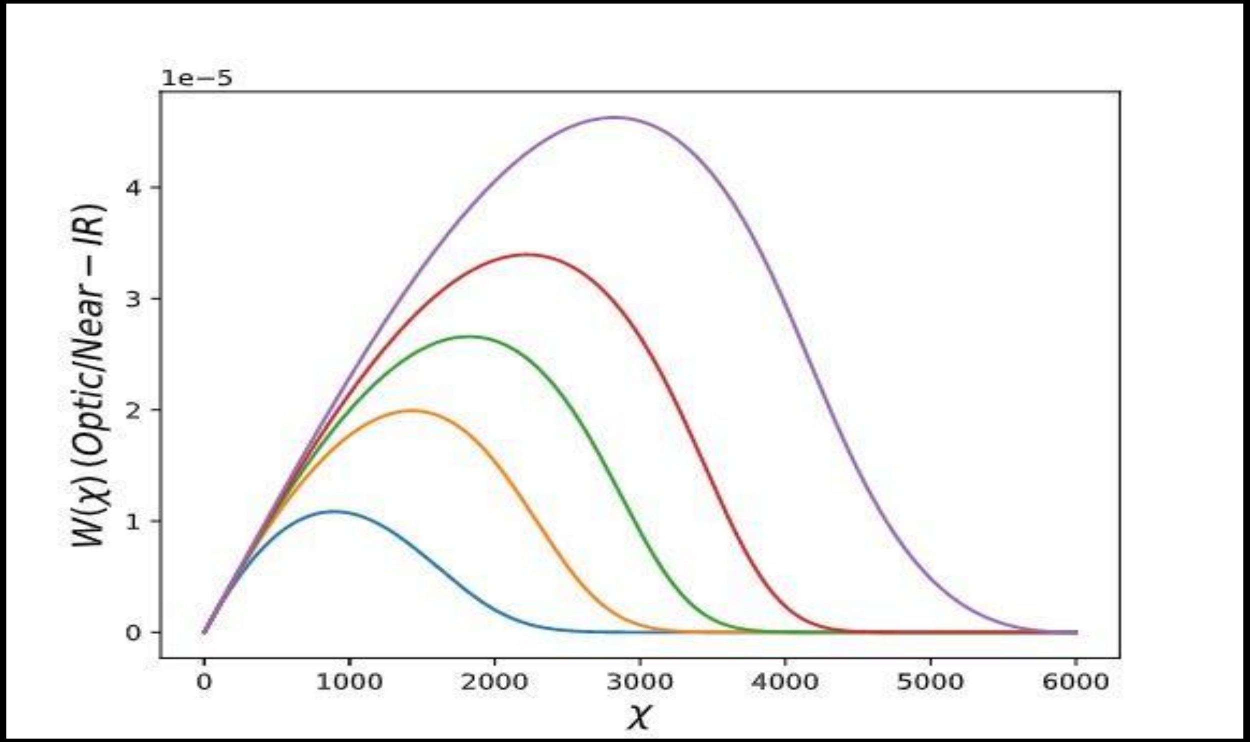


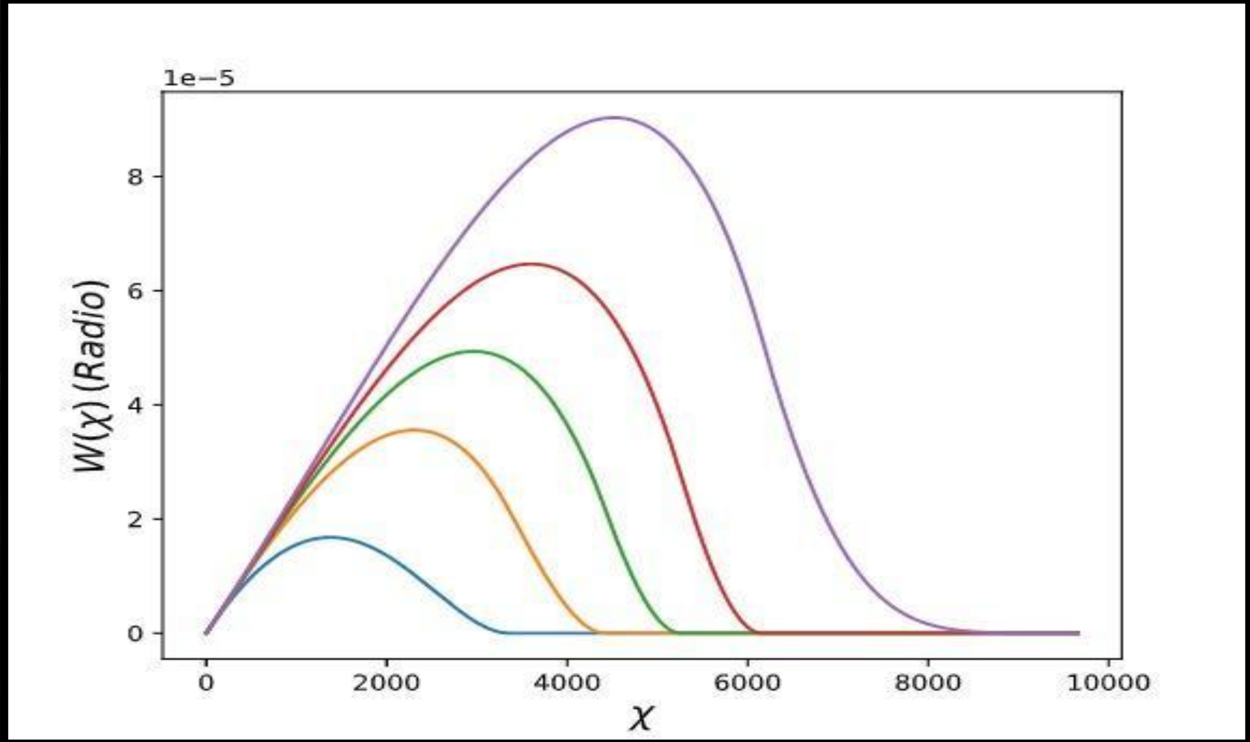


From the galaxies to the spectra

Given an $n(z)$ the shear cumulated effect is calculated by the Shear Kernel functions:

$$W^{E_i}(\chi) = \frac{3}{2} H_0^2 \Omega_m [1 + z(\chi)]\chi \int d\chi' \frac{\chi' - \chi}{\chi'} n_{E_i}(\chi')$$

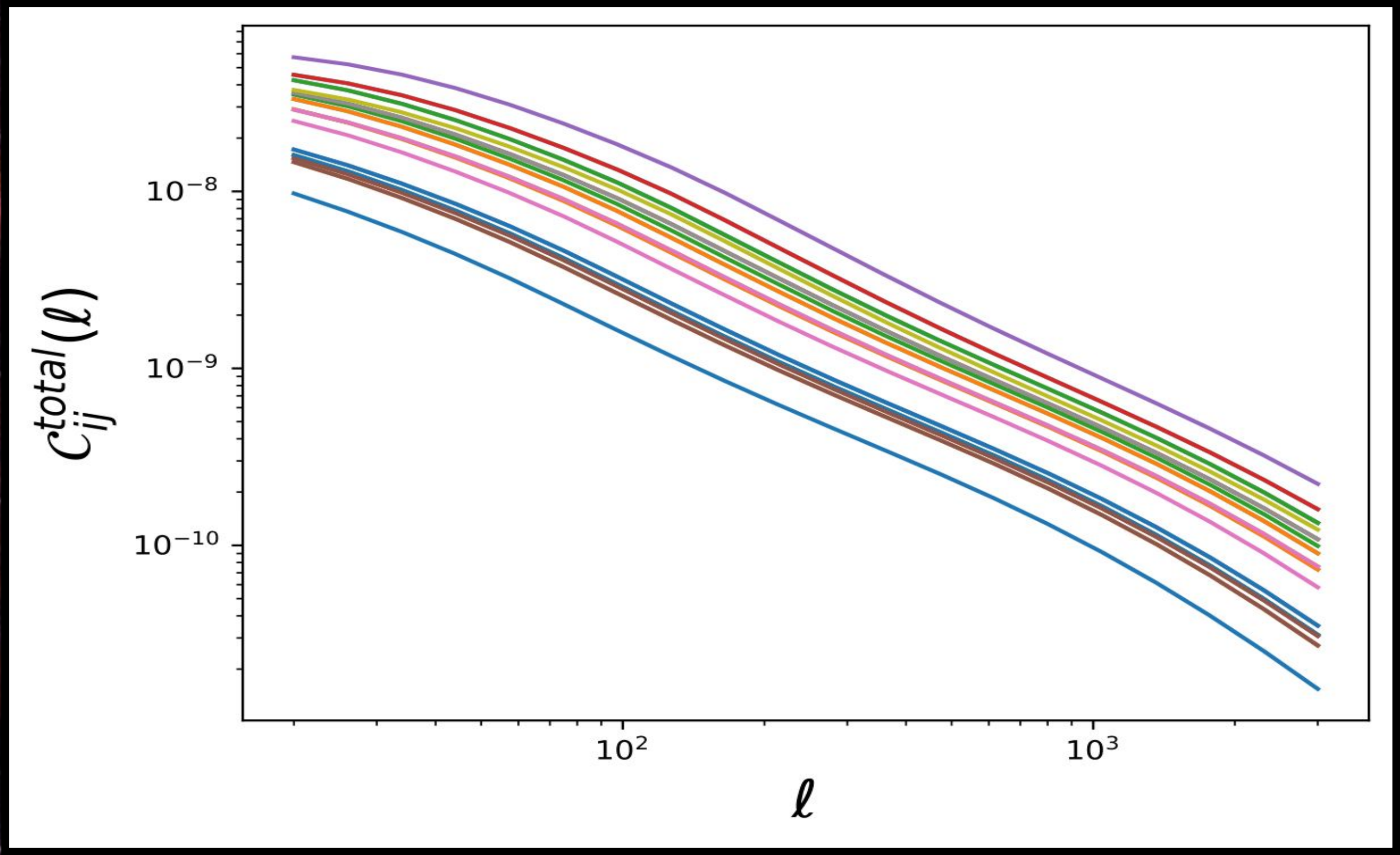




From the galaxies to the spectra

The main ingredients of our analysis are the auto and cross-correlation angular power spectra:

$$C_\ell^{E_i S_j} = \frac{2\pi}{\ell^3} \int d\chi \, \chi W^{E_i}(\chi) W^{S_j}(\chi) \Delta_\delta^2[k_\ell(\chi), \chi]$$



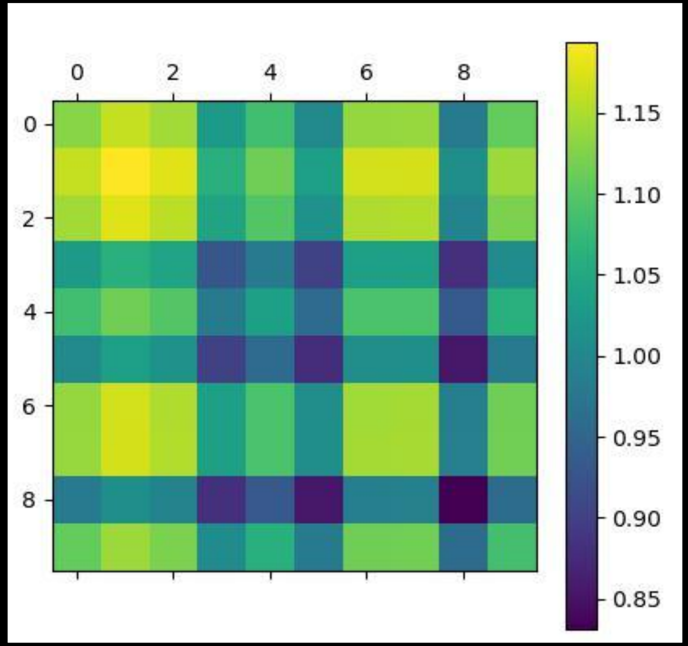
The model and the multiplicative systematics

We adopted for our analysis the standard ΛCDM (as implemented by Pyccl) where we introduced an extra object, a matrix $\mathcal{M}$ generated by a set of random values γ taken in a range $[-0.1, 0.1]$. $\mathcal{M}$ is Hadamard multiplied to the $C_l^{E_i S_j}$, the γ represent the miscalibration impact.

$$\{\mathcal{M}_{ij}\} := 1 + (\gamma_{(E_i} + \gamma_{S_j)})$$

The introduction of $\mathcal{M}$ means that the set of free parameters becomes:

$$\theta = \{\Omega_c, \sigma_8, \gamma_{E_i}, \gamma_{S_j}\}$$



Likelihood

The likelihood fuction we adopted is:

$$\ln\big(L(\theta,d)\big) = \big(d - m(\theta)\big)^T C^{-1}\big(d - m(\theta)\big)$$

where the Covariance Matrix is computed via the Wick Theorem:

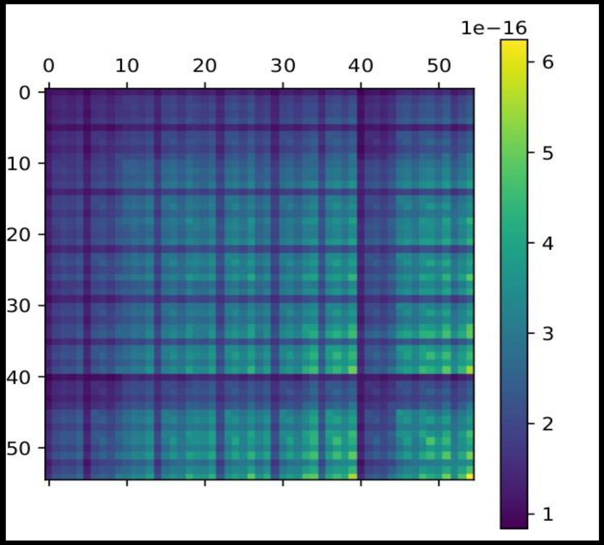
$$C = Cov\left[C_\ell^{E_iS_j}, C_\ell^{E'_l S'_k}\right] = \frac{\left[C_\ell^{E_iE'_l} + N^{E_jE'_k}\right]\left[C_{\ell'}^{S_jS'_l} + N^{S_jS'_l}\right] + \left[C_\ell^{E_iS'_l} + N^{E_iS'_l}\right]\left[C_{\ell'}^{S_jE'_k} + N^{S_jE'_k}\right]}{(2\ell+1)f_{sky}\Delta\ell}\delta_{\ell\ell'}$$

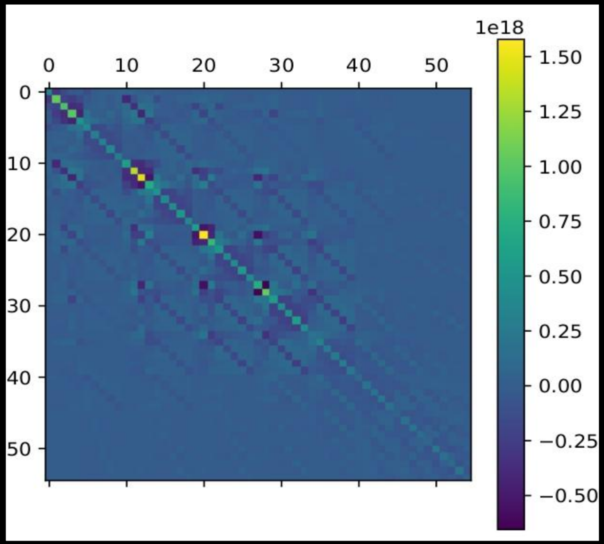
here the N are the noise terms:

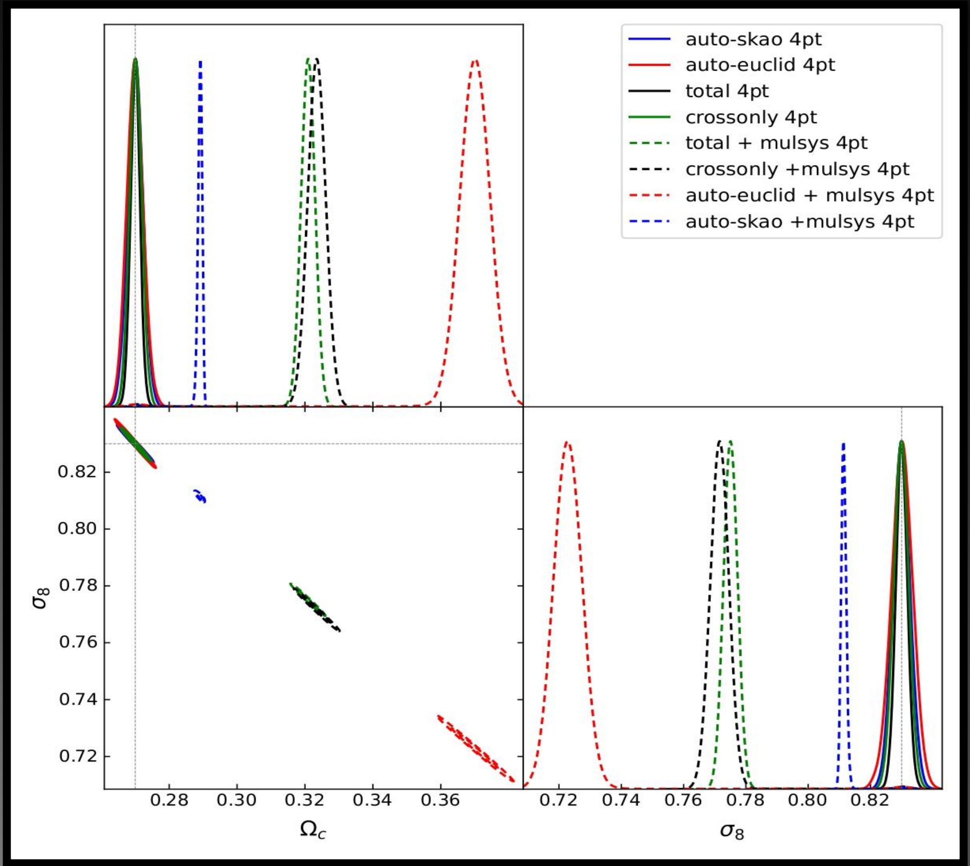
$$N^{X_iX_j} = \frac{\sigma_\epsilon^2}{\overline{n}_i}\delta_{ij}$$

$$N^{X_iY_j} = 0$$

with $\overline{n}_i$ is the number of galaxies per bin and σ_ϵ is the total intrinsic ellipticity dispersion.



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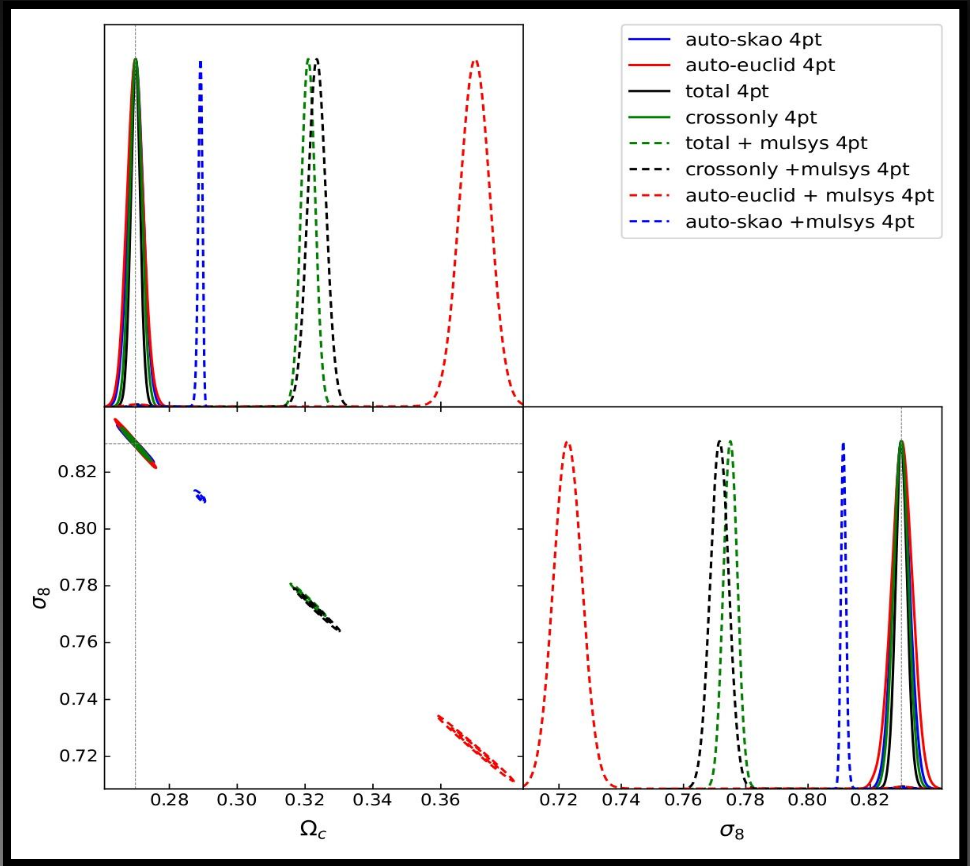
auto-euclid 4pt
total 4pt
crossonly 4pt
total + mulsys 4pt
crossonly +mulsys 4pt
auto-euclid + mulsys 4pt
auto-skao +mulsys 4pt
0.82
0.80
0.78
0.76
0.74
0.72
σ_8
0.28 0.30 0.32 0.34 0.36
Ω_c
0.72 0.74 0.76 0.78 0.80 0.82
σ_8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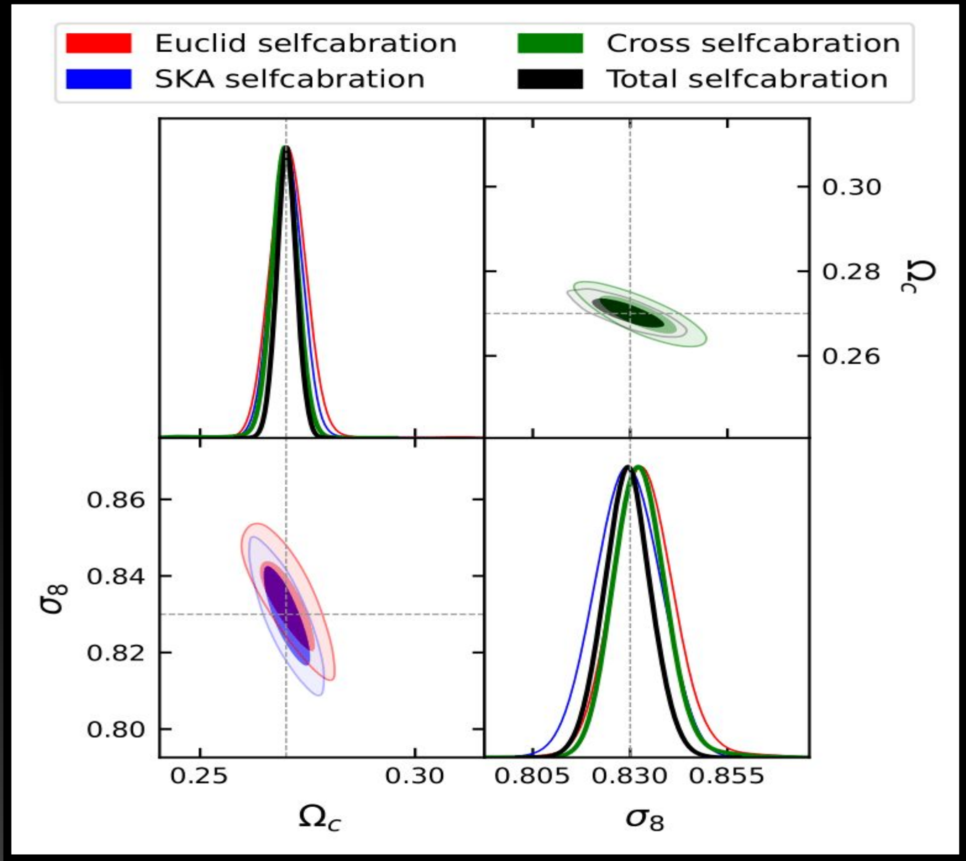
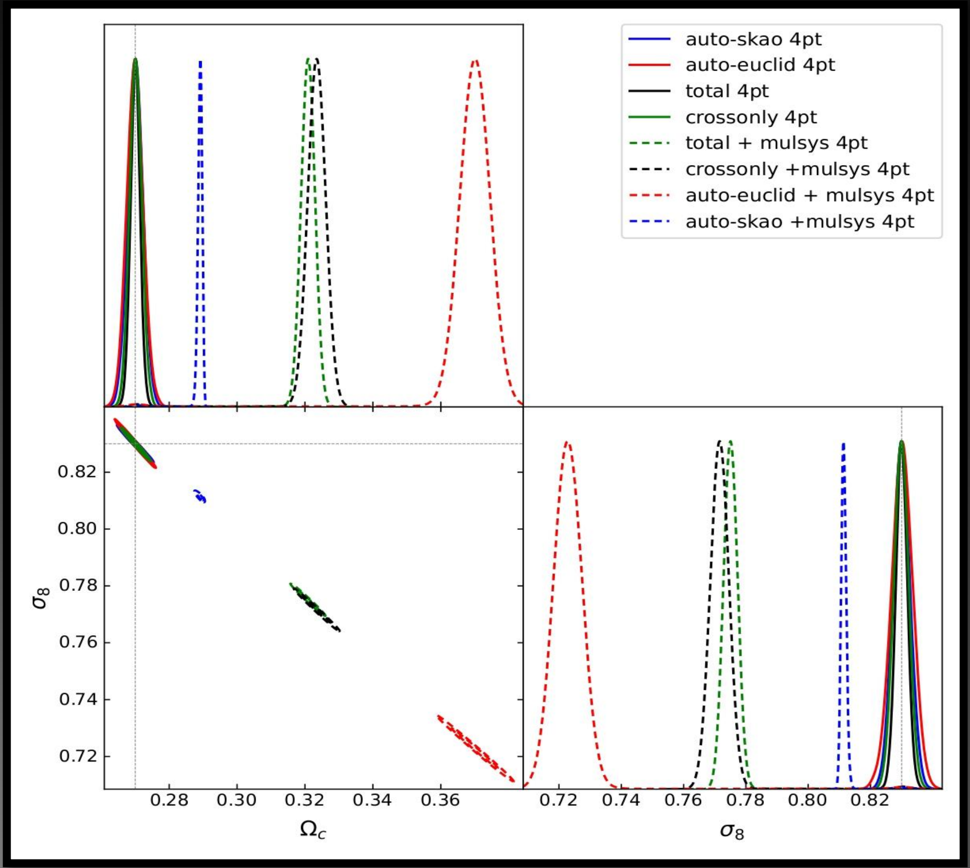
0.72 0.74 0.76 0.78 0.80 0.82
σ_8



Euclid selfcabration
Cross selfcabration
SKA selfcabration
Total selfcabration
0.30
0.28
0.26
Ω_c
0.86
0.84
0.82
0.80
σ_8
0.25
0.30
0.805
0.830
0.855
Ω_c
σ_8



auto-skao 4pt
auto-euclid 4pt
total 4pt
crossonly 4pt
total + mulsys 4pt
crossonly +mulsys 4pt
auto-euclid + mulsys 4pt
auto-skao +mulsys 4pt
0.82
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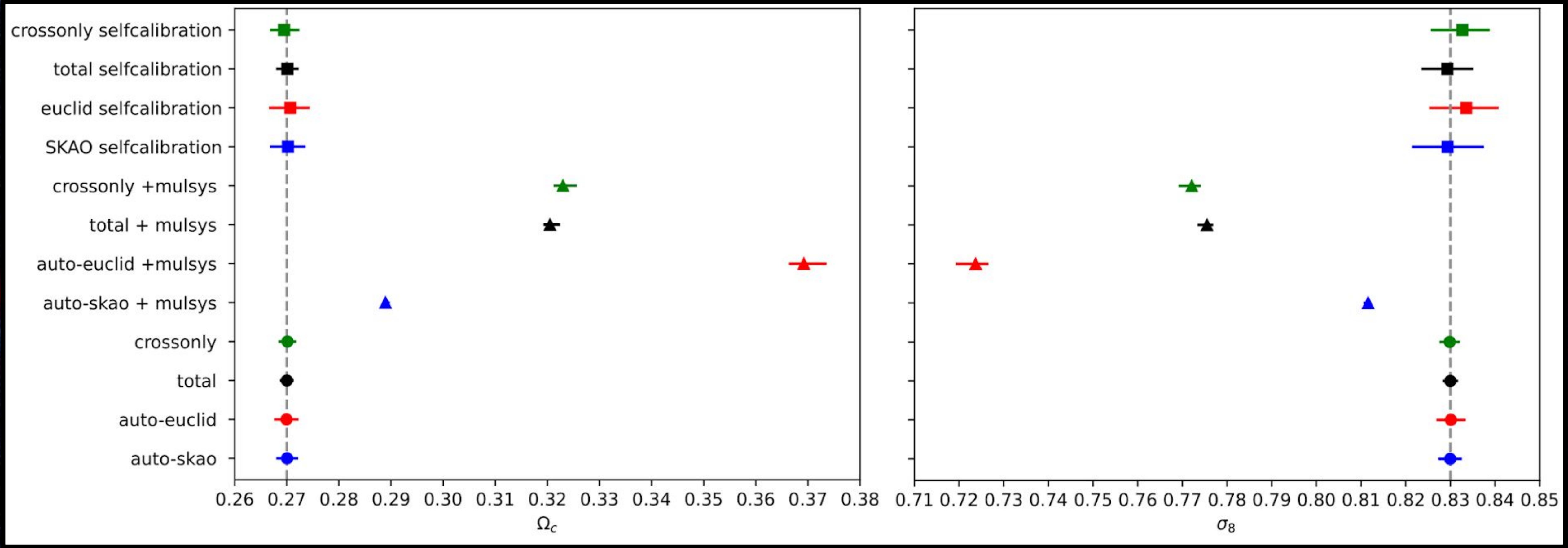
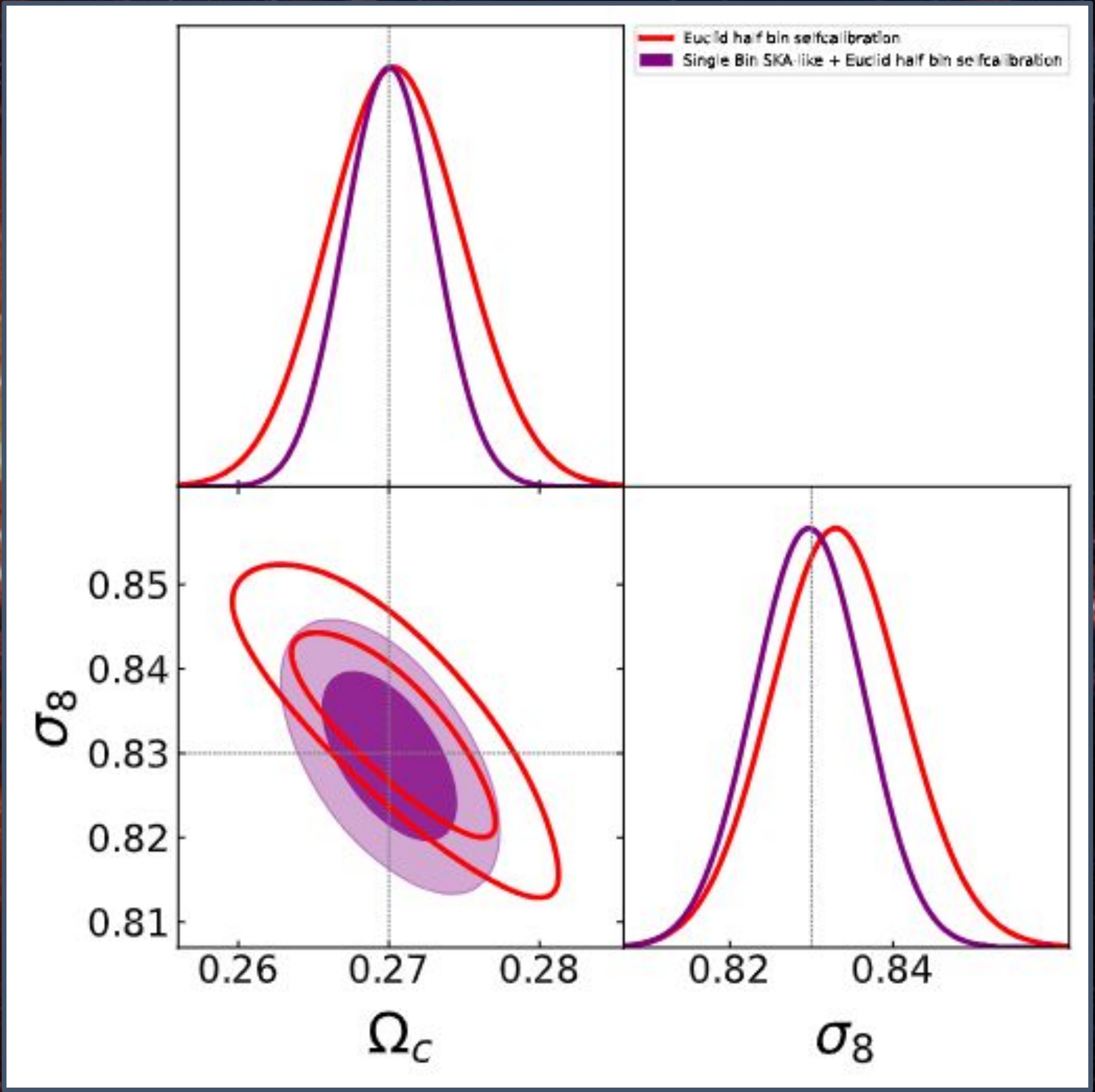
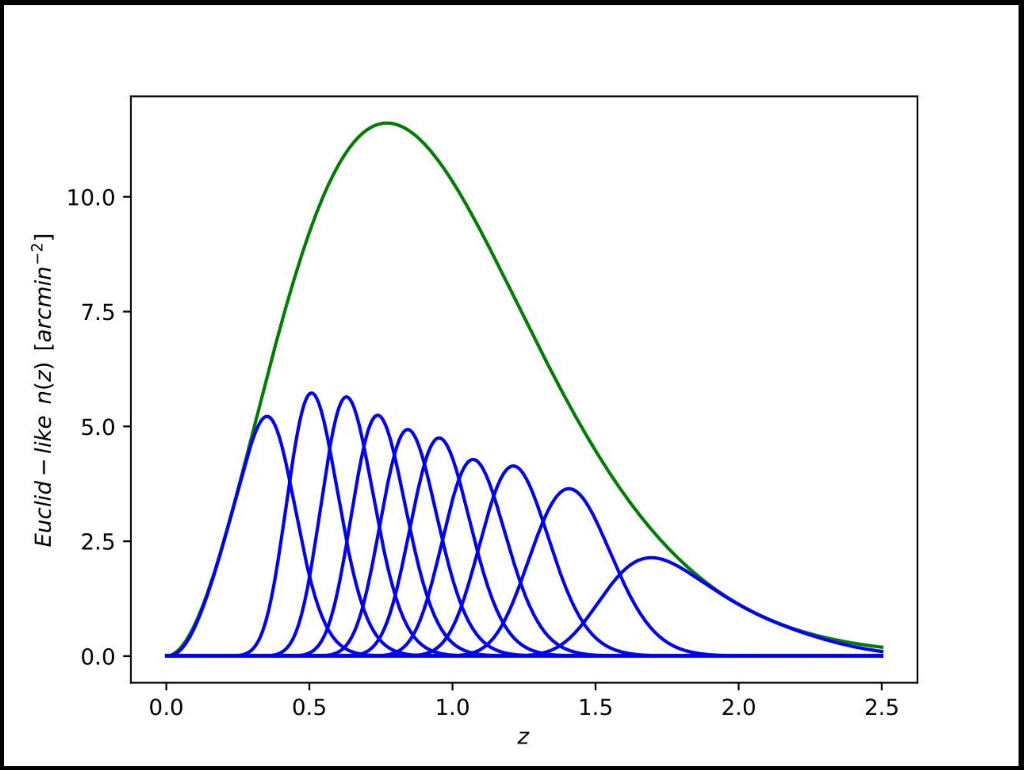
0.30
0.32
0.34
0.36
Ω_c
0.72
0.74
0.76
0.78
0.80
0.82
σ_8

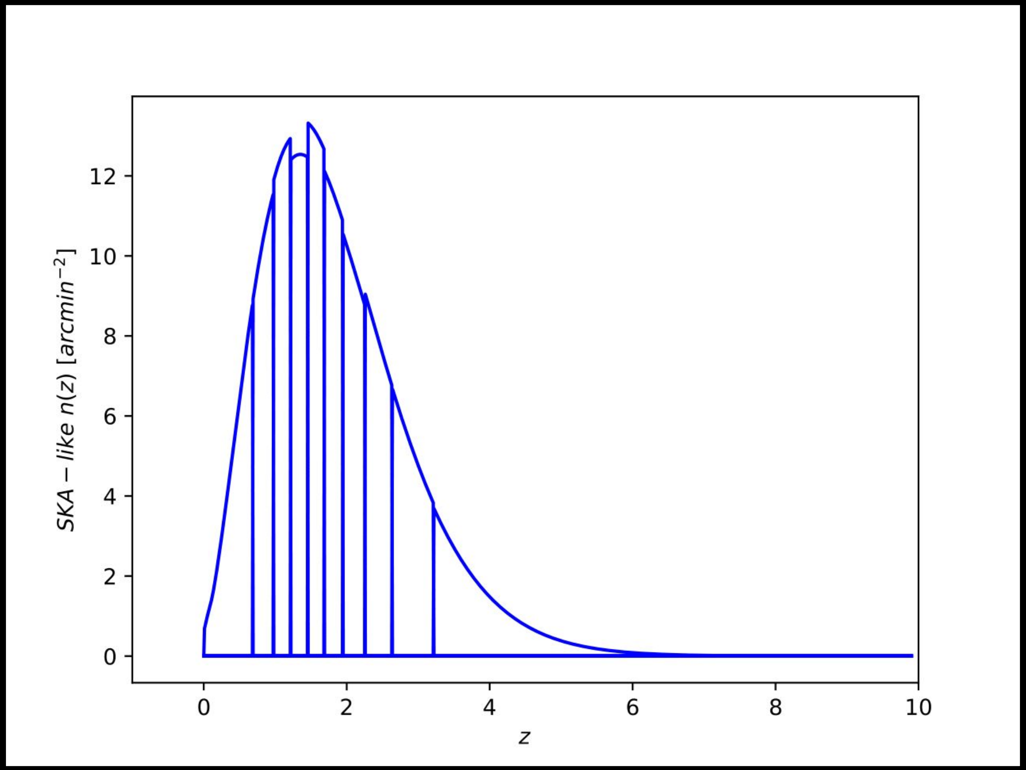

crossonly selfcalibration
total selfcalibration
euclid selfcalibration
SKAO selfcalibration
crossonly +mulsys
total + mulsys
auto-euclid +mulsys
auto-skao + mulsys
crossonly
total
auto-euclid
auto-skao
0.26 0.27 0.28 0.29 0.30 0.31 0.32 0.33 0.34 0.35 0.36 0.37 0.38
Ω_c
0.71 0.72 0.73 0.74 0.75 0.76 0.77 0.78 0.79 0.80 0.81 0.82 0.83 0.84 0.85
σ_8

In order to test the efficiency of the tomography and to see also the effect of a lack in redshift information we produce an analysis with a single bin with all the SKA information merged with the Euclid set we use above.

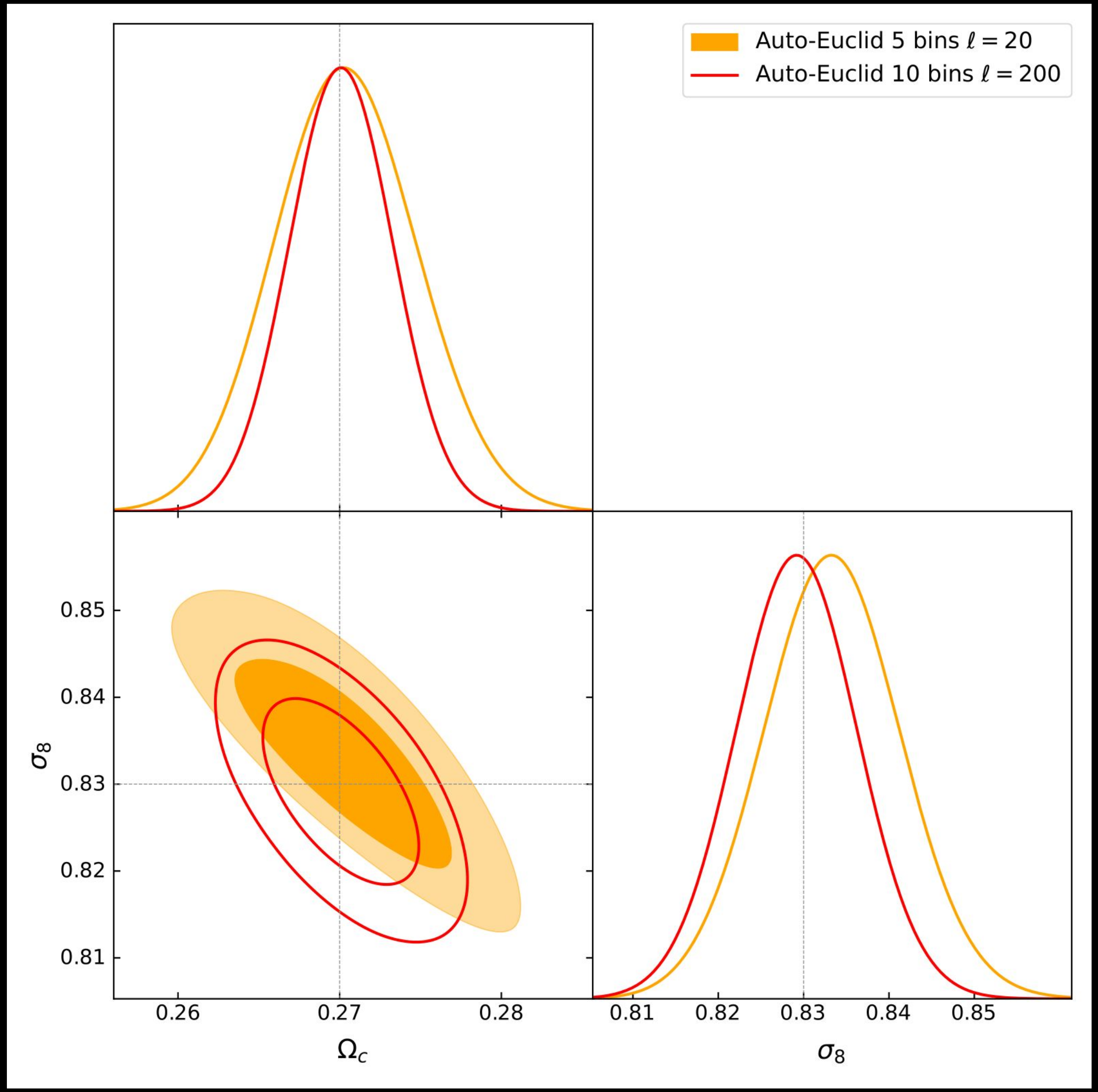


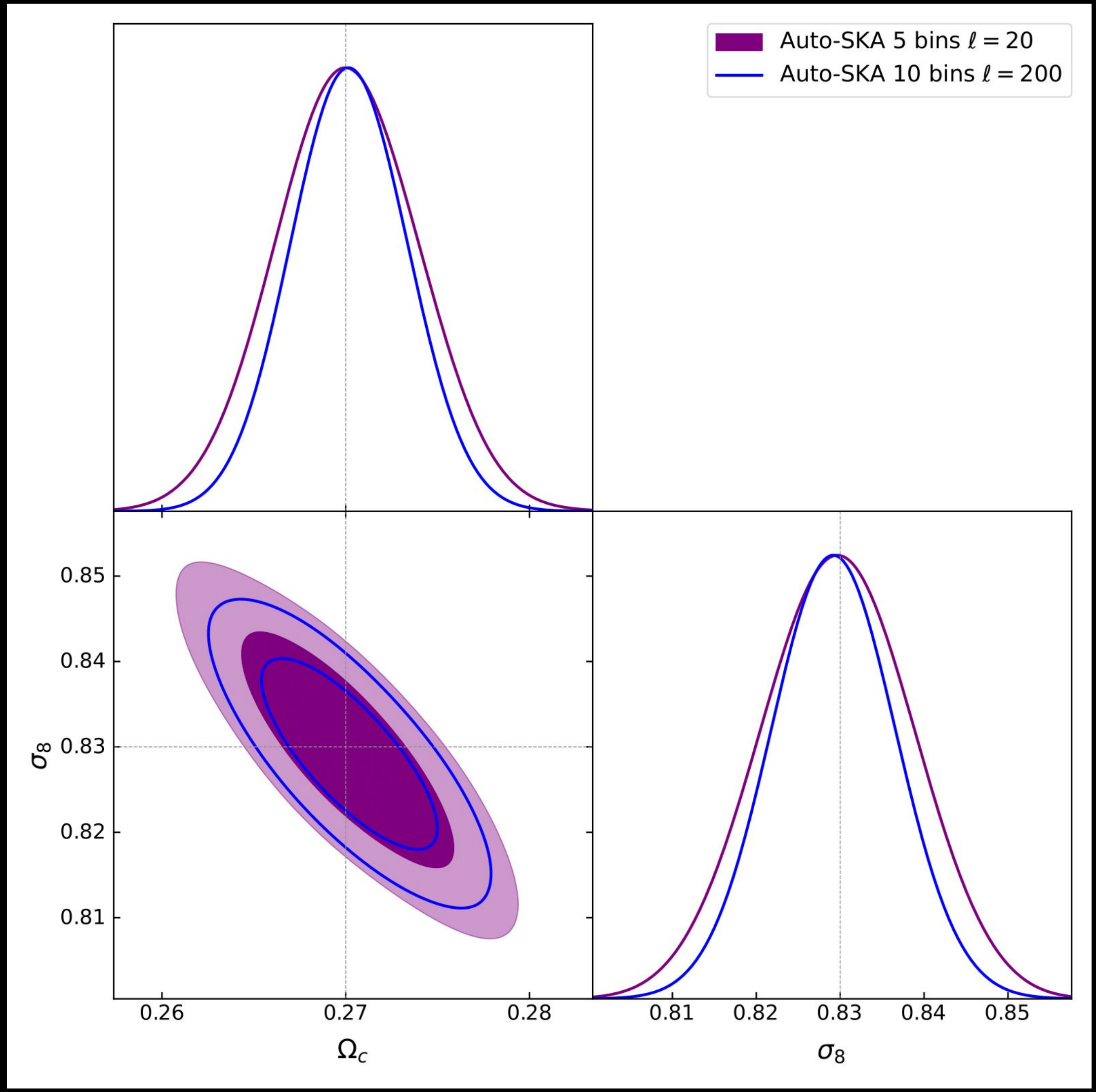
- After the successful implementation of the preliminary version of the code, this was extended to the full set of tomographic bins and to a finer multipoles domain passing from a sampling of $N_\ell = 20$ to $N_\ell = 200$ for the angular power spectra.



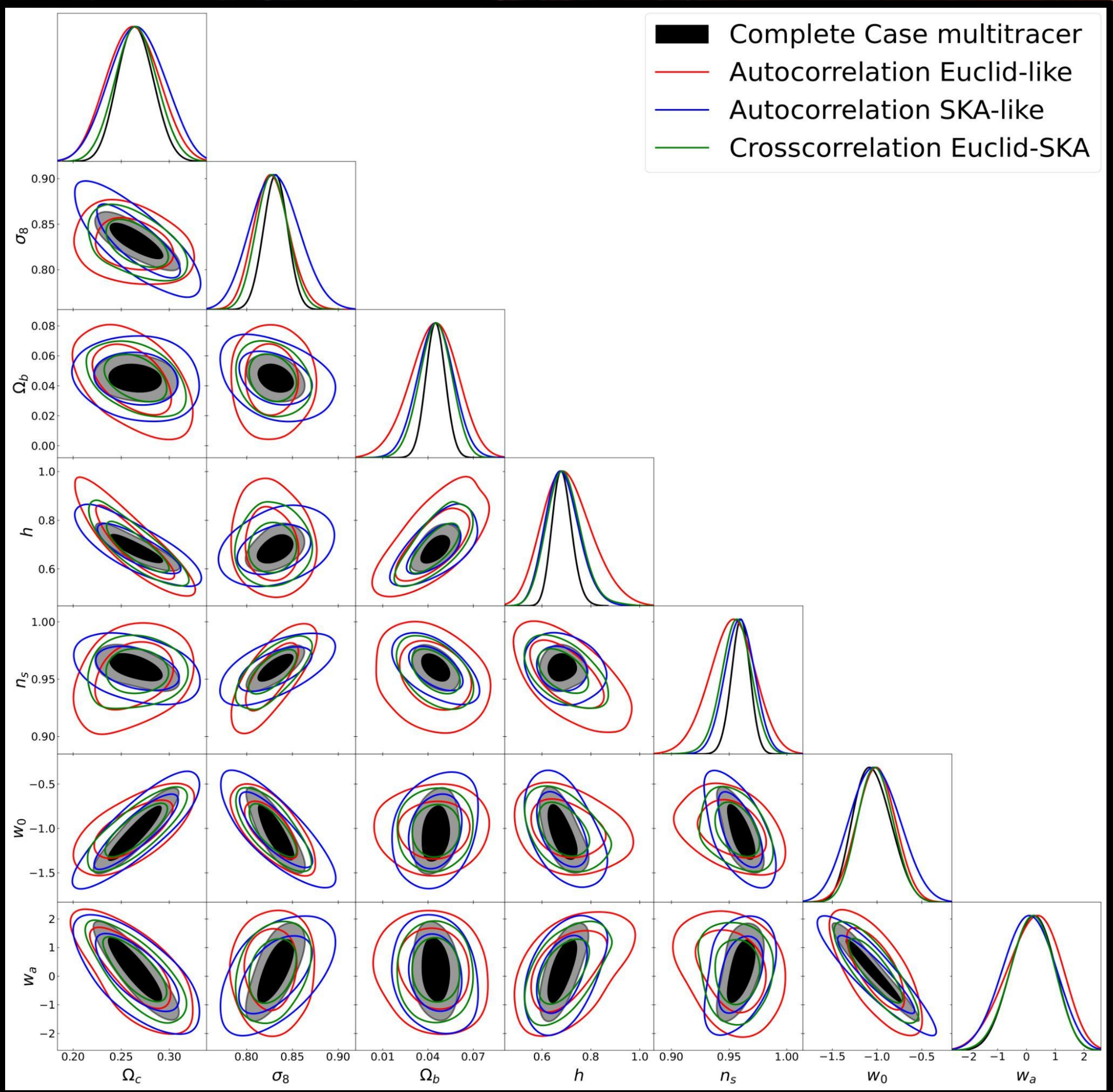


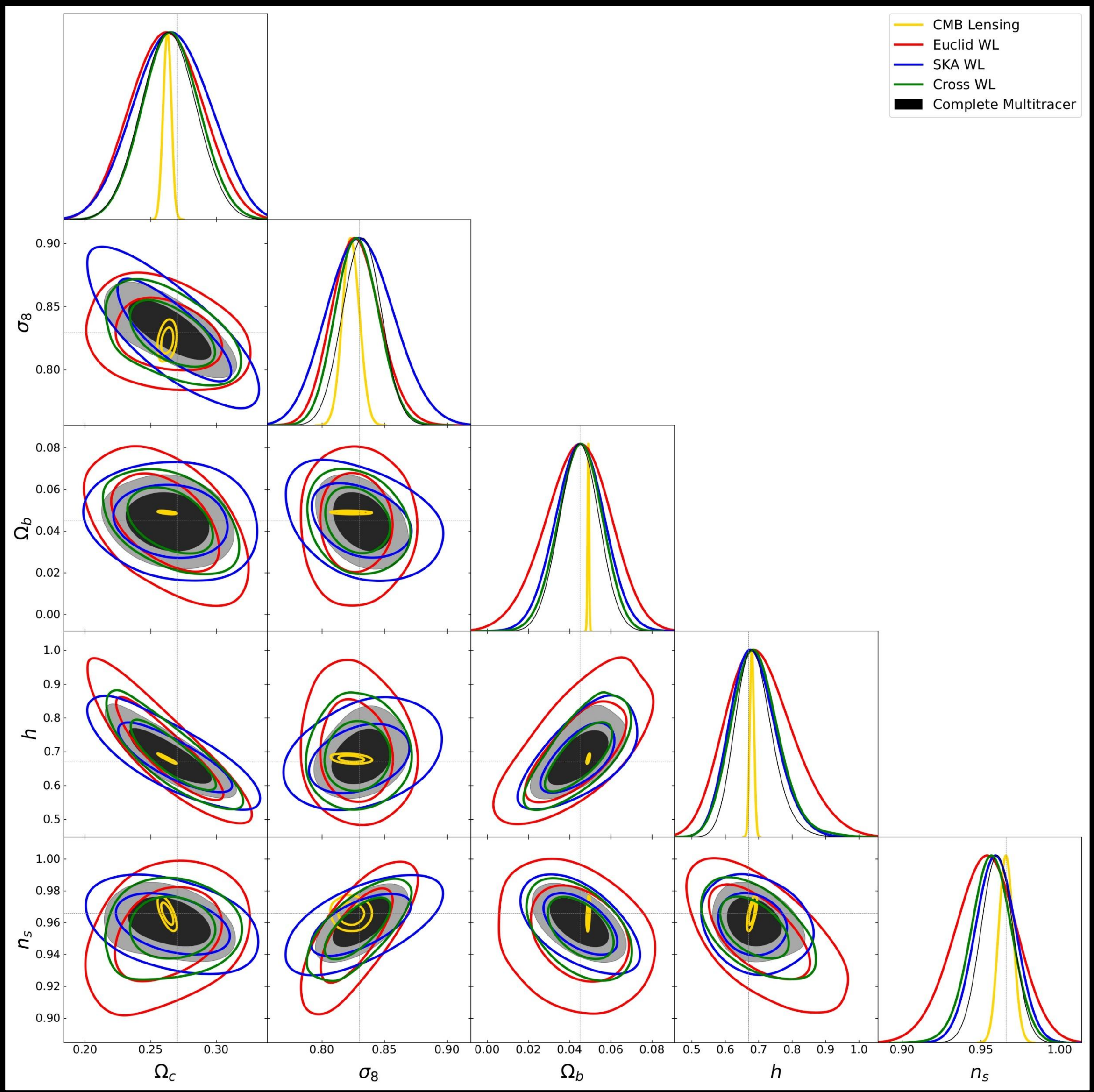
- From the new expanded version of the data set we first reproduced the result for the original parameters $\theta = \{\Omega_c, \sigma_8, \gamma_{E_i}, \gamma_{S_j}\}$ in the auto-correlations cases, with i, j now running over the full 10 bins set.





Next we computed a full cosmological analysis extending the $\theta = \{\Omega_c, \sigma_8, \Omega_b, h, n_s, w_0, w_a\}$ for the cross and auto-correlations cases. We compared it with the CMB Lensing results for the Planck's data (courtesy of Francesco Pace)





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Parameter	Euclid-like Auto-correlation	SKA-like Auto-correlation	Cross-correlation	Multi-tracer
Ω_c	$0.262^{+0.024}_{-0.024}$	$0.266^{+0.025}_{-0.026}$	$0.266^{+0.019}_{-0.019}$	$0.265^{+0.019}_{-0.018}$
σ_8	$0.827^{+0.020}_{-0.018}$	$0.831^{+0.028}_{-0.025}$	$0.828^{+0.015}_{-0.015}$	$0.832^{+0.011}_{-0.011}$
Ω_b	$0.044^{+0.015}_{-0.017}$	$0.045^{+0.010}_{-0.010}$	$0.045^{+0.009}_{-0.009}$	$0.045^{+0.006}_{-0.006}$
h	$0.707^{+0.113}_{-0.085}$	$0.686^{+0.075}_{-0.060}$	$0.692^{+0.076}_{-0.061}$	$0.683^{+0.043}_{-0.036}$
n_s	$0.952^{+0.019}_{-0.020}$	$0.959^{+0.011}_{-0.011}$	$0.956^{+0.011}_{-0.011}$	$0.960^{+0.007}_{-0.007}$
w_0	$-1.011^{+0.186}_{-0.186}$	$-1.023^{+0.242}_{-0.246}$	$-1.017^{+0.171}_{-0.173}$	$-1.048^{+0.225}_{-0.188}$
w_a	$0.228^{+0.837}_{-1.022}$	$0.082^{+0.779}_{-0.793}$	$0.183^{+0.712}_{-0.783}$	$0.205^{+0.709}_{-0.765}$

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Parameter	q Euclid-like Auto-correlation	q SKA-like Auto-correlation	q Cross-correlation	q Multi-tracer
Ω_c	0%	−6.2%	21%	22.3%
σ_8	0%	−38.1%	21.9%	40.6%
Ω_b	0%	34.9%	41.8%	64.7%
h	0%	31.9%	30.9%	60.2%
n_s	0%	43.5%	43.8%	64.8%
w_0	0%	−31.2%	7.4%	−11.1%*
w_a	0%	15.5%	19.6%	20.7%

CONCLUSIONS

- Procedure successfully retrieves the fiducial values of cosmological parameters
- For all parameters expect w_0 the loss of presicion induced by the extra nuissance parameters is mitigated via the multi-tracer approach
- The procedure can be extented to account also for the additive systematics (currently working in progress)