ANGULAR REDSHIFT FLUCTUATIONS AND CMB LENSING

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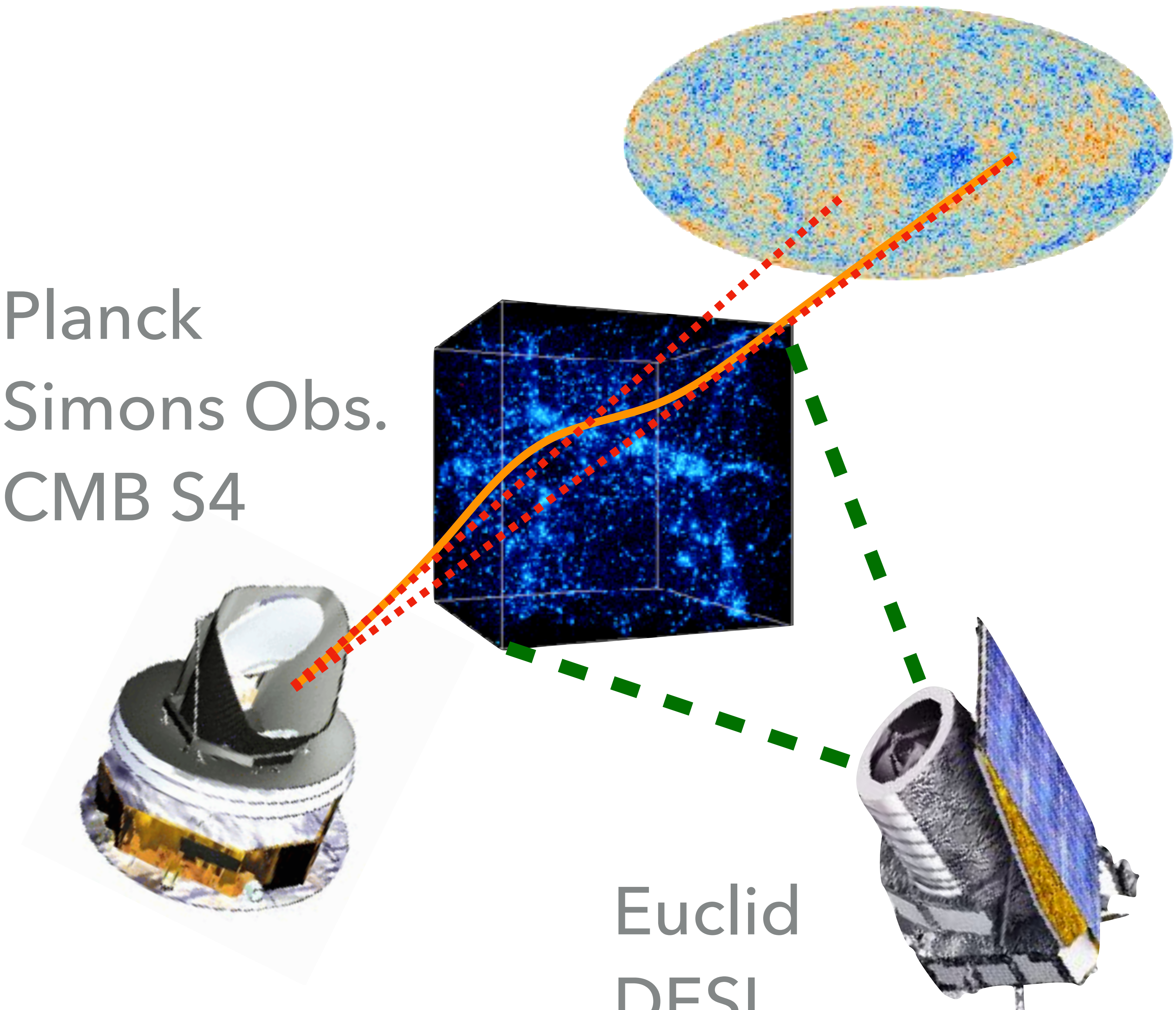
PROBE COMBINATION



- Break degeneracies between:
  - Cosmology
  - Astrophysics
  - Systematic uncertainties

ANGULAR POWER SPECTRA

- Our tool to probe the distribution of matter.

$$C_\ell^{\alpha,\beta} = \frac{2}{\pi}\int_0^\infty dk k^2 P(k)\Delta_\ell^\alpha(k)\Delta_\ell^\beta(k),$$

Matter power spectrum

Kernels specific to the probes

ANGULAR REDSHIFT FLUCTUATIONS

Take the redshift of galaxies as a 3D field:

$$z_{\mathrm{obs}}(z, \hat{\boldsymbol{n}}) = z + (1+z)\frac{\mathbf{v}(z, \hat{\boldsymbol{n}}) \cdot \hat{\boldsymbol{n}}}{c}$$

Project this on a 2D map, under a radial selection function W(z). Measure the fluctuations of this map.

We obtain the theoretical angular power spectrum of this map by linearising at first order in density and velocity.

Make forecast for spectroscopic surveys: DESI and Euclid

ARF KERNELS

$$\Delta_\ell^{\delta_z} = \Delta_\ell^{\delta_z}|_{\delta_m} + \Delta_\ell^{\delta_z}|_{v_{los}}$$

$$C_\ell^{\alpha,\beta} = \frac{2}{\pi}\int_0^\infty dk k^2 P(k)\Delta_\ell^\alpha(k)\Delta_\ell^\beta(k),$$

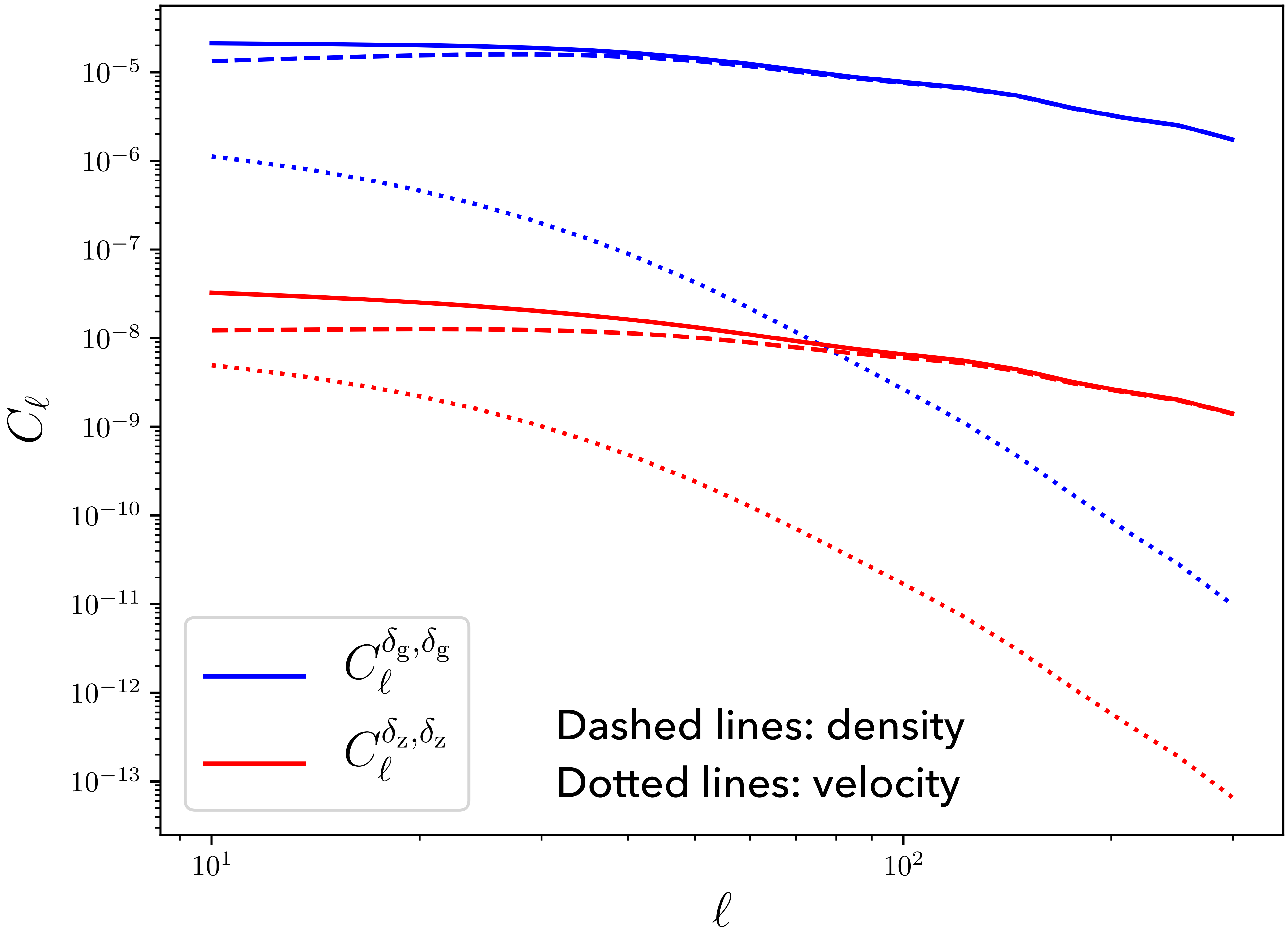
Terms specific to ARF

$$\Delta_\ell^z|_\delta(k) = \frac{1}{N}\int \mathrm{d}V\, \bar{n}_\mathrm{g}(z)\, W(z)\, b_\mathrm{g}(z)\, D(z)\, (z-\bar{z})\, j_\ell(k\, r(z))$$

$$\Delta_\ell^z|_\mathrm{v}(k) = \frac{1}{N}\int \mathrm{d}V\, \bar{n}_\mathrm{g}(z)\, W(z)\, (1+z)\, H(z)\, \frac{\mathrm{d}D}{\mathrm{d}z}\left[1 + (z-\bar{z})\frac{\mathrm{d}\ln W}{\mathrm{d}z}\right]\frac{j_\ell'(k\, r(z))}{k}$$

$$N = \int \mathrm{d}r\; r^2\, \bar{n}_\mathrm{g}(z)\, W_i(z)$$

SENSITIVITY TO PECULIAR VELOCITIES



HOW CAN WE PREDICT ARF FOR FUTURE EXPERIMENTS?

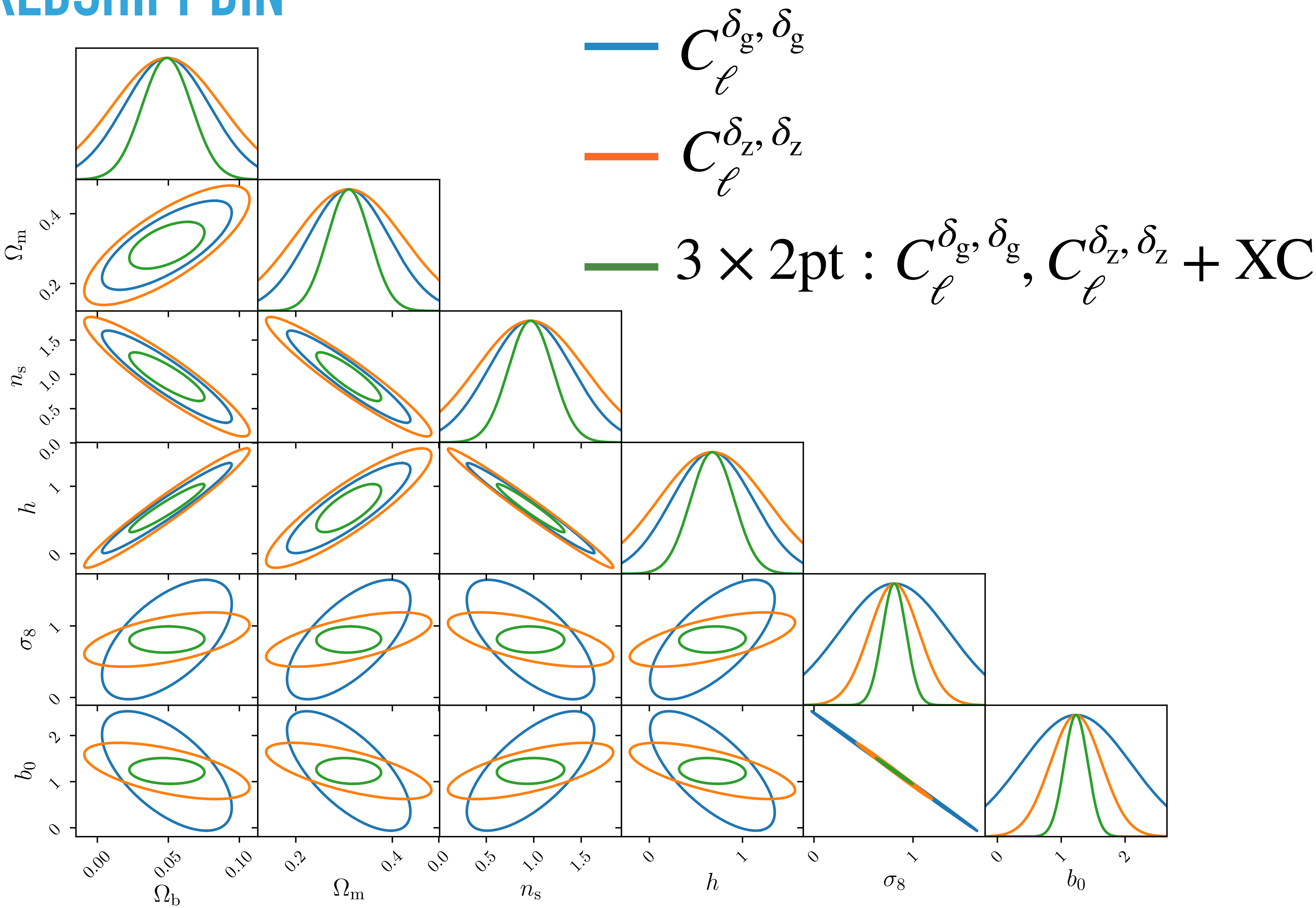
- Fisher formalism:
  - Assumes a gaussian likelihood between parameters.
  - Depend on the survey properties.

- We assume a gaussian likelihood between the probes, such that the fisher matrix is given by:

$$F_{i,j} = \sum_{\ell} \frac{\partial C_\ell}{\partial \lambda_i} \mathrm{Cov}_\ell^{-1} \frac{\partial C_\ell}{\partial \lambda_j}$$

$$\mathrm{Cov}_\ell\left(C_\ell^{\alpha,\beta}, C_\ell^{\gamma,\delta}\right) = \frac{1}{(2\ell+1) f_{\mathrm{sky}}} \times \left[\left(C_\ell^{\alpha,\gamma} + \delta_\gamma^\alpha N_\ell^\alpha\right)\left(C_\ell^{\beta,\delta} + \delta_\delta^\beta N_\ell^\beta\right)\left(C_\ell^{\alpha,\delta} + \delta_\delta^\alpha N_\ell^\alpha\right)\left(C_\ell^{\beta,\gamma} + \delta_\gamma^\beta N_\ell^\beta\right)\right]$$

ONE REDSHIFT BIN



SHOT NOISE

$$N_\ell^{g_i,g_j} = \frac{\delta_j^i}{N_\mathrm{g}^i}$$

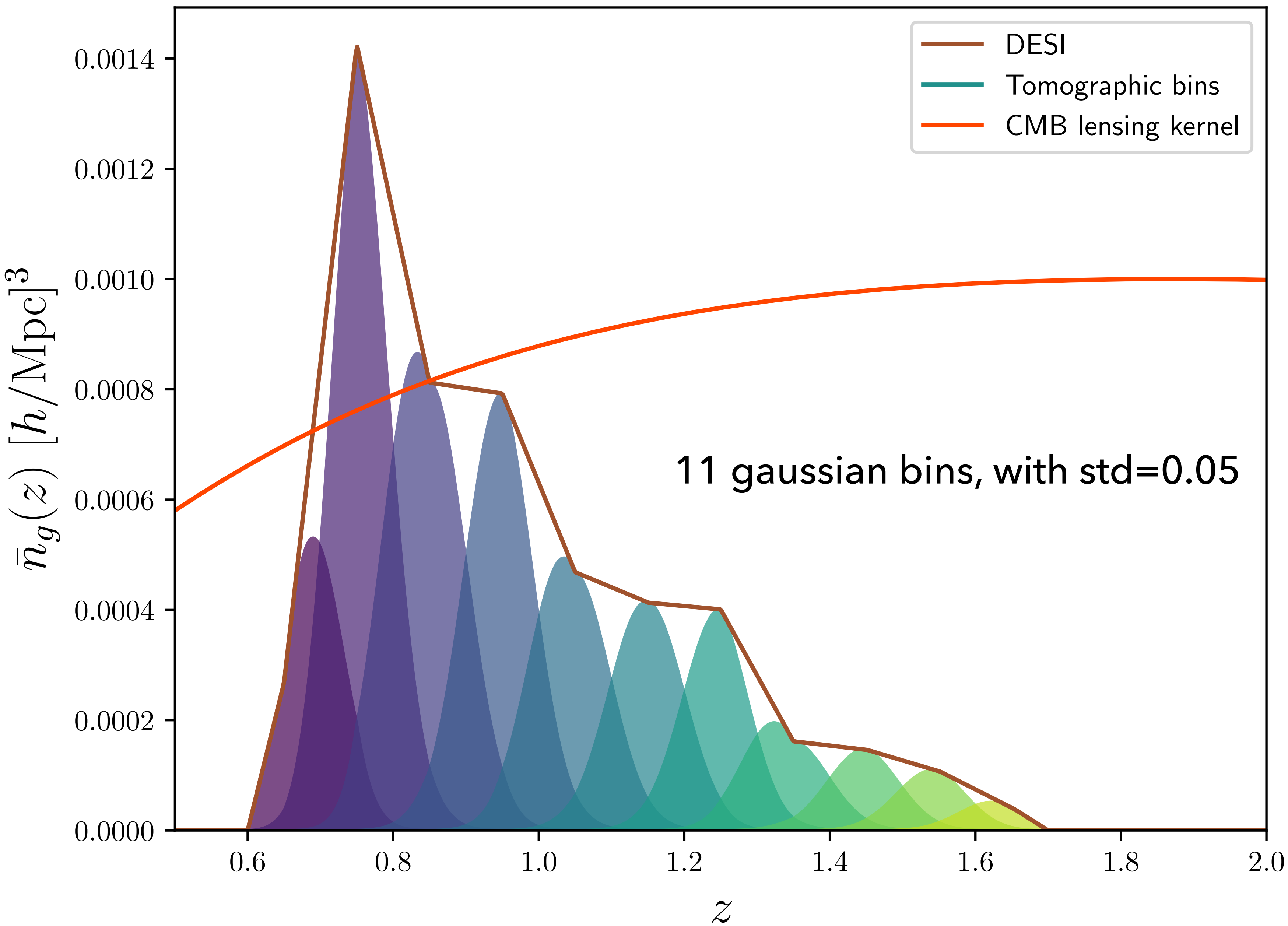
$$N_\mathrm{g}^i = \int \mathrm{d}r\; r^2\, \bar{n}_\mathrm{g}(z)\, W_i(z)$$

$$N_\ell^{z_i,z_j} = \frac{\delta_j^i}{\left(N_\mathrm{g}^i\right)^2} \int \mathrm{d}r\; r^2\, \bar{n}_\mathrm{g}(z)\, W_i(z)\, \left(z - \bar{z}_i\right)^2$$

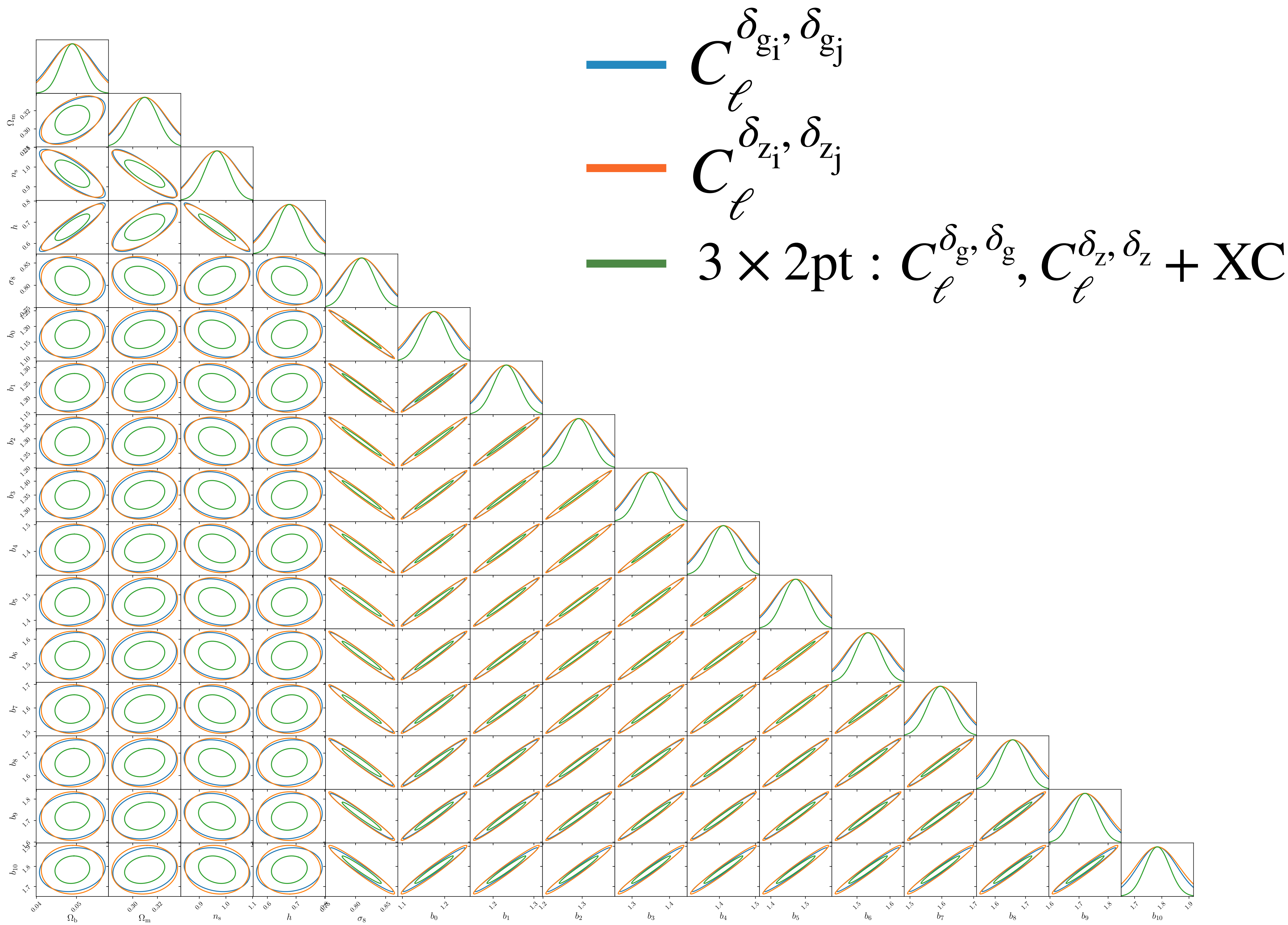
$$N_\ell^{g_i,z_j} = 0$$

DESI EMISSION LINE GALAXIES

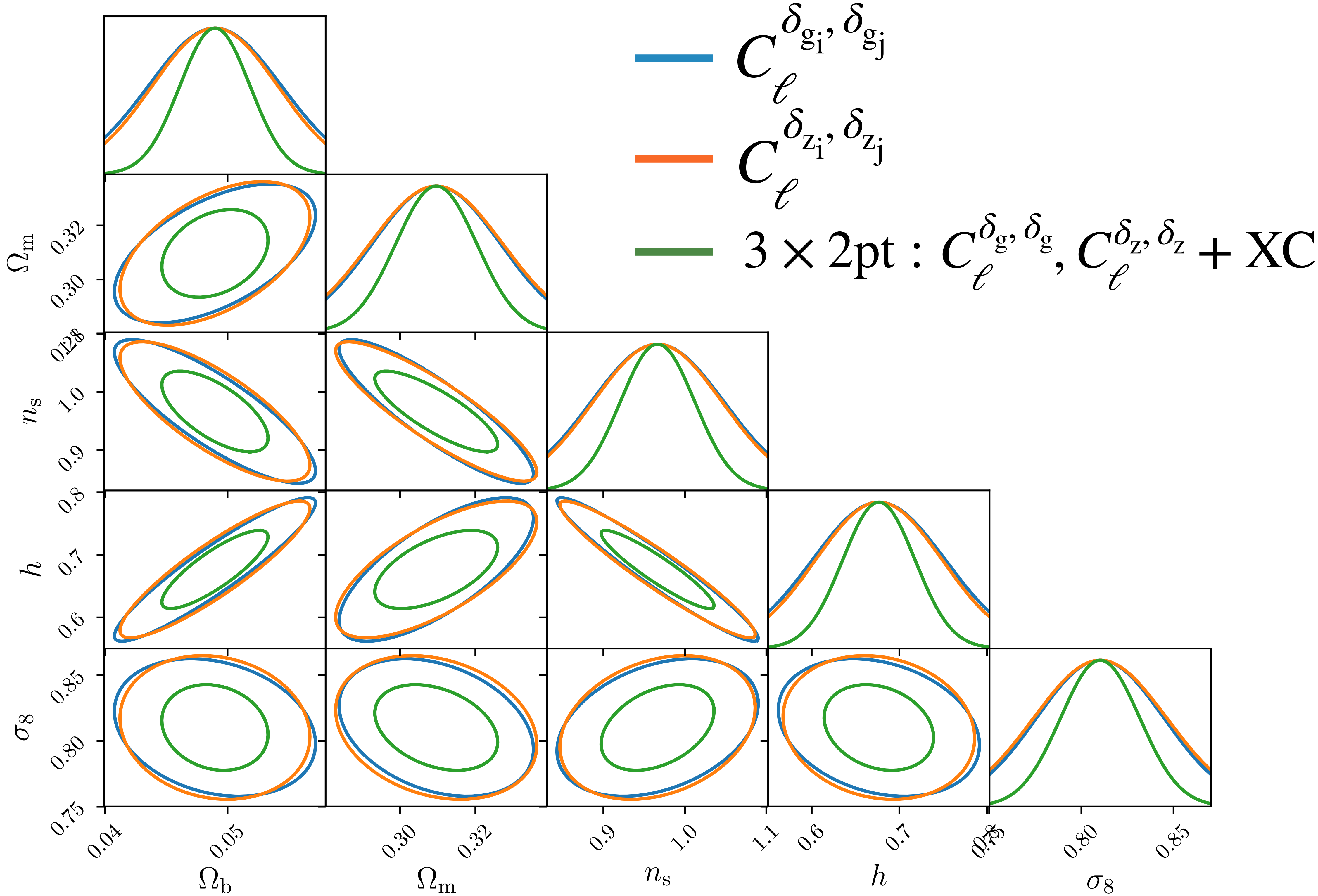
Desi survey = 14 000 deg²



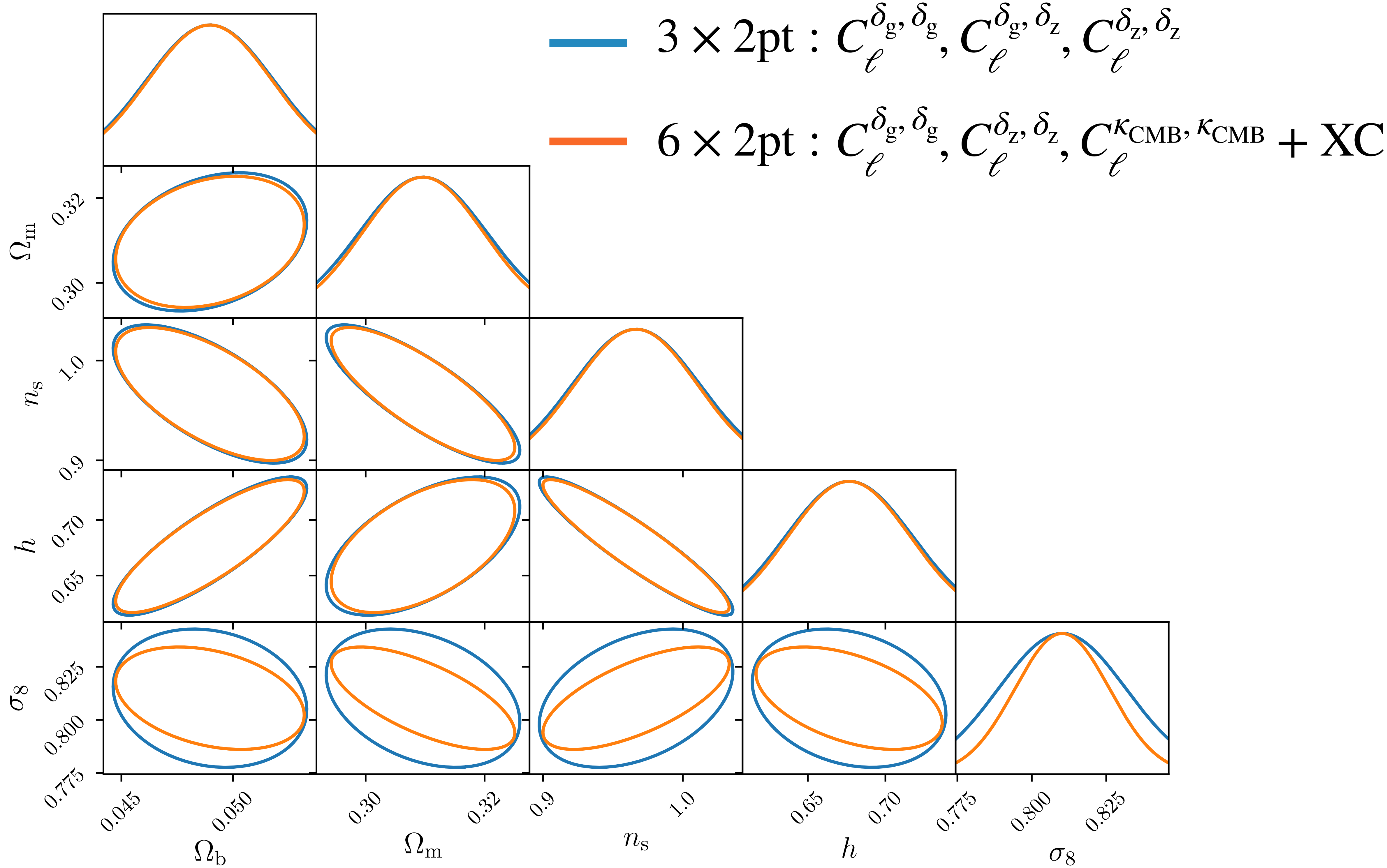
FULL REDSHIFT TOMOGRAPHY



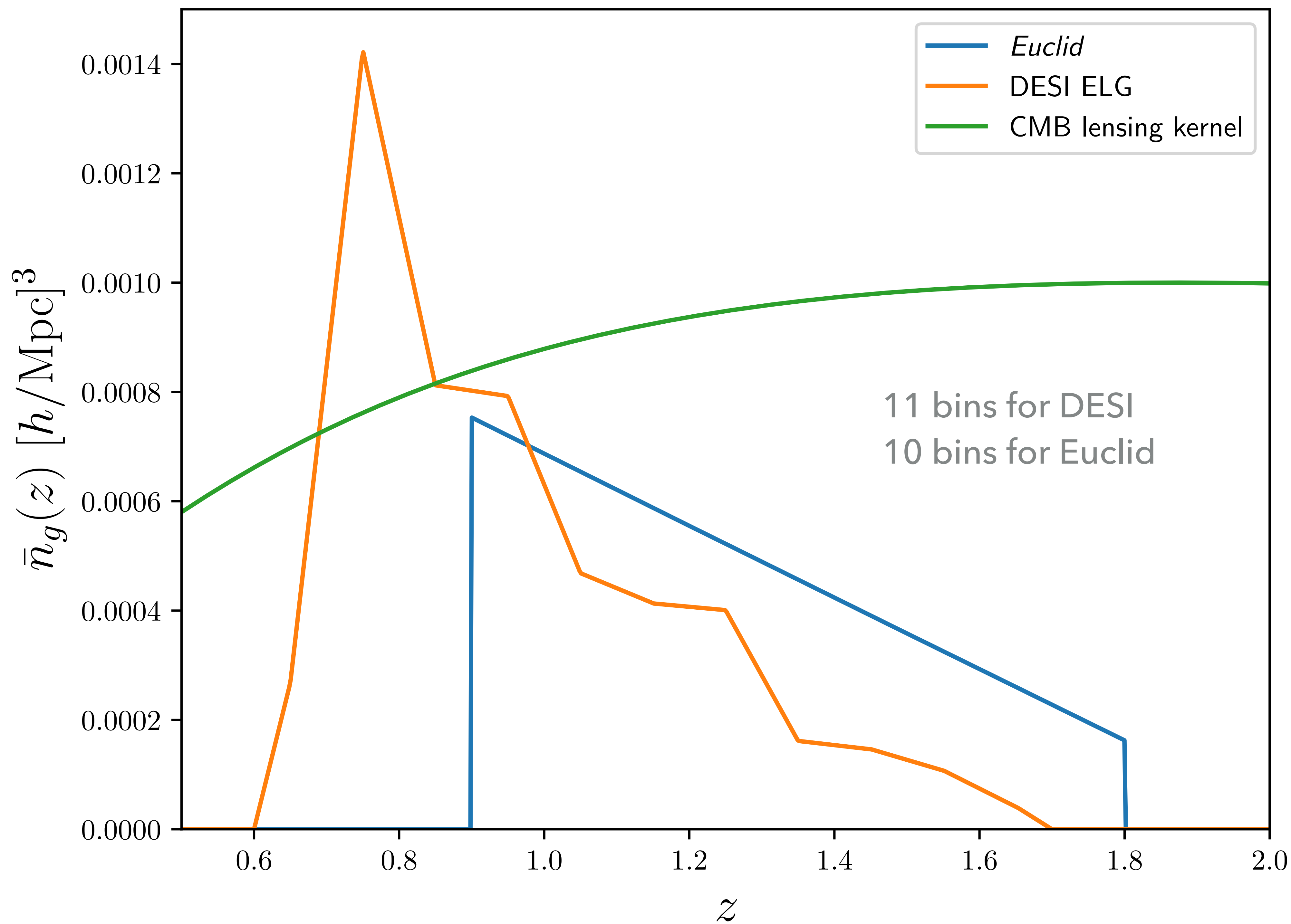
FULL REDSHIFT TOMOGRAPHY



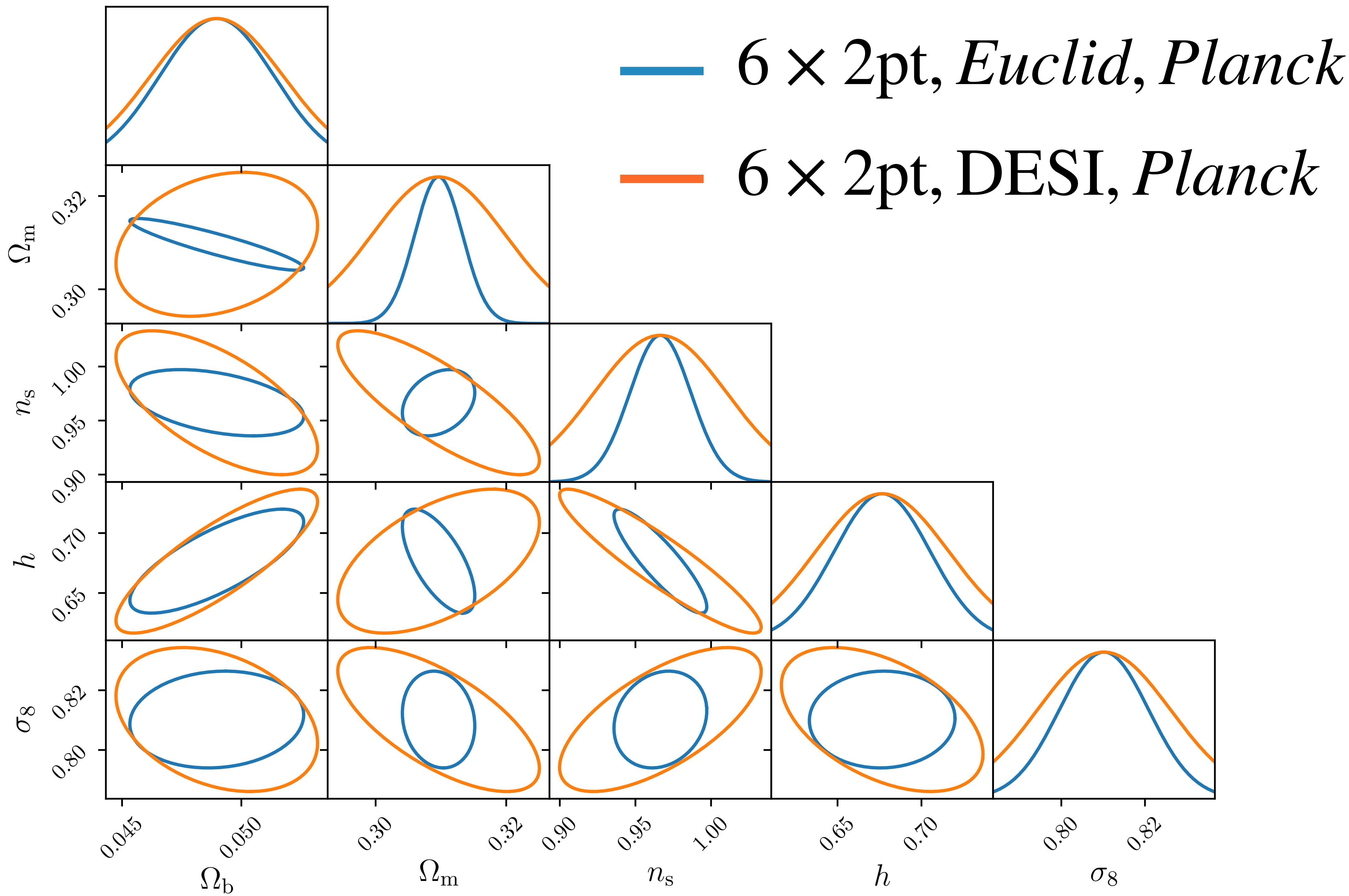
CMB LENSING BREAKS THE SIGMA8-BIAS DEGENERACY



DESI AND EUCLID



COMPARE DESI AND EUCLID



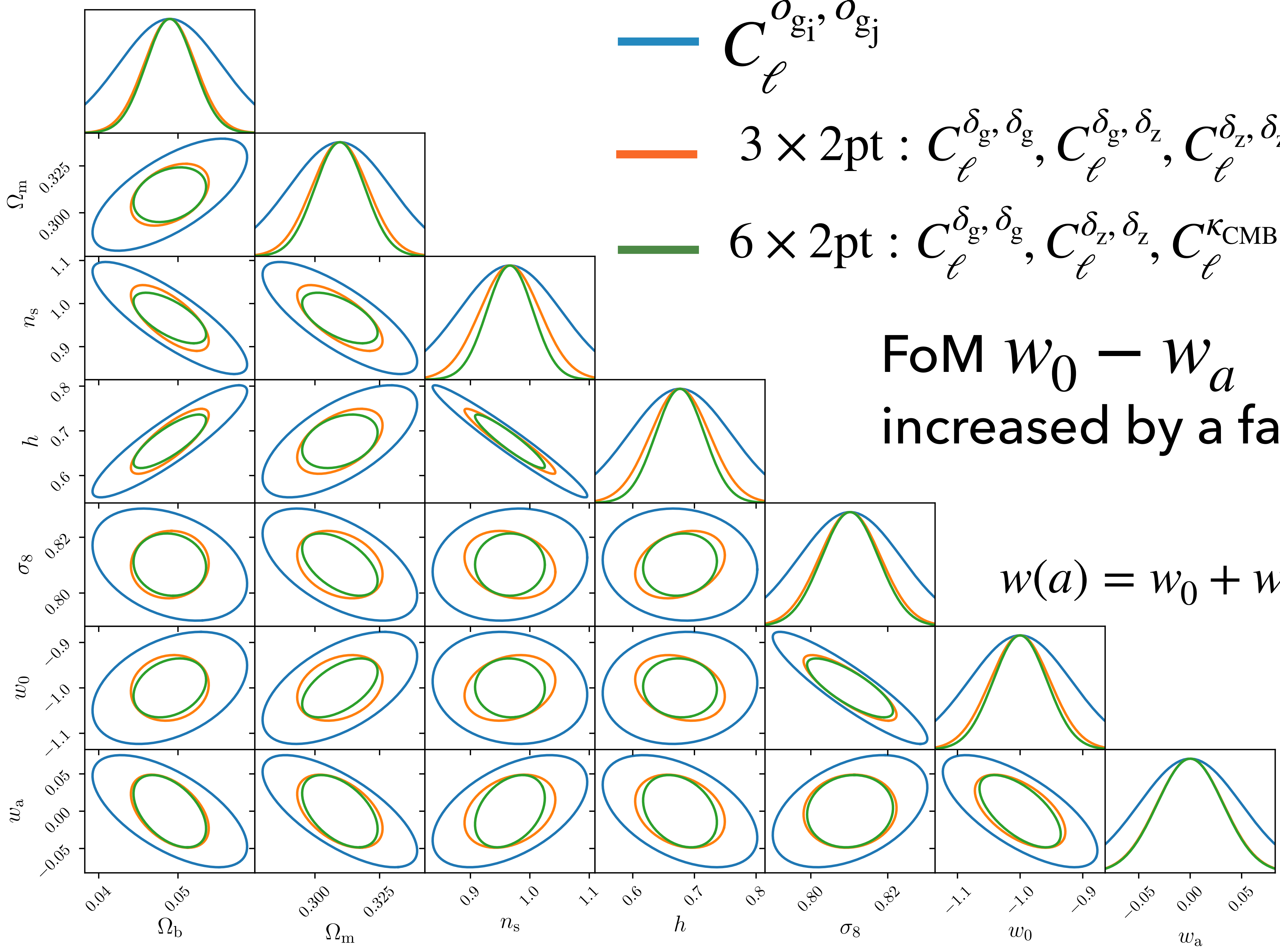
HOW MUCH DO WE GAIN WHEN INCLUDING ARF IN THE ANALYSIS

Figure of Merit ≃ area of the ellipse

Increase on the FoM of $\Omega_{\mathrm{m}} - \sigma_8$ when combining galaxy clustering, ARF and CMB lensing probes.

	+ARF	+ARF +CMB Lensing
DESI	x2.5	x4.6
Euclid	x1.8	x5.8

DARK ENERGY EQUATION OF STATE W0-WA



$C_\ell^{\delta_{g_i}, \delta_{g_j}}$

$3 \times 2\mathrm{pt} : C_\ell^{\delta_g, \delta_g}, C_\ell^{\delta_g, \delta_z}, C_\ell^{\delta_z, \delta_z}$

$6 \times 2\mathrm{pt} : C_\ell^{\delta_g, \delta_g}, C_\ell^{\delta_z, \delta_z}, C_\ell^{\kappa_{\rm CMB}, \kappa_{\rm CMB}} + \mathrm{XC}$

FoM $w_0 - w_a$ increased by a factor 2.3

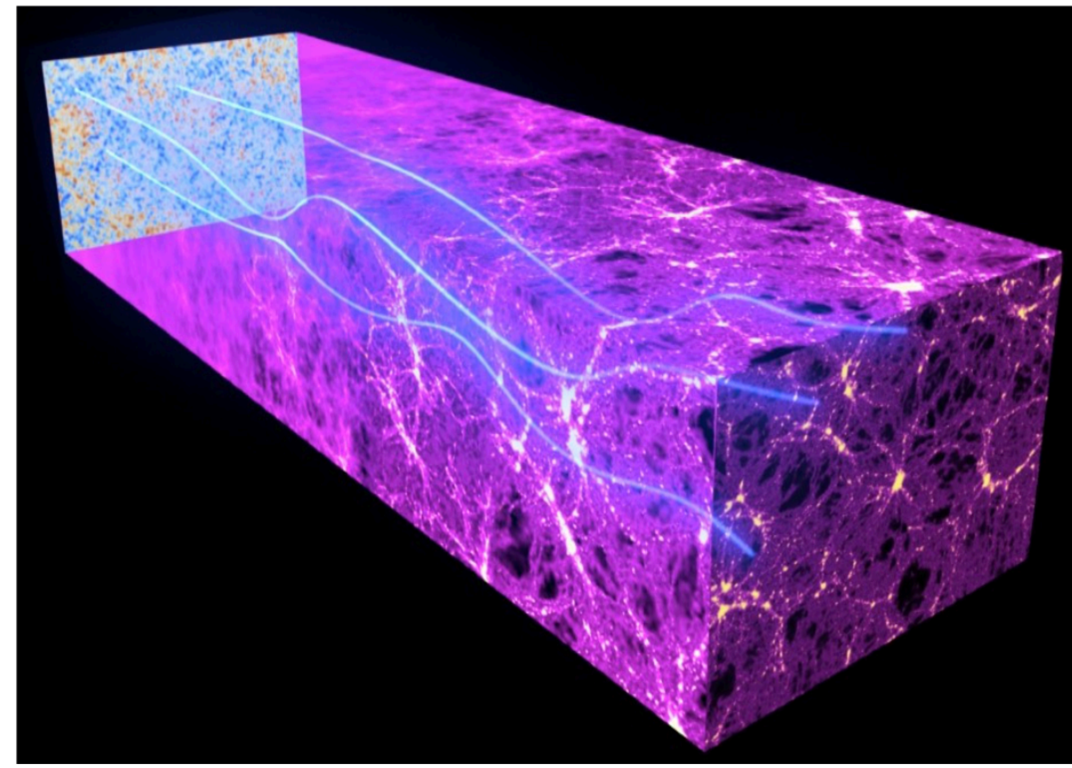
$$w(a) = w_0 + w_a(1 - a)$$

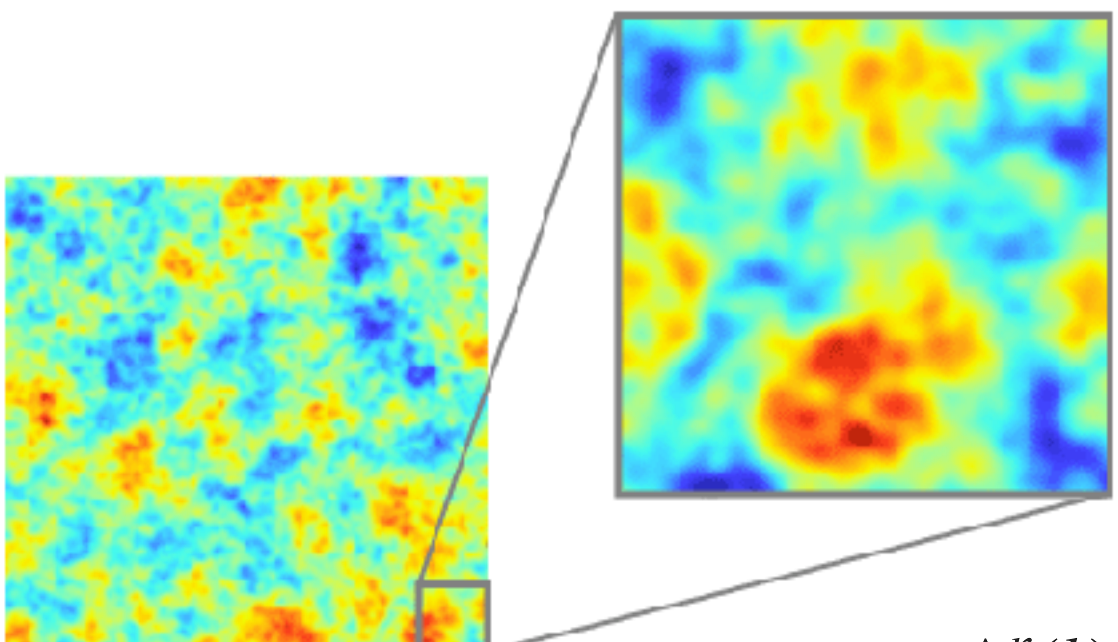
CONCLUSIONS

- ARF are more sensitive to peculiar velocity than the usual galaxy clustering.
- It is a promising way to put additional constraints on cosmological parameters.
- Next steps will be to include the mass of neutrinos as a free parameter.
- Check we get complementary information compared to RSD measurements and to peculiar velocity field reconstructions.

CMB LENSING

The lensing effects on the CMB gives a measurement of the integral of the mass along the line of sight up to the last scattering surface.





Avec effet de lentille gravitationnelle

$$\Delta_\ell^\kappa(k) = \frac{3\Omega_{m,0}}{2}\left(\frac{H_0}{c}\right)^2 \int_0^\infty d\chi \frac{\chi}{a(\chi)} \frac{\chi_* - \chi}{\chi_*} D_{\delta m}(\chi) j_\ell(k\chi)$$