Angular redshift fluctuations and CMB lensing

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Context

Next generation galaxy surveys will provide millions of galaxies with spectroscopic redshift. To describe the distribution of matter and to constrain the cosmological models, new probes are currently being developed. We use here the angular redshift fluctuations (ARF, noted δ_z) [1,2], which measures the fluctuations of the average redshift of galaxies in a tomographic shell. This observable is sensitive to the distribution of matter and to the redshift space distortions, and is complementary to the angular density fluctuations (δ_g). We combine these two galaxy probes with the convergence field of the CMB lensing, which gives a measure of the integral of the mass along the line of sight. We forecast the constraints we can achieve on the dark sector with this combinations.

Power spectra and probe combination

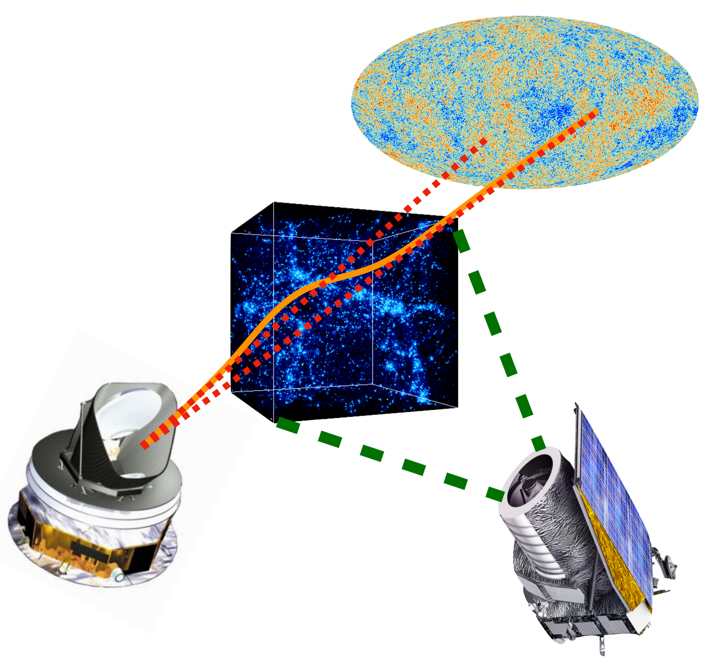
For two probes α and β we have:

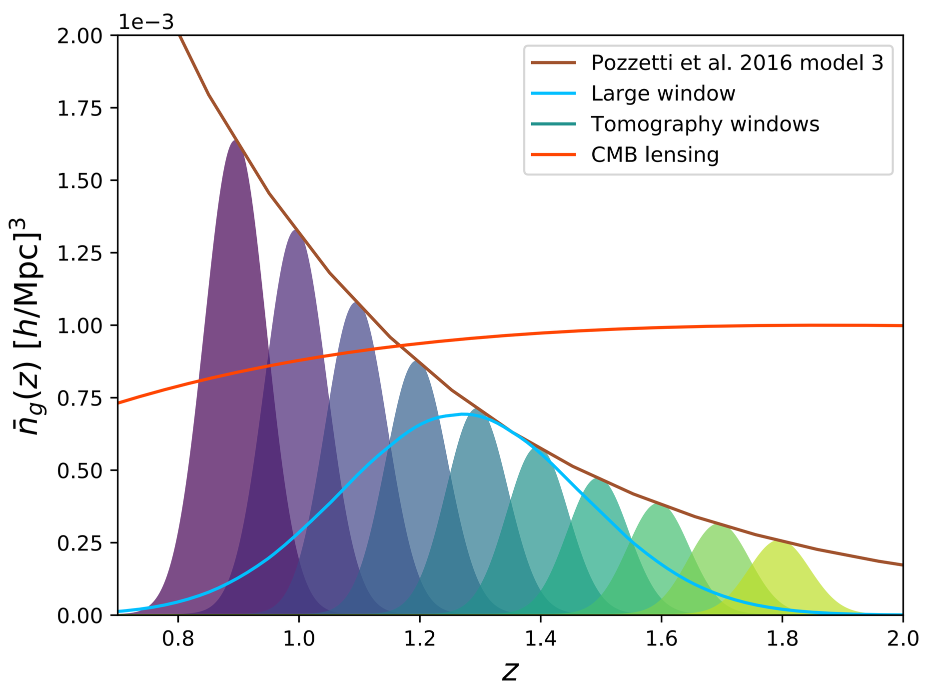
$$C_\ell^{\alpha,\beta} = \frac{2}{\pi}\int_0^\infty dk k^2 P(k)\Delta_\ell^\alpha(k)\Delta_\ell^\beta(k),$$

Matter power spectrum

Kernels specific to the probes

Each probe shows degeneracies between cosmology, and astrophysics and has specific systematic uncertainties. Combining probes can break this degeneracies and reduce systematics.





Angular redshift fluctuations

We measure the variations around the average of the redshift of galaxies in a direction of the sky, weighted by a gaussian shell centered on z_0 of width σ_z:

$$\delta_z(\hat{n}\,|\,z_0,\sigma_z) = \frac{\sum_j (z_j-\bar{z})W(z_j\,|\,z_0,\sigma_z)}{\left\langle \sum_j W(z_j\,|\,z_0,\sigma_z)\right\rangle_{\hat{n}}}, \quad \text{with} \quad \bar{z} = \left\langle \sum_j z_j W(z_j\,|\,z_{obs},\sigma_z)\right\rangle_{\hat{n}}$$

In the power spectra kernels, we can separate the term due to the density fluctuations and the term due to the peculiar velocities:

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

Terms specific to ARF

$$\Delta_\ell^{\delta_z}|_{\delta_m}(k) = \int_0^\infty d\chi\chi^2\bar{n}_g W b_g D_{\delta m}\left[z_H - \bar{z}_H\right] j_\ell(k\chi)$$

$$\Delta_\ell^{\delta_z}|_{v_{los}}(k) = \int_0^\infty d\chi\chi^2\bar{n}_g W(1+z_H)H\frac{dD_{\delta m}}{dz}\left[1 - \frac{dlnW}{dz}|_{(z_{obs}-z_H)}(z_H-\bar{z}_H)\right]\frac{j'_\ell(k\chi)}{k}$$

The angular redshift fluctuations are not affected by systematics that produce a bias constant with redshift, which is not the case for the angular density fluctuations.

CMB Lensing

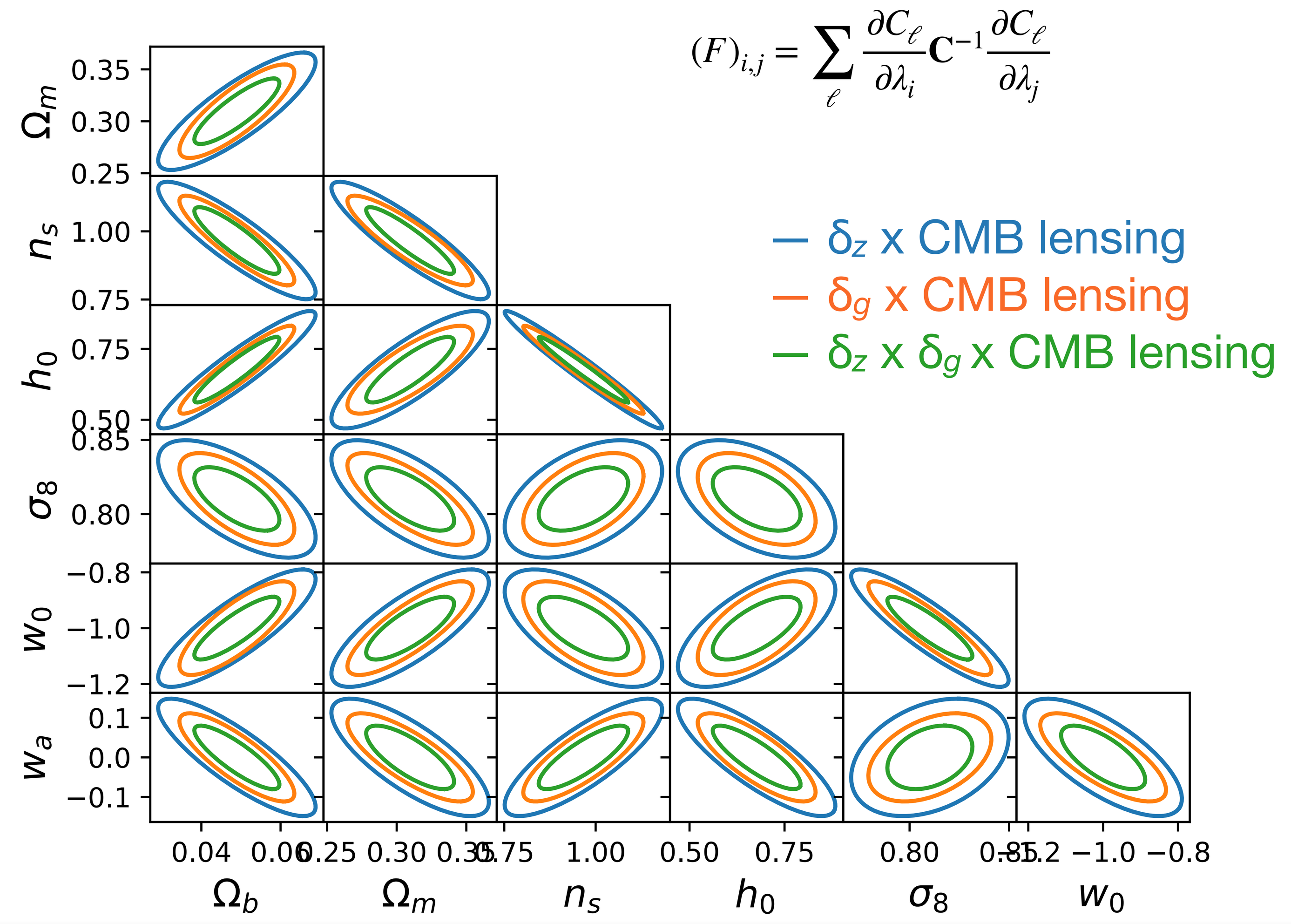
The lensing effects on the CMB gives a measurement of the integral of the mass along the line of sight up to the last scattering surface.

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

Fisher Forecasts

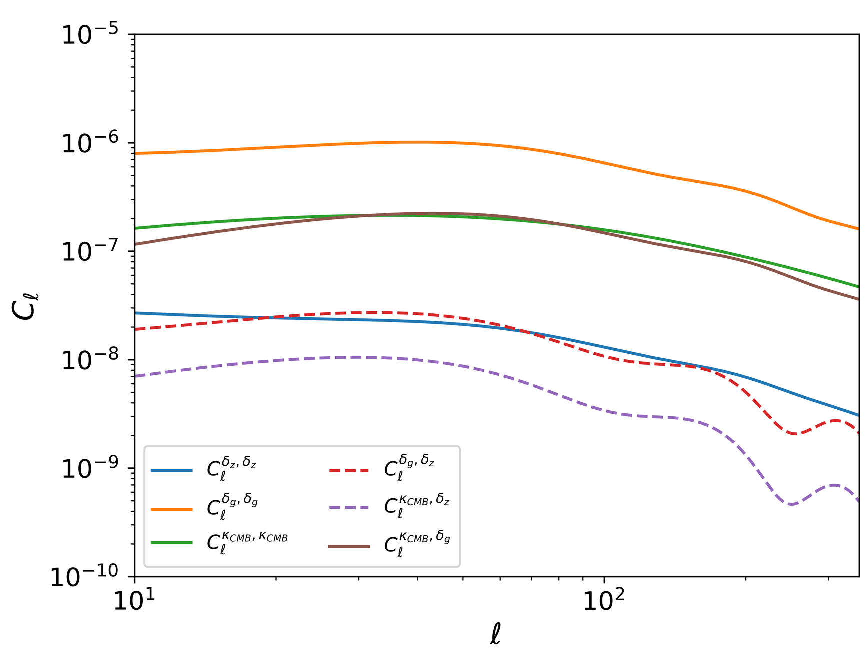
Using the Fisher formalism, we forecast constraints for cosmological parameters with a time varying dark energy equation of state.
The number density of galaxies is given by [3], the bias of galaxies is given by [4]. We model the lensing reconstruction noise for a Planck-like experiment, and we use the expected shot noise for a Euclid-like survey. We suppose a gaussian covariance between each probe.
For the galaxy probes (δ_z and δ_g), we use one large window and ten smaller ones.

$$(F)_{i,j} = \sum_\ell \frac{\partial C_\ell}{\partial\lambda_i}\mathbf{C}^{-1}\frac{\partial C_\ell}{\partial\lambda_j}$$



Power spectra

The figure on the right shows our computation of the different power spectra using a gaussian window of z_0=1.35 and σ_z=0.2, between l=10 and l=350.
Dashed lines are negative values.



Conclusion

Futur surveys are expected to give percent level accuracy on cosmological parameters. All the probes should be used to reach this goal. Beyond standard galaxy clustering and weak lensing, angular redshift fluctuations appears as a new probe able to provide complementary information on the distribution of matter.
Our work shows that combining this new probe with the CMB lensing and the galaxy clustering increases constraints on the dark sector. In a future study we will apply the formalism developed here to existing data from galaxy spectroscopic surveys like BOSS.

[1] C. Hernandez-Monteagudo *et al., in prep.* [2] L. Legrand *et al., in prep.* [3] Pozzetti, L. *et al. 2016 A&A* **590**, A3 [4] Orsi, A. *et al. 2010 MNRAS* **405**, 1006