Cross-correlation of CMB lensing and galaxy surveys data

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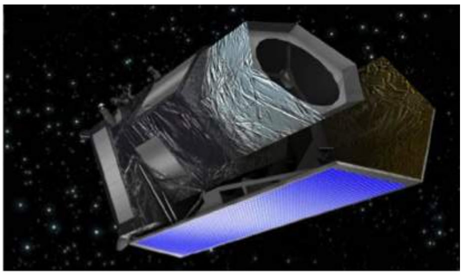
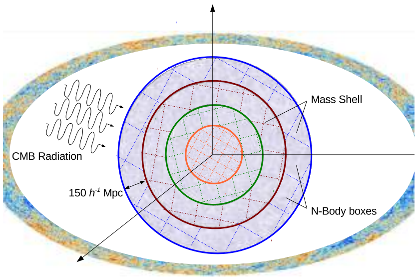
Motivations

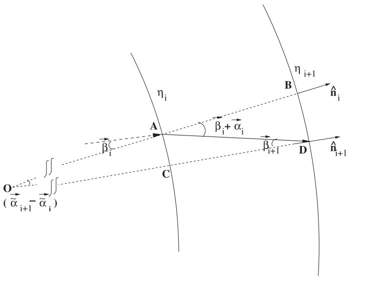


- The upcoming EUCLID satellite will accurately map the matter distribution at $z \lesssim 3$ through galaxy observations.
- On the same timescale, new CMB experiments will produce high fidelity CMB data.
- CMB photons cross all the galaxies observed by EUCLID: we can reconstruct the matter distribution from CMB looking at the gravitational lensing of its photons.
- Joint analysis of EUCLID and CMB lensing maps will increase the statistical power and minimize instrumental systematics contamination on our cosmological constraints.

Multiple lens method



- From time snapshot of N-body simulations we reconstruct the observer lightcone over the full sky using stacking techniques.
- We slice the lightcone into shells of finite comoving thickness and collapse them into planes of surface mass density.
- We solve the Poisson equation in harmonic domain to extract the lensing potential ψ^i and the deflection field $\boldsymbol{\alpha}^i$ for each shell.
- We follow the CMB ray path $\boldsymbol{\beta}(\boldsymbol{\theta}, \chi)$ using pixel-based methods (e.g. LensPix).

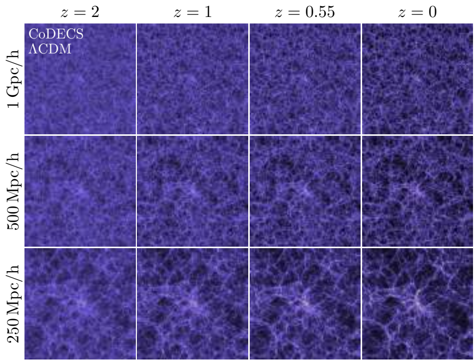


from Das & Bode 2008.

References

[1] Calabrese, Carbone, Fabbian et al. 2015, JCAP, 3, 49.
[2] Fabbian et al. 2017, arXiv:1702.03317
[3] Fabbian & Stompor 2013, A& A, 556, A109.
[4] Castorina, E., Carbone, C. et al. 2015, JCAP, 7, 043.

Challenges



- We need reliable simulations to test statistical estimators of the cross-correlation between CMB lensing and Large Scale Structures (LSS) data and to model the signal in non-standard cosmologies.
- Our approach: capitalize on availability of large, high resolution N-body numerical simulations to study CMB lensing including full non-linear and hierarchical growth of cosmic structures.
- Check approximations and assumptions of widely-used simplified semi-analytic modeling of CMB lensing (e.g. Born approximation).
- Develop a unified formalism for realistic CMB-LSS cross-correlation simulations.

Propagating the CMB magnification matrix

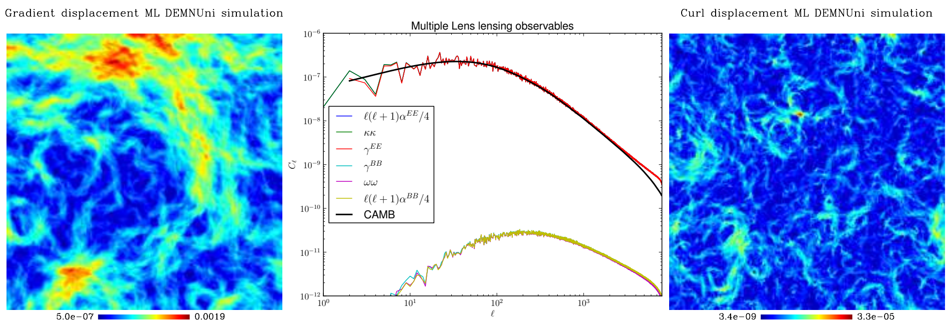
- We propagated for the first time the full lensing magnification matrix $\mathbf{A}$ of CMB lensing in the ML formalism

$$\mathbf{A}(\boldsymbol{\theta}, \chi) = \frac{\partial \beta^j}{\partial \theta_k} = \delta_{jk} - \frac{2}{c^2}\int_0^{\chi} \frac{\chi - \chi'}{\chi\chi'} \Phi_{,\theta_j \theta_k}\left(\beta(\boldsymbol{\theta}, \chi'), \chi'\right) \mathbf{A}_{kj}(\boldsymbol{\theta}, \chi') d\chi'$$

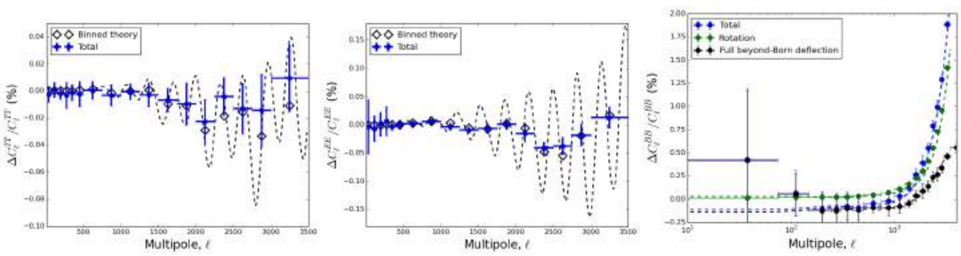
- We adopted the LenS^{2}HAT algorithm [3] to increase numerical efficiency, accuracy and achievable resolution. We can perform $3''$ resolution raytracing simulation on the full sky.
- Beyond-Born corrections add a new curl-component to the effective deflection field.

$$\boldsymbol{\alpha} = \nabla\psi(\vartheta, \varphi) + \nabla \times \Omega(\vartheta, \varphi)$$

- The results are stable to 1% level w.r.t. the number of lens planes used in the simulations.
- We recover consistency relation between lensing observables at $\mathcal{O}(10^{-2})$ accuracy or better.



Raytracing vs Born approximation



- We evaluated the impact of second order lensing correction on CMB angular power spectra and found results matching the most updated and accurate analytical prediction based on perturbation theory.
- Post-born corrections can bias the amplitude of the reconstructed CMB lensing map and galaxy data cross-correlation: it is small but non negligible. Preliminary results indicate those could bias the estimation of neutrino mass from these observables at significant level.
- **Next step**: integrate the simulation of galaxies and clusters emissions correlated with the CMB lensing. Quantify impact of cross-correlation signal on EUCLID science targets.