General Relativistic corrections in density-shear correlations

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(with Ruth Durrer and Elena Sellentin

based on arXiv: 1801.02518)

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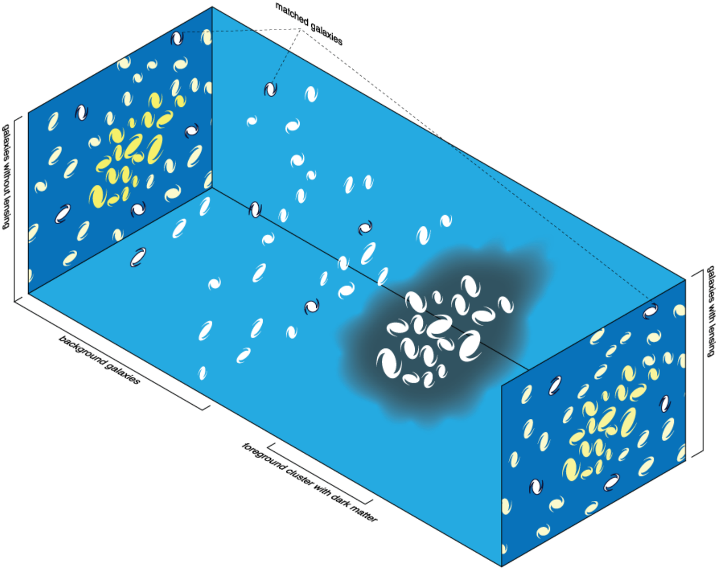
Overview

Introduction

- Counting galaxies in a fixed solid angle and redshift bin does not directly measure the galaxy over-density
- The resulting count is affected by redshift space distortions, lensing and magnification bias, and by large-scale relativistic effects
- A redshift bin of number counts lenses sources in a background bin, and is also lensed by all masses between the observer and the counted source population
- In standard analyses, this additional lensing is only accounted for in the error budget



Credit: Michael Sachs

What this work is about

- We investigate relativistic corrections on galaxy-galaxy lensing: the tangential shear of background sources is correlated with number counts in the foreground
- We mainly study how the lensing term from projection affects the galaxy-galaxy lensing
- We particularly use a mock survey based on the redshift bins of the DES first year results
- Our analysis shows that the DES results could gain in precision by including the lensing term directly into the signal of the number counts

Observable overdensity

$$
\begin{aligned}
\Delta(\mathbf{n}, z, m_{\lim}) \;=\;& b(z)\delta + \frac{1}{\mathcal{H}}\left[\dot{\Phi} + \partial_r^2 V\right] \\
&+(2-5s)\left[\int_0^r \frac{d\tilde{r}}{r}(\Phi+\Psi) \; -\kappa\right] \\
&+(f_{\rm evo}-3)\mathcal{H}V + (5s-2)\Phi + \Psi \\
&+\left(\frac{\dot{\mathcal{H}}}{\mathcal{H}^2} + \frac{2-5s}{r\mathcal{H}} + 5s - f_{\rm evo}\right) \\
&\left(\Psi + \partial_r V + \int_0^r d\tilde{r}(\dot{\Phi}+\dot{\Psi})\right)
\end{aligned}
$$

(Bonvin and Durrer, 2011)

Correlation function between observable galaxy number count and tangential shear

$$\langle \Delta(\mathbf{n}, z)\gamma_t(\mathbf{n}', z')\rangle = \frac{-1}{4\pi}\sum_\ell \frac{2\ell+1}{\ell(\ell+1)} P_{\ell\, 2}(\mathbf{n}\cdot\mathbf{n}') C_\ell^{\Delta,\kappa}(z,z')\,.$$

$$\begin{aligned} C_\ell^{\Delta,\kappa}(z,z') &= b(z) C_\ell^{\delta,\kappa}(z,z') + C_\ell^{\mathrm{rsd},\,\kappa}(z,z') \\ &\quad -(2-5s(z)) C_\ell^{\kappa,\kappa}(z,z') + C_\ell^{\mathrm{ls},\,\kappa}(z,z')\,. \end{aligned}$$

δ: not-directly observable density contrast

rsd: redshift space distortions

κ: convergence

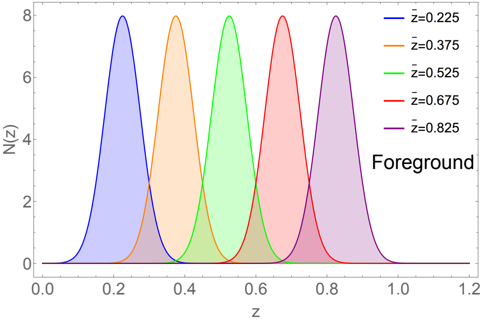
ls: large scale relativistic effects

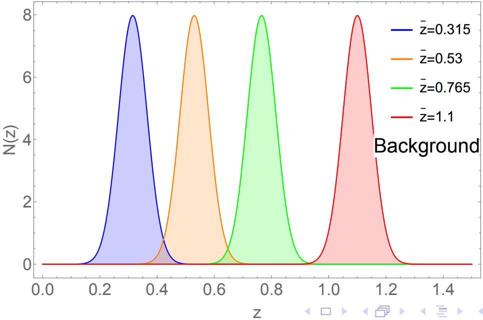
Numerical Examples

- We present changes in the signal for numerical evaluations of these relativistic contributions for the standard ΛCDM cosmology, using CLASS
- We assume purely scalar perturbations with cosmological parameters of the Planck-2015 results
- We set the galaxy bias to unity, $b(z) = 1$, and assume a complete survey, setting magnification bias $s = 0$

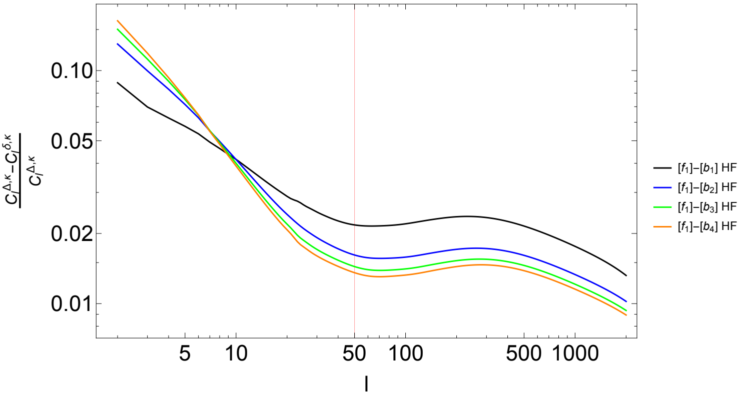
$$s(z, m_{\rm lim}) \equiv \left. \frac{\partial \log_{10} \bar{N}(z, L > L_{\rm lim})}{\partial m} \right|_{m_{\rm lim}}$$

A generic survey with DES-like redshift binning





$$z_{f1} = 0.225 \quad z_{f2} = 0.375 \quad z_{f3} = 0.525 \quad z_{f4} = 0.675$$
$$z_{f5} = 0.825$$
$$z_{b1} = 0.315 \quad z_{b2} = 0.53 \quad z_{b3} = 0.765 \quad z_{b4} = 1.1$$



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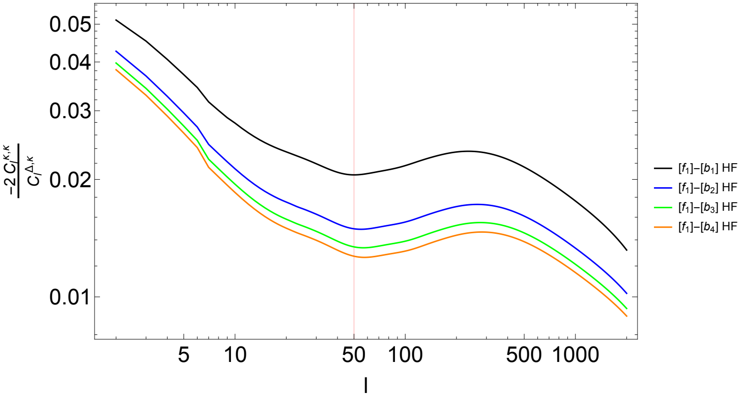

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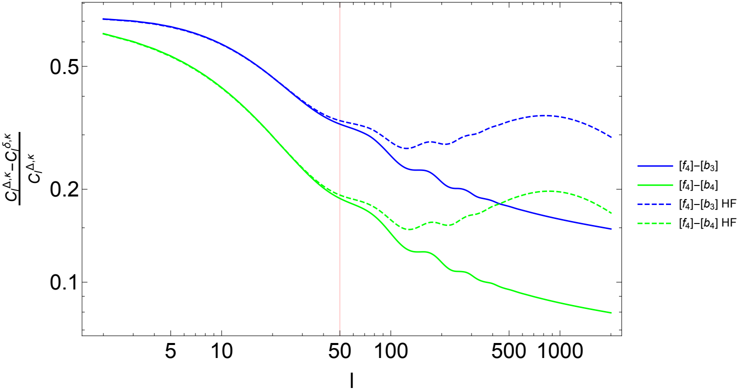

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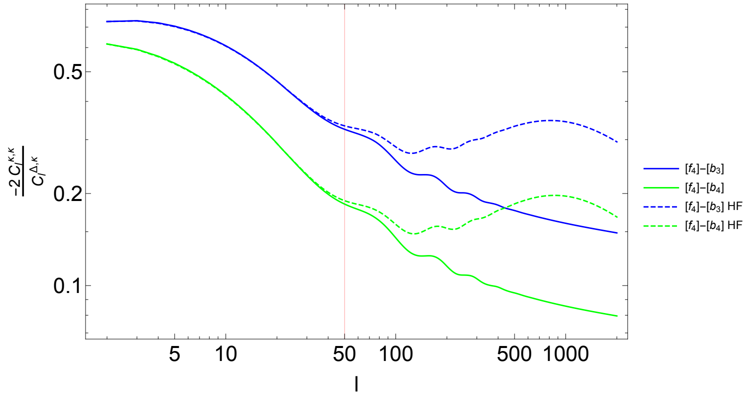

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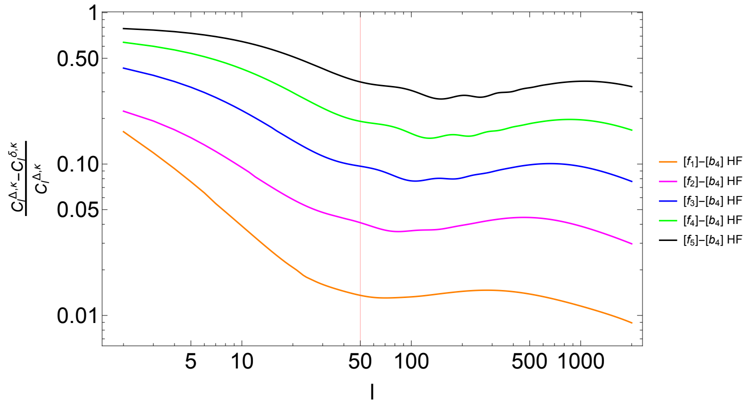

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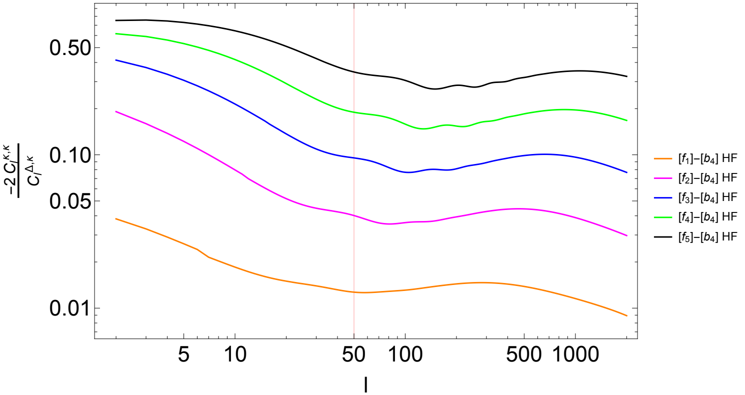
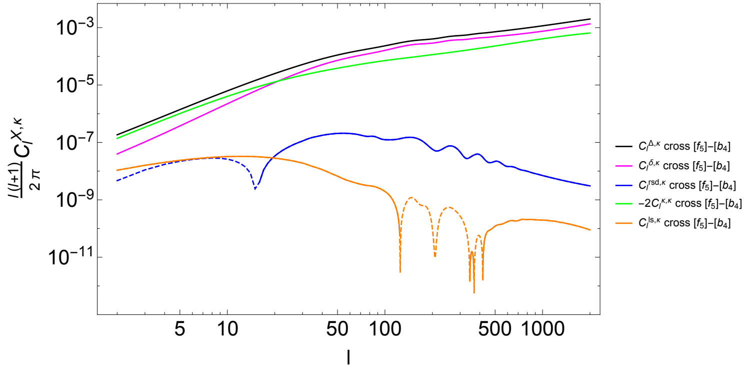
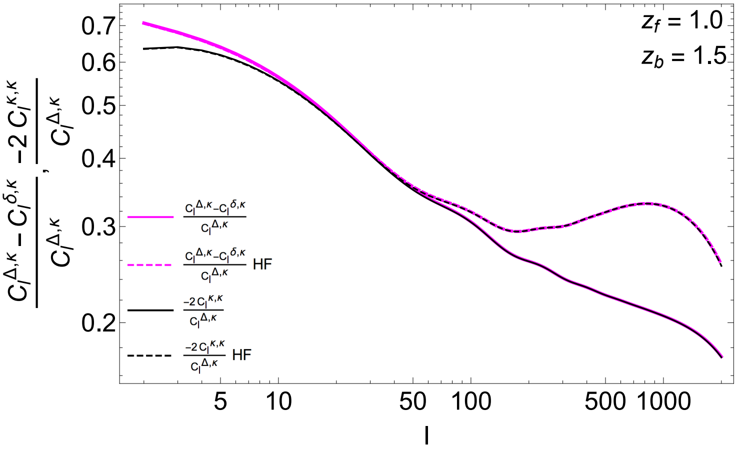


Comparison among all terms

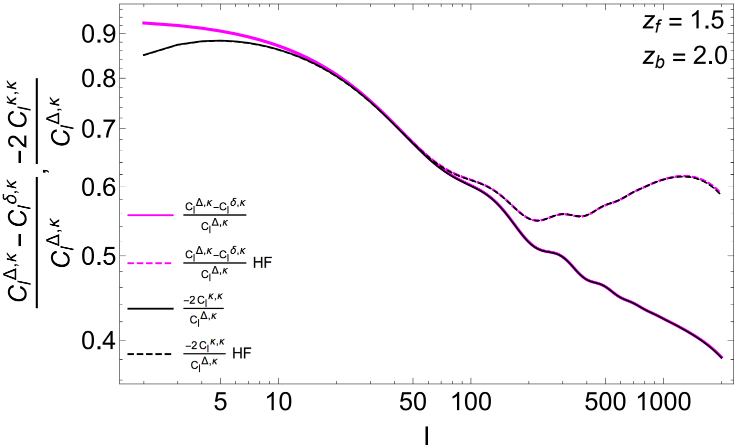


- The redshift space distortions and other relativistic effects have comparatively small contributions, but the one due to lensing is definitely important, and is in fact larger than the density term at very large scales, $\ell < 10$
- For lower redshifts, the lensing term is smaller and at low ℓ redshift space distortions and relativistic effects cannot be neglected

Higher Redshifts



Higher Redshifts



Conclusion

- It is not ideal to simply ‘combine probes’ as is frequently done, and to compute a joint covariance matrix for lensing, galaxy counts and galaxy-galaxy lensing.
- For a DES-like redshift binning, this can lead to a 30% correction of the signal in the density-tangential shear correlation function of the highest redshift bin.
- The increase of lensing at smaller scales is similar to the one of density fluctuations.

Future work

- Compute the correlation functions and check their compatibility with the above results
- Include the correct value of magnification bias $s(z)$
- A detailed signal to noise analysis of the effect in the DES data
- More detailed study taking into account the number count spectra where lensing is not considered in the present DES data analysis

Thank you for listening

Defining convergence, evolution bias and magnification bias

$$\kappa = -\frac{1}{2}\Delta_\Omega \phi \,,$$

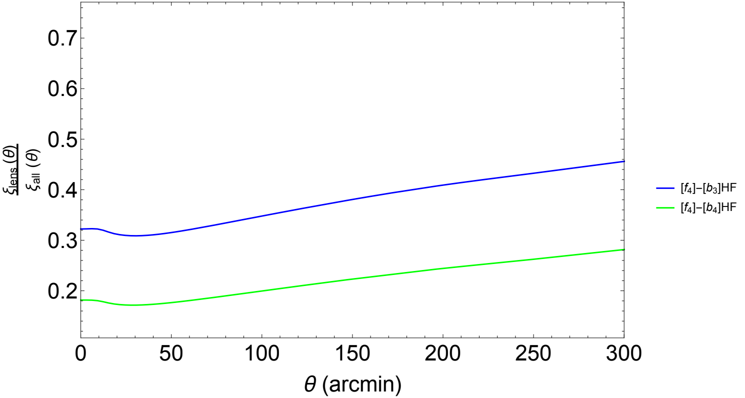
$$\phi(\mathbf{n}, z) = -\int_0^{r(z)} d\tilde{r} \frac{r(z)-\tilde{r}}{r(z)\tilde{r}} (\Phi + \Psi)(\tilde{r}\mathbf{n}, \tau_0 - \tilde{r}) \,.$$

The evolution bias $f_{\rm evo}$ depends on redshift and on limiting luminosity $L_{\rm lim}$ and is defined as

$$f_{\rm evo}(z, L_{\rm lim}) \equiv \frac{\partial \ln \left(a^3 \bar{N}(z, L > L_{\rm lim})\right)}{\partial \ln a} \,.$$

Denoting the limiting magnitude of the survey $m_{\rm lim}$, the magnification bias is given by

$$s(z, m_{\rm lim}) \equiv \left. \frac{\partial \log_{10} \bar{N}(z, L > L_{\rm lim})}{\partial m} \right|_{m_{\rm lim}} \,.$$



0.7
0.6
0.5
0.4
0.3
0.2
$\frac{\xi_{lens}(\theta)}{\xi_{all}(\theta)}$
0
50
100
150
200
250
300
θ (arcmin)
$[f_4]$–$[b_3]$HF
$[f_4]$–$[b_4]$HF