

Tomographic lensing constraints with galaxy clustering



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JCAP 1510 (2015) 070 — FM, Durrer
arXiv:1510.04202 — Di Dio, Durrer, Marozzi, FM

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1 Introduction

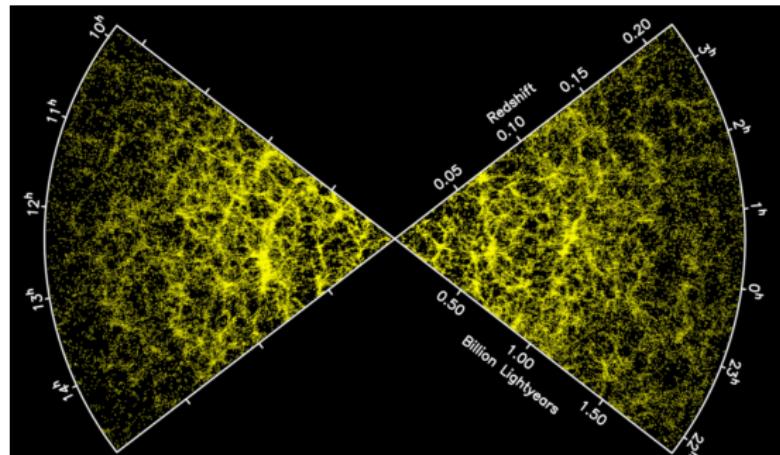
2 Angular power spectrum $C_\ell(z_1, z_2)$

3 Angular bi-spectrum $b_{\ell_1 \ell_2 \ell_3}(z_1, z_2, z_3)$

4 Conclusions

Introduction

Galaxy Number Counts



2dF Galaxy Map

Fundamental observable in a galaxy catalog:

$$\Delta(\mathbf{n}, z) \equiv \frac{n_g(\mathbf{n}, z) - \langle n_g \rangle(z)}{\langle n_g \rangle(z)}$$

Galaxy Number Counts

Not only the density δ , but also angles and redshifts are perturbed:

$$\Delta(\mathbf{n}, z) = \underbrace{\delta_g}_{\text{density}} + \underbrace{\frac{1}{\mathcal{H}} \partial_r (\mathbf{n} \cdot \mathbf{v})}_{\text{z-distortion}} - (2 - 5s) \underbrace{\int_{\tau}^{\tau_o} \frac{r - r'}{rr'} \Delta_{\Omega}(\Psi + \Phi) d\tau'}_{\text{lensing } \kappa}$$

κ measurements from GC are complementary to WL shear.

Angular power spectrum $C_\ell(z_1, z_2)$

Observables in galaxy surveys

- 2PCF:

$$\xi(\theta, z_1, z_2) = \frac{1}{4\pi} \sum_{\ell} (2\ell + 1) C_{\ell}(z_1, z_2) P_{\ell}(\cos \theta)$$

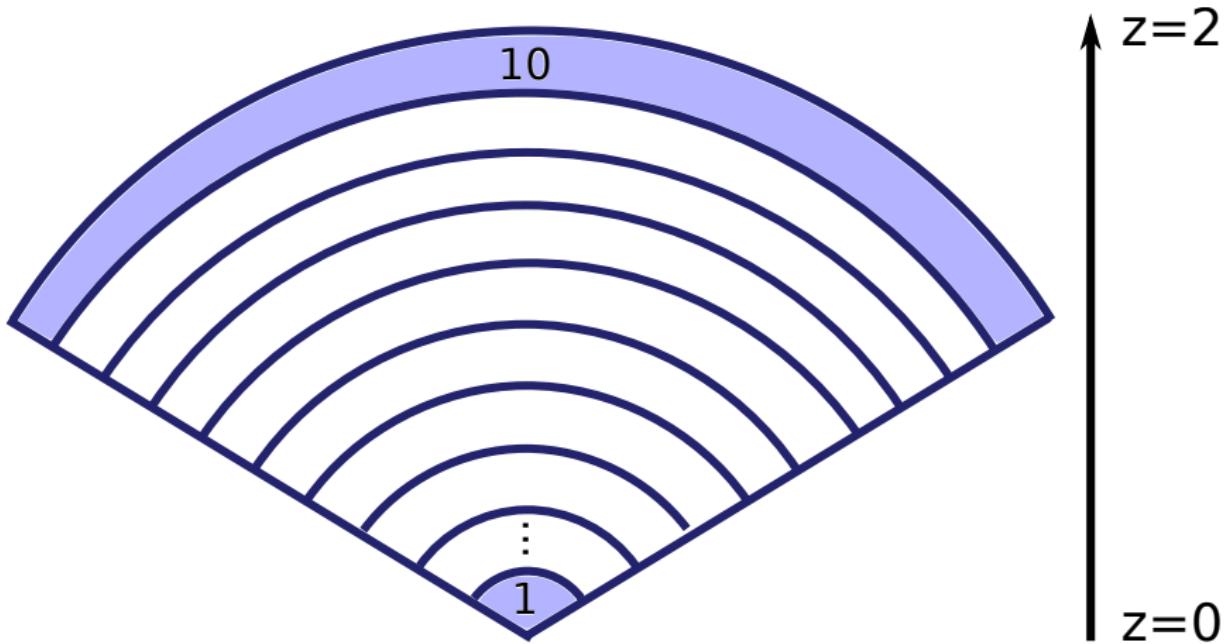
- Angular power spectrum:

$$C_{\ell}(z_1, z_2)$$

C_{ℓ} 's are computed with **CLASSgal** (Di Dio, FM, Lesgourgues, Durrer 1307.1459)

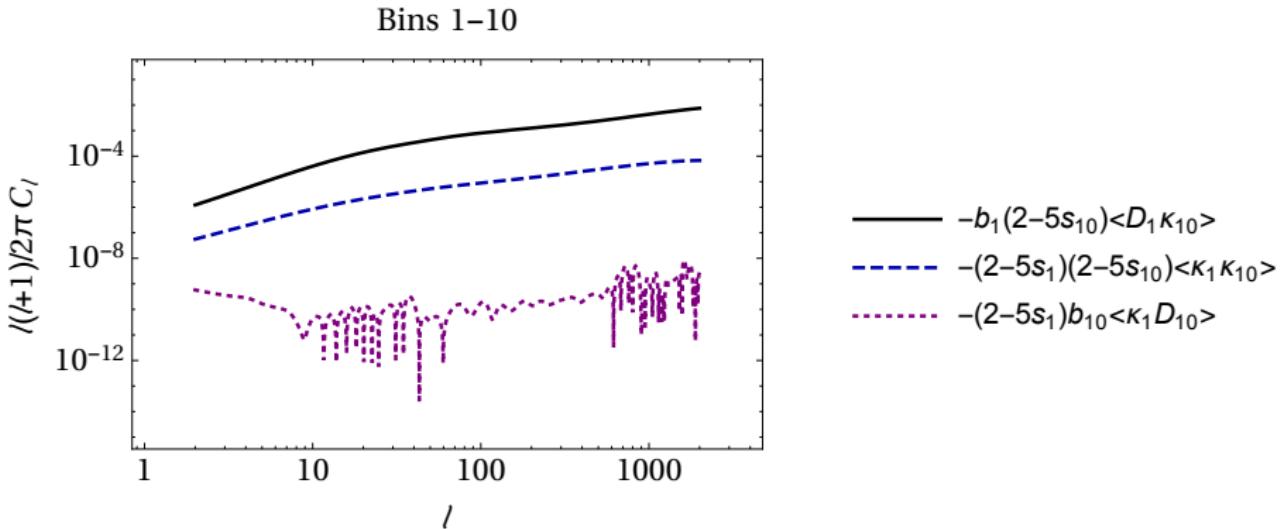
Lensing from tomographic C_ℓ^{ij}

$C_\ell(z_i, z_j) \equiv C_\ell^{ij}$ are computed for bins i, j (e.g., Euclid photo-z)



Lensing from tomographic C_ℓ^{ij}

Distant correlations:
lensing of background galaxies from foreground galaxies



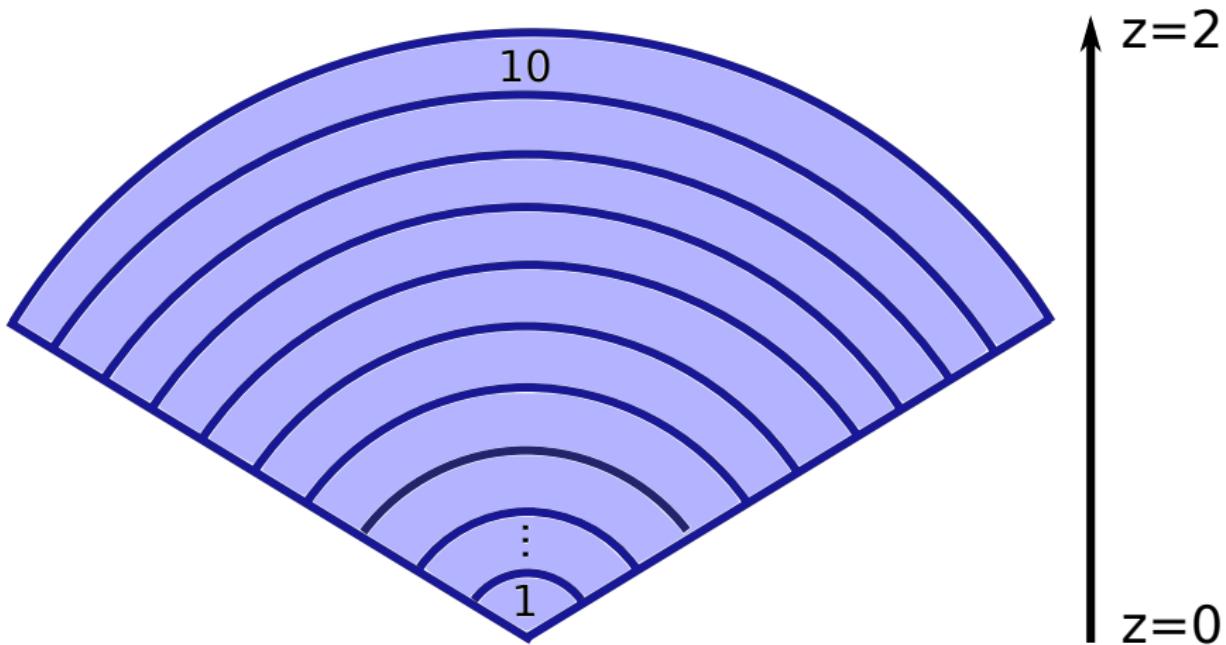
From FM, Durrer 1506.01369

Galaxy Number Counts

- κ usually studied with GC by correlating foreground galaxies and background quasars (many refs, e.g., Scranton et al. 2005)
- here we consider a **tomographic** analysis

Lensing from tomographic C_ℓ^{ij}

How well can we measure lensing?



Lensing from tomographic C_ℓ^{ij}

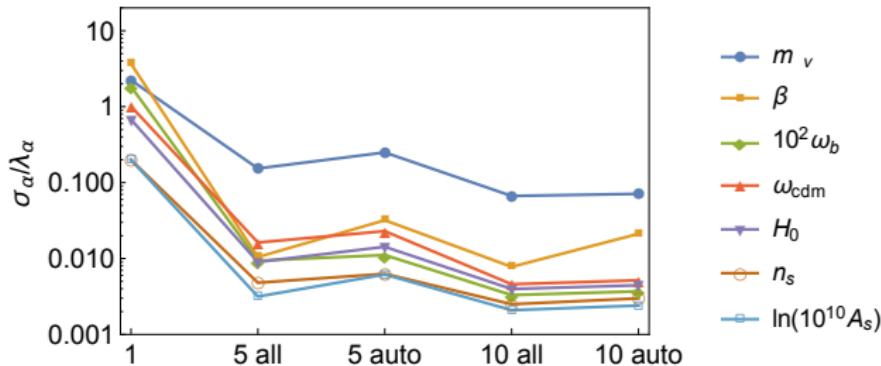
Consistency test:

$$\kappa = -\frac{1}{2} \Delta_\Omega \psi , \quad \psi(z_i, \mathbf{n}) = \beta \psi^{\Lambda\text{CDM}}(z_i, \mathbf{n})$$

- Systematics, modified gravity, ... $\Rightarrow \beta \neq 1$.
- Complementary to shear, growth rate, ...

Lensing from tomographic C_ℓ^{ij}

Relative errors from Fisher matrix
(Euclid photo-z)



From FM, Durrer 1506.01369

Angular bi-spectrum $b_{\ell_1 \ell_2 \ell_3}(z_1, z_2, z_3)$

Non-linear information

- Because of non-linear gravitational effects, the power spectrum does not encode all the statistical information
 - Bispectrum
- In the weakly non-linear regime, 2nd order perturbation theory can be applied

Galaxy Number Counts: 2nd order

Contributions from density fluctuations, redshift space distortions and lensing-like-terms:

$$\begin{aligned}\Delta^{(2)}(\mathbf{n}, z) \approx & \delta^{(2)} + \mathcal{H}^{-1} \partial_r^2 v^{(2)} + \mathcal{H}^{-2} \left[(\partial_r^2 v)^2 + \partial_r v \partial_r^3 v \right] + \mathcal{H}^{-1} \left(\partial_r v \partial_r \delta + \partial_r^2 v \delta \right) \\ & - 2\delta\kappa + \nabla_a \delta \nabla^a \psi + \mathcal{H}^{-1} \left[-2(\partial_r^2 v)\kappa + \nabla_a (\partial_r^2 v) \nabla^a \psi \right] - 2\kappa^{(2)} + 2\kappa^2 - 2\nabla_b \kappa \nabla^b \psi \\ & - \frac{1}{2r(z)} \int_0^{r(z)} dr \frac{r(z) - r}{r} \Delta_2 \left(\nabla^b \Psi_1 \nabla_b \Psi_1 \right) - 2 \int_0^{r(z)} \frac{dr}{r} \nabla^a \Psi_1 \nabla_a \kappa.\end{aligned}\quad (1)$$

From Di Dio, Durrer, Marozzi, FM 1407.0376

(see also Bertacca, Maartens, Clarkson [1405.4403] & Yoo, Zaldarriaga [1406.4140])

Bispectra

Tree-level:

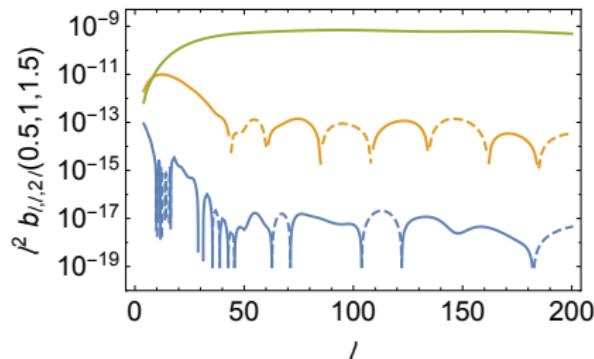
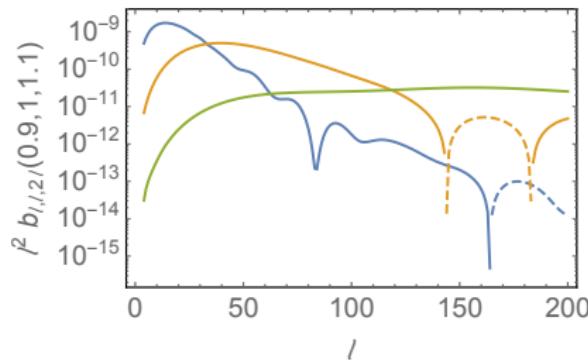
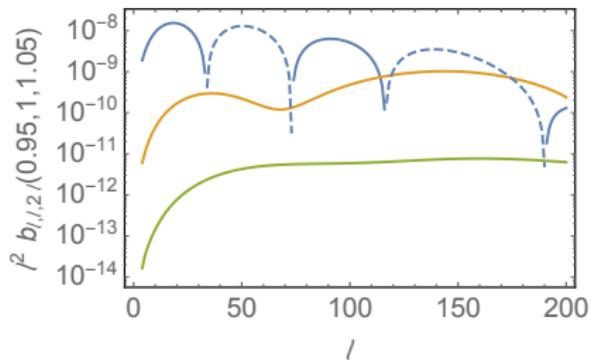
$$B_X(\mathbf{n}_1, \mathbf{n}_2, \mathbf{n}_3, z_1, z_2, z_3) = \langle \textcolor{red}{X^{(2)}(\mathbf{n}_1, z_1)} \delta_\rho^{(1)}(\mathbf{n}_2, z_2) \delta_\rho^{(1)}(\mathbf{n}_3, z_3) \rangle_c + 2 \text{ perm} ,$$

where:

$$X^{(2)}(\mathbf{n}, z) = \begin{cases} \text{Newtonian} \\ \text{Newtonian} \times \text{Lensing} \\ \text{Lensing} \end{cases}$$

Bispectra

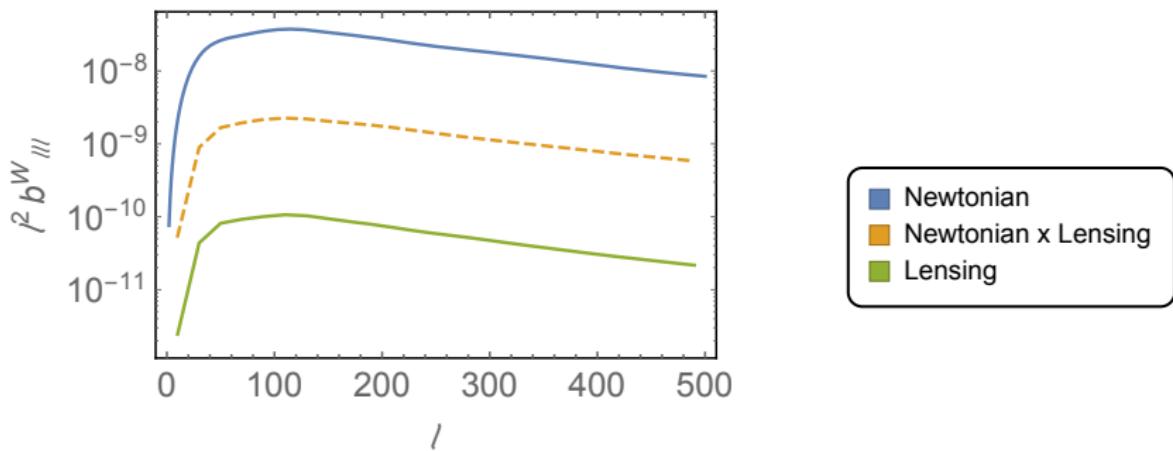
From Di Dio, Durrer, Marozzi, FM 1510.04202



- █ Newtonian
- █ Newtonian x Lensing
- █ Lensing

Bispectra

Large window function $0.5 < z < 1.5$:



From Di Dio, Durrer, Marozzi, FM 1510.04202

Conclusions

Conclusions

- Angular spectra:
 - competitive tomographic constraints on lensing amplitude
- Angular bispectrum:
 - for large redshift separations, lensing-like terms are important
- For the future:
 - MCMC forecasts
 - compute C_ℓ^{ij} from mock catalogs, including all nuisances
 - S/N estimate of lensing-like terms in bispectrum