UNIVERSITÉ DE GENÈVE
FACULTÉ DES SCIENCES

Impact of lensing convergence on galaxy clustering

for spectroscopic and photometric surveys

In collaboration with

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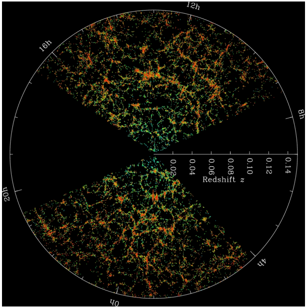
Observable in Galaxy Surveys



Credit: Credit: M. Blanton and the Sloan Digital Sky Survey.

- Galaxy number count

$$\Delta_{\rm gal}(\mathbf{n}, z) = \frac{N(\mathbf{n}, z) - \bar{N}(z)}{\bar{N}(z)}$$

- Several contributions

$$\Delta_{\rm gal} = \Delta_{\rm dens+rsd} + \Delta_\kappa + \Delta_{\rm rel}$$

$$\Delta_{\rm dens+rsd} = b(z)\delta + \mathcal{H}^{-1}\partial_r^2 V$$

$$\Delta_\kappa = (5 \quad \boxed{[s(m^*, z)]} \quad - 2)\int_0^{r(z)} \frac{r(z) - r}{2r(z)r}\Delta_\Omega(\Phi + \Psi)dr$$

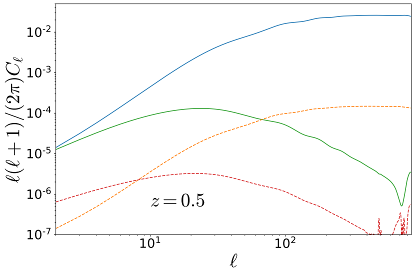
magnification bias!

$\Delta_{\rm rel}$ = Doppler, Shapiro time-delay, Sachs-Wolfe, ISW...

Contributions to angular power spectrum

LSST-like survey

$$b(z = 0.5) \approx 1.4 \qquad s(z = 0.5) \approx 0.2$$
$$\sigma_z = 0.05(1 + z)$$



density RSD Lensing Relativistic

- Density dominates at all scales
- RSD $\sim$ Lensing up to $\ell \sim 60$
- Relativistic effects negligible at all scales

$\rightarrow$ Lensing dominates cross-correlation between distant bins!

Lensing convergence

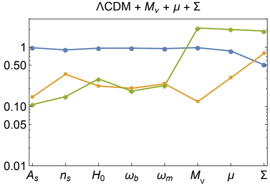
$$\Delta_\kappa = (5 \boxed{[s(m^*, z)]} - 2)\int_0^{r(z)} \frac{r(z) - r}{2r(z)r}\Delta_\Omega(\Phi + \Psi)dr$$

magnification bias!

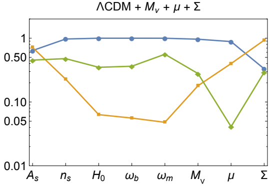
We focus on

- Bias on parameter estimation (see Villa, Di Dio, FL 2017)

Euclid - 10 bins (left)



SKA - 40 bins (right)



Green → Bias   Blue → Errors ratio

- Measurement of the the lensing potential (see Montanary & Durrer 2015)
  - Different systematics compared to weak-lensing

Spectroscopic and photometric analysis

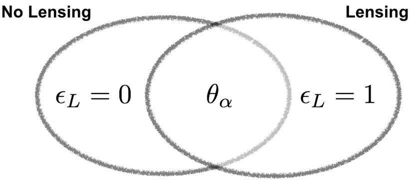
→ C_ℓ has been used for both photometric and spectroscopic surveys

1. Separate analysis for spectroscopic and photometric survey
   - Spectroscopic (DESI, SKA)
     - Real space correlation function (see Goran's talk)
   - Photometric (LSST)
     - Angular power spectrum

2. Lensing impact on parameter estimation and constraints

3. Can we combine C_ℓ and $\xi(r)$ analysis?

Fisher Matrix formalism



$$C_{\ell,\mathrm{th}}(\theta_\alpha, \epsilon_L) = C_\ell^{\mathrm{Dens+RSD}}(\theta_\alpha) + \epsilon_L C_\ell^{\mathrm{Lens}}(\theta_\alpha)$$

- Compare errors on common set of parameters
- Bias on estimated parameters
  - The maximum of the likelihood is shifted.
    By Taylor expanding the likelihood of the correct model

$$\Delta\theta_\alpha = \sum_\beta \left(F^{\theta\theta}\right)^{-1}_{\alpha\beta} F_\beta^{\theta\epsilon_L} ,$$

  - The difference between the two models is small
  - The shifts are small

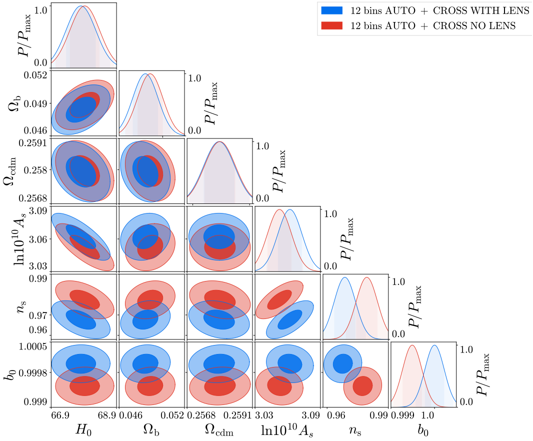
LSST: parameter constraints

Standard ΛCDM cosmology + galaxy bias

$N_{\rm bins}$	H_0	Ω_b	Ω_{cdm}	$\ln 10^{10} A_s$	n_s	b_0
5 bins - $1\sigma_{\rm lens}$ [%]	6.2 %	8.5 %	1.3 %	3.6 %	3.0 %	2.4 %
5 bins - $\sigma_{\rm lens}/\sigma_{\rm no\text{-}lens}$	0.996	0.994	1.004	0.275	0.991	0.119
8 bins - $1\sigma_{\rm lens}$ [%]	3.0 %	3.4 %	0.5 %	2.3 %	1.7 %	2.4 %
8 bins - $\sigma_{\rm lens}/\sigma_{\rm no\text{-}lens}$	0.993	0.998	1.011	0.351	0.999	0.240
12 bins - $1\sigma_{\rm lens}$ [%]	0.7 %	2.4 %	0.2 %	0.4 %	0.5 %	0.02 %
12 bins - $\sigma_{\rm lens}/\sigma_{\rm no\text{-}lens}$	1.000	1.000	0.998	0.998	0.998	0.999

- Errors on cosmological parameters are smaller for larger number of bins
- For 5 and 8 bins → lensing reduce significantly the error on $\ln 10^{10} A_s$ and b_0
- For 12 bins lensing has no impact on the constraints for all parameters

LSST: bias in best-fit



- Significant bias for $\ln 10^{10} A_s$, n_s and b_0
- Neglecting lensing is not a good idea for LSST

Measurement of lensing potential

→ Amplitude of the lensing potential A_L(in GR $A_L = 1$)

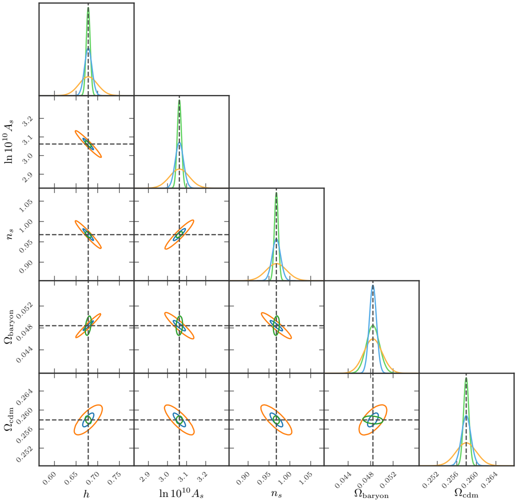
N_{bins}	H_0	Ω_b	Ω_{cdm}	$\ln 10^{10} A_s$	n_s	b_0	A_{L}
5 bins	6.2 %	8.5 %	1.3 %	13.1 %	3.0 %	20.1 %	20.2 %
8 bins	3.0 %	3.4 %	0.5 %	6.5 %	1.7 %	9.9 %	10.2 %
12 bins	0.7 %	2.4 %	0.2 %	0.4 %	0.5 %	0.02 %	2.3 %

- For 12 bins configurations, constrains on the ΛCDM parameters do not change significantly

- For SKA2 with correlation function analysis $\sigma_{A_L} \sim 5\%$

- Photometric surveys provide better constraints on the lensing potential amplitude

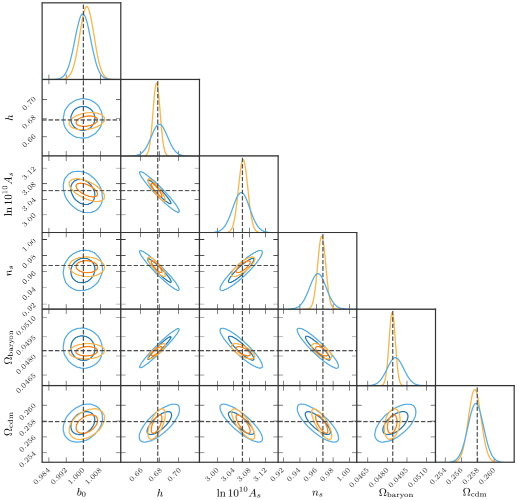
DESI SKA2 LSST



- LSST and SKA2 gives similar constraints on ΛCDM parameters
- For DESI and SKA2 the bias on best-fit is below 1σ
- Lensing cannot be neglected for LSST (shift in best-fit above 1σ)

Combining $\xi(r)$ and C_ℓ analysis

SKA2 alone   SKA2 + cross-correlations LSST



- Spectroscopic analysis neglect cross-correlation between bins: add that information with a C_ℓ analysis
- Apply to SKA2 (8 bins) + LSST
- Cross-correlation improve significantly the constraints
- Does it help adding the cross-correlation with C_ℓ for a spectroscopic survey alone?

Summary

- Spectroscopic surveys are better suited for a $\xi(r)$ analysis, while C_ℓ approach is optimal for photometric surveys
- Fisher matrix analysis to study the lensing magnification impact for the two analysis
- Lensing does not affect the errors on cosmological parameters
- Neglecting lensing lead to significant bias for a photometric survey like LSST
- Lensing magnification is negligible for DESI, but there is ashift in parameters estimation for SKA2 $(< 1\sigma)$

Future perspective

- Apply this analysis to Euclid
- How much we gain combining a correlation function analysis (for the autocorrelation of the z-bins) and a C_ℓ analysis for the cross-correlation between the bins?
- In order to have reliable forecast it will be important to model accurately the magnification bias for Euclid

Thanks for listening!