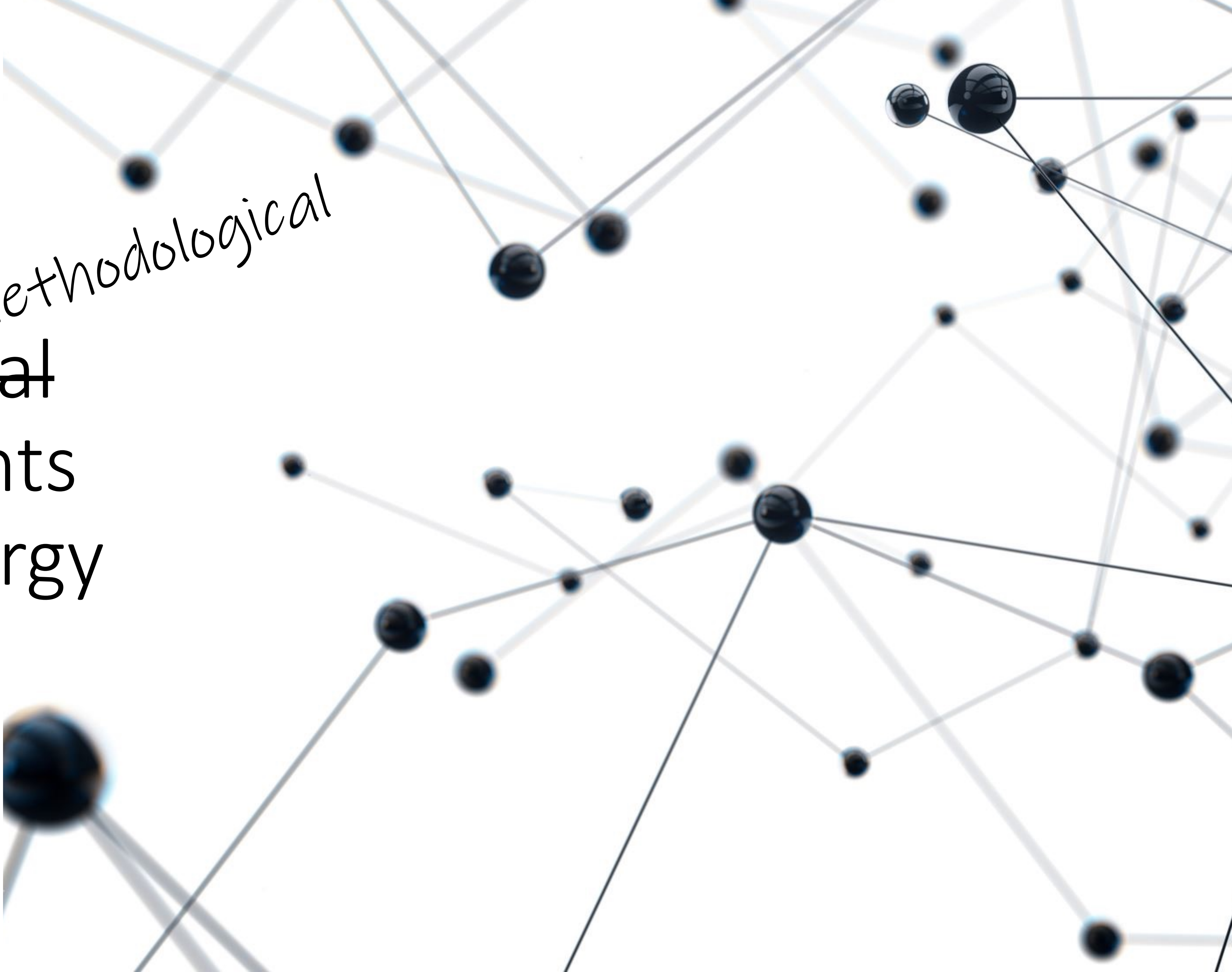
Lastest observational developments on dark energy

Sylvain de la Torre
IPhU – Class meeting
LAM – 23/09/2021

Lastest ~~observational~~ *methodological* developments on dark energy



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Outline

- Angular systematics-free two-point statistics in 3D
  - R. Paviot et al. (to be submitted)
- Impact of magnification bias on 3D clustering observable
  - M.-A. Breton & de la Torre (ongoing work)

Angular modes-free redshift-space clustering

- Classical estimator for the two-point correlation function (LS93):

$$\xi(\mathbf{s}) = \frac{DD(\mathbf{s}) - 2DR(\mathbf{s}) + RR(\mathbf{s})}{RR(\mathbf{s})}$$

Survey selection function

- AMF estimator (Burden 2017):

$$\tilde{\xi}(\mathbf{s}) = \frac{DD(\mathbf{s}) - 2DS(\mathbf{s}) + SS(\mathbf{s})}{RR(\mathbf{s})}$$

→ Use of auxiliary random catalogue S with exact same angular clustering as data

AMF overdensity field

- AMF overdensity:

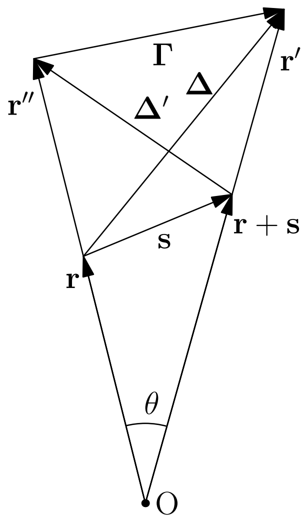
$$\tilde{\delta}(\mathbf{r}) \equiv \frac{n(\mathbf{r}) - \tilde{n}(\mathbf{r})}{\bar{n}(\mathbf{r})} \quad \Rightarrow \quad \tilde{\delta}(\mathbf{r}) = \delta(\mathbf{r}) - \frac{\int \delta(\chi, \gamma)\bar{n}(\chi)\mathrm{d}\chi}{\int \bar{n}(\chi)\mathrm{d}\chi}$$

- AMF two-point correlation function:

$$\tilde{\xi}(\mathbf{s}) \equiv \langle \tilde{\delta}(\mathbf{r})\tilde{\delta}(\mathbf{r}') \rangle = \langle \delta(\mathbf{r})\delta(\mathbf{r}') \rangle - 2\left\langle \delta(\mathbf{r})\hat{\delta}(\gamma') \right\rangle + \left\langle \hat{\delta}(\gamma)\hat{\delta}(\gamma') \right\rangle$$

Modelling

- AMF windowed overdensity: $F(\mathbf{r}) = P(\mathbf{r})\delta(\mathbf{r}) - P(\mathbf{r}) \int \mathrm{d}r' \bar{n}(r')\delta(\mathbf{r}')$
- AMF two-point correlation function: $\tilde{\xi}(\mathbf{s}) \equiv \frac{\int \mathrm{d}^3 r\, F(\mathbf{r})F(\mathbf{r}+\mathbf{s})}{\int \mathrm{d}^3 r\, P(\mathbf{r})P(\mathbf{r}+\mathbf{s})}$



$$\tilde{\xi}(\mathbf{s}) = \xi(\mathbf{s}) - \frac{C(\mathbf{s})}{W(\mathbf{s})} + \frac{A(\mathbf{s})}{W(\mathbf{s})}$$

$$C(\mathbf{s}) = \int \mathrm{d}^3 r\, P(\mathbf{r})P(\mathbf{r}+\mathbf{s}) \left[\int \mathrm{d}r' \bar{n}(r')\xi(\mathbf{r}' - \mathbf{r}) + \int \mathrm{d}r'' \bar{n}(r'')\xi\left(\mathbf{r}'' - \mathbf{r} - \mathbf{s}\right) \right], \quad (23)$$

$$A(\mathbf{s}) = \int \mathrm{d}^3 r\, P(\mathbf{r})P(\mathbf{r}+\mathbf{s}) \int \mathrm{d}r'' \bar{n}(r'') \int \mathrm{d}r' \bar{n}(r')\xi(\mathbf{r}' - \mathbf{r}''), \quad (24)$$

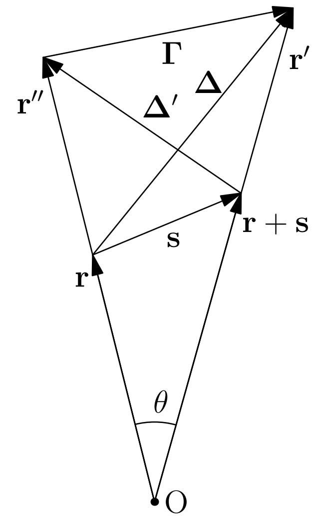
$$W(\mathbf{s}) = \int \mathrm{d}^3 r\, P(\mathbf{r})P(\mathbf{r}+\mathbf{s}). \quad (25)$$

Sensitivity to angular contaminants

- Let's consider a contamination field c(r):
  - No contamination: $F(\mathbf{r}) = P(\mathbf{r})\delta(\mathbf{r}) - P(\mathbf{r}) \int \mathrm{d}r' \bar{n}(r')\delta(\mathbf{r}')$
  - (Additive) contamination:

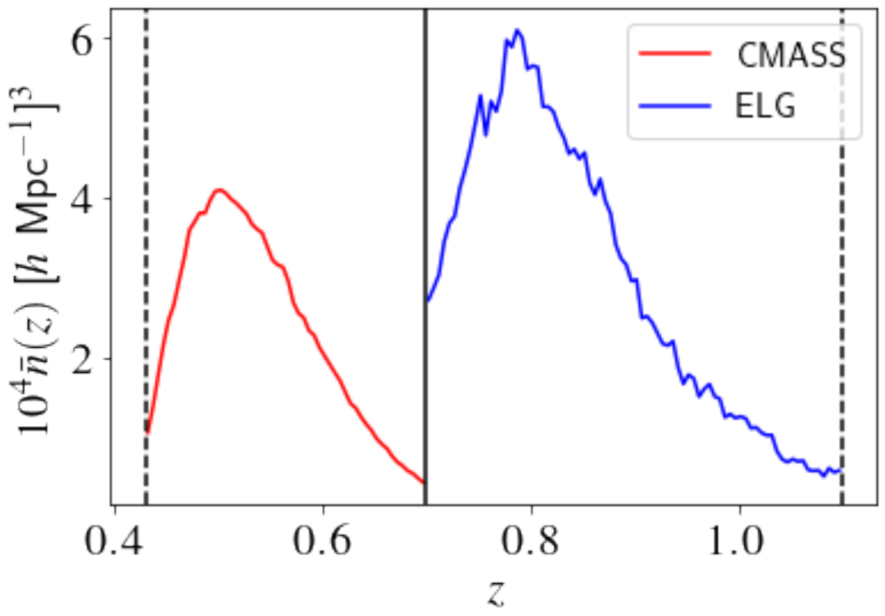
$$F(\mathbf{r}) = P(\mathbf{r})\left(\delta(\mathbf{r}) + c(\mathbf{r})\right) - P(\mathbf{r}) \int \mathrm{d}r' \bar{n}(r') \left(\delta(\mathbf{r}') + c(\mathbf{r}')\right)$$

$$= P(\mathbf{r})\delta(\mathbf{r}) - P(\mathbf{r}) \int \mathrm{d}r' \bar{n}(r')\delta(\mathbf{r}').$$

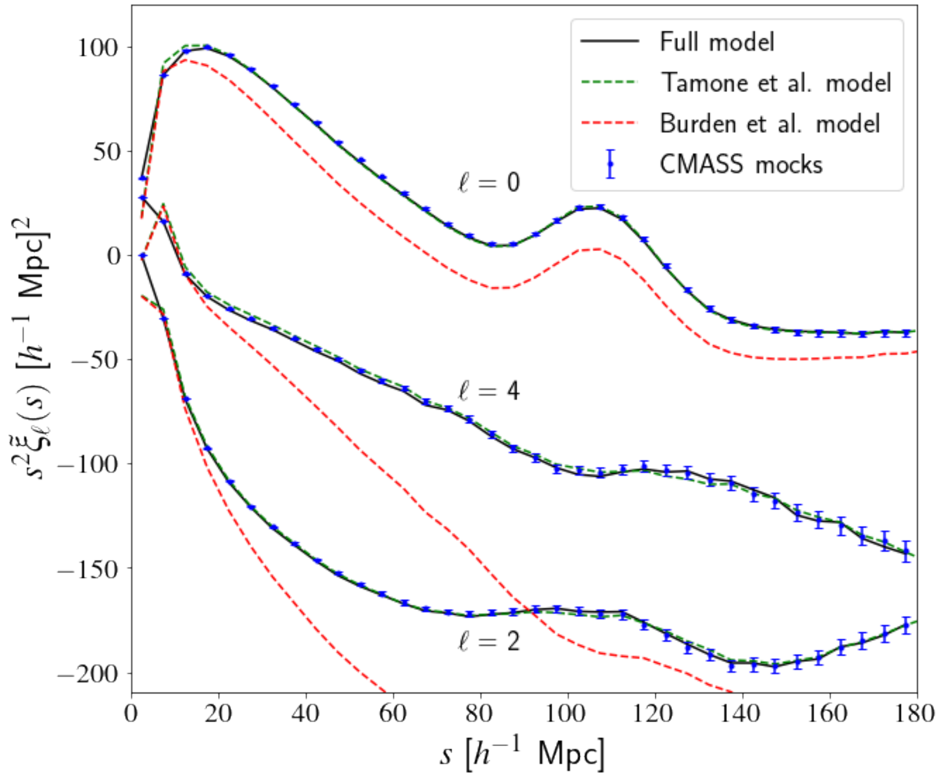


Test on simulations

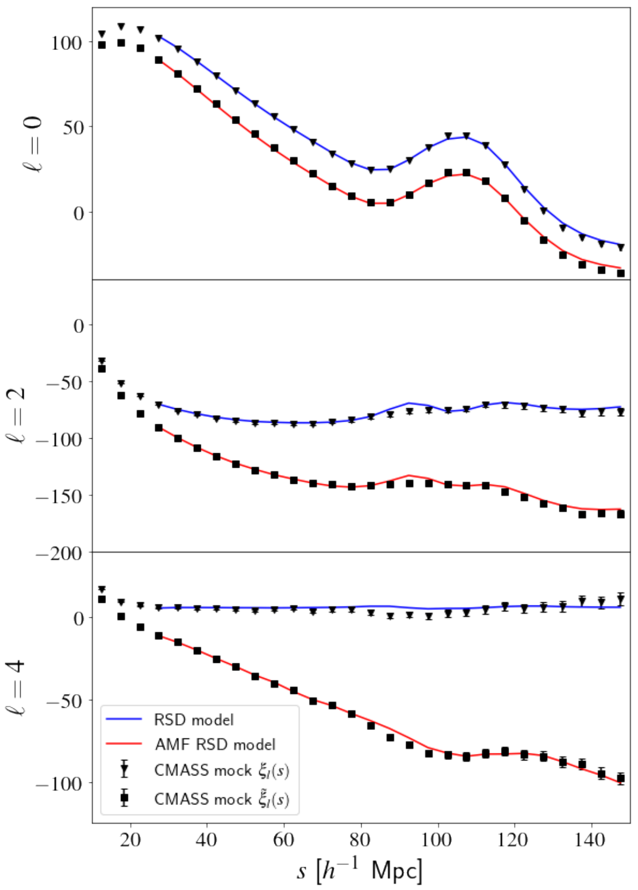
- Work within eBOSS/SDSS-4 collaboration
- Use of LRG (BOSS) 64 mocks and ELG EZmocks

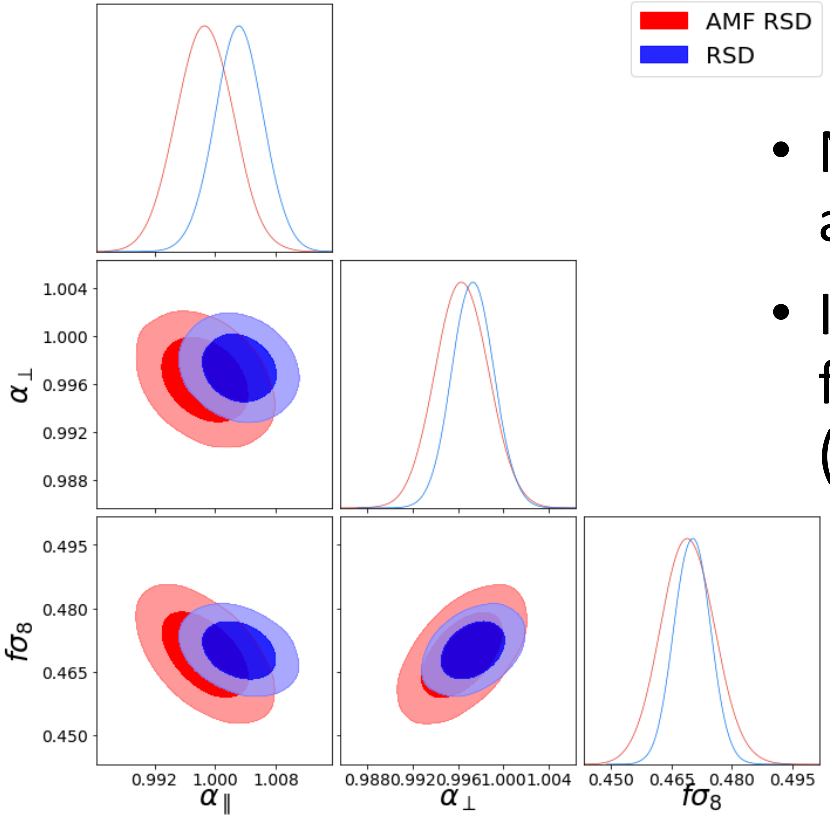


AMF correlation function



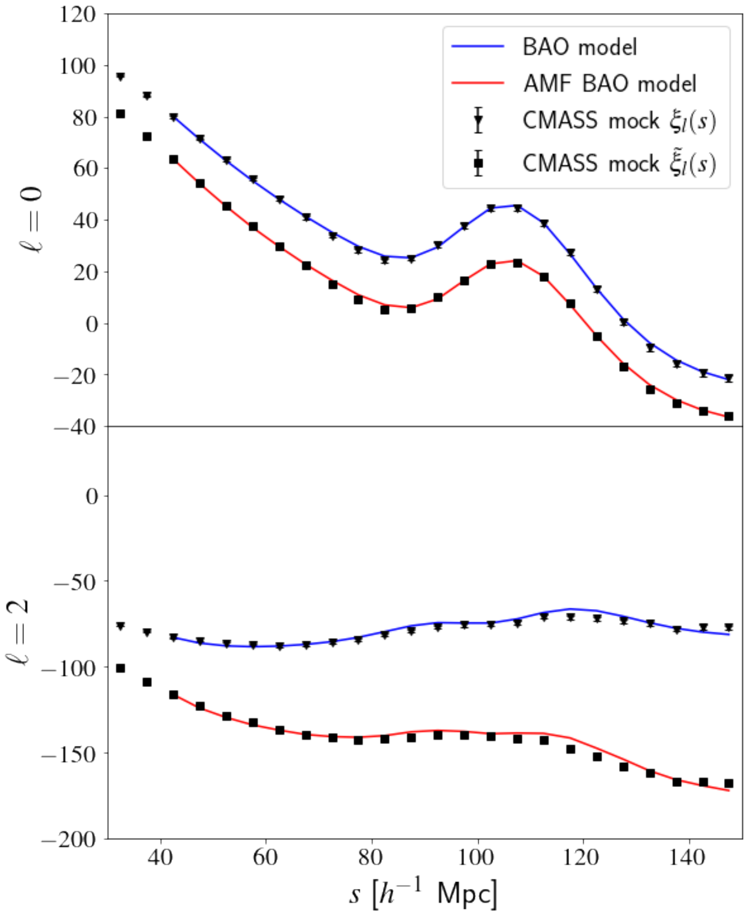
Redshift-space full-shape fit

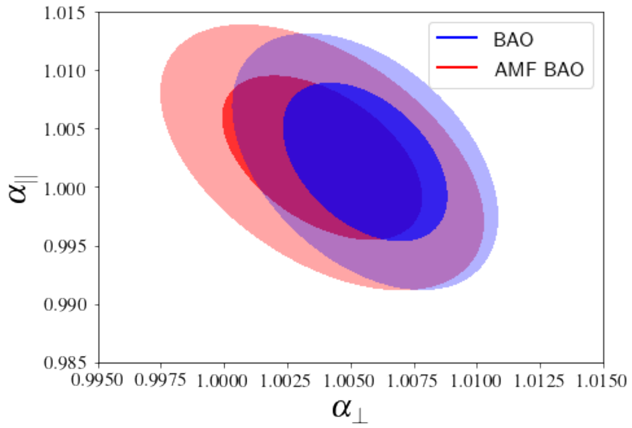




- No significant bias wrt standard approach
- Increase of about 30% on fsigma_8 and alpha_parallel (function of *H(z)*)

BAO-only fit





- Constraints are similar
- No significant bias wrt standard approach
- Increase of 20% on alpha_parallel (function of *H(z)*)

Final constraints

- Details cosmological constraints:

Method	$\alpha_\perp$	$\alpha_\parallel$	$f\,\sigma_8$	$f\,\sigma_{8rs}$
CMASS				
RSD M+Q+H standard	0.9972 ± (0.0019/0.017)	1.0032 ± (0.0032/0.029)	0.4700 ± (0.0044/0.04)	0.4694 ± 0.0044
RSD M+Q+H AMF	0.9962 ± 0.0023	0.9987 ± 0.0038	0.4686 ± 0.0067	0.4696 ± 0.0067
BAO standard	1.0056 ± 0.0022	1.0007 ± 0.0044		
BAO AMF	1.0043 ± 0.0026	1.0011 ± 0.0046		
ELG				
RSD M+Q standard	1.0014 ± (0.0043/0.096)	1.0056 ± (0.0066/0.147)	0.4570 ± (0.0053/0.118)	0.4550 ± 0.0053
RSD M+Q AMF	1.0008 ± 0.0049	1.0092 ± 0.0067	0.4586 ± 0.0065	0.4566 ± 0.0065
BAO standard	1.0023 ± 0.0043	1.0063 ± 0.0062		
BAO AMF	1.0009 ± 0.0051	1.0171 ± 0.0066		

- AMF is less constraining but free from any angular systematics
- Very useful for DESI and Euclid, particularly for testing residual angular systematics in the standard approach

Impact of lensing magnification on 3D redshift-space clustering

Magnification bias

- Magnification bias: flux and size of objects are magnified and any galaxy selection will be affected by that
- Modification of the observed number of sources
- Conservation of surface brightness and counts:

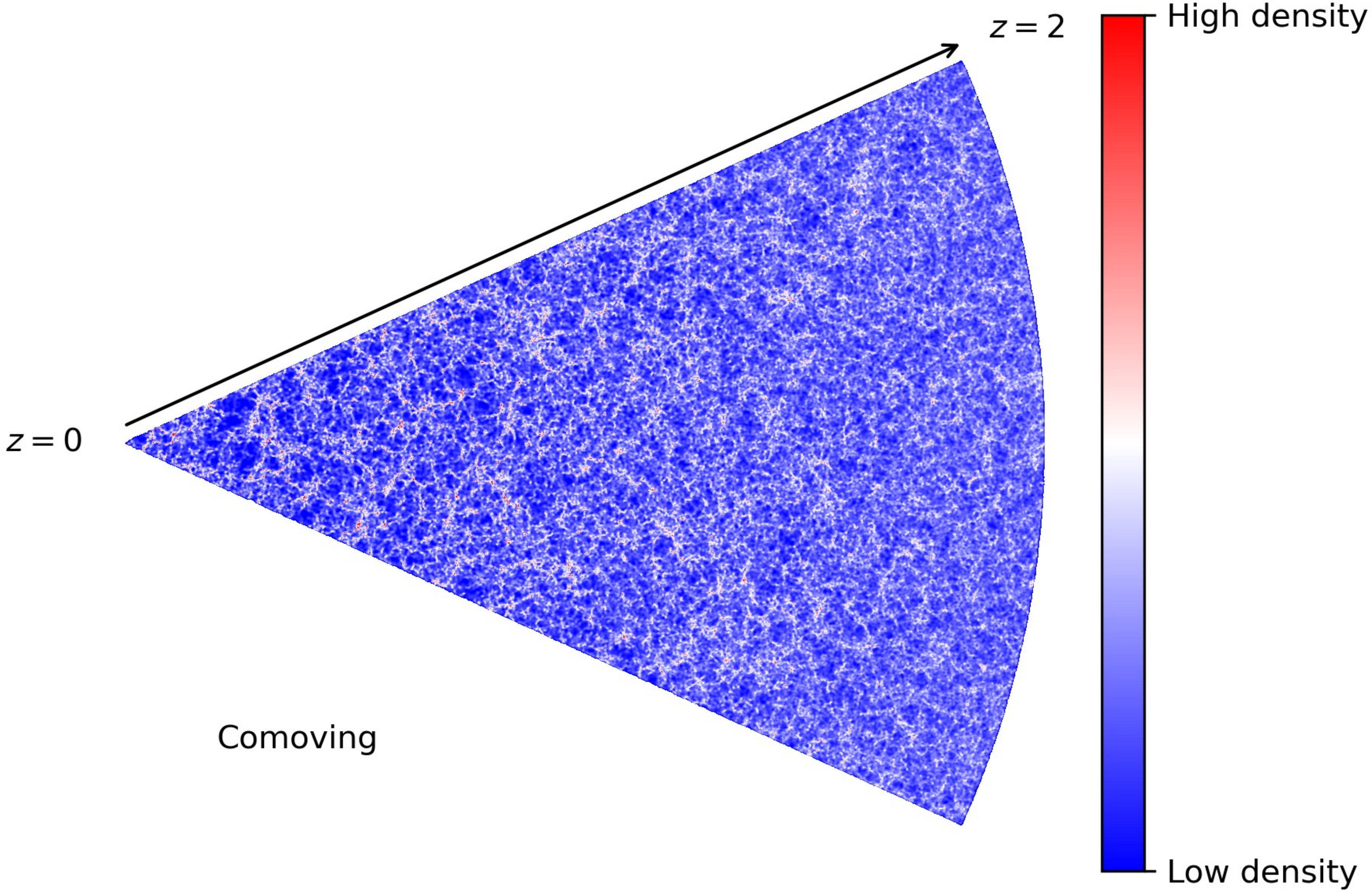
$$S'(\boldsymbol{\theta}) = \mu(\boldsymbol{\theta}) S(\boldsymbol{\theta}),$$
$$\mathrm{d}\Omega'(\boldsymbol{\theta}) = \mu(\boldsymbol{\theta}) \mathrm{d}\Omega(\boldsymbol{\theta}),$$

$$n'(m')\mathrm{d}m'\mathrm{d}\Omega' = n(m)\mathrm{d}m\mathrm{d}\Omega.$$

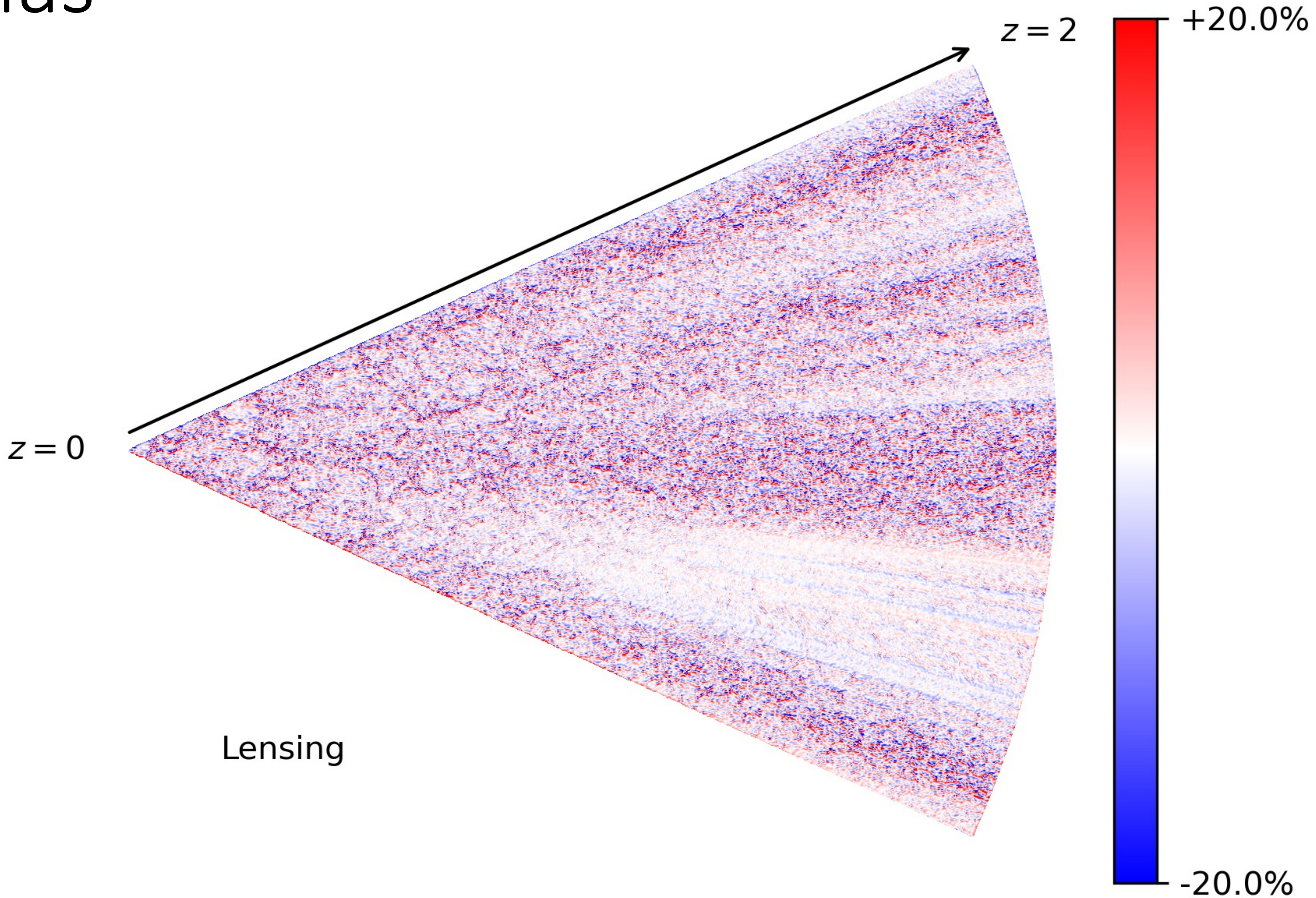
Assumption: $n(< m) \propto 10^{ms}$

$$\Delta_{\mathrm{len}} = \mu^{2.5s-1} - 1$$
$$= (5s - 2)\kappa,$$

Magnification



Magnification bias



Linear theory for magnification bias

- Linear theory in 2PCF:

$$\Delta = \Delta_{\rm den} + \Delta_{\rm rsd} + \Delta_{\rm len}$$

$$\xi_{\rm corr}(\boldsymbol{r}) = \xi_{\text{den-len}}(\boldsymbol{r}) + \xi_{\text{rsd-len}}(\boldsymbol{r}) + \xi_{\text{len-len}}(\boldsymbol{r}),$$

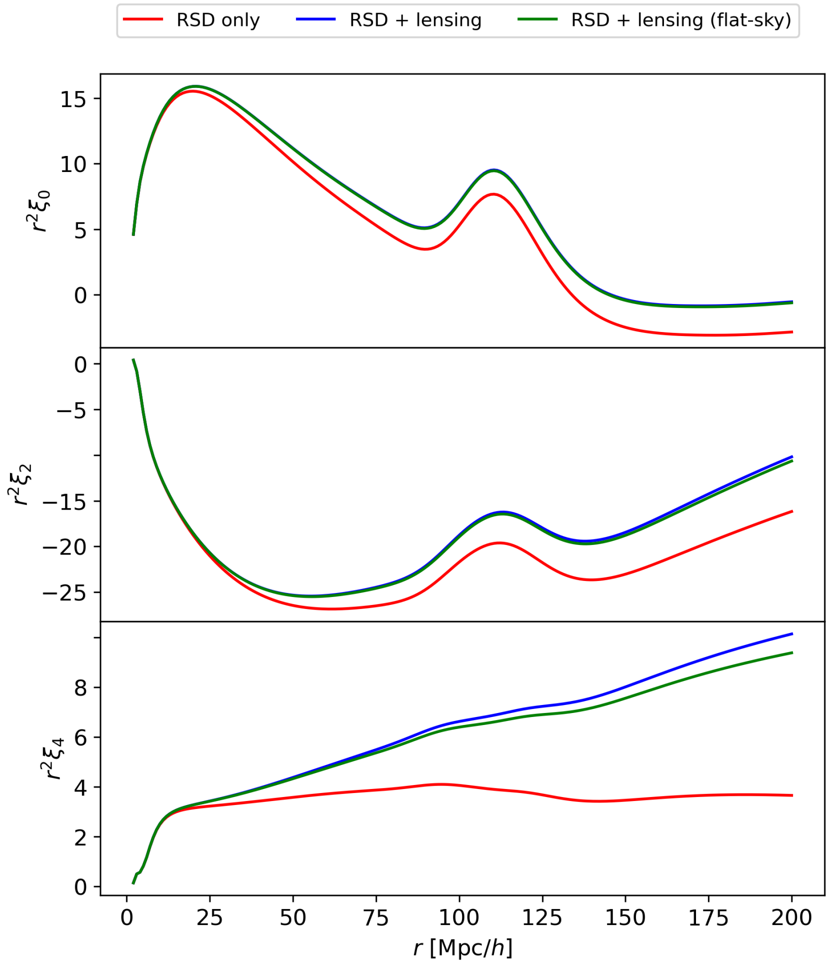
$$\xi_{\text{A-B}}(\theta, z_1, z_2) = \int \frac{\mathrm{d}k}{k} P_{\rm R}(k)\, Q_k^{\rm A-B}(\theta, z_1, z_2),$$

$$Q_k^{\text{den-len}}(\theta, z_1, z_2) = b(z_1) S_D(z_1) \left(\frac{2-5s}{2\chi_2}\right) \int_0^{\chi_2} \mathrm{d}\lambda \frac{\chi_2 - \lambda}{\lambda} S_{\phi+\psi}(\lambda)\, \zeta^{0L}(k\chi_1, k\lambda, \theta)\,,$$

$$Q_k^{\text{rsd-len}}(\theta, z_1, z_2) = \frac{k}{\mathcal{H}(z_1)} S_V(z_1) \left(\frac{2-5s}{2\chi_2}\right) \int_0^{\chi_2} \mathrm{d}\lambda \frac{\chi_2 - \lambda}{\lambda} S_{\phi+\psi}(\lambda)\, \zeta^{2L}(k\chi_1, k\lambda, \theta)\,,$$

$$Q_k^{\text{len-len}}(\theta, z_1, z_2) = \frac{(2-5s)^2}{4\chi_1\chi_2} \int_0^{\chi_1}\int_0^{\chi_2} \mathrm{d}\lambda \mathrm{d}\lambda' \frac{(\chi_1-\lambda)(\chi_2-\lambda')}{\lambda\lambda'} S_{\phi+\psi}(\lambda) S_{\phi+\psi}(\lambda') \zeta^{LL}(k\lambda, k\lambda', \theta).$$

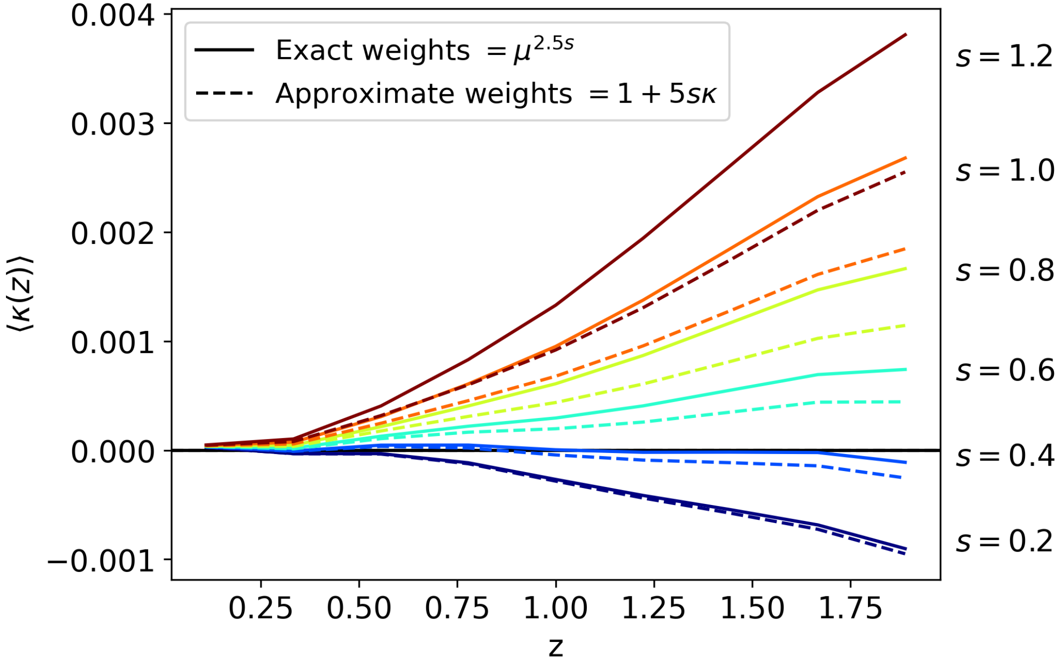
Impact of magnification: theory



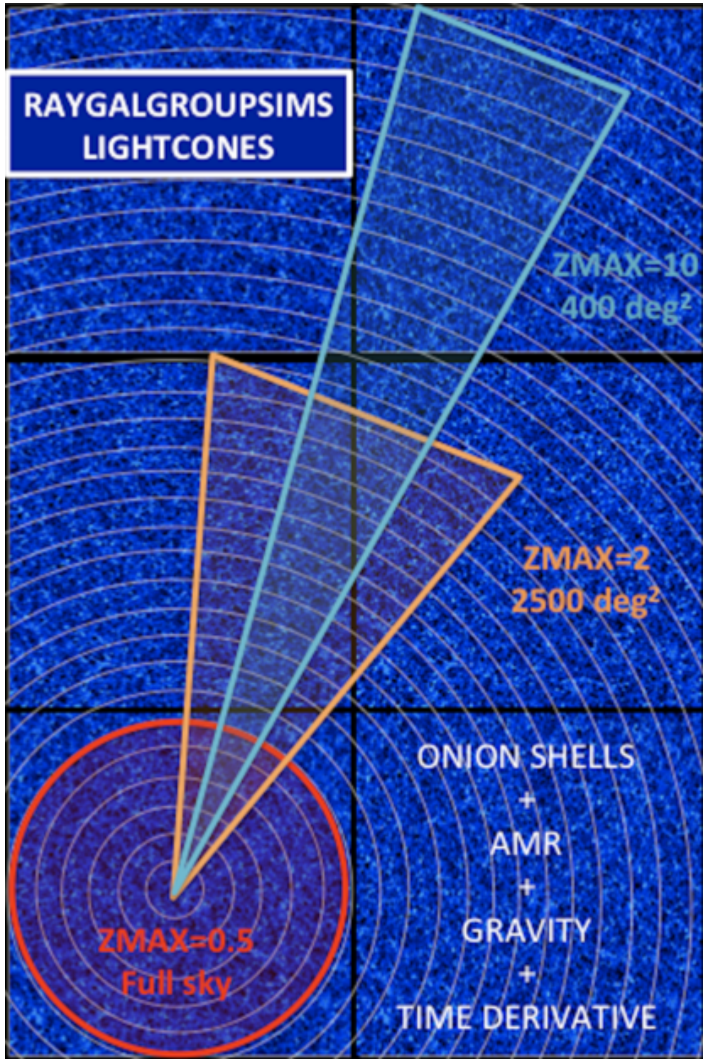
- Impact in the worst case (s=1.2 and z=2) mostly on large scales in monopole and hexadecapole
- Flat-sky approximation good enough in principle

$$\xi_{\rm model}(r_\perp, r_\parallel) = \xi_{\rm CLPT\text{-}GS}(r_\perp, r_\parallel) + \xi_{\rm corr}(r_\perp, r_\parallel)$$

Raygal simulation

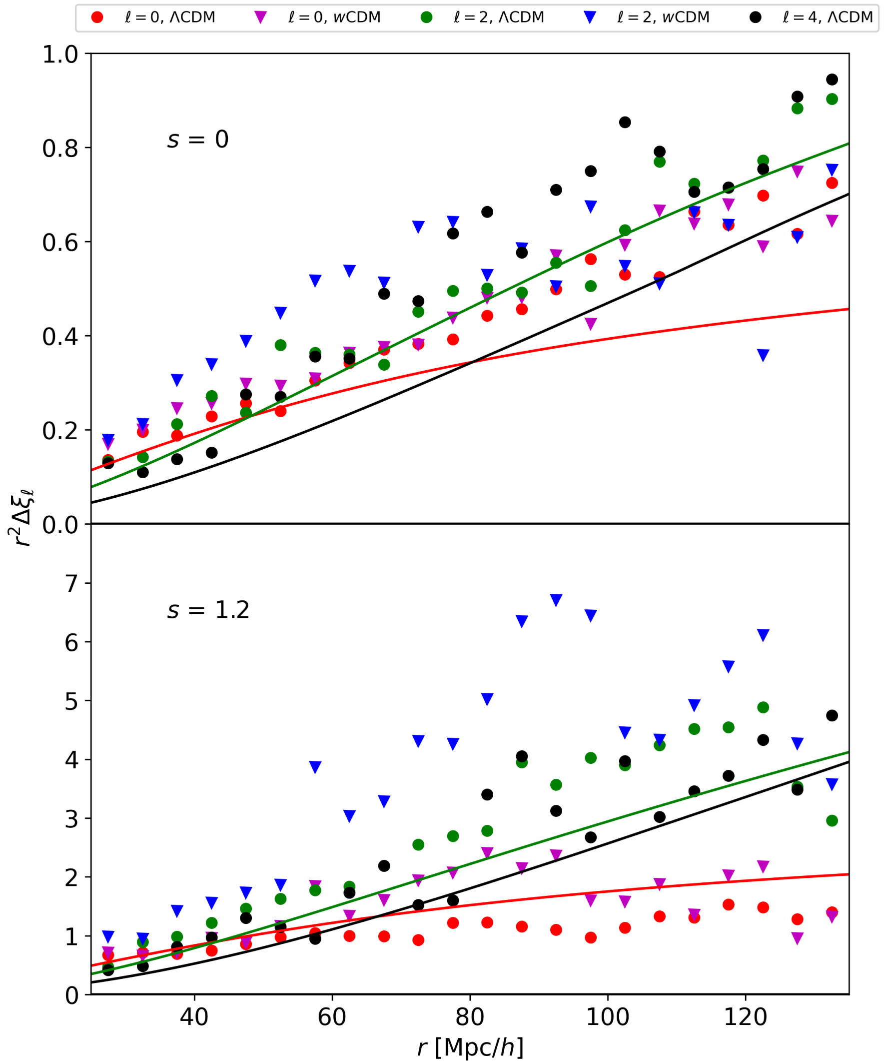


Redshift bin	ΛCDM		*w*CDM	
	Particles ($\times 10^6$)	Haloes ($\times 10^6$)	Particles ($\times 10^6$)	Haloes ($\times 10^6$)
$0.7 < z < 1.0$	7.2	1.9	7.3	2.2
$1.0 < z < 1.3$	9.6	2.2	9.7	2.5
$1.3 < z < 1.6$	11.3	2.2	11.3	2.4
$1.6 < z < 1.95$	14.5	2.1	14.2	2.4



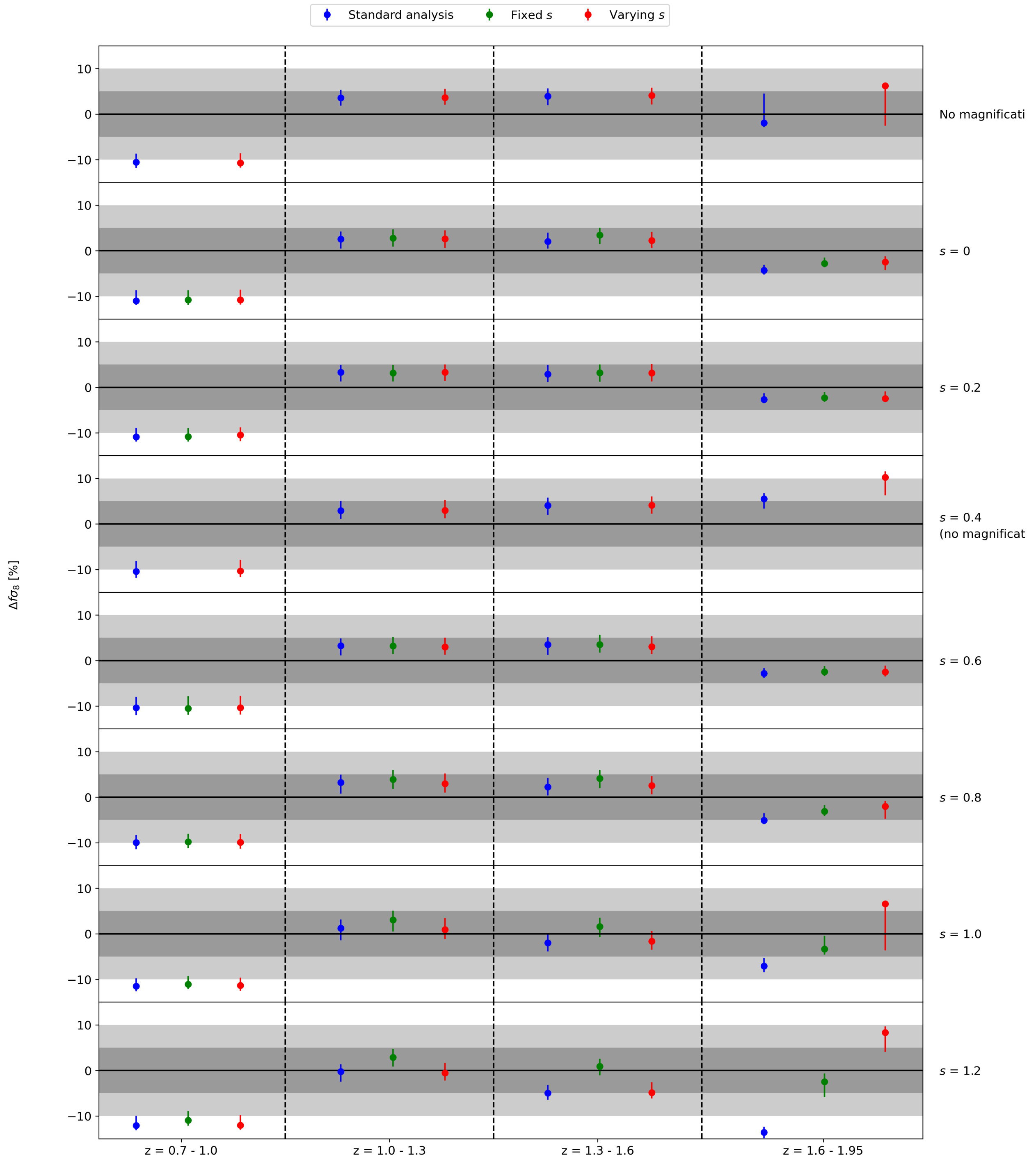
Magnification correction

- Linear is good enough



Impact on fsigma8

- Important to account for magnification (in worst case)
- Free s is not a solution in fits



Impact on fsigma8

- Still, degeneracies between parameters