Romain Paviot

Observational cosmology with the LSS

What i have been doing with my life.

- Clustering of galaxies.
- Semi-analytical model of halo occupation/galaxy-galaxy lensing.
- Intrinsic alignment of galaxies.

Cosmology

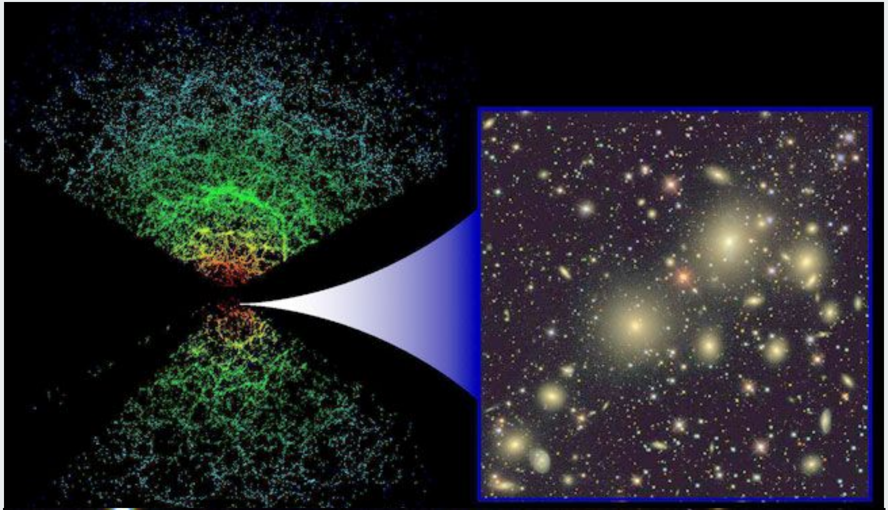
Study of the origin and evolution of the Univers.

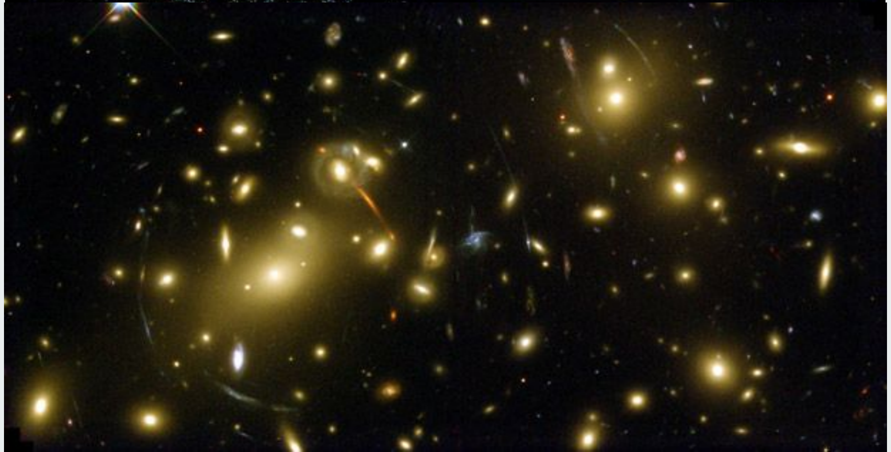
Tracers of the density field :

- ***Galaxies***
- Voids
- Clusters
- ....

Others cosmological probes :

- CMB
- Supernovae
- Lyman-alpha forest
- ....





Clustering of galaxies

Two observables : Redshift space distortions (RSD) and baryon acoustic oscillations (BAO).
Constraints: growth rate of structure and distance ladder measurements

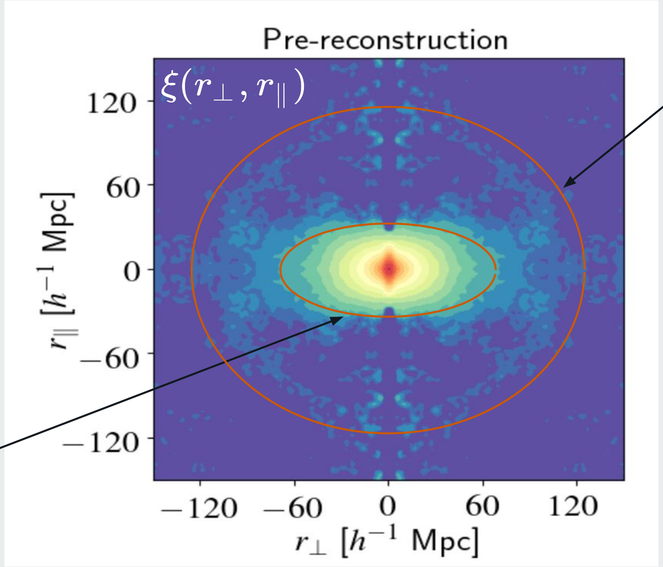
$$z_{\text{eff}} = 0.70$$

eBOSS DR16 luminous red galaxies 2PCF
Bautista, Paviot, Vargas Magaña et al. 2020

$$\delta P = \bar{n}^2 \delta V_1 \delta V_2 (1 + \xi(r))$$

The Landy-Szalay (LS) estimator

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



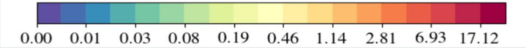
Baryon acoustic oscillations

$$r_d = \int_{z_d}^{\infty} \frac{c_s(z)}{H(z)} dz$$
$$= 147.21 \pm 0.23 \text{Mpc}$$

Anisotropies : Redshift space distortions

Line of sight separation

Transverse separation



$$\mathbf{s} = \mathbf{r} + \frac{\mathbf{v} \cdot \mathbf{n}}{aH(a)} \qquad \beta\delta = -\frac{1}{aH(a)} \nabla \cdot \mathbf{v}$$

Statistics of the density field.

How can one describe the matter density field $\delta(\mathbf{r}) \equiv \frac{\rho(\mathbf{r})-\bar{\rho}(\mathbf{r})}{\bar{\rho}(\mathbf{r})}$?

Useless to to specify δ at every point space. Instead, describe the density field in term of some probability distribution function, totally defined by its moments:

$$\left\langle \delta_1^{\ell_1} \delta_2^{\ell_2} \ldots \delta_n^{\ell_n} \right\rangle \equiv \int \delta_1^{\ell_1} \delta_2^{\ell_2} \ldots \delta_n^{\ell_n} \mathscr{P}_x(\delta_1, \delta_2, \ldots, \delta_n)\, \mathrm{d}\delta_1\, \mathrm{d}\delta_2 \ldots \mathrm{d}\delta_n$$

The power spectrum :

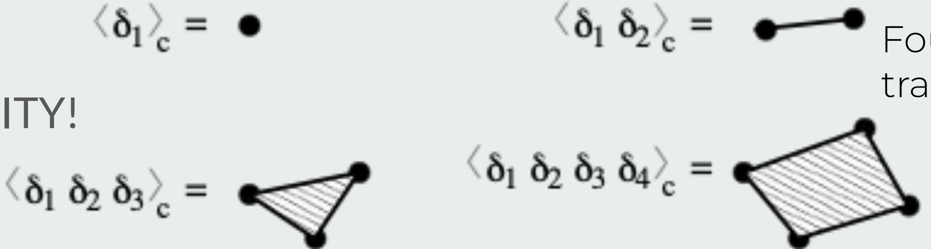
$$P(\mathbf{k}) = \int \mathrm{d}\mathbf{r}^3 \exp(-i\mathbf{k}\cdot\mathbf{r})\xi(\mathbf{r})$$

$$P(k) \equiv \langle |\delta_k|^2 \rangle,$$

First moment, $<\delta(\mathbf{r})>=0$ following cosmological principle.
Second moment, $\xi(\mathbf{x}) \equiv <\delta(\mathbf{r})\delta(\mathbf{r'})>$ where $\mathbf{x} = |\mathbf{r} - \mathbf{r'}|$

Fourier transform

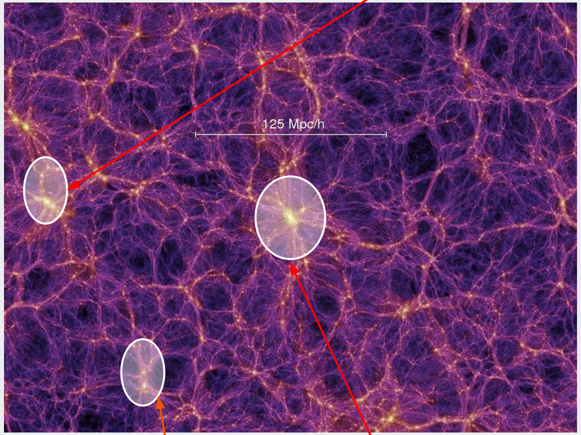
ERGODICITY!



Different moments of the density field.
Bernardeau et al 2001

Galaxies!

100-1000 galaxies

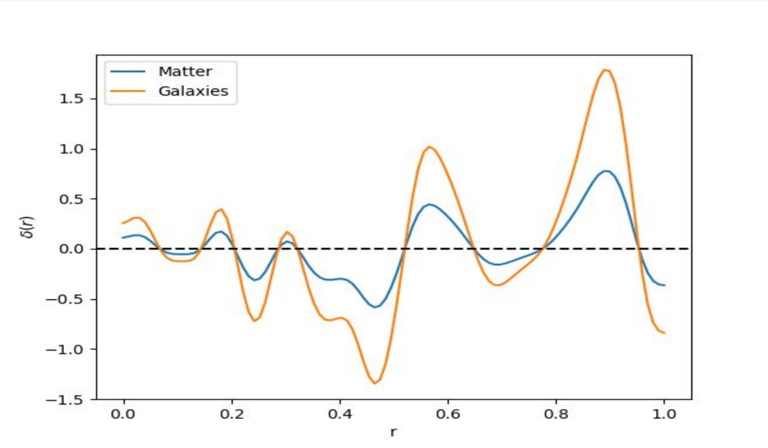


1 galaxy

10-100 galaxies

The Millenium simulation

Galaxies are *biased* tracers of the underlying density field



$$\delta_g(\mathbf{x}) = \mathcal{F}[\delta(\mathbf{x})]$$ Linear :

$$\delta_g = b\delta_m \quad P_g(k) = b^2 P_m(k)$$

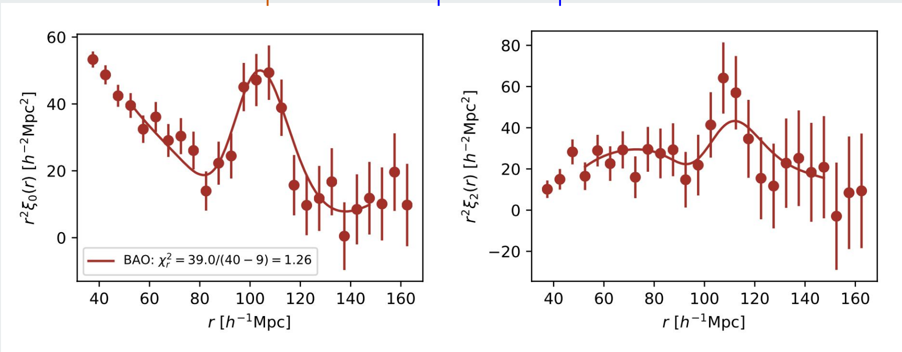
$$P_g^s(k,\mu) = [b + f\mu^2]^2 P_m(k)$$

Perturbation theory

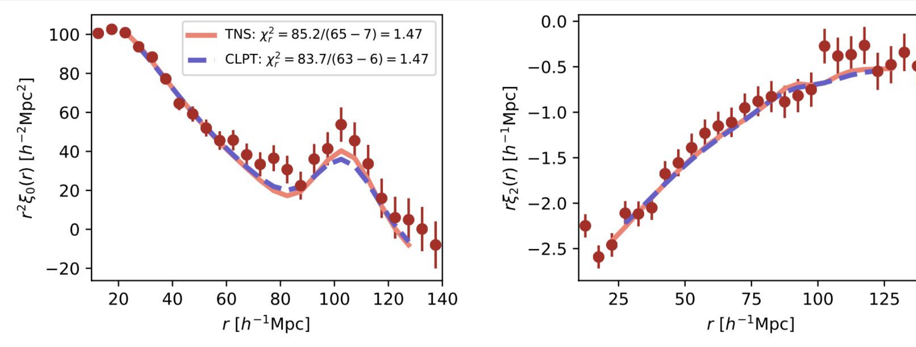
BAO measurement (Julian le S)

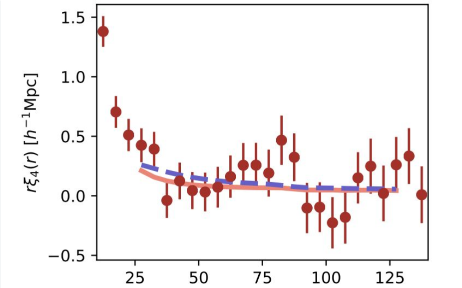
$$\xi^s(s,\mu) = \xi_0(s)L_0(\mu) + \xi_2(s)L_2(\mu) + \xi_4(s)L_4(\mu)$$

Monopole quadrupole hexadecapole



$$\mathbf{D}_{\mathrm{BAO},\xi_\ell} = \begin{pmatrix} D_M/r_d \\ D_H/r_d \end{pmatrix} = \begin{pmatrix} 17.86 \pm 0.33 \\ 19.34 \pm 0.54 \end{pmatrix}$$

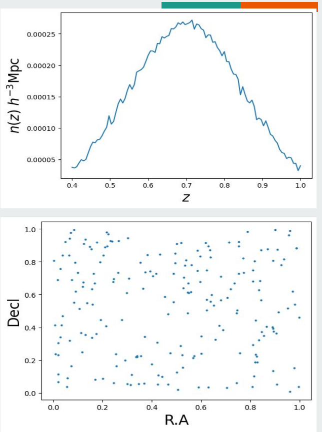




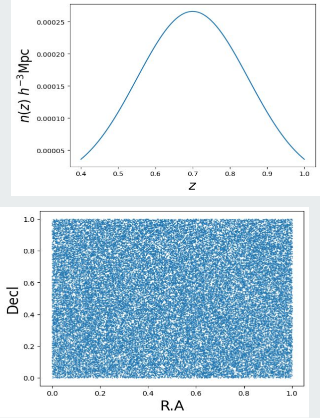
RSD measurements (me and Mariana)

$$\mathbf{D}_{\mathrm{RSD},\xi_\ell} = \begin{pmatrix} D_M/r_d \\ D_H/r_d \\ f\sigma_8 \end{pmatrix} = \begin{pmatrix} 17.42 \pm 0.40 \\ 20.46 \pm 0.70 \\ 0.460 \pm 0.050 \end{pmatrix}$$

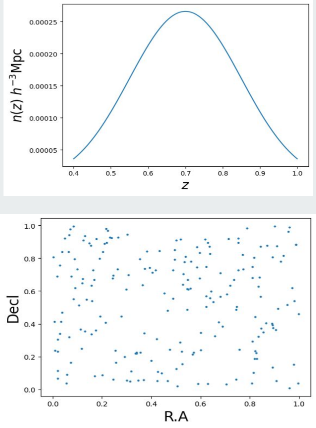
Angular modes free estimator (Paviot et al 2021)



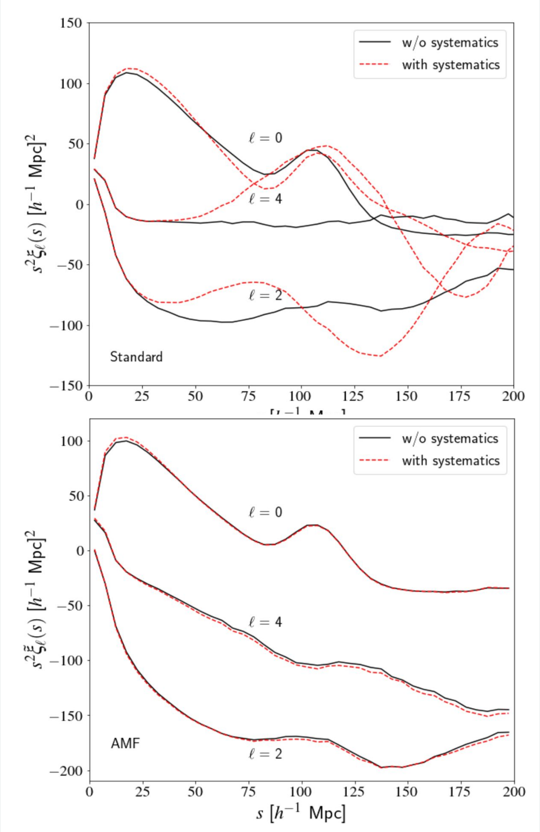
Data catalog



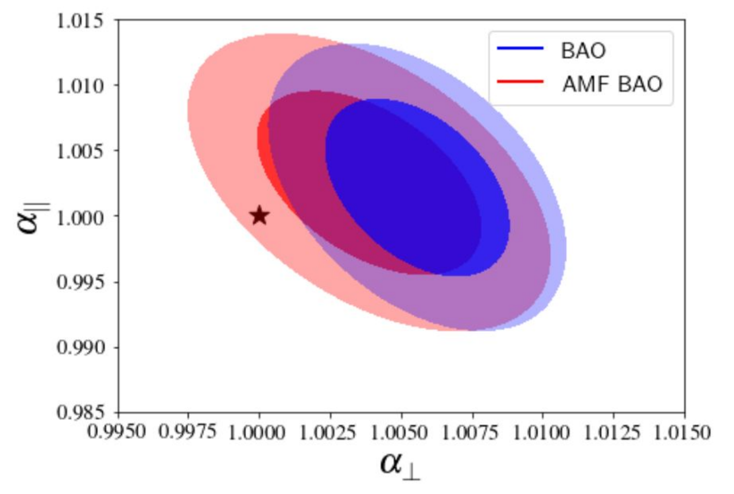
Random catalog R

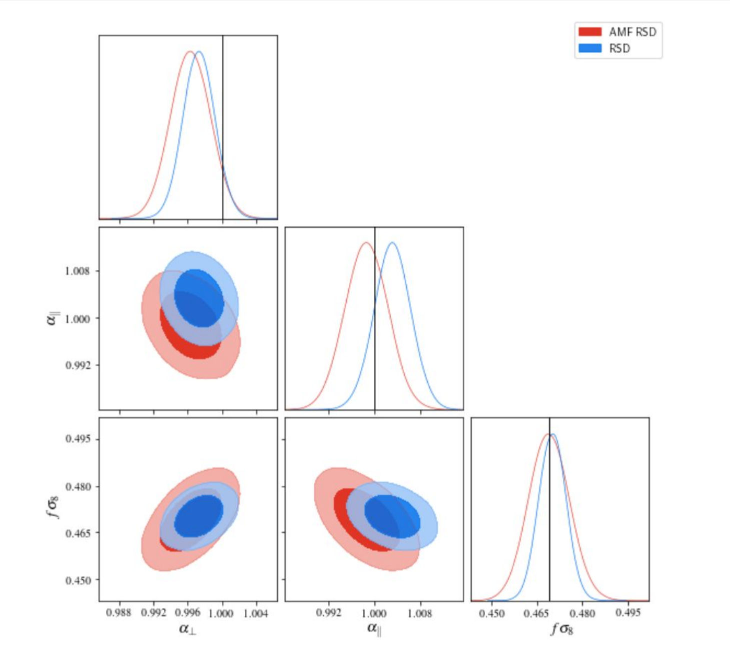


Random catalog S



Angular modes free estimator





New estimator gives consistent constraint compared to the standard one !

Halo occupation model (HOD)

Populate dark matter haloes with galaxy given a semi-analytical model.

$$w_p(r_p) = 2\int_0^{\pi_{max}} \xi(r_p,\pi)d\pi.$$

$$\langle N_{\rm g}|M_{\rm h}\rangle = \langle N_{\rm cen}|M_{\rm h}\rangle + \langle N_{\rm sat}|M_{\rm h}\rangle.$$

Red galaxies

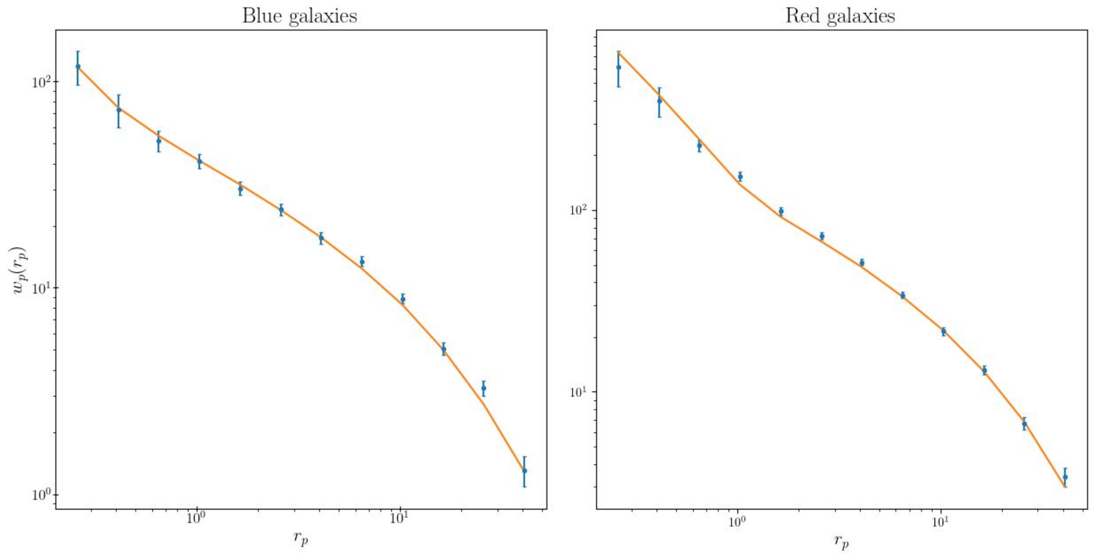
$$N_{\rm cen}(M) = \frac{1}{2}\left[1 + {\rm erf}\left(\frac{\log M - \log M_{\rm min}}{\sigma_{\log M}}\right)\right],$$

Blue galaxies

$$\langle N_{cent}(M)\rangle = \frac{A_c}{\sqrt{2\pi}\sigma_{\rm M}}\cdot e^{-\frac{(\log_{10}(M)-\mu)^2}{2\sigma_{\rm M}^2}}$$

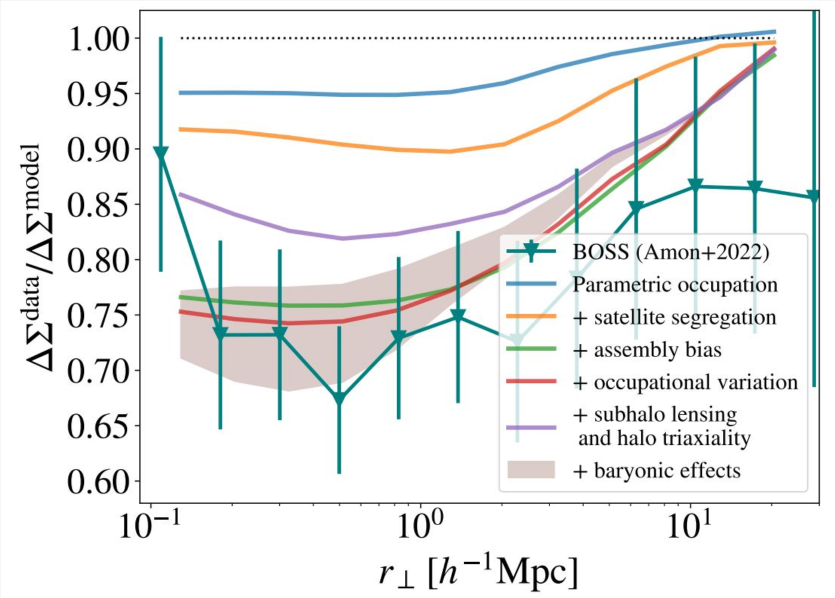
Satellites

$$\langle N_{sat}(M)\rangle = A_s\left(\frac{M-M_0}{M_1}\right)^\alpha$$



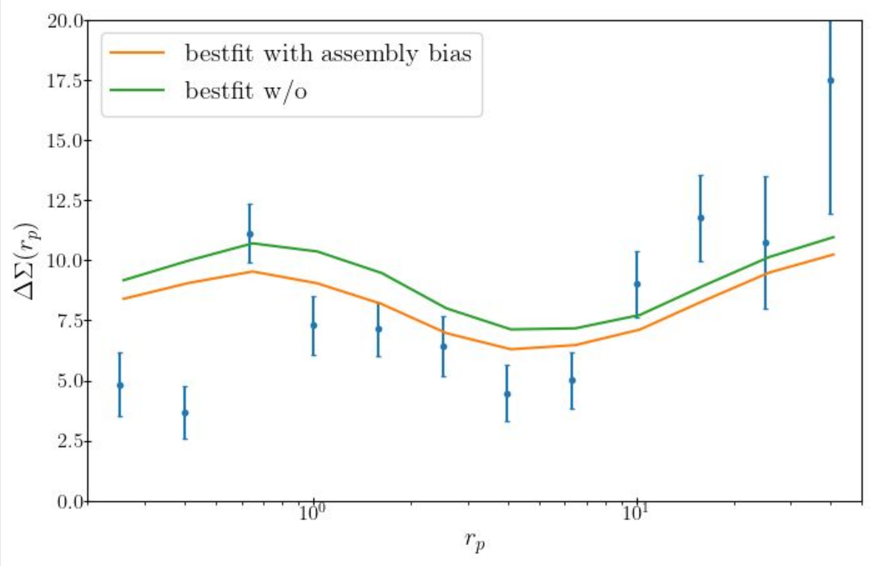
HOD Bestfit of eBOSS ELG and LRG on UCHUU simulations

Halo occupation model (HOD)



Chaves-Montero et al. 2023

HOD description fails to reproduce the lensing signal



UCHUU LRG HOD bestfit

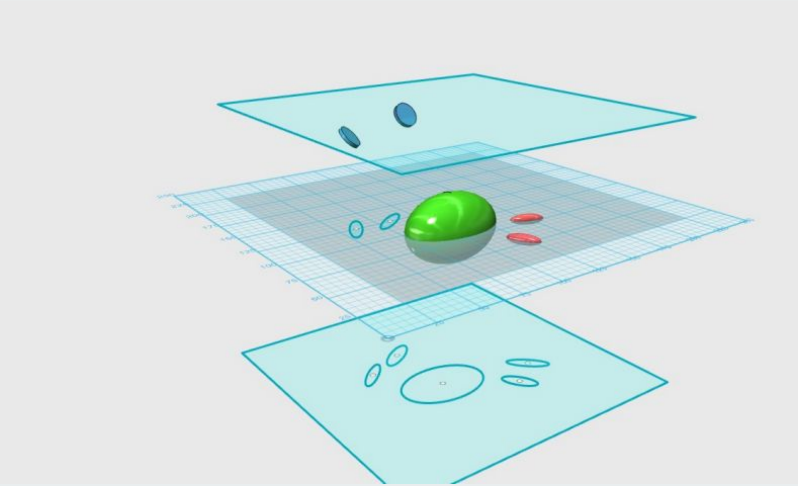
$$\log M_{\rm pseudo} = \log M + Ac_{\rm norm} + B\delta_c + C \cdot shape$$

→ Goal : Combine fit of clustering (Pgg) and lensing (Pgm) to break degeneracy between f and sigma8.

Constraint on galaxy intrinsic alignment (Euclid project)

3 main IA paper in EUCLID :

- Paper 0 : Hoffmann et al. : Semi-analytical of galaxy intrinsic alignments in EUCLID N-Body simulation.
- Paper I : Paviot et al. : Provides prior for cosmological 3x2pt forecast of EUCLID
- Paper II : Tutusaus et al. (Isaac le S): Will do 3x2pt analysis once my work is over !

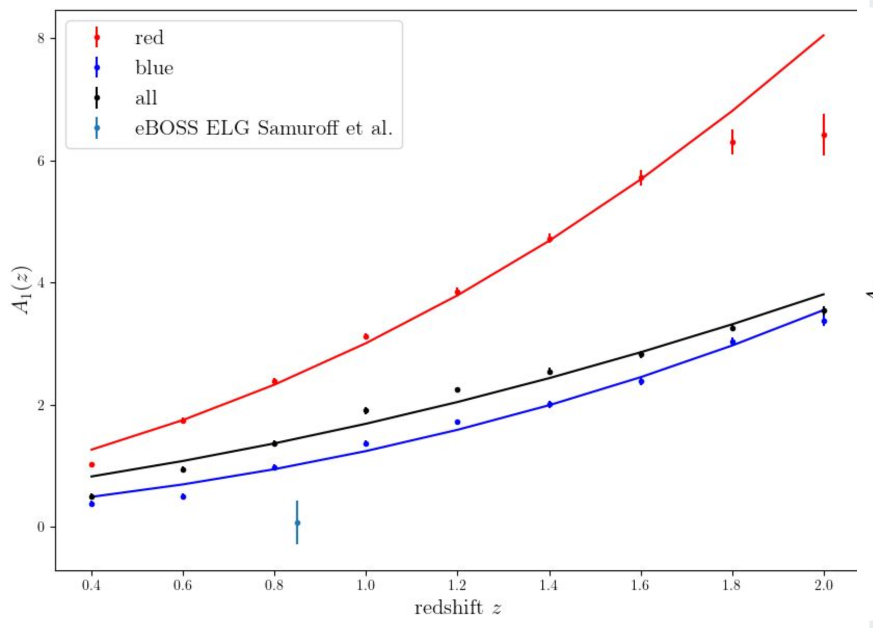


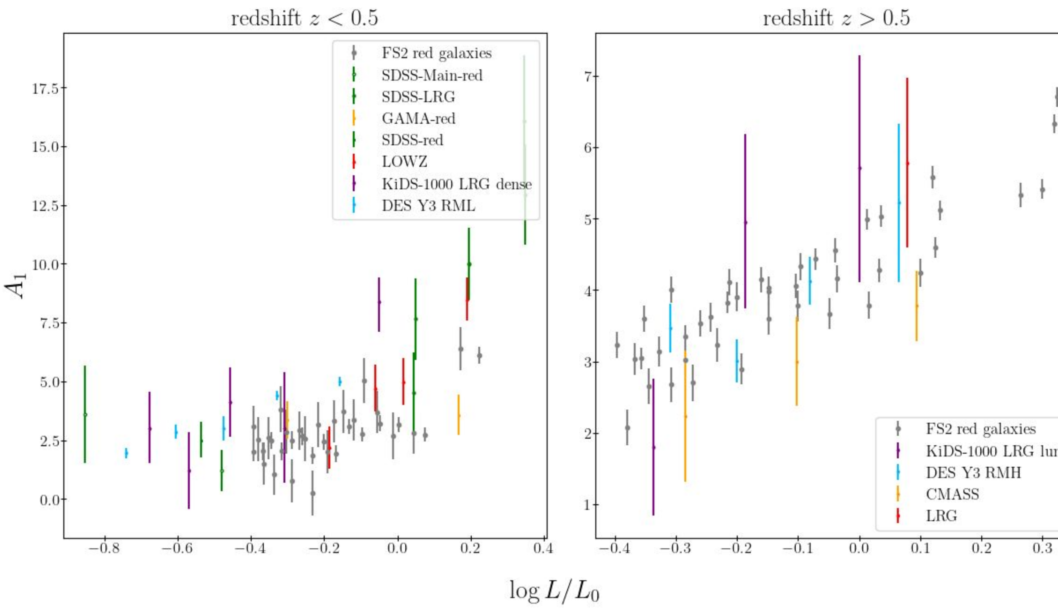
$$\langle\gamma\gamma\rangle = \left\langle \gamma^G\gamma^G + \gamma^G\gamma^I + \gamma^I\gamma^I \right\rangle = \xi_{GG} + \xi_{GI} + \xi_{II}.$$

$$\hat{\xi}_{g+} = \frac{S_+(D - R_D)}{R_S R_D}$$

IA constraint with FS2!

Calibration works OK for red galaxies, problem for blue galaxies!





Conclusion

I do a lot of stuff, but not a lot at the same time.
The future of cosmology looks very promising !


MERCI L'EQUIPE ! VIVE EUCLID !
APERO TIME BB

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Merci Coco pour ce montage 13 NRV!

Semi non-linear regime : TNS (Taruya et al. 2010) with non-linear bias (Assasi et al. 2017)

$$P_{\rm g}^{s}(k,\mu) = D(k\mu\sigma_v)\left[P_{\rm gg}(k) + 2\mu^2 f P_{\rm g\theta} + \mu^4 f^2 P_{\theta\theta}(k) + C_A(k,\mu,f,b_1) + C_B(k,\mu,f,b_1)\right]$$

$$D(k\mu\sigma_v) = (1 + (k\mu\sigma_v)^2/2)^{-2}$$

$$\begin{aligned} P_{gg}(k) = {} & b_1^2 P_{\delta\delta}(k) + b_2 b_1 I_{\delta^2}(k) + 2 b_1 b_{\mathcal{G}_2} I_{\mathcal{G}_2}(k) \\ & + 2\left(b_1 b_{\mathcal{G}_2} + \frac{2}{5} b_1 b_{\Gamma_3}\right) F_{\mathcal{G}_2}(k) + \frac{1}{4} b_2^2 I_{\delta^2\delta^2}(k) \\ & + b_{\mathcal{G}_2}^2 I_{\mathcal{G}_2\mathcal{G}_2}(k) + \frac{1}{2} b_2 b_{\mathcal{G}_2} I_{\delta_2\mathcal{G}_2}(k) \end{aligned}$$