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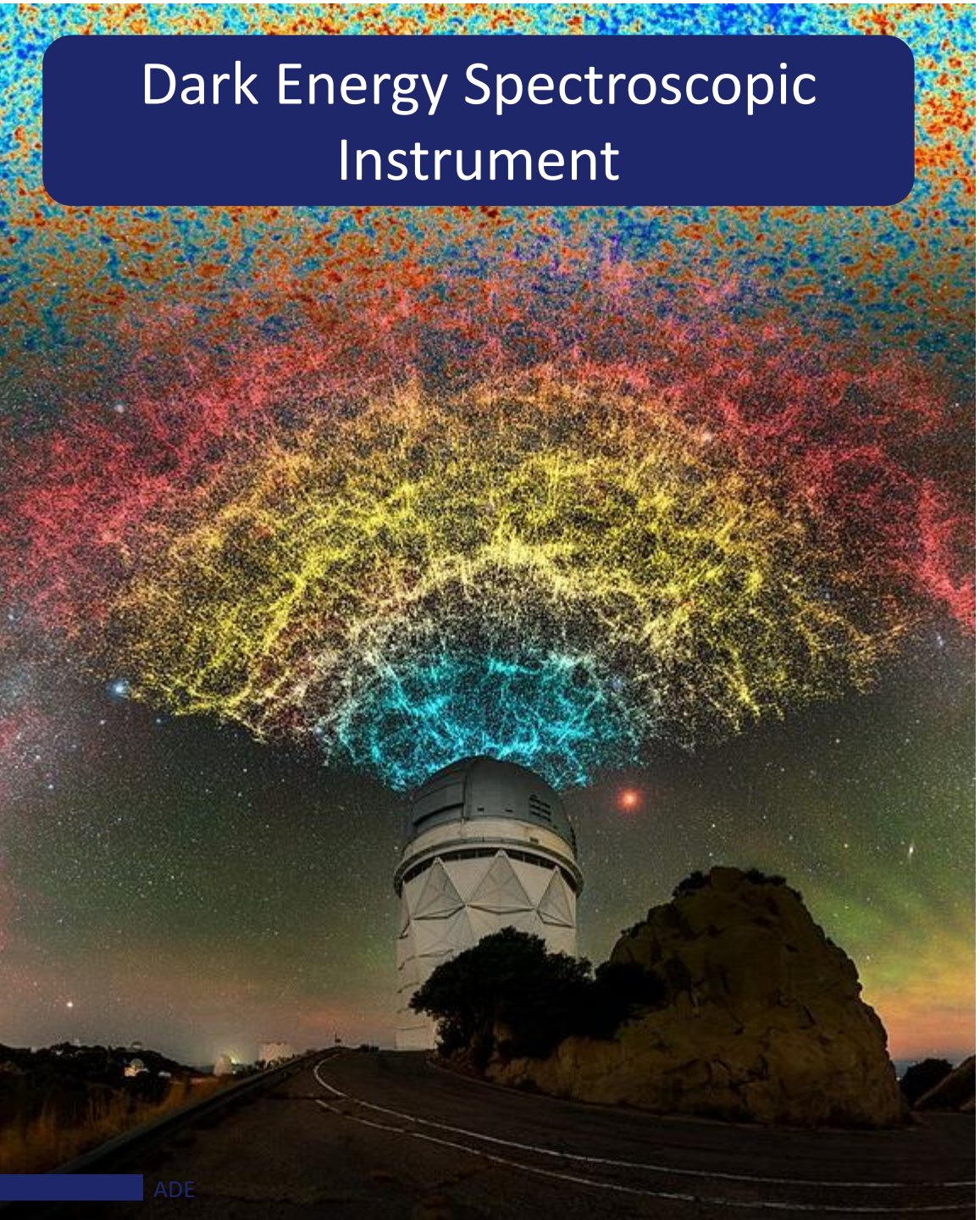
PARIS

Beyond standard galaxy clustering for DESI BGS

SCIENCES
SORBONNE
UNIVERSITÉ

Simon BOUCHARD,
under Pauline ZARROUK supervision

Dark Energy Spectroscopic Instrument



The instrument

- 1st new generation spectroscopic instrument
- 4m Mayall Telescope at Kitt Peak National Observatory
- 5000 spectra measured in one observation of approx. 20’ (previous gen : 1000/1h30)

The goal

- Constrain the dark energy parameters & gravity

Different galaxy samples

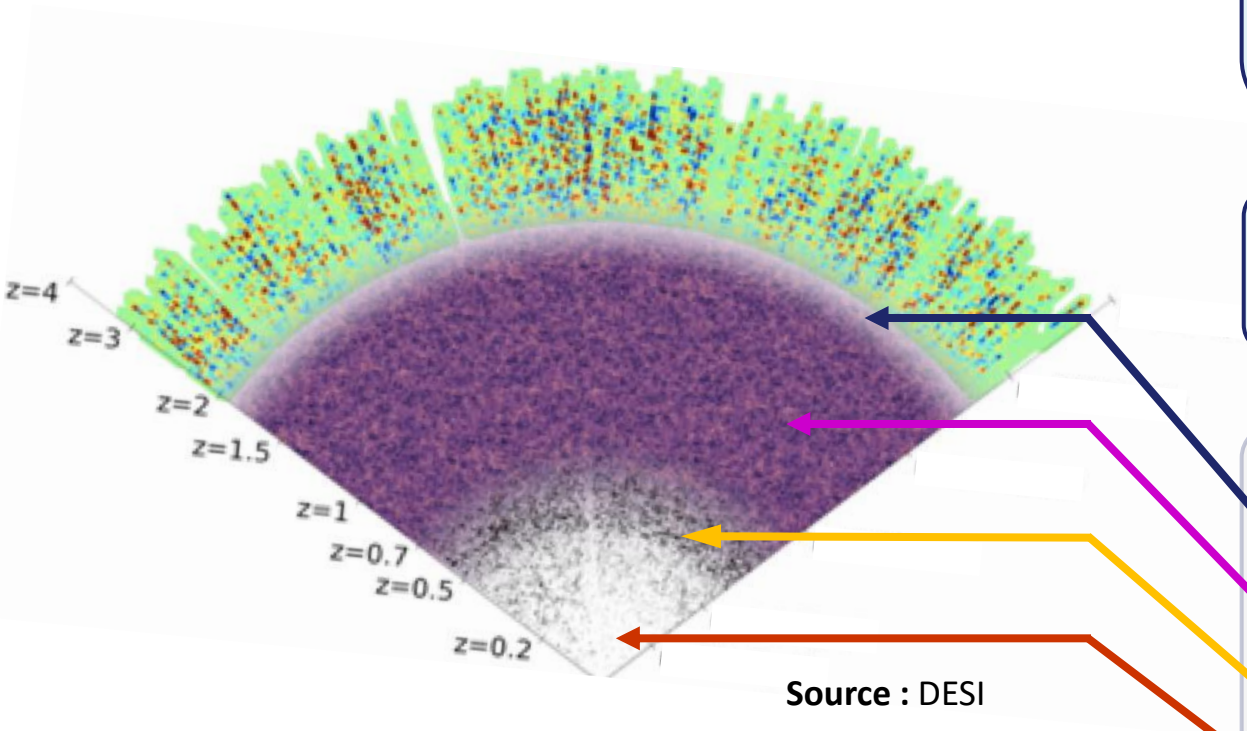
$[z > 1,5]$ **Quasars (3M)**

$[0,6 < z < 1,6]$ **ELG (Emission Line Galaxies, 16M)**

$[0,5 < z < 1,0]$ **LRG (Luminous Red Galaxies, 8M)**

$[z < 0,5]$ **BGS (Bright Galaxy Survey, 13M)**

Dark Energy Spectroscopic Instrument



Source : DESI

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Total : 60M galaxy spectra over 7 years

Data acquisition started in May 2021

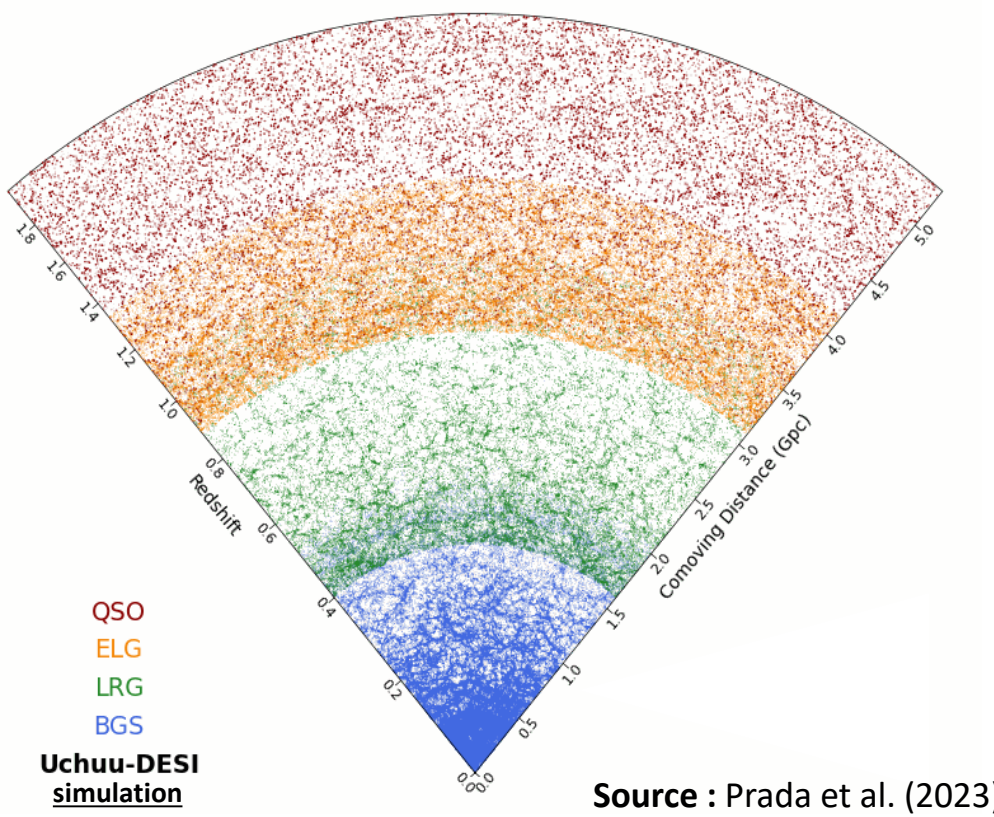
First paper (DR1) published in April

See Arnaud's talk on DESI & BAO Tomorrow, 9h00

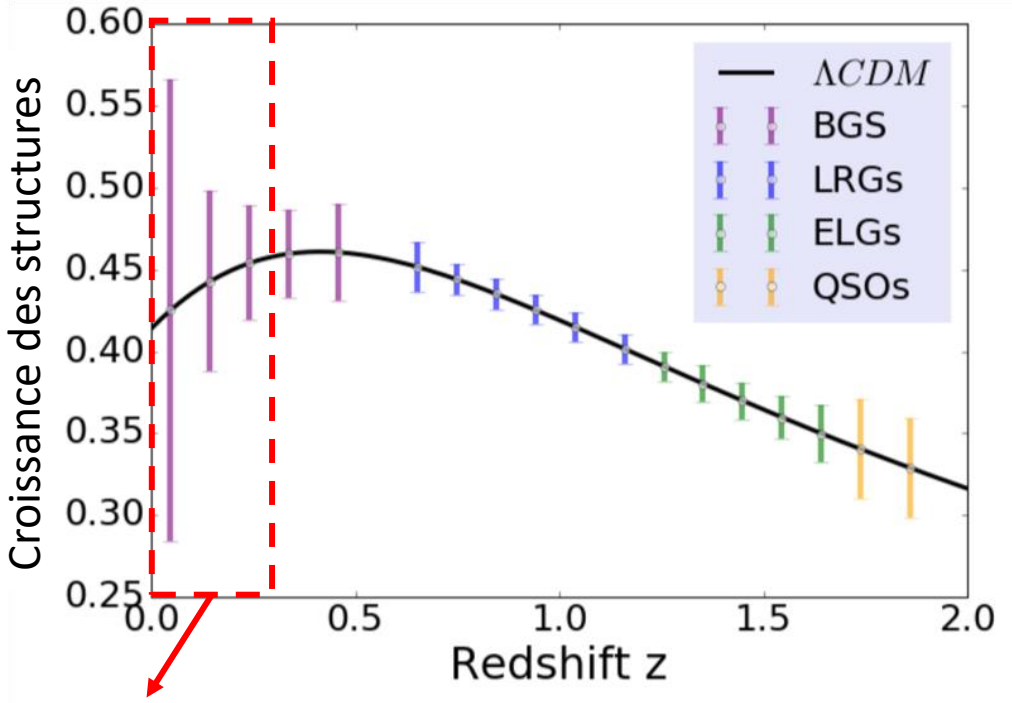
DESI : BGS

Bright Galaxy Survey

- Densest tracer ($n \approx 2.10^{-2}$)
- Closest tracer ($z < 0,5$)



Source : Prada et al. (2023)

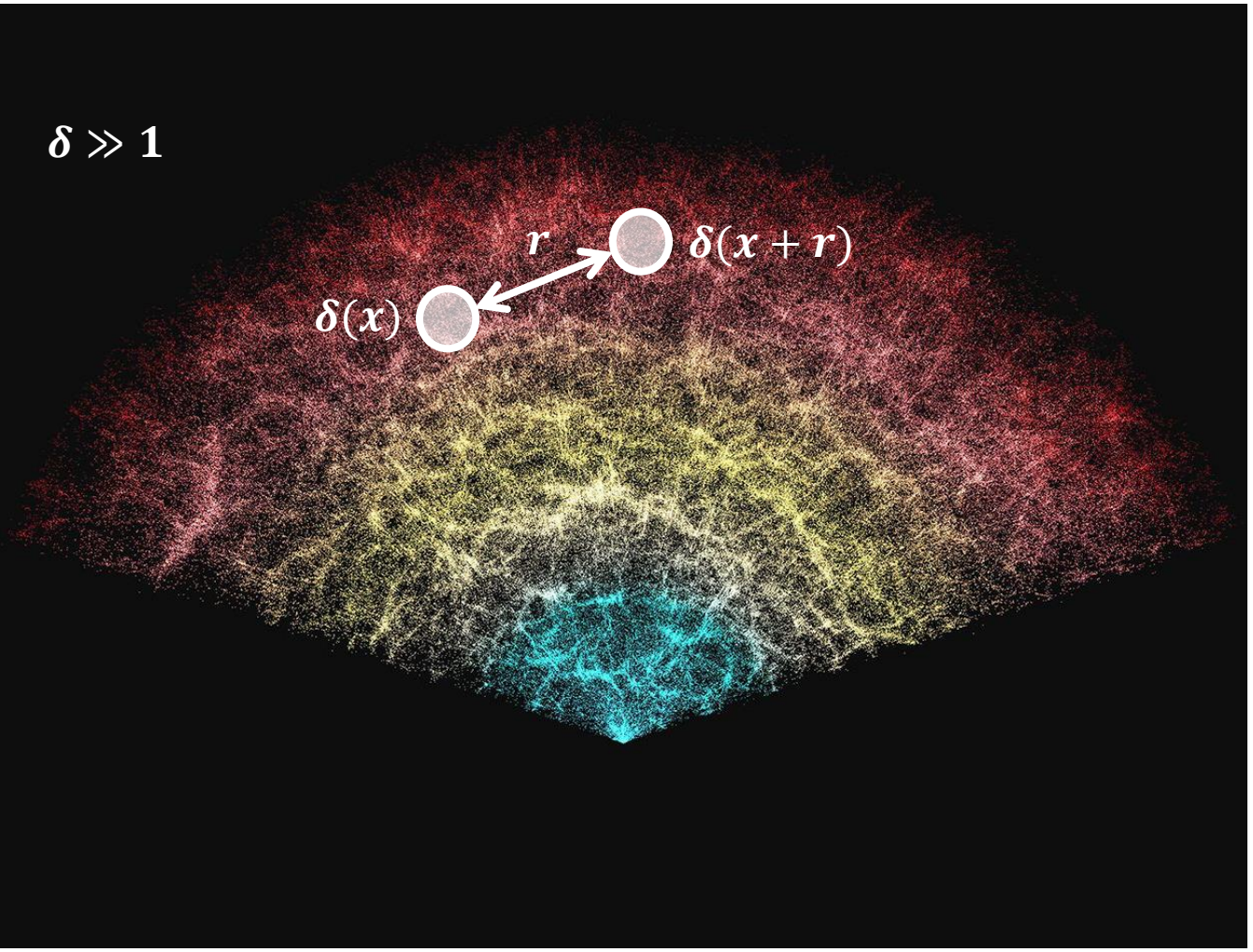


Dominated by
« Cosmic Variance »
(volume sample variance)

Source : DESI Collaboration (2016a)

Cosmological probe

Galaxy clustering



Source : DESI

Density contrast

$$\delta(x) = \frac{\rho(x) - <\rho>}{<\rho>}$$

« Standard » analysis

Two-point correlation function (« 2PCF »)

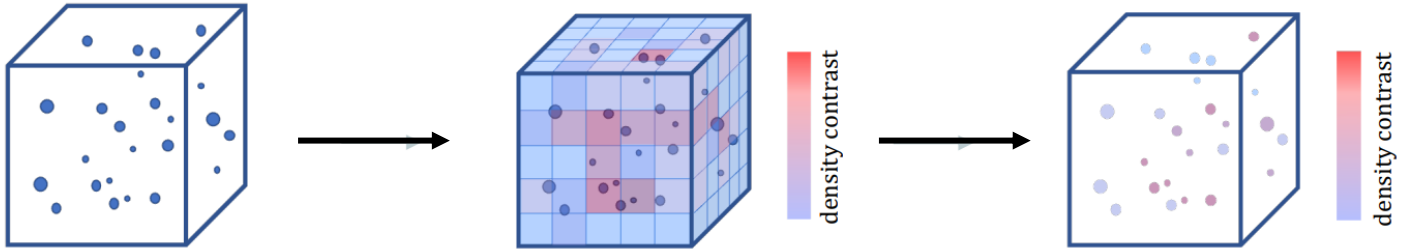
$$\xi(r) = <\delta(x)\delta(x+r)>_x$$

- Statistical tool
- Describes matter structuration
- Only captures gaussian information

Densitysplit

Paillas et al. (2020)

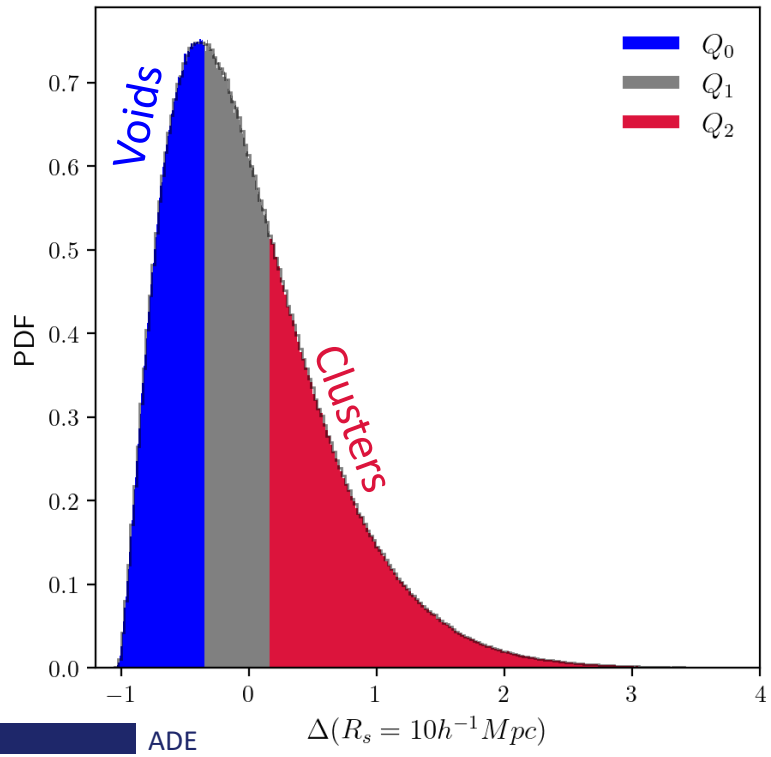
Source : Mathilde Pinon →



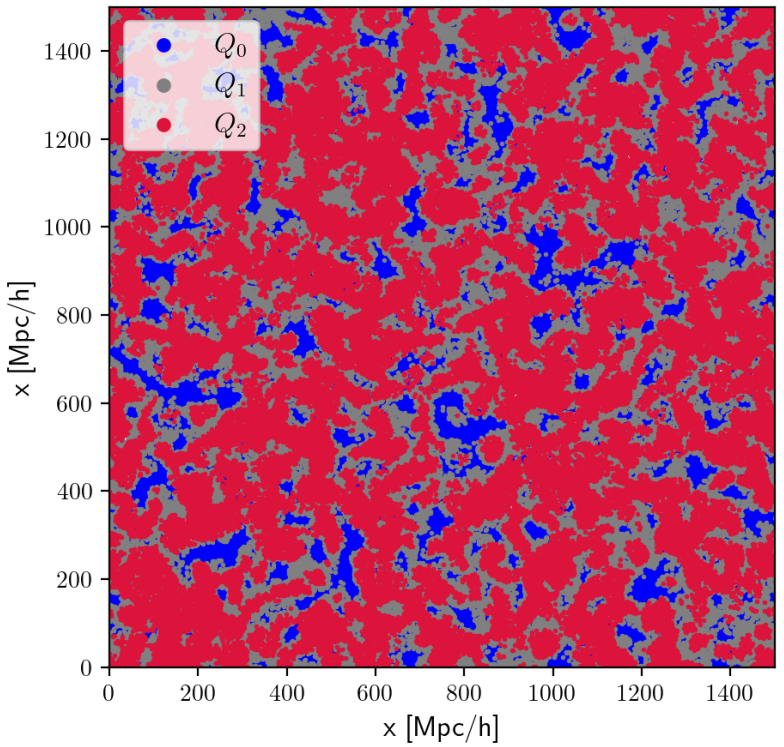
1. Catalog of tracers
2. Density mesh with cell size R
3. Density at each particle location

→ Non-standard analysis !

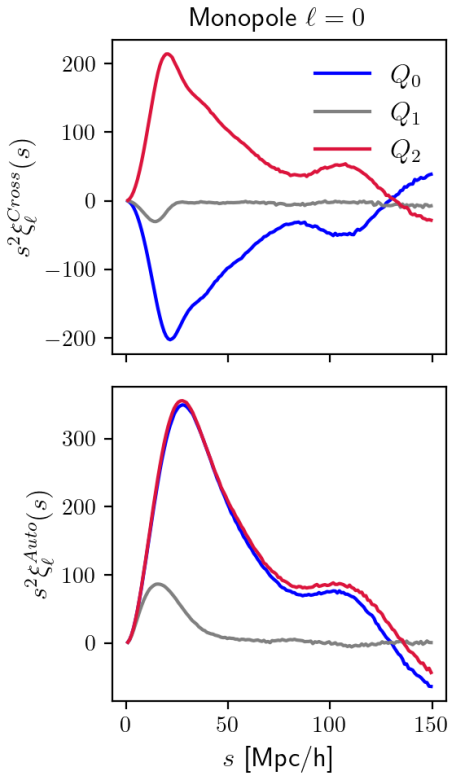
4. Density histogram



5. Split in N quantiles

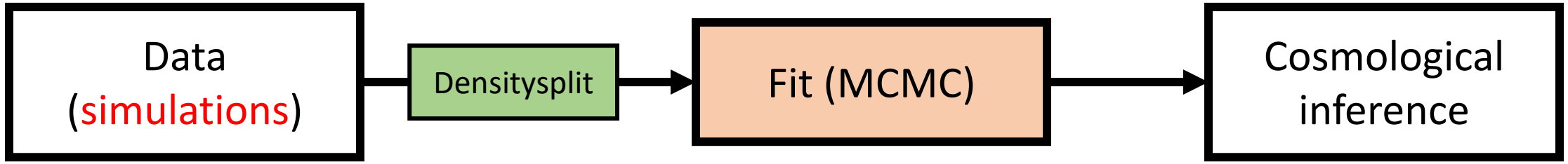


6. Correlations



Inference pipeline

→ Goal : Constrain the cosmological parameters



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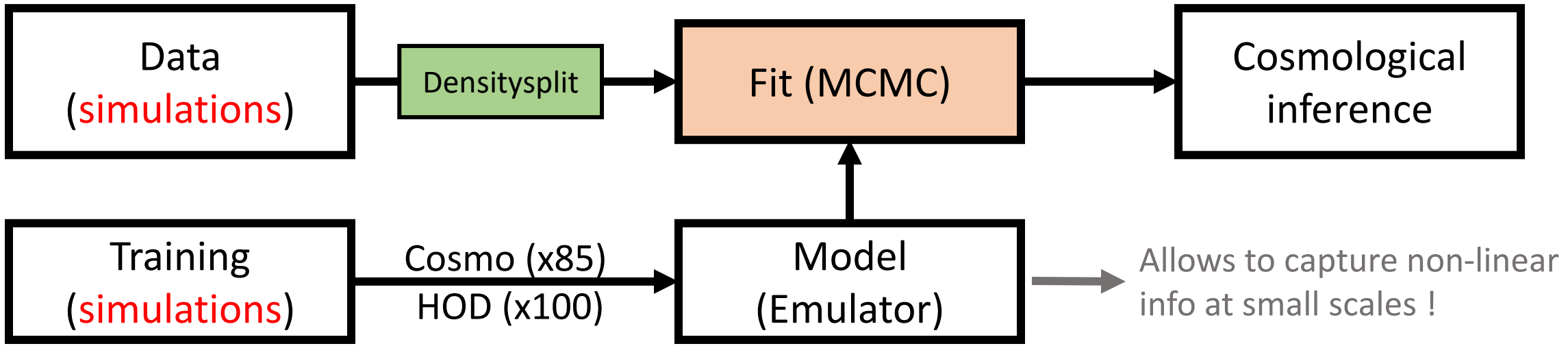

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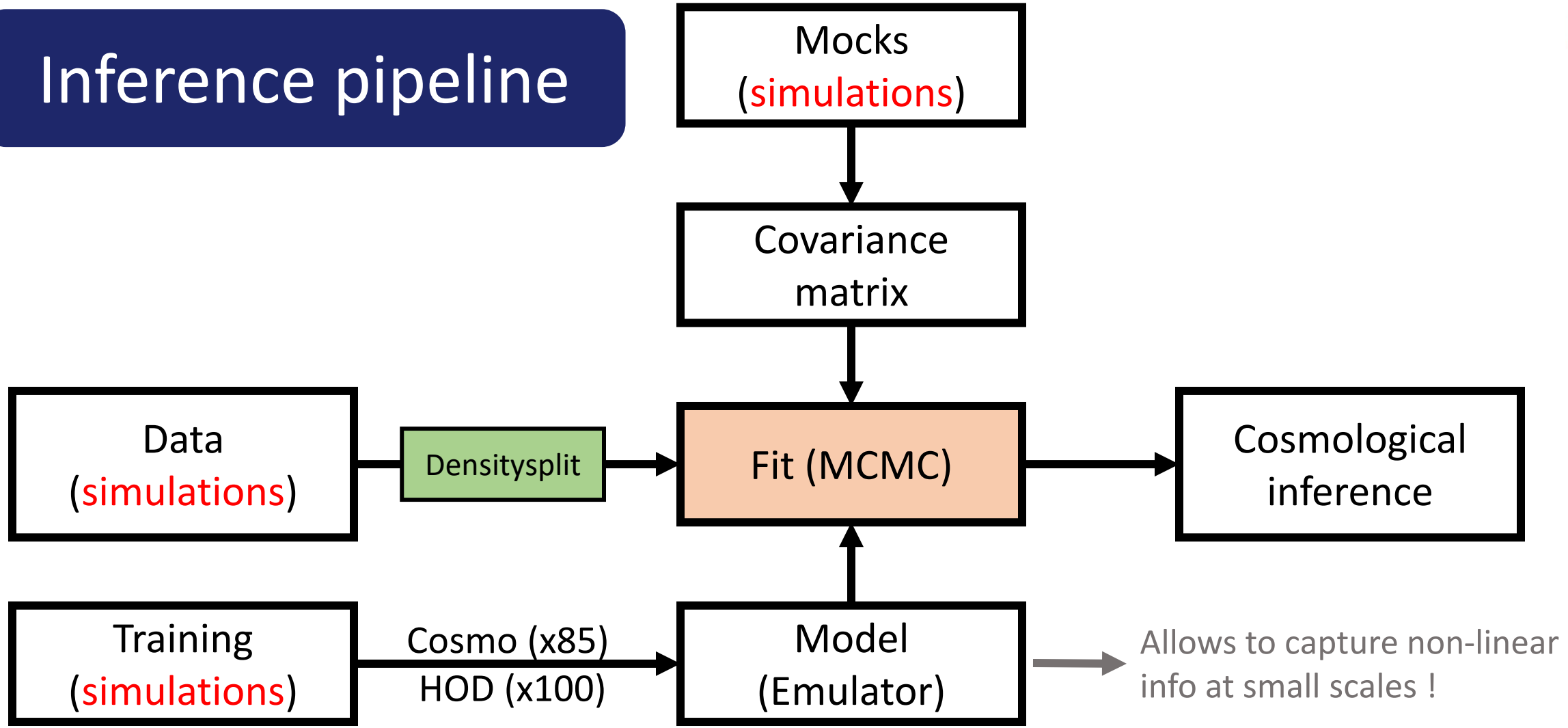
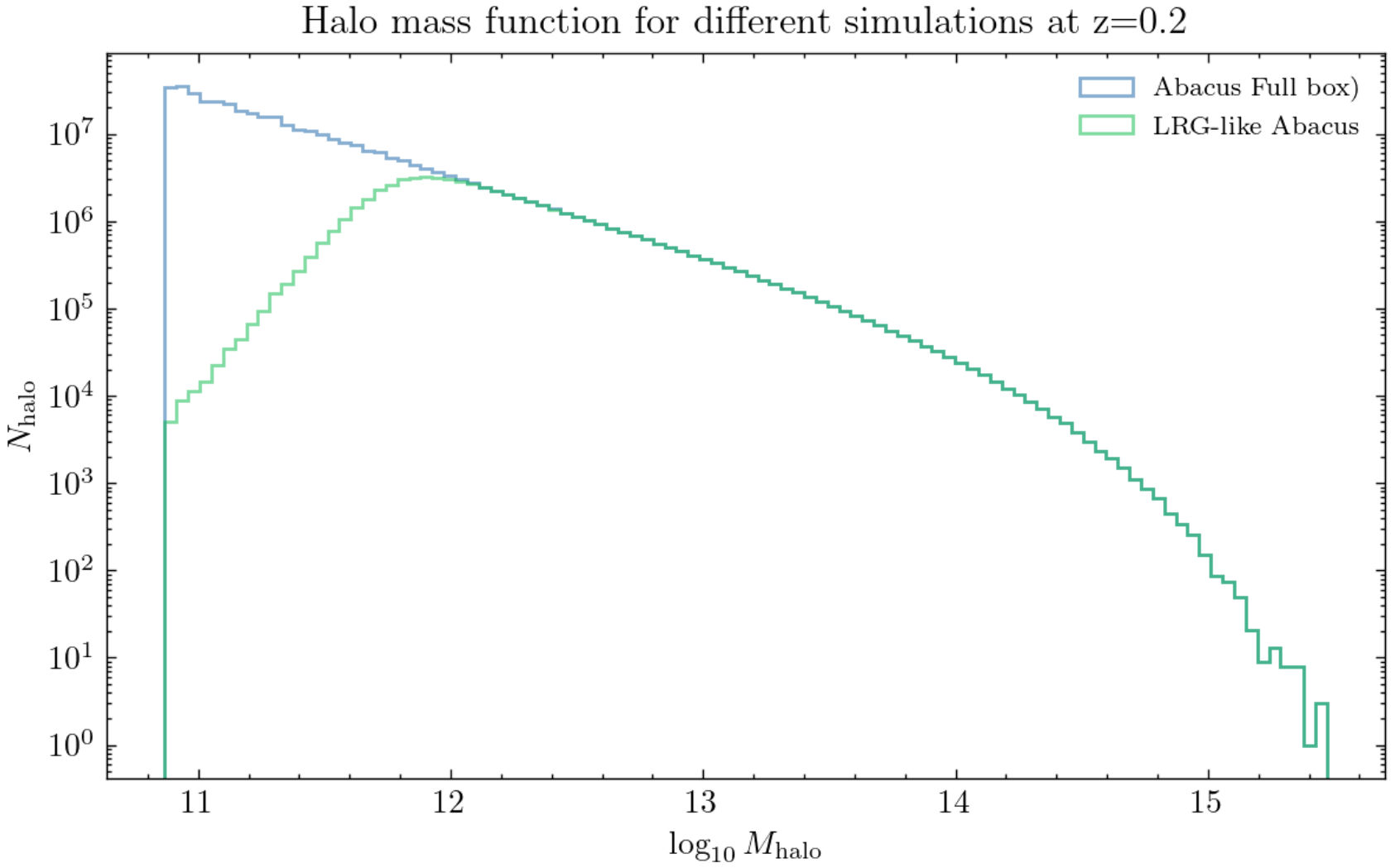


→ Generation of BGS simulations

→ Developing the interface between the codes

N-body simulations

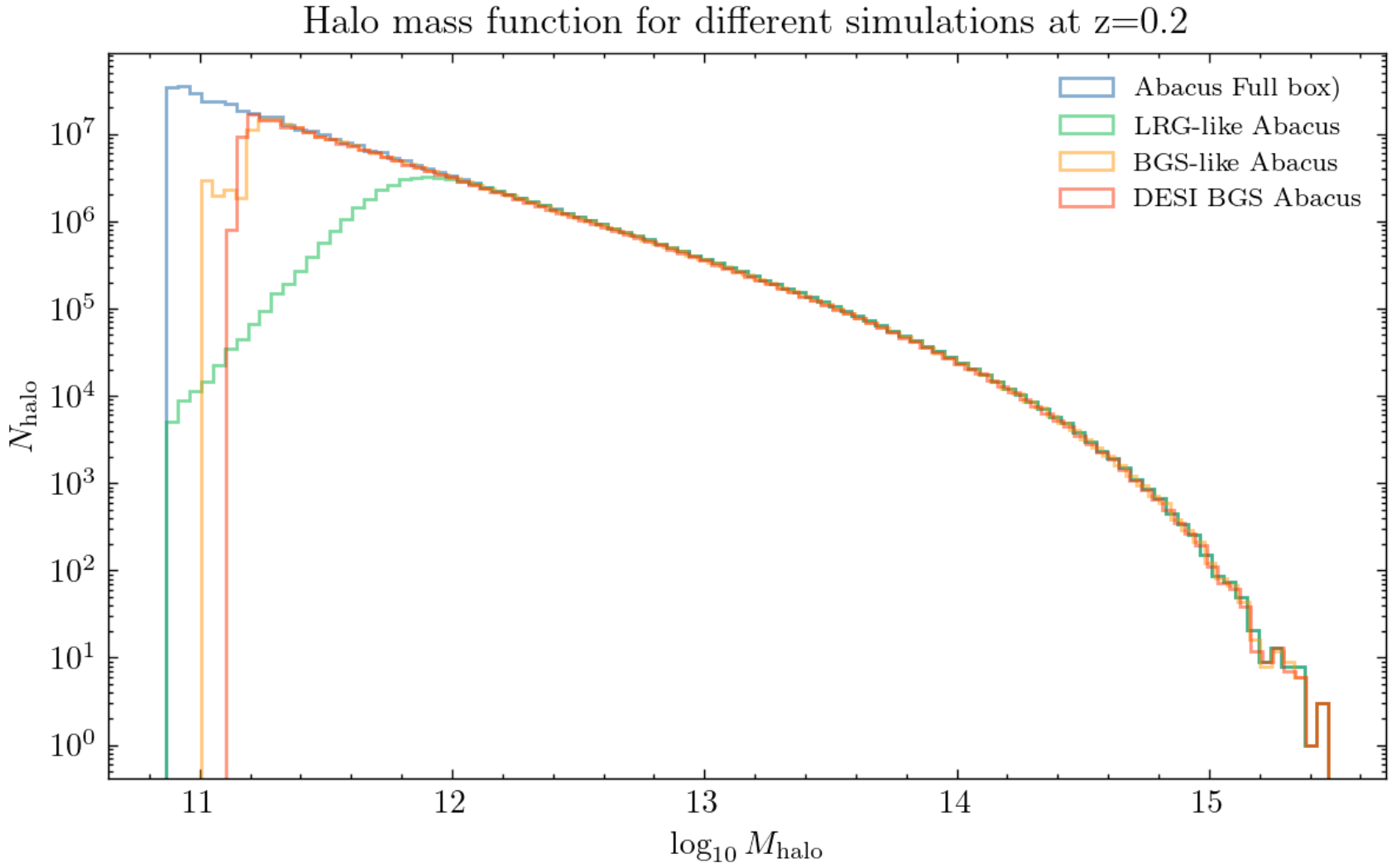
Halo mass function



Simulations : AbacusSummit (Maksimova et al. 2021)

N-body simulations

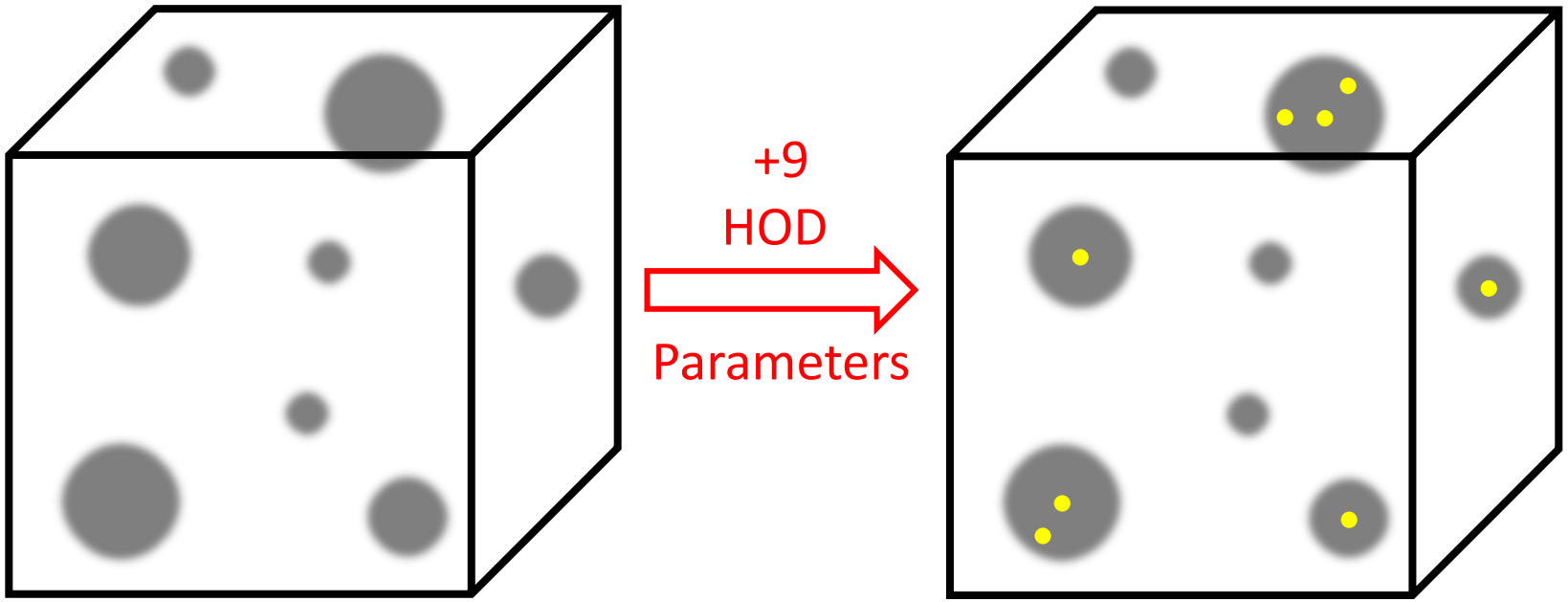
Halo mass function



Simulations : AbacusSummit (Maksimova et al. 2021)

Simulations

HOD Model



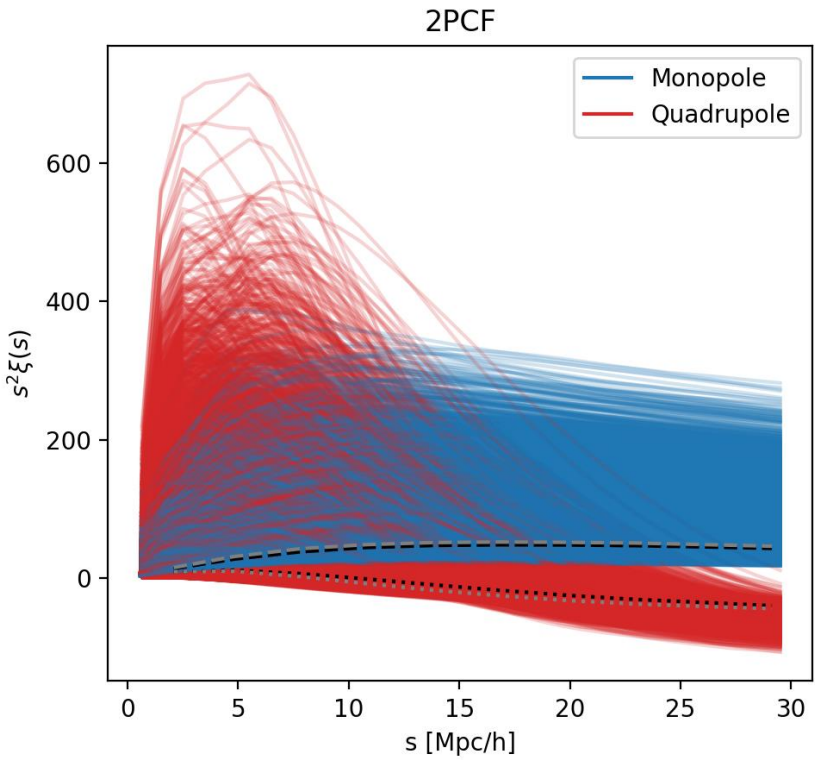
Using AbacusHOD (Yuan et al. 2021)

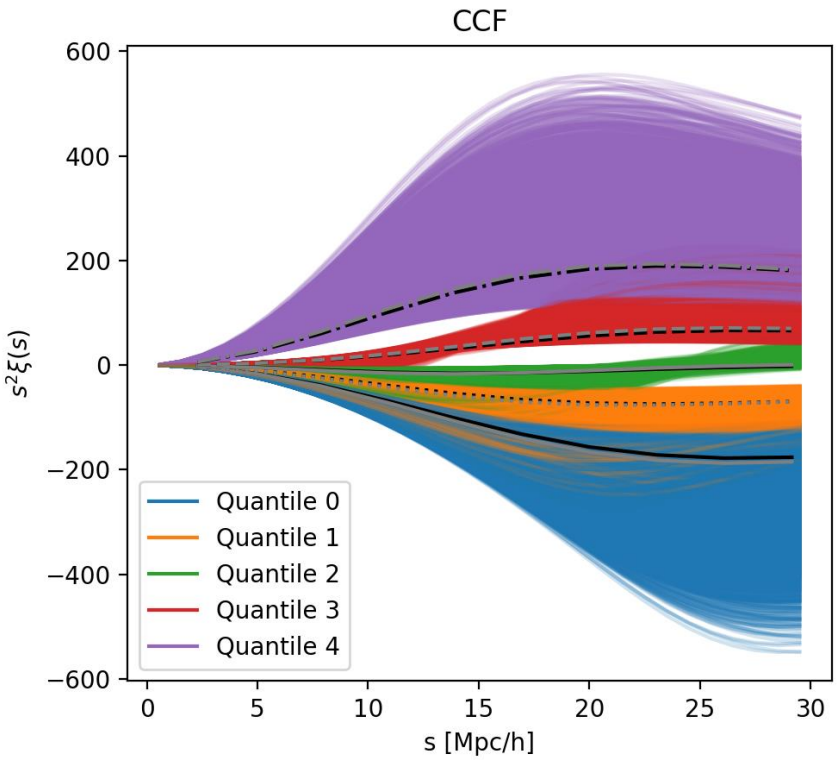
→ $\{M_{min}, \sigma_{\log M}, M_1, \alpha, \kappa, B_{cent}, B_{sat}, \alpha_c, \alpha_s\}$ to fit with cosmological parameters

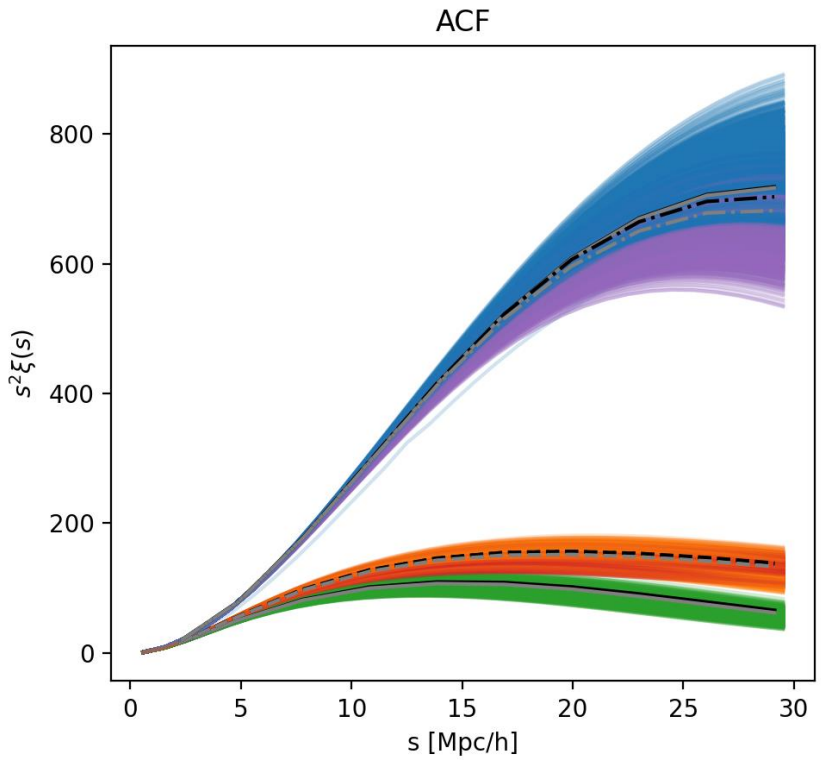
Simulations

Statistics

All HODs for all 85 cosmologies







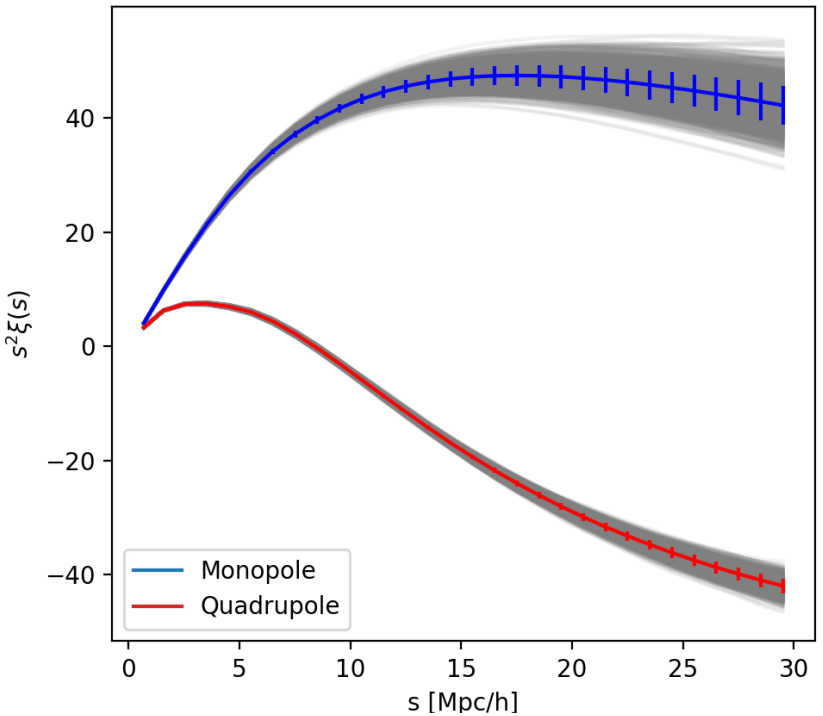
Simulations

Covariance

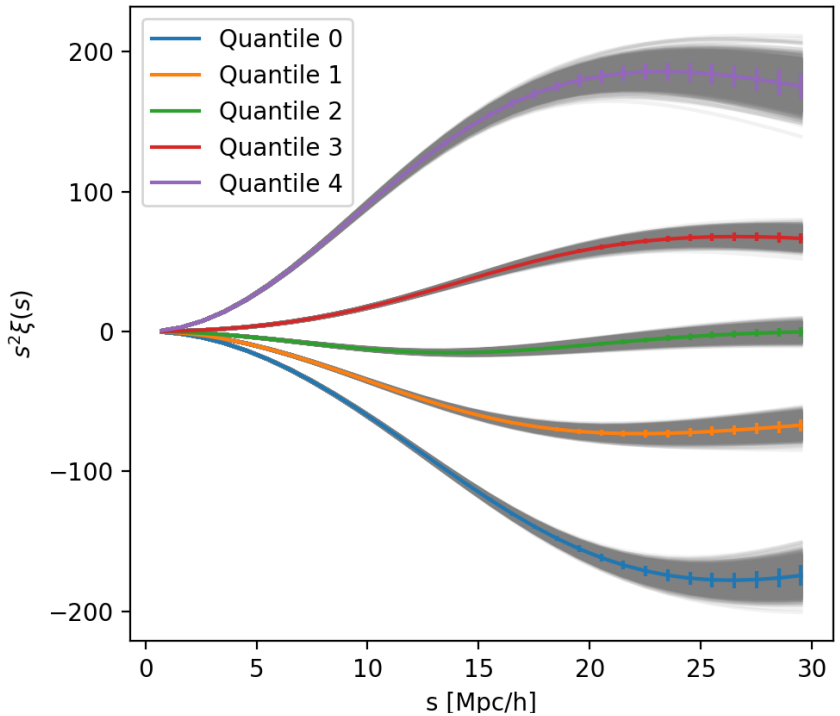
1 cosmo, 1 HOD, 1629 initial conditions

Error bars for 1629 small boxes

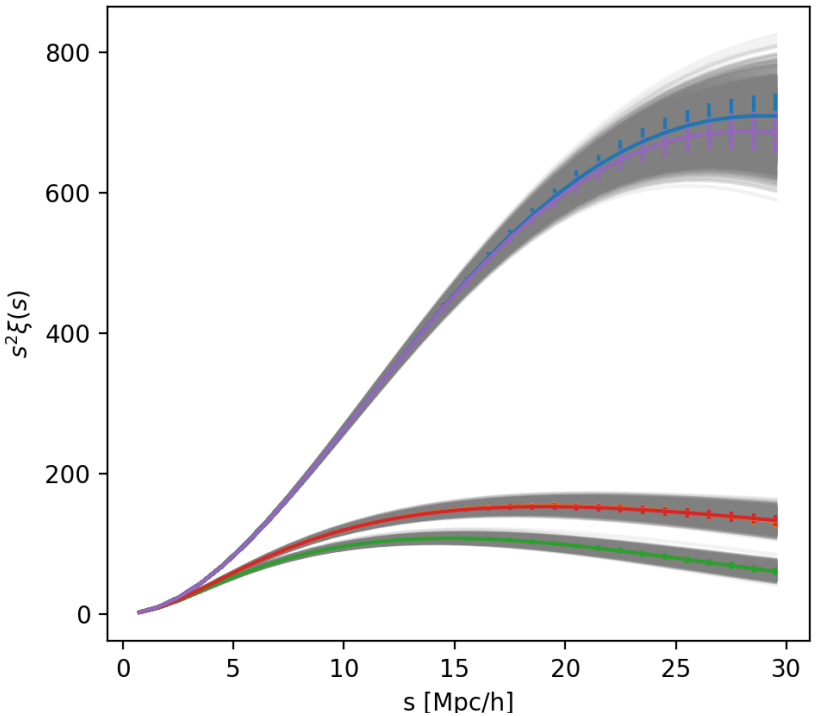
2PCF

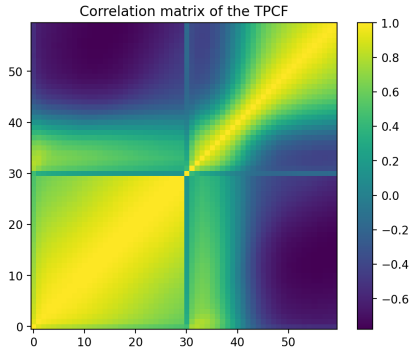


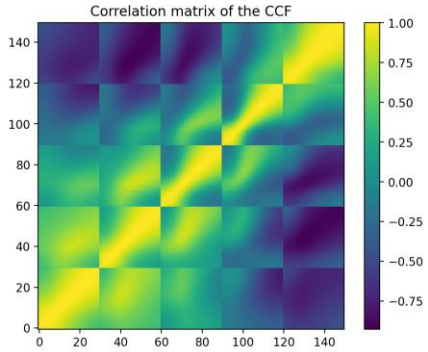
CCF

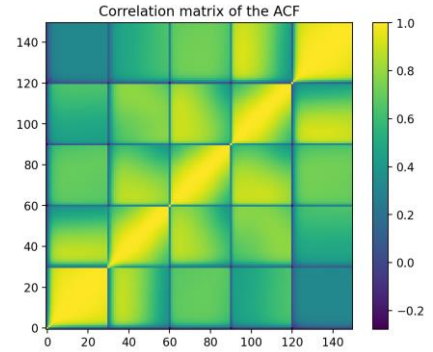


ACF



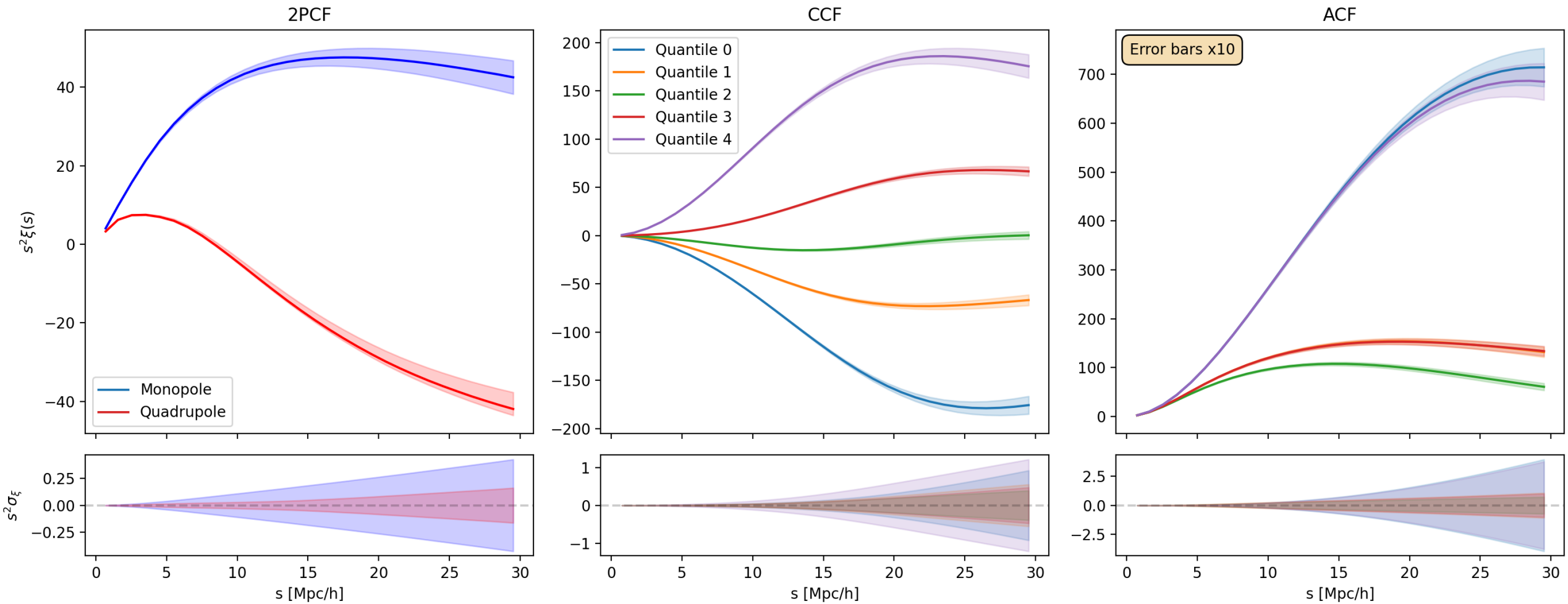




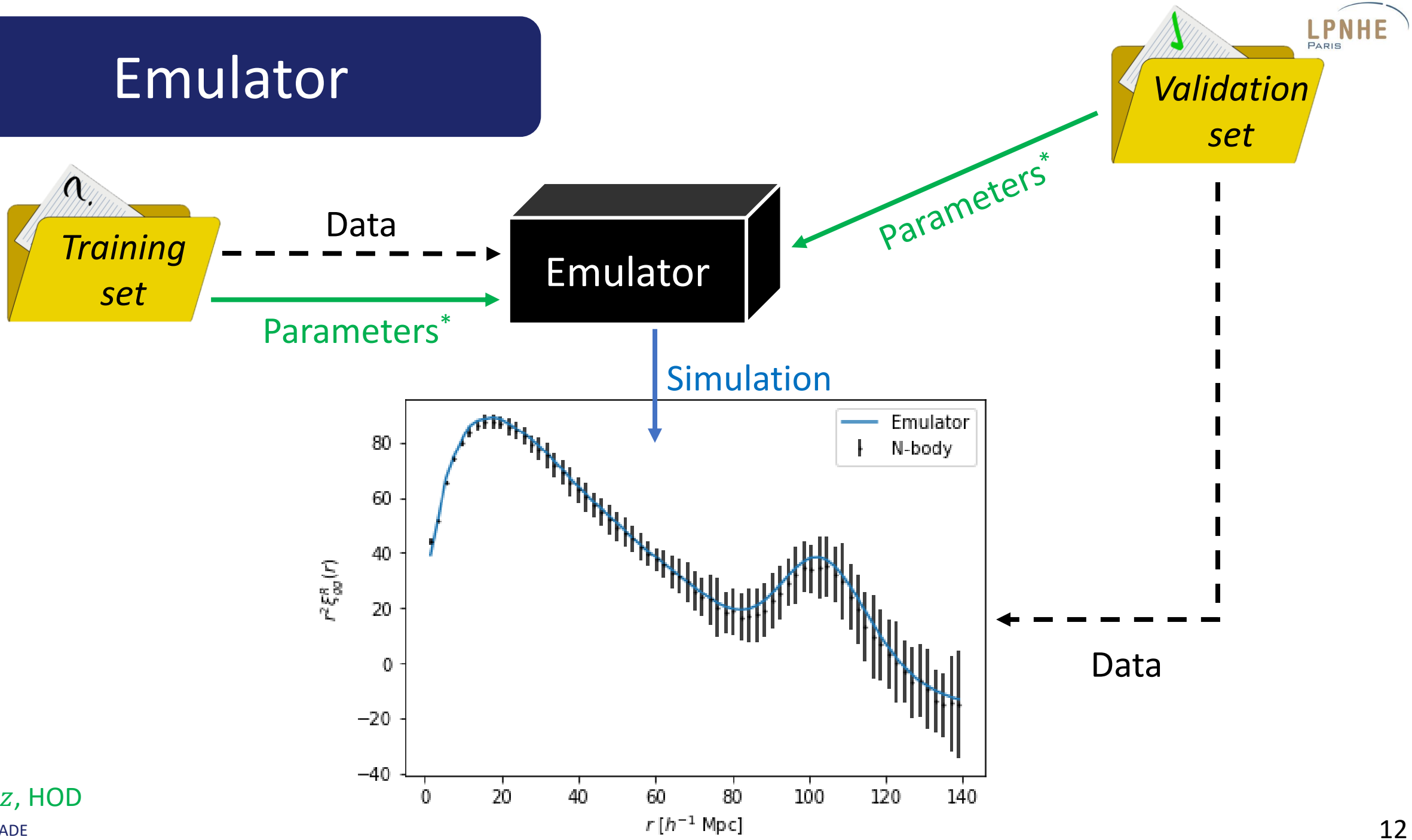


Simulations

Covariance



Emulator

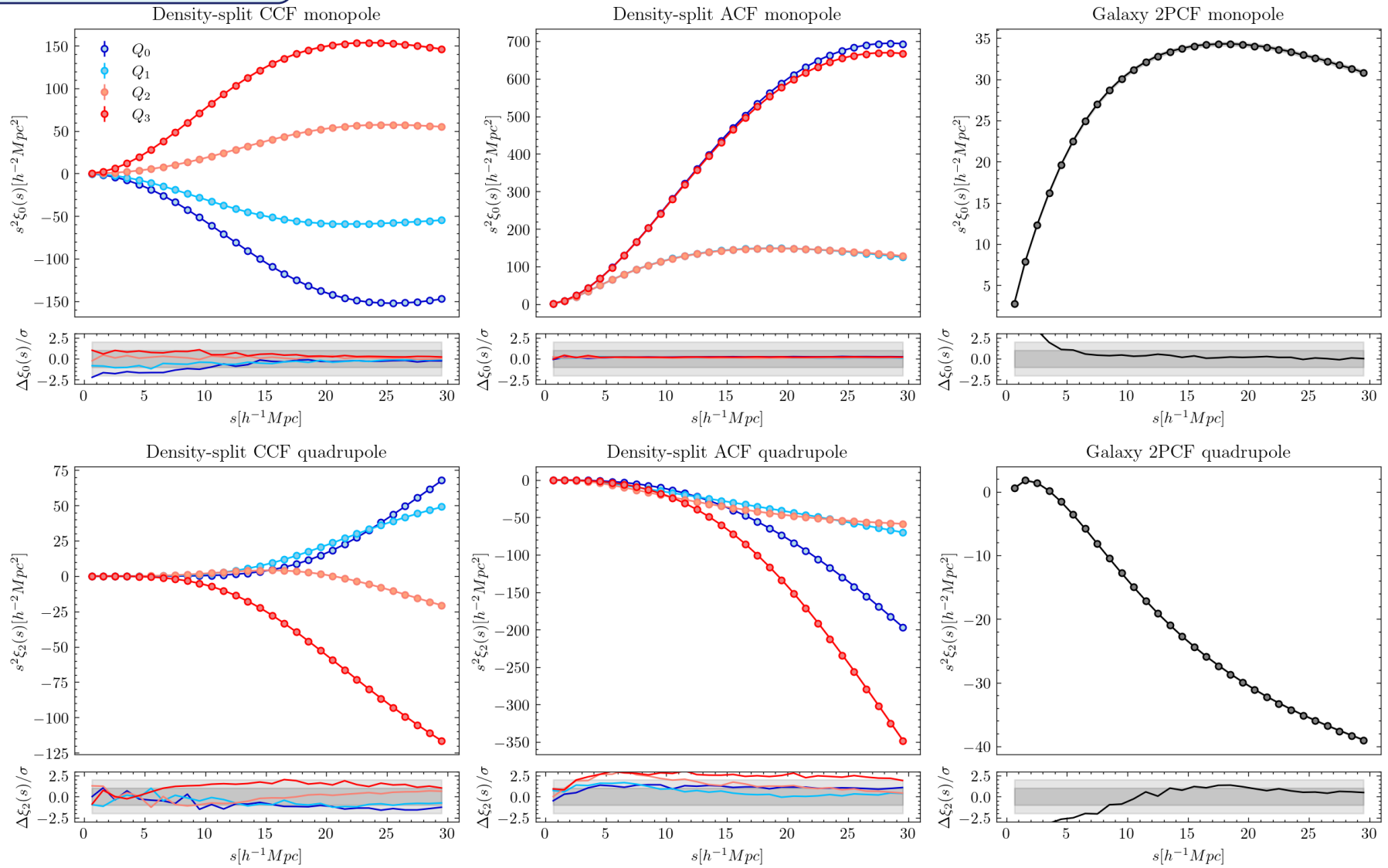


*Cosmo, *z*, HOD

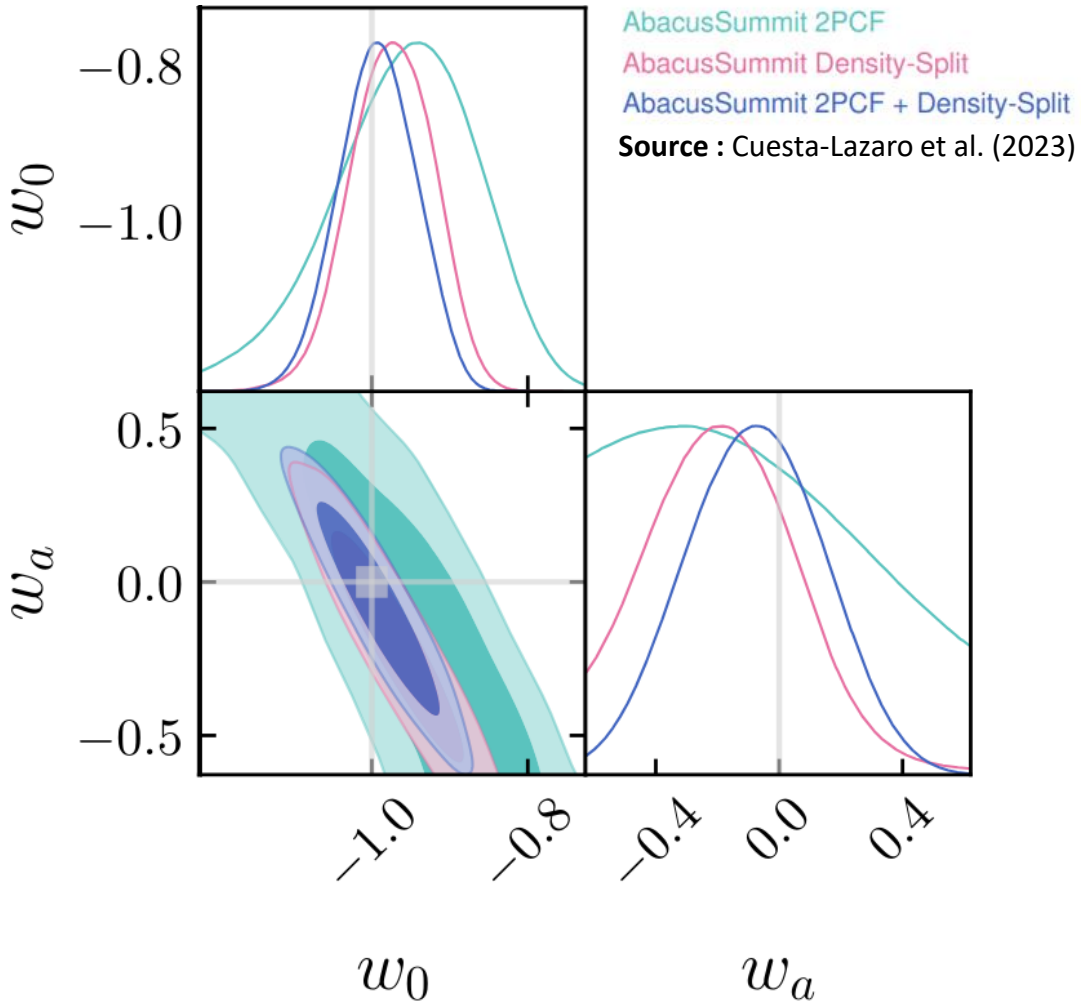
Emulator

Validation

Cosmo: 3, HOD: 9

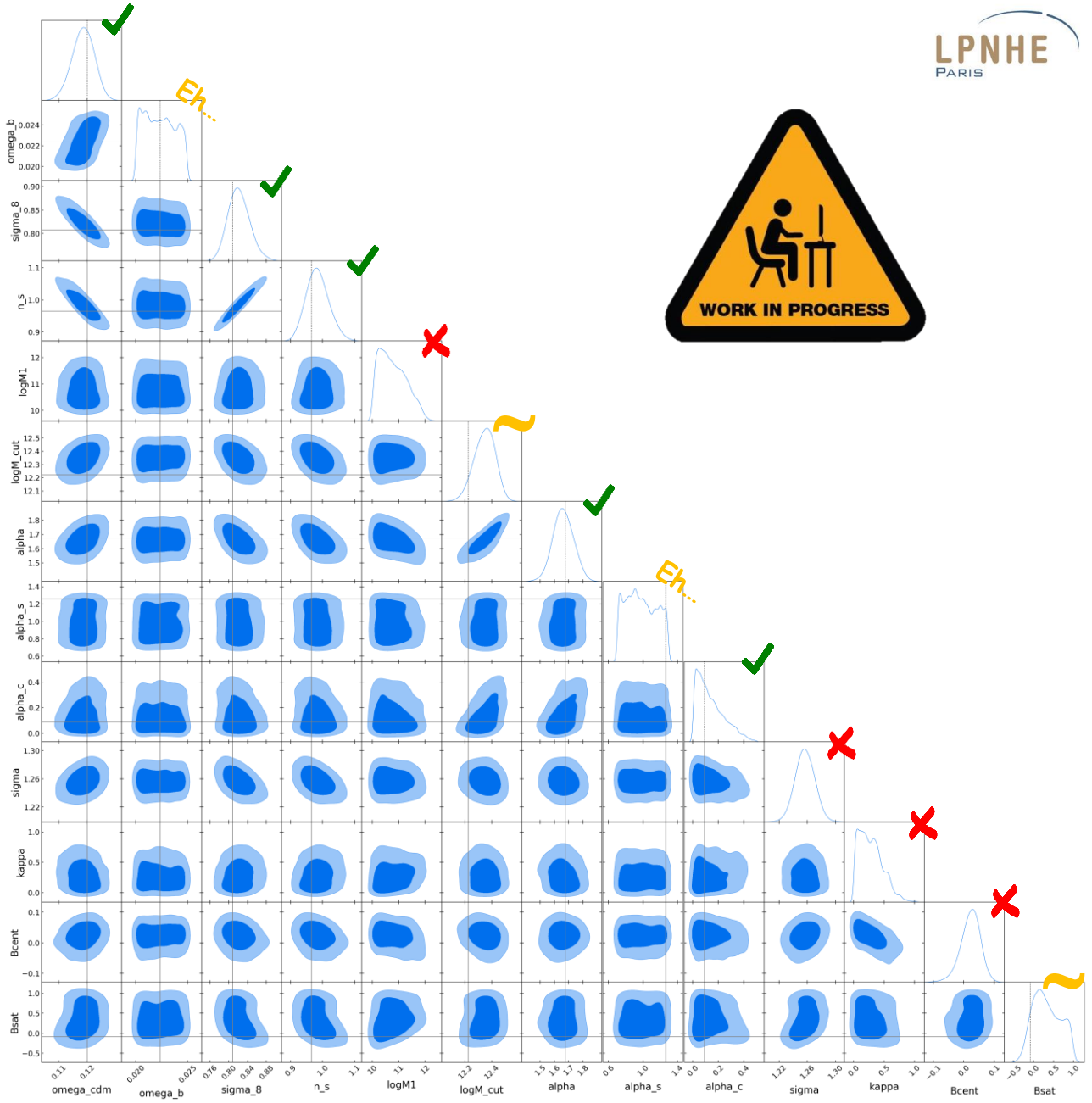


Cosmological inference



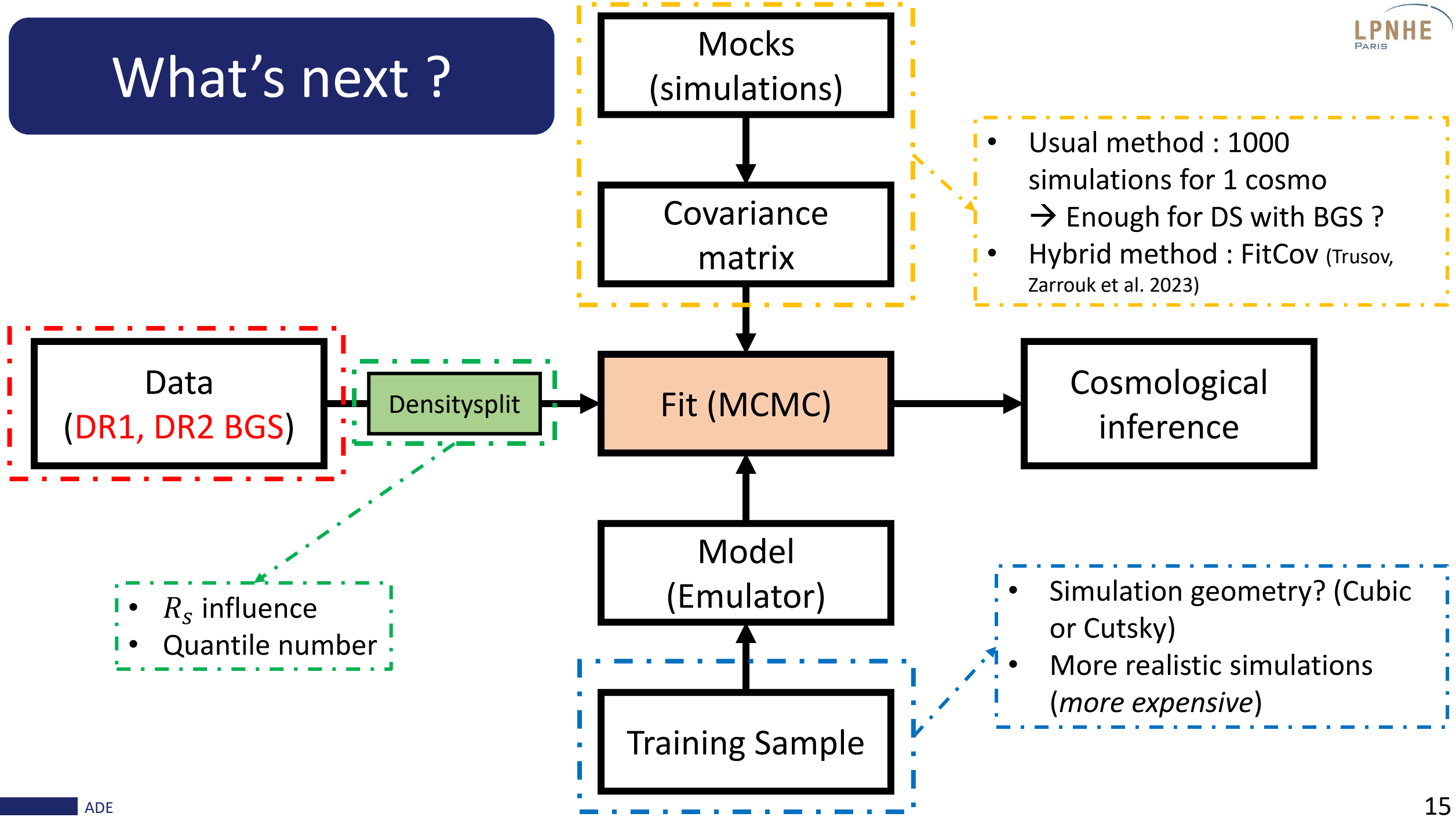
Source : Cuesta-Lazaro et al. (2023)

YES,



BUT

What's next ?


Mocks (simulations)
Covariance matrix
Usual method : 1000 simulations for 1 cosmo → Enough for DS with BGS ?
Hybrid method : FitCov (Trusov, Zarrouk et al. 2023)
Data (DR1, DR2 BGS)
Densitysplit
Fit (MCMC)
Cosmological inference
R_s influence
Quantile number
Model (Emulator)
Training Sample
Simulation geometry? (Cubic or Cutsky)
More realistic simulations (*more expensive*)

Thank you for your attention !

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Annexes

Theory

Modèle HOD

Halo Occupation Distribution

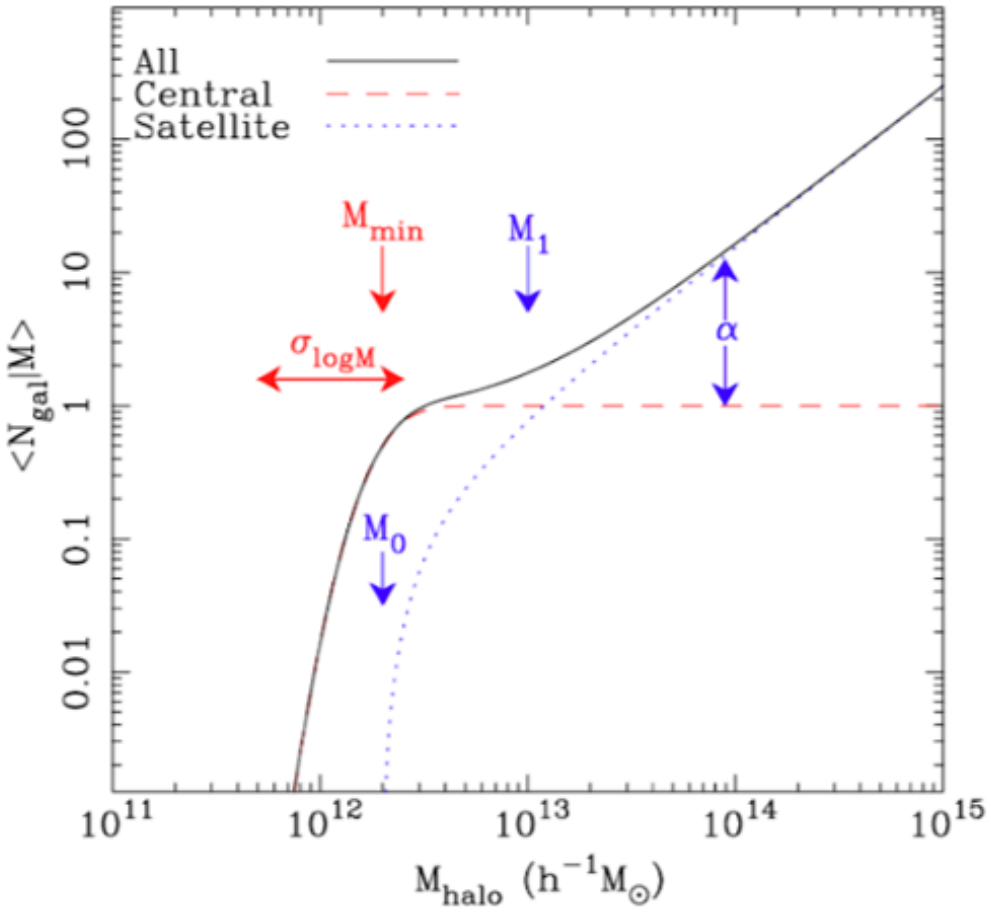
$$\langle N_c \rangle (M) = \frac{1}{2}\left(1 + \mathrm{erf}\left(\frac{\log M - \log M_{\min}}{\sigma_{\log M}}\right)\right)$$

$$\langle N_s \rangle (M) = \langle N_c \rangle (M).\left(\frac{M - M_0}{M_1}\right)^{\alpha}$$

Remarque

$\{M_{min}, \sigma_{\log M}, M_0, M_1, \alpha\}$
sont des paramètres à ajuster !

Source : Wake et al. (2011)



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Covariance matrix

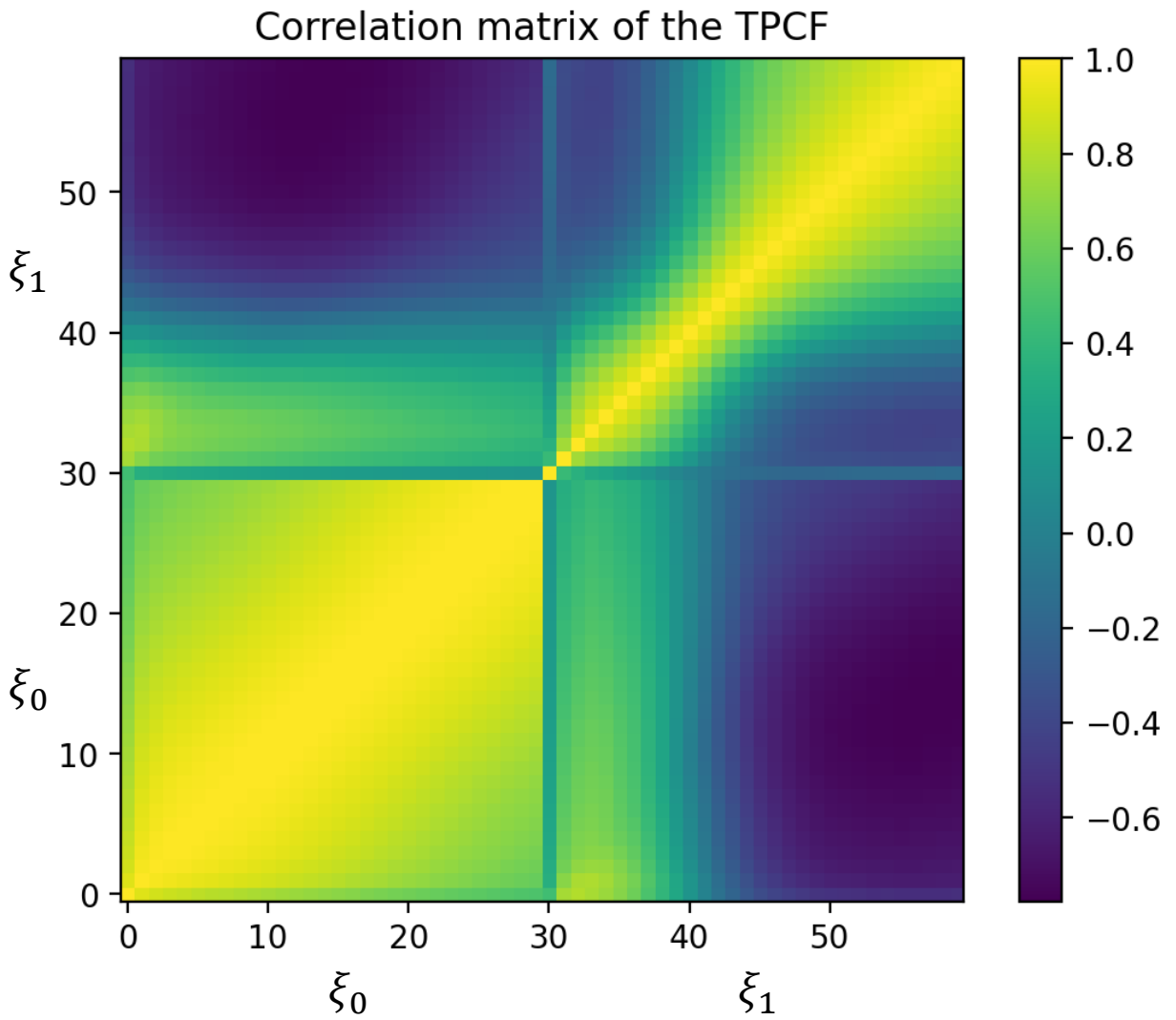
Covariance matrix

$$Cov_{ij} = < x_i x_j > - < x_i >< x_j >$$

Correlation matrix

$$Corr_{jj} = \frac{Cov_{ij}}{\sigma_i \sigma_j}$$

$$\sigma_i = \sqrt{< x_i^2 > - < x_i >^2}$$



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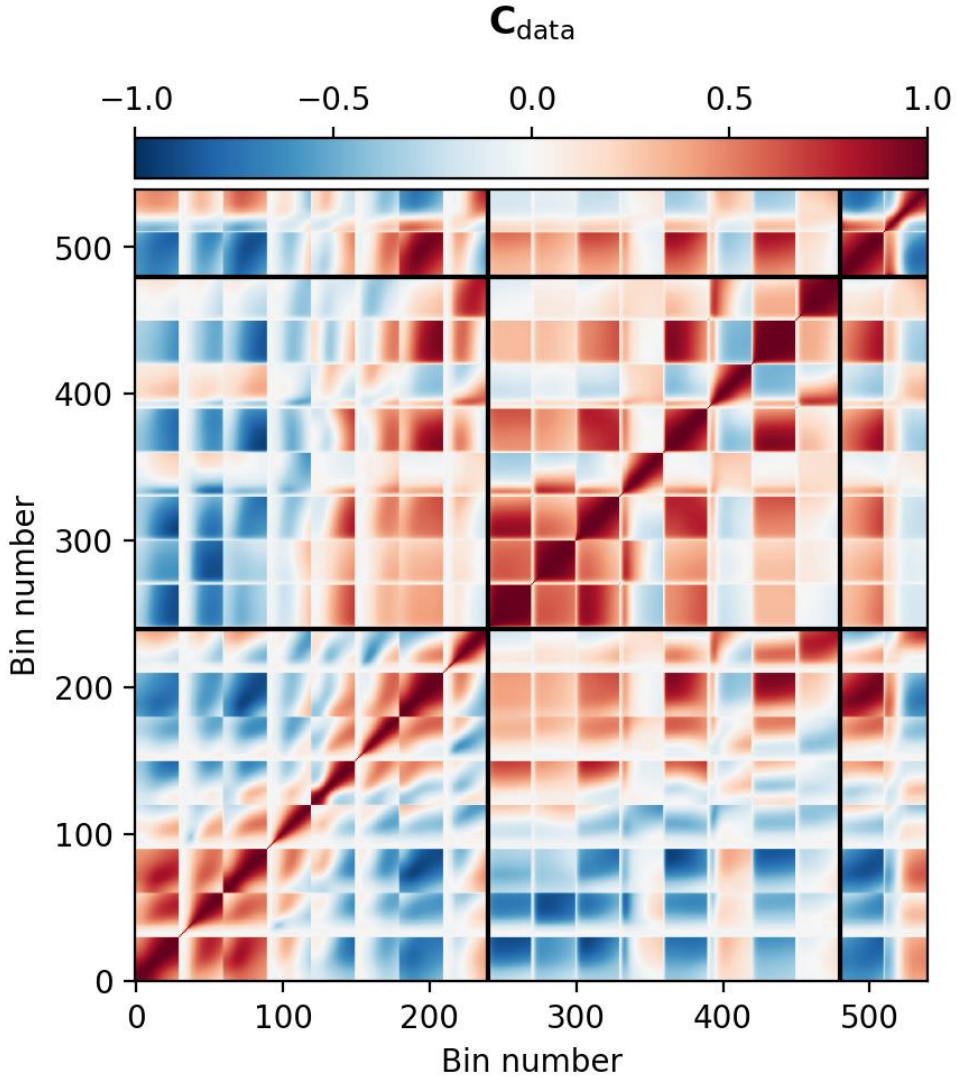
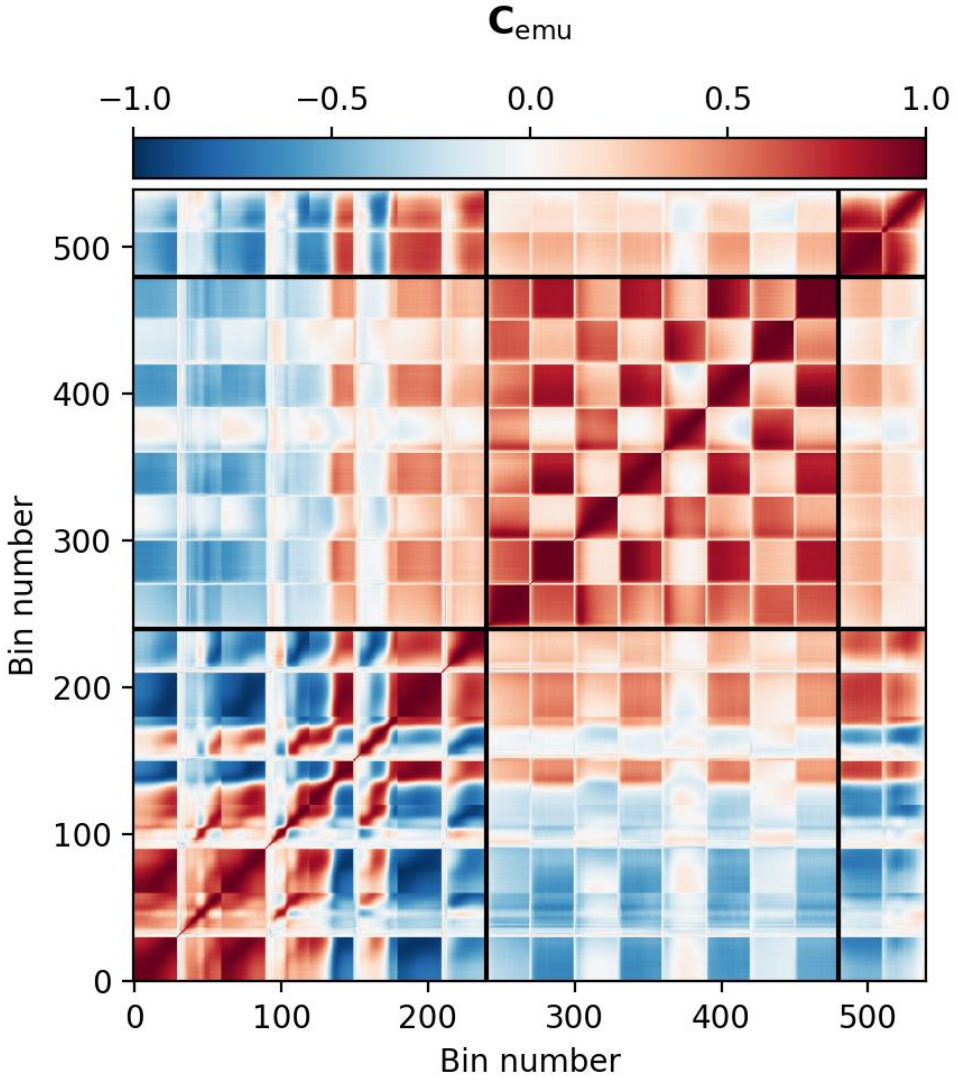
Emulator

Covariance





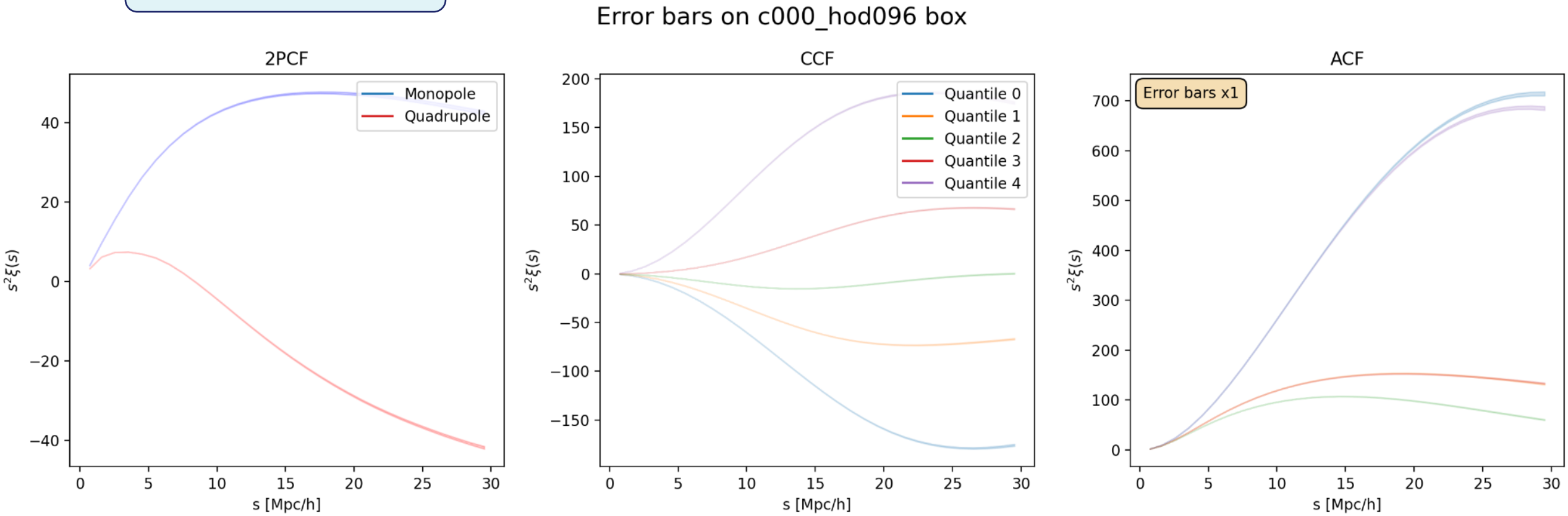
Simulations

BGS challenges

Nb of cosmo	85			
Nb of HOD (per cosmo)	100			
Nb of los	3			
	Time (s) for 1	Total (s)	Total (min)	Total (h)
Time for loading cosmo	340	28900	481,666667	8,02777778
Time for populating HOD	31	263500	4391,66667	73,1944444
Computing density	27	229500	3825	63,75
Computing quantiles	130	39000	650	10,8333333
Time for 2PCF (s<150)	1485	37867500	631125	10518,75
Total estimated time (h)	115862,0556			
2PCF for s<50	80	2040000	34000	566,666667
Total estimated time (h)	6389,138889			
2PCF for s<30	25	637500	10625	177,083333
Total estimated time (h)	2103,722222			

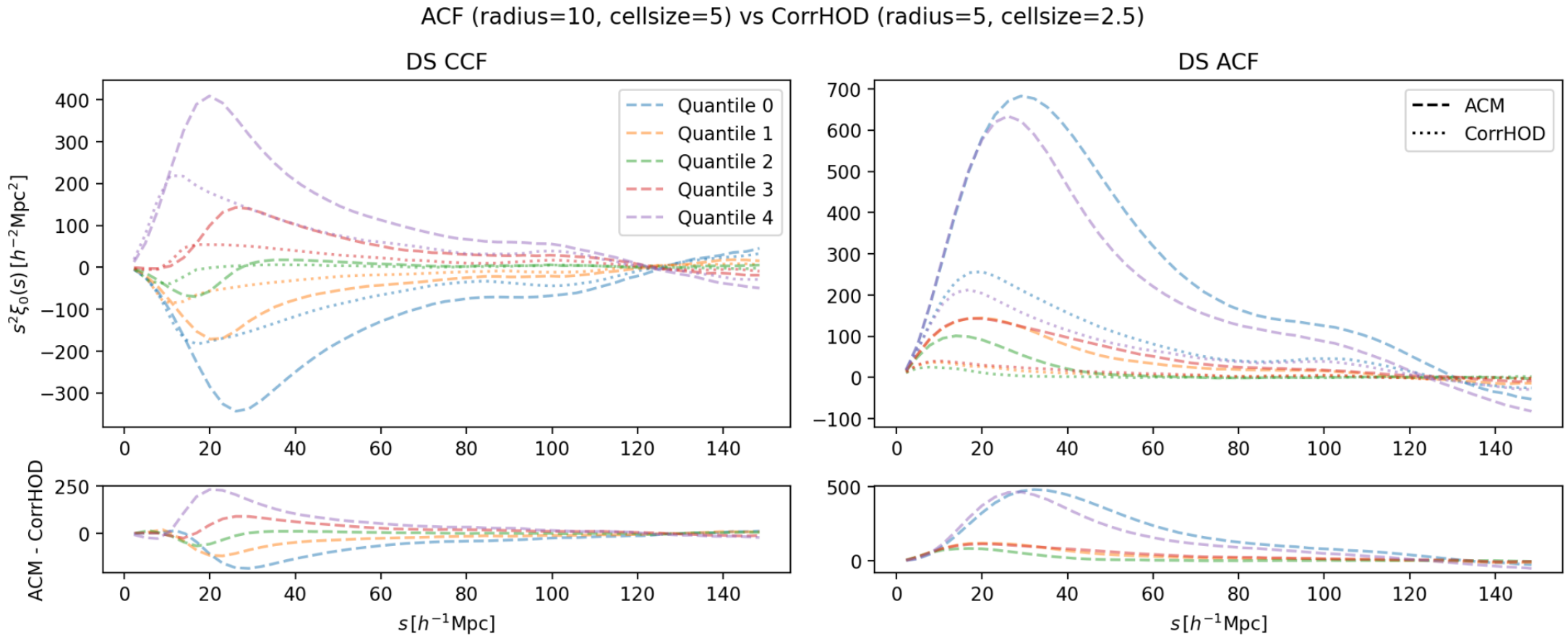
Simulations

Covariance



Other parameters

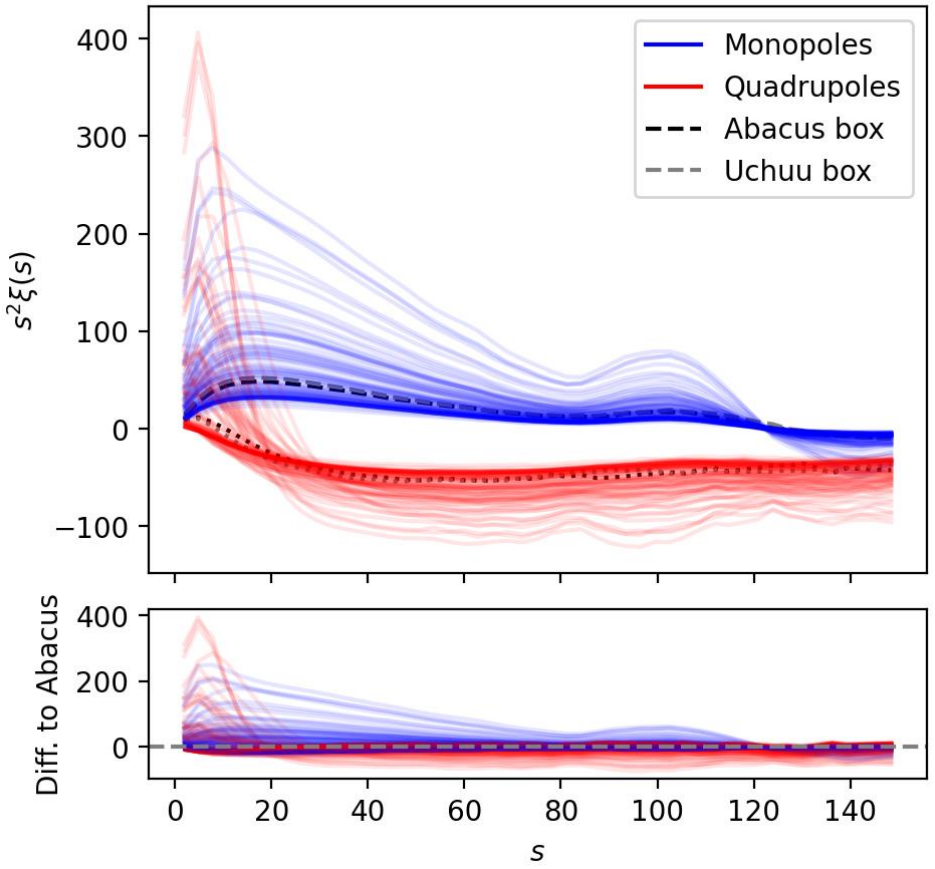
R_s impact



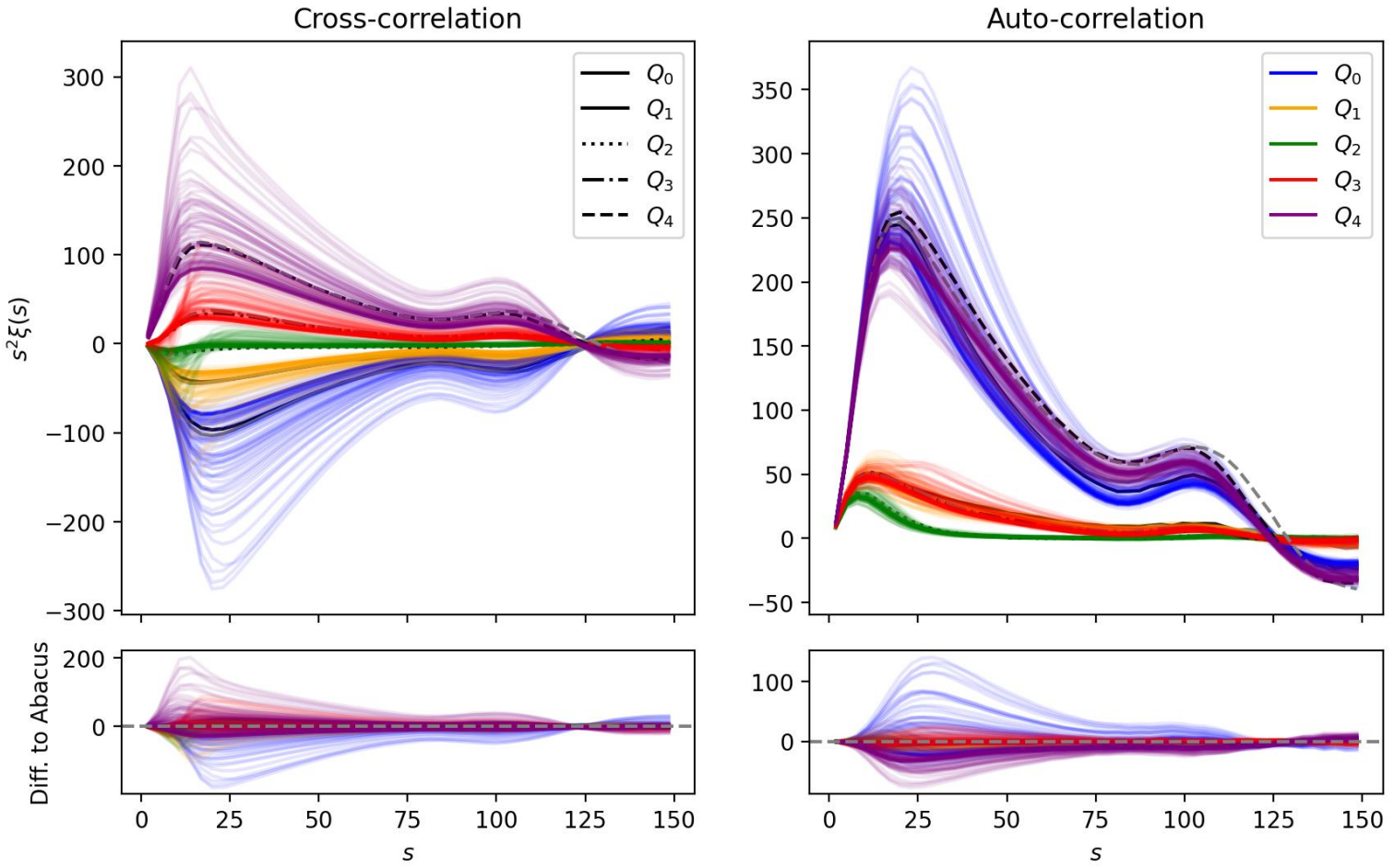
Simulations

Statistics

2PCF of 93 HOD catalogs



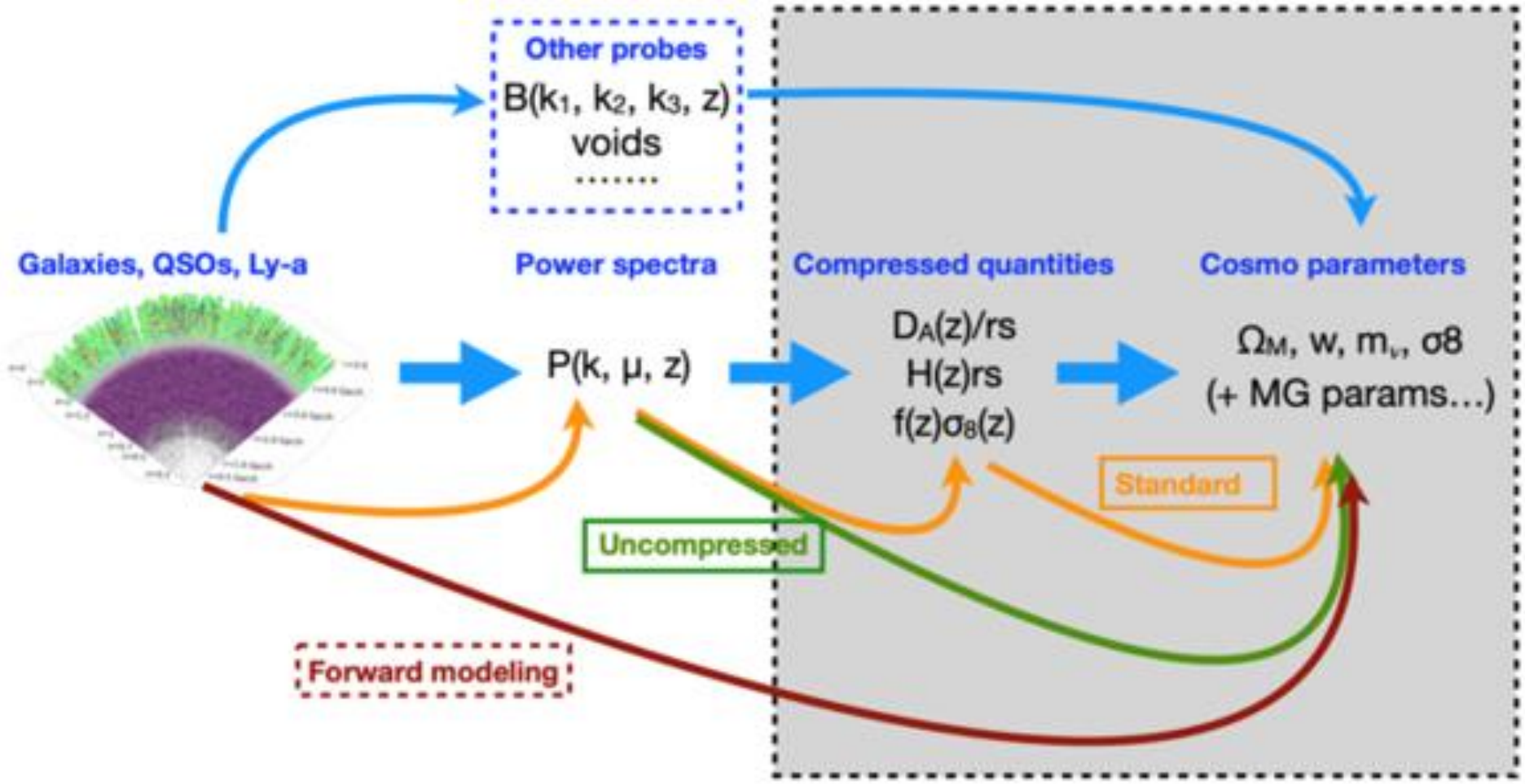
DS monopole of 93 HOD catalogs (Uchuu in gray, Abacus in black)



→ Génération des simulations BGS, calcul des statistiques (2PCF, DS)

Contexte scientifique

Méthodes alternatives



Source : Dragan Huterer & Eva-Maria Mueller (DESI KP7)

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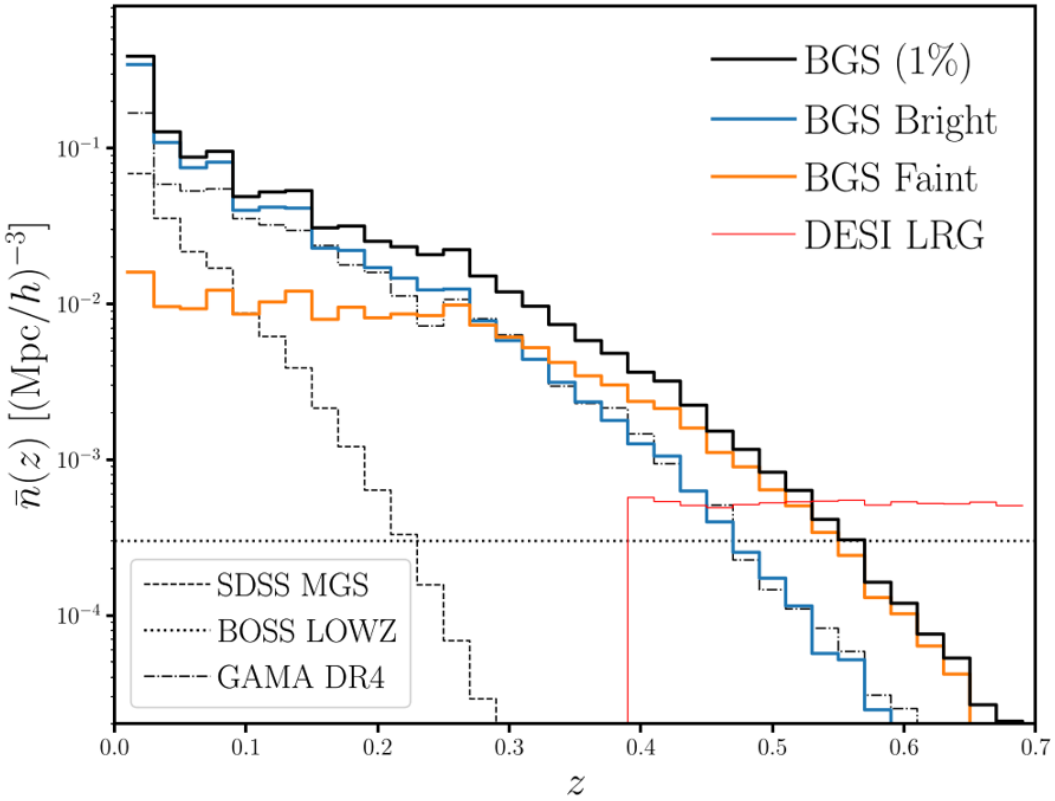
Contexte scientifique

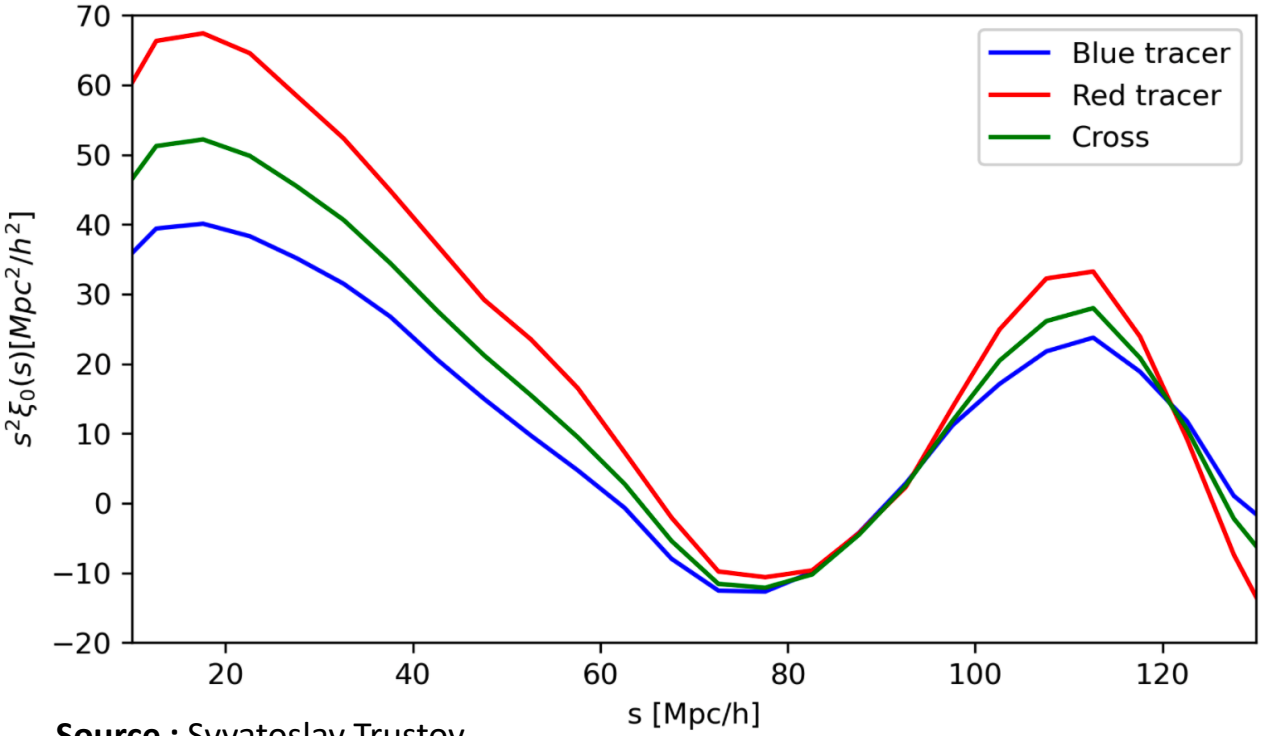
BGS



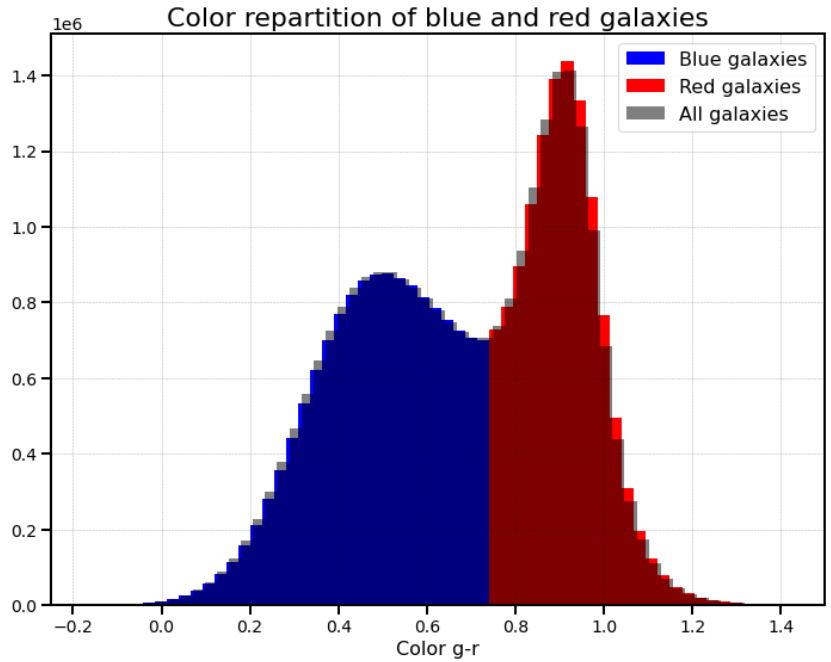
Source : Hahn et al. (2023)

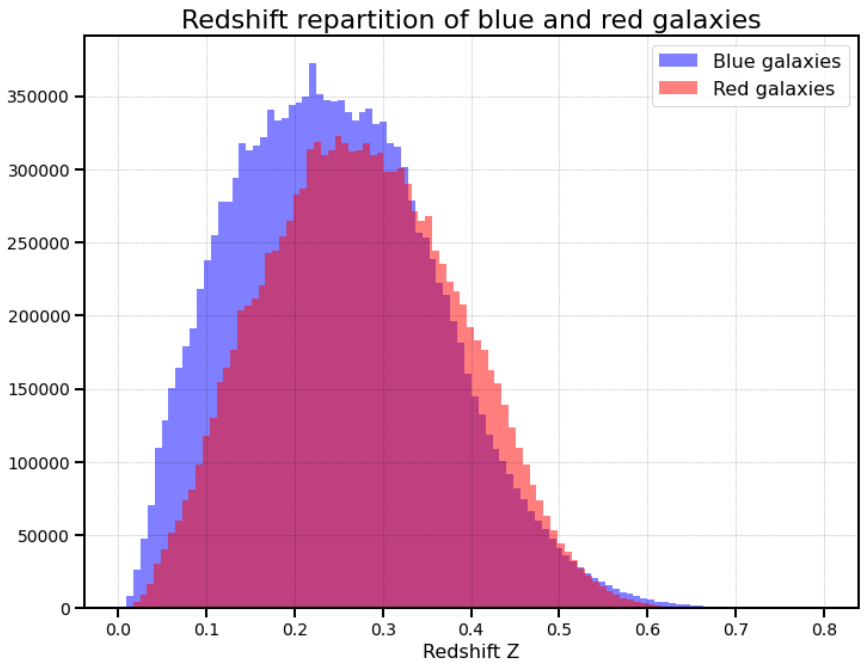
Stage au LPNHE (M1)

Multi-tracer



Source : Svyatoslav Trustov

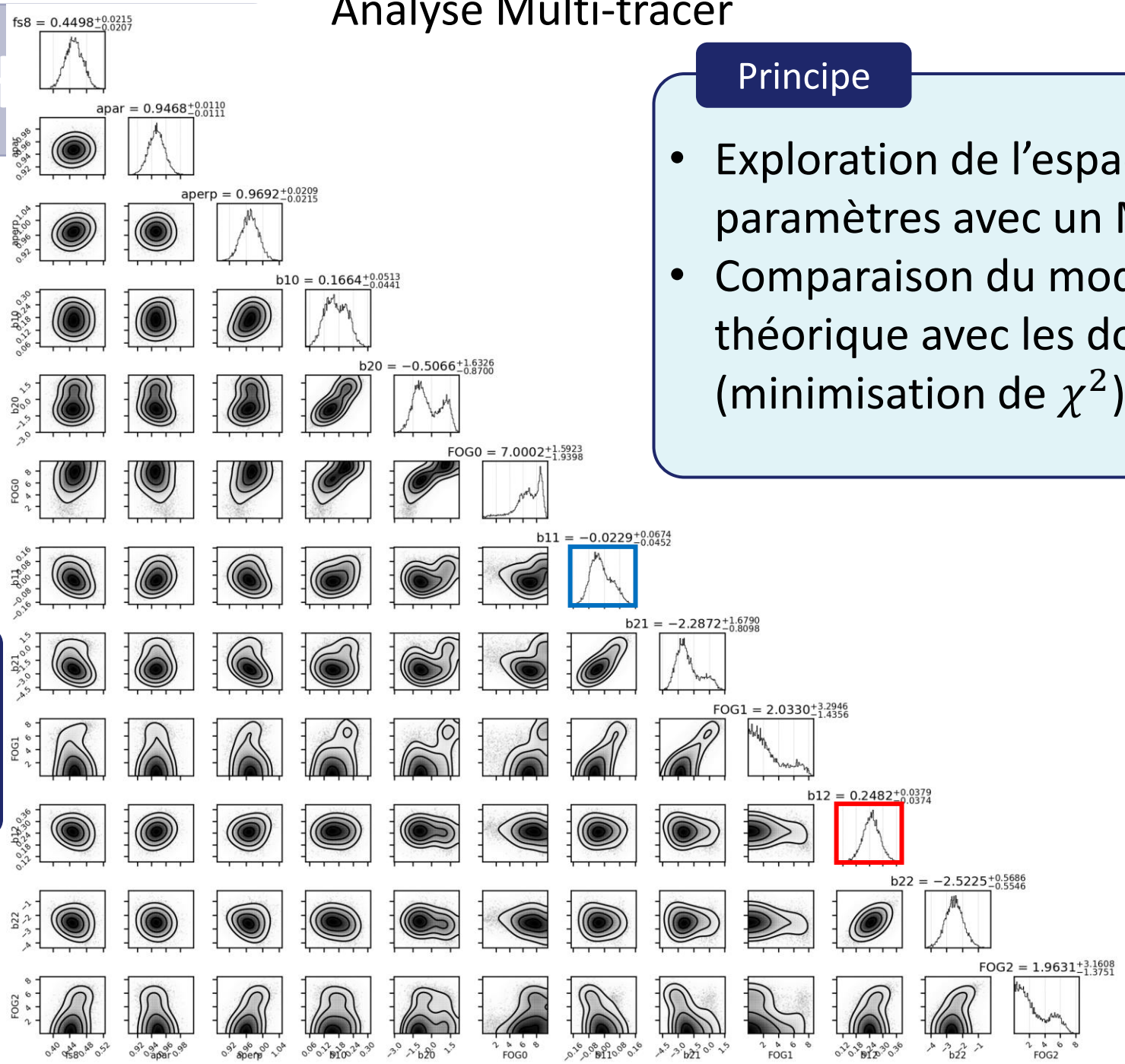




Stage au LPNH

Inférence cosmologique

Analyse Multi-tracer



Principe

- Exploration de l'espace des paramètres avec un MCMC
- Comparaison du modèle théorique avec les données (minimisation de χ^2)

Remarques

- $b_{red} > b_{blue}$
- FOG non contraint

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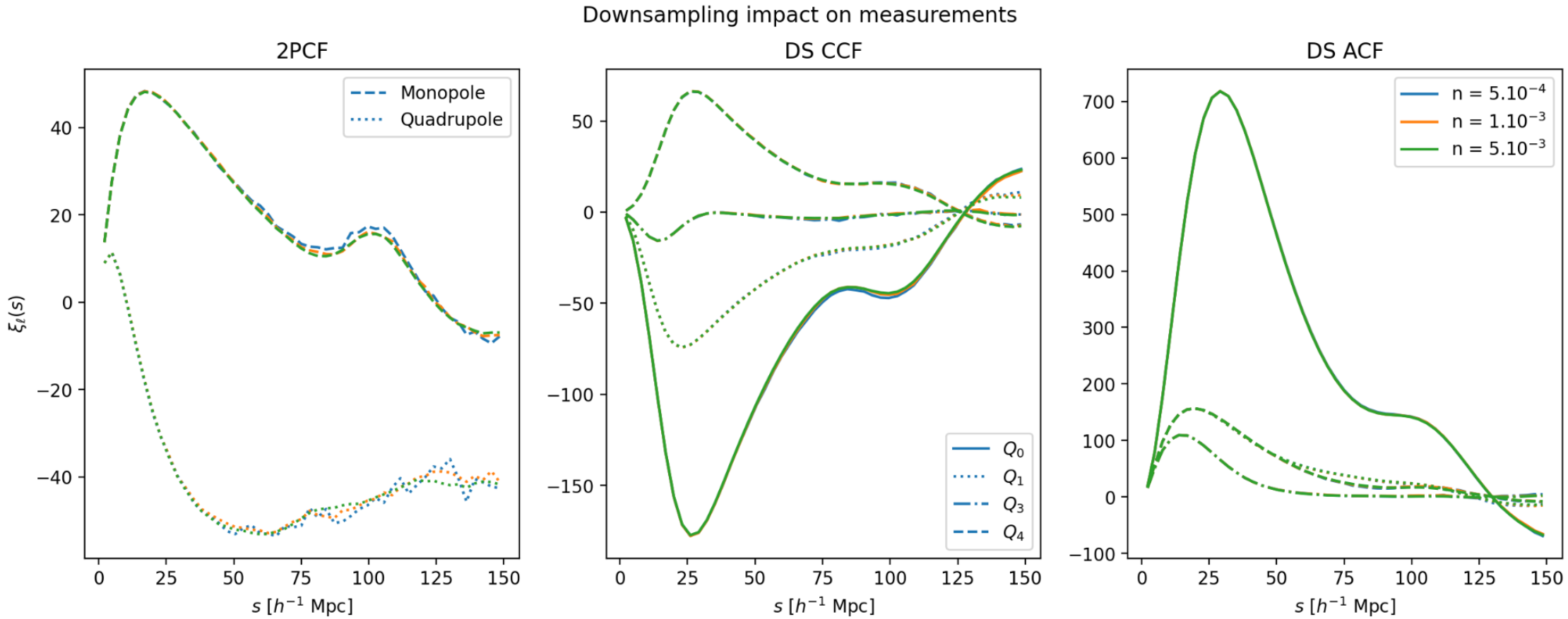
Stage au LPNHE (M2)

Downsampling



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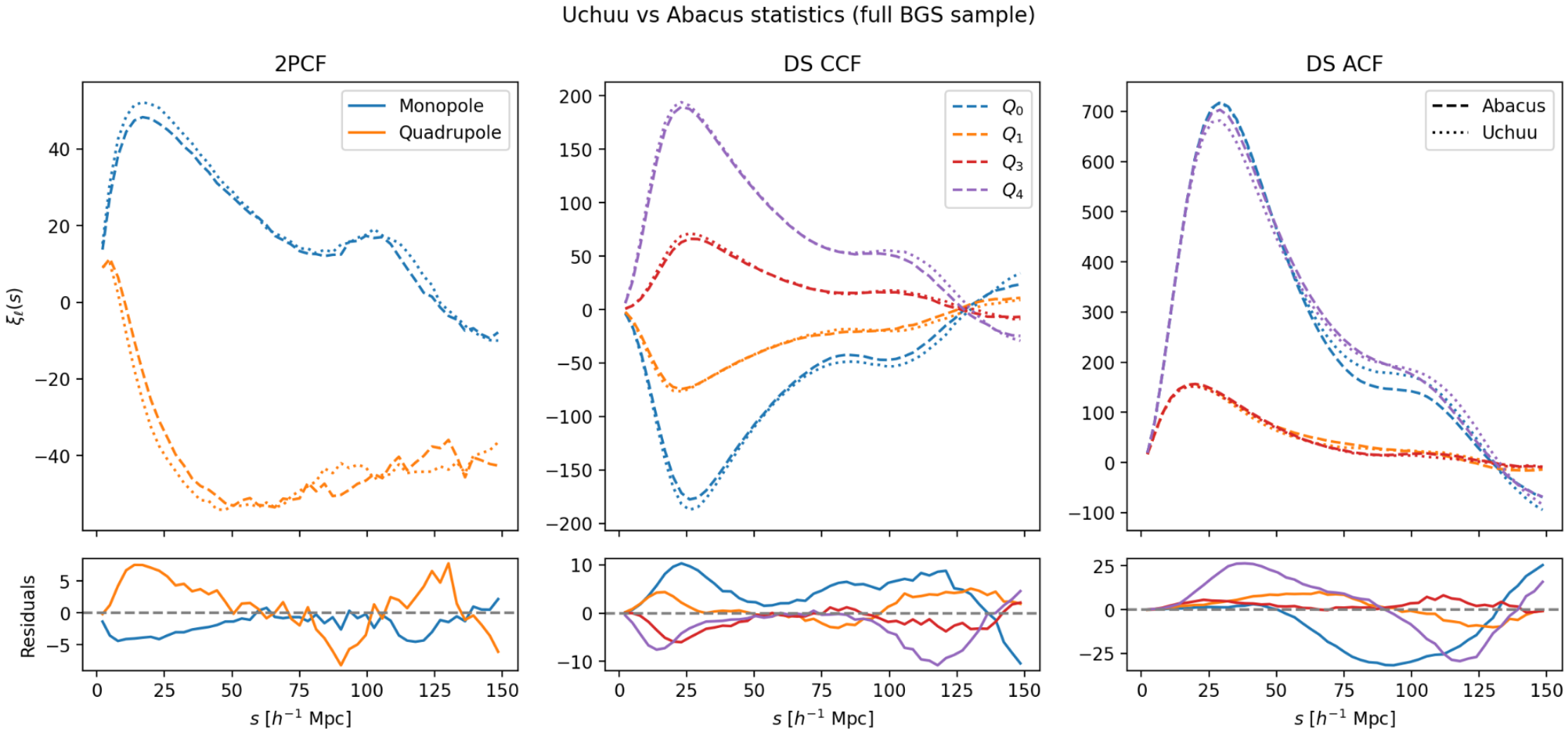
Stage au LPNHE (M2)

Différentes simulations



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