Beyond the Λ-CDM model: modified gravity with Quijote

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Motivation

- Λ-CDM model : Hilbert-Einstein action with cosmological constant :

$$S_\Lambda = \frac{1}{16\pi G}\int \mathrm{d}x^4\sqrt{-g}(R-2\Lambda)$$

- We want to get rid of the Λ

$$S_{MG} = \frac{1}{16\pi G}\int \mathrm{d}x^4\sqrt{-g}f(R)$$

Examples of f : $R-2\Lambda$, $R+\frac{R^2}{6M^2}$ (Starobinski, PBH), etc

Here, we study the Hu and Sawicki model :

$$f(R) = R - m^2\frac{c_1\left(\frac{R}{m^2}\right)^n}{1+c_2\left(\frac{R}{m^2}\right)^n}$$

with $n=1$.

Simulation : Quijote-MG

Parameters of the Λ-CDM : $(\Omega_m, \Omega_b, h, n_s, M_\nu, \sigma_8)$
Parameters of the Quijote-MG simulations : Λ-CDM+f_{R0}

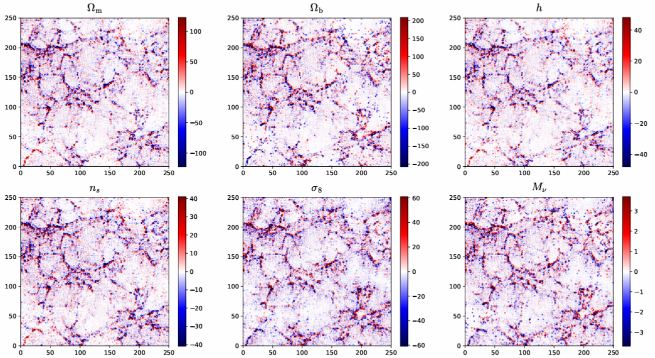
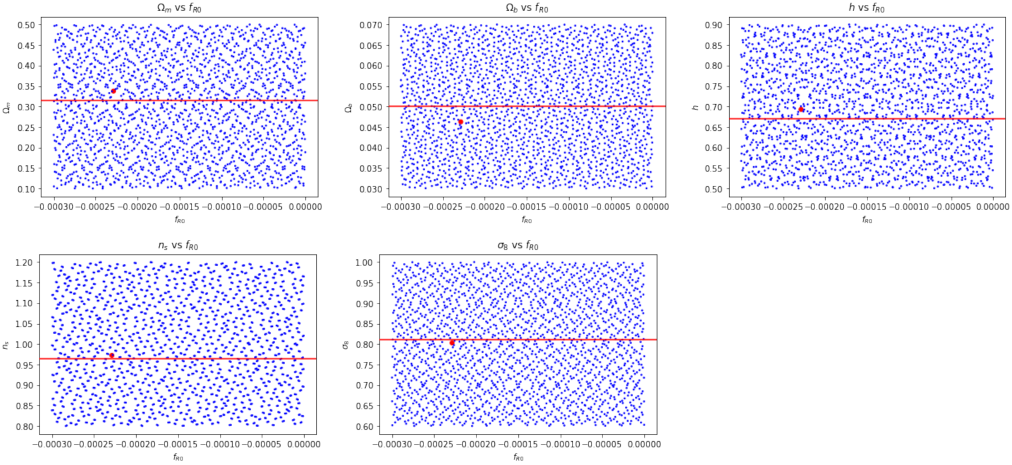


Figure 1. The image on the top shows the large-scale structure in a region of $250 \times 250 \times 15$ $(h^{-1}\mathrm{Mpc})^3$ at $z = 0$ for the fiducial cosmology. We have taken simulations with the same random seed but different values of just one single parameter, and used them to compute the derivative of the density field with respect to the parameters. The panels on the middle and bottom row show those derivatives with respect to Ω_m (middle-left), Ω_b (middle-center), h (middle-right), n_s (bottom-left), σ_8 (bottom-middle), and M_ν (bottom-right). It can be seen how different parameters affect the large-scale structure in different manners. For instance, the filament on the bottom-left part of the plot responses differently to each parameter. Neural networks can use these features to extract information from non standard summary statistics.

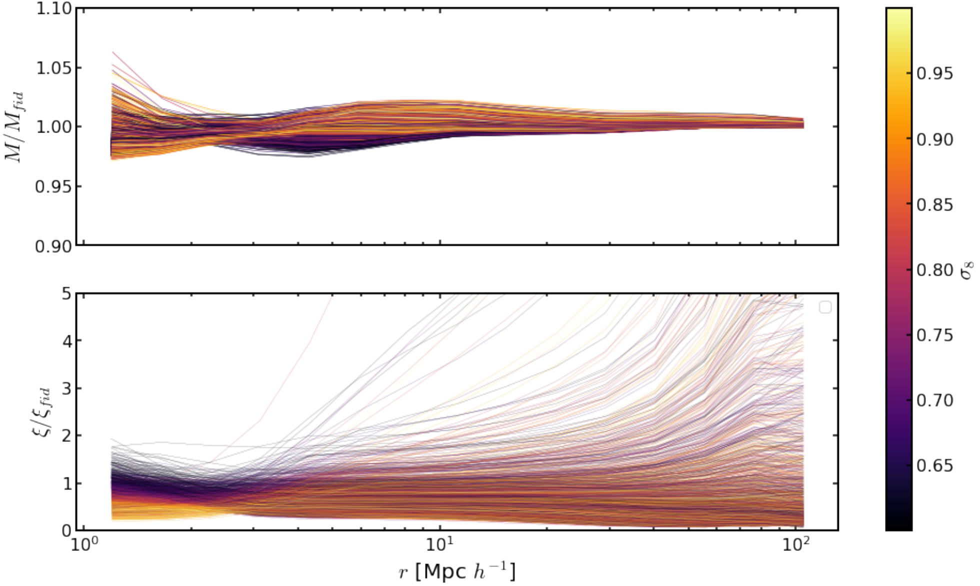
The closest simulation to the fiducial : scattering



Correlation function

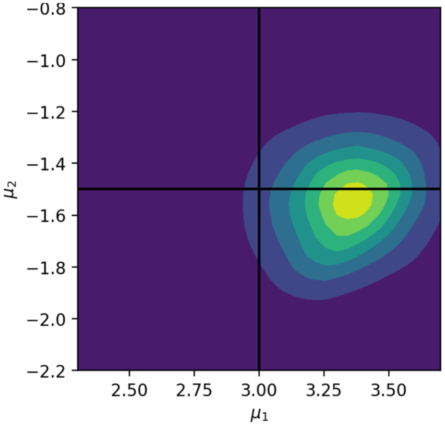
Goal : recover the fiducial parameter with statistical inference

- δ-function : $\delta = \frac{\rho - \overline{\rho}}{\overline{rho}}$
- 2-points correlation function : $\xi(|x-y|) = \langle \delta(x)\delta(y) \rangle$
- Marked correlation function : $\mathcal{M}(r) = \frac{1}{n(r)\overline{m}^2} \sum m_i m_j$, where $m_i = \rho_i^p$
- $M = \frac{1+\mathcal{M}}{1+\xi}$


1.10
1.05
1.00
0.95
0.90
M/M_{fid}
5
4
3
2
1
0
ξ/ξ_{fid}
10^0
10^1
10^2
r [Mpc h^{-1}]
0.95
0.90
0.85
0.80
0.75
0.70
0.65
σ_8

Next step : compute the SBI contour plots

Goal : 6×6 contour plots, hoping find contours centered around the fiducial parameters.



Thank you for your attention !

References :

- THE QUIJOTE SIMULATIONS, https ://doi.org/10.48550/arXiv.1909.05273
- https ://astroautomata.com/blog/simulation-based-inference/