Modelling the galaxy-halo connection from the dark matter density alone

True galaxy density map:

Forward modelled galaxy density map:

**Try to spot the difference!**

-1 ——— Galaxy count contrast ——— 6

ICC — Institute for Computational Cosmology

CEA — Durham Centre for Extragalactic Astronomy

Durham University

Non-local stochastic galaxy bias

Mapping the galaxy density field to the dark matter density map by constructing a semi-analytic model of galaxy bias, *b(x)*:

$$\delta^{\mathrm{g}}(x) = b(x)\,\delta^{\mathrm{DM}}(x)$$

1. Work in **spherical projection** space:

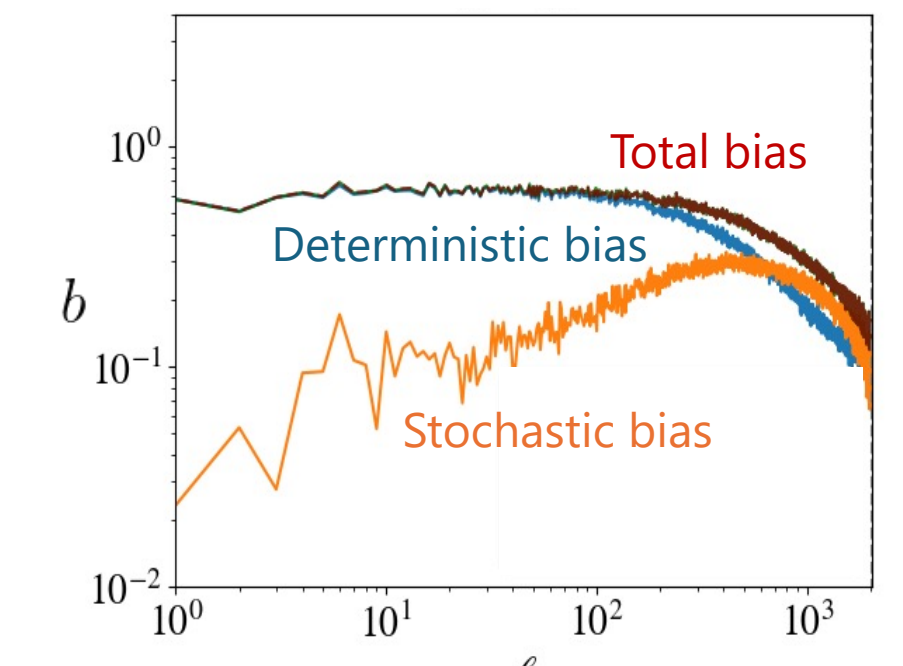$$\delta(\theta) = \sum_{\ell m} \delta_{\ell m}\,{}_0 Y_{\ell m}(\theta) = \int \mathrm{d}z\, W(z)\,\delta(\theta, z)$$
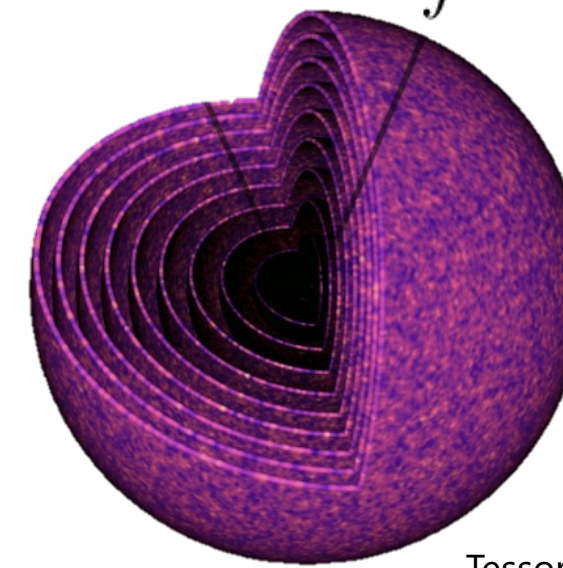
Tessore, et al. (2023)

2. Decompose into **deterministic** & **stochastic** contributions.

3. Calibrate parameters on **only 2pt statistics** from hydro simulations (FLAMINGO; Schaye et al. 2023).

4. Produce a **galaxy bias field** per projected shell.
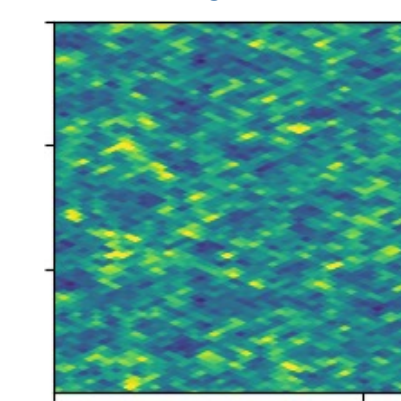

Total bias
Deterministic bias
Stochastic bias

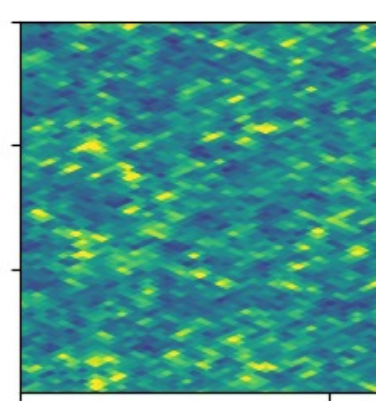Galaxy bias as a function of angular scale measured in FLAMINGO between z = 0.5 & z = 0.55.

The model is calibrated on two-point statistics alone but still **captures more of the higher-order moments** of the galaxy density field.

- The model naturally incorporates **homogeneity**, **isotropy**, **non-locality** and **stochasticity** of the galaxy field with a **minimal amount of degree-of-freedom**.

- The **parameterisation can be conditional** on cosmology, AGN feedback parameters or local quantities (stellar mass, SFR, etc.).

- Enables **fast forward modelling** of galaxies from dark matter-only simulations (e.g. N-body or lognormal random fields).
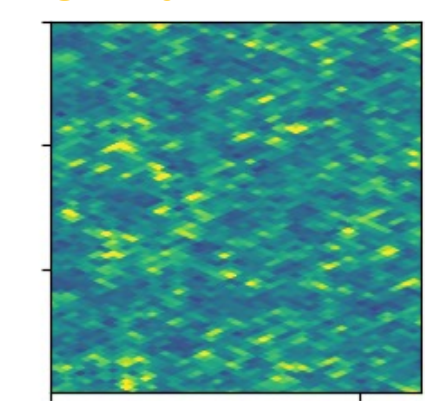

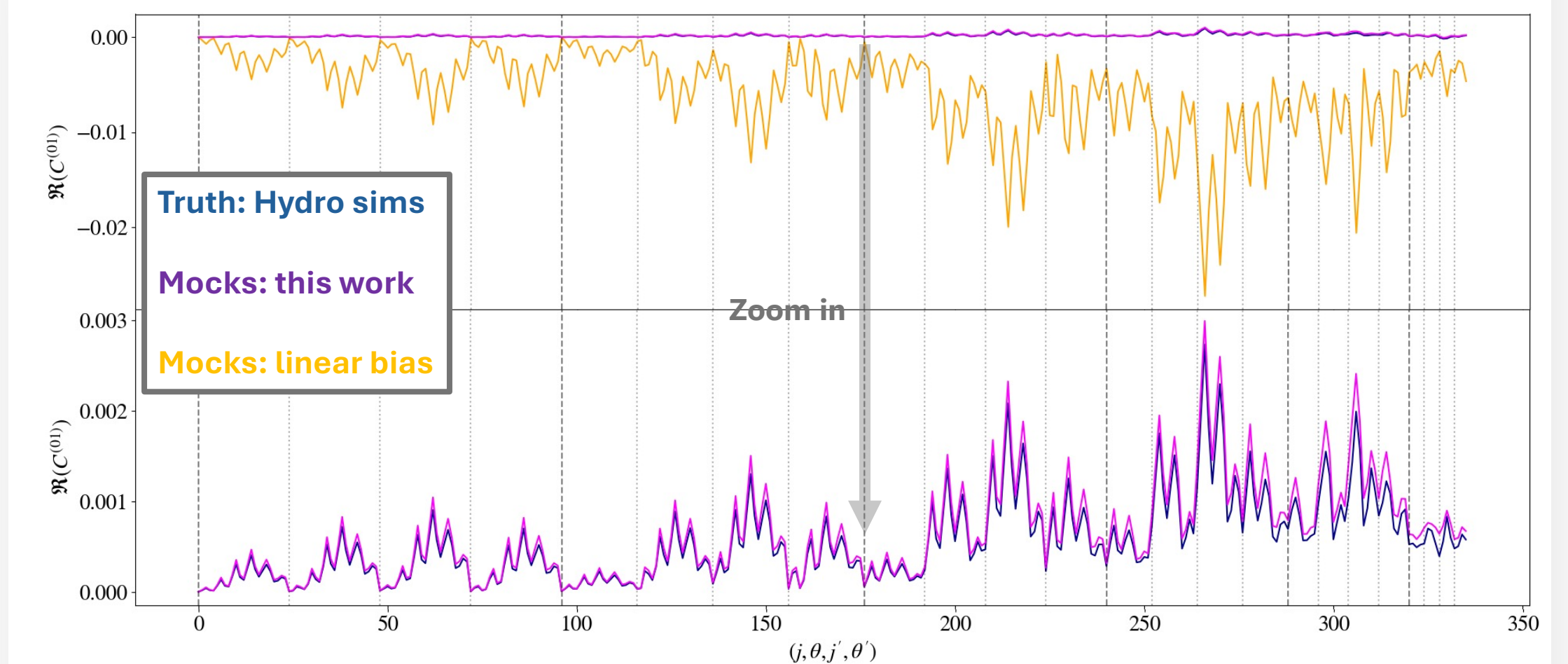
Galaxy density from hydro sims — From this work — Standard linear galaxy bias model

10 deg x 10 deg Cartesian projection

Truth: Hydro sims
Mocks: this work
Mocks: linear bias

Zoom in

Real part of the $C^{(0, 1)}$ term in the wavelet phase harmonic expansion of the fields (Regaldo-Saint Blancard, et al. 2021). It measures the correlation between local levels of oscillation at the scales associated with the bandpasses of two wavelets, $\psi_{j,\theta}$ & $\psi_{j',\theta'}$. Each wavelet is associated with a dilation, j, and a rotation angle, θ.

MAXIMILIAN VON WIETERSHEIM-KRAMSTA,
mwiet.github.io - maximilian.von-wietersheim-kramsta@durham.ac.uk
In collaboration with Nicolas Tessore, Qianjun Hang, Niall Jeffrey, Benjamin Joachimi