FLAMINGO: Using Gaussian process machine learning to calibrate sub-grid models for cosmological simulations
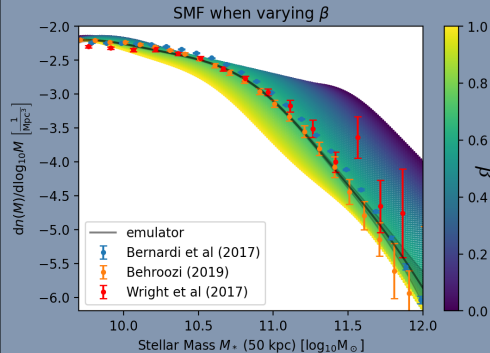

SMF when varying β

Figure 1. Emulated effect of sub-grid parameter beta on the SMF. Beta is denoted as the slope of the boost factor, and boosts Bondi-Hoyle accreation by a further n^β. Some data and the best fit is added for comparison

Why calibration is important

Next generation observations will be more accurate than the current discrepancy between different simulations.

Certain sub-grid parameters have a large impact on the results of the simulation (See Figure 1).

To constrain baryonic effects we calibrate:
1. Gas fractions in groups/clusters
2. The Stellar mass function (SMF)

This gives us a good basis to constrain baryonic effects on on the matter power spectrum, cluster counts, galaxy-galaxy clustering, etc. [McCarthy et al. (2017,2018), Van Daalen et al. (2020)]

Roi Kugel
kugel@strw.leidenuniv.nl

Universiteit Leiden

Full-hydro Large-scale structure runs with All-sky Mapping for the Interpretation of Next Generation Observations (FLAMINGO)

- $(3.2 \text{Gpc})^3$ Volume
- $m_{gas} \approx 10^9 M_\odot$
- Variations in smaller volumes
- Calibration using machine learning
- Will be run soon

Collaborateurs: Joey Braspenning, Marcel van Daalen, Willem Elbers, Carlos Frenk, John Helly, Adrian Jenkins, Juliana Kwan, Ian McCarthy, Jaime Salcido, Matthieu Schaller, Joop Schaye, Sam Stafford

5 Parameters -> Latin Hypercube -> 100 $(140 \text{Mpc})^3$ Simulations -> Gaussian process -> MCMC fit to observations

Conclusions/Future

The method accurately predicts the behaviour of the simulations, given a set of parameters.

Can be expanded to include cosmology

Combination of sub-grid and cosmological parameters can help constraining baryonic effects

References

Behroozi, P., Wechsler, R. H., Hearin, A. P., and Conroy, C. (2019). UNIVERSEMACHINE: The correlation between galaxy growth and dark matter halo assembly from z = 0-10. , 488(3):3143–3194.

Bernardi, M. et al. (2017). The high mass end of the stellar mass function: Dependence on stellar population models and agreement between fits to the light profile. , 467(2):2217–2233.

McCarthy et al. (2018). The BAHAMAS project: the CMB-large-scale structure tension and the roles of massive neutrinos and galaxy formation. , 476(3):2999–3030.

McCarthy et al. (2017). The BAHAMAS project: calibrated hydrodynamical simulations for large-scale structure cosmology. , 465(3):2936–2965.

van Daalen, M. P., McCarthy, I. G., and Schaye, J. (2020). Exploring the effects of galaxy formation on matter clustering through a library of simulation power spectra. , 491(2):2424–2446

Wright et al. (2017). Galaxy And Mass Assembly (GAMA): the galaxy stellar mass function to z = 0.1 from the r-selected equatorial regions. , 470(1):283–302.

Fits to observations

Fit 5 Simulation parameters + 2 bias parameters

Stellar bias -> apertures, SPS, dust models -> offset to stellar mass

Hydrostatic bias -> M500 from that assumption -> offset for halo mass

Running a simulation with the best-fit parameters results in excellent agreement with observations.
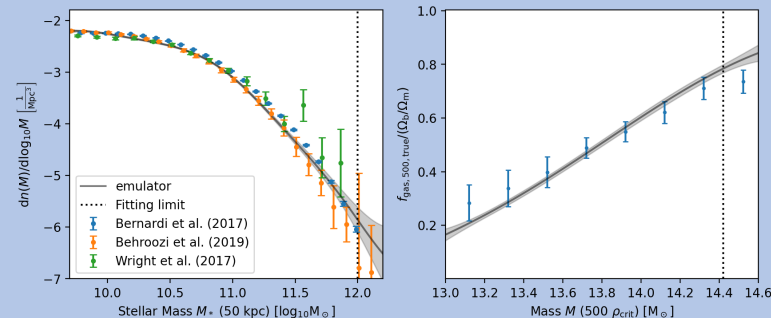

Figure 2. The grey lines shows the best fit results for simultaneously fitting the SMF and gas fractions in clusters. The dotted line indicates the highest mass that is used for fitting.