A Cross-Power Model for Power Suppression in FLAMINGO

Ioannis Koutalios[1]; Marcel van Daalen[1]
[1]Leiden Observatory, Leiden University

INTRODUCTION

The accuracy with which we will be able to estimate cosmology through weak lensing surveys like Euclid will depend on the accuracy of the models we use to interpret the observations. This means that predictions of the matter distribution need to be with about 1% accuracy for all scales of k<10 h/Mpc

The effect of feedback processes like AGN or star formation on the distribution of matter, as measured through the power spectrum, is greater than 1%. Additionally, it is not possible to ignore the contribution of baryons or solve galaxy formation to that degree of accuracy. We, therefore, need to model the baryonic effect. In this work, we apply the model that was introduced in van Loon & van Daalen (2024) to the new FLAMINGO suite of cosmological simulations (Schaye et al. 2023).

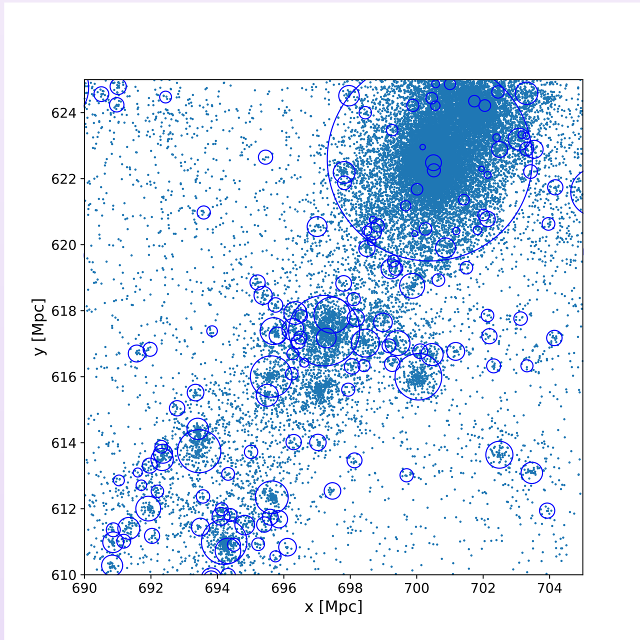

Figure 1. Clustering of mass in the DMO simulation

RETAINED MASS

For each halo we calculate the mean baryon fraction inside R_Δ: $\bar{f}_{b,i,\Delta} = \frac{M_{b,i,\Delta}}{M_{tot,i,\Delta}}$. If only baryonic matter was removed from the halo, we would be able to use the corrected baryonic fraction: $f_{bc,i,\Delta} = \frac{1-\Omega_b/\Omega_m}{1-\bar{f}_{b,i,\Delta}}$.

Realistically, dark matter will also respond, and there will be more mass that gets lost. We therefore need to measure: $f_{ret,i,\Delta} = \frac{M_{tot,i,\Delta}}{M_{tot,i,\Delta,DMO}}$

By mapping f_{ret} with f_{bc} we can easily fit the following equation: $f_{ret} = c - b(1 - f_{bc})^a$ where a, b, c are the fitting parameters. Therefore, we can now obtain f_{ret} by only calculating f_{bc}.

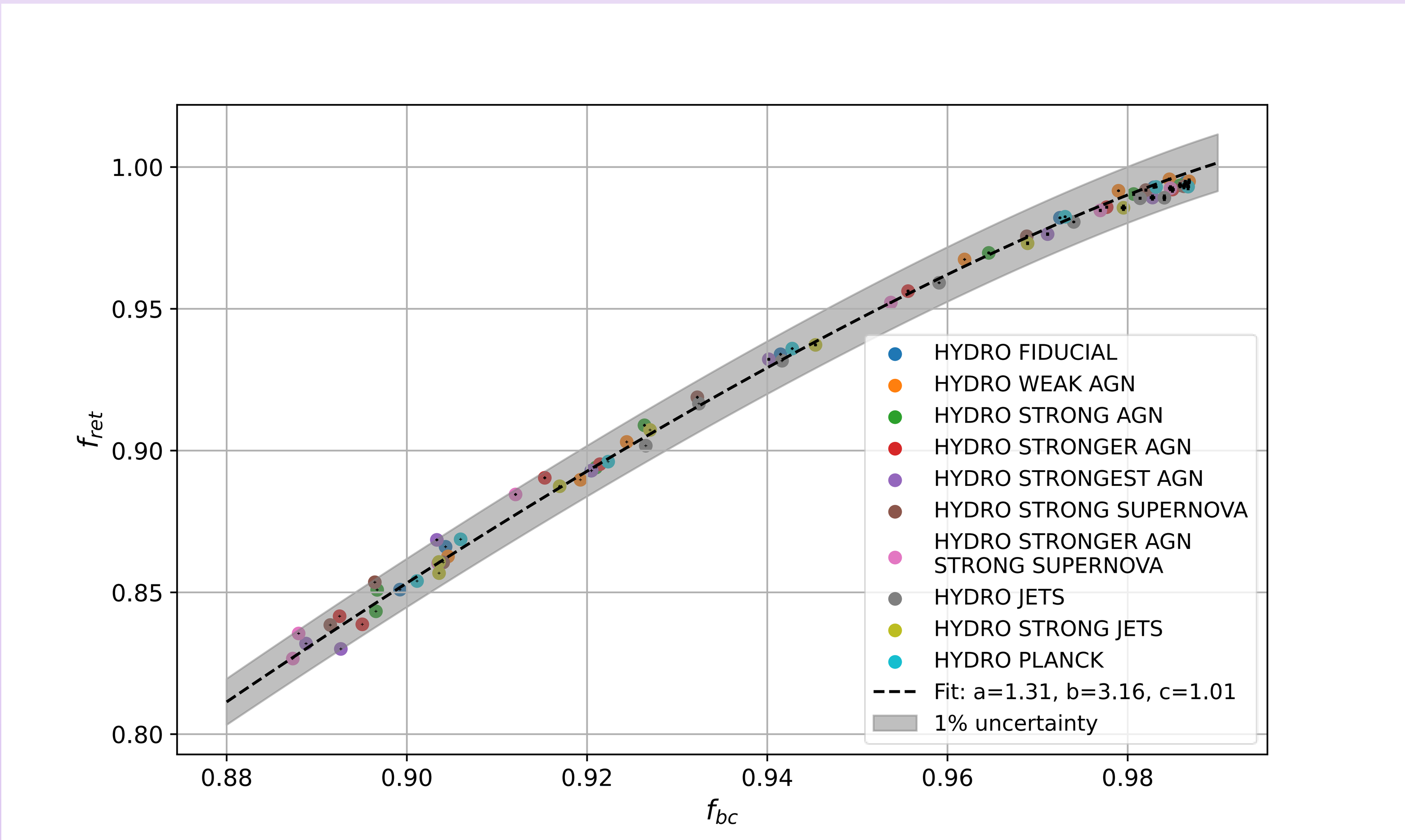

Figure 2. f_{ret} as a function of f_{bc} for the M_{200m} region. We can see how well we can map f_{ret} to f_{bc} which we later use in our model. The results come from a range of different FLAMINGO simulations, with many different feedback strengths and two different cosmologies.

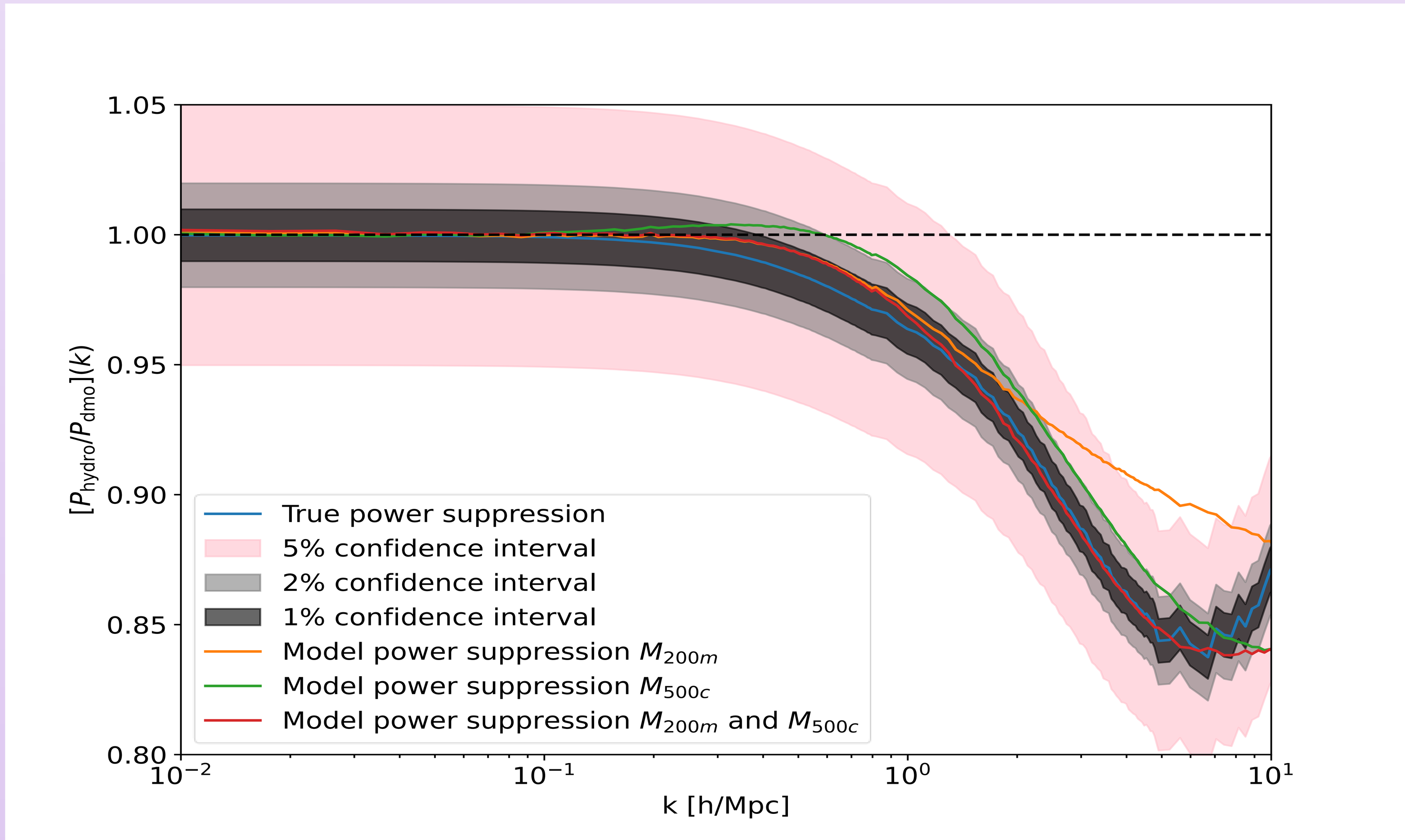

Figure 4. Model results for the Hydro Fiducial simulation. We show the results for 2 different overdensity regions as well as the combination of both regions. The final result is always within 1% of the true power suppression.

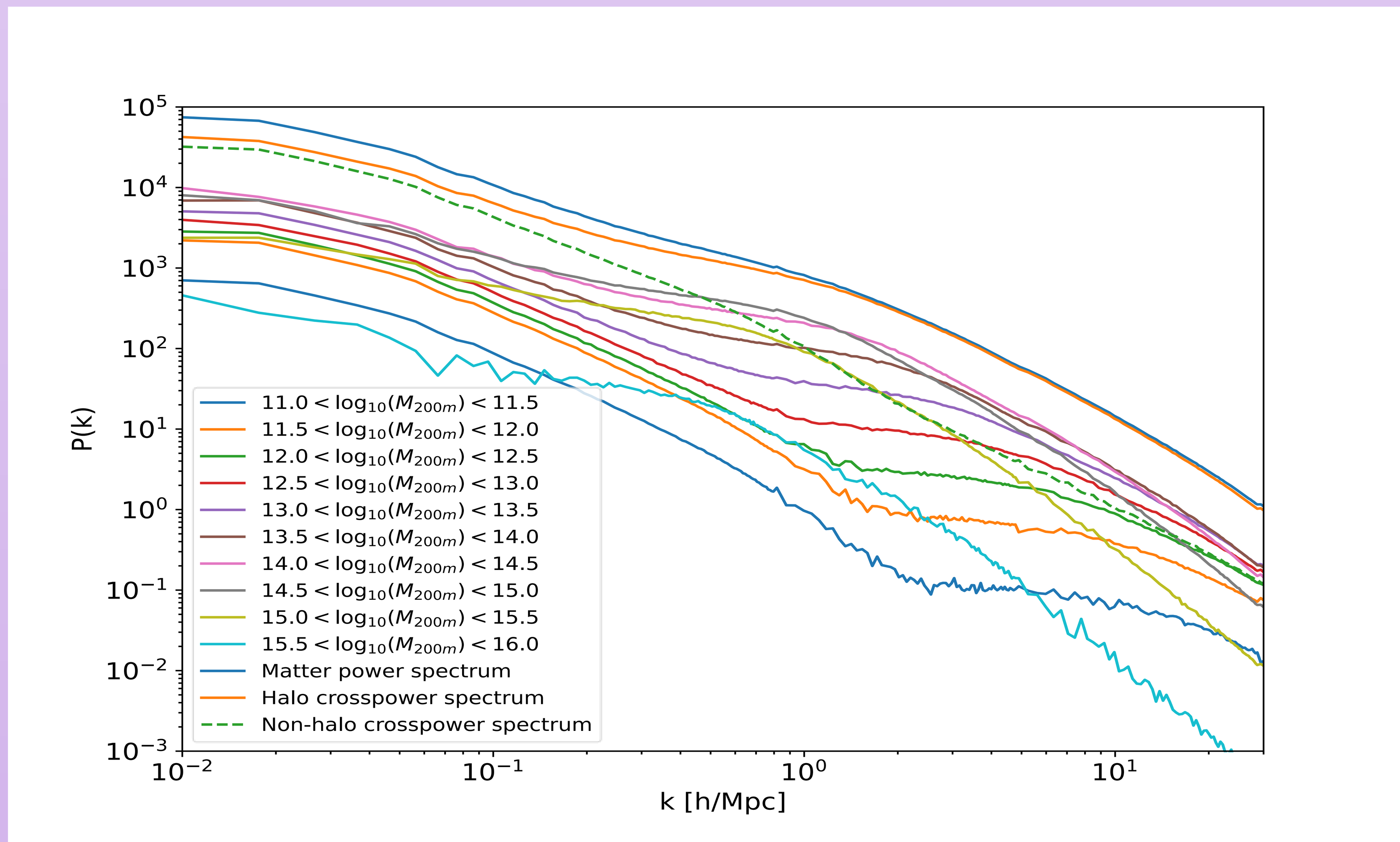

Figure 3. The cross-power spectra of the different halo bins with the matter power spectrum. The halo cross-power spectrum can be calculated by simply adding the cross-power spectra of all the different bins. The non-halo cross-power component is just the difference of the matter power spectrum with the halo cross-power spectrum.

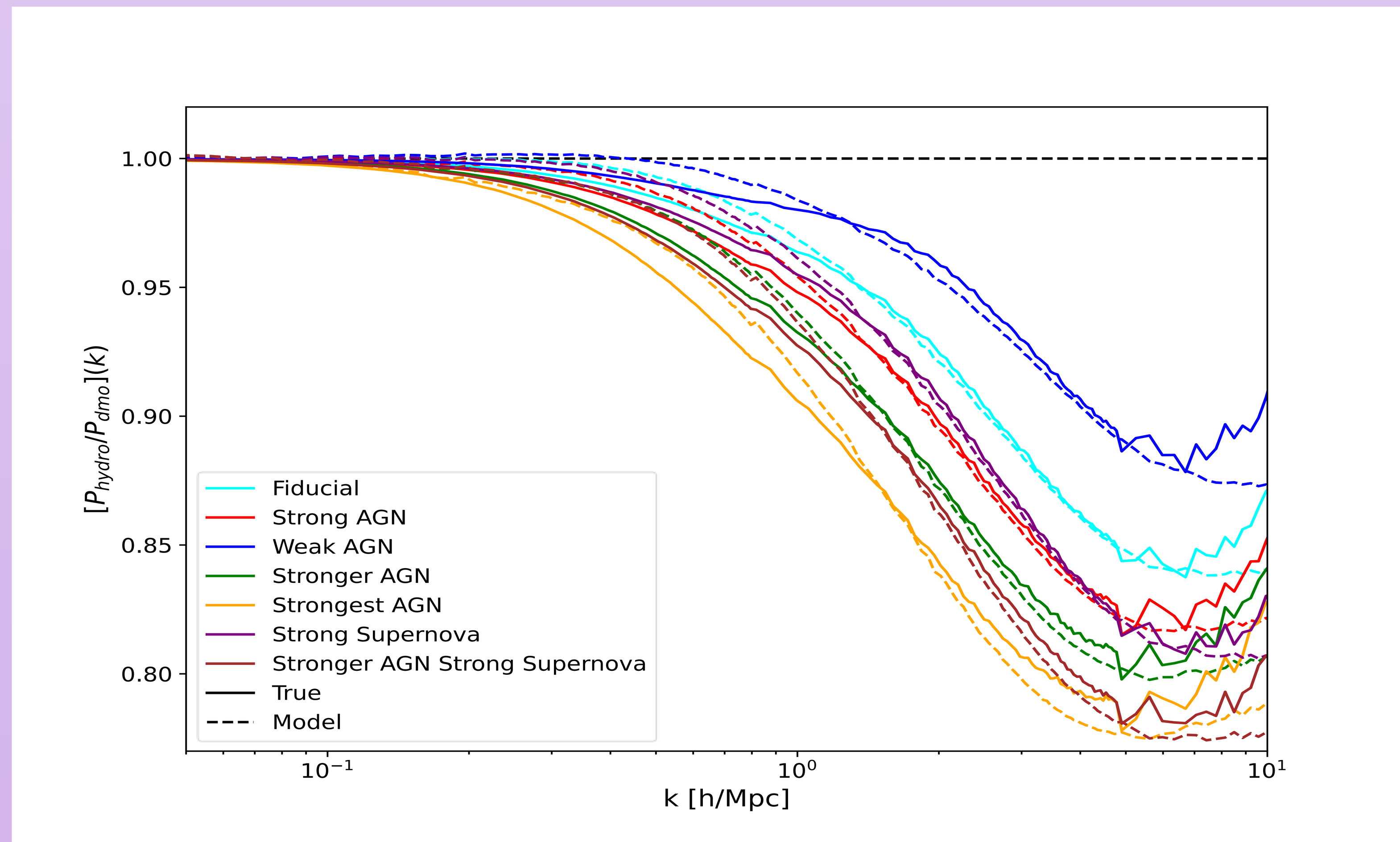

Figure 5. Collective plot of model results for different simulations. We show the result of applying the model for many different simulations. In all cases, we show the combination of M_{200m} with M_{500c}.

THE MODEL

We start with a dark matter only (DMO) simulation and split the halos in different bins based on their total mass (we use M_{200m}). We need both the matter power spectrum and the halo-matter cross power spectra with the halo mass fractions.

We rescale each cross-spectrum for the mass that is lost due to feedback effects and we also scale the non-halo cross-spectrum appropriately to satisfy conservation of mass. Finally, we sum all the halo and non-halo contributions and square the result relative to P_{DMO}.

CONCLUSIONS

Our model is able to predict the power suppression in scales of k<10 h/Mpc within 1%, without introducing any additional free parameters.

Despite its success, the model assumes that matter being ejected from halos will cluster in a similar way with the matter that is already there. If that is not the case the model might fail to give accurate predictions.

REFERENCES

Van Loon & Van Daalen (2024). https://doi.org/10.1093/mnras/stae285
Schaye et al. (2023). https://doi.org/10.1093/mnras/stad2419

Contact

Ioannis Koutalios
Leiden Observatory
Email: koutalios@mail.strw.leidenuniv.nl

Universiteit Leiden
The Netherlands