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The halo bispectrum as a sensitive probe of massive neutrinos and baryon physics

Victoria Yankelevich with Ian G. McCarthy, Juliana Kwan, Sam Stafford, Jia Liu

Based on arXiv:2202.07680

Cosmology from Home 2022, 4 July - 15 July

BAHAMAS project

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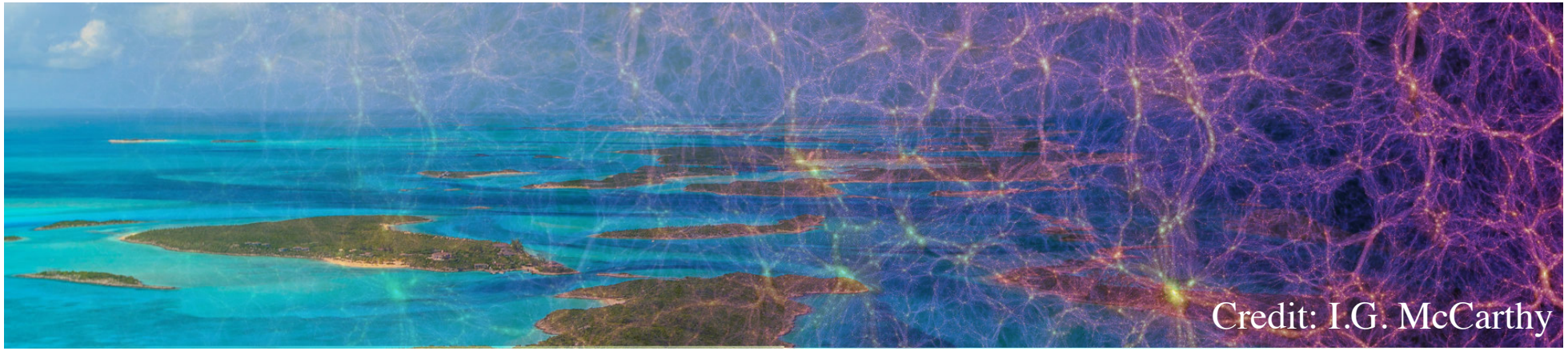
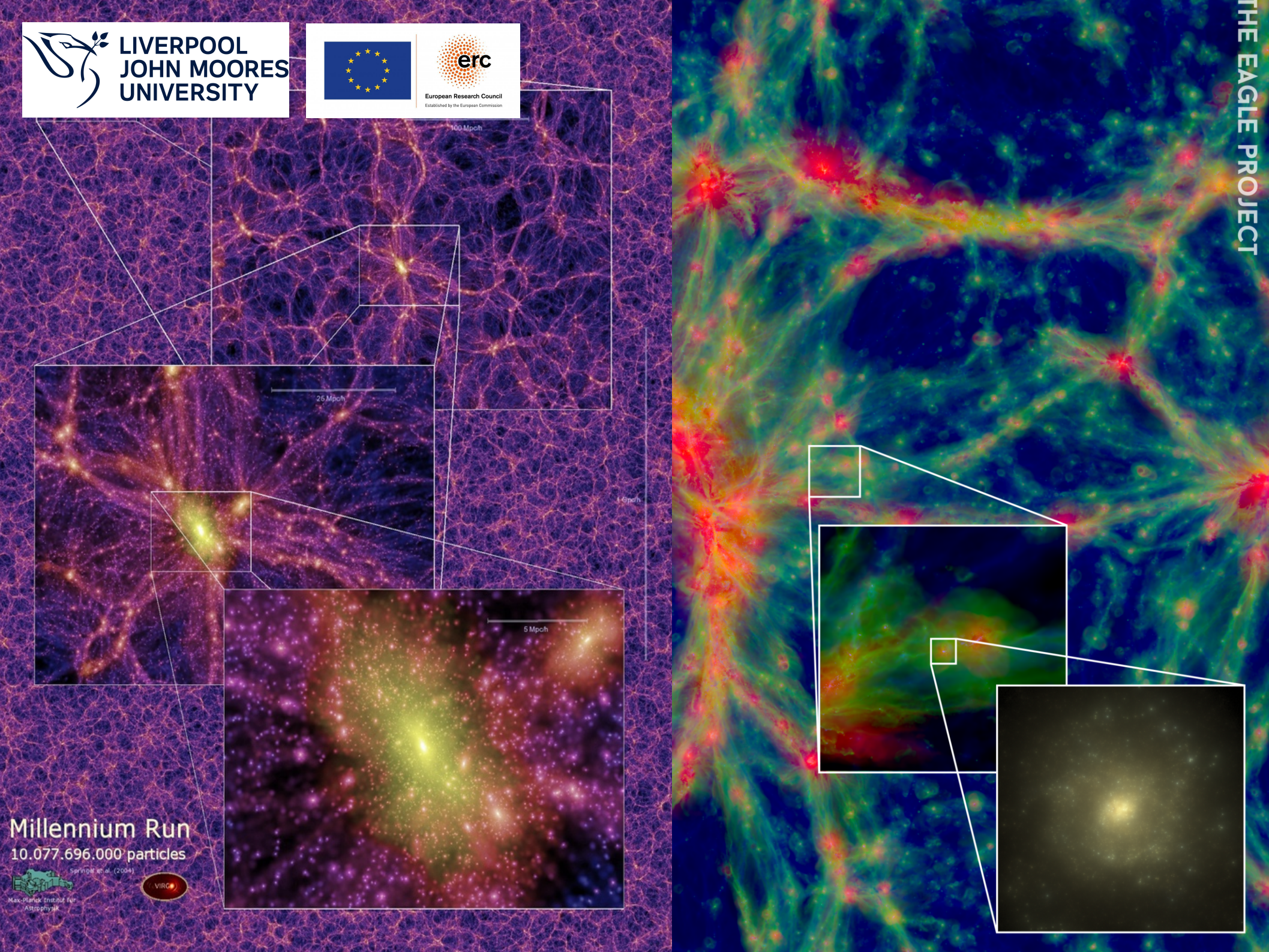
BAHAMAS project
(BAryons and HAloes of MAssive Systems)



Cosmological hydrodynamical simulations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erc
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100 Mpch
25 Mpch
1 Gpch
5 Mpch
Millennium Run
10.077.696.000 particles
Springel et al. (2004)
Max-Planck Institut für
Astrophysik
VIRGO
THE EAGLE PROJECT

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N-body simulation, only dark matter particles

to add baryons

Hydrodynamics

More complicated physics, codes, computational resources, time, etc

Credit: https://www.mpa.mpa-garching.mpg.de/galform/virgo/millennium

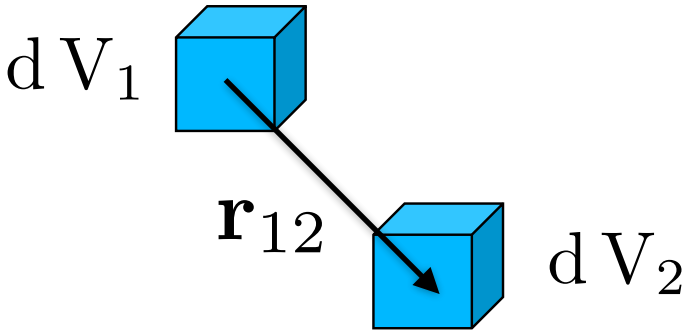
Power spectrum

$$\langle \delta_{\mathbf{x}_1} \delta_{\mathbf{x}_2} \rangle = \xi(\mathbf{r}_{12})$$

2-point correlation function

Probability of finding 2 particles within

2 infinitesimal volume elements at distance $\mathbf{r}_{12}$



↓ Fourier transform

Power spectrum

Information about the amplitudes of the modes of the density field

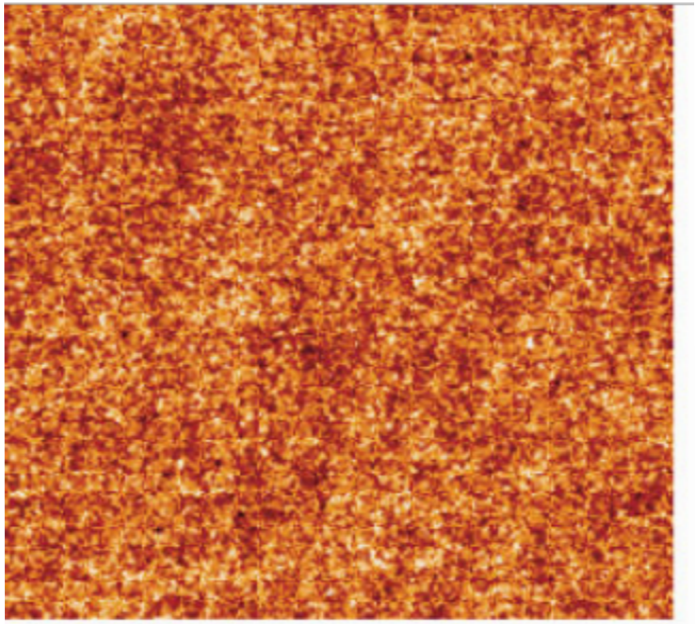
$$\delta(\mathbf{x}) = \frac{\rho(\mathbf{x}) - \bar{\rho}}{\bar{\rho}}$$

density contrast

$$\langle \tilde{\delta}(\mathbf{k}) \tilde{\delta}(\mathbf{k}') \rangle = (2\pi)^3 \delta^D(\mathbf{k} + \mathbf{k}') P(k)$$

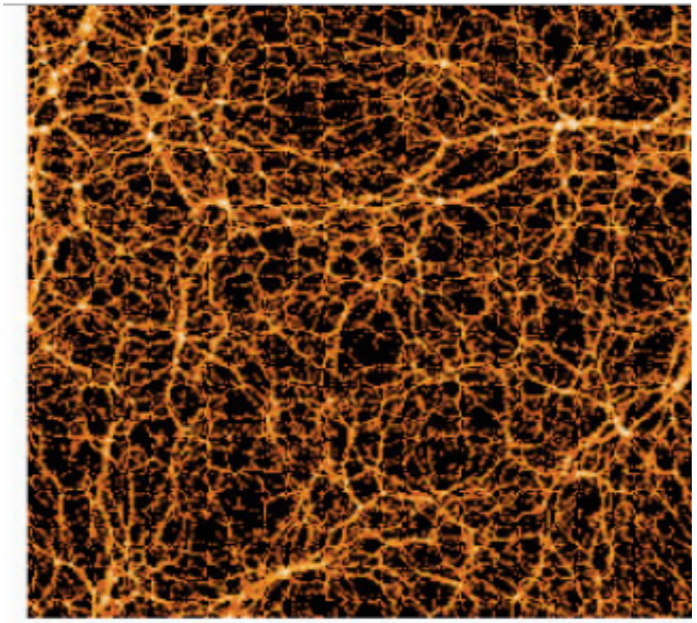
Power spectrum

Gaussian field



Same
power spectrum

Non-Gaussian field



Credit: Cole and Chiang, 2000

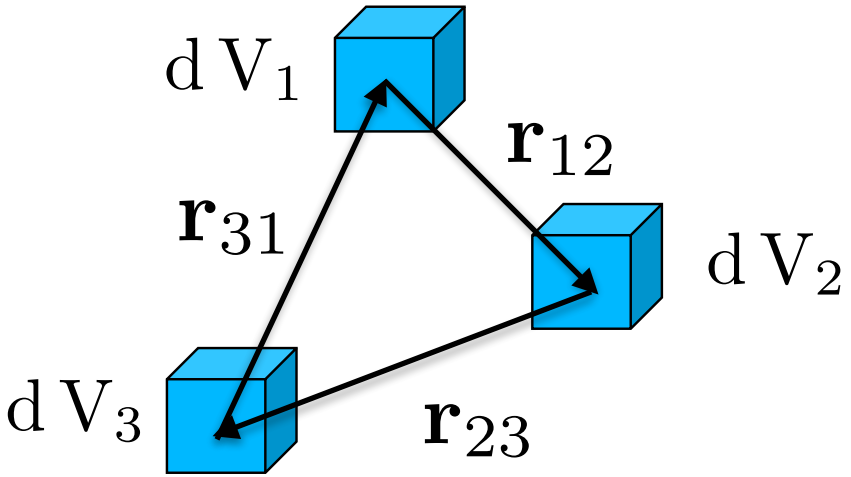
$$P(\mathbf{k}) \sim \left\langle \left| \tilde{\delta}(\mathbf{k}) \right|^2 \right\rangle$$

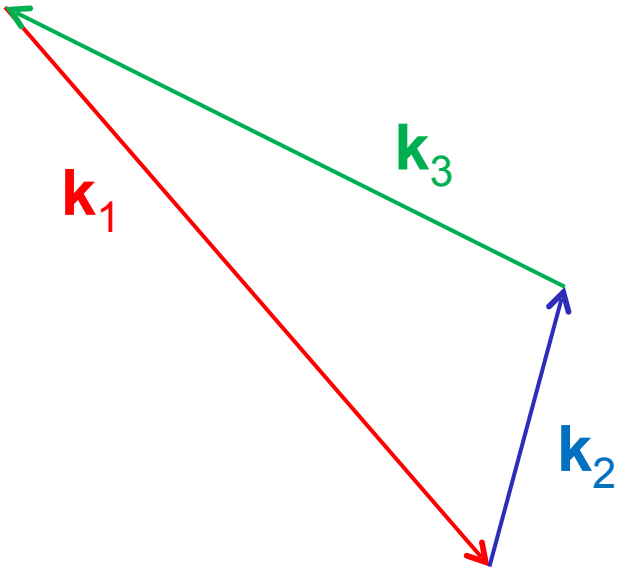
losing phase information

Bispectrum

$$\langle \delta_{\mathbf{x}_1} \delta_{\mathbf{x}_2} \delta_{\mathbf{x}_3} \rangle = \xi(\mathbf{r}_{12}, \mathbf{r}_{23}, \mathbf{r}_{31})$$

3-point correlation function





$$\langle \tilde{\delta}(\mathbf{k}_1) \tilde{\delta}(\mathbf{k}_2) \tilde{\delta}(\mathbf{k}_3) \rangle = (2\pi)^3 \delta^D(\mathbf{k}_1 + \mathbf{k}_2 + \mathbf{k}_3) B(\mathbf{k}_1, \mathbf{k}_2, \mathbf{k}_3)$$

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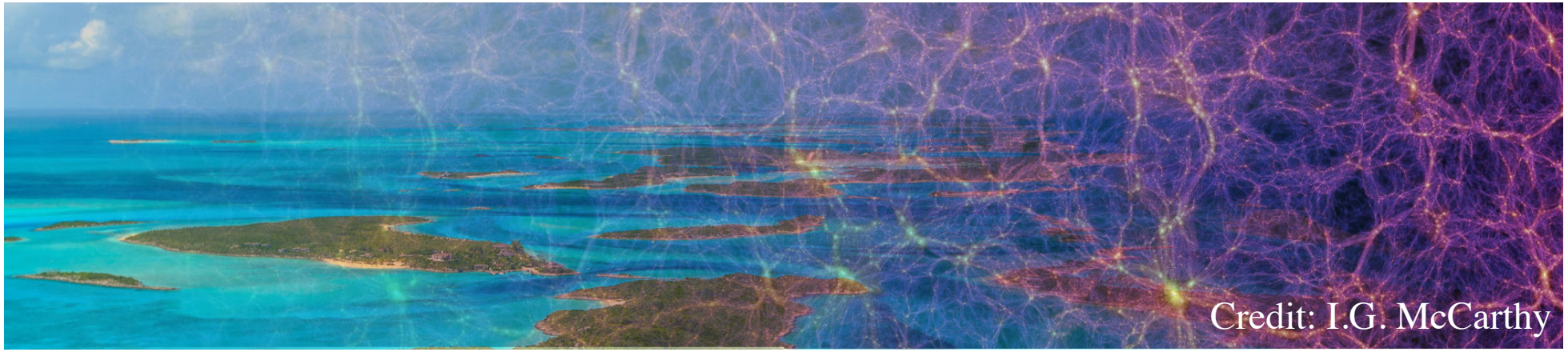
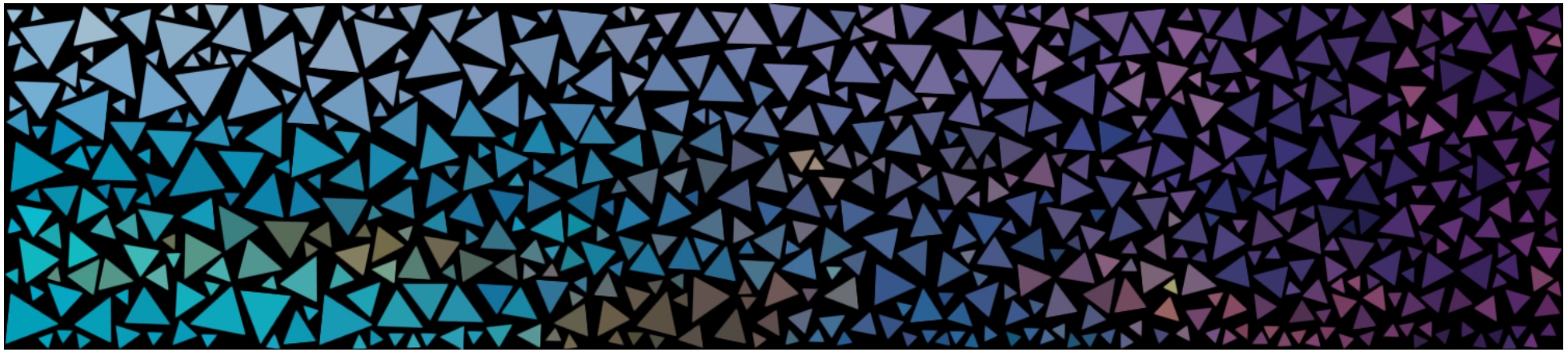
Original



Bispectrum studies



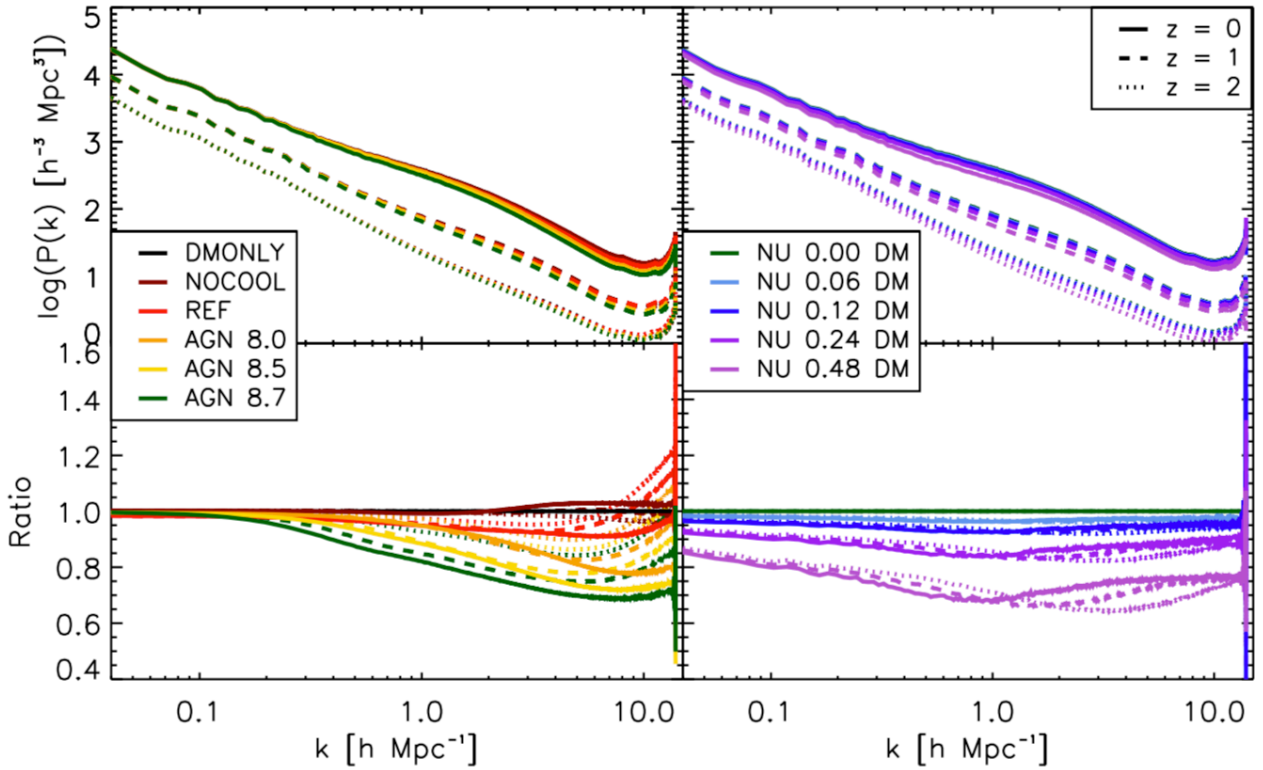


Figure 13. Matter power spectra for different baryon physics models in the absence of neutrino physics in the *WMAP7* cosmology (left) and for different $\sum M_\nu$ values in the absence of baryonic physics in the *WMAP9* cosmology (right) at $z = 0$. As in Fig. 1, colours denote the various runs (see the legend and Table 1), while the different line styles denote different redshifts. The bottom-left panel shows matter power spectra for the cosmo-OWLS runs normalized to the DMONLY case, whereas in the bottom-right panel the collisionless BAHAMASruns have been normalized by the massless neutrino case. Baryonic feedback suppresses the matter power spectrum by 10–20 per cent on small scales ($k \gtrsim 1\ h\ \mathrm{Mpc}^{-1}$). In contrast, the suppression due to neutrino free streaming depends strongly on the choice of summed neutrino mass and has an effect over a much wider range of scales. The suppression due to baryonic feedback grows by a factor of ~2 between $z = 2$ and 0, whereas the level of suppression resulting from neutrino free streaming is only weakly dependent on redshift.

Credit: Mummery B. O., McCarthy I. G., Bird S., Schaye J., 2017, MNRAS, 471, 227

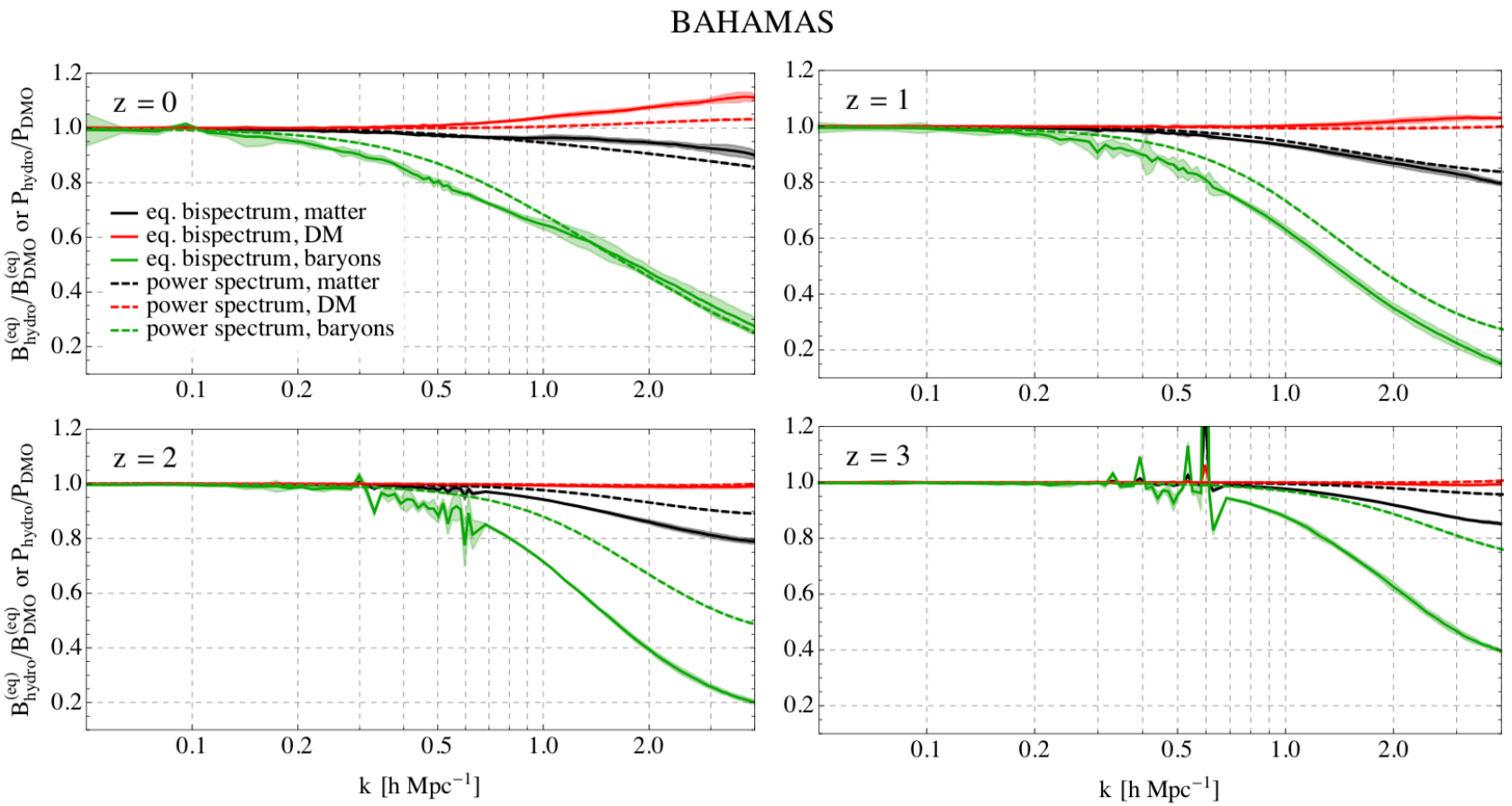


Figure 9. Same as Fig. 1 but for the BAHAMAS simulation with the fiducial AGN feedback prescription. Compared to IllustrisTNG (see Figs. 1 and 2) the spectra are more strongly suppressed at high redshift, likely due to a combination of gas cooling and feedback.

Credit: Foreman S., Coulton W., Villaescusa-Navarro F., Barreira A., 2020, MNRAS, 498, 2887

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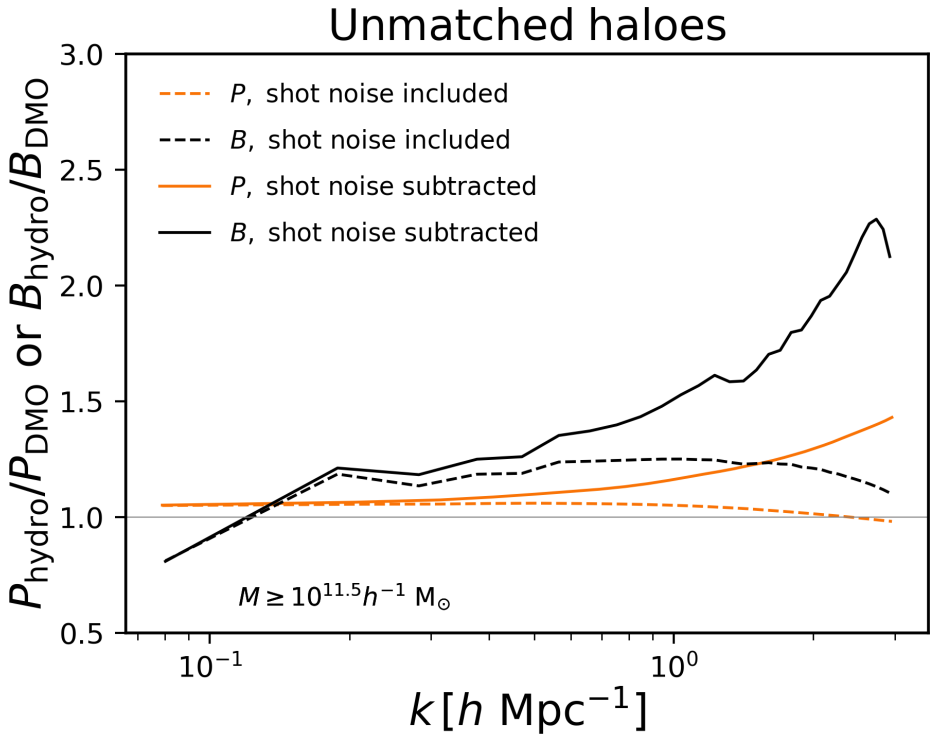
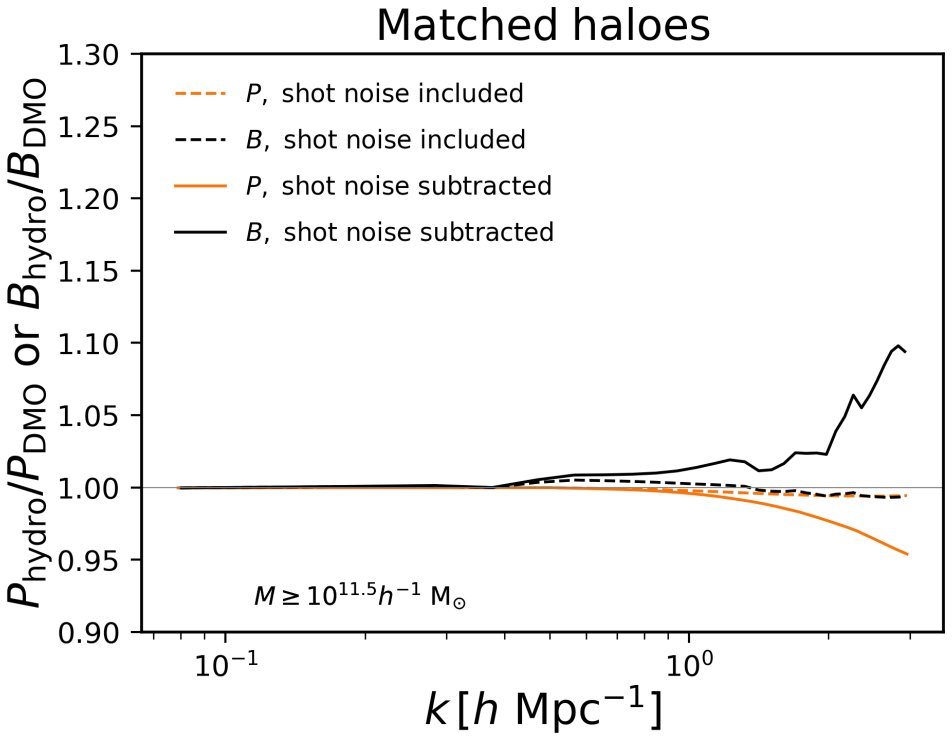
The BAHAMAS project: The halo bispectrum as a sensitive probe of massive neutrinos and baryon physics

- *Halo* bispectrum
- Variety of simulations (different cosmology, neutrino and AGN feedback models)
- Haloes+subhaloes / haloes only/ subhaloes only
- Unmatched & matched haloes
- Modified BSKIT code, Foreman et al., 2020

The BAHAMAS project: The halo bispectrum as a sensitive probe of massive neutrinos and baryon physics





V.Yankelevich at al, arXiv:2202.07680

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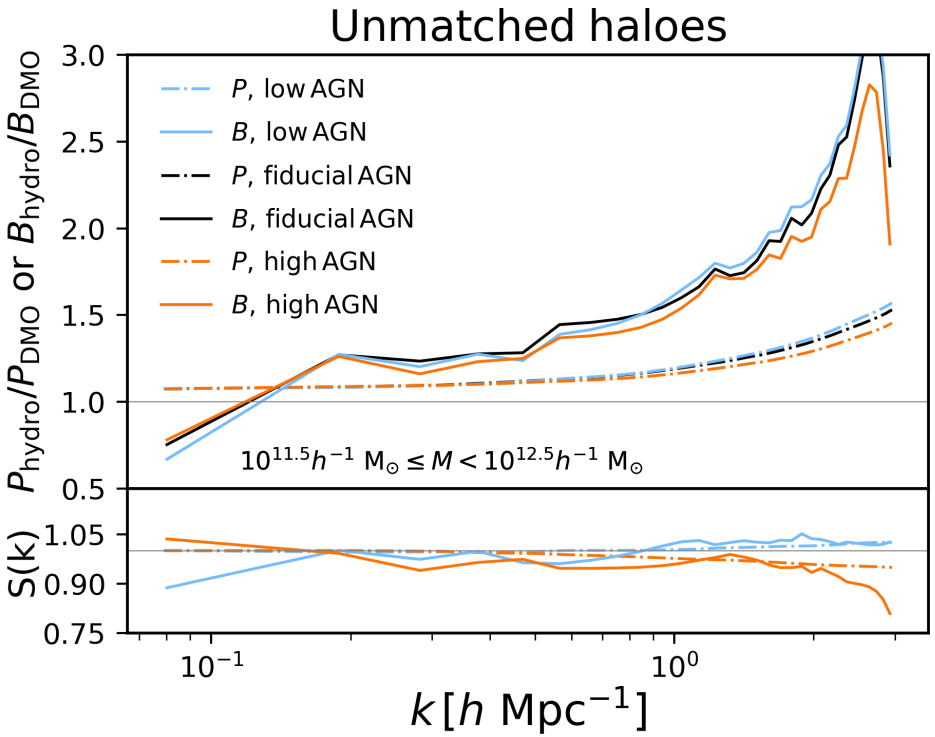

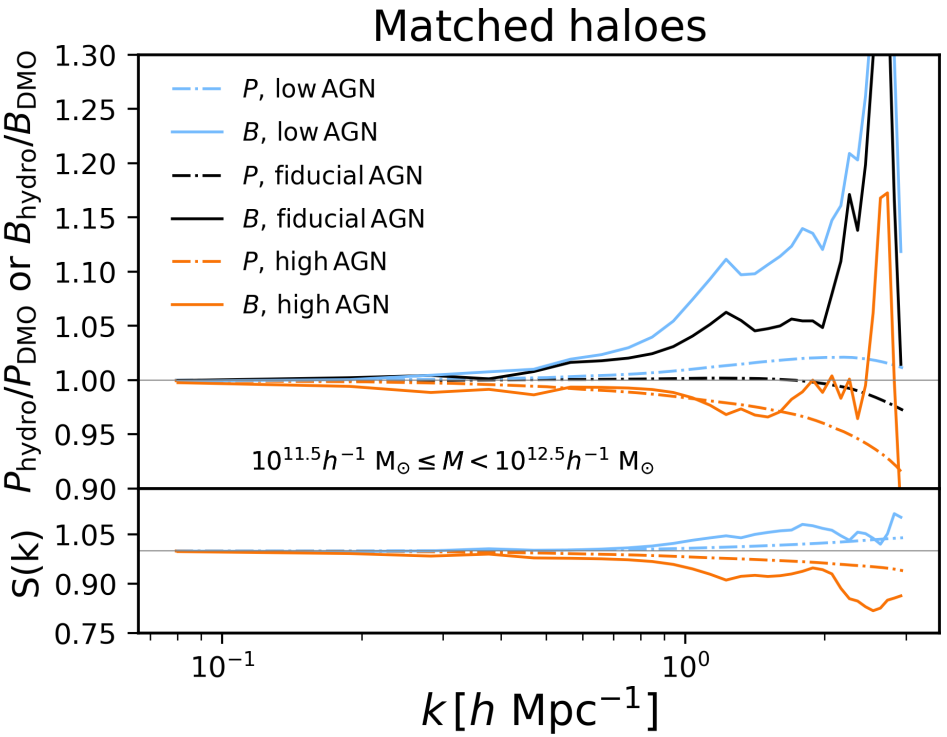

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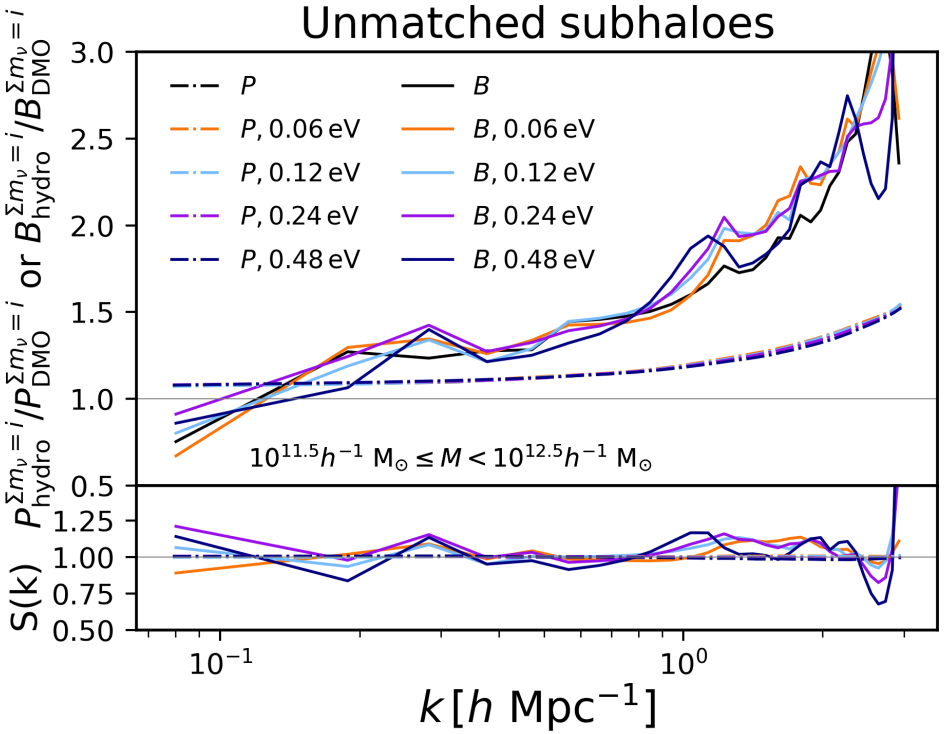

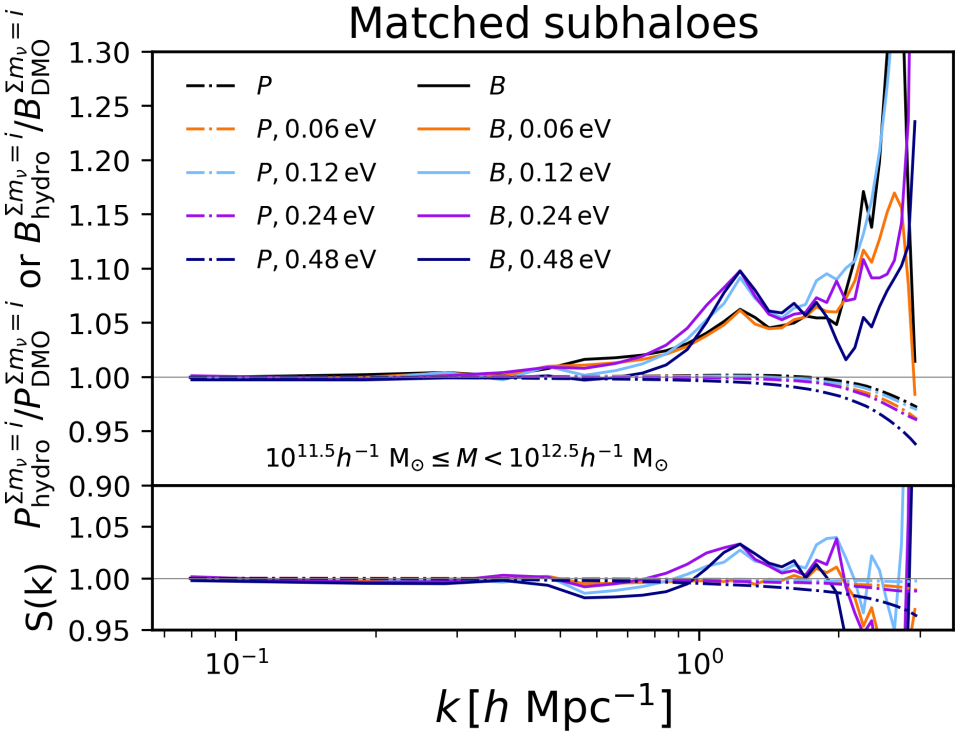

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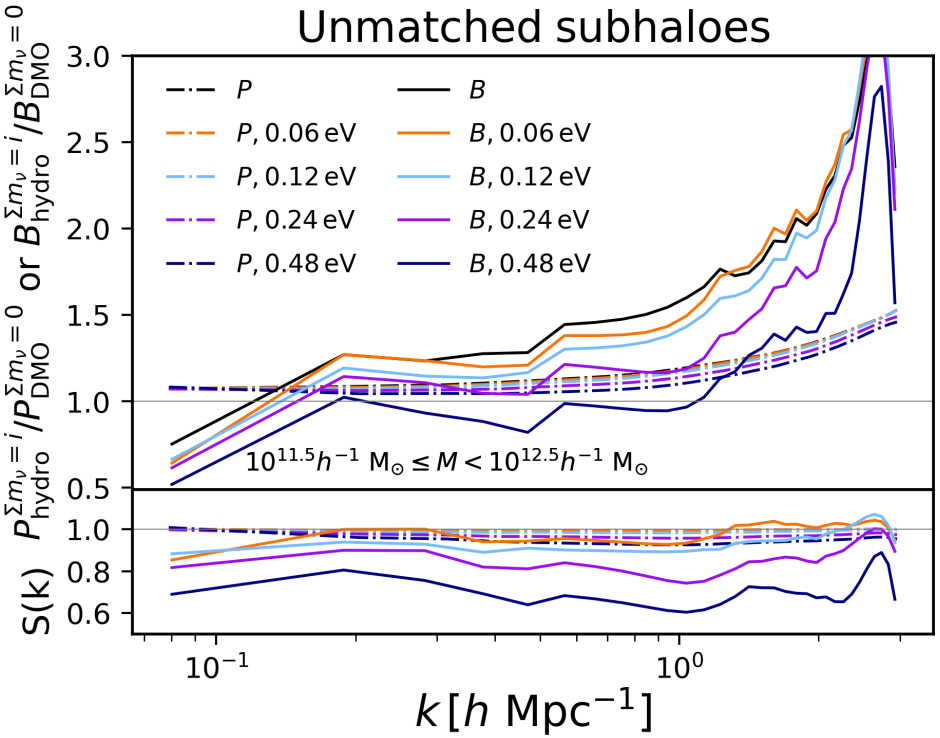

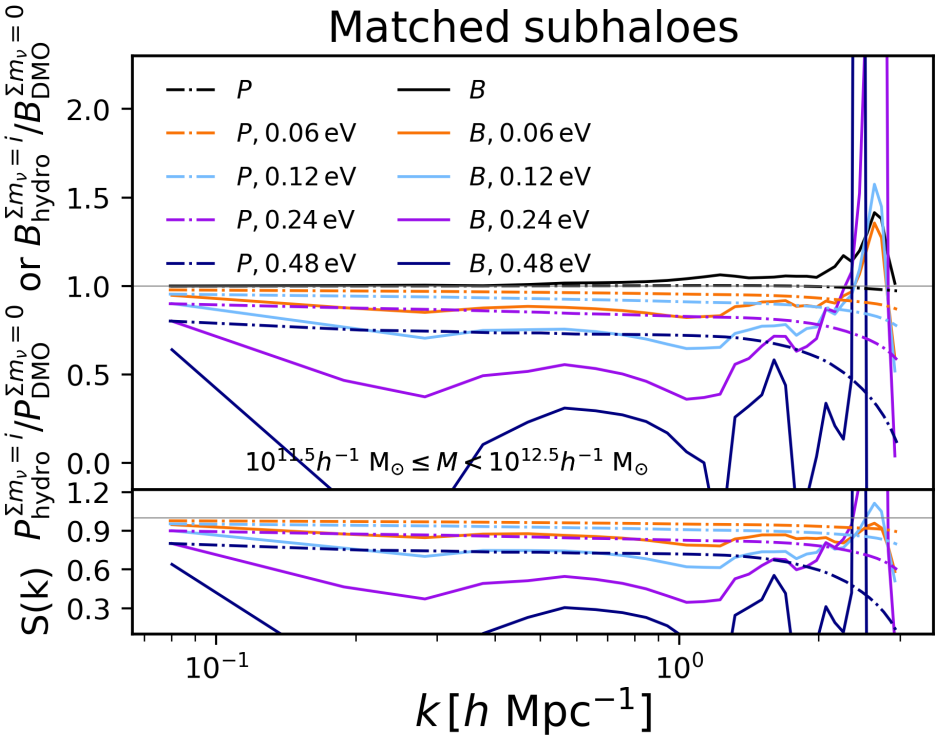

V.Yankelevich at al, arXiv:2202.07680

Conclusions

- Baryonic effects on the halo bispectrum
- Bispectrum is more sensitive than power spectrum
- Test for different cosmology, neutrino and AGN feedback models
- Removing degeneracy between massive neutrinos and baryon physics

Future plans

- BAHAMAS-XL and FLAMINGO

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Thank you!

I am at the job market, so if you want to do bispectrum - just drop me an email