Galaxy clusters observables for cosmological probes

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Abstract

In this PhD project, we are using the BAHAMAS simulations to develop galaxy clusters cosmological probes to be implemented in an LSS emulator. In the first stages of the project, we are studying and describing several galaxy clusters observables (like gas pressure for Sunyaev-Zel'Dovich effect, gas density distribution for X-ray emission) and fit those profiles with a general function based on their mass and redshift. The idea behind those analyses is to tackle down the standard conception of the halo mass function (HMF) that leads the nowadays cosmological theories. The new HMF will be fundamental for testing and analysing the cosmological impact onto these observables.

Methodology

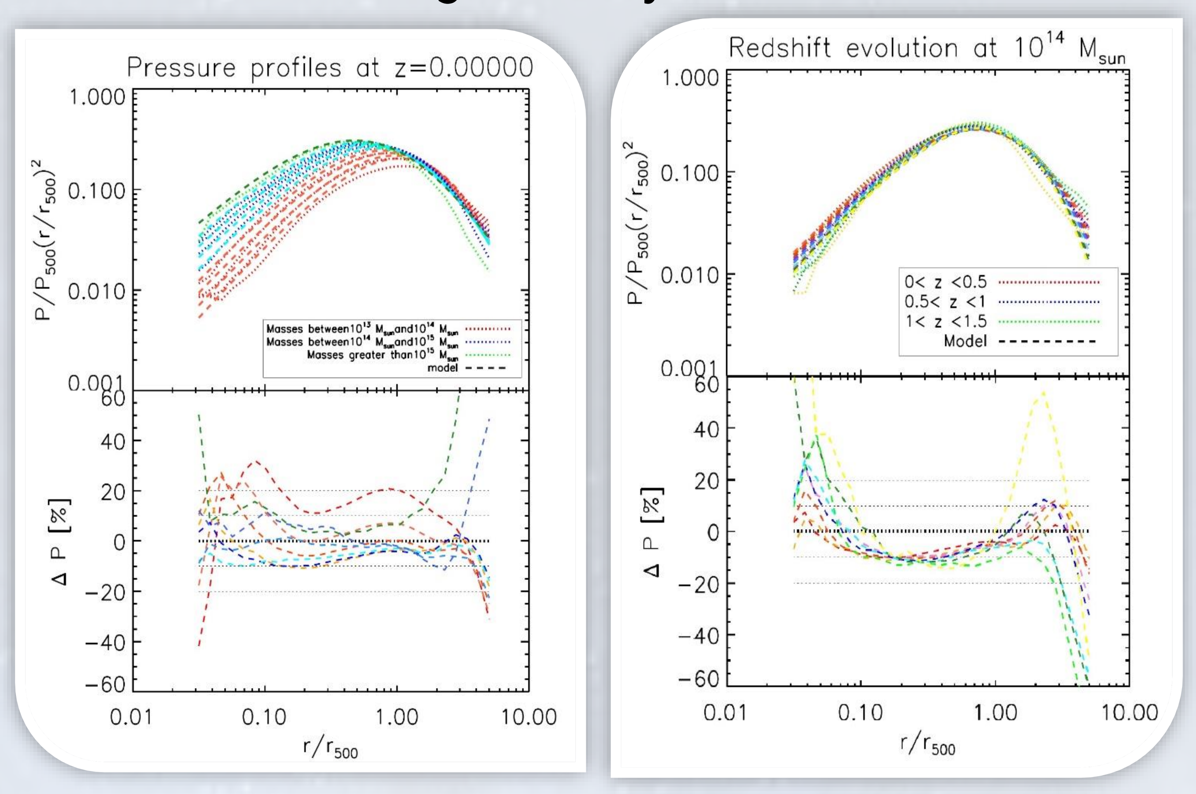
The methodology applied to our analysis is quite simple: we use the data from the simulations (gas density, temperature and particle mass), we compute the derived quantities (pressure) and, with the 3D profiles obtained, we fit them with a generic function, adapted from a generalized Navarro – Frenk – White profile. We track a direct dependency on mass and redshift that allows our profiles to reproduce, with a good agreement, a wide range of galaxy clusters.

$$f(r,M,z) = \frac{Q(M,z)}{\left(\frac{r}{x_{c(M,z)}}\right)^{\alpha(M,z)}\left[1+\left(\frac{r}{x_{c(M,z)}}\right)^{\beta(M,z)}\right]^{\gamma(M,z)}}$$

Each parameter has a direct dependence on the mass of the halo and its redshift. We define Q as a general parameter.

Sunyaev-Zel'Dovich Profiles

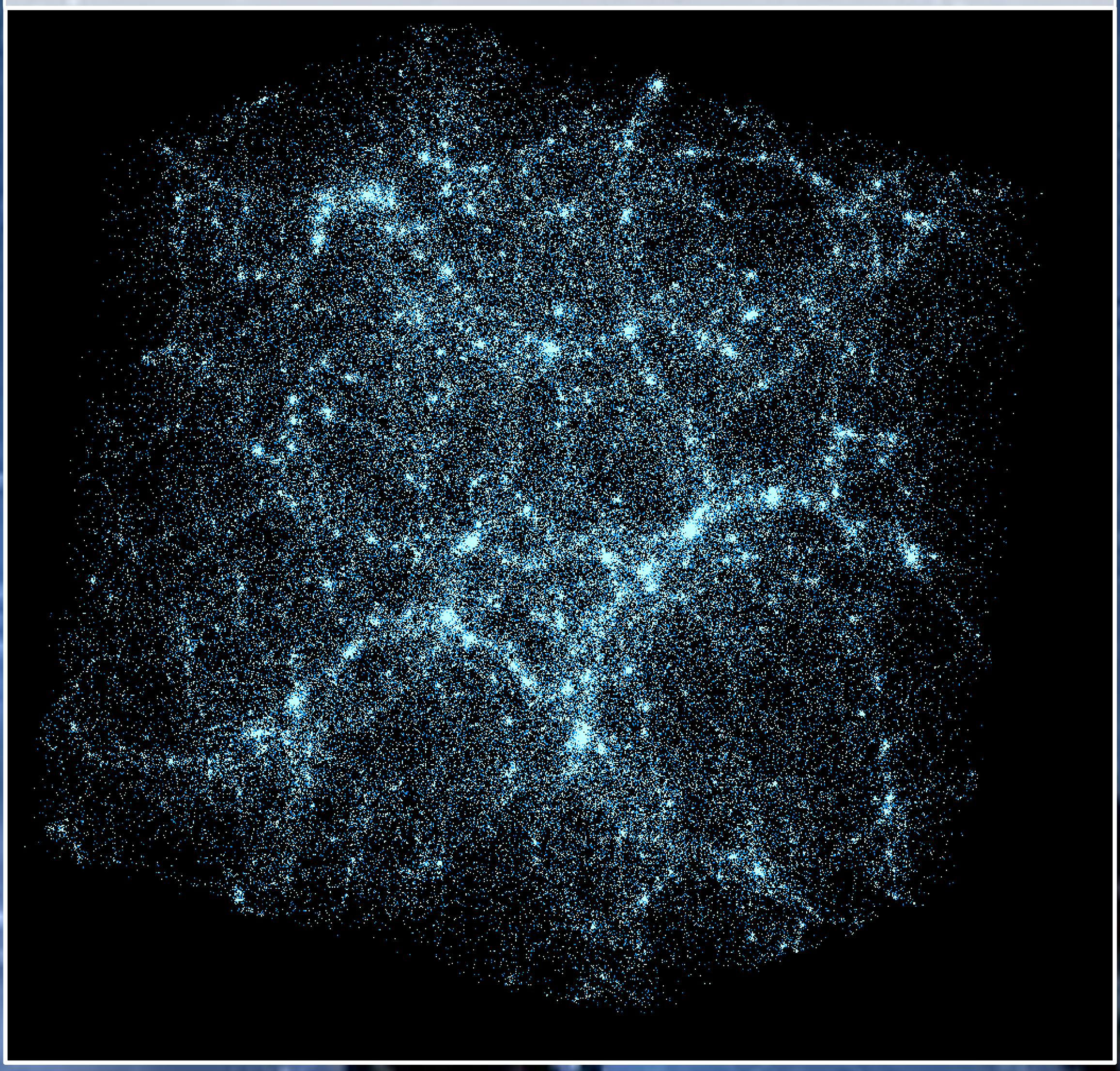
The pressure profiles are an amazing tool to describe the matter distribution into the dark matter halos using the Sunyaev-Zel'Dovich effect.



We show the comparison between our function and the simulations. There is quite good agreement but we are not able to take into account secondary effects of merging and AGN feedback that can be present in the simulations.

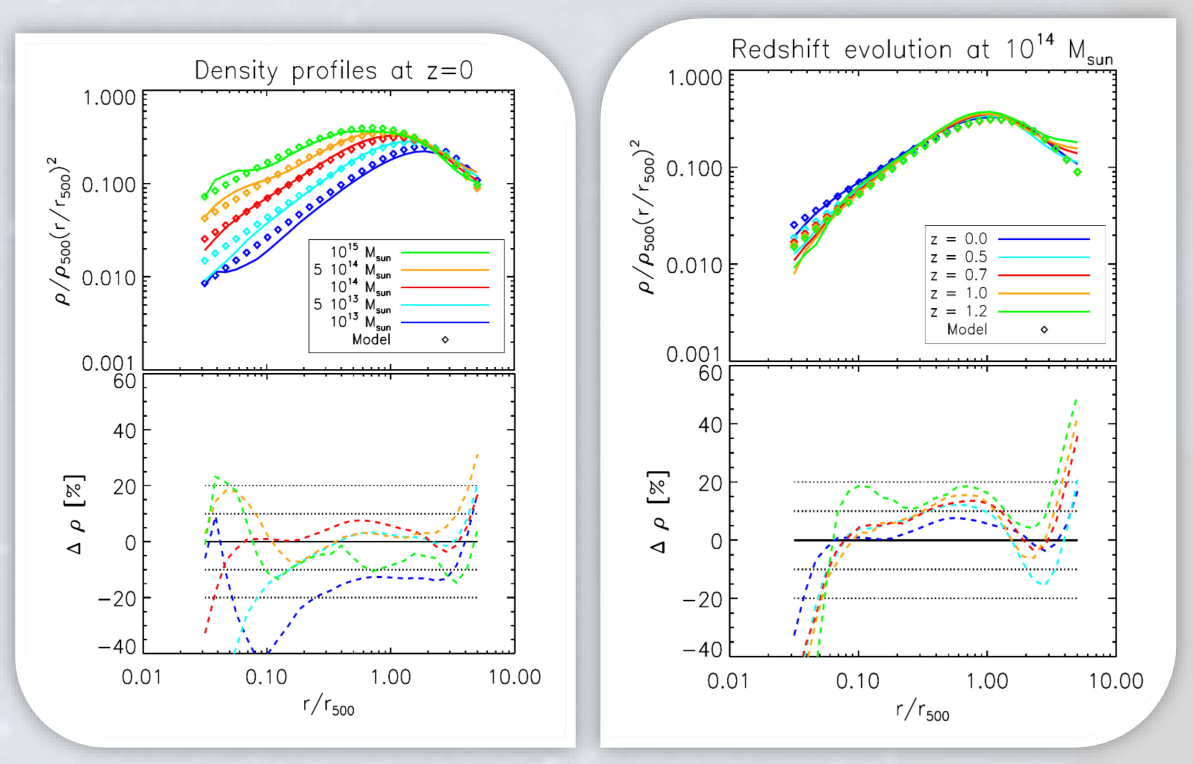
BAHAMAS BOX

Gas density and Dark Matter density



X-Ray Profiles

The density profiles as trackers of the X-ray distribution.



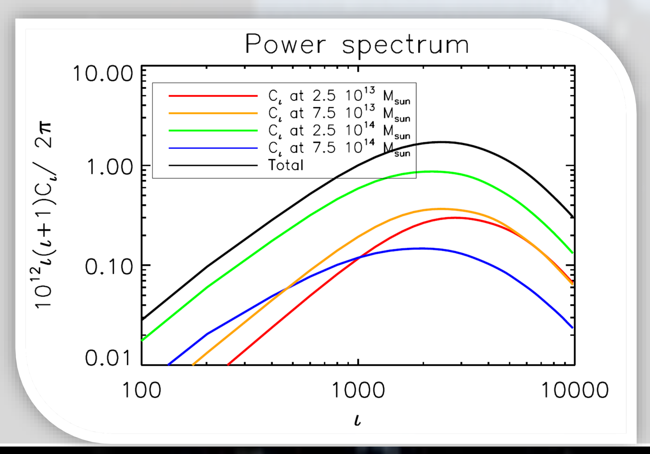
The gas density is really sensitive to dynamical effects, like major mergers and other halos – subhalos interactions and that is why is quite more complicated to describe it. Nevertheless, our profiles show a good agreement both in masses and redshifts.

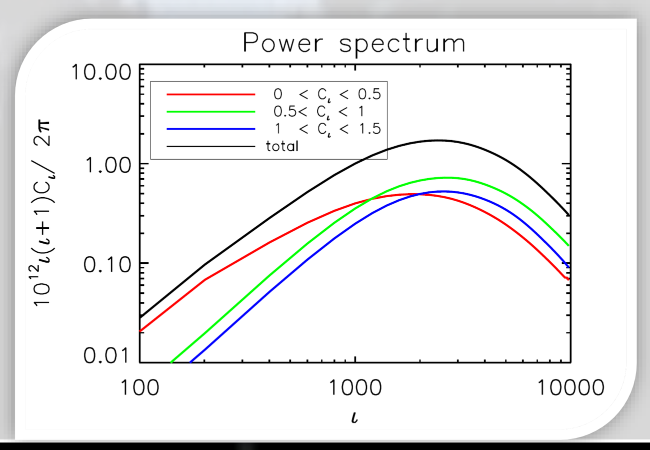
Thermal Sunyaev-Zel'Dovich power spectrum

We present the different impact of the halo masses and redshift in the characterization of the total shape of the SZ power spectrum. The power spectrum is computed between z=0 to 1.5 and between 10^{13} and 10^{15} solar masses. The spectrum is calculated at a frequency (ν) of 150 GHz, ι represents the Fourier transform of the real-space radius and Pe is the Fourier transform of the 3D pressure profile (computed before):

$$C_l = f^2(\nu)\int \frac{dV}{dz}dz \int_{10^{13}M_{sun}}^{10^{15}M_{sun}} \frac{dn(M,z)}{dM}\,|\,y_l(M,z)|^2 dM \qquad \text{where} \quad y_l = \frac{4\pi\sigma_t r_s}{l_s^2 m_e c^2}\int_0^{5r_s} x^2 P_e(x)dx \frac{\sin\left(\frac{lx}{l_s}\right)}{\left(\frac{lx}{l_s}\right)}$$

This tool is extremely important because it is a direct comparison with various observations (Planck and SPT) and it is really sensitive to the changes of the parameters (σ_8 and the halo mass function).





What's next?

- Fit the dark matter density distribution (to address the weak lensing observable).

In the power spectrum, we used the standard halo mass function from Tinker, that is calibrated on dark matter haloes. In order to take into account the baryonic physics we want:

- Elaborate a halo mass function calibrated directly from the BAHAMAS simulations.

It is interesting to compute the SZ power spectrum if we "paint on" the pressure profiles directly onto dark matter simulations, that will avoid the need of HMF and compare the previous results.

References

- McCarthy I. G.,Schaye J., Bird S. Le Brun A. M. C., MNRAS,465:2936–2965, 2017
- Battaglia N., Bond J.R., Pfrommer C., Sievers J.L., ApJ, 758:75, 2012.
- Battaglia N., Bond J.R., Pfrommer C., Sievers J.L., ApJ, 758:74,2012.
- Heitmann K., White M., Wagner C., Habib S., Higdon D., ApJ,715:104–121, 2010
- Heitmann K., Higdon D., White M., Habib S., Williams B.J., Lawrence E. ,Wagner C. ApJ, 705:156–174, 2009.
- Tinker J., Kravtsov A. V., Klypin A., Abazajian K., Warren M., Yepes G., Gottlober S.,Holz D. E., ApJ 688:709-728, 2008.
- Komatsu E. Seljak U.. MNRAS 327:1353–1366, 2001.

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