Including relativistic and primordial Non-Gaussianity contributions in cosmological simulations by modifying the initial condition

500 Mpc/h

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Position: last semester PhD student

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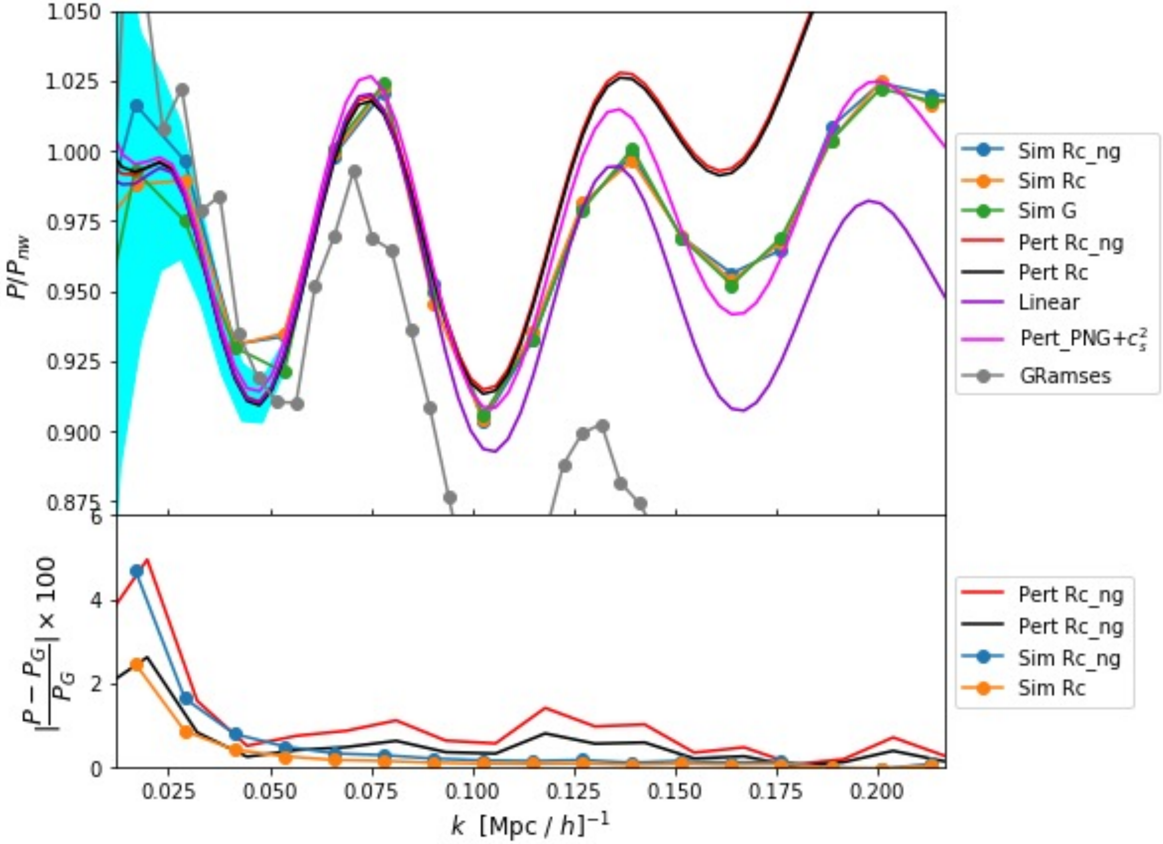
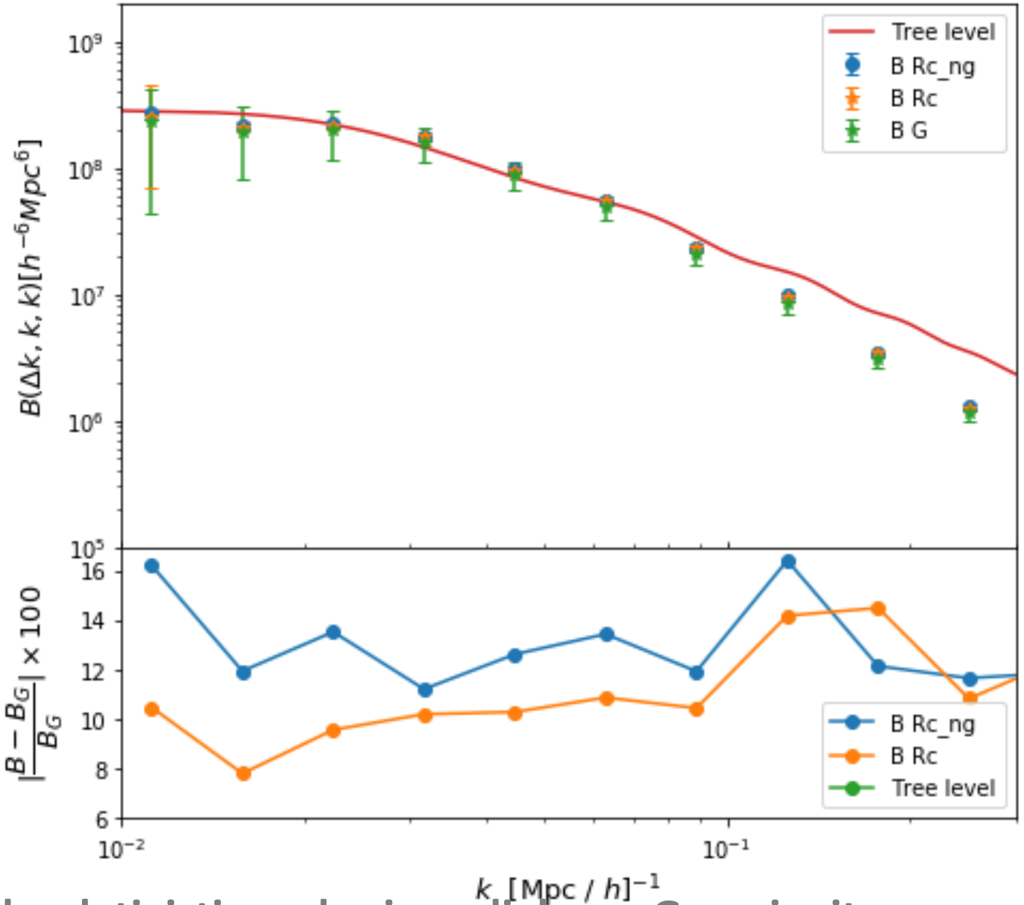
What is this all about

Power spectrum



Bispectrum



M. Enríquez, J. C. Hidalgo and O. Valenzuela, Cosmological simulations with relativistic and primordial non-Gaussianity contributions as initial conditions, 2109.13364.

Newtonian and relativistic correspondance

Newtonian

$$\frac{d\delta_N}{d\tau} = -(1+\delta_N)\nabla^2\nu_N$$

$$\frac{d(\nabla^2\nu_N)}{d\tau} + \mathcal{H}\nabla^2\nu_N + \partial^i\partial_k\nu_N\partial^k + \partial_i\nu_N + 4\pi G a^2\bar{\rho}\delta_N = 0$$

$$\theta = \nabla^2\nu_N = \nabla^2\nu_l^{(1)}$$

$$\theta_k i = \partial^i\partial_k\nu_N = \partial^i\partial_k\nu_l^{(1)}$$

Relativistic

$$\delta' = -(1+\delta)\theta$$

$$\theta' + \mathcal{H}\theta + \theta^i_j\theta^j_i + 4\pi G a^2\bar{\rho}\delta = 0$$

GR. Constrain equation

$$\theta^2 - \theta^i_j\theta^j_i + 4\mathcal{H}\theta + R = 16\pi G a^2\bar{\rho}\delta$$

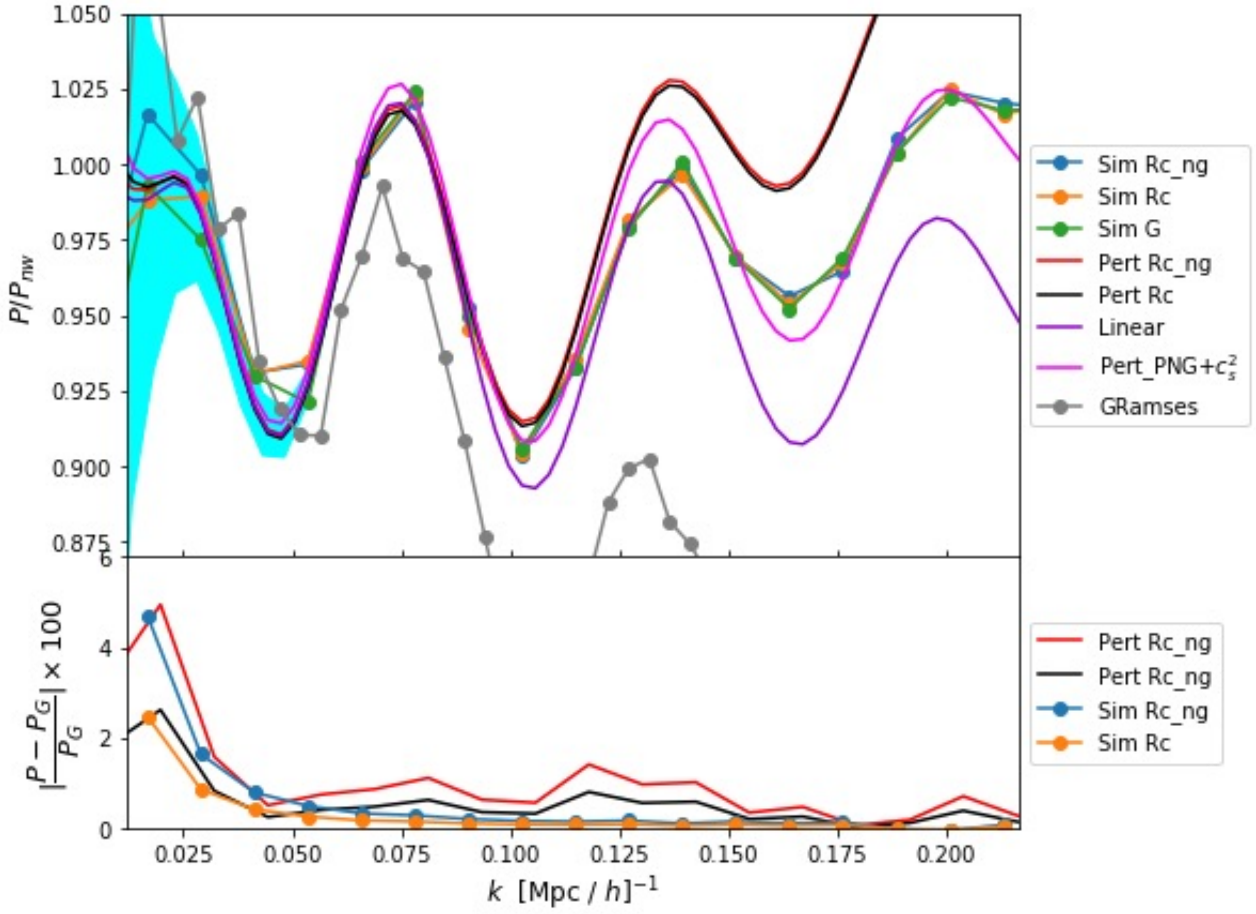
Density field with GR and N-G contributions

$$\delta = \delta^{(1)} + \frac{1}{2}\delta^{(2)} + \frac{1}{6}\delta^{(3)} + \dots$$

$$\frac{1}{2}\delta^{(2)} = \frac{D_+(\eta)}{10\mathcal{H}^2 D_{+IN}} \frac{24}{5}\left[-(\nabla\zeta^{(1)})^2\left(\frac{5}{12} + f_{\rm NL}\right) + \zeta^{(1)}\nabla^2\zeta^{(1)}\left(\frac{5}{3} - f_{\rm NL}\right)\right]$$

$$\frac{1}{6}\delta^{(3)} = \frac{D_+(\eta)}{10\mathcal{H}_{IN}^2 D_{+IN}} \frac{108}{25}\left[2\zeta^{(1)}(\nabla\zeta^{(1)})^2\left(-g_{\rm NL} + \frac{5}{9}f_{\rm NL} + \frac{25}{54}\right) + \zeta^{(1)2}\nabla^2\zeta^{(1)}\left(-g_{\rm NL} + \frac{10}{3}f_{\rm NL} - \frac{50}{27}\right)\right]$$

Results



- We computed the difference with no-wiggle power spectrum.
- The blue shadow corresponds to a Euclid like observed area.
- The difference in the supression with GRAMSES is due to the counter term* as:

$$P_{ctr,1loop} \equiv -2k^2 c_s^2 P_{11}$$

- PNG and relativistic contibutions difference up to 4.5% (fnl=-4.2 gnl=-7000)

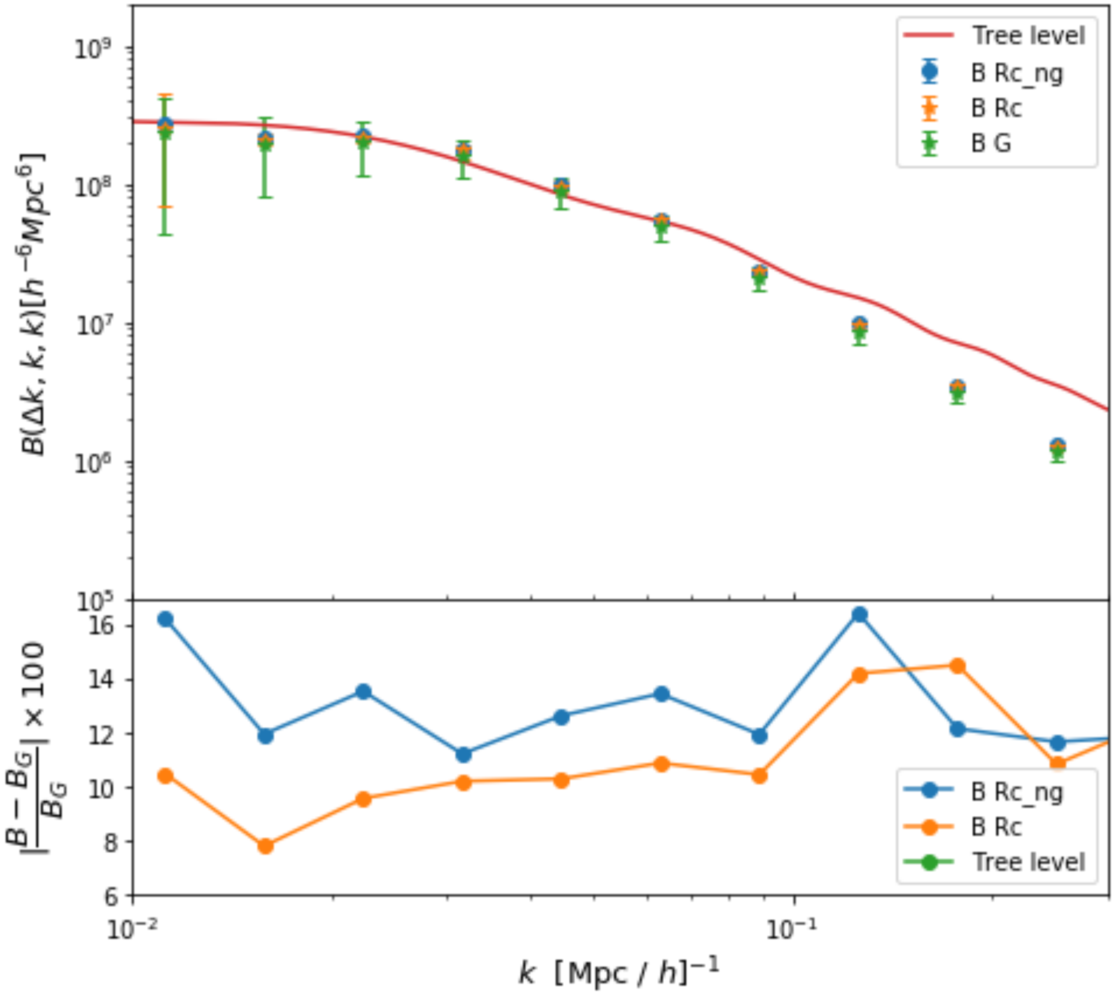
*T. Baldauf, L. Mercolli, and M. Zaldarriaga, "Effective field theory of large scale structure at two loops: The apparent scale dependence of the speed of sound," Phys. Rev. D, vol. 92, p. 123007, Dec 2015.

Results

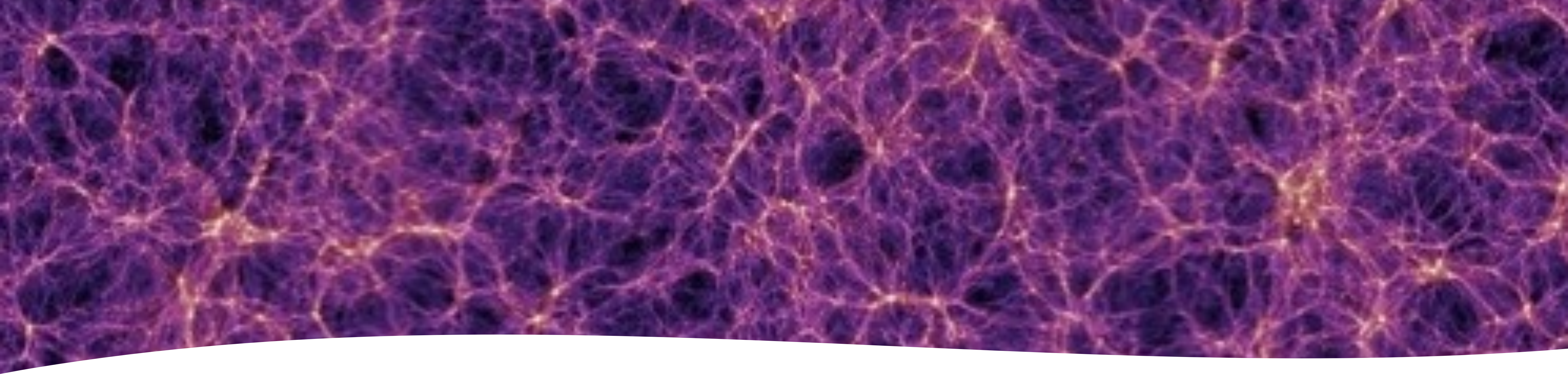
- We computed the bispectrum and compare it with the Tree level bispectrum,, where we found a maximum difference por relativistic contributions with PNG at large scales of 16%

- This calculations were made in Pylians*

- The difference at high k's (i.e. small scales) are because we used just one realization, further tests are needed.



*F. Villaescusa-Navarro, Pylians:Python libraries for the analysis of numerical simulations,2018. ascl: 1811.008



Summary and future work

- Can be added relativistic corrections at initial conditions with Newtonian evolution.
- The non-Gaussianity and the relativistic corrections are observable at high order statistics as the bispectrum.
- There are different triangulations in the bispectrum that are need to be take into account.
- Look at the effects on simulations with larger sensitivity to identify physical effects.

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