Exploring the effects of primordial non-Gaussianity at galactic scales

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Based on 2209.15038

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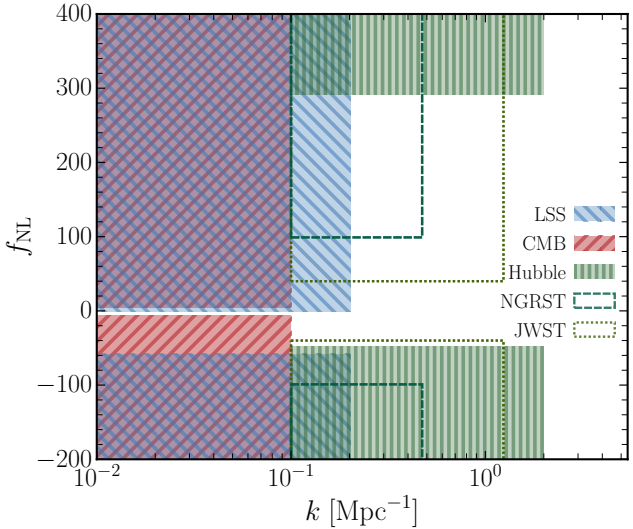
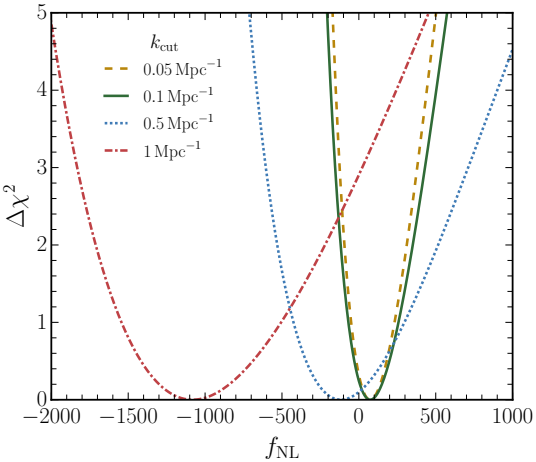
PNG on small scales: current status

propage PNG $\rightarrow$ test inflationary physics

$$\Phi(\mathbf{x}) = \Phi_G(\mathbf{x}) + f_{\rm NL}\left(\Phi_G^2(\mathbf{x}) - \langle\Phi_G^2\rangle\right) . \quad (1)$$



PNG on small scales



Sabti 2009.01245

- Study UV galaxy luminosity function of Hubble telescope
- A detection at 1.7 σ.
  Most likely a bump in the data, but who knows... $\rightarrow$ JWST, NGRST
- Using another model of dust extinction, no more detection

Scale dependant PNG

Several models of strongly scale dependant PNG

Beyond slow roll

- Khoury 0811.3633: time-dependant sound speed
- Riotto 1009.3020: scalar field with abrupt change of mass
- Byrnes 1108.2708: curvaton-self interactions

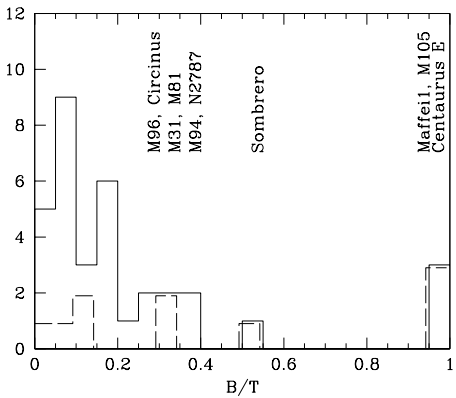
- Can parametrize with $n_{f_{NL}} \equiv \frac{d \ln f_{NL}}{d \ln k}$
- Planck 1905.05697: constraints on running NG $\rightarrow$ compatible with 0.

Large PNG on scales smaller than $k_{CMB/LSS} \equiv k_{\text{cut}} = \mathcal{O}(0.1)$ Mpc^{-1}

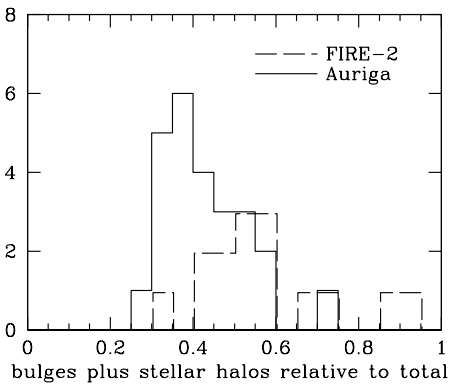
$$B_\Phi = f_{NL} P_\Phi(k_1) P_\Phi(k_2) \Theta(k_i - k_{\text{cut}}) + 5 \text{ perm.} \quad (2)$$

Peebles 2005.07588: study bulge to total luminosity of galaxies

Observations

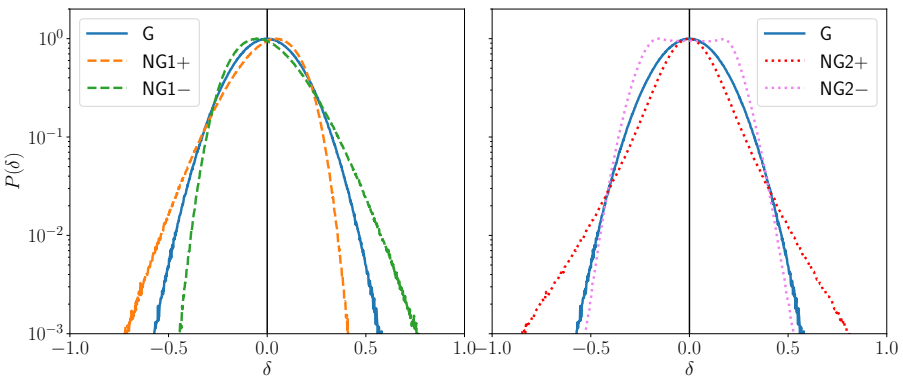


Simulations



- "Hot orbit problem" naturally solved if galaxies have a calmer environment, and form through a calmer history.
- Baryon feedback play a crucial role here
- Initial condition modification has also been tested: *genetic modification* (Stopyra 2006.01841), splicing (Cadiou 2107.03407), modify initial angular momentum (Cadiou 2206.11913).

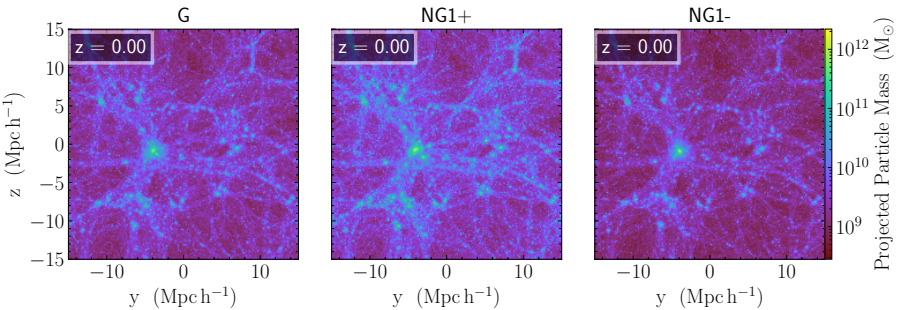
Numerical setup



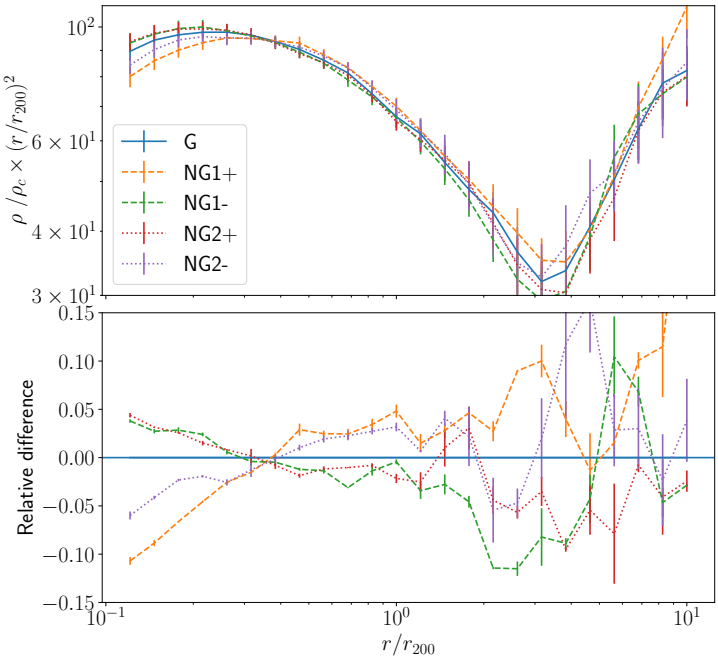
- Toy models: NG of $f_{NL} = \pm\mathcal{O}(1000)$.
- Dark Matter Only simulations[a]
- Grid : 512^3, BoxSize : 30 Mpc/h, softening length 0.5 kpc/h.
- Total mass in the box: $2.3 \times 10^{15} M_\odot$, mass of DM particle $1.7 \times 10^7 M_\odot$

[a] Work with `Gadget4` (`https://wwwmpa.mpa-garching.mpg.de/gadget4/`) and `Monofonic` (`https://bitbucket.org/ohahn/monofonic/src`).

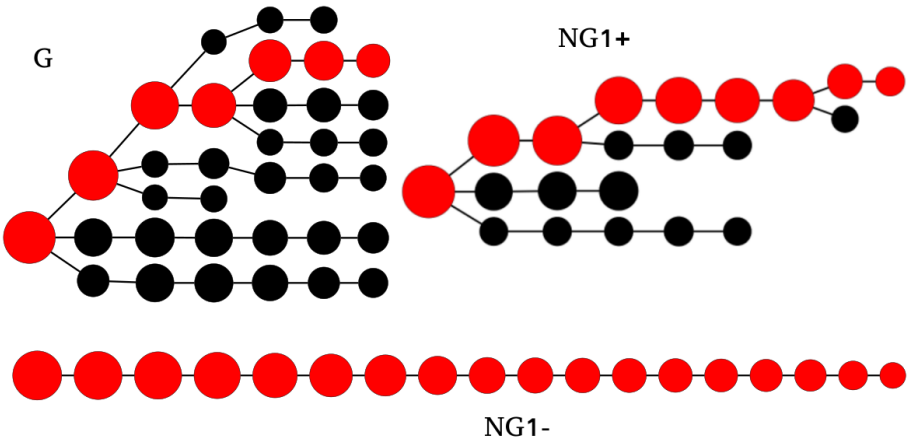
Halos in quieter environments



Density profiles



Merging history



Simulation	G	NG1+	NG1-	NG2+	NG2-
$z_{1/2}$	0.64	0.59	0.67	0.64	0.62
MC [%]	78	52	71	61	108

Planar subhalos?

- Take the 11 more massive subhalos of the 100 more massive halos ($M_h \in 1.6 \times 10^{14}$ to $1.1 \times 10^{12}\, M_\odot$)
- inertia tensor:

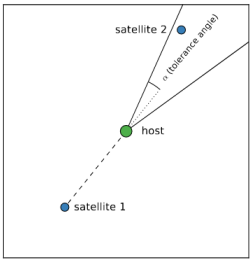
$$I_{ij} = \sum_{n=1}^{N} x_{n,i} x_{n,j} \tag{3}$$

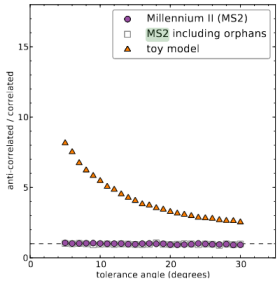
- eigenvalue $\equiv a^2, b^2, c^2$.
- For the MW, 'Vast Polar Structure' (VPOS)=rotating plane of satellite galaxies, observations: $c/a = 0.182$ (Pawlowski 1204.5176).
- Gaia proper motion: 50% to 75% of the satellites within the VPOS are orbiting around that structure (Li 2104.03974)
- Difficult to account for in traditional N-body, see however Sawala 2205.02860

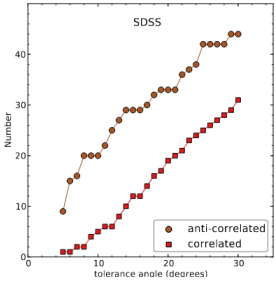
Simulation	G	NG1+	NG1-	NG2+	NG2-
c/a	0.84	0.93	0.74	0.72	0.86

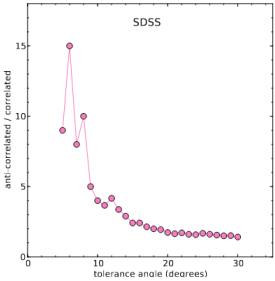
Correlated subhalos?

A classical test of the litterature (Ibata 1407.8178): dwarf satellite galaxies are aligned in thin and kinematically coherent planar structures



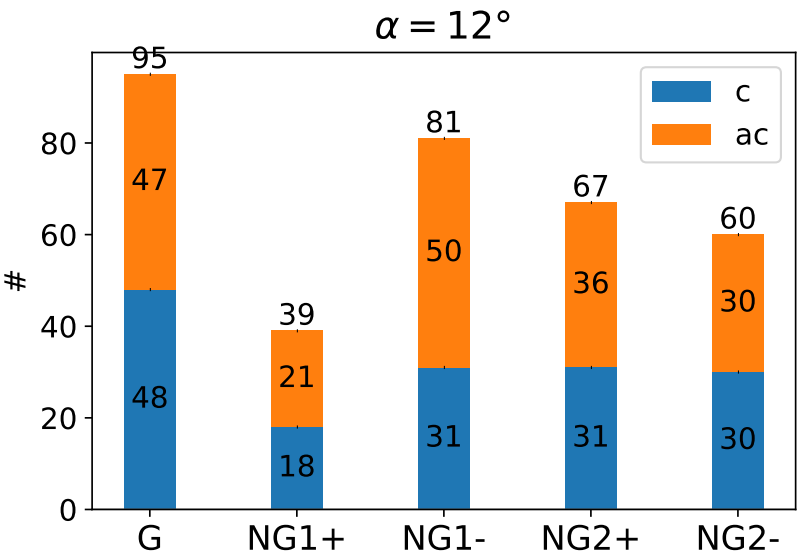




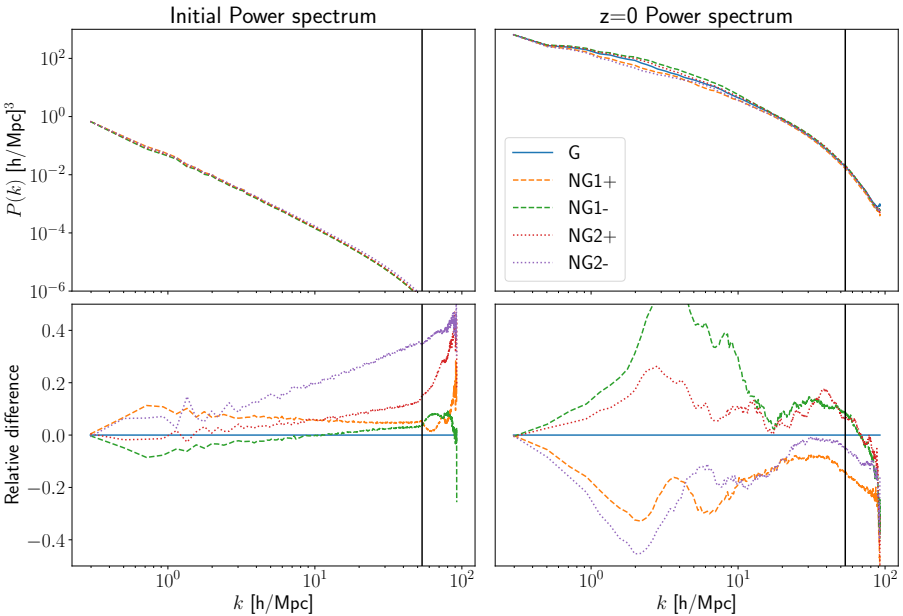


Correlated subhalos?

Simulation	G	NG1+	NG1-	NG2+	NG2-
AC/C, 12 degrees	1.1	1.2	1.7	1.4	1.1



Funny bump in the power spectra at $k_{\rm NL} \sim 3\ h/{\rm Mpc}$

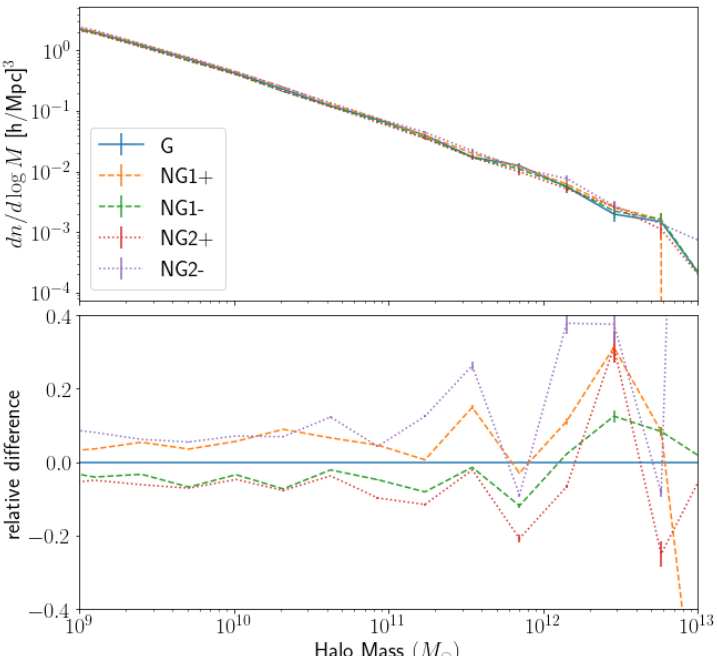


Conclusions

- Explored the effect of large PNG on small scales: Possible to have a quieter merging history leading to more planar and coherent structures (model NG1-)
- The whole (small scales) cosmology needs to be revisited with NG1-: negative (large) f_{NL}.
- Need to back up these explorations with more simulations: zoom on one galaxy in a cosmological background, effects of baryons...
- Refine our templates of PNG: low pass filter, power laws, inflationary sounds models (Riotto 1009.3020).
- Link/degeneracy with feedback parameters and/or inflationary parameters $\rightarrow$ impact of fundamental physics to galaxies.
- Easy to extend to WDM or Effective Theory of DM (α, β, γ parametrization of Murgia 1704.07838 already implemented by us in `MonofonIC`.)
- Funny bump in the power spectra at $k_{\mathrm{NL}} \sim 3\ h/\mathrm{Mpc}$: smoking-gun for NG without scale-dependant bias or bispectrum?

Thank you for your attention

Halo Mass Function



Correlated subhalos?

Simulation	G	NG1+	NG1-	NG2+	NG2-
AC/C, $\alpha = 12$ deg	1.1	1.2	1.7	1.4	1.1
AC/C, $\alpha = 25$ deg	0.95	1.2	1.6	1.2	1.1