Probing Primordial non-Gaussianity with SKA Galaxy Surveys

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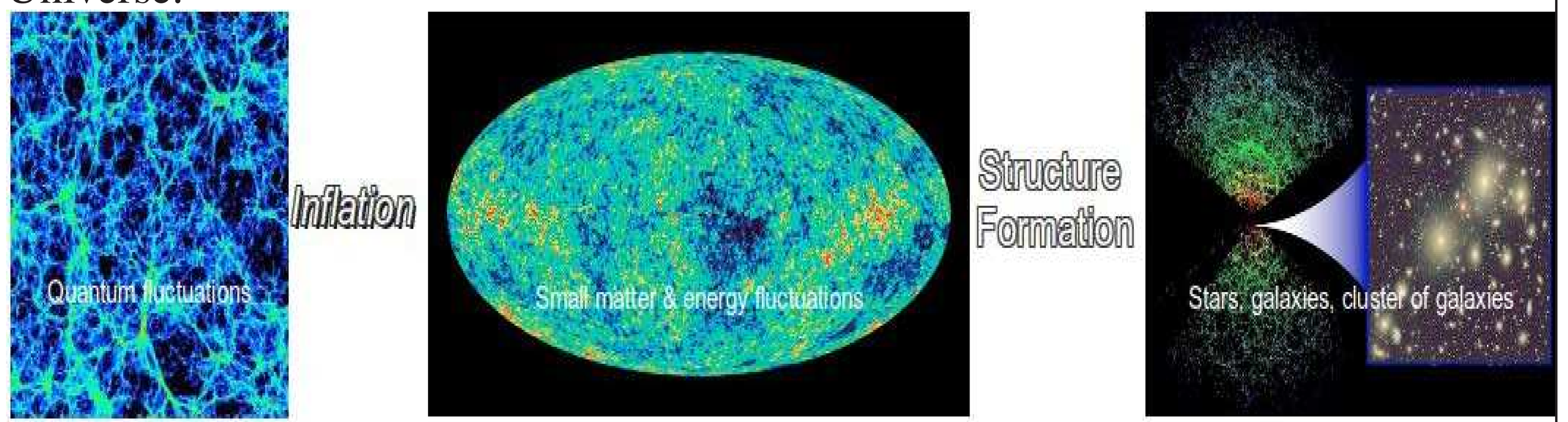
SKA AFRICA SQUARE KILOMETRE ARRAY

Introduction

One of the key goals of experimental cosmology today is to establish the statistical nature of the primordial cosmological perturbations. According to single-field, slow-roll inflation, these perturbations are nearly Gaussian. Therefore, any detection of primordial non-Gaussianity (NG) will signify a deviation from the simplest inflation model and give birth to new physics in the very early Universe.



A simple model of NG is local non-Gaussianity. It is defined as the Taylor expansion of the curvature perturbation around the Gaussian part,

$$\Phi_{NG} = \Phi + f_{NL}(\Phi^2 - \langle\Phi^2\rangle).$$

There are different methods to constrain NG:

- ◇ By measuring the anisotropies in the cosmic microwave background (CMB). Plank satellite recent results gives $f_{NL} = 2.7 \pm 5.8$.
- ◇ NG leaves imprints on galaxy correlations on large scales, which can be measured in future large-volume optical/IR surveys like EUCLID.
- ◇ Future HI surveys (as with SKA) will map billions of galaxies and may be a more powerful probe of NG than the CMB.

The primordial NG signal in the galaxy distribution is stronger on large scales, therefore it is not contaminated by non-linear effects of structure formation. Structure formation on large cosmological scales is also sensitive to the nature of dark energy. This, however, could be degenerate with the primordial non-Gausianity [1]. We are going to illustrate the mutual effect on LSS due to DE perturbations and primordial NG.

Dynamical Dark Energy

The perturbed equations for general two perturbed uncoupled fluids (Dark Matter (DM) +Dynamical Dark Energy (DDE)) are [3]:

$$\Phi' = -\frac{\Phi}{a} + \frac{3}{2}(h)\left[\Omega_m u_m + (1+w)\Omega_x u_x\right], \quad (1)$$

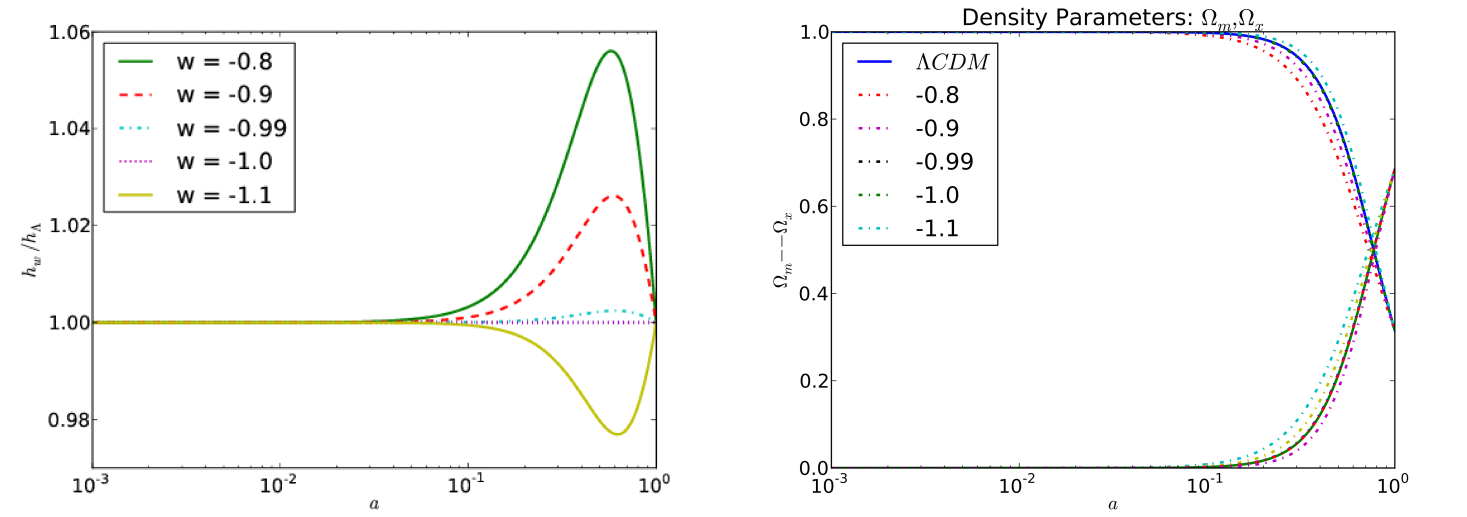
$$u_m' = \frac{1}{a}\left[\frac{1}{ah}\Phi - u_m\right], \quad (2)$$

$$\Delta_m' = \frac{\kappa^2}{a^2 h}u_m + \frac{9}{2}h(1+w)\Omega_x\left[u_m - u_x\right], \quad (3)$$

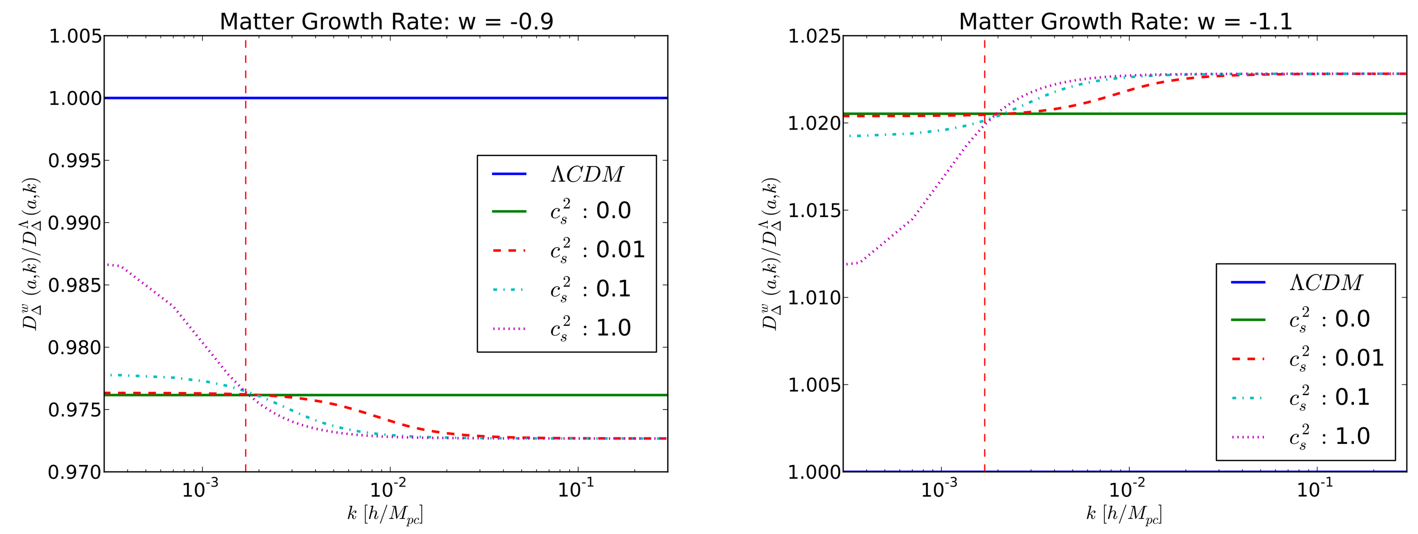
$$u_x' = -\frac{1}{a}u_x + \frac{1}{a^2 h}\left[\Phi - \frac{c_s^2}{1+w}\Delta_x\right], \quad (4)$$

$$\Delta_x' = 3w\frac{1}{a}\Delta_x + \frac{\kappa^2}{a^2 h}(1+w)u_x + \frac{9}{2}h(1+w)(1-\Omega_x)[u_x - u_m]. \quad (5)$$

where $\kappa = k/H_0$, $\Delta_{m,x}$ is the comoving overdensity of DM and DDE respectively and $u_{m,x}$ is the peculiar velocity of DM and DDE.



We considered many different models for DDE, including quintessence, k-essence and constant and variable (CPL) equation of state (EoS). The above figures illustrate the background behaviour (Hubble and density rate) for different values of constant w (EoS). It is clear that on late time, the accelerating behaviour changes for different models.



As show in the figures, the the scale-dependence due to DE perturbation is clear on large scales in the relative growth rate, but with very small amplitude. The range of the scale-dependence changes with changing c_s^2 for the different w cases. The difference between the different c_s^2 cases is due to Jeans instability.

Galaxy Power Spectrum

On large scales, one could phenomenologically relate the galaxy distribution and the dark matter using,

$$\Delta_g = b\Delta_m, \quad or \quad P_g = b^2 P_m,$$

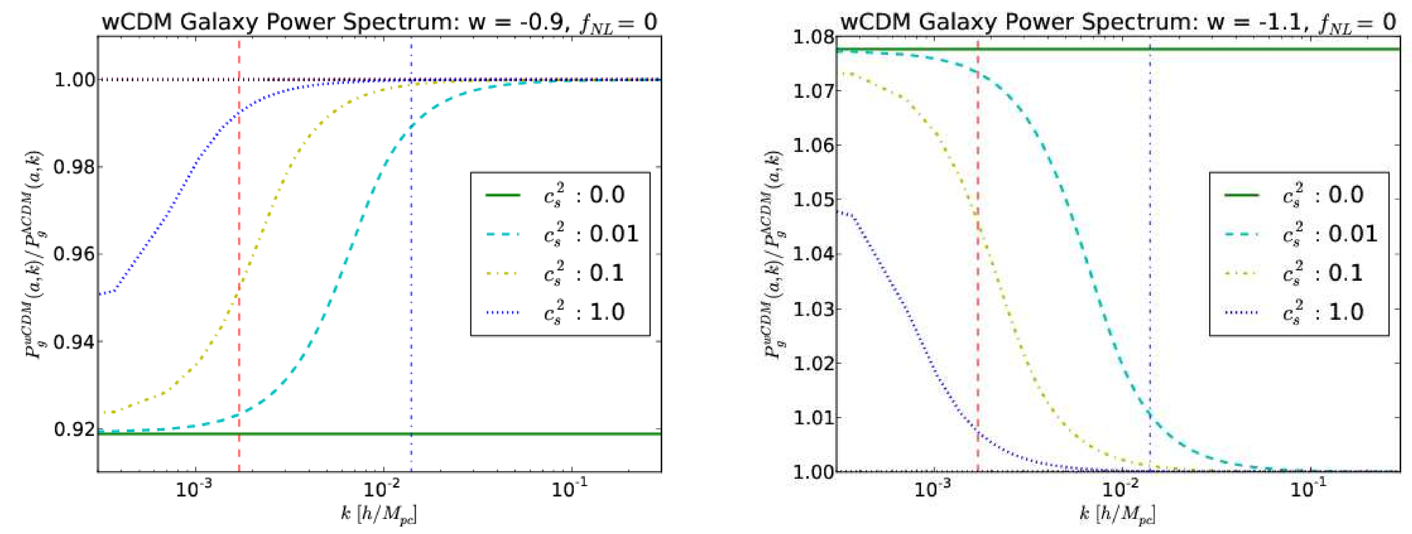
where b is the linear bias parameter and $\Delta_m = \delta_m - 3hu_m$.

For Gaussian perturbations, b = b(a). Primordial NG induces a scale-dependent correlation to the bias [2, 3],

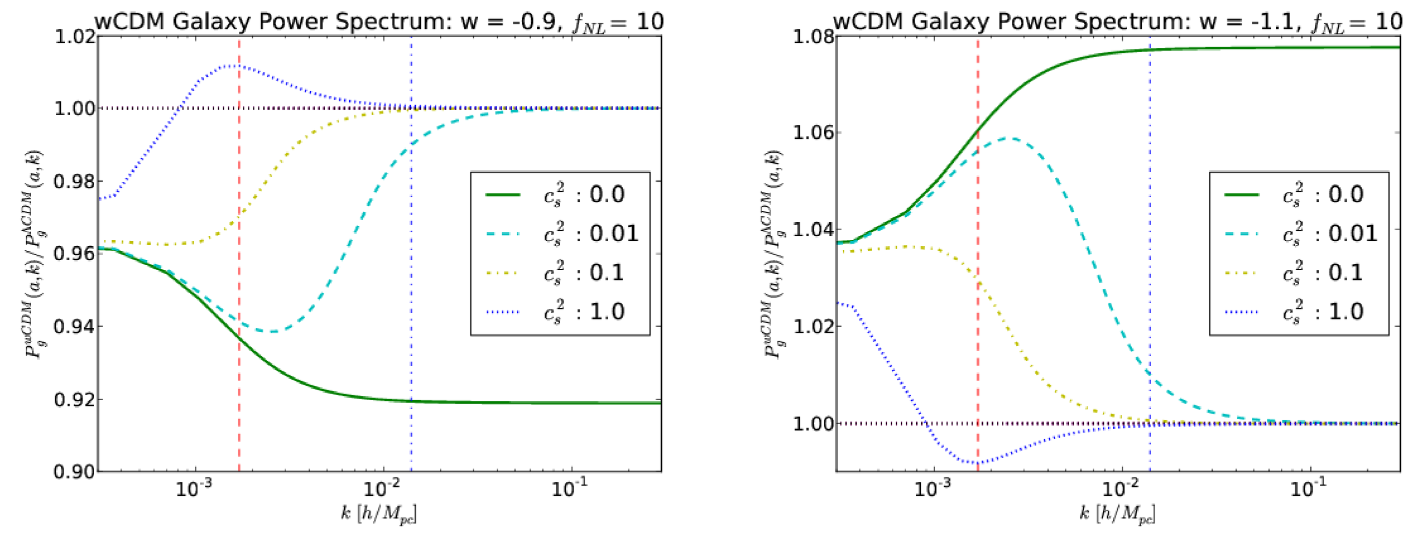
$$b \rightarrow b_{NG} = b + f_{NL}(b-1)\frac{3\delta_c \Omega_{m0} H_0^2}{k^2 T(k)\mu(k) D_m(k,a)},$$

where δ_c is the critical density for collapse ($\delta_c \simeq 1.68$) and $\mu(k)$ is a scale-dependent function, due to DDE clustering and could be calculated from the initial conditions[3].

Current Results



The Gaussian relative galaxy power spectrum is shown in the above figures for two different values of w. The scale-dependence due to the DDE clustering is clear on large scales and the amplitude changes within different models.



As shown is the figures, the relative galaxy power spectrum with positive $f_{NL} = 10$ amplitude has scale enhancement due to DDE perturbations. The amplitude changes for different w cases and within different c_S^2.

Future Work

For future work, we are going to calculate the Bispectrum for different primordial NG models within different dynamical dark energy scenarios. Then, we are going to relate it to the observed quantity within SKA HI surveys. This could give us an enhanced constraint on NG amplitude f_{NL} compared with CMB results.

References

[1] C. Carbone, O. Mena, L. Verde, *JCAP*. . **07**, 1475-7516 (2010).

[2] M. Bruni, R. Crittenden, K. Koyama, R. Maartens, C. Pitrou, D. Wands, *Phys. Rev. D*. **85**, 041301(R) (2012).

[3] M. Hashim, R. Maartens, D. Bertacca, *In Preparation....*