Large scale structure to measure Primordial non Gaussianity

- Primordial non Gaussianity (PNG)
- Bias
- scale dependent bias and PNG

    - T. Giannantonio and W. Percival, 1312.5154
    - N. Dalal et al., 0710.4560
    - J.A. Peacock astro-ph/0309240 (section 6)
    - T. Padmanabhan, structure formation in the universe,
    - T. Giannantonio, C. Porciani et al. 2011

Jean-Marc Le Goff

cosmo-club, may 2014

Primordial non Gaussianity

PNG

- Gaussianity: at primordial time the potential is a Gaussian field
- then the CMB temperature is also a Gaussian field
- late time matter field is non Gaussian due to nonlinear evolution, this is not PNG

PNG probe the early universe

- Non Gaussianity may falsify models

	Canonical inflation	Curvaton scenario	Ekpyrotic universe
Geometry	Flat √ WMAP	Flat √ WMAP	Flat √ WMAP
Spectrum of perturbations	Nearly scale-invariant √ WMAP	Nearly scale-invariant √ WMAP	Nearly scale-invariant √ WMAP
Statistics of perturbations	Nearly Gaussian	Non-Gaussian	Non-Gaussian

Cristiano Porciani

- Planck results on PNG ?
- what about B modes ?

PNG and n-point statistics

- Wick-Esserlis theorem : if $(x_1, \ldots, x_{2n})$ is a zero mean multivariate normal random vector, then

$$E[x_1 x_2 \cdots x_{2n-1}] = 0$$

$$E[x_1 x_2 \cdots x_{2n}] = \prod E[x_i x_j]$$

- for a Gaussian field :

  (2n-1)point ξ are zero

  2n-point ξ can be written in terms of the 2-point ξ

- spectrum corresponds to 2 pt ξ

  bi-spectrum corresponds to 3 pt ξ

- non-zero bi-spectrum => PNG

A simple PNG model

- Most of the local models can be reduced to

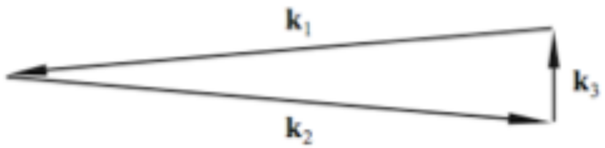
$$\Phi(x) = \phi(x) + f_{NL}\left[\phi^2(x) - \langle\phi^2\rangle\right]$$

where ϕ is a Gaussian field and f_{NL} a real number and this is at some primordial times

Note: $\phi \sim 10^{-5}$ so PNG correction $\sim 10^{-5}\, f_{NL}$

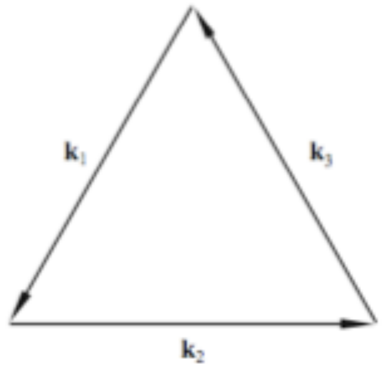
shape of PNG

- bi-spectrum $P(k_1,k_2,k_3)$



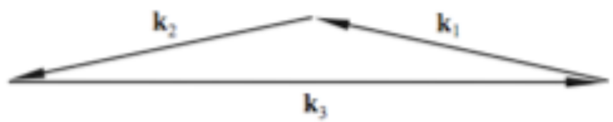
Squeezed (local)

multi-field inflation, curvaton, ekpyrotic



Equilateral

non-canonical kinetic terms, DBI, ghost inflation



Folded

modification of vacuum state

observational constraints

- WMAP 7yr bispectrum :

  $-10 < f_{NL} < 74$

  (Komatsu et al., 2010)

- PlancK bispectrum: f_{NL} at 68% CL:

local	2.7 +- 5.8
equilateral	42 +- 75
orthogonal	25 +- 39

(Ade et al., 2013, 1303.5084)

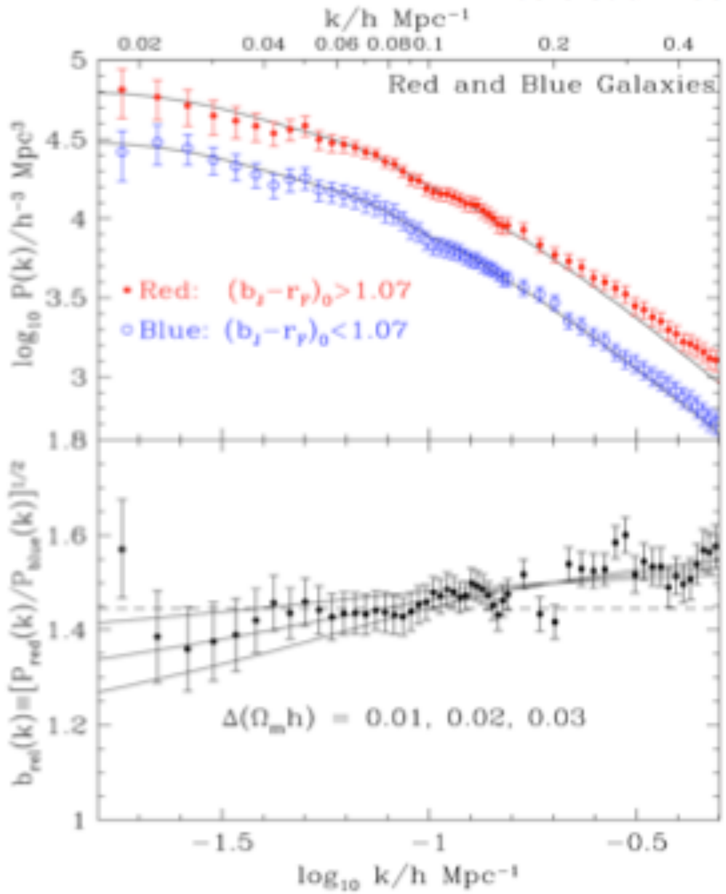
Bias

what is bias

- We measure tracers of matter

  $P_X(k) = b^2(k)\, P(k)$
- on large scale b expected to be independent of k
- bias exists : blue and red galaxies have different biases and the ratio depends on k
- bias is local if $\delta_X(x_0)$ depends only on $\delta(x_0)$
- non-local ⇔ scale dependent

Cole et al. 2005



ξ for high density regions

- field m : δ averaged over box of a given volume
- corr fct of m: $\xi(r)$
- volumes such that m > $\nu\, \sigma_m$ -> corr. fct ξ_ν
- if ν >> 1 and $\xi(r) << \xi(0)$ (r large)

$$\xi_\nu(r) \approx \exp\left[\frac{\nu^2}{\sigma_m^2}\xi(r)\right] - 1$$

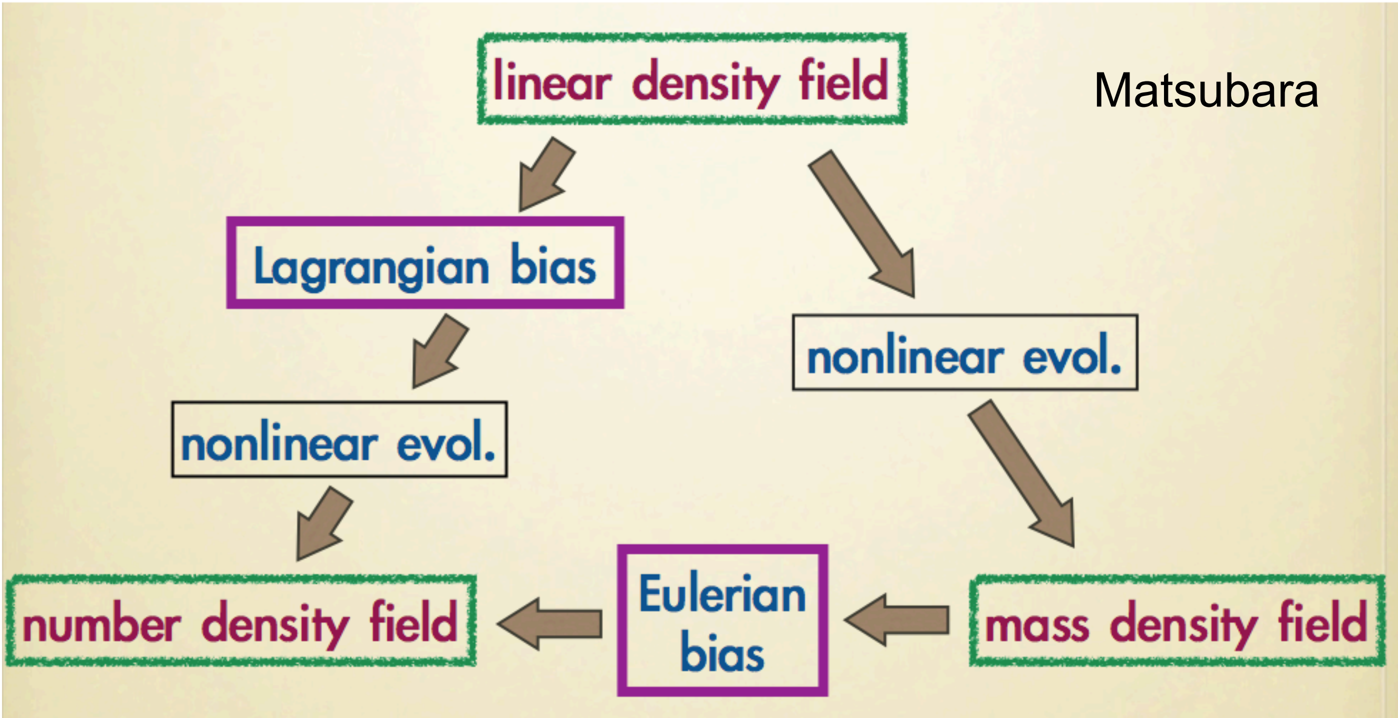
- if [ ] << 1: $\xi_\nu(r) \approx \frac{\nu^2}{\sigma_m^2}\xi(r) = b^2\xi(r)$ bias ~ ν

else: even more bias (but not linear)

high density regions more correlated than the background

T. Padmanabhan section 5.7

Lagrangian and Eulerian biases



- there are models of Lagrangian bias only
- at first order: $b = 1+b_L$

Lagrangian bias

- Collapse to a virialized object is deemed to have occurred where m=<δ> for a box containing mass M reaches δ_c = 1.686 (spherical collapse in EdS, Ω_m=1)
- if we add a constant shift ε over a large region

  then needs only to reach $\delta_c - \varepsilon$

  the number density f -> f $-(df/d\delta_c)\varepsilon$

- Lagrangian bias such that df / f = $b_L\ \varepsilon$

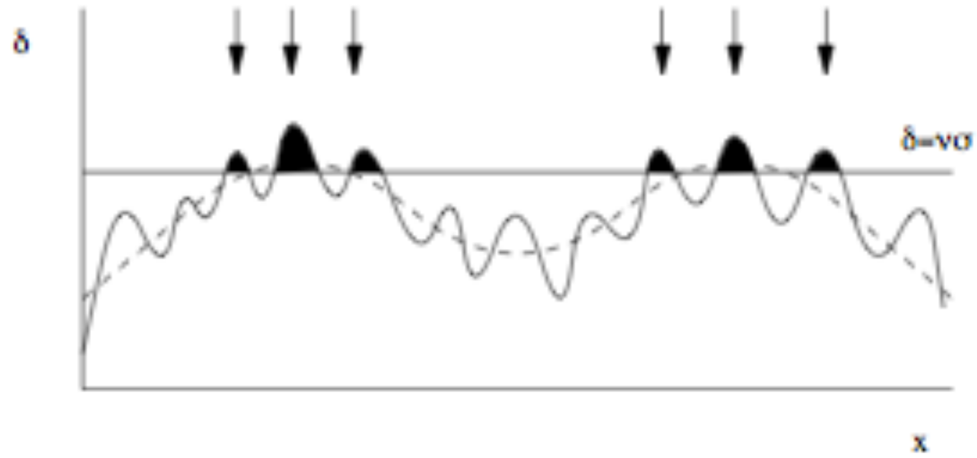
=> $$b_L = -\frac{d\ln f}{d\delta_c}$$

overall Eulerian bias

- in addition the large scale disturbances will move haloes closer together where ε is large -> density contrast $1+\varepsilon$ the overall Eulerian bias ($\delta_{halo} = b\,\varepsilon$)

$$b = 1 + b_L = 1 - \frac{d \ln f}{d\delta_c}$$

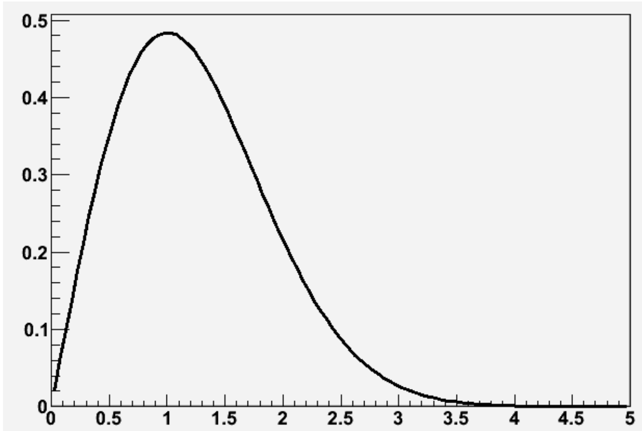
- separate between small scales and large scale – which are identified with ε



Press-Schechter mass function

- Collapse to a virialized object is deemed to have occurred where m=<δ> for a box containing mass M reaches $\delta_c = 1.686$
- f(M) : number density of haloes $\int Mf(M)dM = \rho_0$
- fraction of the mass in unit range in ln (M) :

$$M^2 f(M)/\rho_0 = \sqrt{\frac{2}{\pi}}\nu \exp\left(-\frac{\nu^2}{2}\right)$$



- $\nu = \delta_c / \sigma_m$
- max at $\nu = 1$ => M* haloes

$$b(\nu) = 1 - \frac{d\ln f}{d\delta_c} = 1 + \frac{\nu^2 - 1}{\delta_c}$$

high-peak bias

- $b > 1$ => $\nu = \delta_c / \sigma_m > 1$ => $\sigma_m < 1$

  => massive haloes ($M > M^*$)

  apply for clusters, not for galaxies
- galaxies with $\delta \gg \delta_c$ (and then $\nu > 1$) are formed first

  at high z galaxies are biased
- Then (if $\Omega_m = 1$) galaxies form for all $\delta > \delta_c$ and the bias vanishes
- However, at lower z $\Omega_m < 1$ and galaxy stop forming and the bias remains
- if galaxy formed at z_f bias relative to matter reduces : $b(\nu) = 1 + \frac{D(z_f)}{D(z)} \times \frac{\nu^2 - 1}{\delta_c}$