Non-Gaussian statistics for halos and voids

Marcello Musso
ICTP, Trieste

In collaboration with G. D'Amico, J. Noreña and A. Paranjape
(astro-ph/1005.1203)

Lecce, 4th UniverseNet School, October 2010

Motivations

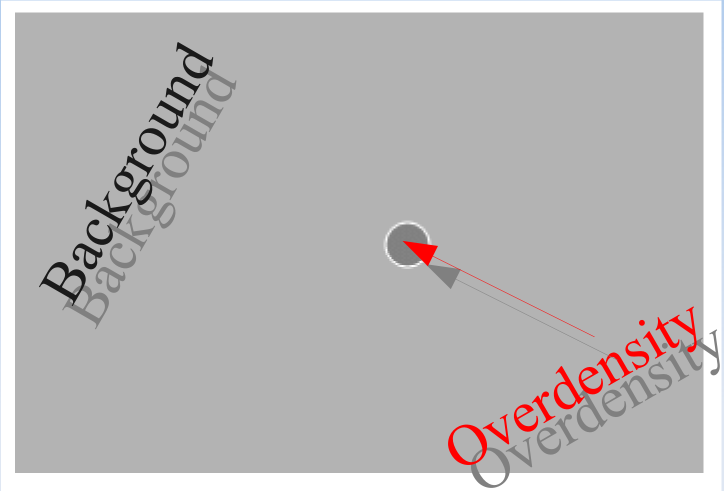
NG in Large Scale Structure is interesting:

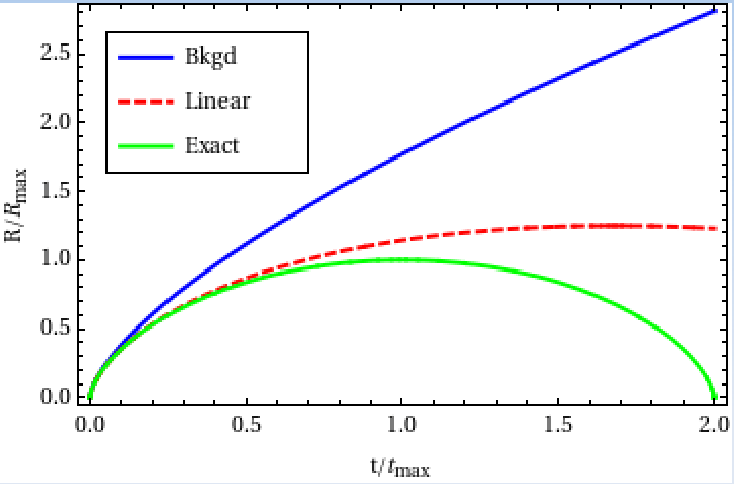
- Competitive constraints on primordial NG from LSS
- Cluster number counts probe smaller scales than CMB (important e.g. for running f_{NL})

Theoretical understanding is needed because:

- Simulations are very heavy
- Not clear how GR can be neglected on Gpc scales
- QCDM? … ?
- Low profile approach: find motivated fits to simulations

Spherical collapse





$$\delta(t) \equiv \frac{\rho(t)}{\bar{\rho}(t)} - 1 \quad ; \quad \delta_{lin}(t) = \frac{3}{20}\left(\frac{6\pi t}{t_{max}}\right)^{3/2}$$

Real objects don't collapse to a point but virialize

$t_{vir} \sim 2\, t_{max}$ $\Rightarrow$ $\delta_{lin}(t_{vir}) \simeq 1.68 \equiv \delta_c$

Mild dependence of δ_c on cosmology

Scale Dependent Smoothing

A cluster forms in x when $\delta_{lin}(z,x) > \delta_c$

How large? It could be part of a more massive object...
Need the LARGEST volume

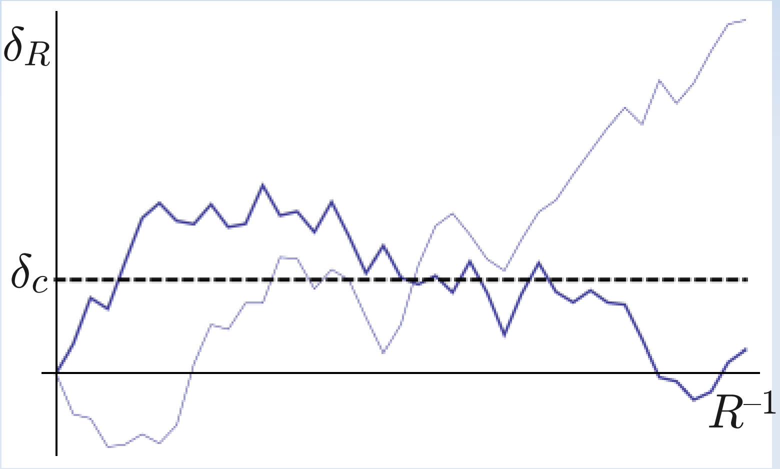
Define the *smoothed* density field:

$$\delta_R(z,x) \equiv \frac{1}{V} \int \mathrm{d}^3y \, W\left(\frac{y-x}{R}\right) \delta_{lin}(z,y)$$

The largest R with $\delta_R(x) > \delta_c$
is the cluster size (and mass $M \propto R^3$)

Excursion Set Theory

Spherical collapse + Smoothing =
Random walk with absorbing barrier



$$P(\delta) = \frac{e^{-\delta^2/2\sigma} - e^{-(2\delta_c-\delta)^2/2\sigma}}{\sqrt{2\pi\sigma}}$$

- Abundance $n(M)$ $\longleftrightarrow$ "first crossing rate" at "time" $\sigma(M)$
- For a Gaussian process: $n(M) \propto \nu e^{-\nu^2/2}$ $(\nu \equiv \delta_c/\sigma)$

Press & Schechter (1974); Bond *et al.* (1990)

Non-Gaussian Corrections

- Corrections to what?? Plenty of 's and 's...

  Dirty way out: just compute the NG/G ratio

Matarrese, Verde & Jimenez (2000)
LoVerde, Miller, Shandera & Verde (2008)

- Extra difficulties: filter effects and multi-scale correlations

Maggiore & Riotto (2009)

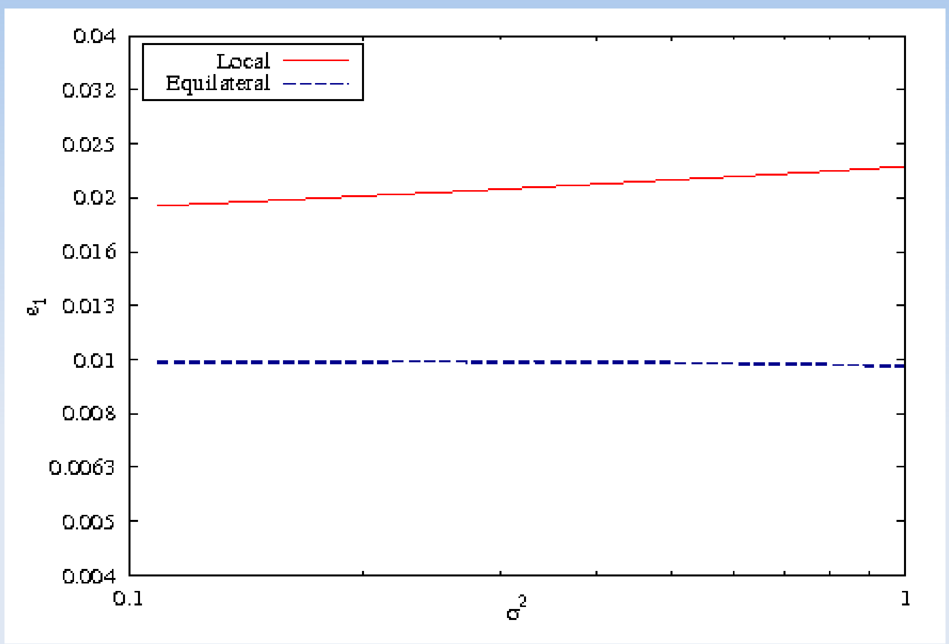
- Careful with perturbations!!

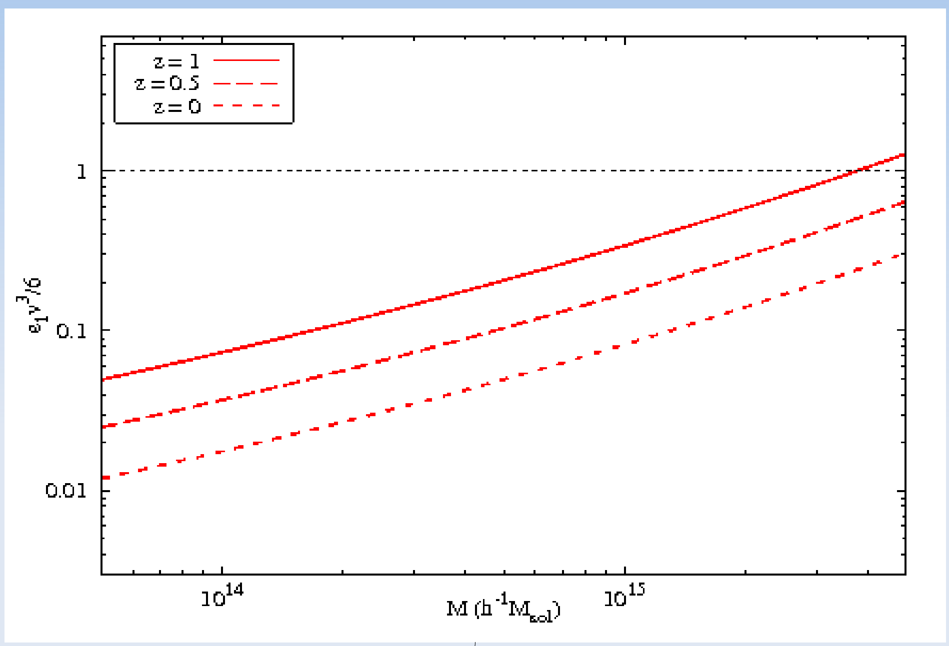
  Reduced moments (~ scale independent): $\epsilon_i \equiv \frac{\langle \delta_R^i \rangle}{\sigma_R^i} \ll 1$

  NG corrections $\sim \epsilon_3 \, \nu^3$, $\epsilon_3 \, \nu$, etc...; but $\nu \gg 1$ on large scales!

D'Amico, Noreña, M.M. & Paranjape (2010)

Non-Gaussian Corrections





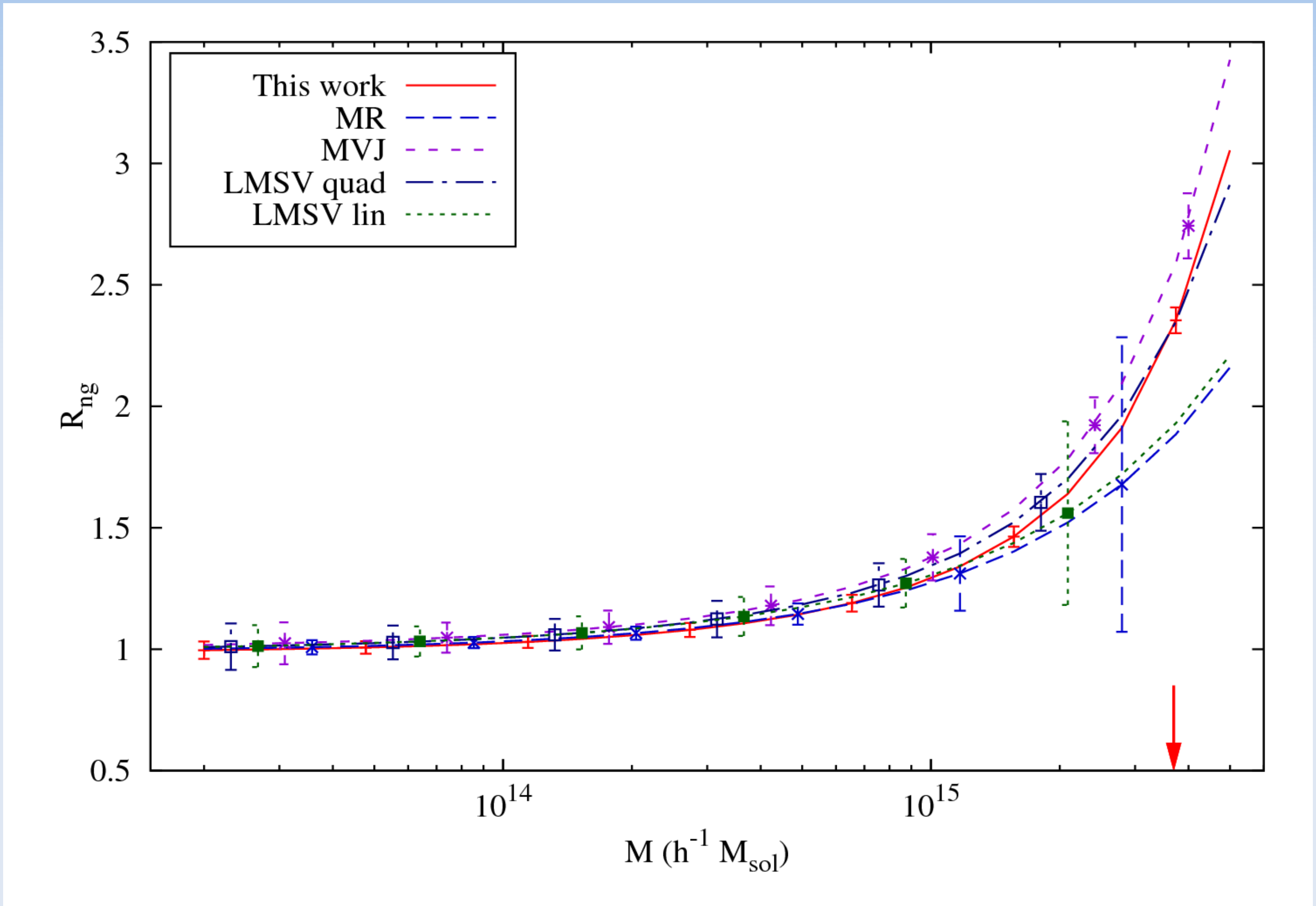
Partial resummation:

$$n(M) \propto \nu \exp\left[-\frac{\nu^2}{2} + \frac{\epsilon_3}{6}\nu^3 + \dots\right]\left(1 + \#\epsilon_3\nu + \dots\right)$$

Higher orders + filter effects

D'Amico, Noreña, M.M. & Paranjape (2010)

Non-Gaussian Corrections



D'Amico, Noreña, M.M. & Paranjape (2010)

Mass Function for Voids

Same logic but with 2 barriers: δ_c and $\delta_v = -2.7$ (shell crossing).

Compute the rate at δ_v:

$$n_G(M) \propto \sum_{n=-\infty}^{+\infty} \nu_n e^{-\nu_n^2/2} \qquad \nu_n \equiv \frac{-\delta_v - 2n(\delta_c - \delta_v)}{\sigma}$$

Sheth & van de Weygaert (2009)

Issue with NG: need to resum more and more ϵ_i's for large n

Extreme tails (highly NG) of an infinite number of PDF's.

Hopefully suppressed but... work in progress...

Conclusions

- Non-perturbative treatment of dangerous NG corrections: reliable at high(er) redshift and large(r) masses
- Estimate of the theoretical uncertainty (scale dependent errors) of the various approaches

Open problems / work in progress :

- Issues accounting for filter effects and uncertainties on the barrier (dominant error)
- Spatial correlations between random walks
- Application to voids (coming soon...)
- Check against NG simulations