1 Intro

We have an underlying dark matter density field. What is the relationship between the number density of dark matter halos (of a given mass) and that density field? We might expect that these are proportional,

$$\frac{n_h}{\bar{n_h}} = \frac{\rho}{\bar{\rho}} \tag{1}$$

or in other words that halos are a poisson sampling of the underlying density field.

If this were the case, dark matter halos would be an unbiased tracer of the dark matter. And if galaxies formed in dark matter halos in an unbiased way, they would also be an unbisaed tracer of the DM.

But, if we look at galaxy surveys we find that there is a massive range of galaxy density. There are incredibly overdense regions and similarly incredibly underdense regions, even on large scales. There are two options here,

1. The underlying DM field is also that nonlinear[1]
2. Galaxies are not tracing the DM

The second of those is right (how do we know? N-body sims and lensing?).

2 The cause of bias: Thresholding

Halos can only form where the underlying matter density reaches a critical value. In an EdS universe (matter dominated) all overdensities eventually collapse. But, the more overdense ones collapse first. This is the visualization with the peaks and the lowering limit.

3 Bias definition

The bias $b(M, z)$ is a measure of the (what exactly, in English)

$$\frac{n_h}{\bar{n_h}} = (1 + b(M, z))\delta \tag{2}$$

In the extended Press Schechter formalism we can derive how bias depends on peak height etc.

$$b(M, z) = 1 + \left(\frac{\nu^2 - 1}{\delta_c}\right) \tag{3}$$

where $\delta_c(z) \approx 1.686$ and doesn't change much with redshift (I think this is the overdensity for collapse in EPS?) and $\nu = \delta(z)/\sigma(M, z)$ is the peak-height.

[1] remember that nonlinear means $\delta = \frac{\rho}{\bar{\rho}} > 1$

4 Halo assembly bias

5 See

- VDB Lecture: Halo bias
- VDB Lecture: Spherical collapse
- RW Lecture: Halo bias
- AK: Cluster formation