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Measurement of dark matter halo concentrations using a bayesian approach

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ABSTRACT
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1 INTRODUCTION

(Navarro et al. 1997)

2 BASICS OF DARK MATTER HALOS AND THE NFW PROFILE

The Navarro-Frenk-White density profile can be written as

$$\rho(r) = \frac{\rho_c \delta_c}{r/R_s(1+r/R_s)^2}, \tag{1}$$

where $\rho_c \equiv 3H^2/8\pi G$ is the Universe critical density, δ_c is the halo dimensionless characteristic density. is a normalization constant and R_s is known as the scale radius, the radius that marks the transition between the two power law behaviour in the $\rho \propto r^{-1}$ for $r < R_s$ and $\rho \propto r^{-2}$ for $r > R_s$.

One can define the scale radius as a fraction of the virial radius, R_{vir},

$$R_s = R_{vir}/c, \tag{2}$$

where $c > 1$ is known as the concentration of the halo.

Taking the virial radius as the radius that encloses 200 times the critical density, the concentration and the characteristic density are related by

$$\delta_c = \frac{200}{3}\frac{c^3}{[\ln(1+c) - c/(1+c)]}. \tag{3}$$

Therefore, for a given value of the overdensity that defines a halo, the density profile has only one free parameter: the concentration.

The total mass enclosed within a radius r can be computed to be:

$$M(<r) = 4\pi\rho_c\delta_c R_s^3 \left[\ln\left(\frac{R_s+r}{r}\right) - \frac{r}{R_s+r}\right]. \tag{4}$$

[H]

Figure 1. FIXME: Mass profile of a halo

If we now define dimensionless variables $x \equiv r/R_{\rm vir}$ and $m \equiv M(<r)/M_{\rm vir}$...

profile can be normalized respect to the virial mass and written in function of the normalized radius respect to the virial radius $r = R/R_{vir}$ and the concentration c

$$m_{\rm NFW}(r; c) = A\left[\log(1+rc) - \left(\frac{rc}{rc+1}\right)\right) \tag{5}$$

Where

$$A = \left[\log(1+c) - \left(\frac{c}{c+1}\right)\right]^{-1} \tag{6}$$

3 BAYESIAN METHOD

In order to obtain a mass profile for each halo in funcion of the radius, the center of each halo must be calculated. However the center of mass will not give an accurate position for the center because some haloes are highly irregular, is more convenient to take the gravitational potential for each particle

$$\phi(\boldsymbol{R}_n) = -\sum_{j\neq n}\frac{1}{\|\boldsymbol{R}_n - \boldsymbol{R}_j\|}$$

Take $\boldsymbol{R}_0 = \min(\phi(\boldsymbol{R}_n))$ as the center then define new coordinates $\boldsymbol{R}'_n = \boldsymbol{R}_0 - \boldsymbol{R}_n$, this $\boldsymbol{R}_0$ will be in the most relevant region for the dynamics of each halo. Organizing the $\{\boldsymbol{R}'_n\}$ in crescent order, the accumulated mass for each $\boldsymbol{R}'_n$ will be $M_n = nM$.

Then the virial radius is obtained and the particles that are beyond the virial radius are removed. After that both the mass and the radius get normalized respect to the mass and virial radius, we will call these new variables m_n and r_n. The last part of the process consists in fitting

[H]

Figure 2. FIXME: Test results

the normalized NFW mass profile to the m_n data using the Metropolis-Hastings algorithm to sample the Likelihood $\mathcal{L}(c) = \exp\left(-\chi^2(c)\right)$ where

$$\chi^2(c) = \sum_n |m_n - m_{nfw}(r_n, c)|^2$$

And taking the values of c where the Likelihood is maximum. Moreover, we can obtain a confidence interval for c doing an histogram of the random walk done by the Metropolis-Hastings Algorithm. Finally we compare this results with the values obtaned by BDM, since the number of halos obtained by FOF and BDM is different, each BDM halo gets related with the nearest halo in FOF. We compute two concentrations, one where the overdensity limit is $360\rho_{back}$ (like in BDMV) an other where the overdensity limit is $740\rho_{back}$ (like in BDMW).

4 MOCK DATA AND SIMULATIONS

5 RESULTS

5.1 Trial Problem with several Generated Halos

Several halos with known values of c were generated. These halos were then processed to determine the acurracy of this method. The number of particles and value of c for each halo were generated randomly.

5.2 Results from the simulations

5.3 What kind of implications (Low resolution simulations, other fitting algorithms)

6 DISCUSSION

7 CONCLUSIONS

REFERENCES

Navarro J. F., Frenk C. S., White S. D. M., 1997, ApJ, 490, 493