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Dark matter halo concentrations with a bayesian approach

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ABSTRACT

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1 INTRODUCTION

(Navarro et al. 1997)

2 BASIC PROPERTIES OF THE NFW DENSITY 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 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 $r > r_s$.

We define the virial radius of a halo, r_v, as the boundary of the spherical volume that encloses an average density of Δ_v times the critical density of the Universe. The corresponding mass M_v can be thus expressed as $M_v = \frac{4\pi}{3}\rho_c \Delta_v r_v^3$.

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

$$M(< r) = 4\pi\rho_c\delta_c r_s^3 \left[\ln\left(\frac{r_s + r}{r}\right) - \frac{r}{r_s + r}\right]. \tag{2}$$

We can now define the concentration of the halo as $c = r_v/r_s$, the dimensioless variable $x \equiv r/r_v$ and $m \equiv M(< r)/M_v$, which allows us to express the total enclosed mass within a dimensionless radius x as:

$$m(< x) = \frac{1}{A}\left[\ln\left(1 + xc\right) - \left(\frac{xc}{xc+1}\right)\right], \tag{3}$$

where

$$A = \left[\ln\left(1 + c\right) - \left(\frac{c}{c+1}\right)\right], \tag{4}$$

meaning that the concentration is the only free parameter to determine the density profile of the halo.

Figure 1. FIXME: Mass profile of a halo

3 A BAYESIAN APPROACH TO HALO FITTING

We proceed to find the value of the concentration parameter that best describes the simulation data, following the model in Eq. (3). We use the integrated mass profile because it allows us to use the data directly with the simulation without binning the particle positions and estimating a density.

We construct the integrated mass profile by ranking the particles by their increasing distance to the center of the halo. Once they are ranked, the total mass at a radius r_i, increases by m_p, where r_i is the position of the i-th particle and m_p is the mass of the computational particle. We define the center of the halo to be at the position of the particle with the lowest gravitational potential. In the process of building the mass profile we discard the particle at the center.

We stop the construction of the integrated mass profile once we arrive at an average density of $\Delta_h\rho_c$. This radius marks the virial radius and the virial mass. We divide the total mass enclosed mass M_i and the radii r_i by these values to obtaine the dimensionless variables x_i and m_i.

Using these positions and masses we define the following χ^2 function

$$\chi^2(c) = \sum_i [\log m_i - \log m(< x_i; c)]^2, \tag{5}$$

where $m(< x_i; c)$ corresponds to the values in Eq.(3) at $x = x_i$ and a given value of the concentration parameter c.

Finally we use a Metropolis-Hastings algorithm to sample the likelihood function distribution defined by $\mathcal{L}(c) = \exp(-\chi^2(c)/2)$ to find the optimum value of c and its associated uncertainty σ_c.

[H]

Figure 2. FIXME: Test results

4 NUMERICAL EXPERIMENTS

4.1 Mock 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.

4.2 Simulation Data

5 RESULTS

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).

5.1 Mock Halos

5.2 Simulation Dat

6 DISCUSSION

6.1 Comparison against other methods

6.2 Concentration as a function of halo mass

6.3 Implication for comparison against observations

7 CONCLUSIONS

REFERENCES

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