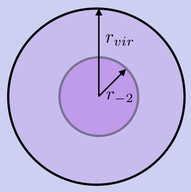
Major Mergers Not a Viable Mechanism to Decrease Concentration?

Nicole E. Drakos, James E. Taylor, Anael Berrouet, Aaron S. G. Robotham and Chris Power

Department of Physics and Astronomy, University of Waterloo, Waterloo, Ontario, Canada

INTRODUCTION

Dark matter halos can be characterized by a concentration parameter [1].



$$c = \frac{r_{vir}}{r_{-2}}$$

Cosmological simulations predict that the median concentration evolves as $c \sim c_0/(1+z)$ [2] or $c \sim c_0\, \rho_c^{-1/3}$ [3]. This implies that concentration decreases with mass [4].

$$r_{vir} \propto \left(\frac{M_{vir}}{\rho_c}\right)^{1/3} \quad \Rightarrow \quad r_{-2} \propto M_{vir}(z)^{1/3} \frac{\rho_c(z)^{-1/3}}{c} \propto M_{vir}(z)^{1/3}$$

Previous studies show conflicting results about whether or not major mergers can cause a decrease in concentration [e.g. 5,6].

Objective: **study isolated major mergers with a wide range of halo models and orbital parameters, determine if concentration decreases, and under which conditions.**

METHODS

Initial halo models created with 5×10^5 particles using our publicly available code, ICICLE https://github.com/ndrakos/ICICLE [7].

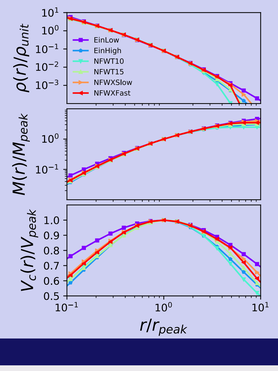


Fig. 1: Comparison of initial conditions (ICs) for halo models. Initial halos are either NFW truncated in various ways, or Einasto, with either a high or low α parameter.

Over 100 simulations were run in GADGET-2 [8], with different ICs and orbits. Initial velocity was either purely tangential (T) or purely radial (R).

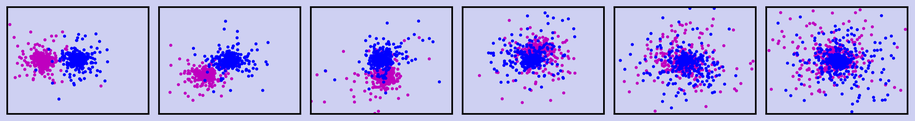


Fig. 2: Sample simulation output. The blue halo is given an initial velocity tangential to the purple halo.

Using energy and momenta conservation laws, you can predict the final energy of the remnant.

$$E_0' = W_{orb} + \frac{1}{2}K_{orb} + 2E_0$$

We define a new parameter, the change in internal energy relative to the self-similar case, κ.

$$\kappa \equiv \frac{E_0'}{E_0}\left(\frac{M}{M'}\right)^{5/3}$$

RESULT 1

Remnants look Einasto, and are not self-similar to ICs.

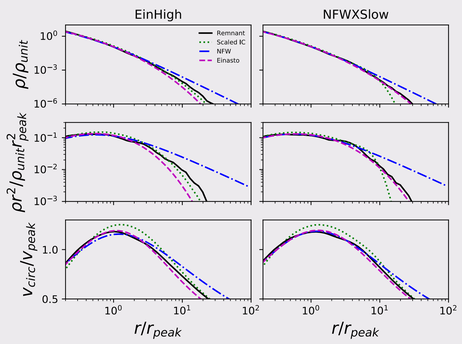


Fig. 3: Remnant halos, fit with either an Einasto or NFW profile.

RESULT 2

Profile evolution can be described by a single parameter, κ.

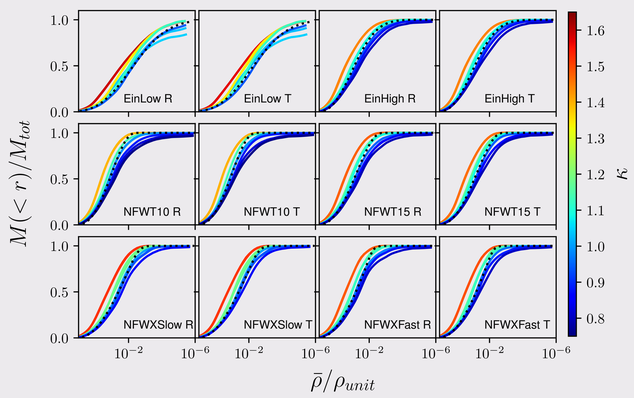


Fig. 4: Changes in mass rearrangement of remnant coloured by the relative change in internal energy, κ.

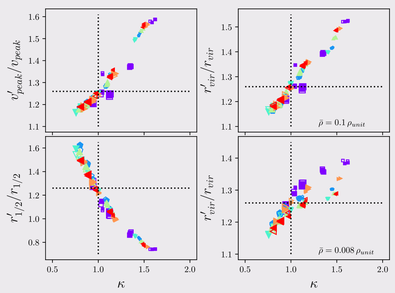


Fig. 5: Change in the peak circular velocity, half-mass radii and viral radii.

(The viral radii are determined using either a mean over-density of 0.1 or 0.08 in simulation units; these correspond to NFW profiles of concentrations 3 and 10, respectively. The dotted lines indicate the self-similar expectation Colours correspond to the IC, and symbol sizes to the initial radial separation.)

RESULT 3

Concentration changes depend on κ as well as the ICs… in general concentration is increased!

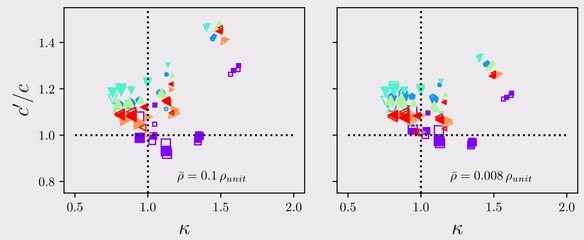


Fig. 6: Changes in halo concentration using two different viral radii. Colours, symbols , lines and viral radii as in Fig 5.

CONCLUSIONS

Concentration is not decreased in major mergers, except in very specific cases.

How this relates to cosmological conditions remains to be determined, since equal-mass mergers as well as isolated merger events are rare.

Overall, the origin of the concentration-redshift relation is still unclear.

CONTACT INFORMATION

Nicole E. Drakos, ndrakos@uwaterloo.ca

James E. Taylor, taylor@uwaterloo.ca

REFERENCES

1. Navarro, JF *et al. ApJ,*1997.
2. Bullock, JS *et al. MNRAS*, 2001.
3. Pilipenko, SV *et al. MNRAS*, 2017.
4. Okoli, C *et al. JCAP 2018.*
5. Kazantzidis, S *et al. ApJ 2006.*
6. Moore, B *et al. MNRAS*, 2004.
7. Drakos, NE *et al. MNRAS, 2017.*
8. Springel, V *et al. MNRAS, 2005.*