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Connection between cusp-core problem and too-big-to-fail problem in CDM model

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Abstract. The standard paradigm of structure formation in the universe, the cold dark matter cosmology, contains several crucial unsolved problems such as "cusp-core problem" and "too-big-to-fail problem". To solve these problems, we study about the dynamical response of a virialized system with a central cusp to the energy feedback driven by periodic supernova feedback using collisionless N-body simulations with the Nested-Particle-Mesh code. The resonance between dark matter particles and the density wave excited by the oscillating potential plays a significant role in the cusp-core transition of dark matter halos. Furthermore, we show that the cusp-core transition with periodic supernova feedback can solve the too-big-to-fail problem.

Keywords. galaxies: dwarf, galaxies: evolution, galaxies: halos, galaxies: structure, Local Group, cosmology: theory, dark matter

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1. Introduction

Cold dark matter (CDM) cosmology explains the statistical property and evolution process the large-scale structure of the universe. However, it has some issues on the small scale such as cusp-core (CC) problem and too-big-to-fail (TBTF) problem. The CC problem is that a central density profile of dark matter halo (DMH) predicted by simulations is inconsistent with observational one. Cosmological simulations (e.g., Navarro *et al.* 1996) always show that the density profile of DMH diverges at the center. On the other hand, observed DMH in dwarf galaxies has revealed almost constant density structures at their center (e.g., Burkert 1995). The TBTF problem (Boylan-Kolchin *et al.* 2011) is that cosmological simulations produce more massive satellite galaxies around a Milky Way (MW) -like galaxy than observed.

To solve these problems, we focus on CC transition driven by supernova (SN) feedback. Ogiya & Mori (2014) showed that periodic SN feedback can solve the CC problem, and the core size depends completely on the frequency of the oscillation. However, Garrison-Kimmel *et al.* (2013) reported that SN feedback failed to solve the CC problem. This contradicting situation motivates us to reexamine this problem using a detailed simulation.

2. Numerical simulations of cusp-core transition

We perform collisionless N-body simulations using the Nested-Particle-Mesh code. In this simulation, we use 16,777,216 particles and the smallest mesh size is 17 pc. DMH is represented by Hernquist sphere (Hernquist 1990) with a total mass of $2.28 \times 10^9\ M_\odot$ and a scale radius of 2.2 kpc. To model the periodic SN feedback, we adopt time-varying potentials with different oscillation periods into the DMH. This time-varying potential

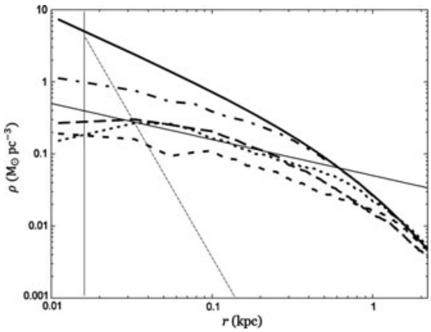

Figure 1. Density profiles of DMH with different oscillation periods: initial state (thick solid line); 500 Myr (long-dashed line); 100 Myr (short-dashed line); 50 Myr (dotted line); 13 Myr (dotted-dashed line). $\rho \propto r^{-0.5}$ (thin solid line); limit of two-body relaxation effect (left side of the thin dotted line); smallest mesh size (vertical thin solid line).

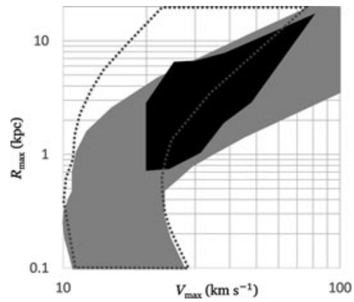

Figure 2. Maximum circular velocity, $V_{\rm max}$, and that position, $R_{\rm max}$, relation of DMHs. The region surrounded by a dotted-line corresponds the observed massive MW satellites (Wolf *et al.* 2010) assuming NFW profile. The prediction of CDM simulations (black region) done by Springel *et al.* (2008) and Diemand *et al.* (2008) indicates the over production of massive satellites.

is also represented by Hernquist sphere with a total baryon mass of 10^8 $M_\odot$ and a scale radius of 210 pc (cf. Garrison-Kimmel *et al.* 2013), and analyze the quasi-equilibrium state of DMH after 10 oscillation times.

The result of simulations shows that the periodic SN feedback can drive a transition from a cuspy dark matter profile to a core like profile, and the core size directly connects with the oscillation period. This result is consistent with Ogiya & Mori (2014). Furthermore, we found newly that the power-law index of the DMH central density is independent of the oscillation period. We also calculated ellipsoidal perturbation and found that DMH central density strongly depends on the shape of perturbation. This result will be reported in a forthcoming paper.

3. Application to the too-big-to-fail problem

We assumed that DMH experienced the CC transition at the starburst epoch (Ogiya *et al.* 2014). Then, the density profile of DMH has changed from NFW profile (cusp) to Burkert profile (core). In contrast to Boylan-Kolchin *et al.* (2011), our model provides consistency between the CDM prediction (black region) and the observations of MW satellites (gray region). We conclude that the CC transition driven by periodic SN feedback can simultaneously solve both the CC problem and the TBTF problem.

References

Boylan-Kolchin, M., Bullock, J. S., & Kaplinghat, M. 2011, *MNRAS*, 415, L40
Burkert, A. 1995, *Apj*, 447, L25
Diemand, J. *et al.* 2008, *Nature*, 454, 735
Garrison-Kimmel, S. *et al.* 2013, *MNRAS*, 433, 3539
Hernquist, L. 1990, *Apj*, 356, 359
Navarro, J. F., Frenk, C. S., & White, S. D. M. 1996, *ApJ*, 462, 563
Ogiya, G., Mori, M., Ishiyama, T., & Burkert, A. 2014, *MNRAS*, 440, L71
Ogiya, G. & Mori, M. 2014, *ApJ*, 793, 46
Springel, V. *et al.* 2008, *MNRAS*, 391, 1685
Wolf, J. *et al.* 2010, *MNRAS*, 406, 1200

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