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Can bars erode cuspy halos ?

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Abstract. One of the major and widely known small scale problem with the Lambda CDM model of cosmology is the "core-cusp" problem. In this study we investigate whether this problem can be resolved using bar instabilities. We see that all the initial bars are thin ($b/a < 0.3$) in our simulations and the bar becomes thick ($b/a > 0.3$) faster in the high resolution simulations. **By increasing the resolution, we mean a larger number of disk particles. The thicker bars in the high resolution simulations transfer less angular momentum to the halo.** Hence, we find that in the high resolution simulations it takes around 7 Gyr for the bar to remove inner dark matter cusp which is too long to be meaningful in galaxy evolution timescales. Physically, the reason is that as the resolution increases, the bar buckles faster and becomes thicker much earlier on.

Keywords. galaxies: kinematics and dynamics,(cosmology:) dark matter, methods: n-body simulations, methods: numerical

1. Introduction

Cosmological simulations confirm that dark matter halos have Navarro-Frenk-White type of density profiles which vary as r^{-1} in the central region while varying as r^{-3} in the outer region (Navarro *et al.* 1997). This inner density profile which rises steeply in the central region is often called a "cusp". The modeling of HI observations of dwarf galaxies show that there is a discrepancy between the observed rotation curves and those calculated theoretically, especially in the inner parts of the galaxies. Galaxy rotation curves studies show that the dark matter profile varies as $r^{-\alpha}$ in the inner region where $\alpha = 0.2 - 0.4$, which is also called "halo core" while it varies as r^{-2} in the outer parts. This is typically called the pseudo isothermal profile. This discrepancy between observations and theoretical models of the inner profiles of galaxy halos is widely known as "Core-Cusp" problem of LCDM cosmology (de Blok 2010).

In this study we use N-body simulation to examine whether bars can alter the initial cusps of dark matter halo profiles though angular momentum transport from disks to to halos. We have generated initial isolated disk models having exponential stellar disk and halo with Hernquist profiles using the GalIC code (Yurin, & Springel 2014). We have generated three models namely L, M and H **with increasing disk resolutions which means larger number of initial disk particles and not a shortening of the softening length. The number of disk particles are** 10^5, 5×10^5 **and** 10^6 **respectively.** All the models are bar unstable within couple of Gyrs (Kataria, & Das 2018) after the isolated evolution using Gadget-2 (Springel 2005). **We find that as the resolution of simulation increases it leads to a different evolution of bar shapes.**

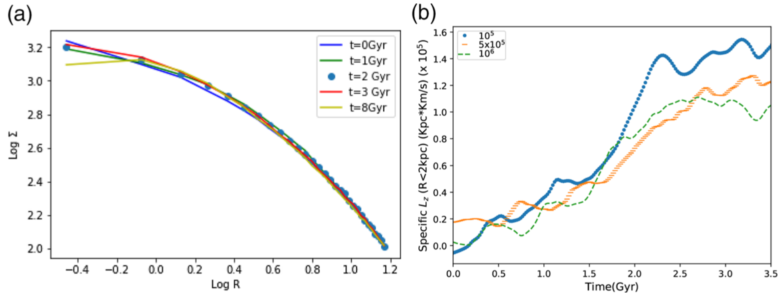

Figure 1. (a) Time evolution of halo profile of high resolution model, namely model H. (b) Angular momentum transfer from disk to inner dark matter within a sphere of 2 kpc.

We find that all the initial bars are thin (b/a <0.3). As the bar evolves with time it transports angular momentum to inner halo through resonance interactions. We find that bar remains thin for low resolution simulations throughout it's evolution while it becomes thicker (b/a >0.3) quickly in high resolution simulations. The thickening is probably due to the bars undergoing buckling instability and our simulations indicate that bars buckle faster in high resolution simulations compared to low resolution ones. We have plotted the inner dark matter specific angular momentum variation in Fig. 1b for all the simulations in order to check the rate of transfer of angular momentum to the inner dark matter halo component within a 2 kpc radius. We see that as the resolution of the simulation increases (bar thickens faster), the total gain in angular momentum by the inner halo reduces. As a result we see that bars are able to transform cuspy halo profile into cores within 4 Gyr of disk evolution in low resolution simulation while it doesn't in high resolution simulation. Instead we find that it takes around 7 Gyr of bar evolution in high resolution simulation to transform inner cusp into a core. We have plotted the evolution of dark matter halo profile in Fig. 1a for high resolution simulation.

2. Summary

We test the role of bars in altering the inner dark matter halo profiles of disk galaxies. We start with cuspy halo models that have disks of increasing number of particles i.e. higher resolution. The disks in our models are bar unstable and form bars around 1.2 Gyr of isolated evolution. We find that the transfer of angular momentum from the disk to the halos by bars depends on the resolution of the simulations or timescale until the bar remains thin. For the high resolution simulation where initial thin bar buckles faster and becomes thick, it takes ∼7 Gyr of bar secular evolution(Fig. ∼ 1b) to transform the halo cusp into a core. This suggests that timescales of cusp to core transition due to bars is too long to be meaningful for isolated galaxy evolution scenarios.

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References

Navarro, J. F., Frenk, C. S., & White, S. D. M. 1997, *ApJ*, 490, 493
de Blok, W. J. G. 2010, *Advances in Astronomy*, 2010, 789293
Springel, V. 2005, *MNRAS*, 364, 1105
Yurin, D. & Springel, V. 2014, *MNRAS*, 444, 62
Kataria, S. K. & Das, M. 2018, *MNRAS*, 475, 1653