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Dark matter bar evolution in triaxial spinning haloes

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Abstract. Dark matter bars are structures that may form inside dark matter haloes of barred galaxies. Haloes can depart from sphericity and also be subject to some spin. The latter is known to have profound impacts on the evolution of both stellar and DM bars, such as stronger dynamical instabilities, more violent vertical bucklings and dissolution or impairment of stellar bar growth. On the other hand, dark matter bars of spherical haloes become initially stronger in the presence of spin. In this study, we add spin to triaxial halos in order to quantify and compare the strength of their bars. Using N-body simulations, we find that spin accelerates main instabilities and strengthens the halo bars, although their final strength depends only on triaxiality. The most triaxial halo barely forms a halo bar, showing that flattening opposes to DM bar strengthening and indicating that there is a limit on how flattened the parent structure can be.

Keywords. galaxies: kinematics and dynamics, galaxies: halos, galaxies: evolution

1. Introduction

Dark matter (DM) bars are structures that may form inside dark matter haloes of barred galaxies. Haloes can depart from sphericity and also be subject to some spin, which is known as cosmological spin parameter $\lambda \equiv J_\mathrm{h}/\sqrt{2}M_\mathrm{vir}R_\mathrm{vir}v_\mathrm{c}$ – where J_h is the halo angular momentum, M_vir and R_vir are the virial mass and radius, and v_c is the circular velocity at R_vir.

Spin has profound impacts on the evolution of both stellar and DM bars. For example, Collier *et al.* (2018) found that dynamical instabilities are accelerated when the disc is embedded in haloes with net rotation. This results in more violent vertical bucklings, which are followed by the dissolution of the stellar bar or impairment of its subsequent recovery. On the other hand, dark matter bars of spherical haloes are stronger in the presence of spin: while the strength before the vertical buckling of the stellar bars is somehow indifferent to λ, that of the DM bars increases with it Collier *et al.* (2019).

2. Methods and Results

In this study, we add spin to triaxial haloes of N-body simulations in order to compare the effects of both variables on the evolution of their DM bars. A set of simulations was run with the code GADGET-2, using the three haloes from Athanassoula *et al.* (2013): a spherical halo, a triaxial halo ($b/a = 0.8$ and $c/a = 0.6$) and a more triaxial halo ($b/a = 0.6$ and $c/a = 0.4$). For each halo, we ran simulations with three different spins: $\lambda \approx 0.00$, 0.03 and 0.07. The spinning haloes were created by inverting the tangential velocities of a certain fraction of retrograde halo particles.

We find that larger spin accelerates stellar bar formation, slightly decreasing its strength before buckling. The capacity of the stellar bar to recover its strength is inversely

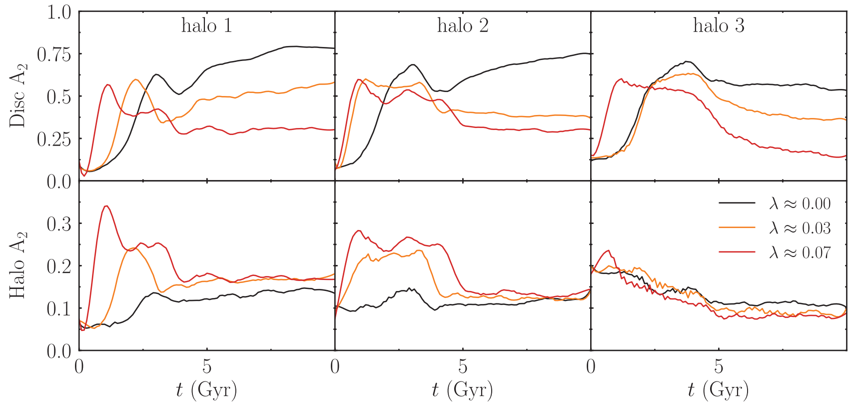

Figure 1. Bar strength (A_2) as a function of time. From left to right, galaxies with increasing halo triaxiality. Colours represent different spin parameters (λ).

proportional to λ. Increasing halo triaxiality does not greatly affect stellar bar strength, but negatively affects the ability of the bar to regrow, causing it to, sometimes, completely dissolve.

Larger spin accelerates the formation of the halo bar, which becomes approximately three times stronger for $\lambda \approx 0.07$. Spin does not affect the final strength of the DM bar in any of the simulated haloes. Increasing triaxiality slightly weakens the final halo bar strength (Figure 1). Spin alone is not capable of developing stronger bars for the most triaxial halo, drawing the line on how flattened haloes can be in order to host a stellar-bar-induced DM bar.

3. Conclusions

In this work, we have recovered the results of Collier *et al.* (2019) for spherical haloes and extended the analyses to fully triaxial spinning haloes. We found that the stellar bars of all the three haloes form earlier, according to their λ, and may eventually dissolve. The DM bars of haloes 1 and 2 form earlier, along with the stellar bar, and become much stronger before buckling, proportionally to λ. On the other hand, the stellar bar of halo 3 is not capable of inducing a halo bar, showing an inverse effect of triaxiality on DM bar strength.

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