Buckling instabilities in N-body simulations of barred galaxies

Daniel A. Marostica & **Rubens E. G. Machado**
Universidade Tecnológica Federal do Paraná
marostica@alunos.utfpr.edu.br

Abstract

The formation of galactic bars is connected to the transfer of angular momentum from the stellar disk to the dark matter halo. This process is uneven during its secular evolution, bringing into evidence a particular phenomenon known as bar buckling. Among other effects, this period of instability is associated with a drastic weakening and thickening of the disk bar, and the formation of a boxy/peanut structure in the galaxy core when observed edge-on. This work aims to conduct a thorough inspection in some features of stellar bar buckling, taking into account its effects on the dark matter halo bar. We analyze and compare three galaxies from N-body hydrodynamical simulations through a period of 10 Gyr. These galaxies differ in halo triaxiality, leading to different bar strengths. By decomposing mass distributions in Fourier series for the upper and lower hemispheres, we quantify the asymmetry for buckling in order to investigate the behaviour of the halo bar during the buckling episode. We find that the buckling of the stellar bar is mimmicked by the dark matter halo bar – which also develops a temporary vertical asymmetry, though in smaller scale – and its magnitude is proportional to the bar strength.

Introduction

Buckling is a temporary vertical asymmetry which reduces the strength and size of the galactic bar, resulting in a boxy/peanut shape of the inner region of the galaxy when seen edge-on (Fig. 1). Its causes are not completely known, but two alternative explanations are usually given: resonant bending (Combes et al., 1990) and firehose instability (Raha et al., 1991). This phenomenon may, among other effects, decrease bar growth rate or even cease it. As demonstrated in Martinez-Valpuesta et al. (2006), bar buckling is recurring, a fact that may increase its influence in the secular evolution of the galaxy. Although commonly detectable in hydrodynamical simulations, more precise observational counterparts are still needed to support numerical results.

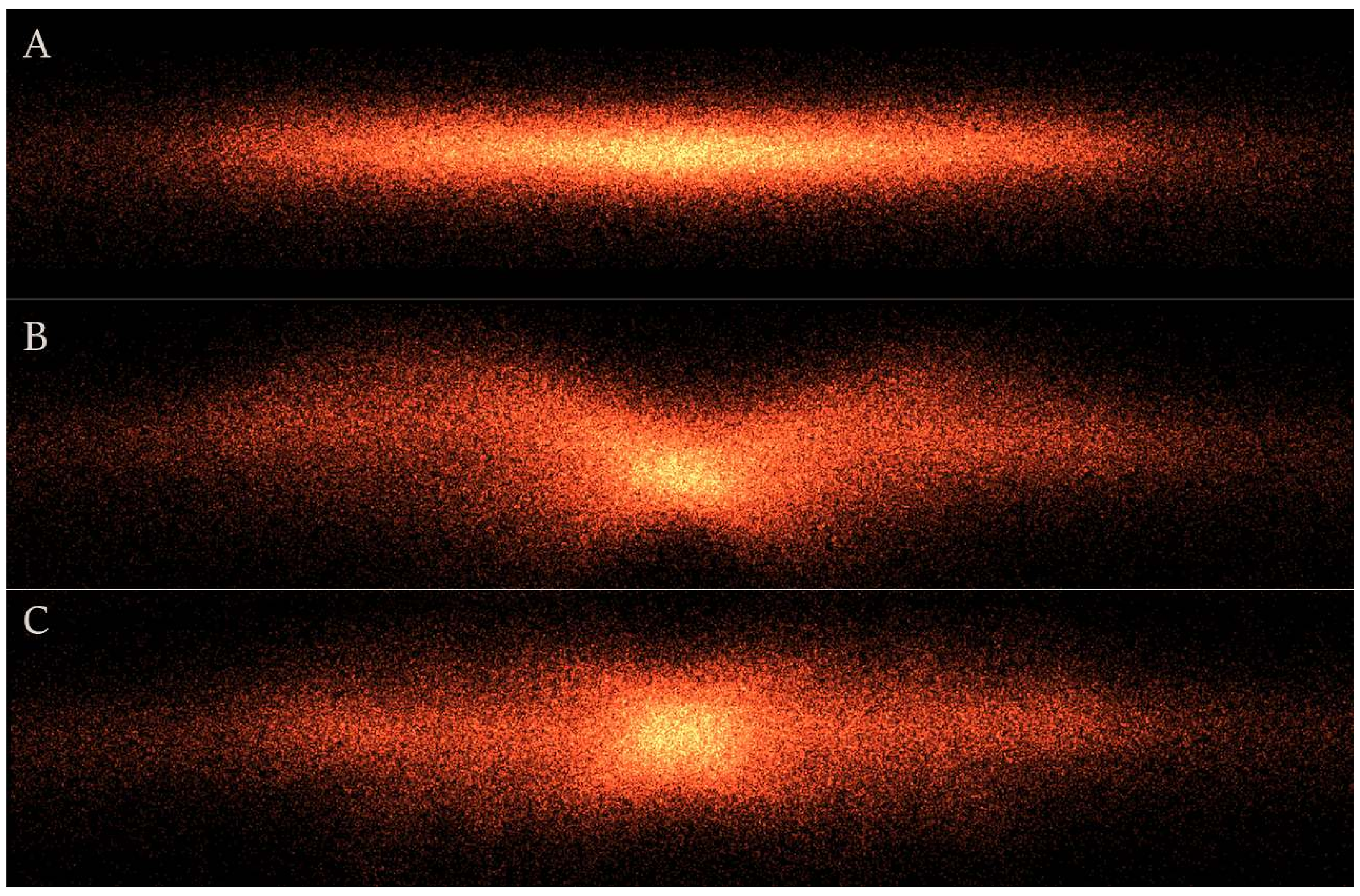

Figure 1: Stellar disk before buckling (A); buckling and disk thickening (B); disk after buckling (C).

Main Objectives

1. To investigate the occurence of bar buckling in the dark matter halo.
2. To inspect buckling instabilities in different shapes of dark matter haloes.
3. To compare the influence of spherical and triaxial haloes over departures from vertical symmetry.
4. To test different techniques of buckling measurement.

Materials and Methods

We analyze and compare three galaxies from N-body hydrodynamical simulations run with `Gadget-2` (Springel, 2005), through a period of 10 Gyr. These galaxies – run by Athanassoula et al. (2013) – differ in halo triaxiality, leading to different bar growth rate and strength. We quantify the asymmetry for buckling in order to investigate the behaviour of the halo bar during the buckling episode by decomposing mass distributions in Fourier series for the upper and lower hemispheres. In addition to that, two different approaches have been used, such as accounting the mean vertical position of particles and the vertical velocity dispersion, which we wish to correlate with the bar strength.

Results

Mean vertical coordinates

Galaxies in either spherical or substantially triaxial dark matter haloes display characteristic vertical asymmetry. This unsteady state does not occur at the same time for all galaxies, so it means that buckling time is also shape-dependent. In Fig. 2, we see a W shape, which is an edge-on view of the mean distribution of disk particles.

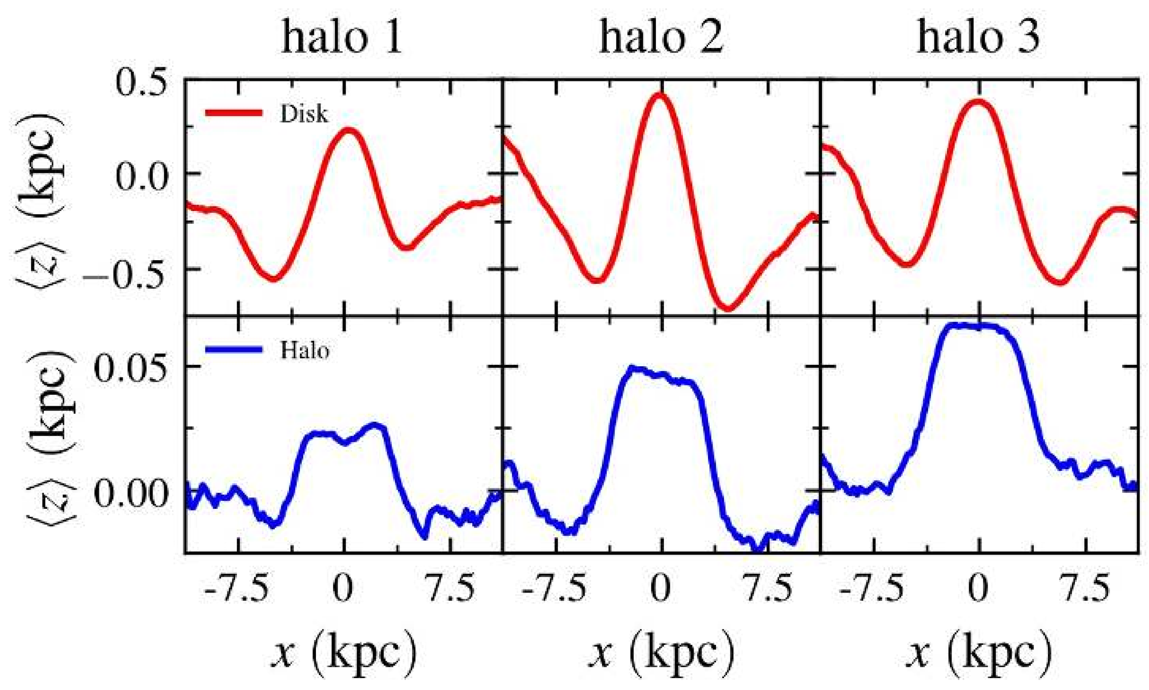

Figure 2: Mean vertical coordinates for the disk (red) and for the halo (blue) along the bar major axis. The three haloes differ in initial shape, but all of them reproduce the disk-concomitant buckling event.

Vertical velocity dispersion

Figure 3 shows an example of our data collected from different evolution stages. We detect a rapid increase in velocity dispersion for the stellar disk while a rapid decrease in the dark matter inner halo values goes against it.

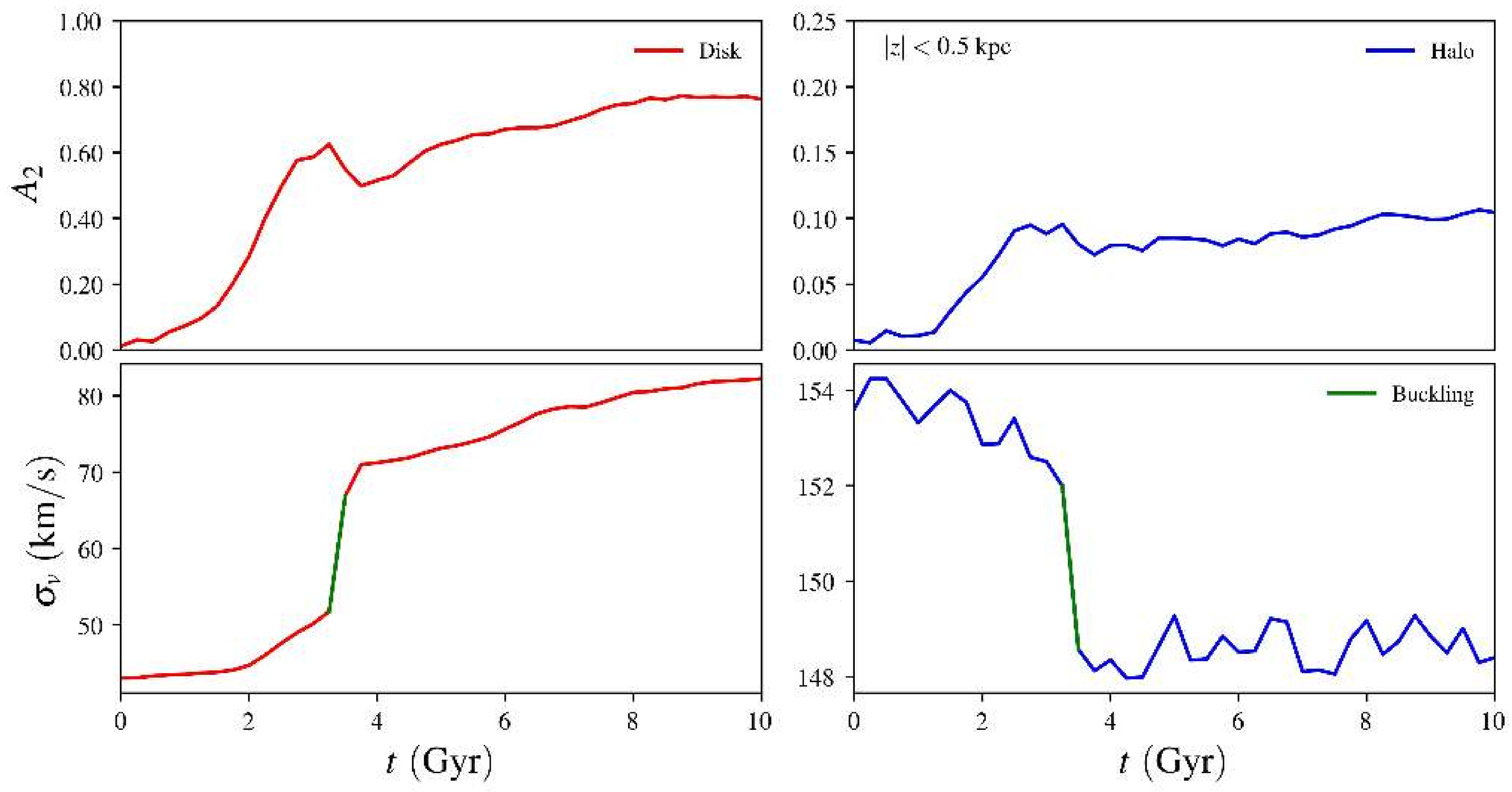

Figure 3: Spherical dark-matter-halo-immersed galaxy – bar strength and velocity dispersion as a fuction of time. In red, the stellar disk; in blue, the dark matter halo. Notice the correlation between bar weakening and shifts in velocity dispersion, for both stars and dark matter particles.

Conclusions

- Dark matter halo bars are also susceptible to the buckling event.
- Buckling instabilities occur at the same secular evolution stage for both the disk and the halo.
- The inner dark matter halo displays detectable peanut shapes, though in much smaller scales than the disk.
- Halo velocity dispersion is inversely proportional to that of the disk, which may point out some interesting momentum exchange among the particles.

Perspectives

We aim to study buckling occurence in spinning dark matter haloes.

References

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