SF2A 2025
A. Siebert, K. Baillié, M. Béthermin, F. Cantalloube, E. Josselin, N. Lagarde, J. Malzac, J. Richard, L. Selliez, O. Venot (eds)

TOWARDS A STUDY OF GAS ACCRETION ONTO SUPERMASSIVE BLACK HOLES: GAS FLOWS IN BARRED GALAXIES

F. Dedieu[1], A. Hallé[1] and F. Combes[1]

Abstract. Due to their strong feedback, Active Galaxy Nuclei (AGN) are thought to be essential in galaxy evolution. It is widely accepted that this requires matter accretion by the central black hole, which may be mainly due to stellar bars in the case of disk galaxies. However, this scenario faces a theoretical problem due to the formation of nuclear rings, which interrupt the accretion process. In this poster, we numerically investigate this scenario as a preliminary work for future studies. We show that: 1) Strongly barred isolated galaxies can be simulated successfully with the RAMSES code; 2) The properties of bars and spirals can be determined by a Fourier analysis; 3) Despite a general good agreement with theory, simulations using RAMSES do not seem to be able to form nuclear rings.

Keywords: Active Galactic Nuclei, Accretion, Galactic bar, Hydrodynamical simulations

1 Introduction

AGN are known to play a critical role in galaxy evolution. This however requires gas accretion. The presence of a stellar bar could explain accretion in the observed time scales (Shlosman et al. 1990). However, a high central concentration of gas always leads to the emergence of a nuclear ring, interrupting the gas inflow until the formation of a nuclear bar and nuclear spirals.This is the "bars within bars" scenario. Such nuclear spirals have started being observed (Combes et al. 2014) but such structures have been very little studied numerically, limiting the understanding of the observations. In this poster, we present preliminary results that lay the groundwork for upcoming studies. With the RAMSES code, we investigate how stellar bars form in simulations and how they affect the gas dynamics. Moreover, we examine how RAMSES is able to form nuclear rings.

2 Methods

We used the RAMSES code (Teyssier 2002). It allows to simulate the coupled evolutions of gas, stars, and dark matter, including numerous astrophysical processes like star formation and feedback. It uses the Adaptive Mesh Refinement (AMR) framework, which allows for an accurate treatment of shocks. The initial conditions are generated using the DICE (Disk Initial Conditions Environment) code (Perret et al. 2014).

3 Results

We started with carrying out N-body simulations of barred isolated galaxies. In this context, bar formation always occurs in the same way: spirals arms form first, due to instabilities occurring in the disk, and end up forming a bar as a stationary wave. We then implemented a method to analyze such periodic perturbations based on Fourier transforms of the matter distribution of RAMSES video frames, through spectrographs (left panel of Fig. 2). This allows to measure the pattern speed Ω_p and the length of the perturbation, as well as the positions of its resonances: the Outer and Inner Lindblad Resonances (OLR/ILR), when $\Omega_p = \Omega \pm \kappa/m$) (where ω is the circular angular speed, κ is the epicyclic frequency, and m is the perturbation periodicity), and the Corotation (CR) when $\Omega_p = \Omega$. In theory, these resonances determine the gas dynamics in the presence of a bar, which is what we observed when we added a little massive gaseous disk. In Fig. 1, we see that the bar

[1] Laboratoire d'étude de l'univers et des phénomènes extrêmes, 61 avenue de l'Observatoire, 75014 Paris, France

drives spirals in the gas, which rotate by 90 degrees at each resonance. In theory, under the action of the bar, the gas should migrate towards the ILRs. We increased the spatial resolution in the central region to investigate more precisely the formation of a nuclear ring (right panel of the Fig. 2), but however did not find any evidence of the formation of such a structure.

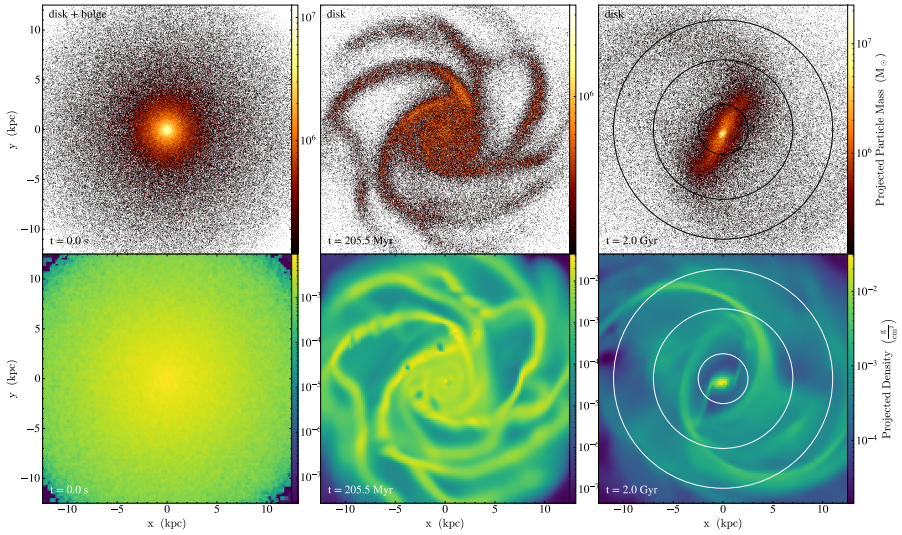

Fig. 1. Barred galaxy simulated with RAMSES. The top panels show the stellar field, while the others depict the projected gas density. In the right column, the circles of increasing radii denote the second ILR, the CR, and the OLR.

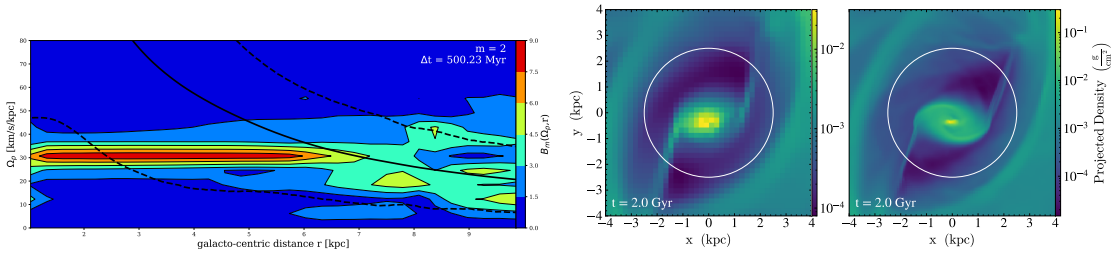

Fig. 2. Left: Spectrograph of the $m = 2$ perturbation, corresponding to the right column of Fig. 1. The colored region corresponds to the identified perturbation (here mainly the bar), and the black lines represent the ILR, CR, and OLR curves. **Right:** zoom-in vs. original simulations ($\simeq$ 200 vs. $\simeq$ 48 pc/pixel in the central region).

4 Conclusions

We simulated strongly barred galaxies using RAMSES and developed a Fourier analysis code for spiral arms and bars. We visualize the gas dynamics in such galaxies and find a general good agreement with theory, apart from the formation of nuclear rings in the expected time scales. This may be due either to numerical (e.g. a too low resolution) or physical reasons, or even to the grid-based Eulerian nature of RAMSES.

Thank you to the organizers of the SF2A 2025!

References

Combes, F. et al. 2014, A&A, 565, A97
Perret, V. et al. 2014, A&A, 562, A1
Shlosman, I. et al. 1990, Nat, 345, 679
Teyssier, R. 2002, A&A, 385, 337