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

PROJECTION EFFECTS AND RADIAL FLOWS IN BARRED GALAXIES

E. Salibur[1], A. Hallé[1] and F. Combes[1, 2]

Abstract. Gas inflows toward supermassive black holes (SMBHs) and the feedback from active galactic nuclei (AGN) are key processes driving galaxy evolution. Kinematic modeling is a powerful tool to investigate these mechanisms, but projection effects in barred galaxies strongly affect the interpretation of radial motions, often blurring the distinction between inflows and outflows. In this work, we use mock data from a simulated barred galaxy to test the performance of the tilted-ring algorithm 3D-Barolo. We show that bar-driven non-circular motions are misinterpreted as radial flows and quantify the spurious detections, highlighting the need for caution in barred systems.

Keywords: galaxies: kinematics and dynamics, galaxies: spiral, galaxies: evolution, galaxies: active

1 Introduction

Barred spiral galaxies represent more than two thirds of all spirals (de Vaucouleurs et al. 1991). Bars play a key role in driving gas toward the central regions by removing angular momentum, ultimately feeding the supermassive black hole (Casasola et al. 2011). In the corotation region, gas follows elongated orbits aligned with the bar, strongly affecting the velocity field.

Kinematic modeling is widely used to estimate inflows and outflows associated with SMBH activity (e.g. Audibert et al. 2021), but projection effects make it difficult to disentangle true radial motions from geometric artifacts. Here we test how the tilted-ring algorithm 3D-Barolo (Di Teodoro & Fraternali 2015; Di Teodoro & Peek 2021) interprets gas motions in the presence of a strong bar, and quantify the spurious flows it detects.

2 Data

We use a simulated giant barred spiral galaxy (gSb) from the GalMer database (Chilingarian et al. 2010), with a total mass of $5.5 \times 10^{10} M_{\odot}$. The system exhibits two spiral arms attached to the bar and an S-shaped distortion in the velocity field, characteristic of barred kinematics. Synthetic datacubes were generated with disk inclination angles in the range $i \in [30°, 80°]$, to study projection effects.

3 Method

Different geometric configurations were tested by varying the bar orientation and the near/far side of the disk (Fig. 1, left). The observed line-of-sight velocity is modeled as:

$$V_{\rm los}(r, \theta) = [V_{\rm rot}(r) \cos\theta + V_{\rm rad}(r) \sin\theta] \sin i(r). \tag{3.1}$$

We fitted the cubes with 3D-Barolo using a three-step procedure with the position angle fixed to avoid a false identification of a tilted disk. First, i, $V_{\rm rot}$, and the velocity dispersion $V_{\rm disp}$ were left free, with $V_{\rm rad} = 0$. Second, i was fixed and $V_{\rm rot}$ and $V_{\rm disp}$ refitted without radial motions. Finally, $V_{\rm rot}$ and $V_{\rm disp}$ were fixed and only $V_{\rm rad}$ was fitted. This staged approach reduces degeneracies between inclination and radial flows.

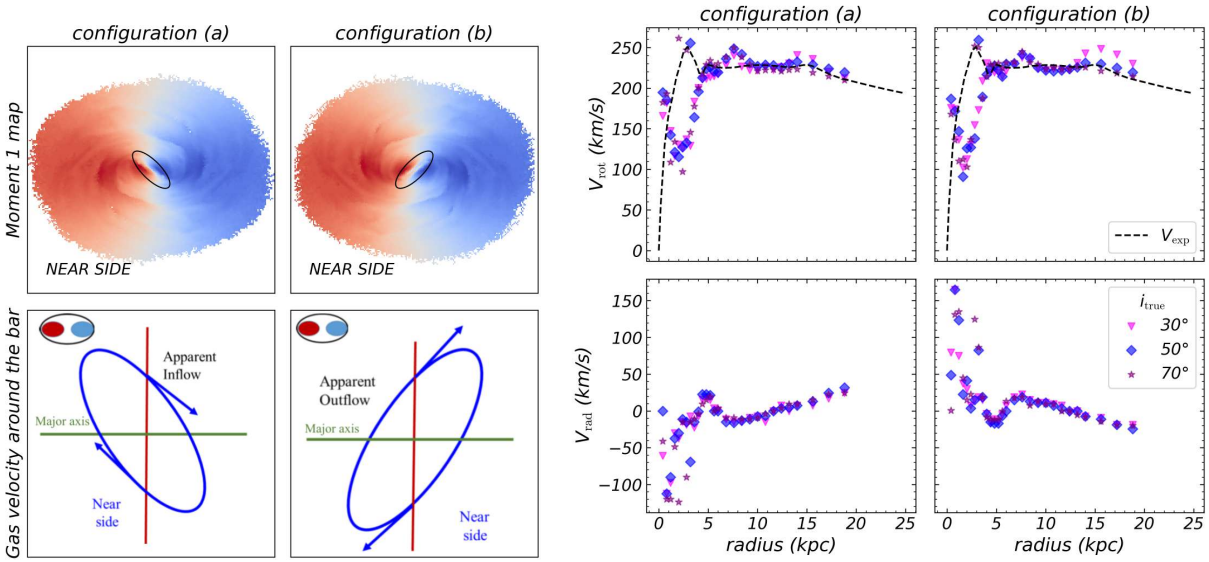

Fig. 1. Left: Geometry of the bar and orientation of the line of nodes. Radial velocities are projected along the minor axis. **Right:** Kinematic parameters recovered with 3D-Barolo. Symbols denote different inclination angles. Top row: rotation curves compared with the expected circular velocity (black dashed). Bottom row: radial velocities fitted. Apparent inflows ($V_{\rm rad} < 0$) and outflows ($V_{\rm rad} > 0$) are induced by projection effects rather than true gas motions.

4 Results

The recovered rotation curves (Fig. 1, top right) match the expected circular velocity outside the bar ($R >$ 2.5 kpc), but inside this region 3D-Barolo fits spurious radial components that inflate mass flow rates. The expected circular velocity $V_{\rm exp}$ computed from the gravitational potential matches the rotational velocity $V_{\rm rot}$ outside the bar region ($R > 2.5$ kpc). 3D-Barolo detects an inflow in configuration (a) and an outflow in configuration (b), as expected.

5 Conclusions

Tilted-ring kinematic modeling with 3D-Barolo reproduces the global rotation curves of barred galaxies but fails to recover the radial velocity field within the bar. Non-circular motions are systematically interpreted as inflows or outflows depending on the bar orientation and disk geometry. These projection-induced artifacts can lead to an overestimation of radial mass flow rates. Reliable assessments of gas transport in barred galaxies therefore require complementary analyses, such as torque calculations or multi-wavelength diagnostics, in addition to standard kinematic modeling.

Thank you to the organizers of the SF2A 2025!

References

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[1] LUX, Observatoire de Paris, Paris, France
[2] Collège de France, Paris, France