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The Vertical Structure of Bars

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1. Introduction

N-body simulations suggest that bars are boxy/peanut-shaped (B/PS) when viewed edge-on (Combes & Sanders 1981). However, because of the difficulty to identify bars in edge-on galaxies, very little is known observationally about the three-dimensional structure of bars. We introduce here new bar diagnostics for edge-on spirals relying on the characteristic kinematics of barred disks. Applying these diagnostics to a large sample of objects, we show that B/PS bulges are systematically barred, while normal bulges appear axisymmetric. This strongly supports the view that real bars are thick and appear B/PS if viewed edge-on.

2. Bar Diagnostics for Edge-On Spiral Galaxies

We used families of periodic orbits as building blocks to model real galaxies. We adopted a two-dimensional mass model composed of a Ferrers bar and two axisymmetric components (Athanassoula 1992a). Our models clearly show that the global appearance of position-velocity diagrams (PVDs) taken along the major axes of edge-on disks are a reliable tool to identify bars. Gaps are present between the signatures of the various periodic orbit families due to the non-homogeneous distribution of orbits in barred disks. The x_1 and x_2 orbits (respectively parallel and perpendicular to the bar) are the most important families for identifying bars and their orientation with respect to the line-of-sight.

Using the same mass model, we also ran hydrodynamical simulations where the gas was treated as ideal, isothermal, and non-viscous (Athanassoula 1992b). The main feature of the PVDs is a gap, present at all viewing angles, between the signature of the nuclear spiral (associated with the x_2 orbits) and that of the outer parts of the disk. Such a gap in a PVD unmistakably reveals the presence of a bar. It occurs because large scale shocks in bars drive gas toward the center and deplete the regions of the disks occupied by an x_1-like flow. The ratio of the maximum velocity reached by the nuclear spiral to that reached by the outer disk is most useful to constrain the viewing angle to the bar.

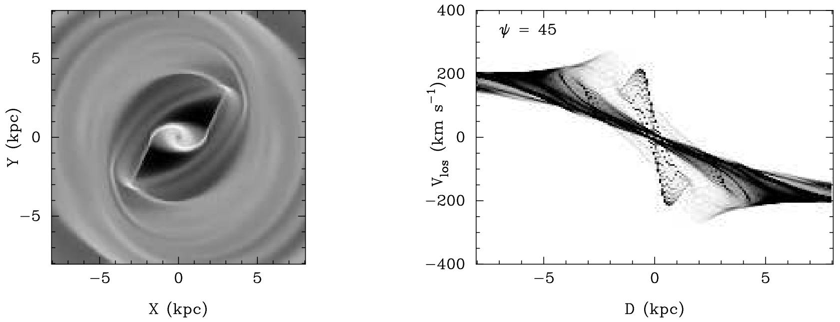

Figure 1. Surface density and projected PVD for a typical simulation.

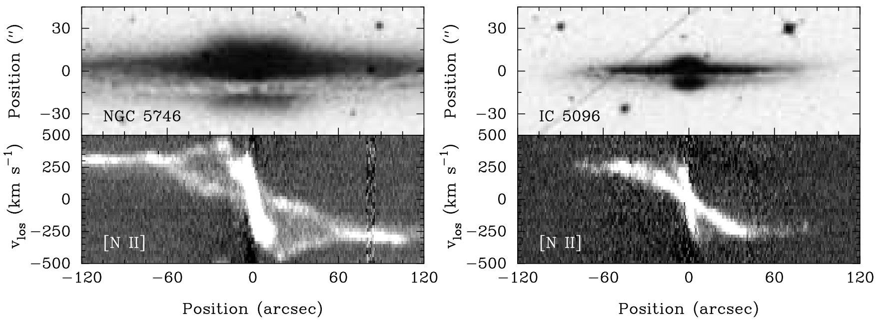

Figure 2. Images and ionized gas PVDs for two B/PS galaxies.

3. The Nature of Boxy/Peanut-Shaped Bulges

We have used the diagnostics described to search for bars in a large sample of edge-on spirals with and without B/PS bulges (and in a variety of environments) using emission-line long-slit spectroscopy. The results of our study are as follow: 14 of the 17 galaxies in the main sample of B/PS bulges display a clear bar signature, and only 3 may be axisymmetric or have suffered recent interactions. None of the 6 galaxies in the control sample shows evidence for a bar.

Our observations thus indicate that B/PS bulges are closely associated with edge-on bars, that accretion plays only minor role in their formation, and that ellipsoidal bulges are indeed axisymmetric. They also suggest that most B/PS bulges are (thick) bars viewed edge-on and that most bars are B/PS when viewed edge-on. Clearly, however, observations of a larger number of non-B/PS bulges are needed to strengthen this converse. Our results are also consistent with the view that boxy bulges are associated with end-on bars and peanut bulges with side-on bars, thus supporting the bar-buckling mechanism for bar thickening.

References

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