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Boxy isophotes in face–on views of barred galaxies

Panos A. Patsis, Charalampos Skokos

Research Center of Astronomy, Academy of Athens, Anagnostopoulou 14, GR-10673 Athens, Greece

E. Athanassoula

Observatoire de Marseille, 2 Place Le Verrier, F-13248 Marseille Cedex 4, France

Abstract. We study the conditions that favour boxiness of isodensities in the face-on views of orbital 3D models for barred galaxies. In particular, we consider several cases with different mass values for the bar, disk and bulge components of the potential, as well as different values of the bar pattern speed. Using orbital weighted profiles of the basic stable periodic orbits of the x1 tree for every model, we show that boxiness is in general a composite effect due to the presence of stable orbits belonging to several 2D and 3D families.

Boxy isophotes is a typical feature at the end of galactic bars observed in early type (SB0, SBa) barred galaxies seen close to face–on, as well as in snapshots of N–body simulations. In order to explain the dynamical reasons of their appearance by means of orbital theory, we study the face–on structures supported by stable periodic orbits in some analytic 3D models of barred galaxies. The potentials of our models consist of three components, namely a Miyamoto disk, a Plummer sphere bulge and a Ferrers bar of index 2. In particular, we consider models A1, A2, A3, B, C, D studied by Skokos, Patsis, & Athanassoula (2002a;b) and the additional model B2 having a very strong bar component, with the bar mass being 40% of the total mass. The backbone for building 3D bars is the x1 tree of families of periodic orbits which consists of the x1 planar orbits and of its 2D and 3D bifurcations (Skokos et al. 2002a). We use these families in order to present the face-on skeletons of the models. We consider for this purpose sets of weighted orbits as in Patsis, Skokos, & Athanassoula (2002), and we construct weighted face–on profiles. An extensive study of the various face–on profiles supported in our models is carried out in Patsis, Skokos, & Athanassoula (2003). Here we summarize the basic results of this study:

1. Boxiness in the face-on views of 3D barred models is an effect caused by the co-existence of several families, each contributing appropriate stable orbits. The morphology of boxy isodensities/isophotes is not necessarily similar to the morphology of individual stable, rectangular-like orbits.

2. In 3D models the family of the planar x1 orbits is subject to vertical instabilities, and thus in several cases it has considerable instability strips at the 4:1 resonance region. At these instability regions we find other

3D stable families, whose face–on projected orbital shapes are, at least near their bifurcations, very similar to those of the x1. They have orbits which are stable over large energy intervals and also have face–on projected shapes that can enhance a rectangular-like bar outline. Thus the inclusion of the third dimension in the models enhances boxiness.

3. There are families of periodic orbits that support boxiness in the outer bar regions, as well as families that support boxiness in somewhat more inner parts. The standard families belonging to the former category are the stable representatives of the x1 orbits (close to the radial 4:1 resonance), and of the families x1v5, x1v7 and x1v9. The families q0 and x1v8 play a major role in model A3 and thus could be essential for fast rotating bars. So, the role of the 3D families is crucial, since they are stable over large energy intervals. Inner boxiness is associated mainly with the x1v1 family and, in model B, with family z3.1s. (For the nomenclature of the orbits see Skokos et al. 2002a).

4. The consideration of several families of orbits for building a profile may lead to boxy features close to the end of bars, with the ratios of their projection on the major axis of the bar to the projection on the minor axis being different from the corresponding ratios of individual orbits or families of orbits.

5. Outer boxiness is favoured by fast bar pattern speeds, while in the slow-rotating model the bar is surrounded by almost circular orbits. In particular, the fast rotating bar (model A3) has a length 0.95 of its corotation radius, while the slow one (model A2) only 0.68. This indicates that boxy bars end close to their corotation, while the end in slow rotating bars might be associated with $n:1$ resonances of lower n values.

6. The rectangular-like orbits in models with faster bars are more elongated than the corresponding orbits in models with slower bars. The second most efficient way of stretching rectangular-like orbits is to increase the mass of the bar (model B2). This mechanism, however, is restricted by the fact that in very strong bars the families of periodic orbits which support the boxy face-on profiles are unstable over large energy intervals.

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