RevMexAA (Serie de Conferencias), **44**, 88–88 (2014)

PITCH ANGLE RESTRICTIONS IN NORMAL SPIRAL GALAXIES BASED ON ORDERED AND CHAOTIC ORBITAL BEHAVIOR

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XIV Latin American Regional IAU Meeting (Florianópolis/SC, Brazil, 25-30 November 2013)
Editors: A. Mateus, J. Gregorio-Hetem & R. Cid Fernandes

We have produced a set of observationally motivated models for the three-dimensional potential of typical Sa, Sb and Sc spiral galaxies with bisymmetric spiral arms. We studied extensively the stellar dynamical effects in the plane of the disk due to structural and dynamical parameters such as pitch angle, spiral arms mass and angular velocity.

Normal spiral galaxies actually present a large scatter in the pitch angle, ranging from about 4° to 50° (Kennicutt 1981; Ma et al. 2000; Davis et al. 2012). In this study two restrictions to the pitch angle of spiral arms are imposed theoretically, one on their steady or transient nature, and one on their maximum pitch angle.

We built a family of non-axisymmetric potential models for normal non-barred or weakly-barred spiral galaxies as defined in the simplest classification of galaxies: the Hubble sequence (Hubble 1926). For this purpose a three-dimensional self-gravitating model for spiral arms `PERLAS` (Pichardo et al. 2003) is superimposed to the galactic axisymmetric potentials. We analyze the stellar dynamics varying only the pitch angle of the spiral arms.

In a first limit, based on ordered behavior, periodic orbits studies show that for pitch angles up to $\sim 15°$, $\sim 18°$, and $\sim 20°$ for Sa, Sb and Sc galaxies (top panels in Figure 1), respectively, the density response (where the orbits crowd producing a density enhancement) supports closely the spiral arms potential at all radii, a requisite for the existence of a long-lasting large-scale spiral structure. Beyond those limits, the density response tends to "avoid" the potential imposed by maintaining lower pitch angles in the density response; in that case the spiral arms may be explained as transient features rather than long-lasting large-scale structures.

In a second limit, from a phase space orbital study based on chaotic behavior, we found that for pitch angles larger than $\sim 30°$, $\sim 40°$ and $\sim 50°$ for Sa, Sb, and Sc galaxies (bottom panels in Figure 1),

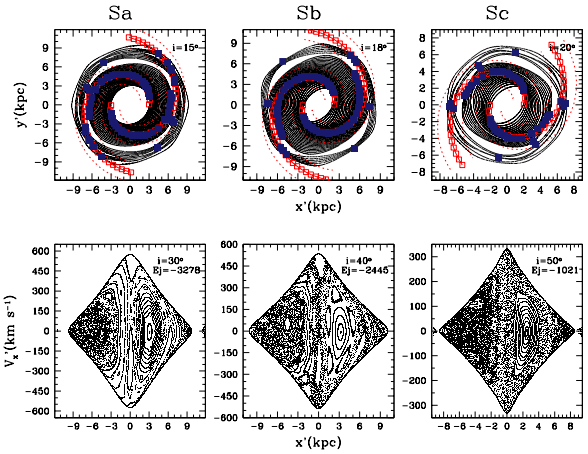

Fig. 1. Top panels show periodic orbits, response maxima (filled squares) and the imposed spiral locus (open squares) for the pitch angles of 15°, 18° and 20° for Sa, Sb and Sc galaxies, respectively. Bottom panels show phase space diagrams with $E_J = -3278, -2545$ and -1021×10^2 km^2 s^{-2}, for the pitch angles of 30°, 40° and 50° for Sa, Sb and Sc galaxies, respectively.

respectively, chaotic orbits dominate all phase space prograde region that surrounds the periodic orbits sculpting the spiral arms and even destroying them. This result seems to be in good agreement with observations of pitch angles in typical isolated normal spiral galaxies.

For more detail about these restrictions for the pitch angle in normal spiral galaxies see Pérez-Villegas et al. (2012, 2013).

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