Galaxy Dynamics: from the Early Universe to the Present
ASP Conference Series, Vol. 3×10^8, *1999*
F. Combes, G. A. Mamon and V. Charmandaris, eds.

Periodic orbits in warped disk

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Abstract. The properties of periodic orbits and orbit resonances in rotating and non-rotating warped disks have been investigated and their shapes compared with the density deformation.

1. Introduction

In the conventional understanding of galaxies embedded in a fat halo of dark matter, the frequently observed pronounced outer warps of neutral hydrogen remains misunderstood. Hypotheses like discrete modes (Sparke 1984; Sparke & Casertano 1988), misaligned dark halos (Dubinski & Kuijen 1995), or gravitational interactions (Hernquist 1991), have been proposed, without clearly matching all the pieces of the puzzle. Moreover, the evidences for non-self-gravitating HI disks are actually weak (Arnaboldi et al. 1997; Becquaert & Combes 1997). The often present clumps and large scale spiral arms suggest on the contrary that self-gravity does play a significant rôle.

In order to understand in a detailed way the underlying dynamics of a possible warped but strongly self-gravitating disk, we have examined the periodic orbits in a simple model. The stability and consistence of the orbits with the density distribution have been determined, as well as the influence of a global rotation of the warp pattern.

2. Model

The galaxy potential is modeled by a triple Miyamoto-Nagai potential containing a warping deformation inducing a z-elevation of the outer disk above the plane tangent to the central disk. The non axisymmetric potential Φ is:

$$\Phi_w(R,\theta,z) = -\sum_{i=1}^{3} GM_i \left[R^2 + \left(a_i + \sqrt{(z - wR^2\cos\theta)^2 + b_i^2}\right)^2\right]^{-1/2} \qquad (1)$$

where GM_i, the mass, a_i, the disk length scale, and b_i, the disk scale-height, are chosen to obtain a nearly constant velocity curve up to large radii (40 kpc). The model allows a global rotation of the warped potential parametrised by the corotation radius R_c. The initial starting location of 3D orbits are perpendicular to the line of node but not necessarily parallel to the warped disk.

Figure 1. Consistency of orbit occupation with the mass density.

3. Results

The main interesting family found is the family corresponding to the circular orbit family in case of axisymmetric galaxy. This stable family can be seen as a succession of inclined quasi-annular rings following the warped disk. The main family generates transverse resonances giving birth to five sub-families.

The consistency of the quasi-annular family with respect of the radius R including a global rotation is presented in Fig. 1. For a direct rotation, periodic orbits tend to destroy the density distribution. For retrograde rotation two consistent zones appear around 3 and 20 kpc growing with increasing rotation.

4. Conclusions

Different stable periodic orbits exist in a warped disk, in particular the quasi-annular orbits which sustain the warp. The sense of a global rotation is crucial. In case of retrograde rotation of the warp figure, the density distribution can be locally reinforced, which might help holding the external warped regions circular. However, the actual shape of a self-consistent warp may be slightly oval in the same sense as the orbits. This question will be better addressed with N-body simulations.

References

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