PERIODIC ORBITS AND WARPS

W.A. Mulder
Sterrewacht, Huygens Laboratorium, P.O. Box 9513,
2300 RA Leiden, The Netherlands

Orbit calculations were done in a rotating triaxial system with a density distribution in accordance with recent observations of spiral galaxies. A search was made for simple closed orbits which are tilted with respect to the plane of the galaxy. A family of stable prograde tilted orbits was found which can explain warps as stationary phenomena.

Tilted disks are common phenomena in many early type and elliptical galaxies (Bertola et al., 1978; Hawarden et al., 1981). Spiral galaxies often show warps. Attempts have been made to explain these configurations in terms of stable closed orbits in rotating triaxial systems. Merritt (Heisler, Merritt and Schwarzschild, 1982) found a family of retrograde tilted orbits. Binney (1981) used Mathieu's equation to show that orbits in the plane of a rotating triaxial potential can be unstable for perturbations perpendicular to that plane.

Here the triaxial density distribution is chosen to be $\rho = \rho_o m^p$ with $m^2 = x^2/a^2 + y^2/b^2 + z^2/c^2$ and $a>b>c$. For the bulge of our Galaxy $p = -1.8$, $c/a = 0.4$ and $M = (9 \pm 2) \times 10^9 M_\odot$ within 1 kpc (Sanders and Lowinger, 1972; Isaacman, 1981). Burstein et al. (1982) found $p=-1.7\pm0.1$ from the rotation curves of 21 Sc galaxies. The density distribution pertains this value even at large radii. Therefore, bulge and halo are modelled with a single density distribution.

The axial ratio's were chosen to be $b/a = 0.8$ and $c/a = 0.5$ with $p = -1.8$ and the rotation frequency of the triaxial system $\omega = 0.1$ around the z-axis. Periodic orbits were calculated numerically with the method described by Magnenat (1982). There are tilted orbits near every $(\omega_o-\omega):\omega_z$ resonance, where ω_o is the rotation frequency in the non-rotating frame and ω_z the oscillation frequency perpendicular to the plane. Most of these orbits are self intersecting, have sharp turnings or are not symmetric with respect to the origin. The most important orbits for gas were found at the $\pm 1:1$ resonance, occuring for the retrograde orbits within CR and for the prograde orbits outside the OLR. The first correspond to those found by Merritt (Heisler et al., 1982). The latter are shown in

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fig. 1. They have an increasing tilt with increasing energy and start to have loops at a specific value of the energy, implying that gas in this type of orbit will have a maximum tilt.

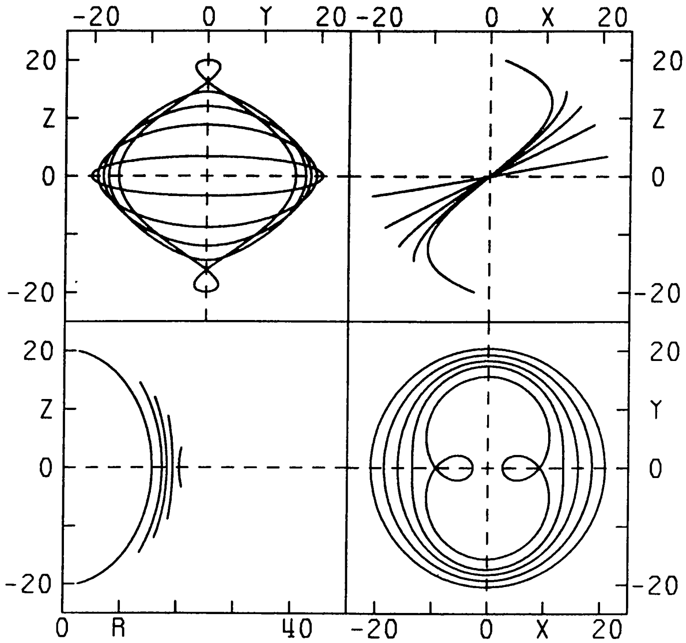

Fig.1. Stable prograde orbits at the -1:1 resonance. The plotted orbits have energies E of 2.75, 3.00, 3.25 and 3.50. The orbit with the loops is at E=4.40. The tilt increases as E increases. CR is at r = 8.4.

The following conclusions can be drawn:

(1) Under the assumption that the motion of gas in the outer part of a spiral galaxy can be described in terms of simple stable periodic orbits, a warp can be explained as a stationary phenomenon in a rotating triaxial system. As this assumption does not hold strongly, the presented calculations are only indicative.

(2) A model based upon these periodic orbits provides a length scale for the galaxy, predicting the locations of the other resonances in the assumed density distribution. It also defines the direction of the long axis of the triaxial figure.

(3) It should be noted that highly non-circular motions can occur in a rotating triaxial system. Interpretations of observations in terms of circular motion might unnecessarily give rise to multi component models for the mass distribution and notions as "expanding gas features".

References.

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