THREE-DIMENSIONAL ORBITS IN TRIAXIAL GALAXIES

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Many elliptical galaxies may be slowly rotating, moderately triaxial systems. Their dynamics are probably characteristic of a 1:1:1-resonance between the frequencies of oscillation along the three principal axes.

For a study of the 1:1:1-resonance it suffices to consider a model potential of the form

$$V = \tfrac{1}{2}\kappa_1^2\, x^2+\tfrac{1}{2}\kappa_2^2\, y^2+\tfrac{1}{2}\kappa_3^2\, z^2+\tfrac{1}{4}\{C_1x^4+C_2x^2y^2+C_3x^2z^2+C_4y^4+C_5y^2z^2+C_6z^4\}$$

where the three harmonic frequencies κ_1, κ_2 and κ_3 are assumed to be nearly equal. A general analytic investigation of motion in such a potential, nonrotating as well as rotating, has been made by de Zeeuw (1982). We are preparing a detailed comparison of these results with numerical computations (Martinet and de Zeeuw, in preparation). Here we limit ourselves to an inventory of the three-dimensional simple periodic orbits that may occur, and a discussion of their importance for real galaxies. (The orbits in the equatorial plane of triaxial models have been already considered by, e.g., de Zeeuw and Merritt (1982) and Martinet (1982)).

First we consider the case of no rotation. We start with κ_1, κ_2 and κ_3 as well as all coefficients C_i (i=1,...,6) equal to one. Three different types of three-dimensional simple periodic orbits exist for all energies:

(i) orbits which are nearly straight lines through the center, inclined to all principal axes;
(ii) elliptic orbits lying nearly in a plane containing one of the principal axes and tilted relative to two principal planes;
(iii) plane elliptic orbits that intersect none of the principal axes.

Making the system triaxial by changing κ_2 and κ_3 we find that these three types of orbits still exist, but not for all energies. The larger the difference between κ_1, κ_2 and κ_3, the further away from the center these orbits first occur. The existence range also depends on the C_i, of course. Some of the periodic orbits are stable, others are unstable in one perpendicular direction or in two independent perpendicular

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directions, depending on the values of the parameters in the potential V. In all cases considered, orbits of type (iii) are stable.

In the rotating case, direct and retrograde motion are distinct due to the Coriolis force. Orbits that in the absence of rotation are in the principal planes perpendicular to the equatorial plane, now tip out of these planes and become true three-dimensional orbits as Magnenat (1982) and Heisler et al (1982) have already found for other potentials. We find that all three-dimensional periodic orbits mentioned above also have rotating counterparts. Their stability is influenced by rotation. Some of the orbits now are complex unstable (see Magnenat 1982 for a definition). However, in all cases considered the retrograde generalization of the type (iii) orbit is stable. Direct stable tilted orbits may also exist in small ranges of energy.

The above results show that the interpretation of dust lanes observed in elliptical galaxies as gas and dust orbiting in certain stable periodic orbit families in a triaxial potential (van Albada, Kotanyi and Schwarzschild, 1982) may be more complicated than envisaged up till now. The existence of the stable orbits of type (iii) is particularly relevant here. Numerical work is in progress to investigate this point in more detail.

Not all periodic orbits described here need exist in a realistic triaxial potential, and certainly not at all energies. In nearly ellipsoidal potentials some of the tilted three-dimensional orbits do not occur at all. We observe that doubly, or complex, unstable orbits are in general accompanied by large stochastic regions in phase-space. Potentials in which these orbits do not exist are therefore likely to admit three isolating integrals of motion for most orbits. At the same time, the presence of type (iii) orbits, with their associated family of tube orbits, provides an additional building block for the construction of triaxial models (Schwarzschild, 1979).

REFERENCES

van Albada, T.S., Kotanyi, C.G. and Schwarzschild, M.: 1982, *M.N.R.A.S.*, 198, 303.

Heisler, J., Merritt, D.R. and Schwarzschild, M.: 1982, *Astrophys. J.*, 258, 490.

Magnenat, P.: 1982, *Astron. Astrophys.* 108, 89.

Martinet, L.: 1982, Proceedings of the CECAM Workshop on *Structure, Formation and Evolution of Galaxies,* held in Paris, August 1981 (eds. J. Audouze and C.A. Norman).

Martinet, L. and de Zeeuw, P.T.: 1983, in preparation.

Schwarzschild, M.: 1979, *Astrophys. J.* 232, 236.

de Zeeuw, P.T.: 1982, Proceedings of the CECAM Workshop on *Structure, Formation and Evolution of Galaxies,* held in Paris, August 1981 (eds. J. Audouze and C.A. Norman).

de Zeeuw, P.T. and Merritt, D.R.: 1982, submitted to *Astrophys. J.*