PERIODIC ORBITS IN STRONG BARS

CH. TERZIDES
Department of Astronomy, University of Thessaloniki, Greece

and

M. MICHALODIMITRAKIS
Department of Theoretical Mechanics, University of Thessaloniki, Greece

(Received 15 April, 1985)

Abstract. The aim of the present investigation has been to investigate numerically the orbits of particles in the gravitational field of barred galaxies for different models of such formations; with special attention to the families of direct periodic orbits in the co-rotating frame.

1. Introduction

The study of orbits of a test-particle in the gravitational field of a model barred galaxy is a first step toward the understanding of the origin of the morphological characteristics observed in real barred galaxies.

In the last few years several works on periodic motion in barred galaxy models appeared (Contopoulos and Papayannopoulos, 1980; van Albada and Sanders, 1982; Athanassoula et al., 1983; Papayannopoulos and Petrou, 1983; Pfenniger, 1984).

The purpose of our work is twofold: to complete the above studies and to check the possible dependence of previous results on the specific choice of model.

The case of strong bars has been studied mainly by Contopoulos and Papayannopoulos (1980), van Albada and Sanders (1982), and Papayannopoulos and Petrou (1983). Here we confine our attention to the basic stable direct symmetric families of periodic orbits existing inside co-rotation: i.e., the families $x_1$ and $x_2$ (in the Contopoulos notation). We study the cases of slow and fast rotation and the cases of small and large central mass concentration.

2. The Model Used

We consider a galaxy which consists of an axisymmetric part and a bar at its center. The axisymmetric part consists of a central bulge and a disk-like part. For the bar we used a homogeneous prolate spheroid. The potential of the spheroid at an exterior point is of the form

$$V_b = GM_b U_b R^*,$$  \hfill (1)

where $G$ is the gravitation constant and $M_b$ and $U_b$ are, respectively, the mass and the volume of the spheroid. The explicit formula for $R^*(x, z)$ is given by Macmillan (1958).
For the axisymmetric part of the galaxy we use a pair of generalized Kuzmin's models. The potential in such a model is

$$V_0 = GM' \left[ r^2 + \left[ a + (z^2 + b^2)^{1/2} \right]^2 \right]^{-1/2},$$  

where $M'$ is the mass and $a, b$ are constants with the dimension of length ($a$ determines the dimension of the galaxy and $b$ its thickness). Both $V_0$ and the corresponding three-dimensional density distribution are free from singularities everywhere in space and differentiable an unlimited number of times with respect to the space coordinates. The density is non-negative everywhere in space and simulates surprisingly well the stratifications of mass both in the central bulge and in the disk parts of real galaxies. The ratio $b/a$ is a measure of the flatness. As $b/a$ decreases the galaxy becomes flatter and flatter (Miyamoto and Nagai, 1975).

The total axisymmetric potential is of the form

$$V_0 = \sum_{i=1}^{2} \frac{GM_i}{R_i^{1/2}},$$  

where

$$R_i = r^2 + \left[ a_i + (z^2 + b_i^2)^{1/2} \right]^2.$$  

A potential of the form (3) with the values

$$a_1 = 0.0 \text{ kpc}, \quad b_1 = 0.495 \text{ kpc}, \quad M_1 = 2.05 \times 10^{10} M_\odot;$$

$$a_2 = 7.258 \text{ kpc}; \quad b_2 = 0.520 \text{ kpc}, \quad M_2 = 25.47 \times 10^{10} M_\odot;$$

of the parameters $(a_i, b_i, M_i)$ has been proposed as a model for the mass distribution of our Galaxy. The values $(a_1, b_1, M_1)$ correspond to a central bulge $(a_1 = 0)$ while the values $(a_2, b_2, M_2)$ to a highly flattened distribution (disk) so that the oblateness of the overall configuration is about $\frac{1}{10}$.

### 3. Parameters of the Problem

We choose the $x$-axis along the major axis of the bar and the $z$-axis along the axis of symmetry of the axisymmetric background. By making the substitutions $l = z\ell$ for the lengths ($\ell$ is the semi-major axis of the bar) and $t = t/\Omega$ (\(\Omega\) is the constant angular velocity of the bar) we put the equations of motion in a dimensionless form and introduce the dimensionless parameters

$$\mu_1 = (M_1 + M_2)/M_b \quad \text{and} \quad \mu_2 = M_2/M_1,$$

giving, respectively, the mass ratio of the axisymmetric part to the bar and the mass ratio of the two components (bulge-disk) of the axisymmetric part. We also introduce the