Rev. Mexicana Astron. Astrof. **12**, 109-113 (1986)

EVOLUTION OF VELOCITY DISPERSIONS IN SOME COLLAPSING SPHEROIDAL DISTRIBUTIONS OF MASS

E. Moreno and P. Pişmiş

Instituto de Astronomía
Universidad Nacional Autónoma de México

RESUMEN. La integración numérica de una muestra de órbitas en algunos potenciales producidos por distribuciones esferoidales de masa en colapso conduce a dos resultados principales: (a) ni el tiempo de colapso ni la distribución particular de masa en el sistema parecen tener el papel dominante en la evolución dinámica del conjunto de órbitas considerando, (b) la distribución inicialmente 'esférica' en las velocidades se conserva aproximadamente en el tiempo.

ABSTRACT. Numerical integration of a sample of orbits performed in the gravitational field of some collapsing spheroidal distributions of mass leads to the following main results: (a) neither the time of collapse nor the mass distribution in the system seem to play a dominant role in the dynamical evolution of the calculated sample of orbits, (b) the form of the velocity distribution, initially 'spherical', is approximately conserved in time.

Key words: GALAXIES-SPHEROIDAL — GALAXIES-VELOCITY DISPERSION

I. INTRODUCTION

In the past there have been many simulations related to galactic evolution, attempting to see the evolutive dynamical forms the system goes through in the course of time. The difficulties involved in treating an overall comprehensive model for galactic evolution have lead to adopt some simplified models to study the dynamical evolution of objects born around the beginning of the collapse or in the course of it (Antonov *et al.* 1975; Yoshii and Saio 1979). In this work we follow this simplified line to study the evolution of the velocity dispersions of objects born at the start of the collapse of different distributions of mass and for different collapse times. This treatment has some bearing on the evolution of extreme Population II objects in galaxies and on conclusions reached earlier (Sandage *et al.* 1970). In Section II we present the simplified models. In Sections III and IV the calculated orbits and some results are briefly discussed.

II. MODELS

As models for possible galactic collapse we have considered the evolution, until a certain time, of homogeneous and heterogeneous spheroidal distributions of mass. The evolution of the homogeneous type has been worked out by Arny (1967); this is the evolution of a cold gas, uniformly distributed within a spheroid and initially rotating as a rigid body. For the heterogeneous type, we have worked out the evolution by means of the virial theorem formalism of the n = 6 case in Pişmiş and Moreno (1984). This is a distribution of mass consisting of a Schmidt spheroid and a shell around it with a R^{-6} density law.

We have fixed the final configuration of the collapse to have a specific form in the distribution of mass; thus the numerical integration is stoped at the time when the dimensions of the Schmidt and homogeneous spheroids are $R_{sph} \sim 12.6$ kpc, $z_{sph} \sim 1.6$ kpc respectively (see Table 1 for actual values). Two cases have been considered for each distribution of mass; these differ only in the initial conditions, and are taken in such a way that the configuration attains approximately the final form mentioned above.

The evolution of the distributions of mass and the orbits treated in the next section are computed numerically (and simultaneously) by means of a Runge-Kutta-Nyström algorithm of the sixth order (Fehlberg 1972). Table 1 gives the initial and final conditions of the four computed cases. The total mass in each distribution is 10^{11} solar masses. Figures 1 and 2 show the evolution of the models, with $R_{sph}(t) = f(t) \cdot R_{sph}(0)$ and $z_{sph}(t) = g(t) \cdot z_{sph}(0)$ the dimensions of the Schmidt and homogeneous spheroids.

TABLE 1. Initial and Final Conditions of the Models

	Case A homogeneous $\Omega(0) = 0.04786$	Case B homogeneous $\Omega(0) = 0.01175$	Case C heterogeneous	Case D heterogeneous
$R_{sph}(0)$	62.729	121.378	50.0	100.0
$z_{sph}(0)$	62.729	121.378	50.0	100.0
$\dot{R}_{sph}(0)$	0.0	0.0	0.0	0.0
$\dot{z}_{sph}(0)$	0.0	0.0	-0.5	-0.122
t_{col}	8.665	22.987	8.706	23.611
$R_{sph}(t_{col})$	12.558	12.609	12.479	12.635
$z_{sph}(t_{col})$	1.544	1.528	1.588	1.564

Distance in kpc, velocity in 10 km s^{-1} units, $\Omega(0)$ in 1.023×10^{-8} yr^{-1} units, time in 0.977×10^{8} yr units. $\Omega(0)$ is the initial angular velocity, t_{col} the time of collapse.

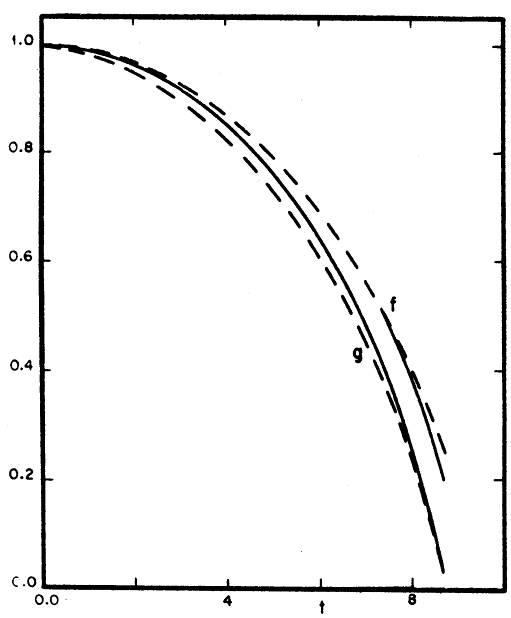

Fig. 1. The evolution of models A (continuous curves) and C (dashed curves). The dimensions of the corresponding spheroid are given by $R_{sph}(t) = f(t) \cdot R_{sph}(0)$, $z_{sph}(t) = g(t) \cdot z_{sph}(0)$. See Table 1 for initial conditions. Time in units of 0.977×10^{8}yr.

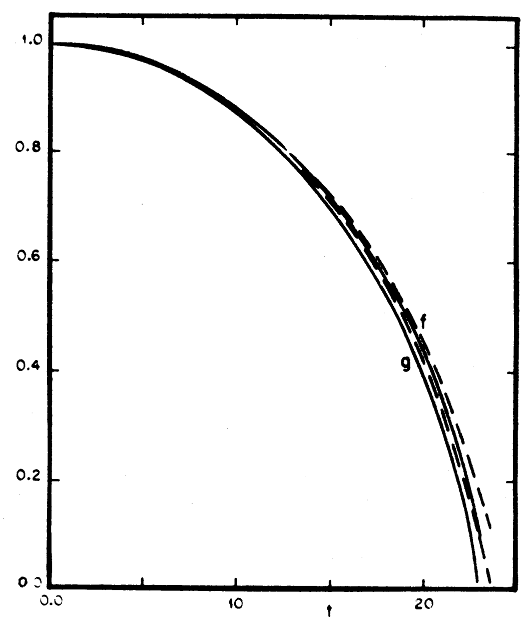

Fig. 2 Evolution of models B (continuous curves) and D (dashed curves). In this and following figures time is given in units of 0.977×10^{8}yr.

III. ORBITS

We investigate the orbital behavior of some objects born at zero time in the distributions of mass given in the last section. In particular the emphasis in this work rests mainly on the evolution of the velocity dispersions in the plane $z = 0$ and in the z direction (rotation and symmetry axis), as measured by an inertial observer. After the collapse the mass distribution is steady and is that attained at the collapse time, t_{col}. The orbits are thus calculated partly in a time-dependent potential and partly in a steady one. For economic reasons we necessarily restrict the study to a sample set of orbits, but expect these will show the characteristic behavior associated with the totality of objects born at the very start of the collapse.

We have taken twelve points equally distributed at three galactocentric distances of 15, 30 and 45 kpc and in the same meridional plane (R,z). These points are also equally distributed in polar angle (θ) with respect to the z axis such that three are at $\theta = 18°$, three at $\theta = 36°$, and so on. In each of these points we have taken five initial velocity conditions to start orbit computation, i.e., five objects are born at each point. In terms of cylindrical components of velocity, (Π,Θ, Z), the initial velocity vectors lie in the directions (1,1,1), (1,1,-1), (-1,1,-1), (-1,1,1), and (0,1,0), all with the same magnitude in velocity, $|\hat{v}| = 40$ km s^{-1}.

Each orbit is computed in all the models given in the last section until 10^9 years after the collapse time, t_{col}. Owing to the symmetry of the mass distributions the five orbits in each point represent a total of twenty orbits.

In order to make the interpretation of the results easier we have fixed the initial conditions of all orbits in all the cases A to D (Table 1), so we do not consider any component to the initial velocity due to a possible motion of the centroid at the point. The main question of this work is then the following: given a set of initial orbital conditions, what is the behavior of the velocity dispersions in different background potentials? Assuming rotational symmetry at the initial position in the birth of objects at the initial time, we can compute, at any epoch, the velocity dispersions of all objects associated with the ones in our initial meridional plane. With respect to an inertial observer the total dispersions are simply $\sigma_{axis} = \sigma_z$, $\sigma^2_{plane} = \frac{1}{2}(\langle v_x{}^2\rangle + \langle v_y{}^2\rangle)$; where $\langle v_x^2\rangle$, $\langle v_y^2\rangle$, σ_z refer to the objects born in the same meridional plane, with the x-axis defined as the intersection of this plane with the plane z=0.

IV. SOME RESULTS AND DISCUSSION

In this section we present some results and try to single out the influence on the orbital behavior of the four cases listed in Table 1. Although these four cases are not straightforwardly comparable with each other, we note that by comparing A, C and B,D we may obtain some idea of the influence of the distribution of mass on the orbital behavior in a slow and fast collapse, respectively. Also, the comparison of A, B and C,D is important with respect to the influence of the time of collapse in homogeneous and heterogeneous distributions of mass, respectively. We make the assumption that at the initial time the dynamical conditions are spherically symmetric, so that all objects born at a given distance R have the same weight. Our computations show that there is no significant difference in the behavior of the three blocks of orbits in a given model, born at 15, 30, and 45 kpc, each taken separately, so that the results are valid for any block. The results we present refer to the three blocks giving equal weight to each one, but there will be no qualitative change if we introduce some weighting factors in accordance with the importance of each block.

Figures 3 to 6 show the main results. For $t < t_{col}$ the velocity dispersions increase faster in the heterogeneous cases C and D than in the homogeneous ones, A and B, however an overall increase at t_{col} is evident; around this time the system configuration is changing quickly (see Figures 1 and 2). At $t > t_{col}$ the dispersions seem to oscillate, a collective behavior already noted by others (Innanen and House 1975; Byl and Ovenden 1973). Quantitatively $\sigma_{plane}(t)/\sigma_{plane}(0)$ tends to a value between 3 and 4 for $t > t_{col}$, independently of the model, although more integration time will be required to justify this statement for case B. In this case (Figure 4) we note a peak in the quantities $\sigma_{axis}(t)/\sigma_{axis}(0)$, $\sigma_{plane}(t)/\sigma_{plane}(0)$ slightly shifted towards higher t, compared to others, as well as a steep fall at later times possibly indicating long-amplitude-and-time- oscillations. The ratio $\sigma_{axis}(t)/\sigma_{axis}(0)$ tends also, in

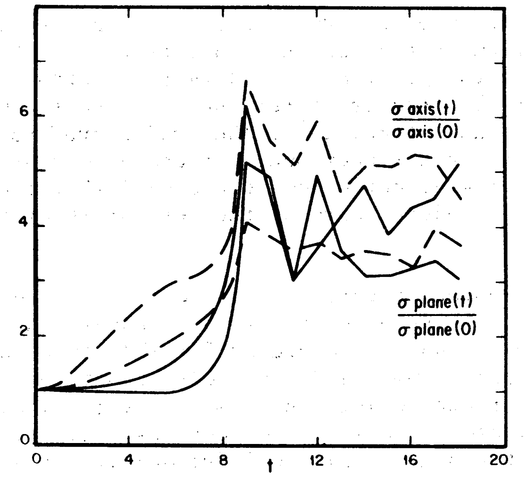

Fig. 3. Evolution of the ratios $\sigma_{axis}(t)/\sigma_{axis}(0)$, $\sigma_{plane}(t)/\sigma_{plane}(0)$ for the sample of orbits, calculated in model A (continuous lines) and model C (dashed lines).

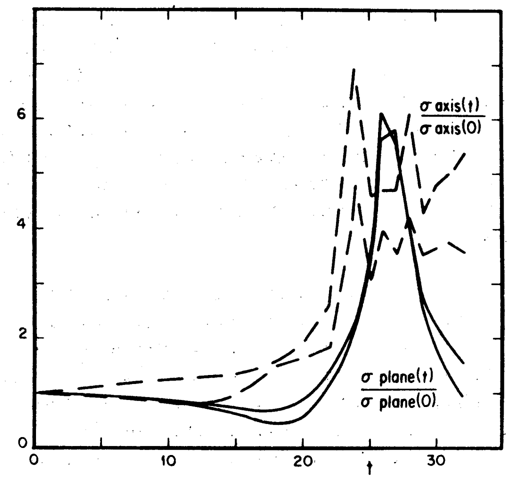

Fig. 4. As in Figure 3, but now for models B (continuous lines) and D (dashed lines).

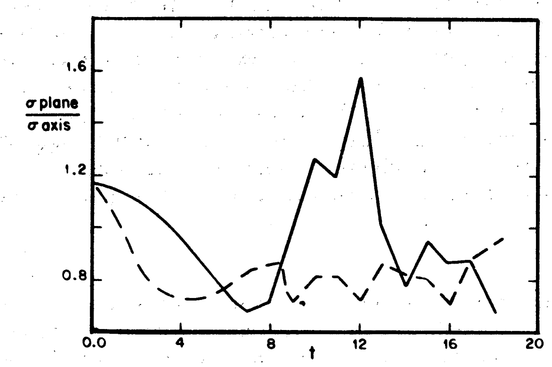

Fig. 5. The evolution of the ratio $\sigma_{plane}/\sigma_{axis}$ of the sample of orbits, calculated in models A (continuous line) and C (dashed line).

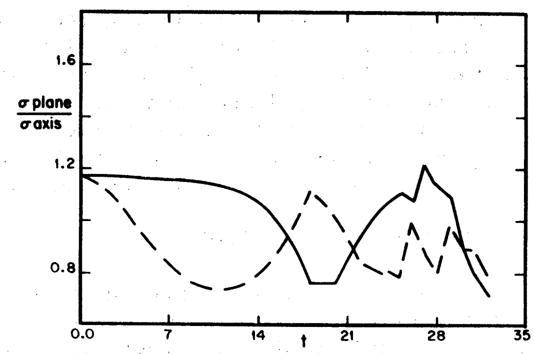

Fig. 6. The evolution of the ratio $\sigma_{plane}/\sigma_{axi}$ of the sample of orbits, calculated in models (continuous line) and D (dashed line).

$t > t_{col}$, to a value around 5 independent of the model (again, case B is marginal).

At the start we assumed a nearly 'spherical distribution of velocities'. As Figures 5 and 6 show, after the collapse we have a distribution almost of the same type: $<\sigma_{plane}/\sigma_{axis}>$ tends to a value around 1, independent of the model. In the heterogeneous models σ_{axis} is in general greater than σ_{plane} and the average value of $\sigma_{plane}/\sigma_{axis}$ is around 0.8 to 0.9. This near-conservation of the form of the velocity distribution is not a trivial one since the orbit are under strong changes in the potential and have enough time to forget their initial conditio In the fast collapse cases A and C, and in $t < t_{col}$, the orbits reflect somehow their initial conditions; but after t_{col} they are strongly bound and make frequent trips around the center of the mass distribution so that their initial behavior is lost. We must keep also in mind that fo $t > t_{col}$ the potential is quite different to that at the beginning.

The near independence of the results on the model is only provisional because of th restricted initial orbital set, but these results may shed some light on the expected evolution extreme Population II objects in galaxies. Frenk and White (1980) have concluded that the stem of Galactic globular clusters is nearly in a state of isotropic velocity distribution, ich is in line with the results here presented.

We have seen that the collapse time and distribution of mass in an evolving galaxy possibly not too important in the evolutive dynamical behavior of initially born objects ken as a whole. An important thing that remains to be done is to confront our data with Lynden-ll's violent relaxation treatment, although in our situation we do not have a self-consistent llapse.

FERENCES

tonov, V.A., Osipkov, L.P., and Chernin, A.D. 1976, *Astrophysics*, 11, 223.
ny, T.T. 1967, *Ann. d'Ap.*,30, 1.
l, J. and Ovenden, M.W. 1973, *M.N.R.A.S.*, 164, 289.
hlberg, E. 1972, *NASA TR R-381*.
enk, C.S. and White, S.D.M. 1980,*M.N.R.A.S.*, 193, 295.
nanen, K.A. and House, F.C. 1975, *Ap. and Space Sci.*,32, 139.
şmiş, P. and Moreno, E. 1984, *Rev. Mexicana Astron. Astrof.*, 9, 171.
ndage, A., Freeman, K.C., and Stokes, N.R. 1970, *Ap. J.*, 160, 831.
shii, Y. and Saio, H. 1979, *Pub. Astr. Soc. Japan*, 31, 339.

lmundo Moreno and Paris Pişmiş: Instituto de Astronomía, UNAM, Apartado Postal 70-264, 04510
México, D.F., México.