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Orbits in a simple model of contracting galaxy: preliminary results

S.D. Buliga, L.P. Ossipkov*

Department of Space Technologies and Applied Astrodynamics, Saint Petersburg State University, 35 Universitetskij Pr., Staryj Peterhof, Saint Petersburg 198504, Russia

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Orbital elements were calculated for a contracting sphere by Kuzmin–Veltmann–Hernquist. It was found that circular orbits become elongated.

Keywords: Stellar dynamics; Celestial mechanics – Galaxies: orbits

1 Introduction

Can we reconstruct Galactic History from statistics of orbital elements of old stars? Eggen et al. [1], Yoshii & Saio [2] and others tried to solve the problem but their pictures of an initial contraction are quite different and their models of a monolithic collapse are not very popular now. We will not discuss alternative scenarios of early galactic evolution but will study a more modest problem: how osculating orbital elements vary for some simple models of time-dependent potentials. Only a few authors tried to investigate this problem. Saslaw [3] qualitatively discussed what happens to orbits during an adiabatic contraction. Lecar [4] studied some models of a contracting uniform sphere. Goodman & Binney [5] considered an adiabatic collapse. Antonov, Ossipkov & Chernin [6] found conditions for orbit escape out of a contracting sphere.

We will consider a "limiting" spherical model [7, 8] discovered later by Hernquist [9]. A positive potential of the model $\Phi(r) = \Phi_0/(1 + r/r_0)$. It is evident that a total mass of the model $M = \Phi_0 r_0/G$. We put $r_0 = r_*/\lambda(t)$, where $\lambda(t)$ is a given function and $\lambda(0) = 1$. Then a condition of mass conservation yields $\Phi_0 = (GM/r_*)\lambda(t)$. We define a dimensionless distance $R = r/r_*$ and dimensionless time $\tau = t/(r_*^3/GM)^{1/2}$. Then we put $\lambda(t) = [1 + \Lambda(\tau/\tau_c)] \,/\, [1 + (\tau/\tau_c)]$, Λ, τ_c being dimensionless parameters, for phenomenological study of contraction (or expansion for $\Lambda \in (0, 1)$).

We integrated equations of motion for various values of a dimensionless specific angular momentum L. Initial distances $R(0)$ were considered as apocentres. We calculated time dependence of osculating orbital elements, namely, an energy, an

*Email: leonidosipkow@yahoo.com

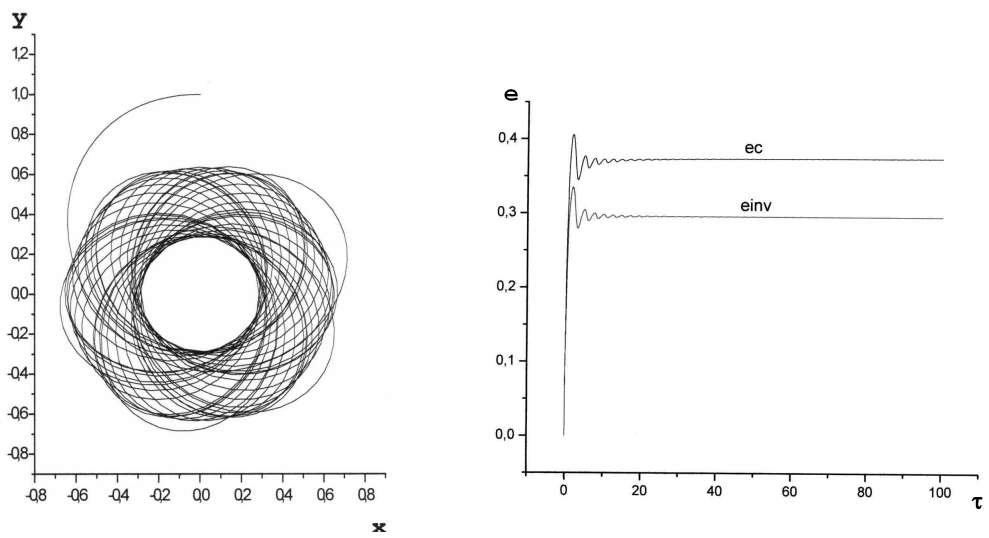


Figure 1 An orbit (left panel) and time-dependence of eccentricities (right panel) for $\Lambda = 10$, $L = 10$, $\tau_c = 5$, $R(0) = 1$.

apocentre R_a, a pericentre R_p, an eccentricity $e_c = (R_a - R_p)/(R_a + R_p)$ and Lynden-Bell's [10] invariant eccentricity e_{inv}. We see (Fig. 1) that both e_c and e_{inv} increase for initially circular orbits. Binney & May [11] wrote that galaxies, like elephants, have long memories. But we conclude that sometimes stars lose their memories.

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