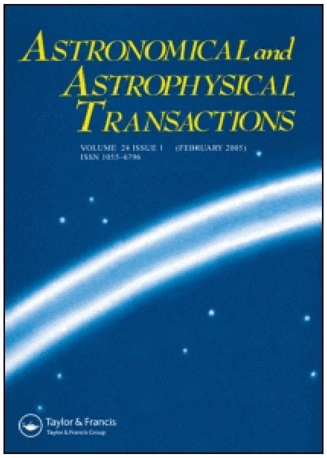

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NON-LINEAR MODELS OF NON-STATIONARY SELF-GRAVITATING SYSTEMS AND THEIR STABILITY PROBLEM†

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Simple analytical non-linear models of non-stationary galaxies are constructed. Their forms are spherical or disk-like. Their radius is

$$R(t) = \Pi(\psi) \cdot R_0,$$

where

$$\Pi(\psi) = \left(1-\lambda^2\right)^{-1}(1+\lambda\cos\psi)\,, \lambda = 1-(2T/|u|)_0.$$

Here λ is the pulsation amplitude, and $(2T/|u|)_0$ is the initial virial ratio,

$$\Omega_0 t = \left(1-\lambda^2\right)^{-3/2}(\psi+\lambda\sin\psi)\,, \Omega_0 = \text{const}\,.$$

If $\lambda = 1$, then the orbits are purely radial.

For example, in the spherical case, we constructed the following phase models without rotation:

$$\begin{aligned}
\Psi_1(r, v_r, v_\perp, t) &= \rho(t)[2\pi v_b(t)]^{-1}\delta(v_\perp - v_b)\delta(v_r - v_a)\chi(R-r)\,, \\
\Psi_2(r, v_r, v_\perp, t) &= \rho(t)\Pi^4(t)[\pi^2\Omega_0 R^2]f^{-1/3}\chi(f)\,,
\end{aligned}$$

and rotating models with

$$\begin{aligned}
\Psi_\mu^{(1)} &= (1+\mu v_\perp v_b^{-1}\sin\Theta\sin\eta)\Psi_1\,, \\
\Psi_\mu^{(2)} &= \left(1+\mu r v_\perp (\Omega_0 R_0^2)^{-1}\sin\Theta\sin\eta\right)\Psi_2\,.
\end{aligned}$$

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Here $\rho(t)$ is the density, $\chi(f)$ is Heaviside's function,

$$
\begin{aligned}
f &= \left(1 - r^2/R^2\right)\left(\Omega_0^2 R^2 \Pi^{-4} - v_\perp^2\right) - \left(v_r - v_a\right)^2 , \\
v_a(t) &= -\Omega_0 \lambda \sin\psi \cdot r \left[\left(1-\lambda^2\right)^{1/2} \Pi^2\right]^{-1} , \\
v_b(t) &= -\Omega_0 r / \Pi^2(\psi) , \\
\sin\Theta &= \left(x^2 + y^2\right)^{1/2} / r , \\
\eta &= \tan^{-1}(v_\varphi / v_\Theta) .
\end{aligned}
$$

Stability problems of the non-stationary models constructed are also studied.

DISCUSSION

Hunter: On the subject of pulsational oscillations of spherical stellar systems, those have been found by R. H. Miller and B. F. Smith in recent N-body calculations. They find that these oscillations are well described by virial estimates, based on the approximation that amplitudes are proportional to distance from the centre.
Antonov: Yes, the virial estimates characterize the intensity of the oscillations. This fact is used in later works of Nuritdinov. Some numerical experiments (see also Merritt, with whom Nuritdinov had the contacts) base on the same or similar models. Numerical results do not contradict to the conclusions of the analytical theory.
Chernin: In which respects does your problem presented here differ from the previous investigation of A. M. Fridman *et al.*?
Antonov: They have investigated a stationary model. As the pulsation amplitude decreases to zero, we recover their results from our formulae. It is correctly deduced. However, there is yet a work on the pulsations of an inhomogeneous sphere consisting of thin shells which move across each other at collisions. The inhomogeneity leads to specific irreversible effects which we cannot obtain in our homogeneous models.
Chernin: What is the criterion of the instability of a non-stationary system?
Antonov: Let the stars of the two systems, stationary and non-stationary ones, be mutually connected by an identical formal numeration. It gives a method for the description of a not weakly pulsating system, its state is determined indirectly through other system. Both systems are spherically symmetric. However we introduce weak perturbations into the non-stationary system. Conditions for asymmetric oscillations are expressed by differential equations with periodic coefficients. Solutions of these equations are represented, by virtue of the well-known theory, by functions of the same period, but with an exponential multiplier $e^{\alpha t}$. If α is a purely imagine value, there is the stability.