Analytical models for ellipticals and bulges with rotation

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Abstract. The results of the analytical study of two disspationless non–linear models are generalized in case of rotation.

1. Non–Linear Models without Rotation

The following non-linear models are very useful for the investigation of dissipationless collapse and the conditions of the formation of ellipticals: model 1 (see V.A. Antonov & S.N. Nuritdinov, 1981, *Sov.Astr.Zh.*, **58**,1158)

$$\Psi_1 = \frac{\rho}{2\pi v_b}\delta(v_r - v_a)\delta(v_\perp - v_b)\chi(\Pi - r) \tag{1}$$

and model 2 (see S.N. Nuritdinov, 1983, *Sov.Astr.Zh.*, **60**, 40)

$$\Psi_2 = \frac{\rho\Pi^3}{\pi^2}[(\Pi^2 - r^2)(\Pi^{-2} - v_\perp^2) - \Pi^2(v_r - v_a)^2]^{-\frac{1}{2}}\chi(\Pi - r). \tag{2}$$

Here $\rho(t)$ is the density at the time t, v_r and $v_\perp$ are the radial and the transverse velocities, χ is the Heaviside step function, $\Pi = \frac{1+\lambda\cos(\psi)}{(1-\lambda^2)}$, $t = \frac{\psi+\lambda\sin(\psi)}{(1-\lambda^2)^{\frac{3}{2}}}$, $v_a = \frac{-\lambda r\sin(\psi)}{\sqrt{1-\lambda^2}\Pi^2}$, $v_b = \frac{r}{\Pi^2}$, $1-\lambda = (\frac{2T}{|U|})_0$. Antonov & Nuritdinov (1981) and Nuritdinov (1983) found the critical value $\Lambda_{\rm cr} = \frac{\sqrt{21}}{5}$ for the ellipsoidal oscillations mode that corresponds to the value of $(\frac{2T}{|U|})_0 = 0.084$ and that is connected with the radial–orbit instability. The numerical experiments of L.Aguilar & D.Merritt (1991, *Ap.J.*, **345**, 33) confirm this result. Nuritdinov (1985, *Sov.Astr.Zh*, **62**, 506) noted an ellipsoidal instability zone $\lambda \in [0.611, 0.873]$, which has a resonance nature and corresponds to $(\frac{2T}{|U|})_0 \in [0.127, 0.389]$. Unfortunately up to now the accuracy of our numerical experiments does not allow to reveal the presence of this zone.

2. Models with Rotation

For the case with rotation we have (see Nuritdinov, 1992, in press)

$$\Psi_\Omega = [1 + \Omega(\frac{v_\perp}{v_b})\sin\theta\,\sin\gamma]\Psi_1, \quad \Psi_\Omega^* = (1 + \Omega r v_\perp \sin\theta\,\sin\gamma)\Psi_2, \tag{3}$$

where $\sin\theta = \frac{\sqrt{x^2+y^2}}{r}$, $\tan\gamma = \frac{v_\varphi}{\theta}$, and Ω characterizes the rotation ($0 \le \Omega \le 1$). The angular velocities of these models are $\omega_1 = \frac{\Omega}{2\Pi^2}$ and $\omega_2 = \frac{\Omega}{4\Pi^2}$. We found a critical dependence of $(\frac{2T}{|U|})_0$ on Ω. It is interesting that the area of the radial–orbit instability connects to the resonance instability area at lowest value of Ω. On the base of these models we can construct a new model $\Psi = (1-\nu)\Psi_{\Omega_1} + \nu\Psi^*_{\Omega_2}$, where ν, Ω_i, $i = 1, 2$ are free parameters.

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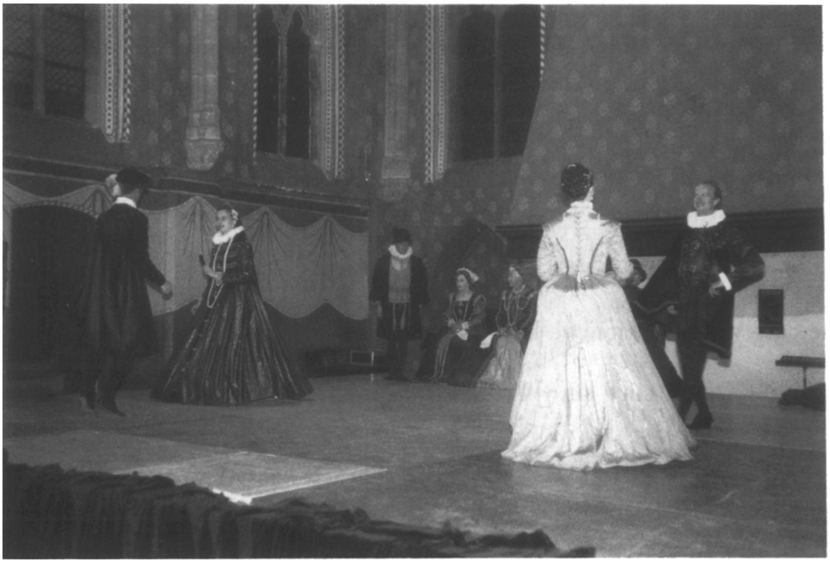
Singers and dancers performing during the cultural event



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