AXISYMMETRIC MODELS OF ELLIPTICAL GALAXIES WITH ANISOTROPY

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It is well known by now that models of elliptical galaxies based on Jeans theorem require the inclusion of a third integral in the distribution function.

When we assume axial symmetry, we have two exact integrals of the motion, the energy E and the angular momentum about the symmetry axis h_z. If we had spherical symmetry, the third integral would have been the modulus of the total angular momentum. In the case of axial symmetry, a plausible assumption is that the third integral is a generalization of the total angular momentum, say of the form:

$$I_3 = h^2/2+g(r,\vartheta) \quad (1)$$

For I_3 to be an exact integral, $g(r,\vartheta)$ must satisfy the two equations

$$g = g(\vartheta) \quad (2)$$

$$g = -r^2\Psi(r,\vartheta)+C(r) \quad (3)$$

where $\Psi(r,\vartheta)$ is the potential of the system and $C(r)$ a function of r. It can be shown that this happens only if $\Psi(r,\vartheta)$ can be written in the form

$$\Psi(r,\vartheta) = F_1(r)+F_2(\vartheta)/r^2 \quad (4)$$

where $F_1(r)$, $F_2(\vartheta)$ are any functions of r and ϑ respectively. Then

$$g(r,\vartheta) = r^2(\Psi(r,\vartheta_o)-\Psi(r,\vartheta)) = F_2(\vartheta_o)-F_2(r) \quad (5)$$

where ϑ_o is some constant value of ϑ, say $\pi/2$.

In general, however, an axially symmetric potential cannot be written in form (4). Instead it can be expanded into an infinite series of even order Legendre polynomials:

$$\Psi(r,\vartheta) = A_o(r)+A_2(r)P_2(\cos\vartheta)+\ldots \quad (6)$$

E. Athanassoula (ed.), Internal Kinematics and Dynamics of Galaxies, 291–292.

Suppose now that the following two assumptions hold for this expansion: 1) Only the first two terms are significant. 2) $A_2(r) \sim r^{-\alpha}$ where $\alpha \sim 2$. Then one can construct an approximate third integral by choosing $g(r,\vartheta)$ as:

$$g(r,\vartheta) = (\Psi(r,\pi/2)-\Psi(r,\vartheta))/A_2(r) \qquad (7)$$

Some models of elliptical galaxies were computed using the above technique and the validity of the above two assumptions was checked a posteriori to be true. Further, the models satisfied Jeans hydrodynamic equations to a good accuracy. The distribution function of the model presented here is:

$$f(E,h_z,I_3) = e^{-\Psi(0,0)}(2\pi)^{-3/2}(e^{-E}-1)(1+\Omega h_z/\sqrt{1+h_z^2})e^{-\Gamma I_3} \qquad (8)$$

where $\Omega=0.3$, $\Gamma=10^{-5}$, $I_3=(h^2-h_z^2)/2+g(r,\vartheta)$ and $g(r,\vartheta)$ is given by (7). The modification in the form of I_3 (by the inclusion of h_z) was done to achieve the depopulation mainly of the orbits of high inclination so that the galaxy looks flat. The observational properties of the model when seen edge on are shown in figures 1,2 and 3. The lengths are in units of core radius r_c where $r_c=\sigma_o/\sqrt{G\rho_o}$ where σ_o, ρ_o are the central dispersion velocity and central density respectively.

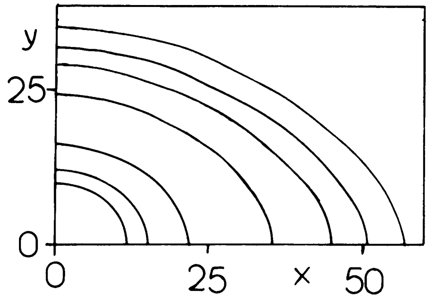

Fig.1: Equidensities. The axial ratio is 0.82, 0.8, 0.75, 0.68, 0.64, 0.63, 0.6 (from inside outwards).

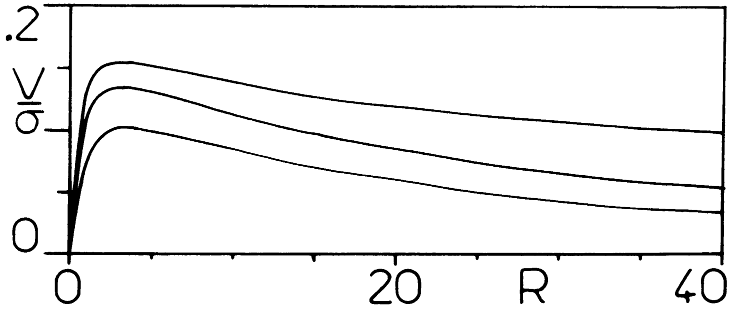

Fig.2: Observed velocity curve for position angles 0^o, 42^o, 64^o measured from the major axis (from top to bottom).

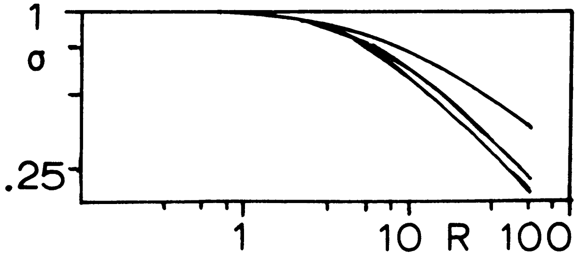

Fig.3: Observed dispersion velocity for position angle 0^o, 42^o, 90^o from top to bottom.