ON THE DISTRIBUTION FUNCTION OF ELLIPTICAL GALAXIES

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Abstract. Distribution functions containing cutoff in energy impose several limitations on systems they describe, e.g., no circular orbits are allowed in the major part of system and spatial boundary is poorly defined. As opposed to these functions, we present here distribution function that describes galaxies of finite extent (i.e., truncated in radius). We discuss properties of systems having this distribution function for spherical and axisymmetric cases and compare their surface brightness, isophotes, and rotation curves with observations of elliptical galaxies. This distribution function can easily be generalized to a triaxial galaxy.

Elliptical galaxies as well as any stellar systems have finite extent and hence they should be described by truncated distribution functions, i.e., the probability to find a star above a certain boundary should be zero. The most commonly used truncated spherical distribution function is the King-Michie one, $f_k \propto (e^{-\varepsilon/\sigma^2} - 1)e^{\alpha J^2}$ which excludes from the system any star with positive energy ε. Prendergast and Tomer (1970) and later Wilson (1975) generalized f_k to a rotating axisymmetric system. However, all the above models do not give adequate fits when applied to observational data. Differently truncated distribution function would produce systems with completely different density profiles (particularly in outer regions) and dynamical properties (e.g., Wilson 1975) and, therefore, it is important to construct consistently truncated distribution function. All distribution functions considered before contained truncation in energy, which means that any star bound to the galaxy must have negative energy with respect to potential at the boundary. However, condition for a star of angular momentum J to be bound to the galaxy of radius R is $\varepsilon < J^2/2R^2$, <u>not</u> $\varepsilon < 0$. Distribution functions with truncation in energy exclude circular orbits from almost half of the system and stars at the boundary would have to move on radial orbits only. This is a rather ad hoc constraint and a more realistic constraint should produce galaxy

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truncated in radius not energy, since any system that forms by collapse and fragmentation would have finite extent.

As opposed to distribution functions truncated in energy, we construct distribution function that is truncated in radius and a priori does not impose constraints on the distribution of stellar orbits (Kashlinsky 1986). Properties of such models are best illustrated by an example of such spherically symmetric system. For a spherical system such a distribution function would be

$f \propto (e^{-\varepsilon/\sigma^2} - e^{-J^2/2R^2\sigma^2})$ and potential can be found by solving Poisson equation $\nabla^2\phi = -4\pi G\int f d^3\underline{v}$ coupled with boundary condition $\phi(r = R) = 0$ that determines R to be used in f which somewhat complicates the problem mathematically. Note that here the distribution of orbits is anisotropic and orbits become predominantly tangential near the boundary. Anisotropy of orbits is a natural product of having stellar system that is truncated in radius and degree of anisotropy does not require any parameters besides specifying the depth of central potential $\phi(o)/\sigma^2$. The resultant velocity dispersion of the system $\sigma^2 = \rho^{-1} \int f v^2 d^3\underline{v}$ is much flatter than that of the King (1966) models which is consistent with observations. Density profile, too, is significantly different from the King one once the surface density drops below $\sim 10^{-4}$ of the central value. We generalize this distribution function to rotating and axisymmetric systems and compare resultant isophotes rotation curves, velocity dispersion profiles, etc., with available observations. The distribution function considered here leads to almost flat rotation curves of elliptical galaxies in agreement with observations. The reason for a much flatter (than in previous models) rotation curve is that outer regions of the galaxy are dominated now by stars on tangential orbits. Because these models are intrinsically anisotropic even in the absence of rotation, it is easy to reproduce an elliptical galaxy of any flattening even for moderate amounts of rotation. Isodensity contours are almost spherical near the center and become more flattened near the boundary. The models can be easily generalized to triaxial galaxies once the relevant integrals of motion are known.

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