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Analytical Galactic Models with Mild Central Cusps

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Abstract. We present a new class of spherical galactic models with mild central cusps whose distribution function (DF) and intrinsic velocity dispersion (IV) can be represented analytically in a unified way in terms of hypergeometric functions for a large number of parameters. This allows an easy comparison of these quantities for models having varying degrees of central cuspiness or outer density falloff. In particular, we study the models for the innermost regions of galaxies harbouring mild cuspy centers with or without supermassive black holes (SBH). Important properties infered from the observed behaviour of the velocity dispersions can be reproduced.

Keywords. galaxies: structure, galaxies: nuclei, galaxies: kinematics and dynamics

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We start from the spherical (relative) potential $\Psi(r) = \frac{b^{\alpha\gamma}}{(b^{\alpha}+r^{\alpha})^{\gamma}}$, whose corresponding density distribution is $\rho(r) = \frac{b^{\alpha\gamma+2}}{1+\alpha}\frac{[(1+\alpha)b^{\alpha}+(1-\alpha\gamma)r^{\alpha}]}{r^{2-\alpha}(b^{\alpha}+r^{\alpha})^{\gamma+2}}$ with $0 < \alpha \leqslant 2; \gamma, b > 0; \alpha\gamma \leqslant 1$. So it goes like $\rho(r) \sim r^{\alpha-2}$ for small r and falls off like $\rho(r) \sim r^{-2-\alpha(\gamma+1)}$ for large r and hence covers a large set of observed density distributions. The above choice of parameters allows for a shallow falloff of the potential and density. Spherical models with similar cusp behaviour have been presented in Dehnen (1993) and Tremaine *et al.* (1994) but the model described here is much more flexible in the outer falloff and still allows the analytical representation of many physical quantities. The isotropic DF as a function of $\mathcal{E}$ (the relative energy) for the above potential/density pair can be represented analytically in terms of Beta functions and hypergeometric series provided that $2/\alpha = n, 1/\gamma = m, 2/(nm) \leqslant 1$ with $n, m \in \mathbb{N}$. We also consider anisotropic models of the Osipkov-Merritt type whose DF is given by the isotropic form (with $\mathcal{E}$ replaced by $\mathcal{Q} = \mathcal{E} - L^2/(2r_a^2)$, r_a the anisotropy radius) and an additional analytical term. It is shown that the anisotropy affects the DFs only outside the central parts for which they do not fall off as steeply with decreasing $\mathcal{Q}$ as for the isotropic models, whereas the increase for large $\mathcal{E}$ or $\mathcal{Q}$ is dominated by the cusp parameter α for both models. Moreover, the IVs decrease more rapidly for less anisotropic models and the IVs and projected velocity dispersions decrease more slowly for decreasing cuspiness. For fixed α, the presence of a central SBH causes the velocity dispersions to rise steeply for small radii for increasing SBH mass which also lead to higher velocity dispersions over a wider radial range. On the other hand, the DFs are lower for increasing SBH mass with fixed α or increasing α with fixed SBH mass respectively.

References

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