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Hydrostatics of dark matter halo: simple spherical models

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Isotropic and anisotropic velocity dispersions were found for two-component spherical systems. The first component was a sphere by Navarro, Frenk, White, and the second one was a 'limiting' sphere by Kuzmin & Veltmann discovered later by Hernquist.

Keywords: stellar dynamics – methods: analytical – galaxies: haloes

1 Introduction

Many authors (e.g., Hansen 2004; Austin et al. 2005; Dehnen & McLaughlin 2005) studied hydrostatics of dark matter haloes to compare equlibrium models with results of ΛCDM simulations. But if we hope to detect dark matter from observations we must develop multi-component models including visible and invisible components (e.g., Peňarrubia et al. 2008). First two-component spherical hydrostatic models were suggested by Ossipkov (1979) and Ciotti & Pelegrini (1992) (see also Ciotti 1999). In this work we construct some more realistic models.

We start with the equation of hydrostatic equilibrium by Coutrez (1950) – Ogorodnikov (1957) (i.e., Jeans' equation for spherical systems) for the i-th component

$$\frac{d\varrho_i\sigma_{r_i}^2}{dr}+\varrho_i\frac{2\sigma_{ri}^2-\sigma_{ti}^2}{r}=-\frac{GM_{\rm tot}(r)}{r^2}$$

with $M_{\rm tot}(r)=4\pi\sum\limits_i\int\limits_0^r\varrho_i(r)r^2\,dr$. We chosen two models of mass distribution, namely, Navarro–Frenk–White's profile

$$\varrho_{\rm NFW}=\frac{\varrho_0}{(r/r_0)(1+r/r_0)^2}\,,\qquad r/r_0\le a$$

and a 'limiting' model by Kuzmin & Veltmann discovered later by Hernquist

$$\varrho_{\rm KVH}=\frac{\varrho_0}{(r/r_*)(1+r/r_*)^3}\,.$$

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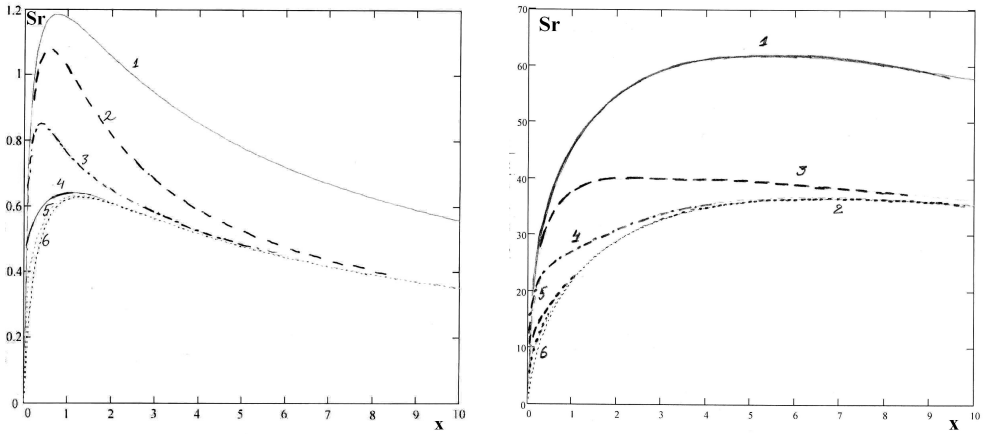


Figure 1 Radial dispersions for a two-component model (left panel) and a one-component one (right panel) for following cases: $\lambda = 0$ (*1*); $\lambda = 1$ (*2*); $\varkappa = 0.1$ (*3*); $\varkappa = 1$ (*4*); $\varkappa = 10$ (*5*); $\varkappa = 30$ (*6*).

Various combinations of these two models were studied. As for anisotropy of velocity distribution, the following cases were considered: a) $\sigma_t^2 \equiv 2\sigma_r^2$ (spherical velocity distribution); b) $\sigma_t^2/\sigma_r^2 = 2\lambda \equiv$ const; c) Eddington's relation $\lambda = 1/(1 + \varkappa r^2/r_0^2)$. As an example we show a run of a dimensionless velocity dispersion $Sr = \sigma_r^2/(GM_{\infty\,\mathrm{NFW}}/r_0)$ for Navarro–Frenk–White's component (Fig. 1). We put $r_0/r_* = 10$ and $M_{\infty\,\mathrm{NFW}} = 10M_{\infty\,\mathrm{KVH}}$. For comparison we calculated Sr for one-component Navarro–Frenk–White's model.

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