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DISK MODEL WITH CENTRAL BULGE FOR GALAXY M94

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A global disk model for spiral galaxies is modified by adding a spherical component to the galactic center to account for the presence of a central spherical bulge. It is verified whether such modification could be substantial for predictions of total mass and of its distribution in spiral galaxy M94.

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1. Introduction

Galaxy M94 (NGC 4736) has been previously examined in the global disk model approximation [1]. The use of the model was justified by incompatibility of rotation curve of this galaxy with the presence of a heavy spheroidal halo in its outer regions. The galactic core, however, might be better approximated by a spherical rather than disk mass distribution. Therefore, the global disk model is modified by replacing the central part with a spherically symmetric matter distribution, whereas the other galaxy parts are described by infinitely thin disk. Similarly as in [1, 2], rotation curve is the starting point for this analysis (not luminosity distribution, which is customarily assumed proportional to the amount of baryonic matter).

2. The method

The division between the spherical and the disk part is performed in the following way. A part of rotation curve is taken out to an arbitrary radius r_{B} (which is assumed to be the bulge radius) and used for direct calculation of mass function of the central bulge by the simple relation $M(r) = G^{-1} r\, v^2(r)$, $r < r_{\mathrm{B}}$. Rotation curve of the bulge is clearly that of the galaxy $v_{\mathrm{c}}(r)$ for $r < r_{\mathrm{B}}$ and Keplerian elsewhere, that is, $v_{\mathrm{B}}(r) = v_{\mathrm{c}}(r)$ for $r < r_{\mathrm{B}}$ and

$v_{\rm B}(r) = v_{\rm c}(r_{\rm B})\sqrt{r_{\rm B}/r}$ for $r > r_{\rm B}$. To calculate the mass distribution in the disk one uses the remaining part of rotation curve not explained by the presence of the bulge. It is determined from the usual law of adding contributions to the overall rotation curve from different components. Let it be called $v_{\rm new}$, then $v^2_{\rm new}(r) = v^2_{\rm c}(r) - v^2_{\rm B}(r)$. To find the corresponding surface mass density in the disk, one applies the iteration method discussed in [1, 3]. In the end, mass distribution of the bulge is projected on to the galactic plane to find its column density, and by adding it to the surface mass density of the disk part, one obtains the overall substitute surface mass density of the galaxy. It is then compared with the surface mass density obtained in the global disk model. The respective mass functions inside radius $r_{\rm B}$ are also compared.

3. Results for M94

As an example, two bulge radii were considered: $r_{\rm B} = 0.43$ [kpc] and $r_{\rm B} = 0.7$ [kpc]. These values are located between the radius determining the nuclear bar and the radius of the inner ring of M94 [4]. The results are shown in Table I. Figure 1 shows surface mass densities for $r_{\rm B} = 0.43$ [kpc] and $r_{\rm B} = 0.7$ [kpc], compared with the surface mass density obtained in the global disk model. The figure shows also the respective decomposition of the rotation curve into the parts due to the bulge and the disk.

TABLE I

Comparison of the results obtained in the global disk model and, for two bulge radii, in the "inner bulge + external disk" model.

	I Global disk	II $r_{\rm B} = 0.43$ [kpc]	III $r_{\rm B} = 0.7$ [kpc]
M (0.43 [kpc])	$3.465 \times 10^9\, M_\odot$	$4.564 \times 10^9\, M_\odot$	—
M (0.7 [kpc])	$5.508 \times 10^9\, M_\odot$	—	$7.148 \times 10^9\, M_\odot$
$M\,(\infty)$	$3.426 \times 10^{10}\, M_\odot$	$3.434 \times 10^{10}\, M_\odot$	$3.441 \times 10^{10}\, M_\odot$

4. Conclusions

The inclusion of a spherical component in the center of M94 does not alter the predictions of the global disk model. As was to be predicted, the only change concerns the column mass density in the central part, however it does not change the overall mass. Thus, the global disk model approximation works well for this galaxy. The same approximation should work well for other spiral galaxies with rotation curves breaking sphericity condition, that is, excluding the presence of massive spheroidal halo of CDM.

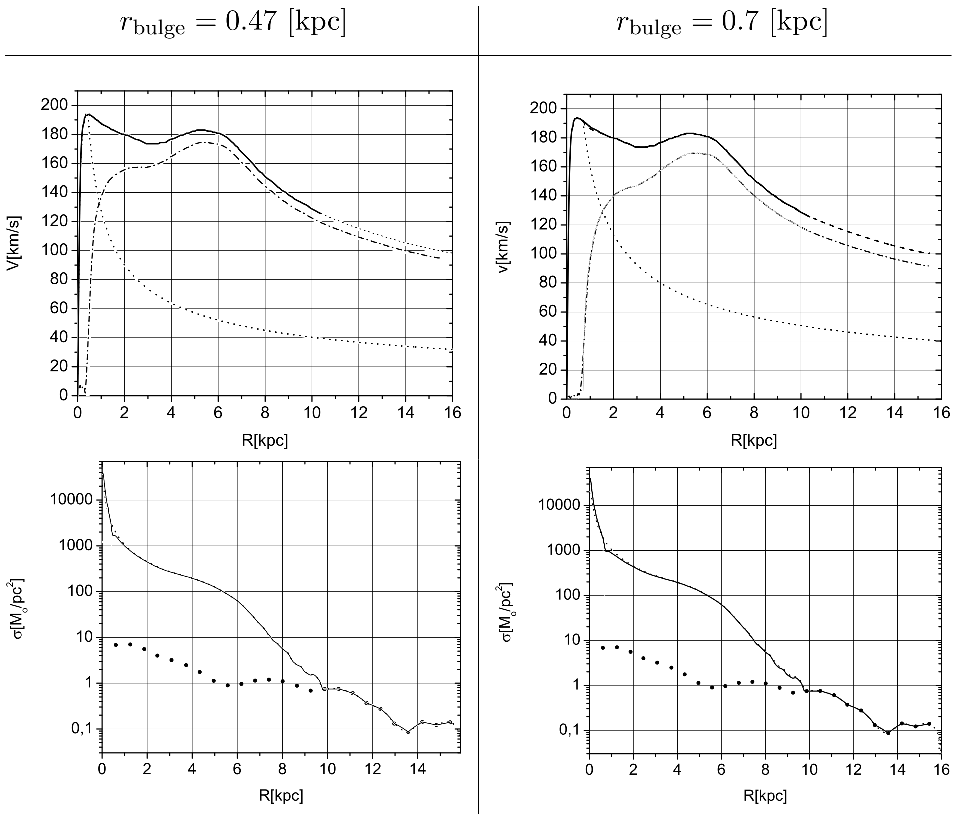

Fig. 1. Upper row: Bulge rotation curve (dotted line), disc rotation curve (dot-dashed line), disk + bulge rotation curve (dashed line), measured rotation curve [5] (solid line). Bottom row: Surface (column) mass density — bulge + disk model (solid line), global disk model (dot-dashed line), neutral hydrogen [6] (solid circles).

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