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THE MASS-DENSITY PROFILES OF LOW SURFACE BRIGHTNESS GALAXIES

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RESUMEN

Analizamos los perfiles masa-densidad de alta resolución para galaxias de bajo brillo superficial y mostramos que los datos disponibles sugieren un modelo de halo dominado por un núcleo de densidad constante, lo cual contradice las predicciones de las simulaciones de materia oscura fría.

ABSTRACT

We discuss high-resolution mass-density profiles of Low Surface Brightness Galaxies and show that the available data point towards a halo model dominated by a constant-density core, inconsistent with the predictions made by Cold Dark Matter simulations.

Key Words: **DARK MATTER — GALAXIES: KINEMATICS AND DYNAMICS**

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Rotation curves of galaxies give direct information about the combined gravitational potential of the mass components of galaxies. As such, they have a great potential to constrain the distribution of dark matter, providing crucial checks to theories of galaxy formation and evolution. Unfortunately, it is not trivial to determine the individual contributions of the mass compontents (stars, gas, dark matter). It is difficult to directly measure the total mass in stars and thus determine the stellar mass-to-light ratio Υ_*. In the absence of information one is thus free to choose any value of Υ_* between 0 (minimum disk) and the maximum value allowed by the observed curve (maximum disk) (van Albada & Sancisi 1986). This has a direct impact on the derived dark matter halo parameters, and ideally one would like to probe galaxies where the stellar component is unimportant. These galaxies exist and are known as Low Surface Brightness (LSB) galaxies. They are unevolved late-type disk galaxies with typical magnitudes $M_B \sim -19$, central surface brightness $\mu_0(B) \sim 23.5$, scale lengths between ~ 0.1 and 10 kpc, and HI masses of a few times $10^9\ M_\odot$ (de Blok et al. 1995, 1996). In these galaxies dark matter dominates at almost all radii, and their rotation curves give an almost direct map of the dark matter distribution. They are ideal laboratories to test cosmological theories. We have obtained high-resolution Hα rotation curves of a large sample of LSB galaxies (see de Blok & Bosma 2002, McGaugh et al. 2001, de Blok et al. 2001a). The Hα curves probe small galaxy radii and we combine them with lower resolution HI curves from the literature to constrain the mass distribution at both inner and outer radii. Our sample contains 65 curves that are of high enough quality to use in comparisons with theoretical predictions. We test two models: the observationally motivated pseudo-isothermal (ISO) model, whose distinguishing characteristic is a large constant-density core. The other model is based on the so-called "universal mass density profile" as derived by Navarro et al. (1996, 1997) from N-body simulations of structure formation in a Cold Dark Matter universe. This NFW model is defined by the presence of a central density cusp where the mass density increases as $\rho \sim r^{-1}$ (in sharp constrast with the ISO model where $\alpha \sim 0$ in the inner parts). Results of the comparison of both models are described extensively in de Blok & Bosma (2002) and de Blok et al. (2001a). One of the main conclusions is that the ISO model fits significantly better than the NFW model for all galaxies investigated. It seems the NFW model is not a good description of the observed shapes of (LSB galaxy) rotation curves. We can show this by looking at the mass density profiles that give rise to the observed rotation curves. By assuming that the stellar population is negligible and that the dark matter is spherically distributed, we can derive the mass-density profile $\rho(r)$ from the rotation curve $V(r)$ by $4\pi G\rho(r) = 2(V/r)(\partial V/\partial r) + (V/r)^2$, see de Blok et al. (2001b) for an extensive description. We have inverted our LSB rotation curves and measured the inner slopes of the mass-density distributions by fitting with a power-law $\rho \sim r^\alpha$. Figure 1 shows a histogram of the values of the inner slope. The strong peak near $\alpha \sim -0.2$ indicates that the inner mass density profiles of LSB galaxies are best described by a nearly constant density core. Some

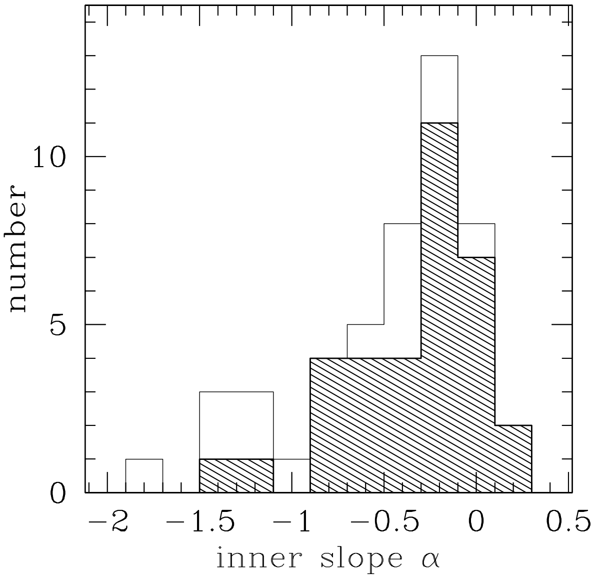

Fig. 1. Histogram of the values of the inner power-law slope α of LSB mass density profiles. We distinguish between well-resolved (hatched histogram) and unresolved (blank histogram) galaxies. The unresolved galaxies generally have higher values of α.

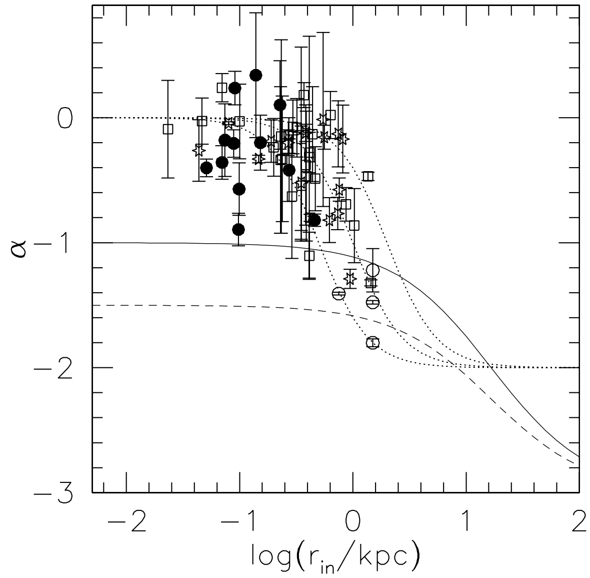

Fig. 2. Value of the inner slope α of the mass-density profiles plotted against the radius of the innermost point. Open circles are from de Blok et al. (2001a). Stars and filled circles are from de Blok & Bosma (2002). Overplotted are the theoretical slopes of a pseudo-isothermal model (dotted lines) with core radii of 0.5 (left-most), 1 (centre) and 2 (right-most) kpc. The full line represents a NFW model, the dashed line a CDM $r^{-1.5}$ model.

galaxies seem to show a steep slope consistent with the NFW predictions ($\alpha = -1$), but their significance becomes clear when we plot the slope versus the linear resolution of the rotation curve, as in Fig. 2. The most resolved galaxies show the flattest slopes. The steep slopes found for some galaxies are due to the low resolution of the curves: these probe the edge of the core where slopes are increasing, rather than the flat central part. These conclusions do not change if subsets of the sample using the best data are investigated, see the contribution by Bosma (this volume).

Feedback is frequently invoked to explain the cores. Here the action of star formation is thought to redistribute the cuspy dark matter distribution into a core. There is however no evidence for violent star formation episodes in LSB galaxies. Their HI disks are regular, they still contain large amounts of HI, and star formation processes in these galaxies seem to proceed at a much more leisurely pace than in brighter galaxies. It is hard to reconcile this with the violent picture that feedback paints.

All available evidence indicates that haloes of dwarf and (non-dwarf) LSB galaxies are dominated by kpc-sized constant-density cores, inconsistent with the predictions of CDM.

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