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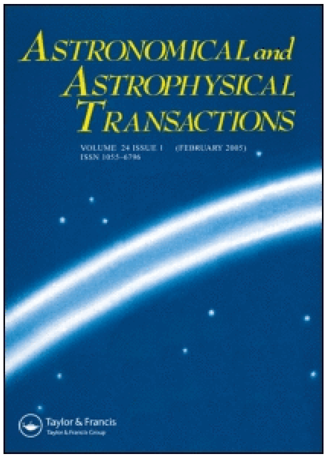

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ON THE GALACTIC BARYONIC HALO

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The variety of observational data suggest that the Galactic halo contains beside non-baryonic matter a noticeable fraction of cold baryonic matter. The numerical modelling of the dynamical evolution of systems which have baryonic haloes in the form of invisible small dense hydrogen molecular clouds shows that the behaviour of the Galactic gaseous disk surface density strongly depends on the baryonic halo parameters. It has been found that only the model with a baryonic halo of mass of order $2 \times 10^{11} M_{\odot}$ and flat rotation curve, which mimics the disk rotation curve, fits well modern observational data concerning the Galactic properties in the Solar cylinder.

KEY WORDS Galaxy, Galaxy halo, dark matter

1 INTRODUCTION

Nowdays it is apparent that there is a strong link between the structural properties of present-day galaxies and the physical processes of their formation. The crucial role in the process of galaxy formation and subsequent evolution seems to be played by dark matter. It is commonly assumed that the galaxy formation process involves the collapse of baryons within the potential well formed by the dark nonbaryonic component (White and Rees, 1978). Numerous assumptions have been made about its nature. However, it should be noted that a considerable amount of the dark baryonic matter could be tied up in hidden, low surface brightness galaxies (Davies, 1993). Moreover, recent observational data (Lequeux *et al.*, 1993; Bajaja *et al.*, 1994; e. g. Lequeux, 1994) have shown the presence of large amounts of molecular hydrogen in the outer regions of galaxies.

Pfenniger *et al.* (1994) supposed that at the level of individual disk galaxies the essential part of the dark matter could be in the form of cold dense gas cloudlets, essentially in molecular form (see also Pfenniger and Combes (1994) and De Paolis *et al.* (1995) for detailed discussion of the problem of cloudlet formation and existence). Such objects are really invisible (Wilson and Mauersberger, 1994). This hypothesis provides a reasonable explanation of a flat rotation curve, constant ratio of dark matter to H I mass in the outer spiral disks, the larger amount of visible gas in interacting galaxies with respect to the isolated ones, the solution of the gas consumption problem of spiral galaxies (e. g. Pfenniger *et al.* (1994)), and can explain the morphology of nearby star formation regions (Lepine and Duvert, 1994), etc. On the other hand, galaxy chemical evolution simulations also present serious arguments for the existence of permanent inflow of heavy element-deficient material into the galactic disk (e. g. Tossi, 1983).

In this paper the dynamical evolution of the Galaxy with a halo which contains aparts from non-baryonic matter some fraction of baryons in the form of invisible cold molecular cloudlets is studied and compared with some parameters of the Galaxy in the Solar cylinder.

2 THE MODEL PARAMETERS

The Galactic gravitational potential is determined by the bulge, disk, dark non-baryonic and baryonic halo components. During galaxy formation the main role is played by the process of collapse of baryonic matter within the potential well formed by the dark non-baryonic component. Its properties as well as the baryonic matter total angular momentum determine the final system parameters. The total system potential changes very slowly due to the accretion of the halo baryonic matter on to the central disk structure. Therefore to simplify the numerical simulations as initial values recent Galaxy bulge, disk and dark non-baryonic halo potentials of Li and Ikeuchi (1992) were adopted:

$$\Phi_{1,2}(x,y,z) = -G \cdot M_{1,2}/[\sqrt{x^2 + y^2 + (a_{1,2} + \sqrt{b_{1,2}^2 + z^2})^2}],$$

where indices 1, 2 refer to the bulge and disk components, respectively, $M_1 = 2.05 \times 10^{10} M_\odot$, $a_1 = 0.0$ kpc, $b_1 = 0.495$ kpc, and $M_2 = 2.547 \times 10^{11} M_\odot$, $a_2 = 7.258$ kpc, and $b_2 = 0.52$ kpc.

For a non-baryonic halo:

$$\Phi_{\rm nbh}(x,y,z) = -G \cdot M_{\rm nbh}/r_{\rm nbh} \cdot [\ln(1+q) + 1/(1+q)] - \Phi_0,$$

where $q = \sqrt{x^2 + y^2 + z^2}/r_{\rm nbh}$ and $M_{\rm nbh} = 1.35 \times 10^{11} M_\odot$, $r_{\rm nbh} = 13.0$ kpc, and $\Phi_0 = 1.4 \times 10^{11}$ m^2 s^{-2}.

Acoording to Pfenniger and Combes (1994) the halo baryonic dark matter is supposed to exist in the form of cold, gravitationally bound molecular cloudlets having radii of about 30 AU and masses of the order of Jupiter. Their total mass $M_{\rm halo}$ and total angular momentum are model parameters and to be determined by fitting of model parameters and observational data. For $t = 0$ the baryonic halo was treated as a spherical structure of radius $A_{\rm halo} = 100$ kpc. The total number of initially homogeneously distributed particles was chosen to be $N = 2109$ which provides a relevant description of the system's dynamics. The particle chaotic velocities were taken to be isotropic and of about $\Delta V = 7.7$ km s^{-1}. They were were assumed to be involved in the global rotational motion.

Owing to the low density of the halo the effective process of slowing-down of halo cloudlets (gravitational and ram pressure retardation) is confined only to the region of the galactic disk. In order to estimate the role of the process of particle capture in the numerical model a capturing disk was formally introduced as a homogeneous ellipsoidal region with semi-axes $a_{accr} = 20.0$ kpc, $b_{accr} = 19.9$ kpc, $c_{accr} = 1.0$ kpc. For the initial moment its mass was set equal to zero. At any fixed moment t its total mass included captured and temporarily occupying particles. When the halo particle dropped into this region, with probability P it was added to the disk. P was taken to be 0.01, which is a typical value for cloudlet capture by Giant Molecular Clouds (GMCs). However, it should be noted that the influence of the adopted value of P is rather weak because of the dominant role played by gravitational capture. The gravitational potential formed by such a capturing disk was calculated according to Chandrasekhar (1973) (see also Berczik and Kolesnik, 1993b). The modified Smoothed Particle Hydrodynamics (SPH) algorithm of individual time steps which allows us to treat effectively the N-body problem (Berczik and Kolesnik, 1993a) was used to carry out the integration of equation of motion for each particle.

3 RESULTS AND DISCUSSION

Model parameters were determined by fitting results of model simulations for different initial conditions with modern data on age, mass inflow rate and disk surface density in the Solar cylinder $\sigma(t = 13.0 \times 10^9 \text{ yr}) \approx 50 M_\odot pc^{-2}$ (e. g. Pagel, 1994). It was found that only the model with a baryonic halo having a mass of $2 \times 10^{11} M_\odot$ and a flat rotation curve

$$\Omega_{0z} = \sqrt{G \cdot M_{\rm halo}/A_{\rm halo}} / \sqrt{A_{\rm halo}^2/100 + x^2 + y^2},$$

which mimics the disk rotation curve, fits modern observational data. The resulting disk surface density $\sigma(t)$ variations with time for different regions can be approximated by the following expressions (σ in $M_\odot$ pc^{-2}, t in 10^9 yr): for the central regions ($0 \div 2$ kpc) $\sigma(t) \approx 75 \cdot [1 - exp(-t/2)]$, for the Solar vicinity ($9 \div 11$ kpc) $\sigma(t) \approx 55 \cdot [1 - exp(-t/5)]$, and for the edge of the capturing disk ($18 \div 20$ kpc) $\sigma(t) \approx 50 \cdot [1 - exp(-t/8)]$. The final (present) form of the Galactic baryonic halo can described as a thick disk with semi-axes ratio 1:3.

The close resemblance between halo and disk rotation curve allows us to assume that baryonic halo formation could be related not only to the protogalactic stage but also to the stage of galactic disk formation, next global, over the whole disk, powerful star formation bursts, significant mass expulsion driven by the collective effect of supernovae and winds from massive stars and the subsequent process of cloud formation. The accretion of halo cloudlets on to the Galactic disk can modify the chemical evolution of the Galaxy and could serve as an efficient mechanism support supersonic turbulent motions observal in GMCs. Such self-gravitating cloudlets captured by GMCs could be seeds triggering the formation of stars with initially heavy element-depleted cores, seriously affecting their observational properties.

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