SOME PECULIARITIES OF THE RADIAL GAS DISTRIBUTION IN GALACTIC DISC

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ABSTRACT. This paper reports on the theoretical investigation of evolution of the Galaxy. The spiral arms and radial gas flows can be considered as some kind of indicators of the dynamical processes in the disc. Investigation the surface density of gas. The velocity profiles of radial gas flows were selected in such a way to have an agreement between the model predictions and observational data. The model with the radial gas flows gives the results that appear to be in the better agreement with the observations. The results of the model predictions differ significantly comparing to the case of the standard Galactic evolutionary model.

Key words: Galaxy: dinamic: spiral pattern.

1. Introduction

At present the very important problem is an investigation of the gas distribution in Galactic disc with an account of the spiral arms. These arms can be considered as some kind of indicators of the dynamical processes in the disc. If one includes into the consideration the radial gas flows then the results of the model predictions could differ significantly comparing to the case of the standard Galactic evolutionary model (see, for example, Lacey & Fall, 1985; Lacey & Fall, 1983). The main criteria of the model reliability is a comparison with some observational data. It is know that spiral arm affect significantly the star formation processes. As a rule, for the angular velocity of the arm rotation is adopted to be 20 km $s^{-1} kpc^{-1}$ (sometimes the value 27 km $s^{-1} kpc^{-1}$ is used), while corotation radius is 9 kpc. There are also two specific regions of the Lindblad resonances in the disc at 2.8 and 12.8 kpc (Andrievsky et al. 2004).

2. Main assumptions and basic equations

In order to determine the evolutionary model parameters of the Galactic disc (or its selected part) let us consider one element of the disc surface (1 pc^2). For this element we can define the surface gas density. Then the system of equations that describe the evolution of this selected area is the following: μ_g - are the surface density of gas, $[\mu_g] = \frac{M_\odot}{pc^2}$; Ψ - the star formation rate, $[\Psi] = \frac{M_\odot}{pc^2 Gyr}$; $f(t)$ - infall rate, $[f] = \frac{M_\odot}{pc^2 Gyr}$; α - is an inverse characteristic distance for the infall rate in the disc, $\frac{1}{\alpha} = 4300$ pc; τ - the characteristic time of infall, $[\tau] = Gyr$; M_p - the present-day mass of the galactic disc, $6 \cdot 10^{10} M_\odot$; $M_\odot$ - mass of sun; $(1-R) \cdot C$ - the part of the matter that is created after the SNe explosions; C - const; t_p - the age of the Galaxy; $t_p = 15$ Gyr; $\frac{z}{y}$ - the gas metallicity normalized to the yield of the primary elements; R_G - the galactocentric radius.

Let us write the following equation for the gas surface density.

$$\{\frac{d\mu_g}{dt} = -(1-R)\,\Psi + f \tag{1}$$

As it was showed by Andrievsky et al. (2004) some characteristics can be written as follows:

$$\Psi = C\mu_g^k$$

$$f(t) = \frac{\alpha^2 M_p \exp\left(-\alpha R_G - \frac{t}{\tau}\right)}{2\pi\tau\left(1 - \exp\left(-\frac{t_p}{\tau}\right)\right)} \tag{2}$$

The result of the analytical solution (1) is the next equation:

$$\mu_g = [\exp\left(-\frac{t}{\tau}\right) - \exp(-(1-R)Ct)] \cdot \frac{A}{(1-R)C - \frac{1}{\tau}}$$

If we consider the spiral arms, then the function of the star formation rate can be modified:

$$\Psi = C\mu_g^k(1+\Delta)$$

$$\Delta = \varepsilon_1\theta_1 \frac{|\,\Omega_D - \Omega_P\,|}{C_s} R_G \tag{3}$$

ε_1 - factor which define an efficiency of the star formation, $\varepsilon_1 = 0.2$; θ_1 - the cut-off factor, $\theta_1 = 0$ for

$R_G < 7$ kpc, $\theta_1 = 1$ for $7 < R_G < 15$ kpc, $\theta_1 = 0$ for $R_G > 15$ kpc; Ω_D - angular speed of rotation of disc of the Galaxy, $\Omega_D = \Omega_D(R_G)$, $[\Omega_D] =$ km $s^{-1}kpc^{-1}$; Ω_P - angular speed of the rotation of the spiral pattern, $\Omega_P = 20$ km $s^{-1}kpc^{-1}$; C_s - the speed of the sound in the interstellar environment, $C_s = 20$ km s^{-1}

To include in addition into consideration of the radial gas flows we use the following equation:

$$\frac{\partial \mu_g}{\partial t} = -(1-R)\Psi + f - \frac{1}{r} \cdot \frac{\partial}{\partial r}(rV_r\mu_g) \qquad (4)$$

V_r - the speed of the radial gas flows.

The gas in-fall from the Galactic halo can be modified too:

$$f(t, R_G) = \frac{\alpha^2 M_p(t_p) \exp\left(-\alpha R_G - \frac{t}{\tau}\right)}{2\pi\tau\left(1 - \exp\left(-\frac{t_p}{\tau}\right)\right)} \qquad (5)$$

The characteristic time of infall:

$$\tau_1 = 6.5$$

$$\tau_2 = 0.075\sqrt{R_G} + 5$$

$$\tau_3 = 0.007 \exp\left(\frac{R_G}{2000}\right) + 3.5$$

The velocity of the radial gas motion is approximated using the following equations:

$$V_r[1] = \left(5.6 + \frac{181.94}{R_G} + 0.45R_G - 0.069R_G^2 - 20\right) R_G$$

$$V_r[2] = -0.0081R_G^2 + 0.5315R_G - 3.6591$$

$$V_r[3] = \left(5.6 + \frac{181.94}{R_G} + 0.45R_G - 0.069R_G^2 - 27\right) R_G$$

These velocity profiles were selected in such a way to have an agreement between the model predictions and observational data (Dickey, 1993, Kuijken & Gilmore, 1991). Below we give our model results (Table 1,2,3) on the gas evolution in the disc taking into account the spiral arms and radial gas flows. μ_g^* - the surface density of gas without spiral pattern. The good model: a. b. respectively

$$k = 1, V_r[2], \tau_i, i = 1, 2, 3$$

$$k = 1, V_r[3], \tau_i, i = 1, 2, 3$$

Inclusion in a researched problem of radial gas flows in a disk results in change of results of modelling.

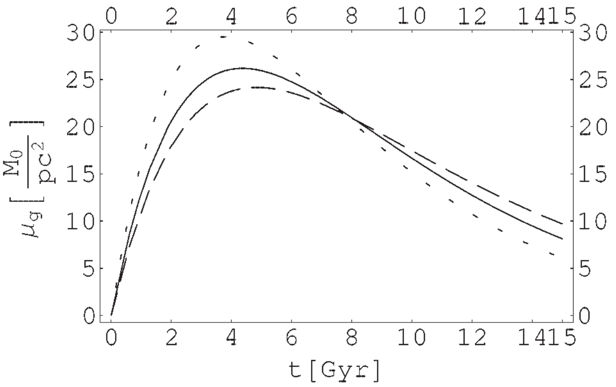

Figure 1: The surfase density of gas, model a. (---- τ_1; _ τ_2; . . . τ_3)

Table 1: Theoretical values of the surface density of gas at various parameters k and τ in the solar neighborhood. $t = 15$ Gyr, model $V_r[1]$

τ	$k1$	μ_g	μ_g^*	$k2$	μ_g^*	μ_g
τ_1	1	11.278	5.123	1.4	3.955	2.643
τ_2	1	9.317	3.765	1.4	3.077	2.005
τ_3	1	7.362	2.488	1.4	2.218	1.3904

Table 2: Same as Table 1, model $V_r[2]$

τ	$k1$	μ_g	μ_g^*	$k2$	μ_g^*	μ_g
τ_1	1	9.705	9.457	1.4	3.808	3.760
τ_2	1	7.853	7.624	1.4	2.948	2.909
τ_3	1	6.076	5.881	1.4	2.127	2.01

Table 3: Same as Table 1, model $V_r[3]$

τ	$k1$	μ_g	μ_g^*	$k2$	μ_g^*	μ_g
τ_1	1	11.368	11.044	1.4	3.985	3.943
τ_2	1	9.404	9.010	1.4	3.114	3.072
τ_3	1	7.478	7.227	1.4	2.269	2.241

Table 4: The observational data of μ_g of Dickey (1993) and Kuijken & Gilmore (1991)

μ_g	Dickey	Kuijken & Gilmore
The bottom limit	6.25	10
Average value	7.5	12.7
The top limit	8.75	15.8

3. Conclusion

It is showed that:

1. Contribution of the spiral arms to the star formation rate changes the resulting radial gas distribution making it non-monotoneous.

2. The model with the radial gas flows gives the results that appear to be in the better agreement with the observations.

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