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The giant vortices near the galactic corotation radius from 21 cm line properties

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The wave density theory predicts giant vortices in the corotation region of spiral galaxies/ we interpretate the 21 cm line profiles of neutral hydrogen emission using 4-arm spiral model of the Galaxy/ the whole 21 cm line profile is used. The centre of giant anticyclone is found near the Sun position and its location determines the value of the corotation radius.

ГИГАНТСКИЕ ВИХРИ ВБЛИЗИ РАДИУСА КОРОТАЦИИ ГАЛАКТИКИ ПО ЛИНИИ 21 cm, Малахова Ю.Н., Петровская И.В., Шеховцова Т.В. – Теория волн плотности предсказывает существование гигантских вихрей в области коротации в спиральных галактиках. С использованием всего профиля линии излучения нейтрального водорода 21 см в рамках 4-рукавной спиральной модели Галактики обнаружен гигантский антициклон, центр которого находится в окрестности Солнца. Положение этого центра согласуется с областью коротации Галактики.

ГІГАНТСЬКІ ВИХОРИ ПОБЛИЗУ РАДІУСА КОРОТАЦІЇ ГАЛАКТИКИ ПО ЛІНІЇ 21 cm, Малахова Ю.Н., Петровская И.В., Шеховцова Т.В. – Теорія хвиль густини передбачує існування гігантських вихорів в області коротації в спіральних галактиках. З використанням всього профілю лінії випромінювання нейтрального водню 21 см у рамках 4-рукавної спіральної моделі Галактики виявлений гігантський антициклон, центр якого знаходиться в околі Сонця. Положення цього центру узгоджується з областю коротації Галактики.

1. THE PROBLEM

The existence of giant vortices (cyclones and anticyclones) is a part of wave structure of spiral galaxies. The position of the vortices relatively to spiral arms is determined by the nature of origin of spiral design. A method of velocity field investigation for the vortice structure in other galaxies showing up is proposed in [1]. For our Galaxy the existence of giant anticyclone in the Solar vicinity is shown by Fridman et al. [3] from data of classical cepheids, open clusters and molecular clouds. Using the observation of neutral hydrogen emission we can find a large scale velocity field model for our Galaxy. In the present paper we add small wave velocity perturbations to the purely rotation of the galaxy. The result of our paper is the finding of vortice structure in the Galaxy near the corotation radius.

The radial and transversal velocity wave components are

$$U = \hat{U}(x)\cos(F_U - m\theta)$$
$$V = \hat{V}(x)\cos(F_V - m\theta) \qquad (1)$$

where m – the number of spiral arms, θ – galactocentric azimuthal angle, $x = R/R_0$, R and R_0 are the distances of the galactic centre to the hydrogen cloud and to the Sun respectively. The amplitudes $\hat{U}(x)$ and $\hat{V}(x)$ of the perturbed velocity components are small comparing with the rotation velocity.

Taking into account the wave additions, the velocity projection on a line of sight is

$$V_r = \Omega \sin l \mp \sqrt{1 - \frac{\sin^2 l}{x^2}}\, \hat{U}(x)\cos(F_U - m\theta) + \frac{\sin l}{x}\hat{V}(x)\cos(F_V - m\theta) + \Pi_0 \cos l \qquad (2)$$

Here $\Omega = R_0(\omega - \omega_0)$, ω – the angular velocity of the Galaxy rotation, ω_0 – the angular velocity of LSR, $\Pi_0 = 3.4$ km/s [5]. For the inner region of the Galaxy ($x < 1$) two points on a line of sight send the emission with the same frequency (having the same velocities). In (2) the upper sign corresponds to the nearest point, and the low – to the distant point.

The optical depth is connected with the density N and with the kinematic parameters

$$\tau = kN \Big/ \left|\frac{dV_r}{dr}\right| \qquad (3)$$

We obtained the velocity gradients in mentioned above two points on a line of sight

$$\frac{dV_r^1}{dx} = \Omega' \sin l + y_1 P_1(l,x,\theta_1) + y_2 P_2(l,x,\theta_2) + y_3 P_3(l,x,\theta_3) + y_4 P_4(l,x,\theta_4) + $$
$$+ y_5 P_5(l,x,\theta_5) + y_6 P_6(l,x,\theta_6) + y_7 P_7(l,x,\theta_7)$$
$$\frac{dV_r^2}{dx} = \Omega' \sin l + y_1 Q_1(l,x,\theta_1) + y_2 Q_2(l,x,\theta_2) + y_3 Q_3(l,x,\theta_3) + y_4 Q_4(l,x,\theta_4) + $$
$$+ y_5 Q_5(l,x,\theta_5) + y_6 Q_6(l,x,\theta_6) + y_7 Q_7(l,x,\theta_7) \qquad (4)$$

where P_i and Q_i are known functions of l, x, θ,

$$y_1 = \frac{\partial \hat{U}}{\partial x}\cos(F_U) - \hat{U}(x)\frac{\partial F_U}{\partial x}\sin(F_U),$$
$$y_2 = \frac{\partial \hat{U}}{\partial x}\sin(F_U) - \hat{U}(x)\frac{\partial F_U}{\partial x}\cos(F_U),$$
$$y_3 = \hat{U}(x)\cos(F_U),$$
$$y_4 = \hat{U}(x)\sin(F_U),$$
$$y_5 = \frac{\partial \hat{V}}{\partial x}\cos(F_V) - \hat{V}(x)\frac{\partial F_V}{\partial x}\sin(F_V), \qquad (5)$$
$$y_6 = \frac{\partial \hat{V}}{\partial x}\sin(F_V) + \hat{V}(x)\frac{\partial F_V}{\partial x}\cos(F_V),$$
$$y_7 = \hat{V}(x)\cos(F_V),$$
$$y_8 = \hat{V}(x)\sin(F_V),$$

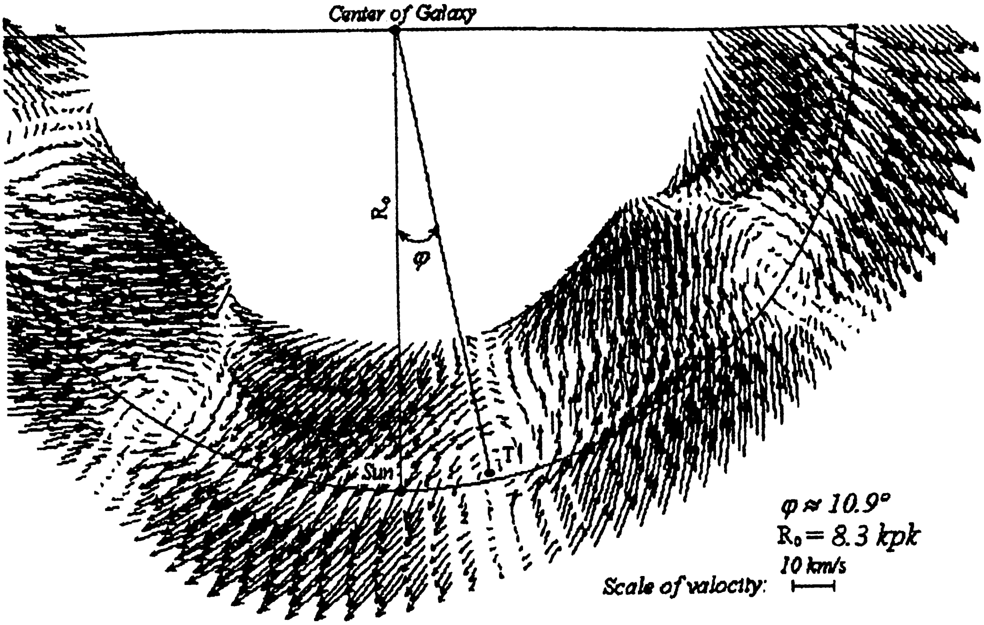

Figure 1. The vortices near the corotation radius in the Galaxy. The Sun is in the region of anticyclone with the center T

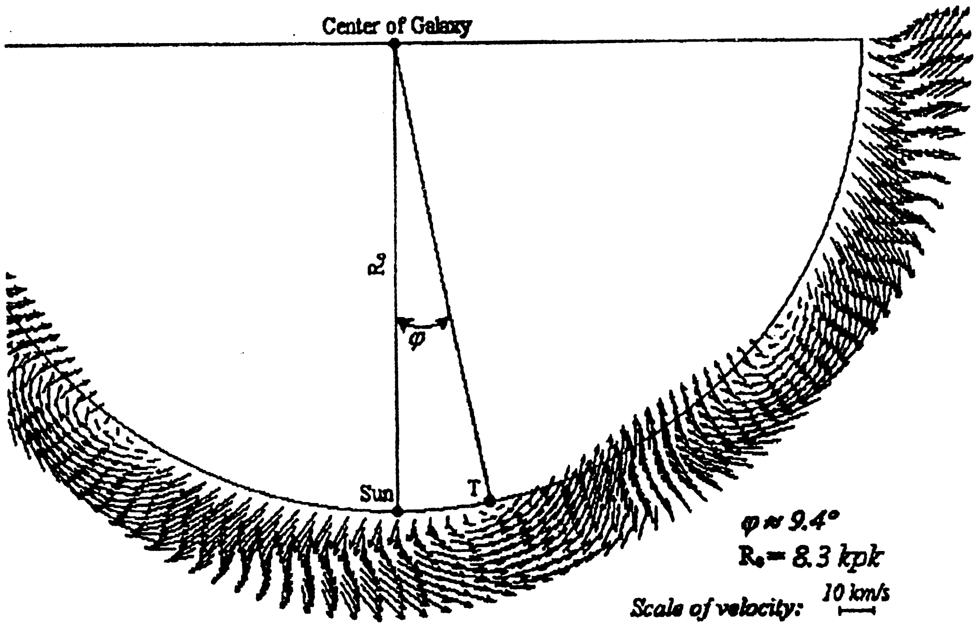

Figure 2. The outer part of anticyclone near the Sun, method 2

2. METHOD 1.

We used the data of 21 cm line observation [4, 6]. We write the equation (3) for each x and l and then we solve the system (3) for each x using the least square method. So we find the amplitudes and the phases of the perturbed velocity components. We present the amplitudes in the linear form

$$\hat{U}(x) = a_1 + b_1 x, \qquad F_U = a_2 + b_2 x$$
$$\hat{V}(x) = a_3 + b_3 x, \qquad F_V = a_4 + b_4 x$$

When the outer region ($x > 1$) of the Galaxy is observed only one point on a line of sight sends the emission with a given frequency, therefore only one point on each line of sight is used. In that case we must take the sing "+" in (2) and one of the expressions (4) for the velocity gradient.

Figure 1 presents the velocity field in the inner and outer regions near the corotation circle. We can see the anticyclone with the centre at the azimuthal galactocentric angle $\approx 11^0$ from the Sun (back to the galactic region).

3. METHOD 2.

We repeated the calculations for the outer region using the quadratic polynomial form for the amplitudes and phases :

$$\hat{U}(x) = a_1 + b_1 x + c_1 x^2, \qquad F_U = a_2 + b_2 x + c_2 x^2$$
$$\hat{V}(x) = a_3 + b_3 x + c_3 x^2, \qquad F_V = a_4 + b_4 x + c_4 x^2$$

The results are presented on Figure 2 and agree with the previous picture. We take the number of the spiral arms $m = 4$ [4]. So we obtain the picture of four anticyclones shared by four cyclones.

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