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## An estimate of $\mathbf{R}_0$ from the kinematic data for neutral and ionized hydrogen

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# AN ESTIMATE OF $R_0$ FROM THE KINEMATIC DATA FOR NEUTRAL AND IONIZED HYDROGEN[†]

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The distance to the Galactic center $R_0 = 7.5 \pm 1.0$ kpc is derived by comparing the rotations of the neutral hydrogen and HII region/molecular cloud complex subsystems. The rotation curve of the Galaxy $\Theta = \Theta(R)$ and the smooth approximations for $\Theta(R)$ applicable for 4 kpc$\leq R \leq$17 kpc are presented.

KEY WORDS   Galaxy, distance to the center, rotation curve

A comparison between the data on the rotation of the neutral hydrogen and HII region subsystems allows to estimate the distance of the Sun to the galactic center $R_0$ (Quiroga, 1980; Knapp, 1983; Fich *et al.*, 1989; Merrifield, 1992). In the present study, we use a more general version of such a method: a simultaneous determination of $R_0$, the specific form and the parameters of a smoothed rotation curve of our Galaxy. The method was applied to the recent data on the Galaxy rotation from the whole 21-cm neutral hydrogen line profile (Petrovskaya and Teerikorpi, 1986; Teerikorpi, 1989; Gerasimov and Petrovskaya, 1990; Malahova and Petrovskaya, 1992; Merrifield, 1992), from HI tangent points (Burton and Gordon, 1978) and from HII region/molecular cloud complexes (Blitz *et al.*, 1982; Chini and Wink, 1984). An axisymmetric galactic rotation model is assumed.

The data were fitted in the $W \equiv \Omega(x)x$ versus $x \equiv R/R_0$ domain, where $\Omega = R_0(\omega - \omega_0)$, $R$ is the distance to the galactic axis, $\omega$ and $\omega_0$ are the angular velocities at the distances $R$ and $R_0$, respectively. Polynomials

$$P_n(x) = \sum_{i=0}^{n} a_i (x-1)^i \tag{1}$$

were taken as smooth approximations for the variation in $W$ with $x$. The data define a system of equation in $a_i$:

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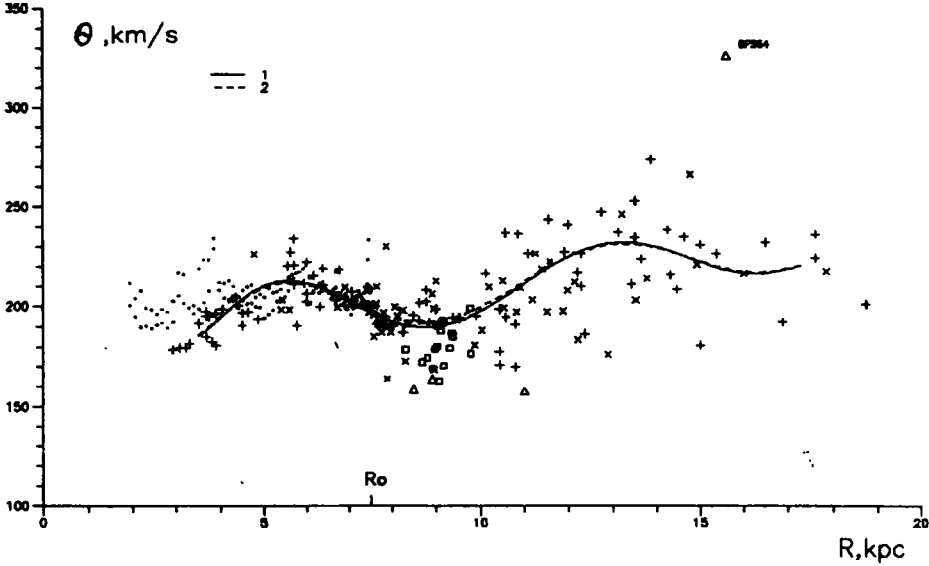[†]Proceedings of the Conference held in Kosalma

**Figure 1** The rotation curve of the Galaxy: the data from the whole 21 cm line profile (+); the HI tangent points (•); the data from HII regions – the objects of the Perseus spiral arm (□), the objects with uncertain data (△), other objects (×); the smoothed rotation curves derived with (1) and without (2) the data on the objects of the Perseus arm.

$$\sum_{i=0}^{n} a_i(x-1)^i = W , \tag{2}$$

which for a given $n$ was solved by the least square method. A determination of $R_0$ can be done through the $R_0$-dependence of the values of $x$ and $W$ for HII regions:

$$x = \frac{(R_0^2 + r^2 \cos^2 b - 2R_0 r \cos b \cos l)^{1/2}}{R_0}, \tag{3}$$

$$W = \frac{V_r x}{\sin l \cos b}, \tag{4}$$

where $r$ is the distance to the object, $l$ and $b$ are the galactic longitude and latitude of the object, $V_r$ is its radial velocity relative to the LSR. A value of $R_0$ was taken as a "best-fit" value for a given $n$ if the quantity

$$\sigma_0^2 = \frac{1}{n_{\text{free}}} \sum_j w_j [W_j - P_n(x_j)]^2 \tag{5}$$

is minimum. In (5), $n_{\text{free}}$ is the number of degrees of freedom, $w_j$ is the weight of the $j$-th data point. Under a detailed reproduction of the rotation curve (the degree $n = 7$ is sufficient) the best-fit values of $R_0$ become unbiased. When the HII regions with $|\sin l| < \sin 15°$ and with uncertain data were eliminated, we found a

value of $R_0 = 7.3$ kpc. Then eliminating the HII regions of the Perseus spiral arm because of possible streaming motions, we arrived at $R_0 = 7.7$ kpc. Our conclusion from these data is $R_0 = 7.5 \pm 1.0$ kpc. The uncertainty in the result is dominated by errors in the distances of HII regions. The rotation curve of the Galaxy $\Theta(R)$ for $R_0 = 7.5$ kpc and $\omega_0 = 26.4$ km/s/kpc (Kerr and Lynden-Bell, 1986) is presented in Figure 1. The smoothed rotation curves corresponding to polynomials $P_7(x)$ derived with and without the data on the objects of the Perseus arm are also shown in Figure 1. These curves seem to be applicable in the range 4 kpc $\leq R \leq$ 17 kpc.

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## DISCUSSION

*Khoruzhii*: What is the value of $n$ for the presented final approximation of the rotation curve?

*Nikiforov*: $n=7$.

*Seleznev*: Are your final results based on the data on ionized gas only, or the whole of data on HII and HI?

*Nikiforov*: It is necessary to use the data on the neutral hydrogen and the HII regions simultaneously for the correct determination of $R_0$ and the smoothed Galaxy rotation curve. Therefore, we used all the data.

*Chernin*: Does $R_0$ depend on whether the number of spiral arms is $m=2$ or $m=4$?

*Petrovskaya*: An estimate of $R_0$ depends on $m$ very weakly and indirectly through the variations of certain of the HI data points. The location of these points on the $(x, W)$ plane does not depend on $R_0$.