ROTATION CURVE OF OUTER DISK FROM UCAC2 CATALOGUE

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ABSTRACT. We present a method for determination of Galactic rotation curve of the outer disk by using statistical parallax based on the USNO CCD Astrograph Catalog (UCAC2). Statistical method is used in order to obtain the heliocentric distance of selected star groups and their rotational velocity with respect to the Galactic center. An anti-galactic-center sample of 6,714 objects is picked as tracers from 48,330,571 UCAC2 stars. Solar peculiar motion component that perpendicular to Galactic plane is employed to calculate distance, and mean proper motion along galactic longitude to calculate the rotational velocity. The result is a flat rotation curve with slight decrease on the assumption that $V_0 = 220\text{kms}^{-1}$.

1. INTRODUCTION

The rotation of our Galaxy for $R > R_0$ is proved hard to measure, because of the solar location in the middle of the Galactic plan. The rotation curve of outer disk has been studied using planetary nebulae, CO clusters of HII regions. The most cited work indicate that the rotation curve rise to 250kms^{-1} at a distance of R=10kpc (Fich, 1991). According to a new classical Cepheids method (Pont, 1997), the rotation curve is flat and slightly decreasing between R_0 and $2R_0$ which has a mismatch of 30km^{-1} compared to HII region rotation curve.

In general, radial velocity and distance must be independently provided with tracers to calculate the rotation curve. However, in UCAC2 (Zacharias, 2004), there is none of them, so we use new technique named statistical parallax in order to find the heliocentric distance of the tracers and in some special scenario the radial velocity is not necessary.

2. THE FUNDAMENTAL HYPOTHESIS AND SAMPLE FROM UCAC2

Anti-Galaxy center star groups are picked as a function of color index and UCAC2 magnitude. Stellar motion with respect to the sun can be divided into three parts: (1)stellar peculiar motion $\vec{V}$, (2)parallactic motion which reflect the solar peculiar motion and (3)components from Galactic rotation.

We suppose that stars move randomly in space, accordingly, the first part has the property that $\sum \vec{V} = 0$, equivalent to $\sum \mu_{lp} = 0$ and $\sum \mu_{bp} = 0$, where the subscript p denotes peculiar motion. In this sense, the average of the catalogue proper motions equals to the parallactic motion $-\vec{V}_\odot$.

For the UCAC2 stars limited in anti Galactic center area, we retain only the data which has photometry and error in proper motions smaller than 50% to confirm the precise of our results. On the other hand, the color index should be in small scope to insure the same type of stars. As a result 6,741 stars are picked from the UCAC2.

3. WORKING ON THE ROTATION CURVE

We divide up this sample into subsamples as a function of UCAC2 magnitude in red bandpass. Stars of each subsample can be considered at the same distance because they have the same color index. Let i be the number of subsamples along the anti-galaxy center and $n_1 \cdots n_i$ express the amount of stars in each group. For each star group: following quantities are calculated: (1)The mean position i.e. the geometrical center on the celestial sphere:

$$l_j = \frac{1}{n_j}\sum_{k=1}^{n_j} l_k \quad b_j = \frac{1}{n_j}\sum_{k=1}^{n_j} b_k \quad j = 1 \cdots i \tag{1}$$

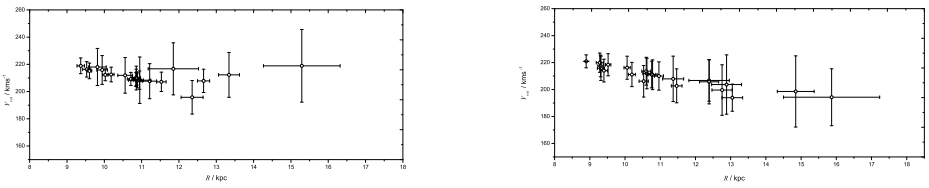

Figure 1: The rotation curve of outer disk with error bars. Each point denotes the projective mean value of corresponding star group. The sun is at the origin of X axis in case of $R_0 = 8.0$kpc and $V_0 = 220\text{kms}^{-1}$. Only groups with $n_j > 10$ are plotted on the figure in order to guarantee the statistical method effective. The left panel: the UCAC2 magnitude interval is 8.0–16.0 and we use samples with $0.3 < E = J_{2MASS} - K_{2MASS} < 0.6$; the right panel: $0.5 < E = J_{2MASS} - K_{2MASS} < 0.7$ and the same magnitude interval as before.

where l and b represent galactic longitude and latitude; (2) The projective components of proper motions on this central direction

$$\begin{pmatrix} \mu'_{lk}\cos b'_k \\ \mu'_{bk} \\ 0 \end{pmatrix} = R_1\left(90^\circ - b_j\right) R_3\left(l_j - l_k\right) R_1\left(b_k - 90^\circ\right) \begin{pmatrix} \mu_{lk}\cos b_k \\ \mu_{bk} \\ 0 \end{pmatrix} \tag{2}$$

We make an assumption that the stars move around the galaxy center along the circular track, accordingly, the radial velocity, which is the third row of velocity vector, equals zero. Because only 2-dimension projection of velocity on the celestial sphere is available in UCAC2, this is the reason why only anti-Galactic sample is picked. As above, the average proper motion of each group is:

$$\mu_{lj}\cos b_j = \frac{1}{n_j}\sum_{k=1}^{n_j}\mu'_{lk}\cos b'_k \qquad\qquad \mu_{bj} = \frac{1}{n_j}\sum_{k=1}^{n_j}\mu'_{bk} \tag{3}$$

Finally the mean distance of each group can be obtained:

$$V_z = -W_\odot = V_{bj}\cos b_j = \kappa\frac{\mu_{bj}}{\pi_j} \qquad \text{i.e.} \qquad r_j = -\frac{W_\odot}{\kappa\mu_{bj}} \tag{4}$$

where $\kappa = 4.74$ is the transition factor and we adopt $W_\odot = 7.17\text{kms}^{-1}$ (Dehnen & Binney, 1998) as the third component of peculiar velocity of the sun. The rotational velocity from statistical distance has following expression:

$$v_{rot} = V_0 + \kappa\mu_{lj}\cos b_j r_j \tag{5}$$

where $V_0 = 220\text{kms}^{-1}$ (Kerr & Lynden-Bell, 1986) is the circular speed of the sun.

It is logical to write $E = J_{2MASS} - K_{2MASS}$ although there is no magnitude in optical bandpass with UCAC2 astrometry. The resulting rotation curve is displayed in Fig.1.

Fitting the rotation curve with linear function gives

$$V_{rot} = 218.89(\pm1.89) - 2.85(\pm0.68)R \quad \text{for} \quad 0.3 < J - K < 0.6 \tag{6}$$

$$V_{rot} = 221.23(\pm1.64) - 3.76(\pm0.39)R \quad \text{for} \quad 0.5 < J - K < 0.7 \tag{7}$$

The slope is about -3$\text{kms}^{-1}\text{kpc}^{-1}$ which means a degressive rotation curve but it is not significantly away from zero. Suppose the rotational velocity is constant, the error of our result is derived from interstellar extinction and selected parameters. We have found that the statistical parallax show coherence with the distance scale of the revised Hipparcos Catalogue.

4. REFERENCES

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