

# RECONSIDERING THE DEFINITION OF GALACTIC COORDINATE SYSTEM AND GALACTIC CONSTANTS

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**ABSTRACT.** The galactic coordinates were originally defined by the IAU in 1958 and thereafter transformed from the B1950.0 system to the J2000.0 system after the new astronomical constants and celestial reference system have been introduced by the IAU as of 1984. In 1994, the IAU GA in the Hague recommended that the celestial reference system FK5 be replaced by the ICRS. Therefore, the present Galactic coordinates may be problematic due to their original definition and transformation, which have led to some confusion in their application and misunderstanding of the concept of the corresponding reference system. On the other hand, the Galactic constants as recommended by the IAU in 1985 have usually been adopted. Various observations in the last decades show that these constants should be updated, including the Galactic distance scale and Galactic rotation. These fundamental constants play a crucial role for the observation and theory of the Galaxy. In this work, we carefully investigate the questions of the Galactic coordinates, and suggest that the relevant IAU commissions set up a new working group in order to reconsider the redefinition of the IAU Galactic constants and coordinates.

## 1. CONFUSED SITUATION ON THE GALACTIC COORDINATE SYSTEM AND CONSTANTS

At the 16th General Assembly of the International Astronomical Union, held in Grenoble in 1976, the IAU recommended several changes in the fundamental reference frame (FK4) which were brought into effect from January 1 1984. Afterwards, the standard coordinate frame was changed from the equinox and equator of B1950.0 to that of J2000.0 and synchronously the unit of time for precession and star proper motions was changed from tropic centuries to Julian centuries. From 1991, IAU agreed to adopt a fundamental reference system based on distant extragalactic sources in order to replace the nearby bright stars (IAU 1991, IAU 1998, IAU 2001). The 23th IAU General Assembly (IAU 1997) adopts that, from 1 January 1998, the IAU celestial reference frame shall be the International Celestial Reference System (ICRS) as defined by the International Earth Rotation Service (IERS).

However, in the past decades, the definition of the Galactic coordinate system has never been changed but has been transferred from one system to another (e.g. from FK4 to FK5, or from B1950.0 to J2000.0, or to ICRS). Various comparisons provide evidence that there exist some misunderstandings during these transformations, which can lead to some confusion. Various works are still on the B1950.0 System: the KPNO international spectroscopic survey for extragalactic emission-line objects (Jangren, 2005); the westerbork northern sky survey for giant radio galaxies (Schoenmakers, 2001); the catalogue of galactic supernova remnants (Green, 1998), etc.

For the general practice of research on the Galaxy, a transformation from the equatorial reference system to the Galactic reference system is necessary. This transformation is given by:

$$[\mathbf{x}_G \ \mathbf{y}_G \ \mathbf{z}_G] = [\mathbf{x} \ \mathbf{y} \ \mathbf{z}] \mathbf{G}, \quad (1)$$

where the matrix  $\mathbf{G}$  is related to the definition of North Galactic pole (NGP) and Galactic center (GC) in the equatorial reference system. For the matrix  $\mathbf{G}$  applied to the B1950.0 FK4-based reference system and the J2000.0 FK5 reference system, Murray (1983 and 1989) gives:

$$\mathbf{G}_{B1950.0} = \mathbf{N}_{B1950.0} \begin{bmatrix} -0.066988739+0.492728466-0.857600811 \\ -0.872755766-0.450346958-0.188374602 \\ -0.483538915+0.744584633+0.460199785 \end{bmatrix}, \quad (2)$$

and:

$$\mathbf{G}_{J2000.0} = \mathbf{N}_{J2000.0} \begin{bmatrix} -0.054875539+0.494109454-0.867666136 \\ -0.873437105-0.444829594-0.198076390 \\ -0.483834992+0.746982249+0.455983795 \end{bmatrix}. \quad (3)$$

in which  $\mathbf{N}$  is the equatorial triad at the epoch. According to Murray's work, the B1950.0 Galactic coordinates is considered to be absolute and should be unaffected by aberration. The procedure is problematic at the current precision level because of the existence of the E-term that cannot be eliminated during the transformation from the FK4 system to the FK5 system:

$$\mathbf{S}_{FK5} = \mathbf{S}_{FK4} - \frac{1}{c} \mathbf{S}_{FK4} \times (\mathbf{S}_{FK4} \times \mathbf{V}_E). \quad (4)$$

The vector  $\mathbf{S}_{FK4}$  and  $\mathbf{S}_{FK5}$  are the arbitrary direction in the reference system denoted by the subscript FK4 and FK5, respectively, and  $\mathbf{V}_E$  is the E-term in the aberration. The Galactic axes will no longer be mutually orthogonal, with an error of 0.33 arcsecond, which means a distortion of the Galactic plane if a direct transformation is applied. On the other hand, in ICRS, the Hipparcos and VLBA observations of Sgr A\* give incoherent value for the transition matrix  $\mathbf{G}$ .

Based on different Galactic reference systems and methods, Galactic constants have been investigated by many authors. In 1964 and 1985, the IAU recommended two sets of constants. In order to understand the possible confusion on these constants, we take the galactocentric distance of our solar system as an example. Another example about the confused situation on Galactic constants is the mass of the Galaxy.

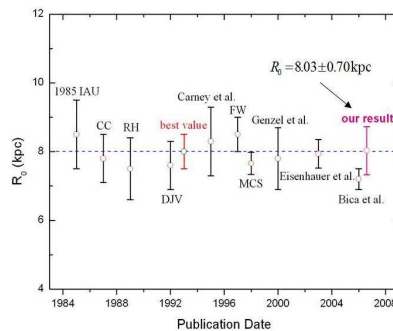


Figure 1: Individual measurements of  $R_0$  in the last decades. Typical values of  $R_0$ : 10 kpc (IAU 1964),  $(8.5 \pm 1)$  kpc (IAU 1985),  $(8.0 \pm 0.5)$  kpc (Reid 1993), and our result derived from open cluster  $(8.03 \pm 0.70)$  kpc.

Based on the assumption of both axisymmetry and equilibrium dynamics, the Galactic mass is expressed as (Rohlfs and Kreitschmann, 1998):

$$M(R) = 2.5 \times 10^5 R V_0^2(R) M_\odot \quad (5)$$

Adopting for the circular speed of the Sun,  $V_0 = 220 \text{ kms}^{-1}$  (Kerr or Lyden-Bell, 1986), or  $V_0 = 270 \text{ kms}^{-1}$  (Mendez 2000), implies for the mass interior to the solar circle, an increase by as much as 50% for the latter  $V_0$  value as compared to the former.

Since various high precision observations have given more reliable and consistent Galactic constants in the last decades, a new recommendation of Galactic constants would be needed in order to avoid confusion in modeling Galactic physics.

## 2. RECONSIDERING THE IAU DEFINITION

As mentioned in the previous section, the present work, which is based on the Galactic coordinate system, suffers from some confusion in the definition of the reference system and constants. It is necessary to redefine the Galactic reference system and constants for uniform practical applications and exact concept of the coordinate system. For high precise observation at micro-arc-second level, the Galactic coordinate system should be directly connected to the ICRS.