TEST OF THE HYPOTHESIS OF CIRCULAR MOTION OF INTERSTELLAR CLOUDS

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The study of the motion of interstellar clouds by direct dynamical methods is hindered by the lack of a complete set of initial conditions of the motion. The hypothesis of the circular motion of interstellar matter of various composition is tested on the basis of the catalog of Brand and Blitz. A modification of the method proposed by Edmondson and Hoerner, which was successfully used for a statistical investigation of the shapes of the orbits of globular clusters, is used. It is established that interstellar clouds move in nearly circular orbits with small deviations, so that data on the spiral structure of the Galaxy obtained by radio-astronomical methods should be considered as close to reality.

1. Introduction

The investigation of the spiral structure and a number of problems of the overall structure of the Galaxy is based on kinematic data on known formations of interstellar matter. Estimates of distances from the sun, even based on relatively nearby indicators of spirals, by optical methods are so unreliable that it is very difficult to construct a more or less realistic picture of the Galaxy's overall structure on their basis. In this connection, an important role may be played by radio-astronomical observations of fairly distant clouds of various forms of interstellar matter, capable of leading to certain concrete conclusions about the spiral structure. The hypothesis that interstellar matter undergoes circular rotation is adopted in the interpretation of radio-astronomical observations. The overall form of the rotation curve of the Galaxy is constructed mainly on the basis of observational data on objects having Galactic longitudes $0 \leq l \leq 180^\circ$, with azimuthal symmetry of the velocity field being assumed. The possible existence of certain streams of (noncircular) motions in the Galactic disk, especially in the Perseus region, has been indicated repeatedly in earlier research [1-6]. This fact to some extent became a cause for doubts about the reality of the hypothesis of the purely circular motion of hydrogen clouds and other types of interstellar formations. Interesting papers [7-11] were subsequently published on the determination of the velocity field of the outer regions of the Galaxy from radio observational data on objects with Galactic longitudes $90^\circ \leq l \leq 270^\circ$ and corresponding distances from the center in the range of $0.2R_0 \leq R \leq 2R_0$ (here $R_0 = 8.5$ kpc is the distance from the sun and $R$ is the distance from the object to the center of the Galaxy). Predominant among these objects are H II clouds, reflection nebulae, and molecular complexes associated with them.

The problem of the correct modeling of the velocity field of various regions of the Galaxy still requires much effort and selectivity in the use of today's rich observational data. In this connection, we decided to carry out a statistical analysis of the possible reality of the hypothesis of circular motion of clouds of interstellar matter of various compositions.

The study of the motion of these objects by direct dynamical methods is hindered by the lack of a complete set of initial conditions of the motion, which can be established only partially, in a certain approximation. In such cases it will be reasonable to use statistical methods of analysis of the motion of these objects, which we successfully used earlier [12, 13] to investigate the motion of globular clusters in the Galaxy. Based on the specifics of the objects being considered here, it is possible to use a method that differs somewhat from that proposed in the classical work of Edmondson [14] and Hoerner [15]. All the observational data that we used were from the paper by Brand and Blitz [11], in which they are collected into...
a special table containing 206 kinematically distinct complexes.

2. Statistical Test of the Hypothesis

It is convenient to test the hypothesis of the circular motion of clouds of different types of interstellar matter using the angle $\theta$ at the object $C$ between the directions toward the center of the Galaxy $O$ and toward the sun $S$ (Fig. 1). Here the sides of the triangle $OSC$ are the distance $r$ of the object from the sun, the distance $R_0$ of the sun from the center of the galaxy, and the distance $R$ of the object from that center, while the angle $l$ at the sun is the Galactic longitude. From Fig. 1 it follows that we have

$$\sin \theta = \frac{R_0}{R} \sin l,$$

(1)

$$\cos \theta = \frac{R^2 + r^2 - R_0^2}{2rr},$$

(2)

i.e., the angle $\theta$ can be determined without difficulty from observational data. Denoting the circular velocity of rotation at the object’s position as $V$, for the rotational component of the radial velocity of that object we find

$$U = V \sin \theta,$$

(3)

We must now consider the testing of the hypothesis that the orbits of various interstellar formations are circles. If the answer to this question is positive, the radial velocity of each object, reduced for all possible motions of the sun in the Galaxy, should vary as a function of the angle $\theta$ in accordance with the law (3). If these objects moved only in the radial direction toward the center of the Galaxy, we would have a cosine law instead of the sine law (3) [12-15].

We used two laws for an object’s circular velocity $V$: 1) the simplest version: objects move in circular Keplerian orbits (the sun’s velocity is $V_o = 220$ km/sec); 2) the law obtained by Fich et al. [16],

$$V = V_0 \left[ a_1 \left( \frac{R}{R_0} \right)^{a_2} + a_3 \right],$$

(4)

where $a_1 = 1.00767$, $a_2 = 0.0394$, and $a_3 = 0.00712$. This law was obtained from modern observational data.

![Geometrical arrangement of the center of the Galaxy (O), the sun (S), and a cloud (C). $V$ is the circular velocity of the cloud and $U$ is its radial velocity.](image-url)