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ON THE STAR ORBITS IN THE MILKY-WAY BULGE

S. Ninković

Astronomical Observatory, Volgina 7, 11160 Belgrade-74, Yugoslavia

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SUMMARY: The Milky-Way bulge is studied through calculating the galactocentric orbits of imaginary bulge stars for initial conditions simulating the bulge. The author assumes a velocity distribution characterised by bulge rotation and isotropy of the residual velocities. The agreement between the obtained orbital elements and traditional geometry of the bulge is good, in favour of the assumptions concerning the velocity distribution. In spite of this the present author's standpoint is that the isotropy of the residual velocities is not quite certain.

1. INTRODUCTION

In general bulges are known as important subsystems in spiral galaxies. The Milky Way is no exception (e. g. Frogel, 1988). The bulge of our Galaxy has been studied for the case of axis-symmetric force field (e. g. Jarvis and Freeman, 1985). The principal results of these two authors are that the slight flattening of the Milky-Way bulge is mainly due to its own rotation and that the distribution of the residual velocities is isotropic.

Proceeding from similar assumptions the present author examines here the properties of the kinematics of the Milky-Way bulge by calculating galactocentric orbits for imaginary test stars of the galactic bulge in a given potential of the Mily Way.

2. THE BASIC ASSUMPTIONS

In view of what is said above it is clear that the first assumptions of the present paper imply the steady state and axial symmetry. Thus the set of initial conditions for a test particle (star) consists of five elements: two coordinates and the three velocity components. Having regard to the bulge being studied the initial position of the test star is expected to be sufficiently near the galactic centre; for convenience the author chooses a point in the galactic plane. As a reasonable initial distance to the galactic centre a value of 1 *kpc* is assumed. This position is kept throughout the numerical experiment. Therefore the set of orbits calculated here pertains to an ensemble of stars. In such a case the initial values of the velocity components are chosen following an assumed kinematical distribution. Like Jarvis and Freeman (1985) the present author expects an isotropic velocity distribution and hence the assumed kinematical distribution function (KDF) depends on the two classical integrals of motion only. It should be said that a KDF of such type was recently also considered by Dehnen and Gerhard (1994).

The contribution of the bulge to the gravitation field of the Galaxy is important so that it appears as an essential contributor in many models of the Milky Way. This is explained by the total-mass value attributed to the bulge (usually about 1×10^{10} $\mathcal{M}_\odot$ - e. g. Bahcall, 1986) and, of course by, its relatively small effective radius. Due to the latter circumstance the bulge is to a high degree self-consistent. This is to be borne in mind in solving the Poisson equation. In the present paper one assumes the model of the Milky Way as proposed by Ninković (1992). This paper assumes for the bulge a mass distribution attaining zero in the infinity. This is at variance with Jarvis and Freeman who advocate King's distribution attaining zero at a finite distance. However, the approach involving a mass distribution where zero is attained in the infinity is a frequent praxis (e. g. Hernquist, 1990; Dehnen and Gerhard, 1994; also slightly truncated functions assumed by Bahcall, 1986, and by Dehnen and Binnney, 1998). In view of this the present author concludes that a KDF of the type studied by Dehnen and Gerhard (1994) and the mass distribution assumed in Ninković (1992) agree well. Therefore, they are adopted here. In the calculation of the orbits the contributions to the galactic potential of the disc and dark corona are taken into account following Ninković (1992). It should be said that in their studying the bulge motions Jarvis and Freeman (1985) adopted the same qualitative formula for the disc potential - that of Miyamoto and Nagai. Of course, their values of the parameters are different.

3. PROCEDURE AND RESULTS

As already said, the procedure of the present paper consists of calculating the galactocentric orbits for given set of imaginary bulge stars situated at a given galactocentric position specified above. The initial values for the velocity components are chosen according to the adopted KDF. Hereby one should specify the values of the KDF parameters. This is performed on the basis of resulting orbital parameters which, clearly, must reflect the spatial distribution assumed for the galactic bulge.

The features of the computing programme were described elsewhere (Ninković *et al.* 1999).

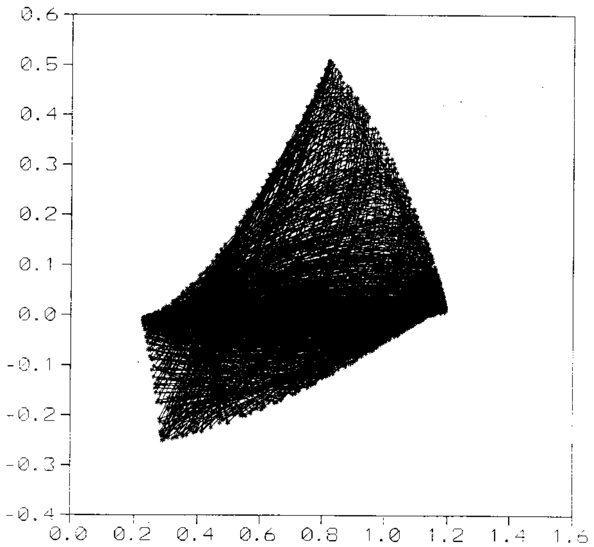

Fig. 1. *An orbit of a bulge star: initial values of the velocity components:* $\dot{X} = 92\ km\ s^{-1}$, $\dot{Y} = 85\ km\ s^{-1}$, $\dot{Z} = 2\ km\ s^{-1}$*; distance unit 1 kpc.*

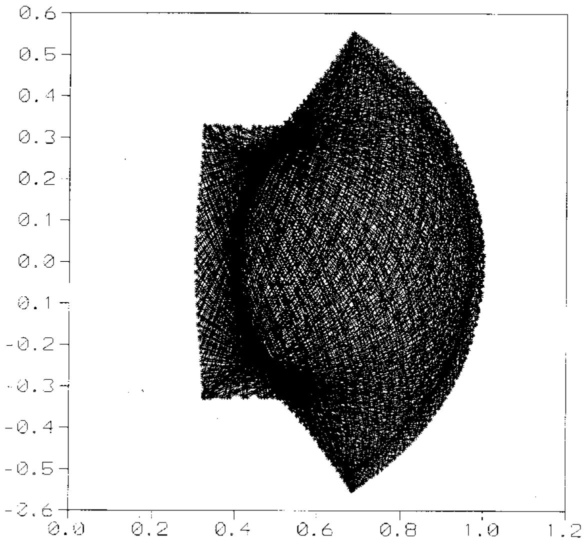

Fig. 2. *An orbit of a bulge star: initial values of the velocity components:* $\dot{X} = 2\ km\ s^{-1}$, $\dot{Y} = 85\ km\ s^{-1}$, $\dot{Z} = 92\ km\ s^{-1}$*; distance unit 1 kpc.*

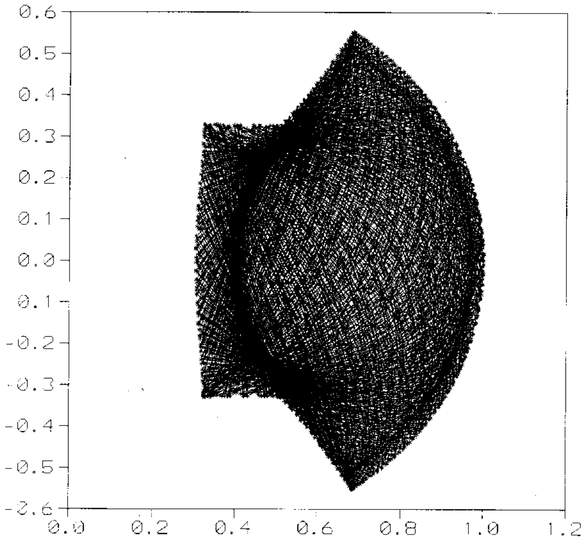

Fig. 3. *An orbit of a bulge star: initial values of the velocity components:* $\dot{X} = 2\ km\ s^{-1}$, $\dot{Y} = 85\ km\ s^{-1}$, $\dot{Z} = 2\ km\ s^{-1}$*; distance unit 1 kpc.*

A number of orbits is calcualted. They are mostly box-shaped, the rangings of R (distance to the rotation axis) do not much exceed the initial value of 1 *kpc*, those in Z are of the order of 10^2 *pc*. Since the model used in the present paper allows changing of its parameters, the ones concerning the disc are varied. This yields practically no changes. Some of the calculated orbits are presented in Figures. As usually, one presents their projection on the meridional plane. The captions of the figures require additional comments. In particular, the initial values of the velocity components are given in the galactocentric system XYZ, however due to the circumstance that the initial position is fixed upon the galactic plane the value of X component coincides with that of the radial one (R) and that of Y with the value for the tangential component. It should be noticed that in the model used in the present paper the galactocentric distance of the Sun is equal to 8.5 *kpc*. The principal moments of the velocity distribution for the bulge at $R = 1$ *kpc*, $Z = 0$ are found to be: rotation velocity about 85 $km\ s^{-1}$, anyone of the dispersions (isotropic distribution) about 90 $km\ s^{-1}$. Note that the galactic potential assumed here for this point yields a circular velocity of about 180 $km\ s^{-1}$.

4. DISCUSSION AND CONCLUSIONS

The question of velocity distribution for the galactic bulge is, of course, a complex one. It does not involve the third-integral problem only. Even if KDF were dependent on three integrals, an additional problem would appear, that is one would have to determine four unknowns - mean velocity (or velocity of rotation) and the three dispersions - while having a data set of three elements only at the disposal - the mean values of the three integrals.

Although the present analysis agrees with the concept of an isotropic velocity distribution for the galactic bulge, because the ratios of the amplitudes are within limits expected for the traditional bulge geometry (slight flattening - e. g. Ninković, 1992; Dehnen and Binnney, 1998), it cannot be said with certainty that the velocity distribution in the bulge is really isotropic. As said above this question is complex and requires additional examinations.

It can be also said that the rotation of the bulge is confirmed in the present paper. The result concerning the influence of the disc leads to the conclusion that this influence is very weak. Such a conclusion is expected since it is almost generally accepted that the bulge gravitation is dominant in the innermost parts of the Galaxy (and probably of other similar galaxies). In other words the bulge is almost self-consistent as enunicated in Section 2. Therefore, the flattening of the bulge should be due to its rotation.

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О ПУТАЊАМА У ЦЕНТРАЛНОМ ОВАЛУ МЛЕЧНОГ ПУТА

С. Нинковић

Астрономска опсерваторија, Волгина 7, 11160 Београд-74, Југославија

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Оригинални научни рад

Централни овал Млечног пута се проучава преко израчунавања галактоцентричних путања његових замишљених звезда за почетне услове који симулирају централни овал. Аутор усваја расподелу брзина коју карактеришу ротација централног овала и изотропија својствених брзина. Слагање између добијених путањских елемената и традиционалне геометрије централног овала је добро што иде у прилог претпоставкама о расподели брзина. Упркос томе ауторово становиште је да изотропија својствених брзина није сасвим сигурна.