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SOME INVESTIGATIONS OF THE SPHERICAL SUBSYSTEM OF OUR GALAXY*

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A short survey of the results recently obtained in this field is presented. The most important question is certainly that concerning the existence of the galactic dark corona. At present, it is difficult to give a definite answer, though the corona seems corroborated by some arguments.

1. Globular clusters

Our own Galaxy is usually studied within its regions, such as the disc, the bulge, the halo, etc. The regions are a product of the galactic evolution. The phenomena seen by us (spiral arms, warps, etc) clearly demonstrate that in the vicinity of the galactic plane the evolutional changes are still strong. This is the so-called flat component of the Galaxy. Unlike it the other one-the spherical component--seems rather steady, or as said by Marochnik and Suchkov$^{1)}$ like a »museum«. One can speak about two spherical components in our Galaxy: the classical one and the »new« one. The latter one has been envisaged recently in order to find a solution of the global hidden mass problem.

The classical spherical component — the galactic halo has been known to astronomers since long ago. It is largely inhabited by Population II stars, typical examples of which are RR Lyrae variables, red giants and subdwarfs. Some of them form globular clusters.

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The globular clusters being among oldest objects in the Galaxy appear to form a well-defined sample today. They inhabit a wide range of galactocentric distances and it seems that the majority of them have been discovered as yet$^{2)}$. For these reasons the spatial distribution and the galactocentric motion of globular clusters have been studied not once. Their spatial distribution can be described either by means of the well-known de Vaucouleurs formula$^{3)}$, or by means of some kind of a power law (e. g. Refs. 4 and 5).

There is a correlation between the spatial distribution (and galactocentric motion) of the globular clusters and their »metallicity« (metallicity is a quantity describing the fraction of heavy elements-heavier than hydrogen and helium — in chemical composition). Globular clusters containing more heavy elements are generally closer to both galactic centre and galactic plane. Their galactocentric orbits are less elongated and less inclined to the galactic plane (e. g. Ref. 6).

However, any use of globular clusters for the purpose of studying the overall galactic structure contains a difficulty since in their case generally only line-of-sight velocities are known. Different approaches have been applied in studying the galactocentric motions of globular clusters. In principle, all of them can be divided into three groups:

i) application of some general assumptions concerning their motion;
ii) use of tidal limits;
iii) determination of proper motions.

One should say that the results obtained by using the former two approaches seem contradictory. Though it appears on the basis of the line-of-sight velocities combined with the spatial distribution and the corresponding evolutionary trends that the galactocentric orbits are very elongated (e. g. Ref. 6 and the references therein), the tidal limits often suggest significantly smaller orbital eccentricities. However, the tidal radius concept involves some difficulties, both of the observational$^{7)}$ and theoretical nature$^{8)}$.

Generally the globular clusters are too distant to make possible direct determinations of their proper motions. Nevertheless, relative methods have been extended. Usually their accuracy has not been satisfactory. Perhaps, the method of measuring the star positions within globular clusters with respect to distant galaxies$^{9,10)}$ will bring some progress. The results obtained as yet are generally in favour of elongated orbits.

2. *Other matter in the »classical« halo*

The halo stars being outside the globular clusters (field stars) have been usually examined in connexion with the determination of the local escape velocity. Since this matter concerns the evidence for the hidden mass, it will be considered below.

Because of the evolutional characteristics mentioned above we cannot expect the galactic halo to possess a lot of interstellar matter. The early prediction of Spitzer (1956) having been in the meantime also confirmed by others, for example$^{5)}$, about the very hot and rarefied gas in the galactic halo is still waiting its observational support$^{11)}$.

Accordingly, one can expect that within the halo the density of cosmic rays and the magnetic field strength are also lower than within the galactic disc. The question of whether the Galaxy possesses its own radio halo, or not, has been a matter of a controversy since a long time. The galactic radio emission has been also studied at the University of Belgrade[12,5]. Despite some controversy in the results a general conclusion may be that any synchrotron radio emission from the galactic halo is extremely weak. This is very well fitted to a general concept of the galactic halo as a region in which the evolutional processes were finished long ago.

3. Dark matter

The appearance of the dark matter problem, especially after the discovery of Ostriker and Peebles[13] concerning the stability of rotating discs, drew attention to the halos of galaxies again. However this criterion of stability is applicable for the mass determination of the halo only within the optical edge of the stellar disc. It should be emphasized that the classical halos like that described in the preceding sections are generally not expected to satisfy the requirements of the dark matter problem. For example, in our own Galaxy there are the following kinds of evidence which can find their explanation in the dark matter assumption:

i) the excess in the local matter density (in the solar neighbourhood), i. e. the real density which can be found by applying dynamical methods may exceed significantly that obtainable by applying stellar statistics only;

ii) rotation curve appearing to be fairly flat for our Galaxy until almost two solar radii;

iii) the large escape velocity at the Sun;

iv) motions of objects situated farther from the galactic centre than the Sun.

The first item is an exception since for an explanation of it a disc-like structure is necessary. In the case of the other three due to the Ostriker-Peebles instability a spherical (dark matter) structure is preferred. This spherical structure is usually called the dark halo or the galactic (dark) corona. It is different from the classical halo since on the basis of various calculations (e. g. Refs. 14 and 15) the galactic corona should be rarefied and very extended with a large total mass.

The second item, the rotation, because such kind of motion is characteristic for the objects of the galactic disc also does not involve the classical halo.

However, the examinations of the star motions in the solar neighbourhood have become very important. Due to their velocity dispersion being significantly larger than that of disc stars the halo stars are the only possibility for estimating the local escape velocity. Unlike the rotation measurements which have been performed for other galaxies, as well, the estimations of the escape velocity at a certain point are possible in our own Galaxy only.

The studies of the local velocities for the halo stars clearly indicate that the moduli are normally distributed up to 450 km s^{-1} with a few exceptions exceeding this value and reaching usually 500 km s^{-1} with respect to the galactic centre[14–17] for example. Thus it seems that the value of 500 km s^{-1} can be accepted as the local escape velocity. Bearing in mind that the local circular velocity is about 200 km s^{-1} (IAU assumes 220 km s^{-1}) it is easily seen that the ratio of the two velocities is about 2.5 indicating in this way that the solar neighbourhood is well inside the Galaxy. Since according to the star distribution the Sun should be in the periphery of the Galaxy, the conclusion is that the value of the local escape velocity is in favour of a dark matter surrounding the visible Galaxy. A study of the orbital eccentricity distribution by the present author reveals that in the case of a weak mass increase beyond the Sun the majority of the so-called high-velocity stars (from the solar neighbourhood) would be merely marginal members of our Galaxy¹⁷⁾.

To a further verification of the dark matter influence upon the kinematics of the halo objects of interest are motions of those objects situated at present significantly beyond the Sun. Of course, space velocities measured at those distances are rare; however, there are two cases at galactocentric distances shorter than 20 kpc. These are the space velocities of two globular clusters determined by Brosche et al.[9,10]. Their space velocities are large enough so that the Galaxy without a dark matter structure cannot retain them as its members. At distances greater than 20 kpc only line-of-sight velocities are available. The evidence based on them is controversial (see Ref. 14 and the references cited therein). It would be, certainly, most desirable, if we had a stronger evidence at large distances from the galactic centre (say between 20 kpc and 100 kpc), because only then it is possible to indicate the space limits of the dark matter structure and its total mass. However, one should bear in mind the serious difficulties: possessing only one velocity component always a jeopardy of a bias; the satellites of our Galaxy situated between 20 kpc and 100 kpc are faint objects, so that the lines in their spectra are difficult to be accurately measured.

As a final conclusion concerning the dark matter in our Galaxy one can say that there is a sufficiently strong evidence at galactocentric distances up to 20 kpc, but beyond that the evidence is not so sure. This circumstance certainly affects the estimate of the total mass of the Galaxy (including the dark matter, as well), since then a lower limit is about $2\times 10^{11}\,M_0$. Such a value is also obtainable dynamically by taking into account the rotation curve[18].

All of this said above concerns the evidence for the dark matter only, not its nature. Since the dark matter problem is by no means a characteristic of our Galaxy only, dealing with this question automatically involves the study of other galaxies and even the universe as a whole. Briefly summarising the examinations done as yet one may say that there are two kinds of hypotheses: baryonic matter (brown dwarfs, white dwarfs, black dwarfs, black holes) and nonbaryonic matter (neutrinos and hypothetical, or not well-known particles). A more interested reader is referred to Trimble's article[19].

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NEKA ISTRAŽIVANJA SFERNOG PODSISTEMA NAŠE GALAKSIJE

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Dat je kratak pregled rezultata rada na ovom polju dobijenih nedavno. Najvažnije pitanje je svakako ono koje se odnosi na postojanje tamne galaktičke korone. Zasada je teško dati definitivan odgovor, ali izgleda da postoje argumenti u prilog postojanja korone.