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THE POSSIBLE RESIDUAL ROTATION OF THE SYSTEM OF GLOBULAR CLUSTERS

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Abstract.

An attempt is made to obtain positive evidence for the presence of a residual rotation of the system of globular clusters. For this the radial velocities of the globular clusters are used. The solar velocity relative to different groups of clusters is determined. The run of the numbers is such as to indicate that a residual rotation to the amount of $\pm$ 50 Km/sec may be present, but the evidence is not conclusive.

Özet

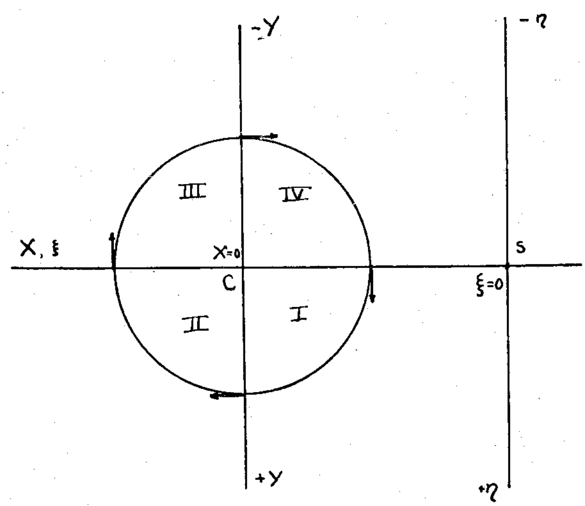
Küresel kümelerin rotasyon hareketine malik olduğuna dair müsbet delillerin bulunması için çalışılmaktadır. Bu maksatla küresel kümelerin radyal hızları kullanıldı ve çeşitli kümelere nazaran güneşin hızı tayin edildi. Neticeler 50 Km-sn lik bir rotasyon hızının mümkün olabileceğini göstermektedir. Fakat bu neticeler kesin değildir.

From the radial velocities of globular clusters for the velocity of the sun relative to the center of the galactic system, *Kukarkin* [1] finds a value of 275 Km/sec. This is the largest value which is derived while using the globular cluster material. Even though the value of the solar velocity as obtained by *Kukarkin* is smaller than that which Mayall derives from the radial velocities of extra galactic systems, viz. 300 Km/sec. As an explanation it has been suggested that the system of globular clusters may have a residual rotation. To this explanation an objection seemed to be that the system of globular clusters apparently has spherical symmetry. However, in a recent paper v.d.

R. Woolley [2] has shown that a spherical system can be rotating while retaining its spherical symmetry. Consequently it is worth while to investigate whether from the distribution of the radial velocities of the clusters any direct evidence can be obtained for the existence of a residual rotation. This is the question considered in the present paper. A rectangular system of coördinates is used of which the $+\xi$ axis is directed from the sun to the galactic center, the $+\eta$ axis towards the point on the celestial sphere determined by $l^{II} = 90°$ and $b = 0°$, while the ς axis is perpendicular to the galactic sphere and positive in the direction of the Northern galactic pole. When the components of solar velocity are indicated by $-V_{\odot,\xi}$, $-V_{\odot,\eta}$ and $-V_{\odot,\varsigma}$ the numerical values of these components are therefore obtained by a least squares solution of the equations:

$$V_R = V_{\odot\xi} \cos l^{II} \cos b + V_{\odot,\eta} \sin l^{II} \cos b + V_{\odot\zeta} \sin b \;\ldots\ldots\; (1)$$

where V_R is the observed radial velocity of a cluster. Adopting a second system of rectangular coördinates X; Y; Z parallel to the first system but with the galactic center as origin (see figure), we can arrange the globular clusters into four subgroups, indicated by I, II, III and IV, each containing the clusters in one of the four quadrants indicated in the figure.



The cluster coördinates ξ, η and ς were obtained from the paper by Lohman [3] and by the simple transformation $X = \xi - 8.2$; $Y = \eta$

and Z= ς the numerical values of, X , Y and Z are obtained. Next by the use of these coördinates the clusters are arranged into the four different groups mentioned before.

It will now be supposed that the system of globular clusters has a residual rotation in the sense as indicated in the figure. It follows from the way in which the solar velocity is defined in equation (1), that in the case of perfect spherical symmetry and all clusters having been observed equally well, a least square solution of (1) will give us the correct value of the solar velocity.

That is to say in the result the influence of the residual rotation will not show up when for the globular clusters

$$\overline{V\xi} = \overline{V\eta} = \overline{V\varsigma} = 0 \quad \ldots\ldots. (2)$$

However, when in some of the quadrants, f.i. II and III the degree of completeness of the observations is less than in the other quadrants, equation (2) no longer holds and the solar velocity which is obtained will be affected by the residual rotation. However, it is not possible to determine to what extent this will be the case. It is next supposed that two different solutions are made. In the first the solar velocity relative to the clusters in the quadrants I + II is determined and in the second relative to those in the quadrants III + IV.

It is at once evident that these solutions will be affected by the residual rotation. The clusters in the quadrants I and II relative to the sun in the mean will have a positive velocity along the ξ axis. The result will be that in this case the solution will indicate a negative value for the component of solar velocity along ξ.

In the quadrants III and IV along the ξ axis the mean velocity of the globular clusters is negative, so that the corresponding component of the solar velocity will be positive. When the same solution is carried out for the clusters in quadrants (II+III) and (IV+I) for the ξ component of solar velocity intermediate values must turn up. So we must expect:

$$-V_{\odot\xi}\,(III+IV) > -V_{\odot\xi}\,(II+III) \rightleftarrows V_{\odot\xi}\,(I+IV) > -V_{\odot\xi}(I+II) \ldots(3)$$

Next consider the case that the solar velocity is determined relative to the clusters in the quadrants IV+I and next relative to those in II+III. Without further explanation it is evident that in these two solutions erroneous values must show up for the η component of solar velocity.

In the solution relative to (IV+I) the component $V_{\odot,\eta}$ must be expected to have a negative excess. Relative to the quadrants (II+III) the excess of $V_{\odot,\eta}$ must be positive, while the solutions (I+II) and (III + IV) must lead to intermediate values $V_{\odot,\eta}$.

These latter conclusions can be summarised in the form:

$$-V_{\odot,\eta}(I+IV) < -V_{\odot\eta}(I+II) \rightleftarrows -V_{\odot,\eta}(III+IV) < -V_{\odot,\eta}(II+III) \quad ...(4)$$

When using the radial velocities of globular clusters as given by Kinman [4] the different sets of numerical values which in the various cases turn up for the three components of solar velocity are as indicated in the table 1.

Actually the table gives two different set of solutions. With the first all clusters are used which occur in the different quadrants. In the second solution only the clusters with $|B| \leqq 45°$ were used. Here B is the angle between the radius vector from the center to the cluster and the galactic plane. Apart from the numerical values $-V_\odot \xi$; $-V_{\odot,\eta}$ and $-V_\odot \varsigma$ the table also indicates the numbers of clusters used in each solution and the standard error affecting the different numerical values. As was to be feared the standard errors are large. Especially the numerical values for $-V_\odot \xi$ which turn up in the solution $|B| < 45°$ are without any practical value.

When the values of the table are inserted in the relations (3) and (4), the following surveys are obtained:

For the component $- V_\odot \xi$

$-V_{\odot\xi}$ (III+IV) >	$-V_{\odot\xi}$ (II+III) ⇄	$-V_{\odot\xi}$ (I+IV) >	$-V_{\odot\xi}$ (I+II)
+ 72	+ 41	+ 22	— 19
+ 75	+ 31	+ 43	+ 3

and for the component $-V_{\odot,\eta}$

$-V_{\odot,\eta}$ (I+IV) <	$-V_{\odot,\eta}$ (I+II) ⇄	$-V_{\odot,\eta}$ (III+IV) <	$-V_{\odot,\eta}$ (II+III
+ 142	+ 215	+ 163	+ 148
+ 125	+ 178	+ 156	+ 135

From these surveys it appears that as far as the component $-V_{\odot}\,\xi$ is concerned, the run of the numbers is such as should be expected if a residual rotation occurs. Roughly the influence of the residual rotation can be evaluated to be 50 KM/sec. but the probable error affecting this value will be of the order of 30 Km/sec. When next the η component is considered, it is seen that as expected for $V\eta$ the smallest value occurs in the quadrants (I+IV).

However, the values which turn up for the quadrants (II+III) are too small. It may be argued that in the quadrants (II+III) the observed radial velocities mainly correspond to the radial components of the orbital velocities of the clusters, while the contribution of the tangential components are small. The influence of the observational errors upon the radial components may therefore be such as to mask the influence of the tangential velocities. Whatever the explanation may be, the main point is that from the η components no convincing evidence is obtained concerning the presence of a residual rotation.

So the only final conclusion allowed is that the general trend of the numbers is such as would be expected in the case a residual rotation is present, but that the total evidence is not conclusive.

References :

1 – Kukarkin; B. W; 1937; A.J.U.S.S.R, 14, 125

2 – v.d.R. Woolley; R.: Observatory 81, 176; 1961

3 – Lohman W; Zs F. Astroph: 30, 234, 1952

4 – Kinman T.D.; MN 119, 172; 1959.

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Table : 1

Numerical values of the componcent of solar velocity for |B |between 0° – 90° and for |B | between 0–45°

0° < |B| < 90°

Quadrants	η (N)	$-V\odot, \xi$	$-V\odot, \eta$	$-V\odot\ \varsigma$ Km/sec
I + II	31	—19 ± 16	+215 ± 28	—59 ± 33
II + III	22	+41 ± 17	+148 ± 38	—129 ± 46
III + IV	35	+72 ± 18	+163 ± 24	+ 21 ± 26
IV + I	44	+22 ± 16	+142 ± 20	+ 25 ± 22

0° > |B| > 45°

I + II	24	+ 3 ± 19	+178 ± 30	— 16 ± 42
II + III	18	+31 ± 19	+135 ± 42	+212 ± 71
III + IV	27	+75 ± 20	+156 ± 27	+ 2 ± 43
IV + I	33	+43,3± 17	+125 ± 21	+ 56 ± 35