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COMMUNICATIONS FROM THE OBSERVATORY AT LEIDEN.

Star-streaming among G, K and M giants, by *A. van Hoof.*

Introduction. In the *Monthly Notices of the R.A.S.*, Vol. LXXV, p. 521, 1915, A. S. EDDINGTON and W. E. HARTLEY have given the results of an investigation of the systematic motions of the stars from their radial velocities. The authors used the radial velocities given by W. W. CAMPBELL in *Lick Bulletins* nos. 211 and 229 and they found a galactic longitude of 345° for the principal vertex. The divergence between this longitude and that found for the centre of the galactic system induced me to investigate whether the present material of radial velocities, which is about three times larger than that used by EDDINGTON and HARTLEY, would give the same deviation. The investigation was restricted to the later type stars. For this purpose I have used the radial velocities given in the recent general catalogue by J. H. MOORE [1]), selecting from this catalogue all stars brighter than 7·0 and of spectral class G5 to Mc. These were subdivided into two groups, G5 to K2 and K3 to Mc. The galactic co-ordinates were determined and the proper motions were found so far as possible. Upon comparison of the numbers of stars between different limits of proper motion, brightness and galactic latitude, b, with the corresponding numbers in *Groningen Publications* no. 30, Table 20, it appeared that some stars with large proper motions should be excluded in order to obtain a homogeneous material. After exclusion of 25 G5–K2 stars and 16 K3–Mc stars on this account, there remained 1061 and 727 stars in the two groups respectively.

Theory. If u, v, w are the rectangular velocity components of a star, the number of velocities between u, v, w and $u + du, v + dv, w + dw$ is, according to SCHWARZSCHILD, given by

$$e^{-s}\, du\, dv\, dw$$

where $s = 1$ is the equation of an ellipsoid. Let this ellipsoid, reduced to its principal axes, have the equation

$$s \equiv u^2/\lambda_1 + v^2/\lambda_2 + w^2/\lambda_3 = 1 \quad . \quad . \quad . \quad . \quad . \quad (1)$$

It can be demonstrated that if we consider the radial velocities of stars in a direction l, m, n (being the cosines of the angles between this direction and the axes of the ellipsoid) the average square velocity is given by

$$\overline{v_\rho^2} = \lambda_1 l^2 + \lambda_2 m^2 + \lambda_3 n^2 \quad . \quad . \quad . \quad . \quad . \quad (2)$$

or, if l, m, n are relative to an arbitrary system of co-ordinates,

$$\overline{v_\rho^2} = \alpha l^2 + \beta m^2 + \gamma n^2 + 2\delta mn + 2\varepsilon nl + 2\zeta lm \quad . \quad (3)$$

If α, β, etc. are known the lengths and directions of the axes of the ellipsoid can be determined by well-known methods.

As EDDINGTON and HARTLEY have shown, it is advantageous for practical computations, and quite admissible, to replace the equation (3) by the following

$$\overline{|v_\rho|} = \alpha l^2 + \beta m^2 + \gamma n^2 + 2\delta mn + 2\varepsilon nl + 2\zeta lm \quad (4)$$

which has been used for the present investigation.

Determination of the elements of the solar motion. The components u, v, w and v_ρ as used in the preceding are supposed to have been corrected for the motion of the sun. The radial velocities taken from the catalogue must first be corrected for this motion. In order to determine the elements of the sun's motion we have devided the sky into 114 roughly equal areas, limited by the circles of galactic latitude 70°, 50°, 30° and 10°. The areas between 70° and 90° extend over 90° in longitude, those between 50° and 70° over 36°, those between 30° and 50° over 22°·5 and those in lower latitudes over 20° in longitude. Putting the average radial velocity equal to

$$X\bar{l} + Y\bar{m} + Z\bar{n} + K \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

[1]) *Publications of the Lick Observatory*, Vol. XVIII, 1932.

where $\bar{l}$, $\bar{m}$ and $\bar{n}$ give the average direction for the stars in the area, X, Y, Z the components of the systematic motion of the stars with respect to the sun and K an eventual systematic error of the radial velocities, we find the following results ($V_{\odot}$ denoting the velocity of the sun, L and B the galactic co-ordinates of the apex). Each area has received a weight equal to the number of stars contained in it.

	G5–K2		K3–Mc	
$V_{\odot}$	19·5 km/sec	± ·9 m.e.	23·1 km/sec	± 1·2 m.e.
L	26°·0	± 2°·9 „	26°·3	± 3°·0 „
B	+ 15°·3	± 2°·2 „	+ 17°·7	± 2°·4 „
K	+ ·90 km/sec	± ·54 „	+ ·16 km/sec	± ·71 „

The two positions of the apex are accordant. Their average corresponds to 18^h27^m right-ascension, +30° declination.

Determination of the elements of the stream-motion. In a first solution no radial velocities were excluded. The velocities were corrected for the motion of the sun as derived above. In order to diminish the number of equations opposite areas were combined and new values of $|v_\rho|$, $\bar{l}$, $\bar{m}$, $\bar{n}$ formed. The derivation of the normal equations was effected according to the scheme proposed by EDDINGTON and HARTLEY in the article mentioned. Weights were given proportional to the number of stars. The results of the least squares solutions are shown in the following table, in which a, b, c represent the average velocities without regard to sign in the directions of the principal axes of the ellipsoid; the galactic longitude and latitude of each axis is denoted by L and B.

A second solution was made after rejecting the highest velocities. The rejection was made in such a way that in each direction 4% of the stars were excluded. In the third solution shown in the table the problem was somewhat simplified by introducing the condition that one of the axes must be directed toward the galactic pole, the equations of condition reducing to

$$|v_\rho| = \alpha\, l^2 + \beta\, m^2 + \gamma\, n^2 + 2\,\zeta\, l m \quad . \quad . \quad . \quad . \quad . \quad (6)$$

The mean error in the co-ordinates of the major axis of the ellipsoid, as found from this solution, was found to be ± 7° for the G5–K2 stars and ± 10° for the K3–Mc stars. It is safe to assume that the uncertainty of the position of this axis in the other solution will be of the same order. Considering these mean errors it may be said that the results give an indication of a slight deviation of the principal vertex from the direction to the centre of the galactic system.

The quantity c/a resulting form the third solution, which quantity is of especial importance for interpreting the dynamical phenomena in the galatic system, is ·66 and ·58 for the two spectral divisions respectively.

Spectrum		n	Major axis			Intermediate axis			Minor axis		
			a	L_1	B_1	b	L_2	B_2	c	L_3	B_3
G5–K2	No exclusion	1061	21·60	351°·6	+ 1°·9	17·51	79°·6	+ 49°·4	13·68	81°·0	− 40°·2
„	High velocities excluded .	1019	19·37	352·9	+ 1·7	14·90	80·4	+ 55·2	12·52	89·4	− 34·3
„	B_2 = 90°	1061	22·00	345·0	0·0	15·99	—	90·0	14·44	75·0	0·0
K3–Mc	No exclusion	727	27·76	332·3	+ 14·0	16·82	79·0	+ 48·3	12·23	51·5	− 39·0
„	High velocities excluded .	698	24·58	329·8	+ 10·7	16·16	76·9	+ 59·8	10·80	53·4	− 29·4
„	B_2 = 90°	727	26·10	333·7	0·0	15·78	—	90·0	15·01	63·7	0·0
gG, K, M	MINEUR, near	907	19·9	351·2	+ 3·1	15·7	113·2	+ 83·3	12·2	80·7	− 5·6
„	MINEUR, distant	1234	19·6	325·1	− 6·2	15·3	47·7	+ 49·9	12·9	60·2	− 39·4
dG, K, M	MINEUR	1031	28·9	339·6	+ 5·1	22·9	67·7	− 15·7	14·6	86·6	+ 73·5

For comparison I have given in the last division of the table the results obtained in a recent study of radial velocities by Mr. and Mrs. H. MINEUR [1]), which results only became known to me when the present computations had been practically finished. The results quoted apply to all G, K and M type stars; by means of trigonometric, spectroscopic and proper motion criteria the stars were subdivided into giants and dwarfs, and the former into two groups according to distance, the mean distances being about 65 and 250 parsecs respectively; all velocities greater than 63 km/sec were excluded. The lengths of the axes

[1]) *Bulletin Astronomique,* Mémoires et Variétés, **7**, 342.