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# BULLETIN OF THE ASTRONOMICAL INSTITUTES OF THE NETHERLANDS.

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## COMMUNICATION FROM THE OBSERVATORY AT LEIDEN.

### The rotational motion of the galaxy determined from stars of the tenth magnitude, by *D. Veldt*.

The present communication contains an extension of OORT's investigation concerning the rotational motion of the galaxy, as given in *B. A. N.* 120 and 132, but this time based on the proper motions of fainter stars. The nature of the problem, and the difficulties connected with it, have been exposed there and thus my work was considerably facilitated. Moreover Dr. OORT, who has personally initiated me in this work, gave me additional information and criticism, for which I want to express my thanks.

The aim of the following investigation is another determination of the term  $B/4.74$  which must appear in the proper motions in galactic longitude in the case of a rotating galaxy\*), together with a new determination of the correction to NEWCOMB's constant of precession ( $\Delta p$ ), to NEWCOMB's planetary precession and the motion of the equinox ( $\Delta\lambda + \Delta e$ ), and the secular parallaxes of the stars on which the investigation has been based, for three zones of galactic latitudes  $-15^\circ$  to  $+15^\circ$ ,  $-50^\circ$  to  $-15^\circ$  and  $+15^\circ$  to  $+50^\circ$ ,  $-90^\circ$  to  $-50^\circ$  and  $+50^\circ$  to  $+90^\circ$ .

The material used consists of the proper motions of some thousands of stars, nearly all of magnitude 9.5 to 10.5, determined by ALDEN and VAN DE KAMP\*\*). They measured the proper motions of these stars relative to 287 Boss stars, and determined with each Boss star the mean proper motion of five to ten stars. The stars are far from being uniformly distributed over the whole sky, the southern hemisphere being very poorly represented (the southern limit of declination is  $-25^\circ$ ); the value of the results is smaller than it would have been if also the southern sky had been taken into consideration. It is impossible to combine diametrically opposite areas and the secular parallaxes cannot be computed independently

\*) Cf. *B. A. N.* 120, pages 276 and 280; 132, page 86.

\*\*\*) *Memoirs of the National Academy of Sciences*, 1927, Vol. XXII.

of  $\Delta p$ ,  $\Delta\lambda + \Delta e$  and the rotational term  $B$ . On the other hand the material has the advantage of being rigorously reduced to the Boss system and of being rather homogeneous.

In this investigation the sky has been divided in 48 areas, each of which covers a range of  $30^\circ$  or  $60^\circ$  in longitude. Zone I, from  $-15^\circ$  to  $+15^\circ$  galactic latitude, has been divided into 12 areas, each covering a range of  $30^\circ$  in longitude, zones IIa and IIb, from  $+15^\circ$  to  $+50^\circ$  and  $-50^\circ$  to  $-15^\circ$ , in 12 areas, covering a range of  $30^\circ$  in longitude, and lastly the polar regions of  $50^\circ$  to  $90^\circ$  northern and southern latitude (zones IIIa and IIIb), in 6 areas each, covering  $60^\circ$  of longitude.

Neglecting the peculiar motions of the stars, which is allowable on account of the large distance of these faint stars, we have for each area two equations of condition of the following form:

a. for the proper motions in galactic longitude:

$$\begin{aligned} \bar{\mu}_l = & \sin \lambda \sin (\eta + \chi) \nu_0 \\ & + [\cos \varepsilon_1 \cos b + \sin \varepsilon_1 \sin b \sin (l - l_1)] \Delta p \\ & - [\cos \varepsilon_2 \cos b + \sin \varepsilon_2 \sin b \sin (l - l_2)] (\Delta\lambda + \Delta e) \\ & + \frac{A}{4.74} \cos b \cos 2(l - 325^\circ) + \frac{B}{4.74} \cos b. \end{aligned}$$

b. for the proper motions in galactic latitude:

$$\begin{aligned} \bar{\mu}_b = & \sin \lambda \cos (\eta + \chi) \nu_0 + \sin \varepsilon_1 \cos (l - l_1) \Delta p \\ & - \sin \varepsilon_2 \cos (l - l_2) (\Delta\lambda + \Delta e). \end{aligned}$$

Here  $\bar{\mu}_l$  and  $\bar{\mu}_b$  are the mean proper motions in galactic longitude and latitude for an area; they have been derived directly from the data given by ALDEN and VAN DE KAMP. The proper motions in declination of the Boss stars however have been corrected according to a table, given by BOSS and JENKINS\*).

$\nu_0$  is the secular parallax of the stars, varying with the zones,  $\eta$  the parallactic angle between the great circle towards the pole of the Milky Way and that towards the

\*) *Astronomical Journal* 884, table VI.

pole of the equator,  $\chi$  the angle between the directions towards the solar antapex ( $A. R. = 6^h$ ,  $D = -30^\circ$ ) and the pole of the equator (taken from an unpublished table of J. C. KAPTEYN);  $l_1$  and  $l_2$  are the galactic longitudes of the ascending node of the ecliptic and the equator respectively on the galaxy. The constant  $A$  has been determined in *B. A. N.* 132 with sufficient accuracy from radial velocities; we adopt the value  $A/4.74 = 0''.0040$ , found there. With the same accuracy we adopt for the galactic longitude of the centre of the Milky Way the value  $325^\circ$ . Further we have for the inclinations  $\varepsilon_1$  and  $\varepsilon_2$  of the ecliptic and of the equator on the galaxy:

$$\varepsilon_1 = 61^\circ.2; \quad \varepsilon_2 = 63^\circ.2.$$

$$l_1 = 153^\circ.5; \quad l_2 = 180^\circ.$$

As a demonstration of the unequal distribution of the stars over the sky we mention that in four of the twelve areas of zone I, in four of the twelve areas in zone II $\hat{b}$  and in three of the six areas of zone III $\hat{b}$  there are no stars at all, these areas having too large a southern declination.

In total we have 74 equations of condition for the six unknowns  $v_o^I$ ,  $v_o^{II}$ ,  $v_o^{III}$ ,  $\Delta p$ ,  $\Delta\lambda + \Delta e$ ,  $B$ . By one single least-squares solution we find for these unknowns the values

$$\begin{aligned} v_o^I &= +0''.0148 \pm 0''.0048 \text{ (m. e.)} \\ v_o^{II} &= +0''.0193 \pm 0''.0030 \\ v_o^{III} &= +0''.0231 \pm 0''.0040 \\ \Delta p &= +0''.0164 \pm 0''.0058 \\ \Delta\lambda + \Delta e &= +0''.0114 \pm 0''.0053 \\ \frac{B}{4.74} &= -0''.0088 \pm 0''.0046 \end{aligned}$$

Each equation of condition has received a weight, proportional to the number of the stars in the corresponding area. Mean errors have been computed from the residuals of the various areas. Their very large values warn us to accept the result with much reserve. The relatively large mean errors of  $B$  and  $v_o^I$  are probably due mainly to the fact that the stars do not cover all galactic longitudes. The run of the three secular parallaxes is rather satisfactory. The result for the correction  $\Delta\lambda + \Delta e$  agrees exactly with that of *B. A. N.* 132. This does not hold for the rotational term  $B/4.74$  and  $\Delta p$ .  $\Delta p$  has here a much larger value than that found by Dr. OORT ( $0''.0113$ ) and also the absolute value of  $B/4.74$  is larger than OORT's value ( $0.0050$  in *B. A. N.* 132). Naturally an increasing value of  $\Delta p$  must cause an increase of the absolute value of  $B/4.74$ .