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## The mean parallax of the Hyades (Errata: 3 V)

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### Citation

Raimond jr., J. J. (1926). The mean parallax of the Hyades (Errata: 3 V). *Bulletin Of The Astronomical Institutes Of The Netherlands*, 3, 221. Retrieved from <https://hdl.handle.net/1887/6165>

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# BULLETIN OF THE ASTRONOMICAL INSTITUTES OF THE NETHERLANDS.

1926 December 30

Volume III.

No. 113.

## COMMUNICATION FROM THE OBSERVATORY AT LEIDEN.

### The mean parallax of the Hyades, by *J. J. Raimond Jr.*

#### *Introduction.*

About a year ago Prof. E. HERTZSPRUNG suggested to me to repeat his computation of the mean parallax of the Hyades \*) from BOSS' proper motions improved by recent meridian observations. The importance of Prof. HERTZSPRUNG's computation lies in the fact that the mean parallax is determined without making use of the coordinates of the convergent, a knowledge of the annual *foreshortening* of the apparent dimensions of the group and of the mean radial velocity being sufficient to determine its distance. In an analogous manner I have also computed the mean parallax from the variation of the radial velocities with the distance from the centre of the cluster, combined with the proper motion of the centre.

Meridian observations were made on six nights, viz: 1925, Nov. 17, 18 and 19 and 1926, Jan. 10, 11 and 12. Though the working lists contained all stars of the cluster and some probable members, not mentioned by BOSS\*\*), only 26 stars were observed on more than one night, mainly because unfavourable weather conditions prevented the rapid finishing of the lists. However this group of 26 stars contained all the outlying members of the cluster, to which preference was given on account of their importance for the intended computations.

#### I. *A catalogue of 26 members of the Hyades for the equinox 1925.0.*

##### 1. *The observations.*

The observations were made by the regular observers of the meridian department with the meridian circle of Pistor and Martins; aperture 162 mm., focal-length 260 cm., magnifying power 200.

The instrument is provided with a travelling wire micrometer\*\*\*), with which the stars have been fol-

lowed during four complete revolutions of the micrometer screw, giving twentyfive contacts. These contacts were recorded on the strips of paper of the chronograph Mayer and Wolf or by the printing chronograph constructed by the Société Genevoise \*).

The observations are entirely differential, using the Boss stars 835, 852, 877, preceding the cluster, and 1240, 1303, 1339, following the cluster, as standard stars.

The clock error and its rate have been expressed in time of the registering clock Knoblich. The validity of this method has been controlled by means of comparison signals between this clock and the standard clock of the observatory Hohwü 17. Determinations of the inclination of the horizontal axis by the hanging level, and of the azimuth of the instrument by the meridian marks, have been made before and after the zones.

The collimation of the fixed central wire was assumed to be constant and was derived from observations of the mercury basin.

The pointing on the horizontal wire has always been made by the observer at the tube immediately after the star had reached the central wire. Another observer read the circle by two microscopes. The inside and outside temperature as well as the barometer were read and used for the computation of the refraction.

By means of two gratings absorbing 2.5 and 5 magnitudes respectively, all the stars have been reduced to about the sixth magnitude, in order to facilitate the observations and to eliminate the magnitude equation.

##### 2. *The reductions.*

The individual contacts of all the stars have been reduced to the reading of the drum corresponding to the point of coincidence of the movable thread with

\*) *A. N.* 5000, Bd 209, Aug. 1919.

\*\*\*) *Astron. Journ.* 604, Vol. 26, Sept. 1908.

\*\*\*\*) *B. A. N.* 32.

\*) *B. A. N.* 84.

the fixed middle thread. The equatorial value of one revolution of the screw,  $3^s.8914$ , was derived from observations of Polaris. The instrumental corrections have been applied to each star individually by means of the formula of Mayer:

$$iI + kK + c'C.$$

The differential principle of the observations has been maintained throughout the reductions.

For each night the clock error, the equator point and their respective rates of change have been computed from the six reference stars.

For the computation of the mean places of the reference stars for 1925.0 the data given in the *P. G. C.* have been used. The reduction to apparent place has been made in duplicate with the  $f, g, h$  from the *Berliner Jahrbuch* and with FINLAY's independent day numbers.

The refraction has been computed from ALBRECHT's tables.

The catalogue is thus automatically reduced to the system of the *P. G. C.*

### 3. The catalogue.

The results have been reduced to the equinox of 1925.0, but no proper motions were applied.

The mean errors of one observation as computed from all the residuals are:

$$\varepsilon_\alpha = \pm 0.043 = \pm 0.64''$$

$$\varepsilon_\delta = \pm 0.64''$$

corresponding to the following weights (on Boss' system)

1 obs.	.5
2 and 3 "	1.0
4,5 or 6 "	1.5

The quantities  $\varepsilon_\alpha$  and  $\varepsilon_\delta$  are rather large, greater than would be expected from former observations by the same observers. The mean internal error, computed from the residuals left by the different contacts during one transit, is only  $\pm 0.014$  for one complete observation. Poor weather conditions and other unfavourable circumstances appear to have influenced the final results.

TABLE I.  
Catalogue of 26 stars of the Hyades for the equinox 1925.0.

Boss Nr.	Name	Mag.	Spectr.	Mean R.A. 1925.0	Number of obs.	Mean Epoch	Mean Dec. 1925.0	Number of obs.	Mean Epoch
892		5.96	F0	h m s 3 48 52.53	5	1925 + .94	17° 6' 17.5"	6	1925 + .95
919		5.76	F0	3 56 29.31	4	.95	17 59 0.7	5	.94
935		5.48	F0	3 59 52.88	6	.95	7 59 26.5	6	.95
952	43 Tauri $\omega'$	5.67	G5	4 4 47.63	6	.95	19 24 43.3	6	.95
961	45 Tauri	5.71	F0	4 7 20.61	5	.97	5 19 43.6	6	.95
980	48 Tauri	6.35	F5	4 11 30.68	5	.97	15 12 50.4	5	.97
991	51 Tauri	5.56	A5	4 13 56.74	3	1.03	21 23 50.0	3	1.03
1004	57 Tauri	5.59	F0	4 15 44.16	2	.88	13 51 18.8	2	.88
1007	58 Tauri $h$	5.27	F0	4 16 21.02	3	1.03	14 54 59.5	3	1.03
1017	61 Tauri $\delta^{(1)}$	3.93	K0	4 18 36.42	2	.88	17 22 4.6	2	.88
1018	63 Tauri	5.68	A2	4 19 6.74	3	1.03	16 36 11.6	3	1.03
1033	69 Tauri $\nu^{(1)}$	4.40	A5	4 21 49.01	2	.88	22 38 41.2	2	.88
1034	71 Tauri	4.60	A5	4 22 4.28	3	1.03	15 26 56.7	3	1.03
1046	78 Tauri $\theta^2$	3.62	F0	4 24 22.73	3	.88	15 42 20.7	3	.88
1047	79 Tauri $b$	5.12	A5	4 24 37.97	3	1.03	12 52 55.8	3	1.03
1056	83 Tauri	5.49	F0	4 26 23.92	3	.88	13 33 44.4	3	.88
1058	85 Tauri	6.04	F0	4 27 34.60	3	1.03	15 41 30.0	3	1.03
1067	86 Tauri $\rho$	4.75	A5	4 29 35.40	6	.95	14 41 16.2	6	.95
1086	89 Tauri	5.80	F0	4 33 51.73	3	1.03	15 53 2.5	3	1.03
1092		5.55	F0	4 35 2.37	2	.88	7 43 22.5	3	.88
1114		5.35	A3	4 40 16.36	3	1.03	11 0 26.4	3	1.03
1120		6.13	K0	4 41 53.93	2	.88	18 36 0.9	2	.88
1143	97 Tauri $i$	5.12	F0	4 46 59.08	5	.97	18 42 48.4	6	.95
1184	101 Tauri	6.70	F5	4 55 25.96	5	.97	15 48 16.8	5	.97
1194	102 Tauri $\iota$	4.70	A5	4 58 36.65	5	.97	21 29 2.2	5	.97
1226	16 Orionis $h$	5.42	A2	5 5 12.01	2	.88	9 44 3.1	2	.88

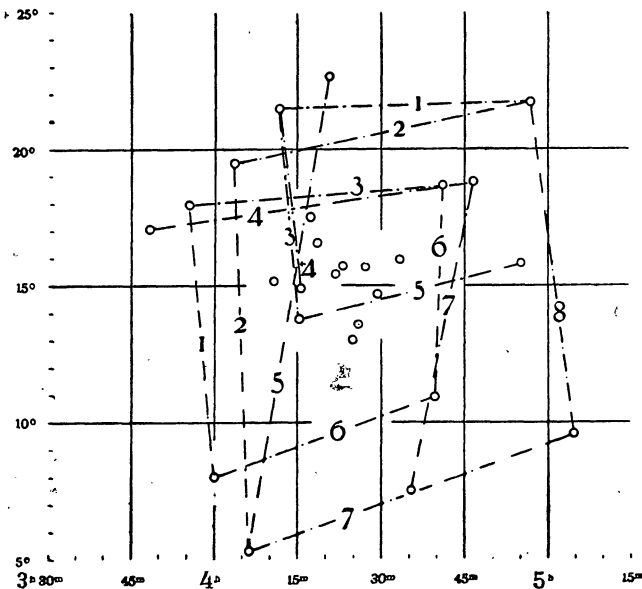
II. *The foreshortening.*

1. *The method.*

In determining the apparent relative motion of the Hyades I have followed a method suggested to me by Dr. C. H. HINS. My thanks are due to him for his excellent guidance and help given freely throughout my work.

Out of the 26 stars I have chosen pairs of stars which are far apart either in  $\alpha$  or in  $\delta$  (see fig. 1) and having as many common previous observations by the same authority as possible. In selecting these pairs I tried to realise the greatest completeness of

Fig. 1.



observations of a very early date and also to get an even distribution of the catalogues over the interval 1755-1925.

Every catalogue containing positions of both stars of a pair gave a value for the distance  $d_i$  in  $\alpha$  or  $\delta$  of that pair, valid for the equinox of the catalogue and the epoch of the observation. Sometimes it was necessary to apply small corrections to the observations in order to bring back the observation from the epoch of the catalogue to the actual epoch of the observation with the proper motion used in the catalogue. In some cases it was necessary to eliminate differences in the epochs at which the two members of a pair were observed; the correction to a common epoch  $t_i$  (the mean epoch of both observations) was in these cases effected by the proper motions from the *P. G. C.*

The *distances* between the two components of each pair were reduced to the equinox of 1900.0. The precession was computed from the data given in BOSS' catalogue. The third term of the precession has only been applied to observations before 1850.0.

The advantage of this method over that used by HERTZSPRUNG is that, whereas in the derivation of absolute proper motions the systematic corrections of the catalogues used play a prominent part, in the differential method, used in this paper, these corrections can be neglected for the greater part, especially so since the  $\alpha$ -pairs were so chosen as to be of about the same declination and the  $\delta$ -pairs so as to be of about the same R. A.

Next the annual variation of the distance of each pair was determined by the method of least squares. The weight of a distance  $d_i$  is:

$$p_i = \frac{p'_i p''_i}{p'_i + p''_i}$$

where  $p'_i$  and  $p''_i$  are the weights of the two components of the pair. The values of  $p'_i$  and  $p''_i$  were taken from the tables in *Appendix III* of the *P. G. C.* and in its supplement by A. J. ROY. For catalogues not contained in these tables the weights given by AUWERS\*) have been assumed after these had been reduced to the unit of weight of the Boss system. In some cases, viz: for Lal.,  $W_1$  and  $W_2$  and Kön. Zod. 1835.0, I assumed weights corresponding to the mean error computed from the residuals of the single observations.

If  $D$  be the weighted mean of  $d_i$ , and  $T$  that of  $t_i$ , the equation of condition \*\*) is:

$$D - d_i = \Delta d (T - t_i),$$

where  $\Delta d$  is the annual decrease of  $d_i$ .

The relative foreshortening,  $f$ , is then found from the formula:

$$f = \frac{\Delta d}{D}$$

2. *The results.*

Table 2 contains the results.

- 1<sup>st</sup> column: current numbers of the pairs, the same as in fig. 1.
- 2<sup>nd</sup> " : Boss numbers of the components of each pair.
- 3<sup>rd</sup> and 4<sup>th</sup> " : mean distance  $D$  between the components and its mean error  $\epsilon_D$ .
- 5<sup>th</sup> " : mean epoch  $T$ .
- 6<sup>th</sup> and 7<sup>th</sup> " : the foreshortening and its mean error  $\epsilon_f$ .

\*) *Astr. Nachr.*, 3615-16, Bd. 151, 1899.

\*\*) The equation of condition used by HERTZSPRUNG

$$\mu_\alpha = A + B\alpha,$$

$B$  being what I call the foreshortening  $f$ , is easily seen to be identical to the equation used here, since:

$$\begin{aligned} f &= \frac{d_{i_1} - d_{i_2}}{d(t_1 - t_2)} = \frac{(\alpha'_{i_1} - \alpha'_{i_2}) - (\alpha''_{i_1} - \alpha''_{i_2})}{(\alpha' - \alpha'')(t_1 - t_2)} = \\ &= \frac{(\alpha'_{i_1} - \alpha'_{i_2}) - (\alpha''_{i_1} - \alpha''_{i_2})}{(\alpha' - \alpha'')(t_1 - t_2)} = \frac{\mu' - \mu''}{\alpha' - \alpha''} = B. \end{aligned}$$

The difference of the two methods is thus a practical one, namely that of the avoidance of systematic corrections.

TABLE 2.

The foreshortening of the dimensions of the Hyades.

Pair	Boss Nr.	Number of obs.	$D$	$\epsilon_D$	$T$	$f$	$\epsilon_f$
$\alpha$ [1	991	28	$44^m 39^s \cdot 050$	$\cdot 007$	$1800^+ 94 \cdot 6$	$\cdot 000 \cdot 00 093$	$\cdot 000 \cdot 000 10]$
	1194						
2	952	34	$53^m 46^s \cdot 732$	$\cdot 006$	$93 \cdot 1$	$095$	$07$
	1194						
3	919	23	$45^m 23^s \cdot 438$	$\cdot 009$	$94 \cdot 0$	$156$	$14$
	1120						
4	892	29	$58^m 4^s \cdot 545$	$\cdot 007$	$100 \cdot 1$	$107$	$11$
	1143						
5	1004	17	$39^m 40^s \cdot 203$	$\cdot 015$	$81 \cdot 2$	$079$	$18$
	1184						
6	935	11	$40^m 21^s \cdot 510$	$\cdot 020$	$92 \cdot 0$	$157$	$26$
	1114						
7	961	21	$57^m 48^s \cdot 700$	$\cdot 011$	$99 \cdot 5$	$151$	$11$
	1226						
$\delta$ 1	919	10	$9^o 59' 29'' \cdot 23$	$\cdot 23$	$90 \cdot 5$	$108$	$22$
	935						
2	952	22	$14^o 4' 55'' \cdot 79$	$\cdot 10$	$94 \cdot 3$	$080$	$09$
	961						
[3	991	17	$7^o 32' 27'' \cdot 66$	$\cdot 20$	$72 \cdot 1$	$008$	$24]$
[4	1004						
	991	22	$6^o 28' 45'' \cdot 01$	$\cdot 14$	$95 \cdot 9$	$012$	$22]$
5	1007						
	1033	20	$17^o 19' 27'' \cdot 59$	$\cdot 18$	$81 \cdot 0$	$074$	$09$
6	961						
	1120	14	$7^o 35' 39'' \cdot 98$	$\cdot 23$	$81 \cdot 3$	$192$	$26$
7	1114						
	1143	12	$10^o 59' 51'' \cdot 24$	$\cdot 26$	$90 \cdot 2$	$065$	$20$
8	1092						
	1194	17	$11^o 44' 46'' \cdot 48$	$\cdot 17$	$89 \cdot 5$	$099$	$12$
	1226						

The most striking feature of this list is that the internal agreement is rather poor, compared with the mean error of the annual variation of  $D$ , which is of the same order as the mean error of a very good proper motion.

However, Boss 991 has a radial velocity of only 6.7 km/sec. It thus becomes very doubtful whether that star belongs to the cluster. I therefore excluded  $\alpha$ -pair 1 and the  $\delta$ -pairs 3 and 4 \*).

A large part of the remaining deviations may be interpreted, as due to internal motions. Dr. J. H. OORT directed my attention to the average size of these motions, which according to VAN RHIJN \*\*) amounts to  $\pm \cdot 008$ . Taking  $\cdot 016$  as a maximum effect, a deviation in  $f$  of  $\cdot 000 \cdot 00053$  may be expected for a pair with a separation of  $30 \cdot 000''$ .

A second source of uncertainty for the results of the  $\alpha$ -pairs may be found in the differences in the individual parallaxes of the components. The  $\delta$ -pairs cannot be influenced in this manner, as their distance

\*) I saw afterwards that RASMUSON, *Meddelanden Lund*, II, 26 page 11, 1921, had already excluded 991 on account of its radial velocity.

\*\*) *Gron. Publ.* 35.

is almost perpendicular to the direction to the apex of the cluster.

The weighted mean of  $f$  is:

$$\cdot 000 \cdot 001 \cdot 03 \pm \cdot 000 \cdot 000 \cdot 04 \text{ (m. e.)}$$

The mean error was computed from the weights of the catalogues, the  $\delta$ -pairs 2 and 6 being taken with weight  $\frac{3}{4}$ .

The mean without weights is:

$$\cdot 000 \cdot 001 \cdot 14 \pm \cdot 000 \cdot 000 \cdot 12 \text{ (m. e., computed from the residuals).}$$

### III. The mean parallax of the Hyades.

#### 1. From the foreshortening.

Let  $d$  and  $\Delta d$  be the spherical distance of two stars and its annual decrease,

$\rho$  „  $\Delta \rho$  be the distance of the cluster and its annual decrease,

$\pi$  be the mean parallax,

$v$  be the mean radial velocity.

We have

$$\frac{\Delta d}{\Delta \rho} = \frac{d}{\rho}$$

$$\frac{1}{d} \frac{\Delta d}{\Delta t} = \frac{1}{\rho} \frac{\Delta \rho}{\Delta t}$$

$$f = k \pi v$$

where  $k = \frac{1}{977100}$  if  $\Delta t$  is expressed in years,  $\pi$  in seconds of arc and  $v$  in km/sec.

Taking  $v = 38 \cdot 1 \pm \cdot 5$  km/sec as the mean of the radial velocities from Table 3 \*), the mean parallax is:

$$\pi = \cdot 026 \pm \cdot 002$$

$$\pi = \cdot 029 \pm \cdot 003$$

corresponding to the two values of  $f$ .

Taking  $v = 37 \cdot 2 \pm \cdot 5$  km/sec for the radial velocity of the centre, computed from the space velocity of the cluster (see IV), the corresponding values are:

$$\pi = \cdot 027 \pm \cdot 002$$

$$\pi = \cdot 030 \pm \cdot 003$$

#### 2. From the variation of the radial velocities.

Following a suggestion of prof. HERTZSPRUNG, which I worked out with the kind assistance of Dr. OORT, I have also computed the mean parallax from the differential radial velocity combined with the apparent tangential motion of the cluster.

Table 3 contains the radial velocities, with their authorities:

$MW$  = Mount Wilson  
 $L$  = Lick  
 $B$  = Bonn (Küstner)  
 $V$  = Victoria  
 $A$  = Allegheny.

\*) In computing this mean I omitted Boss 991, and also 1043 and 1089 for reasons mentioned sub IV.

TABLE 3. Radial velocities of the Hyades.

Star	Remarks	M.W.	L.	B.	V.	A.	Mean	$\lambda$	$d$	$v_{comp.}$	$O-C$
Boss 667		27.0			27.4		27.2	50.4	-21.9	27.3	-0.1
» 892		37.6		25.7			31.6	36.8	-8.5	34.4	-2.8
» 919						32.9	32.9	35.1	-6.7	35.1	-2.2
» 952		31.1		21.6	24.4		25.7	33.5	-5.1	35.8	-10.1
» 961		34.5					34.5	31.3	-0.8	36.6	-2.1
» 991	2 plates					6.7					
» 1000	Spect. Bin.		39.0	39.6	38.4		39.0	30.1	-1.7	37.1	+1.9
» 1017	Var.?	41.0	38.6	43.95 40.32 37.99			40.1	29.8	-1.4	37.2	+2.9
» 1018	Orbit.		36.4				36.4	29.5	-1.2	37.3	-0.9
» 1022	Spect. Bin.		38.0				38.0	29.6	-1.2	37.3	+0.7
Gron. 122	<i>H. D.</i> 27848	42.7					42.7	29.3	-1.1	37.4	+5.3
» 123	<i>H. D.</i> 27859	43.5					43.5	29.0	-1.1	37.5	+6.0
Boss 1025		36.1					36.1	29.9	-1.3	37.2	-1.1
» 1026			41.0				41.0	31.0	-2.0	36.8	+4.2
» 1029			36.4				36.4	29.4	-1.0	37.4	-1.0
» 1033	Bin. <i>Ap. J.</i> 29.										
» 1034	Bin. <i>Ap. J.</i> 29										
Gron. 177		40.3					40.3	28.9	-0.5	37.5	+2.8
» 206		40.0					40.0	28.4	-0.2	37.8	+2.2
Boss 1040					35.7		35.7	30.2	-0.0	37.1	-1.4
» 1043	Var?				50.1		50.1	27.9			
» 1044			39.4	39.4			39.4	29.2	-0.1	37.5	+1.9
» 1045			37.5				37.5	28.2	+0.2	37.8	-0.3
» 1046	Orbit.		42.6				42.6	28.1	+0.3	37.8	+4.8
» 1055		36.1			38.4		37.2	27.5	+0.7	38.1	-0.9
» 1056					39.2		39.2	27.1	+0.1	38.2	+1.0
Gron. 258		43.1					43.1	27.6	+0.6	38.0	+5.1
» 297		39.9					39.9	26.8	+1.3	38.3	+1.6
Boss 1086		40.7			35.6		38.2	25.9	+2.4	38.6	-0.4
» 1089	Binary	23.0					23.0	26.0			
» 1114					38.8		38.8	23.3	+4.9	39.4	-0.6
» 1120		38.8					38.8	25.1	+3.7	38.9	-0.1
» 1143	Bin. <i>Ap. J.</i> 29					41.7 23.7 13.1 25.3					
Lal. 9091		38.0					38.0	23.2	+6.6	39.4	-1.4
» 9109		38.0					38.0	23.6	+6.2	39.4	-1.4
Boss 1184		43.6					43.6	21.0	+7.3	40.1	+3.5
» 1194			42.0				42.0	23.2	+7.8	39.4	+2.6
» 1226						32.4	32.4	17.0	+11.2	41.0	-8.6
» 1501	Orbit.						42.7	4.3	+23.9	42.8	-0.1

The following stars not mentioned by BOSS as belonging to the Hyades are included in Table 3 :

- 6 stars mentioned by VAN RHIJN \*).
- 4 stars mentioned by HERTZSPRUNG, viz: Boss 1089, 1120 and Lal. 9091 and 9109.
- 2 stars which were recently found by Dr. OORT as possible members of the Hyades, viz: Boss 607 and 1501.

Let  $v_x$  : be the radial velocity of the centre,  
 $v_2 = v_x + \Delta v$ : " " " " " a cluster star,  
 $\mu_x$  : be the proper motion of the centre = mean total p. m.,  
 $\pi$  : be the mean parallax,

\*) *Gron. Publ.* 35.

$d_x$  : be the spherical distance of a star from the centre projected on the direction of the mean proper motion \*) (see Table 3).

The accompanying fig. 2 is drawn in the plane passing through the observer  $O$  and two stars  $S_1$  and  $S_2$  of the cluster.  $V$  represents the component in this plane of the space velocity of the cluster. Its size and direction is irrelevant as we shall only make use of the fact that it must be the same for both stars. With the above notation we find from the triangle formed by the arrows  $v_1$ ,  $v_2$  and  $V$  drawn near  $S_1$

\*) A position angle of  $102^\circ$  was adopted for this mean proper motion, in accordance with *G. P.* 35. This value has been checked with the aid of about 12 Boss stars lying near the centre of the cluster.

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It was interesting to compare the observations made at the different observatories \*):

$$\begin{aligned} MW &: 44.4 \pm .7 \text{ km/sec} \\ L &: 44.6 \pm .6 \text{ " } \\ V &: 39.2 \pm 1.3 \text{ " } \end{aligned}$$

The mean errors were computed from the residuals  $O-C$ . The columns headed  $v_{\text{comp}}$  and  $O-C$  give the expected radial velocity of each star computed with a space velocity of 42.9 km/sec and the residuals from the observed values.

The large residual of Boss 952 demands a new determination of the radial velocity (see sub III 2).

#### V. *The proper motion of Boss 991.*

It was interesting to redetermine the p. m. of Boss 991 with the aid of recent meridian observations.

I have to thank Prof. R. SCHORR, Director of the Observatory at Hamburg, for his kindness in sending

\*) The Bonn velocities were considered too heterogeneous to be used in this manner.

me an extract from his index of catalogues. I was thus enabled to get a fairly complete collection of all existing observations of this star.

From 41 observations of the right ascension I found:

$$\mu_{\alpha} = + 5.0074 \pm 5.0002 \text{ (m. e.)}$$

and from 39 observations of the declination

$$\mu_{\delta} = - 0.036 \pm 0.003 \text{ (m. e.)}$$

The mean place for the mean epoch and for the equinox 1900.0 is found to be:

$$\begin{array}{r} 4^{\text{h}} \ 12^{\text{m}} \ 28^{\text{s}}.018 \pm 5.004 \ 1899.5 \\ 21^{\circ} \ 20' \ 5''.58 \pm 0.06 \ 1897.4 \end{array}$$

The p. m. found agrees almost exactly with that derived by Boss, viz:

$$\mu_{\alpha} = + 5.0075$$

$$\mu_{\delta} = - 0.039$$

A new determination of the radial velocity seems very desirable.