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°.

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-

*') A. N. 5000, Bd 209, Aug. 1919.
***) B. A. N. 32.

lowed during four complete revolutions of the micrometer screw, giving twenty-five 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

*) B. A. N. 84.
the fixed middle thread. The equatorial value of one revolution of the screw, 3° 8914, was derived from observations of Polaris. The instrumental corrections have been applied to each star individually by means of the formula of Mayer:

\[ i \pm kK + \varepsilon C. \]

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° 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 \textit{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. \textit{The catalogue.}

The results have been reduced to the equinox of 1925°, but no proper motions were applied.

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

\[ \varepsilon_x = \pm \cdot043 = \pm \cdot64 \]
\[ \varepsilon_y = \pm \cdot64 \]

corresponding to the following weights (on Boss' system)

\[ \begin{array}{cc}
1 \text{ obs.} & 5 \\
2 \text{ and } 3 & 10 \\
4, 5 \text{ or } 6 & 15
\end{array} \]

The quantities \( \varepsilon_x \) and \( \varepsilon_y \) 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 \( \pm 014 \) for one complete observation. Poor weather conditions and other unfavourable circumstances appear to have influenced the final results.

\begin{table}[h]
\centering
\caption{Catalogue of 26 stars of the Hyades for the equinox 1925°.}
\begin{tabular}{|c|c|c|c|c|c|c|}
\hline
Boss Nr. & Name & Mag. & Spectr. & Mean R.A. & Number of obs. & Mean Dec. & Number of obs. & Mean Epoch \\
& & & & 1925° & & 1925° & & \\
\hline
892 & 596 & F0 & 3 48 52 53 & 5 & 1925 & 17 6 17 5 & 5 & 1925 \\
919 & 576 & F0 & 3 56 29 31 & 4 & & 17 59 07 & 5 & \ \\
935 & 548 & F0 & 3 59 52 88 & 6 & & 7 59 26 5 & 5 & \ \\
952 & 567 & G5 & 4 47 63 & 6 & & 19 24 43 3 & 6 & \ \\
961 & 571 & F0 & 4 7 20 61 & 5 & & 5 19 43 6 & 6 & \ \\
980 & 635 & F5 & 4 11 30 68 & 5 & & 15 12 50 4 & 5 & \ \\
991 & 536 & A5 & 4 13 56 74 & 3 & 103 & 21 23 30 0 & 3 & 103 \\
1004 & 559 & F0 & 4 15 44 16 & 2 & 108 & 13 51 18 8 & 2 & \ \\
1007 & 527 & F0 & 4 16 21 02 & 3 & & 14 54 35 9 & 5 & \ \\
1017 & 393 & A5 & 4 18 36 42 & 2 & & 17 22 4 6 & 2 & \ \\
1018 & 568 & A2 & 4 19 6 74 & 3 & & 16 36 11 6 & 3 & \ \\
1033 & 440 & A5 & 4 21 49 01 & 3 & & 22 38 4 2 & 2 & \ \\
1034 & 460 & A5 & 4 22 4 28 & 3 & & 15 26 6 7 & 3 & \ \\
1046 & 362 & A5 & 4 24 2 73 & 3 & & 15 42 20 7 & 3 & \ \\
1047 & 512 & A5 & 4 24 37 97 & 3 & & 12 52 5 8 & 3 & \ \\
1056 & 549 & A5 & 4 26 23 92 & 3 & & 13 33 4 4 & 3 & \ \\
1058 & 604 & A2 & 4 27 34 60 & 3 & & 15 42 30 0 & 3 & \ \\
1067 & 475 & A5 & 4 29 35 40 & 6 & & 14 41 16 2 & 6 & \ \\
1086 & 580 & F0 & 4 33 51 73 & 3 & & 15 53 2 5 & 3 & \ \\
1092 & 555 & F0 & 4 35 2 37 & 2 & & 7 43 22 5 & 3 & \ \\
1114 & 535 & A3 & 4 40 16 36 & 3 & & 11 0 26 4 & 3 & \ \\
1120 & 613 & K0 & 4 41 53 93 & 2 & & 18 36 0 9 & 2 & \ \\
1143 & 512 & F0 & 4 46 59 08 & 5 & & 18 42 48 4 & 6 & \ \\
1184 & 670 & F5 & 4 55 25 96 & 5 & & 15 48 16 8 & 5 & \ \\
1194 & 470 & A5 & 4 58 36 65 & 5 & & 21 29 2 2 & 5 & \ \\
1226 & 542 & A2 & 5 5 12 01 & 2 & & 9 44 3 1 & 2 & \ \\
\hline
\end{tabular}
\end{table}

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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 α or in δ (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 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 α or δ 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. 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.

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 α-pairs were so chosen as to be of about the same declination and the δ-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:

$$p_i = \frac{p_i^1 p_i^2}{p_i^1 + p_i^2}$$

where $p_i^1$ and $p_i^2$ are the weights of the two components of the pair. The values of $p_i^1$ and $p_i^2$ 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 Kón. Zood. 1835.°, 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.

1st column: current numbers of the pairs, the same as in fig. 1.

2nd " : Boss numbers of the components of each pair.

3rd and 4th " : mean distance $D$ between the components and its mean error $\varepsilon_D$.

5th " : mean epoch $T$.

6th and 7th " : the foreshortening and its mean error $\varepsilon_f$.


**) The equation of condition used by Hertzsprung

$$\mu = A + Bz,$$

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

$$f = \frac{d_i - d_4}{(t_i - t_4)} = \frac{(x_i - x_4) - (x_4 - x_i)}{(x_4 - x_i)(t_i - t_4)} =$$

$$= \frac{(x_i - x_4)(x_i - x_4)}{(x_i - x_4)(t_i - t_4)} = \frac{1}{a_i - a_4} = B.$$

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

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Table 2.
The foreshortening of the dimensions of the Hyades.

<table>
<thead>
<tr>
<th>Pair</th>
<th>Boss Nr.</th>
<th>Number of obs.</th>
<th>D</th>
<th>ε₀</th>
<th>T</th>
<th>f</th>
<th>ε/f</th>
</tr>
</thead>
<tbody>
<tr>
<td>α</td>
<td>991</td>
<td>28</td>
<td>44.470</td>
<td>9</td>
<td>149.0</td>
<td>103.0</td>
<td>10</td>
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<tr>
<td>1</td>
<td>1194</td>
<td>54.6732</td>
<td>0.06</td>
<td>93.1</td>
<td>0.95</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>952</td>
<td>34</td>
<td>45.320</td>
<td>0.94</td>
<td>156.0</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>1194</td>
<td>892</td>
<td>23</td>
<td>58.454</td>
<td>0.07</td>
<td>100.1</td>
<td>107.1</td>
<td>11</td>
</tr>
<tr>
<td>3</td>
<td>919</td>
<td>20</td>
<td>39.203</td>
<td>0.15</td>
<td>81.2</td>
<td>0.79</td>
<td>18</td>
</tr>
<tr>
<td>1120</td>
<td>693</td>
<td>17</td>
<td>40.251</td>
<td>0.20</td>
<td>92.0</td>
<td>1.57</td>
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</tr>
<tr>
<td>5</td>
<td>1104</td>
<td>11</td>
<td>57.400</td>
<td>0.11</td>
<td>99.5</td>
<td>1.51</td>
<td>11</td>
</tr>
<tr>
<td>1184</td>
<td>691</td>
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<td>23</td>
<td>90.5</td>
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<td>7</td>
<td>935</td>
<td>11</td>
<td>44.557</td>
<td>0.10</td>
<td>94.3</td>
<td>0.80</td>
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<td>7.32</td>
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<td>72.1</td>
<td>0.08</td>
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<td>26.450</td>
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<td>95.9</td>
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<tr>
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<td>7.35</td>
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<td>81.3</td>
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<tr>
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<td>11.46</td>
<td>17</td>
<td>89.5</td>
<td>0.09</td>
<td>12</td>
</tr>
</tbody>
</table>

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 α-pair 1 and the δ-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 ±0.08. Taking '016 as a maximum effect, a deviation in f of '000 000.53 may be expected for a pair with a separation of 30 000.

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

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

The weighted mean of f is:

\[ \text{f}_{\text{mean}} = 0.000 001 03 \pm 0.000 000 04 \ (m. e. \) \]

The mean error was computed from the weights of the catalogues, the δ-pairs 2 and 6 being taken with weight 4.

The mean without weights is:

\[ \text{f}_{\text{mean}} = 0.000 001 14 \pm 0.000 000 12 \ (m. e., \text{computed from the residuals}) \]

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, \( \rho \) be the distance of the cluster and its annual decrease, \( \pi \) be the mean parallax, \( v \) be the mean radial velocity.

We have

\[ \frac{\Delta d}{\Delta \rho} = \frac{d}{\rho} \]

\[ \frac{\Delta d}{\Delta t} = \frac{\pi}{\rho} \Delta t \]

\[ f = k \pi v \]

where \( k = \frac{1}{97100} \) if \( \Delta t \) is expressed in years, \( \pi \) in seconds of arc and \( v \) in km/sec.

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

\[ \pi = ^{0}026 \pm ^{0}002 \]

\[ \pi = ^{0}029 \pm ^{0}003 \]

corresponding to the two values of \( f \).

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

\[ \pi = ^{0}027 \pm ^{0}002 \]

\[ \pi = ^{0}030 \pm ^{0}003 \]

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:

\[ MW = \text{Mount Wilson} \]
\[ L = \text{Lick} \]
\[ B = \text{Bonn (Küstner)} \]
\[ V = \text{Victoria} \]
\[ A = \text{Allegheny} \]

*) I saw afterwards that Rasmussen, Meddelanden Lund, II, 25 page 11, 1921, had already excluded 991 on account of its radial velocity.

**) Gron. Publ. 35.

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### Table 3. Radial velocities of the Hyades.

<table>
<thead>
<tr>
<th>Star</th>
<th>Remarks</th>
<th>M.W.</th>
<th>L.</th>
<th>B.</th>
<th>V.</th>
<th>A.</th>
<th>Mean</th>
<th>λ</th>
<th>d</th>
<th>v&lt;sub&gt;comp&lt;/sub&gt;</th>
<th>O—C</th>
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<td>270°</td>
<td>37°</td>
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</tr>
<tr>
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<td></td>
<td>37°</td>
<td>66°</td>
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<td>36°</td>
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<tr>
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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 667 and 1501.

Let \( v_1 \) : be the radial velocity of the centre,
\[ v_2 = v_1 + \Delta v \]: " " " " a cluster star,
\[ u \]: be the proper motion of the centre
\[ \pi \]: be the mean parallax,
\[
\begin{align*}
\text{Let} & \quad \pi : \text{be the mean parallax,} \\
\text{Let} & \quad v_1 : \text{be the radial velocity of the centre,} \\
\text{Let} & \quad v_2 = v_1 + \Delta v: \text{" " " " a cluster star,} \\
& \quad u : \text{be the proper motion of the centre} \\
& \quad \pi : \text{be the mean parallax,} \\
& \quad d_1 : \text{be the spherical distance of a star from the centre projected on the direction of the mean proper motion) (see Table 3).}
\end{align*}
\]

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° 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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\[
\frac{\Delta \nu}{\sin d} = k \frac{\mu \rho}{\sin \psi},
\]

and approximately:

\[
\frac{\Delta \nu}{d} = k \frac{\mu}{\pi},
\]

where \(k = 83\) if \(\mu\) and \(\pi\) are expressed in seconds of arc and \(d\) in degrees.

Fig. 2.

\[
\frac{\Delta \nu}{d} = 30 \pm 16 \text{ (m. e.)}
\]

Taking:

\[
\mu = 102 \pm 005 \text{ (m. e.)}
\]

the mean parallax is found to be:

\[
\pi = 4028 \pm 015 \text{ (m. e.)}
\]

A second computation in which only the 17 radial velocities observed at Mount Wilson were used, yields:

\[
\frac{\Delta \nu}{d} = 32 \pm 21 \text{ and } \pi = 4026 \pm 020
\]

In the same manner I find:
from ten Lick observations:

\[
\frac{\Delta \nu}{d} = 38 \pm 23 \text{ and } \pi = 4022 \pm 020
\]

and from 7 Victoria observations

\[
\frac{\Delta \nu}{d} = 19 \pm 47 \text{ and } \pi = 4007 \pm 030
\]

The large deviation of the last value is entirely due to the low velocity of Boss 952 (see sub IV).

IV. The space velocity of the Hyades.

From the velocities in Table 3 I computed the space velocity by the formula:

\[
V = \frac{v}{\cos \lambda}
\]

where:

\(V\) = space velocity,
\(v\) = observed radial velocity,
\(\lambda\) = angular distance of a star from the convergent.

The values of \(\lambda\) (see Table 3) were taken from RASMUSON l. c.; the \(\lambda\)'s not given there were measured on a globe, using the same radiant as RASMUSON (6°13', +7°0).

I found *)

\[
V = 428'8 \pm 8 \text{ (m. e.) km/sec.}
\]

Afterwards I excluded 1089 and 1043 which were suspected of variability **), and found:

\[
V = 429'9 \pm 5 \text{ km/sec.}
\]

Excluding the members suggested by OORT (Boss 607 and 1501) I find:

\[
V = 429'9 \pm 5 \text{ km/sec,}
\]

exactly the same amount.

*) I have weighted the \(v\)'s according to the number of authorities.

B. A. N. 113.

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

\[ MW: 44'4 \pm 7 \text{ km/sec} \]
\[ L : 44'6 \pm 6 \text{ "} \]
\[ V : 39'2 \pm 1'3 \text{ "} \]

The mean errors were computed from the residuals \( O-C \). The columns headed \( \nu_{\text{comp}} \) 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 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:

\[ \mu_\alpha = +^\circ0074 \pm ^\circ0002 \text{ (m. e.)} \]

and from 39 observations of the declination

\[ \mu_\delta = -^\circ036 \pm ^\circ003 \text{ (m. e.)} \]

The mean place for the mean epoch and for the equinox 1900'0 is found to be:

\[ 4^h 12^m 28^s018 \pm^s004 \quad 1899'5 \]
\[ 21^\circ 20' 5^\circ58 \pm^\circ06 \quad 1897'4 \]

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

\[ \mu_\alpha = +^\circ0075 \]
\[ \mu_\delta = -^\circ039 \]

A new determination of the radial velocity seems very desirable.

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