# PHOTOELECTRIC STUDIES. I. COLOR-LUMINOSITY ARRAY FOR MEMBERS OF THE HYADES CLUSTER*

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ABSTRACT

Observations of 64 Hyades cluster stars have been made with photomultiplier photometers on the Washburn 15-inch and the Lick 12-inch refractors. The magnitudes and colors have been reduced to no atmosphere with the use of extinction factors determined each night. The dependence of the extinction factors upon the color of the star has also been determined nightly; the results for a typical night have been described to illustrate the procedure. The color system has a baseline slightly longer and shifted to the violet of the International System. Both the colors and the magnitudes have been reduced to the International System, $Pg_p$ and $C_p$, by comparisons with the North Polar Sequence.

The observed magnitudes have been converted to absolute magnitudes by the use of an unpublished value for the convergent of the cluster, $A = 94\overset{\circ}{.}0$, $D = +7\overset{\circ}{.}6$, derived by R. E. Wilson. The resulting color-luminosity array, consisting of dwarf, bright-dwarf, subdwarf, and giant sequences, satisfies the observations of 52 of the 64 stars observed, within the uncertainties of the proper motions and colors. This result indicates that there is inappreciable "cosmical" dispersion in luminosity for the various sequences of the color-luminosity array. Of the remaining 12 stars, 9 are known, or probable, binaries, 2 stars populate an additional sequence to be described in a later paper, and 1 star is possibly a nonmember of the cluster. It is shown that the stars with high rotational velocities populate mainly the bright-dwarf sequence.

The present paper—the first of a series—is the result of an attempt to realize the advantages of the 1P21 photomultiplier for the precise measurement of magnitudes and colors of stars. This program was started in 1947 with the Washburn Observatory's 15-inch refractor, and it has been continued with the Lick Observatory's 12-inch refractor.

## INSTALLATION

Since the Madison and Lick photometers, designed by Drs. A. E. Whitford and G. E. Kron,[1] respectively, are very similar, only the Lick installation will be described in detail. Figure 1 gives a general view of the instrument mounted on the 12-inch refractor. The optical column of the photometer contains the color filters, focal-plane diaphragm, dark slide, and a guiding eyepiece. The filter slide is 2 inches inside the focal plane. The focal-plane diaphragm has a diameter of 1.42 mm, which has been found to be the smallest possible to use and still clear all the light of a star. The multiplier is mounted in a cylindrical cavity turned in a solid piece of Duraluminum. The 90 volts per stage, required by the photomultiplier, are supplied by batteries mounted in a case permanently installed on the telescope tube. The signal received from the photomultiplier goes through a DC amplifier and records on an Esterline-Angus, 0–1 recording milliameter.

## COLOR SYSTEMS

The color-sensitivity-curves of the photomultiplier with filters were determined at Madison and at Lick with quartz monochromators. The energy of the source was measured at each wave length with a thermocouple, and the response was corrected to constant energy. In Table 1 the column marked "Clear" gives the relative spectral response of the Madison cell, including the 15-inch objective. The columns marked "Blue" and "Yellow" for Madison contain the numbers under "Clear" multiplied by the appropriate

* *Contributions from the Lick Observatory*, Ser. II, No. 25.

[1] A more complete description of the photometer and amplifier may be found in two publications by G. E. Kron; *Lick Obs. Bull.*, 19, 53, 1939 (No. 499), and *Electronics*, August, 1948.

transmissions of the two filters. The columns marked "Blue" and "Yellow" for Lick contain the relative spectral responses of the photomultiplier and 12-inch objective plus the blue and yellow filters, respectively. At Madison the blue filter was Schott BG1, 2 mm thick; the yellow was Schott GG7, 2 mm thick. At Lick the blue and yellow filters are, respectively, Corning 5330 and 3385, both of standard optical thickness.

TABLE 1

CONSTANT-ENERGY COLOR SENSITIVITIES OF PHOTOMULTIPLIER-FILTER COMBINATIONS

| Wave Length | Madison | | | Lick | |
|---|---|---|---|---|---|
| | Clear | Blue | Yellow | Blue | Yellow |
| 3700 A | 1.10 | 1.04 | ... | 0.90 | ... |
| 3800 | 1.80 | 1.75 | ... | 1.88 | ... |
| 4000 | 2.33 | 2.22 | ... | 2.36 | ... |
| 4200 | 2.23 | 1.96 | ... | 2.14 | ... |
| 4400 | 2.15 | 1.33 | 0.01 | 1.89 | ... |
| 4600 | 2.08 | 0.83 | 0.08 | 1.39 | ... |
| 4800 | 1.90 | 0.19 | 0.60 | 0.80 | 1.16 |
| 5000 | 1.63 | 0.08 | 1.34 | 0.39 | 1.99 |
| 5200 | 1.38 | ... | 1.21 | 0.19 | 2.02 |
| 5400 | 1.10 | ... | 0.99 | 0.08 | 1.57 |
| 5600 | 0.73 | ... | 0.67 | 0.03 | 1.07 |
| 5800 | 0.43 | ... | 0.39 | 0.01 | 0.71 |
| 6000 | 0.23 | ... | 0.21 | 0.01 | 0.27 |
| 6200 | 0.12 | ... | 0.11 | ... | 0.08 |
| 6400 | 0.03 | ... | 0.03 | ... | 0.03 |

TABLE 2

PHOTOELECTRIC AND INTERNATIONAL EFFECTIVE WAVE LENGTHS FOR BLACK-BODY SOURCES

| Temperature (° K) | Clear | | Blue | | Yellow | | Y−B | | |
|---|---|---|---|---|---|---|---|---|---|
| | *Pe* | *Pg* | *Pe* | *Pg* | *Pe* | *Pv* | *Pe* | *Pg* | |
| 11,000 | 4420 A | 4240 A | 3980 A | 4240 A | 5260 A | 5430 A | 1280 A | 1190 A | Madison |
| 3,000 | 4950 | 4560 | 4250 | 4560 | 5370 | 5480 | 1120 | 920 | Madison |
| 11,000 | ... | ... | 4020 | 4240 | 5240 | 5430 | 1220 | 1190 | Lick |
| 3,000 | ... | ... | 4410 | 4560 | 5360 | 5480 | 950 | 920 | Lick |

Since the magnitudes and colors are to be reduced to the International System, an attempt has been made to derive the effective wave lengths of the two filter-multiplier combinations. Following F. H. Seares,[2] we have for either yellow or blue:

$$\lambda_e = \frac{\Sigma \lambda s y}{\Sigma s y}, \tag{1}$$

where $s$ is the sensitivity factor under "Blue" or "Yellow" in the present Table 1 and $y$ is the relative energy of a black-body radiator, taken from Seares's Table 1. The resulting

[2] *Ap. J.*, **101**, 15, 1945; *Mt. W. Contr.*, No. 701.

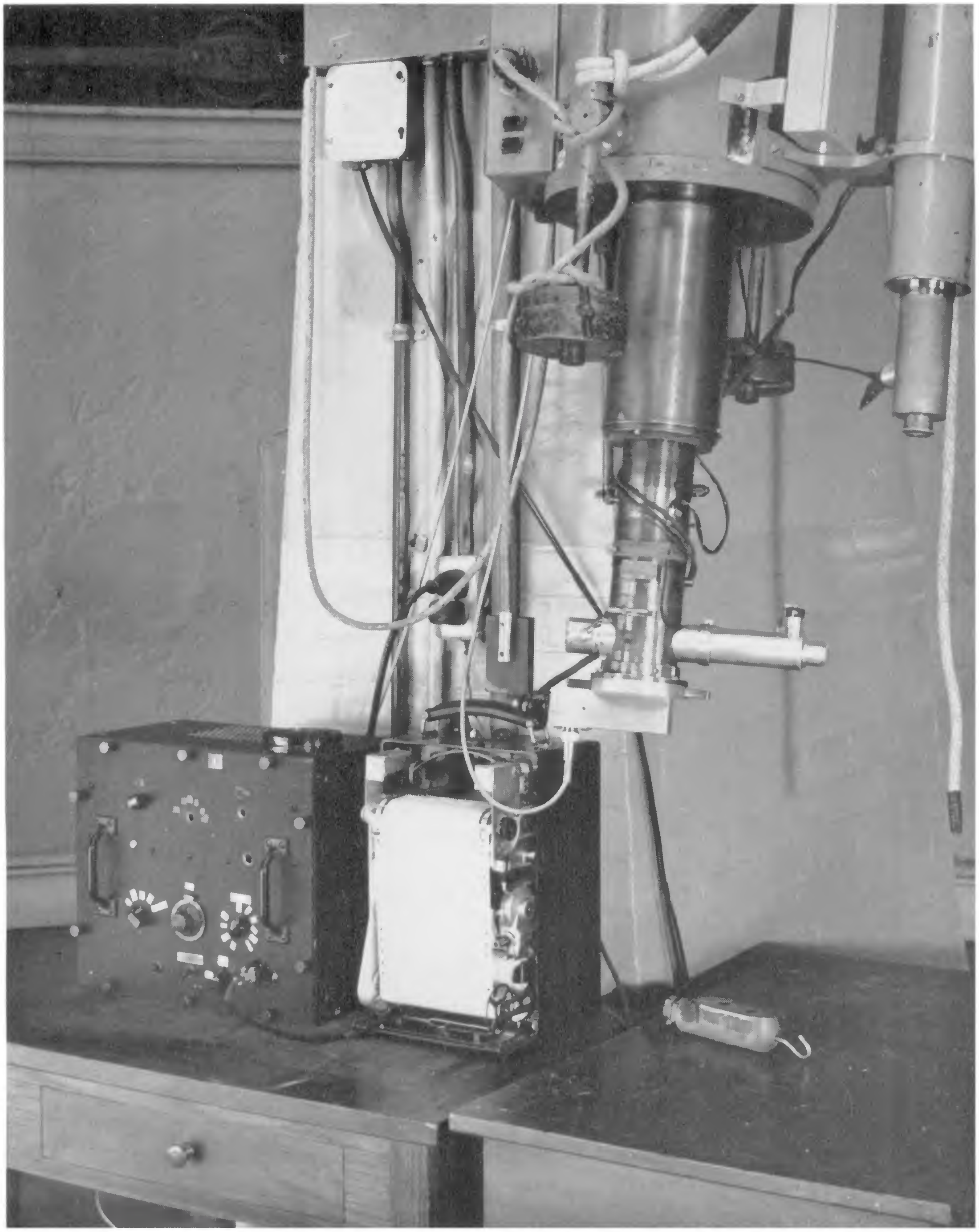

FIG. 1.—Photometer, amplifier, and recorder installation for the 12-inch refractor

photoelectric effective wave lengths and those for the International System from Seares's Table 3, both rounded off to 10 A, are given for two temperatures in the present Table 2. It should be noted that the effective wave lengths derived here are for no atmosphere; those for the International System include the extinction at the Mount Wilson pole.

Since the figures in Table 2 are based upon black bodies and are therefore largely theoretical, we have made the usual comparison with the stars of the North Polar Sequence.

TABLE 3

COLORS AND MAGNITUDES OF THE NORTH POLAR SEQUENCE

| NPS | $Pg_p$ | $C_p$ | $Pg_{int}$ | $C_{int}$ | $C_{s,w}$ | $Pg_p - Pg_{int}$ |
|---|---|---|---|---|---|---|
| 1 | 4.23 | −0.07 | 4.40 | +0.03 | −0.07 | −0.17 |
| 2 | 5.12 | −0.09 | 5.23 | −0.11 | −0.11 | − .11 |
| 3 | 5.72 | +0.16 | 5.79 | +0.18 | +0.16 | − .07 |
| 4 | 5.88 | +0.14 | 5.92 | +0.14 | +0.13 | − .04 |
| 5 | 6.46 | +0.02 | 6.46 | +0.03 | +0.01 | .00 |
| 2s | 6.48 | +0.26 | 6.47 | +0.15 | +0.24 | + .01 |
| 1r | 6.61 | +1.57 | 6.68 | +1.53 | +1.54 | − .07 |
| 3s | 6.66 | +0.33 | 6.63 | +0.23 | +0.31 | + .03 |
| 6 | 7.11 | +0.12 | 7.12 | +0.06 | +0.12 | − .01 |
| 2r | 7.89 | +1.51 | 7.92 | +1.57 | +1.53 | − .03 |
| 8 | 8.31 | +0.25 | 8.30 | +0.23 | ........... | + .01 |
| 9 | 9.09 | +0.20 | 8.94 | +0.14 | ........... | + .15 |
| 0 | 9.21 | +0.17 | 9.13 | +0.12 | +0.16 | + .09 |
| 4r | 9.28 | +1.01 | 9.20 | +1.02 | +1.00 | + .08 |
| 11 | 9.83 | +0.22 | 9.77 | +0.20 | ........... | + .06 |
| 12 | 10.13 | +0.35 | 10.08 | +0.31 | ........... | + .05 |
| 4s | 10.36 | +0.47 | 10.31 | +0.47 | ........... | + .05 |
| 14 | 11.02 | +0.45 | 10.93 | +0.40 | ........... | +0.09 |

In Table 3 the columns labeled $Pg_p$ and $C_p$ are the mean magnitudes and colors computed from the relations

$$\left.\begin{aligned} C_p &= \underset{\pm 0.02}{0.90} + \underset{\pm 0.01}{0.80} C_M \,, && \text{(2a)} \\ Pg_p &= Pe_M + \underset{\pm 0.01}{0.38} C_p \,, && \text{(2b)} \end{aligned}\right\} \text{Madison}$$

$$\left.\begin{aligned} C_p &= \underset{\pm 0.02}{1.16} + \underset{\pm 0.01}{0.89} C_L \,, && \text{(3a)} \\ Pg_p &= Pe_L - \underset{\pm 0.01}{0.21} C_p \,, && \text{(3b)} \end{aligned}\right\} \text{Lick}$$

where the subscripts "M" and "L" refer to photoelectric magnitudes and colors observed at Madison and at Lick, respectively, and the uncertainties are expressed as probable errors. The column labeled "$C_{int}$" contains the International colors according to Seares and Joyner,[3] while the values for $Pg_{int}$ are from the *Rome Report* of the International Astronomical Union[4] adjusted with the values of $C_{int}$ in a manner suggested by Seares. The values of $C_{s,w}$ are the International colors determined by Stebbins and Whitford[5] with a photomultiplier photometer attached to the 60-inch reflector at Mount Wilson. The Madison magnitudes were determined independently of the colors through the use

[3] *Ap. J.*, **101**, 18, 1945; *Mt. W. Contr.*, No. 701.

[4] *Trans. I.A.U.*, **1**, 71, 1922.

[5] *Ap. J.*, **108**, 413, 1948; *Mt. W. Contr.*, No. 753.

were observed. The distribution with magnitude of the stars observed, however, is satisfactory for the present purpose. Since the Hyades is the closest moving cluster, it has the greatest importance for establishing the zero point of absolute magnitudes, and it will therefore be kept on the observing program.

The baseline of the colors has been discussed above and is indicated in Table 2. The zero point of the magnitudes was established through observations of NPS 1 and 4 made at the beginning, middle, and end of each night. Stebbins and Whitford[10] have previously shown that the photographic-magnitude scale diverges from the photoelectric one by 0.2 mag. between magnitudes 5 and 9. This same effect is evident in the last column of Table 3. Therefore, in order to make the present magnitudes more comparable with the photographic results, the values of $Pe_L$ and $Pe_M$ for NPS 1 and 4 were fixed so as to bring the zero point into agreement with $Pg_{\rm int}$ at the mean magnitude of the 6 stars, NPS 4, 5, 2s, 3s, 6, and 8, or at $Pg_{\rm int} = 5.9$–$8.3$.

A single Lick observation usually consisted of deflections through the yellow filter, the blue filter, and again through the yellow filter; the Madison observations included a "clear" deflection. The color systems were chosen to give nearly equal deflections in both the yellow and the blue for the reddest cluster stars observed. The average time spent on each star, per night, was 5 minutes. In all cases each star was observed on at least two different nights.

Measurable "clear" deflections at magnitude 13.5 are obtainable with the installation on the 12-inch refractor, but the use of the filters cuts this limit to photographic magnitude 12. This working limit has been arbitrarily lowered to 11.5, for, to maintain uniform accuracy, the time spent per star increases rapidly at the fainter magnitudes. Over the whole range in magnitude considered here, the average deviations from the mean do not exceed 0.01 mag., and residuals as large as 0.03 mag. are rare in both magnitude and color.

The results of the observations of 65 stars are listed in Table 4. The numbers in the first column are from the list of cluster members supplied by R. E. Wilson. The proper motions are taken from the *Boss General Catalogue*[11] when available, otherwise from a recent publication by Wilson.[12] For 4 stars not contained in either of these lists, the proper motions are taken from an earlier paper by Wilson.[13]

The most recent discussion of the photographic magnitudes in the Hyades region is that of E. Holmberg.[14] Table 5 contains the 39 stars common to Table 4 and Holmberg's lists. The prefixed A or B to the numbers in the second column of the table indicates in which of Holmberg's two catalogues the magnitudes are contained. For the stars brighter than 7.00 mag., Holmberg's catalogues give magnitudes determined by E. Hertszprung;[15] for the fainter stars the magnitudes are a mixture of determinations by Ramberg[7] and by Holmberg. Figure 3 shows graphically the relation between $Pg_p$ and $Pg_p - Pg'(\mathrm{H})$, where $Pg'(\mathrm{H}) = Pg(\mathrm{H}) - 0^{\mathrm{m}}18$. The correction of $-0.18$ mag. to Holmberg's magnitudes brings the two scales into agreement over the same magnitude range as was used in adjusting the $Pg_p$'s to $Pg_{\rm int}$.

Figure 4 shows a plot of $Pg_p$ against $C_p$. The dispersion in magnitude, for a given color, is of the order to be expected from the differential in distance of the individual stars, caused by the depth of the cluster.

[10] *Ap. J.*, **87**, 237, 1938; *Mt. W. Contr.*, No. 586.

[11] Carnegie Institution of Washington, 1937.

[12] *Ap. J.*, **107**, 129, 1948; *Mt. W. Contr.*, No. 741.

[13] *A.J.*, **42**, 49, 1932.

[14] *Medd. Lund. Obs.*, Ser. II, No. 113, 1944.

[15] *A.N.*, **209**, 115, 1919.

interpolation; a few runs with three extinction stars amply proved the validity of this practice. Although observations of a dozen or more stars could be obtained during the time spent determining the extinction each night, rarely more than one hour, the increased accuracy in the slightly smaller output seemed well worth the time and effort.

## THE OBSERVATIONS

The pioneer investigation of the Hyades cluster was published by Lewis Boss[6] in 1908. The succeeding researches are so numerous that no attempt will be made here to list them, since a summary of the work up to 1941 has been compiled by J. Ramberg.[7]

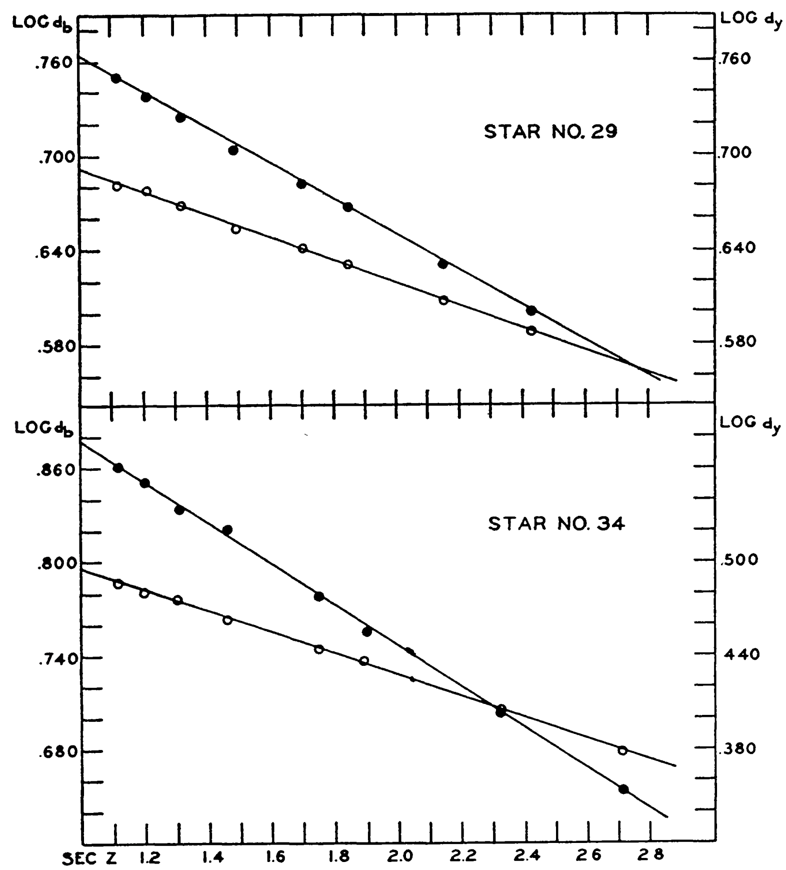


FIG. 2.—Extinction determination for stars Nos. 29 and 34 on January 27, 1949. The open circles represent the yellow deflections; the filled circles, the blue.

The most recently published derivation of the convergent point of the cluster is that of W. M. Smart.[8] However, Seares[9] has since shown that, by neglect of a regression error, the mean distance found by Smart may be too small by as much as 7 per cent. The present program of magnitudes and colors of the Hyades members was begun in 1947 to test the reality of the "cosmical dispersion" of the main sequence as defined by the cluster stars. The observing program has been confined to stars contained in a list of cluster members kindly supplied by Dr. R. E. Wilson of the Mount Wilson and Palomar observatories. The 1947–1948 observing season at Madison and the 1948–1949 winter season at Lick were unusually poor, so that only 64 stars, out of some 140 cluster members,

[6] *A.J.*, **26**, 31, 1908.

[7] *Stockholm Obs. Ann.*, Vol. **13**, 1941.

[8] *M.N.*, **99**, 168, 1939.

[9] *Ap. J.*, **102**, 323, 1945; *Mt. W. Contr.*, No. 716.

of a third, "clear," deflection, whereas only two deflections, alternately through the blue and yellow filters, were taken at Lick; the Lick magnitudes were obtained from the blue deflections. Rewriting the expression (3*b*), we have

$$P e_{\mathrm{L}} - P g_{\mathrm{int}} = 0.21 C_p \,, \tag{3b'}$$

from which it is seen that the "blue" Lick magnitudes are to the violet of $Pg_{\mathrm{int}}$ by $0.21(Pg - Pv)$ or 220 A in the mean for black-body radiators of 11,000° and 3,000°. The corresponding value from Table 2 is $0.18(Pg - Pv)$. Similarly, rewriting expression (2*b*), we have

$$P e_{\mathrm{M}} = P g_p - 0.38 C_p \,, \tag{2b'}$$

from which we find that the "clear" Madison magnitudes are $0.38(Pg - Pv)$ to the red of $Pg_{\mathrm{int}}$. The corresponding value in Table 2 is $0.27(Pg - Pv)$. The agreement in both cases is satisfactory, considering the uncertainty in the black-body effective wave lengths arising from the lack of accurate data on the violet transmissions of both the 12- and the 15-inch objectives.

## EXTINCTION

As already mentioned, the colors and magnitudes herein reported were reduced to no atmosphere, and the necessary reduction factors were determined each night. The dependence of these factors upon the color of the star was also determined nightly by choosing, as "extinction stars," two stars representing the extreme range of colors observed. The method used is best illustrated by an example. Figure 1 shows the logarithms of blue and yellow deflections, $\log d_b$ and $\log d_y$, obtained January 27, 1949, for stars numbered 29 and 34 in Table 4, plotted against Air mass = sec $z$. Least-squares solutions, fitted to the plotted points, gave the following constants and coefficients, with accompanying probable errors:

$$\begin{aligned}
\log d_b(34) &= \underset{\pm 0.001}{1.016} - \underset{\pm 0.001}{0.130} \sec z & &\text{Zenith extinction} = 0^{\mathrm{m}}.32\,; \\
\log d_y(34) &= \underset{\pm 0.001}{0.565} - \underset{\pm 0.001}{0.070} \sec z & &\text{Zenith extinction} = 0^{\mathrm{m}}.18\,; \\
\log d_b(29) &= \underset{\pm 0.001}{0.855} - \underset{\pm 0.001}{0.113} \sec z\,, & &\text{Zenith extinction} = 0^{\mathrm{m}}.28\,; \\
\log d_y(29) &= \underset{\pm 0.001}{0.743} - \underset{\pm 0.002}{0.072} \sec z\,, & &\text{Zenith extinction} = 0^{\mathrm{m}}.18\,.
\end{aligned} \tag{4}$$

That the probable errors are of the right order can be seen from Figure 2. At no atmosphere the color, in magnitudes, of star No. 34 is $2.5(0.565 - 1.016) = -1.13$, and the color of No. 29 is $2.5(0.743 - 0.855) = -0.28$. Applying expression (3*a*), we find $C_p(34) = +0.15$ and $C_p(29) = +0.91$. The differences in the coefficients of sec $z$ in expressions (4) show that the nearly universal practice of using the same photographic extinction for all colors can lead to serious errors. Since the present magnitudes were obtained from the blue deflections, the differential extinction effect at the zenith for stars 34 and 29 is 0.04 mag. on both $P_e$ and $C_{\mathrm{L}}$. If observed at the Lick pole, this effect would become 0.07 mag., which agrees with the figure determined theoretically by Seares[2] for the differential effect between A0 and K0 stars at the Mount Wilson pole. Since the coefficients of sec $z$ for the yellow deflections rarely differ from star to star by more than is indicated in expressions (4), our practice has been to use the mean. For colors midway between the extremes of stars Nos. 29 and 34, the blue extinction was found by simple

# TABLE 4

## Members of the Hyades Cluster

| No. | HD or BD | 1950 α | 1950 δ | Madison $P_{g_p}$ | Madison $C_p$ | Madison n | Lick $P_{g_p}$ | Lick $C_p$ | Lick n | Mean $P_{g_p}$ | Mean $C_p$ | Spectral Class Mt.W. | Spectral Class Y | $\mu$* | $M_{P_{gp}}$ | $V_r \sin i$ | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 24357 | $3^h50^m3$ | +17°11′ | 6.17 | +0.25 | 3 | 6.17 | +0.23 | 3 | 6.17 | +0.24 | F0 | F4 | 0″151 | +3.28 | 25 | |
| 6 | 25102 | 56.9 | +10 11 | 6.64 | + .32 | 2 | 6.66 | + .34 | 2 | 6.65 | + .33 | F3 | F5 | .171 | +4.15 | 25 | |
| 7 | +19°641 | 57.7 | +20 14 | 9.16 | + .59 | 1 | 9.20 | + .58 | 2 | 9.19 | + .58 | G2 | G4 | .154 | +6.39 | ... | |
| 8 | 25202 | 3 57.9 | +18 03 | 6.06 | + .25 | 2 | 6.06 | + .20 | 3 | 6.06 | + .22 | F2 | F4 | .138 | +3.06 | 100 | |
| 9 | 25570 | 4 01.2 | + 8 04 | 5.67 | + .27 | 2 | 5.64 | + .26 | 2 | 5.66 | + .265 | F2 | F4 | .171 | +3.22 | 0 | |
| 10 | 25825 | 03.3 | +15 34 | ... | ... | ... | 8.20 | + .43 | 2 | 8.20 | + .43 | G2 | ... | *.114* | +4.87 | ... | |
| 13 | 26345 | 07.8 | +18 18 | 6.88 | + .30 | 2 | 6.87 | + .28 | 2 | 6.88 | + .29 | F6 | F6 | .121 | +3.76 | 0 | |
| 14 | 26462 | 08.7 | + 5 24 | 5.88 | + .25 | 2 | 5.90 | + .24 | 3 | 5.89 | + .24 | F2 | F4 | .149 | +3.25 | 0 | 45 Tau |
| 15 | 26736 | 11.5 | +23 29 | 8.47 | + .50 | 2 | 8.45 | + .50 | 2 | 8.46 | + .50 | G4 | ... | *.129* | +5.38 | ... | |
| 16 | 26737 | 11.5 | +22 20 | 7.21 | + .32 | 2 | 7.19 | + .31 | 2 | 7.20 | + .315 | F4 | F5 | .097 | +3.54 | ... | |
| 17 | 26756 | 11.6 | +14 30 | 8.92 | + .57 | 2 | 8.94 | + .56 | 2 | 8.93 | + .565 | G5 | ... | *.129* | +6.01 | ... | |
| 18 | 26767 | 11.7 | +12 20 | 8.60 | + .53 | 2 | ... | ... | ... | 8.60 | + .53 | G3 | ... | *.115* | +5.44 | ... | |
| 19 | 26784 | 11.8 | +10 35 | 7.47 | + .40 | 2 | 7.49 | + .40 | 2 | 7.48 | + .40 | F7 | ... | *.125* | +4.52 | ... | |
| 20 | 26874 | 12.8 | +20 42 | 8.39 | + .48 | 2 | 8.42 | + .48 | 2 | 8.40 | + .48 | G6 | G4 | .115 | +5.15 | ... | |
| 21 | 26911 | 12.9 | +15 17 | 6.63 | + .28 | 3 | 6.63 | + .28 | 2 | 6.63 | + .28 | F5 | F5 | .123 | +3.61 | 25 | 48 Tau |
| 23 | 27130 | 14.8 | +16 48 | 8.90 | + .63 | 1 | 8.86 | + .61 | 1 | 8.88 | + .62 | G6 | ... | (.115) | +5.72 | ... | † |
| 24 | 27149 | 15.1 | +18 07 | 7.96 | + .56 | 2 | 7.94 | + .57 | 1 | 7.95 | + .56 | G4 | ... | .116 | +4.79 | ... | † |
| 25 | 27176 | 15.4 | +21 28 | 5.76 | + .21 | 2 | 5.79 | + .22 | 2 | 5.78 | + .215 | A8n | A8 | .104 | +2.33 | 25 | 51 Tau |
| 29 | 27371 | 16.9 | +15 31 | 4.59 | + .92 | ... | 4.61 | + .92 | ... | 4.60 | + .92 | G8 | G9 | .121 | +1.59 | 0 | γ Tau |
| 30 | 27383 | 17.0 | +16 24 | 7.29 | + .43 | 1 | 7.29 | + .42 | 1 | 7.29 | + .425 | F8 | F9 | .124 | +4.34 | 0 | 55 Tau† |
| 31 | 27397 | 17.1 | +13 55 | 5.69 | + .20 | 3 | 5.69 | + .20 | 2 | 5.69 | + .20 | F2 | F3 | .118 | +2.66 | 75 | 57 Tau† |
| 33 | 27429 | 17.5 | +18 37 | 6.32 | + .26 | 2 | 6.32 | + .26 | 2 | 6.32 | + .26 | F3 | F3: | .118 | +3.23 | 50 | † |
| 34 | 27459 | 17.8 | +14 59 | 5.33 | + .15 | ... | 5.32 | + .15 | ... | 5.32 | + .15 | A9n | F0 | .113 | +2.20 | 0 | 58 Tau |
| 35 | 27483 | 18.1 | +13 45 | 6.54 | + .33 | 3 | 6.50 | + .33 | 1 | 6.53 | + .33 | F4 | F6 | .117 | +3.50 | 0 | † |
| 38 | 27561 | 18.8 | +14 18 | 6.82 | + .28 | 1 | 6.85 | + .29 | 2 | 6.84 | + .29 | F6 | F5 | .120 | +3.88 | 0 | |
| 39 | 27628 | 19.2 | +13 58 | 5.85 | + .21 | 2 | 5.84 | + .19 | 2 | 5.84 | + .20 | A4 | A3p | .117 | +2.82 | 0 | 60 Tau† |
| 40 | 27685 | 19.9 | +16 40 | 8.24 | + .54 | 2 | 8.28 | + .56 | 2 | 8.26 | + .55 | G5 | G4 | .153 | +5.80 | ... | |
| 41 | 27691 | 19.9 | +14 56 | 7.38 | + .43 | 1 | 7.34 | + .44 | 2 | 7.35 | + .44 | F9 | ... | (.103) | +4.06 | ... | † |
| 42 | +13°671 | 19.9 | +14 08 | ... | ... | ... | 10.68 | + .56 | 3 | 10.68 | + .56 | G3 | ... | *.107* | +7.48 | ... | |
| 43 | 27697 | 20.0 | +17 26 | 4.68 | + .91 | 4 | 4.68 | + .91 | 4 | 4.68 | + .91 | G9 | K0 | .114 | +1.57 | 0 | δ Tau |
| 47 | 27749 | 20.5 | +16 40 | 5.76 | +0.22 | 3 | 5.80 | +0.23 | 2 | 5.78 | +0.225 | A2 | A1p | 0.110 | +2.62 | 0 | 63 Tau† |

* The majority of the values for the proper motion are taken from the *Boss General Catalogue*. The italicized values are from a recent paper by R. E. Wilson, *Ap. J.*, **107**, 129, 1948; *Mt. W. Contr.*, No. 741. The four values in parentheses are taken from an earlier paper by Wilson (*A.J.*, **42**, 49, 1932).

† See notes to Table 4, p. 73.

TABLE 4—*Continued*

| No. | HD or BD | 1950 $\alpha$ | 1950 $\delta$ | Madison $P_{gp}$ | Madison $C_p$ | Madison n | Lick $P_{gp}$ | Lick $C_p$ | Lick n | Mean $P_{gp}$ | Mean $C_p$ | Spectral Class Mt.W. | Spectral Class Y | $\mu$* | $M_{Pgp}$ | $V_r \sin i$ | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 50 | 27819 | 4h21m.2 | +17°20′ | 4.80 | +0.10 | 3 | 4.84 | +0.09 | 3 | 4.82 | +0.095 | A6n | A6 | 0″.120 | +1.84 | 0 | 64 Tau |
| 52 | 27836 | 21.3 | +14 39 | ..... | ..... | ... | 7.97 | +0.46 | 2 | 7.97 | +0.46 | G1 | ...... | *.106* | +4.77 | ...... | |
| 53 | +17°715 | 21.4 | +17 53 | ..... | ..... | ... | 10.65 | +0.87 | 2 | 10.65 | +0.87 | K4 | ...... | *.111* | +7.49 | ...... | |
| 56 | 27859 | 21.6 | +16 46 | 8.13 | + .48 | 2 | 8.09 | +0.49 | 2 | 8.11 | +0.485 | G0 | G2 | .120 | +5.15 | ...... | |
| 57 | 27901 | 22.0 | +18 56 | 6.23 | + .28 | 1 | 6.25 | +0.27 | 2 | 6.25 | +0.27 | F0 | F4 | .117 | +3.20 | 50 | |
| 59 | 27934 | 22.4 | +22 11 | 4.14 | + .07 | 3 | 4.24 | +0.09 | 3 | 4.19 | +0.08 | A4 | A5 | .111 | +0.96 | 50 | 65 Tau |
| 60 | 27946 | 22.4 | +22 05 | 5.40 | + .20 | 3 | 5.38 | +0.20 | 3 | 5.39 | +0.20 | A8n | A7 | .125 | +2.41 | 150 | 67 Tau |
| 61 | 27962 | 22.6 | +17 49 | 4.23 | + .01 | 2 | 4.24 | +0.00 | 4 | 4.24 | +0.00 | A2 | A1 | .115 | +1.18 | 0 | 68 Tau† |
| 64 | 27990 | 22.9 | +17 55 | ..... | ..... | ... | 9.84 | +0.81 | 3 | 9.84 | +0.81 | K0 | ...... | *.098* | +6.44 | ...... | † |
| 66 | 28024 | 23.3 | +22 42 | 4.34 | + .18 | 2 | 4.44 | +0.18 | 3 | 4.38 | +0.18 | A6 | F0 | .118 | +1.27 | 250 | $\upsilon$ Tau |
| 70 | 28052 | 23.5 | +15 30 | 4.58 | + .18 | 1 | 4.62 | +0.18 | 2 | 4.61 | +0.18 | A5n | F0 | .116 | +1.63 | 150 | 71 Tau |
| 72 | +13°684 | 24.6 | +14 09 | ..... | ..... | ... | 11.45 | +1.05 | 2 | 11.45 | +1.05 | K5 | ...... | *.118* | +8.54 | ...... | |
| 74 | +14°699 | 24.9 | +14 19 | ..... | ..... | ... | 10.33 | +0.86 | 3 | 10.33 | +0.86 | K2 | ...... | (.102) | +7.11 | ...... | |
| 75 | 28226 | 25.0 | +21 31 | 5.84 | + .22 | 2 | ..... | ..... | ... | 5.84 | +0.22 | A6n | A5p | .106 | +2.55 | 25 | † |
| 80 | 28305 | 25.7 | +19 04 | 4.48 | + .95 | 3 | 4.47 | +0.96 | 3 | 4.48 | +0.955 | G9 | K0 | .118 | +1.50 | 0 | $\epsilon$ Tau |
| 81 | 28307 | 25.7 | +15 51 | 4.75 | + .89 | 3 | 4.79 | +0.90 | 1 | 4.76 | +0.89 | G8 | G8 | .109 | +1.62 | 0 | $\theta^1$ Tau |
| 82 | 28319 | 25.8 | +15 46 | 3.46 | + .14 | 3 | 3.48 | +0.15 | 4 | 3.47 | +0.145 | A6 | A7 | .108 | +0.37 | 50 | $\theta^2$ Tau† |
| 84 | 28355 | 26.0 | +12 56 | ..... | ..... | ... | 5.08 | +0.15 | 2 | 5.08 | +0.15 | A5 | A7 | .112 | +2.10 | 25 | 79 Tau |
| 89 | +17°734 | 26.6 | +17 47 | ..... | ..... | ... | 9.63 | +0.72 | 2 | 9.63 | +0.72 | G7 | ...... | .116 | +6.65 | ...... | |
| 90 | +15°634 | 26.7 | +16 08 | ..... | ..... | ... | 11.38 | +1.03 | 3 | 11.38 | +1.03 | K5 | ...... | *.097* | +8.37 | ...... | |
| 91 | 28462 | 27.1 | +16 33 | ..... | ..... | ... | 9.80 | +0.75 | 2 | 9.80 | +0.75 | K0 | ...... | *.109* | +6.72 | ...... | |
| 92 | 28485 | 27.3 | +15 32 | ..... | ..... | ... | 5.75 | +0.25 | 2 | 5.75 | +0.25 | A8n | F0 | .108 | +2.68 | 100 | 80 Tau† |
| 94 | 28527 | 27.7 | +16 05 | ..... | ..... | ... | 4.84 | +0.13 | 2 | 4.84 | +0.13 | A6 | A6 | .114 | +1.88 | 0 | |
| 95 | 28545 | 27.8 | +15 38 | ..... | ..... | ... | 9.58 | +0.73 | 2 | 9.58 | +0.73 | G8 | ...... | *.098* | +6.30 | ...... | |
| 96 | 28546 | 27.8 | +15 35 | 5.56 | + .16 | 1 | 5.57 | +0.17 | 2 | 5.57 | +0.17 | A7 | A5p | .108 | +2.50 | 0 | 81 Tau |
| 102 | 28677 | 29.0 | +15 45 | 6.16 | + .23 | 1 | 6.19 | +0.25 | 1 | 6.18 | +0.23 | F0n | F4 | .108 | +3.14 | 75 | 85 Tau |
| 105 | 28805 | 30.2 | +15 42 | ..... | ..... | ... | 9.20 | +0.64 | 2 | 9.20 | +0.64 | G7 | ...... | (.102) | +6.04 | ...... | |
| 106 | 28878 | 30.8 | +16 38 | ..... | ..... | ... | 10.12 | +0.80 | 2 | 10.12 | +0.80 | K0 | ...... | *.105* | +7.02 | ...... | |
| 117 | 29388 | 35.4 | +12 25 | ..... | ..... | ... | 4.31 | +0.09 | 2 | 4.31 | +0.09 | A5n | A6 | .101 | +1.28 | 0 | 90 Tau† |
| 119 | 29488 | 36.4 | +15 49 | ..... | ..... | ... | 4.69 | +0.10 | 2 | 4.69 | +0.10 | A5n | A7 | .087 | +1.30 | 50 | 92 Tau |
| 138 | 31845 | 56.9 | +15 51 | 7.06 | + .34 | 1 | 7.03 | +0.34 | 1 | 7.04 | +0.34 | F6 | F5 | .094 | +4.23 | ...... | 101 Tau |
| 139 | 32301 | 5 00.1 | +21 31 | 4.60 | + .09 | 1 | 4.65 | +0.10 | 1 | 4.62 | +0.095 | A5n | A7 | .080 | +1.27 | 100 | $\iota$ Tau |
| 141 | 33254 | 06.6 | + 9 46 | 5.55 | +0.16 | 2 | ..... | ..... | ... | 5.55 | +0.16 | A5 | A2p | 0.066 | +2.37 | 0 | 16 Ori† |

NOTES TO TABLE 4

23. Spectroscopic binary; one spectrum; $P = 5.61$ days.
24. Variable velocity (Wilson, *Ap. J.*, **107**, 129, 1948; *Mt. W. Contr.*, No. 741).
30. ADS 3135.
31. Spectroscopic binary; one spectrum (Stillwell, *Pub. Dom. Ap. Obs. Victoria*, **7**, 337, 1945).
33. Two spectra (Wilson).
35. Two spectra (Wilson).
39. Metallic-line star.
41. ADS 3169, brighter star is spectroscopic binary with one spectrum; $P = 4.00$ days.
43. Metallic-line star.
47. Metallic-line star. Spectroscopic binary with one spectrum; $P = 8.4$ days.
61, 64. These two stars from ADS 3286.
75. Metallic-line star.
82. Spectroscopic binary with one spectrum; $P = 140.7$ days.
92. ADS 3264, brighter star is spectroscopic binary with one spectrum (Stillwell).
117. Spectroscopic binary with one spectrum (Stillwell).
141. Metallic-line star.

TABLE 5

COMPARISON OF $Pg_p$ AND $C_p$ WITH MAGNITUDES AND COLORS GIVEN BY HOLMBERG

| No. | H | $Pg_p$ | $Pg$(H) | $C_p$ | $C$(H) | $Pg_p - Pg$(H) |
|---|---|---|---|---|---|---|
| 82 | A470 | 3.47 | 3.74 | +0.14 | +0.13 | −0.27 |
| 61 | B 77 | 4.24 | 4.44 | +0.00 | +0.11 | − .20 |
| 117 | B148 | 4.31 | 4.51 | +0.09 | +0.06 | − .20 |
| 80 | B 90 | 4.48 | 4.79 | +0.96 | +1.03 | − .31 |
| 29 | B 33 | 4.60 | 4.92 | +0.92 | +1.05 | − .32 |
| 70 | A262 | 4.61 | 4.89 | +0.18 | +0.20 | − .28 |
| 43 | B 58 | 4.68 | 4.95 | +0.91 | +0.92 | − .27 |
| 119 | B160 | 4.69 | 4.89 | +0.10 | +0.15 | − .20 |
| 81 | A462 | 4.76 | 4.99 | +0.89 | +0.89 | − .23 |
| 50 | B 64 | 4.82 | 5.02 | +0.10 | +0.11 | − .20 |
| 94 | A635 | 4.84 | 5.00 | +0.13 | −0.01 | − .16 |
| 84 | B 92 | 5.08 | 5.30 | +0.16 | +0.10 | − .22 |
| 34 | B 40 | 5.32 | 5.54 | +0.15 | +0.29 | − .22 |
| 96 | A648 | 5.57 | 5.80 | +0.17 | +0.21 | − .23 |
| 31 | B 37 | 5.69 | 5.92 | +0.20 | +0.38 | − .23 |
| 92 | A608 | 5.75 | 5.91 | +0.25 | +0.15 | − .16 |
| 102 | A765 | 6.18 | 6.38 | +0.23 | +0.24 | − .20 |
| 57 | B 72 | 6.25 | 6.34 | +0.30 | +0.16 | − .09 |
| 33 | B 38 | 6.32 | 6.41 | +0.26 | +0.18 | − .09 |
| 21 | B 9 | 6.63 | 6.71 | +0.28 | +0.29 | − .08 |
| 30 | B 34 | 7.29 | 7.40 | +0.42 | +0.40 | − .11 |
| 41 | A 28 | 7.35 | 7.54 | +0.44 | +0.37 | − .19 |
| 24 | B 18 | 7.95 | 8.16 | +0.57 | +0.47 | − .21 |
| 52 | A107 | 7.97 | 8.17 | +0.46 | +0.44 | − .20 |
| 56 | A120 | 8.11 | 8.41 | +0.48 | +0.54 | − .30 |
| 23 | B 14 | 8.88 | 9.10 | +0.62 | +0.66 | − .22 |
| 17 | B 6 | 8.93 | 9.15 | +0.56 | +0.56 | − .22 |
| 105 | A835 | 9.20 | 9.37 | +0.64 | +0.57 | − .17 |
| 95 | A640 | 9.58 | 9.73 | +0.73 | +0.69 | − .15 |
| 89 | B 96 | 9.63 | 9.65 | +0.72 | +0.62 | − .02 |
| 91 | A579 | 9.80 | 9.83 | +0.75 | +0.71 | − .03 |
| 64 | B 78 | 9.84 | 9.75 | +0.81 | +0.67 | + .09 |
| 106 | A869 | 10.12 | 10.14 | +0.80 | +0.70 | − .02 |
| 74 | A389 | 10.33 | 10.28 | +0.86 | +0.73 | + .05 |
| 53 | B 66 | 10.65 | 10.85 | +0.87 | +0.84 | − .20 |
| 42 | B 57 | 10.68 | 10.75 | +0.56 | +0.63 | − .07 |
| 90 | A542 | 11.38 | 11.36 | +1.03 | +0.85 | + .02 |
| 72 | A356 | 11.45 | 11.57 | +1.05 | +1.00 | −0.12 |

DISCUSSION

The photographic absolute magnitudes, $M_{Pg_p}$, in Table 4 have been computed from the individual parallaxes obtained from the expression

$$\pi = \frac{4.738\mu}{V \sin \lambda}.$$

The $\lambda$'s were computed from a recently determined value for the convergent of the cluster, kindly communicated by R. E. Wilson in advance of publication:

$$A = 94\overset{\circ}{.}0 , \quad D = +7\overset{\circ}{.}6 .$$

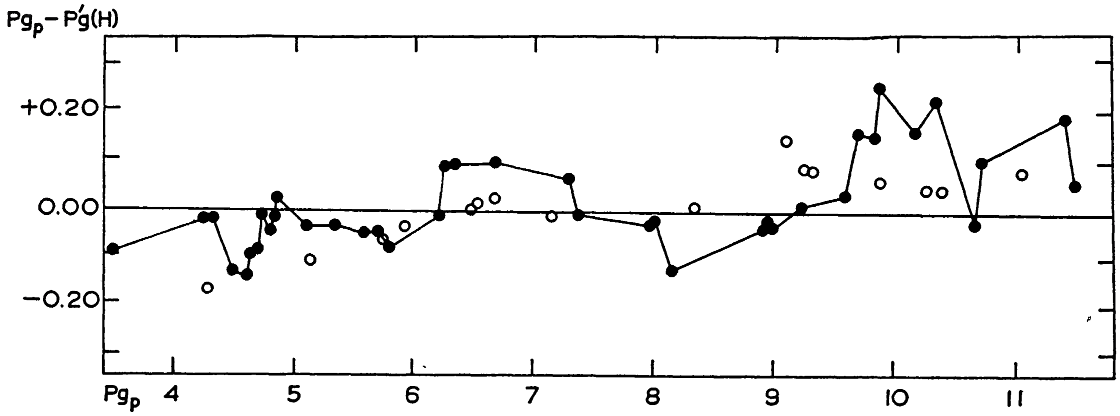


FIG. 3.—Comparison of $Pg_p$ and $Pg'$ (Holmberg). $Pg'(H) = Pg(H) - 0^m18$. The open circles represent the North Polar Sequence; $Pg_p - Pg_{int}$.

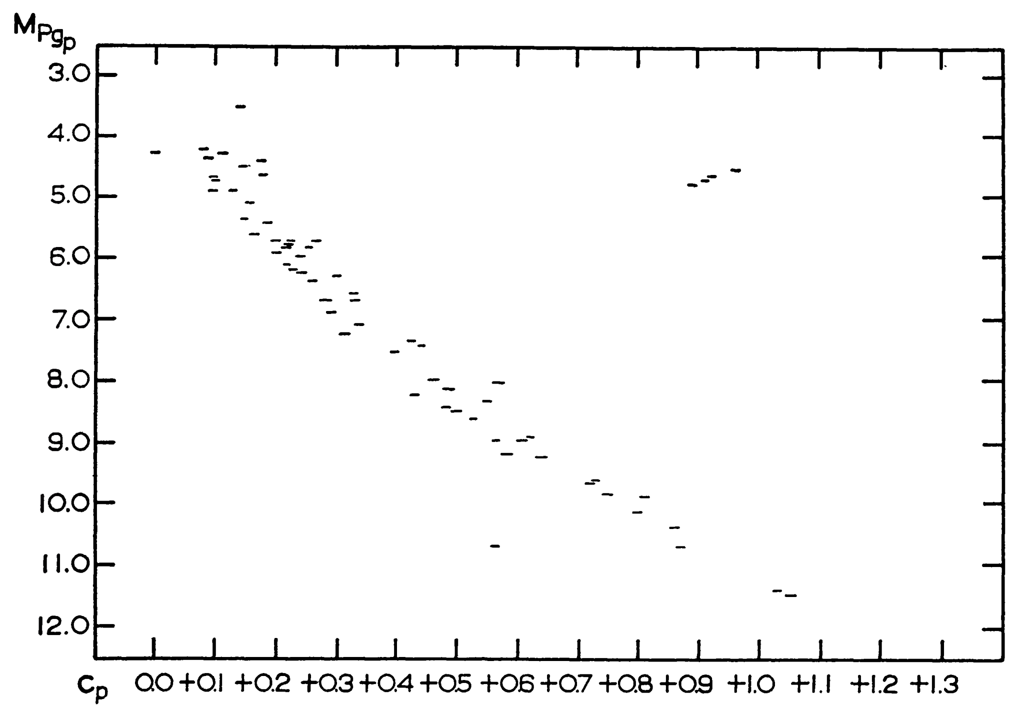


FIG. 4.—Observed magnitudes and colors

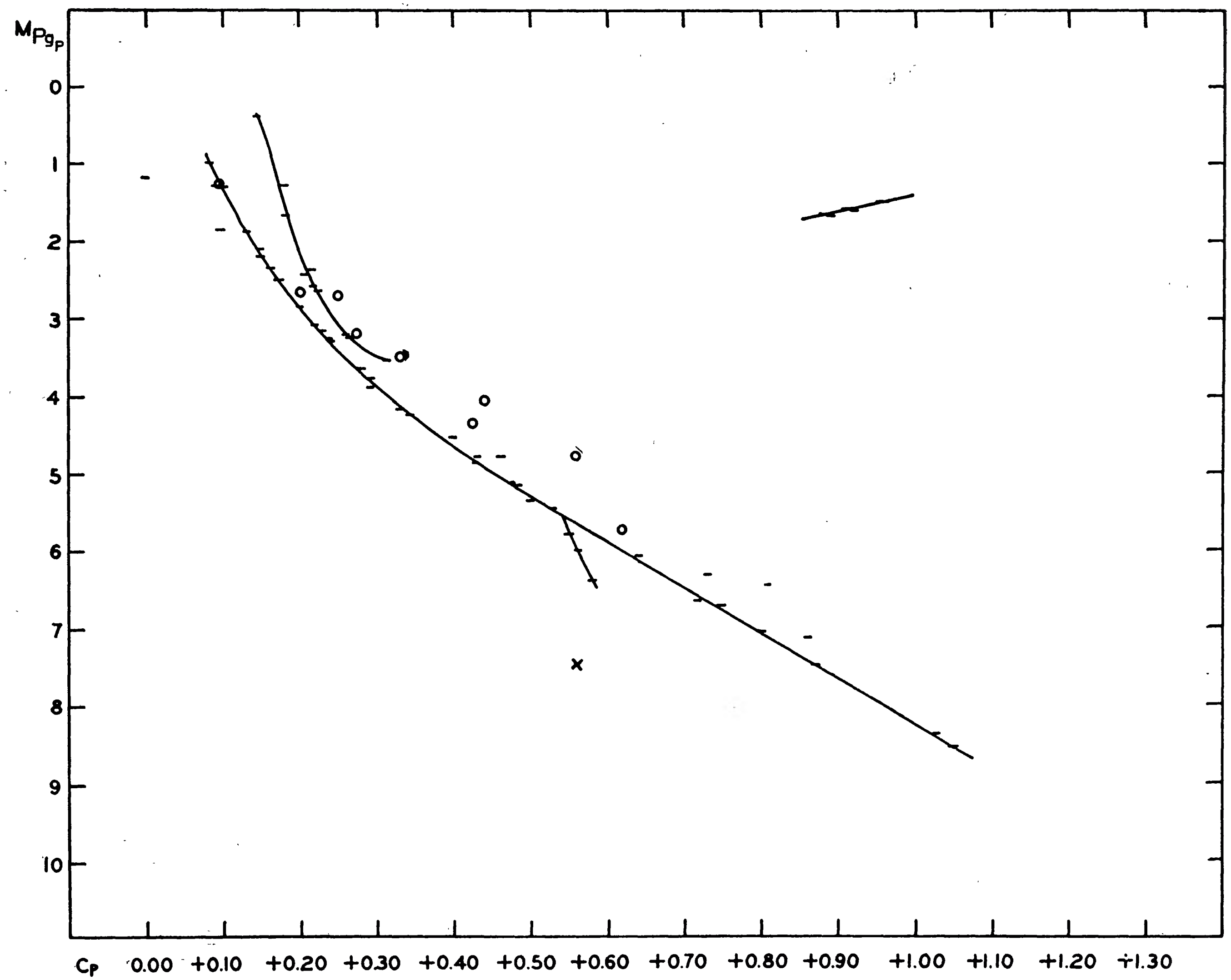


FIG. 5.—Color-luminosity array for the Hyades. The open circles represent known binaries; the cross indicates a possible nonmember.

A mean cluster velocity of 45.3 km/sec has been derived from Wilson's[12] radial velocities of the stars in the table. The resulting mean parallax for these stars is 0″.0246 or a distance of 40.6 parsecs.

Figure 5 shows the color-luminosity array for the cluster. The length of the short, horizontal bar, representing each star, indicates the average deviation of the individual observations of color from the mean—in most cases 0.01 mag. or less. Stars known to be visual doubles, spectroscopic binaries with available orbits, or stars which show two sets of lines in their spectra are represented by open circles; one star which may not be a member of the cluster, No. 42 in Table 4, is marked by an $x$.

For stars bluer than $C_p = +0^{\mathrm{m}}.30$ the color-luminosity array consists of two separate branches, one rising more steeply than the other with increasing blueness. We shall, for the present, refer to the steeper and redder of these two branches as the "bright-dwarf" sequence. Also, the continuous branch, extending from $C_p = +0.08$ to $C_p = +1.05$, will be referred to, in what follows, as the "dwarf sequence." More appropriate designations will be given in future papers of this series, when additional "fine structure" of the

TABLE 6

BRIGHT DWARFS

| No. | $M_{Pgv}$ | $C_p$ | Sp W | Sp Y | REMARKS |
|---|---|---|---|---|---|
| 82 | 0.37 | +0.145 | A6 | A7 | $\theta^2$ Tau; Sp.B; 1 sp |
| 66 | 1.27 | +0.18 | A6 | F0 | $\upsilon$ Tau; constant velocity (Stillwell, *Pub. Dom. Ap. Obs. Victoria*, **7**, 337, 1945) |
| 70 | 1.63 | +0.18 | A5n | F0 | 71 Tau; variable velocity (Stillwell) |
| 25 | 2.33 | +0.215 | A8n | A8 | 51 Tau; constant velocity (Stillwell) |
| 60 | 2.41 | +0.20 | A8n | A7 | 67 Tau |
| 75 | 2.55 | +0.22 | A6n | A5p | Metallic-line star; A5 K-line, F2 metallic lines |
| 47 | 2.62 | +0.225 | A2 | A1p | 63 Tau; metallic-line star; A1 K-line, F5 IV= F0 II–III metallic lines |
| 57 | 3.20 | +0.27 | F0 | F4 | |
| 9 | 3.22 | +0.265 | F2 | F4 | |
| 16 | 3.54 | +0.315 | F4 | F5 | |

color-luminosity array will be described. The ten stars which lie on the bright-dwarf sequence are listed in Table 6. When the existence of this sequence first became evident from the Madison observations, Dr. W. W. Morgan classified the two brightest members, $\theta^2$ and $\upsilon$ Tauri, as of spectral class A7–A8 and luminosity class III, or late A giants. In a later paper of this series, dealing with the stars in the solar region, it will be shown that the lower portion of the bright-dwarf sequence is populated by stars of luminosity class IV—the subgiants. Also in Table 6 are two stars contained in the Yerkes *Catalogue*[16] of metallic-line stars. The bright-dwarf sequence, thus, is evidently composed of A giants and F subgiants, with metallic-line stars representing the junction between them. It is known that the metallic-line spectra of the metallic-line stars in many cases match those of standard stars classified either as F0 III or F5 IV—a fact which is consistent with their intermediate position in the color-luminosity array. It should also be noted that two, less extreme, examples of metallic-line stars occur on the dwarf sequence. Their significance will be dealt with in a later paper.

The four red giants, $\gamma$, $\delta$, $\theta^1$, and $\epsilon$ Tauri, form a short segment of the giant sequence. The mean magnitude and color of these four stars are $M_{Pg_v} = +1^{\mathrm{m}}.57$ and $C_p = +0.92$.

[16] Roman, Morgan, and Eggen, *Ap. J.*, **107**, 107, 1948.

We might compare these means with the observed magnitude and color of Pollux, the giant nearest the sun, with $Pg_p = +2.16$ and $C_p = +0.94$. If the stars are comparable, we arrive at a parallax of 0".076 for Pollux. The two trigonometric values quoted by Schlesinger[17] are 0".110 ± 0.011 (McCormick) and 0".062 ± 0.023 (Yale, Heliometer); the Mount Wilson spectroscopic value is 0".087.

Forty-nine of the 64 stars in Table 4 fall on one of the three sequences discussed above, within the uncertainties of the colors and the proper motions. The remaining 15 stars are discussed in the following paragraphs.

### I. MULTIPLE SYSTEMS

The data for seven stars, which are known binaries, are given in Table 7. The data for the visual binaries have been summarized by Kuiper;[18] the double-lined binaries were found by Wilson.[12] The difference in visual magnitude for the first pair in the table is given by Kuiper as 2.28 mag. If we assume that the brighter component is a bright-dwarf with $M = +2^{\mathrm{m}}.80$ and $C_p = +0.13$, and that the fainter component lies on the dwarf sequence, with $M = +5^{\mathrm{m}}.50$ and $C_p = +0.54$, then the combined light would match the observed color and magnitude. In the same manner we can match the observed color and magnitude of star No. 30 with two dwarf components, $M = +4^{\mathrm{m}}.80$ with $C_p = +0.42$,

TABLE 7

KNOWN BINARIES

| No. | $M_{Pg_p}$ | $C_p$ | Remarks |
|---|---|---|---|
| 92 | 2.68 | +0.25 | ADS 3264; $=P148.3$ years; $\Delta m = 2.28$ mag. |
| 33 | 3.23 | +0.26 | Double lines |
| 35 | 3.50 | +0.33 | Double lines |
| 41 | 4.06 | +0.44 | ADS 3169; $P = 487$ years; $\Delta m = 1.37$ mag.; br. star is Sp.B., $P = 4.00$ days |
| 30 | 4.34 | +0.425 | ADS 3135; $P = 88.9$ years; $\Delta m = 1.12$ mag. |
| 24 | 4.79 | +0.56 | Variable velocity |
| 23 | 5.72 | +0.62 | Sp.B; $P = 5.61$ days; 1 sp |

and $M = +6^{\mathrm{m}}.00$ with $C_p = +0.61$. Star No. 41 lies 0.8 mag. above the dwarf sequence, but it is a triple system, with the brighter star of the visual binary also being a spectroscopic binary. The fainter component of star No. 23, a spectroscopic binary, can be predicted to be 1.2 mag. fainter than the brighter, a fact which would account for the presence of but a single spectrum in the integrated light of the system. Of the spectroscopic binaries found by Wilson—Nos. 24, 33, and 35—Nos. 24 and 35 evidently consist of nearly equally bright components. If the brighter component of No. 33 is a dwarf, then the fainter component must be more than 1 mag. fainter, and the appearance of two sets of lines in the spectrum is unexpected. However, as will be shown later, the bright-dwarf sequence for stars near the sun extends to the red of that shown in Figure 5 but maintains a nearly constant $M \sim +3^{\mathrm{m}}.7$, so that the double-lined binary, No. 33, probably consists of a dwarf and a bright dwarf of nearly equal $M$ but of different $C_p$. Stars Nos. 64 and 95 may be undiscovered binaries; No. 95, however, is above the dwarf sequence by less than 0.4 mag., so that, if it is a binary, Wilson's failure to find double lines in the spectrum is to be expected; on the other hand, if the star is single, a correction of approximately +0".015 to the total proper motion would be necessary to place it on the dwarf sequence. Star No. 64 lies above the dwarf sequence by 0.7 mag., so that, if the star is double, the spectrum should show the lines of the fainter component. Only one set of

[17] *Catalogue of Trigonometric Parallaxes* (New Haven: Yale University Press, 1935).

[18] *Ap. J.*, 86, 166, 1937.

lines, however, was seen by Wilson. This star is listed in Aitken's *Double Star Catalogue*,[19] ADS 3206, as a physical companion to star No. 61. The total proper motions for these two stars, which were used here to calculate the individual parallaxes, differ by 0".017.[20] If the two stars do form a physical system and if the total proper motion of the brighter star is the correct value, then it is necessary to increase the $M$ of No. 64 by $\Delta M = 2.17\Delta\mu/\mu$, or by 0.34 mag. The star would then be but 0.35 mag. above the dwarf sequence, and, if it were a binary, two observable sets of lines would not be expected.

## II. SUBDWARFS

The three stars, Nos. 7, 17, and 40 will be discussed more thoroughly in a succeeding paper concerning the subdwarfs near the sun. Unpublished observations of magnitude and color of the nearest subdwarfs have shown the existence of a well-defined subdwarf sequence which crosses the dwarf sequence at $C_p = +0.55$ and which is populated by both "high-velocity" and "low-velocity" stars. The Hyades stars, Nos. 7, 17, and 40, fall on this subdwarf sequence just below the cross-over point. We may compare star No. 7, the most extreme case of the three, with the high-velocity star $\mu$ Cassiopeiae as

| Star | $Pg_p$ | $C_p$ | $\pi$ | $M_{Pgp}$ |
|---|---|---|---|---|
| Hyades No. 7........ | $9^m.19$ | +0.58 | 0".0276 | $+6^m.39$ |
| $\mu$ Cass............... | 5.69 | +0.58 | 0.130 ± .006 | +6.26 |

in the accompanying tabulation. A comparison of the spectra of these two stars would be of interest; the luminosity criteria of the Yerkes *Atlas of Stellar Spectra*[21] places $\mu$ Cassiopeiae below the dwarf sequence.

## III. MISCELLANEOUS

We have accounted for all but 3 of the 15 stars which lie off the dwarf, bright-dwarf, and giant sequences. Two of these stars, Nos. 50 and 61, will be shown in succeeding papers to be the lone representatives in the Hyades cluster of additional sequences populated more densely by such groups as the Pleiades and by the nucleus of the Ursa Major "cluster." For the present, we shall reject star No. 42 as possibly a nonmember of the cluster.

The HR diagram of the cluster, with spectral types determined at Yerkes[22] and Mount Wilson,[23] is shown in Figure 6. The metallic-line stars are indicated by crosses, the known binaries by open circles.

It is of interest to examine the distribution of the rotational velocity of the stars on the dwarf, bright-dwarf, and giant sequences of the color-luminosity array. The penultimate column of Table 4 contains the rotational velocities for some of the brighter stars in the cluster that have been determined by O. Struve.[24] These velocities are marked on a color-luminosity array in Figure 7. It is not possible to derive very definite conclusions from so few stars, but it does appear that the preponderance of high rotational velocities occurs on the bright-dwarf sequence. In this connection we might recall the results obtained by

[19] Carnegie Institution of Washington, 1932.

[20] In an earlier publication Wilson gives nearly equal values of $\mu$ for Nos. 61 and 64; 0".109 and 0".108, respectively (*Ap. J.*, **42**, 49, 1932).

[21] "Astrophysical Monographs," No. 4 (Chicago: University of Chicago Press, 1943).

[22] Morgan and Titus, *Ap. J.*, **92**, 256, 1940.

[23] *Ap. J.*, **107**, 129 1948; *Mt. W. Contr.*, No. 741. The spectral types for a few stars not already published were kindly supplied by Dr. R. E. Wilson.

[24] *Pop. Astr.*, **53**, 286, 1945.

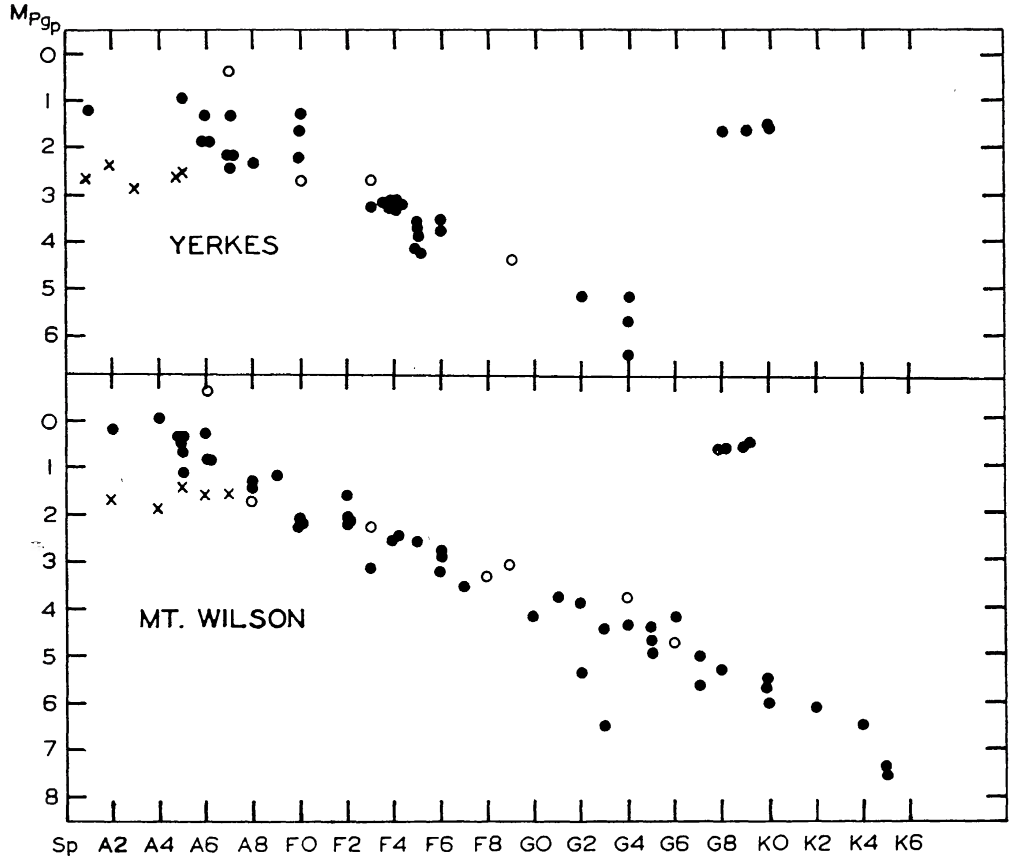


FIG. 6.—HR diagram for cluster members. The open circles indicate known binaries; the crosses, metallic-line stars.

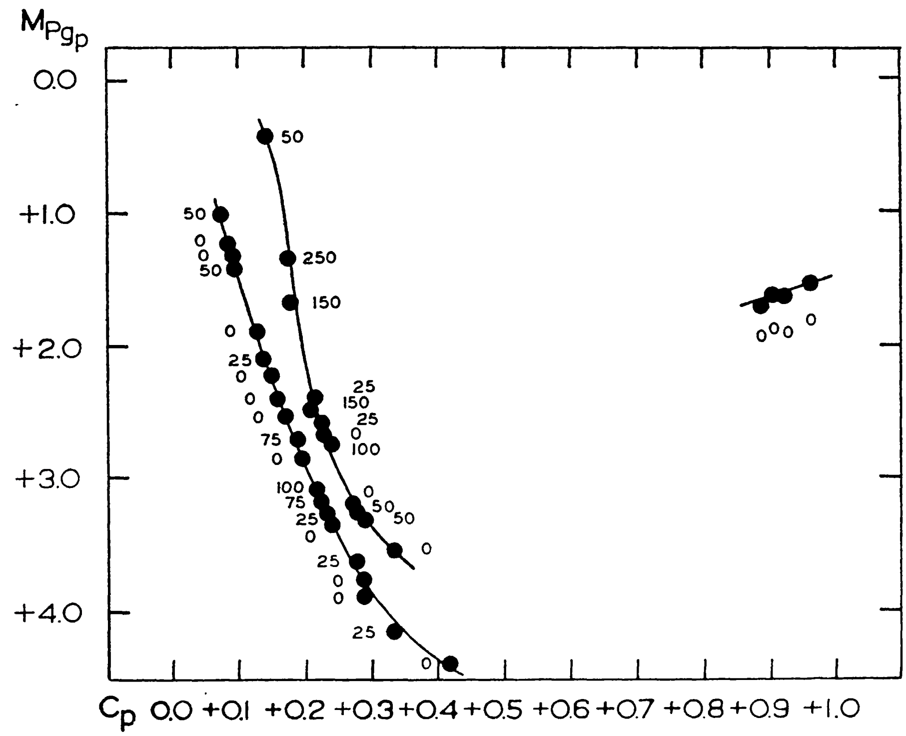


FIG. 7.—Rotational velocities, in km/sec, of the brighter Hyades

Adams and Joy[25] from the spectroscopic parallaxes of the A stars. They have described the appearance of the spectral lines, sharp or nebulous, by appending "s" or "n" to the spectral type, and have found differences in the luminosities of the two groups varying from about 1.5 mag. at A2 to near-equality at F0. This dispersion is comparable with the separation between the bright-dwarf and the dwarf sequences; however, whereas Adams and Joy found the sharp-lined stars to be more luminous, it is apparent from Figure 7 that the stars with nebulous lines or those having high rotational velocities populate mainly the bright-dwarf sequence. Struve[26] has suggested that rapid stellar rotation would produce a spurious absolute-magnitude effect because of the decrease in surface gravity caused by the centrifugal force. Emma T. R. Williams[27] subsequently concluded, from a study of color equivalents, that the n stars do show a higher level of ionization then they would if they had no rotation, thereby confirming Struve's suggestion. Later, J. A. Hynek[28] cast doubt on Miss Williams' results and, from theoretical considerations, computed that in the extreme case of an equatorial velocity of 250 km/sec the change in surface gravity of an A star is such as to change the total absorption of, say, $\lambda$ 4226 of *Ca* I, by less than 5 per cent. In view of these conflicting considerations, it is probably safe to conclude that such a spurious absolute-magnitude effect is not involved in the separation found here between the dwarf and the bright-dwarf sequences, for the effect is just opposite to that which the cited investigations attempted to explain. Figure 7 may also have some bearing on the fact, pointed out by Struve,[29] that, unlike the smooth progression of mass and luminosity with advancing spectral type, the rotational velocities present a sharp cut-off near spectral class F2, or for $C_p \sim +0.25$. Again we are hindered by too few stars, but from Figure 7 it appears that this cut-off in the progression of rotational velocities occurs near the terminal point of the bright-dwarf sequence. It is possible, therefore, that, because both bright dwarfs and dwarfs were lumped together in the spectroscopic material, the cut-off resulted from a sudden diminution of the number of bright dwarfs, for the dwarf sequence contains relatively few rapidly rotating stars.

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[25] *Ap. J.*, **55**, 242, 1922; *Mt. W. Contr.*, No. 244.

[26] *Pop. Astr.*, **43**, 496, 1935.

[27] *Ap. J.*, **82**, 432, 1935.

[28] *Ap.J.*, **83**, 476, 1936.

[29] *Ap. J.*, **102**, 265, 1945; *Pop. Astr.*, **53**, 201, 1945.