# SPECTRAL AND LUMINOSITY CLASSIFICATION OF THE BRIGHT SEQUENCE STARS IN THE C REGIONS 

J. J. Nassau and Donald A. MacRae*<br>Warner and Swasey Observatory, Case Institute of Technology

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#### Abstract

Spectral types and luminosities on the system of the Yerkes Atlas have been obtained for the sequence stars in the Harvard Standard C regions from objective-prism photographs at the Warner and Swasey Observatory.


The magnitude sequences in the Harvard C regions at declination $+15^{\circ}$ and oddnumbered hours of right ascension have been the focus of much attention in photometric work. One of the chief reasons for this interest is that they can be reached from both Northern and Southern hemispheres. In view of the importance of these regions, a series of objective-prism photographs of all twelve fields has been obtained with the Burrell telescope. As the first step in the utilization of this material, the stars which form the photometric sequences have been classified according to spectral type and luminosity, and the results are presented in Table 1.

The $4^{\circ}$ prism gives a dispersion of $283 \mathrm{~A} / \mathrm{mm}$ at $H \gamma$. The emulsion used was Kodak Spectroscopic II $a$-O. On every region two or more good plates (diameter $5^{\circ}$ ) were available with each of the following exposure times: $2^{\mathrm{m}}, 5^{\mathrm{m}}, 15^{\mathrm{m}}, 30^{\mathrm{m}}$; in addition, shorter exposures were made to obtain spectra of the stars at the bright end of the sequences. The faint-magnitude limit ranges from 12 to 12.5 .

Each star was classified from at least two plates, and sometimes from four or five plates, by each author independently. These results were then examined jointly, and a final classification was adopted for each star.

An effort was made to have both luminosity and spectral-type classification conform to the MK system (Johnson and Morgan 1953), although, in general, the criteria used on objective-prism spectra must be quite different from those used on slit spectra. In order to achieve this aim, continuous reference was made to the observatory's collection of objective-prism spectra of stars with published Yerkes classifications. In fact, virtually every star was compared directly with appropriate standard stars by superposition of plates with emulsions in contact. The objective-prism spectra of a standard star consist of a series of varying exposure times, so that a close match of density could always be obtained in making this comparison. The standards are also on the II $a$-O emulsion.

The following information is listed in Table 1: column 1: the letter designation of the sequence star (co-ordinates are given in Harvard Ann., 71, 269, 1917, and charts appear in Harvard Ann., 108, 1, 1939); column 2: the number in the Bonner Durchmusterung; column 3: the photographic magnitude and Miss Cannon's revised spectral type from Harvard Ann., 89, 123, 1937 (the magnitudes are simply Miss Leavitt's reduced to the "1922 system"); column 4: the spectral type and luminosity determined at the Warner and Swasey Observatory.

The letter " $m$ " following the spectral class designates an A-type star which shows the G band. The letter "p" designates a star which shows features not present in a normal star of its class. This includes the A-type stars which show the silicon, strontium, and europium characteristics. The colon (:) indicates a doubtful classification due to faintness or the overlap of a neighboring star. An asterisk (*) following the star letter

[^0]TABLE

| Region | Star | B. D. | Ipg | Sp. (HD) | Sp. \& Lum. (W\&S) | Region | Star | B. D. | Ipg | Sp. (HD) | Sp. \& Lum (W\&S) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| C 1 | A | $14^{\circ} 169$ | 7.19 | F2 | F2 V | C 3 | C | $14^{\circ} 804$ | 7.23 | G0 | G5 V |
|  | B | 13165 | 7.41 | F2 | F2 V | (Cont'd.) | D | 15735 | 7.47 | A 0 | A0 p |
|  | C | 14175 | 7.53 | K5 | M0 III |  | E | 14843 | 7.62 | B9 | A0 |
|  | D | 1697 | 8.02 | G5 | K2 III |  | F | 14839 | 7.75 | A0 | A2 |
|  | E | 15159 | 8.43 | F0 | F0 V |  | G | 14834 | 8.12 | A0 | A2 p |
|  | F | 15164 | 8.58 | G0 | G5 III |  | H | 14831 | 8.31 | G5 | K0 V |
|  | G | 15156 | 8.78 | M0 | M2 III |  | I | 14836 | 8.80 | G5 | G5 III |
|  | H | 15149 | 8.98 | A5 | F0 III |  | K | 15721 | 8.85 | K0 | G8 III |
|  | I | 15161 | 9.34 | F2 | F2 III |  | L | 14812 | 9.10 | F0 | F0 III |
|  | K | 14161 | 9.44 | G5 | G8 V |  | M | 14832 | 9.19 | K0 | K0 III |
|  | L* | 14167 | 9.68 | K2 | K2 V |  | N | 14813 | 9.47 | F8 | F5 V |
|  | M | 14164 | 9.87 | G5 | F5 III |  | 0 | 15733 | 9.60 | A5 | F0 V |
|  | N | 14171 | 10.23 | A2 | A3 p |  | P | 15730 | 10.05 | A2 | A2 m |
|  | 0 | 14168 | 10.37 | K5 | K2 III |  | Q* | 14816 | 10.36 | F5 | F5 |
|  | P |  | 10.66 | G0 | F5 V |  | R | 14822 | 10.54 | K2 | G8 III |
|  | Q | 15162 | 10.84 | G0 | G0 V |  | S | 14828 | 10.63 | K5 | K0 III |
|  | R | 14170 | 11.28 | F5 | G0 |  | T | 14830 | 10.79 | K0 | F8 |
|  | S | 14160 | 11.44 | F8 | G0: |  | U |  | 10.90 | G5 | G5 |
|  | T |  | 11.74 |  | G0: |  | V | 15731 | 11.29 | K5 | G8 |
|  |  |  |  |  |  |  | W |  | 11.29 | G0 | F5 |
| C 2 | A |  |  |  |  |  | X |  | 11.44 | G5 | G2 |
|  | A | 15447 | 6.84 7.25 | A2 | A5 |  | Y |  | 11.85 |  | F0 |
|  | C | 15430 | 7.67 | K0 | K3 III |  | Z | 14827 | 12.06 |  | K |
|  | D | 13496 | 8.24 | G5 | G8 III |  | a |  | 12.12 |  | F |
|  | E | 14518 | 8.29 | G0 | G8 V |  | b |  | 12.38 |  | G |
|  | F | 13494 | 8.78 | K0 | K0 IV |  |  |  |  |  |  |
|  | G | 14511 | 9.20 | F5 | F5 V | C 4 | A | 141558 | 6.70 | B8 | B8 |
|  | H | 13501 | 9.26 | F5 | F2 V |  | B | 151444 | 7.22 | A2 | A3 |
|  | I | 14513 | 9.40 | K5 | K3 III |  | C | 151494 | 7.34 | F0 | F2 III |
|  | K | 14516 | 9.52 | F8 | F8 V |  | D | 151461 | 7.78 | K0 | K0 III |
|  | $L$ | 14509 | 9.92 | K0 | K0 III |  | E | 151473 | 8.01 | F8 | G0 V |
|  | M | 14507 | 10.17 | G5 | G2 V |  | F | 151445 | 8.46 | K0 | K2 III |
|  | N | 14515 | 10.63 | F5 | F8 V |  | G |  | 8.51 | B9 | B8 |
|  | 0 | 14514 | 10.64 | K0 | G8 V |  | H | 141545 15 | 8.88 | K0 | K0 III |
|  | P | 14519 | 10.76 | K | G5 V |  | I | $\begin{array}{ll}15 & 1443 \\ 15\end{array}$ | 8.99 | A0 | B9 |
|  | Q | 14505 | 11.02 | F0 | F0 |  | K | 151459 | 9.51 | K0 | K2 III |
|  | R | 15429 | 11.27 | F5 | F8 |  | $\stackrel{L}{L}$ | 151456 | 9.80 | F5 | F8 V |
|  | S | 15429 | 11.42 | F8 | F8 |  | M | 151457 | 10.02 | F8 | F8 V |
|  | T |  | 11.67 |  | F2 |  | N | 151440 | 10.06 | A2 | A0 |
|  | U | 14510 | 11.75 |  | K |  | $\bigcirc$ | 151458 | 10.25 | F5 | G5 V |
|  | V | 14510 | 12.07 |  | G |  | $P$ | 141556 | 10.41 | K0 | K0 III |
|  | W |  | 12.45 |  | A |  | Q | 151464 | 10.97 | G0 | F5 V |
|  |  |  |  |  |  |  | R |  | 11.28 | G0 | G0 |
|  |  |  |  |  |  |  | S |  | 11.34 | F2 | F5 |
| C 3 | A | 14825 | 6.62 | A2 | A3 p |  | T |  | 11.74 | G5 | G5 |
|  | B | 15713 | 6.94 | F5 | F5 V |  | U |  | 12.17 |  | F8 |


| Region | Star |  | D. | Ipg | Sp. (HD) | Sp. \& Lum. (W\&S) | Region | Star |  | D. | Ipg | Sp. (HD) | Sp. \& Lum. (W\&S) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| C 5 | A |  | ${ }^{0} 2003$ | 7.17 | G5 | K0 V | C 7 | A |  | ${ }^{0} 2573$ | 6.85 | G5 | K0 III |
|  | B | 15 | 1981 | 8.09 | F5 | F5 V |  | B | 16 | 2476 | 7.75 | F2 | F5 V |
|  | C | 13 | 2021 | 8.09 | K2 | K5 III |  | C | 14 | 2585 | 8.19 | F2 | F2 IV: |
|  | D | 13 | 2036 | 8.29 | G5 | G8 III |  | D | 15 | 2541 | 8.29 | F8 | F5 V |
|  | E | 15 | 1960 | 8.48 | F5 | F2 V |  | E | 16 | 2466 | 8.66 | K0 | K2 III |
|  | F | 15 | 1962 | 9.07 | F5 | F8 V |  | F | 15 | 2542 | 9.07 | F8 | G0 V |
|  | G | 14 | 2024 | 9.31 | A3 | A3 |  | G | 16 | 2459 | 9.36 | G5 | G8 V |
|  | H | 14 | 2018 | 9.34 | K7 | K3 III |  | H | 16 | 2461 | 9.78 | F2 | F5 V |
|  | I | 15 | 1969 | 9.73 | F5 | F5 V |  | I | 15 | 2523 | 10.01 | F2 | F5 V |
|  | K | 14 | 2025 | 9.91 | K0 | K2 III |  | K | 16 | 2448 | 10.30 | F8 | G0 V |
|  | L | 15 | 1976 | 10.13 | K0 | G5 V |  | L | 15 | 2535 | 10.33 | K7 | K3 III |
|  | M | 14 | 2022 | 10.32 | G5 | G5 V |  | M | 15 | 2545 | 10.58 | G5 | G8 V |
|  | N | 15 | 1971 | 10.43 | G5 | G8 V |  | N | 15 | 2538 | 10.88 | F2 | G0 V |
|  | 0 | 15 | 1972 | 10.68 | K0 | G5 III |  | 0 | 15 | 2537 | 11.05 | G0 | G5 V |
|  | P | 15 | 1974 | 10.78 | M0 | M3 III |  | P | 15 | 2543 | 11.23 | G0 | G0 V |
|  | Q |  |  | 11.18 |  | F5 |  | Q | 15 | 2536 | 11.47 | G5 | G2 |
|  | R | 14 | 2020 | 11.40 |  | M5 III |  | R |  |  | 11.80 | F8 | F5 |
|  | S |  |  | 11.60 |  | F5 |  | S |  |  | 11.93 | K0 | G5 |
|  | T | 15 | 1970 | 11.99 |  | K2 |  | T* |  |  | 12.25 |  | F8: |
|  | U | 15 | 1980 | 12.06 |  | G2: |  | U* |  |  | 12.50 |  |  |
|  | V |  |  | 12.29 |  | K |  | GA* |  |  | 11.82 |  | K |
|  | W |  |  | 12.46 |  | G |  | GB* |  |  | 12.23 |  | F |
| C 6 |  |  |  |  |  |  | C 8 | A | 16 | 2725 | 7.21 | F8 | G0 V |
|  | A | 13 | 2348 | 6.75 | A0 | A3 p |  | B | 13 | 2899 | 7.25 | A5 | A7 p |
|  | B | 12 | 2284 | 6.88 | F5 | F5 III |  | C* | 15 | 2792 | 7.76 | K0 | K0 III |
|  | C | 16 | 2224 | 7.54 | F0 | F2 V |  | D | 14 | 2812 | 7.98 | K2 | K3 III |
|  | D | 14 | 2345 | 7.59 | F5 | G0 V |  | E | 15 | 2808 | 8.16 | F0 | F0 III |
|  | E | 13 | 2350 | 7.81 | F5 | F5 V |  | F | 15 | 2803 | 8.19 | K0 | K2 III |
|  | F | 14 | 2344 | 8.30 | F5 | F5 V |  | G | 13 | 2879 | 8.91 | F0 | FO p: |
|  | G | 13 | 2358 | 8.61 | K0 | K2 III |  | $\mathrm{H}^{*}$ | 14 | 2850 | 8.93 | F8 | G0 V |
|  | H | 15 | 2283 | 8.69 | K0 | K0 III |  | I | 14 | 2828 | 9.10 | K0 | K2 III |
|  | I | 15 | 2302 | 8.73 | F2 | F5 III |  | K | 14 | 2823 | 9.38 | K0 | K2 III |
|  | K | 15 | 2290 | 9.03 | M1 | M2 III |  | L | 14 | 2824 | 9.69 | F8 | F8 V |
|  | L | 15 | 2294 | 9.20 | F8 | G0 III |  | M | 15 | 2810 | 9.70 | F2 | F2 III |
|  | M | 15 | 2282 | 9.51 | K2 | K3 III |  | N | 15 | 2814 | 9.94 | K2 | K2 III |
|  | $\mathbf{N}$ | 14 | 2338 | 9.58 | F2 | F0 V |  | 0 | 15 | 2807 | 10.09 | K2 | K2 III |
|  | 0 | 15 | 2288 | 9.87 | K0 | K2 V |  | P | 14 | 2839 | 10.18 | G0 | G0 V |
|  | P | 15 | 2281 | 10.27 | G5 | G2 V |  | Q | 15 | 2816 | 10.58 | G0 | G2 V |
|  | Q* | 15 | 2289 | 10.27 | K5 | M0 II: |  | R | 14 | 2835 | 10.74 | F5 | F0 |
|  | $\mathbf{R}$ | 14 | 2337 | 10.74 | G5 | G0 V |  | S | 14 | 2827 | 10.79 | K0 | K5 III |
|  | S | 15 | 2286 | 11.01 |  | G0 V |  | T | 15 | 2818 | 10.86 | K7 | K5 III |
|  | T | 15 | 2284 | 11.16 |  | G5 |  | U |  |  | 10.90 | G0 | F8 V |
|  | U |  |  | 11.35 |  | F5 |  | V | 15 | 2809 | 10.90 | G5 | G5 V |
|  | V | 15 | 2285 | 11.35 |  | G0 |  | W | 15 | 2815 | 11.46 | G0 | G2 |
|  | W | 15 | 2287 | 11.50 |  | G0 |  | $\mathbf{X}$ | 15 | 2817 | 11.61 | F8 | G2 |
|  | X |  |  | 11.78 |  | G2: |  | Y |  |  | 11.66 |  | F8 |
|  | $\mathbf{Y}$ |  |  | 12.07 |  | F8: |  | Z |  |  | 12.06 |  | F8 |
|  | Z |  |  | 12.40 |  | K |  | a |  |  | 12.23 |  | F5 |
|  |  |  |  |  |  |  |  | b |  |  | 12.33 |  | F8 |

TABLE 1

| Region | Star | B. D. | Ipg | Sp. <br> (HD) | Sp. \& Lum. (W\&S) | Region | Star | B. D. | Ipg | $\begin{gathered} \text { Sp. } \\ \text { (HD) } \end{gathered}$ | Sp. \& Lum. (W\&S) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| C 9 | A* | $14^{0} 3180$ | 7.04 | G5 | G5 IV: | C 11 | E* | $15^{\circ} 4320$ | 8.40 | G5p |  |
|  | B | 163083 | 7.19 | A0 | A0 | (Cont'd.) | F | 144537 | 8.56 | F5 | F2 III |
|  | C | 153089 | 7.24 | G0 | G5 V |  | G* | 154325 | 8.95 | A2 | A5 p |
|  | D | 143161 | 7.37 | F0 | F2 IV |  | H | 144520 | 9.17 | A0 | A3 p |
|  | E | 153108 | 7.87 | G5 | K0 V |  | I | 144516 | 9.51 | F5 | F2 III |
|  | F | 153116 | 8.13 | F5 | F8 V |  | K | 144528 | 9.62 | A3 | A5 |
|  | G | 153090 | 8.57 | G5 | G5 V |  | L | 144522 | 10.02 | K5 | K5 III |
|  | H* | 163091 | 8.75 | K5 | K0 III |  | M | 144519 | 10.04 | F0 | F2 V |
|  | I | 143178 | 9.18 | K7 | K5 III |  | N | 144531 | 10.05 | K0 | K2 III |
|  | K | 153096 | 9.71 | K0 | K0 III |  | 0 | 154331 | 10.18 | K7 | K5 III |
|  | L | 153101 | 9.86 | F8 | G2 V |  | P |  | 10.62 | F8 | F2 V |
|  | M | 153104 | 10.30 | G0 | G0 V |  | Q | 144533 | 10.93 | G0 | G5 V |
|  | N | 153106 | 10.72 | M0 | K5 III |  | R* | 144523 | 11.20 |  | G5 |
|  | 0 | 143183 | 10.79 | K0 | G8 III |  | S | 154322 | 11.26 | K0 | G8 V |
|  | P | 153109 | 10.88 | G5 | G2 V |  | T |  | 11.56 |  | F0 |
|  | Q | 153107 | 10.94 | K0 | K2 III |  | U |  | 11.63 |  | F5 |
|  | R | 143187 | 11.02 | G5 | G5 V |  | V* |  | 12.10 |  | F: |
|  | S |  | 11.27 | K5 | K3 III |  | W |  | 12.10 |  | K |
|  | T |  | 11.84 |  | F8 |  | X |  | 12.13 |  | F |
|  | U |  | 12.07 |  | F5 |  |  |  |  |  |  |
| C 10 | A | 153683 | 6.84 | A0 | A2 | C 12 | A* |  | 6.59 | A0 |  |
|  | B | 143755 | 7.36 | G0 | G2 V |  | B | 135059 | 6.99 | G0 | GO V |
|  | C | 153690 | 7.43 | A5 | F0 p |  | C | 154752 | 7.29 | A2 | A3 |
|  | D* | 143745 | 7.89 | B9 | B5 |  | D | 154751 | 7.59 | K0 | K0 III |
|  | E | 143771 | 8.38 | K0 | G8 IV |  | E* | 144916 | 7.89 | K0 | K0 III |
|  | F | 143744 | 8.53 | F2 | F2 III |  | F | 154748 | 8.31 | A0 | A0 p |
|  | G* | 143768 | 8.60 | F5 |  |  | G | 144902 | 8.53 | F0 | F0 p |
|  | H | 153681 | 9.25 | A0 | A0 |  | H | 144894 | 8.71 | A2 | A0 |
|  | I | 143790 | 9.57 | K0 | G8 V |  | 1 | 144912 | 9.12 | K2 | K3 III |
|  | K | 143782 | 9.87 | B9 | B8 |  | K | 154764 | 9.16 | F5 | F5 V |
|  | L | 143772 | 10.25 | F8 | F5 V |  | L | 154750 | 9.48 | F5 | F5 III |
|  | M | 143776 | 10.71 | A2 | A0 |  | M | 154753 | 9.79 | K 2 | K3 III |
|  | N* | 143775 | 10.96 | A2 | A2 |  | N | 144924 | 10.00 | F8 | F5 III |
|  | 0 | 153680 | 11.25 | A3 | A5 |  | 0 | 154761 | 10.12 | K2 | K0 III |
|  | P | 153676 | 11.41 | F0 | F0 |  | P | 154756 | 10.05 | K0 | K0 III |
|  | Q* | 153677 | 11.76 | F8 |  |  | Q | 144932 | 10.60 | K5 | K2 III |
|  | R* |  | 12.14 |  |  |  | R | 154755 | 10.87 | K5 | K5 III |
|  |  |  |  |  |  |  | S | 154754 | 11.32 | K7 | K3 III |
| C 11 | A | 144530 | 6.81 | F5 | F5 III |  | T | 144925 | 11.54 |  | G2 V |
|  | B | 154340 | 7.08 | K0 | K2 IV |  | U* |  | 11.71 |  |  |
|  | C | 134607 | 7.70 | A0 | A2 |  | V |  | 12.06 |  | F8 |
|  | D | 144518 | 7.97 | M1 | M1 III |  | W |  | 12.14 |  | F8 |

## REMARKS ON TABLE 1

C1-L: Double star, ADS 895.
C3-Q: Double star, not in $A D S$.
C6-Q: Overlapping spectra.
C7-T: Overlapping spectra.
C7-U: Double star (Gossner and Gossner 1947); also double on our plates.
C7-GA, GB: These are the stars designated as "A" and "B" by Gossner and Gossner (1947) and as ' 1 '" and ' 2 '" by van Rhijn and Plaut (1950).
C8-C: The $C N$ in the blue region is weak.
C8-H: Because of the off-center position of this star the classification was made from one plate only.
C9-A: On objective-prism plates the spectrum shows peculiarities in the lurninosity characteristics. Slit spectrograms at the David Dunlap Observatory confirm the classifications given here. The space motion is probably about $70 \mathrm{~km} / \mathrm{sec}$.
$\mathrm{C} 9-\mathrm{H}: \lambda 4150$ is strong.
C10-D: This star has a peculiar spectrum. $H$ and $H \epsilon$ have the strength of a B 5 star, and the K line is equivalent to that of an A2 star.
G10-G: Double star, ADS 11999.
$\mathrm{C} 10-\mathrm{N}$ : Overlapping spectra.
C10-Q, R: Overlapping spectra.
C11-E: Composite (G plus A); HD 200428-200429.
C11-G: The G band is also present.
C11-R: Overlapping spectra.
$\mathrm{C} 11-\mathrm{V}$ : Overlapping spectra.
C12-A: Variable; see Kron, White, and Gascoigne (1953).
C12-E: The $C N$ in the blue region is weak.
C12-F: The peculiarity is striking; the color of this star (Fig. 1) corresponds to spectral class F1.
$\mathrm{C} 12-\mathrm{U}$ : Double star, separation about $7^{\prime \prime}$ at $100^{\circ}$.


Fig. 1.-Photoelectric colors ( $R-I$ ) plotted against Warner and Swasey spectral classes for stars in the regions C4, C6, C8, and C12. Crosses: class III stars; open circles: peculiar stars; filled circles: class V stars or stars unclassified according to luminosity. The line indicates the variation of $(R-I)$ with spectral class on the MK or MKK system and was obtained from the ( $R-I$ ) color standards published by Kron, White, and Gascoigne (1953, Table 4). The red A0p star is C12 F, and the red K0 III star is C12 D.
directs attention to the remarks at the end of the table. For the early-type stars up to F0 no luminosity class has been assigned. All appear to be main-sequence stars.

In Figure 1 photoelectric colors from Kron, White, and Gascoigne (1953) are plotted against our spectral types. The line is the relation between the same color system and the Yerkes spectral types. The agreement of the plotted points and the curve speaks well for the systematic accuracy of our spectral classification.

This investigation was supported by the Office of Naval Research; a photometric investigation in the C regions is being carried out at the Leander McCormick Observatory under the same contract, and the results will be presented separately. We are indebted to Dr. A. N. Vyssotsky for checking the identification of the stars given in the catalogue.

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[^0]:    * Now at the David Dunlap Observatory, University of Toronto.

