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# PHOTOMETRY OF STARS IN THE *uvgr* SYSTEM*

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Photoelectric photometry is presented for over 400 stars using the *uvgr* system of Thuan and Gunn. Stars were selected to cover a wide range of spectral type, luminosity class, and metallicity. A mean main sequence is derived along with reddening curves and approximate transformations to the *UBVR* system. The calibration of the standard-star sequence is significantly improved.

*Key words:* photometry—stellar classification

## I. Introduction

The *uvgr* system (Thuan and Gunn 1976, hereafter TG) was developed as a four-color intermediate-to-wide-band photometric system which was designed to avoid a number of pitfalls of the standard *UBV* system. The four bands are nonoverlapping and exclude the strongest night-sky lines. The *u* and *v* filters lie in a region of strong line blanketing in late-type stars and measure the Balmer jump in early-type stars; the *g* and *r* filters lie in less-affected regions and hence provide a measure of stellar temperature. All filters have closed bandpasses and hence the system is not sensitive to the wavelength cutoff of the particular detector being used. The *uvgr* system has become somewhat popular for use with new imaging devices such as CCDs where the darkness and well-defined bandpasses of the *g* and *r* filters are especially appreciated. Results in the *uvgr* system published thus far include studies of globular clusters by Zinn (1980) and Searle, Wilkinson, and Bagnuolo (1980), first-ranked galaxies in clusters by Hoessel, Gunn, and Thuan (1980), and surface photometry of M31 by Hoessel and Melnick (1980).

In this paper, the photometry of over 400 field and cluster stars is reported. An attempt has been made to observe stars with a wide diversity of types in order to establish the ability of the system to distinguish stars of different classes. Types observed include main-sequence stars, giants and supergiants, subdwarfs, white dwarfs, globular-cluster stars, galactic-cluster stars, and a few other miscellaneous stars. A mean main sequence is defined and reddening curves are derived. The ability of the system to separate stars of different luminosities and metallicities is demonstrated. Finally, improved magnitudes and color indices are given for most of the fundamental standard stars.

## II. Observations

The observations were made during several runs from 1976 through 1978 on the Palomar 60-inch (1.5-m) telescope. The instrumentation and equipment were identical with that used by TG. A two-channel pulse-counting S20 photometer allowed for the simultaneous measurement of object and sky. Each star was observed in both apertures except for the globular-cluster stars, where it was necessary to go off the cluster to measure sky. This redundancy was useful in eliminating errant observations (as might be caused by a star in the sky hole). An aperture size of 15″ was used at all times. Integration times were typically 5 or 10 seconds on bright stars and proportionately longer on faint ones. Each channel and each night was reduced independently. Errors on bright objects ($g < 12$) are estimated to be $< 0\overset{m}{.}02$ rms. On the faint globular-cluster stars, errors are estimated to be somewhat larger, perhaps $0\overset{m}{.}05$ in the *u* filter and $0\overset{m}{.}03$ in the others. Crowded fields also contribute to this error.

During one night of observations it was discovered part way through the night that the infamous 60-inch dome (which operates under computer control) was partially occulting the telescope. Normally one would take the data from such a night and deposit it in the nearest trash can. However, it was found subsequently upon reducing the standard-star observations that, while the magnitudes were indeed rubbish, the color indices gave quite reasonable solutions. Hence the reduced color indices from this night have been retained, and such objects are marked in the tables by having a blank in the magnitude column.

Stars were selected from a wide variety of sources which are described in the succeeding sections. In general, all objects have *UBV* observations available as well.

## III. Standard Stars

Early on it became evident that the accuracy of the standard stars originally measured by TG could be im-

*Research reported here was begun while the author was at Palomar Observatory, California Institute of Technology.

proved. A recalibration of the standards was therefore undertaken. In the first step, twelve stars in the fall sky which were observed simultaneously on four nights were reduced by standard techniques using the original magnitudes and color indices given by TG. Using the residuals derived from the least-squares solutions, a mean correction was applied to each star. After applying these corrections, the rms residuals in the least-squares solutions were reduced to $0^m.007$ per observation. This new set of magnitudes and color indices defined a new primary set of standards. Additional standard-star observations were then reduced directly to this fundamental set.

The revised set of standard stars is listed in Table I. Not all original standard stars were reobserved sufficiently, and for these the original TG values are retained. One star, Wilson 12754, has been dropped, as it was in a very crowded field. Another, Ross 451, has also been dropped since it became clear that the published color indices are in error, but not enough new observations were made to derive better values. Two new stars (GL745A and B) have been added; both are quite red subdwarfs. The coordinates for Ross 786 in TG were given for epoch 1950 by mistake; the correct 1900 coordinates are given here.

With this new calibration, +17 4708 no longer defines the zero-point of the magnitudes and color indices directly as it did originally. Nevertheless its new magnitude and color indices differ from the old by at most $0^m.001$.

For reference, the mean extinction coefficients derived from the standard solutions are listed in Table II.

## IV. System Characteristics

In advance of presenting the new photometry, some of the characteristics of the *uvgr* system are first discussed.

### A. *Main Sequence*

A mean main sequence will be plotted in all figures. It was derived using stars with good spectral types in the Pleiades, Hyades, and M34 (with small reddening corrections applied where necessary) and selected field stars. The main sequence so derived is listed in Table III. Values for spectral types earlier than A0 are somewhat uncertain because unreddened stars of these types are too bright to observe with a 60-inch telescope. No values are listed for M dwarfs because not very many stars of these types were observed and the colors of these stars are a quite sensitive function of spectral type.

TABLE I

Standard Stars

| Object | α(1900) | δ(1900) | g | v-g | u-v | g-r |
|---|---|---|---|---|---|---|
| BD +71 31 | $00^h37^m.1$ | $+71^\circ38$ | 10.21 | -0.04 | 0.01 | -0.03 |
| HD 19445 | 03 02.5 | +25 59 | 8.088 | -0.008 | -0.087 | 0.018 |
| Ross 374 | 03 21.1 | +23 26 | 10.851 | 0.096 | 0.000 | 0.079 |
| Ross 34 | 03 22.3 | +37 03 | 11.523 | 1.257 | 0.397 | 0.937 |
| BD +21 607 | 04 08.6 | +22 06 | 9.241 | -0.011 | -0.036 | -0.016 |
| BD +54 1216 | 08 11.7 | +54 25 | 9.727 | 0.019 | -0.053 | 0.002 |
| BD +25 1981 | 08 38.5 | +25 10 | 9.277 | -0.089 | 0.102 | -0.159 |
| Ross 683 | 08 45.1 | +08 00 | 11.40 | 0.46 | -0.01 | 0.25 |
| Ross 889 | 09 35.6 | +01 29 | 10.45 | -0.08 | 0.01 | -0.08 |
| HD 84937 | 09 43.5 | +14 14 | 8.34 | -0.06 | 0.01 | -0.06 |
| Feige 34 | 10 33.8 | +43 37 | 10.893 | -0.825 | -0.755 | -0.787 |
| BD +29 2091 | 10 41.8 | +28 57 | 10.330 | 0.068 | -0.106 | 0.080 |
| Ross 453 | 12 05.8 | +00 58 | 11.119 | -0.007 | -0.062 | 0.015 |
| Feige 67 | 12 39.2 | +17 49 | 11.534 | -0.829 | -0.749 | -0.792 |
| Ross 484 | 13 13.8 | -02 32 | 11.092 | 0.915 | 0.231 | 0.571 |
| BD +26 2606 | 14 44.6 | +26 08 | 9.759 | -0.019 | -0.032 | 0.006 |
| BD +2 3375 | 17 34.8 | +02 28 | 9.987 | 0.002 | -0.042 | 0.040 |
| HD 171164 | 18 28.1 | +28 48 | 8.376 | 1.080 | 0.501 | 0.518 |
| Ross 711 | 18 31.4 | +28 38 | 11.437 | -0.039 | -0.039 | 0.010 |
| GL 745A | 19 02.8 | +20 44 | 11.359 | 1.438 | 0.477 | 1.205 |
| GL 745B | 19 02.8 | +20 44 | 11.348 | 1.434 | 0.480 | 1.202 |
| BD +35 3659 | 19 27.6 | +35 57 | 10.281 | 0.060 | -0.067 | 0.050 |
| BD +28 4211 | 21 46.7 | +28 24 | 10.214 | -0.837 | -0.767 | -0.800 |
| BD +17 4708 | 22 06.7 | +17 36 | 9.500 | 0.001 | -0.001 | 0.001 |
| HD 215732 | 22 42.2 | +29 22 | 8.157 | 1.302 | 0.618 | 0.649 |
| Ross 786 | 23 04.5 | +00 12 | 10.059 | 0.356 | -0.045 | 0.242 |

TABLE II

Atmospheric Extinction Coefficients

| Term | Coefficient |
|---|---|
| $k_g$ | -0.179 |
| $k_{v-g}$ | -0.171 |
| $k_{u-v}$ | -0.212 |
| $k_{g-r}$ | -0.093 |

TABLE III

Standard Main Sequence

| Spectral Class | v-g | u-v | g-r |
|---|---|---|---|
| O5 | -0.84 | -0.77 | -0.80 |
| B5 | -0.61 | -0.30 | -0.68 |
| A0 | -0.37 | 0.36 | -0.56 |
| A5 | -0.17 | 0.42 | -0.40 |
| F0 | -0.02 | 0.24 | -0.19 |
| F5 | 0.12 | 0.09 | -0.02 |
| G0 | 0.27 | 0.05 | 0.08 |
| G5 | 0.42 | 0.09 | 0.14 |
| K0 | 0.66 | 0.18 | 0.28 |
| K5 | 1.06 | 0.37 | 0.58 |
| K8 | 1.29 | 0.46 | 0.79 |

B. *Reddening*

Following Hiltner and Johnson (1956), O stars with various degrees of reddening were measured in order to determine the slope of the reddening function in the $(u-v),(v-g)$ and $(v-g),(g-r)$ planes. These relations were determined to be

$$E(u-v) = 0.574E(v-g)$$

$$E(v-g) = 0.797E(g-r) \quad .$$

Also, from the *UBV* data of Hiltner and Johnson, it was found that

$$E(v-g) = 0.89E(B-V) \quad .$$

Zinn (1980) has measured these numbers for a slightly different filter set and in general finds smaller coefficients. The reason for this discrepancy is not clear, but may be due to the fact that second-order corrections have not been included here though they may be important for some of the very heavily reddened stars. Also, the reddening law is known to vary within the galaxy; the stars sampled here are concentrated toward 90° galactic longitude.

## V. Open Clusters

Observations of stars from four open clusters are listed in Table IV. Stars were selected as follows:

1. Hyades—Stars were taken from the compilation of Johnson, Mitchell, and Iriarte (1962). Spectral types, where given, are from Morgan and Hiltner (1965). Designations are taken from Van Buren (1952), Giclas (1962), and Johnson, Mitchell, and Iriarte (1968).
2. Pleiades—Stars were selected from the lists of Johnson and Morgan (1953) and Johnson and Mitchell (1958). Designations are taken from Hertzsprung (1923). (Note: Johnson and Mitchell use a different numbering scheme given by Hertzsprung (1947). This latter reference provides a cross-reference to the earlier numbering system.) Spectral types are taken from Blanco et al. (1968).
3. M34—Stars were taken from Johnson (1954), and designations are those of Bruggemann (1935).
4. M67—Stars were selected from lists of Johnson and Sandage (1955) and Eggen and Sandage (1964). The designations are from Fagerholm (1906) for objects labeled by F plus number, and Eggen and Sandage (1964) for objects marked with a Roman numeral plus number.

The data from the Pleiades, Hyades, and M34 are plotted as *uvg* and *vgr* two-color diagrams in Figure 1. Also plotted in these diagrams are solid lines which mark the main sequence as described in section IV.A. As can be seen, the clusters provide continuous spectral coverage from B8 to K8. Stars within each cluster form a very tight relation in the two-color diagrams. The Pleiades are reddened by $0^{m}.03$–$0^{m}.07$ mag in $(B-V)$ (Mitchell and Johnson 1957) and M34 is reddened by $0^{m}.09$ (Johnson 1954), so stars in these clusters lie somewhat off the main-sequence curves. In Figures 1(a) a sharp dip in the two-color curve near $(v-g) = -0^{m}.2$ reflects the strong sensitivity of the $(u-v)$ index to the Balmer discontinuity in early-type stars. Reddening lines are drawn in both diagrams. It is seen that for stars redder than $(v-g) = 0^{m}.5$, reddening shifts stars virtually parallel to the main sequence and so reddening cannot be disentangled from spectral type easily on the basis of photometry alone. However, for early-type stars, particularly earlier than B5, reddening is decoupled from spectral type in the $(u-v),(v-g)$ plane and so this diagram can be used to determine reddening to good accuracy (a better calibration is needed before spectral type can be measured).

## VI. Main Sequence

Observations of a large selection of main-sequence field stars are given in Table V. Most stars were selected at random from Blanco et al. (1968), who give coordinates and spectral types as well. Additionally, several reddened O stars were selected from Hiltner and Johnson (1956), some early-type stars at high galactic latitude were taken from Slettebak, Bahner, and Stock (1961), and K and M dwarfs were taken from Veeder (1974). For convenience, Table V is sorted by spectral type. Stars identified only by a number are HD objects; others have fairly standard designations. It should be recognized that many of the spectral types are of questionable accuracy.

The stars in Table V have been divided into two groups of spectral types O–A and F–M and plotted separately in Figures 2 and 3. Several features are immediately evident. First, the two-color relations show much more scatter than for the open clusters in Figure 1, reflecting the diversity in age, composition, and reddening of these field stars. For early-type stars (Fig. 2) the reddening can be especially severe. In Figure 3, the M stars are seen to extend beyond the mean main sequence. In the $(v-g),(g-r)$ plane these stars are seen to make a sharp bend right from the main sequence at $(g-r) = 0^{m}.8$ and remain at constant $(v-g)$ out to $(g-r) = 1^{m}.2$.

## VII. Giants

Table VI contains observations of an assortment of field giants covering luminosity classes I to IV. These stars are plotted in Figure 4. Also plotted are the M-type main-sequence stars to better define the main sequence for these type stars.

Among early-type stars, particularly late-A through F the Balmer discontinuity is expected to be an indicator of both temperature and luminosity. In Figure 4(a) it is seen that there is a scattering of stars with excessively large $(u-v)$ near $(v-g) = 0$, although reddening is also

TABLE IV

Open Cluster Stars

| Name | Sp. Type | g | v-g | u-v | g-r |
|---|---|---|---|---|---|
| | Hyades | | | | |
| VB 3 | | 8.43 | 0.55 | 0.11 | 0.20 |
| VB 10 | | 7.91 | 0.29 | 0.05 | 0.07 |
| VB 15 | G3V | 8.15 | 0.38 | 0.09 | 0.14 |
| VB 17 | | 8.57 | 0.45 | 0.10 | 0.17 |
| VB 18 | | 8.10 | 0.35 | 0.08 | 0.10 |
| VB 21 | K0V | 9.28 | 0.64 | 0.19 | 0.28 |
| VB 22 | | 8.46 | 0.52 | 0.13 | 0.25 |
| VB 25 | K3V | 9.79 | 0.91 | 0.31 | 0.43 |
| VB 26 | G9V | 8.71 | 0.53 | 0.13 | 0.20 |
| VB 27 | G8V | 8.58 | 0.49 | 0.13 | 0.19 |
| VB 29 | F8V | 6.91 | 0.22 | 0.08 | 0.03 |
| VB 31 | G0V | 7.50 | 0.22 | 0.07 | 0.05 |
| VB 39 | | 7.95 | 0.41 | 0.08 | 0.14 |
| VB 42 | | 8.95 | 0.54 | 0.13 | 0.21 |
| VB 43 | K2V | 9.57 | 0.78 | 0.25 | 0.38 |
| VB 46 | | 9.26 | 0.70 | 0.22 | 0.31 |
| VB 49 | | 8.30 | 0.31 | 0.06 | 0.08 |
| VB 50 | G1V | 7.67 | 0.28 | 0.07 | 0.09 |
| VB 52 | | 7.88 | 0.30 | 0.06 | 0.09 |
| VB 57 | F7V | 6.47 | 0.14 | 0.06 | -0.02 |
| VB 58 | G6V | 7.62 | 0.41 | 0.10 | 0.15 |
| VB 59 | F8V | 7.53 | 0.22 | 0.06 | 0.03 |
| VB 62 | F8V | 7.41 | 0.21 | 0.08 | 0.02 |
| VB 63 | G5V | 8.13 | 0.36 | 0.07 | 0.10 |
| VB 64 | | 8.20 | 0.40 | 0.09 | 0.13 |
| VB 65 | F8V | 7.47 | 0.20 | 0.06 | 0.02 |
| VB 73 | G1V | 7.90 | 0.31 | 0.07 | 0.07 |
| VB 76 | | 9.30 | 0.57 | 0.15 | 0.22 |
| VB 79 | K0V | 9.10 | 0.66 | 0.21 | 0.27 |
| VB 85 | F5V | 6.50 | 0.08 | 0.11 | -0.08 |
| VB 87 | G8V | 8.71 | 0.53 | 0.13 | 0.19 |
| VB 91 | K1V | 9.10 | 0.72 | 0.21 | 0.34 |
| VB 92 | G8V | 8.78 | 0.53 | 0.12 | 0.19 |
| VB 93 | K2V | 9.57 | 0.77 | 0.23 | 0.32 |
| VB 96 | K0V | 8.65 | 0.66 | 0.18 | 0.30 |
| VB 97 | G1V | 7.98 | 0.33 | 0.07 | 0.09 |
| VB 99 | K1V | 9.53 | 0.73 | 0.23 | 0.30 |
| VB 102 | G1V | 7.61 | 0.29 | 0.07 | 0.09 |
| VB 105 | | 7.58 | 0.26 | 0.06 | 0.06 |
| VB 109 | | 9.52 | 0.62 | 0.18 | 0.25 |
| VB 115 | | 9.22 | 0.69 | 0.21 | 0.29 |
| VB 116 | | 9.13 | 0.68 | 0.21 | 0.28 |
| VB 117 | | 9.76 | 0.99 | 0.35 | 0.55 |
| VB 140 | | 9.06 | 0.53 | 0.11 | 0.24 |
| VB 142 | | 8.40 | 0.40 | 0.08 | 0.12 |
| VB 143 | | 7.93 | 0.20 | 0.06 | -0.01 |
| VB 145 | | 9.44 | 0.54 | 0.12 | 0.25 |
| VB 173 | | 10.83 | 1.27 | 0.47 | 0.7[illegible] |
| VB 176 | | 9.22 | 0.82 | 0.25 | 0.41 |
| VB 178 | K0V | 9.19 | 0.68 | 0.21 | 0.31 |
| VB 180 | K1V | 9.24 | 0.72 | 0.23 | 0.32 |
| VB 183 | | 9.88 | 0.82 | 0.27 | 0.38 |
| VB 185 | | 9.75 | 1.04 | 0.35 | 0.62 |
| VB 222 | | 10.39 | 1.07 | 0.39 | 0.56 |
| VB 262 | | 11.28 | 1.36 | 0.46 | 0.85 |
| VB 286 | | 11.41 | 1.32 | 0.48 | 0.85 |
| VB 290 | | 11.03 | 1.28 | 0.47 | 0.78 |
| VB 304 | | 10.46 | 1.18 | 0.43 | 0.67 |
| VB 311 | | 10.29 | 1.08 | 0.40 | 0.56 |
| VB 312 | | 9.76 | 1.05 | 0.37 | 0.62 |
| | Pleiades | | | | |
| HS 8 | F5V | 9.52 | 0.12 | 0.11 | 0.00 |
| HS 28 | A7V | 8.18 | -0.05 | 0.36 | -0.27 |
| HS 29 | F5V | 9.60 | 0.14 | 0.07 | 0.01 |
| HS 43 | | 7.98 | -0.10 | 0.42 | -0.33 |
| HS 88 | A2 | 9.12 | 0.09 | 0.21 | 0.00 |
| HS 92 | A8V | 8.12 | -0.05 | 0.31 | -0.23 |
| HS 123 | F3V | 8.98 | 0.04 | 0.15 | -0.09 |
| HS 133 | | 10.51 | 0.31 | 0.06 | 0.14 |
| HS 145 | F2V | 8.97 | 0.03 | 0.14 | -0.10 |
| HS 146 | | 8.58 | 0.02 | 0.38 | -0.17 |
| HS 169 | F3V | 9.03 | 0.09 | 0.16 | -0.04 |
| HS 187 | A3V | 7.99 | -0.08 | 0.47 | -0.29 |
| HS 206 | A9V | 8.60 | 0.01 | 0.31 | -0.14 |
| HS 213 | | 10.23 | 0.25 | 0.10 | 0.13 |
| HS 219 | | 9.79 | 0.19 | 0.06 | 0.05 |
| HS 251 | A2V | 7.77 | -0.11 | 0.48 | -0.34 |
| HS 310 | G0V | 8.75 | 0.30 | 0.06 | 0.08 |
| HS 341 | A2V | 7.25 | -0.21 | 0.45 | -0.43 |

TABLE IV (Continued)

| Name | Sp. Type | g | v-g | u-v | g-r |
|---|---|---|---|---|---|
| HS 385 | | 10.36 | 0.49 | 0.07 | 0.20 |
| HS 388 | F4V | 9.33 | 0.12 | 0.09 | -0.03 |
| HS 396 | F5V | 9.43 | 0.13 | 0.09 | -0.02 |
| HS 420 | | 9.98 | 0.17 | 0.12 | 0.05 |
| HS 424 | | 10.56 | 0.32 | 0.04 | 0.12 |
| HS 428 | | 10.62 | 0.34 | 0.05 | 0.12 |
| HS 457 | A9V | 8.34 | -0.04 | 0.29 | -0.21 |
| HS 484 | F3V | 8.75 | 0.12 | 0.14 | -0.03 |
| HS 501 | A7V | 8.21 | -0.06 | 0.36 | -0.28 |
| HS 513 | A4V | 7.60 | -0.12 | 0.40 | -0.33 |
| HS 534 | A3V | 7.66 | -0.16 | 0.42 | -0.39 |
| HS 610 | | 11.26 | 0.51 | 0.11 | 0.23 |
| HS 620 | | 9.95 | 0.19 | 0.05 | 0.03 |
| HS 681 | F6V | 9.33 | 0.19 | 0.09 | 0.03 |
| HS 695 | F4V | 9.17 | 0.11 | 0.14 | -0.02 |
| HS 698 | | 11.05 | 0.45 | 0.09 | 0.21 |
| HS 862 | | 11.06 | 0.56 | 0.13 | 0.34 |
| HS 891 | | 7.41 | -0.23 | 0.46 | -0.43 |
| HS 919 | | 11.07 | 0.68 | 0.18 | 0.34 |
| HS 922 | | 11.44 | 0.57 | 0.11 | 0.26 |
| HS 936 | | 11.52 | 0.61 | 0.16 | 0.27 |
| HS 948 | F3V | 9.14 | 0.06 | 0.13 | -0.08 |
| HS 986 | | 11.70 | 0.64 | 0.17 | 0.29 |
| | M34 | | | | |
| M34 62 | B9 | 8.35 | -0.33 | 0.46 | -0.46 |
| M34 70 | A2 | 10.36 | -0.15 | 0.46 | -0.42 |
| M34 74 | A2 | | -0.13 | 0.48 | -0.37 |
| M34 80 | | | 0.33 | 0.04 | 0.11 |
| M34 82 | B8 | | -0.39 | 0.28 | -0.54 |
| M34 83 | A5 | 11.48 | -0.01 | 0.29 | -0.17 |
| M34 90 | B7 | | -0.42 | 0.15 | -0.53 |
| M34 93 | B7 | | -0.41 | 0.16 | -0.52 |
| M34 96 | A2 | | -0.17 | 0.45 | -0.40 |
| M34 97 | A8 | | -0.05 | 0.43 | -0.28 |
| M34 101 | B8 | | -0.42 | 0.17 | -0.54 |
| M34 102 | A2 | | -0.05 | 0.41 | -0.26 |
| M34 105 | A5 | | 0.00 | 0.34 | -0.23 |
| M34 109 | A0 | | -0.23 | 0.47 | -0.45 |
| M34 111 | | | -0.22 | 0.47 | -0.46 |
| M34 112 | B8 | | -0.38 | 0.23 | -0.52 |
| M34 114 | B9 | | -0.30 | 0.36 | -0.48 |
| M34 117 | B9 | 9.17 | -0.32 | 0.39 | -0.49 |
| M34 118 | A5 | 11.46 | 0.00 | 0.30 | -0.16 |
| M34 123 | B9 | 8.73 | -0.35 | 0.35 | -0.50 |
| M34 126 | B9 | 9.18 | -0.32 | 0.40 | -0.49 |
| M34 132 | F0 | 11.48 | 0.00 | 0.29 | -0.17 |
| M34 137 | A8 | 11.47 | 0.07 | 0.30 | -0.11 |
| M34 140 | A2 | 10.17 | -0.19 | 0.45 | -0.43 |
| M34 143 | B8 | 8.11 | -0.40 | 0.22 | -0.51 |
| M34 152 | A2 | 10.81 | -0.16 | 0.50 | -0.40 |
| | M67 | | | | |
| M67 F-81 | | 9.70 | -0.58 | -0.07 | -0.63 |
| M67 F-105 | | 10.64 | 1.35 | 0.61 | 0.66 |
| M67 F-108 | | 10.10 | 1.51 | 0.69 | 0.77 |
| M67 F-141 | | 10.72 | 1.06 | 0.48 | 0.50 |
| M67 F-153 | | 11.12 | -0.19 | 0.48 | -0.43 |
| M67 F-224 | | 11.04 | 1.11 | 0.55 | 0.52 |
| M67 F-231 | | 11.75 | 0.95 | 0.47 | 0.46 |
| M67 I-15 | | 11.55 | 0.01 | 0.17 | -0.08 |
| M67 I-20 | | 13.50 | 0.16 | 0.14 | 0.02 |
| M67 I-25 | | 12.70 | 0.26 | 0.09 | 0.09 |
| M67 I-27 | | 11.26 | -0.03 | 0.43 | -0.23 |
| M67 I-49 | | 13.48 | 0.26 | 0.05 | 0.10 |
| M67 I-62 | | 12.91 | 0.50 | 0.18 | 0.22 |
| M67 II-22 | | 13.14 | 0.78 | 0.25 | 0.36 |
| M67 II-25 | | 12.47 | 0.16 | 0.02 | 0.09 |
| M67 II-36 | | 12.78 | 0.21 | 0.12 | 0.06 |
| M67 II-56 | | 13.42 | 0.22 | 0.08 | 0.05 |

contributing an unknown but significant amount to this scatter. Reddening could in principle be measured in the $(v-g),(g-r)$ plane, but a more accurate calibration of the unreddened relation for giants would be needed before this is possible. Also, reddening in this plane shifts stars very nearly parallel to the main sequence, and so in practice it is difficult to disentangle the effects of lumi-

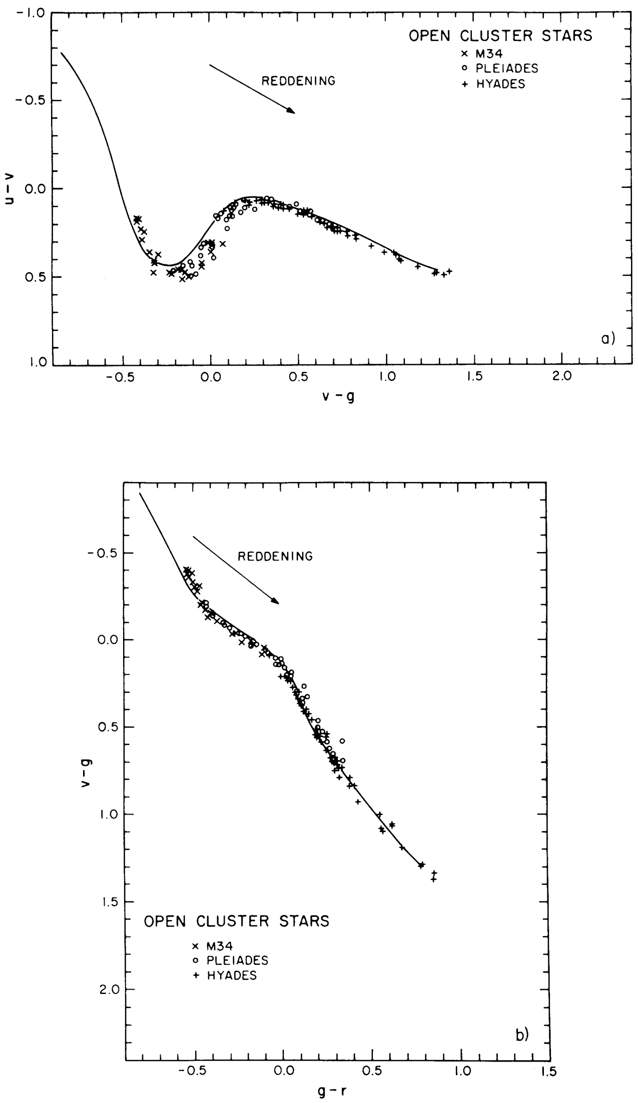


FIG. 1—Two-color diagrams for stars from three open clusters. The solid line is a nominal main sequence.

nosity, spectral type, and reddening from *uvgr* photometry alone.

One errant star is visible in Figure 4(a) at $(u-v) = 0^{m}.9$, $(v-g) = 0^{m}.3$, $+63\ 2105$. An unpublished spectrum shows this star to be a heavily reddened giant of spectral type F3 III. Even unreddened it must still have an unusually large Balmer discontinuity.

The *uvgr* system works much better at isolating late-type giants. In all of the three diagrams in Figure 4, the separation of late-type giants from the main sequence is quite clear-cut, the separation being largest for the latest-type stars. Difficulty is to be had only with giants earlier than K0 for luminosity classes I–III. A detailed comparison with *UBV* photometry shows that *uvgr* provides separation between giants and the main sequence at an earlier spectral type (*UBV* is effective beyond K2) and gives about twice the separation of *UBV*.

## VIII. Special Stars

Collected together in Table VII are observations of subdwarfs and an assortment of stars of other miscellaneous types. They are plotted in Figure 5. The subdwarfs have been augmented by those which have been used as standard stars in Table I.

### A. *Subdwarfs*

Subdwarfs were taken from Blanco et al. (1968) and Sandage (1964, 1969). It is seen from Figure 5 that they lie above the main sequence in the $(u-v),(v-g)$ and $(v-g),(g-r)$ planes. A detailed comparison of this photometry with the *UBV* photometry of subdwarfs by Sandage (1964) shows that the *uvgr* system has a slightly greater sensitivity to metallicity than *UBV* (by about 25%) with the separation from the main sequence being greatest in the $(u-g),(g-r)$ plane.

### B. *White Dwarfs*

A few of these objects were observed. Selections were made from Blanco et al. (1968) and Feige (1959). These objects generally lie in the same regions as reddened O stars.

### C. *Wolf Rayet Stars*

One such object was observed.

### D. *Horizontal-Branch-Type Star*

One such star was observed. It has an enormous Balmer decrement, as can be seen in Figure 5(a). In *UBV* the colors of this star are much closer to those of a normal-A star (Slettebak et al. 1961). Although described by these authors as having a spectrum similar to globular cluster-horizontal branch stars, it has a much larger $(u-v)$ index than those stars which are described in section IX, indicating that it is, in fact, considerably more luminous than a typical globular cluster HB star.

### E. *Field Globular-Cluster-Type Giant*

One such object was observed. It will be discussed further in the next section on globular cluster stars.

## IX. Globular-Cluster Stars

A handful of stars in each of five globular clusters were observed. The stars are listed in Table VIII and plotted in Figure 6. The stars were selected as follows:

1. M2—Arp (1955)
2. M3—Sandage (1970)
3. M5—Arp (1955)
4. M13—Arp and Johnson (1955)
5. M92—Sandage and Walker (1966).

The accuracy of these observations is much poorer than for any previous objects, particularly in the *u* band, which, for red giants, has a very low count rate. The globular-cluster giants are in general much bluer than the field giants which were considered in section VII.

TABLE V

Main-Sequence Stars

| Name | Sp. Type | g | v-g | u-v | g-r |
|---|---|---|---|---|---|
| | | O Main-Sequence | | | |
| -12 134 | OP | 11.48 | -0.83 | -0.75 | -0.72 |
| +60 470 | O8V | 10.04 | 0.05 | -0.21 | 0.28 |
| 12323 | O9V | 8.77 | -0.57 | -0.55 | -0.51 |
| 12993 | O5 | 8.95 | -0.40 | -0.49 | -0.25 |
| 15570 | O5 | 8.33 | 0.03 | -0.27 | 0.33 |
| 191423 | O9V | 7.97 | -0.40 | -0.46 | -0.29 |
| 191978 | O8 | 7.95 | -0.41 | -0.48 | -0.32 |
| 228854 | O8 | 8.71 | 0.06 | -0.17 | 0.35 |
| 229232 | O5 | 9.79 | 0.22 | -0.12 | 0.44 |
| 236894 | O8V | 9.35 | -0.39 | -0.47 | -0.24 |
| | | B Main-Sequence | | | |
| -15 115 | B2 | 10.63 | -0.64 | -0.36 | -0.69 |
| -7 230 | B9 | 10.91 | -0.35 | 0.49 | -0.51 |
| +39 4863 | B9 | 10.21 | -0.31 | 0.38 | -0.48 |
| +40 4845 | B7 | 8.90 | -0.40 | 0.16 | -0.49 |
| +51 3239 | B2V | 9.55 | -0.28 | 0.25 | -0.34 |
| +56 2720 | B6V | 9.48 | -0.09 | 0.35 | -0.09 |
| +80 32 | B2V | | -0.48 | -0.35 | -0.47 |
| 1403 | B9V | 8.91 | -0.35 | 0.36 | -0.51 |
| 1604 | B9V | 8.78 | -0.36 | 0.32 | -0.51 |
| 8323 | B6 | | -0.48 | -0.01 | -0.62 |
| 36542 | B9V | 8.45 | -0.37 | 0.33 | -0.56 |
| 183282 | B8V | | -0.31 | 0.27 | -0.43 |
| 185338 | B9V | | -0.36 | 0.23 | -0.44 |
| 191568 | B9V | | -0.35 | 0.36 | -0.53 |
| 202883 | B3 | | -0.54 | -0.25 | -0.60 |
| 211229 | B9 | | -0.34 | 0.34 | -0.46 |
| 211835 | B3V | 8.32 | -0.51 | -0.47 | -0.39 |
| 213781 | B6 | 8.82 | -0.49 | -0.04 | -0.58 |
| 214022 | B7 | 8.32 | -0.47 | -0.08 | -0.54 |
| 227784 | B8V | | -0.38 | 0.06 | -0.46 |
| 228063 | B8V | | -0.41 | 0.03 | -0.50 |
| 228147 | B9V | | -0.34 | 0.38 | -0.52 |
| AC +9 6-12 | BP | 10.01 | -0.65 | -0.52 | -0.74 |
| | | A Main-Sequence | | | |
| -14 27 | A2 | 10.78 | -0.17 | 0.49 | -0.44 |
| -4 495 | A2 | 10.64 | -0.19 | 0.49 | -0.43 |
| +9 124 | AP | 10.42 | -0.37 | 0.50 | -0.49 |
| +14 4760 | A7 | 10.05 | -0.06 | 0.38 | -0.26 |
| +36 4917 | A5 | 9.74 | -0.08 | 0.43 | -0.23 |
| +37 4655 | A6 | 9.60 | -0.05 | 0.32 | -0.22 |
| +38 4833 | A5 | 9.05 | -0.08 | 0.39 | -0.28 |
| +39 4861 | A5 | 10.82 | -0.16 | 0.46 | -0.37 |
| +39 4943 | A1 | 9.88 | -0.22 | 0.45 | -0.43 |
| 331 | A6V | 8.98 | -0.08 | 0.50 | -0.34 |
| 1017 | A2 | 9.26 | -0.05 | 0.29 | -0.21 |
| 1086 | A0 | 9.73 | -0.13 | 0.46 | -0.35 |
| 1112 | A0 | 8.91 | -0.42 | 0.23 | -0.55 |
| 1151 | A5 | 8.35 | -0.01 | 0.36 | -0.22 |
| 1470 | A3V | 9.03 | -0.10 | 0.44 | -0.30 |
| 1822 | A2V | 9.34 | -0.15 | 0.45 | -0.38 |
| 1875 | A2V | 9.73 | -0.19 | 0.55 | -0.40 |
| 2155 | A3V | 8.53 | -0.20 | 0.41 | -0.48 |
| 2676 | A4V | 9.09 | -0.13 | 0.51 | -0.33 |
| 3202 | A2 | 8.42 | -0.22 | 0.46 | -0.44 |
| 3225 | A7 | 8.84 | -0.12 | 0.53 | -0.34 |
| 3369B | A6V | 8.47 | -0.12 | 0.33 | -0.37 |
| 3604 | A0 | 9.40 | -0.34 | 0.36 | -0.56 |
| 3691 | A3 | 10.61 | -0.14 | 0.43 | -0.34 |
| 3832 | A4 | 10.06 | -0.03 | 0.31 | -0.22 |
| 3885 | AP | 9.60 | -0.44 | 0.16 | -0.56 |
| 4720 | A3 | 8.71 | -0.02 | 0.25 | -0.16 |
| 4729 | A2 | 9.29 | -0.07 | 0.33 | -0.22 |
| 8983 | A5V | 8.59 | -0.10 | 0.44 | -0.38 |
| 19825 | A3 | 8.60 | -0.04 | 0.23 | -0.19 |
| 27821 | A7V | 8.67 | -0.04 | 0.25 | -0.18 |
| 184501 | A7V | 8.01 | -0.12 | 0.44 | -0.37 |
| 191082 | A0V | | -0.40 | 0.16 | -0.52 |
| 192243 | A0V | | -0.31 | 0.39 | -0.54 |
| 192321 | A2V | | -0.25 | 0.49 | -0.48 |
| 210554 | A5 | 8.77 | -0.10 | 0.40 | -0.28 |
| 213371 | A5 | 8.39 | -0.05 | 0.35 | -0.23 |
| 213580 | A2 | 8.98 | -0.12 | 0.42 | -0.34 |
| 214783 | A0 | 8.54 | -0.36 | 0.51 | -0.45 |
| 225186 | A3V | 8.97 | -0.16 | 0.41 | -0.37 |
| FEIGE 16 | A0 | 12.22 | -0.36 | 0.53 | -0.55 |

TABLE V (Continued)

| Name | Sp. Type | g | v-g | u-v | g-r |
|---|---|---|---|---|---|
| | | F Main-Sequence | | | |
| +20 4126 | F6V | 8.72 | 0.21 | 0.06 | 0.03 |
| +21 3810 | F0V | | 0.01 | 0.21 | -0.15 |
| +21 4772 | F2 | 9.06 | 0.08 | 0.25 | -0.07 |
| +28 3192 | F8V | 9.25 | 0.26 | 0.07 | 0.06 |
| +57 2501 | F7V | 9.28 | 0.23 | 0.03 | 0.05 |
| +58 2589 | F6V | 9.58 | -0.12 | 0.27 | -0.13 |
| +61 2571 | F8V | 9.07 | 0.24 | 0.15 | 0.04 |
| 1368 | F9V | 8.92 | 0.19 | -0.02 | 0.05 |
| 1905 | F0V | 9.82 | -0.09 | 0.44 | -0.33 |
| 3158 | F2 | 8.89 | 0.01 | 0.12 | -0.11 |
| 3567 | F5V | 9.28 | 0.05 | 0.00 | 0.00 |
| 3567 | F5V | 9.28 | 0.03 | 0.01 | 0.01 |
| 13721 | F0V | 8.49 | -0.07 | 0.26 | -0.22 |
| 19079 | F7V | 8.85 | 0.11 | 0.11 | -0.06 |
| 179626 | F8V | 9.27 | 0.13 | -0.01 | 0.06 |
| 185270 | F8V | | 0.20 | 0.05 | 0.06 |
| 186225 | F4V | | -0.02 | 0.45 | -0.25 |
| 186657 | F7V | | 0.14 | 0.08 | -0.02 |
| 191177 | F4V | | 0.05 | 0.34 | -0.14 |
| 192405 | F7V | | 0.18 | 0.09 | -0.01 |
| 210643 | F6 | 8.85 | 0.12 | 0.10 | -0.01 |
| 216465 | F8V | 8.48 | 0.06 | 0.13 | -0.07 |
| 216685 | F8V | 8.79 | 0.17 | 0.09 | -0.01 |
| 221900 | F3V | 8.75 | 0.05 | 0.10 | -0.07 |
| | | G Main-Sequence | | | |
| +15 28 | G0V | | 0.21 | -0.02 | 0.07 |
| +25 4607 | G2V | 8.50 | 0.39 | 0.07 | 0.12 |
| +26 3708 | G0V | | 0.21 | 0.02 | 0.07 |
| +27 4219 | G0V | 8.97 | 0.30 | 0.10 | 0.08 |
| +28 3198 | G2V | 8.74 | 0.41 | 0.16 | 0.12 |
| +28 4510 | G2V | 8.88 | 0.48 | 0.15 | 0.24 |
| +29 4828 | G5V | 9.54 | 0.48 | 0.13 | 0.19 |
| +29 4982 | G0V | 9.03 | 0.28 | 0.10 | 0.09 |
| +62 2325 | G2V | 9.78 | 0.41 | 0.12 | 0.13 |
| 3042 | G0V | 9.24 | 0.35 | -0.01 | 0.13 |
| 3556 | G0V | 8.82 | 0.28 | 0.06 | 0.06 |
| 4822 | G0 | 9.53 | 0.21 | 0.00 | 0.06 |
| 7320 | G0 | 9.05 | 0.38 | 0.04 | 0.16 |
| 7983 | G2V | 8.97 | 0.22 | 0.01 | 0.10 |
| 8497A | G5 | 8.88 | 0.40 | 0.12 | 0.17 |
| 15833 | G5 | | 1.02 | 0.29 | 0.50 |
| 17647AB | G5V | | 0.39 | 0.04 | 0.18 |
| 21543 | G2V-V | 8.30 | 0.29 | 0.00 | 0.08 |
| 184700 | G2V | | 0.36 | 0.06 | 0.13 |
| 190605 | G2V | | 0.37 | 0.09 | 0.13 |
| 191898 | G0V | | 0.27 | 0.03 | 0.07 |
| 201860 | G0V | | 0.32 | 0.09 | 0.14 |
| 203030 | G8V | | 0.53 | 0.12 | 0.22 |
| 213570 | G5V | 9.52 | 0.17 | 0.14 | 0.01 |
| 214065 | G4V | 8.36 | 0.37 | 0.08 | 0.16 |
| 215956 | G0V | 8.50 | 0.20 | 0.02 | 0.07 |
| 220056 | G0 | 8.50 | 0.28 | 0.06 | 0.08 |
| 227547 | G5V | | 0.37 | 0.07 | 0.12 |
| | | K Main-Sequence | | | |
| +4 415 | K3V | | 0.81 | 0.21 | 0.43 |
| +22 4567 | K3V | 9.41 | 0.84 | 0.25 | 0.45 |
| +63 137 | K7V | 9.42 | 1.29 | 0.46 | 0.92 |
| 114 | K6 | | 1.24 | 0.48 | 0.70 |
| 5504 | K5 | 9.25 | 1.03 | 0.45 | 0.48 |
| 188268 | K0 | | 0.78 | 0.27 | 0.34 |
| 205855 | K0V | 8.80 | 0.72 | 0.23 | 0.31 |
| GL 39 | K6 | 9.59 | 1.26 | 0.45 | 0.77 |
| GL 851.4 | K0 | | 0.48 | 0.06 | 0.22 |
| GL 854 | K6 | | 1.18 | 0.44 | 0.70 |
| GL 908.1 | K8 | | 1.28 | 0.46 | 0.79 |
| | | M Main-Sequence | | | |
| -15 6290 | M5V | 10.75 | 1.35 | 0.61 | 1.22 |
| +1 4774 | M2V | 9.49 | 1.27 | 0.49 | 1.07 |
| 204587 | M0 | 9.49 | 1.30 | 0.47 | 0.88 |
| GL 96 | M1 | | 1.38 | 0.52 | 1.10 |
| GL 740 | M2 | | 1.35 | 0.53 | 1.10 |
| GL 752 | M3 | | 1.30 | 0.57 | 1.15 |
| GL 809 | M2 | | 1.35 | 0.53 | 1.11 |
| GL 860AB | M3 | | 1.48 | 0.56 | 1.25 |
| Y 49 A | M1V | 8.67 | 1.40 | 0.50 | 1.15 |
| Y 49 B | M6V | 11.67 | 1.65 | 0.50 | 1.34 |

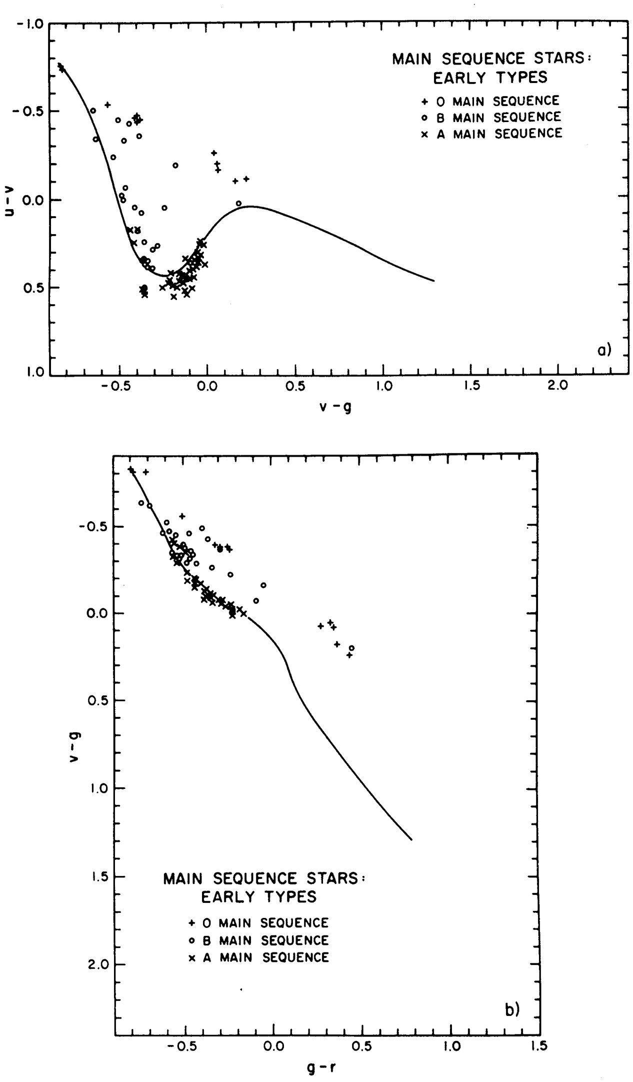


FIG. 2—Two-color diagrams for main-sequence field stars of spectral types O–A. Most of the scatter relative to the nominal main sequence is due to reddening.

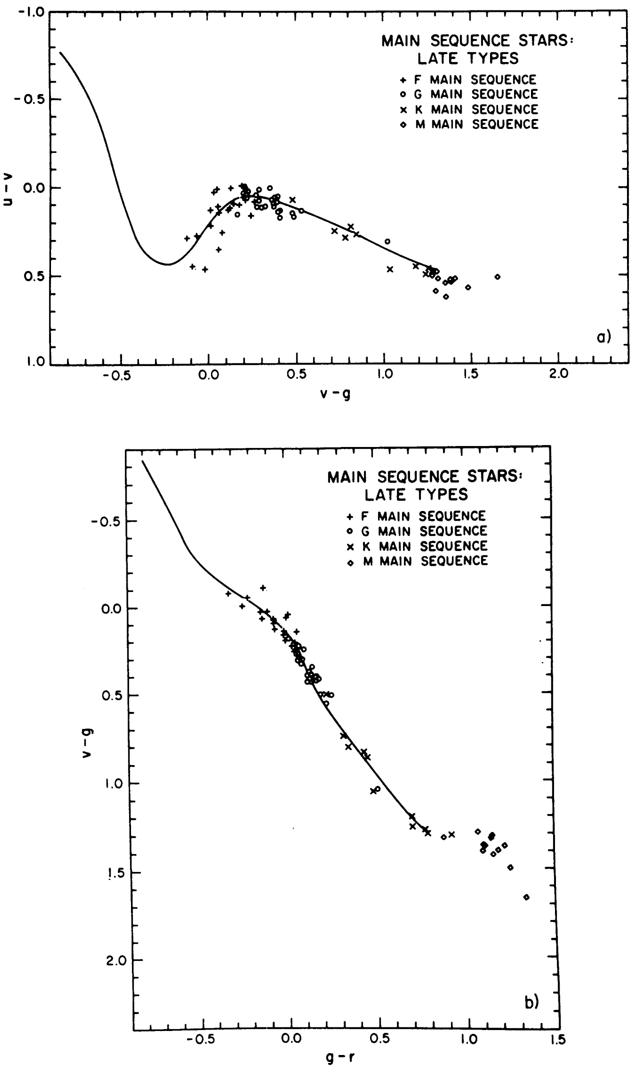


FIG. 3—Same as Figure 2 except for spectral types F–M.

These stars can be separated from the main sequence, lying below it in the *uvg* plane (Fig. 6(a)), just as for regular giants, but rising above it in the *vgr* plane (Fig. 6(b)). This latter separation, which is also characteristic of subdwarfs, is evidently due to metallicity alone, since ordinary giants are indistinguishable from main-sequence stars in this region. Horizontal-branch stars lie near the main-sequence A- and F-type stars. The field globular-cluster-type giant mentioned in section VIII.E lies in the midst of the true cluster giants.

## X. Transformations to *UBVR*

As more observations appear in the literature in the *uvgr* system, occasional need is had for approximate conversions of magnitudes and colors to the standard *UBVR* system. The following transformations have been derived by eyeball fits to plots of stars with photometry on both systems. The plots included main-sequence stars from the Hyades, Pleiades, and M67, and giants from M67 and M3. The *R* photometry is on the Johnson system.

$$\begin{aligned} g &= V - 0.19 + 0.41\,(B-V) \\ r &= R + 0.43 + 0.15\,(B-V) \\ v-g &= -0.47 + 1.37\,(B-V) \\ g-r &= -0.53 + 0.98\,(B-V) \\ g-r &= -0.66 + 1.37\,(V-R) \end{aligned}$$

Other combinations are possible. No transformations for $u$ or $U$ have been determined as they are very nonlinear.

## XI. Conclusions

The *uvgr* system is a photometric system with better designed filters than *UBV*. Its main disadvantage is the relatively low count rate one gets in the $u$ filter. The system shows good sensitivity to metallicity in stars of all types and to luminosity for stars later than K0. For types

TABLE VI

Giants

| Name | Sp. Type | g | v-g | u-v | g-r |
|---|---|---|---|---|---|
| | | **Luminosity Class I** | | | |
| +45 3375 | A1IB | 9.04 | -0.32 | -0.05 | -0.33 |
| +61 2452 | A5IB | 9.99 | 0.16 | 0.25 | 0.05 |
| +62 15 | A1IB | 9.13 | -0.27 | 0.24 | -0.36 |
| 14580 | M0IAB | 9.38 | 2.38 | 0.80 | 1.75 |
| 209678 | B2I | 8.44 | -0.18 | -0.21 | -0.05 |
| 209900 | A0IB | 8.74 | -0.05 | 0.77 | 0.00 |
| 211540 | K5IB | 8.66 | 2.14 | 0.94 | 1.46 |
| 235783 | B1IB | 8.64 | -0.39 | -0.37 | -0.29 |
| 239923 | B3IB | 9.11 | 0.18 | 0.01 | 0.46 |
| | | **Luminosity Class II** | | | |
| 185061 | G8II | | 1.22 | 0.59 | 0.66 |
| 191047 | G5II | | 0.89 | 0.38 | 0.41 |
| 200448 | K1II | 8.37 | 1.31 | 0.64 | 0.64 |
| 221038 | A7II | 7.97 | -0.13 | 0.39 | -0.35 |
| 227472 | K0II | 8.74 | 1.73 | 0.77 | 1.00 |
| 227480 | A2II | | -0.32 | 0.46 | -0.43 |
| 227776 | K0II | | 1.28 | 0.62 | 0.63 |
| 227785 | B9II | 9.23 | -0.39 | 0.05 | -0.49 |
| | | **Luminosity Class III** | | | |
| +12 4789 | K2III | 10.76 | 1.50 | 0.75 | 0.84 |
| +13 4888 | K3III | 9.15 | 1.60 | 0.82 | 0.83 |
| +15 4543 | M5III | | 1.86 | 0.95 | 1.14 |
| +15 4566 | K5III | 9.61 | 1.81 | 0.90 | 1.03 |
| +15 4581 | M0III | 10.59 | 1.87 | 0.93 | 1.07 |
| +15 4582 | K3III | 10.31 | 1.73 | 0.82 | 0.99 |
| +18 4853 | K3III | 10.34 | 1.68 | 0.80 | 0.92 |
| +18 4897 | K2III | 10.85 | 1.43 | 0.66 | 0.80 |
| +19 4787 | M0III | 10.99 | 1.85 | 0.93 | 1.13 |
| +19 4836 | K5III | 10.40 | 1.95 | 0.92 | 1.19 |
| +32 3700 | B6III | 9.13 | -0.38 | -0.09 | -0.40 |
| +46 3097 | A0III | 9.12 | -0.12 | 0.47 | -0.05 |
| +47 3265 | K0III | 9.06 | 1.34 | 0.65 | 0.74 |
| +55 2711 | K0III | 9.49 | 1.42 | 0.75 | 0.76 |
| +56 2679 | A1III | 9.71 | -0.08 | 0.60 | -0.22 |
| +56 2684 | A5III | 9.87 | 0.07 | 0.59 | -0.08 |
| +56 2707 | F4III | 9.18 | 0.11 | 0.14 | -0.07 |
| +58 2612 | F6III | 8.61 | 0.19 | 0.12 | 0.03 |
| +63 2105 | F2III | 9.36 | 0.27 | 0.94 | 0.29 |
| 26 | K0III | 8.45 | 0.88 | 0.11 | 0.41 |
| 163 | F2III | 8.47 | 0.02 | 0.25 | -0.14 |
| 350 | F2III | 8.76 | -0.01 | 0.45 | -0.21 |
| 415 | A7III | 8.95 | -0.03 | 0.54 | -0.23 |
| 680 | K5III | 8.58 | 1.84 | 0.87 | 1.04 |
| 2126 | K0III | 8.46 | 0.91 | 0.36 | 0.45 |
| 183562 | A0III | | -0.39 | 0.25 | -0.50 |
| 185783 | F4III | | -0.01 | 0.34 | -0.24 |
| 191064 | B9III | | -0.39 | 0.23 | -0.58 |
| 191176 | A1III | | -0.29 | 0.51 | -0.48 |
| 191743 | B7III | | -0.39 | 0.09 | -0.52 |
| 192320 | K2III | 8.50 | 1.72 | 0.82 | 0.96 |
| 193612 | A0III | 8.49 | -0.44 | 0.00 | -0.53 |
| 200839 | K0III | 8.55 | 1.20 | 0.58 | 0.57 |
| 208609 | K3III | 7.62 | 1.67 | 0.80 | 0.93 |
| 210627 | K1III | 8.45 | 1.38 | 0.71 | 0.69 |
| 215330 | K5III | 9.47 | 1.53 | 0.73 | 0.82 |
| 223818 | K0III | 8.41 | 0.99 | 0.44 | 0.47 |
| 227421 | A5III | 9.08 | -0.08 | 0.64 | -0.20 |
| 227535 | G8III | | 0.92 | 0.38 | 0.55 |
| 228097 | K0III | | 1.03 | 0.46 | 0.50 |
| 228108 | F4III | | 0.10 | 0.25 | -0.03 |
| 228899A | G8III | 9.48 | 0.84 | 0.34 | 0.38 |
| 228899B | G8III | 9.90 | 0.82 | 0.32 | 0.38 |
| 229234 | O9III | 9.13 | 0.16 | -0.11 | 0.37 |
| | | **Luminosity Class IV** | | | |
| +53 2820 | B0IV | 9.87 | -0.45 | -0.45 | -0.36 |
| +54 2749 | G2IV | 9.46 | 0.59 | 0.22 | 0.23 |
| +56 2694 | B3IV | 9.33 | -0.25 | 0.04 | -0.23 |
| +60 2666 | F5IV | 9.61 | 0.15 | 0.20 | 0.01 |
| 12088 | G8IV | 9.19 | 0.52 | 0.07 | 0.22 |
| 13391 | G2IV | 8.75 | 0.30 | 0.08 | 0.07 |
| 13830 | F6IV | 8.30 | 0.18 | 0.20 | 0.03 |
| 19618 | K0IV- | 9.19 | 0.68 | 0.20 | 0.26 |
| 191227 | F2IV | | -0.01 | 0.39 | -0.18 |

TABLE VII

Subdwarfs and Other Types

| Name | Sp. Type | g | v-g | u-v | g-r |
|---|---|---|---|---|---|
| | | **Subdwarfs** | | | |
| -2 181 | SD | 9.06 | 0.39 | 0.03 | 0.16 |
| -0 4470 | G2SD | 10.05 | 0.35 | -0.04 | 0.23 |
| +10 1091 | SD | 8.92 | 0.20 | -0.09 | 0.14 |
| +16 3924 | SD | 9.47 | 2.04 | 0.88 | 1.52 |
| +66 268 | SD | 10.03 | 0.24 | -0.08 | 0.20 |
| 28571 | G6SD | 9.06 | 0.34 | 0.05 | 0.11 |
| EG145A | K4SD | 10.04 | 0.73 | 0.19 | 0.52 |
| G 5-17 | SD | 9.20 | 0.67 | 0.23 | 0.27 |
| G 18-39 | G0SD | 10.42 | 0.04 | -0.03 | 0.00 |
| G 37-34 | SD | 9.86 | 0.68 | 0.17 | 0.36 |
| G 68-30 | SD | 9.17 | 0.19 | 0.01 | 0.07 |
| G 77-54 | | 8.30 | 0.27 | 0.00 | 0.11 |
| G 190-34 | SD | 9.23 | 0.60 | 0.13 | 0.25 |
| GL 213 | M5SD | 12.04 | 1.39 | 0.56 | 1.21 |
| GL 725 A | M2SD | 9.44 | 1.31 | 0.50 | 1.15 |
| GL 725 B | M2SD | 10.23 | 1.38 | 0.51 | 1.18 |
| SA 115-147 | SD | 8.94 | 0.50 | 0.13 | 0.20 |
| WOLF 1324 | SD | 11.02 | 1.14 | 0.38 | 0.79 |
| | | **White Dwarfs + Wolf-Rayet** | | | |
| 219460 | WR | | 0.10 | -0.19 | 0.27 |
| 26976B | WD A | 9.31 | -0.34 | -0.49 | -0.63 |
| EG 157 | WD | 12.71 | -0.71 | -0.65 | -0.72 |
| FEIGE 24 | | 12.18 | -0.76 | -0.75 | -0.46 |
| FEIGE 26 | | 13.72 | -0.80 | -0.75 | -0.79 |
| FEIGE 108 | | 12.73 | -0.73 | -0.64 | -0.76 |
| FEIGE 110 | WD O | 11.55 | -0.78 | -0.73 | -0.79 |
| | | **Hor. Br. Star** | | | |
| +39 4926 | B8H B | 9.20 | -0.25 | 0.91 | -0.26 |
| | | **Globular Cluster Type Giant** | | | |
| 221170 | GLOB | 8.00 | 0.75 | 0.43 | 0.59 |

earlier than A0 it can measure spectral type and reddening, but not luminosity. For types between late-A and G, it should be sensitive to luminosity, but separation of the effects of reddening and luminosity is difficult, and in practice only unusually luminous stars can be distinguished.

Many of the observations presented here have been circulated and cited in an unpublished form for several years. This paper should now make them more widely available.

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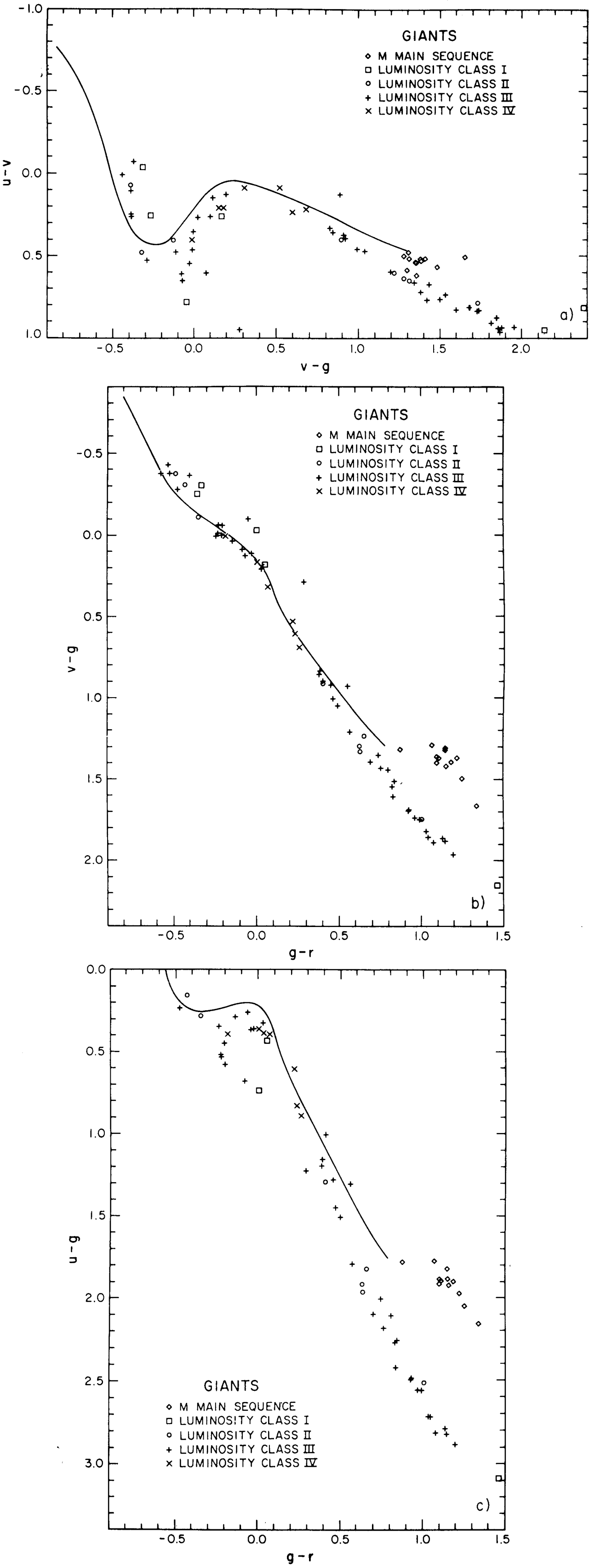


FIG. 4—Two-color diagrams for giants of all spectral types and luminosity classes.

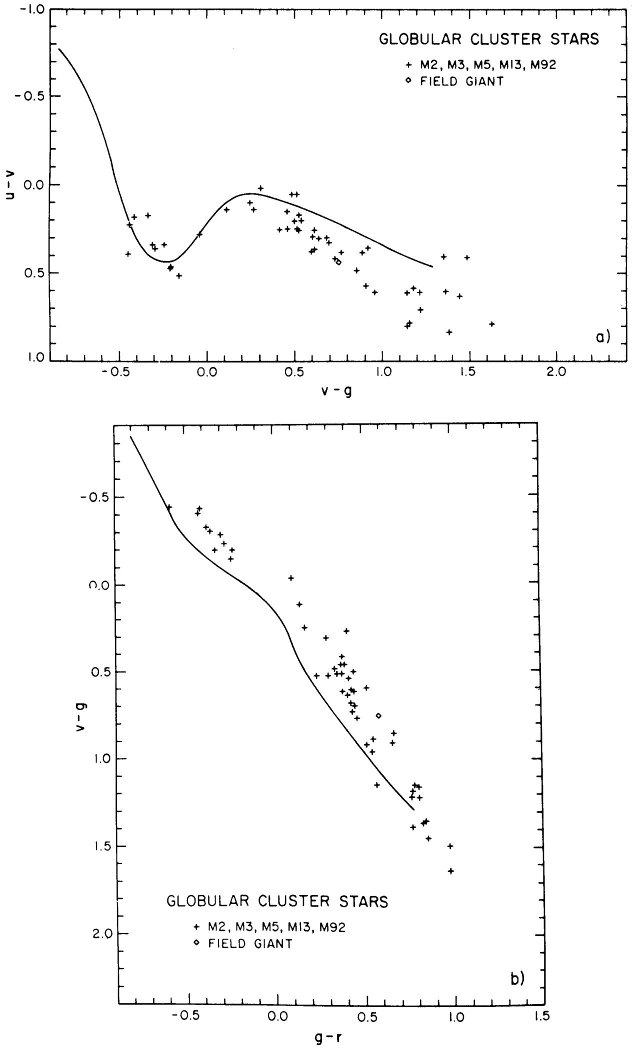


FIG. 5—Two-color diagrams for stars with special properties as indicated.

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TABLE VIII

Globular Cluster Stars

| Name | Sp. Type | g | v-g | u-v | g-r |
|---|---|---|---|---|---|
| | M2 | | | | |
| M2 II-33 | | 14.08 | 0.61 | 0.24 | 0.45 |
| M2 II-59 | | 13.39 | 0.85 | 0.47 | 0.67 |
| M2 II-69 | | 13.44 | 1.14 | 0.79 | 0.79 |
| | M3 | | | | |
| M3 193 | | 15.00 | 0.53 | 0.19 | 0.42 |
| M3 216 | | 14.22 | 0.76 | 0.37 | 0.47 |
| M3 297 | | 13.32 | 1.35 | 0.39 | 0.85 |
| M3 1397 | | 13.24 | 1.48 | 0.40 | 0.98 |
| M3 I-27 | | 15.63 | -0.34 | 0.16 | -0.38 |
| M3 I-30 | | 15.50 | -0.32 | 0.32 | -0.36 |
| M3 II-6 | | 15.35 | -0.25 | 0.32 | -0.28 |
| M3 II-18 | | 14.36 | 0.60 | 0.28 | 0.44 |
| M3 III-28 | | 13.23 | 1.21 | 0.69 | 0.81 |
| | M5 | | | | |
| M5 I-34 | | 15.08 | -0.30 | 0.35 | -0.30 |
| M5 I-55 | | 13.80 | 0.61 | 0.35 | 0.39 |
| M5 I-68 | | 12.84 | 1.36 | 0.59 | 0.83 |
| M5 II-50 | | 14.02 | 0.69 | 0.31 | 0.45 |
| M5 II-80 | | 14.21 | 0.45 | 0.14 | 0.38 |
| M5 II-82 | | 14.62 | -0.21 | 0.46 | -0.24 |
| M5 II-85 | | 12.74 | 1.44 | 0.62 | 0.86 |
| M5 II-86 | | 13.56 | 0.72 | 0.41 | 0.44 |
| M5 III-50 | | 13.10 | 0.95 | 0.60 | 0.55 |
| M5 III-72 | | 13.29 | 0.88 | 0.37 | 0.56 |
| M5 III-78 | | 12.96 | 1.21 | 0.60 | 0.77 |
| M5 IV-19 | | 13.03 | 1.38 | 0.82 | 0.78 |
| M5 IV-26 | | 13.54 | 0.50 | 0.04 | 0.38 |
| M5 IV-67 | | 14.64 | 0.48 | 0.04 | 0.34 |
| M5 IV-68 | | 14.73 | -0.16 | 0.50 | -0.24 |
| M5 IV-69 | | 14.98 | 0.10 | 0.13 | 0.15 |
| M5 IV-73 | | 13.97 | 0.50 | 0.23 | 0.35 |
| | M13 | | | | |
| M13 3 | | 13.56 | 0.91 | 0.34 | 0.52 |
| M13 11 | | 14.76 | -0.21 | 0.45 | -0.33 |
| M13 24 | | 15.13 | -0.46 | 0.38 | -0.59 |
| M13 34 | | 14.89 | 0.52 | 0.24 | 0.24 |
| M13 37 | | 14.67 | 0.52 | 0.16 | 0.31 |
| M13 38 | | 13.77 | 0.68 | 0.29 | 0.43 |
| M13 49 | | 13.87 | 0.63 | 0.29 | 0.41 |
| M13 59 | | 12.63 | 1.62 | 0.77 | 0.98 |
| | M92 | | | | |
| M92 I-14 | | 14.84 | 0.30 | 0.01 | 0.29 |
| M92 II-24 | | 14.73 | 0.26 | 0.13 | 0.41 |
| M92 II-28 | | 15.03 | -0.05 | 0.27 | 0.10 |
| M92 II-40 | | 15.56 | -0.45 | 0.21 | -0.42 |
| M92 II-70 | | 13.29 | 0.59 | 0.36 | 0.52 |
| M92 III-13 | | 12.44 | 1.15 | 0.77 | 0.81 |
| M92 III-65 | | 12.76 | 0.90 | 0.56 | 0.67 |
| M92 VII-5 | | 15.12 | 0.24 | 0.09 | 0.17 |
| M92 VII-18 | | 12.58 | 1.17 | 0.57 | 0.78 |
| M92 VII-46 | | 15.52 | -0.42 | 0.17 | -0.43 |
| M92 X-4 | | 13.12 | 1.14 | 0.60 | 0.58 |
| M92 XII-31 | | 13.97 | 0.41 | 0.24 | 0.38 |
| M92 XII-34 | | 13.59 | 0.49 | 0.19 | 0.45 |
| M92 XII-45 | | 14.11 | 0.45 | 0.23 | 0.40 |

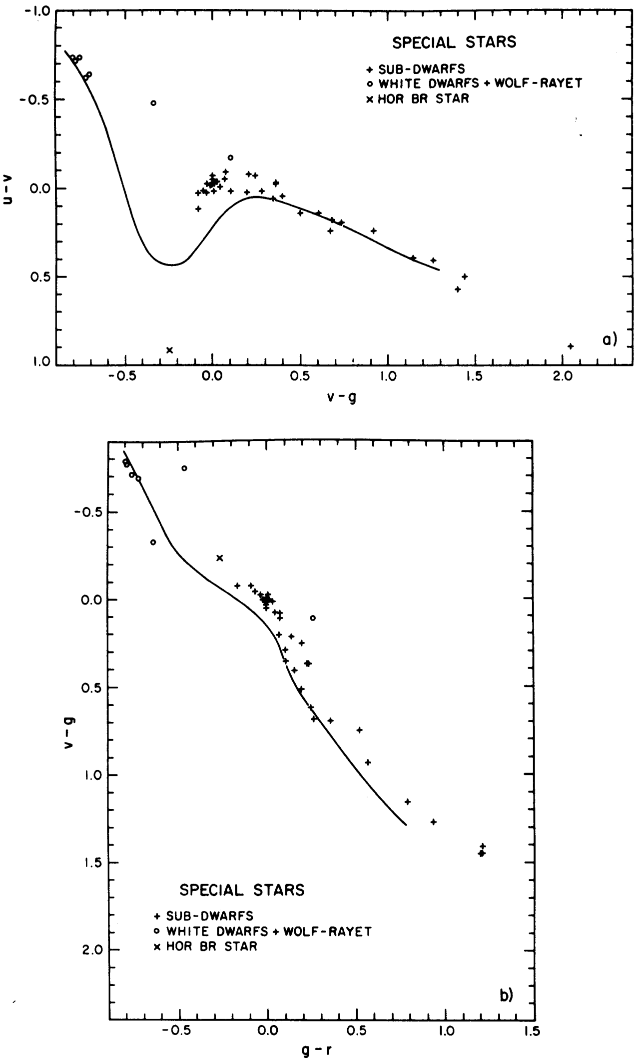


FIG. 6—Two-color diagrams for bright stars selected from five globular clusters. Compare with the plots for giants in Figure 4 and subdwarfs in Figure 5.