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THE INTERMEDIATE-AGE CLUSTER IC 4651

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ABSTRACT

Two hundred and ten *UBV* observations of 102 stars in the region of the open cluster IC 4651 show that it is an intermediate-age cluster with a modulus of 9.5 mag and an ultraviolet excess of +0.06 mag for main-sequence stars with an intrinsic color of $B - V = +0.45$ mag. Observations of seven early-type stars in the region show that the cluster reddening is $E(B - V) = +0.15$ mag. The cluster is apparently only slightly older than NGC 752 but is considerably richer and contains more than a dozen red giants.

A comparison of the various features of the color-luminosity arrays of this and other old and intermediate-age clusters suggests a significant spread in the ages of the stars within a cluster, which would tend to blur some of the indicators used to measure the mean age and the chemical composition of cluster stars.

A photometric survey of the clusters south of $\delta = -45°$ contained in the atlas published by Hogg and Hunt (1965) has revealed several clusters of intermediate age, including IC 4651 ($\alpha = 17^h21^m$, $\delta = -49°55'$; 1950). The region of the cluster shown in Figure 1 is taken from that atlas. The *UBV* observations of the stars numbered in Figure 1 are listed in Table 1 and are shown in the (V_E, $B - V$) plane of Figure 2. Probable field stars are identified by crosses, and objects for which only a single observation is available are shown as open circles in Figure 2. All stars not obviously contaminated by close companions, and brighter than about magnitude 13.5, within the enclosed region of Figure 1 were observed with the 40-inch reflector at Siding Spring. The photometric standards used are listed elsewhere (Eggen 1970).

Photometric results for seven early-type stars in the region of the cluster are listed in Table 2 together with the derived values of the reddening, $E(B - V)$. The moduli, $m - M$, were obtained on the assumption that all are main-sequence objects. The spectral types in Table 2 are taken from the *Henry Draper Catalog*. The reddening in the direction of the cluster reaches +0.15 mag in the first 400 pc and remains unchanged to 1 kpc. The modulus of the cluster, derived below, is 9.5 mag, so a reddening of $E(B - V) = +0.15$ mag has been adopted.

The cluster stars below the obvious gap in the main sequence near $V_E = 13.2$ mag are probably little evolved, and these are shown in the ($U - B$, $B - V$)-plane of Figure 3. The continuous curve in Figure 3 represents the relation for Hyades main-sequence stars (Eggen 1965) modified by $E(B - V) = +0.15$ mag, $E(U - B) = +0.11$ mag. The crosses in Figure 3 represent probable field stars, many of which are judged to be nonmembers on the basis of their position in this figure. The mean ultraviolet excess of these stars, at an intrinsic $B - V$ of +0.45 mag, is $\delta(U - B)_{0.45} = +0.06$ mag. The red giants in the cluster are shown as open circles in Figure 4, where the straight line represents the ($U - B$, $B - V$)-relation for giants in the Hyades group (Eggen 1966*a*), $U - B = 2.00\ (B - V) \perp 1.16$ mag, modified by $E(B - V) = +0.15$ mag. These giants show little or no deviation from the Hyades relation. The cluster stars brighter than 13.5 mag are evolved and therefore should deviate from the main-sequence ($U - B$, $B - V$)-relation in that the gravity effect will offset some of the ultraviolet excess seen in the main-sequence stars (Fig. 3). The stars brighter than $V_E = +13.5$ mag are shown in Figure 5, where the continuous curve is again the relation

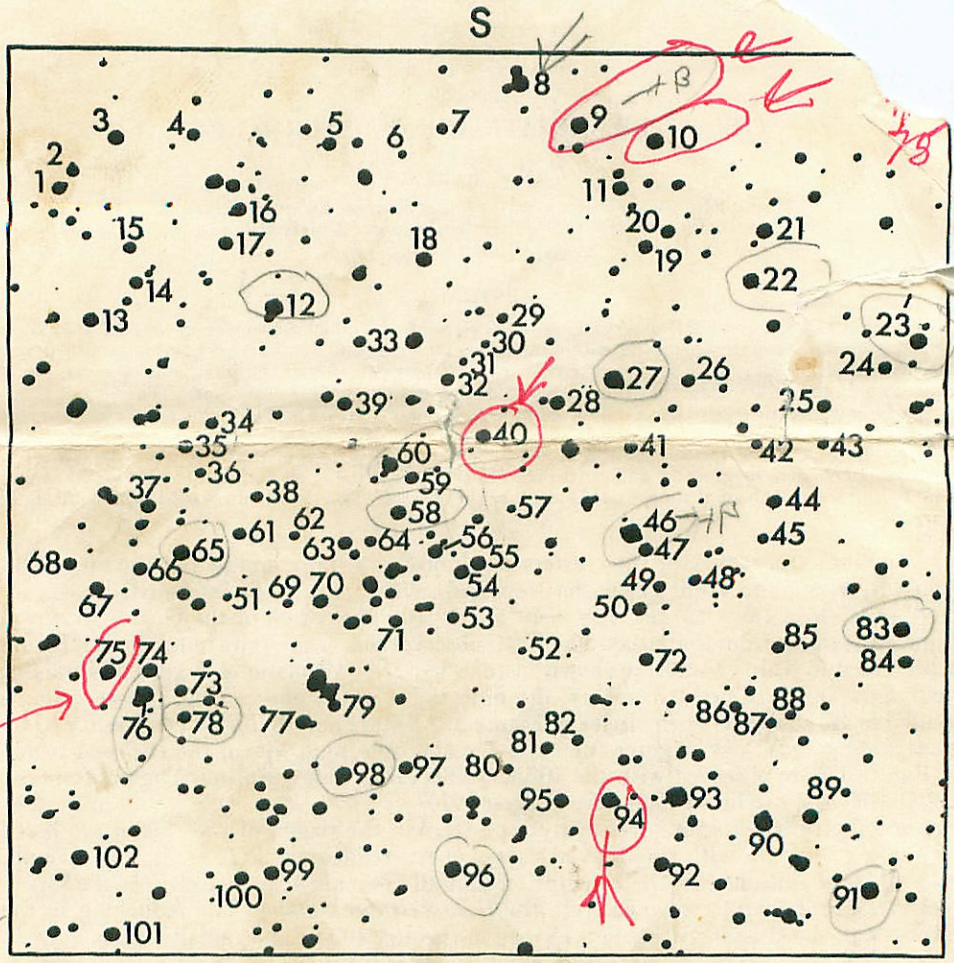

FIG. 1.—Region of IC 4651 taken from Hogg and Hunt (1965)

for Hyades main-sequence stars modified by $E(B - V) = +0.15$ mag. From the observations of wide binaries (Eggen 1966*b*, Table II) it was found that stars 2.0 mag above the main sequence, at an intrinsic $(B - V)$ of $+0.45$ mag, would show an ultraviolet deficiency of 0.10 mag with respect to the main-sequence stars, and for those 1.0 mag above this sequence the deficiency would be 0.04 mag. The cluster stars of magnitude $V_E = 11.5$–12.5 mag in Figure 5 (*filled circles*) are, in the mean, 1.5 mag above the main Hyades main sequence; and, as seen in the figure, in the mean the gravity effects just cancel the ultraviolet excesses. The stars with V_E between 12.5 and 13.5 mag (*open circles*) are, in the mean, only 0.5 mag above the Hyades main sequence, and, as expected, they show nearly the same ultraviolet excess as the main-sequence stars in Figure 3.

After the observed magnitudes and colors were corrected for a reddening of $E(B - V) = +0.15$ mag, the observed main sequence was fitted to that for the Hyades stars with a resulting modulus, $m - M$, for the cluster of 9.5 mag. The resulting color-lumi-