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A SPECTROSCOPIC AND PHOTOMETRIC STUDY OF THE STAR CLUSTER IN COMA BERENICES

Introduction.—Measures of color indices in the (U, B, V) system for the Hyades and Coma Berenices star clusters by Johnson and Knuckles (1955) show that the F and G stars in Coma Berenices radiate about 0.035 mag. more ultraviolet than do similar stars in the Hyades. Strömgren's (1958) measures of *m-indices* show that four F stars in Coma Berenices have a smaller *m-index* than do similar in the Hyades (5 stars), the Pleiades (5 stars) and Praesepe (8 stars) clusters. The results have been interpreted as Coma Berenices having a deficiency in metals with respect to the Hyades and this might mean that Coma is older than the Hyades.

On the other hand Sandage and Eggen (1959) from composite $(B - V, M_v)$ diagrams find that Coma Berenices is 2×10^8 years younger than the Hyades. They exclude as a criterium on the determination of Coma Berenices' age its relative metal content, because, they say, the heavy element abundance of prestellar matter does not increase uniformly with the time from the formation of the galaxy.

The present paper is an investigation of the combined photoelectric and spectroscopic material to see if we can say something else on Coma Berenices' age.

Description of the Observations.—The present investigation is based on a spectroscopic and photoelectric study of 54 stars taken from table 18 of Trumpler's (1938) work on the cluster Coma Berenices. Among these 54 stars 43 are physical members according to Trumpler. The 11 remaining stars were chosen because they have radial velocities measured by Fehrenbach (1956). The observed material is:

a) Spectra of 41 members of Coma Berenices were taken with the one-prism spectrograph attached to the 40-inch refractor of the Yerkes Observatory on Kodak 103a-0 and IIa-0 emulsions. The dispersion is about 125Å/mm at Hγ. The plates were taken during the years 1955 and 1956. These stars were studied photoelectrically by Johnson and Knuckles (1955).

b) The spectra of the remaining 13 stars were taken with the grating nebular spectrograph attached to the 40-inch reflector of the Observatorio Astronomico Nacional, University of Mexico, on the Kodak 103a-0 emulsion. The dispersion is about 260Å/mm. The plates were taken in 1963.

Spectral types and luminosity classes were assigned to these 54 stars according to the criteria of the Yerkes revised Atlas system (MK type) outlined by Morgan (cf. Johnson and Morgan, 1953).

c) The photoelectric observations of the 54 stars under study were made on Johnson's (U, B, V, R, I) system (unpublished; see also Johnson and Mitchell, 1962). An RCA 1P21 photomultiplier was used to measure U, B and V magnitudes. An RCA 7102 photomultiplier was used to measure B, V, R and I magnitudes. The infrared cell was used first and after three or more infrared observations were secured on each star, at least on three different nights, then the observations with the blue cell were started, obtaining two observations on each star, except three of them (see below) which were observed every night that the RCA 1P21 was on. All the photoelectric observations were made with the 40-inch reflector of the Observatorio Astronomico Nacional, University of Mexico, and with a digitized multi-color photometer designed by Johnson. The observations were reduced by R. I. Mitchell.

d) Using the Schmidt Camera of the Tonantzintla Observatory two objective-prism red plates on the Kodak 103a-E emulsion and through a Wratten filter No. 26 were taken. One in 1958 of 90 min and the other in 1962 of 180 min. exposure.

e) With the same Schmidt Camera 22 plates on the Kodak 103a-0 emulsion were taken in 1963 in three nights. On each plate four exposures of ten minutes each were made. These plates form part of an observing program in Tonantzintla to search for rapid variables (flash-stars) in stellar associations and galactic clusters. More plates will be taken and ours should be considered preliminary.

The 24 plates taken with the Schmidt Camera cover an area of 25 square degrees and they are centered, approximately, at $\alpha = 12^h18^{min}$ and $\delta = +\ 26°5$ (1900).

Results of the Observations.—The results of the spectroscopic and photoelectric observations are summarized in Table 1. The columns of Table 1 give, first, the Trumpler number; second, star designation; third, the type on the MK system; fourth, the V magnitude; fifth, sixth, seventh and eighth the values of (B − V), (U − B), (V − R) and (R− I), respectively; ninth, the number of infrared observations on each star. The remarks are given at the bottom of the table. Star T146 was used as the single standard star for the cluster. The transformation to the (U, B, V) system of T146 is independent of the one made by Johnson and Knuckles (1955) The (U − B) value for this star, obtained at Tonantzintla, is − 0.119 mag.; the given by Johnson and Knuckles is − 0.118 mag.

Among the cluster members we find four metallic-line stars, three peculiar stars, a composite spectrum (G2III + A4V) and a star of luminosity class IV-V. We also find from their photometric and spectroscopic characteristics four probable new members. The relation between apparent magnitude and MK type is exhibited graphically in *Figure 1.*

The mean errors of the photoelectric observations are given in Table 2. The columns of Table 2 give, first, the mean error in the magnitude V; second, third, fourth and fifth, the mean errors in (B − V), (U − B), (V − R) and (R − I)− indices, respectively; sixth, the range in V magnitudes in which the mean errors are valid.

Snce (B − V) was measured with two different cells it is interesting to compare observations made with an RCA 1P21 and an RCA 7102. This comparison is shown graphically in *Figure 2.* The values measured with an infrared cell are those obtained at Tonantzintla. The values measured with a blue cell are those given by Johnson and Knuckles (ibid). This comparison practically does not indicate a systematic difference. The photometric characteristics of the stars in Table 1 are illustrated in *Figures 3, 4, 5 and 6.*

The results of the observations with the Schmidt Camera were negative, since in the area covered by the plates not a single Hα emission object was found neither a rapid variable of the type found with the same Camera and technique, in the Orion Nebula (Haro and Morgan, 1953; Haro and Chavira, 1955), the Taurus region (Haro and Rivera, 1954) and the Pleiades (Haro, 1963). However, this last result is of no significance because, per example in the Orion Nebula, a similar material sometimes has not shown flash stars. More plates in Coma area are needed to see if there exist flash stars in Coma Berenices.

The distance modulus of Coma Berenices from Table 1 and Keenan and Morgan's calibration (1951) is 4.5 mag.

Sandage and Eggen (1959) find this distance modulus to be 4.48 mag. after a correction due to differences in the position of the main sequences in the ($B - V$, M_v) —diagram.

The Ultraviolet Excess in Coma Berenices.—The combined spectroscopic and photoelectric results of Coma Berenices are used to determine the ($U - B$) —excess for each spectral-type as compared with similar spectra in the Hyades, the Pleiades and Praesepe. The U-magnitudes for these clusters are given by Johnson and Knuckles (ibid), Johnson and Mitchell (1958) and Johnson (1952); the spectral classification has been made by Titus and Morgan (1940), Mendoza (1956) and Bidelman (1956), respectively. The ($U - B$) observed for the Pleiades has been corrected for interstellar absorption (cf. Mendoza, ibid).

The ($U - B$) which corresponds to each spectral class in one cluster has been calculated as the average ($U - B$) value of all stars with the same spectral type. The results for the four clusters (Coma, Hyades, Pleiades and Praesepe) are summarized in Table 3. The columns of Table 3 give, first, the spectral type; second, third, fourth and fifth, the ($U - B$) for Coma Berenices, the Hyades, Pleiades and Praesepe, respectively, computed as above.

We can compute the ultraviolet excess of Coma with respect to the ultraviolet of the above clusters using Table 3. The results of this computation is summarized in Table 4. The columns of Table 4 give, first, the spectral type; second, third and fourth the ($U - B$) differences between Coma and the Hyades, Coma and the Pleiades, and Coma and Praesepe, respectively. At the bottom of Table 4 are the mean values of these differences. To form Table 4 only stars with types from A5 to G0 were taken, because stars earlier than A5 are a few, their spectra practically do not have any metallic lines and their ($U - B$) —indices might be affected by the Balmer continuum, and the spectral types later than G0 are very few too and their colors have larger mean errors. We note from Table 4 that the A5-G0 stars of Coma radiate 0.05 mag. more ultraviolet than do similar stars in the Hyades and the Pleiades. We also note from this Table that the stars of Coma have an ultraviolet excess of 0.04 mag. as compared with similar stars in Praesepe. These results are shown graphically in *Figures 7, 8 and 9*, in which the ($U - B$) has been plotted for each star individually. We also note from these figures that other stars than A5-G0 have, on the average, a little ultraviolet excess.

Conclusion.—From the spectroscopic and photoelectric results described in this paper, we can draw the following preliminary conclusions:

a) It was confirmed the existence of an ultraviolet excess in Coma Berenices when its colors are compared with the colors of stars with same spectral types in other galactic clusters.

b) The ($U - B$) excesses are not well correlated with the ages of the Hyades, the Pleiades and Praesepe clusters —see Table 4. For instance, Table 4 does not give an ultraviolet excess between the Hyades and the Pleiades and it is well known that the Hyades is much older than the Pleiades. The same Table 4 gives a small ultraviolet excess between the Pleiades and Praesepe in spite of the fact that the Pleiades is younger than Praesepe.

c) Our photoelectric observations, at the present time, cannot be used safely in the determination of the age of Coma Berenices, because we do not have more galactic clusters observations in the (U, B, V, R, I) system. We do plan to observe more clusters in this system.

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