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# UBV photoelectric photometry of the open cluster NGC 2539

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**Abstract.** Photoelectric *UBV* magnitudes have been determined for stars in the region of the cluster NGC 2539. We discuss the cluster membership of all the 135 photoelectrically observed stars, out of which 74 stars have been classified as cluster member. The average value of reddening is $E(B-V) = 0.08 \pm 0.02$ mag and the cluster distance is estimated at $1050 \pm 150$ pc. H–R diagram and age of the cluster are also discussed.

*Key words* : photometry—open cluster

## 1. Introduction

The intermediate age, ill-defined, open cluster C 0808 − 127 ≡ NGC 2539 is situated in the region centred around the coordinates : $\alpha = 08^{h}08^{m}.4$, $\delta = -12°$ 41′; $l = 233°.73$, $b = +11°.12$ (1950). Ruprecht (1966) has classified the cluster as of II 1m type. The cluster has not been studied in detail either photometrically or spectroscopically. Pesch (1961) and Zug (1933) have determined the spectral classes, with an error of approximately 2 sub-divisions, for some stars. Pesch (1961) has also determined the *UBV* photoelectric magnitudes for 59 stars in the cluster region. He has not observed the fainter stars of the cluster region and consequently the cluster sequence towards the fainter side is not known. No extensive photometric study of this cluster has yet been carried out.

The present study is aimed at determining the photoelectric *UBV* magnitudes and colours for a good number of stars in the cluster region, to establish the cluster membership of the stars, and to determine the cluster parameters.

## 2. Observations and reductions

The observations were carried out between 1975 February and 1978 March on the 104-cm Sampurnanand reflector of the Uttar Pradesh State Observatory. The method of observations and instrumentation are the same as described earlier (*cf.* Joshi 1980; Sagar & Joshi 1979). For standardizing the instrumental magnitudes and colours, we have used the photoelectric sequence given by Pesch (1961). The stars used for this purpose are marked in table 1. Standard stars numbered 96 and 102 were used for the determination of atmospheric extinction coefficients on various observing nights. The computed standard deviations of our observations are better than $\pm$ 0.02 mag in $U$, $B$, and $V$ filters. The observations have been made at zenith distances generally not exceeding 60 degrees. A minimum of two sets of observations, on different nights, were taken for each star and the average values adopted.

**Table 1.** Photoelectric *UBV* magnitudes and colours of the stars in the region of cluster NGC 2539. Member stars are represented by letter 'm' and probable members by 'pm'. Stars marked with asterisk belong to the photoelectric sequence of Pesch (1961)

| Star number Present | Star number Pesch (1961) | $V$ mag | $(B-V)$ mag | $(U-B)$ mag | Sp. type | Member-ship | Remarks† |
|---|---|---|---|---|---|---|---|
| 1* | 19 | 11.65 | 0.50 | 0.04 | | | |
| 2 | | 10.47 | 0.97 | 0.17 | | | |
| 3 | | 13.20 | 0.98 | 0.96 | | | |
| 4 | 14 | 10.48 | 0.34 | 0.09 | F2p | | 2 |
| 5 | | 13.01 | 0.42 | 0.01 | | pm | |
| 6 | | 12.65 | 0.24 | 0.21 | | m | |
| 7 | | 13.62 | 0.52 | —0.08 | | pm | |
| 8 | | 13.28 | 0.60 | 0.09 | | | |
| 9 | | 13.64 | 0.69 | — | | | |
| 10 | | 13.40 | 0.73 | — | | | |
| 11 | | 11.41 | 0.51 | 0.14 | | | |
| 12 | | 12.49 | 0.28 | 0.17 | | m | 4 |
| 13 | | 12.71 | 0.70 | 0.38 | | | |
| 14 | | 12.17 | 0.19 | 0.25 | | m | |
| 15 | 59 | 12.16 | 0.16 | 0.15 | | m | 1 |
| 16 | | 13.35 | 0.40 | 1.13 | | m | |
| 17 | | 11.96 | 0.23 | 0.18 | | pm | |
| 18 | | 10.68 | 1.03 | 0.78 | | m | |
| 19 | 58 | 12.01 | 0.41 | 0.00 | | | 1 |
| 20 | | 12.62 | 0.35 | 0.12 | | m | |
| 21 | | 13.38 | 1.07 | 0.74 | | | |
| 22 | | 13.46 | 1.10 | 1.19 | | | |
| 23 | | 12.24 | 0.91 | — | | | |
| 24 | 55 | 12.59 | 0.51 | 0.03 | | | 1 |
| 25 | 54 | 11.86 | 0.18 | 0.16 | | m | 1 |
| 26 | 53 | 13.79 | 1.30 | — | | | 1 |
| 27 | 56 | 12.43 | 0.19 | 0.15 | | m | 1 |
| 28 | | 11.72 | 0.93 | 0.73 | | | |
| 29 | | 11.99 | 0.92 | 0.55 | | | |
| 30 | | 14.24 | 0.79 | 0.67 | | | |
| 31 | 52 | 13.16 | 0.33 | 0.06 | | m | 1 |
| 32 | 57 | 12.15 | 0.17 | 0.15 | | m | 1 |
| 33 | | 13.28 | 0.60 | 0 09 | | m | |
| 34 | | 12.19 | 0.38 | 0.24 | | | |
| 35 | | 12.78 | 0.60 | 0.19 | | | |
| 36 | | 11.34 | 0.18 | 0.16 | | m | |
| 37 | | 10.91 | 0.97 | 0.65 | | m | |
| 38 | | 13.43 | 0.97 | 0.85 | | | |
| 39 | | 12.96 | 0.37 | —0.01 | | pm | |
| 40 | 60 | 10.96 | 0.69 | 0.29 | | | 1 |

*(Continued)*

**Table 1.** (*Continued*)

| Star number Present | Pesch (1961) | V mag | (B−V) mag | (U−B) mag | Sp. type | Member-ship | Remarks† |
|---|---|---|---|---|---|---|---|
| 41 | | 11.48 | 0.14 | 0.15 | | m | |
| 42 | | 12.22 | 0.22 | 0.13 | | m | |
| 43 | | 12.99 | 0.29 | 0.13 | | m | |
| 44 | | 12.32 | 0.33 | 0.15 | | pm | |
| 45 | | 13.00 | 0.55 | 0.18 | A5 | | 3 |
| 46 | | 12.46 | 0.18 | 0.15 | A5 | m | 3 |
| 47 | | 11.15 | 0.17 | 0.12 | A2 | m | 3 |
| 48 | | 11.88 | 0.14 | 0.16 | | m | |
| 49 | | 11.69 | 0.22 | 0.17 | A4 | m | 3 |
| 50 | | 11.55 | 0.97 | 0.67 | | | |
| 51 | 44 | 10.83 | 0.64 | 0.39 | A2 | | 1,3 |
| 52 | 46 | 11.80 | 0.18 | 0.13 | A3 | m | 1,3 |
| 53 | | 11.60 | 0.17 | 0.14 | G5 | m | 3 |
| 54 | 43 | 11.22 | 0.17 | 0.15 | A5 | m | 1,3 |
| 55 | 45 | 12.43 | 0.22 | 0.17 | A2 | m | 1,3 |
| 56 | | 11.86 | 0.15 | 0.16 | A2 | m | 3 |
| 57 | 50 | 11.40 | 0.20 | 0.17 | | m | 1 |
| 58 | 51 | 11.28 | 0.92 | 0.71 | | m | 1 |
| 59 | 42 | 11.14 | 0.93 | 0.70 | K0 | m | 1,3 |
| 60 | | 14.48 | 0.43 | 0.03 | | m | |
| 61 | | 12.25 | 0.34 | — | F2 | pm | 3 |
| 62 | | 13.72 | 0.43 | 0.03 | | | |
| 63 | | 14.41 | 0.89 | 0.67 | | | |
| 64 | | 13.02 | 0.28 | 0.10 | | m | |
| 65 | | 12.34 | 0.41 | — | | | |
| 66 | | 13.07 | 0.58 | 0.11 | | | |
| 67 | 26 | 10.70 | 1.04 | 0.93 | K0 | m | 1,2 |
| 68 | | 12.76 | 0.32 | 0.09 | A5 | m | 3 |
| 69 | | 12.49 | 0.20 | 0.15 | A3 | m | 3 |
| 70 | 49 | 12.48 | 1.05 | 0.96 : | | | 1 |
| 71 | | 11.61 | 0.27 | 0.15 | A3 | pm | 3 |
| 72 | 47 | 11.07 | 1.60 | 1.96 | | pm | 1 |
| 73 | 48 | 10.04 | 0.52 | 0.03 | | | 1 |
| 74 | 38 | 10.54 | 0.61 | 0.42 | F0 | | 1,3 |
| 75 | 41 | 12.43 | 0.25 | 0.20 | A2 | m | 1,3 |
| 76 | 40 | 12.05 | 0.25 | 0.12 | A3 | m | 1,3 |
| 77 | 39 | 11.82 | 0.21 | 0.14 | | m | 1 |
| 78 | | 12.76 | 0.58 | 0.09 | | | |
| 79 | | 13.59 | 0.91 | — | | | |
| 80* | 27 | 11.73 | 0.25 | 0.12 | | m | |
| 81 | | 11.91 | 0.10 | 0.19 | | | |
| 82 | | 13.68 | 0.71 | — | | | |
| 83 | | 11.90 | 0.48 | —0.01 | | | |
| 84 | 12 | 12.16 | 0.50 | 0.14 | | m | 4 |
| 85 | | 12.96 | 0.33 | 0.19 | | m | |
| 86 | | 13.16 | 0.27 | — | | m | |
| 87 | 32 | 10.55 | 1.01 | 0.80 | | m | 1 |
| 88 | | 13.05 | 0.32 | 0.24 | | m | |
| 89 | | 12.61 | 0.22 | 0.20 | | m | |
| 90 | 33 | 11.50 | 0.16 | 0.13 | | m | 1 |

(*Continued*)

**Table 1.** (*Continued*)

| Star number Present | Pesch (1961) | V mag | (B−V) mag | (U−B) mag | Sp. type | Member-ship | Remarks† |
|---|---|---|---|---|---|---|---|
| 91 | | 13.99 | 0.49 | 0.14 | | m | |
| 92 | | 11.96 | 0.23 | 0.18 | | m | |
| 93 | 31 | 12.03 | 0.14 | 0.14 | | m | 1 |
| 94 | | 13.17 | 0.34 | 0.18 | | m | |
| 95 | 5 | 11.94 | 0.20 | 0.15 | | m | 1 |
| 96* | 4 | 9.27 | 0.17 | 0.10 | A5 | | 2 |
| 97 | | 12.79 | 0.23 | 0.24 | | m | |
| 98 | 3 | 12.06 | 0.17 | 0.10 | A3 | m | 3 |
| 99 | 2 | 12.97 | 0.18 | 0.16 | | | |
| 100 | | 12.92 | 0.30 | 0.14 | | m | |
| 101 | | 13.15 | 0.25 | 0.17 | | m | |
| 102* | 6 | 10.74 | 0.94 | 0.76 | B5 | m | 3 |
| 103 | | 13.69 | 0.43 | 0.18 | | m | |
| 104 | | 12.38 | 1.00 | 0.93 | | | |
| 105 | 34 | 11.85 | 0.15 | 0.14 | | m | 1 |
| 106* | 1 | 11.36 | 0.16 | 0.11 | | m | 4 |
| 107 | 37 | 13.29 | 0.35 : | 0.08 | | m | 1 |
| 108 | 36 | 11.65 | 0.12 | 0.12 | | m | 1 |
| 109 | | 13.69 | 0.43 | 0.18 | | pm | |
| 110 | | 12.94 | 0.55 | 0.13 | | m | |
| 111 | | 13.49 | 0.54 | 0.19 | | m | |
| 112 | | 12.78 | 0.46 | 0.16 | | | |
| 113 | 35 | 10.97 | 0.20 | 0.16 | | m | 4 |
| 114* | 28 | 11.02 | 0.98 | 0.79 | | | |
| 115 | | 12.78 | 0.60 | 0.19 | | | |
| 116 | | 12.64 | 0.62 | 0.11 | | | |
| 117 | | 12.22 | 0.37 | 0.25 | | | |
| 118 | | 13.79 | 1.30 | — | | | |
| 119* | 8 | 10.71 | 0.65 | 0.25 | | | |
| — | 7 | 11.54 | 1.07 | 1.08 | | | 1 |
| — | 9 | 12.06 | 0.87 | 0.39 | | | 1 |
| — | 10 | 12.45 | 1.22 | 1.40 | | | 1 |
| — | 11 | 12.57 | 1.14 | 1.04 : | | | 1 |
| — | 13 | 11.44 | 0.17 | 0.13 | A0 | m | 1,2,4 |
| — | 15 | 11.30 | 1.63 | 2.07 : | | | 1 |
| — | 16 | 10.56 | 1.49 | 1.88 | | | 1 |
| — | 17 | 9.13 | 0.20 | 0.16 | | | 1 |
| — | 18 | 11.93 | 1.13 | 1.23 | | | 1 |
| — | 20 | 11.34 | 0.57 | 0.09 | | m | 1,4 |
| — | 21 | 9.56 : | 1.33 | 1.56 | K5I-II | | 1,2 |
| — | 22 | 10.98 : | 1.20 | 1.34 | | | 1 |
| — | 23 | 12.90 : | 0.87 | 0.64 | | | 1 |
| — | 29 | 11.01 | 1.44 | 1.79 | | | 1 |
| — | 30 | 9.13 | 0.10 | 0.09 | A2 | | 1,2 |
| — | 61 | 9.15 | 1.62 | 1.75 | M4III | | 1,2 |

†1. Data borrowed from Pesch (1961); 2. Spectral type estimated by Pesch (1961); 3. Spectral type estimated by Zug (1933); 4. Member according to criterion (b) only (see section 4).

Figure 1 shows the star field of the cluster region and the star numbers. A total of 88 stars have been observed in the cluster region, out of which 12 stars (*i.e.* 1, 4, 80, 84, 96, 98, 99, 102, 106, 113, 114, 119 in table 1) were also observed by Pesch (1961). In figure 2, we compare the present values with those of Pesch (1961).

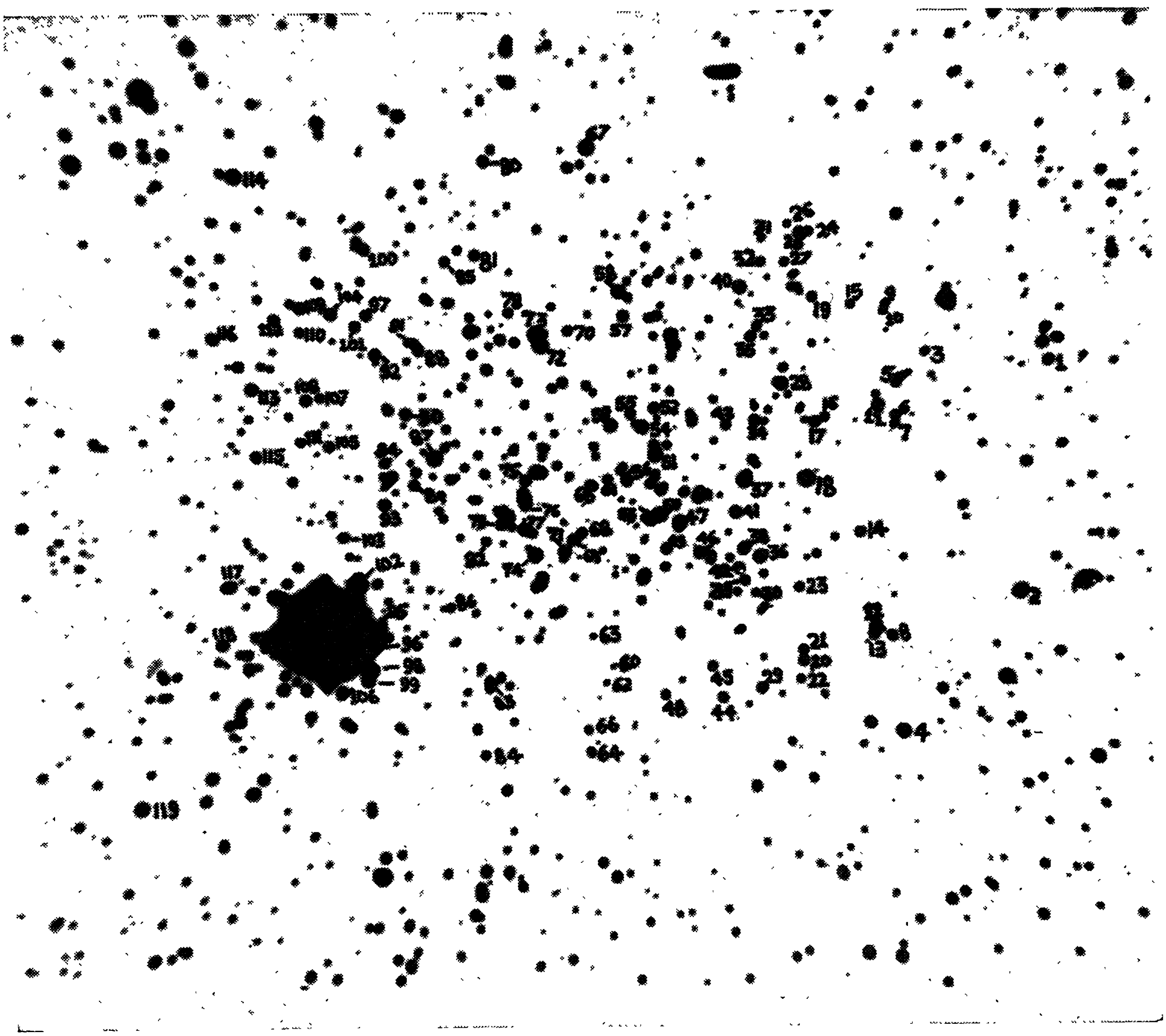

**Figure 1.** Identification chart for the cluster NGC 2539. North is at the top, east to the left.

Since the agreement between the two studies is good, for subsequent studies we have included all the stars observed photoelectrically in the region of the cluster NGC 2539.

## 3. Reddening

The $(U - B)$, $(B - V)$ diagram of NGC 2539 is plotted in figure 3. We have fitted the intrinsic main sequence (MS) given by Schmidt-Kaler (1965) by sliding fit method, taking the slope of the reddening line to be 0.72. We found that the average value of the reddening is $E(B - V) = (0.08 \pm 0.02)$ mag. Based on the spectral classes of the cluster stars, Pesch (1961) has determined the mean value of

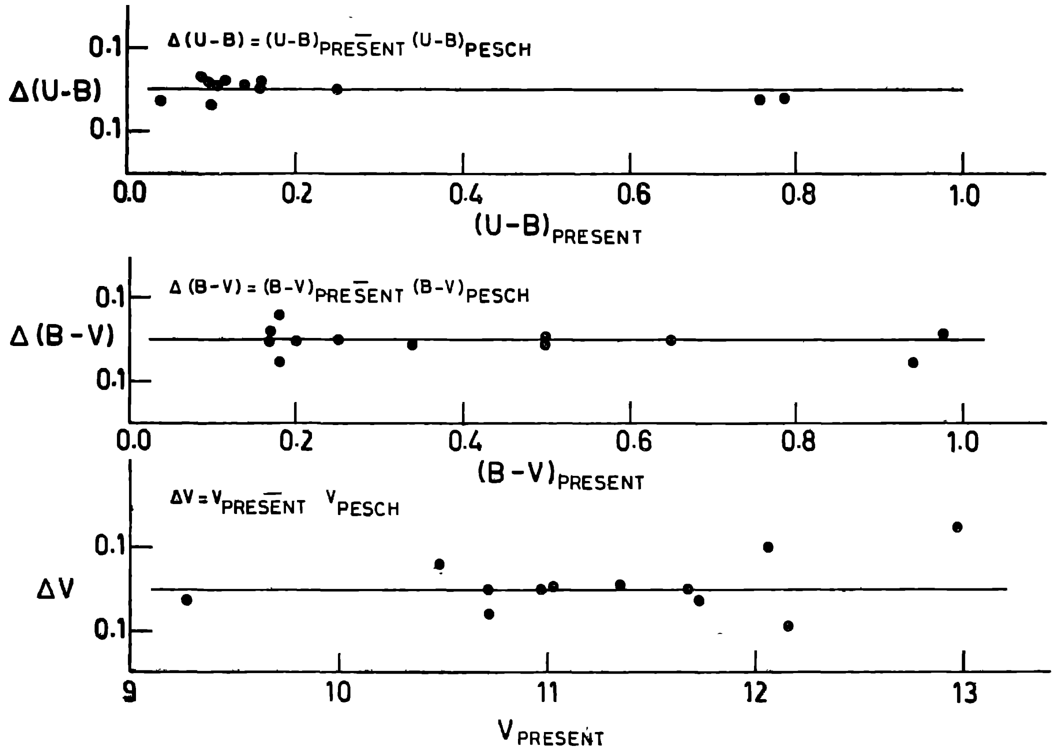


**Figure 2.** A comparison of present *UBV* values with those of Pesch (1961) for the common stars.

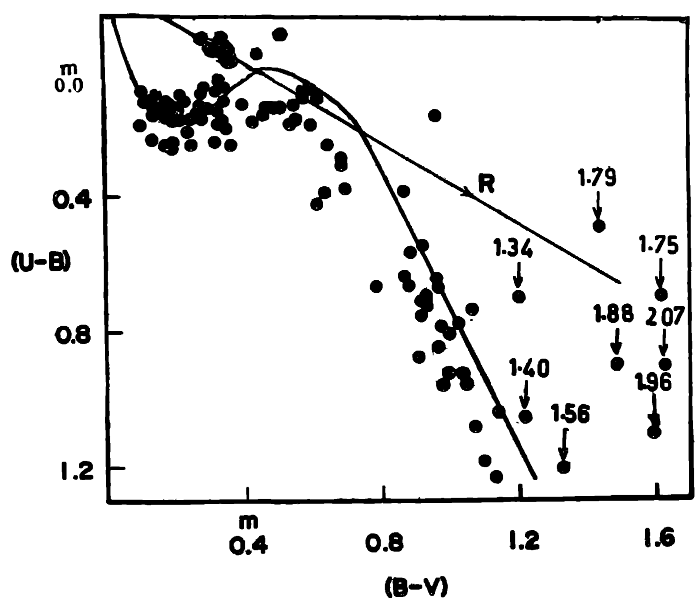


**Figure 3.** $(U - B)$ versus $(B - V)$ diagram of the cluster NGC 2539.

the cluster reddening to be $E(B - V) = (0.10 \pm 0.05)$ mag. Thus our estimate of cluster reddening is in fair agreement with that of Pesch (1961).

## 4. Membership

As the proper motion and radial velocity studies of this cluster region are not available, we have used the colour-magnitude and colour-colour diagrams of stars in the cluster region and the position of the stars in the sky to separate the cluster stars from the field stars. The cluster membership of the stars is decided jointly on the following criteria :

(a) Stars have been considered as cluster members if their spatial positions are within the circle of ~ 10 arcmin (*cf.* Pesch 1961). Such stars are 102 in number.

(b) The location of the star in the colour-colour diagram (figure 3) should be such that the reddening value, $E(B-V)$, of the star must be compatible with the average $E(B-V)$ value of the cluster. In addition to this, the star should also fall into the well defined cluster sequences present in both the colour-magnitude diagrams (figures 4 and 5) of NGC 2539.

In our sample 68 stars, including 9 probable cluster members, satisfy both membership criteria (a) and (b), whereas other 6 stars (marked in table 1) satisfy only the criterion (b). Pismis & Bozkurt (1977) have estimated a cluster diameter of 36 arcmin by performing star counts in and around the region of NGC 2539. Therefore, we have considered as cluster member all the 74 stars of our sample, that satisfy either both the membership criteria or only the criterion (b) and the cluster parameters are determined using these stars only.

## 5. Distance

The distance modulus to the cluster NGC 2539 has been obtained by fitting the ZAMS given by Schmidt-Kaler (1965) in the $V$, $(B-V)$ and $V$, $(U-B)$ digrams of the cluster (figures 4 and 5). The solid lines represent the ZAMS fitted to the

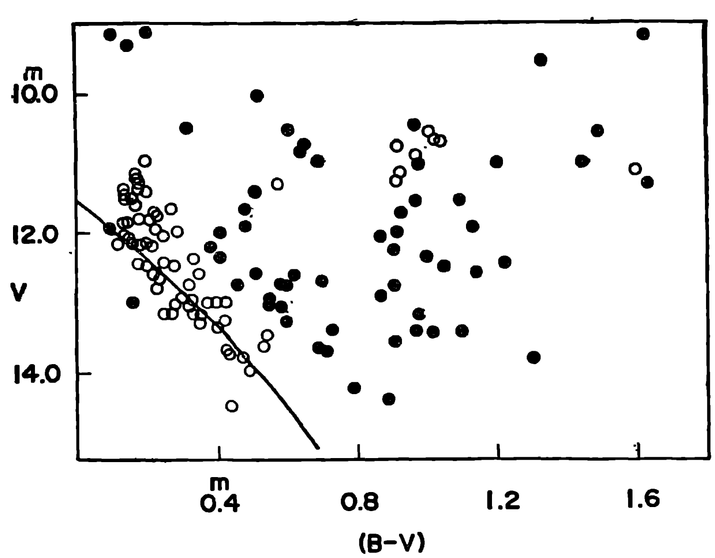


**Figure 4.** $V$ versus $(B-V)$ diagram of the cluster NGC 2539. Open circles and filled circles represent cluster members and non-members respectively.

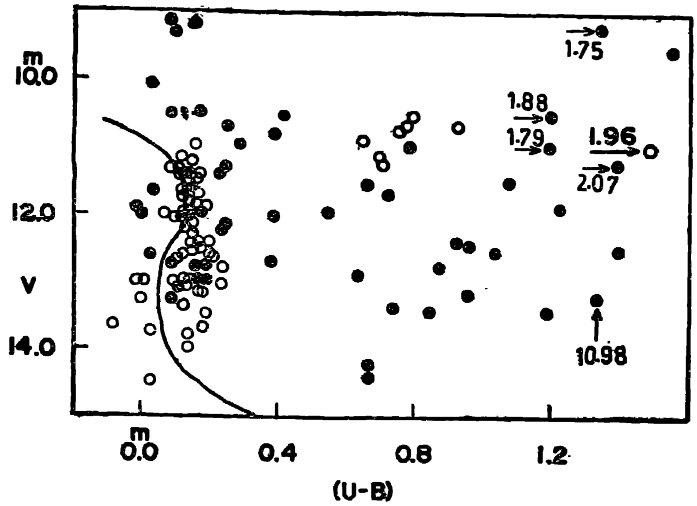


**Figure 5.** $V$ versus $(U - B)$ diagram of the cluster NGC 2539. Symbols as in figure 4.

observed points for a reddening value of $E(B - V) = 0.08$ mag and $E(U - B) = 0.06$ mag, respectively. To avoid the effects of evolution, we have not considered the evolved part of the MS. The apparent distance modulus determined from figures 4 and 5 comes out to be 10.25 ($\pm$ 0.2) mag and 10.50 ($\pm$ 0.2) mag, respectively. A mean value of 10.37 ($\pm$ 0.3) mag has been adopted as the apparent distance modulus to the cluster. Taking the value of $R$, ratio of total to selective absorption, equal to 3.25 (*cf.* Moffat & Schmidt-Kaler 1976), we get the true distance modulus to the cluster :

$$V_0 - M_V = 10.1\ (\pm\ 0.3)\ \text{mag}.$$

This gives the distance to the cluster as (1050 $\pm$ 150) pc. This value of distance modulus is in good agreement with the value 10.5 ($\pm$ 0.5) mag estimated by Pesch (1961) for NGC 2539 using evolved part of the cluster MS. For the same cluster the distance determined by other earlier investigators ranges between 740 pc and 1820 pc (*cf.* Alter, Ruprecht & Vanysek 1970) with a modal value of 1200 pc. The present distance estimate is based on the use of the brighter and fainter part of the cluster main sequence, and consequently the value is more reliable in comparison to the other distance estimates.

## 6. H-R diagram

The H–R diagram of NGC 2539 has been plotted in figure 6 for a uniform reddening of $E(B - V) = 0.08$ mag and an apparent distance modulus of 10.37 mag. From the H–R diagram of the cluster the following inferences can be drawn :

(i) A well defined cluster main sequence which extends from $M_V = 0.6$ mag to $M_V = 3.8$ mag is clearly visible. Sixty-six stars populate the MS part of the cluster.

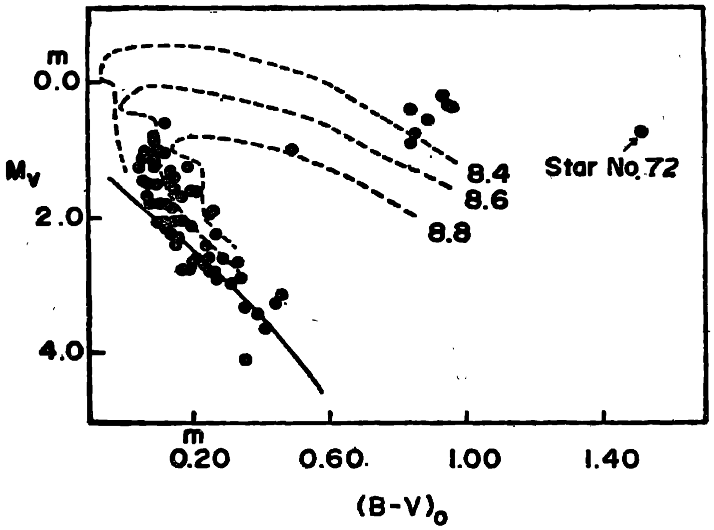


**Figure 6.** H-R diagram of the cluster NGC 2539.

(ii) An evolutionary effect is clearly visible in the upper part of the cluster MS. Eight stars have reached the giant phase of their evolution out of which seven stars are yellow giants and one star (star numbered 72) is a probable red giant.

(iii) The H-R diagram of this cluster appears to be similar to the diagrams of the clusters NGC 752, 1027, 2251, 2281, 6383, IC 4665, NGC 6494 and 6633 (*cf.* Hagen 1970).

## 7. Cluster age

We have used the isochrones for population I ($X = 0.70$, $Z = 0.03$) given by Hejlesen (1980) for a determination of the cluster age after transforming them from the ($M_{bol}$, log $T_e$) plane to the ($M_V$, $(B - V)_0$) plane by using the (($B - V)_0$, log $T_e$) and (B.C., log $T_e$) transformations given by Allen (1973). These isochrones have been plotted in the H-R diagram of the cluster (figure 6) from which we deduce the age of the cluster to be $t = (2.5 \text{ to } 6.3) \times 10^8$ yr.

We have also estimated the age of the cluster on the basis of the turn-off point (*cf.* Sandage 1957). The value of $(B - V)_0$ colour and $M_V$ at the turn-off point are estimated to be 0.08 mag and 1.5 mag, respectively. The corresponding mass and luminosity are taken from Schmidt-Kaler (1965). The age estimate comes out to be $t = 5.4 \times 10^8$ yr which is in fair agreement with the age estimated using the isochrones above as well as with the value $t = 7.9 \times 10^8$ yr given by Sagar *et al.* (1986) on the basis of age distribution function of the cluster members.

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