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UBV photometry of open cluster in the Cassiopeia region. I.Photoelectric observations of NGC 436 and 637*

G. Huestamendia[1], G. del Rio[1] and J.-C. Mermilliod[2]

[1] Observatorio Astronómico de Madrid (Instituto Geográfico Nacional), Alfonso XII, 3 SP-28027 Madrid, Spain
[2] Institut d'Astronomie de l'Université de Lausanne, CH-1290 Chavannes- des-Bois, Switzerland

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Abstract. — Photoelectric *UBV* observations of 34 and 27 stars in NGC 436 and 637, two open clusters not yet studied in this system, have been obtained. NGC 436 (m-M = 13.60, $E(B$-$V)$ = 0.48, $\log t$ = 6.3 × 10^7yr) appears similar in age to the Alpha Persei cluster, while NGC 637 (m-M = 14.10, $E(B$-$V)$ = 0.66, $\log t$ = 1.5 × 10^7yr) is similar to NGC 884. The respective distances (2600 pc and 2500 pc) locate both clusters within the Cassiopeia-Perseus spiral arm.

Key words: open cluster — *UBV* photometry.

1. Introduction.

During the stay of one of us (GH) at the Institute of Astronomy of the University of Lausanne we initiated a comprehensive program to determine the luminosity function of young open clusters and study the stellar formation history in the Cassiopeia region. This part of the sky contains well know open clusters like NGC 457, 581, 654, 663 which define the Perseus (+*I*) spiral arm. They have already been extensively observed because they contain interesting and rare stars like blue and red supergiants. In the first paper of this series we present *UBV* photolectric observations of stars in two more clusters found on the same POSS plate (# 1240 ; 1^h28, $+60^0$) : NGC 436 and 637. In this context first *UBV* photoelectric observations of NGC 659 and new data for stars in NGC 654 have also been made at Calar Alto (Spain). Several CCD frames have been obtained at the Observatorio del Roque de los Muchachos (La Palma, Spain) covering the areas of NGC 436, 457, 637, 654, and 659.

We shall also analyse the available *UBV* data of the other clusters to obtain homogeneous data and better parameter and age estimations. Although most published data were reduced to the international *UBV* system, there remains several potential sources of problems : (1) a large fraction of the existing photometric data is based on photographic material, which presents more or less large systematic and random errors, as revealed by the analysis performed so far ; (2) the difference in matching of the standard system and the standard stars used, especially in the *U*-band , may result in zero-point differences in the colour indices which affects the age estimation ; (3) the photometry of individual stars in these remote and dense clusters is often difficult in presence of crowding, and the choice of positions for sky measurements may be critical. All these facts contribute to the scatter observed in the colour-magnitude diagrams, in addition to the astrophysical causes of dispersion. Therefore, it is important to use the best photometric data and we have undertaken such an analysis for most well-studied clusters of the Cassiopeia-Perseus region. Results on NGC 581 will be presented in a forthcoming paper (Huestamendia and Mermilliod, 1990).

2. Observations.

The photoelectric *UBV* observations were made during several runs from 1985 to 1988 with the 1.52−m reflector of the Observatorio Astronómico de Madrid (IGN) at Calar Alto (Spain). A pulse counting mode photometer equipped with a dry-ice cooled RCA 31034A (EMI 98160B in 1988) photomultiplier was used together with the following Schott filter combinations :

U :	UG1/1mm	+SO_4Cu/5mm ;	
B :	BG12/1mm	+BG18/1mm	+GG400/1mm ;
V :	GG495/2mm	+BG18/1mm.	

Send offprint requests to: G. del Rio.

* Based on observations made with the 1.52-m reflector of the Observatorio Astronómico de madrid (IGN) at calar Alto (Spain) and at the Haute-provence Observatory (France).

For each observing run we observed standard stars from Neckel and Chini (1980) or Landolt's (1983) lists. Counting errors were kept under the 1% level, except for the stars otherwise specified (:) in tables 1 and 3 for which the errors reach 2% . Constant diaphragms were used during each observing run unless otherwise indicated in Tables 1 and 3. The reduction of these observations has been carried out with the program developed by Garcia-Pelayo (Instituto de Astrofisica de Andulacia, IAA), based on Young's (1967) method. All possible nightly tendencies of the observation residuals with azimuth, hour angle, colour and observing time have been taken into account and the corresponding corrections applied. For the standard stars, rms errors smaller than 0.02 mag were achieved.

3. Discussion.

3.1. NGC 436.

NGC 436 (C0112+585, RA = $1^h12^m.5$, Dec. = $58^0 33'$, 1950) is located half a degree north-east of NGC 457. It has been studied by Boden (1950) who obtained photographic magnitudes for 1063 stars and a well-defined cluster main sequence, and by Alter (1944). Becker and Stock (1958) published RGU colour-magnitude diagrams. The distance of 2220 pc (Boden, 1951) results from a combination of photographic magnitudes and spectral types using the Pleiades sequence as reference. This cluster is potentially interesting due to the presence near its center of a red star # 23 and of # 113 (BD + 58^0 206) classified F2 I by Hardorp *et al.* (1959).

The sample selected from Boden's list includes most stars brighter than $m_{pv} = 15.5$ within 2.5 minute of arc from the center, i.e. stars up to # 158. The membership was estimated on the basis of Boden's colour-magnitude diagram, and the measurability was judged from an enlargement from the POSS atlas (Fig. 1a). Therefore bright central stars (# 6, 13 and 23) could not be observed because of crowding and we hope to obtain magnitudes and colours from the CCD data. A few red non-members were added to the observing list in order to use them in the transformation of the CCD data. Altogether 34 stars were measured. The results are given in Table1, which gives Boden's numbers, his rectangular co-ordinates (in mm on the original plate) for identification of the stars on the map (Fig. 1b), the *UBV* data and the number of observations, and remarks : NM stands for non-member,diaph3, for specific use of a smaller diaphragm. Star # 1 appears variable on the basis of our 3 measurements . All observed stars, except the three redder than *B-V* = 1.0 (all non-members) are plotted in Figures 2 and 3. The colour excess determined by eye-fitting of the *U-B* / *B-V* sequence is equal to $E(B\text{-}V) = 0.48$ mag. This is much larger than the value (0.19) found in Lynga's (1988) compilation. The final colour-magnitude diagram (Fig. 4) contains only the probable members and shows a young cluster, similar in age to Alpha Persei (log t = 7.80) and located at 2600 pc ($m\text{-}M = 13.60$). The isochrone has been computed from models including core overshooting and mass loss published by Maeder and Meynet (1989).

The 9 stars (# 1, 4, 5, 18, 20, 43, 58, 68, 73) which form the cluster core (inside $R = 2.5$ units) form a very tight sequence both in the colour-colour and colour-magnitude planes. The parameters derived from these 9 stars are : $E(B\text{-}V) = 0.50$, $m\text{-}M = 13.75$. At this distance from the Sun, it is difficult to correctly take into account the depth effect : since the Milky Way field is rather rich in that part, there may be other stars of about the same age in the adjacent field and one cannot search for members too far from the cluster center.

The star # 23 has a very red colour (CI = 1.87) in Boden (1950) and was classified K0 by Trumpler (1930). As a potential evolved red member, it has been observed with the radial-velocity scanner CORAVEL from the Haute-provence Observatory (France). The three individual velocities are given in Table 2. The mean RV is equal to -74.37 ± 0.26 km s^{-1} and presents no signs of variability in the interval of 1083 days covered by the observations. There are no radial velocity data for other stars in the cluster, and its membership cannot be tested in this way. This star could not be observed photometrically due to the proximity of neighbouring stars. The supergiant star # 113 has unfortunately not been observed too. The BD number quoted in the NLS catalogue (BD + 58^0 204) should, to our opinion, be attached to the star # 23 instead, # 113 being BD + 58^0 206. Photometric observations and spectral classifications of these two evolved stars would be very interesting to asses their membership.

3.2. NGC 637.

NGC 637 (C0139 + 637, RA = $1^h39^m.4$, Dec = $63^0 45'$, 1950) has been studied by Grubissich (1975) in the RGU photographic system. He found a distance of 2400 pc, an earliest spectral of b1 and located the cluster in the Perseus arm. The selection of the stars has been done on the basis of the (*G*, *U-G*) diagram which offers a very good separation between members and field stars. Most members were observed in *UBV*, except those located in the very crowded center around star # 8.

The results are given in table 3, following the numbering system of Grubissich (1975). Stars 73 and 74 are the two brighter stars which form the central crowded image not measured by Grubissich. These two stars are not easy to observe separately and the *UBV* data are based on one measurement only. The colour excess estimated from the colour-colour diagram (Fig. 6) is equal to $E(B\text{-}V) = 0.66$. From the fitting of the ZAMS in the (*V*, *U-B*) diagram (Fig. 7) we determine a distance modulus equal to $m\text{-}M = 14.10$. The isochrone computed from Maeder and Meynet (1989) models with core overshooting and mass loss (Fig. 8) gives an age of 1.5×10^7 yr ($\log t = 7.15$). The distance is equal to 2500 pc and the age is very similar to the other clusters in the Perseus arm. Star # 57 is non-member owing to its location in the colour-magnitude diagrams. To our knowledge no Be stars have yet been identified in this cluster, although there may be some. These results are in good agreement with those of Grubissich (1975), but again quite different from those found in Lynga's compilation.

A conspicuous gap is present in the colour-magnitude diagrams between $11.0 < V < 12.2$ mag. It has been verified that it does not result from the incompleteness of the sample since there are no other stars that bright in the vicinity of the cluster center. It could only partly be due to the binary character of stars # 3, 4 (if member) and 11 which would fall on the isochrone if their magnitude were corrected by 0.75 mag. A similar feature has been detected in NGC 6871 (Garcia-Pelayo, 1989). This gap may be related to that found by Mermilliod (1976) at the types B1-B2. Its width may also be enhanced by the small number of stars in the upper part of the main sequence.

4. Conclusion.

This paper presents the results derived from *UBV* photoelectric observations of two clusters, NGC 436 and 637, previously unstudied in this system. These data allowed to derive new and more accurate parameters for each cluster and are also intended to calibrate the CCD frames we obtained. The results are summarized below :

	NGC 436	NGC 637
$m - M$	13.60	14.10
$E(B-V)$	0.48	0.66
$(V - M_V)_0$	12.06	11.89
distance	2600pc	2500pc
age	6.3×10^7yr	1.5×10^7yr

This gives to NGC 436 an age similar to the Alpha Persei cluster, while NGC 637 is more similar to NGC 884, although it is less rich and does not contain any supergiant star. Further results will be derived from the analysis of the deeper *UBV* CCD frames.

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TABLE 1. *UBV Observations of NGC 436.*

No	X	Y	V	B-V	U-B	n	Remarks
1	+0.0	+0.0	14.34	0.42	0.12	3	Var
4	+0.3	+0.3	11.27	0.35	-0.14	2	BD +58 205
5	+1.1	+1.5	13.37	0.34	-0.19	2	
7	+0.5	+1.9	13.85	0.33	-0.08	2	
8	+0.1	+1.2	14.46	0.40	0.01	1	
9	+0.1	+1.5	14.62	1.28	0.82	1	NM
15	-1.2	+1.2	15.02	0.40	0.23:	1	
18	-0.8	+0.0	15.22	0.49	0.40:	1	
20	-0.8	-0.7	14.00	0.37	-0.06	4	
25	+0.4	-0.5	13.99	1.38	1.03	2	NM
32	+3.0	+0.0	13.64	0.34	-0.13	6	
33	+2.9	+0.8	13.95	0.37	0.01	2	
40	+1.9	+1.8	14.84	0.41	0.19	1	
43	+0.5	+2.4	12.13	0.30	-0.30	5	
50	-0.9	+1.9	15.06	0.38	0.20	1	NM
51	-2.0	+1.5	13.46	0.33	-0.09	5	
53	-2.9	+1.2	16.15	0.86		1	NM
54	-3.0	+0.5	12.82	0.36	-0.08	5	
58	-1.7	-1.5	14.03	0.39	0.00	3	
62	-2.2	-3.3	15.07	0.49	0.26	3	NM
65	+0.1	-3.4	15.29	0.63	0.26	1	NM
67	+0.6	-2.6	15.19	0.42	0.22	2	NM
68	+0.8	-2.2	12.54	0.35	-0.22	6	
69	+1.1	-2.8	11.11	0.24	-0.12	3	NM
72	+1.4	-1.8	16.24	1.30	0.82:	1	NM, Diaph 3
73	+1.4	-1.4	12.68	0.30	-0.35	3	
77	+3.0	-0.5	14.65	0.34	0.09	7	NM
78	+2.6	-0.4	13.55	0.32	-0.12	2	
86	+1.3	+4.0	13.92	0.36	-0.11	4	
89	-0.5	+4.2	14.23	0.38	0.03	4	
90	-0.6	+5.6	14.98	0.43	0.23	4	
98	-3.9	+0.6	15.34	0.50	0.42:	1	Diaph 3
112	+1.7	-5.4	15.53	0.58	0.37	3	NM
147	-6.4	+1.8	13.27	0.39	-0.20	5	NM
158	-1.5	-6.1	13.29	0.46	0.30	3	NM

TABLE 2. *Radial velocity observations of NGC 436 # 23.*

JD	Vr	eps
2446032.323	-74.42	0.42
2446384.314	-73.91	0.66
2447115.397	-74.51	0.44

TABLE 3. *UBV Observations of NGC 637.*

No	V	B-V	U-B	n	Remarks
1	10.02	0.40	-0.53	3	
3	10.65	0.41	-0.42	3	
4	10.95	0.45	-0.38	3	
6	10.39	0.42	-0.51	5	
7	10.71	0.40	-0.48	3	
11	12.74	0.42	-0.27	2	
13	13.20	0.45	-0.19	4	
16	14.05	0.51	-0.05	6	
17	13.39	0.48	-0.19	1	
18	13.78	0.56	0.14	6	Var
27	13.63	0.55	-0.06	3	
31	14.75	0.52	0.21:	1	
33	13.20	0.44	-0.29	4	
35	12.22	0.47	-0.32	2	
36	13.32	0.54	0.02	3	
37	13.64	0.52	-0.10	4	
39	14.10	0.49	0.00	2	
40	14.13	0.49	0.01	3	
44	14.77	0.52	-0.02:	1	
46	13.80	0.49	-0.05	2	
47	15.34	0.61	0.35:	1	
50	14.15	0.49	0.17	1	
55	14.08	0.54	0.00	4	
56	12.48	0.41	-0.35	6	
57	12.35	0.61	0.23	3	NM
73	10.18	0.35	-0.52	1	
74	10.79	0.40	-0.41	1	

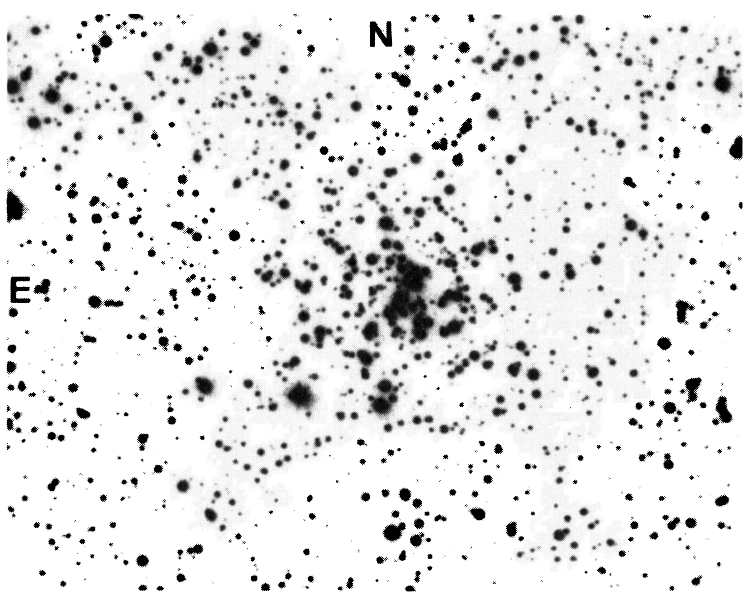

FIGURE 1a. Field of the cluster NGC 436 from the POSS atlas.

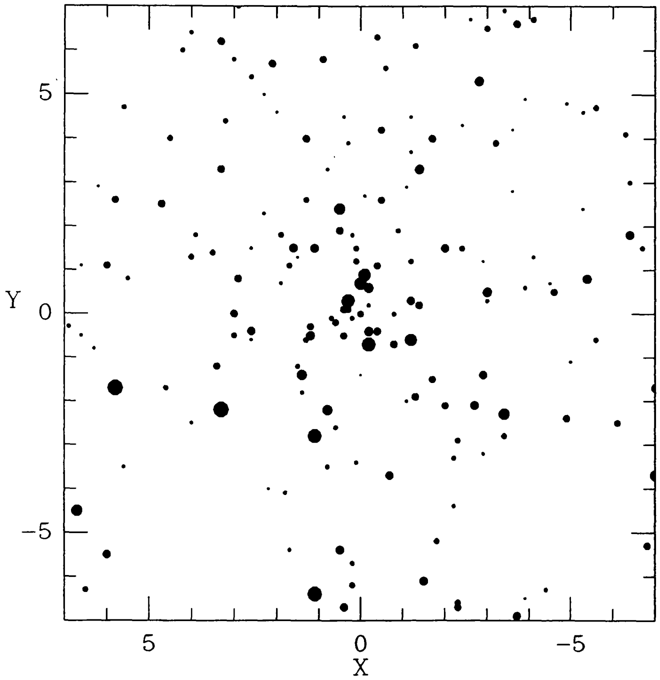

FIGURE 1b. Identification chart plotted from the (X,Y) positions of Boden (1950), in arbitrary units.

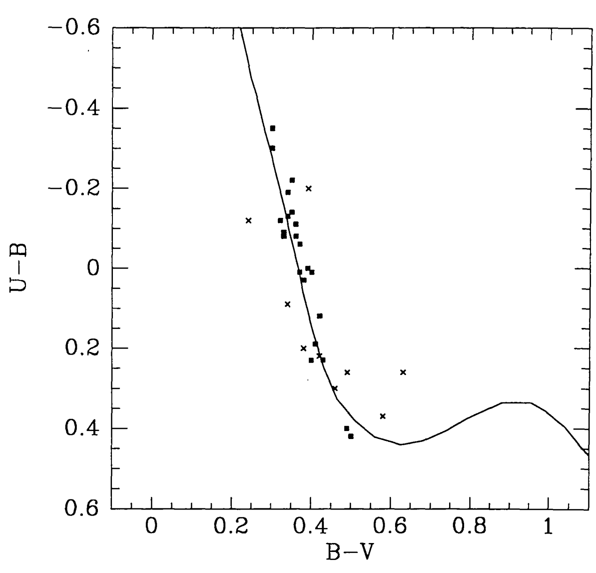

FIGURE 2. Colour-colour diagram of NGC 436. The *UBV* sequence is fitted with a colour excess equal to 0.48. Filled square represent the selected members, and the crosses (×), the non-members.

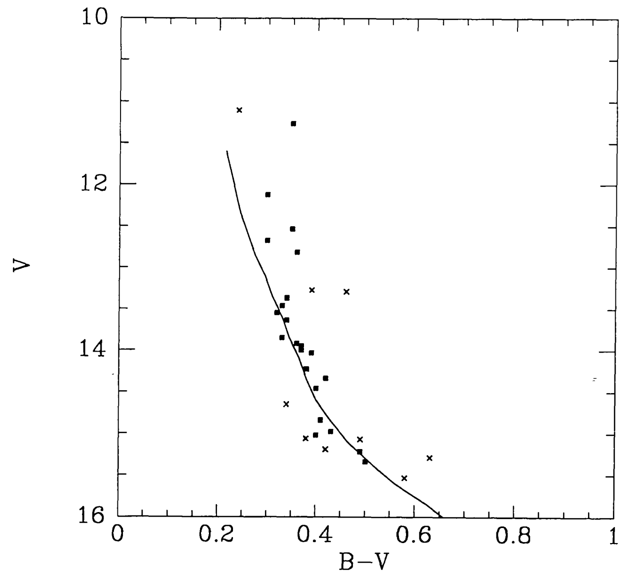

FIGURE 3. Observed colour-magnitude diagram for NGC 436. Symbols as in Figure 2. The ZAMS is plotted according to a distance-modulus equal to 13.60.

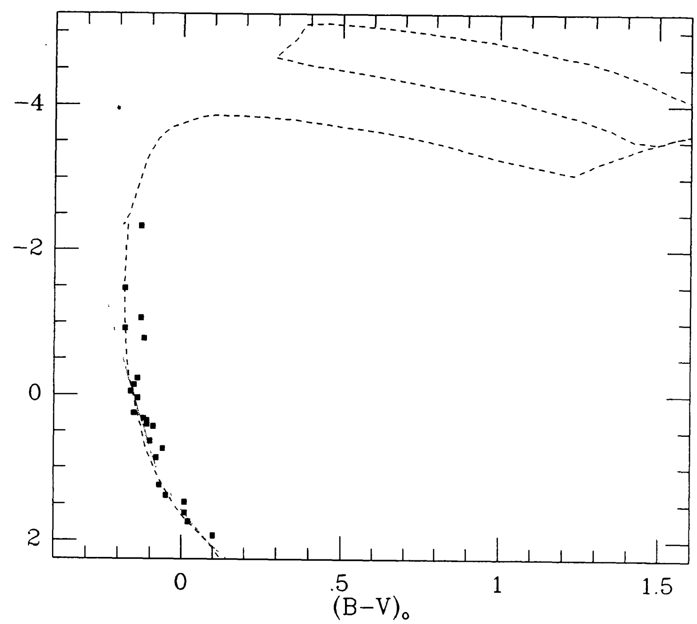

FIGURE 4. Colour-magnitude diagram of NGC 436 (members only) with an isochrone ($\log t$ = 7.80) from Maeder and Meynet (1989) models. This cluster is similar in age to the alpha Persei cluster.

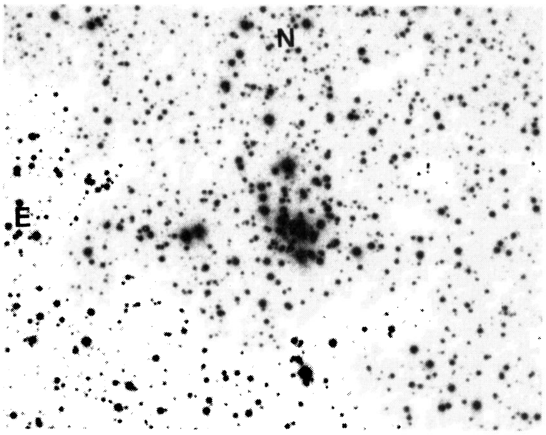

FIGURE 5. Field around NGC 637 from an enlargement of the POSS atlas.

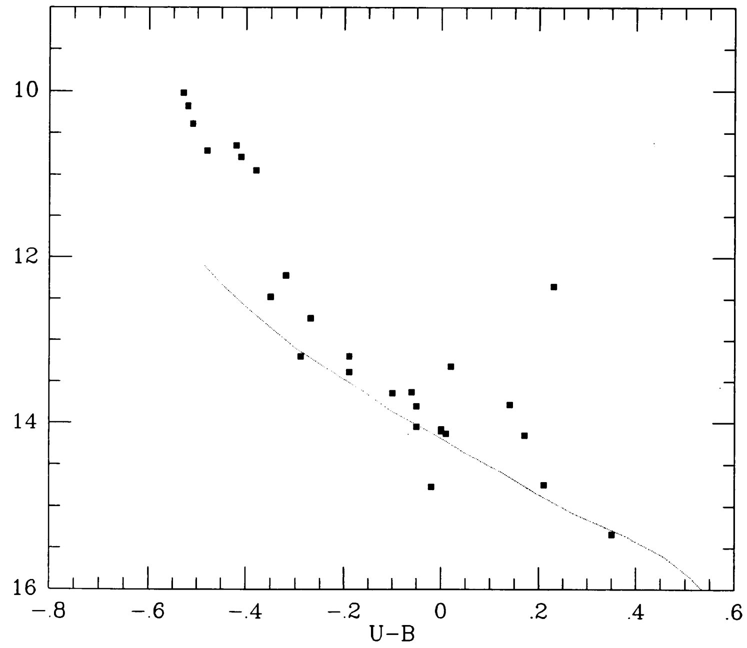

FIGURE 7. Colour-magnitude diagram of NGC 637. The fitting of the ZAMS gives a distance modulus 14.10. There is as large gap at $11 < V < 12$. Only star # 57 appears to be non-member.

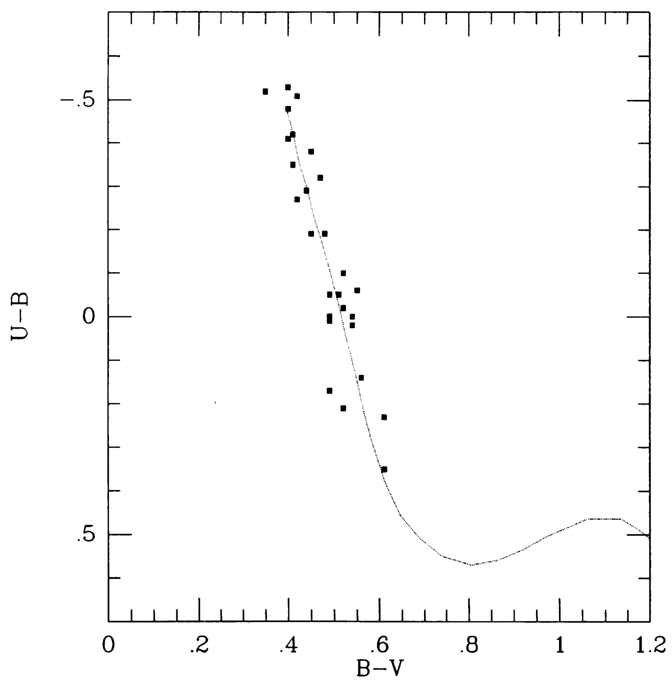

FIGURE 6. Colour-colour diagram of NGC 637. The sequence is fitted with a colour excess equal to 0.66 mag.

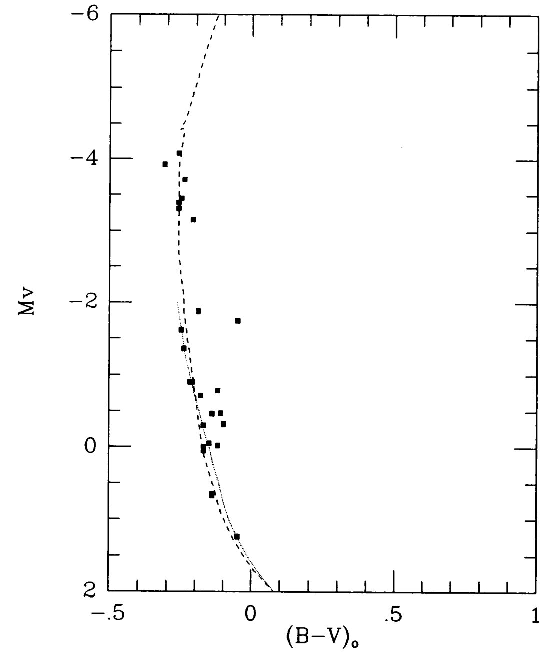

FIGURE 8. Colour-magnitude diagram of NGC 637. An isochrome ($\log t = 7.15$) from Maeder and Meynet (1989) models has been superimposed to the cluster data.