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Integrated photometric parameters of open and globular clusters

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Abstract. In this work we have discussed *UBV* parameters of 142 galactic clusters and 32 globular clusters. Comparison of the integrated parameters of galactic clusters with the theoretical ones confirms the validity of the basic assumptions about the stars, which have been used to calculate the theoretical parameters. Evolutionary effects on integrated parameters of open clusters have also been discussed.

Key words : integrated parameters—open clusters—globular clusters

1. Introduction

The integrated magnitudes and colours of galactic as well as globular clusters within the galaxy are important parameters, in as much as they allow comparisons to be made with such parameters of clusters in other galaxies, wherein it is impractical to observe individual stars, or even to visually separate out open and globular clusters. On the other hand, in such cases the integrated parameters can still be observable. Based on these, the parameters of galactic clusters for which the colour-magnitude diagrams cannot be constructed may be estimated (Gray 1965; Piskunov 1974). For studies of stellar populations in galaxies, it would be desirable to have a knowledge of the integrated appearance of open and globular clusters which are respectively prototype of populations I and II. Also, a comparison of these observational parameters with the theoretical ones can be used to check the validity of the basic assumptions of the theory of the internal structure and evolution of stars, made in these theoretical calculations.

Integrated parameters of the galactic clusters have been computed by Gray (1965) and Schmidt-Kaler (1967). However, for lack of definitive information about cluster membership these authors made no attempts to sort out the field stars. In order to lessen the effect of field stars, Gray (1965) considered only clusters with apparent distance moduli not exceeding 12.0 mag. The effect of the field stars on the integrated parameters has been discussed by Piskunov (1974) who calculated the integrated parameters for 22 open clusters with known membership and compared them with his theoretical model given earlier (Piskunov 1972). An extension of this work, in the light of subsequent data, was therefore considered worthwhile.

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In this work we consider 142 open clusters, for which published *UBV* photometric data are available and the membership based either on proper motions or on *UBV* photometry is also known. In case the membership is known from both these methods, preference has been given to results based on proper motions. We have taken clusters with apparent distance moduli up to 17.7 mag, though not all clusters with this qualification may have been considered.

2. Data and reduction

Integrated absolute *V*-magnitudes and the $(B-V)_0$, $(U-B)_0$ colours for 120 of the 142 open clusters discussed here have been calculated using the method of Gray (1965). For the remaining 22 clusters, these values are taken directly from the literature, because the available integrated values are based only on member stars. The apparent distance moduli $(m-M)$, and colour excesses $E(B-V)$ have been taken from the respective references of *UBV* data, if available; otherwise, they are taken from Becker & Fenkart (1971). If the reddening across any cluster is variable, the mean value for the reddening has been taken. The colour excess $E(U-B)$ has been calculated from the relation (Hiltner & Johnson 1956)

$$E(U-B) = 0.72E(B-V) + 0.05E(B-V)^2.$$

The apparent distance moduli and the colour excesses of the open clusters have been used to convert the apparent integrated *V*-magnitudes and colours to the respective absolute values which are listed in table 1, along with references and other relevant data. Corresponding data for 32 globular clusters, taken from Kukarkin (1974) are listed in table 2.

Table 1. Data for the open clusters

Name of open cluster	$(m-M)$ (mag)	$E(B-V)$ (mag)	log t (t in yr)	Integrated absolute values: $I(M_V)$ (mag)	$I(B-V)_0$ (mag)	$I(U-B)_0$ (mag)	References for columns: (2, 3)	(4)	(5, 6, 7)
1	2	3	4	5	6	7	8	9	10
NGC 188	11.12	0.09	9.556	−3.51	0.89	—	17	83	83
NGC 457	13.94	0.45	7.301	−7.93	−0.13	−0.75	62	62	62
NGC 559*	11.90	0.45	9.079	−2.40	0.65	—	49	49	49
NGC 581	13.30	0.38	7.602	−6.89	0.03	−0.63	74	74	74
NGC 654	14.69	0.98	—	−7.88	0.09	−0.33	62	—	62
NGC 659	13.53	0.54	—	−5.40	0.02	−0.21	58	—	58
NGC 663	14.55	0.86	—	−8.64	−0.19	−0.85	62	—	62
NGC 752	7.99	0.08	—	−2.49	0.51	0.10	12	—	12
NGC 1039	8.68	0.11	8.04	−3.36	−0.02	−0.18	6	6	6
NGC 1664	11.06	0.20	—	−4.64	0.06	—	42	—	42
NGC 1778	12.20	0.34	8.204	−4.35	0.10	−0.23	41	41	3,41
NGC 2168	10.20	0.17	7.929	−4.62	0·04	−0.21	85	85	85
NGC 2169*	10.63	0.18	6.954	−4.53	−0.23	−0.86	73	73	73
NGC 2186	12.30	0.31	—	−3.90	0.07	−0.10	68	68	68
NGC 2232	7.83	0.01	7.301	−3.71	−0.14	−0.60	7	7	7
NGC 2264	9.98	0.15	6.477	−5.75	−0.35	−1.06	77	77	77
NGC 2269	·12.20	0.44	—	−2.12	−0.07	−0.22	68	68	68
NGC 2281	8.70	0.10	8.740	−2.94	0.42	0.19	1	1	1
NGC 2302	10.96	0.25	—	−2.08	−0.07	−0.37	68	68	68
NGC 2335	11 25	0.40	8.176	−3.11	0.16	−0.20	9	9	9
NGC 2343	10.45	0.20	8.025	−2.94	0.29	−0.15	8	8	8
NGC 2345	13.30	0.65	7.778	−5.80	0.19	−0.17	64	64	64

Continued

Table 1—*Continued*

Name of open cluster	(m−M) (mag)	E(B − V) (mag)	log t (t in yr)	Integrated absolute values I(M_V) (mag)	I(B − V)_0 (mag)	I(U − B)_0 (mag)	References for columns (2, 3)	(4)	(5, 6, 7)
1	2	3	4	5	6	7	8	9	10
NGC 2360	10.51	0.07	—	−3.30	0.54	0.24	13	—	13
NGC 2374	10.50	0.0	8.544	−1.48	0.18	−0.02	23	23	23
NGC 2420	11.46	0.02	9.518	−2.93	0.68	—	57	57	57
NGC 2421	12.85	0.47	—	−4.51	−0.07	−0.60	68	—	68
NGC 2423	10.00	0.28	8.554	−3.64	0.10	−0.05	31	31	31
NGC 2439	14.35	0.37	7.301	−8.24	0.43	−0.39	87	87	87
NGC 2453	13.80	0.47	7.602	−4.66	0.16	−0.45	67	67	67
NGC 2482	9.50	0.04	—	1.95	0.35	0.16	68	—	68
NGC 2483*	13.86	0.42	—	−5.60	−0.01	—	55	—	55
NGC 2489*	11.60	0.40	8.398	−3.20	0.34	—	55	55	55
NGC 2516	8.36	0.12	7.778	−4.92	0.23	0.13	22	22	22
NGC 2527	9.00	0.10	8.699	−1.90	0.30	0.09	54	54	54
NGC 2533*	13.27	0.34	7.954	−5.17	0.28	—	47	47	47
NGC 2546*	10.45	0.17	7.477	−5.35	0.03	—	48	48	48
NGC 2567*	11.61	0.12	8.041	−3.71	0.22	—	47	47	47
NGC 2571*	12.51	0.32	7.477	−5.41	−0.08	—	47	47	47
NGC 2632	6.00	0.0	8.954	−2.74	0.37	0.17	4	84	36
NGC 2682	9.56	0.06	9.653	−2.81	0.62	0.18	16	2	16
NGC 3105	17.77	1.09	—	−6.95	0.11	−0.69	66	—	66
NGC 3324	13.88	0.47	6.342	−6.71	−0.30	−1.06	10	10	10
NGC 3572	13.70	0.46	—	−6.82	−0.32	−1.10	69	—	69
NGC 3590	13.20	0 51	—	−4.73	−0.19	−0.77	69	—	69
NGC 3680	9.62	0.04	—	−2.06	0.74	0.27	14	—	14
NGC 4609	11.68	0.36	7.778	−4.06	−0.24	−0.52	21	21	21
NGC 5138*	11.60	0.27	8.477	−3.50	0 27	—	52	52	52
NGC 5617	12.30	0.52	7.653	−4.26	0.01	−0.62	70	45	70
NGC 6025	9.91	0.17	8.000	−4.38	−0.12	−0.46	19	19	19
NGC 6031	11.70	0.47	—	−2.50	−0.07	−0.33	70	—	70
NGC 6134*	10.50	0.45	8.845	−2.90	0.40	—	52	52	52
NGC 6167	11.70	0.89	—	−4.63	0.0	−0.56	70	—	70
NGC 6208*	10.55	0.18	9.000	−3.05	0.62	—	52	52	52
NGC 6231	12.50	0.42	—	−8.36	−0.24	−0.93	81	—	81
NGC 6250	11.10	0.38	—	−3.22	−0.17	−0.75	70	—	70
NGC 6281	10.05	0.15	8.097	−4.42	0.21	0.01	20	20	20
NGC 6322	12.64	0.67	—	−6.32	−0.26	−1.10	70	−	70
NGC 6396	13.67	0.96	—	−5.06	−0.02	−0.68	70	—	70
NGC 6530*	12.35	0.35	6.301	−6.40	−0.15	−0.74	75	75	75
NGC 6604	14.77	0.96	6.602	−7.80	−0.23	−1.12	27	27	27
NGC 6611	13.70	0.70	6.602	−7.66	−0.16	−1.11	76	76	76
NGC 6913*	11.90	0.47	7.477	−4.80	−0.12	—	50	50	50
NGC 6633	8.00	0.17	9.000	−2 77	0.20	0.13	34	34	34,79
NGC 6704	13.74	0.71	7.301	−3.66	−0.16	−0.56	27	27	27
NGC 6716*	9.30	0.13	8.176	−2.30	−0.06	—	50	50	50
NGC 6811*	10.70	0.17	8.619	−3.60	0.48	—	51	51	51
NGC 6819*	12.60	0.30	9.301	−4.90	0.75	—	53	53	53
NGC 6823	15.46	0.85	6.398	−8.66	−0.15	−0.97	78	78	78
NGC 6830	12.94	0.56	8.000	−5.43	−0.14	−0.39	62	62	62
NGC 6834	13.95	0.72	7.903	−6.20	−0.10	−0.45	62	62	62
NGC 6866	10.82	0.14	8.450	−2.42	0.25	0.13	4	2	43
NGC 6939	12.00	0.50	9.000	−4.13	0.56	—	5	5	5
NGC 6940	10.50	0.25	8.602	−3.99	0.41	0.15	4	2	86
NGC 7039	11.50	0.19	9.000	−2.93	0.57	0.34	28	28	28
NGC 7062	12.70	0.48	8.875	−3.48	0.43	0.22	28	28	28
NGC 7067	15.71	0.83	7.000	−3.85	−0.22	−0.49	28	28	28
NGC 7082	11.50	0.28	9.204	−3.70	0.19	−0.06	28	28	28
NGC 7092	7.18	0.02	8.845	−2.65	0.04	0.02	59	59	59
NGC 7209	10.20	0.21	8.300	−2.67	0.27	—	4	2	44
NGC 7235	14.57	0.96	6.301	−7.77	−0.19	−0.77	62	62	62
NGC 7380	15.69	0.59	6.301	−7.53	−0.24	−0.99	61	61	61
NGC 7789	12.20	0.28	9.086	−4.21	0.89	—	4	2	43
IC 1369	12.66	0.52	9.079	−3.04	0.65	0.10	28	28	28
IC 1805	14.29	0.81	6.176	−8.26	−0.27	−1.08	62	62	62

Continued

Table 1—*Continued*

Name of open cluster	$(m-M)$ (mag)	$E(B-V)$ (mag)	log t (t in yr)	Integrated absolute values $I(M_V)$ (mag)	$I(B-V)_0$ (mag)	$I(U-B)_0$ (mag)	References for columns (2, 3)	(4)	(5, 6, 7)
1	2	3	4	5	6	7	8	9	10
IC 1848	14.10	0.72	6.000	−8.18	−0.33	−1.12	62	62	62
IC 1893	14.76	0.55	6.398	−7.78	−0.26	−1.06	62	62	62
IC 2391	6.05	0.04	7.477	−3.42	−0.18	−0.60	4	71	71
IC 2581	13.26	0.42	7.000	−6.82	−0.06	−0.76	18	18	18
IC 2602	6.02	0.04	6.602	−4.06	−0.18	−0.85	33	33	33
IC 4651*	10.70	0.12	8.778	−4.10	0.72	—	52	52	52
IC 4665	8.11	0.17	—	−2.94	−0.12	—	4	—	80
IC 4756	8.50	0.19	—	−3.65	0.43	0.16	32	—	32
Ba 11	10.90	0.0	8.301	−1.24	0.11	0.13	23	23	23
Ba 12	12.65	0.57	—	−2.71	0.85	0.42	29	—	29
Ba 13	11.55	0.34	—	−2.24	0.48	0.16	29	—	29
Ba 14	12.00	0.65	—	−2.53	0.40	−0.19	29	—	29
Ba 15	12.80	0.67	—	−3.68	0.40	−0.06	29	—	29
Be 94	15.50	0.67	7.000	−6.90	−0.28	−1.04	88	88	88
Bo 1	14.80	0.55	—	−6.92	−0.37	−1.19	68	—	68
Bo 3	12.00	0.24	—	−2.06	−0.05	−0.39	68	—	68
Bo 4	10.20	0.19	—	−2.98	−0.12	−0.59	68	—	68
Bo 5	13.82	0.63	—	−5.05	−0.36	−1.14	68	—	68
Bo 10	13.15	0.36	—	−6.52	−0.24	−1.05	69	—	69
Bo 14	15.40	1.62	—	−6.08	−0.11	−0.95	70	—	70
Bochum 15	14.80	0.50	—	−7.99	−0.24	−0.96	26	—	26
Collinder 140	7.93	0.05	4.342	−4.17	0.04	−0.60	11	11	11
Collinder 463	10.44	0.44	8.255	−3.83	0.06	−0.24	82	82	82
Coma	4.55	0.0	8.813	−1.95	0.20	0.12	4	84	37
Cr 185*	11.55	0.21	7.903	−2.45	−0.01	—	48	48	48
Cr 268	12.35	0.36	—	−2.78	0.13	−0.14	70	—	70
Cr 347	14.61	1.16	—	−4.93	−0.24	−0.86	70	—	70
Dolidze 25	16.19	0.81	—	−7.91	−0.06	−0.68	68	—	68
Ha 6	10.25	0.0	8.898	0.24	0.35	0.02	23	23	23
Ha 8	11.10	0.0	8.748	−0.87	0.33	−0.04	23	23	23
Haffner 18ab	16.44	0.70	6.000	−6.36	−0.34	−1.11	24	24	24
Haffner 19	15.64	0.45	6.778	−5.77	−0.20	−0.90	24	24	24
Haffner 20	13.70	0.55	8.301	−2.54	−0.08	−0.18	25	25	25
Haffner 21	13.20	0.20	8.301	−2.86	−0.24	0.27	25	25	25
Ho 17	12.72	0.54	7.778	−3.62	0.12	−0.22	46	46	46
Hogg 15	16.80	1.16	6.903	−6.93	−0.33	−1.07	63	63	63
Hyades	3.00	0.0	8.954	−2.54	0.39	0.17	4	84	37
Ly 2*	10.77	0.19	7.477	−3.87	−0.18	—	45	45	45
Lynga° 6	15.20	1.35	—	−4.38	0.01	−0.65	56	—	56
MEL 71	12.25	0.0	8.623	−3.83	0.33	0.0	30	30	30
Pi 1*	13.05	0.51	7.954	−2.35	−0.03	—	48	41	48
Pismis 4	8.80	0 03	—	−2.78	0.11	−0 41	68	—	68
Pleiades	5.65	0.06	7.114	−4.40	−0 12	−0.31	4	2	34,48,39
Ros 4	15.00	0.91	7.000	−5.05	−0.17	−0.79	72	72	72
Ruprecht 18	12.20	0.67	—	−2.62	0.09	−0.25	68	—	68
Ruprecht 32A	14.20	0.36	—	−4.42	−0.26	−1.02	68	—	68
Ruprecht 32B	15.92	0 63	—	−4.26	−0.25	−0 58	68	—	68
Ruprecht 44	16.35	0.70	6.000	−8.46	−0.35	−1.21	65	65	65
Ruprecht 55	14 93	0.54	—	−7.01	−0.18	−0.91	68	—	68
Ruprecht 67	11.90	0 47	—	−2.54	−0.05	−0.20	68	—	68
Ruprecht 79	14.10	0.82	—	−4.22	0.06	−0.52	68	—	68
Ruprecht 127	14.23	1.03	—	−5.11	−0.19	−0.84	70	—	70
Stock 13	12.90	0.24	—	−5.37	−0.22	−1.04	69	—	69
Tr 1*	13.30	0.52	7.415	−4.69	−0 18	−0.64	40	40	40
Tr 18	11.45	0.29	—	−3.41	−0.12	−0.54	69	—	69
Tr 22*	12.74	0.53	8.954	−4.40	0.25	—	46	46	46
α Per	6.30	0.08	7.477	−6 00	0.17	−0.26	60	2	60
ζ Sculp	6.96	0.02	7.477	−2.49	−0.10	−0.43	15	15	15

Notes : (i) Asterisk denotes that the data for the cluster are taken directly from the literature.

(ii) For references to the literature cited in Columns 8–10 *see* Appendix.

Table 2. Data for globular clusters taken from Kukarkin 1974

Name of globular cluster	$(m-M)$ (mag)	$E(B-V)$ (mag	$I(M_V)$ (mag)	$I(B-V)_0$ (mag)	$I(U-B)_0$ (mag)
NGC 104	13.12	0.07	−9.08	0.81	0.29
NGC 1851	15.17	0.11	−8.47	0.64	0.07
NGC 4147	16.37	0.02	−6.09	0.60	0.05
NCG 5024	16.17	0.03	−8.46	0.62	0.04
NCG 5139	13.81	0.12	−10.16	0.67	0.10
NGC 5286	15.40	0.02	−7.92	0.70	0.15
NGC 5694	17.90	0.12	−7.73	0.60	−0.02
NGC 5927	15.50	0.50	−7.55	0.81	0.47
NGC 6205	14.06	0.02	−8.20	0.67	0.05
NGC 6254	13.97	0·26	−7.34	0.66	0.05
NGC 6273	15.10	0.36	−8.27	0.64	0.09
NGC 6284	16.20	0 29	−7.17	0.68	0.15
NGC 6293	15.90	0.35	−7.52	0.62	0.02
NGC 6316	16.80	0.60	−7.80	0.70	0.14
NGC 6333	15.60	0.39	−7.85	0.57	0.02
NGC 6356	16.37	0.32	−8.08	0.82	0.35
NGC 6402	16.43	0.50	−8.94	0.76	0.24
NGC 6441	16.00	0.49	−8.76	0.76	0.44
NGC 6517	18.20	0.97	−7 90	0.84	0.29
NGC 6522	15.22	0.47	−6.47	0.73	0.30
NGC 6528	15.92	0 66	−6.25	0.77	0.47
NGC 6544	15.10	0.70	−6.80	0.76	0.18
NGC 6553	15.10	0.84	−6.97	0.79	0.46
NGC 6569	15.70	0.48	−6.94	0.81	0.19
NGC 6624	16.20	0.30	−7.89	0.80	0.35
NGC 6637	14.53	0.18	−6.74	0.84	0.35
NGC 6638	16.70	0.37	−7.69	0.75	0.27
NGC 6652	16.60	0.13	−7.67	0.76	0.27
NGC 6656	13.33	0.38	−8.26	0.62	0.01
NGC 6681	15.70	0.04	−7.52	0.68	0.11
NGC 6715	16.20	0.15	−8.59	0.69	0.13
NGC 7089	15.43	0.06	−8.93	0.62	0.04

The integrated magnitudes $I(M_V)$ and the colours $I(B-V)_0$ for 24 of the open clusters, common to this study and that by Gray (1965), are compared in figures 1A and 1B. The values of $I(M_V)$ obtained by Gıay appear to agree generally with the present values for the faint clusters (figure 1A), though for some bright clusters the former are brighter than the present values, which may be due to the inclusion of field stars by Gray. The values of $I(B-V)_0$ obtained by Gray are in fair agreement with the present values of $I(B-V)_0$ (figure 1B).

3. Accuracy of the parameters of the open cluster

The accuracy of the calculated integrated parameters depends upon :

(i) the accuracy of the magnitudes and colours of individual stars. For photoelectric data this accuracy is generally around $\pm$ 0.02 mag and for photographic data $\pm$0.06 mag;

(ii) the error in the reddening. The maximum effect due to this error could be $\pm$0.1 mag but it could be more for those clusters in which the reddening is variable across the cluster face;

(iii) the accuracy of the distance modulus. The maximum error in $I(M_V)$ due to this effect could be $\pm$0.4 mag;

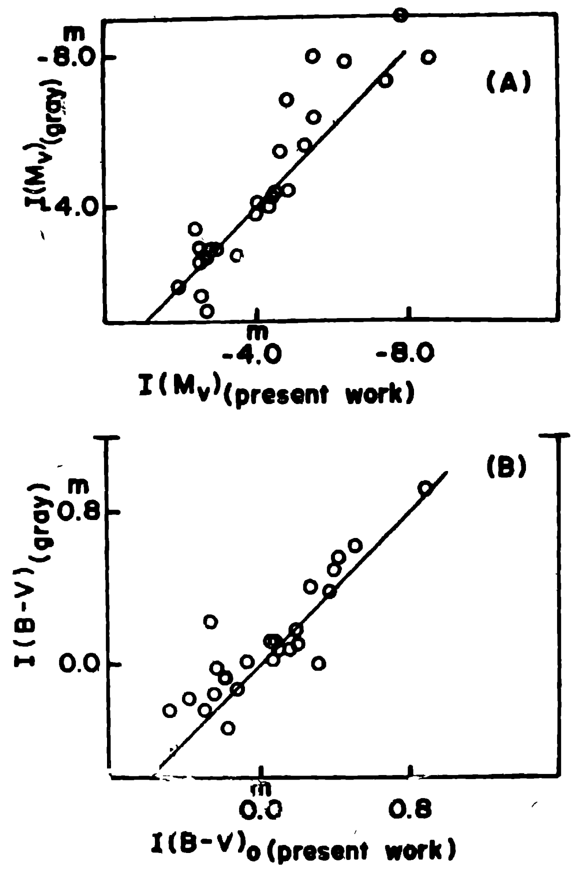

Figure 1. Comparison of the integrated magnitudes and $(B-V)_0$ colours obtained in this work with those given by Gray (1965). The straight lines are of slope 45 deg.

(iv) the possibility that some field stars may get included and some member stars left out in the calculations. If this happens for the relatively fainter stars, the effect will be negligible, but if relatively brighter stars are involved, the effect can be substantial. The actual error introduced by this factor cannot be estimated;

(v) the slope of the luminosity function at the magnitude where the summation was stopped. The maximum error introduced will be ± 0.1 mag in $I(M_V)$ and ± 0.05 mag in the colours $I(B-V)_0$ and $I(U-B)_0$.

If we take into account, all the effects mentioned above, one can expect a maximum error of ± 0.5 mag in $I(M_V)$ and ± 0.2 mag in the integrated colours.

4. The colour-magnitude and colour-colour diagrams

The integrated colour-magnitude diagram and colour-colour diagram of all the open and globular clusters considered in this study are plotted in figures 2 and 3 respectively.

4.1 Open clusters

The scatter of the open cluster representative points in figure 2 cannot be explained in terms of errors in the integrated parameters. Piskunov (1974) has stated that

$I(M_V)$ is related linearly to the total mass of the cluster. Therefore, for the same total mass the integrated colours, $I(B-V)_0$ can differ by as much as 1.2 mag (figure 2). This effect can be understood if one considers the number N of red giants/supergiants present in the cluster. For a given total mass of the cluster, the value of N will depend upon the age and the mass function (MF) of the cluster. For open clusters having the same MF and total mass, the number N and consequently the $I(B-V)_0$ increase as the cluster age increases (see section 5). On the other hand for open clusters having the same age and total mass, but differing mass function (*cf.* Van den Bergh & Sher 1960; Burki 1977; Sagar 1979) the integrated colours of those open clusters will be relatively redder in which relatively heavier stars are present since, due to evolution, these stars will become red giants/supergiants and will therefore affect the integrated colours. In order to verify the above statement, we have plotted in figure 2 the open clusters by three different symbols according to the value of N. In figure 2 and elsewhere open circles represent open

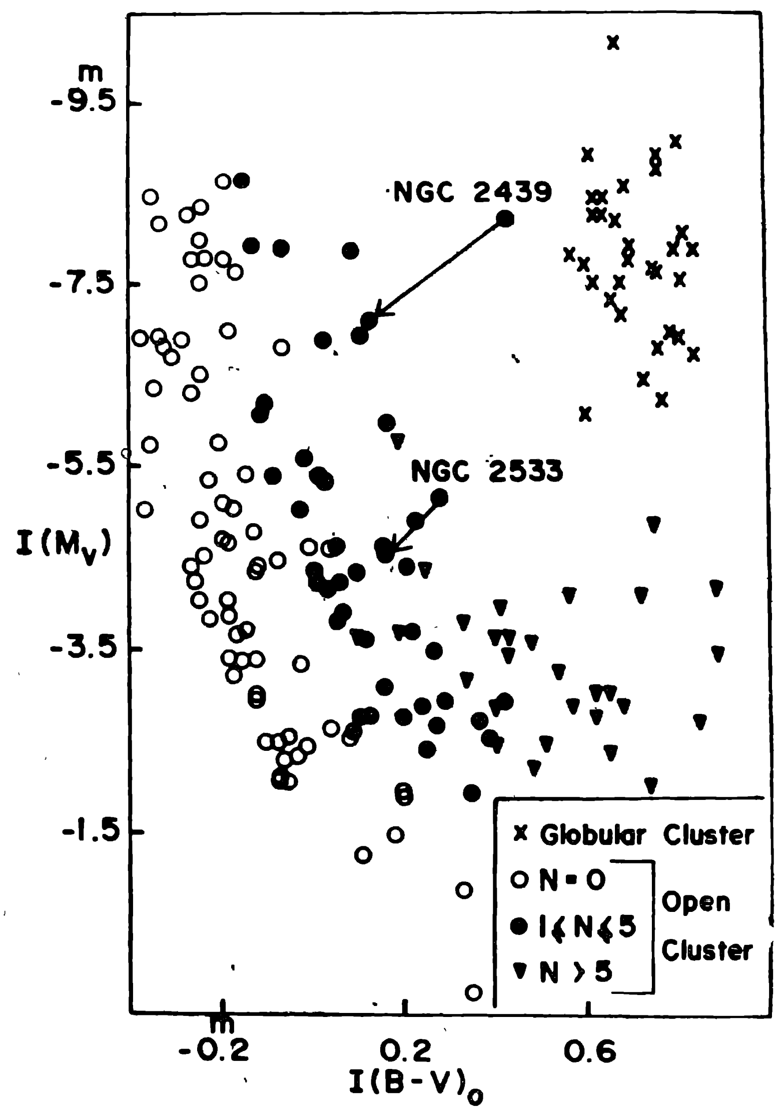

Figure 2. The $I(M_V)$, $I(B-V)_0$ diagram. N is the number of red giants/supergiants in the open clusters.

clusters with $N = 0$, filled circles those with $1 \leqslant N \leqslant 5$, and triangles represent the clusters with $N \geqslant 6$. The scattering of the point in figure 2 can thus be explained within the error of the parameters. Contrary to the suggestion by Gray (1965), the relation between $I(M_V)$ and $I(B - V)_0$ does not seem to be linear.

In figure 3 the scatter of the open cluster representative points is small in comparison to that in figure 2. This is due to the errors in these parameters being relatively small. Recently theoretical integrated *UBV* colours have been calculated for population I clusters by Barbaro & Bertelli (1977). In figure 3 we have plotted these theoretical curves calculated for the main sequence (MS) part of the cluster as well as for the whole cluster. The theoretical curve for the MS agrees fairly well with the open clusters with $N = 0$, whereas the other curve agrees fairly well with the clusters in which red giants are present. Contrary to the suggestions by Gray (1965) these theoretical as well as the observed relations between $I(U - B)_0$ and $I(B - V)_0$ are not linear.

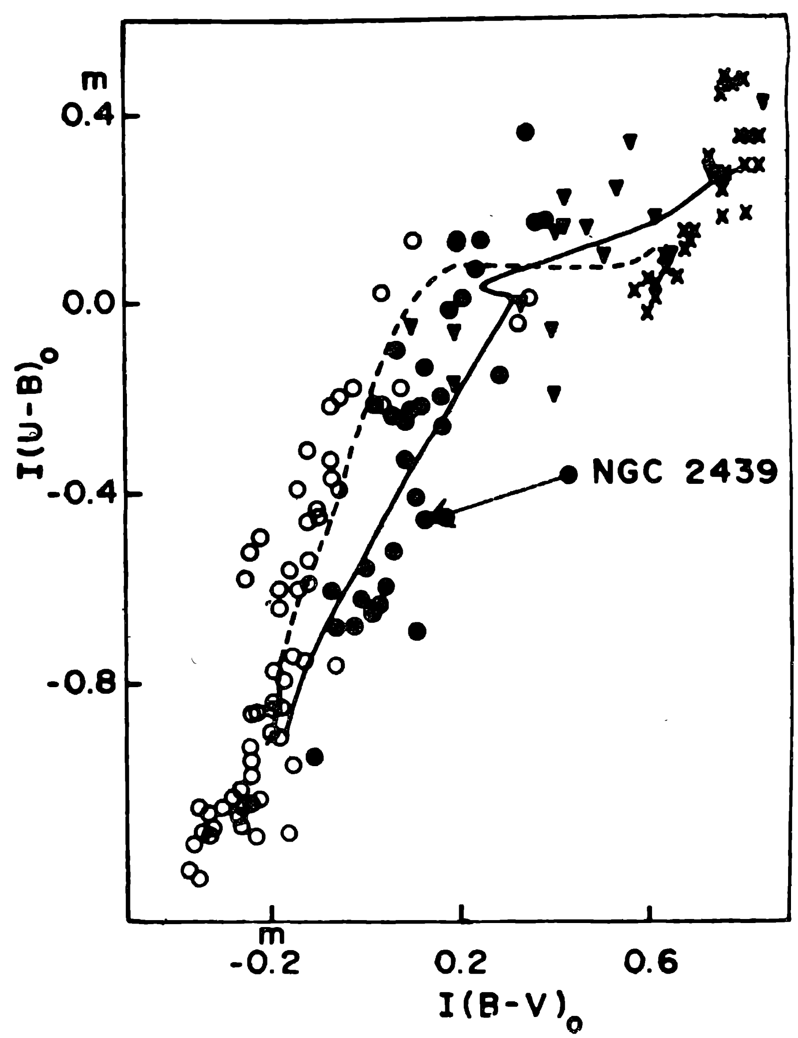

Figure 3. The $I(U - B)_0$, $I(B - V)_0$ diagram. The notations are the same as in figure 2. Dashed curve represents the locus of the theoretical $I(U - B)_0$, $I(B - V)_0$ curve calculated for the main sequence part of the cluster and the continuous curve represents the same curve calculated for the whole cluster (cf. Barbaro & Bertelli 1977).

An inspection of figures 2 and 3 shows that the above explanation for the scatter of the cluster representative points does not explain the positions of the clusters NGC 2439 and NGC 2533 in these figures. The position of NGC 2439 in figures 2 and 3 is not in the region of the clusters having $1 \leqslant N \leqslant 5$ while it actually belongs to that group. The *UBV* parameters of the brightest member of this cluster, which is a red supergiant, are $V = 6.61$ mag, $B - V = 1.17$ mag and $U - B = 0.94$ mag; for the next brightest member they are $V = 8.90$ mag, $B - V = 0.16$ mag and $U - B = -0.76$ mag. If by chance the brightest member is a field star, then the absolute integrated parameters for the cluster become $I(M_V) = -7.12$ mag; $I(B - V)_0 = 0.13$ mag; $I(U - B)_0 = -0.46$ mag and the corresponding changed positions are shown by arrows in figures 2 and 3. The changed position lies in the region of the clusters having $1 \leqslant N \leqslant 5$.

In NGC 2533, five red giants are present while it lies in the region where $N \geqslant 6$. For this cluster, $I(M_V)$ and $I(B - V)_0$ have been calculated including the brightest red giant star with doubtful membership. The next brightest member is 1.9 mag fainter. If we remove the former star, then the integrated parameters become $I(M_V) = -4.58$ mag; $I(B - V)_0 = 0.16$ mag and the corresponding changed position is shown by an arrow in figure 2, which lies in the region where clusters having $1 \leqslant N \leqslant 5$ are situated. The location of the globular clusters on the colour magnitude diagram is distinctly different from those of open clusters. This information can therefore be used to identify these objects in other galaxies, where only the integrated parameters are observable. In the colour-colour diagram (figure 3) older open clusters and globular clusters populate the overlapping regions of the diagram.

5. Evolutionary effects

In figure 4, we plot log t against the integrated intrinsic colour, $I(B - V)_0$ for the open clusters, where t is the age of the cluster in years. From this diagram it is clear that as the age of the cluster increases, its integrated $(B - V)_0$ colour becomes redder. Thus the present data support and extend the findings of the earlier workers (Crampin & Hoyle 1961; Sandage 1963; Gray 1965, 1967), though contrary, again, to the findings of Gray (1965), the integrated colour does not change linearly with log t. We also show in figure 4, the theoretical curves corresponding to the main sequence part of the cluster and to the whole cluster, given by Barbaro & Bertelli (1977). In this figure also the theoretical curve corresponding to the main sequence part of the cluster agrees fairly well with the clusters in which only main sequence stars are present while the curve for the entire cluster agrees fairly well with the clusters for which $1 \leqslant N \leqslant 5$. These theoretical relations between log t and $I(B - V)_0$ are also not linear.

In figure 4, one can see that the spread in the integrated colours of the clusters of the same age increases from 0.15 mag to 0.70 mag as the age of the cluster increases from log t = 6 3 to log t = 9.2. It may be due to the fluctuation in the mass distribution function of the evolved stars (Barbaro & Bertelli 1977).

6. Conclusions

From the above discussions the following conclusions can be drawn :

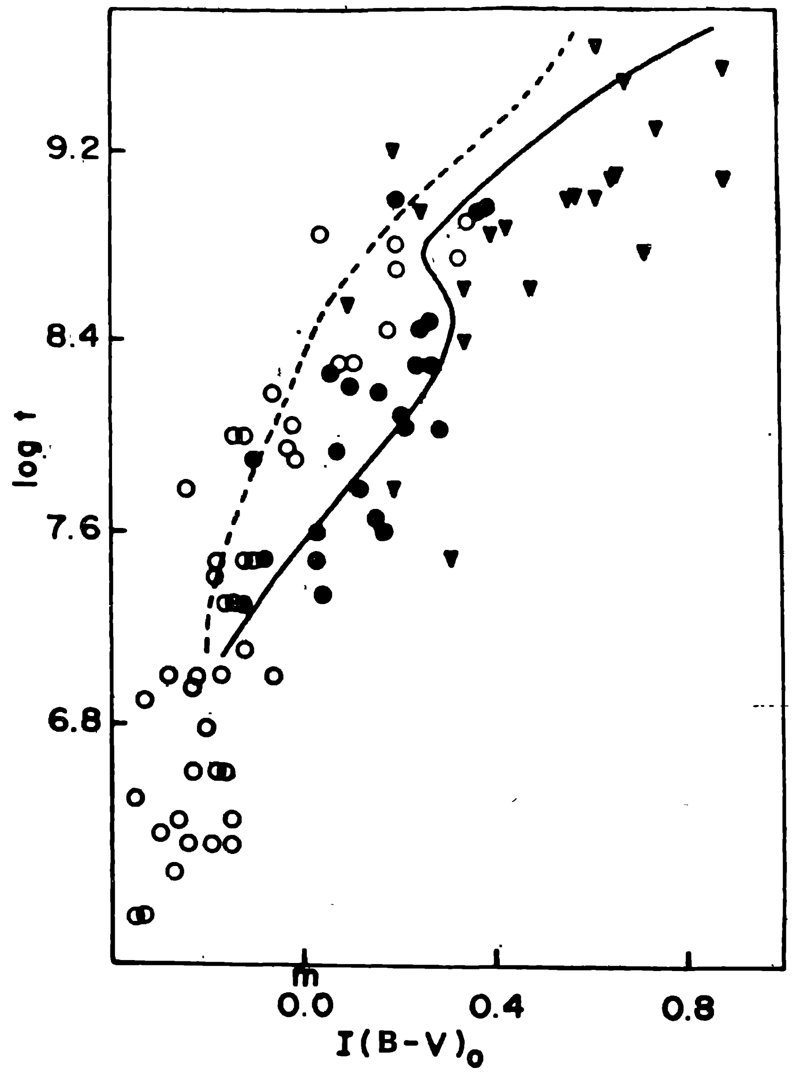

Figure 4. Plot of log t versus $I(B - V)_0$, where t is the age of the clusters in years. The notations are the same as in figure 2. Dashed and continuous curves represent the same curves as in figure 3.

(i) Contrary to the findings of Gray (1965), the relations between $I(M_V)$, $I(B - V)_0$; $I(U - B)_0$, $I(B - V)_0$; and log t, $I(B - V)_0$ are not linear

(ii) The dispersion of the open cluster representative points in the various diagrams can be understood in terms of the difference in age of the cluster and in mass function of the open clusters having the same total mass. This shows that initial luminosity function is not the same for all open clusters

(iii) Comparison of the observed parameters of the open clusters with the theoretical calculations confirms the validity of the basic assumptions of the theory of internal structure and evolution of stars involved in the model calculations.

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Appendix

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