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Membership, binarity and metallicity of red giants in the southern open cluster NGC 2354*

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Abstract. We present new Coravel radial-velocity observations and photoelectric photometry in the UBV, DDO and Washington systems for a sample of red giant candidates in the field of the intermediate-age open cluster NGC 2354. Photometric membership probabilities show very good agreement with those obtained from Coravel radial velocities. The analysis of the photometric and kinematical data allow us to confirm cluster membership for 9 red giants, one of them being a spectroscopic binary, while 4 confirmed spectroscopic binaries appear to be probable members. We have also discovered 4 spectroscopic binaries not belonging to the cluster. A mean radial velocity of (33.40 ± 0.27) km s^{-1} and a mean reddening $E(B-V) = 0.13 \pm 0.03$ were derived for the cluster giants. NGC 2354 has a mean ultraviolet excess $< \delta(U-B) > = -0.03 \pm 0.01$, relative to the field K giants, and a mean new cyanogen anomaly $\Delta CN = -0.035 \pm 0.007$, both implying [Fe/H] ≈ -0.3. The moderately metal-poor character of NGC 2354 is confirmed using five different metal abundance indicators of the Washington system. The cluster giant branch is formed by a well defined clump of 7 stars and 4 stars with high membership probabilities seem to define an ascending giant branch. The whole red giant locus cannot be reproduced by any theoretical track.

Key words: open clusters: individual: NGC 2354 — stars: HR diagram; abundances

1. Introduction

Our actual knowledge of the red giant phase in the evolutionary history of the stars is still rather uncertain and incomplete. This is mainly due to the lack of numerous and sufficiently accurate observational data of red giants in open clusters to be compared with the theoretical predictions. In particular, intermediate-age open clusters are in an evolutive stage which is well suited to study the morphology of the red giant branch as well as to check the issue of convective overshooting (see, e.g. Bertelli et al. 1985).

NGC 2354 (C0712−256; Trumpler class III-2m) is an intermediate-age open cluster located in Canis Major at (B1950) $\alpha = 7^{\rm h}\ 12\overset{\rm m}{.}2$, $\delta = -25^\circ\ 39'$; $l = 238\overset{\circ}{.}42$, $b = -6\overset{\circ}{.}80$. Although it is interesting for the number of red giant candidates it contains, this cluster has so far received little attention. The only photometric study was published by Dürbeck (1960) who derived a reddening $E(B-V) = 0.14$, a distance of 1850 pc and an age of 7.0 10^8 years. These values, however, are rather uncertain as they have been determined from UBV photographic data. More recently, Ahumada & Lapasset (1996) reported preliminary results of a CCD $UBVR$ photometric study in an area of about $10'$ centered on NGC 2354. They obtained a mean reddening $E(B-V) = 0.15$, a distance of 1445 pc, and a somewhat larger age of about 1 Gyr. A photometric search for variable stars among the blue stragglers (BS) in this cluster led them to the discovery of one eclipsing binary BS (Lapasset & Ahumada 1996).

As part of a long-term project to determine abundances and astrophysical properties of red evolved stars in southern open clusters, we present here Coravel radial-velocity observations and accurate UBV, DDO and Washington photometry of red giant candidates in the

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field of NGC 2354. The present data are used to discuss cluster membership, to detect spectroscopic binaries among the red giants, to determine individual $E(B-V)$ colour excesses as well as to derive the cluster metal content. Preliminary results on the NGC 2354 red giants were published by Clariá & Piatti (1994).

2. The observational material

2.1. Photometric observations

A total of 27 stars in the field of NGC 2354 brighter than $V = 13.1$ and redder than $B-V = 0.78$, were selected as red giant candidates from the colour-magnitude diagram published by Dürbeck (1960). With the exception of one star (#152), all the red giant candidates were observed in the Washington photometric system (Canterna 1976), while nineteen of them with $V \leq 11.9$ were observed in the UBV and DDO systems with the purpose of obtaining additional information about their reddening and metallicity. Three additional stars fainter than $V = 11.9$ were also observed in the UBV system.

The photometric data reported here were obtained at Cerro Tololo Inter-American Observatory (CTIO) using the 0.6- and 1.0-m telescopes in January 1992 and January 1993. Single-channel pulse-counting photometers were used at CTIO in conjunction with dry-ice cooled Hamamatsu R943-02 and EMI 9781A photomultipliers for the UBV and DDO observations, while Hamamatsu R943-02 and RCA 31034A phototubes were used for the CMT_1T_2 observations. Only the four primary filters of the DDO system were used, since they provide adequate information for the present purposes. Mean UBV, DDO and CMT_1T_2 extinction coefficients for CTIO were used to reduce the photometric data, and nightly observations of about 13-15 standard stars from the lists of Cousins (1973, 1974), Graham (1982), McClure (1976), Dean (1981) and Canterna (1976), were used to place the observations in the standard UBV, DDO and Washington systems. Some UBV measurements were also done in March 1992 at the Complejo Astronómico El Leoncito (CASLEO) using the 2.15-m telescope and the photopolarimeter VATPOL (Magalhães et al. 1986), which has two Ga-As RCA 31034 phototubes refrigerated with dry ice. Mean extinction coefficients derived by Minniti et al. (1989) for CASLEO were used. A comparison of the observed mean values with the published ones for the standard stars yields the external mean errors of a single UBV, DDO and CMT_1T_2 observation, an indication of how closely the standard systems have been reproduced. External mean errors of the UBV and Washington photometries range between 0.01 and 0.02 mag, while those of the DDO photometry are typically lower than 0.01 mag.

The observed UBV, DDO and Washington photometric data together with their mean internal errors σ, in units of 0.001 mag, are given in Tables 1 and 2 (using the numbering system of Dürbeck 1960), where n_1, n_2, and n_3 indicate the number of nights on which each star was observed in the UBV, DDO, and CMT_1T_2 systems, respectively. Stars #292, 293 and 298 in the tables are those denoted as B, C, and H, respectively, by Dürbeck. A comparison of the previous photographic V and $B-V$ data of Dürbeck (1960) and the present photoelectric ones is rather poor, the mean differences (previous minus present value) being: $\Delta V = -0.05 \pm 0.20$ (s.d.) and $\Delta(B-V) = 0.04 \pm 0.19$ (s.d.). The large standard deviations are almost entirely due to the low accuracy of Dürbeck's photographic data. However, if the four most discrepant stars #47, 161, 200 and 248 are omitted, the mean differences are: $\Delta V = 0.04 \pm 0.10$ and $\Delta(B-V) = 0.04 \pm 0.07$.

Table 1. Washington photometry of red giant candidates

No	$C-M$	σ	$M-T_1$	σ	T_1-T_2	σ	T_1	σ	n_3
11	1.382	29	0.970	30	0.653	6	10.898	5	2
37	1.243	42	0.835	6	0.577	2	11.397	2	2
46	1.256	8	0.848	3	0.599	17	12.299	12	3
47	1.296	5	0.811	12	0.537	16	10.354	47	2
59	1.287	31	0.868	7	0.601	4	12.414	3	3
66	1.240	25	0.835	2	0.585	11	11.105	6	2
91	1.166	17	0.838	23	0.570	20	11.082	15	3
113	1.094	3	0.744	17	0.523	4	11.236	28	3
125	1.115	11	0.765	12	0.538	11	11.231	25	2
161	1.118	9	0.728	6	0.471	4	9.326	21	3
166	1.267	5	0.833	29	0.544	4	10.648	9	2
167	1.157	8	0.817	8	0.576	5	12.064	8	3
179	0.888	4	0.696	2	0.488	27	10.893	37	3
183	1.397	31	0.962	20	0.631	12	10.969	15	3
184	1.619	10	1.133	2	0.774	7	10.866	6	2
198	1.124	10	0.884	10	0.650	8	11.795	10	3
200	2.075	1	1.285	3	0.837	16	8.916	35	2
205	1.350	3	0.872	17	0.567	4	10.793	24	2
217	1.029	10	0.714	2	0.467	12	9.635	16	2
219	0.907	29	0.707	1	0.485	3	10.562	13	2
248	1.320	62	0.782	27	0.557	55	9.633	179	2
269	1.175	8	0.792	9	0.531	4	11.175	11	2
292	1.475	25	0.889	17	0.562	4	9.803	31	2
293	1.173	28	0.797	37	0.841	10	10.119	52	2
298	1.121	2	0.802	5	0.534	2	11.479	10	3

2.2. Coravel radial velocities

Radial velocity observations have been obtained in February 1989, March 1990 and January 1994 and 1995 with the radial velocity scanner CORAVEL (Baranne et al. 1979) installed on the 1.54 m Danish telescope at the ESO observatory at La Silla (Chile). The candidate giants were selected from the list of Dürbeck (1960). It appears that star #157 ($V = 11.04$, $B-V = 1.31$) has been inadvertently dropped from the list. We shall try to get some observations for this object because it could be a probable member lying on the ascending giant branch. Usually three observations were obtained for non variable, member stars, while binaries received more attention. The radial velocity system is that defined by Mayor & Maurice (1985)

Table 2. *UBV* and *DDO* photometry of red giant candidates in NGC 2354

Star	V	σ	$B-V$	σ	$U-B$	σ	n_1	$C(45-48)$	σ	$C(42-45)$	σ	$C(41-42)$	σ	n_2
11	11.595	41	1.182	2	0.840:	121	2	1.242	1	0.880	5	0.208	2	2
47	10.935	14	1.050	27	0.882	32	2	1.203	1	0.909	9	0.178	1	2
59	12.980	5	1.137	11	0.868	22	2							
66	11.605	16	1.070	10	0.792	31	3	1.184	4	0.872	4	0.135	3	3
91	11.558	2	1.088	10	0.799	11	3	1.222	4	0.813	10	0.144	13	3
113	11.659	21	1.008	13	0.613	6	2	1.186	13	0.781	29	0.099	14	4
125	11.651	9	0.989	22	0.633	13	2	1.187	20	0.787	16	0.149	4	2
152	12.870	1	1.124	1	0.760	29	2							
161	9.818	21	0.975	11	0.739	5	2	1.156	2	0.815	5	0.200	7	2
166	11.234	19	1.082	2	0.873	14	2	1.207	4	0.883	10	0.197	3	2
167	12.600	10	1.050	18	0.710	26	2							
179	11.428	90	0.862	21	0.454	41	2	1.099	11	0.684	3	0.126	1	2
183	11.655	16	1.177	33	0.975	19	3	1.238	1	0.928	18	0.170	2	2
184	11.623	17	1.380	20	1.169	17	2	1.335	11	1.005	14	0.222	19	4
200	9.755	22	1.649	14	0.938	5	2	1.428	7	1.303	12	0.271	6	2
205	11.387	21	1.149	1	0.981	17	2	1.242	13	0.916	4	0.212	16	2
217	10.019		0.939		0.647		1	1.150	1	0.794	2	0.135	4	2
219	11.014	38	0.867	1	0.449	1	3	1.119	10	0.699	5	0.119	4	2
248	10.076	8	1.052	19	0.954	21	2	1.196	11	0.925	3	0.238	7	2
269	11.668	28	1.041	13	0.761	36	2	1.166	12	0.877	17	0.150	25	2
292	10.386	21	1.190	4	1.192	15	2	1.250	3	0.94	2	0.291	8	2
293	10.610	17	1.005	4	0.771	3	2	1.175	3	0.841	7	0.184	11	2

which is a natural system for the southern CORAVEL. It corresponds to the IAU standard system defined by the faint list ($V > 4.3$). Columns (2) to (7) of Table 3 give in succession the mean radial velocity and its uncertainty in [km s^{-1}], the number of radial-velocity observations, the ratio of the external to internal errors (E/I), the probability $P(\chi^2)$ that the scatter is due to random noise, the time interval covered by the observations of each star, and remarks on membership and duplicity The star designations are from Dürbek (1960). Although most stars have only three observations, the interval of time, nearly six years and the good agreement between the observations mean that binaries with periods less than about 5000 days have been detected. The probability to obtain three radial velocities at the same values over six years is quite low, although, of course, not zero.

$V \sin i$ for the red giant members is small: either $V \sin i$ is smaller than 1.8 km s^{-1} or only an upper limit has been determined. The two different cases are #179 and 219, with $V \sin i$ equal to 3.8 ± 1.8 and 5.6 ± 1.7 km s^{-1} respectively.

Individual observations, including the Julian dates, are listed in Table 7, which is only available in electronic form.

Table 3. Radial velocity data of red giants in NGC 2354

Star	V_r	ϵ	N	E/I	$P(\chi^2)$	ΔT	Rem
11	50.49	0.26	3	0.93	0.429	2190	nm
37	15.99	0.35	2	0.68	0.495	739	nm
46	73.51	0.42	2	0.78	0.438	739	nm
47	79.40	1.57	3	7.39	0.000	2190	nm, sb
59	31.31	0.35	3	0.69	0.626	1798	m
66	33.67	0.26	3	0.77	0.553	1798	m
91	33.69	0.28	3	0.81	0.524	1798	m
113	28.10	1.77	6	10.19	0.000	2836	m?, sb
125	32.09	0.27	3	0.90	0.445	1798	m
152	33.84	0.40	3	1.35	0.168	2184	m
161	43.19	0.19	3	0.75	0.570	2183	nm
166	52.45	0.22	3	0.35	0.886	2185	nm
167	40.18	0.29	3	0.16	0.976	2185	nm
179	38.06	0.62	6	2.98	0.000	2836	m?, sb
183	33.80	0.24	3	0.85	0.503	2182	m
184	34.92	0.62	3	2.54	0.002	2182	m, sb?
198	64.48	1.66	3	4.63	0.000	2189	nm, sb
200	33.08	0.55	3	3.03	0.000	2182	m, sb
205	33.31	0.23	3	0.48	0.798	2182	m
217	0.91	0.18	3	0.99	0.378	2185	nm
219	31.19	0.37	4	1.44	0.125	2183	m
248	81.91	1.26	3	6.65	0.000	2190	nm, sb
258	62.75	0.38	2	0.37	0.714	738	nm
269	39.10	2.02	5	11.71	0.000	2835	m?, sb
292	42.78	0.19	3	0.36	0.876	2184	nm
293	52.81	0.21	3	0.42	0.842	2189	nm
298	19.52	2.45	3	7.80	0.000	2189	nm, sb

3. Analysis and discussion of the data

3.1. Cluster membership and interstellar reddening

The observed colour-magnitude (CM) and colour-colour (CC) diagrams of NGC 2354 with the stars listed in

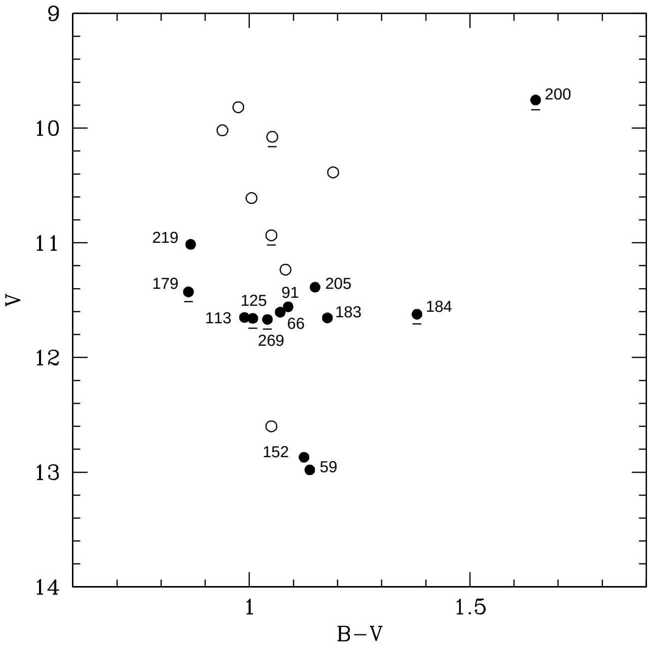

Fig. 1. The colour-magnitude diagram for red giant stars in NGC 2354. Confirmed or possible cluster members and red field stars are represented by filled and open circles, respectively. Spectroscopic binaries (underlined) are also indicated. The distance between the apparent ascending giant branch and the clump is much too large when compared to theoretical models

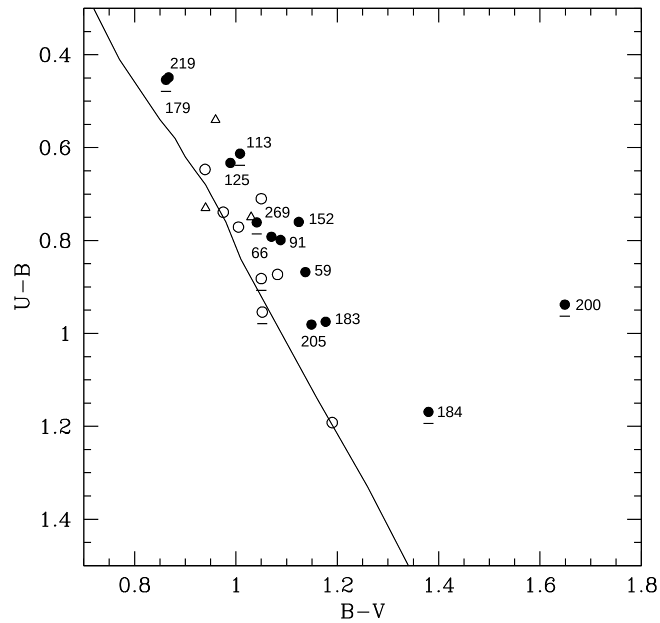

Fig. 2. The UBV two-colour diagram for the same stars as in Fig. 1, with the same notation. Triangles represent photographic data from Dürbeck (1960). The continuous curve is the standard two-colour relationship for typical G and K giants as given by Fitzgerald (1970). Star #200 has a peculiar $U-B$ colour

Table 2 are shown in Figs. 1 and 2. The selection process for cluster membership is here primarily based on the radial velocity data.

Fourteen stars with mean radial velocities larger than 40 km s^{-1} or lower than 20 km s^{-1} are undoubtedly non-members, four of them most probably spectroscopic binaries (see Table 3). The radial velocities of six non-SB obvious members from Table 4 (stars #66, 91, 125, 152, 183 and 205) fall within an interval of only 1.7 km s^{-1}. The mean radial velocity of these stars is 33.40 $\pm$ 0.27 km s^{-1} (s.e. of the mean) and has been adopted for NGC 2354.

When the mean radial velocities of some stars differ by some $2-2.5$ km s^{-1} from the cluster mean velocity, i.e. differences well larger than 3 σ, it is more difficult to derive the membership from the radial velocity only. The examination of the colour-magnitude diagram may provide further help to the decision. Generally, there is a very good agreement between the kinematic and photometric membership estimates, but in the case of NGC 2354, there appear to be some contradictions. Although it is formally possible to compute membership probabilities, practically the results do not bring much insight in the membership determination. The six stars listed above would have high membership probabilities, and all other would be close to 0. In fact it does not properly take into account the case of the binaries, because the rough mean velocities are not fully representative of the true mean values. Further observations, and not only radial velocities, but also proper motions, are needed to settle the point.

Stars #59 and 219 differ by 2.1 and 2.2 km s^{-1} from this mean velocity so that they are possible cluster members. They could be long period, low amplitude binaries with an eccentric orbit. The position of both stars in the colour-magnitude diagram (Fig. 1) may also indicate that they are non-member. However, star #59 falls very close to star #152, which has a radial velocity (33.84 km s^{-1}) very close to the cluster mean. Star #219 has a high $V \sin i$, like #179 which is a binary. The status of star #184, a possible spectroscopic binary, is difficult to decide because it has a radial velocity close to the cluster mean but its position in Figs. 1 and 2 falls also too red, if one uses available isochrones to analyse the distribution of the red giants in the colour-magnitude diagram of NGC 2354. Finally, #200, the brightest red giant contributes to the definition of a plausible ascending giant branch.

The mean velocities of the confirmed spectroscopic binaries #113, 179 and 269 are based on observations not well distributed with respect to the mean cluster velocity as a result of the telescope time allocation. Accordingly, they are not yet representative of the real mean velocities of these stars. Although these mean values differ by about 5.3, 4.7 and 5.8 km s^{-1} from the cluster mean, these stars are considered as probable members, because the observed individual radial velocities for each star do scatter around the cluster mean. A definitive statement about their membership will await more observations and the determination of the orbits.

With the exception of stars #59, 152, 184 and 200, all the remaining members form an elongated clump of stars near $V \simeq 11.5$ in the CM diagram. The position of stars #179 and 219 in the CM diagram is due to their binary character, certain for star #179 and probable for 219. The morphology of the CM diagram will be discussed later.

Cluster membership was also examined by applying the photometric criteria A and B described by Clariá & Lapasset (1983). Taking into account the different combinations that might result from the application of both criteria, we decided to consider a star to have a high probability of being a cluster member if one (or both) of the criteria implies membership, while the other indicates that the star is a probable member. If one criterion (or both) suggests non-membership, the star is rejected as a cluster member. Finally, if both criteria simultaneously indicate probable membership, the star is then considered to be a probable member of the cluster.

To apply criteria A and B, the colour excess $E(B-V)_{\rm MS} = 0.15$ mag and true distance modulus $(m-M)_0 = 10.80$ both derived by Ahumada & Lapasset (1996) were adopted. The *DDO* colours were dereddened according to the reddening coefficients of McClure (1973) and the predicted luminosity class for each observed star was determined from the Schmidt-Kaler (1982) calibration assuming $R = A_v/E(B-V) = 3.0$.

Columns (6)-(9) of Table 4 contain the results from applying the photometric and kinematic criteria and the membership status finally adopted for each star (sb = spectroscopic binary, m = member, nm = non-member). Column (2) of Table 4 lists the $E(B-V)_{\rm GK}$ colour excesses derived from Janes's (1977) iterative procedure, which is abundance independent and valid over a wide range of luminosities for Population I stars. The standard deviation $\sigma_{\rm E}$, calculated from Clariá's (1985) Eq. (10) is given in Col. (3), while Cols. (4) and (5) include the predicted luminosity class (LC) and the MK spectral type inferred from the dereddened *DDO* colours.

Although the results obtained from criterion A should be taken with caution because of the probable non-uniform reddening in the cluster field (Ahumada & Lapasset 1996), the agreement between the photometric analysis and the kinematic data is really excellent. This demonstrates once again that the photometric criteria A and B lead to reliable membership results provided the *BV* and *DDO* photometric data are of high quality. The only discrepant star (#184), an apparent radial velocity member, has a reddening significantly larger than those of the cluster giants (see Table 4), compatible with its position in the CM and CC diagrams. Since this star is located in an apparently obscured region in the cluster field and has a metal content nearly similar to that of the remaining red giants (see Sect. 3.2.1), we have retained it as a possible cluster member.

Table 4. Red giant membership results

Star	$E(B-V)$	$\sigma_{\rm E}$	LC Pred.	MK DDO	Membership Photom. (A)	(B)	$V_{\rm r}$	Fin.
11	0.20	0.02	II/III	G9 III	nm	m	nm	nm
47	0.00	0.06	II/III	K1 III	nm	m	nm	nm (sb)
59[a]							m	m
66	0.14	0.03	III	K0 III/IV	m	m	m	m
91	0.17	0.03	II/III	G5 II/III	m	m	m	m
113	0.12	0.06	III	G5 III	m	m	m?	m? (sb)
125	0.09	0.06	III	G5 II/III	m	m	m	m
152[a]							m	m
161	0.07	0.03	II	G8 III	nm	pm	nm	nm
166	0.08	0.02	II/III	K0 III	nm	m	nm	nm
179[b]							m?	m?(sb)
183	0.16	0.08	III	K0/1 III	m	m	m	m
184	0.31	0.05	II/III	K1 III	nm	m	m	m? (sb?)
200	0.17	0.04	II	K4/5 III	m	pm	m	m (sb)
205	0.09	0.03	III	K0/1 III	pm	m	m	m
217	0.02	0.03	II	G5/8 III	nm	pm	nm	nm
219[b]							m	m
248	0.00	0.05	II	K1/2 III	nm	pm	nm	nm (sb)
269	0.12	0.05	III	K0 III	m	m	m?	m? (sb)
292	0.02	0.02	II/III	K1/2 III	nm	m	nm	nm
293	0.04	0.02	II/III	G9 III	nm	m	nm	nm

[a] Not observed in the DDO system.
[b] Star outside the range of the DDO calibration.

The interstellar reddening derived from Janes's (1977) method average to $\langle E(B-V)_{\rm GK}\rangle = 0.13 \pm 0.03$ mag, in very good agreement with the previous values derived by Dürbeck (1960) and Ahumada & Lapasset (1996). However, the individual $E(B-V)_{\rm GK}$ values listed in Table 4 were used to correct the *DDO* photometry for interstellar reddening.

3.2. Metal content

3.2.1. *DDO* and *UBV* abundance parameters

As a first abundance indicator, we have used the intrinsic *DDO* colour index $C_0(41-42)$, which is an excellent abundance indicator measuring the strength of the λ4216 cyanogen band, such that the larger the index the greater the absorption by this band. Using this parameter we have computed for each cluster red giant the new cyanogen anomaly, ΔCN, defined by Piatti et al. (1993) as the difference between the dereddened $C_0(41-42)$ and the standard value of this index corresponding to a star with the same temperature and surface gravity, but not with the same $C_0(42-45)$ and $C_0(45-48)$ as the star in question. Column (3) of Table 5 lists the cyanogen anomaly ΔCN obtained for nine cluster giants. No value could be determined for

Table 5. Abundance parameters of cluster giants

Star	$\delta(U-B)$	ΔCN	Δ'_1	Δ'_2	Δ'_3	Δ'_4	Δ'_5
59[a]	−0.06	–	−0.203	−0.065	−0.267	−0.120	−0.143
66	−0.02	0.008	−0.190	−0.069	−0.258	−0.096	−0.121
91	−0.01	−0.054	−0.207	−0.039	−0.246	−0.153	−0.167
113	−0.12	−0.066	−0.102	−0.049	−0.151	−0.023	−0.040
125	−0.08	−0.032	−0.138	−0.055	−0.192	−0.054	−0.073
179[b]	0.00	-	−0.176	−0.035	−0.210	−0.111	−0.121
183	0.00	−0.028	−0.206	−0.024	−0.230	−0.187	−0.197
184[c]	-	−0.047	-	-	-	-	-
200[c]	-	−0.028	-	-	-	-	-
205	−0.03	−0.031	−0.012	0.000	−0.011	−0.014	−0.014
219[b]	0.00	-	−0.146	−0.019	−0.163	−0.103	−0.107
269	−0.01	−0.037	−0.051	−0.016	−0.066	−0.023	−0.027

[a] Not observed in the *DDO* system.
[b] Outside the range of the *DDO* calibration.
[c] Outside the range of the Washington calibration.

stars #59, 179 and 219 which fall outside the range of Piatti et al. (1993) calibration. The mean cyanogen anomaly is $<\Delta CN> = -0.035 \pm 0.007$ (m.e.), the negative sign indicating a weak cyanogen band compared with the mean for solar neigbourhood K giants. The cluster metallicity derived from the [Fe/H] versus ΔCN relation given by Piatti et al. (1993) is then [Fe/H] $= -0.29 \pm 0.10$. We note that the *DDO* abundance derived for star #184 ([Fe/H] $= -0.3$) suggests again that this is a cluster giant.

We also examine the cluster abundance by determining the ultraviolet excesses $\delta(U-B)$ with respect to the field K giants. These quantities were derived using Janes's (1979) Eq. (7) and comparing the $(U-B)_0$ and $(B-V)_0$ intrinsic colours of the cluster giants with the standard class III two-colour line of Fitzgerald (1970) (see Fig. 2). The derived *UV* excesses are then directly comparable to ΔCN, which is also based on typical field stars. The computed $\delta(U-B)$ excesses are given in Table 5. The mean value $<\delta(U-B)> = -0.03 \pm 0.01$ (m.e.) derived from 10 cluster giants implies [Fe/H] $\simeq -0.3$, if Janes's (1979) Eq. (8) and Janes's (1975) Eq. (2) are used. We note that this value practically does not change if the three spectroscopic binaries #113, 179 and 269 are omitted. The resulting metallicity is then in excellent agreement with that found from the *DDO* data. Therefore, both ΔCN and $\delta(U-B)$ values support the conclusion that NGC 2354 is a moderately metal-poor open cluster.

3.2.2. Washington abundance parameters

The Washington photometric system provides several independent metallicity indicators. Geisler et al. (1991) have defined fiducial lines for solar abundance giants in the Washington colour-colour diagrams, including the $(C-T_1)_0\,/\,(T_1-T_2)_0$, $(C-M)_0\,/\,(M-T_2)_0$ and $(C-T_1)_0\,/\,(M-T_2)_0$ relations. The abundance-sensitive index Δ is the difference between the observed colour and the solar-abundance colour at the observed (T_1-T_2) [or $(M-T_2)$], where all colours refer to dereddened values. Geisler et al. (1991) described a method for correcting the decrease in abundance sensitivity with temperature and established new empirical calibrations of the abundance indices $\Delta'_1 - \Delta'_5$ with [Fe/H], where $\Delta'_1 - \Delta'_5$ refer respectively to $\Delta'(C-M)_{T_1-T_2}$, $\Delta'(M-T_1)_{T_1-T_2}$, $\Delta'(C-T_1)_{T_1-T_2}$, $\Delta'(C-M)_{M-T_2}$ and $\Delta'(C-T_1)_{M-T_2}$. These Δ' indices can be calculated from the Δ indices using Eq. (2) of Geisler et al. (1991). The derived Washington abundance indices for NGC 2354 giants are given in Cols. (4)-(8) of Table 5. Stars #184 and 200 fall outside the range of the Washington calibration. The resulting mean values and standard deviations of the mean from ten cluster giants are:

$$<\Delta'_1> = <\Delta'(C-M)_{T_1-T_2}> = -0.14 \pm 0.03,$$
$$<\Delta'_2> = <\Delta'(M-T_1)_{T_1-T_2}> = -0.04 \pm 0.01,$$
$$<\Delta'_3> = <\Delta'(C-T_1)_{T_1-T_2}> = -0.18 \pm 0.03,$$
$$<\Delta'_4> = <\Delta'(C-M)_{M-T_2}> = -0.09 \pm 0.02,$$
$$<\Delta'_5> = <\Delta'(C-T_1)_{M-T_2}> = -0.10 \pm 0.02.$$

These values practically do not change if the three spectroscopic binaries #113, 179 and 269 are omitted. Using the abundance calibration of Geisler et al. (1991), the above mean indices yield $[\mathrm{Fe/H}]_1 = -0.37 \pm 0.06$, $[\mathrm{Fe/H}]_2 = -0.33 \pm 0.06$, $[\mathrm{Fe/H}]_3 = -0.37 \pm 0.06$, $[\mathrm{Fe/H}]_4 = -0.32 \pm 0.07$ and $[\mathrm{Fe/H}]_5 = -0.32 \pm 0.07$. The average of the five Washington abundance estimates, [Fe/H] $= -0.34 \pm 0.02$ (s.d.), is in very good agreement with the values derived from both the *DDO* data and the *UV* excesses.

NGC 2354 is therefore on the metal-poor side of the distribution of the intermediate-age open clusters. Since this cluster is located about 1.4 kpc from the Sun at $l = 238°$, its adopted metallicity ([Fe/H] $= -0.30$) is consistent with the existence of a radial metallicity gradient in the Galactic disk (see, e.g., Janes 1979; Piatti et al. 1995).

4. The colour-magnitude diagram

The M_V vs. $(B-V)_0$ diagram for the giant members or probable members of NGC 2354 is plotted in Fig. 3. By adopting the true distance modulus $(m-M)_0 = 10.80$ from Ahumada & Lapasset (1996) and our mean $E(B-V)$ colour excess, the age of NGC 2354 may be estimated by fitting theoretical isochrones computed by Bertelli et al. (1994), which include mass loss and moderate overshooting. In Fig. 3 we plotted the isochrones for $Y = 0.25$, $Z = 0.008$, equivalent to [Fe/H] $= -0.4$, and $\log t = 8.8$, 9.0 and 9.2. A reasonable fit has been found for the isochrone of $\log t = 9.0$ both for the Bertelli et al. (1994) and Schaller et al. (1992) isochrones. A better age determination is awaiting more precise CCD data to replace the old, photographic data of Dürbeck (1960) and the determination of membership of main-sequence stars. Neither set is able to reproduce correctly the distribution of all red giants, the Italian isochrones being too blue and the Swiss ones too red. The peculiar appearance of the red giant clump is partly due to the position of the binaries: binarity has a tendency to move points towards bluer $B-V$ colours. A photometric decomposition of the two most pronounced binaries (#113, 179) has been attempted. The primary of #179 falls with the other single clump stars, while that for #113 falls close to #183 and would define the ascending giant branch.

From this, we could conclude that the shape of the isochrone is in good agreement with the overall distribution of the member red giants when the effect of binarity on the joined colours is properly taken into account. However, the positions of the four stars (#59, 152, 184 and 200) is quite puzzling. If the case of #184 may be explained by differential reddening as mentioned above, no convincing explanation have been found for the three others. The agreement of the radial velocities with the cluster mean ($V_{\rm r}$ = 33.4 km s^{-1}), in particular that for #152 (33.84 km s^{-1}) and #200 (33.08 km s^{-1}), cannot be fortuitous. Red giants with colours redder that those of the bottom of the ascending red giant branch have been found in NGC 6940 (Mermilliod & Mayor 1989) and in NGC 2360 (Mermilliod & Mayor 1990), but both stars are binaries, which does not seem to be the case of stars #59 and 152. Five stars in an anomalous position with respect to the isochrone have been identified in the somewhat older cluster NGC 752 (Mermilliod et al. 1998), but they are bluer than the isochrone, not redder.

In many photometric analysis of the colour-magnitude diagrams, stars located outside the regular sequences are generally rejected, which gives the impression that sequences are clean. Independent kinematical data sometimes support the membership of stars located in an anomalous position. Clearly, additional observations are necessary before one can conclude that the four anomalous stars in NGC 2354 are really non-members. Meanwhile, the observed distribution of the red giants cannot be reproduced by any available model.

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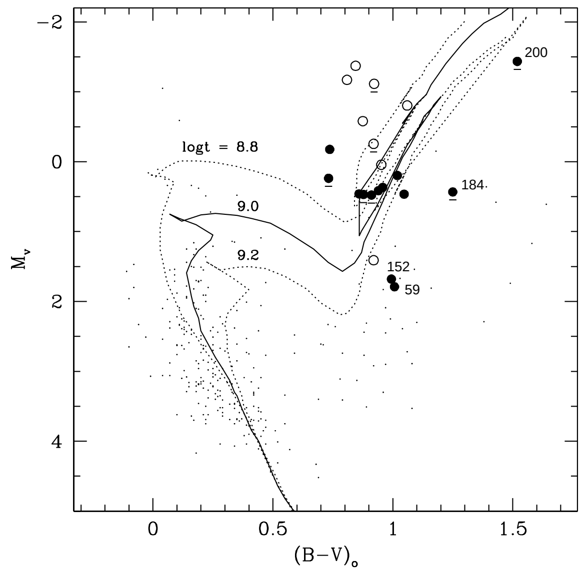

Fig. 3. M_v vs. $(B-V)_0$ diagram for NGC 2354. Confirmed or possible red giant members and red field stars are represented by filled and open circles, respectively. Spectroscopic binaries (underlined) are indicated. Dots represent photographic data from Dürbeck (1960). Isochrones corresponding to $\log t$ = 8.8, 9.0 and 9.2 (Bertelli et al. 1994) are plotted

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