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UBV, DDO and Washington photometric study of late-type evolved stars in the open cluster NGC 2447: membership and chemical composition

Juan J. Clariá

Observatorio Astronómico de Córdoba, Argentina, claria@oac.uncor.edu

Andrés E. Piatti

IAFE, Buenos Aires, Argentina, andres@iafe.uba.ar

Emilio Lapasset and M. Celeste Parisi

Observatorio Astronómico de Córdoba, Argentina,
lapasset@oac.uncor.edu, celeste@oac.uncor.edu

Abstract. UBV, DDO and Washington photometric data for 14 red giant candidates of the open cluster NGC 2447 are presented. Membership results emerging from the application of two photometric criteria are in excellent agreement with those derived from published Coravel radial velocities. A mean cluster reddening E(B-V) = 0.05 ± 0.04 is derived. Both the ultraviolet excesses and the cyanogen anomalies of the cluster giants imply [Fe/H] ≈ -0.1. Five Washington abundance indicators yield a mean cluster metallicity of $[Fe/H]_W$ = -0.09 ± 0.06, thus confirming NGC 2447 to be a slightly metal-poor open cluster.

Resumen. Presentamos datos fotométricos UBV, DDO y Washington de 14 estrellas candidatas a gigantes rojas del cúmulo abierto NGC 2447. Los resultados que se obtienen al aplicar 2 criterios fotométricos para distinguir miembros físicos del cúmulo muestran excelente acuerdo con los derivados a partir de velocidades radiales Coravel publicadas. Derivamos un enrojecimiento medio E(B-V) = 0.05 ± 0.04 para el cúmulo. Tanto los excesos ultravioletas como las anomalías de cianógeno de las gigantes del cúmulo implican [Fe/H] ≈ -0.1. Cinco indicadores de abundancia del sistema de Washington conducen a una metalicidad media de $[Fe/H]_W$ = -0.09 ± 0.06, lo que confirma que NGC 2447 es un cúmulo abierto ligeramente pobre en metales.

1. Introduction

NGC 2447′s inherent interest lies in the number of red giant candidates it contains. As part of a project to determine metallicities of late-type evolved stars in open clusters, we present here high-quality UBV, DDO and Washington photometric data of yellow and/or red giant candidates in the cluster field. These data are used to discuss the likelihood of membership, to determine individual reddening values, and to estimate independent metal abundance parameters.

2. Photometric observations

Eleven stars with V $\geq$ 10.5 and B-V $\geq$ 0.80 were selected as red giant candidates from the cluster CMD. Three yellow stars brighter than V = 10.0 with 0.40 $<$ B-V $<$ 0.50 were also selected as probable cluster evolved stars. All these stars were observed in the UBV, DDO and Washington photometric systems with the Las Campanas 61-cm telescope and the 1.0-m telescope of the Cerro Tololo Inter-American Observatory. Single-channel pulse-counting photometers were used in conjunction with different dry-ice cooled phototubes. The resulting UBV and DDO data are listed in Table 1, wherein the first column gives the star designation from Becker et al. (1976). The washington photometric data are available upon request to the first author. Photometric errors are typically $\sim$ 0.01-0.02 in all photometric indices.

Tabla 1
UBV-DDO photometry and radial velocities of red giant candidates in NGC 2447

Star	V	(B-V)	(U-B)	n_1	C(45-48)	C(42-45)	C(41-42)	n_2	V_r(km/sec)
3	8.206	1.420	1.689	5	0.263	1.146	1.349	2	+20.81
4	10.127	0.920	0.551	2	0.172	0.760	1.137	2	+23.25
7	8.373	1.400	1.558	2	0.327	1.133	1.35	7	+21.97
25	9.915	0.807	0.452	3	0.151	0.667	1.106	3	+21.96
26	9.846	0.450	0.127	2	0.053	0.470	0.890	2	+20.90
28	9.888	0.930	0.663	3	0.204	0.754	1.162	5	+21.25
34	10.138	0.912	0.604	5	0.210	0.767	1.139	2	+22.08
38	9.861	0.470	0.243	2	0.071	0.477	0.899	2	+22.86
41	10.038	0.935	0.595	2	0.170	0.802	1.153	3	+21.51
42	9.806	0.493	0.223	2	0.066	0.472	0.908	2	+15.04
71	10.213	0.883	0.579	4	0.161	0.744	1.156	3	+21.87
85	10.169	0.910	0.587	2	0.173	0.756	1.145	2	+20.56
93	10.436	0.890	0.507	4	0.106	0.774	1.136	2	+22.65
102	10.078	1.446	1.717	4	0.261	1.182	1.273	2	-

3. Membership, reddening, and metal content

Mermilliod & Mayor (1989, MM89) obtained Coravel radial velocities for 13 of the 14 stars observed in this study. As shown in Table 1, these radial velocities demostrate clearly that all 13 stars are cluster members.

Cluster membership was also examined by applying the photometric criteria A and B defined by Clariá & Lapasset (1983). Criterion A was applied by computing for each star the difference $\Delta E = |E(B-V)_{MS} - E(B-V)_{GK}|$, where $E(B-V)_{MS}$ is the cluster reddening derived from the main sequence (MS) stars and $E(B-V)_{GK}$ represents the star reddening obtained from combined UBV and

DDO data, after applying the method described by Janes (1977). A value of E(B-V)$_{MS}$ = 0.04 has been adopted as the average of previous reddening determinations. To apply criterion B, the difference ΔL = |LC(predicted) -LC(DDO)| was computed for each star, where LC (predicted) is the luminosity class that the star would have in order to be cluster member and LC(DDO) is the luminosity class derived from the reddening-corrected DDO colours. The latter data were obtained from the reddening ratios given by McClure (1973). The predicted LC was determined from the Straizys (1992) calibration assuming R = A$_V$/E(B-V) = 3.5 (Straizys 1992) and adopting the cluster distance derived by Bica & Bonatto (2005). Table 2 gives in succession the resulting E(B-V)$_{GK}$ values, the standard deviation of E(B-V)$_{GK}$ calculated from equation (2) of Clariá & Lapasset (1983), the predicted LC, the MK spectral type derived from the calibration of Clariá et al. (1994) and the membership results. Stars 25, 26, 38 and 42 fall outside the range of the DDO calibrations. Only one object (star 102) should be considered a field star according to the photometric criteria. These results are in excellent agreement with those found from the Coravel radial velocities (see Table 1). The mean reddening derived for the red cluster giants is $< E(B-V) >$ = 0.05 ± 0.04 (s.d.), in good agreement with the adopted value for the MS stars.

Tabla 2
Results from applying two photometric membership criteria

Star	E(B-V)$_{GK}$	σ_E	LC (predicted)	MK(DDO)	Criteria (A) (B)	Membership
3	0.12	0.06	II	K3 II-III	pm m	m
4	0.06	0.05	II-III	G5/8 III	m m	m
7	0.08	0.05	II	K3 II	m m	m
28	0.06	0.07	II-III	G5 II	m m	m
34	0.03	0.03	II-III	G5/8 III	m m	m
41	0.01	0.04	II-III	G8 III	m m	m
71	0.02	0.05	II-III	G2/5 II	m m	m
85	0.05	0.05	II-III	G5 III	m m	m
93	0.00	0.06	II-III	G5/8 III	m m	m
102	0.19	0.05	II-III	K4 III-IV	nm pm	nm

To determine the cluster metal content from the DDO data, we applied the iterative procedure proposed by Piatti et al. (1993, PCM). Column 2 of Table 3 lists the resulting cyanogen anomalies as defined by PCM. The mean ΔCN value implies [Fe/H]$_{DDO}$ = -0.12 ± 0.08, if equation (2) of PCM is used. The metallicity was also estimated from the ultraviolet excesses δ(U-B) of the cluster giants determined with respect to the field K giants (FitzGerald 1970). Unreddened (U-B)$_o$ colours were previously derived from equation (9) of Janes (1979). The mean δ(U-B) value from Table 3 implies δCN = 0.01, if equation (8) of Janes (1979) is used, which in turn yields [Fe/H]$_{UV}$ = -0.09 ± 0.05 (McClure 1979). Therefore, both mean δCN and δ(U-B) values support the conclusion that NGC 2447 is slightly metal poor.

Geisler et al. (1991, GCM) proposed an iterative procedure to derive metallicities of G and K giants from Washington indices. They established empirical calibrations of the abundance indices Δ'_1 - Δ'_5 with [Fe/H], where Δ'_1 - Δ'_5 are defined by GCM. The derived indices for the cluster giants are given in columns 4-8 of Table 3. Using the calibrations of GCM, the mean values and corresponding standard deviation of the mean are: $[Fe/H]_1$ = -0.10 ± 0.07, $[Fe/H]_2$ = -0.13 ± 0.04, $[Fe/H]_3$ = -0.11 ± 0.06, $[Fe/H]_4$ = -0.06 ± 0.07 and $[Fe/H]_5$ = -0.06 ± 0.007. The unweighted average of these five estimates turns out to be $< [Fe/H]_W >$ = -0.09 ± 0.06, in very good agreement with the two previous estimates. We finally adopted [Fe/H] = -0.10 ± 0.08 for NGC 2447, in good agreement with the metallicity recently derived by Hamdani et al. (2000) from echelle spectroscopy of only three cluster giants.

Tabla 3
Abundance parameters for red giants in NGC 2447

Star	ΔCN	δ(U-B)	Δ'_1	Δ'_2	Δ'_3	Δ'_4	Δ'_5
3	-0.057	0.11	0.098	0.010	0.108	0.081	0.084
4	0.059	-0.02	-0.051	-0.004	-0.054	-0.037	-0.037
7	-0.007	0.00	0.094	0.007	0.100	0.088	0.091
28	-	0.06	-0.033	-0.004	-0.036	-0.021	-0.021
34	0.091	0.03	-0.051	-0.010	-0.060	-0.028	-0.030
41	0.013	-0.02	-0.078	-0.020	-0.097	-0.044	-0.050
71	-0.011	0.04	-0.199	-0.043	-0.161	-0.050	-0.064
85	0.040	0.00	-0.078	-0.012	-0.089	-0.054	-0.057
93	-0.050	-0.08	-0.087	-0.013	-0.099	-0.058	-0.061

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