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DISTRIBUTION AND STUDIES OF THE INFRARED STELLAR POPULATION IN THE GALAXY. VI. THE HALO[1]

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RESUMEN

Se presentan observaciones infrarrojas J, H y K de 69 estrellas locales del halo de la Galaxia. Se producen los diagramas de dos colores (JHK) y color magnitud (K versus $(J-K)$) para esta muestra estelar y se comparan con los mismos diagramas para las poblaciones estelares de los cúmulos globulares M3, M13, M92 y 47 Tucanae y del cúmulo abierto viejo M67; también se comparan con los diagramas de la población estelar del bulbo galáctico.

ABSTRACT

We present infrared J, H and K observations of 69 local galactic halo stars. We produce the two colour (JHK) and the colour magnitude (K versus $(J-K)$) diagrams for this stellar sample and compare them with the same diagrams for the stellar populations in the globular clusters M3, M13, M92 and 47 Tucanae and in the old open cluster M67; we also compare these diagrams with those for the stellar population in the galactic bulge.

Key words: **GALAXY–HALO — INFRARED–STARS**

1. INTRODUCTION

The study of stellar populations has been an ac- ve field since Baade (1944) proposed for the first me the concepts of Populations I and II. An im- ɔrtant step forward was given by Eggen, Lynden- ell, & Sandage (1962) when they clearly associated ellar atmospheric characteristics (UV excess) with nematical properties of the orbits of the stars they udied; and thus were able to propose a galaxy for- ıation scenario much exploited and discussed, and ɜnerally known as the ELS scenario. Later, Searle, Zinn (1978) proposed an alternative formation sce- ɑrio in contraposition to the ELS proposal. Ma- ɔr landmarks in the field of stellar populations have ɜen periodically reached (see, O'Connell 1958; Tins- y & Larson 1977; Norman, Renzini, & Tosi 1986; arbuy & Renzini 1992; van der Kruit & Gilmore 995), and the recent compilations dedicated exclu- vely to single components of a galaxy such as Jarvis ; Terndrup (1990), Dejonghe & Habing (1993), Mor- son & Sarajedini (1996).

[1] Based on observations collected at the Observatorio stronómico Nacional, San Pedro Mártir, B.C., México.

In this paper, as continuation of our IR study of the Galaxy's stellar populations, we present IR photometry for a sample of 69 local halo stars taken from the Sommer-Larsen & Zhen (1990) sample; and we compare their two colour JHK and their colour magnitude M_K versus $(J-K)$ diagrams with those for the globular clusters M3, M13, M92, and 47 Tucanae; the old open cluster M67, and the galactic bulge, in order to establish similarities and/or differences.

In § 2 we present the observations and the data, while § 3 gives the results, and § 4 presents our summary and conclusions.

2. THE OBSERVATIONS

We observed a number of stars that are presumed to be members of the galactic halo. They were extracted from the local, metal-poor sample of Sommer-Larsen & Zhen (1990). The original 118 stellar sample consists of stars selected without kinematic bias and with a metallicity value of $[Fe/H] \leq -1.5$ and a mean value of $[Fe/H] \sim -2.0$.

The photometry was obtained with the Observatorio Astronómico Nacional (OAN) InSb infrared photometer (Roth et al. 1984) attached to the 2.1-m

TABLE 1

OBSERVING SESSIONS

Session	Date
1	1 – 6 December, 1990
2	30 June – 3 July, 1991
3	11 – 15 November, 1992

telescope. A wobbling secondary with a frequency of 20 Hz was utilised to eliminate the background. A number of standard stars (Tapia, Neri, & Roth 1986; Carrasco et al. 1991; Ruelas-Mayorga & Noriega-Mendoza 1993) were also observed. The reduction techniques were those usual for this type of work. The observations were obtained over a series of observing sessions as shown in Table 1.

The photometric results are presented in Table 2 where the first column gives the star name; columns 2 and 3 give the position $(\alpha, \delta)(2000)$; column 4 gives the distance from the Sun in parsecs (taken from Sommer-Larsen & Zhen 1990); column 5 gives the spectral type taken from the Simbad database, where w = weak line, e = spectrum with emission lines, m = metallic lines, and p = peculiar spectrum; columns 6, 7, 8, 9, 10, and 11 show the reddening corrected values of J, H, K, $J-H$, $H-K$, and $J-K$ transformed to the California Institute of Technology (CIT) IR system. The transformation to the CIT system is achieved by the use of the following equations (taken from Carrasco et al. 1991)

$$K_{\rm CIT} = -0.0176(\pm 0.0141) + 1.0047(\pm 0.0030)K_{\rm OAN} \quad , \qquad (1)$$

$$(J-K)_{\rm CIT} = 0.0356(\pm 0.0048) + 0.8962(\pm 0.0083)(J-K)_{\rm OAN} \quad , \qquad (2)$$

$$(H-K)_{\rm CIT} = 0.0138(\pm 0.0042) + 0.8593(\pm 0.0264)(H-K)_{\rm OAN} \quad . \qquad (3)$$

The reddening for each star, although small, is calculated using the galactic model published by Ruelas-Mayorga (1991a), in which the absorption material is supposed to be distributed in exponential forms, both radially and perpendicularly, to the galactic plane. The local values for the absorption coefficients are $a_J = 0.33$ (mag kpc^{-1}), $a_H = 0.16$ (mag kpc^{-1}) and $a_K = 0.08$ (mag kpc^{-1}).

We found an upper limit value for the photometric errors equal to ± 0.02 mag. We shall attach this uncertainty to all our measurements.

Among the observed stars there were 6 variables. They are all RR-Lyrae stars and their results are presented in Table 3 where the columns are given exactly as for Table 2, except for column 12 in which the date of observation is given. The number of observations is not large enough to be able to establish their pulsation period; however, a mean variation of some tenths of magnitude is seen for each star. RV Cet seems extraordinarily weaker in K with respect to its values in J and H. No obvious reason for this fact has been found.

3. RESULTS

As mentioned in the introduction, this paper forms part of a series in which we study the IR characteristics of the stars that belong to different galactic components.

In Figure 1*a* we present the two colour (JHK) diagram for the halo stars in this paper (stars in Table 2 only); we also show the intrinsic dwarf (solid line) and giant (broken line) sequences from Bessell & Brett (1988). We notice that most of the stars concentrate in the intervals $0.2 \leq J-H \leq 0.8$ and $0.0 \leq H-K \leq 0.2$, although there appears to be a number of stars with bluer $(H-K)$ colour. All the magnitudes and colours presented in this paper have been transformed to the California Institute of Technology IR system —thus the CIT subscript— so comparison with photometry published by other authors is directly possible. The RR Lyrae stars observed are not plotted in any of the figures of this paper. In Figure 1*b* we present the same JHK diagram on a different horizontal scale so that it is also possible to plot the reddening corrected values of Cohen, Frogel, & Persson (1978) for the globular clusters M3 (open circles), M13 (open squares), and M92 (open diamonds) and for the old open cluster M67 (crosses). Points for the globular cluster 47 Tucanae (skeletal triangles) are also plotted (Frogel, Persson, & Cohen 1981) as well as bulge IR photometry from Frogel & Whitford (1987) (three pointed stars) and Ruelas-Mayorga & Teague (1992a) (four pointed stars). This figure (Fig. 1*b*) shows that the local halo stars and those in globular clusters agree excellently well in position in the interval $0.4 \leq (J-H)_{\rm CIT} \leq 0.6$, above $(J-H)_{\rm CIT} \sim 0.6$ there are fewer local halo stars in this diagram and only the stars from globular clusters are present, being those belonging to 47 Tuc the ones that climb to redder $(J-H)$ colours. Below $(J-H)_{\rm CIT} \sim 0.4$ there are also fewer local halo stars and mainly only the stars from M67 extend into this realm. From this comparison it is fair to say that, as expected, the IR two colour JHK diagram for the local halo stars is similar to the same diagram for globular clusters and old open clusters stars; although, most probably (see below) the halo stars presented in this paper are mainly dwarfs, whereas those in clusters are in their majority giants.

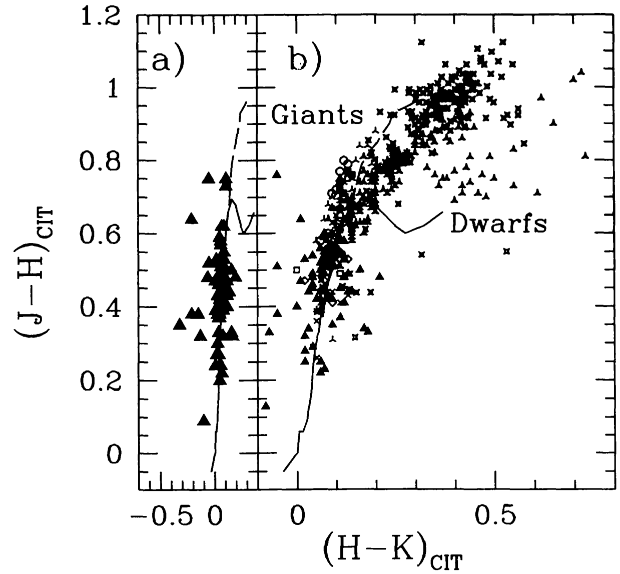

Fig. 1. *a*) *JHK* diagram for the halo stars studied in this paper. The intrinsic dwarf (solid line) and giant (broken line) sequences from Bessell & Brett (1988) are shown. *b*) *JHK* diagram for the halo stars in this paper and stars belonging to other stellar populations: M3 (open circles), M13 (open squares), M92 (open diamonds), M67 (crosses), 47 Tucanae (skeletal triangles), BW stars from Frogel & Whitford (1987) (three pointed stars) and BW stars from Ruelas-Mayorga & Teague (1992a) (four pointed stars).

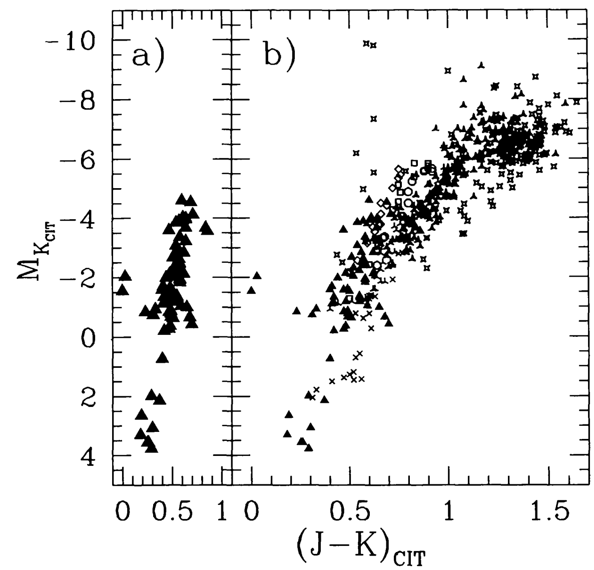

Fig. 3. *a*) Colour-magnitude ($M_{K_{\rm CIT}}$ versus $(J-K)_{\rm CIT}$) diagram for the halo stars studied in this paper. *b*) The same colour-magnitude diagram in which the halo stars are seen in comparison with stars from other stellar populations. The symbols are as for Figure 1*b*. Note how the halo stars extend to bluer colours and fainter magnitudes.

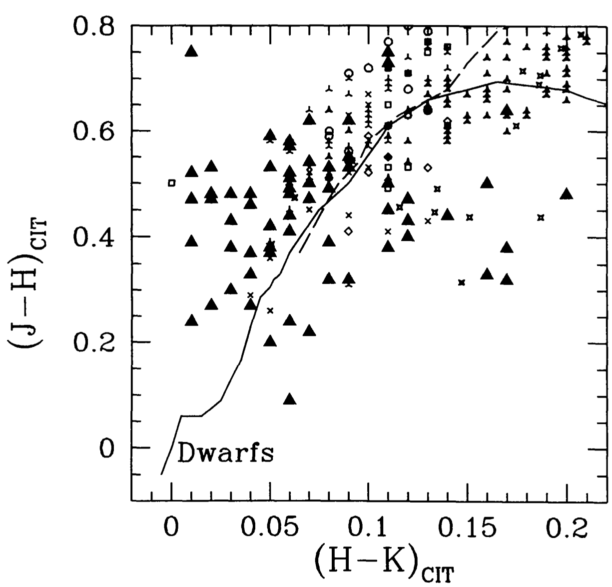

Fig. 2. *JHK* diagram for a more restricted area. Note how the halo stars seem to extend further down and to the left than most of the stars from the other stellar populations. The symbols are as for Figure 1*b*. The dwarf (solid line) and giant (broken line) sequences are shown.

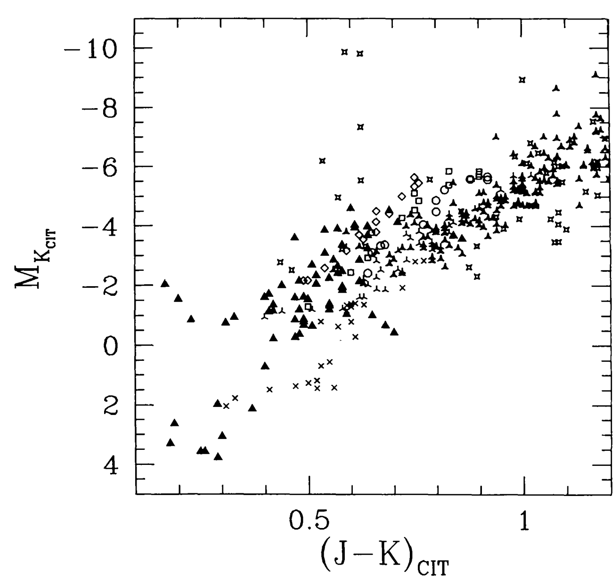

Fig. 4. The same colour-magnitude diagram for a more restricted section of the plot.

TABLE 2

PHOTOMETRY OF HALO STARS IN THE CIT SYSTEM

Halo Star	R.A. (2000)	Dec. (2000)	d(pc)	Sp. Type	J	H	K	$(J-H)$	$(H-K)$	$(J-K)$
HD 20	00 05 15.1	−27 16 16	490	F2 V	7.79	7.27	7.25	0.53	0.02	0.55
HD 97	00 05 46.0	−19 40 06	500	G5 V	8.14	7.65	7.49	0.50	0.16	0.65
HD 2372	00 16 16.5	−22 34 38	600	K0 III	8.16	7.70	7.69	0.47	0.01	0.48
HD 2796	00 31 16.9	−16 47 38	650	Fw	6.77	6.33	6.22	0.45	0.11	0.56
HD 3171	00 34 50.5	−21 52 52	860	G8 V	8.28	7.84	7.70	0.44	0.14	0.58
HD 4306	00 45 27.0	−09 32 40	630	G0	7.31	6.81	6.76	0.49	0.06	0.55
HD 6268	01 03 18.3	−27 52 47	700	G0	6.52	5.77	5.66	0.75	0.11	0.86
HD 6461	01 05 25.2	−12 54 14	190	G3 V	6.09	5.64	5.60	0.46	0.04	0.49
HD 6755	01 09 38.5	+61 32 46	150	F8 V	6.07	5.68	5.60	0.39	0.08	0.47
HD 6833	01 09 52.1	+54 44 19	310	G9 III	4.40	3.86	3.77	0.55	0.09	0.64
HD 8724	01 26 17.3	+17 07 39	800	G5 V	6.18	5.68	5.60	0.49	0.08	0.57
BD − 10 388	01 50 31.9	−09 21 04	250	F3	9.25	9.02	8.96	0.22	0.07	0.29
HD 11582	01 53 00.1	−34 17 56	390	G5/G6 V:w	8.16	7.53	7.74	0.64	−0.21	0.42
HD 13359	02 10 06.9	−20 45 51	410	G1/G2V	8.33	7.57	7.63	0.75	−0.05	0.70
HD 13979C	02 15 20.6	−25 54 52	910	G0	7.62	7.13	7.11	0.48	0.03	0.51
BD + 44 493	02 26 49.1	+44 57 48	190	B2	7.52	7.20	7.12	0.32	0.08	0.40
BD − 17 484	02 31 25.2	−16 59 00	210	sdG2	9.42	9.10	9.24	0.32	−0.13	0.19
HD 16031	02 34 11.0	−12 23 00	120	F0 V	8.75	8.51	8.46	0.24	0.06	0.30
CD − 361052	02 47 37.0	−36 06 30	740	F2	9.34	8.86	8.67	0.48	0.20	0.68
HD 21581	03 28 54.1	−09 25 00	620	G0	6.96	6.60	6.92	0.35	−0.32	0.03
CD − 241782	03 38 41.0	−24 02 50	560	?	8.54	8.23	8.05	0.32	0.17	0.49
HD 26297	04 09 03.2	−15 53 28	520	G5/G6 IVw	5.24	4.70	4.63	0.54	0.07	0.61
HD 25532	04 04 10.7	+23 24 32	420	F6 IV-V	6.56	6.47	6.56	0.09	−0.10	0.00
HD 27928	04 22 54.9	−37 15 46	720	G0	7.93	7.39	7.34	0.53	0.05	0.58
HD 31128	04 52 09.2	−27 03 50	070	F3/F5 Vw	8.28	8.01	8.00	0.27	0.02	0.29
HD 33073	05 06 31.9	−28 33 36	600	F3 V	8.16	7.68	7.74	0.48	−0.06	0.42
HD 37828	05 40 54.5	−11 11 58	390	K0	4.61	4.04	3.97	0.57	0.06	0.64
HD 44007	06 18 48.1	−14 50 42	370	G5 IV:w	6.31	5.83	5.79	0.48	0.04	0.52
HD 45610	06 27 06.3	−32 09 55	260	G3 IV/Vw	5.55	5.02	4.94	0.53	0.09	0.62
HD 63791	07 54 29.0	+62 08 15	470	G0	6.13	5.59	5.51	0.53	0.09	0.62
BD − 20 2583	08 32 14.0	−20 44 30	760	?	8.20	7.81	7.81	0.39	0.01	0.40
HD 74000	08 40 49.4	−16 20 18	110	sdF6	8.68	8.29	8.50	0.38	−0.21	0.18
HD 74462	08 48 20.2	+67 27 05	710	G5 IV	6.65	6.07	6.02	0.59	0.05	0.64
BD + 54 1323	09 42 19.2	+53 28 27	620	G2we	7.84	7.40	7.37	0.43	0.03	0.47
BD + 58 1218	09 52 39.8	+57 55 03	1000	F8	8.33	7.80	7.85	0.52	−0.05	0.48
CD − 248642	09 59 35.0	−24 51 30	620	K0	8.18	7.71	7.63	0.47	0.07	0.55
HD 88609	10 14 28.8	+53 33 41	1000	G5 IIIwe	6.68	6.21	6.14	0.48	0.06	0.54
BD + 04 2466	11 26 50.0	+03 51 55	780	G5	9.07	8.74	8.59	0.33	0.16	0.49
BD − 01 2582	11 53 37.6	−02 00 30	540	F0	8.21	7.74	7.61	0.47	0.12	0.59
BD + 52 1601	11 59 59.0	+51 46 17	630	G5 IIIm	7.18	6.78	6.67	0.40	0.12	0.52
HD 105546	12 09 02.9	+59 01 08	410	G2 IIIm	7.24	6.81	6.68	0.43	0.12	0.55
HD 108317	12 26 37.0	+05 18 11	220	G0	6.58	6.09	6.07	0.48	0.03	0.51
HD 119516	13 43 26.8	+15 34 32	480	G5	7.79	7.41	7.56	0.38	−0.15	0.23
HD 122563	14 02 32.4	+09 41 14	350	F8 IV	4.29	3.75	3.68	0.53	0.08	0.61
HD 122956	14 05 13.2	−14 51 23	390	G6 IV/Vw	5.17	4.64	4.58	0.52	0.06	0.58
HD 126587	14 27 00.2	−22 14 36	890	Gw...	7.21	6.73	6.67	0.49	0.06	0.54
HD 128279	14 36 48.2	−29 06 29	240	G0	6.50	6.10	6.04	0.41	0.06	0.47
BD − 08 3901	15 04 51.2	−08 49 00	760	G0	7.56	7.05	6.99	0.51	0.06	0.57

TABLE 2 (CONTINUED)

Halo Star	R.A. (2000)	Dec. (2000)	d(pc)	Sp. Type	J	H	K	$(J-H)$	$(H-K)$	$(J-K)$
BD + 01 3070	15 22 40.0	+01 15 50	480	G0	8.50	8.07	8.02	0.42	0.05	0.48
HD 140283	15 43 07.2	−10 55 45	050	sdF3	6.00	5.66	5.63	0.33	0.04	0.37
BD + 11 2998	16 30 16.6	+10 59 52	510	F8	7.59	7.23	7.18	0.37	0.05	0.42
BD + 17 324	17 28 14.8	+17 30 32	740	A0	7.78	7.40	7.34	0.38	0.05	0.44
HD 165195	18 04 40.1	+03 46 49	430	K3p	4.74	4.12	4.04	0.62	0.09	0.71
HD 166161	18 09 40.9	−08 46 37	620	G5	5.83	5.44	5.36	0.39	0.08	0.47
HD 176203	19 00 04.0	−23 03 41	370	F5 V	7.12	6.75	6.71	0.37	0.04	0.41
HD 178443	19 10 36.7	−43 16 31	840	F8	8.32	7.94	7.91	0.38	0.03	0.41
HD 181743	19 23 43.2	−45 03 37	090	F3/F5w	8.59	8.35	8.33	0.24	0.01	0.25
HD 187111	19 48 39.4	−12 07 17	670	G8wvar	5.27	4.64	4.58	0.62	0.07	0.69
HD 188031	19 54 58.3	−42 37 59	130	F5 V	9.39	9.19	9.13	0.20	0.05	0.26
HD 199854	21 00 13.6	−15 06 52	460	F7:w	7.86	7.60	7.56	0.27	0.04	0.31
HD 204543	21 29 28.1	−03 30 53	490	G0	6.38	5.88	5.81	0.50	0.07	0.57
HD 206739	21 44 23.7	−11 46 21	510	G5 V	6.65	6.12	6.06	0.52	0.06	0.58
HD 210295	22 09 41.5	−13 36 15	640	G8/K0w	7.76	7.25	7.18	0.52	0.06	0.58
HD 213487	22 32 03.2	−21 35 56	740	G8 IV	8.22	7.75	7.72	0.47	0.02	0.49
HD 214362	22 37 57.9	−22 38 38	500	Gw...	7.88	7.58	7.56	0.30	0.03	0.33
HD 215601	22 46 47.7	−31 52 13	480	G6/G8w...	5.56	4.83	4.73	0.73	0.11	0.84
HD 216143	22 50 31.2	−06 54 45	680	G5	5.81	5.23	5.16	0.58	0.06	0.64
HD 218857	23 11 24.7	−16 14 59	480	G6w	7.36	6.92	6.87	0.44	0.06	0.50
HD 221170	23 29 28.8	+30 26 00	770	G2 IV	5.43	4.93	4.83	0.50	0.11	0.60

TABLE 3

PHOTOMETRY OF VARIABLE STARS IN THE HALO IN THE CIT SYSTEM

Halo Star	R.A. (2000)	Dec.	d(pc)	Sp. Type	J	H	K	$(J-H)$	$(H-K)$	$(J-K)$	Date
XX And	01 17 27.2	+38 57 05	970	A2	9.56	9.47	8.23	0.09	1.24	1.33	13/14 Nov 9
XX And	...	...	...	...	10.01	9.94	8.67	0.07	1.27	1.34	same date
RR Cet	01 32 08	+01 20 32	610	A0	8.27	7.74	7.68	0.53	0.06	0.59	13/14 Nov 9
RR Cet	...	...	...	...	8.83	8.55	8.51	0.28	0.03	0.31	same date
RR Cet	...	...	...	...	9.28	9.01	8.96	0.27	0.04	0.31	same date
RV Cet	02 15 15.6	−10 48 05	1000	F	10.23	9.78	14.03	0.45	−4.25	−3.80	13/14 Nov 9
RV Cet	...	...	...	...	10.67	10.23	14.47	0.44	−4.24	−3.80	same date
X Ari	03 08 30.6	+10 26 50	460	A0	8.46	8.15	8.06	0.31	0.08	0.39	13/14 Nov 9
X Ari	...	...	...	...	8.91	8.62	8.50	0.29	0.11	0.40	same date
SV Eri	03 11 51.7	-11 21 21	680	A0	8.92	8.60	8.52	0.32	0.07	0.39	12/13 Nov 9
SV Eri	...	...	...	...	9.01	8.75	8.71	0.26	0.04	0.30	13/14 Nov 9
SV Eri	...	...	...	...	9.46	9.19	9.16	0.27	0.03	0.30	same date
RX Eri	04 49 44.2	−15 44 28	600	F2	10.03	9.49	9.46	0.54	0.03	0.57	4/5 Dic 90
RX Eri	...	...	...	...	9.59	9.23	9.29	0.36	−0.06	0.30	11/12 Nov 9

The comparison between our local halo stars and the stars in Baade's Window (BW) is striking because of the strong difference present. There is a slight coincidence in $0.0 \leq (H-K)_{\rm CIT} \leq 0.2$, but mainly the BW stars which are presumably bulge members in their majority, are much redder both in $(J-H)$ and $(H-K)$. However, this only reveals the fact that observations of stars in the galactic bulge have only been possible for extreme giants of spectral types K and M mainly. Figure 2 presents the JHK diagram restricted to the intervals $0.0 \leq (J-H)_{\rm CIT} \leq 0.8$ and $0.0 \leq (H-K)_{\rm CIT} \leq 0.2$. In this diagram the coincidences and differences reported above are appreciated as well. Of the 69 local halo stars, 3 are subdwarfs, 23 belong to luminosity class IV or V, 5 belong to class III, and 38 have no luminosity class determination. From the two-colour diagram, we see that the halo stars with $(J-H)_{\rm CIT} \leq 0.35$ appear more or less near the dwarf intrinsic sequence; however, only 3 of these stars (HD 16031, HD 25532, and HD 188031) are confirmed as dwarfs from their spectral classification; above $(J-H)_{\rm CIT} \sim 0.35$ the stars present a wide spread around the dwarf and giant intrinsic sequences. Their spectra indicate that among this group we have subdwarfs, dwarfs, and giants. Most probably, the majority of the halo stars studied in this paper are dwarfs, whereas the cluster and BW stars are giants. This is probably the main reason for the differences between the group of halo stars studied in this paper and the other stellar groups.

It is interesting to notice that there is a branch of the local halo stars which extends from $(H-K)_{\rm CIT} \sim 0.12$, $(J-H)_{\rm CIT} \sim 0.5$ towards redder $(H-K)$ colours and bluer $(J-H)$ colours. This branch is matched neither by the cluster stars nor by the bulge stars.

Figure 3*a* presents the colour-magnitude ($M_{K_{\rm CIT}}$ versus $(J-K)_{\rm CIT}$) diagram for the local halo stars studied in this paper. They concentrate in the intervals $0.0 \leq (J-K)_{\rm CIT} \leq 1.0$ and $-5.0 \leq M_{K_{\rm CIT}} \leq 4.0$. Each halo star is corrected for the distance modulus corresponding to the distance at which it is located.

In Figure 3*b* we present the same colour magnitude diagram, this time with a longer horizontal scale, so that it is also possible to plot points for stars in other stellar systems. We superpose the sequences for M3, M13, M92, M67, 47 Tuc and the bulge (symbols are the same as for Figure 1*b*). The $K_{\rm CIT}$ magnitudes for the clusters are corrected for distance modulus whose values are, for M3, M13, M92 and M67: 14.83, 14.33, 14.57, and 9.38 respectively (Cohen et al. 1978), for 47 Tuc it is 13.14 (Frogel et al. 1981), for the Frogel & Whitford (1987) data for BW the distance modulus is 14.2, and finally for the BW data of Ruelas-Mayorga & Teague (1992a) it is 14.71.

In this diagram the local halo stars coincide with cluster stars in the intervals $0.4 \leq (J-K)_{\rm CIT} \leq 0.8$ and $-4.0 \leq (H-K)_{\rm CIT} \leq 0.0$; some stars extend to bluer $(J-K)_{\rm CIT}$ colours and fainter absolute magnitudes. What we see in this diagram is a long sequence starting at $(J-K)_{\rm CIT} \sim 0.3$, $M_{K_{\rm CIT}} \sim 4.0$ and ending at $(J-K)_{\rm CIT} \sim 1.5$, $M_{K_{\rm CIT}} \sim -8.0$ which represents a sequence from dwarf to giant stars.

Figure 4 presents the colour magnitude diagram for a more restricted section, so that the coincidences or differences pointed out above may be more clearly appreciated.

4. SUMMARY AND CONCLUSIONS

i) We observe 69 local halo stars in the IR J, H, and K filters in order to establish their similarities and differences with other stellar populations in the Galaxy.

ii) From the two colour JHK diagram we see that the halo stars match rather well, as expected, with the cluster stars, but differ strongly from the bulge stars.

iii) The colour magnitude diagram ($M_{K_{\rm CIT}}$ versus $(J-K)_{\rm CIT}$) shows the halo stars to coincide with the lower part of the cluster data, however, they (the halo stars) extend down to bluer colours and fainter magnitudes.

iv) The halo stars are most probably dwarfs in their majority. This is the main reason for the observed differences between them and the stars in clusters and in BW.

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