

Analysis of Gaia DR3 data of selected R stars (warm carbon stars)

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Abstract

An analysis of Gaia DR3 data of 67 R stars is presented and 57 of them are at high galactic latitudes. Three new variable stars are found. The long period luminous variable R stars and R8 stars may be variable carbon stars on the AGB. The R stars seem to have luminosities throughout the RGB range. Several R stars are found to be high velocity stars. The determination of s-process elements abundances and C12/C13 ratio of the stars listed in Table 1 will enable us to further understand the R stars phenomenon. The process by which the atmospheres of these stars are enriched with carbon is still a puzzle.

Keywords: Stars: R Stars-Stars: Carbon- Stars: Evolution

1. Introduction

The warm carbon stars (R-stars) have effective temperatures and luminosities that are like that of G and K giants (Red Giant Branch (RGB) stars) (Keenan 1993). However, unlike the G and K giants the R stars have an overabundance of carbon and low carbon isotope ratios which is unusual. Their luminosities are too low when compared to that of classical carbon stars (Asymptotic Giant Branch (AGB) stars). Hence, they have not undergone the AGB nucleosynthesis and third dredge-up.

McClure (1997) monitored the radial velocities of many R stars and found that they are not binaries. Hence the origin of overabundance of carbon in R stars is intrinsic. The favored hypothesis for carbon overabundance in R stars is helium core- flash (Dominy 1984, McClure 1997, Parthasarathy 1991). However, the models do not produce mixing at He-flash, and it is not clear how the carbon is brought the surface (Piersanti et al. 2010). Zhang and Jeffery (2013) proposed that a helium white dwarf subducted into a low-core-mass red giant could produce an R star. To further understand the luminosities (distances) and evolutionary status of R stars I present an analysis of Gaia DR3 data of 67 stars extracted from the Gaia DR 3 data base (Gaia Collaboration 2022) (CDS Strasbourg, France). The R stars are selected from Keenan (1993), Barnbaum et al. (1996), McClure (1997), and Knapp et al. (2001). Other types of carbon stars are not included. The Gaia DR 3 data of selected R stars is given in Table 1.

2. Analysis

All the stars listed in Table 1 have very accurate Gaia DR3 parallaxes (distances). For seven stars the RUWE values are more than 1.4. The absolute visual magnitudes Mv are derived

using the observed V magnitudes and B-V colors and E(B-V) values are estimated from the spectral types and intrinsic and observed B-V colors (Cox 2000, Keenan 1993). The Teff, log g and [Fe/H] values given in Table 1 are from the Gaia DR3 data and for a few stars they are from Dominy (1984). The radial velocities (RV) given in Table 1 are from the Gaia DR3 data. For a few stars they are from Wilson's (1953) catalogue.

HD 48733, HD 178316 and HD 188934 are found to be new variables (from their Gaia DR3 light curves). HD 1994, HD 19557, HD 52432, HD 57884, HD 63353, HD 77234, HD 79319 HD 93506, HD 107957, HD 117819, HD 164889, HD 168227, HD 206382 and HIP 33042 are known variable stars. Some of them are long period variable stars (LPV). All the above-mentioned stars have Gaia DR3 light curves and spectra. HD 57884 is classified as an R8 star (Vandervort 1958). It is a high luminosity and very low surface gravity (log g) star. HD 63353 is also a luminous R8 star. It is difficult to distinguish between R8 stars and normal carbon stars, it is likely that some of the late-type long period variable R stars are long period variable carbon stars on the AGB stage of evolution. Of the above-mentioned variables 10 are classified as R5 stars and several of them have absolute visual magnitudes (Mv) like that of RGB stars. Abia et al. (2022) are of the view that R-type carbon stars have luminosities extending all along the RGB.

In this sample several high velocity stars have been found and they are: HD 57884, HD 88627, HD 164889, HD 170282, HD 187216, HD 188934, HD 198140, BD -19 290, BD-8 456, BD+2 4338, BD+19 3109, BD+30 2637, BD+33 1194, HIP 39118, HIP 40374, HIP 33042, HIP 71464, HIP 85117. BD+19 3109 is most likely a galactic halo star. HIP 40374 radial velocity is +204 km/sec, but its galactic latitude is -0.02 degrees. High velocities and high galactic latitudes indicate that these are indeed low mass stars belonging to the thick disk population.

Based on the Gaia DR 3 data HD 164889 (W CrA), BD-19 290 and BD -18 3055 are found to be single lined spectroscopic binary stars (SB1) with periods of 1.205, 0.5 and 1054 days respectively.

3.0 Conclusions

Some of the R stars are found to be variable stars. The more luminous long period variable R stars and R8 stars may be variable carbon stars on the AGB. Several R stars have been found to be high velocity stars and many of them are at high galactic latitudes. The R stars seem to have luminosities throughout the RGB range. The process for the overabundance of carbon in R stars is still not found. It may be intrinsic (such as helium core-flash) or extrinsic (such as merger of two evolved low mass stars). Determination of s-process elements abundances and carbon isotope ratio (C12/C13) of all the 67 R stars listed in Table 1 is needed to further understand the evolution of these stars and an analysis of Gaia DR3 spectra and light curves is

also important. Using carbon overabundance as the criteria, an analysis of spectra of G and K giants in the Gaia DR3 database may reveal many new R stars.

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References

Abia, C., de Laverny, P., & Romero-Gomez, M., et al., 2022, A & A 664, A45

Barnbaum, C., Stone, R.P.S., & Keenan, P. C., 1996, ApJS 105, 419

Cox, A.N., 2000, Allen's Astrophysical Quantities (4th edition)

Dominy, J.F., 1984, ApJS 55, 27

Gaia Collaboration DR3 2022, Part 1, Part 3, & Part 4

Keenan, P.C., 1993, PASP 105, 905

Knapp, G., Pourbaix, D., & Jorissen, ., 2001, & A 371, 222

McClure, R.D., 1997, PASP 109, 256

Parthasarathy, M., 1991, A & A 247, 429

Piersanti, L.., Cabezon, R.M., & Zamora, O., et al., 2010, A & A 522, A80

Vandervort, G.L., 1958, AJ 63, 477

Wilson, R.E., 1953, General Catalogue of Stellar Radial Velocities

Zhang, X., & Jeffery, C.S., 2013, MNRAS, 430, 2113

Table 1. Gaia DR 3 data of selected R stars

Star	**l deg**	**b deg**	**V**	**B-V**	**Sp.**	**G mag**	**RV km/s**	**mu mas/ yr**	**d pc**	**Mv**	**Teff K**	**log g**	**[Fe/ H]**
HD													

1994	118.98	-8.37	9.29	1.81	R5	8.36	-36.0	6.393	553	-2.5			
7526	292.44	-68.40	10.0	1.28	R0	9.72	31.7	20.974	607	-0.3			
16115	181.98	-59.82	8.15	1.21	R3	7.85	15.5	12.486	409	-0.34	4500	2.1	-0.2
19557	140.67	-0.06	8.59	1.45	R5	6.28	-7.4	2.893	569	-1.14	4374	0.84	0.4
24281	249.49	-50.62	8.29	1.8	R3	7.84	21.0	15.121	723	-3.38			
26667	283.30	-39.0	10.65	1.17	R3	10.2	4.0	3.464	1756	-0.87	3558	1.84	-0.56
48733	280.61	-26.50	9.36	1.39	R0	9.07	32.2	1.982	1085	-2.3	4750	2.5	0.65
52432	216.92	0.65	8.76	1.22	R5	6.27	21.6	6.283	812	-1.51			
57884	220.32	5.09	9.0	2.7	R8	8.0	49.2	0.742	2372	-6.46	3535	0.0	-0.57
58337	196.61	17.12	9.57	1.43	R3	9.43	-0.84	10.238	974	-1.53	4582	2.10	-0.40
58364	196.64	17.12	9.23	1.44	R3	8.88	-8.05	8.110	1129	-2.02			
63353	214.64	15.20	8.72	2.51	R8	7.79	16.0	4.223	1222	-4.62			
76846	190.31	40.28	9.42	1.29	R2	9.11	25.2	3.155	621	-0.60			
77234	168.73	41.33	9.43	1.56	R5	8.77	5.1	9.205	1141	-2.18			
79319	215.75	37.89	8.57	1.67	R4	7.82	-2.8	4.459	692	-1.75			
88627	132.92	36.87	10.83	1.52	R5	10.2	-92.0	9.857	1721	-2.33	4863	1.75	-0.08
90395	280.47	5.96	9.49	1.27	R0	9.22	-2.32	3.557	631	-0.86	5040	2.10	0.19
93506	290.46	-5.83	10.20	0.9	R5	7.52	-20.1	18.749	968	-0.06			
95405	273.81	30.67	8.33	1.18	K5 R	8.04	5.55	33.354	260	0.59	4582	2.1	0.01
100764	276.86	44.41	8.79	1.02	R2	8.51	9.79	16.662	297	0.9	4846	2.2	-0.59
107957	298.45	13.2	7.60	1.85	R5	6.71	-41.0	10.932	640	-3.91	4489	1.21	0.31
112127	0.97	89.35	6.88	1.26	R4	6.55	5.76	3.693	128	1.01	4398	1.91	0.22
113801	307.72	42.67	8.50	1.17	R3	8.22	-9.83	16.496	668	-1.28	4710	2.20	-0.26
117619	309.07	8.55	8.51	2.1	R5	7.67	-32.2	6.950	1350	-4.02			
122547	57.68	73.73	9.54	1.23	R2	9.18	-28.2	20.624	707	-0.56	4460	2.0	0.03
123821	97.46	61.56	8.63	1.05	R2	8.42	-20.3	13.312	678	-1.05	4900	2.60	0.04
156074	67.0	35.40	7.61	1.14	R2	7.39	-12.3	41.354	290	-0.36	4574	2.0	0.05

163838	93.56	30.47	10.72	1.12	R4	10.5	-42.5	9.043	1524	-0.81			
164889	352.97	-8.69	9.91	1.72	R5	9.23	-105	23.796	2472	-3.37			
168227	15.43	-0.18	8.66	1.89	R5	7.43	-16.2	1.036	1121	-2.88			
170282	356.02	-12.65	9.88	1.46	R5	9.31	-71.9	10.241	1370	-1.46			
178316	19.29	-11.52	10.32	1.4	R0	9.96	-36.1	7.114	708	-0.25			
187216	117.81	26.37	9.56	1.64	R3	9.08	-129	4.402	1847	-3.36	3500	0.40	-2.5
188934	40.87	-14.57	9.37	2.01	R3	8.66	61.9	12.429	1435	-4.05			
198140	27.49	-34.15	10.14	1.32	R1	9.95	56.7	8.693	1102	-1.19			
201266	343.74	-41.88	9.79	1.5	R5	9.06	14.9	4.271	910	-1.65			
206382	327.38	-42.12	10.07	1.39	R0	9.39	18.6	8.111	1291	-2.1			
216649	63.64	-55.76	10.75	1.21	R0	10.5	-31.1	9.467	2024	-1.94			
218851	105.37	13.11	9.93	1.3	R2	9.61	-41.3	8.103	886	-0.8			
218875	42.58	-66.45	9.32	1.24	R0	8.95	42.2	36.534	792	-1.43			
223392	96.42	-53.25	8.50	1.5	R3	8.14	-20.6	16.878	293	0.04			
286436	178.46	-30.17	10.2	1.6	R2	9.82	-34.3	16.315	687	-0.96			
BD													
-19 290	179.58	-76.06	11.07	1.34	R0	10.1	112	19.325	4219	-3.18	4234	0.77	-3.58
-18 3055	268.5	35.56	10.6	1.1	R2	10.2	-4.55	8.099	1376	-0.62	4250	3.0	0.49
-8 456	176.70	-59.69	9.55	1.75	R0	8.97	50.3	0.994	1296	-2.96	4437	1.74	0.04
+2 2446	263.42	58.54	10.17	1.29	R2	9.94	11.6	10.467	817	-0.02	4472	2.21	-0.26
+2 4338	55.0	-30.51	9.78	1.32	R2	9.45	-52.8	9.142	1183	-1.74			
+4 2735	322.31	65.40	9.64	1.46	R0	9.34	-14.3	30.887	442	0.98	4189	1.63	0.04

+16 2188	231..1	60.90	10.11	1.29	R0	9.8	24.5	7.367	464	0.98	4293	1.56	-0.38
+17 3325	41.63	22.05	8.73	1.18	R0	8.37	-47.5	2.020	431	-0.36			
+19 3109	36.48	39.75	10.29	1.59	R2	9.96	-187	18.977	2956	-4.01			
+21 64	117.73	-40.28	9.65	1.32	R2	9.46	12.5	10.229	762	-0.3	4383	2.0	-0.09
+23 601	169.4	-21.85	10.5	1.3	R2	10.0	-10.5	7.344	845	-0.22			
+23 2998	42.65	36.95	9.80	1.2	R3	8.80	-30.8	14.396	572	0.62			
+30 2637	46.1	57.9	9.74	1.04	R0	9.53	-95.3	33.783	754	-0.24			
+33 1194	177.01	4.62	10.4	1.5	R2	9.98	-56.3	11.170	789	-0.74			
+71 600	128.70	46.15	10.15	1.25	R2	9.89	-21.4	8.301	1131	-0.94	4423	1.81	-0.28
+83 442	118.12	33.06	9.97	1.05	R0	9.69	-14.8	2.885	1316	-1.12	4616	2.09	-0.19
HIP													
19050	170.42	-21.31	10.71	1.28	R0	10.5	31.62	4.313	396	1.8			
33042	241.94	-13.58	10.62	2.12	R8?	9.79	54.0	9.781	2165	-3.6			
39118	225.26	12.96	11.2	1.95	R2	10.7	96.2	1.867	3253	-4.5	4795	1.21	-0.42
40374	252.67	0.02	11.37	1.79	R3?	11.1	204	20.034	1810	-2.53			
71464	328.53	27.36			R3	11.7	94.3	16.241	2779		4344	1.76	-0.16
75745	330.49	10.31	11.7	1.26	R3	11.3	-32.9	7.264	1265	0.33			
85117	351.16	-0.23	9.54	1.62	R3	8.91	-80.6	15.605	506	-0.76			
89239	42.18	15.21	10.71	1.3	R4	10.4	10.5	2.214	1649	-1.56	4785	1.85	-1.2
90199	35.26	8.78	11.7	1.19	R0	11.5	-32.2	22.344	570	1.68	5226	3.27	0.01