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A-shell stars in the Geneva system

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Abstract. Among the various kinds of A stars having a peculiar spectrum, we find the A-shell stars. Many questions are still open concerning these stars, including their evolutionary status. In the present study we have used data from the Hipparcos catalogue to examine this point. We have found that the majority of A-shell stars are well above the main sequence. No differences could be established between A-shell stars in luminosity classes III and I and those in luminosity class V as regards variability, duplicity, or the importance of the shell feature.

Key words: techniques: photometric – stars: general – stars: peculiar

1. Introduction

The publication of the Hipparcos and Tycho catalogues enables us to consider, or reconsider, the evolutionary status of various kinds of peculiar stars. Among these, we find the A-shell stars. These stars are characterized by the coexistence of two types of line profiles in their spectra: one originating in the stellar photosphere and the other one originating in the cooler shell. While the former lines are broad, the latter are sharp and narrow. Usually lines of Ca II, H I and Fe II belong to the second category. Recently, Jaschek and Andrillat (1998) published a study of 14 Ae- and A-shell stars and one of their results was an overbrightness of A-shell stars. As their sample is relatively small, we will attempt to establish whether this conclusion can be confirmed by using data available in the Geneva photometric system. The binarity and variability of A-shell stars will also be examined, mainly on the basis of Hipparcos and Tycho data.

2. Our sample

For our study, we have considered the stars mentioned as A-shell in the following papers:

1. Jaschek C. and Egret D. (1982)
2. Jaschek M., Jaschek C. and Andrillat Y. (1988)
3. Andrillat Y., Jaschek C. and Jaschek M. (1995)
4. Jaschek C., Jaschek M., Andrillat Y. and Egret D. (1991)
5. Abt H. and Morell N. (1995)
6. Gray R.O. and Garrison R.F. (1987)
7. Slettebak A. and Carpenter K.G. (1983)
8. Cowley A.P. and Hiltner W.A. (1969)
9. Slettebak A. (1986)

Seventy-six stars have been found and Table 1 lists our sample. Two stars belong to a star cluster: HD 23862 is a Pleiades' star (H2181) and HD 108283 is a Coma Berenices' star (Tr 125). HD 38545 and HD 217782 are also considered as λ Bootis stars. Among these seventy-six stars, fifty-seven were measured in the Geneva photometric system (identified as G), while sixty-two stars were observed by Hipparcos (identified as H).

We give also the spectral type, taken mainly in SIMBAD, and the reference for it. The sources for the spectral types are:

1. Bidelman W.P. (1958)
2. Cowley A.P. et al. (1969)
3. Cowley A.P. (1973)
4. Herbig G. and Spalding J.F. (1955)
5. Houk N. and Cowley A.P. (1975)
6. Houk N. (1978)
7. Houk N. (1982)
8. Houk N. and Smith-Moore M. (1988)
9. Jaschek C. et al. (1991)
10. Jaschek M. et al. (1986)
11. Jaschek M. et al. (1988)
12. Molnar M.R. (1972)
13. Osawa K. (1959)
14. Slettebak A. (1966)
15. Slettebak A. (1982)
16. Weaver H.F. (1952)

3. A-shell stars in the Geneva system

Our main purpose being to consider whether these stars are main sequence stars or evolved stars, we have selected those observed in the Geneva system. Among the fifty-seven stars found in the Geneva system fifty-three are in the Hipparcos catalogue. The stars observed in the Geneva system are listed in Table 2. The use of this system makes it possible to derive a luminosity class by various methods. The first one is a calibration based on

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Table 1. Sample of A-shell stars used in the present study

name	BS	HD	ref		Sp. type	ref	name	BS	HD	ref		Sp. type	ref
	10	256	1	GH	A2IV/V	8			102423	1		B9.5/A0V	5
	422	8837	2	GH	A0III	2			105777	1		A1V	5
71 Cet	704	15004	1	GH	A0III	2	14 Com	4733	108283	1	GH	F0psh	16
	716	15253	1	GH	A2pshe	2		4893	112028	1	GH	A1IIIshe	2
		19818	1	GH	B9Vne	5			117949	1		A0V	5
	1056	21620	1	GH	A0Vn	2	24 CVn	5112	118232	1	GH	A5Vsh	2
	1062	21688	2	GH	A5III/IV	8			126986	1	G	B9.5Vnn	6
BU Tau	1180	23862	2	GH	B8p	15			129067	1		F6V	7
	1227	24863	1	GH	A4V	5			130912	1		B8V	5
		28942	1	H	A0				133901	1	G	B8/B9.5Iab	6
	1550	30823	5	GH	A3III	2	γ UMi	5735	137422	1	GH	A3II/III	2
		31648	1	GH	A2psh	10	ν^2 Boo	5774	138629	1	H	A5V	2
	1615	32188	1	GH	A2IIIshe	2			139614	1	G	A7V	6
12 Lep	1968	38090	1	GH	A2/A3V	8	V839 Her	5938	142926	9	GH	B9psh	12
131 Tau	1989	38545	3,5	GH	A3V(λBoo)	2	V1027 Sco	6000	144667	1	GH	A1.5III	7
		38616	1	GH	A2Ib/IIp	5			146803	1		A1IV	6
β Pic	2020	39060	1	GH	A5Vsh	6	25 Her	6123	148283	1	H	A5V	2
	2025	39182	1	GH	A3III	13	19 Oph	6232	151431	4	GH	A3V	2
ξ Aur	2029	39283	3	GH	A2V	2			151873	1		Apsh	5
SS Lep	2148	41511	1	GH	A2sh	2		6253	152082	1	GH	A0III	5
	2174	42111	1	GH	A3Vsh	9		6507	158352	1	GH	A8Vsh	2
ϕ^2 CnC B	3310	71150	4	H	A6V	2			163296	1	GH	A1Ve	8
ι CnC B	3474	74738	4	H	A3V	2		6864	168646	1	GH	A3III	7
		75485	1	H	B9II	5			168936	1	H	A1IIp	8
67 Cnc	3589	77190	1	GH	A8Vn	2			179218	1	GH	A0IV-Ve	14
29 Hya	3744	81728	1	GH	A2V	11	V923 Aql	7415	183656	1	GH	A0she	2
		84948	3	H	F0		ν Vul	7731	192518	7	GH	A7IVnsh	2
	3921	85905	1	GH	A2/A3III	8		7782	193621	5	GH	A0III	2
17 Sex	3989	88195	1	GH	A1V	2	1 Del	7836	195325	1	GH	A1she	2
		92234	1		B9.5/A0V	5	29 Vul	7891	196724	6	GH	A0V	2
	4218	93526	6	GH	A0III	2	DV Aqr	8024	199603	1	GH	A9V	8
		95306	1		A3IIIm	5			208612	1	GH	A0IV	11
		95881	1	G	A1/A2III/IV	5	π Peg	8454	210459	9	GH	F5III	4
CU Cha		97048	1	GH	A0pshe	5	2 And	8766	217782	1	GH	A3Vn	2
ϕ Leo	4368	98058	1	GH	A7IVnsh	2		9043	223884	1	GH	A5V	8
55 UMa	4380	98353	3	GH	A2V	2			224463	1	GH	F2V	7
	4398	99022	1	GH	A4:p	5			225010	7	GH	A2V	1
		101215	6		A1IV/V	7		9102	225200	6	H	A1V	7

the d vs B2–V1 diagram (Hauck 1986), d being a luminosity parameter and Δd being used to estimate the luminosity class. However, this calibration is not applicable to reddened stars and stars hotter than A2. Another calibration was proposed by Kobi and North (1990) for stars cooler than A2 and by North and Nicolet (1990). Künzli et al (1997) have superseded this calibration. Data are taken from the Geneva database maintained by G. Bürki.

For stars hotter than A2, the North and Kobi calibration presents the same problem as the Hauck calibration, while that of North and Nicolet can be used for reddened stars. Nevertheless, the situation near A0 is ambiguous. Recently Künzli et al. (1997) have proposed a revised version of both parts, but of course, it is still a problem with reddened stars. This calibration allows us to derive log g. To derive the luminosity class, we can also use the d vs. Δ plane, as proposed by Golay (1980). As d and Δ are both reddening free parameters, we can use the d vs. Δ plane for all stars in our sample.

Another interesting point in the Geneva system is the existence of a parameter of blanketing, Δm_2. For normal stars, this parameter is well correlated with [Fe/H] (Hauck, 1978). In the case of shell stars we do not know whether this is still the case. Unfortunately the lack of [Fe/H] determination for these stars does not allow us to reach any conclusion. However, an abnormal value of Δm_2 could be the signature of a peculiarity.

As the colours of shell stars can be affected by the peculiar nature of these stars, it is difficult to know how they could be reddened. However, we can at least compare the star's colours with the intrinsic colours for the same spectral type by using the table of Hauck (1994).

In Table 2 we give the HD number and the spectral type, repeated from Table 1, then Δd, Δm_2, and the luminosity class

Table 2. A-shell stars measured in the Geneva system

HD	Spectral type	Δd	Δm_2	lum class Δd	$\log g$	lum class d/Δ	$(M_v)Hip$	$\sigma(\pi)/\pi$	lum class $(M_v)Hip$	lum class adopted
256	A2IV/V	0.183	-0.042	III	3.23	V	0.18	0.136	III	III
8837	A0III	-	-	-	2.93	III	-0.66	0.206	III	III
15004	A0III	-	-	-	3.35	III	-0.14	0.212	III	III
15253	A2pshe	0.168	-0.078	r	3.05*		0.03	0.185	III	III
19818	B9Vne	-0.024	-0.064	r	3.72*	V	1.33	0.257	V	V
21620	A0Vn	0.148	-0.029	r	3.46*	V	0.51	0.113	V	V
21688	A5III/IV	0.31	-0.011	V	3.43	V	0.02	0.091	III	III
23862	B8p	-	-		3.41	III	-0.25	0.102	III	III
24863	A4V	0.207	-0.031	r	3.76*	V	1.31	0.056	V	V
30823	A3III	0.401	-0.033	III	3.13	III	-0.32	0.13	III	III
31648	A2psh	0.034	-0.027	r	3.93*	V	2.14	0.155	V	V
32188	A2IIIshe	0.851	0.023	r		I	-2.87	0.487	I	I
38090	A2/A3V	0.342	-0.03	III	2.75	III	-0.97	0.157	III	III
38545	A3V(λBoo)	0.152	-0.015	III	3.58	V	0.16	0.12	III	III
38616	A2Ib/IIp	-	-		2.65	III	-0.08	0.146	III	III
39060	A5Vsh	-0.022	-0.028	V	4.31	V	2.42	0.01	V	V
39182	A3III	0.316	-0.031	III	2.83	III	-0.14	0.182	III	III
39283	A2V	-	-		3.99	V	0.62	0.053	III	V
41511	A2sh	0.773	-0.018	I (r?)	1.48	I	2.66	0.22	I	I
42111	A3Vsh	0.266	-0.034	III	2.98	III	-0.66	0.228	III	III
77190	A8Vn	0.015	-0.013	V	4.33	V	2.23	0.052	V	V
81728	A2V	-	-		3.45	V	-1.48	0.584	(III)	III
85905	A2/A3III	-	-		3.45	V	0.50	0.098	III	III
88195	A1V	-	-		2.91	III	-0.13	0.25	III	III
93526	A0III	-	-		3.05	III	-2.23	0.482	(I)	III
95881	A1/A2III/IV	0.44	-0.061	r	3.01*	III				III
97048	A0pshe	0.52	0.026	r	1.8*	V	2.22	0.133	V	V
98058	A7IVnsh	0.203	-0.003	III	3.69	V	0.56	0.053	III	III
98353	A2V	-0.045	-0.032	V	4.12	V	1.01	0.042	V	V
99022	A4:p	-	-		2.56	III, V	-0.69	0.13	III	III
108283	F0psh	0.335	0.018	III	3.11	V	0.30	0.063	III	III
112028	A1IIIshe	-	-		3.14	III	0.54	0.162	V	III
118232	A5Vsh	0.092	-0.013	V	3.89	III	0.85	0.036	V	V
126986	B9.5Vnn	0.073	-0.16	r	4.16	V				V
133901	B8/B9.5Iab	0.556	-0.236	r	3.2	I, III				I
137422	A3II/III	0.451	-0.008	I	2.53	I	-2.84	0.068	I	I
139614	A7V	0.026	-0.044		4.35	V				V
142926	B9psh	-	-		3.7	III	-0.12	0.078	V	V
144667	A1.5III	-	-		4.12	V	-0.26	0.2	V	V
151431	A3V	0.292	-0.018	III	3.48	III	0.17	0.137	III	III
152082	A0III	0.267	-0.069	III	2.73	III	0.30	0.116	III	III
158352	A8Vsh	0.107	-0.013	V	4.04	V	1.40	0.044	III	V
163296	A1Ve	-0.051	-0.05	?	4	V	1.43	0.12	V	V
168646	A3III	0.686	0.027	r	1.6*	III	0.33	0.15	III	III
179218	A0IV-Ve	0.189	-0.036	r	3.33*	V	0.44	0.22	V	V
183656	A0she	-	-		2.94	I	-1.31	0.245	III	I
192518	A7IVnsh	0.257	-0.015	III	3.52	V, III (?)	0.18	0.058	III	III
193621	A0III	-	-		3.22	III	0.20	0.107	III	III
195325	A1she	-	-		2.81	III	-0.17	0.17	III	III
196724	A0V	-	-		4.11	V	0.73	0.044	V	V
199603	A9V	0.088	0.003	V	4.08	V	1.31	0.07	III	V
208612	A0IV	-	-		3.69	V	0.17	0.189	V	V
210459	F5III	0.355	-0.019	II-III	2.2	V	-0.16	0.048	III	III
217782	A3Vn	0.207	-0.023	III	3.31	V	-0.06	0.075	III	III
223884	A5V	0.159	-0.017		3.92	V	1.41	0.085	V	V
224463	F2V	0.039	-0.013	V	4.26	V	3.97	0.141	V	V
225010	A2V	0.22	-0.033	III (r?)	4.25	V	-	-	-	V

derived from Δd. Some stars are too hot for our calibration and therefore no Δd nor Δm_2 values are given. If the star is reddened we indicate it by an “r” in the sixth column. Then we give log g, as obtained with the Künzli et al. calibration. Values followed by an asterisk are affected by the reddening. In the following columns, we indicate the luminosity class derived from the position in the d vs Δ plane, the absolute magnitude from the Hipparcos parallax and apparent magnitude V of the Geneva system, the ratio $\sigma(\pi)/\pi$ and finally the luminosity class derived from the Hipparcos absolute magnitude. This last estimation was obtained by using M_v (Hipparcos) and the Schmidt Kaler tables (1982). As a few stars are members of a binary system (visual or spectroscopic), we have corrected the bsolute magnitude of multiplicity effects by using the procedure described by North et al. (1997). Table 3 gives all information concerning these systems.

In considering all these luminosity class determinations, we show a generally good agreement among them. There are, however, a few discrepancies due, in most cases, to the difficulty using the d vs. Δ plane for stars near A0 and for F giants. In the last column of Table 2 we give our estimation of the luminosity class obtained after a critical evaluation of each determination. On the basis of our estimate we can see that the majority of stars in our sample, i.e. 51%, are giants, while 40 are dwarfs and 9% are supergiants. As an ultimate check, we have examined whether the location of main sequence stars and giant stars on the M_v vs B2–V1 plane is in good agreement with the results of Jaschek and Gomez (1998). These authors have examined the absolute magnitude of the early type MK standards determined from Hipparcos parallaxes. If we transpose their M_v vs spectral type plane into a M_v vs B2–V1 plane, we are in good agreement. The table given by Hauck (1994) was use d to convert from MK type to B2–V1 and in both cases M_v is obtained by using the Hipparcos parallaxes.

Δm_2 is a blanketing parameter well correlated, for dwarf and giant stars, with [Fe/H]. In the case of A-shell stars we have no indication of the meaning of Δm_2. We can, however, try to determine whether this parameter has a significance for the A-shell. Twenty-six unreddened stars have a useful value of Δm_2. Twelve of them are dwarfs, the other thirteen being giants. The values of Δm_2 are in the interval (-0.069; +0.018). In terms of [Fe/H], based on the relation obtain d by Berthet (1990) the interval is (-0.40; +0.20). If this conversion makes sense, we can conclude that these stars have solar metallicity. No clear distinction can be made between dwarfs and giants. Six dwarfs and six giants have a Δm_2 value greater than or equal to -0.015 (or $[Fe/H] = -0.01$). Six giants have a Δm_2 value of less than -0.015.

4. Multiple systems

Here we have considered stars belonging to a multiple system (mainly visual double and spectroscopic binaries). Table 3 lists these stars. The first column gives the HD number, the second and third columns indicate respectively the information found in the Bright Star Catalogue for radial velocity variability and binarity, then, in the fourth column, we give the type of variability in the Hipparcos catalogue (contents of field H52) with the reference flag (field H48) for photometric parameter nd finally (m, the value applied to correct the apparent magnitude of a binarity effect. Thirty-seven stars are members of a multiple system, which represents 40% of our sample.

Table 3. Binary A-shell stars

HD		BS		Hip		Gva	Δm
15253		1.3	2.8	D	*	?	0.3
24863		6.1	22.8				
30823	V						0.2
38545	V			D	*		0.2
41511	SB2O			U		VR	0.05
42111		1.2	29.3 (3)	D	A		
71150		.1	5.2	U	*		
74738		2.5	30.4	D	B		
75485				D	*		
77190	SB	2.8	103.5			B	0.2
81728		.0	.3 (3)	D	-	D	0.75
88195				D	*		
93526	SB	.3	6.9 (3)	-			0.2
98058	V?	4.7	96.9	M			
108283	SB					B	0.2
112028	V	.5	21.6	D	A		0.2
118232	V						0.2
137422	V					B	0.2
138629	V?	.0	.1				0.75
142926	SBO			U			0.65
144667		0.4	44.1 (3)	D			-
151431	SB	23.6	23.4			D	0.2
152082		6.9	7.				-
183656	V			U		VR	0.2
195325	V?	1.8	0.9 (3)	D	*		0.2
196724	V						0.2
199603	SBO					VR	0.2
217782	SB	3.07	.04	D	*	DB	0.24
225010		1.5	15.2	D	B		

5. Variability

Among our list of A-shell stars, fourteen are variable, either previously known as such or detected to be variable by Hipparcos. Among these fourteen stars, four are considered as possibly microvariable. Table 4 lists these stars.

Twelve other stars are suspected variable stars according to the Hipparcos and Tycho catalogues. They are listed in Table 5.

Thus, in a sample of seventy-six stars, twenty-six, or 34%, are variable or suspected variable stars. As nine stars in Table 4 are measured in the Geneva system and have a ratio $\sigma(\pi)/\pi$ of less than 0.140, we have examined whether these stars occupied a special location on the M_v vs B2–V1 plane. However, the number of stars is too small to reach any conclusion. If we add the suspected variable stars (seven), there does not appear to be any special location on the M_v vs B2–V1 lane for variable stars.

Table 4. Variable A-shell stars

HD	Name	Possibly microvariable
21668		M
23862	BU Tau	
31648		
41511	SS Lep	
71150		
97048		M
98058		M
137422	γ UMi	
142926		
158352		M
163296		
183656	V923 Aql	
192518	ν Vul	
199603	DV Aqr	

6. Final remarks

As indicated in the third paragraph, A-shell stars are in majority evolved stars. We have attempted to determine whether there are differences between evolved (or luminosity class III and I) and unevolved stars (or luminosity class V). As regards variability and duplicity there appears to be no difference. We have also examined whether any correlation could be established between the importance of the shell feature and the luminosity class. In their paper Jaschek and Andrillat (1998) have defined a atio $R = W(P17)/W(P12)$, with W(P17) and W(P12) being respectively the equivalent width to the Paschen lines 17 and 12. Using their values of R and our determination of luminosity class, we have found that the R ratio falls in two different regions for giants and dwarfs, separated by the value 0.13. This is also the result obtained by Andrillat et al. (1995) for normal stars. Jaschek et al. (1988) have given a qualitative indicator describing the richness of the shell of some A-shell e have used this indicator to determine whether stars of luminosity class III have well pronounced shells. Out of a sample of fourteen stars, seven have a “very poor” or “poor” shell and seven have a “moderate” or “rich” shell. Thus the “quality” is not related to the luminosity class. In our sample two stars, HD 38545 and HD 217782 are λ Bootis type stars. Gray (1988) had suspected that the absorption core seen in the CaII K line of HD 111786 was probably due to circumstellar material. Three years later Hohlweger and Stürenburg (1991) mentioned the presence of a circumstellar component in the spectrum of three λ Boo stars, while Bohlender and Walker (1994) found that HD 38545 (131 Tau) has circumstellar components in its spectrum. Then more circumstellar components were found in λ Boo stars (Hohlweger and Rentzsch-Holm, 1995; Hauck et al. 1995, 1998). Circumstellar matter thus seems to occur frequently around λ Bootis stars. General properties and definitions of λ Boo stars are reviewed by Farraggiana and Gerbaldi (1998) and Paunzen (1998). We can mention two important properties: these stars are metal-deficient but belong to Population I and they are main sequence stars. We see that λ Boo stars have properties common with those of the stars of our sample. However, their evolutionary status appears not to be quite comparable.

Table 5. Suspected variable A-shell stars

HD 19818	HD 21620	HD 24863	HD 32188
HD 39060	HD 98353	HD 99022	HD 118232
HD 138624	HD 152082	HD 210459	HD 224463

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