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Properties of Am, δ Del, and δ Sct stars in the *VBLUW* system

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Summary. *VBLUW* photometric observations of 115 Am, δ Del, and δ Sct stars are presented and discussed. The spread with respect to the main sequence in the two-colour diagrams (corrected for reddening if possible), is discussed and can be mainly attributed to gravity effects. Exceptions to this rule can be recognized from a comparison of their positions in these diagrams and in the reddening independent diagram $[L-U]/[B-L]$: some δ Sct stars must have suffered of relative high reddenings and others are presumably metal poor. Temperatures and gravities compare reasonably well with those of Davis Philip et al. (1976) based on $uvby\beta$ photometry. However, the temperatures derived by Babu and Shylaja (1981, 1982) and based on spectral energy distribution, reveal that the photometric temperatures (and thus also gravities) are underestimated. This is caused by line blanketing on the colour indices $b-y$ and $V-B$, of which the size as a function of the temperature can be roughly estimated.

The relation between the temperature sensitive colour indices $V-B$ (of the *VBLUW* system), $b-y$ ($ubvy\beta$ system) and B_2-V_1 (Geneva system) for A/F type stars is investigated. It appears that the $V-B$ is more sensitive to line blanketing than the other two indices.

A PLC relation for the colour $V-B$ is derived using Breger's (1979) relation for the colour $b-y$.

Key words: photometry – metallic line stars – δ Scuti stars – δ Delphini stars

1. Introduction

So far no extensive observations of Am, δ Del, and δ Sct stars exist in the Walraven *VBLUW* photometric system. Only sporadic studies of a few specimen have been made: Ponsen (1963): ϱ Pup; Ponsen and Oosterhoff (1966): δ Sct and δ Del; Oosterhoff and Walraven (1966): all the three variables; van Genderen (1973): again δ Del and Lub (1979) included these three variables in his discussion on the properties of RR Lyrae stars in the *VBLUW* system.

Since many observations and discussions exist of Am, δ Del, and δ Sct in the Strömgren and Geneva photometric systems (see for references for example Hauck and Curchod, 1980; Gómez et al., 1981), it was worthwile to obtain also observations of this very complex field of A and F type stars in the *VBLUW* system.

2. The observations and reductions

The observations were made with the simultaneous *VBLUW* photometer of Walraven attached to the 90-cm lightcollector of the former Leiden Southern Station (at the SAAO annex) in South Africa mainly in the years 1977. A description of the photometric system is given by Walraven and Walraven (1960), Rijf et al. (1969), and Lub and Pel (1977).

In total 115 stars, usually brighter than the 7th mag, were selected. They consist of 64 Am type stars, 9 δ Del and 42 δ Sct type stars. Each program star was measured relative to standard stars in three to six nights. Table 1 tabulates the average standard deviation in the average photometric parameters for the three star types separately (for the *VBLUW* system in log intensity scale and for the *UBV* system with subscript J in mag). Mean errors are thus smaller. The larger standard deviation for the δ Sct star is likely caused by their variability. The classification of stars into these two types depends only on their spectroscopic character, while the classification into the δ Sct class is mainly based on their instability. A star can thus be of the δ Del- as well as of the δ Sct type, like in the case of the prototypes δ Del and δ Sct. Because of this overlap of classification criteria and confusing about naming, there is sometimes much ambiguity in literature about the true type of a star (see for an extensive discussion on these problems Breger, 1979, 1980).

The V of the *VBLUW* system can be transformed into the V of the *UBV* system (with subscript J) with the aid of a formula given by Pel (1976). The $V-B$ colour index of the *VBLUW* system can be transformed into the equivalent $B-V$ colour index of the *UBV* system (with subscript J) by Table 7 in Walraven et al. (1964), but corrected for a slight change in the V passband (Lub and Pel, 1977).

Tables 2 and 3 tabulate the photometric parameters (*VBLUW* and *UBV* systems) for the 115 stars. The number of times that a star has been measured is indicated in the column "N".

Table 1. The average standard deviation in the photometric parameters for the three types of stars in the *VBLUW* system and the *UBV* system (with subscript J)

Type	V	$V-B$	$B-U$	$U-W$	$B-L$	V_J	$(B-V)_J$
		(log intensity)				(mag)	
Am	0.007	0.006	0.007	0.009	0.004	0.018	0.015
δ Del	0.006	0.006	0.006	0.010	0.003	0.015	0.015
δ Sct	0.010	0.005	0.006	0.012	0.004	0.025	0.012

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Table 2. The photometric parameters of the Am stars in the *VBLUW* system (in log intensity scale) and in the *UBV* system (in mag scale and with subscript *J*)

HR	HD	Name	V	V-B	B-U	U-W	B-L	N	V_J	$(B-V)_J$
323	6619		0.094	0.049	0.459	0.136	0.205	3	6.63	0.123
547	11522		0.410	0.100	0.426	0.160	0.197	3	5.83	0.255
4599	104671	θ^1 Cru	1.014	0.109	0.404	0.171	0.176	3	4.32	0.280
4629	105702	11 Vir	0.461	0.136	0.408	0.158	0.231	3	5.70	0.320
4650	106251	12 Vir	0.411	0.100	0.410	0.143	0.202	3	5.83	0.255
4703	107566	ζ^2 Mus	0.689	0.073	0.466	0.149	0.194	3	5.14	0.184
4794	109536		0.698	0.092	0.406	0.131	0.200	3	5.11	0.232
4836	110575		0.169	0.100	0.403	0.140	0.196	3	6.44	0.255
4847	110951	32 Vir	0.622	0.124	0.420	0.157	0.209	3	5.30	0.330
4872	111588		0.462	0.045	0.477	0.146	0.189	5	5.71	0.112
4900	112097	41 Vir	0.246	0.112	0.377	0.153	0.190	3	6.24	0.285
5008	115331		0.418	0.076	0.441	0.132	0.209	4	5.82	0.192
5040	116235	64 Vir	0.399	0.042	0.429	0.099	0.192	4	5.87	0.104
5093	117651		0.209	-0.007	0.384	0.083	0.143	4	6.35	-0.025
5094	117661	73 Vir	0.343	0.078	0.444	0.128	0.208	4	6.00	0.197
5171	119938		0.377	0.107	0.399	0.139	0.201	4	5.91	0.275
5349	125158		0.658	0.105	0.437	0.152	0.229	5	5.21	0.265
5359	125337	λ Vir	0.942	0.053	0.447	0.126	0.199	4	4.51	0.133
5401	126504		0.415	0.122	0.426	0.155	0.221	4	5.82	0.310
5531	130841	α^2 Lib	1.651	0.058	0.437	0.127	0.195	4	2.74	0.148
5577	132219	59 Hya	0.483	0.102	0.441	0.158	0.207	4	5.65	0.260
5591	132851	60 Hya	0.414	0.066	0.464	0.144	0.202	4	5.83	0.166
5663	135235		0.360	0.078	0.419	0.134	0.201	4	5.96	0.197
5682	135730		0.232	0.068	0.437	0.139	0.208	4	6.28	0.172
5762	138413		0.545	0.065	0.458	0.151	0.208	4	5.50	0.163
5848	140417	η Lib	0.579	0.091	0.410	0.146	0.205	4	5.41	0.230
5872	141296		0.297	0.115	0.373	0.153	0.195	4	6.11	0.290
5875	141378		0.535	0.046	0.428	0.110	0.197	4	5.53	0.115
5892	141795	ε Ser	1.260	0.058	0.432	0.120	0.199	4	3.71	0.148
5900	142049		0.431	0.141	0.407	0.166	0.218	4	5.77	0.357
5980	144197	δ Nor	0.855	0.093	0.436	0.150	0.213	4	4.72	0.235
5992	144426		0.234	0.032	0.459	0.129	0.181	4	6.28	0.079
6129	148367	ν Oph	0.892	0.073	0.414	0.121	0.203	4	4.63	0.184
6193	150366		0.321	0.081	0.429	0.137	0.208	4	6.06	0.205
6250	151956	47 Her	0.555	0.038	0.443	0.116	0.200	4	5.48	0.094
6366	154783		0.371	0.107	0.443	0.177	0.222	3	5.93	0.270
6358	155375		0.115	0.029	0.443	0.110	0.192	3	6.58	0.073
6611	161321		0.267	0.075	0.473	0.137	0.215	3	6.19	0.189
6957	170920	61 Ser	0.367	0.059	0.504	0.149	0.182	3	5.95	0.148
6986	171819		0.417	0.096	0.440	0.169	0.200	4	5.82	0.242
6988	171856		0.375	0.079	0.472	0.155	0.204	3	5.92	0.200
7011	172546	26 Sgr	0.262	0.096	0.429	0.146	0.209	3	6.20	0.242
7274	179009	τ Pav	0.244	0.076	0.478	0.177	0.200	3	6.25	0.192
7369	182490	2 Sge	0.234	0.022	0.418	0.098	0.174	2	6.29	0.054
7411	183552		0.435	0.121	0.458	0.192	0.222	3	5.77	0.307
7431	184552	51 Sgr	0.489	0.066	0.463	0.146	0.215	3	5.64	0.166
7498	186219	70 Pav	0.592	0.098	0.434	0.183	0.210	3	5.38	0.247
7510	186543	ν Tel	0.607	0.072	0.448	0.174	0.210	3	5.34	0.181
7579	188097		0.446	0.090	0.463	0.203	0.217	3	5.74	0.227
7624	189118	θ^2 Sgr	0.627	0.066	0.435	0.122	0.201	3	5.30	0.166
7990	198743	μ Aqr	0.843	0.126	0.411	0.159	0.206	3	4.75	0.320
8018	199443		0.383	0.063	0.445	0.130	0.205	3	5.91	0.158
8045	200052		0.322	0.017	0.438	0.120	0.193	3	6.07	0.041
8278	206088	γ Cap	1.268	0.126	0.450	0.174	0.225	4	3.68	0.345
8293	206546		0.256	0.097	0.439	0.150	0.215	3	6.22	0.244
8295	206561	44 Cap	0.390	0.102	0.428	0.160	0.194	4	5.88	0.260
8302	206677	45 Cap	0.366	0.086	0.405	0.130	0.195	4	5.95	0.237
8362	208149		0.283	0.093	0.457	0.176	0.207	3	6.15	0.235
8410	209625	32 Aqr	0.625	0.089	0.453	0.154	0.217	4	5.30	0.225
8583	213464	58 Aqr	0.181	0.117	0.389	0.158	0.188	5	6.40	0.298
8616	214484		0.448	0.013	0.445	0.126	0.163	4	5.75	0.031
8662	215545		0.113	0.116	0.414	0.162	0.208	4	6.57	0.294
8722	216823	τ^3 Gru	0.458	0.087	0.460	0.166	0.217	4	5.71	0.220
8944	221675	14 Psc	0.391	0.115	0.435	0.160	0.220	4	5.88	0.291

3. The two-colour diagrams

In order to construct the two-colour diagrams with reddening free colour indices, most stars were therefore corrected with the reddenings given by Davis Philip et al. (1976) in the *uvbyβ* system: $E(b-y)$. For a number of stars no reddening was available. Therefore we derived them ourselves by the same method as described by Davis Philip et al. and Davis Philip and Egret (1980). For this purpose the necessary *uvbyβ* parameters were taken from the catalogue of Hauck and Mermilliod (1980). If stars were also not listed in this catalogue, their reddenings were adopted to be zero. Nearly all reddenings are small anyway, because of the proximity of the program stars. The reddenings seldom surpass $E(b-y)=0.03$ or $E(B-V)_J=0.05$ or $E(V-B)=0.02$. If the computations of the reddenings resulted into negative values, or when the reddenings listed by Davis Philip et al. were negative we adopted them to be zero. The total number of stars with zero reddening is about 30.

The reddening $E(V-B)$ for the *VBLUW* system could then be computed with the aid of the relation:

$E(V-B)=E(b-y)/1.653$

(Lub and Pel, 1977). Figure 1 shows the three two-colour diagrams for the Am stars (the panels on the left) and the δ Del and δ Sct stars (the panels on the right). The main sequence and reddening trajectories are indicated. In the $V-B/B-U$ diagrams we sketched the $T_{\mathrm{eff}}=$constant lines according to the computations of Lub and Pel based on the Kurucz (1979) models for solar composition and $v_{mi}=2\,\mathrm{km\,s^{-1}}$. In order to prevent confusion only the $\log g=3.5$ line is shown. The main sequence is situated in between the lines for $\log g=4$ and 4.5.

Table 3. The same as Table 2 but now for the δ Del stars (first group) and the δ Sct stars (second group)

HR	HD	Name	V	V-B	B-U	U-W	B-L	N	V_J	$(B-V)_J$
421	8829	47 Cet	0.512	0.121	0.358	0.137	0.190	3	5.57	0.307
2094	40292		0.628	0.112	0.380	0.151	0.191	3	5.29	0.285
2255	43760	6 Mon	0.043	0.140	0.459	0.182	0.211	3	6.74	0.354
3228	68703		0.160	0.114	0.426	0.121	0.218	3	6.46	0.290
3649	74198		0.893	0.003	0.422	0.105	0.162	3	4.64	0.004
6492	157919	55 Oph	1.029	0.159	0.389	0.193	0.219	4	4.28	0.400
6561	159876	ξ Ser	1.329	0.105	0.434	0.159	0.210	5	3.53	0.265
8322	207098	δ Cap	1.590	0.110	0.395	0.153	0.197	4	2.88	0.280
8787	218227	θ Gru	1.028	0.167	0.422	0.195	0.240	4	4.28	0.420
242	4919	ρ Phe	0.462	0.141	0.416	0.183	0.216	4	5.70	0.357
	6870	BS Tuc	-0.257	0.091	0.376	0.150	0.170	3	7.50	0.230
401	8511	AV Cet	0.250	0.090	0.409	0.140	0.199	4	6.23	0.227
431	9065	WZ Scl	0.094	0.119	0.388	0.155	0.185	5	6.62	0.302
	9133	XX Scl	-0.826	0.081	0.437	0.132	0.199	4	8.93	0.205
515	10845	VY Psc	0.116	0.105	0.444	0.154	0.201	3	6.57	0.265
812	17093	UV Ari	0.666	0.089	0.405	0.132	0.195	2	5.19	0.225
	24550	V479 Tau	-0.219	0.164	0.430	0.155	0.225	1	7.39	0.413
1225	24832	DL Eri	0.270	0.101	0.426	0.159	0.207	2	6.18	0.257
1298	26574	σ^1 Eri	1.122	0.126	0.413	0.168	0.207	3	4.05	0.320
1351	27397	V483 Tau	0.522	0.119	0.398	0.134	0.202	2	5.55	0.300
1356	27459	V696 Tau	0.654	0.092	0.423	0.118	0.207	2	5.22	0.232
1412	28319	θ^2 Tau	1.392	0.085	0.452	0.130	0.200	3	3.38	0.215
1611	32045	S Eri	0.832	0.107	0.452	0.194	0.197	3	4.78	0.270
1653	32846	X Cae	0.218	0.124	0.387	0.167	0.180	3	6.31	0.313
2100	40372	V1004 Ori	0.375	0.087	0.446	0.170	0.204	4	5.92	0.220
2107	40535	V474 Mon	0.295	0.118	0.409	0.172	0.203	3	6.12	0.300
2707	55057	V571 Mon	0.572	0.114	0.428	0.179	0.207	3	5.43	0.290
2989	62437	AZ CMi	0.153	0.078	0.460	0.135	0.202	4	6.48	0.197
3185	67523	ρ Pup	1.625	0.160	0.425	0.197	0.238	5	2.79	0.403
3265	69997	HQ Hya	0.224	0.123	0.427	0.125	0.219	2	6.29	0.310
3524	75747	RS Cha	0.320	0.089	0.420	0.175	0.199	3	6.06	0.225
3588	77140	FZ Vel	0.685	0.093	0.450	0.150	0.213	3	5.15	0.235
	100363	SU Crt	-0.701	0.115	0.377	0.158	0.187	1	8.61	0.260
	106384	FG Vir	0.127	0.104	0.400	0.141	0.195	3	6.54	0.265
4684	107131	FM Com	0.176	0.070	0.422	0.119	0.186	1	6.42	0.156
5005	115308	DK Vir	0.066	0.127	0.396	0.157	0.189	6	6.69	0.320
	116994	V743 Cen	-0.718	0.118	0.413	0.165	0.193	5	8.65	0.300
5788	138917	δ Ser	1.222	0.101	0.426	0.165	0.205	4	3.80	0.257
6290	152830	V644 Her	0.198	0.131	0.382	0.154	0.201	6	6.36	0.330
	153747		-0.221	0.054	0.446	0.130	0.178	6	7.42	0.136
6581	160613	ο Ser	1.049	0.031	0.459	0.126	0.183	6	4.25	0.077
	170625	V668 Cra	-0.277	0.085	0.472	0.145	0.215	6	7.55	0.215
7020	172748	δ Sct	0.833	0.145	0.416	0.177	0.217	4	4.77	0.368
	174553	V369 Sct	1.007	0.190	0.447	0.157	0.229	6	9.36	0.472
7331	181333	V1200 Aql	0.520	0.095	0.454	0.163	0.212	5	5.56	0.240
7340	181577	ρ Sgr	1.167	0.081	0.440	0.154	0.207	5	3.94	0.298
7524	186786	NZ Pav	0.327	0.125	0.404	0.174	0.193	5	6.04	0.315
7859	195961	ρ Pav	0.795	0.173	0.434	0.198	0.234	5	4.86	0.433
7928	197461	δ Del	0.967	0.106	0.402	0.150	0.192	4	4.44	0.270
8006	199124	EM Aqr	0.110	0.100	0.402	0.147	0.197	5	6.58	0.255
8102	201707	EW Aqr	0.149	0.108	0.438	0.167	0.211	5	6.48	0.273

It is obvious that Am stars can be somewhat hotter than the other two types of stars, since they extend further to the blue, even up to 10,000 K. Most of the scatter in the diagrams is certainly due to the gravity effects, especially the $B-U$ index is most sensitive for gravity differences, while the $B-L$ is the least sensitive. From other studies we do know that many stars of these three classes are slightly evolved. Nevertheless it is necessary that a few other causes which can take part in the scatter are shortly discussed, although they are considered to be much smaller.

3.1. *Binarity*

According to Abt (1965) and Abt and Bidelman (1969) all Am stars may possess a fainter and thus redder main sequence star as a companion. Consequently their colours may be slightly reddened, depending on the brightness of the companion. It is to be expected that this influence is small, not more than a few percent, since the redder the companions are, the lower their luminosities are.

3.2. *Blanketing effects*

The enhanced metal line strengths, especially in the case of the Am type stars, may redden the $V-B$ colour index. According to Babu and Shylaja (1982) the effect on $(B-V)_J$ is of the order of 0.2 mag near $T_{\text{eff}} \sim 10{,}000$ K, but diminishes towards zero near $T_{\text{eff}} \sim 7000$ K (see Sect. 5). However, the position of the two hottest Am stars in Fig. 1 (HD 117651 and HD 214484) is on the right place considering the spectral types assigned to them by Houk and Cowley (1975) and by the HD catalogue as A0V and A0, respectively. Perhaps the Am characteristics are very weak in these stars.

According to Hauck and Curchod (1980) the metallicity, being defined in the Geneva system by $\Delta m_2 (= m_2(\text{obs}) - m_2(\text{Hyades}))$, is greater for cooler Am stars than for hotter ones (their Fig. 3). Although the B, L, U, and W passbands are very sensitive for metallicity, the effect on the colour indices $B-U$ and $U-W$ will be partly cancelled. Further, a certain amount of scatter in Fig. 1 will be introduced by the fact that each metallic line star has its own spectroscopic characteristics.

3.3. *Reddening by interstellar dust*

Inaccuracies in the reddening values applied in Fig. 1 and for a small number of stars even unknown reddenings, will in general introduce very small extra scatter of probably not more than a few hundredths of a mag. The average reddening which has been

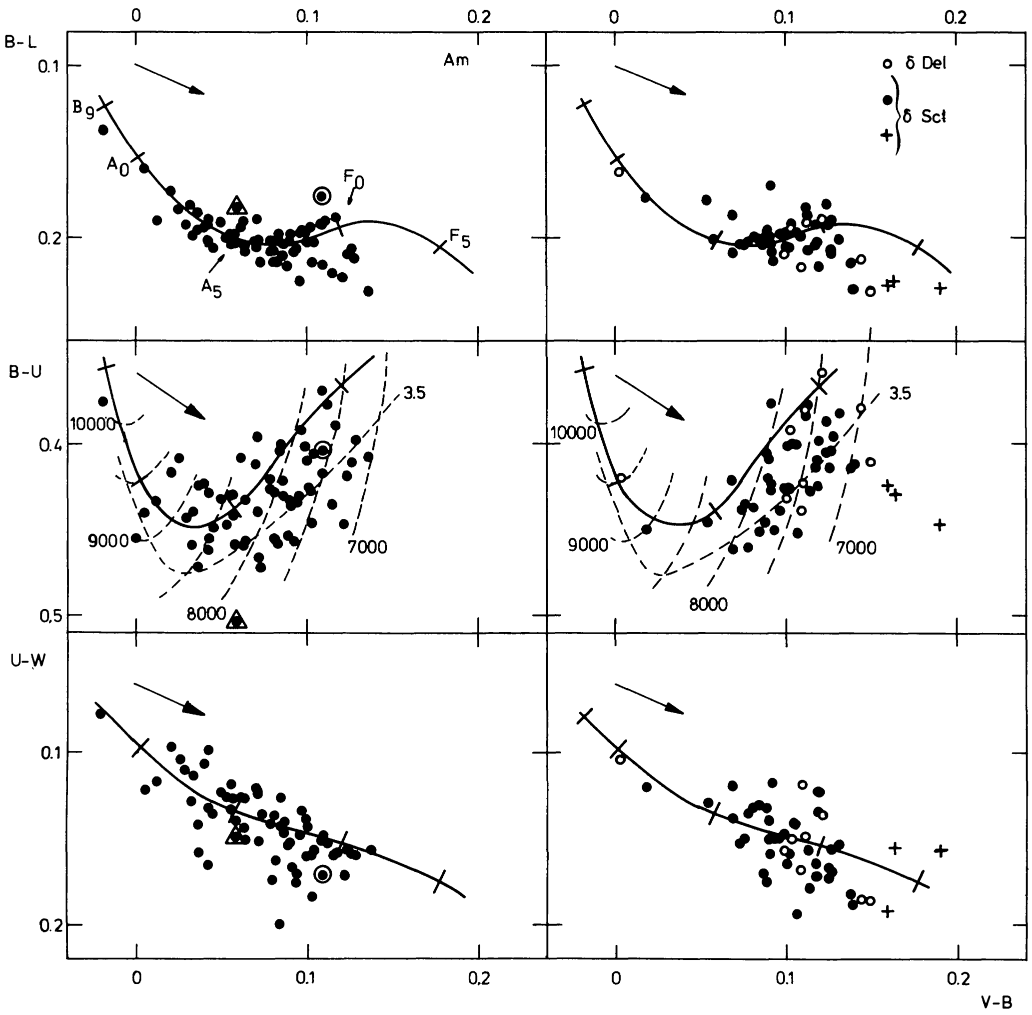

Fig. 1. The two-colour diagrams for the Am Stars (on the left) and δ Del and δ Sct stars (on the right). Sketched are the main sequence (full curve), a number of $T_{\mathrm{eff}}=$const lines and the $\log g = 3.5$ line (dotted curves) in the $V-B/B-U$ diagrams and the reddening trajectories (arrows). Special symbols will be explained in the text

applied is $\overline{E(B-V)}_J = 0.02$ mag only. A few δ Sct stars for which no proper reddening could be derived by the method mentioned before and which likely have suffered a much higher reddening, are HD 174553 (V 369 Sct), HD 195961 (ϱ Pav), and HD 24550 (V 479 Tau). They are indicated by crosses in the right panels of Fig. 1. According to Hall and Mallama (1980) the reddening of the first one may amount to $E(B-V)_J = 0.12$ adopting that its luminosity class is III. If we adopt that the star's intrinsic position is amidst the other δ Sct stars, we find $E(B-V)_J = 0.17 \pm 0.05$ mag. This is in good agreement with the previous value. The reason that we suspect the other two stars of also relative high reddenings will be explained in Sect. 4. According to Davis Philip et al. (1976) the reddening for the second star is $E(b-y) = 0.022$, but this may well be underestimated by a factor of four. We shall return to this in Sect. 4.

Thus we conclude that the bulk of the scatter in Fig. 1 is likely introduced by gravity differences. As a possible extreme specimen we like to mention the Am star HD 170920 (21 Ser) (triangles in Fig. 1). Its position in the $V-B/B-L$ and $V-B/B-U$ diagram points into the direction of a very low gravity: $\log g \sim 3$ but according to its position in the $V-B/U-W$ diagram it may be somewhat higher. We shall indicate this star also in further diagrams by a triangle. Spectroscopy should throw more light on its evolutionary status.

4. The $[L-U]/[B-L]$ diagram

In Fig. 2 we show the reddening *independent* two-colour diagram $[L-U]/[B-L]$. Both indices are defined as

$$[L-U] = (L-U) - 0.21(V-B)$$

and

$$[B-L] = (B-L) - 0.43(V-B).$$

Sketched are a few $T_{\mathrm{eff}}=$const lines for $\log g$ in the range 3.5–4.5 for solar composition and a microturbulence of $v_{mi} = 2\,\mathrm{km\,s^{-1}}$ based on the computations of Lub and Pel (1977). The empirical main sequence is represented as a dashed curve. According to Pel et al. (1981) a slight zero shift had to be applied on the cool part of the theoretical relations, in order to match them with the empirical main sequence. This zero point shift decreases at hotter temperatures, but since we do not know yet exactly how much, we adopted them to be zero for 8000–10,000 K.

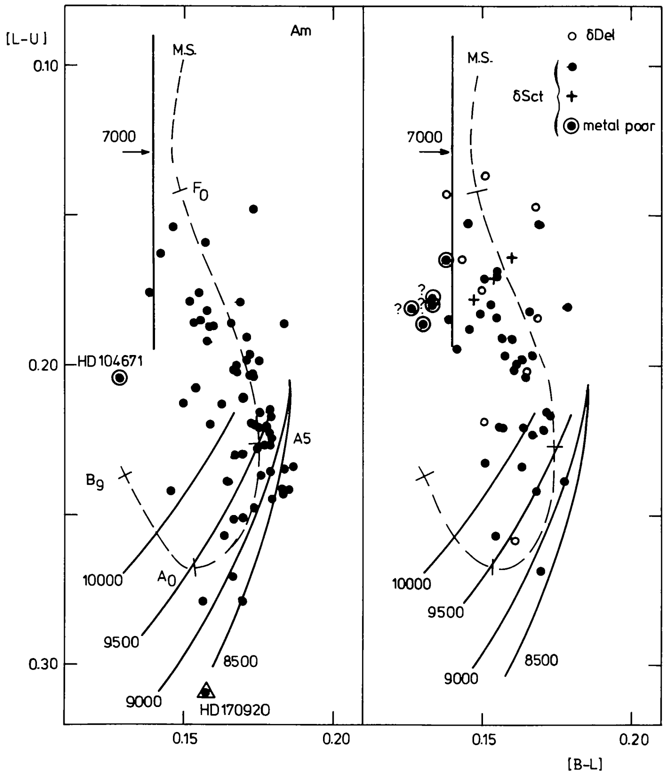

Fig. 2. The reddening independent two-colour diagram $[L-U]/[B-L]$ for the Am stars (on the left) and δ Del and δ Sct stars (on the right). Sketched are the main sequence (dashed curve) and a number of $T_{\rm eff}=$const lines (full curves)

It can be seen that some overlap exists between the theoretical relations for 7000–8500 K and 8500–10,000 K. The relations for $T_{\rm eff}<7000$ K (not shown) overlaps partly those for $T_{\rm eff}>7000$ K.

The benefit of this diagram is that reddening effects caused by interstellar dust are not present. The position of the three δ Sct stars (crosses) are now normal with respect to the other δ Sct stars, not only confirming the reddening estimated by Hall and Mallama (1980) for HD 174553 (V 369 Sct), but also confirming our suspicion that HD 195961 (ϱ Pav) and HD 24550 (V 479 Tau) must be reddened too by relative large amounts. We estimate for both stars reddenings in the order of $E(B-V)_J\sim0.12\pm0.04$ mag. This reddening is much higher than Davis Philip et al. determined for HD 195961 (ϱ Pav) (see Sect. 3).

The abnormal Am star HD 170920 (61 Ser) from Fig. 1 is also peculiar here because of its high $[L-U]$ index (triangle in the left panel of Fig. 2) and possibly indicating a low gravity.

One Am star, HD 104671 (θ' Cru) (encircled in Fig. 2 in the left panel), shows a rather large deviation with respect to the other Am stars, caused by its low value for $[B-L]$. The position in the $V-B/B-L$ diagram of Fig. 1 is then also relatively high above the main sequence (encircled in Fig. 1 left panels). The spectral types assigned to it by means of the strength of the metal lines varies between A 5 and A 8 (see for references the catalogue of Hauck and Curchod, 1980). In the Geneva photometric system the star is striking because of its abnormal low metallicity index ($\Delta m_2=-0.031$) compared to its temperature and colour index ($B_2-V_1=+0.084$). In fact its position at the left of the solar composition grid of Fig. 2 also points into the direction of a metal underabundance, since an other benifit of this diagram is that $[B-L]$ is a sensitive metal index parameter in contrast with $[L-U]$ (Pel and Lub, 1978, their Fig. 1). However a quantitative number cannot be given because of the difficulty to obtain accurate physical data of peculiar stars from photometry alone (see Sect. 5).

In this context we can also mention the δ Sct stars encircled in the right panel of Fig. 2 and which may be also metal deficient stars: HD 6870 (BS Tuc), HD 9065 (WZ Scl), HD 32846 (X Cae), HD 100363 (SU Crt), and HD 115308 (DK Vir). Indeed, Breger (1979) remarks in the "Notes" belonging to his Table 1 that HD 6870 and HD 100363 are known to be metal deficient. Thus presumably they are Population II δ Sct stars with high space velocities (Breger, 1979). The metal deficiency of the other three stars is not yet confirmed by other means (they are indicated in Fig. 2 by question marks).

5. Determination of $T_{\rm eff}$ and log$g$

We investigated how well $T_{\rm eff}$ and log$g$ derived from the *VBLUW* and the *uvbyβ* photometric systems agree with each other. These parameters for the latter system are given for most of the stars by Davis Philip et al. (1976). Since we are dealing with stars with abnormal spectral characteristics, it is also important what $T_{\rm eff}$ and log$g$ are when they are derived by means of spectral energy distribution studies. These studies (Babu and Shylaja, 1981, 1982) are more independent of things like spectral anomalies and small reddenings (but not independent of effects caused by duplicity).

For the purpose of $T_{\rm eff}$ and log$g$ determination, Fig. 2 would be most suitable, were it not that overlapping problems of certain temperature regions play a too important role. Therefore we have chosen the $V-B/B-U$ diagram (Fig. 1). The grid of theoretical colours is however only suitable for $V-B>0.045$, again because of overlapping problems and the converging of $T_{\rm eff}$- and log$g$ =const lines at bluer colours.

The result is that for the Am stars our values for $T_{\rm eff}$ and log$g$ are on the average 100 K and 0.4 lower, respectively, than those of Davis Philip et al. These differences practically disappear for the δ Del and δ Sct stars. Thus there is a satisfactory agreement between the two methods. However individual differences between both methods may amount to 300 K and 0.8 in log$g$.

As discussed before, blanketing by metallic lines in the $(B-V)_J$ index (and thus also in $V-B$ and $b-y$) cannot be ignored, especially for the hot stars. Indeed, when spectral types are considered, the photometric temperatures appear to be too low by many hundreds of degrees. We found that 13 Am stars from the catalogue of Davis Philip et al. (of which four in common with us) are also studied by Babu and Shylaja. It appears that the temperatures of the latters are indeed hotter than the photometric ones. Figure 3 shows the relation between this difference ($T_{\rm eff}$(ph)$-$$T_{\rm eff}$(BS)) and the true temperature (based on the energy distribution) of Babu and Shylaja $T_{\rm eff}$(BS). The right hand scale of Fig. 3 indicates the reddening by blanketing of the $V-B$ (in log int. scale) and $(B-V)_J$ colour indices. The size of the blanketing effect and its dependence on temperature is similar to that found by Babu and Shylaja (1982, their Fig. 2). They compared their temperatures and $(B-V)_J$ indices with the temperature scale for main sequence stars of Code et al. (1976).

Because of the blanketing effect, the photometric gravities are also underestimated by a few tenths in log$g$.

Blanketing effects must be also present in δ Del stars since they also are metallic line stars. Indeed the $T_{\rm eff}$ of the one specimen we have in common with Babu and Shylaja (HD 207098 = δ Cap) is estimated too cool by us by 600 K and Davis Philip et al. even found it to be 900 K cooler.

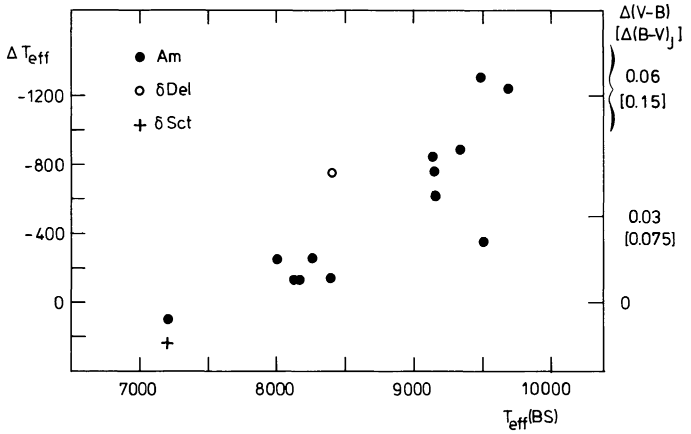

Fig. 3. Diagram showing the difference between photometric and energy distribution temperature ($\Delta T_{\rm eff}$) as a function of the latter ($T_{\rm eff}$(BS)). The scale on the right roughly indicates the reddening by line blanketing on $V-B$ (in log int. scale) and on $(B-V)_J$ (in mag)

The one δ Sct star we have in common with Babu and Shylaja (HD 197461 = δ Del) is estimated 400 K and 100 K *hotter* by us and Davis Philip et al., respectively, while one should expect an opposite inconsistency. Perhaps this inconsistency is not so surprising since the star is complicated by the presence of a spectroscopically detected companion by Preston (quoted by Kuhi and Danziger, 1967). Both stars are plotted in Fig. 3 (for $\Delta T_{\rm eff}$ we also took the average between the two photometric methods).

6. A comparison of the colour indices $V-B$, $b-y$ and B_2-V_1

We investigated the relations between the temperature sensitive colour indices $V-B$ of the Walraven system with $b-y$ (Strömgren system) and with B_2-V_1 (Geneva system) for normal A/F type stars and for Am, δ Del, and δ Sct stars.

For this purpose we searched the *uvbyβ* catalogues of Hauck and Mermilliod (1980) and Breger (1979) and the Geneva system catalogues of Rufener (1976) and Hauck and Curchod (1980) for stars in common. The $V-B$ colour indices of the normal main sequence stars were taken from Lub and Pel (1977).

Figure 4 shows the $b-y/V-B$ diagram. The curve represents the relation for main sequence stars within the range $V-B = 0-0.17$. The maximum dispersion around this curve (of which the details are not shown) is ± 0.01 in $V-B$. It is obvious that the Am and δ Del stars at constant $b-y$ are too red by 0.005–0.010 in log intensity scale with respect to normal stars. Apparently the $V-B$ index is more sensitive for line blanketing than the $b-y$ index. This is comprehensible since $\lambda_{\rm eff}(B) < \lambda_{\rm eff}(b)$ (4325 and 4670 A, respectively).

The Am star HD 170920 (61 Ser) already discussed before, is also in Fig. 4 peculiar (triangle). Giants and supergiants taken from the list of Pel (1976) are indeed situated above this line, thus supporting our suspicion that this star is rather far evolved. (In fact this diagram is nothing more than an ordinary two-colour diagram.) Although most of the Am, δ Del, and δ Sct stars are supposed to be in a slightly evolved phase, they lie in general *below* the main sequence. Apparently the spectral anomalies are still stronger than the gravity effects in most of these stars. However many δ Sct stars tend to lie also on or above it, indicating less influence by metallicity. The two δ Sct stars with high reddenings (ϱ Pav and V 479 Tau) and known $b-y$ indices are indicated by large crosses. Their deviating position far below the main sequence relation, may be caused by the fact that high reddenings act differently on the two colour indices.

Figure 5 shows the $B_2-V_1/V-B$ diagram. We have fewer stars in common with the Geneva system observers. The range in

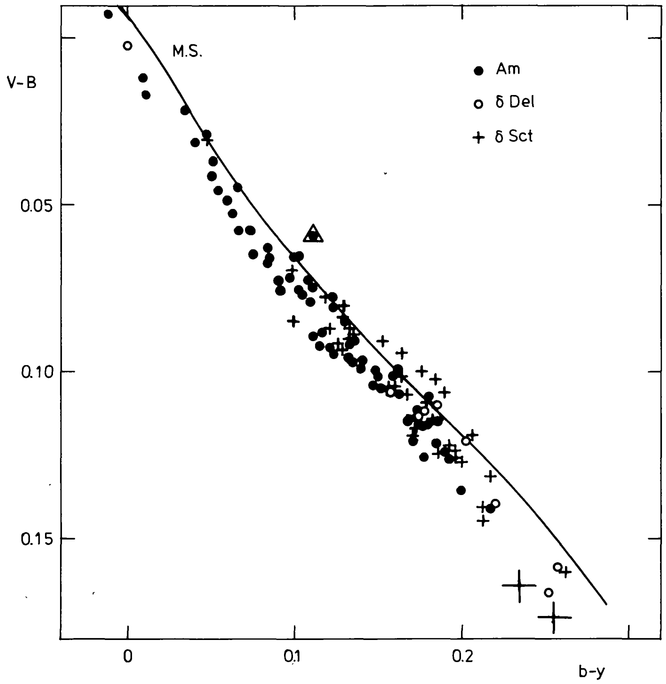

Fig. 4. The $b-y/V-B$ diagram for Am, δ Del, and δ Sct stars. The full curve is the relation for normal main sequence stars of type A/F

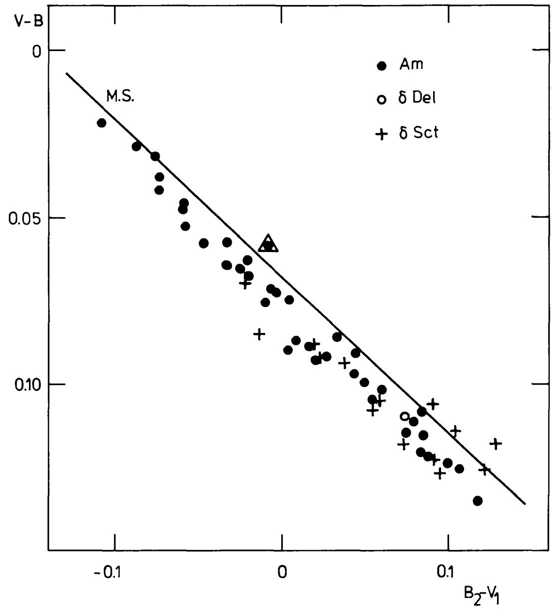

Fig. 5. The $B_2-V_1/V-B$ diagram for Am, δ Del, and δ Sct stars. The full line is the relation for normal main sequence stars of type A/F

$V-B$ is then also smaller than in Fig. 4. The relation for main sequence stars has a similar spread as in Fig. 4. At constant B_2-V_1, $V-B$ is redder by 0.005–0.010 in log int. scale, thus also here $V-B$ is apparently more sensitive for line blanketing than B_2-V_1 with the same amount as in Fig. 4. Yet the difference in $\lambda_{\rm eff}$ of B and B_2 is not so large as between B and b ($\lambda_{\rm eff}(B_2) = 4480$ A). The reason is likely that $\lambda_{\rm eff}(V) > \lambda_{\rm eff}(V_1)$ (5467 and 5405 A, respectively).

Again the Am star HD 170920 (21 Ser) is situated above the main sequence (triangle).

It appears that a linear eye-fitted relation exists between $V-B$ and B_2-V_1 for main sequence stars within the range $-0.1 < V-B < 0.32$ or $-0.3 < B_2-V_1 < 0.5$, which can be approximately represented by the equation:

$$B_2-V_1 = 2.086(V-B) - 0.146 .$$

The maximum spread in $V-B$ is ~ 0.010 around this relation.

7. The PLC relation for δ Sct stars

Although Gupta (1978) found that separate PLC relations for δ Sct stars pulsating in different modes are more meaningful, we only use the overall PLC relation of Breger (1979) to replace $b-y$ by $V-B$. Therefore we adopted a linear relationship between both indices for δ Sct stars in Fig. 4 viz.:

$$b-y = 1.867(V-B) - 0.028 .$$

The result then becomes:

$$M_v = -3.05 \log P + 15.79(V-B) - 3.36 .$$

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