SPECTROPHOTOMETRIC STUDY OF Be STARS

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Abstract. A large sample of Be stars has been studied spectrophotometrically in the visible region. The continuum energy distribution data for 23 Be stars included in the list of Harmanec *et al.* (1983) are presented and discussed in the wavelength range $\lambda\lambda$3200 Å–8000 Å. For 15 Be stars the observations reported in the present work are new. By comparing the observed continua with models, the effective temperatures of these stars have been estimated. It is found that, in general, Be stars have lower effective temperature than the corresponding normal B stars. The present study shows that the early-Be stars (B0–B5) possess near-ultraviolet and near-infrared excess emissions more frequently than the late-Be stars (B5–B9). The seven new Be stars are detected to show pole-on characteristics.

1. Introduction

The nature of Be phenomenon is still not well understood. Since, Be stars are a very inhomogeneous group, it might be necessary to observe a large sample of these objects, simultaneously, with different techniques covering wide spectral range. Such observations can contribute much to the improvement of models for Be stars. An excellent work has been done by Schild *et al.* (1974) and Schild (1976, 1978) on the energy distribution of Be stars in the past years. They have measured the continuum energy distributions of a large number of Be stars. Their observations of the continuum are very much valuable for investigating the variations of the continuum by comparing new observations. They have added much to the understanding of peculiarities of these objects.

Recently, there is a growing interest in Be stars (Harmanec, 1983) and special attention is being paid to the systematic photometric observations of these objects. Realizing the importance of systematic photometric observations of Be stars, an international observing campaign (Harmanec, 1980; Harmanec *et al.*, 1980; and Harmanec *et al.*, 1982) has been organised to obtain photometric data of a large but defined group of bright Be stars over a period of some ten years. Such data would increase our knowledge of different possible types of the photometric variability of Be stars. They can also help us in classifying relation between photometric and spectroscopic, photometric and spectrophotometric behaviour of Be stars, etc.

Since, the photometric variations for many Be stars are related to the ultraviolet and infrared excess emissions, it is desired to find the type of relation between them. The exact knowledge of ultraviolet and infrared excess emission comes primarily from the continuum energy distributions in the appropriate spectral range. Thus, the continuum energy distribution data in the optical region can provide valuable complementary data to the photometric observations obtained simultaneously. In the present paper we present the new measurements of the continuum of Be stars.

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TABLE I

Basic data for program Be stars

Sr. No.	HR	HD	Sp.T.[a,b]	m_V[a]	$E(B-V)$	$E(B-V)$[c,d]	T_{eff} (K)	log g	$v \sin i$[b]	Suspected category
1	1051	21551	B8IVe	5.8	+0.04	+0.07	12000	4.0	340	
2	1204	24479	B9Ve	4.9	+0.00	−0.06	11000	4.0	115	pole-on
3	1305	26670	B5Ve	5.7	+0.02	+0.02	15000	4.0	–	
4	1500	29866	B7Ve	6.1	+0.07	–	14000	4.0	305	
5	1761	34959	B5Ve	6.5	+0.03	+0.05	17000	4.0	320	
6	1763	34989	B1Ve	5.8	+0.06	+0.14	25000	4.0	55	pole-on
7	1786	35407	B5Ve	6.3	+0.03	+0.03	17000	4.0	435	
8	1820	35912	B2Ve	6.4	+0.06	+0.06	22000	4.0	45	pole-on
9	2142	41335	B2IVe	5.2 V	+0.08	+0.14	22500	4.0	445	
10	2231	43285	B5Ve	5.9	+0.00	+0.00	15000	4.0	310	
11	2418	47054	B8Ve	5.5	+0.02	+0.02	13000	4.0	260	pole-on
12	2521	49643	B8Ve	5.8	+0.00	+0.00	13000	4.0	–	
13	3135	65875	B3Ve	6.5	+0.09	+0.14	21000	4.0	170	pole-on
14	6873	168797	B3Ve	6.1	+0.07	+0.16	18000	4.0	295	
15	6881	169033	B8IVe	5.7	+0.10	+0.14	13000	4.0	245	pole-on
16	6984	171780	B5Ve	6.1	+0.03	+0.03	16000	4.0	310	
17	7318	180968	B0.5IVe	5.4 V	+0.14	+0.28	27000	4.0	295	
18	7335	181409	B2IVe	6.6	+0.02	+0.05	22500	4.0	–	
19	7403	183362	B2Ve	6.4	+0.04	+0.10	22000	4.0	260	pole-on
20	7446	184915	B0IIIe	5.0	+0.18	+0.28	30000	3.5	270	
21	7807	194335	B2Ve	5.9	+0.02	+0.02	21000	4.0	–	
22	7983	198625	B4Ve	6.3	+0.06	+0.12	17000	4.0	–	
23	9068	224544	B5IVe	6.5	+0.03	+0.06	16000	4.0	–	

References:
[a] Harmanec *et al.* (1983).
[b] Hirshfeld and Sinnott (1982).
[c] Jamar *et al.* (1976).
[d] Macau-Hercot *et al.* (1978).
[e] Uesugi and Fukuda (1982).

2. Observations and Reduction

The stars were observed during 1980–1982 with the 52-cm and 104-cm reflectors of Uttar Pradesh State Observatory. A Hilger and Watts monochromator was used for obtaining observations. The observational procedure and instrumentation have been described earlier (Goraya, 1984). An exit slit of 50 Å pass band was used for securing continuous scans of the stars. The stars included in the present program are listed in Table I. Alongwith the Be stars, the standards, ξ^2 Cet, α Leo, and γ Gem were observed for applying extinction corrections and to reduce observations of Be stars to absolute values. The observed continuum of each star was transformed to the standard system. The transformation corresponds to the absolute calibration system of Tug *et al.* (1977). The absolute monochromatic magnitudes of Be stars were measured at 46 wavelengths separated by 100 Å. The standard deviation of the measurements on an individual night does not exceed $\pm 0^m.03$ in the entire wavelength range.

Especially important in the determination of effective temperature for Be stars from continuum energy distribution is the calculation of colour excess for interstellar reddening. It has already been discussed in our earlier paper (Goraya, 1984) that direct measurement of interstellar reddening in Be stars is difficult, mainly because of the existence of ultraviolet and infrared excess emissions. To avoid this difficulty we have used the distance moduli method (Goraya, 1984) for the determination of colour excess, $E(B-V)$, of Be stars for the present study. The values of $E(B-V)$ estimated by this method are listed in the sixth column of Table I. The values by Jamar *et al.* (1976) and Macau-Hercot *et al.* (1978) are given in the seventh column of Table I for comparison. It is clear from these two sets of $E(B-V)$ values that the values of Jamar *et al.* (1976) and Macau-Hercot *et al.* (1978) are, in general, higher (much higher in some stars) than those determined by us. This is most probably because their $E(B-V)$ values are also contaminated by infrared excess emission in Be stars, whereas ours are free of this effect.

For the present stars the reddening corrections were calculated by using $E(B-V)$ values determined by us. The mean value of total-to-selective extinction, $R = 3.25$ was adopted from Moffat and Schmidt-Kaler (1976). Different interstellar reddening curves by Lucke (1980) were used for different regions. The monochromatic magnitudes of Be stars were corrected for interstellar reddening and were normalised to wavelength λ5500 Å. The de-reddened normalised magnitudes thus obtained are tabulated in Table II.

3. Measured Continua and Effective Temperatures

The de-reddened continuum energy distribution data tabulated in Table II are displayed in Figures 1 and 2. We have arbitrary divided Be stars into two groups:

(i) early-Be stars (B0–B5); and

(ii) late-Be stars (B5–B9).

Figure 1 contains early-Be stars and Figure 2 shows a plot of late-Be stars. In Figures 1 and 2 the measured continua are shown by filled circles. The double circle at

TABLE II

De-reddened normalised magnitudes of Be stars

Wavelength (Å)	$1/\lambda$ (μ^{-1})	Early-Be stars										
		HR 7446	HR 7318	HR 1763	HR 2142	HR 7335	HR 1820	HR 7403	HR 7807	HR 3135	HR 1873	HR 7983
3200	3.13	$-0^m.837$	$-0^m.737$	$-0^m.666$	$-0^m.550$	$-0^m.458$	$-0^m.488$	$-0^m.360$	$-0^m.249$	$-0^m.320$	$-0^m.160$	$0^m.034$
3300	3.03	−0.851	−0.665	−0.616	−0.286	−0.380	−0.432	−0.367	−0.268	−0.270	−0.122	0.068
3400	2.94	−0.749	−0.575	−0.562	−0.312	−0.405	−0.333	−0.331	−0.198	−0.265	−0.106	0.042
3500	2.86	−0.708	−0.588	−0.505	−0.250	−0.315	−0.311	−0.290	−0.186	−0.210	−0.063	0.023
3600	2.78	−0.698	−0.475	−0.457	−0.206	−0.275	−0.337	−0.261	−0.179	−0.211	−0.010	0.026
3700	2.70	−0.625	−0.485	−0.440	−0.225	−0.214	−0.270	−0.214	−0.136	−0.150	0.030	0.075
3800	2.63	−0.537	−0.391	−0.361	−0.117	−0.215	−0.283	−0.236	−0.125	−0.121	0.062	0.065
3900	2.56	−0.466	−0.363	−0.270	−0.200	−0.140	−0.215	−0.209	−0.118	−0.096	0.088	0.132
4000	2.50	−0.400	−0.367	−0.214	−0.080	−0.077	−0.180	−0.184	−0.140	−0.065	0.035	0.190
4100	2.44	−0.440	−0.404	−0.300	−0.157	−0.180	−0.227	−0.263	−0.266	−0.209	−0.124	−0.123
4200	2.38	−0.414	−0.405	−0.373	−0.306	−0.270	−0.336	−0.312	−0.317	−0.311	−0.226	−0.275
4300	2.33	−0.376	−0.396	−0.390	−0.340	−0.310	−0.340	−0.352	−0.322	−0.336	−0.270	−0.320
4400	2.27	−0.354	−0.333	−0.334	−0.345	−0.330	−0.309	−0.324	−0.312	−0.307	−0.298	−0.280
4500	2.22	−0.304	−0.330	−0.302	−0.315	−0.309	−0.298	−0.281	−0.300	−0.304	−0.280	−0.268
4600	2.17	−0.280	−0.282	−0.268	−0.267	−0.257	−0.270	−0.251	−0.270	−0.250	−0.250	−0.248
4700	2.13	−0.239	−0.262	−0.250	−0.256	−0.255	−0.227	−0.240	−0.225	−0.225	−0.206	−0.205
4800	2.08	−0.200	−0.205	−0.210	−0.207	−0.216	−0.215	−0.203	−0.192	−0.200	−0.185	−0.193
4900	2.04	−0.166	−0.170	−0.193	−0.196	−0.177	−0.160	−0.139	−0.158	−0.156	−0.150	−0.149
5000	2.00	−0.141	−0.155	−0.150	−0.145	−0.168	−0.145	−0.149	−0.155	−0.127	−0.133	−0.152
5100	1.96	−0.115	−0.109	−0.130	−0.136	−0.103	−0.131	−0.118	−0.113	−0.120	−0.117	−0.100
5200	1.92	−0.090	−0.084	−0.100	−0.077	−0.095	−0.080	−0.098	−0.030	−0.082	−0.055	−0.075
5300	1.89	−0.050	−0.059	−0.049	−0.075	−0.080	−0.055	−0.048	−0.017	−0.057	−0.044	−0.063
5400	1.85	−0.035	−0.020	−0.036	−0.030	−0.016	−0.035	−0.022	−0.024	−0.020	−0.025	−0.015
5500	1.82	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5600	1.79	0.035	0.019	0.029	0.035	0.048	0.010	0.030	0.025	0.036	0.025	0.034
5700	1.75	0.057	0.063	0.057	0.065	0.070	0.010	0.038	0.065	0.042	0.050	0.050
5800	1.72	0.080	0.096	0.091	0.063	0.080	0.063	0.080	0.072	0.092	0.086	0.062
5900	1.69	0.122	0.108	0.100	0.120	0.096	0.115	0.114	0.118	0.112	0.085	0.096

Table II (continued)

Wavelength (Å)	$1/\lambda$ (μ^{-1})	Early-Be stars										
		HR 7446	HR 7318	HR 1763	HR 2142	HR 7335	HR 1820	HR 7403	HR 7807	HR 3135	HR 1873	HR 7983
6000	1.67	0.150	0.144	0.142	0.122	0.137	0.125	0.130	0.125	0.120	0.125	0.127
6100	1.64	0.159	0.157	0.155	0.160	0.148	0.116	0.166	0.165	0.152	0.132	0.153
6200	1.61	0.192	0.203	0.170	0.186	0.202	0.135	0.175	0.190	0.187	0.173	0.155
6300	1.59	0.230	0.214	0.214	0.211	0.207	0.162	0.220	0.196	0.196	0.186	0.195
6400	1.56	0.241	0.240	0.212	0.250	0.260	0.160	0.239	0.234	0.215	0.211	0.223
6500	1.53	0.274	0.287	0.231	0.284	0.255	0.186	0.265	0.256	0.225	0.244	0.220
6600	1.51	0.314	0.298	0.252	0.310	0.309	0.212	0.270	0.286	0.261	0.270	0.233
6700	1.49	0.320	0.315	0.248	0.300	0.310	0.185	0.286	0.310	0.255	0.275	0.242
6800	1.47	0.340	0.328	0.268	0.340	0.318	0.220	0.300	0.320	0.270	0.302	0.260
6900	1.45	0.361	0.325	0.260	0.346	0.335	0.257	0.336	0.341	0.313	0.334	0.284
7000	1.43	0.373	0.359	0.292	0.363	0.376	0.243	0.333	0.349	0.322	0.350	0.270
7100	1.41	0.415	0.380	0.305	0.406	0.392	0.240	0.350	0.394	0.311	0.380	0.300
7200	1.39	0.421	0.380	0.331	0.429	0.420	0.258	0.366	0.392	0.346	0.385	0.330
7300	1.37	0.450	0.414	0.337	0.438	0.444	0.293	0.368	0.448	0.366	0.391	0.352
7400	1.35	0.449	0.420	0.386	0.457	0.432	0.321	0.410	0.445	0.350	0.400	0.355
7500	1.33	0.430	0.455	0.384	0.470	0.421	0.310	0.411	0.490	0.416	0.433	0.390
7600	1.31	0.471	0.444	0.414	0.520	0.516	0.357	0.439	0.508	0.440	0.453	0.413
7700	1.29	0.460	0.460	0.412	0.560	0.550	0.392	0.482	0.539	0.420	0.472	0.413
7800	1.27	0.530	0.489	0.425	0.544	0.561	0.394	0.483	0.535	0.488	0.480	0.440
7900	1.25	0.546	0.525	0.421	0.611	0.602	0.426	0.520	0.550	0.462	0.501	0.470
8000	1.23	0.600	0.575	0.410	0.640	0.641	0.471	0.562	0.595	0.453	0.520	0.516

Table II (continued)

Wavelength (Å)	$1/\lambda$ (μ^{-1})	Late-Be stars											
		HR 1786	HR 1761	HR 6984	HR 9068	HR 1305	HR 2231	HR 1500	HR 2521	HR 2418	HR 6881	HR 1051	HR 1204
3200	3.13	$0^m.015$	$0^m.008$	$0^m.028$	$0^m.167$	$0^m.339$	$0^m.360$	$0^m.365$	$0^m.438$	$0^m.420$	$0^m.416$	$0^m.717$	$0^m.910$
3300	3.03	0.050	0.037	0.072	0.152	0.315	0.334	0.363	0.509	0.425	0.410	0.730	0.863
3400	2.94	0.080	0.040	0.117	0.196	0.321	0.410	0.390	0.487	0.472	0.394	0.702	0.875
3500	2.86	0.080	0.057	0.104	0.151	0.275	0.366	0.375	0.520	0.445	0.425	0.706	0.860
3600	2.78	0.112	0.102	0.142	0.148	0.266	0.409	0.391	0.540	0.432	0.413	0.696	0.837
3700	2.70	0.140	0.094	0.180	0.219	0.259	0.390	0.393	0.577	0.463	0.403	0.690	0.805
3800	2.63	0.115	0.140	0.159	0.246	0.270	0.412	0.384	0.563	0.455	0.406	0.695	0.810
3900	2.56	0.125	0.161	0.220	0.266	0.324	0.413	0.380	0.529	0.448	0.387	0.675	0.790
4000	2.50	0.100	0.150	0.170	0.175	0.214	0.267	0.327	0.470	0.356	0.330	0.671	0.689
4100	2.44	−0.152	−0.075	−0.085	0.000	−0.002	−0.050	0.065	0.025	−0.001	−0.050	0.117	0.150
4200	2.38	−0.260	−0.200	−0.223	−0.199	−0.212	−0.248	−0.215	−0.185	−0.200	−0.236	−0.198	−0.171
4300	2.33	−0.275	−0.257	−0.264	−0.231	−0.250	−0.266	−0.240	−0.195	−0.234	−0.256	−0.240	−0.240
4400	2.27	−0.290	−0.276	−0.275	−0.275	−0.264	−0.275	−0.267	−0.223	−0.236	−0.260	−0.231	−0.227
4500	2.22	−0.264	−0.280	−0.240	−0.263	−0.241	−0.230	−0.239	−0.222	−0.220	−0.245	−0.225	−0.203
4600	2.17	−0.245	−0.235	−0.233	−0.220	−0.225	−0.229	−0.208	−0.220	−0.207	−0.199	−0.194	−0.183
4700	2.13	−0.207	−0.199	−0.200	−0.202	−0.200	−0.194	−0.190	−0.182	−0.196	−0.187	−0.175	−0.172
4800	2.08	−0.186	−0.192	−0.170	−0.183	−0.155	−0.160	−0.175	−0.170	−0.155	−0.161	−0.149	−0.150
4900	2.04	−0.166	−0.165	−0.159	−0.150	−0.142	−0.146	−0.153	−0.124	−0.150	−0.125	−0.140	−0.113
5000	2.00	−0.131	−0.118	−0.119	−0.127	−0.120	−0.122	−0.105	−0.115	−0.115	−0.126	−0.110	−0.100
5100	1.96	−0.094	−0.115	−0.098	−0.107	−0.087	−0.112	−0.090	−0.090	−0.090	−0.088	−0.080	−0.086
5200	1.92	−0.075	−0.067	−0.085	−0.064	−0.084	−0.084	−0.053	−0.057	−0.060	−0.057	−0.083	−0.075
5300	1.89	−0.042	−0.050	−0.064	−0.040	−0.040	−0.044	−0.030	−0.038	−0.036	−0.052	−0.051	−0.039
5400	1.85	−0.035	−0.020	−0.010	−0.028	−0.025	−0.013	−0.028	−0.020	−0.037	−0.023	−0.012	−0.025
5500	1.82	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5600	1.79	0.015	0.015	0.013	0.038	0.030	0.038	0.025	0.015	0.030	0.013	0.013	0.026
5700	1.75	0.043	0.058	0.066	0.070	0.036	0.062	0.048	0.046	0.055	0.015	0.048	0.035
5800	1.72	0.066	0.070	0.068	0.059	0.074	0.065	0.055	0.070	0.057	0.060	0.070	0.059
5900	1.69	0.103	0.105	0.105	0.100	0.090	0.093	0.094	0.093	0.081	0.087	0.084	0.080

Table II (continued)

Wavelength (Å)	$1/\lambda$ (μ^{-1})	Late-Be stars											
		HR 1786	HR 1761	HR 6984	HR 9068	HR 1305	HR 2231	HR 1500	HR 2521	HR 2418	HR 6881	HR 1051	HR 1204
6000	1.67	0.120	0.127	0.127	0.118	0.116	0.115	0.102	0.116	0.109	0.111	0.109	0.086
6100	1.64	0.140	0.164	0.138	0.146	0.136	0.141	0.143	0.113	0.118	0.108	0.115	0.095
6200	1.61	0.150	0.150	0.152	0.155	0.165	0.135	0.165	0.140	0.144	0.125	0.142	0.085
6300	1.59	0.178	0.112	0.168	0.196	0.175	0.160	0.193	0.175	0.163	0.115	0.162	0.103
6400	1.56	0.220	0.212	0.190	0.214	0.192	0.203	0.200	0.174	0.193	0.129	0.192	0.099
6500	1.53	0.232	0.242	0.230	0.216	0.212	0.240	0.204	0.214	0.220	0.132	0.183	0.123
6600	1.51	0.252	0.263	0.256	0.234	0.220	0.252	0.220	0.240	0.198	0.160	0.225	0.150
6700	1.49	0.265	0.270	0.213	0.275	0.211	0.238	0.263	0.242	0.208	0.153	0.225	0.136
6800	1.47	0.288	0.280	0.236	0.282	0.245	0.275	0.270	0.258	0.220	0.172	0.255	0.152
6900	1.45	0.316	0.284	0.240	0.287	0.248	0.310	0.294	0.267	0.245	0.187	0.257	0.165
7000	1.43	0.388	0.310	0.304	0.335	0.270	0.316	0.296	0.298	0.233	0.183	0.290	0.190
7100	1.41	0.355	0.333	0.320	0.356	0.294	0.334	0.302	0.327	0.275	0.196	0.306	0.190
7200	1.39	0.380	0.364	0.317	0.384	0.305	0.341	0.333	0.348	0.262	0.185	0.326	0.209
7300	1.37	0.386	0.391	0.321	0.410	0.300	0.392	0.355	0.364	0.303	0.210	0.336	0.205
7400	1.35	0.394	0.421	0.342	0.402	0.334	0.370	0.377	0.394	0.300	0.240	0.362	0.230
7500	1.33	0.415	0.432	0.374	0.450	0.325	0.425	0.390	0.419	0.311	0.270	0.390	0.232
7600	1.31	0.425	0.461	0.365	0.479	0.360	0.420	0.420	0.415	0.330	0.261	0.415	0.257
7700	1.29	0.412	0.482	0.412	0.494	0.405	0.462	0.423	0.427	0.362	0.296	0.420	0.256
7800	1.27	0.446	0.512	0.406	0.525	0.402	0.463	0.459	0.445	0.375	0.313	0.433	0.295
7900	1.25	0.439	0.522	0.416	0.510	0.450	0.500	0.456	0.480	0.417	0.357	0.455	0.315
8000	1.23	0.475	0.558	0.450	0.530	0.473	0.532	0.486	0.473	0.427	0.388	0.416	0.340

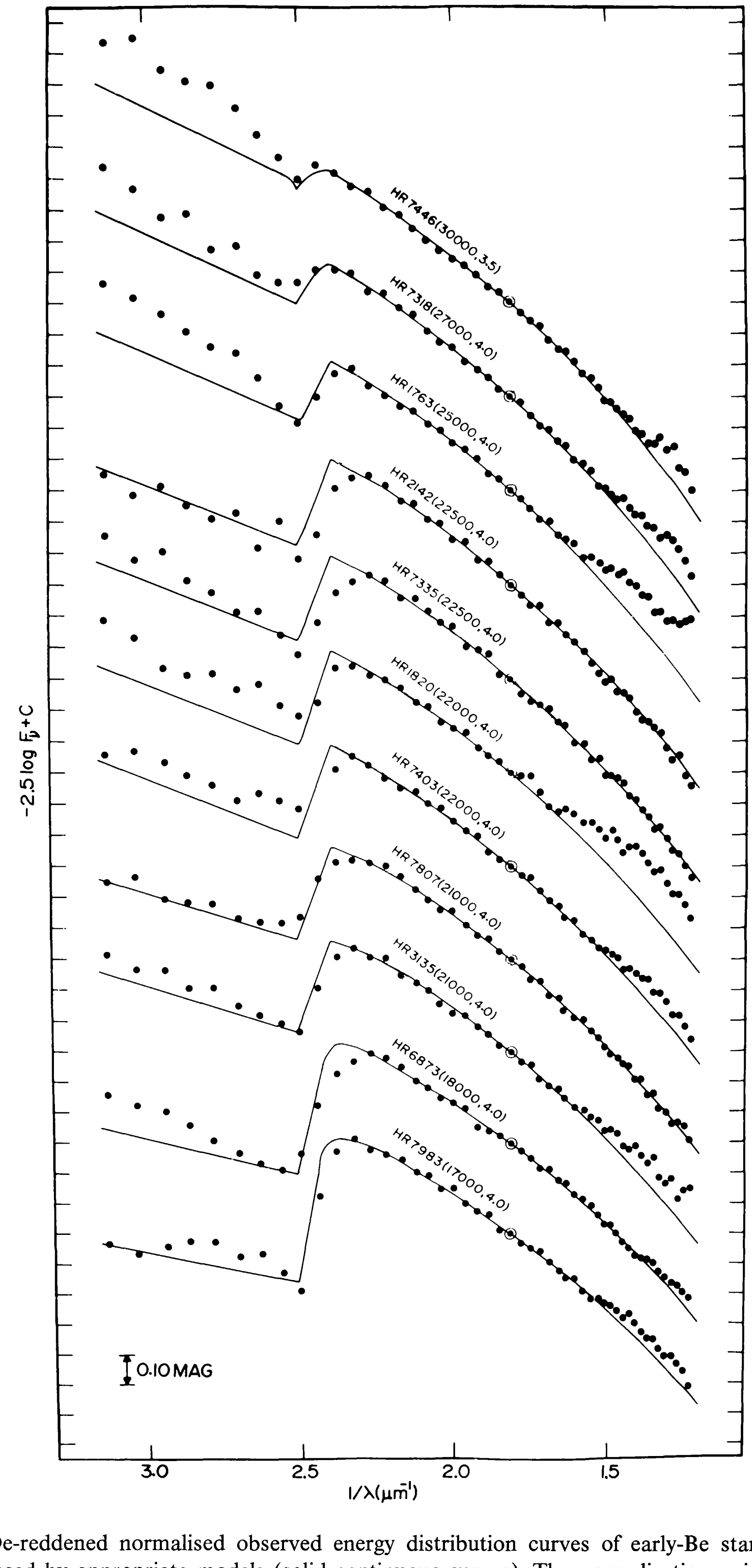

Fig. 1. De-reddened normalised observed energy distribution curves of early-Be stars (filled circles) superimposed by appropriate models (solid continuous curves). The normalisation point at λ5500 Å is shown by double circle.

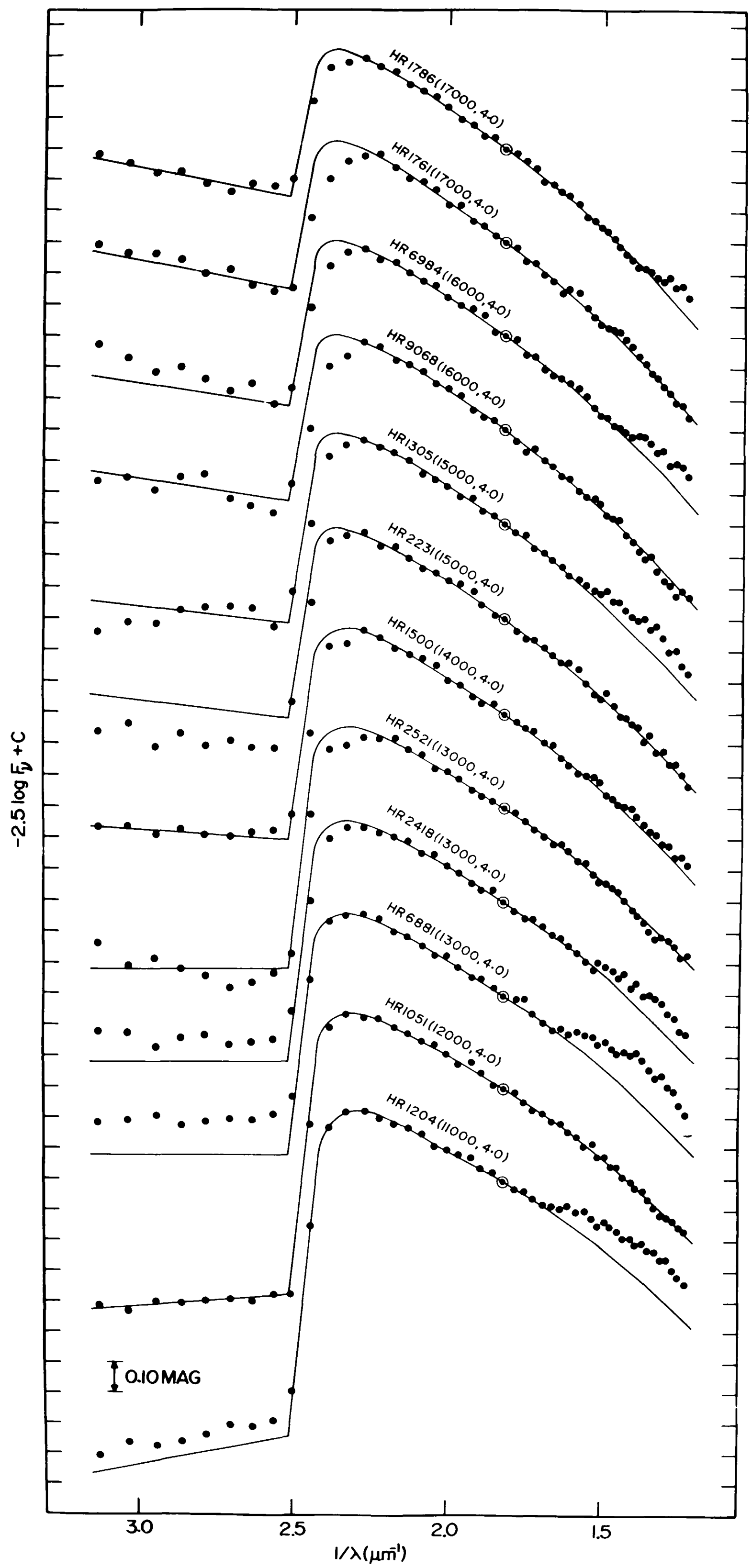

Fig. 2. De-reddened normalised observed energy distribution curves of late-Be stars (filled circles) superimposed by appropriate models (solid continuous curves). The normalisation point at $\lambda 5500$ Å is shown by double circle.

$\lambda 5500$ Å indicates the normalization point in each of the measured continuum. Since most of the energy is emitted in the visible region in early-type stars, so the observed continua can be used to derive effective temperatures of these objects.

It is well known that most of the Be stars possess ultraviolet and infrared excess emissions. As a result of these excess emissions the continuum of Be stars is disturbed appreciably. The ultraviolet excess radiation affects the Balmer continuum shortward of $\lambda 4000$ Å and the infrared excess radiation disturbs the Paschen continuum longward of $\lambda 5500$ Å. The part of the Paschen continuum from $\lambda 4000$ Å to $\lambda 5500$ Å is least disturbed by these excess emissions. Therefore, in order to estimate effective temperatures of Be stars, we have compared the observed continuum with the synthetic models (Kurucz, 1979); primary in the $\lambda\lambda 4000$–5500 Å wavelength range. A comparison of models with observations is shown in Figures 1 and 2. The grid of models superimposed on the measured continua are indicated by continuous curves and filled circles, respectively. The numbers in the bracket (followed by HR number of the star) attached to each continuous curve indicate the value of the effective temperature (T_{eff}) and effective gravity ($\log g$), respectively, of the best fitted model. In deriving effective temperatures of Be stars we have assumed that $\log g = 3.5$ for luminosity class III and $\log g = 4.0$ for luminosity class IV and V (Kontizas and Theodossiu, 1980). The derived values of effective temperatures are given in Table I.

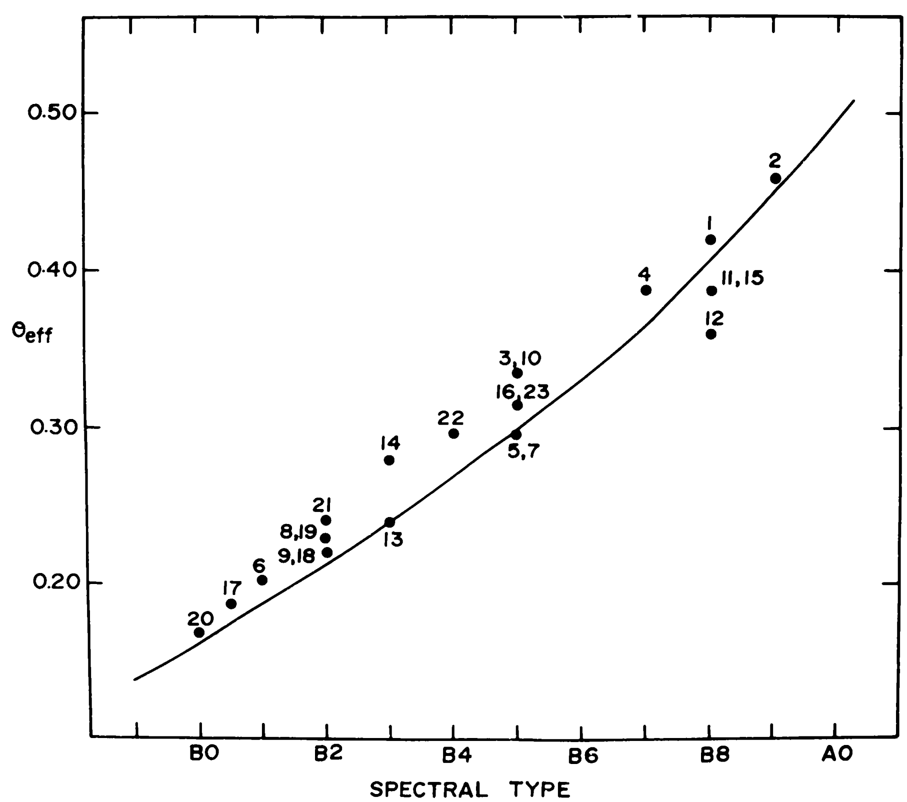

Fig. 3. The position of observed Be stars (filled cirlces) on the θ_{eff}-spectral type plot for normal B stars. The relation for normal B stars is shown by the solid continuous curve.

The uncertainty in the derived temperature is ± 2000 K around 30 000 K and ± 700 K around 10 000 K. The effective temperatures of Be stars derived in the present paper were converted into θ_{eff}. The position of Be stars (filled circles) are shown on the θ_{eff}-spectral type plot as shown in Figure 3. The solid curve in Figure 3 corresponds to the relation for normal B stars obtained from the data for early-type stars given by Kontizas and Thedossiu (1980). From this figure one can easily make out that, in general, Be stars have some tendency to give lower effective temperatures than normal B stars. This effect is slightly more pronounced for early Be stars.

4. Excess Radiation in Be Stars

Figures 1 and 2 give the comparison of observed continua with theoretical curves. It is obvious from these figures that the observed continua of most of the Be stars deviate remarkably from the theoretical curves, either in the near-ultraviolet or in the near-infrared region or in both. The observed continuum of six stars viz. HR 1051, HR 1761, HR 2142, HR 2521, HR 7807, and HR 9068 matches well with models in the whole observed spectral range ($\lambda\lambda$3200–8000 Å). These stars show normal continuum energy distributions. The other star-HR 2231 is found to show near-ultraviolet deficiency in its continuum. The rest of the 16 Be stars show excess radiation. The excess emissions in Be stars are known to originate from the circumstellar envelopes of Be stars. The nature of ultraviolet excess emission is not well known but the infrared excess emission is relatively well understood. The most widely accepted explanation for the infrared excess emission is the free-free and bound-free emission originating in the ionized circumstellar envelopes (Schild *et al.*, 1974; Gehrz *et al.*, 1974; and Scargle *et al.*, 1978).

In the present study we have suspected seven Be stars as belonging to the category of 'pole-on' stars. The term 'pole-on' was introduced by Slettebak (1949). Later on Schild (1973) used the term *extreme Be stars* to denote those stars formerly called pole-on. He suggested that extreme Be stars have permanent strong hydrogen lines than another group of stars. From infrared observations, Schild (1973) also concluded that extreme Be stars are, as a class, strong infrared sources. According to Schild (1973), the existence of the stars with measured projected rotational velocities $v \sin i$ no greater than those of the stars identified as pole-on but with properties very similar to the majority of Be stars (Balmer line emission, infrared excess, etc.) can give rise to the identification of the *true pole-on stars*. The seven Be stars: HR 1204, HR 1763, HR 1820, HR 2418, HR 3135, HR 6881, and HR 7403 in the present study have projected rotational velocity less than those identified as pole-on (Schild, 1973) and possess strong near-infrared excess emission (see Figures 1 and 2). We hope that these stars belong to the group of pole-on stars. In order to confirm the pole-on character of these stars it is necessary to observe these stars in the Hα line and infrared regions. Permanent strong Hα and infrared emission can prove their pole-on nature.

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