SPECTRAL ENERGY DISTRIBUTION AND INTERSTELLAR REDDENING

(Review Paper)

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Abstract. - We review the recent results on flux distribution of Be stars from 320 to 850nm. It appears that data are available for only 10 to 15 % of the objects recognized as "normal" Be stars. The main current problems appear to be the variability of the continuous radiation, and the correction for interstellar reddening. Various attempts to solve these matters are discussed. We stress the need for fairly high (1nm) resolution spectral scans obtained simultaneously with data in other spectral ranges, repeated at appropriate intervals of time. Such requirements make it necessary to restrict the observing programmes to a limited sample of carefully chosen objects.

Although emission lines have been recognized in B-type spectra already in 1866, it took more than 50 years to realize that such objects might have also spectral energy distribution different from non-emission-line stars of nearby spectral types. Partial reviews on the subject are somewhat scattered over the literature, but a clear and thorough account will be found in Doazan (Underhill and Doazan, 1982).

Early work on Be stars continuous spectra has been done either photographic spectrophotometry (Greaves and Martin, 1938; Barbier and Chalonge, 1941) and also by observers of early-type stars in the UBV by photometric system. The UBV system is, for obvious reasons, not well suited for flux distribution studies, but it is useful for detecting brightness variations. The reddening is most of the time characterized by a E(B-V) color excess.

There are two specific areas which deserve careful work in this respect:

- the first one is the collection of highly accurate calibrated data on intrinsic Be star fluxes over the whole wavelength range; this implies that we are able to correct the spectral observations for the effects of interstellar obscuration;
- the second is the problem of light variability, which implies repeated measurements over appropriate time scales.

This means that obtaining accurate energy distributions from the satellite ultraviolet to the microwave region even for a limited number of objects is a rather formidable task and that, with regard to such a goal the present situation is all but satisfactory. Nevertheless, considerable progress has been accomplished in the recent years,

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especially in the infrared, which is the subject of a separate review for this colloquium, and will thus not been reported on here. So we shall be mainly concerned here with the visible region and with the ultraviolet inasmuch it has to do with interstellar reddening effects.

The current situation is summarized in Table 1, giving the main sources of information on continuous energy distribution of Be stars (see the detailed reference table at the end of the report). Noting that the recent Catalogue of Stellar Groups(Jaschek and Egret, 1982) contains 1260 bona fide Be stars with an MK type, this means that we have spectrometric observations for roughly 10% of this restricted sample in the visible and in the infrared, and that the situation is somewhat better in the ultraviolet.

Results of the new observations in the 13-color system (Johnson and Mitchell, 1975) have been published by Alvarez, Schuster, and Guichard (Alvarez and Schuster, 1981, 1982; Schuster and Alvarez, 1983; Schuster, 1984; Schuster and Guichard, 1984). The 13 color (13C) system is based on filters of intermediate bandwidths, covering the 337 to 1100 nm range. 8 color indices are used to characterize the stars photometrically and, although the system is very sensitive to reddening, it permits to construct unreddened indices (Mendoza et al, 1983).

According to the authors such data serve to determine "intrinsic colors, reddening values, approximate MK spectral types, surface gravities,

Table 1

Instrument/ Author	Wavelength Range (nm)	Resolution (nm)	Filters (N°)	N° of Be stars (approx.)
IUE	115-320	0.7		167
S2/68 Spectra	136-255	4		176
S2/68 Fluxes	136-274	40	4	564
ANS	150-330		6	?
OAO - 2 Wisc	120-360	1.2-2.2		8
OAO - 2 Phot	133-425	10-20	11	17
Copernicus	75-320	0.005-0.04		19
Breger	330-1050	± 5		56
Geneva	320-620	± 20	7 col	291
13 C Photom	330-1100	10-20	13 col	97
D. Kaiser	320-850	1		26(+16)
B C D	320-620	+ 0.5		51(+66)
Catalogue of infrared obs	2000-20000			163
IRAS	12000-60000		3	94

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distances, angular and linear diameters for normal B stars", and, "with only a few assumptions", most of these procedures can be extended to Be stars. In his paper where he establishes the calibration of the 13C system , Schuster (1984) explains how to derive intrinsic color excesses for Be stars. His method is based primarily on the idea that a Be star may be assigned a non emission B MK type, for which intrinsic colors are known from standard stars photometry. Second, he assumes that the 400nm-450nm color excess is entirely due to an interstellar absorption whose properties are isotropic and invariable with distance. Hence, the observed colors of the Be star are dereddened according to this scheme. The remaining differences between the standard MK-type colors and the dereddened Be stars colors give the "intrinsic" color excesses. It is shown that way that an extra Balmer edge absorption is observed for 48 Lib, while for Chi Oph, it appears in emission, while both stars have a marked color excess in the red. These results are well-known from other types of spectrometries. However, in the 13C system all indices are such that they are close to zero for an average main sequence A0 star, and are not really calibrated in terms of flux ratios. Hence, it is difficult to translate the color indices into physical quantities. For instance, the Balmer jump is evaluated by the 330nm-630nm index, and requires correction for reddening. On the other hand, the sample of comparison stars is rather limited (20 objects) in the spectral range where most Be stars are found. A standard star may show up to 0.2 magnitude in E(B-V) excess, which amounts to a large absorption in the ultraviolet. Schuster and Guichard (1984) give 8 and 6 color photometry of 89 Be and shell stars, among which 22 show light and/or color variations. The variations range from possibly variable objects (0.05 mag.) to very variable objects (0.15m) in the 580 nm band.

Luminosity and colour variations of 88 Her in the 155-550nm range have been studied by Barylak and Doazan (1986). During the period 1972-1983, the star has passed from a quasi-normal B phase to a Be phase. Doazan, Thomas and Barylak (1986) propose to associate the luminosity drop at the onset of the Be phase with an increase of mass outflow and a photospheric temperature drop of about 1000 °K. The strengthening of the shell spectrum, associated with an increase of luminosity reflects either an increase in photospheric radius or a mild increase in photospheric temperature but no change in photospheric radius.

In the frame of a general, statistical approach to the problem of B star variability, Waelkens and Rufener (1983) have indicated how important it is to start from a large and unbiased sample. From measurements made in the Geneva color system, these authors build up parameters which are strictly photometric and which permit to separate the various types of variables, and in particular, the Be stars.

A general study of the Be variability has been made by Kogure (1984), who characterizes the three relationships between emission line intensities and the V magnitude as parallel, mutually independent, and antiparallel. Photometric and spectroscopic behaviour of Pleione and EW Lac indicate a correlation between an increase of the U-B excess and a higher optical depth in H alpha. This phenomenon may be due to an increase of electron density in the envelope.

Since the pioneering work of Mendoza (1958), it is known that Be stars, classified in the MK system show in the U-B, B-V plane a large scatter around the reddening vector. Recent work in the UBV system brought up interesting new results concerning the light and color variabilities namely :

- the discovery of the eclipsing binary nature of zeta Tau (Pavlovski and Bozic, 1982);
- the strictly periodic variations of 4 Be stars (over 7) in the cluster NGC 3766 (Balona and Engelbrecht, 1986). The amplitudes are of a few percent in B, with periods of the order of one day. The authors find that the observations are best represented by a spotted rotator model;
- The same type of explanation is proposed by Harmanec (1984, a, b) for rapid variations of 3 Be stars.
- let us also mention studies in UBV by Hopf et al (1982, Pleione), Bartoloni et al (1982), Pavlovski (1983), Fernandes (1984) and Balona (1985). A list of stars with periods around one or two days has been published by Percy (1982).

Harmanec and his collaborators organized an international campaign of Be stars watch. Many observers (and among these Z.H. Guo, L. Huang, V.M. Lyuti, J.R. Percy, A.S. Sharov, C. Stagg and J. Ziznowsky) joigned the team and reports are regularly issued in the Be star Newsletter, edited by M. Jaschek.

The Walraven VBLUW system has been used by van Leeuwen et al (1982) to study Pleione.

HD 172256 has shown in the Strömgren uvby system a period shorter than one day (Heck et al, 1984). In this system, several Be stars have been included in a survey program of "Long Term Photometry of Variables", currently under development at ESO (Sterken, 1984). D. Baade is the coordinator for the Be star group.

Narrow band systems allow to isolate lines and compare continuum and line emission or absorption (H-alpha, HeI 5876) Mendoza et al (1983), measured hot stars (O4-B8) in their system called lambda (9), alpha (16). (For details, see Mendoza 1975, 1976, 1979 a, b, 1981). The alpha (16) index allows to single out stars with emission at H-alpha. Be and shell stars are clearly separated from non-emission B stars in the alpha (16), lambda (9) plane. Mendoza et al (1983) also find a correlation between the alpha (16) index and the mass loss rate.

Guinan and Hayes (1984) succeeded in watching photometrically a major mass loss onset in omega Ori at the H-alpha wavelength. Large variations have also been seen in the continuum at 435 and 658.5 nm. A preliminary study using interference filters has been started by Cester et al (1982) on Be stars.

Various papers by Goraya (1984, 1985 a, b, c; Goraya and

Singh, 1984; Goraya and Joshi, 1982), based on 50 A resolution scans, indicate that early Be stars (B0-B5)show more frequently color excess in the near UV and near infrared than do later sub-types. Some Be stars have an effective temperature lower than normal B stars (Goraya, 1985), but other Be's are in this respect very similar to non-emission B stars (Goraya and Singh, 1984). The infrared color excess is a common feature of Be stars. Goraya also finds a correlation between the infrared excess and the intensity of the Balmer jump in emission.

Such a conclusion on the temperature of Be stars is also reached by Zorec et al (1983). They use data from the BCD classification scheme and ultraviolet monochromatic magnitudes from the S2/68 experiment.

They introduce an ultraviolet reddening free index $G = m(146) - m(274) - K\, m(146) - m(235)$, K being the appropriate ratio of color excesses, for which they find a relatively high value (-11.21), using the average interstellar reddening law of Savage and Mathis (1979). This high value is due to a relatively small value of the color excess E(146nm - 235nm). The scatter in the diagram spectral type-G index is then fairly high, especially for representative points of emission line stars, relatively to the average curve representing BIV-BV stars. This is not too surprising when one realizes the variety of individual reddening curves. Furthermore the G index computed from Kurucz models is in serious disagreement with the values obtained from observations, especially for supergiants.

Their conclusion is that around 235nm most Be stars would have more fluxes either higher and sometime lower than B stars and that these differences simultaneously with strong emission characteristics (strong low Balmer lines, high Paschen lines emission, infrared excess). They suggest that the Be stars be classified into 2 categories according to their emission strength. They also find no correlation between their ultraviolet color index and V sin i.

Such a method is perhaps not entirely free from interference of circumstellar material. Schild (1983) has shown that among 7 Be stars, four stars may show color excesses due to absorption by circumstellar matter, producing no 220nm-bump in the ultraviolet. This is an alternate explanation to the large value of the E(B-V) excess as due to supplementary emission in the V band.

An attempt has been made also by Zorec and Briot (1985) for establishing the part of the E(B-V) color excess due to interstellar reddening. They first try to solve the problem starting from normal B stars, where usual procedures of the UBV system and the Paris BCD classification parameters lead to a classical value of E(B-V) for non emission stars. Results of the method levelling off the 220nm depressio as described by Beeckmans and Hubert Delplace (1980) are shown to lead t values somewhat smaller than for non-emission stars.

An alternate method makes use of fitting the 220nm feature with a Lorentz profile(Gutler et al, 1982) which leads to values consistent with the previous one (as corrected by Zorec and Briot).

Surrounding stars then provide a new method based on a relationship between the color excess and distance in the direction close (2° to 5°) to the direction of the star studied. Hence, this method requires the knowledge of the absolute magnitude of the star. It is then applied to 55 Be stars and the authors recognize that their application is not just as straight forward as in the case of non-emission stars, due to a poor knowledge of absolute magnitude (they do not seem to consider Be stars in clusters) and to variations in V. Assuming a non variability of the absolute magnitude of the Be stars, they deduce a V magnitude of the Be stars as it were outside a shell phase. This V magnitude serves to compute the distance, using the absolute magnitude of a B star of the same spectral type of the Be star.

There are of course several sources of uncertainties in the determination of E(B-V) by such a procedure. It seems that the method using surrounding stars leads to smaller E(B-V) values that the 220nm absorption bump. This might be an indication of a possible contribution of circumstellar matter to the Be flux depression around 220nm, a result in some way in contradiction with Schild's findings that circumstellar matter would contribute to E(B-V) and not to the 220nm bump.

This means that the matter of flux comparison between B and Be stars in the 215-235nm region is far from being settled. Let us note that Divan and Zorec (1982) applied to 59 Cygni a method based on a gradient discrepancy between the stars (observed during a non-emission-phase) and an unreddened object of similar BCD spectral type. This method led to values in good agreement with E(B-V) values obtained from UV fluxes.

A more physical attempt to obtain the true interstellar + circumstellar part of the color excess E(B-V) has been recently made by D. Kaiser (1984). In his doctoral thesis, he develops a method of finding the fundamental characteristics of the underlying photosphere of a Be star. The main assumption in this work is the fact that a Be star may be modellized by a system made of a normal B star, plus a temporary shell, responsible for the photometric variations and optically thin in the near infrared region.

Observations consist of high quality scans of 26 bright Be stars from 320 to 880nm (Kaiser, 1986). The sample has recently been extended to 16 other stars by Hanuschik (1986). The main idea is to determine a set of values of E(B-V) interstellar , Teff and log g from fitting interpolated model fluxes to the observed flux distribution in the widest possible range. A basic procedure developed for 3 standard non-emission stars leads to results in good agreement with other determinations. This makes use of a fitting also of the Balmer jump.

The situation is of course less favourable for Be stars since the two discontinuities already observed in the BCD spectra also appear, restricting the wavelength range to 370 to 880nm. At this point, another difficulty appears, namely that even that for this spectral region, no set of parameters E(B-V), Teff and log g will lead to a satisfactory agreement, because of the well-known infrared radiation excess. The fluxes being normalised at 550nm, it is clear that the difference between the observed fluxes and the model fluxes at wavelengths longer than 556nm are only minimal values.

Theoretical considerations on energy distribution emitted by a thin envelope lead Kaiser to determine the amount by which the 556nm magnitude has to be corrected to account for the shell contribution. Hence a new flux for the stellar photosphere is determined and a new and final determination of the Be star photosphere may be determined, as well as an interstellar E(B-V) value. Results indicate rather low values of interstellar E(B-V) but most of the observed stars are bright and relatively close.

These objects have also been observed in the ultraviolet. Taking into account the correction proposed by Kaiser at 556nm, it is possible to compare the observed fluxes by S2/68 (Jamar et al, 1976), IUE (Heck, 1984) or OAO-2 (Code et al, 1980) with fluxes derived from the Kurucz model parameters proposed by Kaiser for the same star. In general, observed fluxes are somewhat (0.2 to 0.4 magnitude) lower than the fluxes expected from the models. Such a discrepancy may be interpreted in terms of a too high temperature scale, or in terms of a complementary source of opacity in the stellar or circumstellar atmosphere.

In conclusion, we may say that much remains to be done to have a satisfactory knowledge of Be type star flux distributions in the visible wavelength range. In order to separate the effects of interstellar and intrinsic reddening, it is advisable to have accurate and well resolved (1nm) energy distribution over a range 320 to 900nm. It is clear that these observations have to be carried out simultaneously over all practicable wavelength ranges. Because of normalisation problems, it would be advisable to have absolute fluxes at one wavelength. Furthermore because of variability problems, it is necessary to repeat at appropriate intervals of time the observations and hence to concentrate on a restricted observing list of objects.

A TABLE OF DATA ON CONTINUOUS ENERGY DISTRIBUTION OF Be STARS.

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a : IUE Low-Dispersion
Spectra Reference Atlas
Part. 1 Normal Stars
A. Heck, D. Egret, M. Jaschek, C. Jaschek
European Space Agency

b : Merged Log of IUE observations
January 26, 1978 - March 31, 1985

c : Ultraviolet Bright-Star Spectrophotometric Catalogue
C. Jamar, D. Macau-Hercot, A. Monfils, G.I. Thompson,
L. Houziaux, R. Wilson.
ESA SR-27 November 1976.

d : Supplement to the ultraviolet Bright-Star spectrophotometric catalogue.
ESA SR-28 October 1978.

e : Catalogue of Ultraviolet Fluxes.
G.I. Thompson, K. Nandy, C. Jamar, A. Monfils,
L. Houziaux, D.J. Carnochan, R. Wilson.

f OAO-2 : Wisconsin Astrophysics.
Ultraviolet photometry from the orbiting astronomical observatory.
An Atlas of ultraviolet Stellar Spectra.
A.D. Code and M.R. Meade
Space Astronomy Laboratory
University of Wisconsin
Madison, Wisconsin

g : Absolute Ultraviolet Spectrophotometry with the TD-1 Satellite.
XI. Spectrophotometric Study of Be Shell Stars with the S2/68 experiment.
F. Beeckmans and A.M. Hubert-Delplace
Astron. Astrophys. 86, 72-86 (1980)

h Voyager 1 and 2 : -Long term variability in the far UV flux of Be Stars
G.J. Peters and R.S. Polidan, This colloquium
-Short term FUV variability in Be Stars
R.S. Polidan and G.J. Peters, This colloquium
-The flux distribution of Be Stars in the far UV
R. Stalio, R.S. Polidan and G.J. Peters, This colloquium.

i : A catalog of 0.2 Å Resolution for-ultraviolet stellar spectra measured with Copernicus.
Theodore P. Snow, JR. and Edward B. Jenkins
The Astrophysical Journal supplement Series, Vol.33, n° 3, 1977 March.

j : Catalog of spectrophotometric scans of stars.
Michel Breger
The Astrophysical Journal Supplement Series, Vol. 32, n° 1, 1976 September

k : The Thirteen-color photometric system II.
W.J. Schuster and J. Guichard
Rev. Mexicana Astron. Astrof., 9, 141-151, 1985

Thirteen-color photometry of sixteen variable Be Stars. I. Photometry
Manuel Alvarez and William J. Schuster
Rev. Mexicana Astron. Astrof., 5, 173-178, 1982.

Be and Shell stars observed with the 13-color photometric system.
William J. Schusters and Manuel Alvarez
Publications of the Astronomical Society of the Pacific 95, 35-42, January 1983.

l : Third catalogue of stars measured in the Geneva Observatory photometric system.
F. Rufener, Observations de Genève, 1980.

m D_BFB : Fringant A.M.
Berger J.
Communication privée 1986.

n : Kontinuierliche Energieverteilungen der Be-Sterne im optischen Spektralbereich.
Dietrich Kaiser
Dissertation, Bochum, 1984.

o : Catalog of infrared observations
Daniel Y. Gezari
Marion Schmitz and Jaylee M. Mead
NASA Publication 1118 - May 1984.

p : IRAS observations of Be Stars
A statistical study of the IR excess of 101 Be Stars
J. Coté
L.B.F.M. Waters
Submitted to : Astronomy and Astrophysics, Main Journal, 1986

Letters c, d, e, j are followed by the number of the page where the data appear.

HD	HR	REFERENCES
144	7	a c6 e2 l
698		b e2 k
2905	130	a b d6 e6 k l o
3369	154	a c6 e6 k l o
4180	193	a d6 e7 g k l m p
5394	264	a d6 e9 f g h k l m p
6343		e10
6811	335	a c6 e11 k l p
7636		e12 o
7902		l o
9105		l o
9311		o
9709		e14 k l
10144	472	a c6 e15 f h j11 k l n p
10516	496	a c6 e16 f g k l m o p
11606		e17 g m
12302		e18 l o
12856		l m
12882		e19 l
13051		l m
13256		l m
13267	627	e19 k l
13429		l
13661		e20 o
13669		e20 l m o
13854	654	a k l o
13867		e20
13890		l
13900		l
14134		a k l o
14143		a l o
14422		a j 13 l o
14605		j13 l o
14818	696	a e21 k l o
14850		e21
15238		o
15472		e22
18552	894	e27 k l
18877		e28
19243		e29 k
20017		e30
20336	985	a c7 e31 g k l m o p
20340		e31

HD	HR	REFERENCES
20566		e31
20899		e32
21212		n o
21291	1035	a b e33 l o
21641		e33 k l
21650		e34 m
22192	1087	a c7 e35 g k l m p
22298		e35
22780	1113	a d7 e36 l
22920	1121	a c7 e36 l
23016	1126	c7 e36 l
23180	1131	a c7 e36 i k l o
23302	1142	a b e37 k l p
23480	1156	a b c8 e37 j18 k l p
23552	1160	e37 l p
23630	1165	a b c8 i k l p
23862	1180	a e38 k l p
24398	1203	a c8 e39 f i j19 k l o
24479	1204	a c8 e39 l
24534	1209	c8 e39 g k l m
24560		e39
25487		a l
25940	1273	a c8 e42 g j20 k l m p
26398		e43 l
26420		e43
26670	1305	a c8 e43 l
28497	1423	a c9 e48 g k l m n p
29332		e50
29441		e50 m
29866	1500	k p
30076	1508	a c9 e52 g l m n p
30123		e52 l
31293		a e54
31648		o
32190		e57 l
32343	1622	a c9 e57 g k l m p
32991	1660	a d7 e59 g k l m p
33051		e59
33152		e60
33232		e60 o
33357		a e60
33461		e61 m o
33579		e61

HD	HR	REFERENCES
33604		e61 m
33988		e62 m
34085	1713	a c10 e62 f i j25 k l o
34257		e63
34302		e63 m
34507		e64
34664		o
34921		e65 l
35165	1772	c10 e66 k l o
35345		e66 l m
35347		e66
35411	1788	a d7 e67 f k l
35439	1789	a c10 f g j26 k l m p
35621		e67 m
35652		e67
36012		e68 j27
36376		e70
36576	1858	a d8 e70 g k l m p
36665		a e71
37115		a l
37128	1903	a c10 e72 f i j28 k l o
37202	1910	a c10 e73 g j29 k l m p
37318		e73
37490	1934	a d8 e74 f g j29 k l m n p
37541		e74
37622		e74
37657		e74
37742	1948	a c11 e75 f i j29 k l o
37795	1956	c11 e75 i j30 k l n p
37836		o
37867		e75
37967	1961	a c11 e76 g k m p
37974		o
37998		e76
38010		c11 e76 g k m
38063		e76
38116		e76
38191		e76
38708		e78 o
39018		e79
39340		e80 m
39478		e80
39680		l m o
40978		e85 g m
41117	2135	a b c11 e86 k l o
41335	2142	a c11 e87 g k l m n o p
41698		e88
42054	2170	c11 e90 p
42087		a c11 e90 l o
42259		e90 o
42406		e91
42529		e91
42908		e93
43285	2231	c12 e95 g k l m
43544	2249	a c12 e96 l
43703		m
44351		e99 m o
44458	2284	a c12 e100 g k l m n o p
44637		e100 l m
44674		e101
44996	2309	c12 e102 l
45166		e102 l o
45260		e103
45314		c12 e103 g k l m o
45542	2343	c12 g l m o p
45626		o
45677		a e105 l o
45725	2356	c12 f k l p
45726	2357	d8
45727	2358	d8
45901		e105
45910		a e105 k l o
45995	2370	a c12 g k l m p
46056		e106 l
46380		e107 o
46658		e108
47054	2418	a b c13 e110 l p
47129	2422	b c13 e110 k l o
47202		e110
47359		a e111 l
47761		e112
48282		e114
48917	2492	c13 e116 k l n p

HD	HR	REFERENCES	HD	HR	REFERENCES
49330		e118 l	55271		e136
49336	2510	c13 e118 l	55394		e136
49699		e119	55439		e136
49787		e119	55606		e137
49888		e120	55806		e137
49977		e120 o	56014	2745	a c15 e138 j34 k l
49992		e120	56039		e138
50013	2538	a c14 e120 j33 k l n p	56139	2749	a c15 e138 j34 k l n p
50064		a l m o	56806		e140
50083		a c14 e120 g k m	56847		e140 l o
50091		e120 o	57150	2787	c15 e141 k l m
50123	2545	c14 l p	57219	2790	c15 o
50138		a b e121 k l m o	57386		e142 m
50209		e121	57393		e142
50424		e122	57775		e143
50658	2568	c14 e122 k	57910		e144
50696		e123	58011		c15 e144
50820	2577	a e123 l	58050	2817	c15 e144 g m
50846		a e123	58055		e144
50850		e123	58127		e144
50868		e123	58131		e144 l
50891		l	58155	2819	e144 l
50938		e123	58343	2825	a c16 e145 g j34 k l m n o p
51193		e124			
51285		a e124	58715	2845	c16 e146 j34 k o p
51354		a e125 m			
51404		e125	58978	2855	a c16 e147 l n o p
51452		e125	59094		e147 o
51480		a e125 k o	59281		e148
51585		o	59319		e148
52112		e127	59497		e148
52244		e127	59773		e149
52437	2628	c4 e128 l	60260		e150
52597		e128	60307		e150
52721		b c14 e128 k o	60606	2911	d8 e151 k l n p
52812		c14 e129	60757		e152
53179		a e130	60855	2921	a c16 e152 k l p
53367		a b e130 k o	61224	2932	e153 l
53416		e130	61778		e155
53428		e131	61925	2968	c16 e155 l
53667		e131 l o	62367		e156 g k m
54086		e132	62532		e157
54309	2690	c15 e133 l n o	62753		c16 e158
54464		e133	62780		e158
54575		e133	63150		e159 l
55135		e135	63359		e159

HD	HR	REFERENCES
63462	3034	a c16 e160 k l n p
64109		e162 m
64298		e162
64315		e162 l
64511		e163
65079		e164
65176		e164 n
65818	3129	a c17 e166 l o
65875	3135	c17 e166 g k m o p
66194	3147	j35 l n p
66700		e169
67632		e171
67888	3195	a e171 l p
68423	3217	e172 l
68980	3237	a c17 e174 j36 k l n o p
69168		d9 e174
69404		a c17 e174
69425		e174
69464		e175 l o
70557		e177
71072		e179 k o
72014		a c18 e181
72063		e181
72067	3356	a c18 e181 l p
72754		a e183
73658		a e185
73834		e185
75311	3498	a c18 e189 j38 l n p
76341		e191 l
76868		e192 m o
77320	3593	c19 e193 l
78764	3642	a c19 e196 l
79621	3670	e197 l
80077		o
81753	3745	e200 l
83043		e203
83953	3858	a c19 e204 k l n o
86612	3946	d9 e208 l o
87543	3971	l p
87643		a o
88825	4018	e211 l p
89080	4037	e212 f l p
89249		o
89884		e213 k m o
89890	4074	e213 l p
90177		a
90490		e214
90657		l
90966		e214
91120	4123	a e214 k l m o
91269		e215 l
91465	4140	a c20 e215 f j42 l n p
92027		e216
92420		e216
92964	4198	a e217 l o
93237	4206	d9 e217 l
93563	4221	e218 l p
94878		l
94910		a
95826		e221
96042		e221 l
96261		e221
96728		e222
96864		a e222
97151		e222
98624		o
98927		e224
100324		e226
102567		a e228
102766		a
105056		a e231 l
105382	4618	j47 l p
105435	4621	a c20 e231 j47 k l p
105521	4625	d10 e231 k l
107348	4696	c20 l
109387	4787	a b c20 e235 g k l m p
109857	4804	e236 l p
110335	4823	d10 e236 j49 l p
110432	4830	l o
112078	4897	a c21 e238 f j49 l p
112091	4899	c21 j50 l p
113120	4930	e239 l p
114441		e240
114800		e240
115842	5027	e241 l o
120324	5193	a d10 e245 f h j53 k l p
120678		e246 l o

HD	HR	REFERENCES
120958		e246
120991	5223	l o
124367	5316	e249 l p
124448		a l o
124639	5327	e249 l
127972	5440	a d11 e252 f j55 l p
128293		d11 e253
131492	5551	c21 e256 l
133738		e258
135160	5661	a c22 e259 l
135734	5683	d11 l p
137387	5730	e262 l
138749	5778	a c22 e264 k l p
141569		e267 k
142184	5907	e268 k l p
142926	5938	a c22 e269 k l m
142983	5941	a c23 e269 g h k l m o p
143448		l
144320		e271
144965		e272
147756		e275
148184	6118	a d12 e275 g j61 k l m o p
148259		e276
148379	6131	a b l o
148688	6142	c23 e276 l o
149671	6172	a c23 e278 l
150193		o
150422		a e279
152235	6261	a e282 k l o
152236	6262	e282 j63 k l o
152291		e282
152478	6274	c23 e283 l o p
152667	6283	a b e283 k l o
153261	6304	d12 e284 o p
153879		e285
153977		e285
154090	6334	a d12 e285 l o
154154		e286
154165		e286
154218		e286
154243		e286
154450		e286
155851		e289 o
155896		e289
156325	6422	k l
156633	6431	a c24 e291 g m
156831		e291
157042	6451	c24 e291 l p
157056	6453	c24 e291 j63 k l
157099		e291
157246	6462	a c24 e292 i l o
157832		e293
158319		e294
158427	6510	c24 e294 l p
159684		e297
159848		e297
160095		e298
160202		l
160319		e298
160886		e299
161004		e300
161103		e300
161261		e300 l o
161306		e300 m
161543		e301
161660		e301 l
161756	6621	e301 l
161774		e301
161807		c24 e301
162428		e303 k m
162568		e303
162717		e304
162732	6664	a e304 k l
163007		e304
163454		e305
163868		e306
164105		e307
164246		e307
164248	6712	a c25 e307 g h j66 l m p
164447	6720	e308 k l
164865		a l o
164906		c25 o
164950		e309
164971		e309
164993		e309
165132		e309
165285		e310
165517		e311
165952		e312
166188		e312
166345		e313

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HD	HR	REFERENCES
166443		e313
166566		e313
166612		a e314
166629		e314
166734		1 o
166937	6812	a c25 e314 1
166967		e315
167128	6819	c25 e315 1 p
167233		e315
167311		1
167362		o
167775		e317
168056		e317
168135		e317
168144		e317
168229		e318
168331		e318
168797	6873	c25 e319 j67 k 1
168957		a c25 e320
169033	6881	a c25 e320 1
169226		o
169454		a e321 1 o
169515		a
169753		a e321
169805		e322
170097		e322
170146		e322
170235	6929	c25 e323 1 o p
170638		e324
170682		e324
170714		e324
171012		e325 1 o
171032		e325
171054		e325
171219		e326 1
171348		e326
171406	6971	c26 k
171757		e327
171780	6984	c26 e327 k 1
172175		a e328 1
172252		o
172256		e329
172324		e329 1
172579		e330
172694		a e330 o
173219		a e331
173292		e331
173371		e331 k
173530		e332
173637		e332
173817		e333 m
173948	7074	a c26 e333 j68
174105		e333
174237	7084	a c26 e334 g k 1 m p
174513		e335
174571		e335
174638	7106	a c26 f k 1
174705		e335
174775		e335
174886		e336
175511		e337
175754		d13 e338 1 o
175863		e338 m
175869	7158	a c26 e338 1
176159		e339
177015		e341
177291		e341 o
177427		e342
177648		e342 m
178175	7249	a d13 e343 g k 1 m o p
179218		e346 1 m
179405		e346
180398		e348 m
181182	7326	a e350
181231		e350 m
181308		e350 m
181803		e352
183143		a b e355 1 o
183326	7403	c27 e355 g j71 k 1 m p
183656	7415	a e356 g k 1 m
183914	7418	b c27 1 o
184279		a e358 k 1 m
185037	7457	c28 e359 1
186296		e363
186456		e363
187350		e366 m
187399		e366 1 o
187567	7554	c28 e366 j72 p
187811	7565	a c28 e367 j73 k 1 p
189687	7647	a c28 e371 g j73 1

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HD	HR	REFERENCES
189689		e371 l m
190150		e372 l
190467		e373 l m
190603	7678	b e373 j74 l o
190944		a e374 m o
191610	7708	a c28 e375 g h j74 k l m p
192019		l
192044	7719	c29 e376 l
192445		e377
192968		e379
193009		e379 g k m
193237	7763	a d13 e380 k
193322	7767	c29 e380 l o
193516		l
193911	7789	c29 e381 l p
194279		l o
194335	7807	a c29 e383 g j75 m
194839		l o
194883		e384
195407		e385 o
195554	7843	c29 e385 l
195592		e385 l o
195907		e386
196712	7890	e388 l
197406		l o
197419	7927	c29 e390 j76 l
197434		e390 m o
197702		a e390
198183	7963	c29 e391 l p
198478	7977	a b c29 e392 k l o
198512		e392
198895		m
198931		o
199218	8009	e394 l
199356		e394 k o
199478	8020	a b e394 l o
200120	8047	a b c30 e395 g h j77 k l m
200310	8053	a b c30 e396 g l m
200775		a e396 o
201522		e398
201733	8103	c30 e398 k o
202904	8146	a c30 e400 g j78 l m
203025	8153	e401
203338	8164	a e401
203356		l
203374		c30 e401 g m
203467	8171	a c30 e401 g j78 l m p
203699		e402 g k m
203731		e402
204116		e403
204722		e404
205060		e404 k
205551	8259	e405 l
205618		e405
205637	8260	a d13 e405 g j79 l m p
207232		e408 l
207329		e408 l
207757		e409 l m
208057	8356	a c31 e409 g j80 l m
208220		l
208392		a l
208682	8375	a c31 e410 g l m p
209014	8386	c31 e411 l p
209409	8402	a c31 e412 j80 p
209522	8408	c31 e412 l
210129	8438	d14 e413 j80 k l
211835		e416 l
212044		e416 g m o
212076	8520	a d14 e416 l
212571	8539	a b c31 e417 g j81 l m n o
212666		e417 l
212791		e417
213088		l
213129		e417
214168	8603	d14 e419 j81 l
214197		e419 l
214748	8628	c32 e420 j81 l n p
215227		e420
216057	8682	c32 e421 g j82 k l m
216411		l m o
216851		e422 l
217050	8731	c32 e423 g k l m o p
217543	8758	c32 e423 g k l m o

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HD	HR	REFERENCES
217675	8762	a c32 e424 g k l m
217891	8773	a d14 e424 g j83 l m n p
218393		a e425 k l m o
218674		e425 g k l m
220582		e428 l
221650		l
221692		l
223036		e431
223387		e432
223501		e432
224055		l m
224424		l
224544	9068	c33 e433 k
224559	9070	c33 e433 k
224686	9076	a c33 e433 l n
225094	9097	a e434 l o
225095		e434 o
225146		a e434 l o
225985		o
227611		l
228041		l
228766		l
229059		o
229239		l
230211		e434
231193		e435 l
232552		e435
235565		e436
235668		e436
235795		e436
235834		l
236689		o
236737		m
236935		l
236940		l
236970		l o
237056		l
239758		e436
242750		e436
245310		e437
245493		e437 m
245770		a
246338		e437
246878		e437
247331		e437
248060		e437
248753		e437
249695		e437
250028		e437 o
250550		a o
253659		e438
256577		e438
257366		e438
259431		a e438 l
259597		e438 l o
259631		e438
269006		a o
269217		o
269227		o
269700		a
303492		o
306070		o
322422		l
322447		l
326823		o
351123		o
351582		e422

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DISCUSSION FOLLOWING HOUZIAUX

Doazan:

I would like to recall that our analysis of the luminosity changes of 88 Her, from the far UV to the visual, through phase changes (quasi-normal B to Be shell) has shown that the occurrence of a shell spectrum is *preceded* by a luminosity drop in all the observable wavelengths, indicating a decrease in photospheric temperature of about 1000 K. There is no far UV excess nor deficiency relative to a normal Be star's radiative energy distribution. Such a change indicates that the thermodynamic state of the photosphere is linked to the formation of a shell, i.e. an enhancement of the mass outflow from the star.

Peters:

When one observes a B star in the visual spectral region, one is observing but a few percent of the total flux from the star. We have been obtaining continuum data on selected Be stars with the *Voyager* spacecraft, which are capable of recording 40- 70% of the flux of such a B star. Tomorrow we will present evidence from *Voyager* data that the surface temperature of α Eri varies by 750 K. This value is consistent with the run of values (except for one extreme one) given in your table.

Houziaux:

It may well be indeed that the effective temperatures obtained by various authors at different times reflect variations of temperatures of Be stars as you demonstrated in the case of α Eri. This proves, however, that although a small amount of the total energy is concentrated in the range 320-850 nm, this range is sufficient to obtain an accurate value of T_{eff}. On the other hand the correction for interstellar reddening is much safer in this range than in the far ultraviolet. From what you are saying, it seems that in the future, it will be necessary to assign to a Be star not only a value of T_{eff} but also a range of variation in T_{eff}. Such variations may reflect the release of matter opaque to continuum radiation affecting also the photospheric radius.

Snow:

I have comments on the determination of interstellar extinction. First, I was interested to learn that there is statistical evidence of enhanced 2200 Å absorption in Be stars. I think it's far more likely that this is due to extra line absorption than to circumstellar extinction, because there is an extensive literature showing no evidence for circumstellar dust in Be stars and no circumstellar 2200 Å absorption, even in stars with dust. Also, I think the use of diffuse interstellar band strengths to indicate interstellar extinction ought to be more widely applied. The diffuse bands correlate well with E(B-V) and apparently are never formed in circumstellar material. Furthermore, with modern detectors the relatively narrow bands in the red can be accurately measured even in stars with E(B-V) as small as 0.10. This method of finding E(B-V) avoids problems with using clusters or nearby stars to estimate reddening.

Houziaux:

I agree inasmuch it is proven that these relationships of diffuse features versus E(B-V) are isotropic.