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Spectroscopic observations of Hα emission-line stars from Sanduleak & Stephenson's 1973 (SS73) list*

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Abstract. We present spectroscopic observations of 33 emission line stars from the Sanduleak & Stephenson's (1973) list. This work is part of a program to investigate emission-line objects in the southern hemisphere whose nature is not well established in the literature. The objects were observed at two different spectral regions providing full coverage in the 3100–8700 Å interval. In this paper we describe the main spectroscopic features and discuss the nature of the objects. It is proposed that 16 of them are Be stars, 5 are peculiar Be stars, 4 are T Tauri stars, 7 are M-type stars with emission-lines and 1 is a Herbig object.

Key words. stars: emission-line, Be – stars: general – stars: pre-main sequence – stars: late-type

1. Introduction

The majority of the first surveys of Hα emission-line objects have been done with objective-prism plates and further spectroscopic follow-up is necessary in order to determine the true nature of them. With this in mind five years ago we started a spectroscopic survey of these objects at the European Southern Observatory (ESO). Previous results of this kind of work led to the discovery of a new WN4 Wolf-Rayet star (Pereira et al. 1998) and to the identification of 16 new Be stars and 7 new T Tauri stars in the Canis Majoris region (Pereira et al. 2001).

In the present work we concentrate on some stars of Sanduleak & Stephenson's (1973) list, hereafter SS73. The SS73 survey consists of 179 stars, several of which are located in the direction of the Galactic Center but with concentrations in other regions of the Galaxy too (Figs. 1a–c of SS73). The first paper dedicated to investigate most of the stars from SS73 sample was by Allen (1978, hereafter A78). As result of Allen's (1978) investigation (as well as from SS73) the number of symbiotic stars doubled. Although most of the stars from the sample of SS73 were investigated by several other authors there are still a number of objects that deserve spectroscopic follow-up. This is illustrated by the recent analysis by us for two stars of this sample, SS73 11 and SS73 71. The former may be a LBV or a post-AGB object (Landaberry et al. 2001) while the latter is a symbiotic object (Pereira et al. 2002). Moreover even nowadays there are some stars in this survey whose nature is either still not well known (such as SS73 7, and 52) or with poor information about their nature, as is the case of SS73 80, 83 and also SS73 118 which is M-supergiant. Another reason for this spectroscopy survey is given by stars as SS73 39 (Hen 2-91), SS73 156 (MWC 922) and SS73 170 which belong to the list of unclassified B[e] stars defined by Lamers et al. (1998, hereafter L98).

The purpose of this paper is to present homogeneous spectra of 33 poorly-studied objects, suggesting classifications for all of them. In Sect. 2 we describe the observations and the data reduction procedures. In Sect. 3 we discuss the observed spectra of each object. In Sect. 4 our findings are summarized.

2. Observations and reductions

The spectroscopic observations were performed using a Boller & Chivens spectrograph at the Cassegrain focus of the ESO 1.52 m telescope in La Silla (Chile). A UV-flooded thinned Loral Lesser CCD #39 (2048 × 2048, 15 μm/pixel) was used as detector; it gives a high quantum efficiency in the blue and in the UV. The setup employed is the same used to investigate other emission-line objects at the 1.52 m telescope (Pereira et al. 2001). Two instrumental setups were employed. The first made use of grating #23 with 600 l/mm, providing a resolution of 4.6 Å in the range 3500 Å–7500 Å. The other setup adopted grating #31 with 1200 l/mm, resulting in a resolution of 1.9 Å in the range 3100–5100 Å.

The spectra were reduced using standard IRAF tasks, from bias subtraction, flat-field correction, through spectral extraction and wavelength and flux calibration. Spectrophotometric standards from Oke (1974) and Hamuy et al. (1994) were also observed. The slit orientation in the range (3110 Å–5100 Å) was aligned with the parallactic angle in order to minimize the

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* Based on observations made with the 1.52 m telescope at the European Southern Observatory (La Silla, Chile) under the agreement with the Observatório Nacional, Brazil.

Table 1. Observation log of SS73 stars.

Star	Date	Wavelength range	Exp time (s)
SS73 1	1997 Nov. 07	3680 Å–7515 Å	900
SS73 2	1998 Jan. 19	3150 Å–5110 Å	1200
	1999 Mar. 03	3380 Å–7200 Å	900
			60
	1999 Mar. 04	3175 Å–5110 Å	900
SS73 3	1998 Jan. 19	3150 Å–5110 Å	900
	1999 Mar. 03	3380 Å–7200 Å	30
			180
	1999 Mar. 04	3175 Å–5110 Å	900
			180
SS73 6	1997 Nov. 07	3680 Å–7515 Å	1200
			300
	1998 Jan. 19	3150 Å–5110 Å	1200
SS73 7	1999 Mar. 02	3350 Å–7190 Å	900
	1999 Mar. 03	3380 Å–7200 Å	180
	1999 Mar. 04	3175 Å–5110 Å	1200
SS73 12	1998 Jan. 19	3150 Å–5110 Å	1200
	1998 Mar. 14	3540 Å–7413 Å	200
			60
SS73 16	2001 Feb. 03	3674 Å–8639 Å	1200
SS73 17	1999 Mar. 03	3380 Å–7200 Å	60
	1999 Mar. 04	3175 Å–5110 Å	900
SS73 24	2001 Fev. 03	3674 Å–8639 Å	600
			60
	2001 Jun. 14	2686 Å–6200 Å	900
SS73 28	1997 Jan. 19	3208 Å–7027 Å	600
	1997 Jan. 18	3235 Å–5164 Å	900
SS73 31	1997 Feb. 23	3250 Å–5080 Å	900
	1997 Feb. 24	3490 Å–7400 Å	300
			300
	1999 Apr. 16	3547 Å–7360 Å	1200
SS73 33	1997 Feb. 23	3250 Å–5080 Å	900
	1997 Feb. 24	3490 Å–7400 Å	600
	1999 Apr. 16	3547 Å–7360 Å	1200
			600
SS73 34	2001 Feb. 03	3674 Å–8639 Å	900
SS73 35	1997 Feb. 23	3250 Å–5080 Å	300
			600
	1997 Feb. 24	3490 Å–7400 Å	240
			120
SS73 39	1997 Feb. 24	3490 Å–7400 Å	300
	1997 Feb. 24	3490 Å–7400 Å	300
SS73 41	1997 Feb. 24	3490 Å–7400 Å	600
	1997 May 21	3600 Å–7400 Å	420
	1997 May 21	3600 Å–7400 Å	10
SS73 44	1997 Feb. 25	4100 Å–7492 Å	600
	1999 Mar. 05	3150 Å–5103 Å	1500
SS73 51	1998 Mar. 14	3540 Å–7413 Å	900
	1999 Mar. 04	3175 Å–5110 Å	1200

Table 1. continued.

SS73 52	1997 May 22	3540 Å–7410 Å	600
	1998 Mar. 14	3540 Å–7413 Å	900
	2001 Jun. 09	3300 Å–8550 Å	900
	2001 Jun. 13	2686 Å–6200 Å	1200
SS73 62	2000 Mar. 25	3704 Å–8740 Å	620
			60
SS73 63	2001 Jun. 09	3300 Å–8550 Å	600
			30
SS73 67	2001 Jun. 09	3300 Å–8550 Å	1200
SS73 80	2000 Mar. 25	3704 Å–8740 Å	600
	2001 Jun. 15	3250 Å–5660 Å	1200
SS73 83	2000 Mar. 25	3704 Å–8740 Å	900
	2001 Jun. 15	3250 Å–5660 Å	1320
SS73 116	1997 Jul. 20	3550 Å–7383 Å	1200
SS73 118	2000 Mar. 24	3661 Å–8840 Å	300
SS73 120	2000 Mar. 25	3704 Å–8740 Å	600
			60
SS73 125	2001 Jun. 09	3300 Å–8550 Å	120
	2001 Jun. 09	3300 Å–8550 Å	900
SS73 156	2001 Jun. 15	3250 Å–5660 Å	1200
	2001 Jun. 09	3300 Å–8550 Å	1200
SS73 158	2000 Mar. 25	3704 Å–8740 Å	600
SS73 170	1999 Jun. 20	3460 Å–7250 Å	900
	1999 Jun. 20	3460 Å–7250 Å	300
SS73 173	2001 Sep. 24	3400 Å–8560 Å	1800
SS73 175	1999 Jun. 20	3460 Å–7250 Å	300
			600
	2001 Jun. 14	2686 Å–6205 Å	720

light loss due to atmospheric refraction. Table 1 shows the log of observations. Column 1 lists the objects by their number in the SS73 survey. Column 2 gives the date of our observations, Col. 3 shows the wavelength coverage and the exposure time is given in the last column.

3. Discussion of the data

In the following subsections we present the spectra and comment on the nature of each observed object.

3.1. M-type stars

The spectra of the objects we propose to be M-type stars are shown in Figs. 1 and 2. Spectral type of the M stars identified in our sample were based on the TiO-index of O'Connel (1973) and is defined as

$$[\mathrm{TiO}] = -2.5\ \log\left(\frac{F_{6180}}{[F_{6100} + (F_{6370} - F_{6100})]\left(\frac{6180-6125}{6370-6125}\right)}\right)\cdot \quad (1)$$

Table 2 shows the [TiO]-index and the spectral type derived. Following the derivation of the [TiO] strength, the spectral type of the M stars were obtained through the

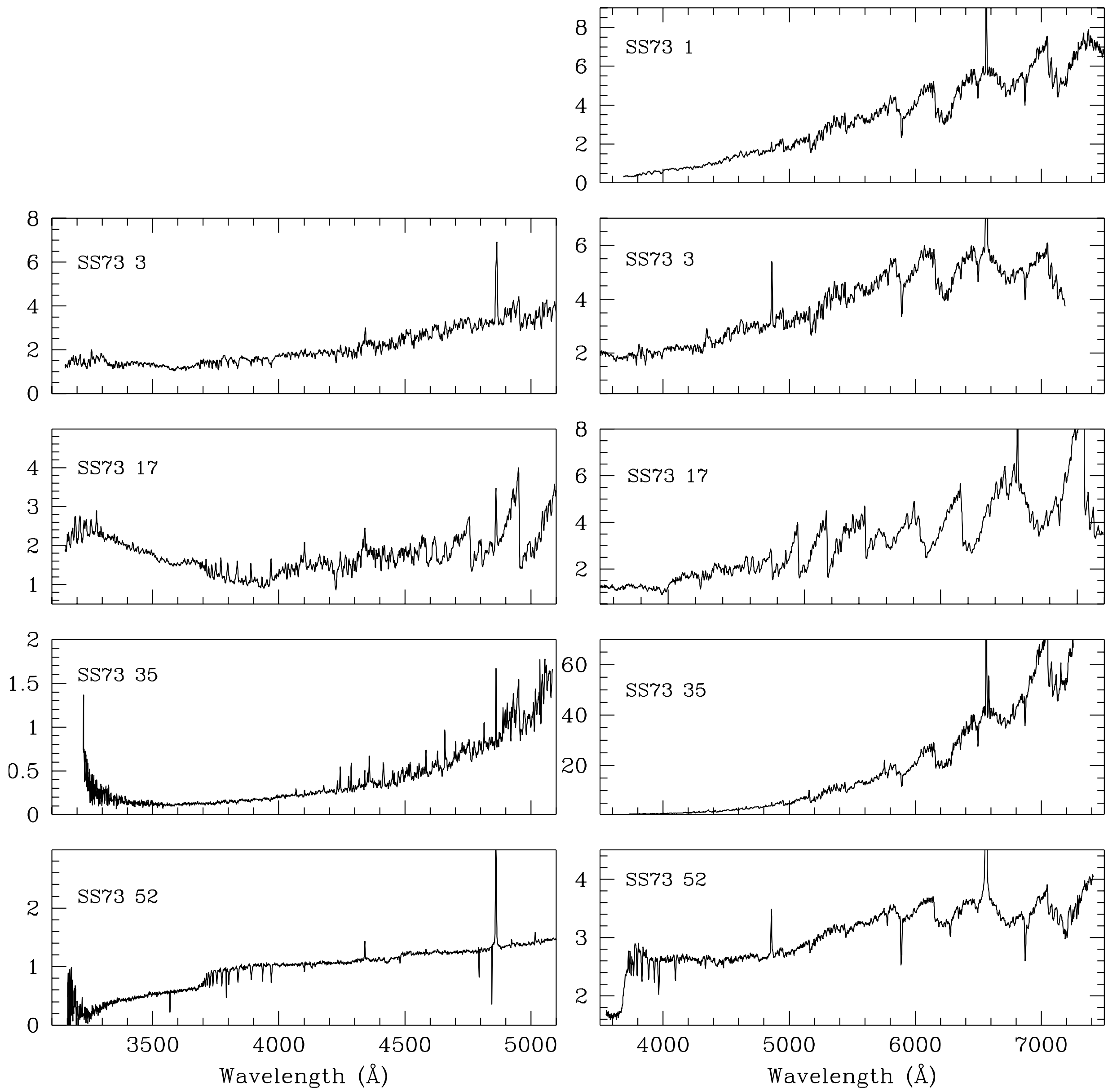

Fig. 1. Relative flux versus wavelength (Å) spectra of M-type stars SS 73 1, 3, 17, 35 and 52 identified in our sample, between 3100 Å and 5100 Å and between 3500 Å and 7500 Å.

relation between the index and spectral types of M giants and supergiants seen in Fig. 1 of Kenyon & Fernandez-Castro (1987). As a check we also compared our data on M stars and on T Tauri stars with spectra of several spectral classes available in the literature (such as Jacoby et al. 1984, hereafter JHC or Turnshek et al. 1985) and the Stellar Spectral Atlas available in Perry Berlind's homepage (`cfa-www.harvard.edu/~pberlind/atlas/atframes.html`, hereafter PB).

3.1.1. SS73 1 and SS73 3

SS73 3 = IRAS 07178-1925 = NSV 3539 = BD-19 1821

Both stars were suspected to present composite spectra of M- and OB-type stars by SS73. A78 has concluded that there was no indication of being OB star for SS73 1. This suspicion might have been because of some strong absorption features seen in the blue part of the spectrum which could be misinterpreted with the high levels of Balmer series at the low-dispersion spectrogram of SS73. We attribute those features at λ3826, λ3860 and λ3910 to absorption lines of neutral iron which are very strong in the solar spectrum. The sodium lines are very intense in both stars while the single ionized calcium line at λ4226 is moderately strong. Only Hα and Hβ can be seen in emission in SS73 1 while in SS73 3 Hγ is also present in emission. The TiO bands can easily be seen in our data. Comparing our spectrum with some displayed in JHC and Turnshek et al. (1985) the shape of the continuum looks very similar to a M supergiant. The spectra of SS73 1 and 3 are very similar to PB's observation of VV Cep (=HD 208816) (Fig. 2). SS73 3 was also observed at the spectral range 3175–5110 Å where Hδ can be seen in emission as a very weak line.

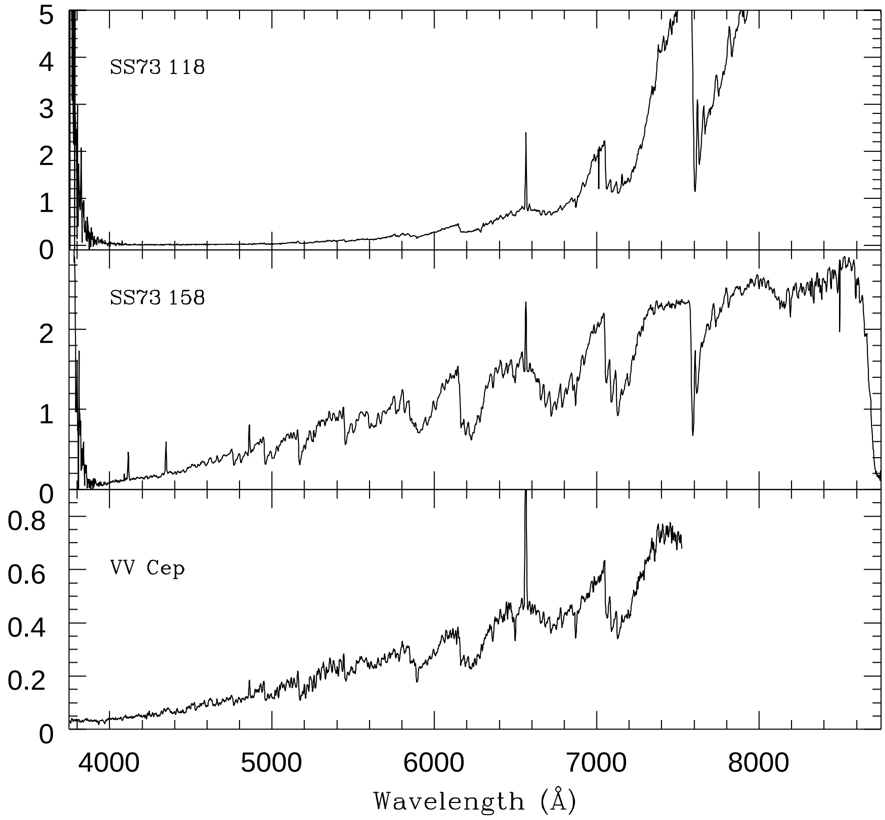

Fig. 2. Relative flux versus wavelength spectra of M-type stars SS 73 118 and 158 identified in our sample, between 3500 Å and 7500 Å. See also the spectrum of VV Cep (=HD 208816) used for comparison.

Table 2. TiO-index ([TiO]) and spectral (SpT) type of M-type emission-line stars identified in our sample.

	SS73 1	SS73 3	SS73 17	SS73 35	SS73 52	SS73 118	SS73 158
[TiO]	0.3	0.23	0.57	0.36	0.12	0.34	0.66
SpT	M1 I	M1 I	M4 III	M2 I	(M0-M1)I	(M2-M3)I	(M4-M5)III

3.1.2. SS73 17 and SS73 158

SS73 17 = Hen 3–380 and SS73 158 = V1862 Sgr are examples of Mira type stars. Their spectra are very similar to those presented in the JHC sample of M giants with several absorption bands of TiO. Henize (1976) describes SS73 17 as having Balmer lines in emission through H 10 as well as single ionized calcium in emission. Probably his observations were done during the object maximum phase where the lines reach the maximum strength. SS73 has classified SS73 17 as a M3ep+OB and SS73 158 as a M3ep. Our data of SS73 17 show it as a normal giant having Hα and Hβ in emission. The calcium H and K lines are in absorption as well as the neutral line at 4226 Å in both stars. In SS73 158, Hγ and Hδ are in emission.

3.1.3. SS73 35

SS73 35 = Hen 3–814 is also a M supergiant as can be judged by the appearance of the continuum. Like SS73 118 (see below), it also shows some degree of reddening. This object has been classified by SS73 as Mep+OB, by Henize (1976) as a peculiar emission-line star and by Bidelman (1954) as "binary of the VV Cephei type". Our data confirm Bidelman's (1954) earlier suspicion. Hα and [N II]6584 Å are seen in emission as well as the other emission line at λ5754 Å. In the spectral range 3100 Å–5100 Å several emission lines (mostly due to single ionized iron) are present. Hβ, Hγ and Hδ are also seen.

3.1.4. SS73 52

SS73 52 = MR 59 = Hen 3–1179 has been classified as a Wolf-Rayet star by Roberts (1962) and as a possible T Tauri star by Henize (1976). SS73 has classified it as M-star with emission line (Mep). In fact, our data shows TiO absorptions from 5000 Å over a continuum increasing towards the red. However there are also several other Balmer lines in absorption below 4000 Å. The red continuum of SS73 52 looks very similar to SS73 1 and SS73 3 which are M-supergiants. In the spectral range 3200–5500 Å the Balmer lines can be seen up to H 15 plus the calcium line at 3933 Å. The other calcium line at 3967 Å is blended with the Hε hydrogen line.

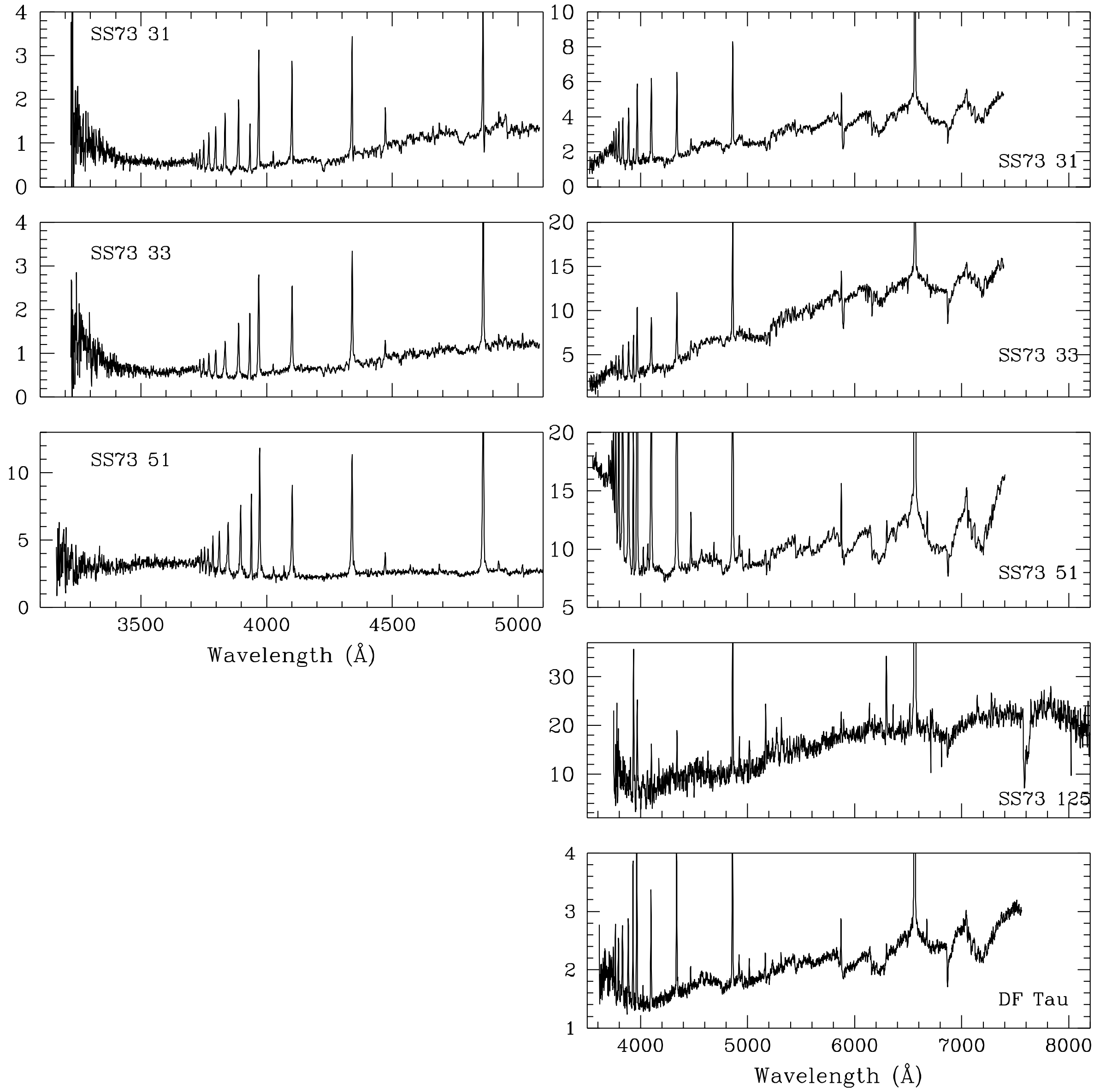

Fig. 3. Relative flux versus wavelength spectra of T Tauri stars SS 73 31, 33 and 51 between 3100 Å and 5100 Å and of SS73 31, 33, 51 and 125 between 3500 Å and 7500 Å identified in our sample. See also the spectrum of DF Tau used for comparison.

3.1.5. SS73 118

SS73 118 = Hen 3–1560 = Ve 4–64 = IRAS 17593–2325 = IRC-20418 was discovered as an infra-red source by Nuegebauer & Leighton (1969) during the Two-Micron Sky Survey. Later, Hansen & Blanco (1973) recognized that this star had a peculiar emission at 8600 Å. Grasdalen & Sneden (1979) and Lockwood (1985) classified it, respectively, as a M5 and M3ep. Using infra-red data from IRAS, Raharto (1991) recognized that SS73 118 has a large infra-red excess. He also classified SS73 118 as a M4 I. Our data confirm that SS73 118 is highly reddened. The continuum below 6000 Å is very extinguished. Hα is seen in emission and the feature in emission redward of Hα is probably [N II]λ5754 Å. Our spectrum reaches the wavelength ≃8730 Å. In this region we have detected the infra-red triplet of single ionized calcium at λ 8498, 8542 and 8662. No emission is seen in this region; it might probably be that since the continuum increases almost sharply towards the red, this region has been confused with an emission.

3.2. T Tauri stars

The spectra of the objects we propose to be T Tauri stars is shown in Fig. 3. Table 3 presents line emission identifications and their strengths relative to Hβ = 100 for the four T Tauri stars identified in our sample and the Herbig Ae/B[e] object. SS73 51 is recognized of being associated with a star-forming region. SS73 51 is present in Table 8 of Schwartz & Noah (1978) who list emission-line line stars in the dark-cloud complex in Lupus. The stars SS73 31 and 33, despite being close to each other in the sky, have no information or any clear evidence suggesting whether they are associated with any star-forming region. Their finding charts show these stars as field stars and not associated with any dark-cloud complex.

Table 3. Observed emission line fluxes relative to Hβ = 100 of T Tauri stars SS73 31 and 33, the Be stars SS73 6, 7, 12, 28, 34 and 39 and the peculiar Be stars SS73 2 and 24.

λ	Ion	SS73 2	SS73 6	SS73 7	SS73 12	SS73 16	SS73 24	SS73 28	SS73 31	SS73 33	SS73 34	SS73 39
3771	H 11	–	–	–	–	–	–	–	28.0	11.0	–	–
3798	H 10	–	–	–	–	–	–	–	33.3	16.0	–	–
3835	H 9	–	–	–	–	–	–	–	43.2	25.8	–	–
3889	H 8	–	–	–	–	–	–	–	49.4	31.8	–	–
	He I											
3933	Ca II	–	–	–	–	–	–	–	27.2	37.6	–	–
3967	Ca II	–	–	–	–	–	–	–	85.5	64.1	–	–
3968	Hϵ	10.7	–	7.7	–	–	–	–	–	–	–	–
4101	Hδ	20.7	–	33.7	12.2	–	11.2	15.0	91.3	52.4	–	–
4287	[Fe II]	–	–	–	–	–	–	4.4	–	–	–	–
4340	Hγ	46.9	23.0	53.0	24.9	–	26.1	26.1	97.1	62.0	–	–
4358	[Fe II]	–	–	–	–	–	–	10.1	–	–	–	–
4413	[Fe II]	–	–	–	–	–	–	10.0	–	–	–	–
4471	He I	–	–	–	–	–	–	–	15.5	6.2	–	–
4861	Hβ	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
4924	Fe II	8.8	–	15.4	2.6	26.7	15.5	–	–	–	–	–
5018	Fe II	12.6	–	19.7	6.0	34.0	19.7	–	–	–	–	–
5159	[Fe II]	–	–	–	–	–	–	8.9	–	–	–	–
5169	Fe II	8.4	5.7	18.7	5.0	49.8	21.2	6.9	–	–	–	–
5182	[Fe II]	–	–	–	–	–	–	–	–	–	–	–
5197	Fe II	–	–	–	–	23.3	13.4	–	–	–	–	–
5234	Fe II	–	–	–	–	31.4	16.0	–	–	–	–	–
5261	[Fe II]	–	–	–	–	–	–	3.5	–	–	–	–
5316	Fe II	7.1	–	15.4	7.4	41.6	23.0	–	–	–	–	–
5754	[N II]	–	–	–	–	–	–	8.9	–	–	–	33.7
5876	He I	–	4.8	–	11.6	–	4.2	–	21.0	13.8	–	–
5895	Na I	–	–	–	–	–	–	–	–	–	–	–
5957	Fe II	–	2.8	–	–	–	–	–	–	–	–	–
6300	[O I]	–	6.8	–	4.0	28.5	–	176.0	–	–	197.8	60.3
6317	Fe II	2.7	5.1	–	6.5	15.0	10.7	–	–	–	–	38.4
6363	[O I]	–	–	–	–	16.0	–	58.5	–	–	76.2	21.4
6385	Fe II	2.9	4.5	4.6	6.1	12.0	10.8	–	–	–	–	35.5
6432	Fe II	–	–	–	–	14.7	–	–	–	–	–	–
6457	Fe II	1.6	–	–	–	34.0	13.8	–	–	–	–	35.7
6516	Fe II	–	–	–	–	–	12.0	–	–	–	–	42.3
6563	Hα	sat	1587.2	420.7	1433.0	1996.0	sat	sat	428.5	558.5	3190.6	6363.6
6678	He I	–	4.1	–	5.3	–	–	–	9.6	6.7	–	–
7065	He I	–	–	–	4.6	–	–	–	–	–	–	–

sat: saturated line.

SS73 125 is present in Herbig's (1957) paper of emission-stars in the emission nebulae M 8. From that work its photographic magnitude was estimated as 16.5.

3.2.1. SS73 31 and SS73 33

SS73 31 = WRAY 15–813 and SS73 33 = WRAY 15–934 = Hen 3–748 = SPH 143 = IRAS 12024–6503. The spectra of SS73 31 and 33 look very similar to each other at the two dispersions used in this work. The Balmer lines are seen in emission over a continuum of late K-early M. Both stars were previously classified as Be! stars (=extreme Be-like objects, stars with emission lines of He I, Fe II and [Fe II]) by SS73. A78 noted a strong continuum with Balmer and Ca II emission. SS73 33 is also present in Schwartz's et al. (1990) list of emission-line stars as well in Henize's (1976) list. In both stars, the single ionized calcium is seen in emission. In the range of 3500 Å–7500 Å the spectra look very similar to the well known T Tauri star DF Tau (Fig. 3). The calcium absorption line at 4226 Å and TiO band at ≃4800 Å are clearly seen in the blue range. In SS73 31 Hβ, Hγ and Hδ show inverse P-Cygni profiles. The Balmer lines are seen up to H 13 in SS73 33 and up to H 16 in SS73 31.

3.2.2. SS73 51

SS73 51 = HBC 624 = SZ 134 = Hen 3–1146 = WRAY 15–1423. This object was classified as Mep? by SS73. A78 noticed a weak TiO absorption with Balmer, Ca II and [O II] in emission. Henize (1976) classified it as a probable T Tauri object.

Table 3. continued. Observed emission line fluxes relative to Hβ = 100 of T Tauri star SS73 51 and 125, the Herbig object SS73 44, the Be stars SS73 62, 80, 83 and 170 and the peculiar Be stars SS73 67, 156 and 175.

λ	Ion	SS73 44	SS73 51	SS73 62	SS73 67	SS73 80	SS73 83	SS73 125	SS73 156	SS73 170	SS73 175
3771	H 11	–	18.1	–	–	–	–	–	–	–	–
3798	H 10	–	25.8	–	–	–	–	–	–	–	–
3835	H 9	–	33.6	–	–	–	–	–	–	–	–
3889	H 8	–	41.8	–	–	–	–	–	–	–	9.4
	He I										
3933	Ca II	95.1	26.7	–	–	–	–	75.3	–	–	–
3967	Ca II	–	91.2	–	–	–	–	58.0	–	–	–
3968	Hϵ	–	–	–	–	–	–	–	–	–	5.6
4101	Hδ	9.3	81.8	–	7.0	14.0	10.0	29.6	–	5.2	20.3
4244	[Fe II]	–	–	–	–	–	–	–	36.2	–	–
4276	[Fe II]	–	–	–	–	–	–	–	24.4	–	–
4287	[Fe II]	–	–	–	–	–	–	–	48.8	–	–
4358	[Fe II]	–	–	–	–	–	–	–	67.6	–	–
4414	[Fe II]	–	–	–	–	–	–	–	66.2	–	–
4340	Hγ	21.6	89.8	–	23.8	24.5	21.0	36.1	16.7	14.4	33.8
4471	He I	–	10.5	–	–	–	–	–	–	–	–
4861	Hβ	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
4905	[Fe II]	–	–	–	–	–	–	–	34.7	–	–
4924	Fe II	49.6	–	–	13.0	5.8	13.0	22.0	39.1	8.0	8.2
4950	[Fe II]	–	–	–	–	–	–	–	32.0	–	–
5018	Fe II	47.7	–	–	23.7	12.4	22.0	28.3	74.4	14.5	11.8
5159	[Fe II]	–	–	–	–	–	–	–	137.4	–	5.3
5169	Fe II	144.6	–	–	26.2	13.2	21.6	41.9	95.0	17.0	–
5182	[Fe II]	59.0	–	–	–	–	–	–	25.3	–	–
5198	Fe II	–	–	–	–	–	–	–	24.5	9.3	5.5
5220	[Fe II]	–	–	–	–	–	–	–	27.2	–	–
5234	Fe II	59.0	–	–	11.7	7.9	10.8	–	26.0	5.4	6.3
5261	[Fe II]	–	–	–	–	–	–	–	105.0	–	–
5272	[Fe II]	–	–	–	–	–	–	–	122.0	–	5.2
5316	Fe II	79.3	–	–	30.6	15.0	24.5	–	44.0	14.7	7.2
5754	[N II]	–	–	–	17.3	–	–	–	–	–	–
5876	He I	65.3	10.4	–	–	–	–	–	–	10.9	–
5895	Na I	55.4	–	–	–	–	7.8	–	–	–	–
5957	Fe II	–	–	–	8.0	–	7.8	–	–	–	–
6300	[O I]	25.3	6.6	45.2	90.0	32.6	22.0	46.2	100.0	24.0	–
6317	Fe II	–	–	–	24.3	10.5	22.0	–	53.2	14.7	–
6363	[O I]	–	–	13.9	36,7	–	–	–	83.5	–	–
6383	Fe II	–	–	–	15.0	9.7	20.2	–	43.5	14.7	–
6432	Fe II	25.4	–	–	–	10.6	–	–	–	–	–
6457	Fe II	41.3	–	–	14.5	10.0	16.0	–	31.4	9.1	–
6515	Fe II	38.2	–	–	–	–	–	–	66.2	–	–
6563	Hα	1440.0	371.7	2188.0	3333.0	sat	sat	897.6	5294.1	3900.0	sat
6584	[N II]	–	–	–	93.3	–	–	–	–	–	–
6678	He I	36.6	6.6	–	–	–	–	–	–	–	–

sat: saturated line.

A short description of the spectrum is given by Schwartz & Noah (1978), which noted Hα, He I 5876, 6678 Å and [O I] in emission. Its continuum spectrum is very similar to the two T Tauri stars mentioned above. Balmer lines, helium lines and the H and K lines of single ionized calcium are in emission. In the blue range, Balmer lines are seen up to H 16. He II at 4686 Å is seen in emission, a feature not usually seen in T Tauri spectra. In addition, the sulfur forbidden lines at $\lambda\lambda$4068, 4076 are also present in SS73 51.

3.2.3. SS73 125

SS73 125 = LkHA 117 = CSI–24–18026. This is the faintest object of our sample and it was only observed with the lowest dispersion. It was classified by SS73 as "Very-Steep-Balmer-Decrement-Object", (X symbol in Col. 7 of their paper). In fact our data show that Hα/Hβ ratio is $\simeq$10.0. SS73 125 is probably a T Tauri object as can be judged by the shape of the continuum, mid K-type star. Besides the hydrogen recombination lines that are present in the spectrum, the calcium H and K lines are also in emission.

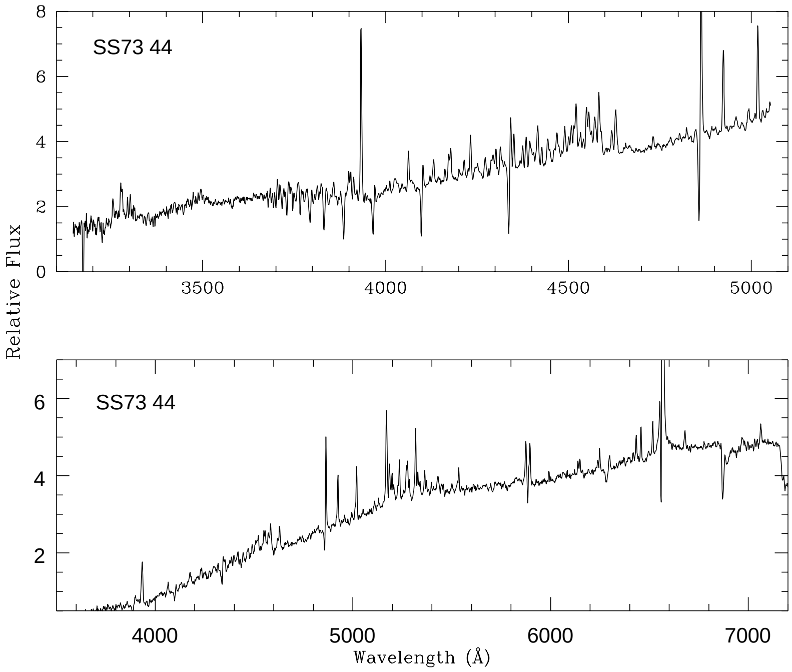

Fig. 4. Relative flux versus wavelentgh of the spectra of the Herbig Ae/B[e] star SS 73 44 discussed in this work.

3.3. Herbig Ae/B[e] star

3.3.1. SS73 44

SS73 44 = HBC 596 = IRAS 14592–6311 = VdBH 65b. This is the only Herbig Ae/B[e] object analyzed in this work. Figure 4 shows the spectra in the two spectral range. Classified by SS73 as Z^- (probably symbiotic with He II4686 < Hβ), by A78 as a P-Cygni Be star with Fe II, Ca II and He I in emission and by The et al. (1994) (hereafter T94) as Beq. Its nature as a young stellar object was later assigned after several studies of van den Bergh & Herbst (1975), Gahm & Malmort (1980), Ray & Eislöffel (1994) and Henning et al. (1994). Our data show SS74 44 with a reddened continuum with Balmer lines, He I, Fe II and Na I in emission. In the blue range, Balmer lines exhibit P-Cygni profiles. Line intensities for some emission lines were estimated by Gahm & Malmort (1980) and our data agree with their evaluation.

3.4. Be stars

Although many stars discussed in the following subsections have already been suggested to be Be stars in the past, there have been no good spectra available in the literature. The term Be star has been used in the past to address a very heterogeneous class of objects, i.e. B-type stars with emission lines. Nowadays a classical Be star is clearly defined as a non-supergiant, spectral class B star, which presents (or has already presented) emission permitted lines. In general the emission is restricted to the first terms of the Balmer series (and perhaps a few Fe II lines), and the objects shows a substantial reddening. On the other hand, B[e] stars are characterized by forbidden emission lines. Again, this term is quite general and includes objects in different evolutionary stages. Recently it was proposed to call them "stars with the B[e] phenomenon", rather than B[e] stars (L98). Among them there are the B[e] supergiants (believed to be evolved objects with high initial masses), Herbig Ae/B[e] stars (pre main sequence) and compact planetary-nebulae or post-AGB stars.

We will not make any attempt to assign a precise classification to any of the stars in this subsection. Mostly because their distances are unknown, which means that their luminosity are also unknown, their evolutionary status remains unclear. In some cases, they can be classified as post-AGB stars or supergiant B[e] stars or can also belong to Table 5 of unclassified B[e] stars of L98. On the other hand, some Be stars of our sample have been separated by us according to the excitation degree, as indicated by the presence of numerous and stronger iron lines. These stars are discussed in the Sect. 3.5 and were tentatively classified as "Be Peculiar stars". The remaining stars were classified as Be stars either to the shape of the continuum (increasing towards to the blue, SS73 6, and 28) and/or presence of some iron lines (all of stars in this section) and finally due to presence of the oxygen forbidden line [O I] at 6300 Å (Zickgraf 1989).

Before discussing the nature of the stars in the following subsections we first derive the amount of reddening. In order to have an estimate of the amount of the reddening we adopted three procedures according to the star. In first one we used the observed equivalent widths of the λλ 5780,5797 diffuse bands using Herbig's (1975) data to relate line intensity to reddening. In the other procedure we compared the observed data with spectra of main sequence, giant and supergiant B-stars reddened by some amount. For the second procedure we first reddened the spectrum of the B-star and later normalized both the spectra of some stars from the SS73 sample and a reddened B-star. We were only interested to see how the shape of the continuum changes, for given spectral type, according to degree of

Table 4. Equivalent widths of the observed diffuse bands and the value of the reddening.

Object	$W_\lambda(5780)$ (Å)	$W_\lambda(5797)$ (Å)	$E(B-V)^1$	$E(B-V)^1$	$E(B-V)^2$	$E(B-V)^3$	$E(B-V)^4$	$E(B-V)^5$	Ref;[6]
SS73 2	0.36	0.13	0.55	0.43	–	0.24	0.38	–	–
SS73 6	–	–	–	–	–	–	1.12	1.46	C92
SS73 7	–	–	–	–	–	0.09	0.09	–	–
SS73 12	0.78	0.28	1.16	0.91	–	1.25	1.14	–	–
SS73 24	0.55	–	0.81	–	–	1.00	0.90		
SS73 16	–	0.43	–	1.38	–	–	1.38	–	–
SS73 34	0.82	0.49	1.22	1.58	–	–	1.4	0.97	H75
								0.82	GM80
SS73 39	1.58	–	2.34	–	–	–	2.34	1.81	C01
SS73 41	1.55	0.56	2.30	1.81	3.0	–	2.53	–	–
SS73 62	1.07	0.31	1.60	1.01	–	–	1.3	–	–
SS73 63	0.42	0.14	0.63	0.46	–	–	0.55	–	–
SS73 80	1.01	0.57	1.50	1.84	–	1.60	1.64	1.5	C01
SS73 83	1.02	0.37	1.50	1.2	–	–	1.35	–	–
SS73 116	0.73	0.29	1.08	0.94	–	–	1.01	–	–
SS73 120	1.47	0.61	2.18	1.97	2.8	–	2.44	–	–
SS73 170	0.9	0.37	1.34	1.22	–	–	1.28	–	–
SS73 173	0.7	0.63:	1.04	2.00:	2.3	–	1.76	–	–
SS73 175	–	–	–	–	–	0.53	0.53	–	–

[1] Diffuse bands.
[2] Reddened B-star.
[3] Balmer decrement.
[4] Adopted.
[5] Previous determinations.
[6] C92: Cahn et al. (1992) H75: Herbst (1975);C01: Cidale et al. (2001); Gahm & Malmort (1980).

the reddening. As template B-stars, we used some stars from the library of JHC. In the third method we used the Balmer decrement. For this we used the line ratios of Hβ/Hγ, Hα/Hβ and Hβ/Hδ.

Table 4 gives the measured equivalent widths of the diffuse bands used for reddening determination, the $E(B-V)$ value which results from the three methods and any previous reddening determinations.

In two stars of the Sect. 3.4.1 it was not possible to derive the reddening using a B reddened star. For SS73 63 and 116 the shape of their continuum seems to be affected by a non-standard extinction law. Figure 6 shows the normalized observed spectra as well as the best fit of B-type reddened spectrum. These five stars are those that mostly resemble classical Be stars, since they only present Hα (and sometimes Hβ) emission lines and their continua can be fitted by a reddened B-type star. However, comparing the spectra of the stars SS73 41, 63, 120 and 173 with SS73 22 (Fig. 5), a proto-planetary nebulae with a strong OH maser emission (Sahai et al. 1999; Allen et al. 1980), we see that they all look similar. In this case, we cannot exclude the possibility that the reddened SS73's stars analyzed in Sect. 3.4.1 may be proto-planetary candidates. Their spectra would be a result of a reflection nebulae illuminated by a hidden star.

For the other Be stars or peculiar Be stars we used either the diffuse bands above mentioned and/or the Balmer decrement. In SS73 6, 12, 80 and 83 we first corrected the observed line intensities for the underlying stellar absorption using the procedure described in Pereira (2000).

For SS73 28, 67 and 156 we could not measure the diffuse bands. Moreover the Hβ and Hγ lines in these three stars are too weak, probably affected by strong reddening, to be used for reddening determinations; their line ratios fall out of the Netzer (1975) reddening diagram. In fact, Rudy et al. (1992), using Paschen lines, derived a lower limit of 3.0 for the color excess for SS73 156.

Table 3 presents the line intensities of some emission-lines of the stars discussed in Sects. 3.4 and 3.5.

3.4.1. SS73 41, 63, 116, 120 and 173

The stars discussed in this subsection have a continnum increasing towards the red as a result of some degree of interstellar and/or circumstellar reddening. The spectra of SS73 41, 63, 116, 120 and 173 stars are shown in Fig. 5. SS73 41, 63, 120 and 173 were at least once classified as M stars. SS73 116 also shows some degree of reddening but differs from the others due to the shape of the blue continuum. Below we briefly discuss the available information in the literature.

(i) SS73 41 = WRAY 15–1119 = THA 17–48 = [W74] 67: This star was classified as a very "Very-Steep-Balmer-Decrement-Object" by SS73, Be star with a steep Balmer decrement by A78 and M7 by The (1962). It is also present in Henize's (1976) and in Weaver's (1974) list of emission-line stars.

(ii) SS73 63 = WRAY 16–232 = VRMF 115 = Hen 2–179 = PK 339+00 2 = IRAS 16396–4555: Webster (1966) rejected it as a planetary nebula, by Henize (1967) as doubtful

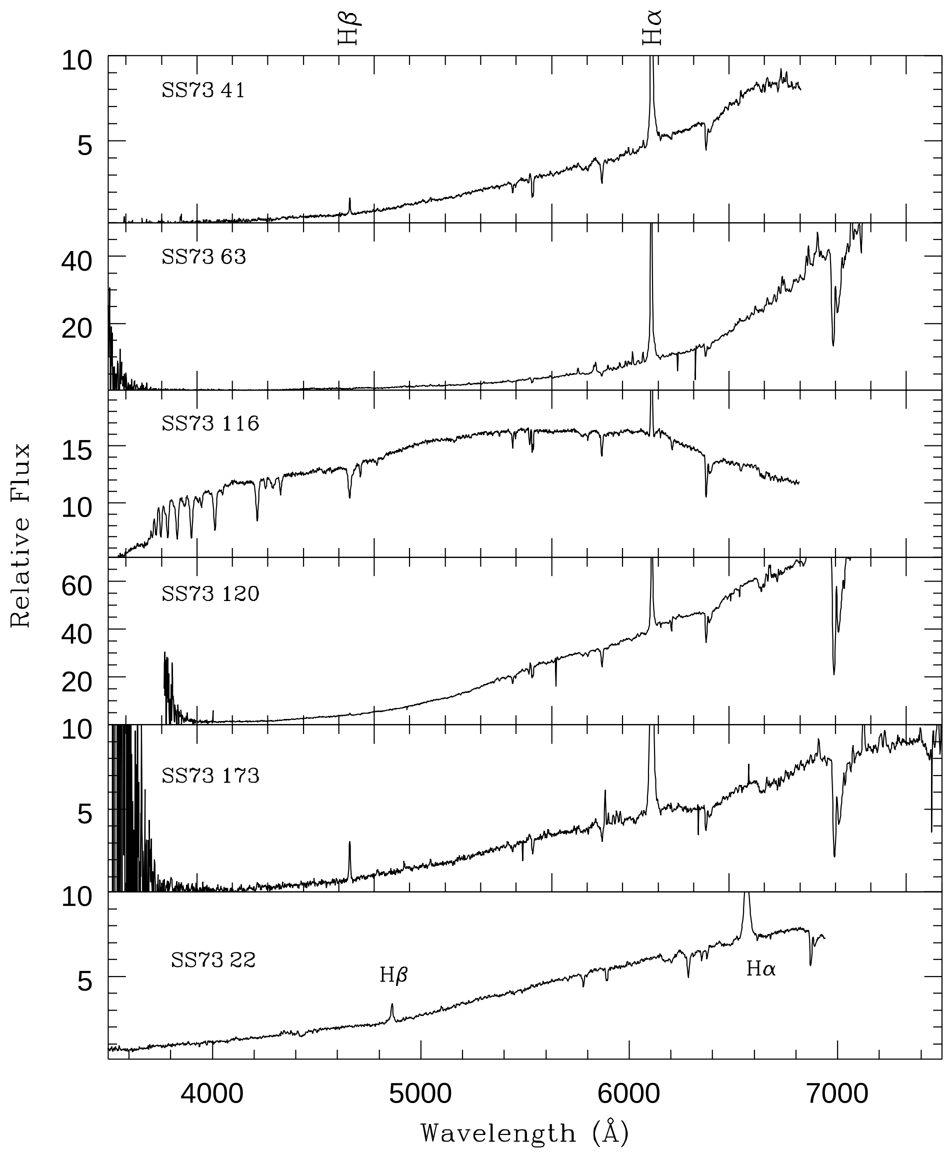

Fig. 5. Relative flux versus wavelength spectra of the reddened Be stars SS73 41, 63, 116, 120 and 173 identified in our sample, between 3500 Å and 7500 Å. It is also shown the spectrum of SS73 22 for comparison.

planetary nebulae, by SS73 as a "Very-Steep-Balmer-Decrement-Object", by Allen et al. (1982) as a highly obscured Be star, by MacConnel (1983) as M supergiant, by Acker et al. (1987) and rejected as a planetary nebula by Stenholm & Acker (1987) and by Acker et al. (1992) as a peculiar emission-line star.

(iii) SS73 116 = Hen 2–325 = PK 003–01 1: It is also a Be reddened star, however, it differs from the other four above because of the presence of a blue continuum. It was classified as a probably planetary nebula by Henize (1967), Mep?+B by SS73 and rejected as a planetary nebula by Acker et al. (1987) and Stenholm & Acker (1987). Our data show a continuum that increases toward the red with several Balmer and helium absorption lines. In addition, the diffuse bands centered at 4430 Å and 6284 Å can also be observed.

(iv) SS73 120: Classified by SS73 as Mep? and by A78 as a reddened Be star.

(v) SS73 173 = AS 319 = IRAS 18406–0508: Classified by SS73 as "Very-Steep-Balmer-Decrement-Object" and by A78 as a probably reddened Be star.

The spectra of SS73 16, 28, 34, 39, 62, 170, 6, 7, 12, 80, and 83, between 3500 Å and 7500 Å and between 3100 Å and 5100 Å are shown in Figs. 7 and 8.

3.4.2. SS73 6

SS73 6 = PN M 1–15 = PK 234–00 1. It was classified by SS73 as a Be star and rejected as a planetary nebula by Acker et al. (1987). Shaw & Kaler (1989) suspected that this could be a symbiotic star. These authors measured line intensities of He II 4686 Å [O III]5007 Å and [N II]5754 Å which were not observed by us. Our spectra show Balmer, Fe II and weak He I 5876 in emission over a blue continuum. The continuum distribution looks similar to some Be stars investigated in Pereira et al. (2001). In the range 3100 Å–5100 Å the Hβ, Hγ

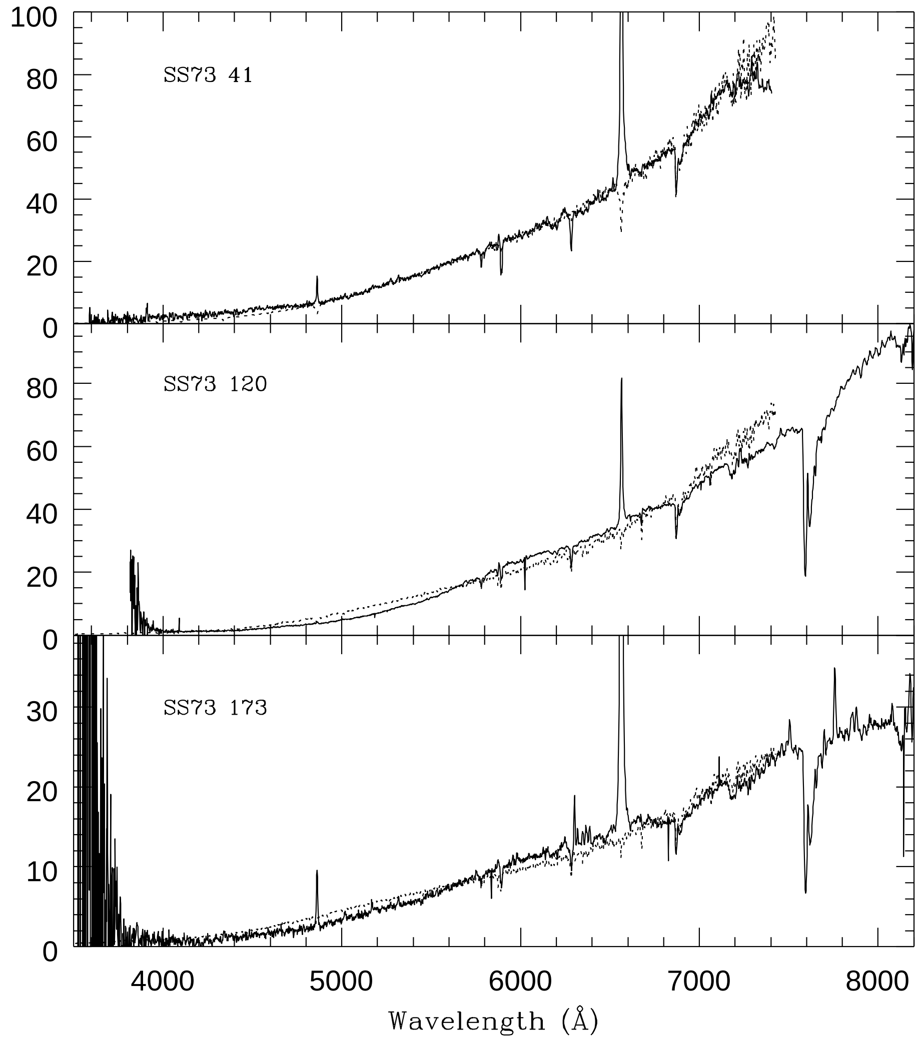

Fig. 6. Normalized spectra of the observed reddened Be stars SS73 41, 120 and 173 (solid lines) and reddened B-stars (dotted lines).

and Hδ lines are seen as emissions over absorptions of the same transitions. In addition neutral helium lines at 4026 Å, 4387 Å and 4471 Å are in absorption. A finding chart of SS73 6 is presented in Fig. 9, where we can easily see a nebulae around the central object.

3.4.3. SS73 7

Classified by SS73 as Be! and by A78 as a Be object having numerous Fe II lines. SS73 7 exhibits some degree of reddening. Its continuum looks similar to SS73 12 (Sect. 3.4.4). The spectrum presents Balmer lines in emission as well as some Fe II lines.

3.4.4. SS73 12

SS73 12 = WRAY 15–310 = PK 266–00 1. It was classified by SS73 as a Be! and T94 as a Be. In the range 3500 Å–7500 Å the continuum slightly increases to the red, with Balmer and Fe II lines in emission. The spectrum looks similar to the post-AGB object Hen 3–1475 (Riera et al. 1995). At higher resolution in the blue we can see Balmer lines in emission over the absorptions. Also, neutral helium lines at 3820 Å 4009 Å 4026 Å 4144 Å 4387 Å and 4471 Å are in absorption.

3.4.5. SS73 16

SS73 16 = WRAY 15–507 = PDS 37 = Hen 3–373 = IRAS 10082–5647. Classified by SS73 as a Be!, by Henize (1976) as a B-type, by Allen & Swings (1976) as a typical Be (grouped in their Group 1), by Gregorio-Hetem et al. (1992) as a probable Herbig Ae/B[e] star and by T94 as Bep. Our data show SS73 16 as a reddened Be star with Balmer and weak Fe II lines in emission.

3.4.6. SS73 28

SS73 28 = Hen 2–61 = Hen 3–573 = PK 288+05 1. Classified by Henize (1976) as a probable planetary nebula, by SS73 as a "Very-Steep-Balmer-Decrement" and rejected as a planetary nebula by Acker et al. (1987). A78 noticed a strong emission of [O I], as well as other Balmer and single ionized iron in emission. SS73 28 is present in two other catalogues however with no definitive classification (Henize 1967; Acker et al. 1992).

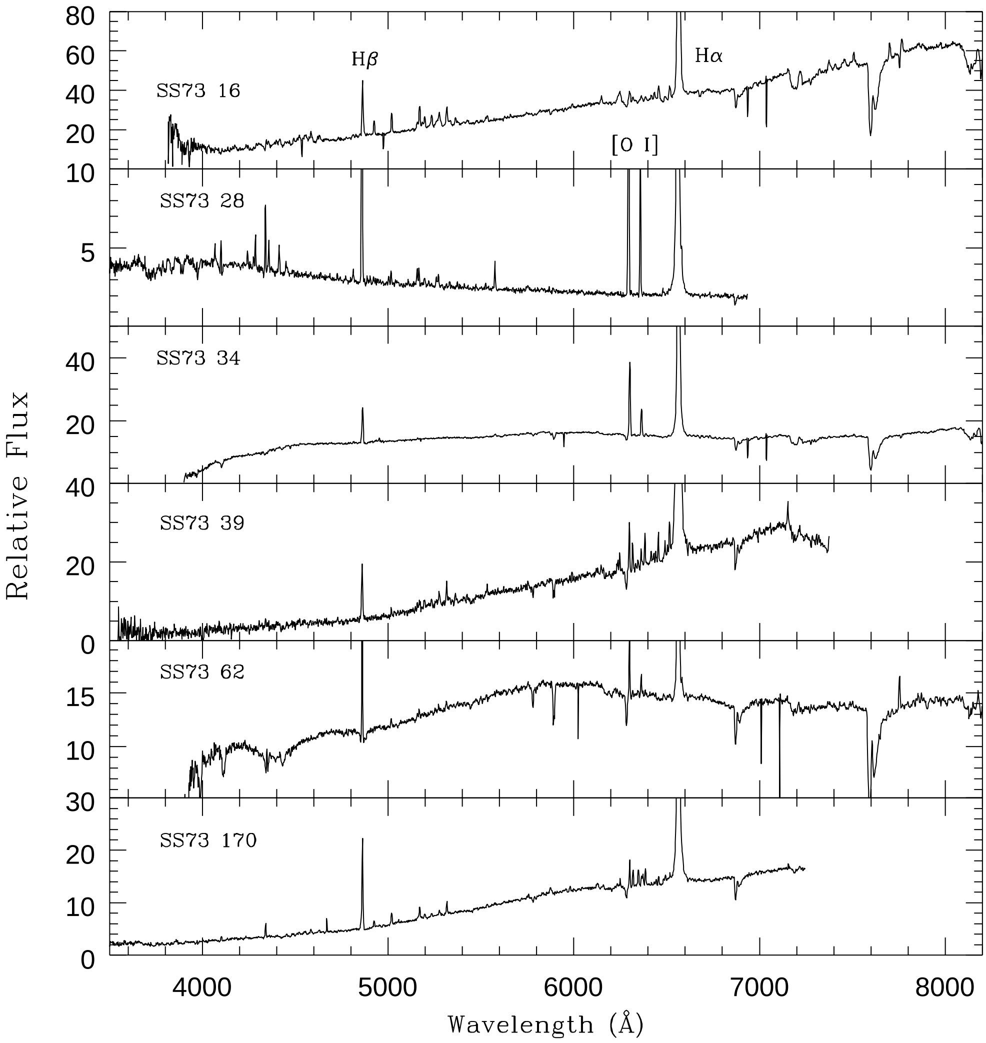

Fig. 7. Relative flux versus wavelength spectra of Be stars SS73 16, 28, 34, 39, 62 and 170 identified in our sample, between 3500 Å and 7500 Å.

Our data show Balmer, weak Fe II and strong [O I] in emission, as already noticed by A78. The continuum shows the presence of a hot star. In the blue range, Balmer lines are in emission and in absorption indicating the presence of an ionized nebula.

3.4.7. SS73 34 and SS73 62

SS73 34 = WRAY 16–110 = Hen 2–80 = VdBH 57a = [GM76] 5 = PK 299–00 1 and SS73 62 = WRAY 15–1520 = Hen 2–174 = Hen 3–1227 = SPH 151 = PK 338+01 1 = IRAS 16348–4517. Our data, for both stars, show a continuum of a reddened Be star with Hα, Hβ and [O I] in emission. Hγ and Hδ are in absorption. In SS73 62, Hγ is in emission. SS73 34 and 62 were observed in several other surveys in the past. They were both classified as a probable planetary nebula by Webster (1966) and Henize (1967), peculiar Be star (SS73 34) and a star with only Hα, Hβ and [O I] emission (SS73 62) by Swings (1973). SS73 34 was classified as a dusty planetary nebula by Allen (1973) and Allen & Glass (1974), "Very-Steep-Balmer-Decrement" by SS73, peculiar Be star by Allen & Swings (1976), B star with forbidden line emission by Allen et al. (1982) and rejected as a planetary nebula by Stenholm & Acker (1987) and by Acker et al. (1987). In addition, SS73 34 is present in the list of emission-line objects of van den Bergh & Herbst (1975), Gomez & Mendoza (1976) and T94 and in a study of Moreno et al. (1987) where the spectrum presents a flat continuum with emission lines of Hα, Hβ and [O I]. Gahm & Malmort (1980) in a study of southern dust clouds also observed SS73 34. They derived a spectral type of B8Ie and a color excess of 0.82 based on *U*, *B*, *V* photometry. They also concluded that SS73 34 is not a member of Centaurus association. Early determinations of color excess were given by Herbst (1975), who derived a color excess of 0.97. SS73 62 was classified as Be! by SS73, as a typical Be star by Allen & Swings (1976) and rejected as a planetary nebula by Stenholm & Acker (1987) and by Acker et al. (1987).

3.4.8. SS73 39

SS73 39 = WRAY 16–126 = Hen 2–91 = [W74] 44 = PK 305–00 1 = IRAS 13068–6255. Classified by Webster (1966) and Henize (1967) as a possible planetary nebula, by Allen (1973)

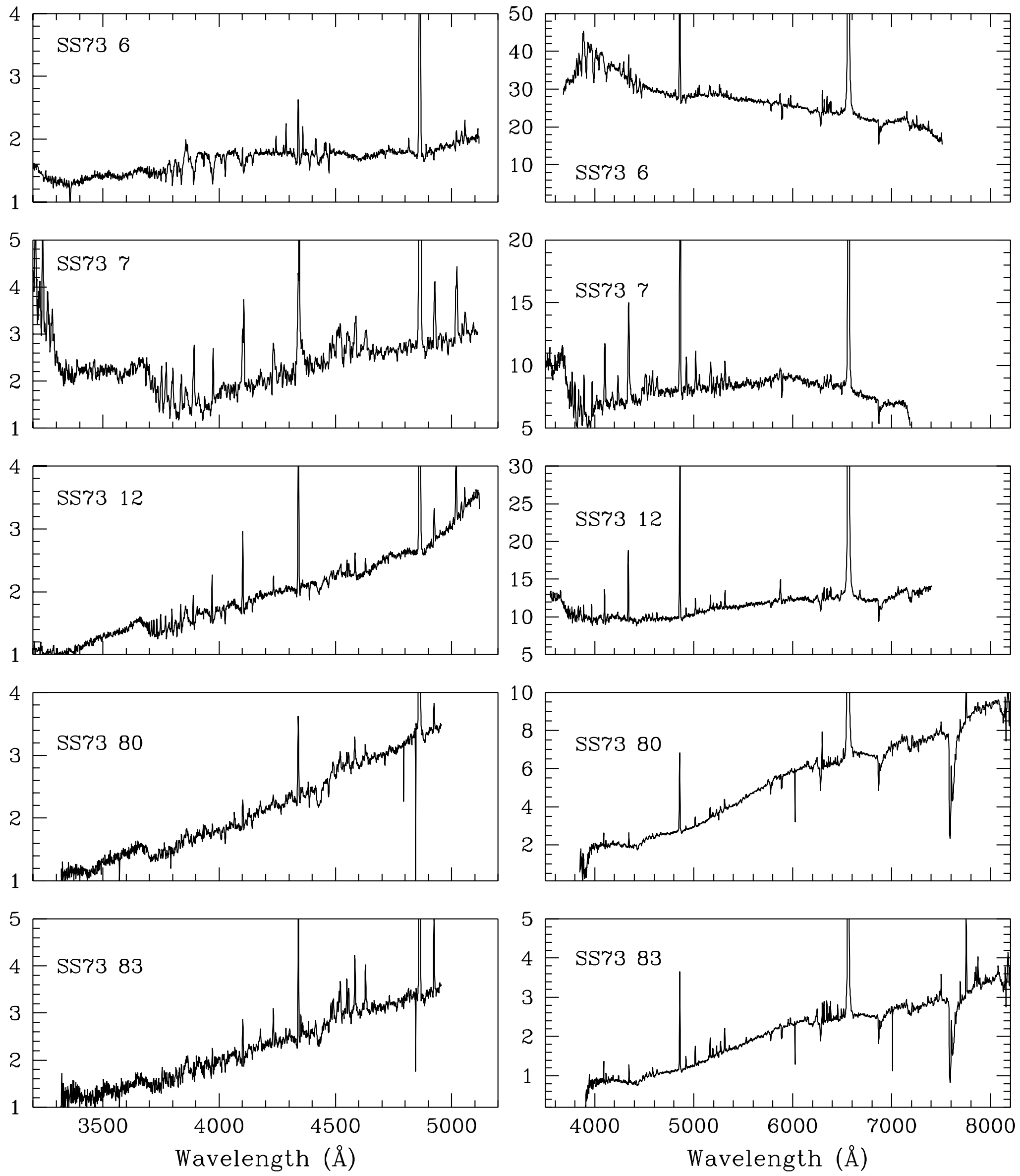

Fig. 8. Relative flux versus wavelength spectra of Be stars SS73 6, 7, 12, 80 and 83 identified in our sample, between 3500 Å and 7500 Å and between 3100 Å and 5100 Å.

as a planetary nebula, by SS73 as a "Very-Steep-Balmer-Decrement", by Allen et al. (1982) as a B star with forbidden emission line, by MacConnel (1983) as a M star with emission and rejected as a planetary nebula by Moreno et al. (1987), Stenholm & Acker (1987) and Acker et al. (1987) and by T94 as B[e]. It is also present in the emission-line list of The (1962) and Weaver (1974). Allen & Swings (1976) classified it as a peculiar Be star. This star is present in Table 5 of L98 of stars classified as B[e]. Our data show SS73 39 as a reddened Be star with Hα, Hβ, weak iron and [O I] in emission.

3.4.9. SS73 80 and SS73 83

SS73 80 = WRAY 15–1646 = AS 222 = Hen 3–1356 and SS73 83 = WRAY 15–1684 = AS 225 = Hen 3–1386 = IRAS 17175–3757. Their spectra look very similar to each other. Classified by SS73 as Be! (SS73 80) and "Very-Steep-Balmer-Decrement" (SS73 83). Both stars have been classified by Allen & Swings (1976) as typical Be stars and by T94 as Be. Our spectra, in both spectral ranges, show SS73 80 and 83 as reddened Be stars, with Balmer, Fe II and weak [O I] in emission. The spectrum of SS73 80 between 3600 Å and 5200 Å is shown in Cidale et al. (2001), and presented the same characteristics as ours.

3.4.10. SS73 170

SS73 170 = HBC 285 = LkHA 358. Classified by SS73 as a "Very-Steep-Balmer-Decrement", and by T94 as B[e]. It has been classified as a Herbig Ae/B[e] star by Hamman & Persson (1992) and as an unclassified B[e] star by L98. Our data shows that SS73 170 is similar to other Be stars studied in this work, such as SS73 12, 16, 39, 80 and 83.

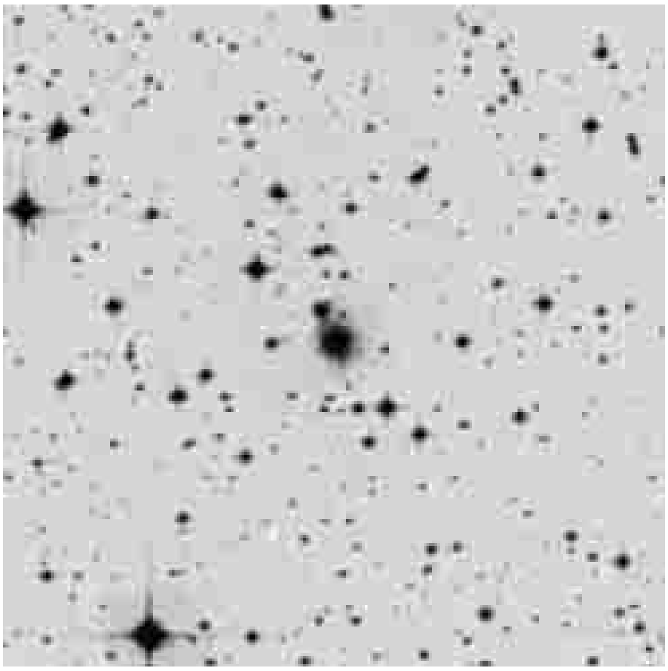

Fig. 9. Finding chart of SS73 6 showing a nebula around the object.

3.5. Peculiar Be stars

The spectra of SS73 2, 175, 24, 67 and 156 between 3500 Å and 7500 Å and between 3100 Å and 5100 Å are shown in Fig. 10.

3.5.1. SS73 2 and 175

Given the similarities of the spectra of these two stars they will be discussed together. SS73 2 = MWC 553 and SS73 175 = WRAY 15–1882 = Hen 3–1728 = AS 325 = CD–26 13521. Both were classified by Merril & Burwell (1943) as Be, by SS73 as Be! and by A78 as a Be star with strong Balmer and weak Fe II emission. Our data show Balmer lines in emission as well as several Fe II lines over a continuum increasing to the blue. At higher resolution in the blue range we can see that Balmer and some Fe II lines present P-Cygni profiles. The K-line of the Ca II appears stronger than the H-line as a result of being partly contaminated by the emission line $H\epsilon$.

Much of what has been said about SS73 2 could also be said about SS73 175, except for the absence of P-Cygni profiles in the later one. Both SS73 2 and 175 have the same shape of the continuum. Classified by SS73 as a "Fe pec" and by T94 as an Ae/Fe. The spectrum at intermediate resolution is discussed in Bopp & Howell (1989). Although the authors suggest that SS73 175 (AS 325) could be another iron star, similar to Merril's (1951) iron star XX Oph, our spectroscopic data do not seem to indicate this. Comparing our data with XX Oph in Blair et al. (1983) and in de Winter & The (1990) we are able to see that what they have in common is just some iron lines and the Balmer lines in emission. The continuum distribution is different in the two stars in SS73 175 we see the continuum increasing towards the blue while it is just the opposite in XX Oph.

3.5.2. SS73 24

SS73 24 = WRAY 15–642 = Hen 3–485. Classified by SS73 as a Be! pec, by Henize (1976) as B-type and by T94 as a Bep. A78 noticed Balmer lines, several Fe II and [Fe II] lines in emission and also lines of higher excitation such as [O III] and [Ar III]. Allen & Swings (1976) grouped SS73 24 among the typical Be stars. The spectrum of SS73 24 presents a flat continuum with Balmer and some iron lines in emission, which is similar to Hen 401 a proto-planetary nebulae (García-Lario et al. 1999). We did not detect [O III] or [Ar III]. In the blue range, we see the higher levels of Balmer series with P-Cygni profiles, in addition, the Balmer continuum is in emission.

3.5.3. SS73 67

SS73 67 = WRAY 15–1552 = Hen 2–183 = PK 341–00 1. Classified by SS73 as "Very-Steep-Balmer-Decrement", by Henize (1967) as probably planetary and by Webster (1975) as Be. It was rejected as a planetary nebula by Stenholm & Acker (1987) and by Acker et al. (1987). Its spectrum is similar to the probable LBV or post-AGB candidate object SS73 11 (Landaberry et al. 2001), i.e., it is flat with some single ionized iron as well as Balmer lines in emission; however the degree of excitation seems lower and the number of lines is smaller than in SS73 11. [O I] is strong which suggests that this object could be a supergiant B[e], rather than a LBV object (Landaberry et al. 2001).

3.5.4. SS73 156

SS73 156 = MWC 922 = Hen 3–1680 = IRAS 18184–1302. Classified by SS73 as a "Very-Steep-Balmer-Decrement", by Henize (1976) as a peculiar Be star, by T94 as B[e] and as an unclassified B[e] star by L98. Its spectrum is briefly discussed in Allen & Swings (1976) and belongs to a group of peculiar Be stars with infrared excess. Most of the observations up to now of SS73 156 were done in the infrared (Rudy et al. 1992; Meixner et al. 1999 and Cohen et al. 1989, just to name a few) and there is no published blue-optical spectrum of this object. Our data show SS73 156 as a very reddened object with $H\alpha$, $H\beta$ and several Fe II lines in emission. In addition, [O I] is weak in emission as well as [N II] 6584 Å. There is no evidence of [N II]5754 Å. The He I and Na I lines are in absorption. In the blue region, the spectrum is also dominated by several emission lines of single ionized iron. Its evolutionary status is not yet clear; it might be a post-AGB object or a supergiant B[e] star.

4. Summary

As part of a spectroscopic survey of emission-line objects in the Southern Hemisphere, we have observed and studied spectroscopically 33 objects from the list of Sanduleak & Stephenson (1973) (SS73 stars). We have proposed that 16 of them are Be stars, 5 are peculiar Be stars, 4 are T Tauri stars and 7 are M-type stars with emission lines and 1 Herbig object. The group named peculiar Be stars reveals more interesting features and they deserve further analysis based on high resolution spectra.

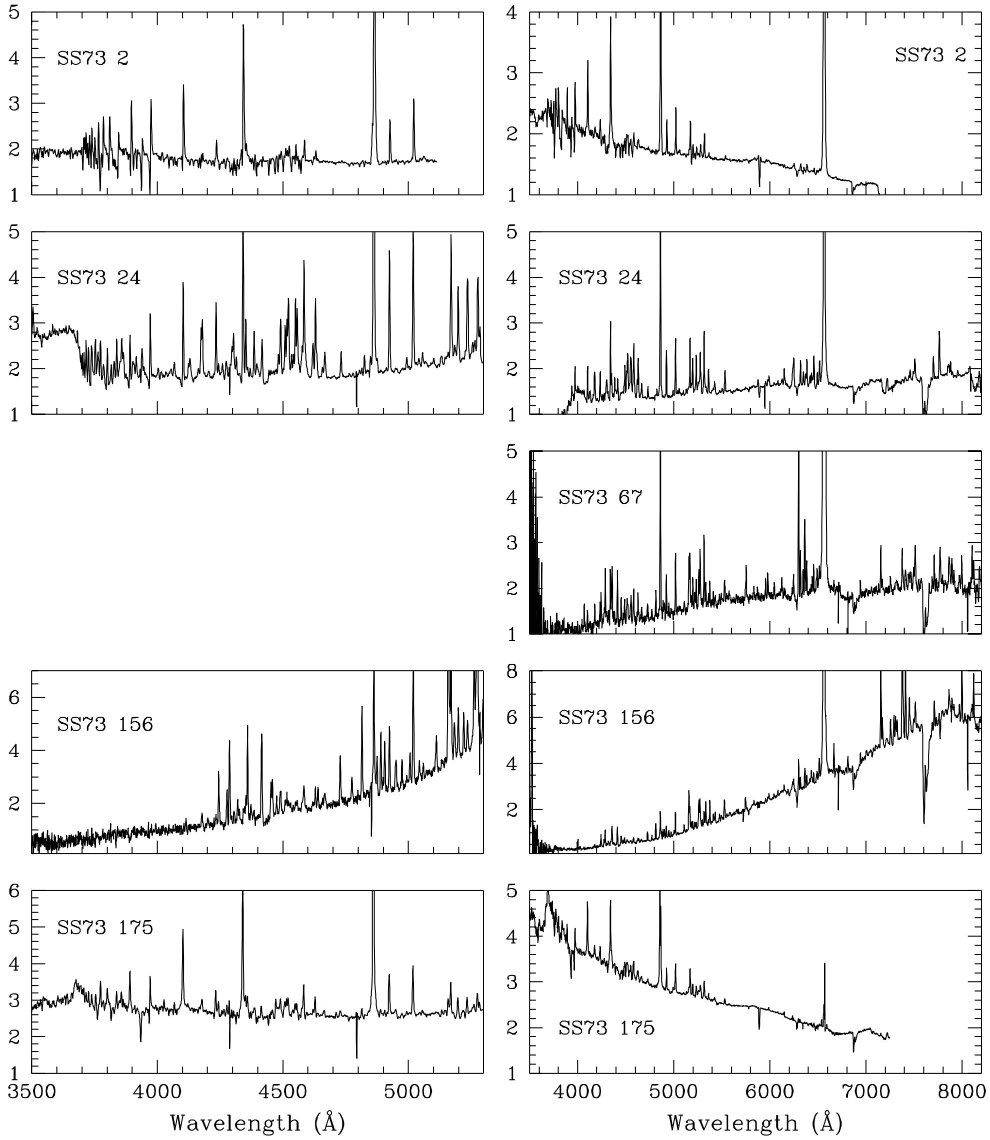

Fig. 10. Relative flux versus wavelength spectra of Be stars SS73 2, 24, 67, 156 and 175 identified in our sample, between 3500 Å and 7500 Å and between 3100 Å and 5100 Å. Hα is saturated in SS73 175.

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