5.5 THE PHOTOSPHERIC LINES

In the blue region of the spectrum of δ-Sco, we detected the following absorption lines called photospheric lines: *HeI* λ4388, 4471, 4921, 4713, *MgII* λ4481, *HeII* λ4686, *OII* λ4416, 4650, 4662, *SiII* λλ4553, 4568, 4576. For this study, we only analysed *HeI*λ4388, 4471, 4921, *MgII* λ4481 and *HeII* λ4686. One of the important issues in Be stars is the rotational velocity of the star. Through a certain technique, the measurement of the photospheric lines can lead to a calculation of the rotational velocity of the star, because these lines originate from its photospheric layer. However, in this study, we were only studying the variation of the *FWHM* value. Although photospheric lines come from a region close to the star, some of them might still be affected by the emission lines. Table 5.4 lists the parameters of the line profiles of *EW* and *FWHM* of several photospheric lines for this study. The *FWHM* values for the photospheric lines were derived under a Gaussian distribution.

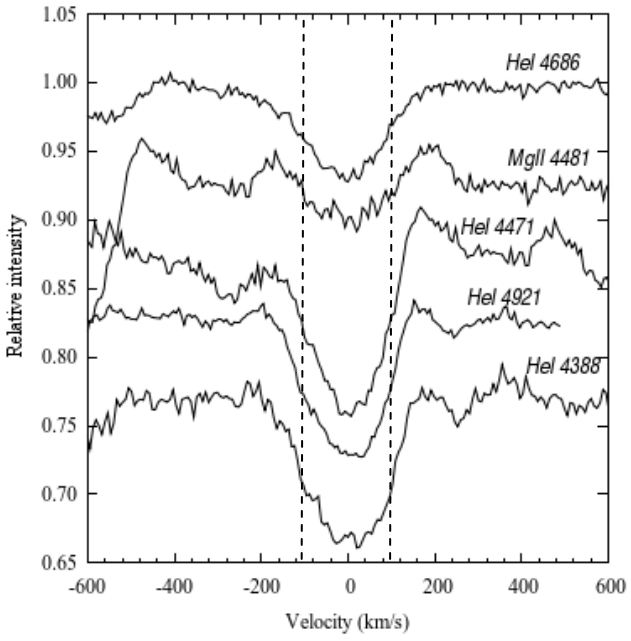

Figure 5.24 – Dashed lines denote the estimation of *FWHM* on some of the photospheric lines.

Table 5.4 – *EW* and *FWHM* of *HeI*λ4388, 4471, 4921, *MgII* λ4481, and *HeII* λ4686. Column 2 and 3 show the observation dates. Column 5 and 6, respectively show the *EW* and *FWHM* values in Angstrom. Column 7 is the *FWHM* in the units of km/s.

Delta Scorpii: Photospheric lines

Line	Date	MHJD+ 2454000	EW (A)	FWHM (A)	FWHM (km/s)
HeI λ 4388	20090317	907.66	0.40	3.10	211.95
	20090503	954.60	0.43	3.59	245.45
	20100221	1248.72	0.36	2.98	203.74
	20100313	1268.64	0.42	3.40	232.46
	20100411	1297.60	0.37	3.43	234.51
	20100415	1301.55	0.48	4.37	298.77
	20100522	1339.44	0.30	2.81	192.12
	20100604	1352.44	0.30	3.25	222.20
	20100624	1372.40	0.40	4.14	283.05
	20100704	1382.40	0.36	3.16	216.05
	20100718	1396.37	0.32	3.48	237.93
	20100830	1439.31	0.38	3.94	269.38
MgII λ 4481	20080717	665.39	0.17	2.65	177.41
	20080724	672.40	0.16	3.06	204.86
	20090317	907.66	0.21	3.37	225.61
	20090503	954.60	0.18	3.76	251.72
	20100221	1248.72	0.15	3.03	202.85
	20100313	1268.64	0.18	3.57	239.00
	20100411	1297.60	0.11	2.97	198.83
	20100415	1301.55	0.13	3.09	206.87
	20100522	1339.44	0.14	2.81	188.12
	20100624	1372.40	0.09	2.50	167.37
	20100704	1382.40	0.12	2.83	189.46
	20100707	1385.40	0.10	2.63	176.07
	20100718	1396.37	0.08	2.87	192.14
	20100830	1439.31	0.09	2.54	170.05
HeII λ 4686	20080709	657.48	0.22	3.07	196.56
	20080717	665.39	0.23	3.05	195.27
	20080724	672.40	0.19	2.84	181.83
	20090327	917.64	0.25	3.02	193.35
	20090418	940.52	0.19	3.10	198.48
	20090503	954.60	0.23	3.24	207.44
	20100221	1248.72	0.25	3.30	211.28
	20100313	1268.64	0.21	3.11	199.12
	20100411	1297.60	0.23	3.28	210.00
	20100415	1301.55	0.21	3.08	197.20
	20100522	1339.44	0.23	3.32	212.56
	20100604	1352.44	0.19	3.06	195.92
	20100624	1372.40	0.16	2.93	187.59
	20100704	1382.40	0.18	2.81	179.91
	20100707	1385.40	0.19	3.26	208.72
	20100718	1396.37	0.15	3.17	202.96
	20100830	1439.31	0.18	3.33	213.20
	20100903	1443.30	0.15	3.00	192.07

Table 5.4 - Continue

Delta Scorpii: Photospheric lines

Line	Date	MHJD+ 2454000	EW (A)	FWHM (A)	FWHM (km/s)
HeI λ 4921	20090317	907.66	0.36	3.51	213.94
	20090503	954.60	0.38	3.82	232.84
	20100313	1268.64	0.39	3.16	192.61
	20100522	1339.44	0.24	2.80	170.66
	20100624	1372.40	0.46	5.08	309.63
	20100704	1382.40	0.48	5.34	325.48
	20100718	1396.37	0.42	5.01	305.37
	20100830	1439.31	0.45	5.23	318.78
	20100221	1248.72	0.40	3.27	199.31
	20100411	1297.60	0.42	3.99	243.20
	20100415	1301.55	0.56	3.99	243.20
	20100604	1352.44	0.33	3.66	223.08
	20100707	1385.40	0.47	5.45	332.19

Figure 5.25 shows the profile variations of *HeI* λ4388, 4471, 4921, *MgII* λ4481, and *HeII* λ4686 from 2008 to 2010. From Figure 5.25 we identified several kinds of variations: emission wings appeared at the blue and red sides of *HeI* λ4471 and λ4921 line profiles, in addition *HeI* λ4471 had strongly blended with other lines; *MgII* λ4481 shows a noisy profile; *HeII* λ4686 and *HeI* λ4388 clearly show a normal profile of photospheric line. The analyses of their *EW* and *FWHM* are depicted in Figures 5.26 and 5.27. The figures show that *HeII* λ4686 had the most stable value among other photospheric lines, in which the value of *FWHM* and *EW* are in the range of 2.81 to 3.30 Å and from 0.15 to 0.25 Å, respectively, whereas *HeI* λ4388 had a larger range of *FWHM*: from 2.81 to 4.37 Å and *EW*: from 0.32 to 0.48 Å. The more stable values in the *HeII* λ4686 profile indicates that the line was not affected by the lines produced by the envelopes.

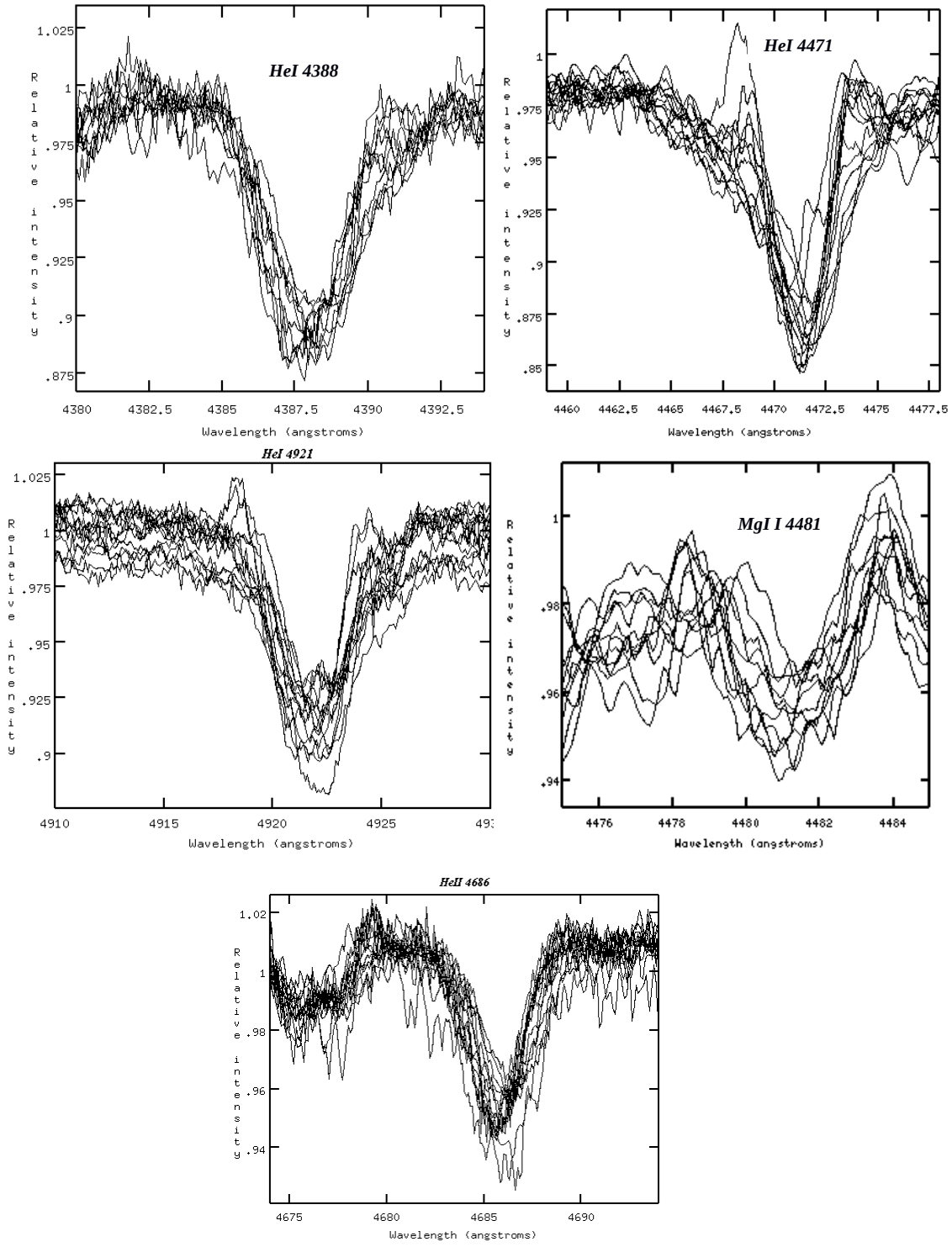

Figure 5.25 – Profiles of photospheric lines in the blue region of δ-Sco spectra from 2008 to 2010 observing runs. *HeII* λ4686 was clearly not affected by the emission. There were emission wings on both sides of the profile of *HeI* λ4921 and 4471.

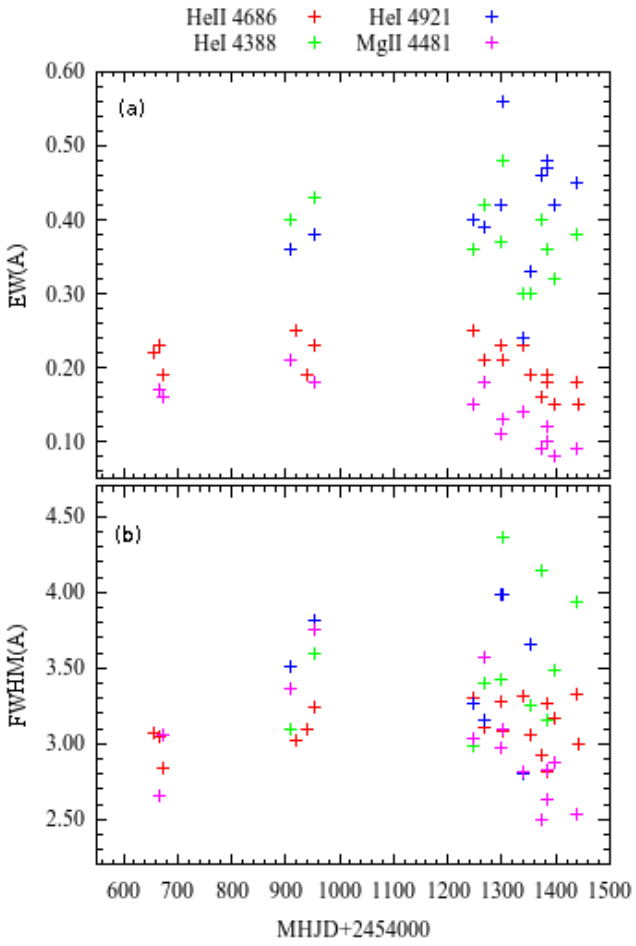

Figure 5.26 – Variations of *EW*(a) and *FWHM*(b) of *HeI*λ4388, 4921, *MgII*λ4481, and *HeII* λ4686 from 2008 to 2010.

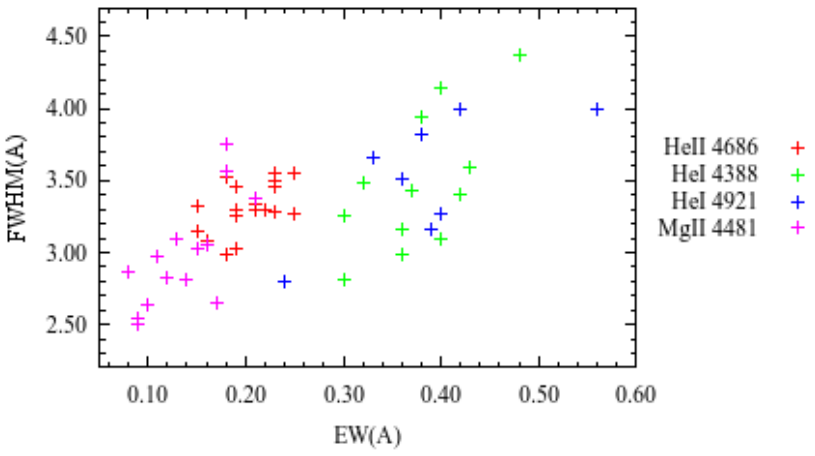

Figure 5.27 – Correlation of *FWHM* and *EW* of *HeI* λ4388, 4471, 4921, *MgII* λ4481, and *HeII* λ4686. The graph also shows the variation of each line. *HeII*λ4686 was observed to be the least affected by the circumstellar envelope's lines.

We also correlated the behaviour of the line profiles in the circumstellar envelope and in the atmospheric regions. From the variation of *EW* in 2010, shown in Figure 5.28, the strength of H_α and *HeI* λ6678 were gradually decreased, whereas *HeII* λ4686 and *MgII* λ4481 were slightly decreased. In contrast to *HeI* λ4921 and *HeI* λ4388, neither of the lines showed any significant reduction; moreover, they have stronger *EW* values compared with the other photospheric lines. This is possibly because of effects from the circumstellar lines. In the meantime, the emitting region closer to the stellar surface, *HeI* λ6678, shows a decrease in strength.

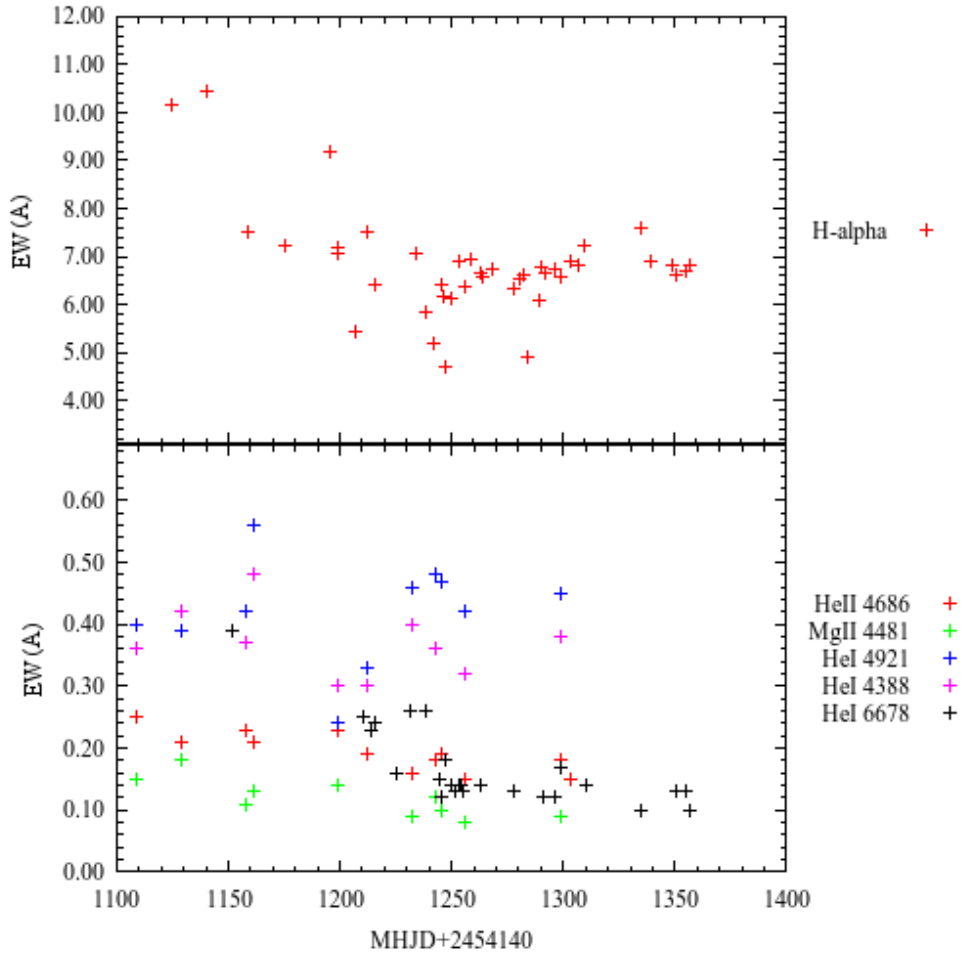

Figure 5.28 – Variation of the line strength in the circumstellar envelope: H_α and *HeI* λ6678 and photospheric lines: *HeII* λ4686, *HeI* λ4921, *HeI* λ4388.

From chapter 2, we know that fast rotation is one of the characteristics of Be stars. The rotation model of Be stars was first proposed by Struve (1931), in which the instability produced by the rapid rotation leads to the ejection of material from the equatorial region of the flattened body of the star, forming a gaseous equatorial ring. We know that the value of *FWHM* has a relationship with the rotational velocity of the star and thus, the photospheric lines under study have been examined to determine the star's rotational velocity, especially when close to the periastron passage. The star is presumed to rotate at a constant value on its axis; thus, we expect the variation in the value of *FWHM* to be because of the condition in the local environment of the regions.

5.6 THE 2011 PERIASTRON PASSAGE OF δ-SCO

After the last periastron that occurred in 2000, δ-Sco once again encountered the moment of its secondary at the closet distance to the primary. Many studies have been done to predict the date and physical parameters of the event. The distance of the primary and secondary at the periastron passage was estimated at 0.84 AU by Tango et al. (2009); Tycner et al. (2011) expected the periastron to occur on UT2011 July 6 ± 2 days with an expected minimum separation of 6.14 ± 0.07 mas (14 stellar radii).

5.6.1 *EW, I/Ic* and *V/R* variations

In this study, we analysed the line profiles in the circumstellar disc and the representative photospheric line, *HeII* 4686. We found the equivalent width of the Balmer lines: H_α, H_β and H_γ, were largely increased when the stars became closer to the periastron. The other lines, *HeI*λ 6678 and *HeII*λ 4686 also revealed an increment in their strength but by smaller amount. Figure 5.29 shows the variation and the increment of the lines' strength when the stars were close to the periastron passage.