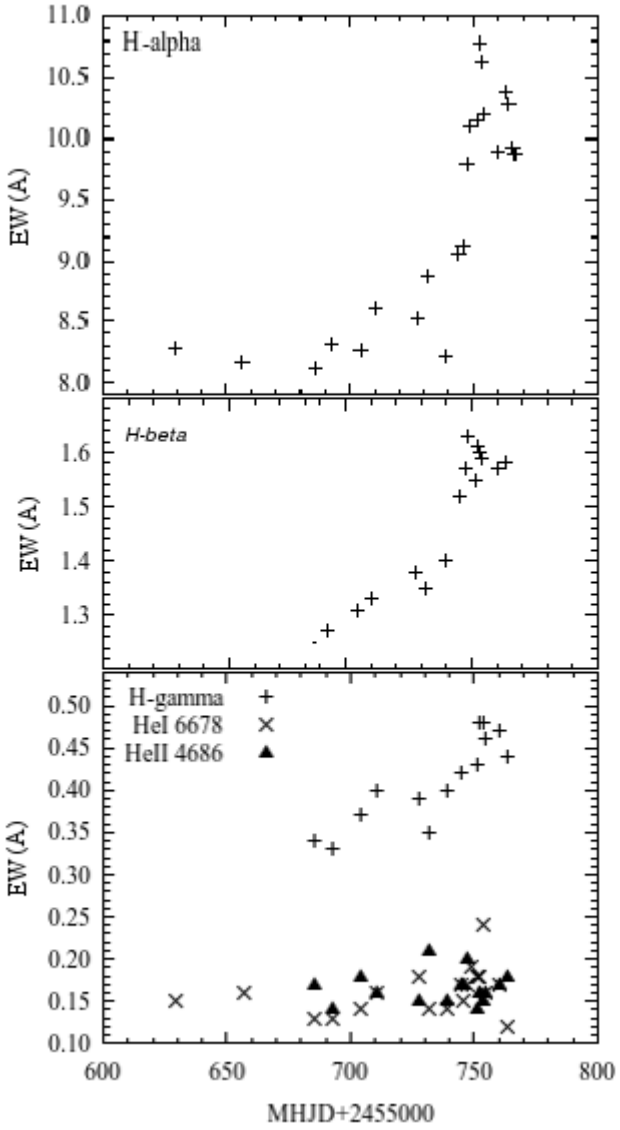

Figure 5.29 – Variation of equivalent width of the outer envelope represented by H_α, H_β and H_γ and the inner envelope by *HeI* 6678. *HeII*4686 represents the photospheric layer of the star. The EW in the plots was taken as positive value.

We performed a comparison of the relative intensity *I/Ic* of H_α in 2010 and 2011, as depicted in Figure 5.30. The H_α line profile sometimes appears in a double-peaked and sometimes as a single asymmetric profile. In order to justify the intensity of those types of

profiles, we used two kinds of methods: for a double peak profile, we measured the mean intensity of both violet and red peaks, i.e.,$(I_v + I_r)/2$ and for a single-peaked asymmetric profile, the central intensity is justified by fitting a Gaussian distribution to the line profile.

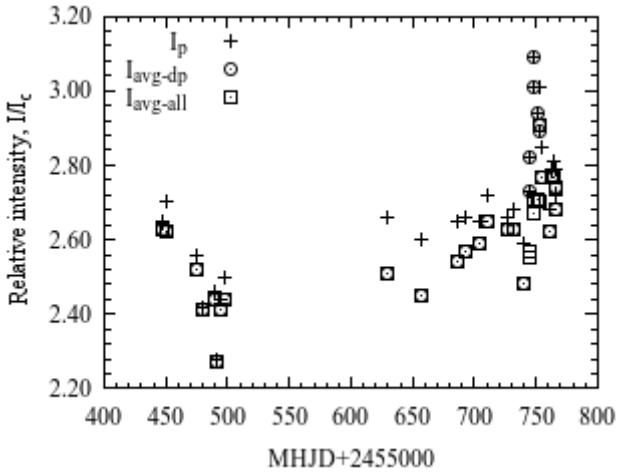

Figure 5.30 – Relative intensity of H_α in 2010 (MHJD+400-500) and in 2011 (MHJD+600-800). The highest intensity of the H_α profile during periastron is represented by *Ip* and I_{avg-dp}. The highest relative intensity *Ip* of periastron is measured at 3.09. The $I_{avg-all}$ represents the average of the H_α profile.

In the study of the variation of the relative intensity of H_α, we divided the profile into three cases. First, we measured the highest intensity *Ip*, without concerning for whether the highest was violet, or red. In the second case, we applied the mean intensity measurement for the double peak only, I_{avg-dp} and in the third case, we considered both cases $I_{avg-all}$ in justifying the relative intensity of H_α. All three cases are depicted in Figure 5.30. Overall, we found that the relative intensity of $H_\alpha$decreased in 2010 but increased in 2011. Without concern for the average intensity, we found that the relative intensity of H_α reached the highest peak of 3.01 to 3.09 between the 4th and 5thJuly 2011. In the last periastron, which occurred between the 7th and 12th September 2000, the highest peak that

this line reached was in the range 1.72 to 1.77 (Miroshnichenko, 2001). The value of*EW* of H_α in the last periastron was also found to be smaller than in this recent periastron by a factor of about 1.7. The increment of *EW*, as well as its relative intensity in the outer envelope in the 2011 periastron, indicates the growth of the circumstellar disc of δ-Sco. The growth of the disc is also supported by the presence of *HeI* λ6678 in emission, whereby this line appeared as an absorption line during the last periastron (Figure 5.31).

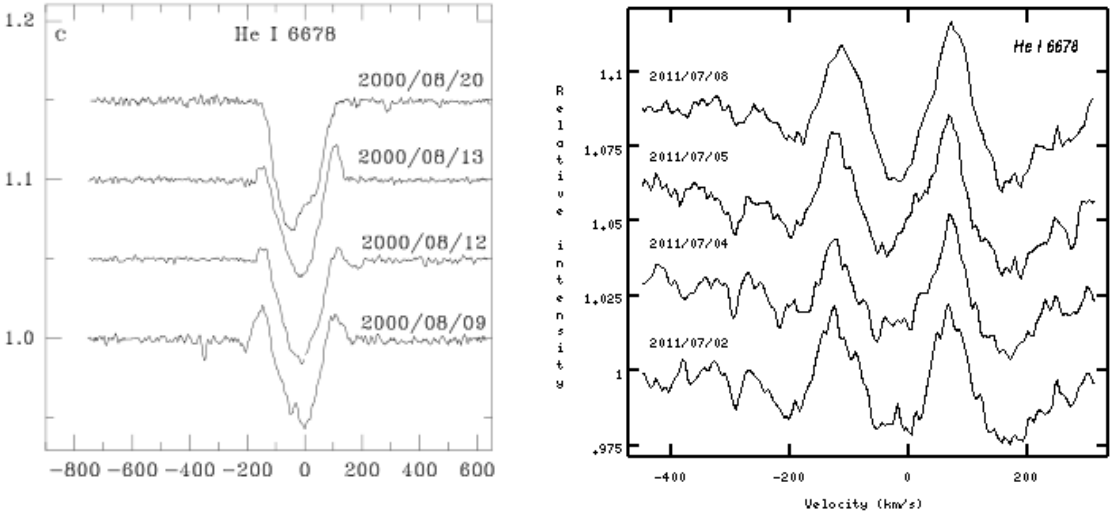

Figure 5.31 – The *HeI* λ6678 profile during the periastron passage: (Left) profile of the last periastronin Sept 2000 (Miroshnichenko, 2001) and (Right) profile during the recent periastron between 4th and 5th July 2011 (in this study).

All four lines from the emitting regions: H_α, H_β, H_γ and *HeI* λ6678, show the same pattern of variation: the relative intensity, *V/R* ratio, radial velocity and *EW* when going through the periastron passage. For the Balmer lines, as the star approaches its periastron, the red peak becomes higher and became the highest at the periastron, before it receded with *V/R >1*. Based on the *V/R* variation of H_β and H_γ, depicted in Figure 5.32, we found that the *V/R* ratio is minimum at periastron, in which the ratios for H_β and H_γ, between the 4th and 5thJuly 2011, were in the range of 0.57–0.59 and 0.48–0.47, respectively. For H_α, the

V/R ratio values were 'missing', as the companion approached the closest distance to the primary. This is because the H_α profiles became an unresolved blue-asymmetric single-peak profile.

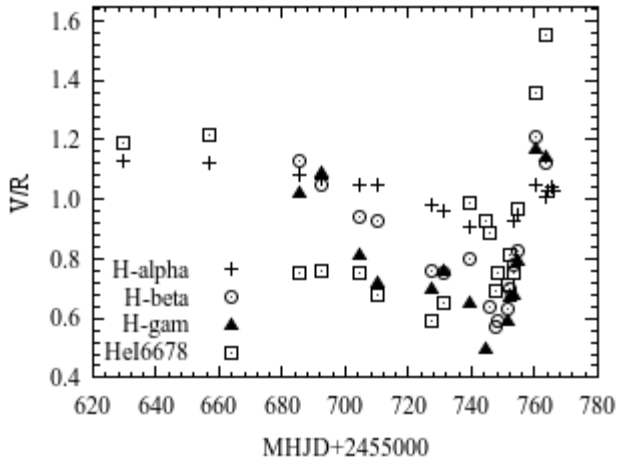

Figure 5.32 – The *V/R* variation of the lines from the emitting regions of H_α, H_β, H_γ and *HeI* λ6678.

5.6.2 Radial velocity

One of the observational parameters to predict the periastron passage is the radial velocity (*RV*) of the primary star. As δ-Sco has high eccentricity, the variation of its radial velocity is rather small for a long time and becomes apparently large only about one month before the closest encounter. Figure 5.33 shows the radial velocity of *HeII* λ4686 and H_α from 9th March to 23rd July 2011. The radial velocity of *HeII* λ4686 drops significantly after MHJD+700, that is, in early June and it shows the lowest values of between -58 to -54 km/s on the 4th and 5th July, before the value begins to climb. The expected date of the periastron passage was determined correctly within the range by Tycner et al. (2011). If we compare the graphs of *V/R* and radial velocity, we can see from the relationship of both that the most blue-shifted radial velocity corresponds to the smallest *V/R* ratio (*V/R<<1*).

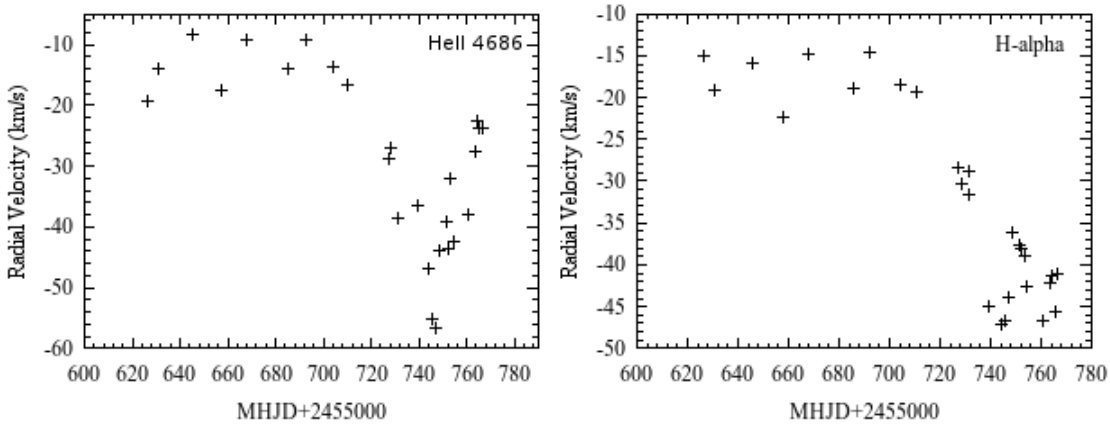

Figure 5.33 – Radial velocity of *HeII* λ4686 (left) shows clear changes when closer to the periastron passage compared with the H_α line (right).

The measurement of radial velocity is more accurate by photospheric lines than the lines from the disc because the closer the distance of its companion to the primary, the greater the effects of the wobble movement of the primary star at the centre compared with the outer disc regions.

5.6.3 Lines profile variation

It has been noticed from the radial velocity of *HeII* λ4686 that the close encounter occurs from 4th to 5th July 2011. Tycner et al. (2011) estimates that the companion will be separated from the primary at the periastron passage by about 14 stellar radii. This means, that as the companion gets closer to the primary, it will eventually enter the outer disc of the primary up to 14 stellar radii inside the disc, which is in the region of H_α. Figure 5.34 shows the evolution of the H_α line profile from March towards the periastron. Looking at the profiles, we can recognise that a small peak on the redwing becomes discernible as the star approaches the periastron passage.

We can see the small peak on the redwing of the H_α line profile depicted in Figure 5.34. We believe that the appearance of a small peak on the red wing is a consequence of the increasing activities in the particular region where the interaction between the star and disc is aroused. The companion is most likely a dwarf of type B2 with a mass of 8 $M_\odot$ (Cox, 2000). The H_α profile in the last periastron passage of 2000 is compared in Figure 5.35. We found the intensity *I/Ic*, of the profile to be about half that of the recent periastron passage; the profile appears with multiple peaks with a small narrow absorption line on the red side and this absorption line varies with time. We are not dismissing the possibility that one of the reasons for the differences of the features from the recent periastron passage could be due to a higher resolving power of about two times.

As the companion approaches its periastron passage, the *EWs* and relative intensities of the region increased significantly starting from 1st July, i.e., the *EW* and *I/Ic* increased from 8.22 and 2.59 Å on 26th June to 9.05 and 2.73 Å on the 1st July, respectively, before the moment of periastron passage was reached between the 4th and 5th of July 2011.

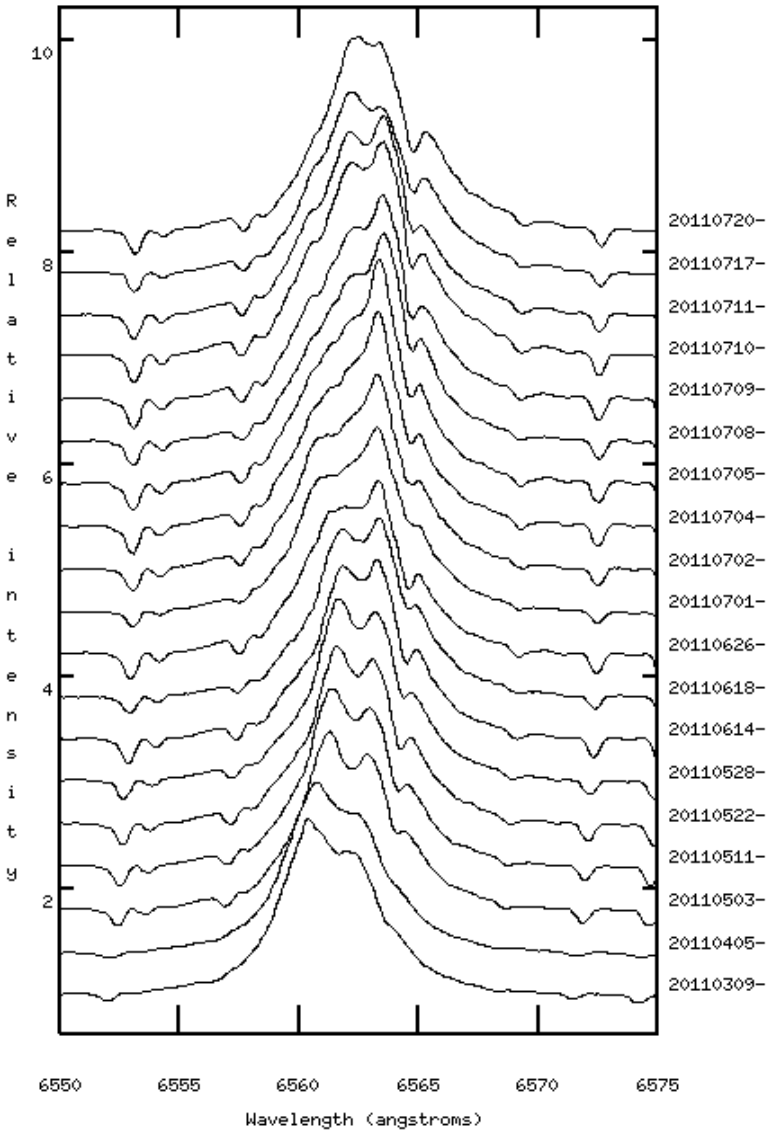

Figure 5.34 – Evolution of H_α line profile variation with time for 2011 starting from March to 20th of July. In the beginning, the profile shows the violet peak higher than the blue with the *V/R* ratio decreasing as the star moves closer to the periastron passage. The small peak on the redwing also becomes discernible. Starting from the end of June, the profile shows a kind of 'shoulder' shape on the violet side replacing the blue peak. Within this period, the profile turns into a blue-asymmetric profile before a double-peak profile appears again on 10th July.

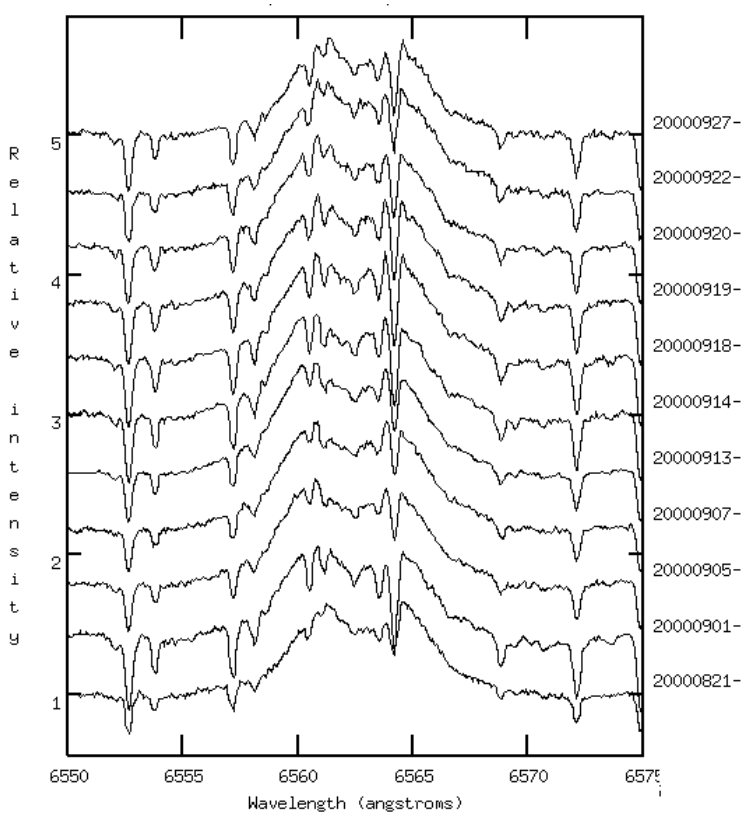

Figure 5.35 – Variation of H_α line profile in the last periastron passage, which occurred between 7th to 12th September 2000. We found that the profile had the intensity of about half that of the recent ones with multiple peaks. Data were taken from Archive Database of Ritter Observatory.

An inspection of the effects of the periastron passage have also been done on the inner layers of the Be disc, such as the H_β and *HeI* λ6678 emitting regions. Table 5.5 shows the values of the H_α and H_β line profiles vary over time. From the table, the *EW* of H_β shows the highest increment of between 1.57 to 1.63 Å as well as the relative intensity of the red peak *Ir*, which corresponds to the lowest *V/R* ratio, i.e., from 0.57 to 0.59 for the period of the periastron passage. In the beginning, the *EW* of H_β increases with increasing disc radius. However, the disc radii as well as *EW* decreased, as the star got closer to periastron passage. The values increased again after passing through the close encounter.

The correlation of *EW* and *Rd/R** is shown in Figure 5.36(top). The relation between *V/R* and *Rd/R**, shown in Figure 5.36(below), is that the *V/R* ratio decreases towards the close encounter and reaches a minimum at the periastron, as does the disc radius, before they begin to increase afterwards. On the other hand, no significant changes of *EW* were noticed upon the close encounter for the layer of the Be disc closest to the stellar surface, such as *HeI* λ6678 (see Figure 5.27).

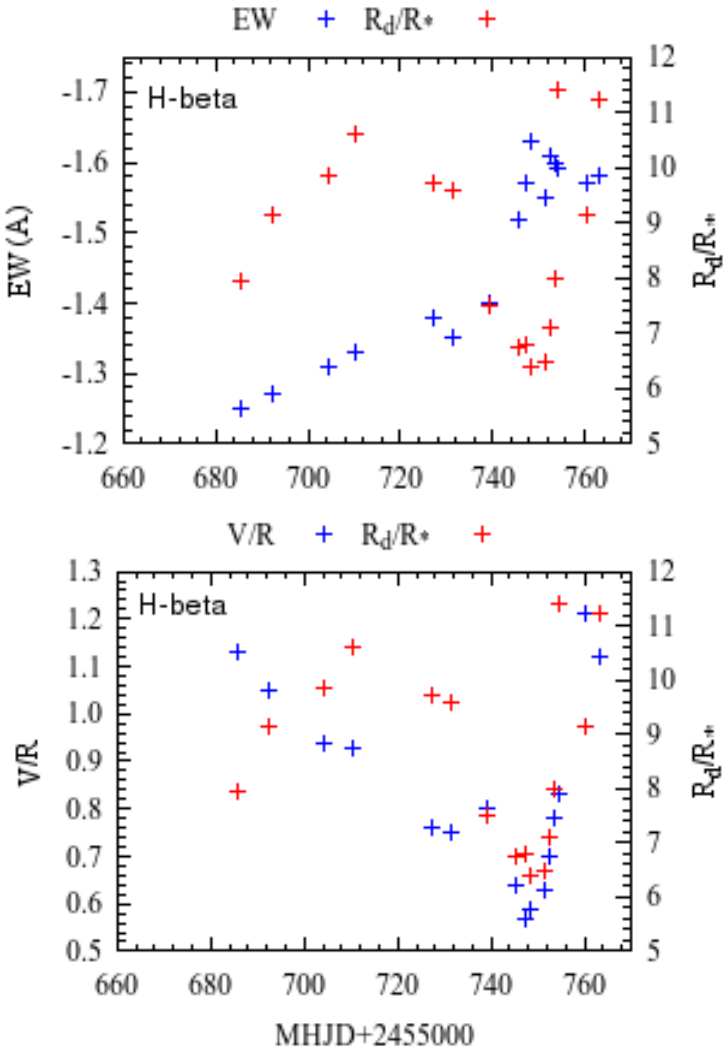

Figure 5.36 – Correlation of *EW* and *Rd/R** of H_β (top) and correlation between *V/R* and *Rd/R** (below) when closing to the periastron passage.