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Short-Term Hα Line Variations in Classical Be Stars: 59 Cyg and OT Gem

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Abstract. We present the optical spectroscopic study of two classical Be stars, 59 Cyg and OT Gem obtained over a period of few months in 2009. We detected a rare triple-peak Hα emission phase in 59 Cyg and a rapid decrease in the emission strength of Hα in OT Gem, which are used to understand their circumstellar disks. We find that 59 Cyg is likely to be rapid rotator, rotating at a fractional critical rotation of ∼0.80. The radius of the Hα emission region for 59 Cyg is estimated to be $R_d/R_* \sim 10.0$, assuming a Keplerian disk, suggesting that it has a large disk. We classify stars which have shown triple-peaks into two groups and find that the triple-peak emission in 59 Cyg is similar to ζ Tau. OT Gem is found to have a fractional critical rotation of ∼0.30, suggesting that it is either a slow rotator or viewed in low inclination. In OT Gem, we observed a large reduction in the radius of the Hα emission region from ∼6.9 to ∼1.7 in a period of three months, along with the reduction in the emission strength. Our observations suggest that the disk is lost from outside to inside during this disk loss phase in OT Gem.

Keywords. Stars: emission-line—Be—circumstellar matter—stars: individual (59 Cyg, OT Gem)—stars: rotation—techniques: spectroscopic.

1. Introduction

Classical Be stars, most commonly known as Be stars are very rapidly rotating main sequence B-type stars, which through a constrained process, form an outwardly diffusing gaseous, dust-free Keplerian disk (Rivinius *et al.* 2013). This disk is formed from the material ejected from the fast-spinning central star. Be stars exhibit line emissions, mostly Balmer lines over the photospheric spectrum (Porter & Rivinius 2003). The emission lines originate from the geometrically thin, circumstellar disk rotating with near-Keplerian velocity surrounding the central star (Carciofi & Bjorkman 2006).

Be stars are well known variable stars and the period of spectroscopic variation, which includes short-term and long-term variations in emission lines, vary from few minutes to few decades (Porter & Rivinius 2003). The profile structure of the Hα emission line vary from star to star which mainly depends on the inclination angle of the system as explained by Struve (1931). Catanzaro (2013) used the classification scheme proposed by Hanuschik *et al.* (1988) for the observed Hα profile types as single peak, double peak, shell structure emission and also absorption. Spectroscopic monitoring of Be stars indicate Hα emission line variations in equivalent width (EW), profile shape and V/R value (Dachs 1987; Hanuschik *et al.* 1988; Hubert 1994; Hanuschik 1996). In this paper, we discuss the Hα line variability of two classical Be stars i.e., 59 Cyg and OT Gem. The large variations observed in the Hα emission line for these two stars are rapid and vary in a short span of few months.

Studying variation of emission lines is expected to provide insights into the changes in the circumstellar disk. It can be used to derive the distribution of material and kinematics of the circumstellar disk (Bhat *et al.* 2016). In this paper, we present the emission line variability of 59 Cyg and OT Gem (see Table 1) based on spectroscopic data, 7 spectra of 59 Cyg and 8 spectra of OT Gem, obtained over a period of about three months in 2009. We discuss the observed features and changes in the spectra of these stars. We have used similar methods adopted by Bhat *et al.* (2016) to estimate the radius of the circumstellar disk using the Hα line and also to determine the rotational velocity of the central star from prominent HeI absorption lines.

Table 1. Program stars.

HD	HR	Name	Spectral type	RA	δ	V
200120	8047	59 Cyg	B1 Ve	20 59 49.55716	+47 31 15.4216	4.75
58050	2817	OT Gem	B2 Ve	07 24 27.64809	+15 31 01.9061	6.41

The paper is arranged as follows. Section 2 gives a brief overview of these two stars mainly on their spectroscopic variability from previous studies. Section 3 addresses the details of spectral observations and data reduction techniques. In section 4, we present the spectra and discuss the major results from the spectral line analysis of both the stars. The conclusions drawn from this study are listed in section 5.

2. Previous studies

2.1 *59 Cyg*

59 Cyg is a well known Be star because of its pronounced spectral variations in emission line profiles and intensities which is summarized by Barker (1982) and Harmanec *et al.* (2002). It was first discovered of its emission lines in 1904 by Cannon and had shown emission components with variable intensities all throughout except in 1912 and 1916 (Hubert-Delplace & Hubert 1981; Barker 1982). Strong V/R variations were reported in 1926–1929, 1941–1942 and in 1946–1948; a slow increase of emission was also observed from 1945–1950 by Merrill & Burwell (1949). Afterwards, a quiescent phase had set in from 1953–1970 with the emission features being relatively stable (Hubert-Delplace & Hubert 1981). Emission was at maximum in 1956 and in 1961 and at minimum in 1967 (Moujtahid *et al.* 1998).

Kogure & Hirata (1982) mentioned that the star showed the first gradual strengthening of emission lines in 1971–1972 and came up with rich shell lines in June 1973. This constituted the first shell phase, in which strong shell absorption lines were detected in Balmer lines (up to H30), HeI, MgII and in some singly ionized metals (Doazan *et al.* 1975; Hubert-Delplace & Hubert 1981). In the period 1973–1974, shell lines changed to second strengthening of emissions with asymmetric profile ($V/R > 1$) and Hβ as single emission line with a very deep core. With the declining of emission components and the appearance of double emission peaks, 59 Cyg proceeded to the second shell phase in October 1974, which lasted till March 1975 and was stronger than the first shell phase (Hubert-Delplace & Hubert 1981). Barker (1982) describes the 1974–1975 shell phase as a 160-day episode with a general outline of spectral changes with detailed line profile variations.

Soon after, in 1978, a new Be phase began to develop which was observed in the far UV and optical regions by Doazan *et al.* (1989). They observed the star again in the time interval 1978–1987 and saw the V/R variability and intensity changes in the emission of Hα. Doazan *et al.* (1985) gives the V/R variability period of Hα on a long term to be about 2 years. Barker (1983) describes the transient emission events of the star, after the minimum of 1977, with a V/R variation on a short-lived quasi-period no longer than 28 days.

59 Cyg is a part of the multiple system (ADS 14526) of the Trapezium type. Optical components are separated from 59 Cyg A by 20″, 26″ and 38″ respectively. It was confirmed as a single-lined spectroscopic binary by studying the variations of photospheric lines, like HeI 4471 with a period of 28.1702 ± 0.0014 day by Rivinius & Štefl (2000) who compared it to ϕ Per. 59 Cyg was confirmed to be a Be + sdO binary as the companion was suspected to be a compact object by Maintz *et al.* (2005).

2.2 *OT Gem*

OT Gem has exhibited strong spectral variations during the past years. The first evidence of the emission changes was presented by Merrill & Burwell (1943). The spectroscopic behaviour between 1954–1975 was described by Hubert-Delplace & Hubert (1979), where the strong emission of Balmer and FeII lines was clearly seen. The strength of the emission steadily decreased after the maximum in 1961–1962, with slight variations and finally reaching a minimum at the end of 1980 (Hubert-Delplace *et al.* 1982). Dachs *et al.* (1986) described the Hα emission as a single, sharp emission peak with slightly decreasing strength from 1981 to 1983 which is in good agreement with the Hα measurement obtained in 1981 by Andrillat (1983). This slight decrease of Balmer emission line intensity is from 1961 as described by Hubert-Delplace *et al.* (1982) which had still continued to 1981–1983.

Hanuschik (1996) classified OT Gem as a non-shell star and concluded that a significant part of the disk is projected against the sky. Božić *et al.* (1999) compared the variations of OT Gem to ω CMa and said that the physical process might be same for the two stars. The Hα peak intensities of 4.3 (Andrillat 1983) and 3.2 (Doazan *et al.* 1991) were reported. Poretti (1982) classified OT Gem as a γ Cas type but (Arellano Ferro *et al.* 1998) considered it to be a mild-γ Cas because the intensity of the emission at Hα reached only 3 in OT Gem unlike 5 in γ Cas. They also mentioned about the scarcity of available spectroscopic data for this star to give any correlation with the photometric measurements. Catanzaro (2013) reported a triple-peaked structure for Hα in one of the nights between 2008 and 2009.

3. Observations and data reduction

The spectra of 59 Cyg and OT Gem were acquired during several observation runs from February 2009 to July 2009 and the journal of observations is given in Table 2. The spectra were obtained using the Universal Astronomical Grating Spectrograph (UAGS) at the Cassegrain focus of the 1.0-m Carl Zeiss reflector located at Vainu Bappu Observatory, Kavalur, India which is operated by the Indian Institute of Astrophysics (IIA). The CCD consists of 1024 × 1024 pixels of 24 μm size, where the central 1024 × 300 pixels were used for spectroscopy. The typical readout noise is about $4.8e^-$ and the gain is $1.22e^-$/ADU. Bausch and Lomb 1800 lines per millimetre grating was used, which in combination with the slit provided a resolution of 1 Å at Hα. The medium resolution data taken in the wavelength region 3800–4600 Å included absorption lines like Hγ to Hθ and also HeI lines and data taken in the range 6200–6800 Å had Hα in emission.

Table 2. Journal of observations for 59 Cyg and OT Gem.

Star name	Date of observation in 2009	Spectral range (Å)	No. of spectra (integration time in seconds)
59 Cyg	1 June	3800 – 4300	1 (1800)
	2 June	3800 – 4300	1 (1800)
	29 June	3800 – 4300	2 (1800)
	11 July	6200 – 6800	1 (2700)
	23 July	6200 – 6800	2 (2400)
OT Gem	4 February	6200 – 6800	1 (2700)
	27 April	6200 – 6800	2 (1800, 2700)
	28 April	6200 – 6800	2 (1800)
	29 April	6200 – 6800	1 (2700)
	30 April	6200 – 6800	1 (2400)
	1 May	6200 – 6800	1 (2400)

The reduction of all the spectra was performed using several routines in the NOAO/IRAF [1] (Image Reduction and Analysis Facility) package. The wavelength calibration was performed using Fe–Ar arc lamp spectra. Typical S/N near Hα for 59 Cyg is ∼200 from 3 spectra and for OT Gem is ∼100 from 8 spectra.

The spectra were initially normalized to the continuum. IRAF tasks were later used to measure parameters of the emission line profiles, such as Equivalent Widths (EW), Full Width at Half Maximum (FWHM), V/R ratios, peak separations (ΔV) and intensity of peak with respect to continuum (I_p/I_c). All the measurements are reported in the next section.

4. Analysis and discussion

59 Cyg was observed in June 2009 in the shorter wavelength region to investigate the HeI lines. It was also observed in July 2009 in the Hα region. Representative sample spectra for 59 Cyg in different wavelength regions is shown in Fig. 1. OT Gem was observed from February to May, 2009 in the Hα region only. In the following section, we discuss the rotational velocity of the two stars. Section 4.2 deals with variability of the Hα emission line of both the stars.

4.1 *Rotational velocity estimation*

Be stars belong to the most rapidly rotating class of non-degenerate stars and it is also observed that a few stars may be rotating very close to the critical velocity (Rivinius *et al.* 2013). In this study, to estimate the rotational velocity ($v \sin i$), we have considered the HeI absorption lines in the blue spectral region, HeI λ4009, λ4026 and λ4143 (refer left panel of Fig. 1), for the star 59 Cyg. These lines are assumed to be unaffected by the emission from the disk.

Steele *et al.* (1999) derived the rotational velocities for a sample of 58 Be stars and made a fit to the FWHM - $v \sin i$ correlation of Slettebak *et al.* (1975). They obtained the relations (1)–(4) in their paper for four different HeI lines. We estimate the $v \sin i$ only for HeI λ4026 and λ4143 using the respective relations between FWHM and $v \sin i$ as given in their paper. We do not have a similar relation given for HeI λ4009 in Steele *et al.* (1999), so we use a basic relation between

[1] IRAF is distributed by the National Optical Astronomy Observatory, which is operated by the Association of Universities for Research in Astronomy, Inc.

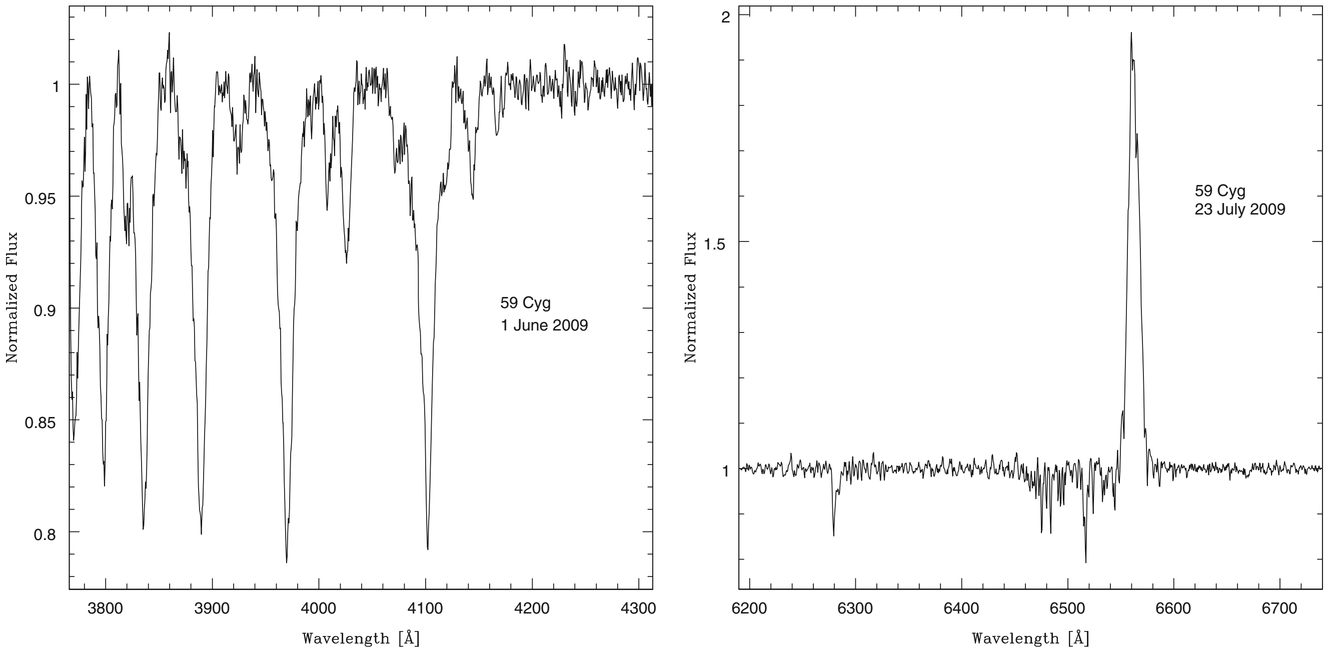

Figure 1. Representative sample spectra of 59 Cyg (*Left*: 3800–4300 Å showing Hδ, Hϵ, Hζ, Hη, Hθ along with HeI 4026 Å and FeII absorption lines, *Right*: 6200–6800 Å showing Hα emission along with HeI 6678 Å and FeII absorption lines).

the FWHM of the HeI line and the $v \sin i$ of the star as given in the relation below.

$$v \sin i = \frac{c(\mathrm{FWHM})}{2\lambda\sqrt{\ln 2}}. \qquad (1)$$

The FWHM of the selected HeI lines and the estimated $v \sin i$ values are shown in Table 3 for 59 Cyg. It can be seen that the values derived using HeI λ4009, are similar to those from the other two HeI lines. The average $v \sin i$ estimated for this star from 4 spectra is shown in Table 4. The error tabulated for all the values corresponds to the standard deviation. The average values obtained were compared with the values from Rivinius *et al.* (2006), Harmanec *et al.* (2002) and Slettebak (1982). HeI λ4026 was well resolved in most of the spectra and was consistently detected well throughout the sample, and the estimated $v \sin i$ is found to be within the error. All the individual averages of HeI lines, as well as the collective average calculated from the individual averages for 59 Cyg matches with the literature values, except that of Slettebak (1982).

Harmanec *et al.* (2002) studied the long term as well as rapid variability of 59 Cyg using photometry and spectroscopy. They estimated the basic physical properties of 59 Cyg. Rivinius *et al.* (2006) categorized 59 Cyg into a different class which have emission ⇔ emission and shell transitions. These type of stars show a very high $v \sin i$ values, which matches with our estimation.

The critical velocity, v_c value was taken from Yudin (2001) which was estimated for a particular spectral class and luminosity class. Thus, for the spectral type indicated in Table 1, v_c was obtained and critical fractional rotation, ω given by $v \sin i/v_c$ was estimated. The uncertainty in ω is not only from $v \sin i$ but also from the spectral and the luminosity classes (Rivinius *et al.* 2006). The critical fractional rotation obtained in our study using the HeI lines was compared with the

Table 3. FWHM and $v \sin i$ measurements for 59 Cyg from the spectra using HeI 4009, 4026 and 4143 Å.

Date of observation	HeI 4009 Å		HeI 4026 Å		HeI 4143 Å	
	FWHM (Å)	$v \sin i$ (km s^{-1})	FWHM (Å)	$v \sin i$ (km s^{-1})	FWHM (Å)	$v \sin i$ (km s^{-1})
01/06/09	7.9	355.5	8.5	389.5	8.7	387.2
02/06/09	11.3	506.9	7.9	362.0	8.3	369.4
29/06/09	9.3	415.6	6.9	316.2	10.7	476.3
29/06/09	10.1	453.0	8.5	389.5	10.1	449.6

Table 4. Rotational velocity parameters. $v \sin i$ averaged from 4 spectra for the HeI lines for 59 Cyg is compared with three other estimations; ω was calculated using v_c given in Table 2 of Yudin (2001), who interpolated values given by Moujtahid *et al.* (1999).

Parameters	Reference	Value
$v \sin i$	4009 Å	433 ± 32
(km s^{-1})	4026 Å	364 ± 17
	4143 Å	421 ± 25
	Average	406 ± 25
	Rivinius *et al.* (2006)	≥379
	Harmanec *et al.* (2002)	450
	Slettebak (1982)	260
v_c (km s^{-1})	Yudin	520
ω	4009 Å	0.83
	4026 Å	0.7
	4143 Å	0.81
	Average	0.78

values obtained by Rivinius *et al.* (2006). ω value estimated using HeI 4026 Å seem to be very close to the literature value, but those estimated using the 4009 and 4143 Å lines show about 10% deviation. This is due to the fact that the $v \sin i$ itself is different for the two HeI lines.

For OT Gem, though there were no spectra available in the blue region, HeI 6678 Å was available in the red region spectra. This line is usually affected by the emission from the disk. We can consider the line to be minimally affected during our observation since the star is in a disk loss phase and hence the emission is declining in its strength. Measurements for OT Gem like that of 59 Cyg was obtained and $v \sin i$ was estimated using equation (1) and is shown in Table 5. The average $v \sin i$ from 8 HeI profiles for OT Gem is found to be 126 ± 4 km s^{-1}. Božić *et al.* (1999) quoted a value of 130 km s^{-1}. Our value matches very well with that of the literature. The critical velocity, v_c = 483 km s^{-1} value was taken from Yudin (2001) based on the spectral type of OT Gem. Thus the critical fractional rotation for OT Gem is found to be only ∼0.26. This indicates that the star OT Gem is a very slow rotator and this might be an effect also due to the low inclination angle.

4.2 *Variability of the Hα line*

Circumstellar decretion disk of Be stars are formed due to the material ejected from the central star and is equatorially flattened. The emission lines seen in the spectra arise from the disk and the most common emission seen for Be stars is the Hα emission line. The radius of the Hα emission disk is estimated according to the rotational velocity law as shown in equation (2) for both the stars in the following subsections. The extent of the Hα emission region, R_d is estimated in terms of the stellar radius R_* by assuming the region to be in Keplerian orbit around the star (Huang 1972). R_d is also estimated for non-Keplerian orbit by changing the rotational parameter j from 1/2 to 1.

Table 5. FWHM and $v \sin i$ measurements for OT Gem from the spectra using HeI 6678 Å.

Date of observation	FWHM (Å)	$v \sin i$ (km s^{-1})
04/02/09	3.9	105.5
27/04/09	4.6	125.2
27/04/09	5.0	135.3
28/04/09	4.5	120.7
28/04/09	4.5	122.4
29/04/09	5.0	134.0
30/04/09	5.0	133.5
01/05/09	4.8	129.3

$$\frac{R_d}{R_*} = \left(\frac{2\, v\, \sin\, i}{\Delta V}\right)^{\frac{1}{j}}. \tag{2}$$

The variability of the Hα emission line is seen for the two stars and are discussed separately in the following subsections. The time series of the Hα profile of 59 Cyg is shown in Fig. 2 and OT Gem in Fig. 3.

4.2.1 59 Cyg – triple peak in Hα emission. The 59 Cyg was observed once on 11 July and twice on 23 July 2009 in the Hα region. Triple-peak feature in the Hα emission was observed on all the nights, where the profile shows three emission peaks in the Hα spectral line. The third central peak became prominent on 23 July compared to 11 July and appeared to be more connected to the V peak of the profile. V/R ratio was measured considering the extreme peaks and the value was initially 1 and then changed to ∼1.3 on 23 July. The I_p/I_c, EW, ΔV and V/R of Hα line for 59 Cyg has been shown in Table 6 for the two observed dates. The average values and the estimation of the radius of the disk is shown in Table 7. The error in EW and ΔV are the standard deviation of the available observations.

Slettebak *et al.* (1992) assumed Keplerian geometry for the circumstellar disk and estimated the range for the radius of the Hα emitting region in classical Be stars to be 7–19R_*. Comparing our estimation i.e., ∼10R_* to this range, we can conclude that 59 Cyg has

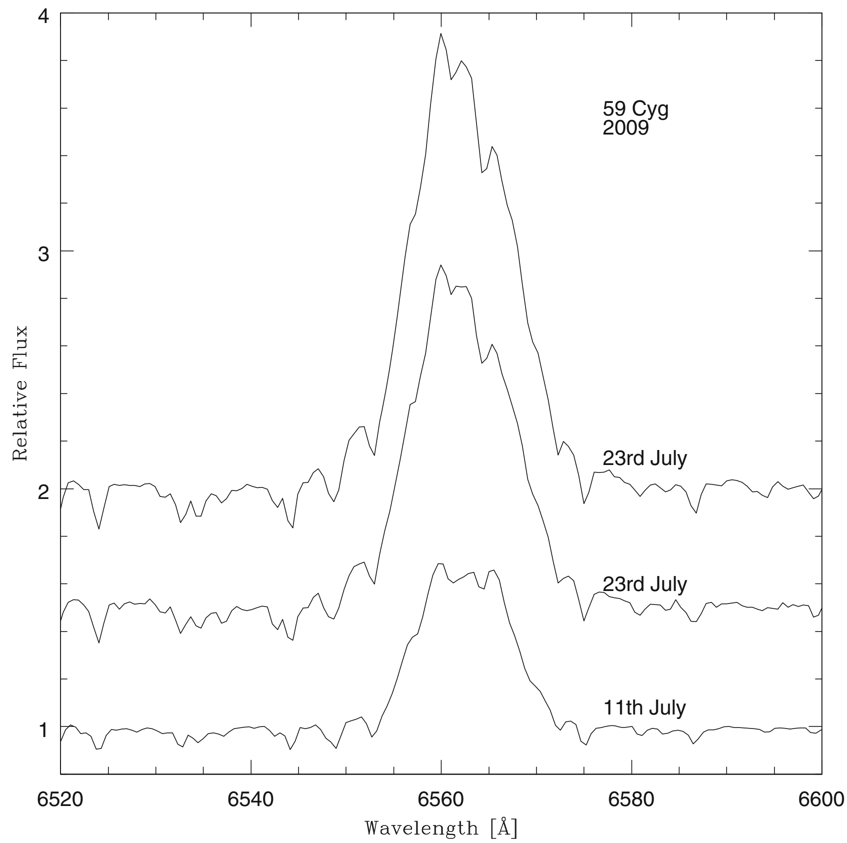

Figure 2. Time series of 59 Cyg Hα line observed in July 2009; (Spectra are offset and labelled with the observation date, the oldest appears at the bottom and most recent at the top. Note that although the spectra are displayed evenly spaced, they are not evenly distributed in time.)

a circumstellar disk, whose extent is similar to those seen for many other Be stars. We have not given the errors in the values of the radius as it would suffice to give only a typical range of them. The range of the radius of the disk is given by 8.6 – 11.6R_*. An inspection of the Hα profile suggests that the emission is going through a V/R variation and that it is shifting from $V \sim R$ to $V > R$, see Table 6. We see that the EW increased during the period mainly due to the increased emission in the violet part of the profile. All the three spectra show the presence of the peak in between the V and R peaks, giving rise to three peaks. We checked the BeSS database (Neiner *et al*. 2011) for spectra taken immediately after our observations. We found spectra obtained on 17 August 2009, 6, 7 and 10 September 2009. An inspection of the spectra obtained on 17th August 2009 suggest that, the profile is dominated by emission in the V, and the emission in the R side is found to be low, suggesting a V-dominated profile. The spectra obtained in September 2009, show that the R side of the profile is strengthened almost to the level of V, but still with a profile V/R slightly greater 1.0.

4.2.2 OT Gem – Rapid disk loss phase. The OT Gem was observed only in the Hα wavelength region during our observations. It was observed totally 8 times on 6 nights. This star showed a very good strength in Hα emission in February but later emission decreased in strength and went below the continuum level. Even though the emission had reduced significantly, the two peaks were still seen clearly in the spectra obtained in April and May. The I_p/I_c, EW, V/R, ΔV and R_d/R_* of Hα line for OT Gem are tabulated in Table 8 for all the observation dates. R_d/R_* was estimated using equation 2, by considering the $v \sin i$ to be 126 km s^{-1} for OT Gem as discussed in section 4.1. Table 8 clearly shows the change in the strength of the Hα emission line from February to April. The measurements of I_p/I_c, EW and ΔV, all show a significant change in strength.

The disk of OT Gem is seen to be dissipating and the observed variability is a result of the long-term variation associated with the disk i.e., the disk loss phase of a Be star. The period of such long-term variability for Be stars can be generally from several years to several decades (Rivinius *et al.* 2013). The OT Gem was

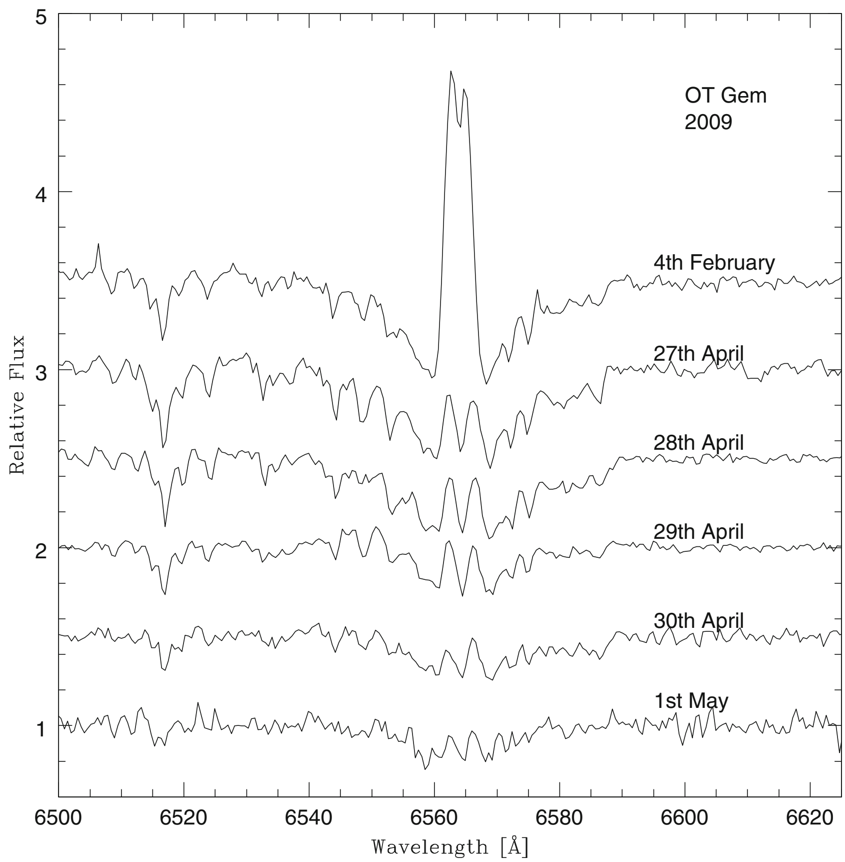

Figure 3. Time series of OT Gem Hα line from February to May 2009; (Spectra are offset and labelled with the observation date, the oldest appears at the top and most recent at the bottom. Note that although the spectra are displayed evenly spaced, they are not evenly distributed in time.)

Table 6. Measurements of parameters using Hα emission for 59 Cyg.

Date of observation	I_p/I_c	EW (Å)	ΔV (km s^{-1})	V/R
11/07/2009	1.69	–11.0	259.8	1.04
23/07/2009	1.96	–13.2	243.3	1.3
23/07/2009	1.96	–12.7	241.4	1.33

observed by few amateur astronomers and the spectra is archived in BeSS database (Neiner *et al.* 2011). From BeSS, it is observed that in 2009, during the time of our observation, there is only one spectra in March and as expected, it shows a decrease in strength compared to our February observations. Later, the star continued to have a decreased strength in 2010 but suddenly had an increase in emission strength during 2011. It again decreased in strength during 2012, eventually going into absorption in 2013. The 'B-phase' has continued till March 2016 and is showing an emission again from April 2016. The period of our observation might be during short rapid phase within a period of slow dissipation. The recent re-building of the disk can be an interesting observation and continuous monitoring of this star is being carried out.

As previously mentioned, the radius of the Hα emitting region given by Slettebak *et al.* (1992) is 7–19R_*. The range of radius during our observations for OT Gem is between 1.7–6.9R_*. In February, the OT Gem had a radius which was already below the general observed range and later in April, it went below the limit. In this episode of disk loss, the outer disk is lost and the feeble emission comes from only the inner disk. OT Gem lost about a little more than half of its disk within three months. We have captured this short-term phenomenon of sudden loss of disk and detected a change in the disk radius as well. This clearly indicates the need of continuous monitoring of such systems. There are very less spectroscopic study of OT Gem in the past. Thus our study would add significantly for any future variability study of this star.

Table 7. Hα emission line parameters and estimation of the radius of the disk for 59 Cyg.

I_p/I_c	EW (Å)	ΔV (km s^{-1})	$v \sin i^{\dagger}$ (km s^{-1})	R_d/R_* $j = 1/2$	R_d/R_* $j = 1$
			364	8.63	2.94
			421	11.55	3.40
1.87	–12.26 ± 0.66	248.2 ± 5.9			
			379	9.33	3.05
			260	4.39	2.10

†Refer Table 4.

Table 8. Hα emission line parameters and estimation of the radius of the disk for OT Gem.

Date of observation	I_p/I_c	EW (Å)	V/R	ΔV (km s^{-1})	R_d/R_* $j = 1/2$	R_d/R_* $j = 1$
04/02/09	1.34	−4.1	1.09	96.0	6.89	2.63
27/04/09	0.95	−0.7	0.83	181.8	1.92	1.39
27/04/09	0.96	−0.7	0.92	165.7	2.31	1.52
28/04/09	0.96	−0.8	1.00	194.8	1.67	1.29
28/04/09	0.97	−0.7	1.12	191.2	1.74	1.32
29/04/09	0.95	−0.8	0.84	174.6	2.08	1.44
30/04/09	0.96	−0.6	2.11	190.3	1.75	1.32
01/05/09	0.97	−0.8	1.98	167.7	2.26	1.50

4.3 *Discussion*

In this study, we have captured two different types of short-term variation in classical Be stars, helpful in providing insights into the properties of their circumstellar disk. We also estimated various parameters of the two stars, 59 Cyg and OT Gem. We estimated the rotational velocity, $v \sin i$ of the stars to be 406 ± 25 km s^{-1} for 59 Cyg and 126 ± 4 km s^{-1} for OT Gem. 59 Cyg has been classified as emission ⇔ emission and shell transition type of star by Rivinius *et al.* (2006). Thus, the very high rotational velocity generally seen for shell stars is observed even for 59 Cyg. Whereas, OT Gem has been classified as a non-shell star by Hanuschik (1996) and thus the estimated low rotational velocity is consistent with the definition of shell star being an edge-on star and non-shell star having a lower inclination angle. By assuming the critical velocity based on the spectral class, we estimated that the fractional critical rotation is about 0.78 for 59 Cyg, suggesting that the star is rotating very close to the break-up velocity. For OT Gem, the fractional critical rotation is only about 0.26 which indicates that it is a very slow rotator, or viewed in low inclination. We also estimated the radius of Hα emission, and is found to be in the range 8.6–11.6R_* for 59 Cyg and 1.7–6.9R_* for OT Gem. In summary, we find that 59 Cyg is a fast rotator with the Hα emission region far from the star and OT Gem is a slow rotator or viewed in low inclination, with a feeble emission coming from the inner disk very close to the star.

59 Cyg is known to be a Be binary with a sdO companion (Maintz *et al.* 2005). It is often compared to ϕ Per as they both are binaries with sdO companion and also have been reported similar profile variations. The emission sometimes show rapid variability. The rapid variability is likely to be associated with the changes in the distribution of material within the disk. Maintz *et al.* (2005) reported the phase-locked emission variability of 59 Cyg to have a period of 28.192 days. The appearance of the third peak has been observed for a few other well known classical Be stars like ϕ Per, ζ Tau, ν Gem, χ Gem, Pleione.

Štefl *et al.* (2007) reported V/R variations of ζ Tau, ν Gem, ϕ Per along with others. They reported that a triple-peak profile was observed in ζ Tau and ν Gem. They observed that the triple-peak appeared only in a particular part of the phase. In the case of ζ Tau, the triple-peak appeared during the $V < R$ to $V > R$ transition, whereas it appeared during the $V > R$ to $V < R$ transition for ν Gem. The triple peak and the V/R

variation detected in 59 Cyg, is similar to that of ζ Tau. Thus stars which show triple-peak profile can be classified into two types:

(1) $V > R$ to $V < R$ transition: Case-I (e.g. ν Gem).
(2) $V \leq R$ to $V > R$ transition: Case-II (e.g. ζ Tau, 59 Cyg).

Case I can be seen as a case of a perturbation moving in the disk, with the same sense of rotation of the disk, and hence a prograde case. Štefl *et al.* (2007) stated that the triple-peak case can neither be explained by Okazaki's model (Okazaki 1991) nor by the rapidly expanding circumstellar ring model of Arias *et al.* (2007). They concluded that the link to the phase of the $m = 1$ oscillation and assumed Keplerian rotation are inconsistent with large radial velocity fields in the disks. Štefl *et al.* (2007) mentioned that disks with large eccentricity can precess in a prograde direction and ν Gem is found to have large eccentricity. In Case II, the perturbation has to move with the opposite sense of rotation and hence can be termed as the retrograde case. Thus, in 59 Cyg and in ζ Tau, the appearance of triple-peak and the V/R variation are in the opposite sense and is thus, a retrograde case. This retrograde kind of motion is difficult to explain since the density sub-structure has to move against the sense of rotation of the disk to be seen as the third peak. Štefl *et al.* (2007) also reiterated that the appearance of triple-peak is not related to the binary period. 59 Cyg has a very large radial velocity field due to the large Hα emission region as reported in our study. We have been able to capture this short-lived triple-peak emission in Hα, which is generally seen in binary systems. We still do not fully understand the triple-peak profile. The triple-peak feature is not seen in many stars and our study shows that all such stars are different from each other. Further observations and continuous monitoring of such stars during different V/R phase can provide valuable inputs to the understanding of processes in the circumstellar disk.

OT Gem underwent a short-term disk loss during our observations. We captured the phase of disk loss and detected a change in the disk radius of the star within three months of observations. During dissipation of the disk, the Hα emitting region shrank, from about 6.9 to 1.7. This might suggest that the disk is dissipated from outside to inside. The outer disk is lost initially and later the feeble emission is still seen due to the inner disk. This star showed a disk loss in a very short time scale unlike the general duration of years to decades. Also, at present from BeSS database (Neiner *et al.* 2011), this star is seen to have emission which means that the star is building the disk again and would be an interesting case to determine the period of such variability. This is the second time that the emission has reappeared after our 2009 observations. We demonstrate that monitoring of these systems are important to understand the way in which the Be star disk is dissipated as well as rejuvenated.

Our study reveals that short-term monitoring is important to understand different types of variations seen in the classical Be stars. The short term variations which are detected in our observations give valuable insights into their circumstellar disk and the physical processes governing the material in the disk. This study also is important, especially since these observations can be performed with moderate telescope equipped with a spectrograph.

5. Conclusions

(1) We have presented the spectroscopic analysis of the two classical Be stars, 59 Cyg and OT Gem which were observed in 2009.
(2) The rotational velocity, $v \sin i$ was calculated using HeI lines and is found to be $\sim$400 km s^{-1} for 59 Cyg and $\sim$130 km s^{-1} for OT Gem . The fraction of critical rotation for 59 Cyg is found to be $\sim$0.8, suggesting it to be a rapid rotator and $\sim$0.3 for OT Gem, indicating it to be a slow rotator or viewed in low inclination.
(3) The radius of the circumstellar disk R_d/R_* using the Hα double-peaked emission profile is found to be $\sim$10.0, assuming a Keplerian orbit for 59 Cyg. This implies that the Hα emission disk is very large for 59 Cyg.
(4) Triple-peak is observed for 59 Cyg and the Hα profile variation is also detected. We make an attempt to classify stars observed to show triple-peak into two groups. The mechanisms for the formation of triple-peak in both the cases remains a mystery.
(5) The EW of the Hα emission line profile for OT Gem varied from -4.1 to -0.7 Å in a span of four months.
(6) OT Gem underwent a disk loss phenomenon during our observations and lost the outer disk very rapidly but continued to have a feeble emission from the inner disk. This suggests that the disk loss happened from outside to inside during this phase.
(7) We conclude and confirm that these two stars show rapid short-term variations in Hα emission and their close monitoring is important to understand the physical processes in their circumstellar disk.

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