Süleyman Demirel Üniversitesi Fen Edebiyat Fakültesi Fen Dergisi
Süleyman Demirel University Faculty of Arts and Sciences Journal of Science
2018, 13(2): 72-82
DOI: 10.29233/sdufeffd.440797

Frequency Analysis of a Potential SPB Star η Tau

Doğuş ÖZUYAR[*1, 2]

[1]*Ankara University, Science Fac., Dept. of Astronomy and Space Sci., 06100, Ankara, Turkey*
[2]*The University of Birmingham, School of Physics and Astronomy, B152TT, Birmingham, UK*
**corresponding author email: dozuyar@ankara.edu.tr*

(Received: 04.07.2018, Accepted: 12.10.2018, Published: 30.11.2018)

Abstract: In this study, five years of photometric data of η Tau obtained from the *STEREO* satellite between 2007 and 2011 are presented. The high-precision data are compared with the results derived from the spectroscopic findings to gain a better understanding of the Be phenomenon in the star. The spectroscopic data cover the same time interval as the photometric observations. η Tau displays a double peaked Hα emission profile in its spectra. In order to analyze this profile, the Hα emission lines are examined by measuring their equivalent widths and line intensities. As a result of the photometric and spectroscopic analyses, it is revealed that the frequency distribution and amplitude intensities of the star are different from those of a typical Be star. Based on its physical parameters such as temperature and luminosity values, it may be conclude that the star is a Slowly Pulsating B type emission star. On the other hand, the equivalent width values of the emission lines does not appear to be clearly related to the oscillation frequencies and their amplitudes. Therefore, it can be concluded that there is no significant relation between the photometric variations and environmental disk structure.

Key words: η Tau, Emission line, Be stars, Data analysis, STEREO satellite

Potansiyel Bir SPB Yıldızı Olan η Tau Yıldızının Frekans Analizi

Özet: Bu çalışmada, η Tau yıldızının 2007 ile 2011 yılları arasında *STEREO* uydusundan alınan beş yıllık fotometrik verileri sunulmaktadır. Yüksek duyarlılığa sahip veriler, yıldızdaki Be olgusunu daha iyi anlamak için tayfsal bulgulardan elde edilen sonuçlarla karşılaştırılmıştır. Tayfsal veriler fotometrik gözlemlerle aynı zaman aralığını kapsamaktadır. η Tau, tayflarında çift pikli Hα salma profili göstermektedir. Bu profili analiz etmek için, Hα salma çizgileri, eşdeğer genişlikleri ve çizgi şiddetleri ölçülerek incelenmiştir. Fotometrik ve tayfsal analizler sonucunda, yıldızın frekans dağılımı ve genlik şiddetlerinin tipik bir Be yıldızından farklı olduğu ortaya çıkmıştır. Sıcaklık ve parlaklık değerleri gibi fiziksel parametrelerine dayanarak yıldızın Yavaş Zonklayan B tipi bir emisyon yıldızı olduğu sonucuna varılabilir. Diğer yandan, emisyon çizgilerinin eşdeğer genişlik değerleri, salınım frekansları ve genlikleri ile açıkça ilişkili görünmemektedir. Dolayısıyla, fotometrik değişimler ile çevresel disk yapısı arasında önemli bir ilişki olmadığı sonucuna varılabilir.

Anahtar kelimeler: η Tau, Emisyon çizgisi, Be yıldızları, Veri analizi, STEREO uydusu

For Citation: D. Özuyar, "Frequency Analysis of a Potential SPB Star η Tau", *Süleyman Demirel Üniversitesi Fen Edebiyat Fakültesi Fen Dergisi*, 13(2), 72-82, 2018.

1. Introduction

Be-type variables are defined as non-supergiant B-stars exhibiting spectral line emissions in the hydrogen Balmer series, particularly in the Hα line [1]. Despite sharing the same region with *β* Cephei and Slowly Pulsating B stars (SPB) on the H-R diagram, classical Be-stars have higher rotational velocities (250-500 km/s; [2]). They demonstrate periodic modulations in their light curves (LCs) and have line profiles changing on time-scales from minutes to decades. Long-term variations are attributed to a dense circumstellar disk ejected from the star [3-5]; the emission lines observed are thought to be connected with this equatorial disk. Also, short-term changes are ascribed to non-radial pulsations (NRPs), which might be responsible for the formation of the circumstellar disk.

Disk structure seems to be a persistent feature in some Be-stars whereas it is much more sporadic in others. Its formation and dissipation stand out as a transformation from a normal B-star to a B-emission or a Be-shell star in the spectrum [6]. Although it is not clear why only some B-stars turn into Be-variables, the evolutionary stage of the central star and its rapid rotation are considered to be the keystones for this phenomenon [3]. However, the actual rotational velocity of the star cannot be easily calculated due to gravity darkening [7]. Further, the rotation might not be the main reason for mass ejections since most of the Be-stars rotate below the critical break-up velocity.

To gain a better understanding of all these properties, it is important to observe several Be stars both photometrically and spectroscopically. This study presents five years of photometric and spectroscopic data of η Tau, collected from the *STEREO* satellite and archival sources, respectively. The pulsation characteristics, particularly variations in both frequency and amplitude of the star are revealed and compared to the spectroscopic results. Following this, the connection between the circumstellar disk structure and NRPs is discussed.

η Tau (B7III, V = 2.87 mag) is a well-studied bright emission star and the primary component of a binary system [8]. The first important spectroscopic research on this star was performed by [9], who stated that there was no significant variation in the Hα emission profile from 1953 to 1976. Slettebak and Reynolds (1978) [10] confirmed this constancy between 1975 and 1977, and reported a single-peaked structure. Unlike these studies, Andrillat and Fehrenbach (1982) [11] observed a double-peaked and broad Hα emission showing no equivalent width (EW) variation.

The spectral analysis performed by Jarad et al. (1989) [12] exhibited no change in emission line. However, they detected three significant frequencies at 0.2419, 1.2416, and 2.2439 c/d in the power spectrum. After the first EW value was given by Apparao et al. (1993) as -6.90(5) Å, Banerjee et al. (2000) [14] determined the Hα line parameters to be: separation of V and R components (Δν) = 1.543 Å, FWZI = 12.73 Å, FWHM = 5.08 Å, EW = -8.62 Å and V/R = 1.02. They described the line feature as symmetrical with regards to V and R components. Their study also pointed out that emission strength was 30% higher than the continuum level. Since the profile had remained constant for many years, Tycner et al. (2005) [15] considered this situation as an incorrect continuum normalization, which resulted in a miscalculation of peak intensity. For this reason, they made corrections for the filling-in effects of absorption profile based on the procedure suggested by Cote (1987) [16], and gave the net EW to be -10.2(3) Å. Goraya et al. (2009) [17] reported a symmetrical, sharp, and single-peaked emission profile with an EW of -3.61 Å, and stated that emission line was associated with a disk-shaped absorption line, so violet and red edges remained under the continuum level. Recently, the mean EW value was calculated as -3.1 Å by Jones et al. (2011) [18]. Their *F*-test (F = 12.24) also showed that the Hα line profile was variable at the greater than 99% confidence level.

2. Material and Method

The high-precision photometric data of η Tau are taken from the HI-1A instrument of the *STEREO* satellite between 2007 and 2011. Annual data comprised an observation interval of ~20 days. The cadence of each data chunk is 40 minutes and the Nyquist frequency is around 18 c/d. More information about the HI instruments and data preparation can be accessed from [19-21].

In order to carry out an effective examination of the star, the analysis was advanced in two different ways. In order to clean LCs from external and internal effects [20], an IDL[1] pipeline coded in house was used, and thus the most appropriate data for NRP detection were obtained. Five years of annual and combined time series were analyzed with the Lomb-Scargle (LS) algorithm. For each periodogram, regional noise levels were determined by averaging the noise values in every 0.5 c/d, and a specific noise characteristic was thus established. Based on this characteristic, the significance level was calculated with 99% probability. Those frequencies whose amplitudes were greater than this level were then detected.

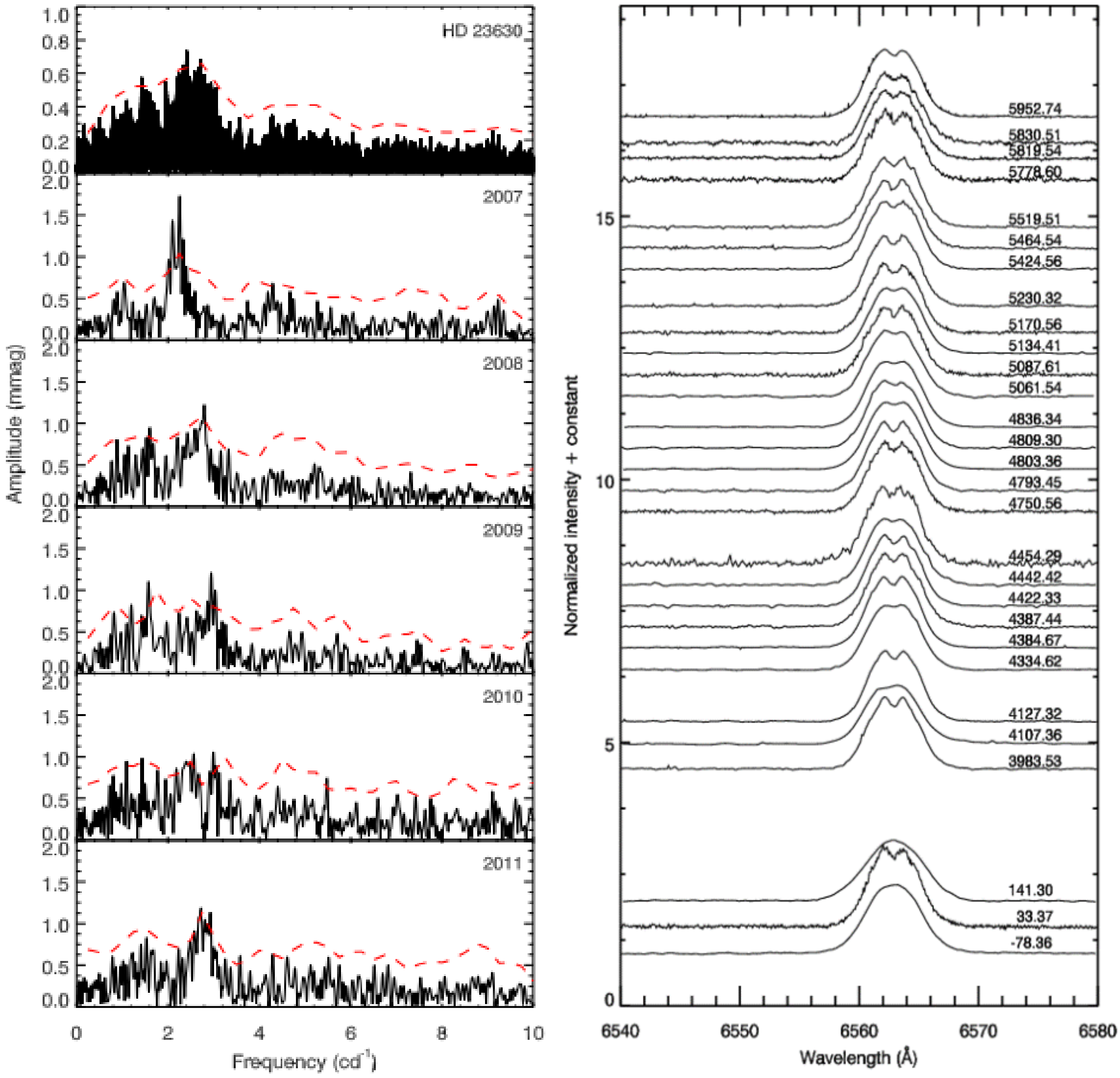
The photometric data were supported with 29 low- to mid-resolution Hα observations taken from the Be Star Spectra Database [22]. These spectra were taken from different observation sites by the help of several equipment in France and Spain between 2006 and 2012. In order to conduct the analysis, I applied heliocentric velocity corrections, and removed telluric lines by using a reference spectrum. The margin of error was considered to be 3% for the continuum normalization [18]. I also used the SPLOT package of the IRAF for the calculation.

3. Results

In this study, I analyzed combined and seasonal light curves of η Tau. As seen in Figure 1a, each periodogram displayed a complicated frequency spectrum, which prevented the detection of significant peaks in time series analysis. However, I was able to determine 10 frequencies in the five-year (2007-2011) combined data. These frequencies were obtained based on a specific significance threshold, shown with a dashed line in the figure. From the three periods given by Jarad et al. (1989) [12], I found only the frequency at 2.2413 c/d; it was not possible to identify either 0.24 c/d or 1.24 c/d in the combined periodogram. Further, I determined that the seasonal amplitude spectra contained a few, relatively distinctive peak region around 2.00 c/d, and other frequencies were gathered around it. The details of these findings are presented in Table 1 and Table 2.

As shown in Figure 2 (the second row), the seasonal main frequencies appeared to be considerably variable. Accordingly, the frequency increased from 2.25 c/d on HJD2454223 to 2.99 c/d on HJD2455257, and dropped down to 2.72 c/d on HJD2455601. In addition, the frequency at around 2.96 c/d had a similar downward-curving change, whereas the variations in 2.43, 2.58 and 2.68 c/d exhibited an increasing trend over time. Compared to the amplitudes of these frequencies, the only significant change was seen in

[1] https://www.harrisgeospatial.com/Software-Technology/IDL



(a) **(b)**

Figure 1. **(a)** Five years of combined and seasonal amplitude spectra of HD 23630, **(b)** the Hα emission profiles obtained between 2006 and 2012. The numbers given on the right-hand side are the mid-observation times in Heliocentric JD (HJD-2450000).

the amplitudes of the f_1 values. Contrary to the change in the main frequencies, their amplitudes showed an upward-curving parabolic variation between HJD2454223 and HJD2455601. However, it should be considered that none of the amplitude spectra showed clear peaks, and that these variabilities might not be real, due to miscalculations. Furthermore, I detected reflections of a δ Scuti type variation at 16.4484 c/d in the periodograms. Thus, this variation might be responsible for the complexity of the amplitude spectra, and hence for the inconsistency in the frequencies.

Table 1. Frequency analysis results for the five-year combined data.

HD 23630 Frequencies						
Mid-Obs.Time (HJD)	**No #**	**Freq. (c/d)**	**Amp. (mmag)**	**SNR**	**A_m (mmag)**	**Comments**
Combined	f_1	2.41217(4)	0.79(09)	4.43	0.18	

	f_2	2.71428(4)	0.80(09)	4.31	0.19	
	f_3	2.66768(6)	0.62(09)	3.38	0.18	
	f_4	2.33646(5)	0.67(09)	3.75	0.18	
	f_5	2.24125(5)	0.65(09)	3.61	0.18	
	f_6	2.57472(6)	0.62(09)	3.44	0.18	$3f_3 - 2f_2$
	f_7	2.80538(6)	0.60(09)	3.19	0.19	
	f_8	2.48498(6)	0.59(09)	3.32	0.18	
	f_9	1.43392(6)	0.56(09)	3.65	0.15	
	f_{10}	1.95915(6)	0.54(09)	3.33	0.16	$2f_4 - f_2$

Table 2. Frequency analysis results for the seasonal data.

Mid-Obs.Time (HJD)	No #	Freq. (c/d)	Amp. (mmag)	SNR	A_m (mmag)	Comments
			2007 Frequencies			
2454223	f_1	2.255(3)	1.59(16)	4.95	0.32	
	f_2	2.104(3)	1.85(16)	6.48	0.29	
	f_3	2.185(3)	1.37(16)	4.30	0.31	
	f_4	2.327(5)	1.02(16)	3.28	0.31	
	f_5	4.291(6)	0.79(16)	3.90	0.20	$2f_3$
	f_6	4.197(7)	0.68(16)	3.29	0.21	$2f_2$
			2008 Frequencies			
2454568	f_1	2.801(4)	1.28(18)	4.03	0.32	
	f_2	2.756(4)	1.32(18)	3.93	0.34	
	f_3	1.606(6)	0.95(18)	3.69	0.26	
	f_4	2.582(5)	1.03(18)	3.22	0.32	$3f_2 - 2f_1$
	f_5	2.707(5)	1.01(18)	3.02	0.34	
	f_6	2.425(6)	0.95(18)	3.22	0.29	$2f_4 - f_2$
	f_7	0.884(7)	0.80(18)	3.31	0.24	$f_6 - f_3$
	f_8	3.335(7)	0.75(18)	3.44	0.22	$f_6 + f_7$
			2009 Frequencies			
2454912	f_1	2.952(5)	1.11(17)	4.67	0.25	
	f_2	1.580(5)	1.10(17)	4.64	0.23	
	f_3	3.052(6)	0.89(17)	3.55	0.25	
	f_4	1.202(7)	0.77(17)	4.24	0.18	$2f_1 - f_2 - f_3$
	f_5	2.242(7)	0.77(17)	3.45	0.23	$f_1 + 2f_4 - f_3$
			2010 Frequencies			
2455257	f_1	3.000(5)	1.26(21)	5.07	0.25	
	f_2	2.564(5)	1.13(21)	4.32	0.26	
	f_3	2.427(5)	1.34(21)	4.92	0.27	
	f_4	2.343(5)	1.23(21)	4.62	0.27	$2f_3 - f_2$
	f_5	1.439(7)	0.95(21)	3.24	0.29	$f_2 + 2f_3 - 2f_1$
	f_6	3.046(6)	0.98(21)	3.69	0.27	
	f_7	1.103(7)	0.87(21)	3.17	0.28	$f_2 - f_5$

	f_8	2.656(6)	0.98(21)	4.16	0.24	$2f_2 - f_3$
	f_9	2.179(7)	0.93(21)	3.88	0.24	$2f_7$
	f_{10}	5.478(9)	0.73(21)	3.66	0.20	$f_1 + f_3$
2011 Frequencies						
2455601	f_1	2.723(4)	1.41(18)	4.09	0.34	
	f_2	2.929(4)	1.22(18)	4.29	0.28	
	f_3	2.586(4)	1.32(18)	4.77	0.28	$2f_1 - f_2$
	f_4	2.672(4)	1.21(18)	3.71	0.33	
	f_5	2.875(5)	1.06(18)	3.36	0.32	
	f_6	2.447(6)	0.86(18)	3.51	0.25	$2f_1 - f_2$
	f_7	3.575(9)	0.59(18)	3.64	0.16	

Apart from these, 29 spectra of the star covering the period between 1995 and 2012 were examined in detail (Figure 1b). However, only the results between 2006 and 2012 are given in Figure 2 (the first row) in order to compare them with the photometric findings obtained in the same time period. Accordingly, it was confirmed that a great number of the Hα lines was formed of double-peaked structures, as reported by Andrillat and Fehrenbach (1982) [11] and Slettebak (2007) [23]. The rest of the spectra showed single-peak profiles as mentioned by Slettebak and Reynolds (1978) [10], but I determined that these single peaks occurred due to low spectrometer resolutions ($6000 \leq R \leq 8000$) instead of emission variations. I also found that V/R ratios were almost constant between 2006 and 2012. I calculated the mean ratio of this variation to be V/R = 1.12. Moreover, I detected that the separation of V and R peaks varied from 1.24 Å to 1.61 Å (mean separation $\Delta v = 1.52$ Å) over six years.

As shown in Figure 2, the EWs of the Hα profile decreased from -7.07 Å on HJD2454454 to -6.23 Å on HJD2455464. I calculated the degree of the variation to be $F = 0.987$ with the confidence level of $C = 49\%$ by using the F-test. Since the F value was quite close to 1.0, this variation might be considered as insignificant. By fitting the EWs with the least-squares method, the variation seemed to show a sinusoidal structure with extremum points on HJD2454379 and HJD2455601. The half-period of this structure was estimated to be around 3.62(12) years.

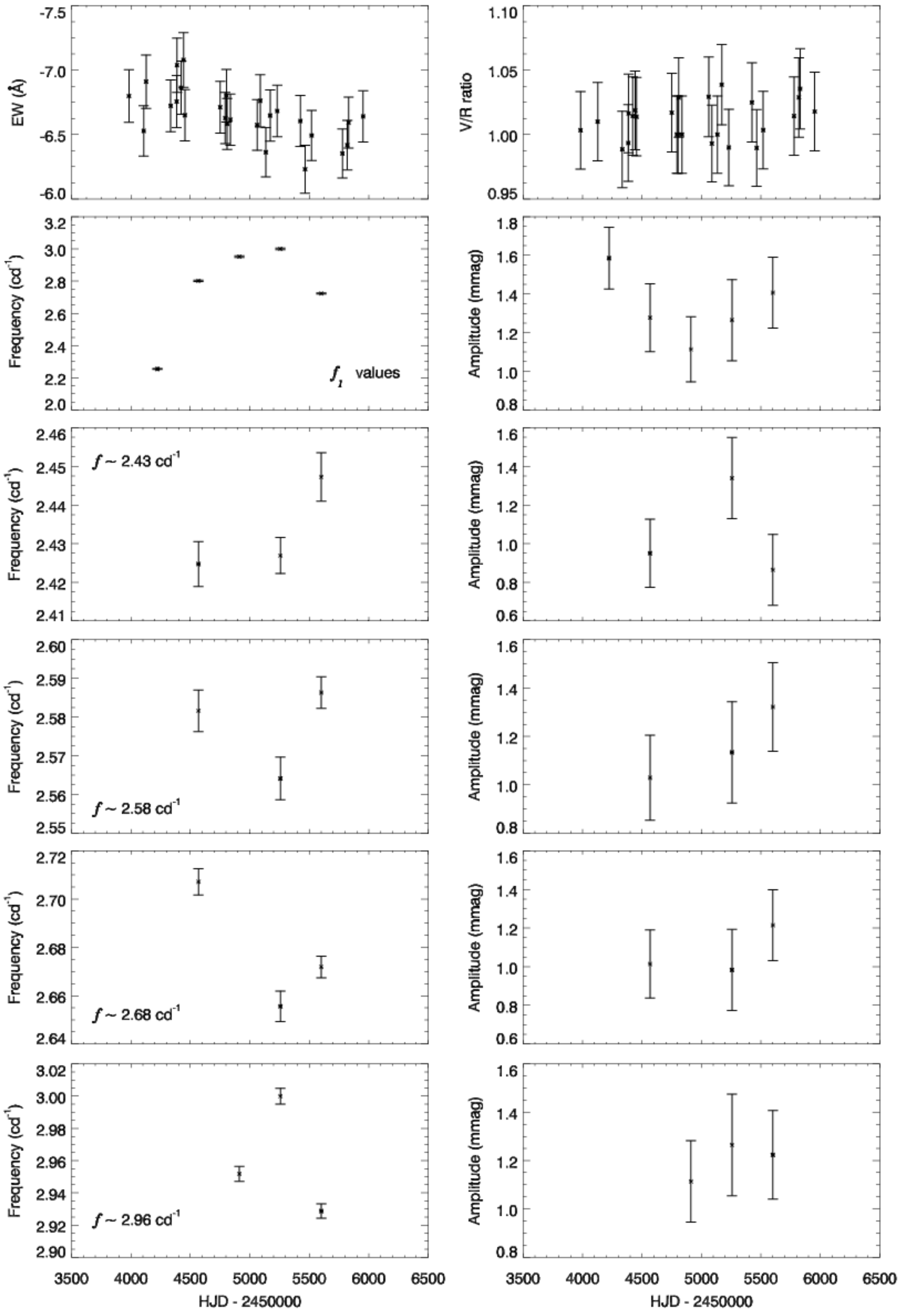


Figure 2. A comparison of photometric and spectroscopic results is given in the figure. The variations in the Hα line are given in the first row and the potential changes in both frequencies and amplitudes derived from *STEREO* LCs are presented in the following rows.

A comparison of the photometric and spectroscopic data indicated no specific correlation between frequency and EW variations. However, the change in the main frequencies seemed to be inversely correlated with the EW variations, whereas the amplitudes of these frequencies showed a similar change with EWs.

4. Conclusion and Comment

In this study, five years of consecutive LCs belonging to η Tau were obtained from the HI-1A instrument of the *STEREO* satellite. The data were collected between 2007 and 2011 to detect a maximum number of periodicities and establish a connection with the archival spectroscopic data taken in the same time interval.

As a result of the Fourier analyses, I not only discovered a great number of frequencies, but also revealed valuable information related to the pulsation characteristic of the star. The most important feature standing out in both seasonal and combined periodograms was that η Tau did not demonstrate explicit frequency groups similar to those of typical Be stars. Additionally, the amplitude intensities of the star were notably lower. The star also displayed NRPs with similar amplitude intensities instead of one or two dominant peaks. As discussed by Percy (2007) [24], this type of structure is a typical characteristic of late-type SPB stars, and is an indication of a replacement of the convective core with a radiative dense one. In the radiative dense core, the Brunt-Vaisala frequency is quite high. This therefore causes a radiative damping that results in a shortening of the wavelengths of g-modes [25].

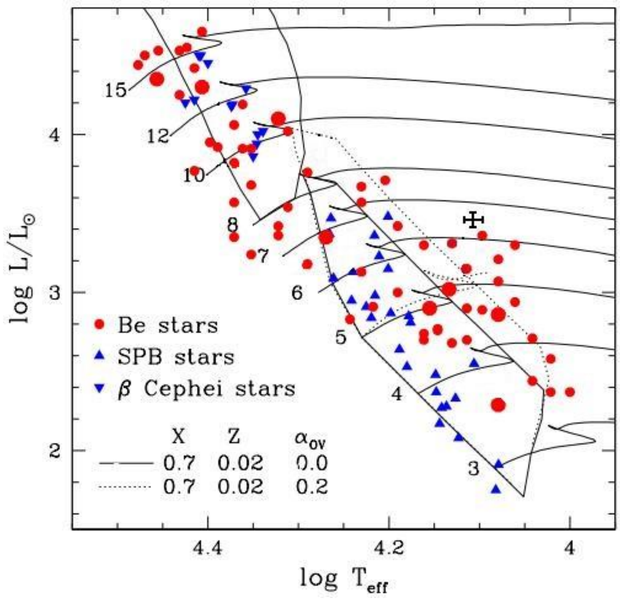


Figure 3. Position of η Tau on the H-R diagram is presented in the figure. SPB and *β* Cephei type stars are shown with triangles and inverted triangles, respectively. Archival Be-stars are given with red filled circles. Big filled circles represent the Be-stars with NRPs found by MOST and CoRoT satellites. Theoretical models are generated based on *X* = 0.7 and *Z* = 0.02. Solid lines are evolutionary tracks and instability boundaries for p- and g-modes produced from models without core overshooting and dotted lines are from models with core overshooting of 0.2 Hp (taken from Saio (2013) [25]).

In order to confirm whether η Tau is an SPB type star, the position of the star on the H-R diagram was investigated. Its temperature value (*logT* = 4.110(10)) was taken from Fremat et al. (2005) [26]. Since there was no luminosity value in the literature, this physical parameter (*log* $(L/L_{\odot})$ = 3.435(44)) was estimated from Hipparcos parallax and spectral type by following [27]. These parameters were then used in the model produced by Saio (2013) [25] for comparison (Figure 3). In Figure 3, the locations of SPB and β Cephei type stars taken from Saio (2013) [25] are shown with triangles and inverted triangles, respectively. Archival Be-stars and the STEREO samples are given with red filled circles and black plus symbols, respectively. Large filled circles represent the Be-stars with NRPs found by MOST and CoRoT satellites. Theoretical models are generated based on X = 0.7 and Z = 0.02. Solid lines are evolutionary tracks and instability boundaries for p- and g-modes produced from models without core overshooting, and dotted lines are from models with core overshooting of 0.2 Hp. According to this figure, η Tau is not exactly located within the SPB instability strip but quite close to it. The inconsistency in the position on the H-R diagram may be explained by the uncertainties of the physical parameters of the star. Still, the location of the star around the SBP instability strip confirms the abnormal oscillation behaviors in the periodograms.

Moreover, the variation degree of the EW values is close to 1.0 (F = 0.987) and this means that the variation in the Hα emission line might not be significant. Also, the change seen in EWs does not seem to show a clear correlation with the photometric frequencies and their amplitude. Apart from this point, it should be mentioned that sudden frequency or amplitude variations are also seen in the periodograms. Even though there is a possibility that these short time-scale changes are a consequence of our LC refinement procedure, they coincide with critical variations in EWs: the jumps and drops in η Tau (the frequencies of 2.58, 2.68, and 2.96 c/d) may be connected with the mass loss process as well as disk formation.

Since η Tau is not a well-studied star, it is not possible to make a final decision related to the connections between NRPs and circumstellar material around the star; more photometric and spectroscopic observations are needed to confirm such a relationship. However, although *STEREO* has a shorter seasonal observation duration and collects less data points compared to other space missions, its high-precision measurements and uninterrupted monitoring ability enable researchers to measure NRPs with great accuracy and provide hints about the interactions between these pulsations and mass loss, disk formations, and variations in emission lines. In this sense, the *STEREO* satellite is an important resource in terms of analyzing the behavior of Be-stars.

Acknowledgments

I acknowledge assistance from Prof. Dr. Ian R. Stevens, Dr. Vino Sangaralingam and Dr. Gemma Whittaker in the production of the data used in this study. This work has made use of the BeSS database, operated at LESIA, Observatoire de Meudon, France: http://basebe.obspm.fr. The STEREO Heliospheric imager was developed by a collaboration that included the Rutherford Appleton Laboratory and the University of Birmingham, both in the United Kingdom, and the Centre Spatial de Lige (CSL), Belgium, and the US Naval Research Laboratory (NRL), Washington DC, USA. The STEREO/SECCHI project is an international consortium of the Naval Research Laboratory (USA), Lockheed Martin Solar and Astrophysics Lab (USA), NASA Goddard Space Flight Center (USA), Rutherford Appleton Laboratory (UK), University of Birmingham (UK), Max-Planck-Institut fr Sonnen-systemforschung (Germany), Centre Spatial de Lige (Belgium), Institut dOptique Thorique et Applique (France) and Institut dAstrophysique Spatiale (France). This research has made use of the SIMBAD data base, opened at CDS, Strasbourg, France. This research has also made use of NASA's Astrophysics Data System.

References

[1] M. Jaschek, C. Jaschek, A. M. Hubert-Delplace, and H. Hubert, "A classification of Be stars," *Astronomy and Astrophysics Supplement Series*, vol. 42, pp.103-114, October 1980.
[2] O. Struve, "On the Origin of Bright Lines in Spectra of Stars of Class B," *Astrophys. J.*, vol. 73, pp. 94, March 1931.
[3] J. M. Porter and T. Rivinius, "Classical Be Stars," *Publ. Astron. Soc. Pac.*, vol. 115, pp. 1153-1170, October 2003.
[4] A. C. Carciofi, A. T. Okazaki, J. B. Le Bouquin, S. Stefl, T. Rivinius, D. Baade, J. E. Bjorkman, and C. A. Hummel, "Cyclic variability of the circumstellar disk of the Be star ζ Tauri. II. Testing the 2D global disk oscillation model," *Astron. Astrophys.*, 504:915-927, September 2009.
[5] S. R. Cranmer, "A Pulsational Mechanism for Producing Keplerian Disks Around Be Stars," *Astrophys. J.*, vol. 701, pp. 396-413, August 2009.
[6] T. A. A. Sigut and P. Patel, "The Correlation between Hα Emission and Visual Magnitude during Long-term Variations in Classical Be Stars", *Astrophys. J.*, vol. 765, pp. 41, March 2013.
[7] R. H. D. Townsend, S. P. Owocki, and I. D. Howarth, "Be-star rotation: how close to critical?," *Mon. Not. R. Astron. Soc.*, vol. 350, pp. 189-195, May 2004.
[8] H. A. Abt and O. Cardona, "Be stars in binaries," *Astrophys. J.*, vol. 285, pp. 190-194, October 1984.
[9] A. M. Hubert-Delplace and H. Hubert, "An atlas of Be stars", *Paris-Meudon Observatory,* 1979.
[10] A. Slettebak and R. C. Reynolds, "Halpha variations in spectra of the brighter, northern Be stars", *Astrophysical Journal Supplement Series*, vol. 38, pp. 205-228, November 1978.
[11] Y. Andrillat and C. Fehrenbach, "Study of H-alpha profile in 72 Be stars", *Astronomy and Astrophysics Supplement Series*, vol. 48, pp. 93-136, April 1982.
[12] M. M. Jarad, R. W. Hilditch, and I. Skillen, "A radial-velocity study of 18 emission-line B stars", *Monthly Notices of the Royal Astronomical Society*, vol. 238, pp. 1085-1106, June 1989.
[13] K. M. V. Apparao, S. P. Tarafdar, R. P. Verma, K. V. K. Iyengar, and K. K. Ghosh, "Simultaneous infrared and H-alpha measurements of Be stars", *J. Astrophys. Astron.*, vol. 14, pp. 131-134, December 1993.
[14] D. P. K. Banerjee, S. D. Rawat, and P. Janardhan, "Hα observations of Be stars," *Astronomy and Astrophysics Supplement Series*, vol. 147, pp. 229-242, December 2000.
[15] C. Tycner, J. B. Lester, A. R. Hajian, J. T. Armstrong, J. A. Benson, G. C. Gilbreath, D. J. Hutter, T. A. Pauls, and N. M. White, "Properties of the Hα-emitting Circumstellar Regions of Be Stars," *Astrophys. J.*, vol. 624, pp. 359-371, May 2005.
[16] J. Cote and L. B. F. M. Waters, "IRAS observations of Be stars. I - Statistical study of the IR excess of 101 Be stars," *Astron. Astrophys.*, vol. 176, pp. 93-106, April 1987.
[17] P. S. Goraya, N. Kumar, B. S. Salaria, and H. S. Ghumman, "Spectroscopic Study of Four Members of Balmer Series in Be Stars", *Asian J. of Chem.*, vol. 21, pp. 184-187, March 2009.
[18] C. E. Jones, C. Tycner, and A. D. Smith, "The Variability of Hα Equivalent Widths in Be Stars," *Astron. J.*, vol. 141, pp. 150, May 2011.
[19] C. J. Eyles, R. A. Harrison, C. J. Davis, N. R. Waltham, B. M. Shaughnessy, H. C. A. Mapson-Menard, D. Bewsher, S. R. Crothers, J. A. Davies, G. M. Simnett, R. A. Howard, J. D. Moses, J. S. Newmark, D. G. Socker, J.-P. Halain, J.-M. Defise, E. Mazy, and P. Rochus, "The Heliospheric Imagers Onboard the STEREO Mission," *Sol. Phys.*, vol. 254, pp. 387-445, February 2009.
[20] V. Sangaralingam and I. R. Stevens, "STEREO TRansiting Exoplanet and Stellar Survey (STRESS) - I. Introduction and data pipeline," *Mon. Not. R. Astron. Soc.*, vol. 418, pp. 1325-1334, December 2011.
[21] G. N. Whittaker, "The Analysis and Removal of Systematic Trends in STEREOs HI-1A Photometry and a Search for Planetary Transits", *PhD thesis*, Astrophysics and Space Research Group, School of Physics and Astronomy, The University of Birmingham, December 2013.
[22] N. Rossat, N. Delmotte, N. Fourniol, B. Pirenne, and A. Dobrzycki, *Astronomical Data Analysis Software and Systems XIV*, vol. 347, pp.674, 2005.
[23] A. Slettebak, "H-alpha and near-infrared spectra of late-type Be and A F-type shell stars", *Astr. Soc. Pac.*, vol. 98, pp. 867-871, September 1986.
[24] J. R. Percy, "Understanding Variable Stars", Cambridge: Cambridge University Press, xxi, 350, ISBN: 9780521232531 (hbk.), May 2007.

[25] H. Saio, "Prospects for Asteroseismology of Rapidly Rotating B-Type Stars". In M. Goupil, K. Belkacem, C. Neiner, F. Ligni`eres, and J. J. Green, editors, *Lecture Notes in Physics*, Berlin Springer Verlag, vol. 865 of Lecture Notes in Physics, Berlin Springer Verlag, pp. 159, 2013.

[26] Y. Fremat, J. Zorec, A. M. Hubert, and M. Floquet, "Effects of gravitational darkening on the determination of fundamental parameters in fast-rotating B-type stars", *Astronomy and Astrophysics*, vol. 440, pp. 305-320, September 2005.

[27] P. J. Flower, "Transformations from Theoretical H-R Diagrams to C-M Diagrams," *Astronomy and Astrophysics*, vol. 54, pp. 31, January 1977.

Doğuş ÖZUYAR, dozuyar@ankara.edu.tr, ORCID: https://orcid.org/ 0000-0001-8544-0950