V/R Variations in Hα Emission Line Spectra of B-emission Star EW Lac Based on Its Spectral Physical Parameters

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ABSTRACT

B-emission (Be) stars are non-supergiant B-type stars whose spectra have shown one or more Balmer emission lines. B emission stars usually have variability on their spectra emission and the variability varies differently on each star. EW Lacertae (HR 8731) is one of B-emission stars which is still studied until now since the star has periodic variability on V/R (violet to red intensity ratio) feature of the emission line. The goal of the research is to analyze V/R variations of Hα emission line in the spectrum of B-emission Star EW Lac based on its spectral physical parameters. The data are downloaded from BeSS (B-Emission Star Spectra) database from 2001 to 2020. IRAF (Image Reduction and Analysis Facility) program is used to data reduction. The spectra's parameters calculated are peak velocity V_v and V_r, radial velocity V_c, FWHM, EW, peak separation $2\Delta_p$, and absorption depth D_c. The results show: the period of V/R long term variation in EW Lac is ±8 years and 4 months; all of the physical parameters have a weak correlation with V/R long term variation; and the long term V/R variation is suspected come from one-armed oscillation in the central equatorial disk of the star.

Key Words: *B-Emission Star – EW Lac Star – Spectroscopy*

1 INTRODUCTION

B-emission (Be) star is a B type non supergiant star that ever have an emission line in its spectra, or have the emission line now. This emission line presumed to have arisen because of star envelope's rotational motion (Struve, 1931). B[e] star have a really high rotation speed, in some stars the rotation speed almost approaching their critical speed.

The thing that makes Be star an interesting object to study is the characteristic of this star which has emission features in its spectrum. Besides that, this star also has a wide range of variability in the parameters of the emission line. This is an interesting object of study for researchers because the cause of this variability is still unknown. Some of the proposed scenarios include non-radial pulsations, rotational modulation, and one-armed oscillations in the disk surrounding the Be star.

One of the Be stars which actively studied until now is EW Lac (EW Lacertae) or HR 8731. EW Lac is a Be star with B4IIIpe class and has a shell emission profile. The observed rotational speed ($v \sin i$) is 265 km/s (Chauville, et al., 2001). EW Lac is already known as a Be star which shows periodic variability in the value of V/R (violet to red ratio) in the Hα spectrum. This variability has existed since 1975 (Kogure and Suzuki, 1984).

Hubert et al. (1987) divided the spectral state of this star into two phases named the quiet phase in the Be-shell state (1960-1974) and the active phase when variations occurred (1975-1984). The V/R variation period has an average of 7 years, and the results of a recent study by Mon et al. (2013) found that the characteristics of the variation in 2007 – 2012 were similar to those that occurred in 1976 – 1986.

In this work, further research will be carried out on the star EW Lac. The research will focus on the V/R variations that exist in the spectrum of this star, especially looking for periods of variability by utilizing the data from previous work and adding the latest data. Data from variations of other parameters contained in the Hα spectrum and looking for its relation with V/R variations. From this work, it is expected to determine what causes the V/R variability that occurs.

2 RESEARCH METHOD

Spectral data for the star EW Lac were taken from the B Emission Star Spectra database. All spectra from various observers and instruments will appear in this database. For research purposes, the Hα spectrum data taken is the spectrum from 2001 to 2020. The spectrum is first sorted, only the spectrum in the Hα region (6562Å) will be taken and spectrum separation is also carried out with clear emission features.

The 79 data will be processed using software assistance. The software used is IRAF (Image Reduction and Analysis Facility).

3 RESULT AND ANALYSIS

Data obtained from the spectrum using fitting and deblending tools on IRAF are continuum line value, emission peak and central core absorption's wavelength, flux, equivalent width, and full width at

half maximum. After the data is processed, the parameter value obtained are V/R ratio, emission peak and central core absorption's velocity, radial velocity, emission line's full width at half maximum and equivalent width, peak separation, and absorption depth.

The resolution of the data is various depending on the instrument that is used. The data that is used in this research was taken from the database of BeSS, the minimum resolution range is 5000 while the largest is 50000. This, when converted into uncertainty, becomes 1.3 Å for data with a resolution of 5000 and 0.13 Å for data with a resolution of 50000 so that the range the data uncertainty is ±0.13 – 1.3 Å. All the result is shown on Figure 1 – Figure 7.

3.1 Long Term V/R Variation Period of Hα Line in EW Lac

The V/R graph show two emission peaks in July 2008 and December 2016. From here it can be concluded that long term V/R variation period of EW Lac is 8 years and 4 months. This result only has 4 months difference with Mon et al., (2013) that found the long-term V/R variation period ranged between 7 until 8 years. This imply that V/R variation from 1970 until 2020 may be have the same cause.

The one-armed oscillation also indicated from the V/R value. When the V/R value is really high, as in 2008, it signifies the envelope's part that move to observer's direction is more than the opposite part. This difference show that the one-armed oscillation is present in star's envelope. Meanwhile, when the V/R ratio is 1 (one), then one-armed oscillation may be not occurred in the star's envelope at that time.

3.2 Relation Between V/R Variation with Other Physical Parameters in Hα Emission Spectrum In EW Lac

Red and Violet Peak Velocity. In general, peak velocity have a very low correlation with V/R variation value at the same time. This is observed in violet and red peak. Violet peak velocity is higher than violet peak at 2007 – 2016. From this, we can predict that emission spectrum is more dominant to undergo blue shift, and this can be caused by an area in star's envelope that move closer to the observer.

Radial Velocity. EW Lac's radial velocity have an oscillating value with period shorter than V/R variation. The radial velocity oscillation have approximately one year period. This value can be analyzed further by considering if there is effect from the earth's orbital velocity and rotation that affect the observation.

Equivalent Width (EW). Equivalent width value show abundance of hydrogen in star's envelope. In general, emission equivalent width not showing a strong correlation with V/R variation. Starting in 2013, EW emission value keep decreasing. This is because the absorption is getting stronger as time getting by. When the absorption become stronger, emission feature became smaller so that the EW emission also getting smaller. In 2008 when V/R variation is in the peak, the EW value is still high, indicating that there is area in star's envelope that have higher density than the others. This area with higher density can cause one-armed oscillation phenomenon, causing the V/R peak in that year.

Full Width at Half Maximum (FWHM). Red and violet peak's FWHM graph have a very similar form, except in 2006 – 2011 that coincide with V/R maxima in 2008. FWHM value also have a weak correlation with V/R value.

Absorption Depth. In general, correlation between absorption's depth and V/R is not found. But, this depth value seem to oscillate with a random value and period.

Peak Separation. Peak separation value can be used to determine envelope's radius. If assumed that star envelope is circle and move with Keplerian rotation, then the average envelope radius is 4.52 star radius. Other interesting thing is in 2017, peak separation value increased quite sharply, this arises because the emission feature is getting wider. Peak separation value show rotational velocity field, associated with conservation of angular momentum. If the velocity field is small, as in 2017, then at that time the envelope's density is distributed evenly throughout the area and the one-armed oscillation don't appear.

3.3 The Cause of Long Term V/R Variation in EW Lac

Model about the cause of long term V/R variation that actively progress and used by many people is one-armed oscillation model. This model first suggested by Okazaki (1991) based on global oscillation theory in thin and non-self-gravitating disk. According to Okazaki (1991), long term V/R variation is caused by global one-armed oscillation phenomenon in cold equatorial disk. In isothermal equatorial disk, one-armed oscillation model also can explain well about long term periodicity that observed in B-emission star.

Newest assumption about the cause of V/R variation in EW Lac is explained on Mon et al. (2013). The article explained that the cause of long term V/R variation is one-armed oscillation, but the

movement is retrograde. It is because there is difference in electron amount in different optical depth, indicate that there is a rise in density at the disk. This density enhancement assumed to be one-armed oscillation in star's equatorial disk.

4 CONCLUSION

Based on this research, it can be concluded that:

- The period of time scale long term V/R variation from 2001 until 2020 is 8 years and 4 months.
- Every physical parameter discussed has a weak correlation with V/R value.
- EW Lac star's long term V/R variation is caused by global phenomenon one-armed oscillation in a cold equatorial plane.
- One armed oscillation in EW Lac star can be shown from some parameters. For example, in 2008 equivalent width value is high, thus give rise to difference in envelope's density and create one-armed oscillation.

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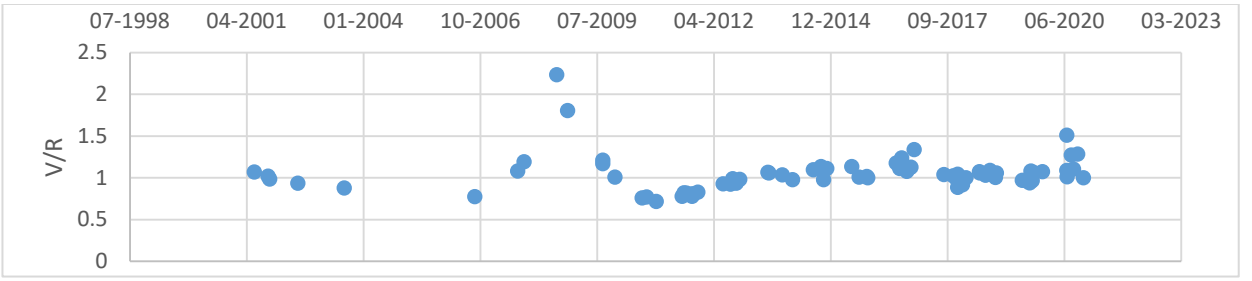

Figure 1. Long term variation of V/R from 2001 until 2020 in EW Lac.

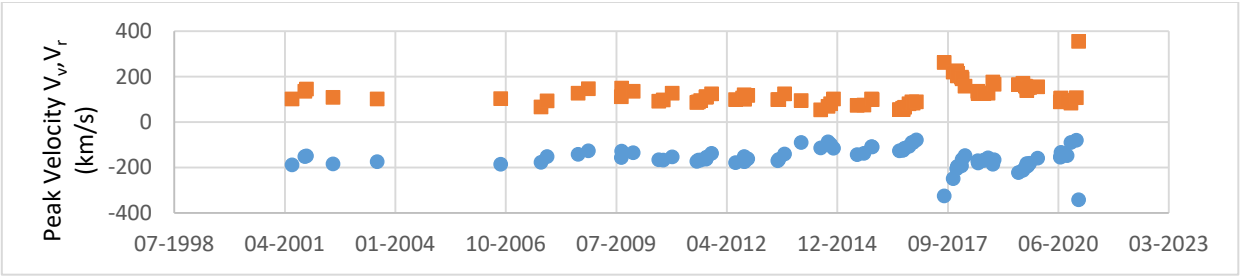

Figure 2. Long term variation of peak velocities from 2001 until 2020 in EW Lac.

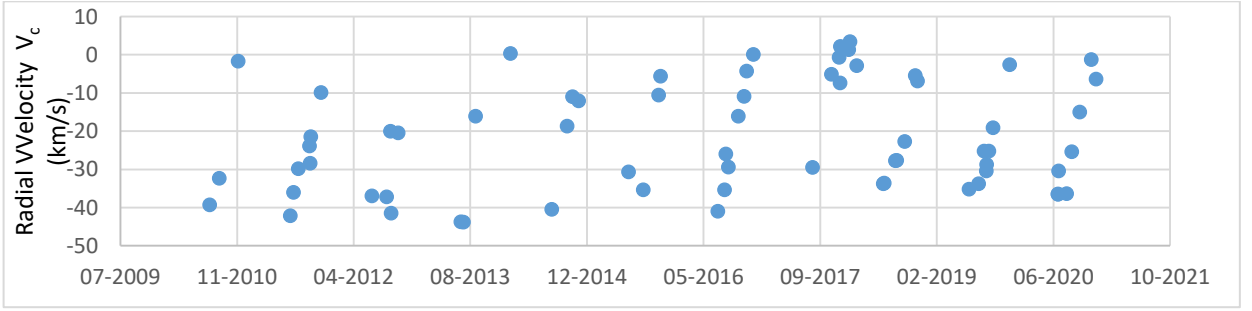

Figure 3. Long term variation of radial velocities from 2010 until 2020 in EW Lac.

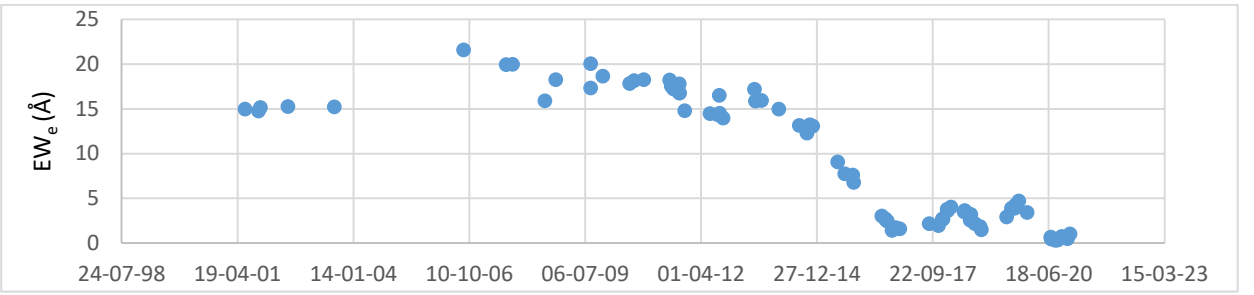

Figure 4. Long term variation of equivalent width from 2001 until 2020 in EW Lac.

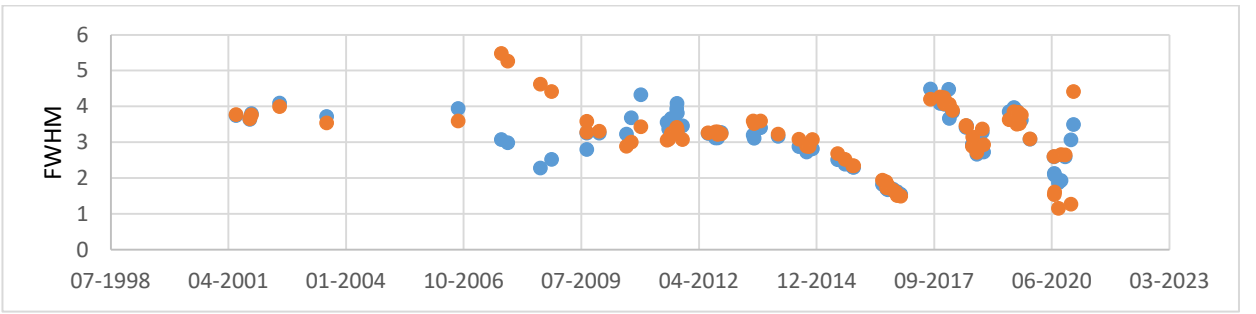

Figure 5. Long term variation of Full Width at Half Maximum from 2001 until 2020 in EW Lac.

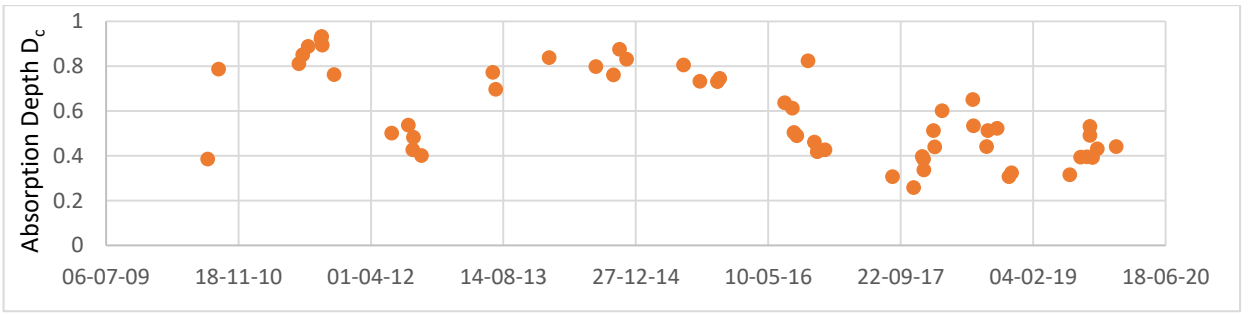

Figure 6. Long term variation of Absorption Depth from 2010 until 2020 in EW Lac.

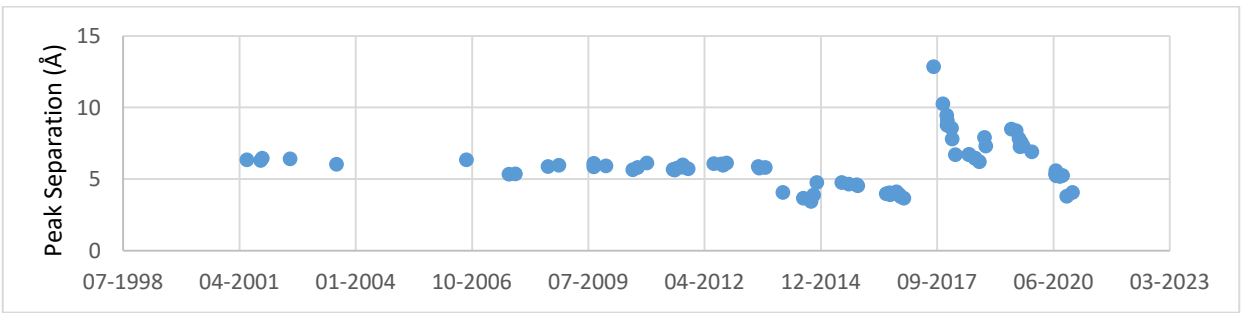

Figure 7. Long term variation of Peak Separation from 2001 until 2020 in EW Lac.