Final Report

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August 2022

1 Introduction

RR Lyrae stars are pulsating stars that occupy the horizontal branch of the Hertzsprung-Russell diagram in the instability strip. They have already lived through their main sequences and red giant phases of life, and now burn helium in their cores [3]. RR Lyrae Variables are "standard candles" in measuring galactic distances and are more often found in globular clusters. There are three main classifications: "ab," "c," and "d." Some RR Lyrae stars experience the Blazhko effect, which observes a change in amplitude and frequency over time. Sergey Blazhko noted this effect in 1907, but the cause of the it has remained a mystery for 115 years. We are trying to better observe the changes from one Blazhko cycle to the next. My research being conducted this summer will focus on using data from the Transiting Exoplanet Survey Satellite (TESS) [4] to analyze and create models of these stars' pulsations in order to further understand why the Blazhko effect occurs, and what causes it to happen.

2 Procedure

The TESS data from six different RR Lyrae stars (type "c") will be used in our sample. Period 04 [6] will be used to analyze picked up frequencies (primary, harmonic, and sidebands). Models will then be created using the data from Period 04. We will also use the Fourier series, which assists in the relative analysis of the Blazhko period:

$$y(t) = Z + \sum A_i sin(\omega_i t + \phi_i) \tag{1}$$

where Z is the zero-point offset. The Blazhko period (P_B) shifts can be measured while keeping careful note of any amplitude changes. The scattered background light will also need to be subtracted when measuring these shifts. Using the Global Astrometric Interferometer for Astrophysics (GAIA) [5], we can make more observations and measurements on different stellar parameters of these variable stars, such as luminosity. We can do this because of GAIA's high-precision, which allows us to use parallax to compute said luminosity.

The research being done this summer will mostly involve data analysis, but there may be opportunities for observational work as well. This will be conducted using the MacAdam Student Observatory to obtain light curve data from the Blazhko sample stars. To reduce and analyze this data, we will use AstroImageJ [2]. This program is useful because it allows us to check for spacial resolution. TESS data uses very large pixels (about 21 arc seconds) so neighboring celestial objects fall on the data pixel. The MacAdam data (which has a spacial resolution of about 3 arc seconds) can be used to test the contribution of the neighboring objects to light curve variations because of the high spatial resolution.

3 Period04

Period04 conducts a statistical analysis using multiple frequency fits. The Fourier series is used to calculate a primary frequency. From there, sub-harmonic frequencies can be calculated. These sub-harmonic frequencies are multiples of the primary frequency, which establishes a pattern. This allows for a better fit of the tens of thousands of data points provided by TESS. These sub-harmonic values can be further calculated until the signal-to-noise ratio (SNR) is around five. Going too low can result inaccurate data. It is important to note that these frequency fits are made for independent data sectors that are separated by time gaps. These gaps exist because there are periods where TESS is downloading data.

Once the SNR is at five (or very close to it), a model can be graphed on the scatter plot that is provided by Period 04. The more frequencies that are involved in the model, the more accurately the fit will be. From one sector to the next, we can observe that the model becomes less and less accurate, indicating a change in period and/or amplitude. This modulation is indicative of the Blazhko Effect, though stars like BV Aquarius do get out of phase over time, as shown in Figure 1 and Figure 2 below.

3.1 BV Aquarius

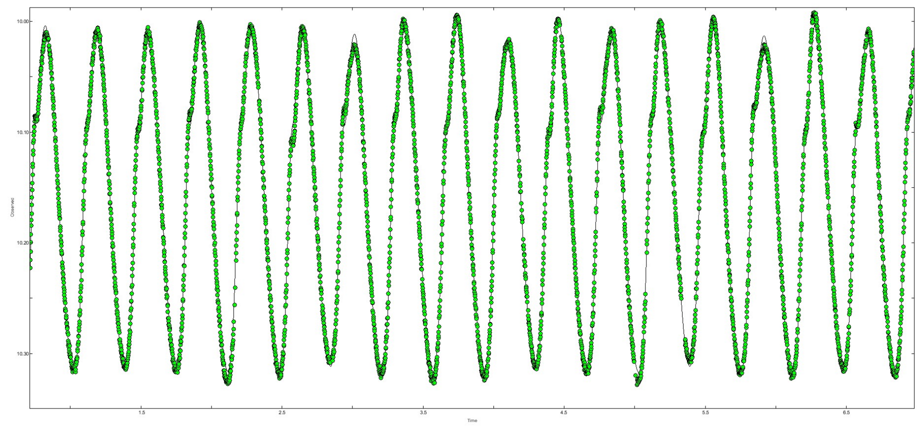

Figure 1: BV Aquarius - Sector 1

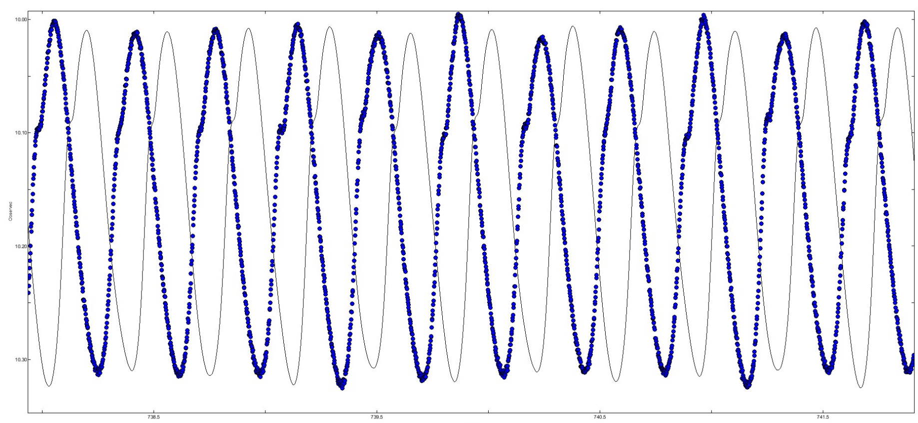

Figure 2: BV Aquarius - Sector 2

The model used in Sector 1, over time, does not accurately fit Sector 2. The pulsations become out of phase from one model to the next. This phase difference is depicted in Figure 3.

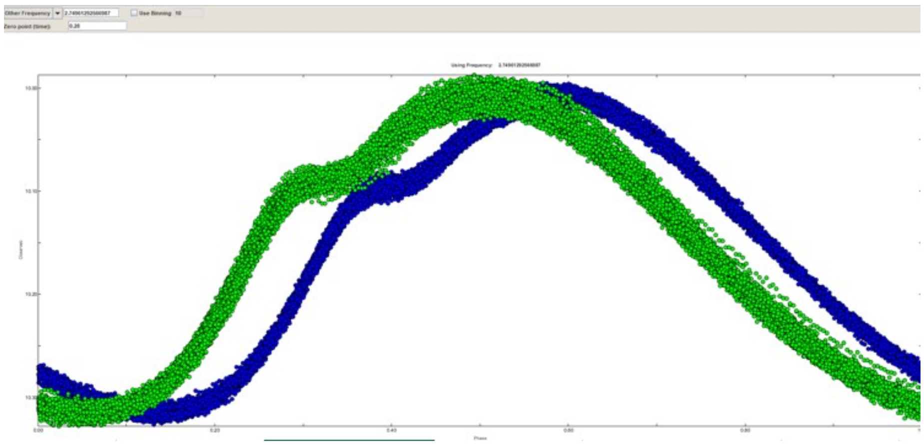

Figure 3: BV Aquarius - Phase v. Observed

4 Excel

Excel has been vital to beginning to understand where period changes begin to occur. To begin the work on Excel, two artificial data files (one from each sector) were created over the same range. It is important to note that each data point in each file was taken two minutes apart but the time step was 0.0015 between points.

Both files were adjusted to begin at the first amplitude minimum in order to create alignment. The residuals were calculated from subtracting the amplitudes from each other (Sector 1 was subtracted from Sector 2). The standard deviation of the residuals was then calculated. The shift (time from Sector 1 subtracted from Sector 2) should also be noted. From there, small time step adjustments can be made. For example, we can shift Sector 1 ahead by five time steps, and find the standard deviation again. The goal is to find where in making adjustments the standard deviation is the smallest. This will tell us where the two sectors are most closely aligned.

Time shifts from 10 steps back until 30 steps forward were made. It was expected that our first point, where the amplitude minimums were aligned, was where the standard deviation would be the smallest. However, the two sectors were aligned 20 minutes ahead of that point (10 steps forward), as shown in Figure 4.

Table 1

Time Shift	Julian Shift (Days)	Standard Deviation
10 Back	0.117	0.057611
5 Back	0.1245	0.0447722
No Shift	0.132	0.032711
5 Forward	0.1395	0.022827
10 Forward	0.147	0.018772
15 Forward	0.1545	0.023488
20 Forward	0.162	0.033237
25 Forward	0.1695	0.044704
30 Forward	0.177	0.056765

Plotting the Julian Shift against the Standard Deviation yields the follow parabolic curve and its associated trend-line (Figure 4):

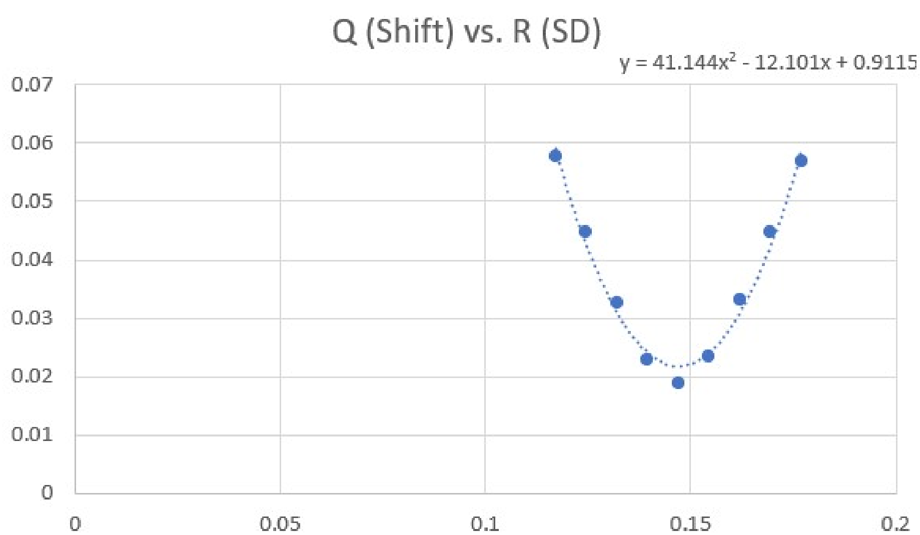

Figure 4: BV Aquarius - Julian Shift (Days) v. Standard Deviation

4.1 Using the Minimum

By taking the derivative of the equation in Figure 4, we can determine the minimum of our parabola provided by the parabolic trend-line. This yields the following value: 0.147056679. This minimum can be used to find the seconds per cycle in different parts of the sector, or even between sector. For example, a Julian Date can be converted to cycles by multiplying by the primary frequency, and then taking that result and dividing by our minimum (converted to seconds). This process can be repeated throughout a sector.

4.2 Conclusions

Taking the primary frequency, and fitting it with its corresponding sub-harmonics, gives us an indication of what the period should be. We can do this process in both sectors of BV Aqr and compare them to see if there are changes in period over time by taking the fit for Sector 1 and extending it over to Sector 2. However, this method can yield faulty results because Period 04 may pick up hidden sidebands within its calculations. These sidebands can alter the primary frequency and therefore the period change is no longer accurate.

An O-C (observed versus calculated) method was used in Section 3.1, where the fit for Sector 1 was extended to Sector 2. As can be observed in comparing Figure 1 and Figure 2, they are not in phase with each other any more, and are now off by approximately 0.147057 days. It can not be exactly determined how BV Aqr is behaving during the times where no data was taken. Its period could have very suddenly changed or it could have changed in a more cyclic nature, such as the Blazhko stars discussed in Section 5. The O-C method would not yield the same value of 0.147057 days in shift because the cyclic nature would mean a lot of the time would be spent pulsating either near Sector 1 or 2, or somewhere in between when data was taken. It can be concluded that there is period shifting occurring in this star yet no clear amplitude change. Because the period shifting can not be concluded as cyclic, it is not classified at a Blazhko star.

5 The Blazhko Stars

Conducting data analysis on BV Aqr was essential to better understanding how certain properties, such as amplitude and phase, are able to change over time. However, BV Aqr is not categorized as a Blazhko star. The following stars were analyzed throughout this report:

- V0575 Hya
- V0389 Tel
- V1141 Her
- V1283 Her
- LS Her
- TV Boo

Each of these stars experiences the Blazhko Effect to some degree. These stars in particular were chosen because they are some of the brightest RRc TESS Targets, making them good targets for potential spectroscopic follow-up. As mentioned above, TESS is the source for all data used in this characterization. While all six stars are categorized as RRc Lyrae Variables, they all have very different light curves. V1141 Her, V0575 Hya, TV Boo, and V0389 Tel all had additional data files from TESS with enough substantial data to conduct data analysis to compare possible changes to the Blazhko cycle.

The goal with this characterization is to determine Blazhko periods for each star. Also, we want to search for possible modulations to the Blazhko period, and see if other parameters affect the Blazhko period itself or how it changes. We are able to determine the Blazhko period through measuring sidebands of the Blazhko frequency diagrams created in Period 04. Sidebands are combination lines of the primary frequency and the Blazhko frequency. The sub-harmonic frequencies are are integer multiples of the primary frequency. Side-bands can also be seen in the sub-harmonic peaks.These sidebands make notable peaks. Finding the difference between the two symmetrical sidebands close to the primary frequency yields the Blazhko period. The problem with this direct method is that the sidebands are not always reliable, so a second way to check the accuracy of this Blazhko period is to measure the amount of days (in the light curve) it takes for one period of pulsation to occur.

In order to correctly find the Blazhko period for each of the six stars, all notable frequencies should be noted, as well as any anomalies.

5.1 Finding Frequencies

Period 04 can be used to find the primary frequency and its corresponding sub-harmonics and sidebands. Each star's frequencies are below.

Table 2.1

V1141 Her Frequencies - Data Set 1		
Primary	Sub-harmonics	Sidebands
3.122197008713	6.244394017426	3.15345121951154
	9.366591026139	3.18227357151366
		6.27232094372153
		6.36139898096917
		*2.17213234462495

*This frequency is not a noted combination line, yet still creates a significant peak

Table 2.2

V1141 Her Frequencies - Data Set 2		
Primary	Sub-harmonics	Sidebands
3.15320071748969	6.30747323922657	3.06879093466203
	9.45997512777735	3.12116197367045
	12.6172927036106	3.18036579305084
		6.27352398066618
		6.36090535344674
		12.6655871510099

Table 2.3

V0575 Hya Frequencies - Data Set 1		
Primary	Sub-harmonics	Sidebands
3.29754621006078	6.59509242012156	3.17992442610003
	9.89263863018234	3.41462528942541
	13.1901848402431	6.47746037542897
	16.4877310503039	9.77527014030746
	19.7852772603647	
	23.0828234704255	
	26.3803696804862	
	29.677915890547	

Table 2.4

V0575 Hya Frequencies - Data Set 2		
Primary	Sub-harmonics	Sidebands
3.2975682756777	6.59515458913001	3.18021276504275
	9.89283157350241	3.41234558483461
	13.1902732051686	6.3604742885186
	16.4886264377862	6.47778081900174
	19.786019385283	9.77457227327823
	23.0865826923414	13.0731143757492
	26.3834527896085	13.3087664125045
		16.3714382541693
		19.6691160298772

Table 2.5

TV Boo Frequencies - Data Set 1		
Primary	Sub-harmonics	Sidebands
3.19971485794798	6.39908854714285	3.09310653980489
	9.59883212526482	3.14452298744583
	12.7988594317919	3.30059053932716
	15.9985742897399	6.29941337605638
	19.1982891476879	6.50186007002139
	22.3980040056359	9.70051626941102
	25.5977188635838	12.6992975717819
	28.7974337215318	
	31.9971485794798	

Table 2.6

TV Boo Frequencies - Data Set 2		
Primary	Sub-harmonics	Sidebands
3.19960898127552	6.39921796255104	3.09514218854647
	9.59882694382656	3.19920198459778
	12.7984359251021	3.3022863915052
	15.9980449063776	6.29449682635265
	19.1976538876531	9.70259787270966
	22.3972628689286	
	25.5968718502042	
	28.7964808314797	
	31.9960898127552	
	35.1956987940307	

Table 2.7

V0389 Tel Frequencies - Data Set 1		
Primary	Sub-harmonics	Sidebands
3.3304866834767	6.6609733669534	3.25562408080025
		3.42248395270986
		3.51671856943928
		6.75083644425354
		6.84510726548732

Table 2.8

V0389 Tel Frequencies - Data Set 2		
Primary	Sub-harmonics	Sidebands
3.33052892264455	6.6610578452891	3.42330606511661
		3.51486084295742
		6.75543731590046
		6.84799276809165

Table 2.9

V1283 Her Frequencies- Data Set 1		
Primary	Sub-harmonics	Sidebands
3.66680570942729	7.33115384271932	3.64128993066615
	7.33115384271932	3.69900778523458
	10.9893118891917	7.30899456503677
	14.649048184345	7.35973330745464
	18.3340285471364	10.9710937460034
	22.0008342565637	11.0490560176935
	25.667639965991	14.6400978084042
		14.7106987026565

Table 2.10

LS Her Frequencies Frequencies - Data Set 1		
Primary	Sub-harmonics	Sidebands
4.33073051895523	8.66146103791046	4.26227688180641
	12.9921915568657	4.40445057575991
	17.3229220758209	8.78722422691848
	21.6536525947761	
	Sector 2	
4.34040933676603	8.68081867353206	4.30041302007703
	13.0212280102981	4.4118994784455
	17.3616373470641	8.77315032703912
	21.7020466838302	
	Sector 3	
4.3362551723703	8.6725103447406	4.25847298881194
	13.0087655171109	4.41698447250721
	17.3450206894812	8.76505236874264
	21.6812758618515	
	26.0175310342218	
	Sector 4	
4.33282539757021	8.66565079514042	4.2535157749798
	12.9984761927106	4.41161985930605
	17.3313015902808	8.57290045485247
	21.6641269878511	8.76392732485317
	25.9969523854213	13.0801805329532

It should be noted that there are more possible sideband frequencies. Period 04 can not always accurately conduct the Fourier series to pick up more frequencies, as discussed in 6.1.

6 Measuring the Period vs. Amplitude

Originally, period vs. amplitude graphs were going to be used to characterize these six stars. Period refers to the pulsation period of the star while amplitude refers the amplitude over one or more Blazhko cycles. We expect to have one of the following possibilities in terms of pattern: a closed loop, a loop that does not close, a loop that is not superimposed, or spiraling loop. A closed loop of points means that the period and amplitude are changing together and will be able to be observed over multiple Blazhko cycles. This means that the Blazhko period is consistent. A loop that is not closed or is not superimposed indicates that there is modulation occurring. A spiraling pattern implies that the Blazhko Effect is taking place within the star.

The light curves, in Period 04, were divided into several small subsections and fitted. The small subsections were made in order to gain an accurate average frequency and so minimums and maximums in the amplitude were not grouped together. The small subsections also allow us to note changes in the average frequency and minimize the amount of amplitude "blending" across the Blazhko cycle. However, this division caused issues.

6.1 Accuracy Issues

In Figure 5, LS Her was divided into 4 sectors (separated by time gaps), and those sectors were further divided into 22 subsections.

Period 04 does not have enough data in each subsection to properly conduct the Fourier Series. The peaks are widened and sidebands are picked up, causing for amplitude changes upon hitting "Improve All."

The graph of LS Her (Figure 5) represents these errors. While the data makes a figure-eight loop pattern, there are several outliers that can no longer contribute to the analysis. It is important to note that the red scatter points represent Sector 1 (6 subsections), orange represents Sector 2 (5 subsections), yellow represents Sector 3 (5 subsections), and green represents Sector 4 (6 subsections). There is simply not enough data points to indicate how this loop is traveling. The sectors seem to overlap one another. The loop appears to be closed, but the behavior traveling across each sector is not clear. The amplitude blending in the Fourier analysis creates several outliers that do not accurately depict how the period and amplitude behavior over time. This methodology, at least through analysis in Period 04, can not be trusted to truly show us the presence of modulation.

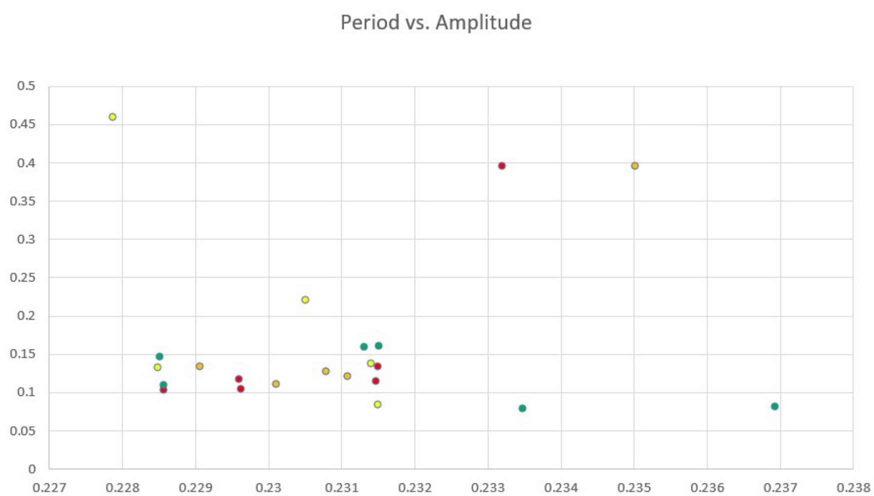

Figure 5: LS Her - Period (days) vs. Amplitude

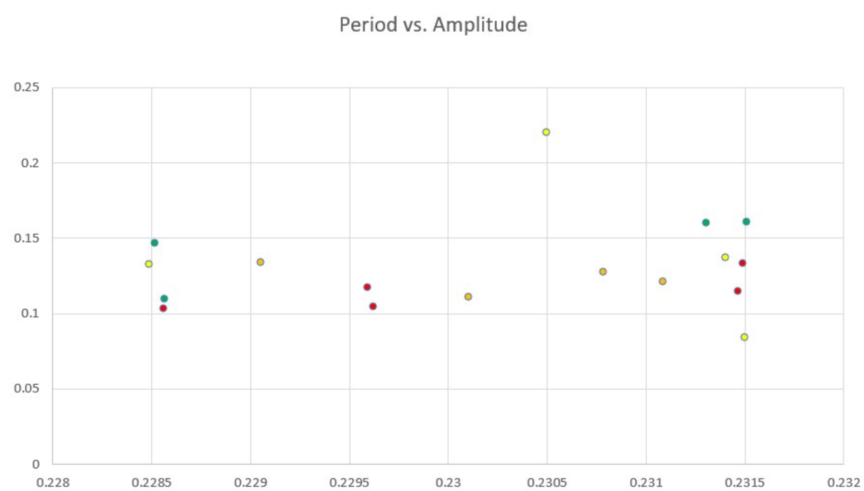

Figure 5.1

Figure 5.1 is Figure 5 with adjusted axes in order to more clearly see the figure-eight loop pattern.

6.2 Dr. Carrell's Model

In order to attempt to make more accurate models, a model for LS Her made by Dr. Kenneth Carrell was used. He used the light curve data to make a graph plotting Julian date against frequency. He used a smaller time interval of 4 in his analysis. This took the 22 subsections used above and reduced it to 14. He also only used the primary frequency and two sub-harmonic frequencies to make his fit.

The behavior in LS Her is peculiar. The behavior in this star is similar to that in Figure 2. The Blazhko Effect is prominent in this star due to the clear changes in amplitude. It is important to note that not only are the changes in amplitude occurring, but how the amplitude changes is changing within itself as each Blazhko cycle progresses. This characteristic is seen in many Blazhko stars, but this amplitude variation suggests there is another modulation occurring that requires more in-depth research.

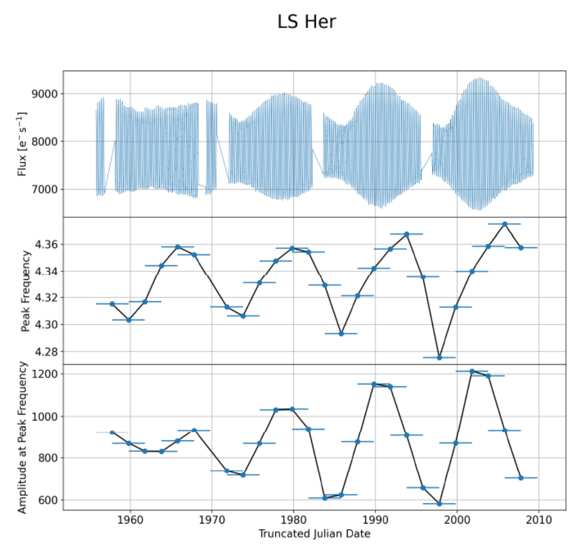

Figure 2: Top: The full lightcurve of LS Her. Middle: The primary frequency of 4-day bins of the data. Bottom: The amplitude of the peak frequency from a Lomb-Scargle analysis of the 4-day bins.

Figure 6: LS Her - Dr. Carrell's Models

I attempted to recreate his bottom model as well as a corresponding period vs. amplitude graph.

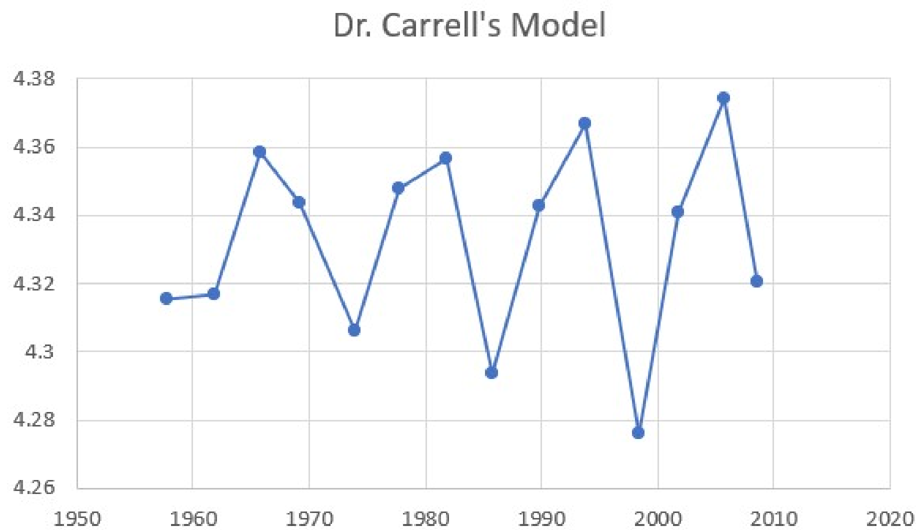

Figure 7: LS Her - Julian Date (days) vs. Peak Frequency

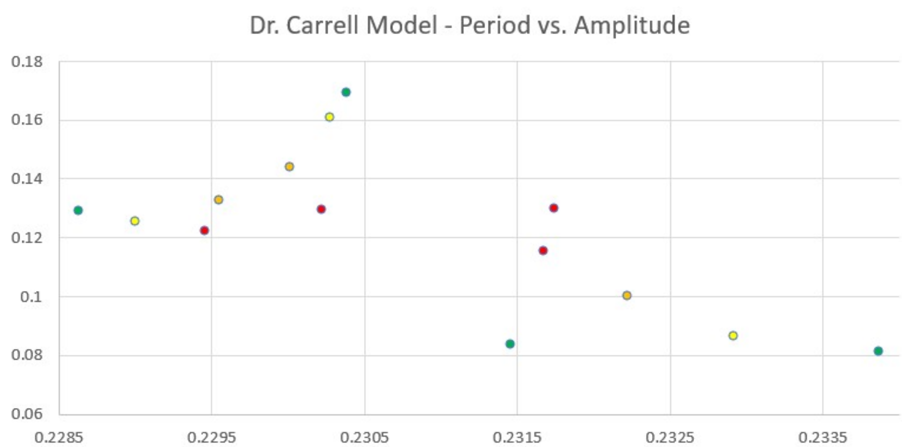

Figure 8: LS Her - Period (days) vs. Amplitude

I was able to create a model that was pretty close to Dr. Carrell's, though mine is a bit less precise. Figure 8 corresponds to Figure 7, though its pattern is hard to pick out at first. There is a counterclockwise loop patterns occuring. The data begins at the inner red points, then loops counterclockwise to the orange, then yellow, then green. There is still not enough data to truly depict the exact loop pattern that is occurring, but there is definitely a pattern. This process was repeated with the other stars, though the results did not give any real indication of the behavior of any star. It should be noted that the fewer subsections allowed for less errors in the amplitude calculation. While the fit of these models were less accurate, there was much more stability in the amplitude.

The lack of data and ability to gain an accurate model led to a different direction: phase vs. amplitude plots.

7 Measuring the Blazhko Phase vs. Amplitude

The goal in characterizing these stars is to use the Blazhko periods to determine the Blazhko phase. Each Blazhko period was found through measuring the distance between the symmetrical sidebands of the primary frequency. This value can also be determined by measuring a period of the light curve in Period 04. Each star's Blazhko period is listed in Section 8.1.

Using the Julian dates and dividing by the Blazhko period, we can set the result against the more accurately calculated amplitudes. The calculated phase values are the result of the above calculation minus their integer, so we can more clearly observe one period. V1141 Her, V0575 Hya, TV Boo, and T0389 Tel each had an additional set of data (as noted by their frequencies in Section 5.1) so phase comparisons over time could be made. The time gaps between these four stars are as follows:

Table 3

Time Gap Between Data Set 1 and Data Set 2	
Star Name	Time Gap (Julian days)
V1141 Her	682.990973
V0575 Hya	713.915181
TV Boo	685.595154
V0389 Tel	353.922012
V1283 Her	N/A
LS Her	N/A

Before the final plots were made, each graph was shifted so the maximums of each data set occurred at 0.5 of the period. The data was also extended to two periods, so the behavior can be seen over multiple cycles.

7.1 Blazhko Phase Diagrams

This graphing method, overall, was much more successful. We can now observe the behavior at specific percentages of the way through each cycle. Figures 9-14 represent the Blazhko phase diagrams for all six stars. A more in-depth analysis of Figures 9-14 is in Section 8.

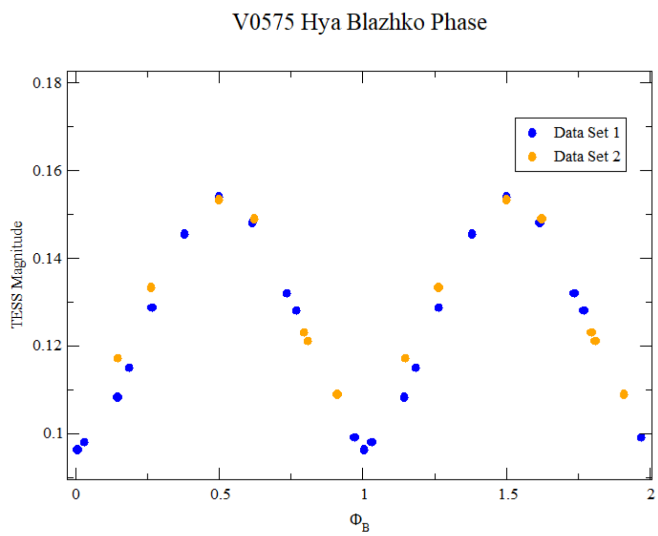

Figure 9: V0575 Hya - Blazhko Phase

V0575 Hya was the most "stable" star out of the six. In this research, "stable" can be defined as having a near constant Blazhko period over time with no clear amplitude modulation.

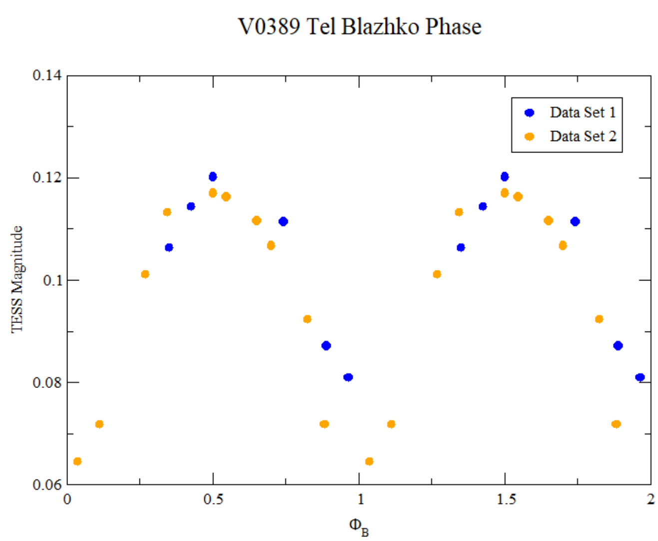

Figure 10: V0389 Tel - Blazhko Phase

V0389 Tel's data sets are, like V0575 Hya, very in phase. Its Blazhko period remains mostly constant with minor modulation. The amplitude variation is more apparent, though it is not drastic.

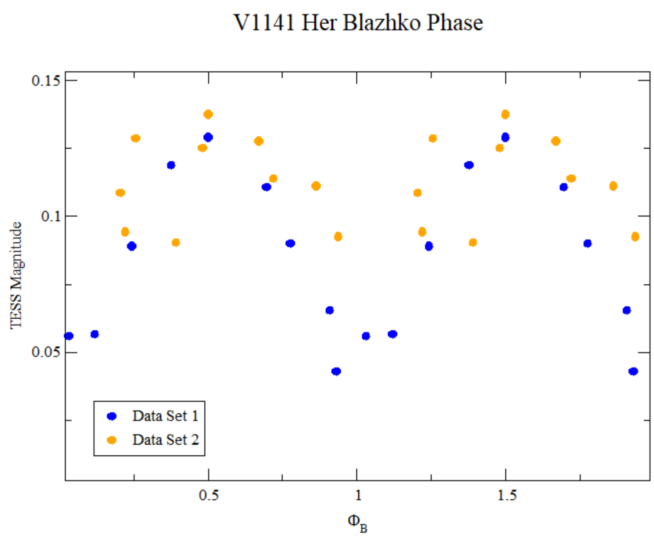

Figure 11: V1141 Her - Blazhko Phase

V1141 Her has apparent amplitude variation between the two sets. Data Set 2 seems to encounter more variation in its phase than Sector 1, which indicates there may be phase modulation. However, the sets are mostly in phase with each other while the amplitude seems to experience change.

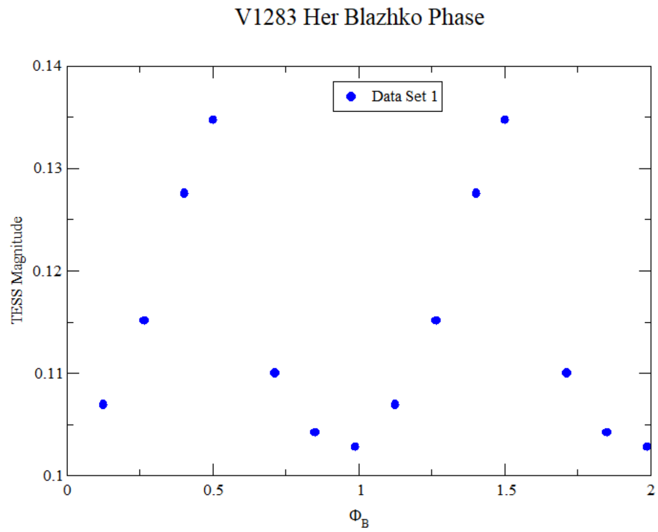

Figure 12: V1283 Her - Blazhko Phase

V1283 Her does not have two available data sets, but there is an apparent cyclic relationship between the Blazhko phase and the amplitude. There are sharper peaks on these phase curves than the other stars.

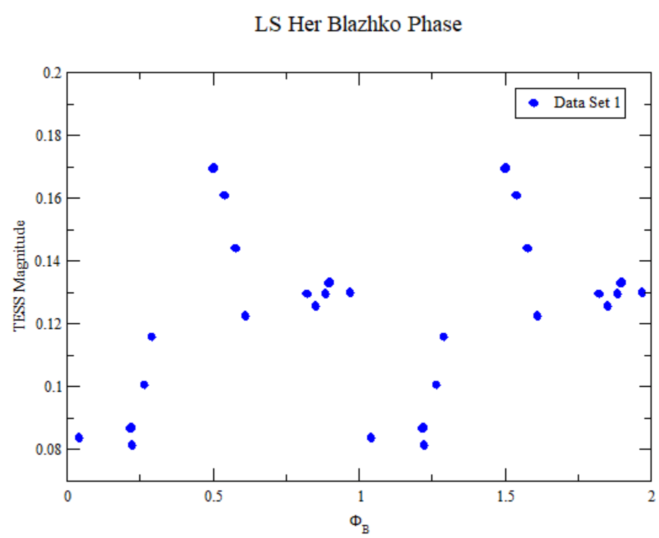

Figure 13: LS Her - Blazhko Phase

LS Her appears to have what looks like a normal cyclic curve but then "clusters" between 75 percent and 100 percent of its Blazhko period. LS Her experiences some extreme modulation, which is discussed further in Section 8.

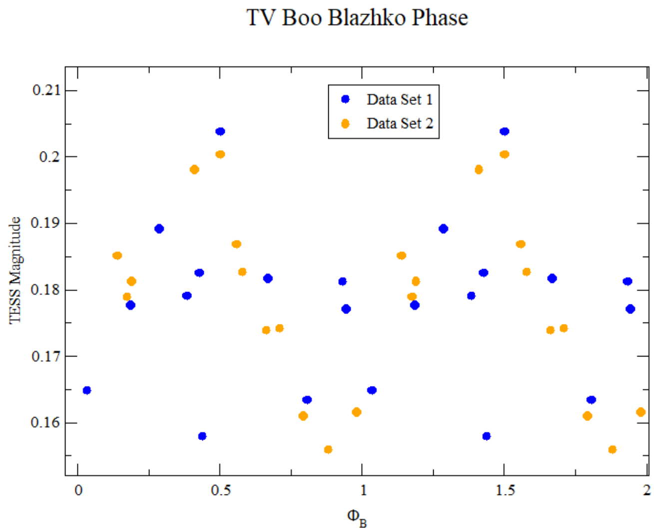

Figure 14: TV Boo - Blazhko Phase

TV Boo is the least stable of the six stars. Data Set 1 experiences a lot of variation that does not have an organized patterns. The pattern in Data Set 2 is more apparent than in Data Set 1. This may suggest a more complex modulation that needs more research, as mentioned below in Section 8.

7.2 Parameters

Each star varies in its behavior as it pulsates. Some stars are more in phase over time than others. Even though V1283 Her and LS Her do not have second data sets, their cyclic patterns are observable. Ideally, more data would be available to truly map the behavior, but patterns can be noted. Comparing the Blazhko phase against different parameters of each star can indicate possible correlations between the Blazhko Effect and a characteristic.

Table 4

Blazhko Star Parameters					
Star Name	Oscillation Period (days)	Blazhko Period $\Omega_B(days)$	Distance (pc)	Metallicity ([Fe/H])	Abs. Mag. (M)
V1141 Her	0.32028728398 0.31713807321	22.53902307	1462	N/A	0.44026314
V0575 Hya	0.30325579576 0.30325376653	8.510638334	1048	-1.79	0.78319359
TV Boo	0.31252784838 0.31253819008	9.8874797	1355	-2.44	0.34530352
V0389 Tel	0.30025641746 0.30025260948	10.80897381	1370	-2.71	0.92139716
V1283 Her	0.27271693109	28.93673046	855	N/A	0.940169426
LS Her	0.23090792549 0.23039301651 0.23061373472 0.23079628377	12.46669333	1002	N/A	1.28066139

Data Set 1 Data Set 2

Distance and Metallicity values were provided by SIMAD [7]

8 Conclusions and Possibilities

V0575 Hya is the most stable of the Blazhko stars in this research. Its Blazhko period remains very consistent over time and its amplitude experiences no apparent modulation, as can be referenced in Figure 9. This star is what we would like to ideally see in a Blazhko star as its stability can be compared to stars that experience more amplitude and pulsation or Blazhko period changes. We can observe similar behavior above (Section 3.1) in BV Aqr, which is not a Blazhko star.

V0389 Tel appears to be very stable over time with only minor changes in the amplitude. It can be seen in Figure 10 that the two data sets appear to be in phase. The data for V0389 Tel has roughly one year less of break in data than the other stars with two data sets, so it is possible that if another set of data was taken by TESS two years apart from Data Set 1 , there would be more phase or amplitude modulation. However, only a small change in the amplitude can be clearly noted for these data sets. This star also has a very low absolute magnitude of approximately 0.92. The dust extinction value must be accounted for. GAIA gives an approximate dust extinction value of 0.78, though it may not be completely reliable. This tends to be the case when extinction values are high. However, this could change the absolute magnitude to a value that is more like one of a typical RR Lyrae variable star. Future work will take care of this extinction.

V1141 Her has a pretty consistent Blazhko period with a more variable amplitude. Its absolute magnitude is also high for an RR Lyrae star, as shown below in Table 4. While this star has a longer Blazhko period (Table 4) than the other stars (except for V1283 Her), it seems to remain constant over its time gap. In Figure 11, we can observe a more structured and organized phase cycle in Data Set 1 than in Data Set 2. There seems to be some amplitude modulation between the two sets. There are also outliers that do not clearly line up with the curves of the data sets. This could indicate faulty data or there is underlying modulation that needs more attention.

V1283 Her is actually proposed to be an eclipsing binary on SIMBAD rather than a Blazhko star, but is still not certain at this time. The peaks of Figure 12 appear to be sharper compared to the other stars. Its absolute magnitude is also very low. We can not make any claims on how its phase, amplitude, and pulsation and Blazhko periods change without more data. However, there is a clear curve that can be observed in Figure 12.

LS Her is the strangest of these stars with very variable light curves. Its absolute magnitude suggests this could be a different type of star completely, as it is extremely low. Most RR Lyrae variables lie between 0.55 and 0.70 in absolute magnitude. LS Her, as referenced in Table 4, is approximately in 1.28 in absolute magnitude. GAIA did not have a dust extinction value for this star, which may be because it is too variable. The varied data in Figure 13 may be explained by an additional modulation period. A modulation period for the Blazhko period has been detected by Wils et. al 2008 [1], which is valued at 109 $\pm$ 4 days. Confirming this number will be a part of future work on the Blazhko Effect.

TV Boo has the least amount of correlation within its data sets, especially in Data Set 1 in Figure 14. Data Set 2 seems to follow a much more obvious pattern. There is a study on TV Boo by Skarka Zejda 2012 [8] that says there is a second modulation period of 21.5 $\pm$ 0.2 days. It could account for the erratic variation in the Blazhko phase diagram. If this modulation period was taken into account with the data in Figure 14, there could be better phasing. The presence of a second modulation period may be essential to understanding changes in the Blazhko period, and the Blazhko Effect as a whole. Also, TV Boo has a very low metallicity and absolute magnitude, as seen in Table 4. It is possible that its low absolute magnitude could say something about its intrinsic properties.

8.1 Moving Forward

There is clearly still a lot of work to be done on Blazhko stars. There is a lot of variation within the stars, and a lot of ways the Blazhko Effect presents itself in light curves. All of these stars need further research conducted. The more parameters we can define for Blazhko stars, the more conclusions and correlations will be found. Moving forward, more analysis will be conducted with LS Her [8] and TV Boo [1] because of the published modulation periods. If the modulation periods phase up with the data in this research, that would give more insight to how the Blazhko Effect changes within itself. Currently, there are ongoing observations of LS Her so this modulation will be able to be tested. The spectroscopy of LS Her will be observed in the near future as well.

There is one parameter that seems to be consistent between these stars: low metallicity. Metals add opacity to a star. Stars typically have a metallicity of -1.6, though the stars in this study all have metallicities lower than this average. According to Table 4, V0575 Hya has a metallicity of -1.79, TV has a metallicity of -2.44, and V0389 Tel has a metallicity of -2.71. These three stars, especially the latter two, are very metal-poor. While three stars is not enough to distinguish a pattern, three other stars not included in this research, which are also RRc variable stars, also seem to exhibit this characteristic. All of the following metallicities and Blazhko periods are provided by SIMBAD. V0701 Pup has a metallicity of -2.89 and a Blazhko period of 8.1 days. ASAS J110522-2641.0 has a metallicity of -1.79 and a Blazhko period of 7.4 days. BO Gru has a metallicity of -1.82 and a Blazhko period of 10.24 days.

The average metallicity of these six stars is -2.24 and the average Blazhko period is approximately 9.16 days. While no claims can be made about this correlation, especially with such a small data set, it would be worthwhile to investigate the correlation between low metallicity and short-period Blazhko stars.

9 Acknowledgements

Thank you to Dr. Wilhelm for his support, guidance, and expertise throughout this program. Thank you to the University of Kentucky and the Department of Physics and Astronomy for hosting me and this REU program. Thank you to the National Science Foundation for the funding to make this research possible. This work is funded in part by the National Science Foundation under grant PHY-1950795.

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