

Analysis of the Blazhko effect for field RR Lyrae stars using LINEAR and ZTF light curves

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ABSTRACT

We analyzed the incidence and properties of RR Lyrae stars that show evidence for amplitude, period, and phase modulation (the so-called Blazhko Effect) in a sample of $\sim 3,000$ stars with LINEAR and ZTF light curve data. A preliminary subsample of about ~ 240 stars was algorithmically pre-selected using various data quality and light curve statistics, and then ~ 140 stars were confirmed visually as displaying the Blazhko effect. CONCLUSIONS? Although close to 8,000 Blazhko stars were discovered or confirmed in the Galactic bulge and LMC/SMC by the OGLE-III survey, only about 200 stars have been reported in all field RR Lyrae stars studies to date; the sample presented here nearly doubles the number of field RR Lyrae stars displaying the Blazhko effect. With time-resolved photometry expected from LSST, a similar analysis will be performed for RR Lyrae stars in the southern sky and we anticipate a higher fraction of discovered Blazhko stars due to better sampling and superior photometric quality.

Key words. Variable stars — RR Lyrae stars — Blazhko Effect

1. Introduction

RR Lyrae stars are pulsating variable stars with periods in the range of 3–30 hours and large amplitudes that increase towards blue optical bands (e.g., in the SDSS g band from 0.2 mag to 1.5 mag; Sesar et al. 2010). For comprehensive reviews of RR Lyrae stars, we refer the reader to Smith (1995) and Catelan (2009).

RR Lyrae stars often exhibit amplitude, period, and phase modulation, or the so-called Blazhko effect (hereafter, “Blazhko stars”). For examples of well-sampled observed light curves showing the Blazhko effect, see, e.g., Kepler data shown in Figures 1 and 2 from Benkő et al. (2010). The Blazhko effect has been known for a long time (Blažko 1907), but its detailed observational properties and theoretical explanation of its causes remain elusive Kovács (2009). Various proposed models for the Blazhko effect, and principal reasons why they fail to explain observations, are summarized in Kovacs (2016).

A part of the reason for the incomplete observational description of the Blazhko effect is difficulties in discovering a large number of Blazhko stars due to temporal baselines that are too short and insufficient number of observations per object (Kovacs 2016; Hernitschek & Stassun 2022). With the advent of modern sky surveys, several studies reported large increases in the number of known Blazhko stars, starting with a sample of about 700 Blazhko stars discovered by the MACHO survey towards the LMC (Alcock et al. 2003) and about 500 Blazhko stars discovered by the OGLE-II survey towards the Galactic bulge (Mizerski 2003). Most recently, about 4,000 Blazhko stars were discovered in the LMC and SMC (Soszyński et al. 2009, 2010), and an additional $\sim 3,500$ stars were discovered in the Galactic bulge (Soszyński et al. 2011), both by the OGLE-III survey. Nevertheless, discovering the Blazhko effect in field RR Lyrae stars that are spread over the entire sky remains a much harder problem: only about 200 Blazhko stars in total from all the studies of field

RR Lyrae stars have been reported so far (see Table 1 in Kovacs 2016).

Here, we report the results of a search for the Blazhko effect in a sample of $\sim 3,000$ field RR Lyrae stars with LINEAR and ZTF light curve data. A preliminary subsample of about ~ 240 stars was selected using various light curve statistics, and then ~ 140 stars were confirmed visually as displaying the Blazhko effect. This new sample greatly increases the number of known field RR Lyrae stars that exhibit the Blazhko effect. In §2 and §3 we describe our datasets and analysis methodology, and in §4 we present our analysis results. Our main results are summarized and discussed in §5.

2. Data Description

Analysis of field RR Lyrae stars requires a sensitive time-domain photometric survey over a large sky area. For our starting sample, we used $\sim 3,000$ field RR Lyrae stars with light curves obtained by the LINEAR asteroid survey. In order to study long-term changes in light curves, we also utilized light curves obtained by the ZTF survey which monitored the sky ~ 15 years after LINEAR. The combination of LINEAR and ZTF provided a unique opportunity to systematically search for the Blazhko effect in a large number of field RR Lyrae stars.

We first describe each dataset in more detail, and then introduce our analysis methods. All our analysis code, written in Python, is available on GitHub¹.

¹ https://github.com/emadonev/var_stars

59 **2.1. LINEAR Dataset**

60 The properties of the LINEAR asteroid survey and its photo-
 61 metric re-calibration based on SDSS data are discussed in Sesar
 62 et al. (2011). Briefly, the LINEAR survey covered about 10,000
 63 deg² of the northern sky in white light (no filters were used, see
 64 Figure 1 in Sesar et al. 2011), with photometric errors ranging
 65 from ~0.03 mag at an equivalent SDSS magnitude of $r = 15$ to
 66 0.20 mag at $r \sim 18$. Light curves used in this work include, on
 67 average, 270 data points collected between December 2002 and
 68 September 2008.

69 A sample of 7,010 periodic variable stars with $r < 17$ discov-
 70 ered in LINEAR data were robustly classified by Palaversa et al.
 71 (2013), including about ~3,000 field RR Lyrae stars of both ab
 72 and c type, detected to distances of about 30 kpc (Sesar et al.
 73 2013). The sample used in this work contains 2196 ab-type and
 74 745 c-type RR Lyrae, selected using classification labels and the
 75 *gi* color index from Palaversa et al. (2013). The LINEAR light
 76 curves, augmented with IDs, equatorial coordinates, and other
 77 data, were accessed using the astroML Python module².

78 **2.2. ZTF Dataset**

79 The Zwicky Transient Factory (ZTF) is an optical time-domain
 80 survey that uses the Palomar 48-inch Schmidt telescope and a
 81 camera with 47 deg² field of view (Bellm et al. 2019). The
 82 dataset analyzed here was obtained with SDSS-like *g*, *r*, and *i*
 83 band filters. Light curves for objects in common with the LIN-
 84 EAR RR Lyrae sample typically have smaller random photomet-
 85 ric errors than LINEAR light curves because ZTF data are deeper
 86 (compared to LINEAR, ZTF data have about 2-3 magnitudes
 87 fainter 5 σ depth). ZTF data used in this work were collected be-
 88 tween February 2018 and December 2023, on average about 15
 89 years after obtaining LINEAR data.

90 The ZTF dataset for this project was created by selecting
 91 ZTF IDs with matching equatorial coordinates to a correspond-
 92 ing LINEAR ID of an RR Lyrae star. This process used the
 93 *ztfquery* function, which searched the coordinates in the ZTF
 94 database within 3 arcsec from the LINEAR position. Our sam-
 95 ple starting consisted of 2857 RR Lyrae stars with both LINEAR
 96 and ZTF data.

97 **3. Analysis Methodology: Searching for the Blazhko
 98 Effect**

99 Given the two sets of light curves from LINEAR and ZTF, we
 100 searched for amplitude, period, and phase modulation, either
 101 during the 5-6 years of data taking by each survey, or during
 102 the average span of 15 years between the two surveys. We used
 103 two principal methods that are sensitive to different types of light
 104 curve modulation: direct light curve analysis and periodogram
 105 analysis, as follows.

106 *CHECK:* For efficient and robust analysis, another algorithm
 107 was developed to select viable Blazhko candidates to be visually
 108 analyzed. The algorithm removed all stars with unrealistic data
 109 or insufficient data points (250 for LINEAR and 40 for ZTF).

110 **3.1. Direct Light Curve Analysis**

111 The Blazhko effect most commonly presents as a modulation of
 112 amplitude, period, or both. We phased the light curves, calcu-

lated their fit, and χ^2 value was also calculated. The χ^2 value
 113 gives a quantitative representation of "goodness of fit", which
 114 shows us if modulation is present. Fig 1 shows an example star
 115 with LINEAR and ZTF phased light curves, along with their fits.
 116

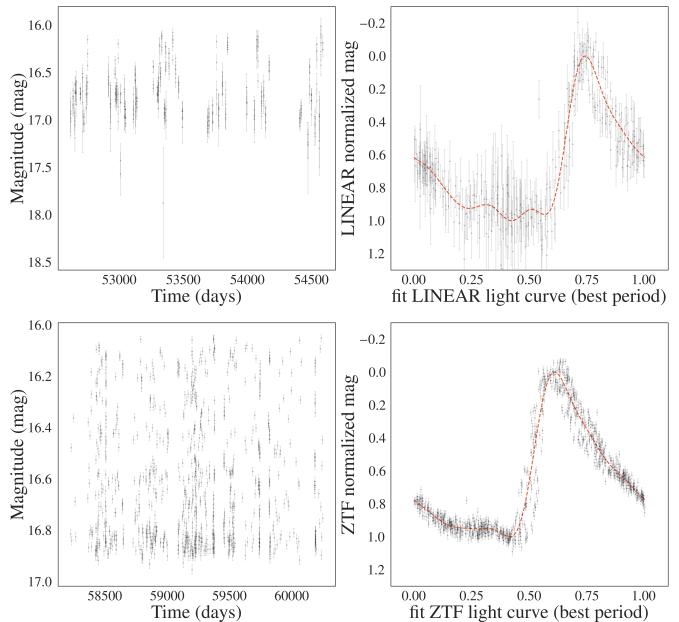


Fig. 1. An example of period search and resulting phased light curves for LINEAR and ZTF data.

117 **3.2. Periodogram Analysis**

The periodic shape change of light curves for Blazhko stars is
 118 equivalent to periodic phase and amplitude changes of the har-
 119 monics that make up the light curve. This work used the Lomb-
 120 Scargle method for period calculation and periodogram analy-
 121 sis. By finding specific harmonics that create the final shape of
 122 the light curve and representing their power of fit using a peri-
 123 odogram, we can find a potential *blazhko frequency*.
 124

Comparing the Blazhko effect as a *blazhko frequency* inter-
 125 fering with the intrinsic frequency of pulsation of an RR Lyrae, it
 126 is observed that modulation of either period or amplitude arises.
 127 The effect is known as **interference beats**, described by the
 128 equation below:
 129

$$y(t) = 2 \cos(2\pi \Delta f) \sin(2\pi f_{avg})$$

Where Δf is the difference between the primary and Blazhko
 131 frequency, and f_{avg} is the average between the two frequencies.
 132

A periodogram from a Blazhko star would contain a central
 133 peak with two equally distant local peaks at frequencies f_- and
 134 f_+ , with $f_- < f_0 < f_+$, where f_0 is the frequency of the main
 135 pulsation. The sideband peaks can be highly asymmetric Alcock
 136 et al. (2003). Observing periodograms can sometimes be much
 137 more complex Szczygieł & Fabrycky (2007).
 138

139 For this project, we created an algorithm that searches for
 140 an interfering *blazhko frequency* by folding the periodogram
 141 through the main peak and comparing if the folded peaks were
 142 statistically more significant than the background noise. The al-
 143 gorithm utilized the increased SNR due to the multiplication of
 144 peaks. It also eliminated stars with a yearly alias.
 145

The Blazhko period, calculated if the algorithm finds the
 146 Blazhko frequency, is defined as

$$P_{BL} = |f_{-,+} - f_0|^{-1},$$

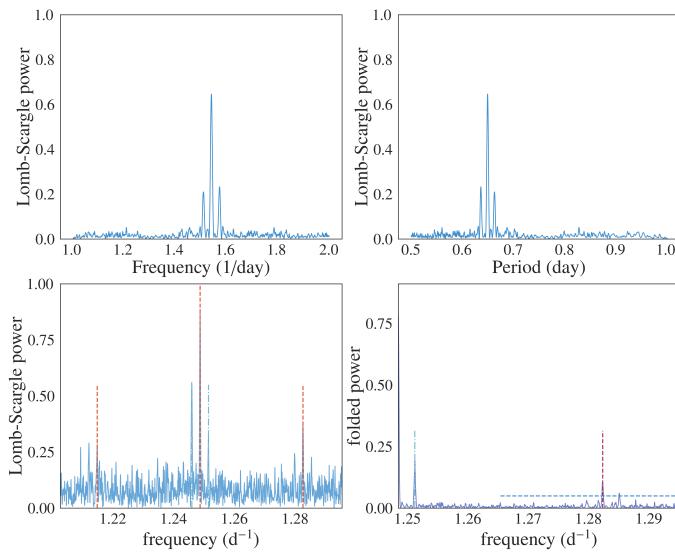


Fig. 2. Comparison of theoretical interference beats for a simulated light curve and real periodogram data from LINEAR and ZTF datasets.

where $f_{-,+}$ means the Blazhko sideband frequency with a higher amplitude is chosen.

The observed Blazhko periods range from 3 to 3,000 days, and Blazhko amplitudes range from 0.01 mag to about 0.3 mag (Szczygieł & Fabrycky 2007). In this work, we select a smaller Blazhko range due to the range of our data.

Fig 2 compares the theoretical periodogram produced by interference beats with our algorithm's periodogram, signifying that local Blazhko peaks are present in real data.

The correctness of the algorithm in recognizing the *blazhko frequency* was examined. Fig 5 shows an example where the LINEAR periodogram is a perfect example of how the algorithm correctly identifies two very prominent peaks. If the peaks were aligned with the yearly aliases (like for the ZTF counterpart) or were not statistically significant, or if the algorithm detected a false signal, the star did not satisfy this phase.

3.3. Visual Confirmation of the Blazhko Effect

Then, it removed stars whose *blazhko peak* was a yearly/daily alias, whose relative strength of peaks was below 0.05, and whose significance was below 5—their Blazhko period had to be between 30 and 325 days.

The selection of stars based on the period difference (difference between LINEAR and ZTF period, divided by the mean period), amplitude, and the χ^2 value was made using a scoring mechanism.

Based on the distribution of period differences and χ^2 values, it was determined for LINEAR that $1.8 < \chi^2 < 3.0$ was worth 2 and $\chi^2 > 3.0$ worth 3 points, while for ZTF $2.0 < \chi^2 < 4.0$ and $\chi^2 > 4.0$ were the limits. If both χ^2 parameters were satisfied, it was worth 4 or 6 points, respective of the limits. The limits of the period difference were $0.00002 < dP < 0.00005$ worth 2, and $dP > 0.00005$ worth 4 points. Finally, $0.05 < ample < 0.15$ was worth one, and $0.15 < ample < 2.00$ was worth 2 points. A star could score a maximum of 12 points or be directly selected via its *blazhko frequency*.

A smaller sample of 239 Blazhko candidates was selected. Visual analysis was separated into five categories: LINEAR or ZTF *blazhko frequency*, LINEAR or ZTF χ^2 value, and none of the above.

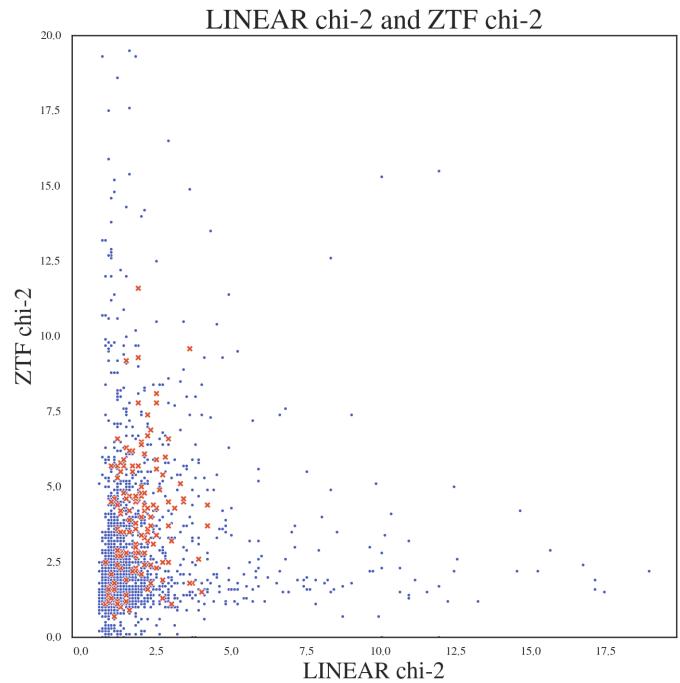


Fig. 3. χ^2 values for LINEAR and ZTF, where blue are all RR Lyrae stars and red are Blazhko stars.

Firstly, the shape and noisiness of the phased light curves were examined.

If it was deemed that the light curve was precise enough, and if the phase contained different shapes.

Fig 4 shows the first phase of visual analysis, where the ZTF fit shows signs of the Blazhko effect.

Thirdly, the general shape of the light curve was examined. Fig 6 depicts a case where the criteria are not satisfied: the overall shape of the data is rectangular, with perhaps slight amplitude modulation, which is unnoticeable. The criteria would be satisfied if the data had a clear wave-like pattern.

The final phase is the most important, analyzing the light curve fit for each observation season. Fig 7 shows an example of a Blazhko star, where from season to season, we can notice slight **phase and amplitude modulation** in the LINEAR data, while in the ZTF data, the phase modulation is quite visible.

If a star has satisfied the criteria of the first and final stage, only the second stage, or all four stages, it is most likely a Blazhko star. After visually analyzing the starting 239 Blazhko candidates, only 136 remain confirmed Blazhko stars.

4. Results

After analysis of 2857 RR Lyrae stars from LINEAR and ZTF data, we found 136 Blazhko field stars. In Appendix A, the reader can find all of the Blazhko stars and some elementary data describing each star.

In the Blazhko star sample, most were selected by a high χ^2 value in the ZTF dataset rather than in the LINEAR dataset, as shown in the following figure.

Another important note highlighting the difficulty of finding Blazhko stars is that the absolute Blazhko frequency difference from the main frequency is approximately $0.028 d^{-1}$. Also, the average period difference between LINEAR and ZTF in Blazhko stars was around 0.0001 days. These minimal differences require precise observations over a long temporal baseline. The distribu-

221 tion of RRab and RRc type RR Lyrae in our sample is repre-
 222 sentative of other surveys, where 71% were type RRab and 29%
 223 RRc type.

224 Finally, we have discovered that in some Blazhko stars, the
 225 effect cannot be detected ten years later or beforehand. When
 226 comparing LINEAR and ZTF data, some pairs have the effect
 227 present in only one dataset and others in both. This finding could
 228 mean that the Blazhko effect is not always present and gives us a
 229 clue about its mechanism. However, the precision of data is also
 230 a factor for consideration.

231 5. Discussion and Conclusions

232 The reported incidence rates for the Blazhko effect range from
 233 5% (Szczygieł & Fabrycky 2007) to 60% (Szabó et al. 2014). For
 234 a relatively small sample of 151 stars with Kepler data, a claim
 235 has been made that essentially every RR Lyrae star exhibits mod-
 236 ulated light curve (Kovacs 2018). The difference in Blazhko inci-
 237 dence rates for the two most extensive samples, obtained by the
 238 OGLE-III survey for the Large Magellanic Cloud (LMC, 20%
 239 out of 17,693 stars; Soszyński et al. 2009). Moreover, the Galac-
 240 tic bulge (30% out of 11,756 stars; Soszyński et al. 2011) in-
 241 dicates a possible variation of the Blazhko incidence rate with
 242 underlying stellar population properties. In this work, 4.67% of
 243 the original RR Lyrae dataset are Blazhko stars. Since our sam-
 244 ple size is considerable, we conclude that the incidence rate of
 245 Blazhko stars in our work is representative and aligns with other
 246 works. We theorize that the difference in incidence rates occurs
 247 due to varying data precision, the temporal baseline length, and
 248 differences in visual or algorithmic analysis. We also conclude
 249 that our algorithm's success rate in finding 136 out of 239 poten-
 250 tial Blazhko stars is 57%. This high number indicates that the
 251 algorithm is very successful and can be used and refined further
 252 for efficient Blazhko star selection.

253 For future research, we would like to explore the final finding
 254 and find a connection or a factor that might give rise to a mecha-
 255 nism that explains the Blazhko effect. The project is an excellent
 256 example of automatizing the search for Blazhko stars. It can fur-
 257 ther be improved by training a neural network to replace visual
 258 analysis, and our current algorithms can be improved with other
 259 models. This work can provide a base for finding more Blazhko
 260 stars for the future Vera Rubin observatory. The Legacy Survey
 261 of Space and Time (LSST; Ivezić et al. 2019) will be an excel-
 262 lent survey for studying Blazhko effect (Hernitschek & Stassun
 263 2022) because it will have both a long temporal baseline (10
 264 years) and a large number of observations per object (nominally
 265 825; LSST Science Requirements Document³).

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 267 Graham for *ztfquery* example. Ž.I. acknowledges funding by the Fulbright Foun-
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³ Available as ls.st/srd

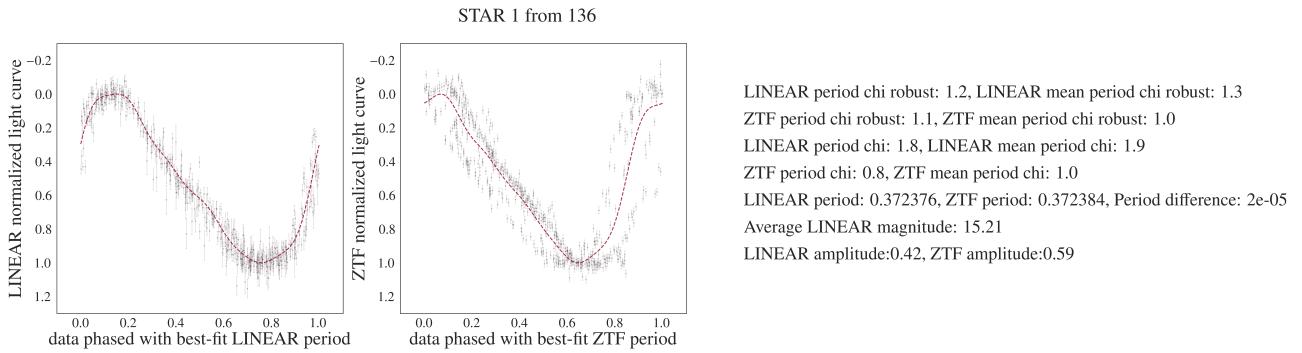


Fig. 4. Phase 1 of visual analysis of Blazhko candidates.

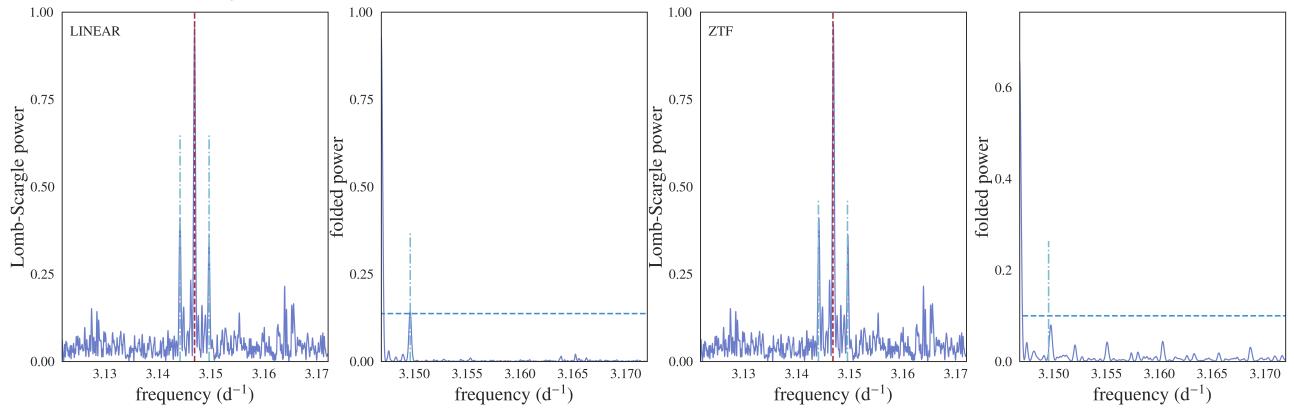


Fig. 5. Phase 2 of visual analysis of Blazhko candidates.

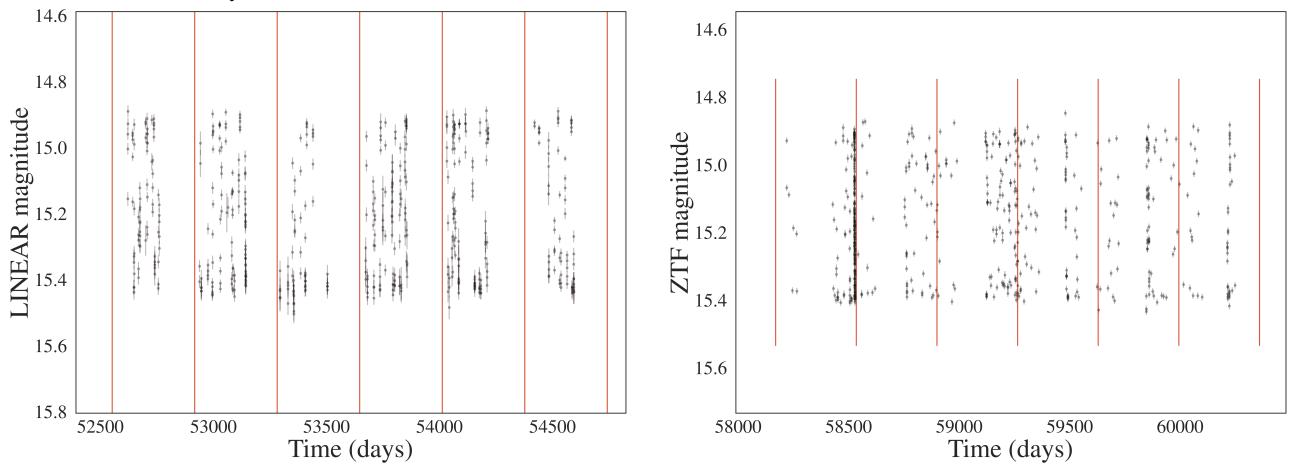
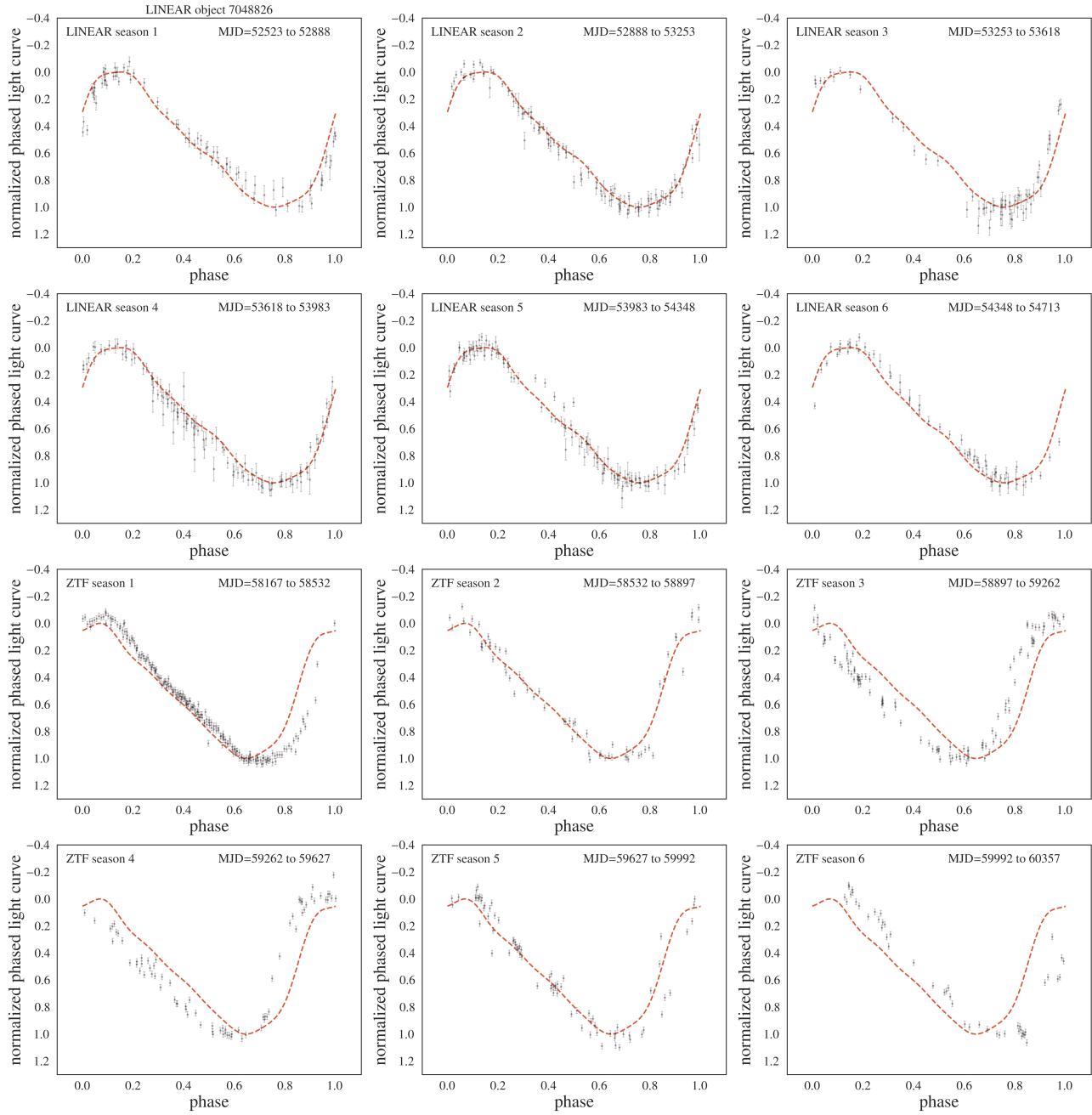


Fig. 6. Phase 3 of visual analysis of Blazhko candidates.

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**Fig. 7.** Phase 4 of visual analysis of Blazhko candidates.

Appendix A: Full table of results

Here we present all the confirmed Blazhko stars with their LINEAR IDs, equatorial coordinates, and calculated periods and χ^2 values.

LINEAR ID	RA	DEC	LINEAR period	ZTF period	LINEAR chi-2	ZTF chi-2
523832	207.529404	33.706001	0.372376	0.372384	1.20	1.10
1240665	206.202469	34.058662	0.632528	0.632522	3.00	1.10
1736308	206.096115	36.648674	0.555848	0.555843	1.30	1.00
2669011	206.229523	38.758453	0.591153	0.591151	1.10	0.70
2742032	207.355225	39.589951	0.629676	0.629692	0.90	1.40
2812086	206.805511	40.859066	0.646015	0.646000	3.00	3.20
3507643	206.557358	39.536449	0.801141	0.801132	1.60	0.90
5931160	207.177231	41.918797	0.664700	0.664708	0.80	1.10
6665721	206.020233	41.646141	0.643318	0.643325	1.00	1.70
17185566	206.387268	43.314617	0.614160	0.614169	1.50	1.90
22828215	206.657028	43.543236	0.574536	0.574535	1.50	1.40
29848	206.917358	44.971054	0.557020	0.557040	1.40	3.50
158779	207.772202	45.916824	0.609207	0.609189	1.60	3.90
263541	207.172470	45.713154	0.558218	0.558221	2.90	6.60
514883	206.594757	46.482040	0.557723	0.557737	1.70	5.50
737951	206.435547	45.881615	0.357023	0.357023	2.20	6.70
810169	169.297485	6.265203	0.465185	0.465212	2.10	2.80
924301	169.713531	6.963072	0.507503	0.507440	1.90	9.30
1092244	207.060974	5.649392	0.649496	0.649558	1.20	3.60
1244554	206.944962	5.346962	0.536875	0.536962	1.80	2.30
1307948	206.223587	6.741248	0.527474	0.527415	1.80	4.50
1332201	207.992432	-4.603579	0.580711	0.580731	1.60	4.20
1390653	207.220245	-3.214271	0.521867	0.521871	1.30	4.10
1435279	207.824600	-3.712567	0.381858	0.381860	2.10	4.20
1448299	206.582916	51.406654	0.606912	0.606940	2.70	5.40
1593736	169.096771	5.428976	0.592628	0.592650	1.20	5.70
1748058	207.353790	53.020401	0.310237	0.310176	1.40	5.70
1857382	206.026001	56.421604	0.566428	0.566407	2.70	2.50
1882354	207.117645	56.313797	0.695061	0.695029	1.50	2.80
2041979	206.848053	55.248009	0.653694	0.653639	1.20	5.30
2075949	207.733643	62.320267	0.477806	0.477666	1.60	4.70
2117028	207.188278	61.978554	0.591245	0.591243	2.20	3.50
2122319	206.210190	62.778843	0.359422	0.359424	2.10	6.10
2229607	207.042603	65.877083	0.575179	0.575211	1.20	4.40
2243683	206.780823	8.893113	0.579777	0.579803	3.10	4.30
2248787	206.407776	7.914382	0.563528	0.563539	2.10	2.40
2334384	206.454544	7.380644	0.555341	0.555333	2.00	6.50
2397296	168.680649	51.998081	0.488814	0.488836	1.20	6.60
2414841	206.101624	7.666218	0.559611	0.559592	1.70	5.70
2455568	168.211075	51.534416	0.594119	0.594092	2.00	2.10
2612592	207.693237	-5.975360	0.571562	0.571543	1.30	2.80
2653982	168.135025	51.014339	0.607082	0.607110	1.00	2.10
2766997	207.782440	-7.099904	0.289881	0.289943	1.80	3.60
2892940	209.495773	2.587467	0.539855	0.539896	1.30	4.20
3036295	209.338211	2.393512	0.629705	0.629714	1.80	2.20
3140139	208.758163	-0.100046	0.304590	0.304585	2.50	5.60
3183285	208.391159	0.479103	0.349653	0.349664	1.20	2.80
3196582	208.521881	0.740297	0.268017	0.268018	2.50	3.40
3196780	169.384384	53.303658	0.504148	0.504199	2.20	3.20
3294319	169.550766	53.459976	0.555460	0.555473	1.90	4.70
3437725	208.845749	12.514306	0.542457	0.542478	1.50	6.30
3591037	208.146072	14.167974	0.558643	0.558609	1.30	3.50
3941776	209.073120	13.401526	0.532222	0.532209	2.80	6.00
4101289	209.351425	13.537904	0.379225	0.379250	1.20	2.70
4586691	208.326218	15.475822	0.621459	0.621446	2.00	3.40
4804945	209.674210	16.421736	0.556172	0.556217	2.50	7.80
5421989	208.014435	18.561077	0.534510	0.534527	0.80	2.50

LINEAR ID	RA	DEC	LINEAR period	ZTF period	LINEAR chi-2	ZTF chi-2
6582265	209.421219	17.441139	0.691751	0.691749	2.90	3.70
6651516	208.909760	17.881287	0.308488	0.308496	1.30	5.80
6819457	209.491974	20.296762	0.436282	0.436265	3.60	9.60
6883239	208.333481	19.276327	0.563711	0.563712	2.90	2.50
6967017	208.406662	21.846382	0.529691	0.529677	2.30	6.90
7048826	208.492981	22.591896	0.317781	0.317790	1.40	5.90
7254801	209.648148	22.561989	0.561133	0.561071	1.30	5.50
7279621	208.915436	24.833937	0.415469	0.415467	1.90	4.60
7283275	208.409698	26.350325	0.543342	0.543331	2.20	3.60
7344401	209.188583	26.111385	0.330201	0.330226	1.80	2.70
7580734	209.349243	26.322409	0.314956	0.314957	2.00	4.00
7657340	208.098282	27.700201	0.495480	0.495493	2.30	4.00
7811366	208.457687	30.868412	0.489523	0.489521	2.00	4.70
7827663	208.047531	30.799057	0.390832	0.390832	3.40	4.50
7846640	209.106400	4.330462	0.551495	0.551518	1.50	9.20
8222011	209.258850	3.100914	0.350920	0.350914	2.00	4.80
8311517	208.212936	4.452833	0.523354	0.523359	1.80	3.60
8331094	208.446945	3.969552	0.267543	0.267549	2.10	3.30
8343291	208.919601	-2.689821	0.569785	0.569791	3.30	5.10
9063194	169.357468	57.331566	0.575781	0.575760	2.40	3.10
9236215	209.009872	-1.607280	0.352570	0.352572	1.80	2.80
9449335	209.488937	-2.928472	0.475720	0.475695	2.00	5.00
9532981	168.695602	60.104759	0.591000	0.591042	1.70	6.20
9918809	209.255295	-2.089725	0.479460	0.479509	1.90	11.60
9968431	209.717804	-2.437493	0.302266	0.302211	1.70	2.20
9979905	208.905365	31.572962	0.338739	0.338739	2.50	2.30
10030349	209.547668	32.537975	0.545073	0.545074	2.10	4.40
10260828	208.891602	32.249817	0.380655	0.380643	2.20	7.40
10814742	209.570526	31.039347	0.462687	0.462683	2.50	4.30
11215595	208.180191	33.574619	0.546960	0.546943	1.30	2.30
16991760	209.105652	33.977589	0.549098	0.549096	2.90	3.70
17247918	169.489120	59.391106	0.481867	0.481865	1.80	4.60
17275627	208.806717	33.957424	0.537775	0.537771	2.10	4.80
17302403	209.807205	35.285717	0.488261	0.488343	2.00	6.40
17544856	208.748581	36.859768	0.614297	0.614296	2.00	3.40
19775800	208.958618	36.484657	0.310856	0.310867	1.30	2.70
21488669	209.334930	37.248749	0.501644	0.501661	1.90	5.70
21556651	208.269577	38.000725	0.614826	0.614808	1.80	3.10
21619184	208.125366	37.095997	0.557343	0.557320	2.30	3.70
21806402	208.151657	39.543987	0.592081	0.592104	1.60	6.20
21874209	209.602371	40.245346	0.611295	0.611286	2.50	5.90
21967825	209.202347	39.452202	0.540607	0.540600	1.80	4.70
22244513	208.742203	41.386112	0.604149	0.604077	2.50	8.10
22319996	209.734711	42.773571	0.479505	0.479495	2.60	4.90
22518636	208.239105	41.299026	0.283996	0.283998	1.80	3.00
22959674	209.018127	41.835575	0.405333	0.405409	1.80	3.80
22980793	208.105713	44.400867	0.540348	0.540353	1.90	2.80
23135759	209.604721	45.746510	0.402730	0.402732	4.20	4.40
23148883	209.446594	45.757584	0.390130	0.390124	1.40	4.80
23184808	208.547745	47.825001	0.338821	0.338888	1.00	5.70
23193507	208.703445	49.226929	0.473158	0.473174	3.40	4.60
23653629	209.116013	50.653641	0.442052	0.442055	2.40	4.40
24019356	208.649506	50.454273	0.517473	0.517460	1.50	4.60
24020106	209.853088	5.836339	0.542397	0.542396	2.90	4.50
24216004	209.385406	6.251467	0.382077	0.381912	1.90	7.80
880588	208.532242	6.762656	0.600138	0.600134	1.20	2.40
1212611	208.592422	6.144436	0.630896	0.630893	0.90	1.20
1876491	209.131027	5.983884	0.760128	0.760123	1.20	1.20
3048546	209.125137	-4.194337	0.656287	0.656293	1.00	1.30
5272753	208.115189	-4.847239	0.485827	0.485831	0.90	1.60
8610884	208.744736	-4.852155	0.592421	0.592429	2.20	4.30
8907563	209.521454	-3.322183	0.513164	0.513164	1.10	4.60

LINEAR ID	RA	DEC	LINEAR period	ZTF period	LINEAR chi-2	ZTF chi-2
9852554	208.390961	-4.619442	0.651339	0.651367	1.00	4.50
9961135	209.178848	52.903030	0.590896	0.590891	1.10	1.80
10503746	208.417831	54.266953	0.573563	0.573570	2.70	1.90
21948290	209.862518	56.455978	0.511127	0.511115	2.30	2.40
23596342	209.988663	56.828396	0.602841	0.602846	1.20	2.90
23898397	121.150764	42.483574	0.563018	0.562989	1.60	3.50
1882088	208.323578	58.245502	0.315984	0.316041	4.00	1.50
2936953	208.351578	57.226521	0.328746	0.328733	2.70	1.30
3219035	209.858856	60.601982	0.326746	0.326509	3.90	2.60
4320492	168.062149	65.801857	0.361005	0.360942	3.70	1.80
8036191	208.732498	59.448402	0.363860	0.363893	2.20	1.60
10420063	209.945786	61.264187	0.487395	0.487394	4.20	3.70
10662468	209.124405	61.076996	0.445180	0.445167	3.60	1.80
21688272	209.311371	62.800976	0.304803	0.304790	2.30	1.80
2714034	168.354202	65.678604	0.610868	0.610800	1.50	1.20
5592590	208.440872	65.857277	0.346945	0.346980	1.20	1.10
8799313	208.821136	7.846983	0.327560	0.327542	1.10	1.60