BAV Journal

2022 No. 65 ISSN 2366-6706

Bundesdeutsche Arbeitsgemeinschaft für Veränderliche Sterne e.V.

https://bav-astro.de

BH UMa - RRc type star with strong Blazhko effect

Berthold, Thomas[1], Agerer, Franz[2]

1) Hartha, Germany, agv@sternwarte-hartha.de
2) Zweikirchen, Germany, agerer.zweik@t-online.de

Bundesdeutsche Arbeitsgemeinschaft für Veränderliche Sterne e.V.

June 2022

Abstract: *Current observations confirm BH UMa to be of RRc type with a highly variable light curve driven by a strong Blazhko effect of short period.*

Introduction:

BH UMa (BV 36, GSC 03449-00652, TIC 53450382) has been discovered by Geyer and announced as short-period variable (Geyer, Kippenhahn and Strohmeier, 1955). First elements have been derived by Meinunger (1965) who ascertained eclipsing light changes with a period of 0.698685 days. The Brno O-C Gateway database (Paschke, 2007) lists 78 times of minimum light out of the years 1942-2020.
Krajci (2005) reported observations from Tashkent observatory revealing RRc type variability without further information. More recent surveys (SuperWASP, ASAS-SN, TESS and GAIA DR2) have confirmed this.

This paper contains the results of our photoelectric measurements with the proof of a Blazhko modulation. A period analysis for the fundamental period and the determination of the Blazhko period is given.

Observations:

Photoelectric observations were carried out using the equipment listed in Table 1.

Observer	Telescope	Camera	Filter	Remarks
Agerer	Schmidt-Cass. C8 / Telephoto lens f=300/4.0	Sigma 1603	-Ir (IR Blocking)	n=201
Berthold	Cassegrain 360/5250mm	Canon EOS1100D	TG (Bayer array G-Band)	n=312

Table 1: Instrumentation and Observations

Examining the results yielded striking features of a variable light curve. Figures 1-3 are given as examples for both the brightness range and the short-time character of these complex alterations. Brightness measurements in Figs. 1-2 are folded with Ephemeris (1).

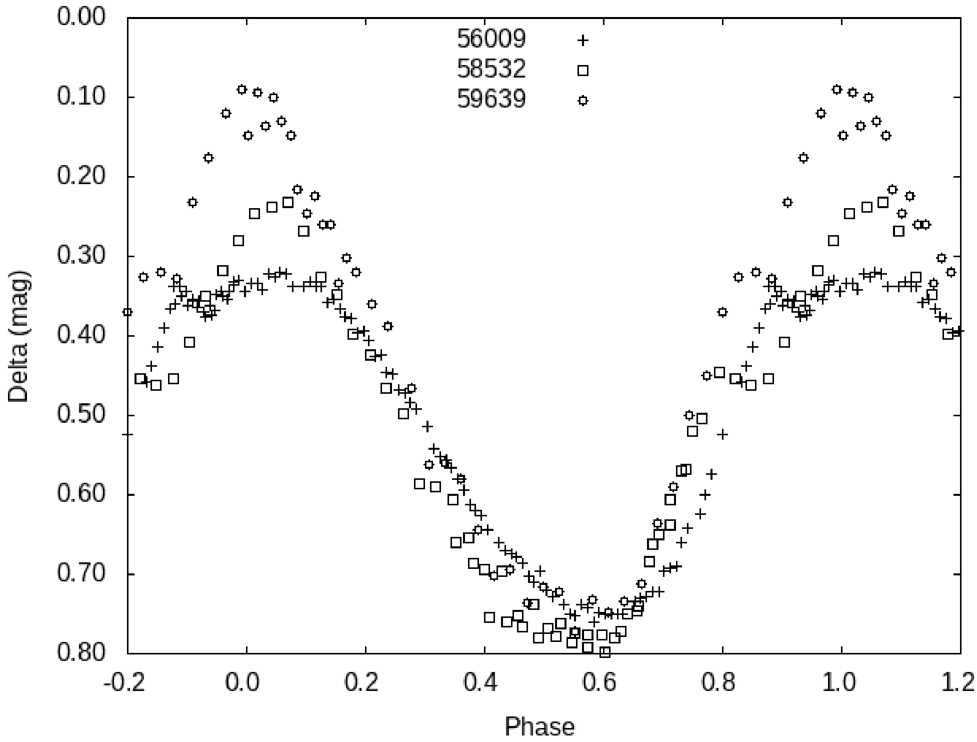

Fig. 1: Measurements of Agerer. Magnitudes relative to TYC 3449-746-1. Dates truncated to JD-2400000.

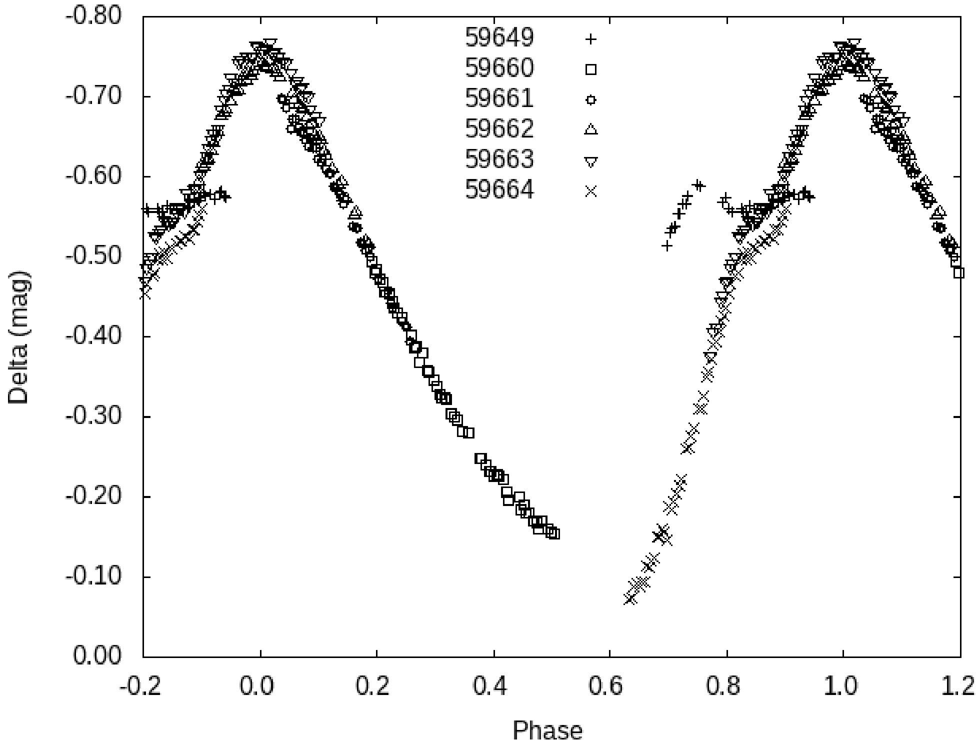

Fig. 2: Measurements of Berthold. Magnitudes relative to TYC 3449-707-1. Dates truncated to JD-2400000.

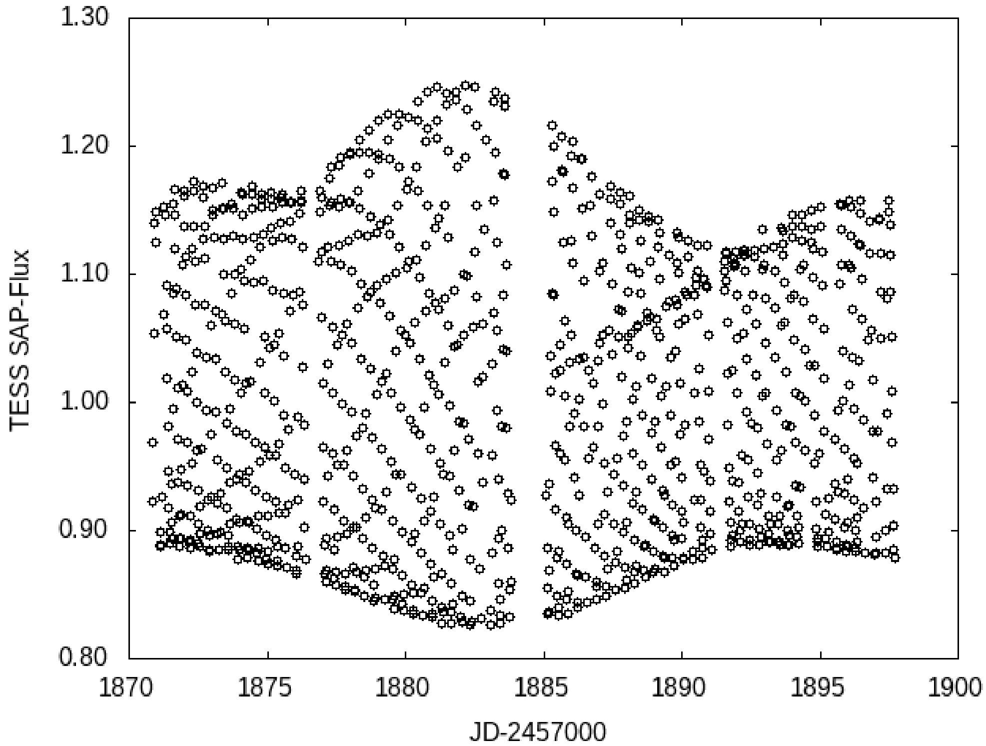

Fig. 3: TESS Single Aperture Photometry Data series.

Data analysis:

Fundamental period:

After a first review of the photometric data we gathered all available times of maximum light from publications. Additionally the survey data from SuperWASP, ASAS-SN and TESS have been evaluated to derive individual maximum data.

A least-squares analysis of these data (listed in Table 2) has yield the following linear ephemeris:

$$\text{Max HJD} = 2458882.1788\ (20) + 0.34936773\ (58) \cdot E \qquad (1)$$

Some remarks to the timing data in Table 2:

The shape of the light curve varies according to the phase of the Blazhko-Period. In particular this affects timings of the maxima in cases with a preceding ‘secondary’ maximum. The first appearance of this feature in presumably every Blazhko cycle occurs in ascending light around fundamental phase Φ=0.75 and this secondary maximum is more or less fainter than the following one. During the next couple of periods this wave travels quickly with increasing brightness towards the following ‘main’ maximum. They merge when the secondary maximum has reached the main maximum.

Fig. 1 demonstrates two different appearances of this behaviour. Observations from JD 2456009 show nearly equally bright maxima (due to a Blazhko-induced faint ‘main’ maximum at this state), whereas at JD 59639 the secondary maximum is clearly fainter than the main one.
Already published results from Agerer (in Hübscher et al., 2013 and in Pagel, 2020) have been carefully re-examined.

To be consistent, the table lists only the times for the main maxima which have been used to determine ephemeris (1).

One timing from the list of Ferrand & Vandenbroere (HJD 57081.492) has been rejected for the analysis due to the amount of the (O-C) value. This one is likely to be a secondary maximum.

n	HJD - 2400000	Epoch	O-C	Remarks
1	54447.6465	-12693	-0.0077	SuperWASP
2	55258.514	-10372	-0.023	Vandenbroere, Salmon (2010)
3	55265.502	-10352	-0.022	Vandenbroere, Salmon (2010)
4	56009.3460	-8223	0.0180	Agerer
5	56758.372	-6079	-0.004	Ferrand, Vandenbroere (2015)
6	56802.7695	-5952	0.0274	ASAS-SN
7	56911.0480	-5642	0.0019	GAIA DR2
8	57010.9950	-5356	0.0297	ASAS-SN
9	57032.9926	-5293	0.0172	ASAS-SN
10	57109.8436	-5073	0.0073	ASAS-SN
11	57131.470	-5011	-0.027	Ferrand, Vandenbroere (2015)
12	57460.9506	-4068	-0.0003	ASAS-SN
13	57697.1207	-3392	-0.0028	ASAS-SN
14	57869.7444	-2898	0.0332	ASAS-SN
15	58532.4772	-1001	0.0155	Agerer
16	58855.2815	-77	0.0040	Höcherl (in Pagel 2021)
17	58875.5171	-19	-0.0237	TESS (1.1625)
18	58876.2270	-17	-0.0126	TESS (1.1657)
19	58876.9298	-15	-0.0084	TESS (1.1698)
20	58877.2812	-14	-0.0065	TESS (1.1840)
21	58877.6329	-13	-0.0041	TESS (1.1940)
22	58877.9841	-12	-0.0023	TESS (1.2009)
23	58878.3345	-11	0.0013	TESS (1.2081)
24	58878.6853	-10	0.0002	TESS (1.2129)
25	58879.0361	-9	0.0016	TESS (1.2195)
26	58879.3859	-8	0.0020	TESS (1.2257)
27	58879.7365	-7	0.0033	TESS (1.2299)
28	58880.0878	-6	0.0052	TESS (1.2288)
29	58880.4370	-5	0.0050	TESS (1.2377)
30	58880.7863	-4	0.0050	TESS (1.2424)
31	58881.1362	-3	0.0055	TESS (1.2472)
32	58881.4861	-2	0.0060	TESS (1.2472)
33	58881.8358	-1	0.0064	TESS (1.2490)
34	58882.1845	0	0.0057	TESS (1.2480)
35	58882.5367	1	0.0085	TESS (1.2469)
36	58883.2356	3	0.0087	TESS (1.2480)
37	58883.5857	4	0.0094	TESS (1.2400)
38	58885.3321	9	0.0090	TESS (1.2190)
39	58885.6806	10	0.0082	TESS (1.2070)
40	58886.0289	11	0.0071	TESS (1.2057)
41	58886.3795	12	0.0083	TESS (1.1961)
42	58886.7302	13	0.0096	TESS (1.1851)
43	58887.0765	14	0.0066	TESS (1.1718)
44	58887.4273	15	0.0080	TESS (1.1702)
45	58887.7707	16	0.0020	TESS (1.1654)
46	58888.1197	17	0.0016	TESS (1.1615)
47	58888.4676	18	0.0002	TESS (1.1510)

n	HJD - 2400000	Epoch	O-C	Remarks
48	58888.8154	19	-0.0014	TESS (1.1481)
49	58889.1648	20	-0.0014	TESS (1.1434)
50	58889.8583	22	-0.0066	TESS (1.1355)
51	58890.5510	24	-0.0126	TESS (1.1233)
52	58890.8977	25	-0.0153	TESS (1.1246)
53	58891.5889	27	-0.0229	TESS (1.1195)
54	58891.9350	28	-0.0261	TESS (1.1164)
55	58892.2834	29	-0.0271	TESS (1.1194)
56	58892.6222	30	-0.0376	TESS (1.1186)
57	59639.6074	2168	-0.0006	Agerer
58	59662.3191	2233	0.0022	Berthold
59	59663.3690	2236	0.0039	Berthold

Table 2: Individual times of main maximum light folded with ephemeris (1). Flux values for TESS observations (in brackets) were derived with PERANSO.

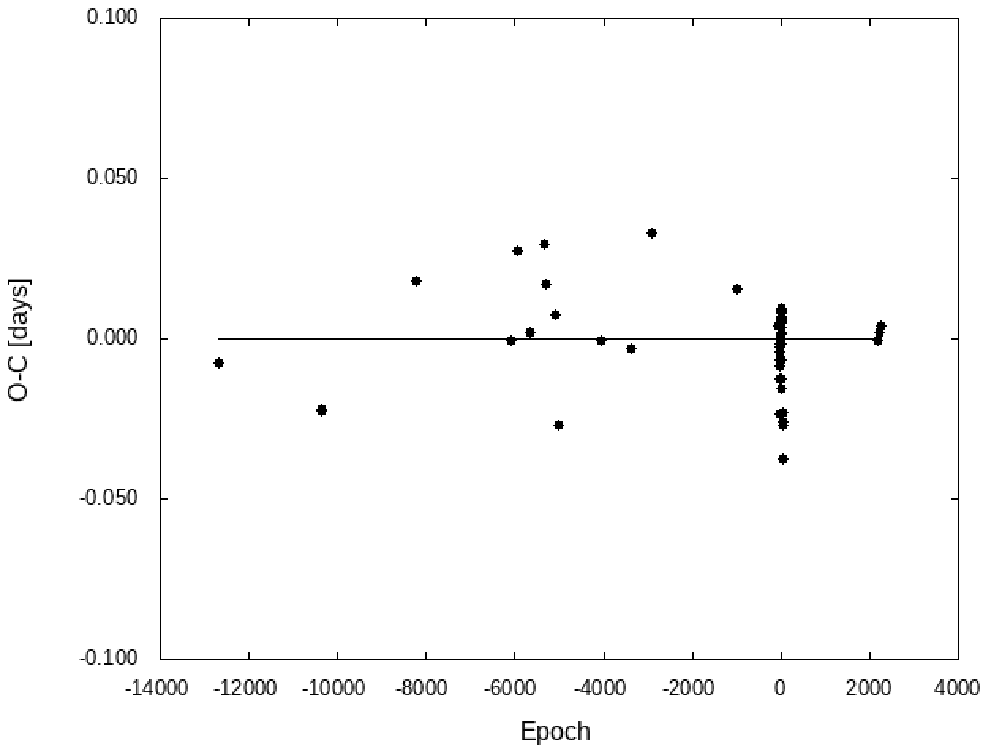

Fig. 4: O-C values from Table 2. The inserted line stands for ephemeris (1).

The fundamental period seems to be constant within the remaining error band over the investigated time. The modulation of the light curve can be held responsible for the scatter. In detail the impact of the Blazhko mechanism can be seen from Fig 5.

Blazhko period:

A first view at the TESS photometric data (see Fig. 3) proves strong modulation of the light curve due to the Blazhko effect.

These data offer an excellent possibility to determine a value for the Blazhko period. Unfortunately the length of the dataset is only in the order of the Blazhko period what limits the precision especially towards the longer edge of the Blazhko period error band.

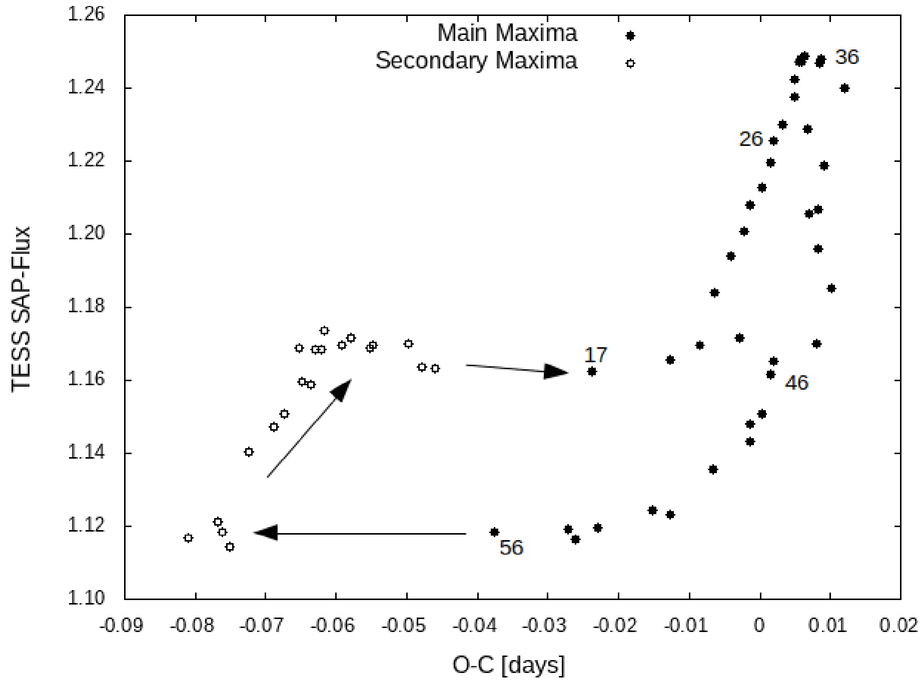

Fig. 5: Variation of maximum brightness during the Blazhko cycle covered by the TESS data. Numbers refer to those from the first column of Table 2. O-C values are according to ephemeris (1).

Using the CLEANEST algorithm of the PERANSO software package (Paunzen & Vanmunster, 2016) we got values of about 22.5 days for the variation of the brightness extrema, what gives an acceptable match to a first guess from Fig. 3. See Fig. 6 for illustration.

Additionally a Fourier analysis of the individual measurements yields an independent way to derive the length of the Blazhko period. Results are plotted in Fig. 7.
These calculations were done using the Period04 package (Lenz & Breger 2005).

One can derive the frequencies of interest from the side peaks visible in the two portions of the Fourier spectrum in of Fig. 7.

Fundamental:	$f_0 = 2.864105\ d^{-1}$	$P_0 = 0.349149$ d
Blazhko:	$f_0 + f_B = 2.908297\ d^{-1}$	$P_B = 22.6$ d
	$f_0 - f_B = 2.822651\ d^{-1}$	$P_B = 24.1$ d

The additive case agrees very well with the results from the brightness analysis and the position of the left-side peak is probably within the uncertainty of the period determination (considering the short TESS data interval).

Results:

BH Uma is a RR Lyr type variable showing strong light curve modulations. Despite the large overall amplitude of 0.7 mag, the shape of the light curve and the temporary appearance of double maxima suggest a RRc type classification.

Clear evidence was found for a Blazhko effect with a period length of about 22.5 days from brightness modulation and Fourier analysis as well. Nevertheless, the extent of the TESS dataset is somewhat short to get fully consistent results.
According to Molnár et al. (2022) the short Blazhko period gives some additional support for the assumption of a RRc affiliation.

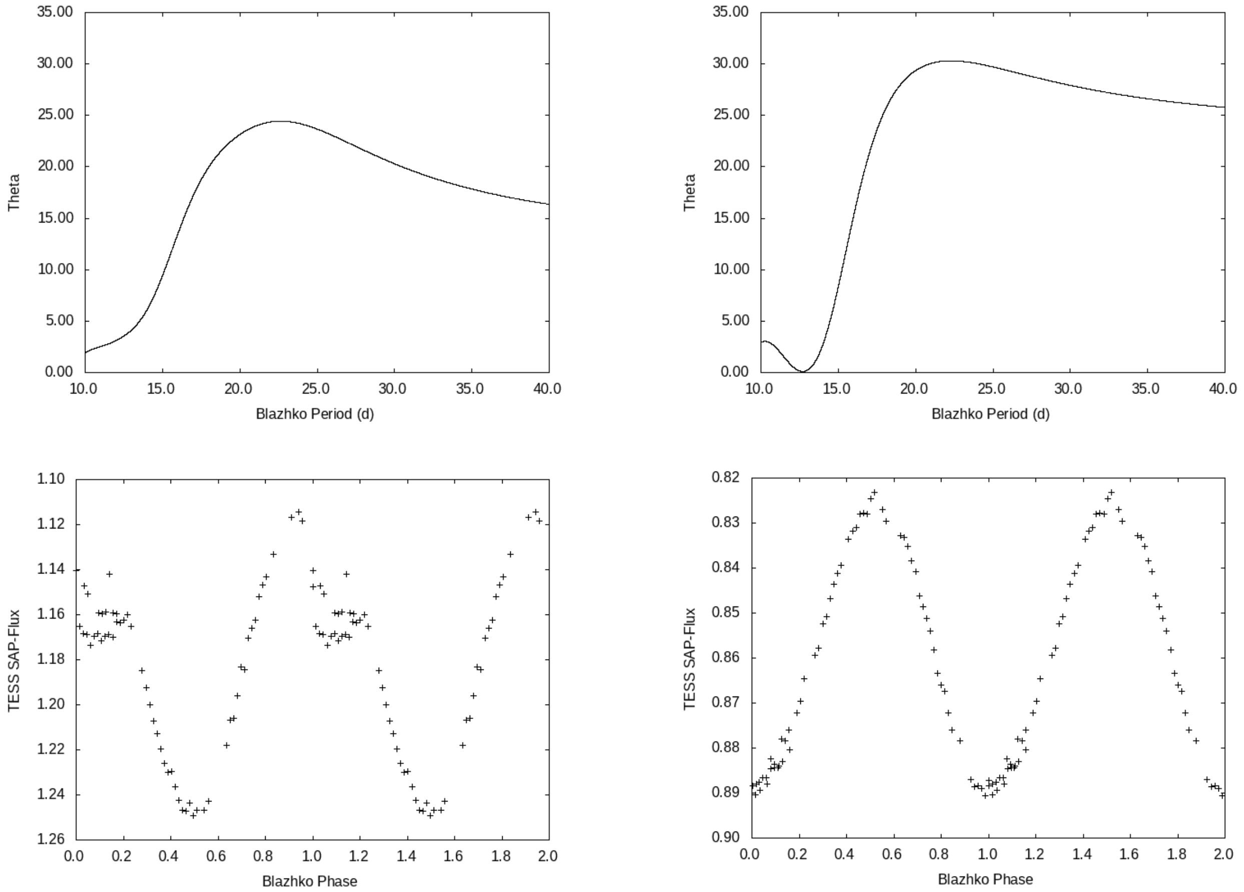

Fig. 6: Determination of the Blazhko period from the flux variations of the maxima (left) and minima (right) as supplied by TESS Photometry. CLEANEST algorithm was used to derive periods of 22.64 and 22.29 days resp. Flux values in the lower panels are plotted against these values.

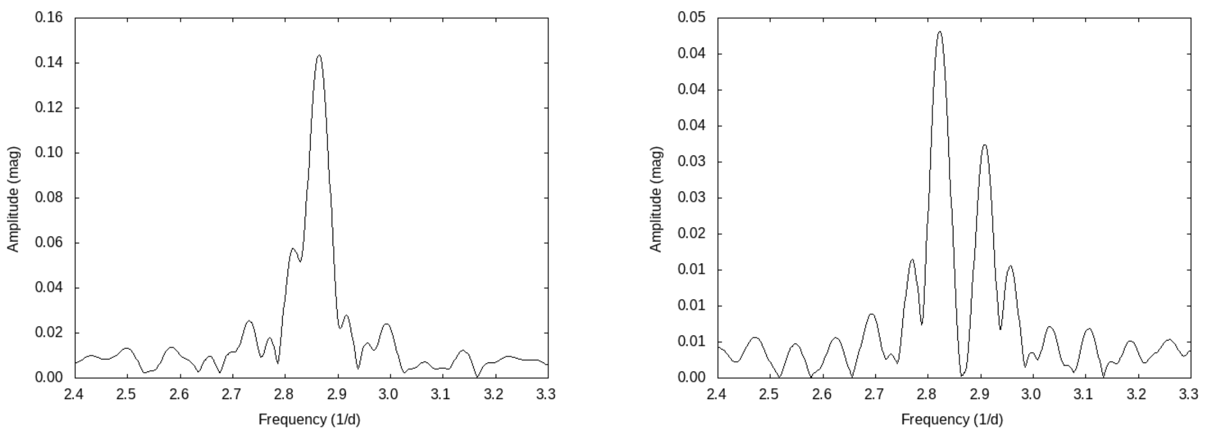

Fig. 7: TESS data Fourier Analysis. The dominant peak on left chart shows the fundamental period. The right panel gives the results of the same data pre-whitened with the fundamental period and its first thee harmonics. The side peaks on the left and the right side were caused by the Blazhko modulation (f_0 + f_B) and (f_0 - f_B) respective. See text for further explanations.

Acknowledgements:

This research has made use of the SIMBAD database and the VizieR catalogue access tool, operated at CDS, Strasbourg, France (Wenger et al. 2000).

This work has made use of data from the European Space Agency (ESA) mission Gaia, processed by the Gaia Data Processing and Analysis Consortium (DPAC), the first public release of the WASP data (Butters et al. 2010) as provided by the WASP consortium as well as from the ASAS-SN All-Sky Automated Survey (Kochanek et al. 2017). This paper includes data collected by the TESS mission, which are publicly available from the Mikulski Archive for Space Telescopes (MAST).

References:

Butters et al., 2010, *Astronomy and Astrophysics*, **520**, L10, 4, 2010A&A...520L..10B

Ferrand, S. & Vandenbroere, J., 2015, *GEOS RR Lyr Database*, http://rr-lyr.irap.omp.eu/dbrr/index.php

Geyer, E., Kippenhahn, R., Strohmeier, W.; 1955, *Kl. Veröff. Bamberg*, **9**

Hübscher, J. et al., 2013, *Information Bulletin on Variable Stars*, **6048**, 2013IBVS.6048....1H

Kochanek, C. S. et al., 2017, *Publications of the Astronomical Society of the Pacific*, **129**, 980, 2017PASP..129j4502K

Krajci, T., 2005, *Information Bulletin on Variable Stars*, **5599,** 2005IBVS.5699...12K

Lenz, P. & Breger, M., 2005, *Communications in Asteroseismology*, **146**, 53, 2005CoAst.146...53L

Meinunger, L., 1965; *Mitteilungen ueber Veraenderliche Sterne*, **3**.1.9

Molnár, L. et al., 2022, *The Astrophysical Journal Supplement Series*, **258**, 1.8, 44, 2022ApJS..258....8M

Pagel, L., 2020, *BAV Journal*, **33**, 2020BAVJ...33....1P

Pagel, L., 2021, *BAV Journal*, **52**, 2021BAVJ...52....1P

Paunzen, E. & Vanmunster, T., 2016, *Astron. Nachrichten*, **337**, 3, 239, 2016AN....337..239P

Paschke, A., 2007, *O-C Gateway*, http://var.astro.cz/ocgate

Vandenbroere J. & Salmon G., 2010, *GEOS Circular RR45*

Wenger, M. et al. 2000, *Astronomy and Astrophysics Supplement*, **143**, 9, 2000A&AS..143....9W