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23 Years of Observations of V505 Ser

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Abstract: V505 Ser is a short-period eclipsing RS CVn system discovered in 2005. We report here new observations from 2020 and 2021 that extend the period of observations to 23 years and further support the previously suspected spot cycle duration of about 5.5 years. Furthermore, we present the results of a detailed investigation of the O-C values of the entire observing span.

Introduction

V505 Ser (GSC 02038-00293) is an "active" eclipsing binary star of the RS Canum Venaticorum type (RS CVn) with an extremely short period of about half a day [1]. Its variability was discovered by Bernhard in 2005 and the star entered the General Catalogue of Variable Stars (GCVS; [11]) under the designation of V505 Ser [5].

According to the detailed study of V505 Ser [3], the temperature of the spotted primary star (0.87 solar masses) is about 4750 K. The temperature of the secondary star (0.27 solar masses) is only about 3515 K. For further details of this extraordinary binary system see our last report of our ongoing observing campaign [7].

Up to the present time, long and uninterrupted time series, which are indispensable for the investigation of long-term brightness development (see e.g. [9] and [10]), are only available for a relatively small number of RS CVn stars.

Therefore, V505 Ser was observed during every season since its discovery. The most recent update of our campaign was in the aforementioned report, published in 2019 [7] and includes observations up to and including 2019. We present here two more years of observations (2020 and 2021). Together with the "prediscovery" data from the NSVS [12], and ASAS [8] surveys, the observations of V505 Ser now span a period of 23 years.

Observations and data analysis

The follow-up observations were carried out with a 102mm/f5.0 TeleVue Refractor and a SIGMA 1603 CCD-Camera containing a cooled Kodak KAF1603ME chip (Velden/Germany; two nights in 2020, four nights in 2021, Peter Frank). Further observations were made using a robotic 400 mm f/3.7 ASA Astrograph equipped with a cooled FLI Proline 16803 CCD-Camera and BVRI-filters (Nerpio/ Spain, two nights in 2020, two nights in 2021, Wolfgang Moschner), which was controlled from Lennestadt/Germany via internet.

Muniwin [15] and self-written programs by Franz Agerer and Lienhard Pagel were used for the analysis of the frames and after-bias, dark and flatfield correction of the exposures. Period analysis was performed by using Peranso [6] and Period04 [4].

Results

The elements presented in our first publication in 2006

(1) HJD MinI = 2453560.491±3 + 0.495410±1 × E

have been improved in 2012 [3] to

(2) HJD MinI = 2453560.4925±9 + 0.4954115±5 × E.

Period data can be taken from Kreiner [13] (=0.4954104 d) and GCVS 2018 [11] (= 0.4954131 d). For both slightly differing periods, the O-C values were calculated using the minima times determined by StarCurve (Lienhard Pagel, BAV). The two corresponding O-C diagrams are presented in Fig.1a and Fig.1b.

Apparently, the O-C curve has a very complex shape. In addition to an obviously generally relatively abrupt change of period (lengthening of the period around JD 2457000), 2 "peaks" occur in the first section of the light curve around JD 2454700 and 2456000. These two peaks have no obvious connection with the respective general starspot activity (see Figure 3).

Since the period in GCVS 2018 (= 0.4954131 d) corresponds sufficiently well to the present one, the O-C values of the individual minima were calculated using the instantaneous ephemeris given below (Table 1):

(3) HJD MinI = 2458963.4511±7 + 0.4954131±1 × E

In the following, only the MinI were considered, as the secondary minima are too strongly influenced by the very strong spot activity. In addition to the self-observed minima, those that were accessible via the Brno O-C gateway [14] were also included in the calculations:

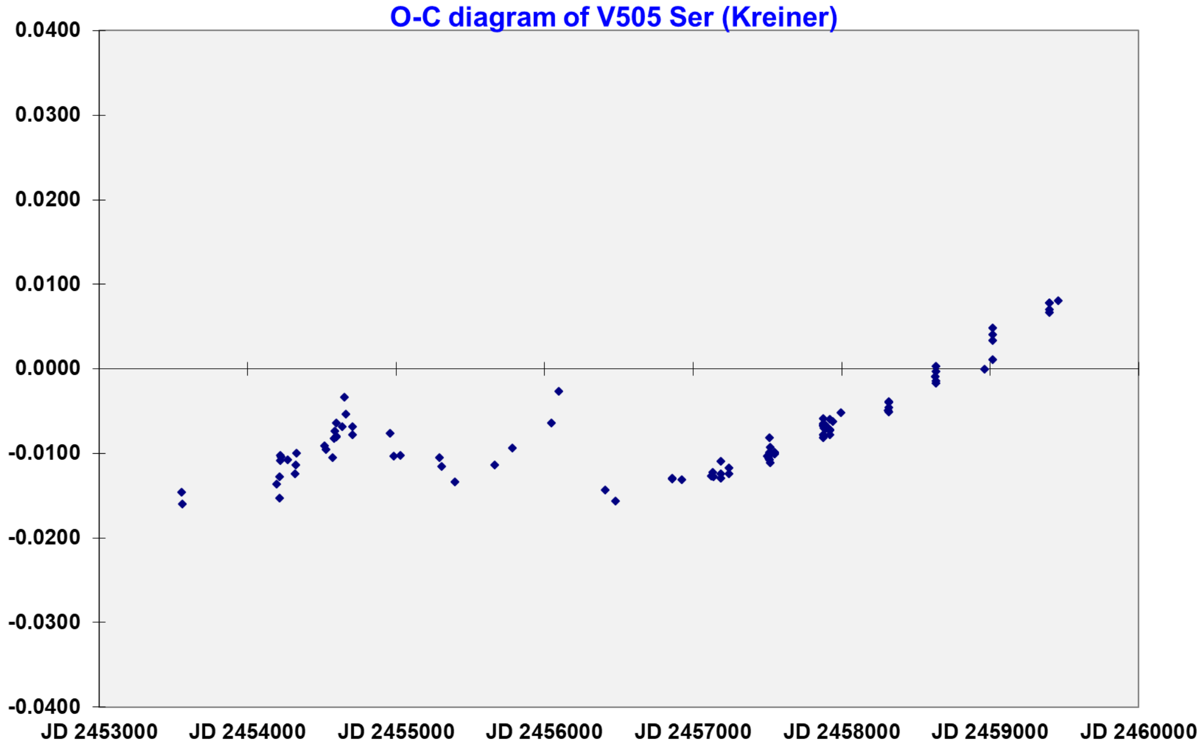

Fig.1a: O-C (d) diagram using the period of Kreiner (0.4954104 d).

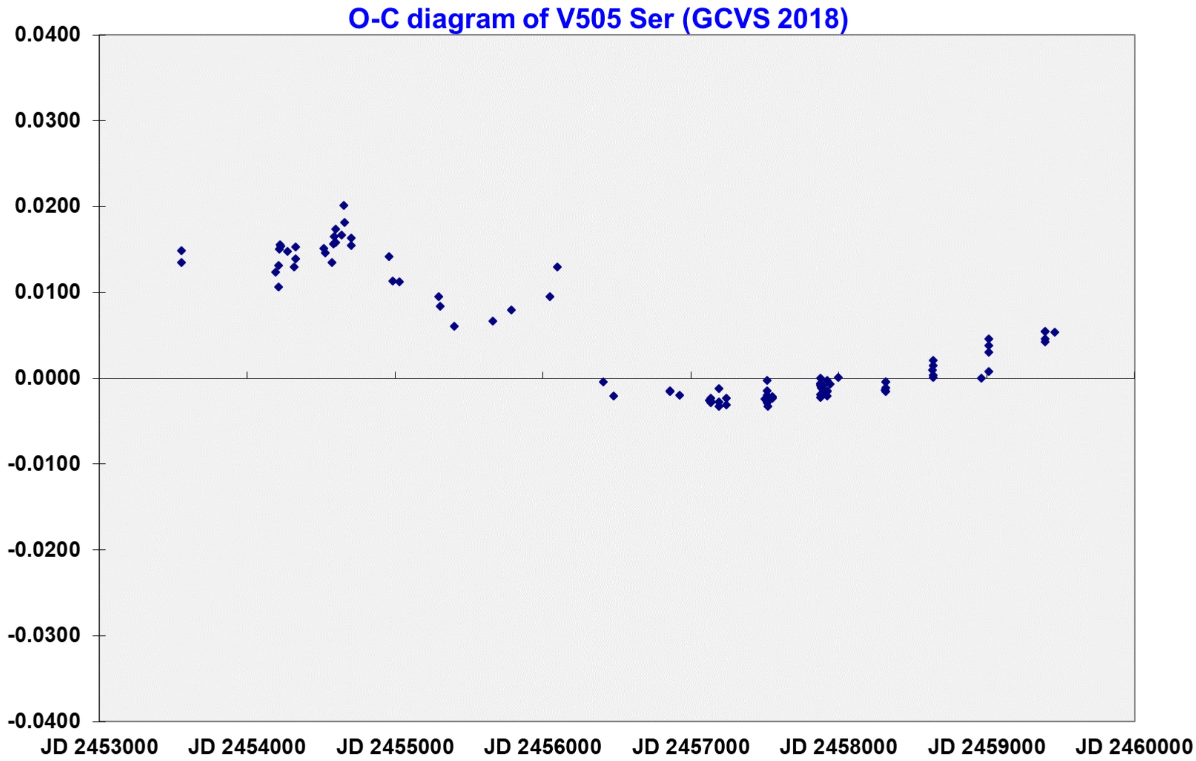

Fig.1b: O-C (d) diagram using the period of GCVS 2018 (0.4954131 d).

Table 1: List of observed Minima and calculated O-C data.

No.	observer	hel. JD min. (UTC)	type	epoch	O-C(d)	filter
1	P. Frank	2453555.5366	I	-10916	0.0149	-Ir
2	P. Frank	2453557.5168	I	-10912	0.0135	-Ir
3	P. Frank	2454192.6353	I	-9630	0.0124	-Ir
4	P. Frank	2454213.4409	I	-9588	0.0106	-Ir
5	S. Esin	2454213.4434	I	-9588	0.0131	BVR
6	S. Esin	2454219.3903	I	-9576	0.0151	BVR
7	P. Frank	2454221.3725	I	-9572	0.0156	-Ir
8	S. Esin	2454226.3264	I	-9562	0.0154	BVR
9	P. Frank	2454271.4084	I	-9471	0.0148	-Ir
10	P. Frank	2454318.4708	I	-9376	0.0129	-Ir
11	P. Frank	2454325.4076	I	-9362	0.0140	-Ir
12	P. Frank	2454326.3998	I	-9360	0.0153	-Ir
13	P. Frank	2454516.6382	I	-8976	0.0151	-Ir
14	S. Esin	2454526.5460	I	-8956	0.0146	BVR
15	P. Frank	2454570.6366	I	-8867	0.0135	-Ir
16	P. Frank	2454583.5195	I	-8841	0.0156	-Ir
17	S. Esin	2454587.4837	I	-8833	0.0165	BVR
18	P. Frank	2454594.4188	I	-8819	0.0158	-Ir
19	P. Frank	2454596.4004	I	-8815	0.0158	-Ir
20	P. Frank	2454597.3928	I	-8813	0.0174	-Ir
21	P. Frank	2454636.5298	I	-8734	0.0167	-Ir
22	S. Esin	2454651.3956	I	-8704	0.0201	BVRI
23	S. Esin	2454659.3202	I	-8688	0.0181	BVRI
24	P. Frank	2454703.4093	I	-8599	0.0155	-Ir
25	P. Frank	2454703.4102	I	-8599	0.0164	-Ir
26	P. Frank	2454959.5366	I	-8082	0.0142	-Ir
27	R. Diethelm	2454983.8090	I	-8033	0.0113	V
28	P. Frank	2455029.3869	I	-7941	0.0112	-Ir
29	P. Frank	2455293.4404	I	-7408	0.0095	-Ir
30	P. Frank	2455304.3383	I	-7386	0.0084	-Ir
31	P. Frank	2455397.4736	I	-7198	0.0060	-Ir
32	P. Frank	2455662.5202	I	-6663	0.0066	-Ir
33	P. Frank	2455784.3932	I	-6417	0.0079	-Ir
34	P. Frank	2456045.4775	I	-5890	0.0095	-Ir
35	P. Frank	2456094.5268	I	-5791	0.0130	-Ir
36	P. Frank	2456407.6145	I	-5159	-0.0004	-Ir
37	P. Frank	2456475.4844	I	-5022	-0.0021	-Ir
38	P. Frank	2456856.4576	I	-4253	-0.0016	-Ir
39	P. Frank	2456856.4577	I	-4253	-0.0015	-Ir
40	P. Frank	2456924.3288	I	-4116	-0.0020	-Ir
41	P. Frank	2457122.4934	I	-3716	-0.0026	-Ir
42	F. Agerer	2457132.4016	I	-3696	-0.0027	-Ir
43	P. Frank	2457133.3928	I	-3694	-0.0023	-Ir

44	P. Frank	2457134.3831	I	-3692	-0.0028	-Ir
45	Moschner/Frank	2457187.3919	I	-3585	-0.0032	I
46	Moschner/Frank	2457187.3924	I	-3585	-0.0027	B
47	Moschner/Frank	2457187.3939	I	-3585	-0.0012	V
48	P. Frank	2457238.4204	I	-3482	-0.0023	-Ir
49	P. Frank	2457241.3921	I	-3476	-0.0031	-Ir
50	P. Frank	2457499.5030	I	-2955	-0.0024	-Ir
51	P. Frank	2457508.4202	I	-2937	-0.0026	-Ir
52	P. Frank	2457508.4205	I	-2937	-0.0023	-Ir
53	P. Frank	2457514.3650	I	-2925	-0.0028	-Ir
54	P. Frank	2457514.3658	I	-2925	-0.0020	-Ir
55	F. Agerer	2457514.3675	I	-2925	-0.0003	-Ir
56	P. Frank	2457515.3563	I	-2923	-0.0023	-Ir
57	F. Agerer	2457515.3564	I	-2923	-0.0022	-Ir
58	P. Frank	2457516.3480	I	-2921	-0.0014	-Ir
59	P. Frank	2457517.3370	I	-2919	-0.0033	-Ir
60	Moschner/Frank	2457547.5581	I	-2858	-0.0024	R
61	W. Moschner	2457547.5581	I	-2858	-0.0024	R
62	Moschner/Frank	2457547.5583	I	-2858	-0.0022	V
63	W. Moschner	2457547.5583	I	-2858	-0.0022	V
64	P. Frank	2457873.5404	I	-2200	-0.0019	-Ir
65	P. Frank	2457874.5324	I	-2198	-0.0007	-Ir
66	Moschner/Frank	2457876.5125	I	-2194	-0.0022	B
67	Moschner/Frank	2457876.5139	I	-2194	-0.0008	I
68	Moschner/Frank	2457876.5142	I	-2194	-0.0005	R
69	Moschner/Frank	2457876.5148	I	-2194	0.0001	V
70	F. Agerer	2457879.4853	I	-2188	-0.0019	-Ir
71	P. Frank	2457879.4861	I	-2188	-0.0011	-Ir
72	P. Frank	2457890.3855	I	-2166	-0.0008	-Ir
73	P. Frank	2457891.3759	I	-2164	-0.0012	-Ir
74	Moschner/Frank	2457918.6228	I	-2109	-0.0021	R
75	Moschner/Frank	2457918.6233	I	-2109	-0.0016	I
76	Moschner/Frank	2457918.6234	I	-2109	-0.0015	V
77	Moschner/Frank	2457918.6246	I	-2109	-0.0003	B
78	P. Frank	2457940.4224	I	-2065	-0.0006	-Ir
79	P. Frank	2457995.4140	I	-1954	0.0001	-Ir
80	P. Frank	2458312.4769	I	-1314	-0.0014	-Ir
81	W. Moschner	2458317.4309	I	-1304	-0.0015	V
82	W. Moschner	2458317.4313	I	-1304	-0.0011	R
83	W. Moschner	2458317.4320	I	-1304	-0.0004	I
84	W. Moschner	2458317.4320	I	-1304	-0.0004	B
85	P. Frank	2458630.5344	I	-672	0.0009	-Ir
86	W. Moschner	2458635.4877	I	-662	0.0001	I
87	W. Moschner	2458635.4880	I	-662	0.0003	V
88	W. Moschner	2458635.4891	I	-662	0.0015	B
89	W. Moschner	2458635.4897	I	-662	0.0021	R
90	P. Frank	2458963.4511	I	0	0.0000	-Ir

91	**W. Moschner**	**2459015.4703**	**I**	**105**	**0.0008**	**I**
92	**W. Moschner**	**2459015.4725**	**I**	**105**	**0.0031**	**R**
93	**W. Moschner**	**2459015.4733**	**I**	**105**	**0.0038**	**V**
94	**W. Moschner**	**2459015.4741**	**I**	**105**	**0.0046**	**B**
95	**W. Moschner**	**2459396.4464**	**I**	**874**	**0.0043**	**R**
96	**W. Moschner**	**2459396.4468**	**I**	**874**	**0.0046**	**B**
97	**W. Moschner**	**2459396.4476**	**I**	**874**	**0.0054**	**I**
98	**W. Moschner**	**2459396.4476**	**I**	**874**	**0.0055**	**V**
99	**P. Frank**	**2459460.3558**	**I**	**1003**	**0.0054**	**-Ir**

The filter labeled -Ir is an IR Cut filter.

The phased light curve of the observations of Peter Frank (-Ir filter) and Wolfgang Moschner (BVRI filter) are shown in Figs. 2 (2020) and 3 (2021). They have been phased using the ephemeris given in equation (3).

Different nights are marked as different colours in the phased (-Ir filter) light curves (Figs. 2a and 3a).

The brightnesses of the different color bands in the two BVRI light curves (Figs. 2b and 3b) are shifted for better visualization (B+0.04, R-0.03, I-0.06). Due to the spot activity, secular brightness variations are possible within a few days, which has an influence on the reduced light curves (see e.g. around phase 0 in Figure 3b).

Our observations illustrate the obviously high starspot activity in 2020 - 2021, considering that the pronounced "secondary minima" (phase 0.3-0.7), which are not due to eclipses but exclusively caused by starspots. The high starspot activity in 2020 and 2021 also manifests itself in a strong variation in the appearance of the light curves between 2020 and 2021 (especially compare Fig. 2a and Fig. 3a).

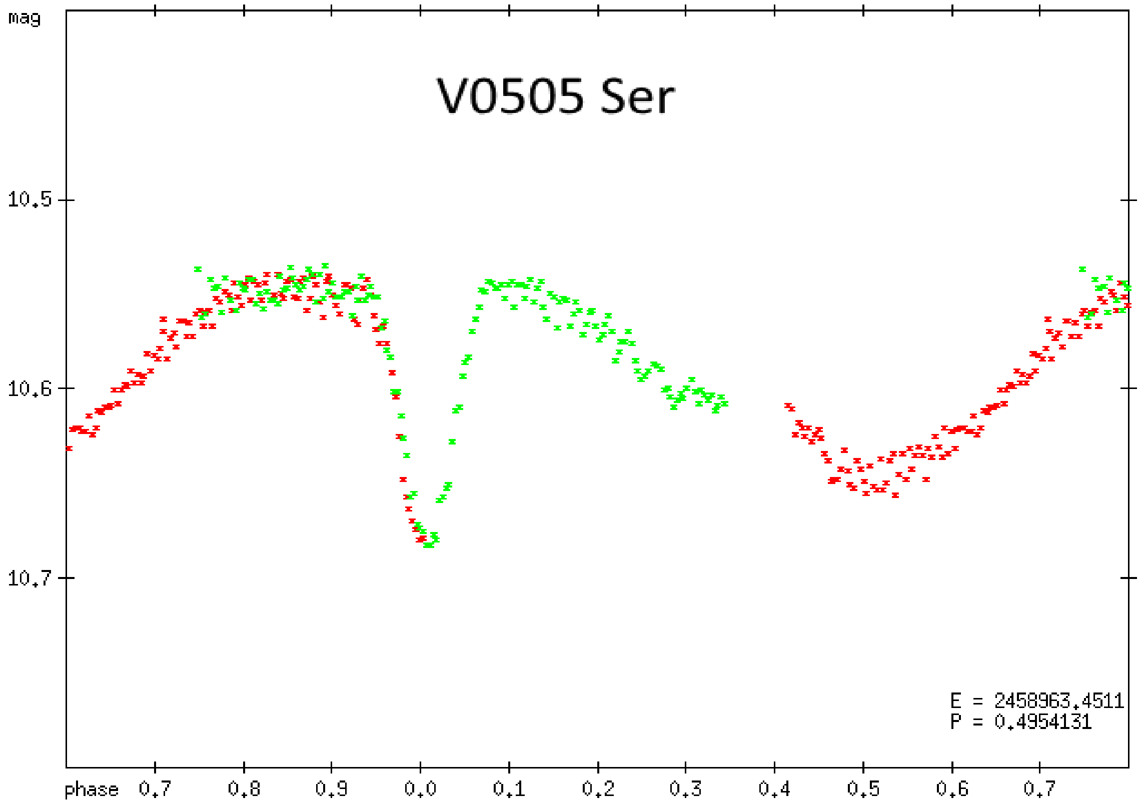

Fig. 2a: Phased (-Ir filter) lightcurve of V505 Ser in 2020, based on observations acquired in Velden, Germany (Peter Frank). Different colors denote different observing nights.

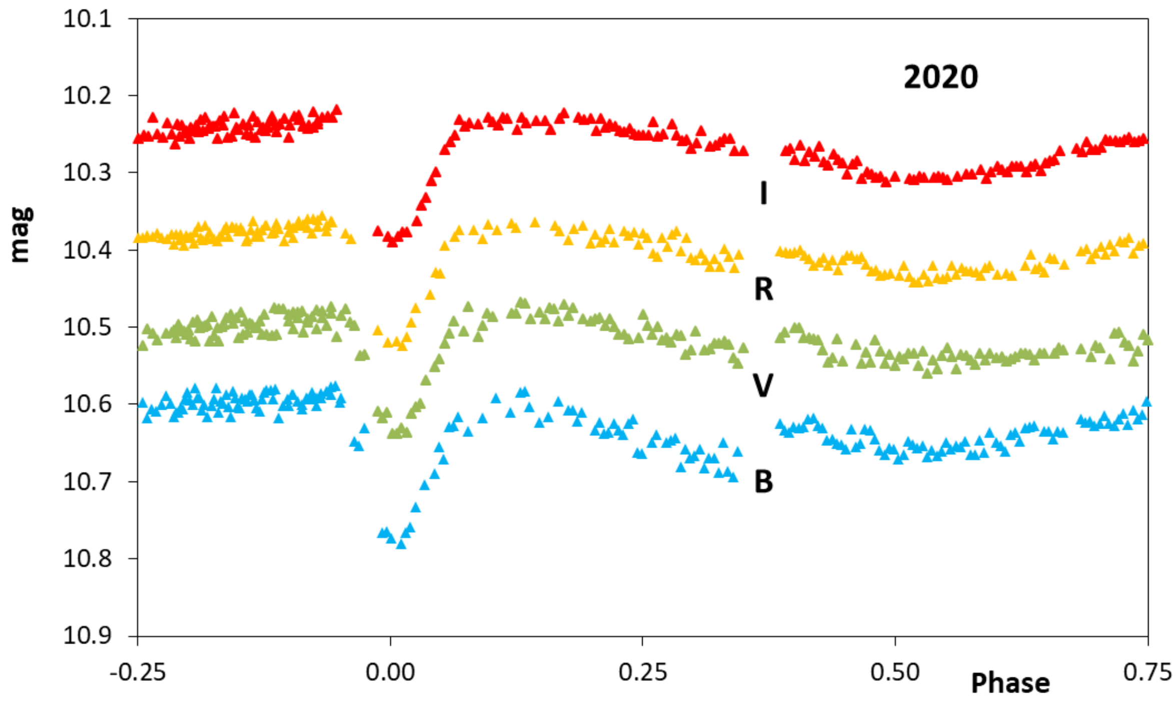

Fig. 2b: Phased (BVRI filter) lightcurve of V505 Ser in 2020, based on observations acquired in 2020 in Nerpio, Spain (Wolfgang Moschner). The individual color bands were displayed one above the other. These are non-calibrated brightnesses.

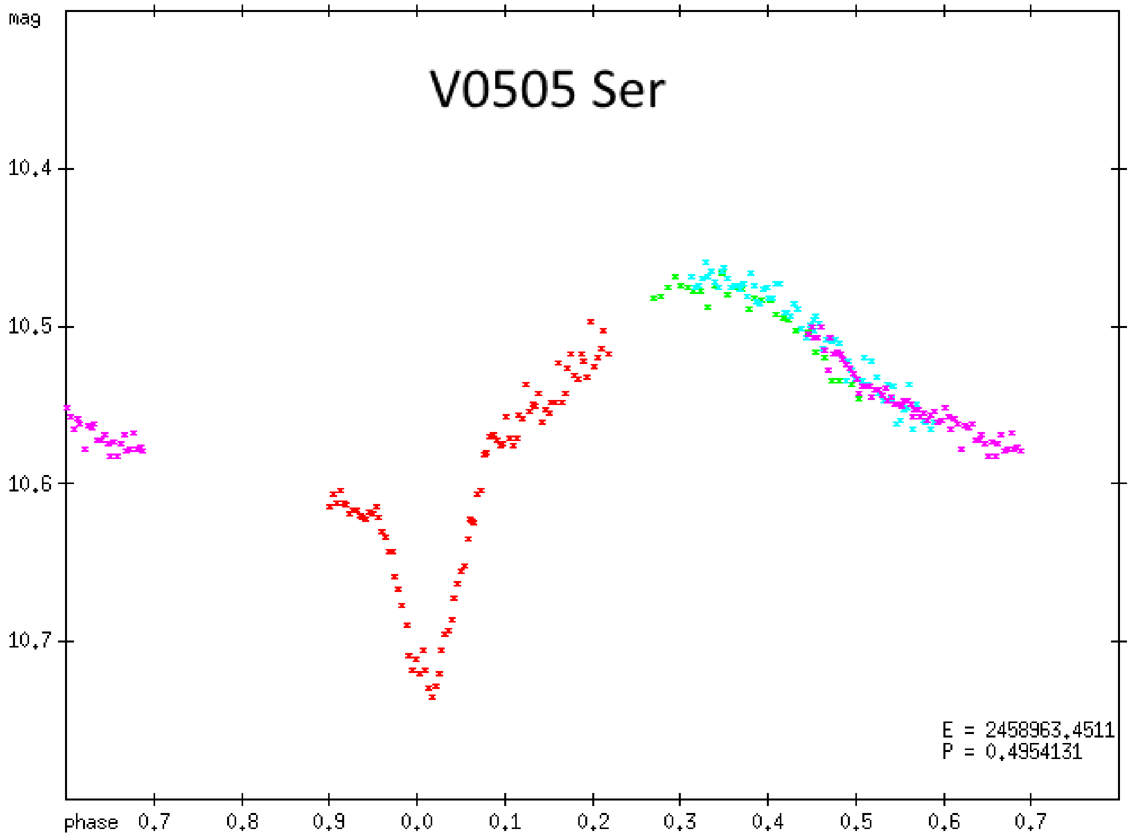

Fig. 3a: Phased (-Ir filter) lightcurve of V505 Ser in 2021, based on observations in Velden, Germany (Peter Frank). Different colors denote different observing nights.

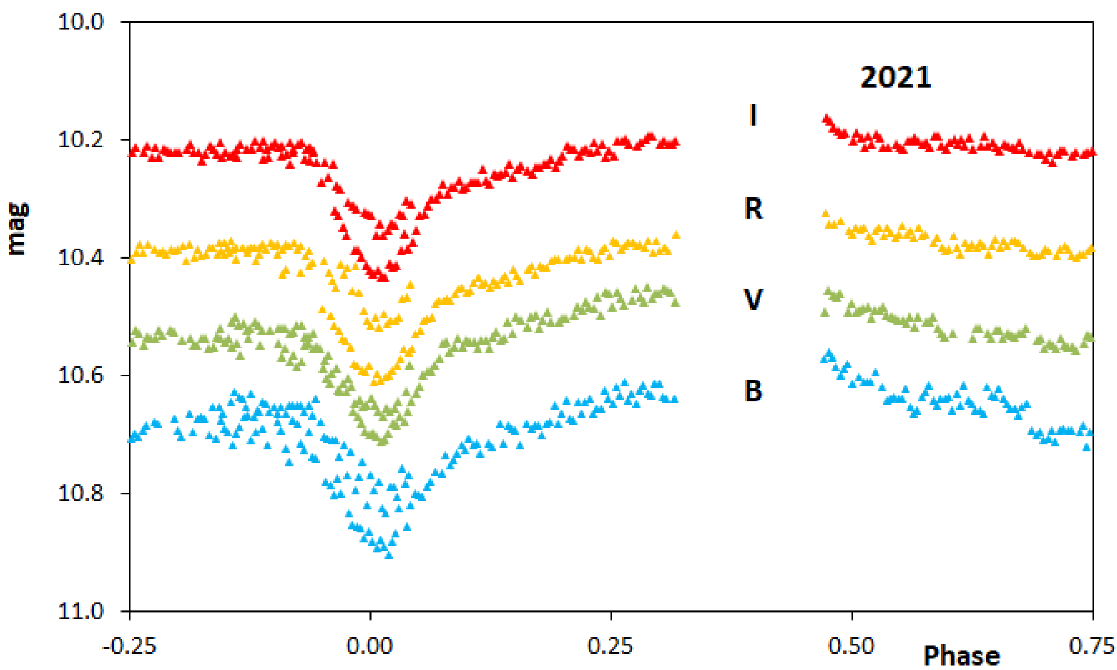

Fig. 3b: Phased (BVRI filter) lightcurve of V505 Ser in 2021, based on observations in Nerpio, Spain (Wolfgang Moschner). The individual color bands were displayed one above the other. These are non-calibrated brightnesses.

We followed the methodology employed in our earlier publications and determined the level of star spot activity of the two further years 2020 and 2021 by low-order polynomial fits (Fig. 4; cf. also [2]). This confirms an increase in starspot activity since 2018, but it is not yet clear whether or not another (weak) maximum has already occurred around 2021. In general, however, the observations of 2020 and 2021 fit well into the picture of a 5 to 6-year starspot cycle.

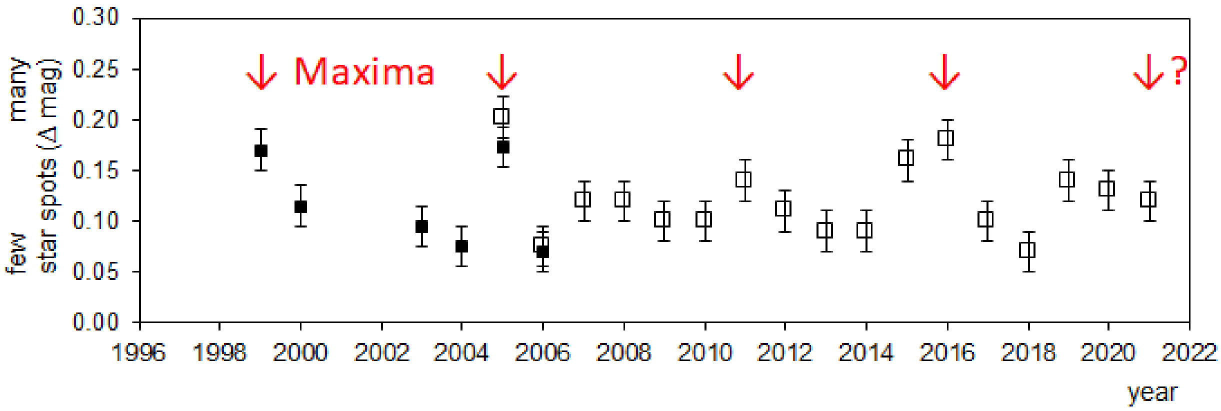

Fig. 4: Amplitudes of the "secondary minima" caused by starspots during the observing seasons 1999 to 2021 (with error bars; filled squares: ASAS, NSVS; open squares: our measurements).

To sum up, the observations of 2020 and 2021 presented here provide further support of the suspected ~5.5 year starspot cycle, which obviously exhibits strong secular fluctuations, as is observed for other active stars. We will therefore continue to acquire further observations of the outstanding object V505 Ser.

Acknowledgements

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