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20 Years of Observations of V505 Serpentii

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Abstract: V505 Ser is a short-period eclipsing RS CVn system discovered by Bernhard (2005). We here report on new unfiltered and *BVRI* observations taken in 2018 and 2019 that enlarge the time span of observations to 20 years and provide further evidence for the previously suspected spot cycle duration of about 5.5 years. The next maximum of activity will probably occur in 2020.

Introduction

V505 Ser (GSC 02038-00293) is an "active" double star of the RS Canum Venaticorum (RS CVn) type 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.

Similar to what is observed for our Sun, the position and extent of the star spots on the primary component change constantly, which leads to secondary variability of the light curve that is otherwise dominated by the eclipse by the secondary component. However, due to the lower temperature and the much higher rotational speed (factor of about 50; period ~0.5 d as compared to ~25 days for the Sun), the spots are much larger than those of our Sun. The long-term light curve of V505 Ser is also indicative of long-term changes in spot activity, the monitoring of which allows to investigate the regularity and length of the star spot cycle and therefore provides important input for the understanding of the physics of convective sun-like stars.

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]), are only available for a relatively small number of RS CVn stars. While the commissioning of diverse automated sky surveys has somewhat augmented this situation, the resulting data mostly span a few years and hence only permit detailed study of very short activity cycles (see e.g. [10]).

Therefore, V505 Ser was observed during every season since its discovery. The most recent update of the results of our campaign was published in 2017 [2] and includes observations up to and including 2017. We here present two more years of observations (2018 and 2019). Together with the "prediscovery" data from the NSVS [12], and ASAS [8] surveys, the observations of V505 Ser now span a period of 20 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; five nights in 2018, three nights in 2019, 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 2019, Wolfgang Moschner), which was controlled from Lennestadt/Germany via internet.

Muniwin (http://c-munipack.sourceforge.net, David Motl) 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

were refined in 2012 [3] to

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

The only completely observed Min I in the years 2018 and 2019 (2458630.53441 ±0.0035, observer Peter Frank) boasts an (O-C) value of only 0.0006 d, indicating that the ephemeris of 2012 is still valid.

The phased light curve of the observations acquired since the last update of 2017 are shown in Figs. 1 and 2. They have been phased using the ephemeris given in equation (2).

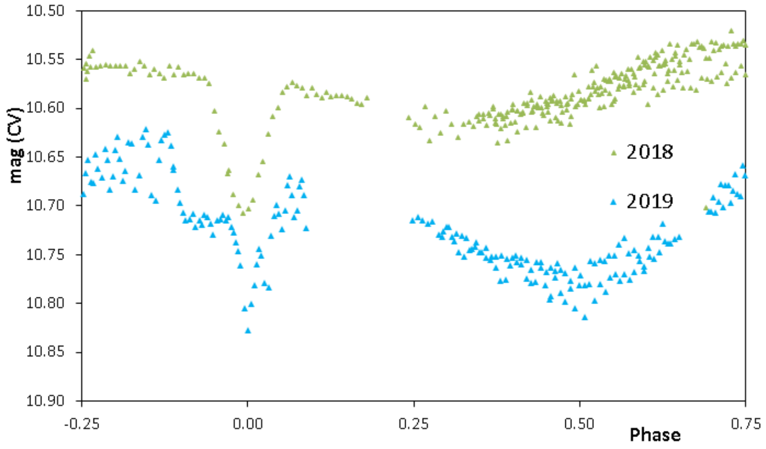

Fig. 1: Phased lightcurve of V505 Ser, based on observations acquired in Velden, Germany (Peter Frank). Observations of 2019 are shifted by +0.15 mag for clarity.

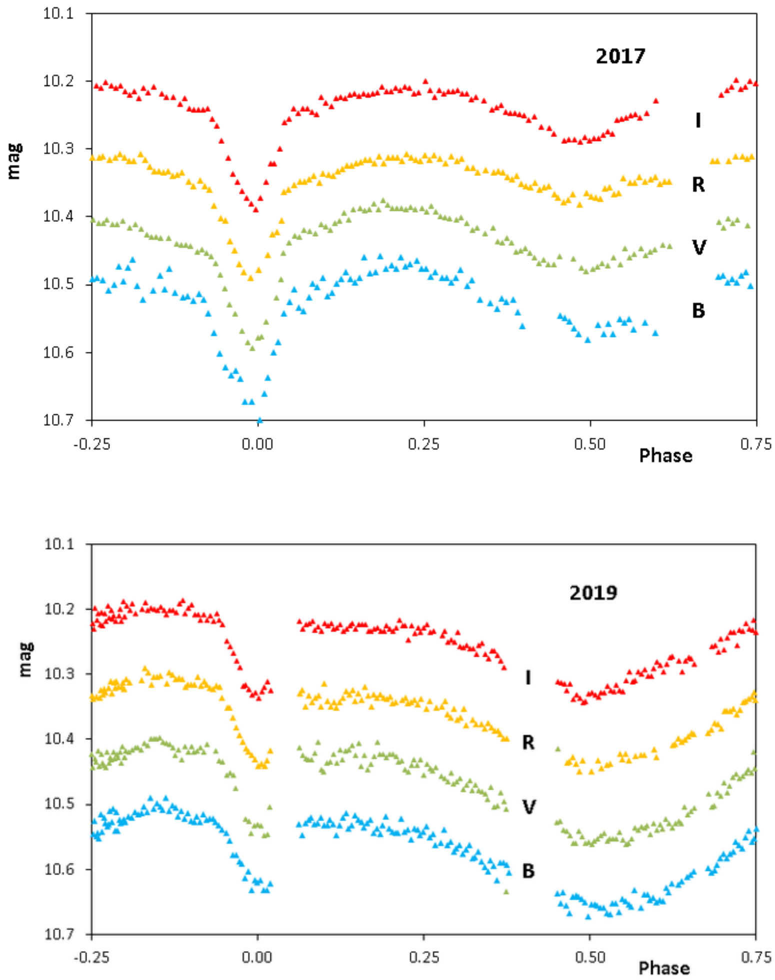

Fig. 2: The lower panel illustrates the phased lightcurve of V505 Ser, based on observations acquired in 2019 in Nerpio, Spain (Wolfgang Moschner). For comparison, the upper panel shows the 2017 observations from the same location.

Our observations illustrate the occurrence of significant light curve changes within one year (Fig. 1) and, in particular, between different years (Fig. 2). The depth of the “secondary minimum” (phase 0.4-0.7), which is not due to an eclipse but exclusively caused by star spots, has substantially increased between 2017 and 2019, as illustrated in Fig. 2.

We followed the methodology employed in our earlier publications and determined the level of star spot activity by low-order polynomial fits (Fig. 3; cf. also [2]). Strong activity maxima were observed in 2005 and 2015, with weaker maxima taking place in 1999 and 2011. The observations of 2018 and 2019 indicate an increase in spot activity in 2019, which could signify the onset of a new activity maximum that we predict to take place in 2020. This fits well into the picture of a 5 to 6 year star spot cycle.

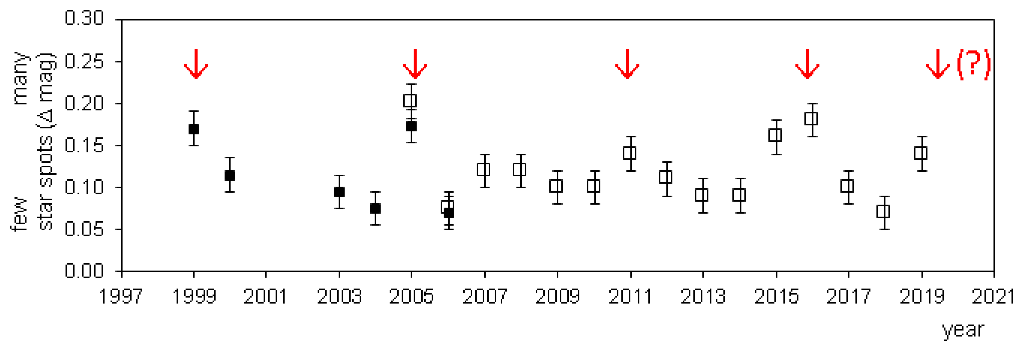

Fig. 3: Amplitudes of the "secondary minima" caused by star spots during the observing seasons 1999 to 2019 (with error bars; filled squares: ASAS, NSVS; open squares: our measurements). Here, Δ mag denotes the amplitude between maximum brightness and the brightness during the minima caused by spots.

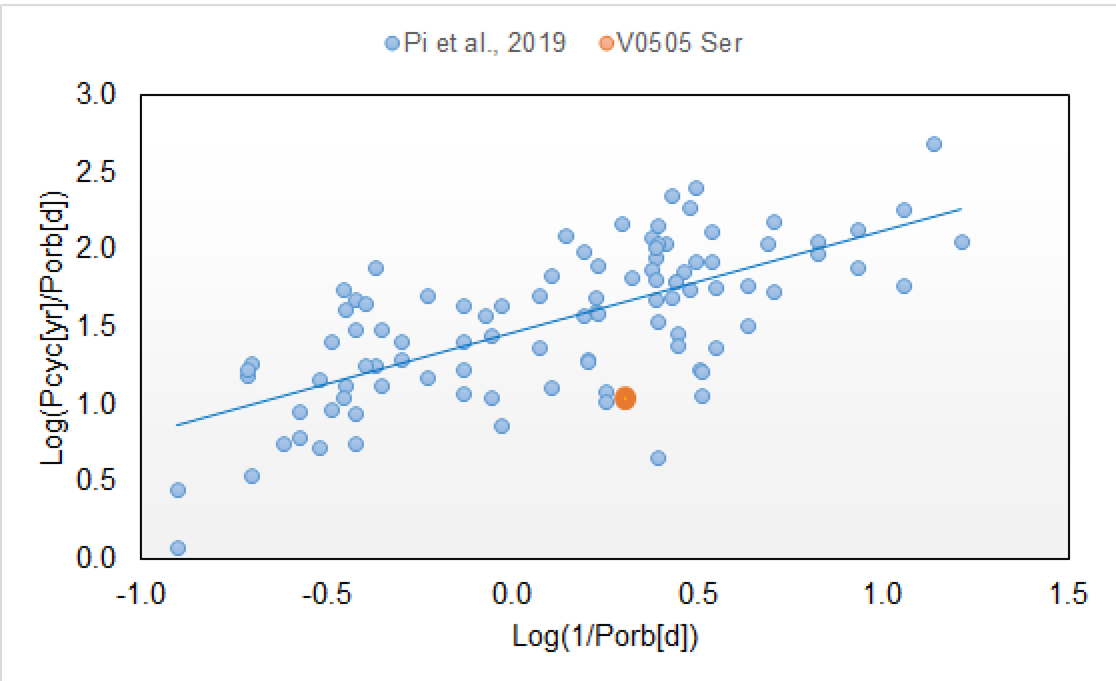

Fig. 4: The $1/P_{orb}[d]$ versus $P_{cyc}[yr]/P_{orb}[d]$ diagram in logarithmic scales, which investigates the relationship of orbital period and star spot cycle period for a set of short-period eclipsing RS CVn-type binaries. The position of V505 Ser is marked by the red circle. The figure has been based on Fig. 12 in [7]. The solid line represents a linear fit.

Fig. 4 shows the $1/P_{orb}$[d] versus P_{cyc}[yr]/P_{orb}[d] diagram, which investigates the relationship of orbital period and star spot cycle period for a set of short-period eclipsing RS CVn-type binaries. The figure has been adapted from Fig. 12 of Pi et al. (2019), who find a weak linear correlation between these quantities and suggest that a common dynamo might be at work in these binary systems. V505 Ser fits the relation well.

To sum up, the here presented observations of 2018 and 2019 provide further evidence of the suspected ~5.5 year star spot cycle, which obviously exhibits strong secular fluctuations as is observed for our Sun. We predict the next maximum to occur in 2020 and we will continue to acquire further observations of V505 Ser. As the amount of data builds up, we will be able to further narrow down the time spans involved and evaluate whether or not the previously observed pattern of alternating maximum levels will continue. The resulting data set will render V505 Ser an outstanding object in the investigation of long-term activity cycles in RS CVn stars.

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