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Short- and long-term variability of the ultrashort-period eclipsing RS CVn star V0648 Aur

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Abstract: Based on observations between 2006 and 2018, revised elements of the ultrashort-period eclipsing RS CVn variable V0648 Aur are given: HJD MinI = 2457800.356(3) + 0.42246710(7)×E. An analysis of the observed times of minima reveals a probable near sinusoidal oscillation with a period of about 800 days. The corresponding (O-C) values of the secondary minima are situated opposite to the primary minima, which favours an interpretation in terms of the presence of pronounced starspots on at least one component over the assumption of a third, gravitationally-bound body. In addition to the star's highly variable light curve shape, observations of a probable flare event in 2012 and the appearance of an apparent hot spot in 2017 provide evidence for intense chromospheric activity and interaction between the two components.

1 Introduction

RS Canum Venaticorum (RS CVn) variables are close binary stars with active chromospheres that can cause large stellar spots (see e.g. Berdyugina 2005). RS CVn systems show variability of time scales from minutes (flares) to days (rotation of spots, eclipses) to years (activity cycles).

The variability of GSC 3377-0296 (RA 06 41 16.765, Dec +46 49 08.969, J2000, Gaia DR2, Brown et al. 2018) was discovered during an investigation of the optical counterparts of X-ray sources from the ROSAT All-Sky Survey Bright Source Catalogue (1RXS; Voges et al. 1999, cf. also Lloyd, Bernhard and Monninger 2007). The relatively bright object (V=11.765 mag, B-V=0.834 mag, Henden et al. 2015), which subsequently received the final designation V0648 Aur according to the GCVS system (Samus et al. 2017), turned out to be an RS CVn binary with an ultrashort-period of about 0.4225 days. Only about 4 percent of the RS CVn binaries listed in the AAVSO International Variable Star Index (VSX) exhibit periods shorter than 0.5 days, which are therefore called ultrashort-period RS CVn stars (e.g. Vida et al. 2013). Significant long-term changes in the shape of the light curve were detected, which are in agreement with the presence of cool star-spots on the surface of the primary star with a probable spectral type of K3 (Lloyd et al. 2007). This spectral classification is in agreement

with temperature estimates (~5000 K) based on the Gaia DR2 distance. Not much is yet known about the spectral type of the fainter secondary component.

A subsequent study by Vida et al. (2013) confirmed the derived period and variability type and suggested a star spot cycle of 530 d, which is in agreement with the cycle lengths observed in other ultrashort-period RS CVn stars such as EY Dra and V405 And (300 to 500 d).

2 Observations

In order to analyse the long-term behaviour of V0648 Aur, observations were made in 55 nights (Gerold Monninger: 33 nights, Gregor Srdoc: 22 nights) between 2006 and 2018, so that a total of eight observation seasons were covered. As comparison and check stars, we employed GSC 3377-0179 (V=12.549 mag; B-V=0.692 mag, Henden et al. 2015) and GSC 3377-0811 (V=12.141 mag; B-V=1.159 mag; Henden et al. 2015), respectively.

The following instruments were used:

- Gerold Monninger; Gemmingen, Germany
  34-cm Cassegrain telescope with SBIG ST-6, V-filter (2006-2009)
  (f/9, pixel scale 1.5“ x 1.8“)
  34-cm Cassegrain telescope at f/6 with ST-10XME, V-filter (2012-2018)
  The CCD was configured in a 3x3 binning mode resulting in an angular resolution of 2.1“/pixel (the field of view is 24'x16').

- Gregor Srdoc; Kotizarovci Observatory, Rijeka, Croatia
  Meade LX200 Classic 12" with SBIG ST7XME Baader, red 610 nm longpass filter (f/5, pixel scale 1.2 arcsec/pic)

3 Results

The period analysis of the combined data sets was performed with Peranso (www.peranso.com). The following improved ephemeris (Eq. (1)) has been derived, which is well within the error range of 0.422467(1) d as given in the discovery publication (Lloyd, Bernhard and Monninger 2007).

(1) HJD_MinI = 2457800.356(3) + 0.42246710(7)×E

Figure 1 illustrates the long-term development of the light curve folded on the ephemeris given in Eq. (1).

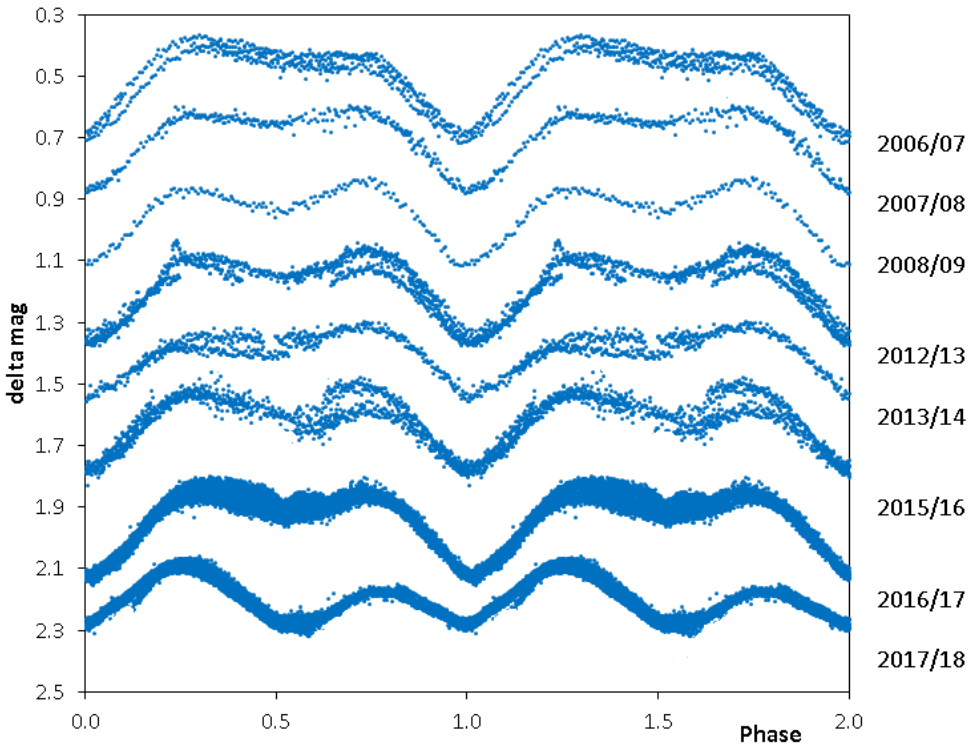

Figure 1: Light curves of V0648 Aur (2006-2018) folded on the period of 0.42246710 d. For clarity, the different observation seasons have been shifted by adding a constant value.

A comparison of the phase plots from the individual seasons reveals significant changes in light curve shape. However, in some years (e.g. 2012/2013, 2013/2014, 2016/2017), noticeable variations also occurred on short time scales. The changing height of the light curve maxima is typical for chromospherically active stars and likely caused by star-spots (O'Connell effect).

The pronounced chromospheric activity of V0648 Aur has also been confirmed by the observation of a probable strong flare with an amplitude of 0.1 mag on December 15, 2012 (Figure 2; cf. Monninger 2012).

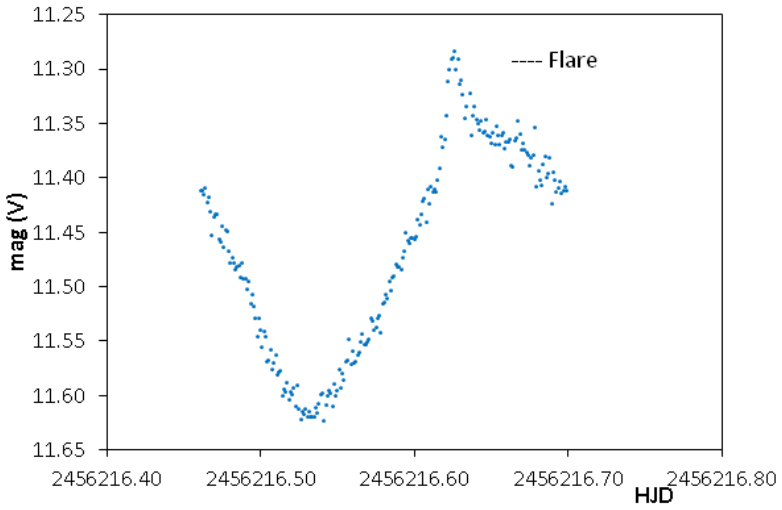

Figure 2: Probable flare event on V0648 Aur, observed on December 15, 2012.

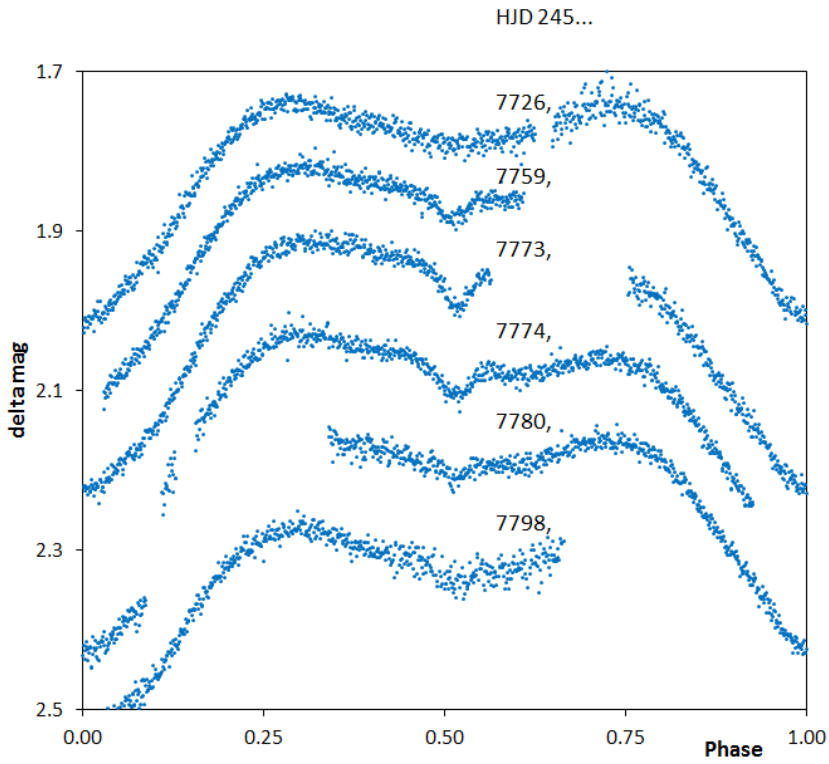

Figure 3: Light curves of V0648 Aur folded with the period of 0.42246710 d for 6 nights from the 2016/2017 observation season. For clarity, the different nights have been shifted by adding a constant value.

A further noticeable single event occurred in January 2017, which is presented in Figure 3. On January 5, 2017 (HJD 2457759) a short-term decrease in brightness was observed around the secondary minimum for the first time and remained visible at least until January 26

(HJD 2457780). Neither before nor after, this light curve feature has not been detected again during the 12 years of observation.

Due to the fact that this short-term decrease in brightness changed its shape and was always detected at the same orbital phase, it seems extremely unlikely that it is caused by the eclipse of a third body in the system (e.g. a planet or white dwarf). More likely, a flow of matter from the hotter primary star to the secondary component formed a temporary hot spot, which was briefly eclipsed. This scenario is further corroborated by an examination of the (O-C) values of the primary and secondary minima, as outlined below. The list of minimum times including their errors were determined using the spline function in Peranso (www.peranso.com) and is included as a suplementary material.

Comparing the observed times of the primary minima to those calculated with the ephemeris given in Eq. (1), we derive a probable near-sinusoidal oscillation with a period of about 800 days. Interestingly, the corresponding (O-C) values of the secondary minima are situated opposite to the primary minima.

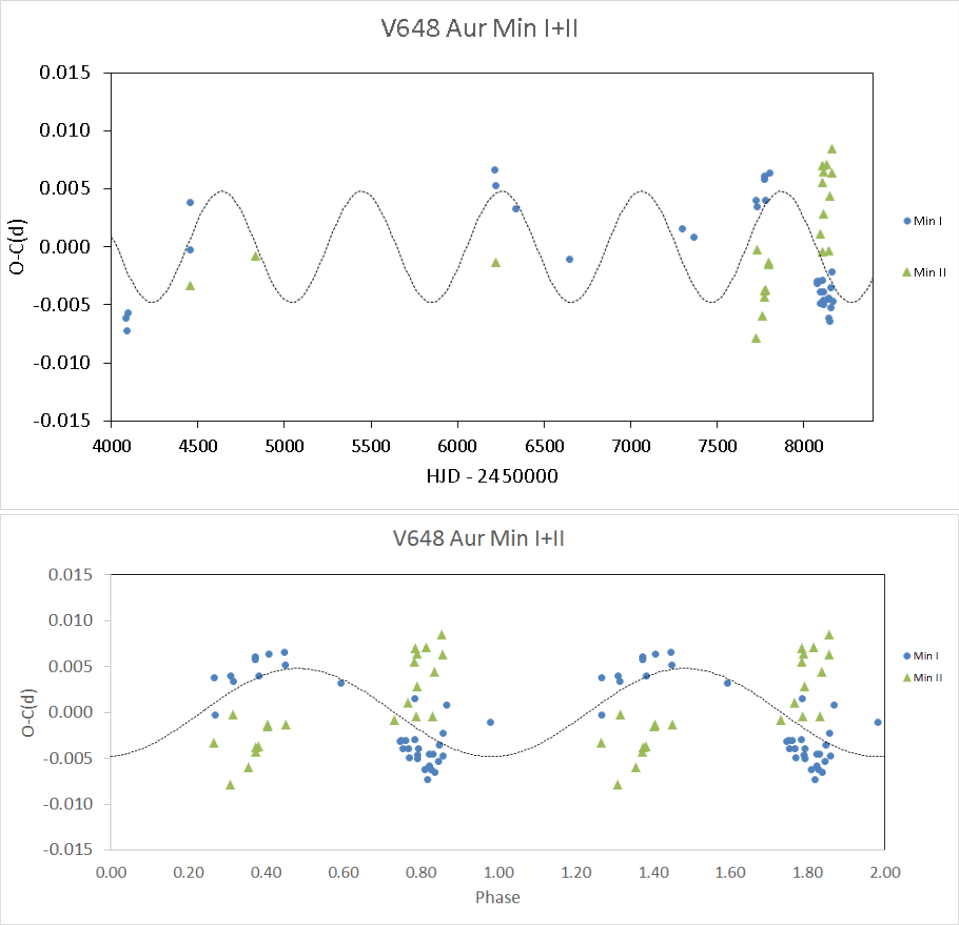

Figure 4: (O-C) diagram of primary and secondary minima in the observed time span (top) and the corresponding plot with the phased minima (p=808 d; bottom). The solid line indicates a sinus fit to the primary minima.

According to Tranh (2013), this (O-C) behaviour, which can be observed in some close binary stars, can be explained by assuming pronounced starspots on at least one component and does not agree with assuming a third, gravitationally-bound body.

4 Conclusions

V0648 Aur is an active ultra-short period RS CVn star with a highly variable light curve shape. Further observations are encouraged to describe the long-term behaviour of this star system in more detail and to clarify whether the observed hot spot signifies the onset of a longer-term mass exchange between the two components.

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References

Berdyugina, S. V., 2005, Living Reviews in Solar Physics. Institute of Astronomy ETHZ,2 , 8
Brown, A.G.A. et al., GAIA collaborations, 2018, Astron. Astrophys., 616, A1
Henden, A., Levine, S., Terrell, D., Welch, D. L., 2015, American Astronomical Society, 225, 336, 16
Lloyd, C., Bernhard, K. & Monninger, G., 2007, IBVS, 5772
Monninger, G. 2012, BAVSR, 61, 229
Samus, N.N., Kazarovets, E.V., Durlevich, O.V., Kireeva, N.N., Pastukhova, E.N., GCVS 5.1, 2017, ARep, 61, 1
Tran, K., 2013, Massachusetts Institute of Technology, https://dspace.mit.edu/bitstream/handle/1721.1/83779/864908364-MIT.pdf?sequence=2
Vida, K., Kriskovics, L. & Olah, K., 2013, AN, 334, 9, 972-975
Voges, W., et al., 1999, Astron. Astrophys. 349, 389