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Photometric study of the asynchronous polar V1432 Aql in 2017-2018 at the Crimean Astrophysical Observatory

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Abstract. We present the results of our research of the eclipsing asynchronous polar V1432 Aql. Photometric observations were obtained during 21 nights in 2017-2018 using the 38-cm telescope of the Crimean Astrophysical Observatory. We obtained 22 moments of dips associated with the orbital variability of the binary system and 40 minima associated with self-eclipses of accretion columns in the binary system. We found out that accretion in the system occurs at least on three accreting areas. According to our observations, the spin period of the white dwarf is 0.1405429(102) days in 2017 and 0.1404547(29) days in 2018. The improved orbital period is 0.140234676(15) days.

Key words: cataclysmic variables – accretion – stars: individual: V1432 Aql

1. Introduction

V1432 Aquilae (RX J1940.1-1025) belongs to a unique subclass of variable stars – asynchronous polars. To date, only four objects of this type are known (Ritter & Kolb, 2015).

This star is unique in this subtype. First, the V1432 Aql is the only one of these objects for which, thanks to a successful orientation of the system's orbit, eclipses and self-eclipses of accretion columns can be observed. And secondly, this is the only asynchronous system, in which the rotation period of the white dwarf exceeds the orbital period. The presence of eclipses allows us to determine the value of the orbital period with a high accuracy photometrically, $P_{orb} =$ 3.365 hours. In addition to the usual eclipses of V1432 Aql, which were usually called "dips" (deep narrow "dips" on the light curve), the star has self-eclipses of the accretion column with a smaller depth and wider width. Andronov & Baklanov (2007) found that the accretion in the system occurs simultaneously into two poles. Rana et al. (2005) found three maxima in the X-ray during the spin period.

2. Observations

Observations were carried out at the Crimean Astrophysical Observatory with the 38-cm telescope using an Apogee Alta E47 CCD camera. To increase the accuracy of determining extremes, we obtained our observations in unfiltered light. Totally, our observations covered 6 nights (1281 points) in 2017 and 13 nights (3452 points) in 2018. Fig. 1 shows individual light curves of V1432 Aql in 2017 – 2018.

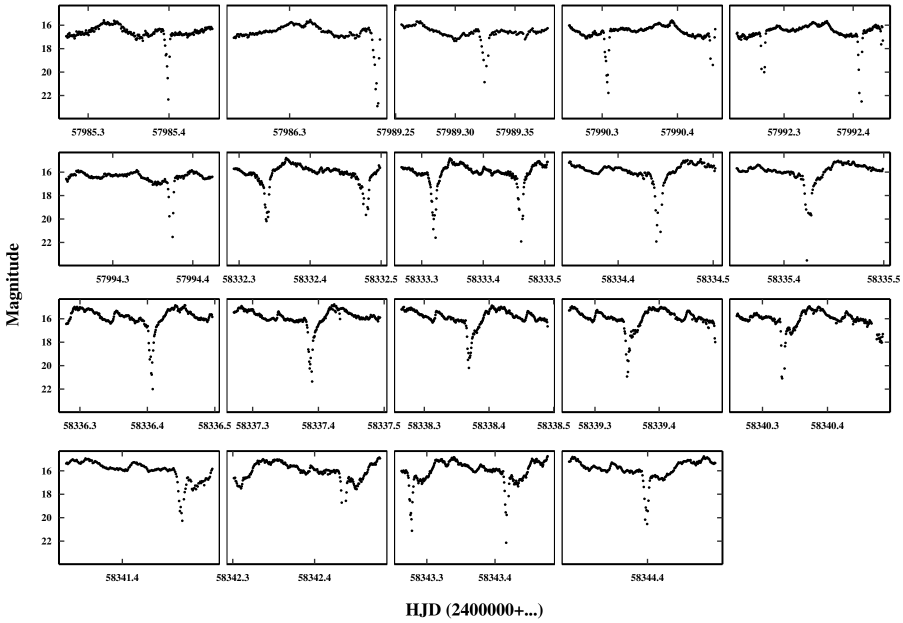

Figure 1. Individual light curves of V1432 Aql in 2017 – 2018.

3. Four types of minima

On the light curve, we can see the minima related to both the eclipse in the system and the self-eclipses of the accretion columns. Using the program MAVKA-OM (Andrych et al., 2017) (the method of asymptotic parabolas (Andronov, 1994)), 62 minimum moments with their errors were determined. All the moments of the minima were plotted on the diagram $(O - C)$ in Fig. 2 using the ephemeris obtained by Littlefield et al. (2015):

$$2454289.51352(4) + 0.1402347644(18) \times E.$$

All minima can be divided into four types.

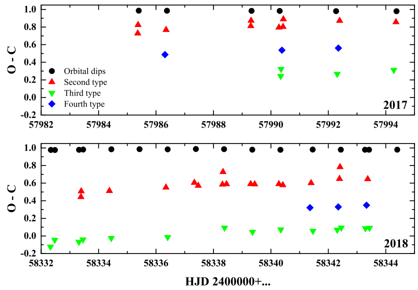

Figure 2. $(O - C)$ diagrams for four types of minima.

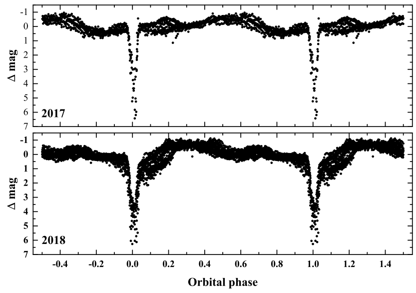

Figure 3. Orbital phase curves of V1432 Aql in 2017 and 2018

The first group of minima is parallel to the abscissa axis and corresponds to the orbital variability and is associated with eclipses of the white dwarf in the system. $(O - C)$ values of this type of minima systematically differ from 0. The $(O - C)$ average value is 0.9836 and 0.9817 in 2017 and 2018, respectively, which indicates that the orbital ephemeris of Littlefield et al. (2015) requires improvements.

The second group of minima, the most numerous, is located at an angle to the first group, which indicates that their period is rather larger than the orbital period. We associate this group of minima with the self-eclipses of the first accretion column (see Fig. 3).

The third group of minima is also located at an angle to the first group and shifted relative to the second group by 0.5 of the orbital period. We associate this group of minima with the self-eclipse of the second accretion column.

The fourth group of minima is inclined to the first group and is shifted relative to the second group by 0.7. This group can be associated with the self-eclipse of the third accretion column, or another bright accretion structure. This is the rarest type of minima, and contains only 6 points. We were able to identify these eclipses reliably only in a few consecutive nights, perhaps because the phenomenon causing this minimum is temporary and depends on the spin-orbit beat phase.

4. Orbital variability

Since the first type of minima on the $(O-C)$ diagram systematically differs from 0, we specified the value of the orbital period using the initial epoch of the minima by Littlefield et al. (2015). The adjusted period was 0.140234676(15) days. Phase curves with the improved orbital period are shown in Fig. 3.

5. Improvement of the spin period

To improve the spin period of the white dwarf in the system, we performed a periodogram analysis of the non-eclipse part using a 5-th order trigonometric polynomial fit realized in the program MCV (Andronov & Baklanov, 2004). The periodograms are shown in Fig. 4. The maxima of the periodogram correspond to 0.1405429 and 0.1404547 days in 2017 and 2018, respectively. The values of the periods were improved by the method of differential corrections (Andronov, 1994) and amounted to 0.1405429(102) and 0.1404547(29) days in 2017 and 2018, respectively. Mean phase curves using these periods are shown in Fig. 5. Between August 2017 and August 2018, the spin period decreased by 0.0000882(106) days (7.6 seconds $= 8.3\sigma$) or 0.063% of the orbital period.

As we see, mean spin phase curves in 2017 and 2018 are different. First of all, this difference is caused mostly by observations at different phases of the spin-orbital beat period. We can't exclude other causes, but these need additional study.

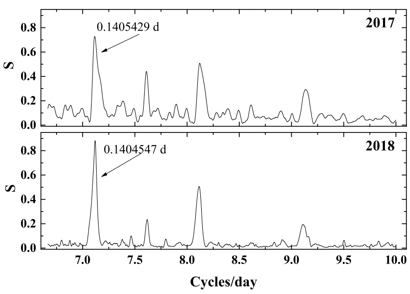

Figure 4. Periodograms for non-eclipsed parts of light curves in 2017 and 2018.

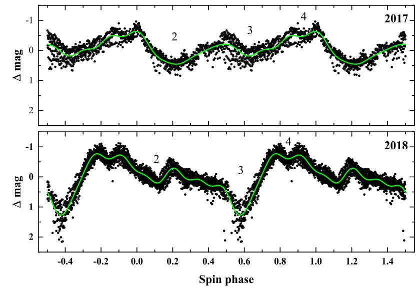

Figure 5. Spin phase curves of V1432 Aql in 2017 and 2018, excluding eclipses. Numbers corresponds to the group of minima and are described in section 3.

6. Conclusion

Our study confirms the complex structure of the accretion stream in V1432 Aql. We demonstrated that in the system there could be self-eclipses of at least three accretion columns. The improved orbital period is 0.140234676(15) days. We also obtained the rotation period of the synchronizing white dwarf in the system in August 2017 and August 2018 – 0.1405429(102) and 0.1404547(29), respectively. During the year, the period of the white dwarf slightly decreased by more than 7.5 ± 1 seconds.

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