Long-term periodicities in the MV Lyrae and KR Aurigae light curves

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Abstract. We obtain long-term cycles in the AAVSO light curves with duration 13.4 yr for MV Lyr and 13.6 yr for KR Aur. The phase curves of the cycles are presented. The magnetic activity of the secondary is the most plausible cause of such behavior.
Key words: cataclysmic variables, long-term cycles; individual: MV Lyr, KR Aur

Introduction

Cataclysmic variables (CVs) are evolved close binaries which contain a white dwarf and donor star (secondary), usually a red dwarf. The latter transfers material via the inner Lagrangian point L1. Red dwarfs in CVs have smaller masses than the Sun and could be mostly or fully convective stars. They have stronger magnetic fields than the Sun and more active chromospheres and coronas.

During the last years there have been many spectroscopic, polarimetric and photometric studies on stellar magnetic cycles similar to the solar 11 (or polarity reversal 22) yr cycle (e.g. Suárez Mascareño et al., 2016; Bondar et al., 2020; Bellotti et al., 2025; Ibañez Bustos et al., 2025). Many statistical dependencies (or lack of them) were obtained between the length of magnetic cycles, spectral class of stars, different activity indicators, rotation periods, amplitudes of brightness changes, etc. for single stars. The durations of cycles are from a few to 80 yr, mostly in the range of 7–18 yr, which are close to the solar one. The studies concerning close binaries and CVs are significantly fewer, e.g. Bianchini (1990), Maceroni et al. (1990), Ak et al. (2001). Vogt and Vega-Manubens (2023) reported 160 dwarf novae with significant long-term semi-periodic variability (or trends) in quiescence with lengths of the cycles between 1.2 and 13 yr. The existence of such cycles with durations of years of the secondaries can explain the observed long-term behavior of some systems. Cycles similar to the solar one with periods of 3–4 yr can be noticed easy in the light curves, while detecting very long ~ 100 yr cycles requires longer datasets.

MV Lyr and KR Aur are members of the VY Scl sub-class of the nova-likes – cataclysmic variables with high accretion rate and stable bright accretion disk and rare drops from 2(3) to 6 magnitudes lower than the normal state. These two variables show long minima with duration of ~ 10 years. During minima, the brightness varies, and occasional outbursts can be seen that last for several hundred days, similar to the ones observed in dwarf-novae. The reducing of the mass-transfer rate at minimum of the magnetic activity of the secondary red star can cause the appearance of low states and unstable disks in VY Scl variables (e.g. Bianchini, 1992; Warner, 1988; Boeva et al., 2025).

The long-term variability of MV Lyr and KR Aur was studied by Bianchini (1990) (only MV Lyr) and Kraicheva et al. (1996, 1998) (both). The accumulation of observations obtained from scientists and amateurs and longer observational sets of data provides an opportunity to check and refine the obtained periods.

1. Data and data analysis

To study the long-term periods in the light curves of MV Lyr and KR Aur, we used the AAVSO[1] database. It contains visual data from 1970 for MV Lyr and from 1967 for KR Aur. Since 1990, Jonson V data are available. These combined light curves are presented in Fig. 1.

We use the AAVSO multi-platform VStar (Benn, 2012) for data extraction and plotting. The periodogram analysis was performed using the Date Compensated Discrete Fourier Transform (DC DFT) method implemented in VStar. To check the results we use other programs based on the Phase Dispersion Minimization (PDM) and Lomb-Scargle (LS) periodogram algorithms. The periods obtained using different methods are very similar.

2. Results

The AAVSO database contain over 30500 points for MV Lyr and over 8000 for KR Aur. The data are not homogeneous over time, especially for KR Aur – there are long periods without points, up to about 1500 days. Regardless of it, we carried out a periodogram analysis individually for visual data and Jonson's V band because of the different magnitude limits. In deep minimum MV Lyr reaches ~ 18 mag and KR Aur ~ 19 mag which is hard to estimate visually using an amateur's equipment. The typical low limit of visual observations is about 15–16 mag and so the lowest brightness values are missed.

2.1. MV Lyr

Previous studies of the long-term variability of MV Lyr show existence of periods in different time-scales. The historical light curve form 1928 to 1983 published by Wenzel and Fuhrmann (1983) shows long unstable states with brightness drops, but it is difficult to derive their durations. Bianchini (1990) obtained a cycle with duration between 11 and 22 yr. In Bianchini (1992) the period was estimated as 11–12 yr. Kraicheva et al. (1996) received 13.56 and 7.27 yr cycles. In their later analysis from 1998 of the mean yearly or daily 65 years long high state light curve, they obtained another result: 4.7 ± 0.2 and 21.2 ± 4.8 yr.

Many authors note diverse periods in shorter time-scales of 100–450 d, which are distinctive for different extended low or high states (Wenzel and Fuhrmann, 1983; Kraicheva et al., 1996; Pavlenko and Shugarov, 1999).

Fig. 2 presents long-term periods and its amplitudes of MV Lyr data. The coverage is much better than that of the KR Aur data and probably in the light curve there are no absent risings and falls. The visual sequence is much longer – 55 yr against only 35 in V.

In the light curve (Fig. 1, top) two types of behavior are clearly seen: 3 minima with dips and rises and duration 8–10 yr (~ 3000–3800 d) and bright states

[1] https://www.aavso.org/

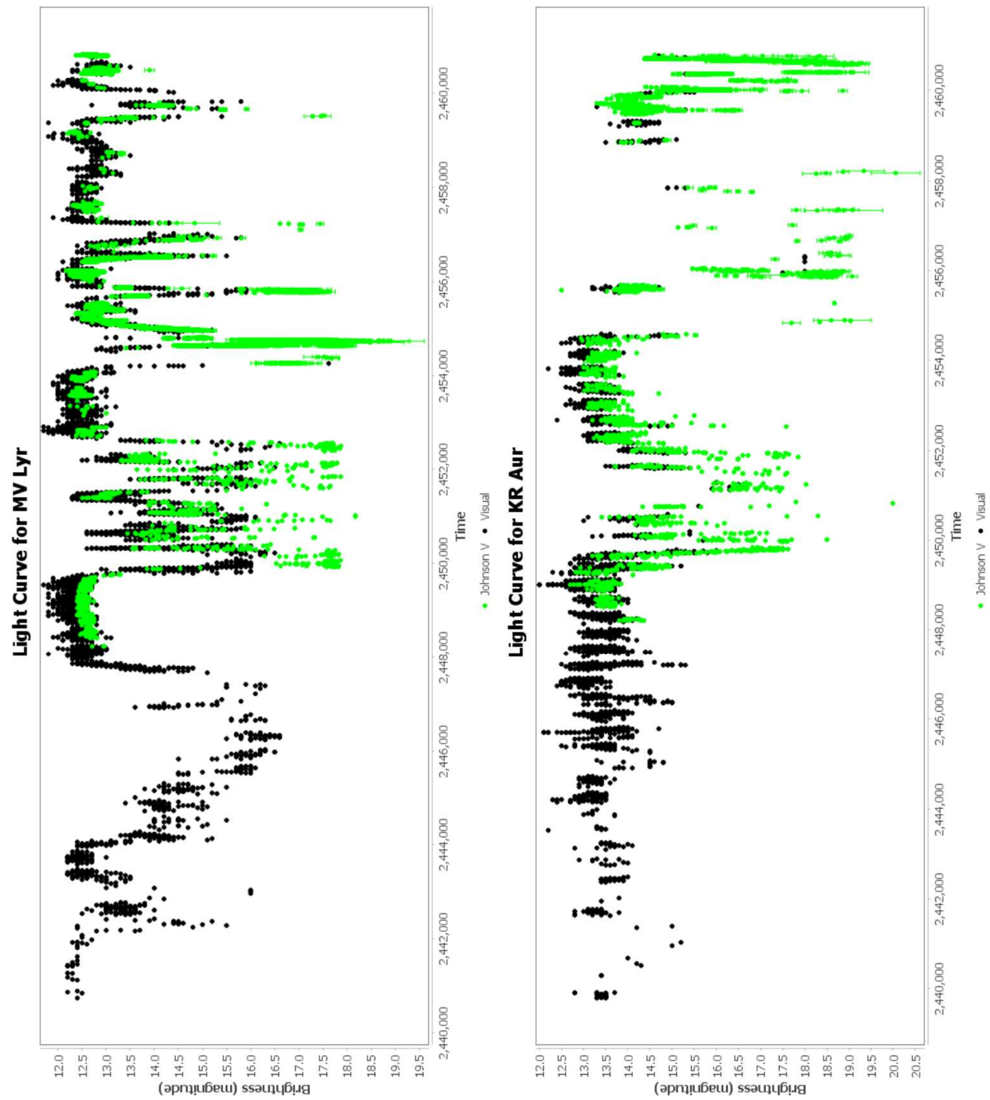

Fig. 1. Long-term light curves of MV Lyr (1970–2025, top) and KR Aur (1967–2005, bottom) from AAVSO.

without any falls lasting 750–2100 d. The shortest high state (1977–1979) was followed by the longest minimum (1979–1989). As a result of periodogram analysis we receive the most powerful wide period peak in visual observations of about 4942 d. This value is equal to 13.53 yr and practically coincides with the one derived by Kraicheva et al. (1996). Using other methods – PDM and LS, we obtain 4910 d and 4870 d respectively.

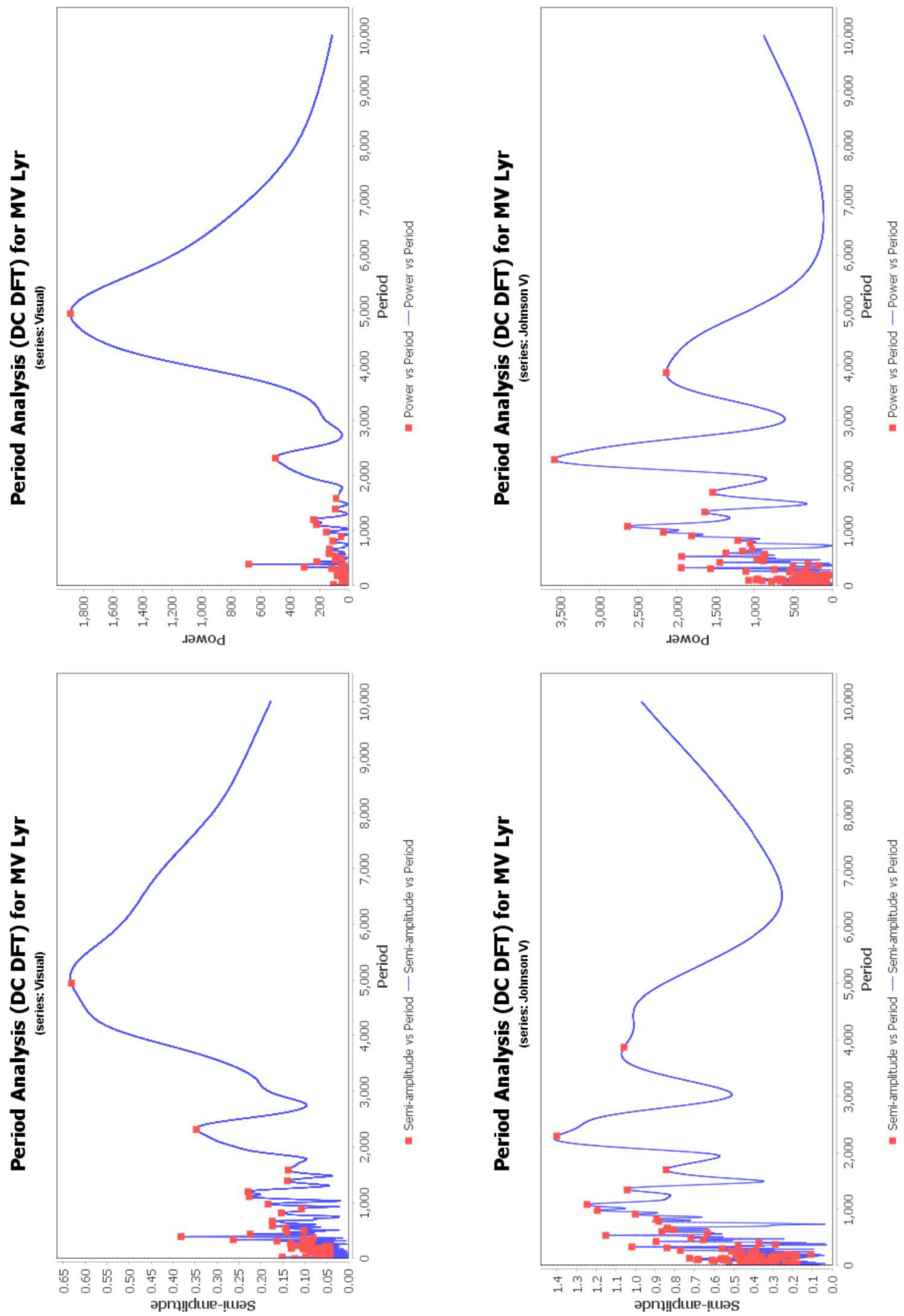

Fig. 2. Periods and their semi-amplitudes in visual and Jonson's V observations of MV Lyr.

The V data show a weaker peak at 3870 d, probably due to the shorter time span of the observations (only 2 minima present) and differences in the minima. The first one consists of many outbursts with maxima ~ 1 mag under the normal state, but second one is dominated by 2 long outbursts with duration of ~ 800–900 d and the brightness reaches the normal high state values (due to different optic systems and filters of many observers, some shifts may appear in the V data). Every new stable high state starts about 5000 d after the previous one. This result gives us the opportunity to predict (with some uncertainty) the long-term behavior of the variable star.

Another period of ~ 2250–2300 d (~ 6.2 yr) persists in both periodograms but at different semi-amplitude and power. It is not clear what the reason for this period is. The only close period is found by Kraicheva et al. (1996) 7.27 yr, studied only at high luminosity states.

Various periods in the range of 100–400 (500) d are visible with a maximum around 330–395 d. They are connected with durations and intervals between outbursts in low states and can vary from one minimum to another, but Kraicheva et al. (1996) found 320–340 d periods in bright state curves too. A weak maximum about 1000–1200 d exists which can be due to shorter cycles of magnetic activity. Such multiple cycles of variability in addition to the dominant magnetic one was found by Oláh et al. (2016) for many single stars with a maximum on the timescale of 3–4 years.

The phase curve with the average long-term period 4907 d is shown in Fig. 4 (top). We prefer this cycle's period rather to the ~ 3900 d one because of the better phase curve of the observational data.

2.2. KR Aur

Past studies that searched for cyclical variations in the long-term light curve of KR Aur are present only in the works of Kraicheva et al. (1996, 1998). They analyze a historical light curve published by Liller (1980) and additional data. Kraicheva et al. (1996) detected a 8.16 yr cycle in the interval 1890–1933 in a high luminosity curve and a short cycle of 250–300 d. In the interval 1933–1994, two cycles were obtained: 10.1 ± 2 yr cycle for the dips at low state and 3.4 ± 0.85 yr for the dips to intermediate state.

AAVSO data points for KR Aur are very unevenly distributed. After 2008 visual data are only a small amount with gaps up to 4 yr. In 2011–2017 only 4 visual points are available. V data also contains gaps up to 1–1.5 yr.

Several extended low states with rises and falls and duration up to 3300 d have been clearly seen – e.g. 1933–1942, 1994–2003, 2008–2019. From the historical light curves and AAVSO data it is difficult to determine the exact moments of the beginning and the end of these states. November 2019 as a start of new maximum state is derived by our observations.

Fig. 3 shows the results of applying the periodogram analysis. The better period peak 5039 d is from V observations but the visual dataset gives a similar value of 4802 d. Other methods applied on all the data show a cycle in the range between 4909 to 4973 d. An average value of 4974 d is used in the phase curve in Fig. 4 (bottom).

Similar to MV Lyr, KR Aur shows shorter periods. The strongest of them are about 680 d and in the range of 300–370 d. Their duration can vary in

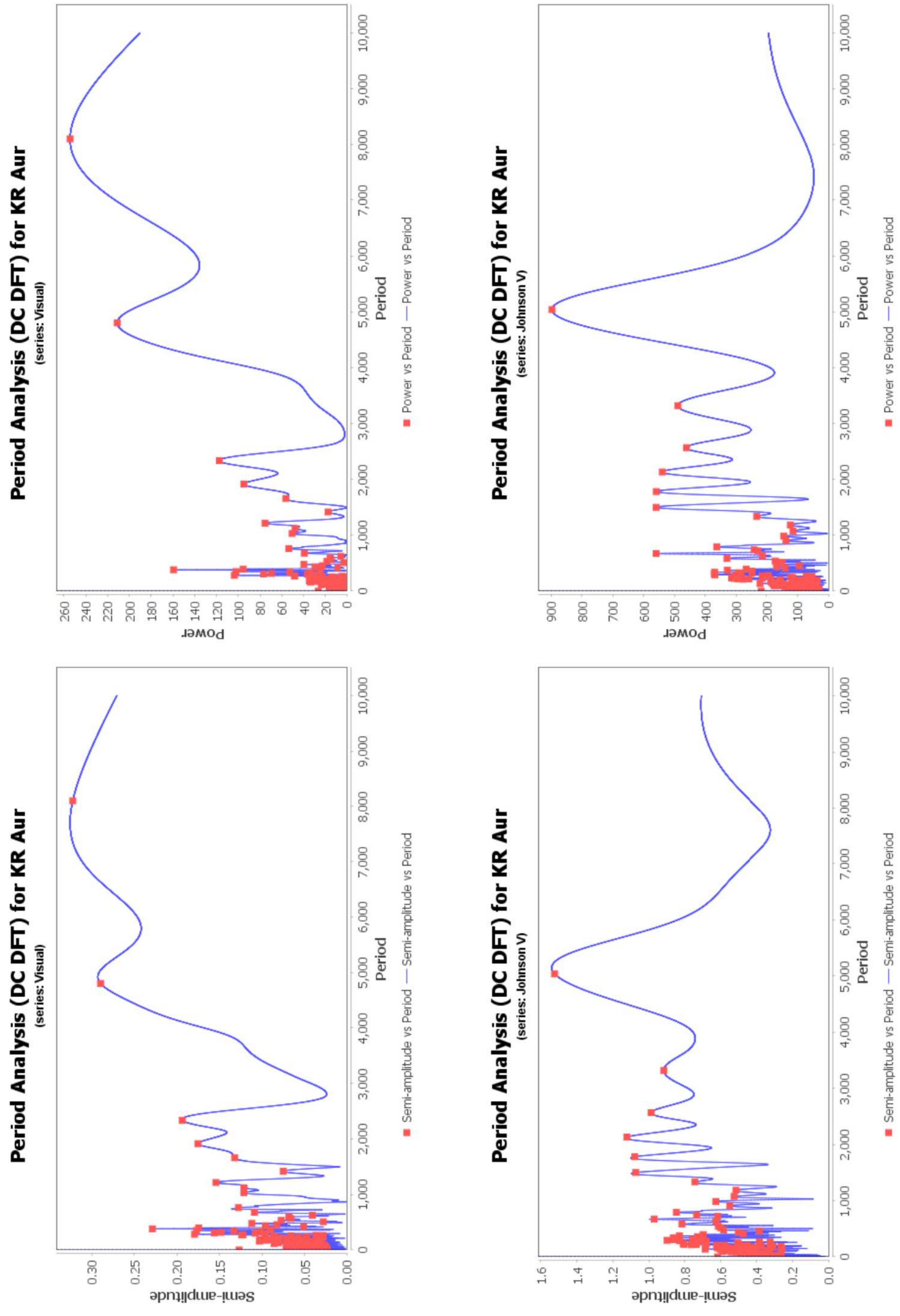

Fig. 3. Periods and their semi-amplitudes in visual and Jonson's V observations of KR Aur.

two consecutive minima. Periods of around 1000–1200 d can be noticed in the visual data only.

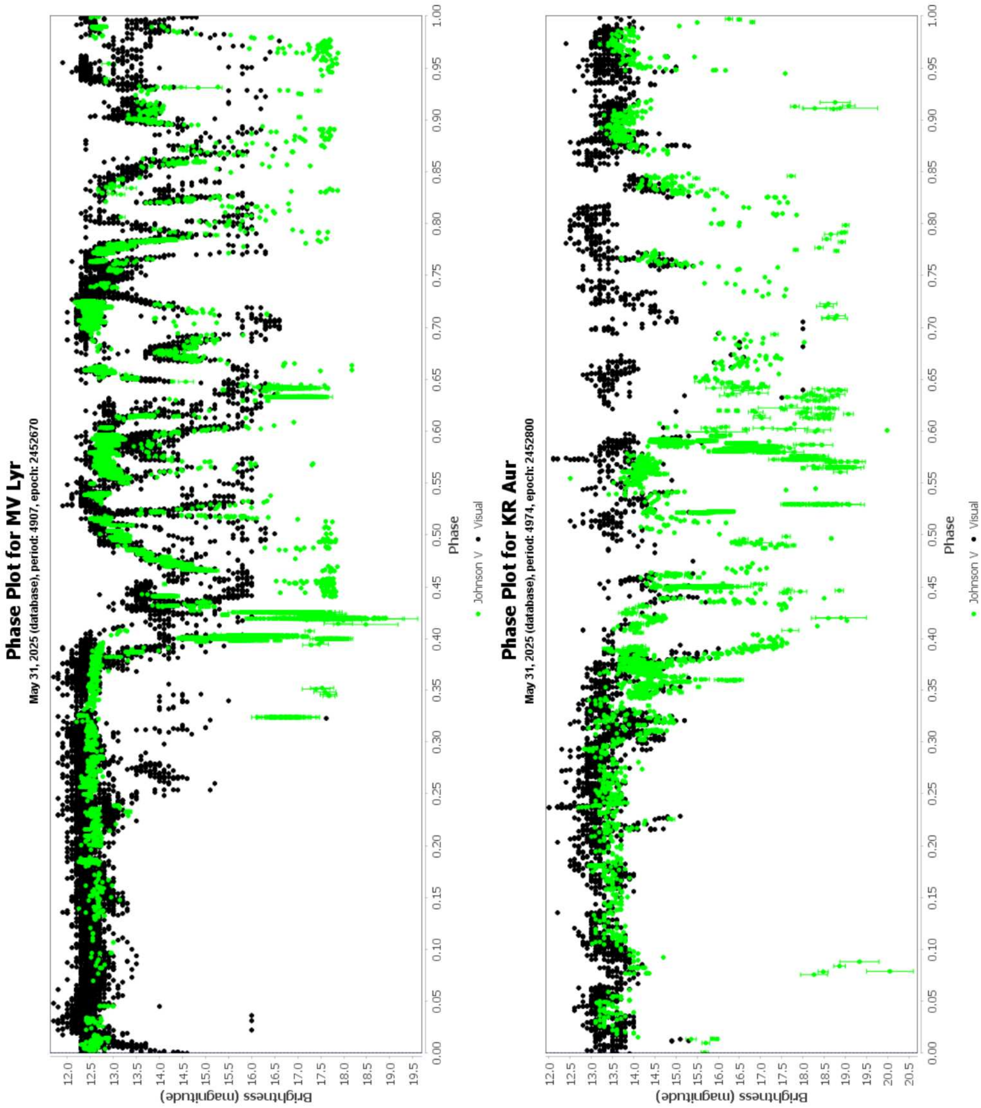

Fig. 4. Phase curves with the best periods for MV Lyr (top) and KR Aur (bottom).

The obtained cycles differ from the published by Kraicheva et al. (1996, 1998). To perform an additional test we identified the beginnings of stable bright states as far as possible in the historical data. Such states take place around 1928 (or after 1926), 1942, 1952, 1961, 1975, 1989, 2003 and 2019 yr. There are 7 cycles in the interval 91–93 yr with a mean duration 13.0–13.3 yr. From 1961 to 2003 the average cycle is 14 yr long, but there are also cycles between 10 and 16 yr (the last one being from 2003 to 2019). 3 years could be a real deviation from the mean duration of the cycle. Our periodograms on V data from 1990 to 2025 also show about 1000 d uncertainty of the period. The 3320 d period in V can probably be connected with the mean duration of the minimum state. The 1500–2000 d peaks can be considered as a result of the unequal duration of the bright state (mean ~ 1700 d).

3. Discussion

The photometric amplitude of the main magnetic cycle is usually less than 0.1–0.2 mag and only for fast-rotating cool dwarfs it can reach ~ 0.5 mag. The rotation period of the secondaries in CVs coincides with the orbital one. In the case of MV Lyr and KR Aur the secondaries are cool M4-5V red dwarfs with rotational period 3.19 and 3.91 h. By using the dependence of the amplitude, duration of the cycle and orbital period for single G-M dwarfs from Bondar et al. (2020), we roughly estimate the contribution of the secondaries in MV Lyr and KR Aur in the brightness variations to be 0.4–0.8 mag. Then the contribution of the accretion disk is about 5 mag more in high state compared to the low state (there are some evidences that the accretion disk does not disappear completely).

In contrast to a single stars, a red dwarfs in close binary systems like CVs could influence the brightness more strongly. The luminosity of the system is dominated by the accretion disk and depends on the mass-transfer rate. The latter is determined by the mass-loss rate of the red dwarf. The magnetic activity of the secondary varies during its magnetic cycle and inconstant mass-loss, which could explain the appearance of high and low photometric states in VY Scl and other types variables. In the phase curves (Fig. 4), in about 1/3 of the cycle stable bright states exist without any drops of the magnitude while in 2/3 of the cycle the systems vary quasiperiodically from low state to intermediate or slightly under the high state level. Probably the length of the cycle is not absolutely strict but such variations were observed in the past for the solar 11 yr cycle too. The behavior of the two variables in low state is very similar to that of dwarf-novae. We can conclude that the mass-transfer rate is enough to supply a stable accretion disk during only about 1/3 of the magnetic cycle's length.

To validate the received almost equal durations of the magnetic cycles of MV Lyr and KR Aur, we used empirical dependencies for dwarfs by Oláh et al. (2016) (their sample consists of both singles and binaries) and Bondar et al. (2020). They obtained different slopes (0.76 and 1.25) of the relation between the observed rotational and cycle periods. For a period of 0.1329 and 0.1629 d and respectively $\log(1/P_{rot})$ of 0.88 and 0.79, we can expect values for $\log(P_{cyc}/P_{rot})$ between 3.9–5.0 for MV Lyr and 3.8–4.9 for KR Aur. For a cycle length 4907 and 4974 the obtained values are 4.6 and 4.5, which are acceptable and a little larger than the values 4.2 and 4.1 determined as per Suárez Mascareño et al. (2016) with a slope coefficient 1.01. The amplitude of the magnetic cycle for fast rotating M dwarfs increases with the decrease of the rotational period, but there is not a definite relation between the cycle length and the rotation period.

The mass-loss rate of the secondaries can vary during longer cycles like the solar Gleissberg cycle with duration ~ 100 yr but observational datasets are not long enough to define them. Such cycles can explain the different mass-transfer rates observed in consecutive minima. The two variables have similar orbital periods and consist of stars of similar mass (~ 0.3–$0.4\,M_{\odot}$) and spectral class, as well as similar accretion rates. This probably explains the similar lengths of the long-term brightness variation, the duration of the low states and the periodicity of the outbursts observed in them. The low states themselves should be considered not as single dips to a low level, but as time intervals between two maxima, with an overall sustained decrease in the accretion rate and existence of a thermal-viscous unstable disk similar to the dwarf-nova disks, driven by decreased magnetic activity of the secondary. The fast rotation of the red dwarfs in MV Lyr and KR Aur is dew to the synchronization of the rotation and orbital periods in close binaries.

The derived ~ 5000 d cycle for these variables makes their future behavior somewhat predictable. In particular we can expect MV Lyr and KR Aur to continue to show dips and rises over the next approximately 4 years and 8 years respectively until they reach a steady high state brightness. The cycles of 13.33–13.53 and 13.44–13.80 yr are close to the ones found by Bianchini (1990) and confirmed by Kraicheva et al. (1996) 12.6 yr cycle for another member of VY Scl type variables – TT Ari.

Conclusion

We analyzed the long-term AAVSO light curves of MV Lyr and KR Aur. The best long-term periods of about 4907 and 4974 d respectively are used to phase the light curves of the variables. Although other explanations are possible, the magnetic activity of the secondaries is the most likely explanation for time-scales of ~ 5000 d. Both systems show stable high photometric state in approximately 1/3 and unstable behavior in the remaining 2/3 of the duration of the cycle. This could be interpreted as two different states of the accretion disk with high or low mass-transfer rate caused by the magnetic activity and the relevant mass-loss of the secondaries.

The cycle length is not strict and can vary within several years (~ 20 %). Due to a different mass-transfer rate the light curve at the different low states can show various periods in the range of several hundred days.

The increase of the length of observational datasets and better time coverage will refine received periods.

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