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# Long-term photometric behavior of the eclipsing cataclysmic variable V729 Sagittarii

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## Abstract

We present the analysis results of an eclipsing cataclysmic variable (CV) V729 Sgr, based on our observations and American Association of Variable Star Observers data. Some outburst parameters are determined, such as outburst amplitude ($A_{\rm n}$) and recurrence time ($T_{\rm n}$), and then the relationship between $A_{\rm n}$ and $T_{\rm n}$ is discussed. A cursory examination of the long-term light curves reveals that there are small-amplitude outbursts and dips present, which is similar to the behavior seen in some novalike CVs (NLs). More detailed inspection suggests that the outbursts in V729 Sgr may be Type A (outside-in) with a rise time ~1.76 d. Further analysis also shows that V729 Sgr is an intermediate between dwarf nova and NLs, and we constrain its mass transfer rate to $1.59 \times 10^{-9} < \dot{M}_2 < 5.8 \times 10^{-9}\, M_{\odot}\, {\rm yr}^{-1}$ by combining the theory for Z Cam type stars with observations. Moreover, the rapid oscillations in V729 Sgr were detected and analyzed for the first time. Our results indicate that the oscillation at ~25.5 s is a true dwarf nova oscillation (DNO), being associated with the accretion events. The classification of the oscillations at ~136 and 154 s as longer-period DNOs (lpDNOs) is based on the relation between $P_{\rm lpDNOs}$ and $P_{\rm DNOs}$. Meanwhile, quasi-periodic oscillations with periods of hundreds of seconds are also detected.

**Key words:** binaries: eclipsing — novae, cataclysmic variables — stars: individual (V729 Sagittarii)

## 1 Introduction

Dwarf novae (DNe) are a subclass of cataclysmic variables (CVs) which exhibit repetitive eruptions of amplitudes 2–6 mag, with some rare objects (e.g., WZ Sge) having up to an 8 mag range (Osaki 1996). Their outbursts are much smaller in amplitude and higher in frequency than the classical novae (CNe). V729 Sgr was identified as an eclipsing DN by Cieslinski et al. (2000). As early as 1928, van Gent (1932) discovered the variability of the star. Follow-up observations by Ferwerda (1934) showed that this object may be an irregular variable. It was first classified as a cataclysmic variable by using the photometric results of Cieslinski, Jablonski, and Steiner (1997) and the spectroscopic results of Cieslinski, Steiner, and Jablonski (1998). Cieslinski et al. (2000) studied it in more detail, publishing a lot of eclipsing light curves and deriving an orbital period of 0.1734055 d. In addition, these authors also estimated the outburst amplitude and recurrence time using their data together with published photometric data. Finally, V729 Sgr was classified as a possible Z Cam type DN. In fact, the outburst nature of this star is quite complex and little is known about it todate.

Apart from the large-scale changes of dwarf nova outbursts, there are rapid brightness variations of moderate coherence such as dwarf nova oscillations (DNOs) with periods in the range from several seconds to tens of seconds, and quasi-periodic oscillations (QPOs), which have larger amplitudes and much longer periods that range from a few minutes to several thousand seconds. Studies of the rapid oscillations in brightness of CVs have been published in a series of papers (Woudt & Warner 2002, hereafter Paper I; Warner & Woudt 2002, Paper II; Warner et al. 2003, Paper III; Warner & Woudt 2006, Paper IV; Pretorius et al. 2006; Paper V; Warner & Pretorius 2008, Paper VI; Woudt & Warner 2009, Paper VII; Woudt et al. 2010, Paper VIII). In general, most of the DNe in outbursts, and many novalike variables (NLs), exhibit such variations. DNOs and QPOs in V729 Sgr were therefore analyzed for the first time by us in order to understand the accretion disc and accreted events.

In present paper, we focus on two aspects of V729 Sgr's nature. First, combining the data from the American Association of Variable Star Observers (AAVSO) with our observations, the outburst properties of V729 Sgr are discussed. Secondly, rapid oscillations in the system are detected for the first time using the Fourier transform method following the modifications by Lomb (1976) and Scargle (1982).

## 2 Observations and data preparation

V729 Sgr was monitored photometrically during the period from 2010 to 2015 using the 2.15 m Jorge Sahade telescope (JST) mounted on the Roper Scientific, Versarray 1300B camera with a thinned EEV CCD36-40 de 1340 × 1300 pixel CCD chip at Complejo Astronómico E1 Leoncito (CASLEO), San Juan, Argentina. During the observations, $I$ band was used on 2010 June 7 and 2011 April 5, and no filters were used for other data. All observed CCD images were taken using the aperture photometry package of IRAF. Integration time is ∼5–15 s. Differential photometry was performed, with a nearby nonvariable comparison star. For all observations, the same comparison star was used to calculate the relative brightness. All observations during 2010–2015 are shown in figure 1. The light curves were phased by the following ephemeris:

$$\mathrm{Min.\,HJD} = 2456889.6965 + 0.1734055 \times E, \qquad (1)$$

where HJD 2456889.6965 is the initial epoch from our mid-eclipse times observed on 2014 August 8, and 0.1734055 d is the orbital period provided by Cieslinski et al. (2000). Our observations exhibit at least three outburst episodes, seen in figure 1. It is shown that there is an outburst with an amplitude of ∼1.82 mag in the time interval between 2014 July 20 and August 23. To investigate the outburst properties, the long-term light-curves were required. Fortunately, the AAVSO data of ∼15 yr provide a good opportunity to study V729 Sgr's outbursts and other variations. The upper panel of figure 2 shows the full AAVSO light curves of V729 Sgr from 2000 July to 2015 June. More detailed analysis is given in subsection 3.1.

## 3 Results and discussion

### 3.1 Outburst properties

The outburst amplitudes of ∼1.0–1.5 mag and recurrence time of several tens of days in V729 Sgr were reported by Cieslinski et al. (2000) using the published historical data. However, a lack of historical data coverage may reduce the reliability of the conclusions. Fortunately, all 783 observations from AAVSO were offered to study V729 Sgr's outburst (see figure 2). A detailed inspection of the upper panel reveals outbursts with amplitudes of ∼0.6–2.2 mag and recurrence times of ∼22–34 d for long outbursts and ∼8.6–17 d for short outbursts. The Lomb–Scargle power spectrum derived using the method of Lomb (1976) and Scargle (1982) for all data shows the strongest peak near 26.5 d and some secondary peaks corresponding to the cycles between

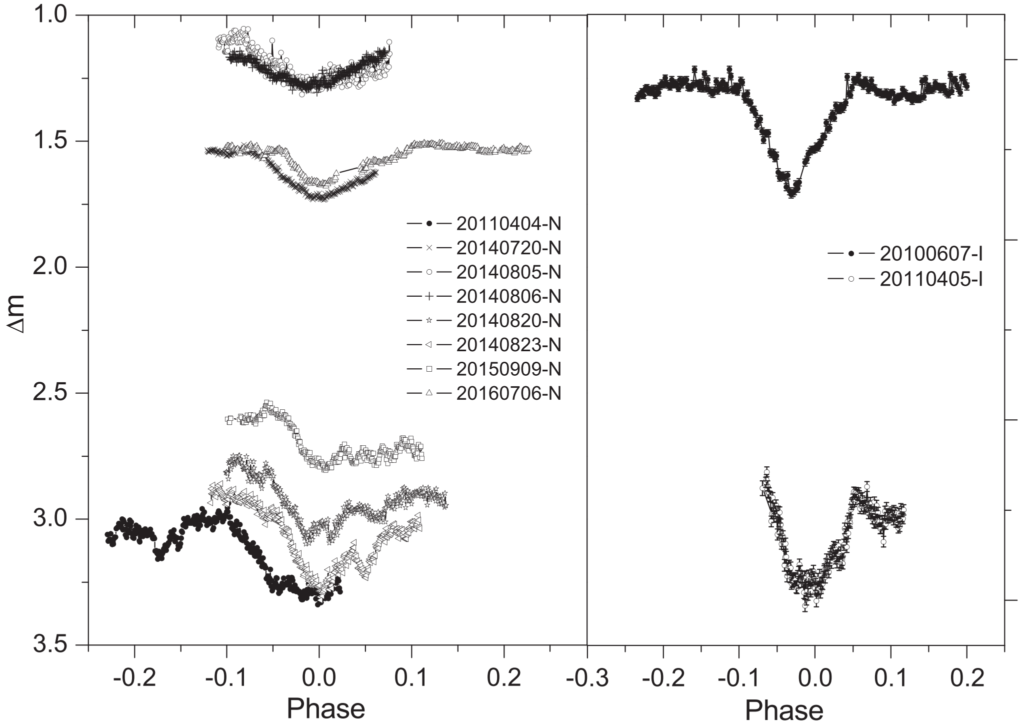

**Fig. 1.** All light curves of V729 Sgr plotted in phase using equation (1). The light curves shown in the left-hand panel were observed in the *N* band, the light curves shown in the right-hand panel were obtained in the *I* band. The data exhibit at least three outburst episodes.

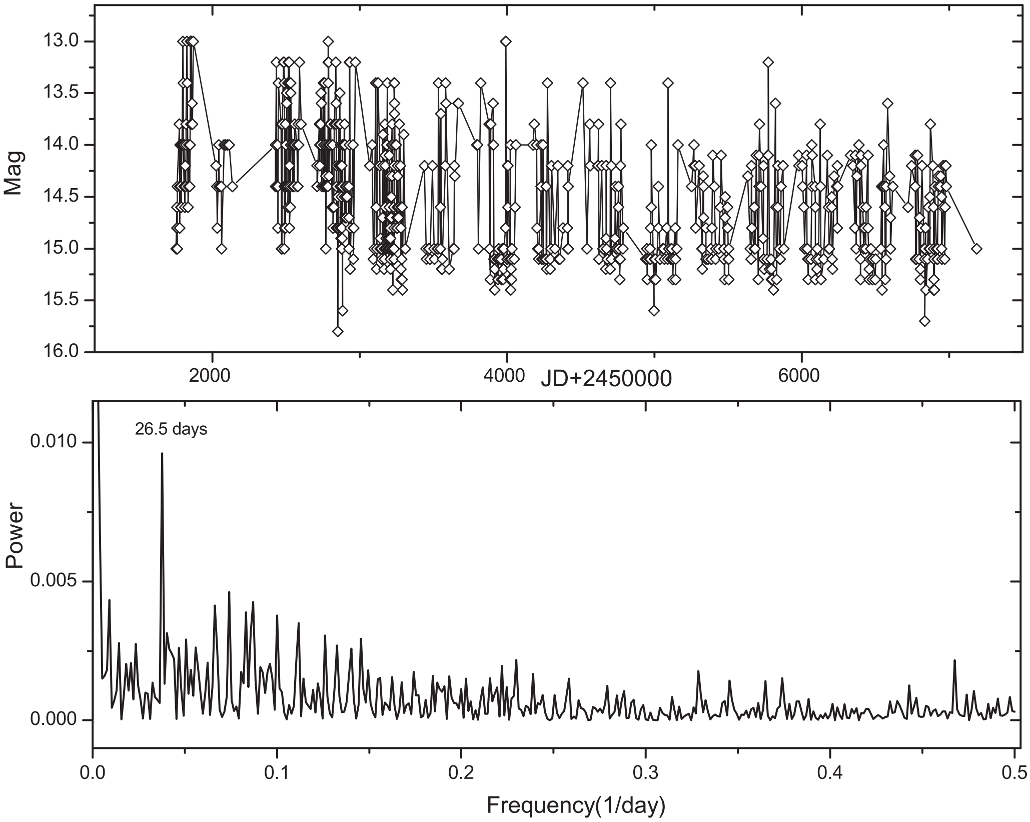

**Fig. 2.** Top panel: Long-term observations from AAVSO on V729 Sgr. Lower panel: Power spectrum derived using all data; the strongest peak corresponds to 26.5 d.

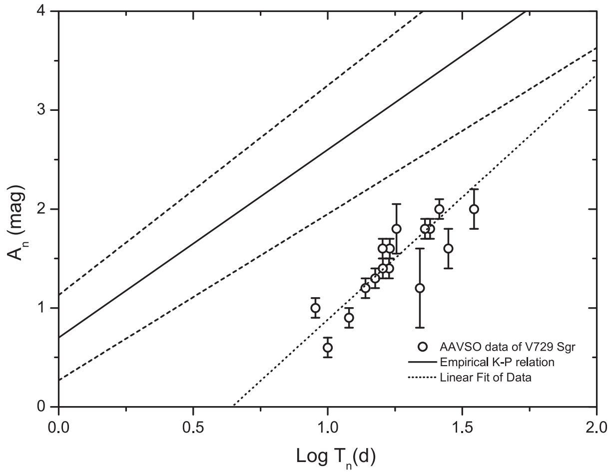

**Fig. 3.** Comparison of the K–P relation and AAVSO observational data for V729 Sgr. The open circles represent the statistical data. The dashed lines refer to the upper and lower uncertainties of the K–P relation.

9.1 and 15.6 d. This implies that these prominent peaks may represent the typical recurrence times. Kukarkin and Parenago (1934) first noted that there was a relation between the outburst amplitude $A_{\mathrm{n}}$ and the outburst recurrence time $T_{\mathrm{n}}$ for DNe and recurrence novae (RNe). Since then, that relation has been revised many times and improved to constrain its range application of application. For example, a general correlation was found by analysing DNe normal outbursts from van Paradijs (1985). Moreover, this relation is also extended by including the orbital period (Richter & Braeuer 1989). The most common version of the Kukarkin–Parenago (K–P) relation from Warner (1995) is as follows:

$$A_{\mathrm{n}} = 0.7(\pm 0.43) + 1.9(\pm 0.22) \log T_{\mathrm{n}}. \tag{2}$$

This is an empirical relation. To explore if this relation is model-dependent, a theoretical K–P relation was derived by Kotko and Lasota (2012) using the disc instability model (DIM):

$$A_{\mathrm{n}} = C_1 + 2.5 \log T_{\mathrm{n}}, \tag{3}$$

where the constant term $C_1 = 2.5 \log 2\tilde{g} - 2.5 \log t_{\mathrm{dec}} + BC_{\mathrm{max}} - BC_{\mathrm{min}}$, which depends on the properties of the primary star and the viscosity parameter $\alpha$. The parameters of outbursts in V729 Sgr and the K–P relation are plotted in figure 3. The open circles represent the statistical data from the AAVSO database and the solid line refers to the empirical K–P relation, while the dashed lines denote the relation's upper and lower uncertainties. Note that $\log T_{\mathrm{n}}$ values in figure 3 have a larger range, which is consistent with the peaks near 26.5 d and between 9.1 and 15.6 d. However, the observational data were not covered in this K–P relation. Note that this relation is significant for only those systems with $A_{\mathrm{n}} > 2.5$ mag (Warner 1995). For comparison, a least-squares linear fit to the data gives the K–P relation for V729 Sgr (dot line in figure 3):

$$A_{\mathrm{n}} = -1.59(\pm 0.48) + 2.48(\pm 0.29) \log T_{\mathrm{n}}. \tag{4}$$

This equation can also be expressed as

$$A_{\mathrm{n}} = 1.65(\pm 0.30) + 2.48(\pm 0.29)[\log T_{\mathrm{n}} - 1.31(\pm 0.08)], \tag{5}$$

where 1.65( ± 0.30) and 1.31( ± 0.08) are the mean values of $A_{\mathrm{n}}$ and $\log T_{\mathrm{n}}$, respectively. The slope is larger than 1.9 of the empirical relation and is equal approximately to 2.5 of the theoretical relation. Thus, the theoretical K–P relation follows the overall trend of observational data in V729 Sgr reasonably well. The intercept ($C_1 = -1.59$) should be connected with the nature of the system (see Kotko & Lasota 2012). Finally, we suggest that the K–P relation may be model-dependent and represents general properties of DNe outbursts.

Figure 4 shows the partial data extracted from the upper panel in figure 2 during the period from 2004 March to October. Apart from several normal outbursts, we note the presence of two smaller-amplitude outbursts (marked out with solid asterisks in figure 4 and labelled A and B) with amplitudes of ~0.6 and 0.9 mag. The smaller-amplitude outbursts are similar to a few NLs which show "stunted" outbursts with amplitudes up to 1 mag (e.g., Honeycutt et al. 1995, 1998; Warner 1995; Ramsay et al. 2016). Another feature in figure 4 is that there are dips following the outbursts; i.e., the dips are paired with outbursts. Although the data are fragmentary and there is some uncertainty in the light curves, there is nevertheless an obvious dip accompanying outburst A (see figure 4). This dip has a depth of ~0.2 mag and a duration of 2 d. Honeycutt, Robertson, and Turner (1998) reported that some dips exist in several old novae and NLs, which have a depth of 0.2–0.5 mag with a FWHM ranging from 2 to 50 d. In fact, these dips have some resemblance to dips of a subtype of NLs: VY Scl stars. Most recently, a NL KIC9202990 also shows two dips of depths 0.4 and 0.6 mag with a FWHM of 2–3 d (Ramsay et al. 2016). It is thought that this behavior is caused by a temporary reduction in mass transfer rate due to the activity of a secondary star (e.g., Howell et al. 2000; Kafka & Honeycutt 2005).

More detailed examination of the AAVSO data reveals that there are diverse outburst behaviors and the rise speed is generally faster than the decay one. We also used several more complete outbursts to estimate the parameters, which are listed in table 1. It seems that the decay time is dependent on the magnitude at the maximum (see table 1), which is

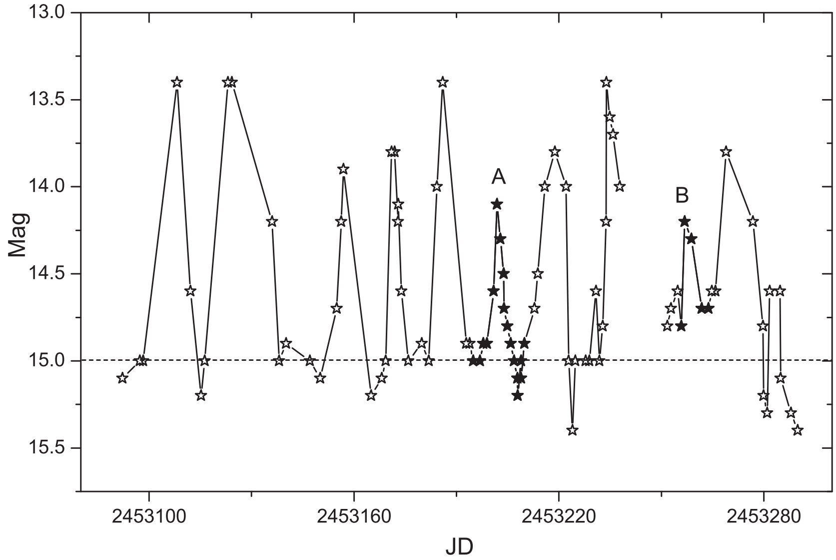

**Fig. 4.** Part of the light curve extracted from the upper panel in figure 2 during the period from 2004 March to October. Apart from several normal outbursts, there are the smaller-amplitude outbursts (the solid asterisk) and dips.

**Table 1.** Parameters of the rise and decay of several outbursts.

| JD | $V_{\max}$ (mag) | $\tau_{\text{rise}}$ (d/mag) | $\tau_{\text{decay}}$ (d/mag) | Type |
|---|---|---|---|---|
| 2453170 | 13.6(0.3) | 1.42(0.05) | 3.33(0.11) | A |
| 2452787 | 13.4(0.3) | 1.43(0.02) | 2.86(0.07) | A |
| 2453550 | 13.7(0.3) | 1.57(0.03) | 4.01(0.06) | A |
| 2454702 | 13.2(0.2) | 1.88(0.06) | 2.14(0.10) | A |
| 2452930 | 13.4(0.4) | 2.22(0.08) | 2.94(0.06) | A |
| 2453186 | 13.8(0.3) | 2.58(0.02) | 4.55(0.10) | A |
| 2453202 | 14.1(0.2) | 3.65(0.05) | 5.45(0.10) | A |

similar to the magnetic dwarf nova DO Dra (Andronov et al. 2008). The nature of a rapid rise and a slower decay indicates that the outbursts are outside-in outbursts (Type A: Smak 1984). The rise time for a Type A outburst is

$$t_{\text{out-in}} \sim \frac{R_{\text{d}}}{\alpha_{\text{h}} c_{\text{s}}}, \tag{6}$$

where $R_{\text{d}}$ is the radius of the accretion disc, $\alpha_{\text{h}} c_{\text{s}}$ is the velocity of the inward-moving heating front, and $c_{\text{s}}$ represents sound speed. The outer disc radii during outbursts in DNe can be approximated to $R_{\text{d}} \sim 0.9\,R_{\text{L}}$ (e.g., Smak 2001), where $R_{\text{L}}$ is the effective radius of the Roche Lobe of the primary star, derived by Eggleton (1983) as

$$\frac{R_{\text{L}}}{a} = \frac{0.49q^{2/3}}{0.6q^{2/3} + \ln(1 + q^{1/3})}, \tag{7}$$

where $a$ is the orbital separation, and $q = M_1/M_2$. Combining the physical parameters of V729 Sgr (Cieslinski et al. 2000) with Kepler's third law,

$$P_{\text{orb}}^2 = \frac{4\pi^2 a^3}{G(M_1 + M_2)}, \tag{8}$$

yields $a \approx 9.6 \times 10^{10}$ cm. Thus, $R_{\text{L}} \approx 0.44a = 4.2 \times 10^{10}$ cm and $R_{\text{d}} \sim 0.9\,R_{\text{L}} \approx 3.8 \times 10^{10}$ cm. Typical parameters in CVs are $c_{\text{s}} \sim 2.5 \times 10^6$ cm s$^{-1}$ and $\alpha_{\text{h}} \sim 0.1$ during outbursts (Frank et al. 2002). Applying these parameters and using equation (5) we find $t_{\text{out-in}} \sim 1.76$ d, in rough agreement with observations.

V729 Sgr was classified as a Z Cam type DN by Cieslinski et al. (2000). The Z Cam type stars generally have relatively high mass transfer and accretion rates, and their outburst amplitudes are lower than those for most DNe (Szkody et al. 2013). A distribution of both the outburst and the modulation amplitude in the brightness of CVs is displayed in figure 5 using the data of both the 77 DNe obtained from AAVSO database and the 33 NLs given by AAVSO and literature (e.g., Honeycutt et al. 1998, 2014; Honeycutt 2001; Gies et al. 2013; Ramsay et al. 2016), and the values of V729 Sgr are also added. It is shown that V729 Sgr may be an intermediate between DNe and NLs. Many authors (e.g., Smak 1984; Cannizzo 1993; Osaki 1996; Lasota 2001; Buat-Ménard et al. 2001) have described the model of Z Cam type stars' outbursts and standstill. The model pointed out that the systems with mass transfer rates below the critical value ($\dot{M}_{\text{crit}}$) generate DN outbursts, while those above the critical rate will become NLs. The Z Cam systems are thought to fall on the boundary between the thermally stable NLs and thermally unstable DNe. This may explain why V729 Sgr exhibits

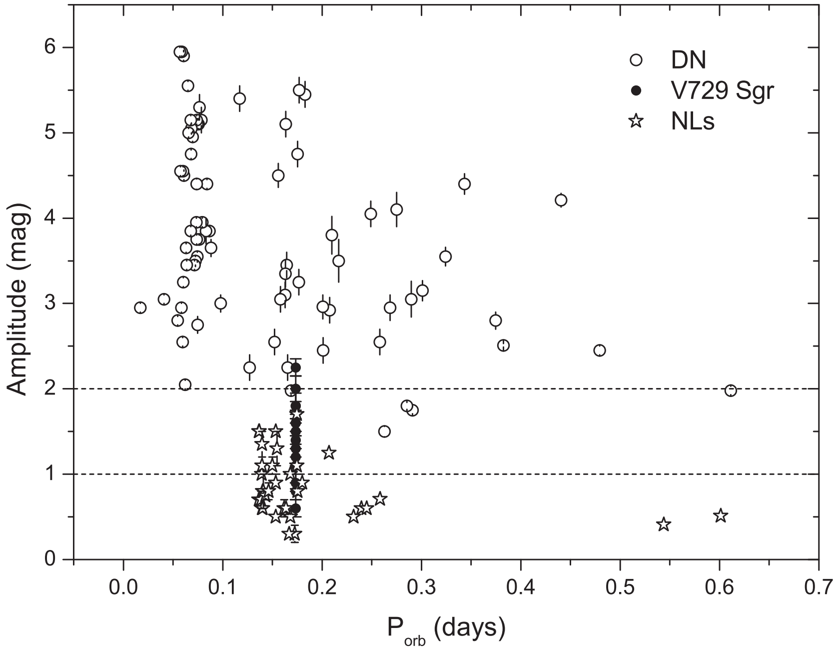

**Fig. 5.** A distribution of the amplitude of outburst or modulation in brightness in CVs using the data of both 77 DN and 33 NLs obtained from AAVSO observations and literature. The position of V729 Sgr shows that it has a wide amplitude range and is thought to be a link between DN and NLs.

rich and complex behavior such as the "stunted" outbursts and dips seen in NLs and the normal DNe outbursts. The importance of the critical mass transfer rate means it is very necessary to estimate it. Frank et al. (2002) gave an expression for $\dot{M}_{\rm crit}$:

$$\dot{M}_{\rm crit} \simeq 3 \times 10^{-9}(P_{\rm orb}/3)^2\, M_\odot\ {\rm yr}^{-1}, \tag{9}$$

where $P_{\rm orb}$ is measured in hours. For V729 Sgr, we find $\dot{M}_{\rm crit} \simeq 5.8 \times 10^{-9}\, M_\odot\ {\rm yr}^{-1}$. As noted above, most of the normal outbursts in V729 Sgr are Type A (outside-in). Osaki (1996) pointed out that when $1.59 \times 10^{-9} < \dot{M}_2 < 4.76 \times 10^{-9}\, M_\odot\ {\rm yr}^{-1}$, the outburst is Type A; when $4.76 \times 10^{-9} < \dot{M}_2 < 1.59 \times 10^{-8}\, M_\odot\ {\rm yr}^{-1}$, the recurrence time will be shorter, and this may correspond to the "stunted" outbursts (<1 mag) in V729 Sgr. If $\dot{M}_2 > 5.8 \times 10^{-9}\, M_\odot\ {\rm yr}^{-1}$ in V729 Sgr, however, it will cross the instability boundary, becoming an NL that remains in a constant high state, i.e., standstill. Unfortunately, so far, no sign of standstill is found. Therefore, $\dot{M}_2$ is restricted to the range of from $1.59 \times 10^{-9}$ to $5.8 \times 10^{-9}\, M_\odot\ {\rm yr}^{-1}$.

### 3.2 DNOs and QPOs in V729 Sgr

As well as large-scale outburst brightness variations, there are rapid brightness oscillations of moderate coherence and low amplitude in CVs. These are generally divided into two types: DNOs and QPOs, which were most detected in DNe during outburst and in many NLs. A review article has been given by Warner (2004). Normally, DNOs have low-amplitude oscillations in brightness with short periods, and QPOs are longer-timescale modulations with larger amplitudes. The relation between $P_{\rm QPOs}$ and $P_{\rm DNOs}$ is $P_{\rm QPOs} \approx 16 \times P_{\rm DNOs}$. In addition, Paper III also reported the existence of longer-period DNOs (lpDNOs), with typical intermediate periods between $P_{\rm QPOs}$ and $P_{\rm DNOs}$: the relation is $P_{\rm lpDNOs} \approx 4 \times P_{\rm DNOs}$.

Our observations for V729 Sgr show distinct oscillations, and contain at least three outburst episodes (see figure 1). In order to explore the nature of these changes, a frequency analysis was performed using the Fourier transform (FT) method described by Lomb (1976) and Scargle (1982). Due to the system's low orbital inclination (~71°) (Cieslinski et al. 2000), the accretion disc is partly visible during the eclipses. Figure 1 shows the simultaneous presence of both eclipses and the rapid brightness oscillations. To investigate more details of DNOs and QPOs, the data should be prepared by subtracting a mean eclipse profile trend from each light curve individually before computing the FT. Figure 6 show the processed light curves near the outburst maximum (the left-hand panel) and their Fourier spectrum diagrams (the right-hand panel). Meanwhile, we have also calculated FTs of other light curves in order to compare them at their different states. Table 2 gives results of the analyses of DNOs and QPOs for each light curve. As mentioned above, only one outburst near the maximum was observed (see table 2). Our analysis will first concentrate on this outburst. This system on 2014 August 5 was

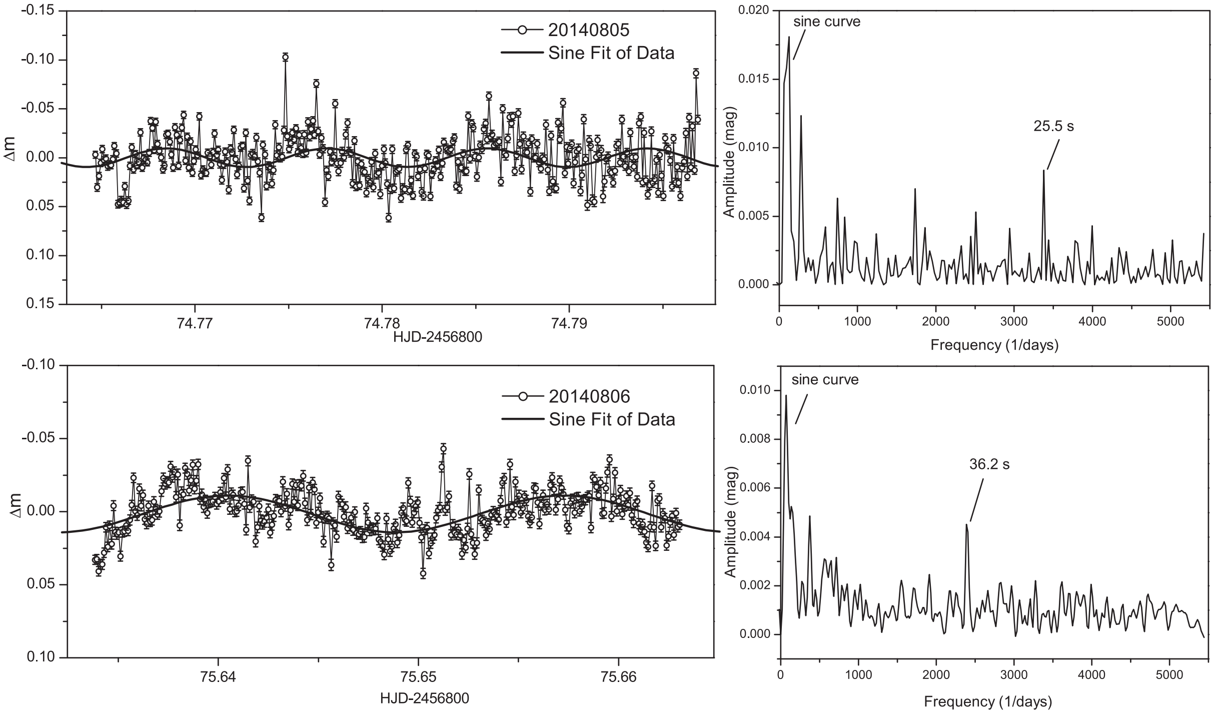

**Fig. 6.** Light curves and their Fourier spectrums near the outburst maximum on 2014 August 5 and 6.

**Table 2.** DNOs, lpDNOs, and QPOs in V729 Sgr at the different states.*

| Date | Outburst type | $P_{\mathrm{DNO}}$ (s) | $P_{\mathrm{lpDNO}}$ (s) | $P_{\mathrm{QPO}}$ (s) | Filters |
|---|---|---|---|---|---|
| 2010 Jun 07 | Rise/decline | — | 136? | — | I |
| 2011 Apr 04 | Quiescence | — | — | 378 | N |
| 2011 Apr 05 | Quiescence | — | — | 322 | I |
| 2014 Jul 20 | Late rise | — | — | 478 | N |
| 2014 Aug 05 | Maximum | 25.5 | 49.9? | 308 | N |
| 2014 Aug 06 | Early decline | 36.2 | — | 231 | N |
| 2014 Aug 20 | Late decline | — | — | 587 | N |
| 2014 Aug 23 | Quiescence | — | 154 | 324 | N |
| 2015 Sep 09 | Early rise? | — | — | 408 | N |
| 2016 Jul 06 | Early decline? | — | — | — | N |

*The question marks represent uncertain cases.

observed at the outburst maximum, and the dominant feature of the light curve is a higher-coherence, stronger short-period oscillation than that in the rise phase, and rapid oscillations are visible directly in the light curve. Moreover, its Fourier spectrum also shows larger amplitude and more peaks. The top right-hand panel of figure 6 displays the FT of the light curve at the outburst maximum. Note that the signal at ∼25.5 s is only detected at the outburst maximum, implying that the signals of ∼25.5 s and 36.2 s in table 2 may be true DNOs being associated with accretion events. The reason is that most of the DNOs are generated from high-accretion CVs such as DNe in outburst and NLs. Returning to table 2, there is another possible DNO at ∼36.2 s, present at the early decline (see the lower panel of figure 6). The 36.2 and 25.5 s periodicities are close to a 3 : 2 ratio, which is similar to the harmonic of the synodic period in VW Hyi (Paper IV; Paper VIII).

The possible oscillations at ∼136 and 154 s are classified as lpDNOs rather than QPOs because they are close to four times the DNO period [$P_{\mathrm{lpDNOs}}/P_{\mathrm{DNOs}} \approx 4$ for 36.2 s and ≈5.7 for 25.5 s (mean value)]. Moreover, a signal at 49.9 s observed simultaneously with DNOs on 2014 August 5 was also identified as a possible lpDNO, but there is some ambiguity because the ratio $P_{\mathrm{lpDNOs}}/P_{\mathrm{DNOs}}$ in this case is only ∼1.96. The largest amplitude modulations in all FTs are not caused by a normal QPO but are related to the sine-fitting curve in figures 6 and 7. However, it is not clear whether the sinusoidal signal in the light curves is true or not. A typical example with an obvious QPO is given in figure 7, which shows a 408 s QPO. In this individual case, $P_{\mathrm{QPO}}/P_{\mathrm{DNO}} \approx 15.94$, which is very close to the typical value of 16.

## 4 Conclusion

We have presented the photometric results of an eclipsing dwarf nova V729 Sgr using our observations together with AAVSO data. Our analysis is focused on the outburst properties and rapid oscillations in brightness. The main conclusions are summarized as follows.

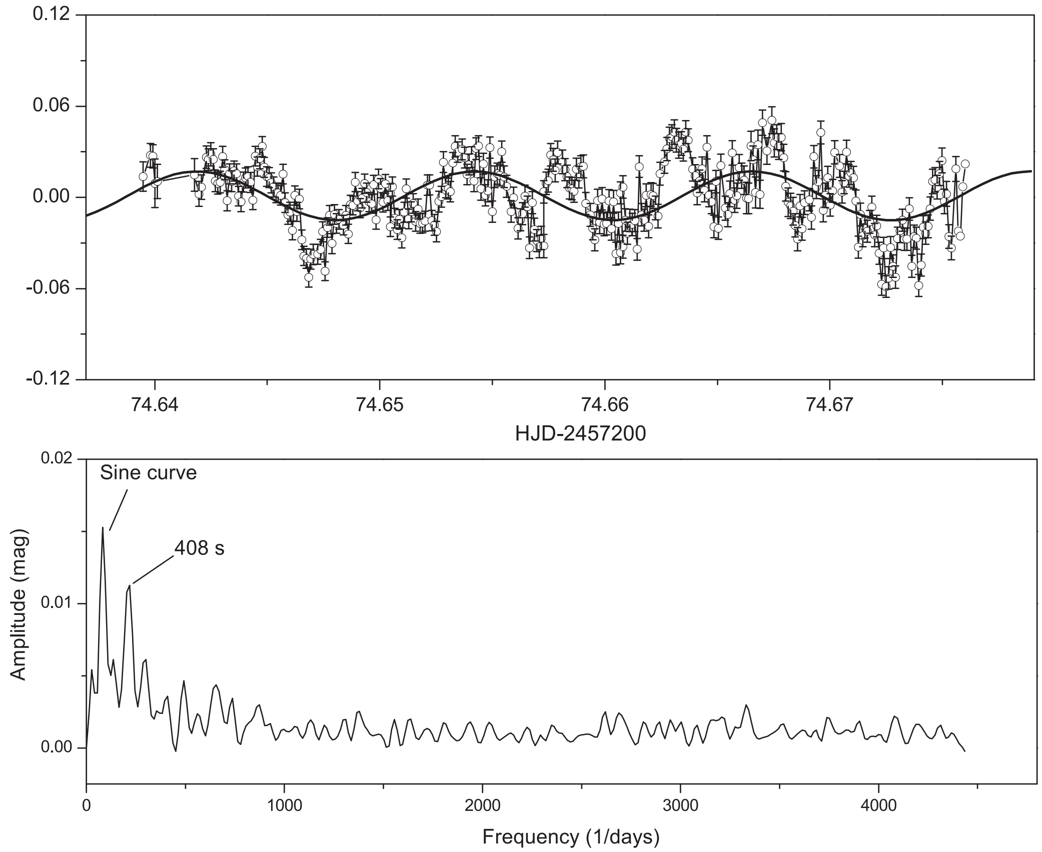

**Fig. 7**. Light curve and its Fourier spectrum on 2015 September 9. A QPO at ~408 s is clearly visible in the light curve.

(i) Based on our new observations and the ~15 yr of AAVSO data we have found that the outburst amplitude is in the range of 0.6–2.2 mag. The power spectrum of the AAVSO data indicates that there are some prominent peaks corresponding to the typical recurrence times, which are ~26.5 d for a normal outburst and 9.1–15.6 d for a short outburst. By comparing the observational data of V729 Sgr and the K–P relation, we believe that the K–P relation represents general properties of DN outbursts and is model-dependent. Moreover, the long-term outburst curves display the presence of the small-amplitude outbursts and dips, which is very similar to the "stunted" outbursts found in some NLs. Further examination revealed that V729 Sgr may be undergoing Type A outburst. The rise time for Type A was estimated to be ~1.76 d, roughly consistent with observations. As a Z Cam type star, V729 Sgr exhibits diverse outburst behavior, containing the normal outbursts in DN and the "stunted" outbursts in NLs. Combining the distribution diagram of outburst amplitudes in CVs, we suggest that it is an intermediate between DN and NLs. We also constrain the mass transfer rate in this system to $1.59 \times 10^{-9} < \dot{M}_2 < 5.8 \times 10^{-9}\, M_\odot\,\mathrm{yr}^{-1}$ by considering the critical mass transfer rate and the outburst properties in V729 Sgr.

(ii) We have detected rapid oscillations in V729 Sgr, the first to be reported for this star. A DNO at ~25.5 s in V729 Sgr was found during its outburst, indicating that it is related to the accretion from the inner regions of the accretion disc onto the surface of white dwarf. The classification of the oscillations at ~136 and 154 s as lpDNOs is based on the relation $P_{\mathrm{lpDNOs}}/P_{\mathrm{DNOs}} \approx 4$. For QPOs, a typical example is that there is a clear QPO with a period of 408 s present in the 2015 September 9 light curve, and $P_{\mathrm{QPO}}/P_{\mathrm{DNO}} \approx 15.69$. To be certain of these conclusions, we are encouraged by further observations.

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Database. Finally, we thank the anonymous referee for their helpful comments and suggestions.

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