NSV 1440: First WZ Sge-type Object in AM CVn stars and candidates

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Abstract

In 2015 and 2017, the AM CVn candidate NSV 1440 showed superoutbursts having the characteristic features of WZ Sge-type dwarf novae (DNe). By analogy with hydrogen-rich cataclysmic variables (CVs), we can interpret these outbursts as “double superoutbursts” which are composed of the first superoutburst with early superhumps and the second superoutburst with ordinary superhumps. The object also showed multiple rebrightenings after the main superoutbursts. Early superhumps had been never observed in AM CVn stars and candidates, thus NSV 1440 is the first confirmed WZ Sge-type AM CVn candidate. We obtained the early superhump period of 0.0252329(49) d and the growing (stage A) superhumps period of 0.025679(20) d from the 2015 superoutburst. We regarded the early superhump period as the orbital one. By using these periods we estimated the mass ratio \(q = 0.045(2)\). This value suggests that NSV 1440 is indeed an AM CVn star and that the secondary is a semi-degenerate star.

Key words: accretion, accretion disks — stars: novae, cataclysmic variables — stars: dwarf novae — stars: individual (NSV 1440)

1 Introduction

AM CVn stars are a subclass of cataclysmic variables (CVs), which are close binary systems composed of a white dwarf (WD) primary and a mass-transferring secondary. Their secondary stars are helium stars or helium WDs. They are characterized by absences of hydrogen lines in their spectra and their ultra-short orbital periods of 5–65 min (for reviews of AM CVn stars, see Nelemans 2005; Solheim 2010).

Outbursts in AM CVn stars are theoretically studied by Tsugawa, Osaki (1997) and are basically understood
by analogy with the thermal instability model in H-rich dwarf novae (DNe). However, the outburst behaviors of AM CVn stars are complicated, e.g. dips, rebrightenings and so on. Kotko et al. (2012) argued that variation of the mass-transfer rate, may be caused by irradiation of the secondary, is necessary for reproducing their light curves on the basis of their model calculation. Warner (1995) and Warner (2015) interpreted the typical outbursting AM CVn stars as VY Scl-type objects, which show brightness variations owing to the change of the mass-transfer rate. More detailed observational studies are required to understand the outburst mechanism and the stability of the mass-transfer rate.

Some AM CVn stars show not only normal outbursts but also superoutbursts with superhumps (Patterson et al. 1993; Warner 1995). Superhumps are small-amplitude modulations whose period $P_{\text{SH}}$ is a few percent longer than the orbital period $P_{\text{orb}}$. Superoutbursts and superhumps are characteristic phenomena of SU UMa-type DNe and are explained by the thermal-tidal instability (TTI) model (Osaki 1989). When an outer disk reaches the 3:1 resonance radius, the disk becomes eccentric and begin to show periodic modulations, i.e. superhumps (Whitehurst 1988; Lubow 1991a; Lubow 1991b; Hirose, Osaki 1990). Kato et al. (2014) and Isogai et al. (2016) confirmed that the period variations of superhumps in AM CVn stars are consistent with those in H-rich DNe, and proposed that the superoutbursts in AM CVn stars are also interpreted by the TTI model.

AM CVn stars typically have an extreme low mass secondary (cf. Nelemans et al. 2001). We know that $P_{\text{orb}}$ of outbursting AM CVn stars are typically longer than 1300 s $\sim$ 0.015 d (Solheim 2010), and that $M_1$ of 0.65$M_\odot$ is often used (e.g. Bildsten et al. 2006). From these values and the theoretical evolutionary tracks (see section 5.3 and equation 1 and 2), we can approximately estimate that $q$ of typical outbursting AM CVn stars are less than 0.1. Because disks in CVs with $q < 0.25$–0.30 can reach the 3:1 resonance radius, many outbursting AM CVn stars can show superhumps.

Many hydrogen-rich DNe with $q < 0.09$ are known as WZ Sge-type DNe, which are a subclass of SU UMa-type DNe. It is known that WZ Sge-type DNe show longer and larger superoutburst in comparison with SU UMa-type DNe and show few normal outbursts (for a review of WZ Sge-type DNe, see Kato 2015). The analogy between WZ Sge-type DNe and some AM CVn stars has sometimes been discussed. For instance, Nogami et al. (2004) pointed out that the outburst behavior of V406 Hyi resembles with that of the WZ Sge-type star EG Cnc in that the object showed the multiple rebrightenings after the main superoutburst. Levitan et al. (2015) proposed that the long $P_{\text{orb}}$ systems have low mass-transfer rates and will show rare and large outbursts. Thus, they indicated that such objects may be WZ Sge-type AM CVn stars. To date, “WZ Sge-type” in AM CVn stars has basically meant that an object shows multiple rebrightenings or that an object shows rare and larger-scale superoutbursts.

The larger-scale WZ Sge-type superoutbursts are explained by the presence of the 2:1 resonance. If a system has extreme low mass ratio and enough mass is accumulated in the disk, the outer edge of the disk can reach the 2:1 resonance radius beyond the 3:1 one (Osaki, Meyer 2002). The two-armed dissipation pattern in the disk is caused by the 2:1 resonance, then the early superhumps begin to grow (Lin, Papaloizou 1979). Because the 2:1 resonance suppresses the 3:1 resonance (Lubow 1991a; Osaki, Meyer 2003), ordinary superhumps begin to grow after the end of the early superhump phase. It is widely known that early superhumps have double-wave profiles and the periods are close to $P_{\text{orb}}$ (Kato 2002). For instance, Ishioka et al. (2002) have confirmed that the early superhump period of AL Com is 0.05 % shorter than $P_{\text{orb}}$. Patterson et al. (2002) also proposed that the signal of the early superhumps in WZ Sagittae is “essentially consistent with orbital frequency”. It is considered that a vertical extended disk originates such modulations. Thus, early superhumps are only observed in high-inclination systems. On the other hands, low-inclination systems show a long plateau phase with no superhumps which is brighter than the superoutburst plateau with ordinary superhumps. Such a plateau phase is also regarded as a kind of early superhump phases. Because WZ Sge-type superoutbursts are essentially different from SU UMa-type ones, WZ Sge-type DNe are defined by the presence of the early superhump phase according to the modern criteria (Kato 2015). For these reasons, WZ Sge-type superoutbursts are brighter and longer than SU UMa-type ones.

As indicated in Levitan et al. (2015), many AM CVn stars could show WZ Sge-type superoutbursts since they have low $q$ and low mass-transfer rate, especially in long period systems. Actually, some objects have shown WZ Sge-like light curves. However, the reliable evidence of WZ Sge-type superoutbursts, namely the early superhump phase, has never been observed in AM CVn stars and candidates. Because we can estimate $P_{\text{orb}}$ from the early superhump period, WZ Sge-type superoutbursts are not just large and rare superoutbursts but the important messengers of the binary parameters. Furthermore, we can also estimate the mass ratios from intensive time-series observations of WZ Sge-type superoutbursts and evaluate the evolutionary path as will be discussed in sec-
In this paper, we report on our time-series observations of the 2015 and 2017 outbursts of the AM CVn candidate NSV 1440. Although there is no spectroscopic confirmation, the short period superhump and outburst behavior suggest that the object is an AM CVn star. Actually, the object is often treated as an AM CVn star, e.g. Ramsay et al. (2018). The object showed the first WZ Sge-type superoutbursts in AM CVn stars and candidates. This fact implies that we can understand outbursts in AM CVn stars by analogy with hydrogen-rich DNe.

2 NSV 1440

NSV 1440 was a variable star candidate listed in the New Catalogue of Suspected Variable Stars (NSV, Kukarkin et al. 1982) with the brightness range from 12.6 up to 15.0 mag. The object is also known by the names BV 1025, ASASSN-15sz and GALEX J035517.7-822612. The coordinates of the object are RA = 03:55:17.83 and Dec = -82:26:11.5 at J2000. The quiescent magnitudes in Gaia Data Release 2 are $G = 18.5126(72)$, $BP = 18.4139(331)$ and $RP = 18.4239(684)$ (Gaia Collaboration et al. 2016; Gaia Collaboration et al. 2018; Riello et al. 2018). By using these values and table A.2 in Evans et al. (2018), we can estimate the quiescent $V$ mag of 18.53(5). The object has a GALEX counterpart with near-UV (NUV) and far-UV (FUV) magnitudes of 18.305(57) and 18.286(96) (Martin et al. 2005). Two historical outbursts were recorded in the All Sky Automated Survey-3 (ASAS-3, Pojmański 2002), cf. the light curve of ASAS-3 in figure E2. The 2003 outburst was detected at 13.544 mag on BJD 2452929.740037, and the 2005 one was detected at 13.492 mag on BJD 2453669.797309.

The 2015 outburst was detected at $V = 13.8$ on November 20 (BJD 2457339.62) by the All-Sky Automated Survey for Supernovae (ASAS-SN) (Shappee et al. 2014). The 2017 outburst was detected at a visual magnitude of 13.0 on August 21 (BJD 2457987.27) by R. Stubbings (vsnet-alert 21352). After these detections, we performed the observation campaigns.

3 Observation and Analysis

Our time-series observations are summarized in table E1 and E2. The typical exposure time is 30–120 sec. The data were acquired by time-series unfiltered CCD photometry using 30–40 cm class telescopes by the VSNET Collaboration (Kato et al. 2004). The times of the observations were corrected to Barycentric Julian Date (BJD). We adjusted the zero-point of each observer to the data of Franz-Josef Hambsch.

We used the phase dispersion minimization (PDM) method for analyzing the superhump periods. We estimated 1σ errors by using the methods in Fernie (1989) and Kato et al. (2010). Before our period analyses, we subtracted the global trend of the light curve which was calculated using locally-weighted polynomial regression (LOWESS, Cleveland 1979). We used $O – C$ diagrams which are sensitive to subtle variations of the superhump period. The times of superhump maxima, which are used to draw the $O – C$ diagrams and are listed in table E3 and E4, were determined by the same method as described in Kato et al. (2009). The number in the parentheses after each value represents 1σ error, e.g. 0.12(3) means 0.12 ± 0.03.

4 Result

4.1 Overall Light Curve

Figure 1 shows the overall light curves of the 2015 and 2017 outbursts. We also added the $V$ and $g$-band data obtained by the ASAS-SN Sky Patrol (Shappee et al. 2014; Kochanek et al. 2017). We should note that the ASAS-SN data around 16.5 mag might include systematic errors due to their limiting magnitudes. The horizontal axis “Date” of the 2015 and 2017 outbursts are defined to be BJD − 2457346.751 and BJD − 2457982.000, respectively. Each light curve shows two superoutbursts (double superoutburst) and rebrightenings. We respectively marked the superoutbursts, rebrightenings and “small rebrightenings” with the labels “SO”, “R” and “r”. The overall light curves are roughly consistent with each other.

According to the 2015 light curve, the maximum brightness value of the first superoutburst (SO1) is $V=12.85$ on Date $= 0.85$. The SO1 lasted for about 4 d and the object rapidly faded to 18.0 mag. Then the object brightened again and reached the maximum of the second superoutburst (SO2) on Date $= 7.6$. The duration of the SO2 is about 5 d. Unfortunately, there is no data of the plateau of the SO1 in 2017 due to the observational gap, hence we cannot exclude the possibility that the SO1 in 2017 is not a superoutburst but a precursor outburst. After the end of the SO2, the object showed a slow decline with multiple rebrightenings. In 2017, the object returned to the quiescent magnitude of $V = 18.53$ around Date $= 120$. 

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1 VSNET-alert archive is available at <http://oorui.kusastro.kyoto-u.ac.jp/pipermail/vsnet-alert/>
2 Figure E1–E2 and tables E1–E4 are available online as the supplementary data for this article.
4.2 Early superhumps

During the SO1, we succeeded in detecting double-wave modulations with a constant period of 0.0252329(49) d. The result of the period analysis and the averaged profile are shown in the left panels of figure 2. Because the SO1 is brighter than the SO2 which shows the ordinary superhumps, the disk should expand beyond the 3:1 resonance radius and reach the 2:1 one. As explained in introduction, the 2:1 resonance suppresses the 3:1 resonance (Lubow 1991a; Osaki, Meyer 2003). If the disk did not reach the 2:1 resonance radius, the object should show ordinary superhumps during the SO1. As explained in next section, the growing ordinary superhumps were detected in the rising part of the SO2, thus we propose that the modulations in the SO1 are early superhumps. The constant period and the characteristic double-wave profile also suggest that they are early superhumps. Thus, we can use the period of the early superhump as $P_{\text{orb}}$.

4.3 Ordinary superhumps

After the end of the SO1, ordinary superhumps began to grow. We drew the $O-C$ diagrams of superhump maxima (figure 3). For the classification and the interpretation of the superhump stages, see Kato et al. 2009 and Kato, Osaki 2013. In WZ Sge-type DNe, “late-stage superhumps” are usually observed instead of stage C ones after the main superoutburst (Kato 2015). $P_{SH}$ in the late stage is shorter than in stage A but longer than in stage B.

We can distinguish between stage A, B and late-stage
superhumps from the O–C diagrams. Around the rapid fading from the SO1 (marked “F” in figure 3), the object showed short-period modulations (hereafter we call this term “fading stage”). We will discuss the modulations in the fading stage in section 5.2. We summarized the estimated periods and the Dates used for our analysis in table 1. The periods in 2017 have significantly larger errors due to the lacking data, thus we will basically use the values in 2015. The right panel of figure 2 shows phase-averaged profiles in 2015.

Table 1. List of the estimated periods.

| Period (day) Date       |
|-------------------------|
| 2015                    |
| Early superhump * 0.0252329(49) 0.891–4.769 |
| Stage A 0.025679(20) 6.872–8.082 |
| Stage B 0.025356(2) 8.522–12.082 |
| Fading stage 0.025211(16) 12.177–14.786 |
| Late stage 0.0254019(4) 14.850–64.348 |
| 2017                    |
| Stage A 0.02562(21) 7.790–7.899 |
| Stage B 0.0253478(17) 8.787–11.897 |
| Fading stage 0.02531(17) 12.776–12.903 |
| Late stage 0.0253926(7) 14.770–29.892 |

* We use the early superhump period as Porb.

4.4 Rebrightenings

Each light curve shows eight rebrightenings. The timings of the rebrightenings are almost the same except for the last one. The duration and the amplitudes are 1.5 d and 2.1–2.6 mag, respectively. Only in the 2015 outburst, the object showed two “short rebrightenings” whose duration and amplitudes are respectively ~0.6 d and ~1 mag (you can see the enlarged light curve of the rebrightenings in figure E12).

We extracted the linear rising/fading part of the rebrightenings in 2015 and evaluated the rising/fading rates. The averaged rising/fading rates in the normal rebrightenings are approximately -15(2) mag/d and 2.2(2) mag/d, respectively. Such a rapid rising suggests that the normal rebrightenings are outside-in outbursts. In contrast, the rising/fading rates in the short rebrightenings are about -6 mag/d and 4.7 mag/d, respectively. The slow rising implies that the short rebrightenings are inside-out outbursts and arose only in the inner part of the disk.

5 Discussion

5.1 WZ Sge-type superoutburst

As mentioned in the introduction, many AM CVn stars have low q and can potentially cause a WZ Sge-type superoutburst. A part of H-rich CVs with extreme low $q < 0.06$ show double superoutbursts which are composed of the first superoutburst with early superhumps and the second superoutburst with ordinary superhumps (Kato 2015). Because the growth time of the 3:1 resonance is proportional to $q^2$ (Lubow 1991a), the systems having low q cannot maintain the superoutburst just after the disappearance of the early superhumps. When the ordinary superhump sufficiently develops, the object undergoes the second superoutburst (Kimura et al. 2016). The outburst behaviors of NSV 1440 are in agreement with this interpretation. Although we don’t know the true Porb of NSV 1440, we can interpret the modulations in the SO1 as early superhumps on the basis of the outburst morphology. Thus NSV 1440 is the first promising WZ Sge-type DN in AM CVn stars and candidates.

WZ Sge-type superoutbursts in AM CVn stars could be double superoutbursts because of their extreme low q. Levitan et al. (2015) investigated the long-term light curves of many AM CVn stars and confirmed WZ Sge-type DNe-like light curves. The light curve of SDSS J172102.48+273301.2 resembles those of NSV 1440 closely (figure 10 in Levitan et al. 2015). There is however no time-resolved data and we cannot confirm the presence of early superhumps. SDSS J090221.35+381941.9 reported in Kato et al. (2014) showed a precursor outburst one week before the SU UMa-type superoutburst. The precursor may have been a superoutburst with early superhumps, but they missed the overall profile of the precursor. Recently, SDSS J141118.31+481257.6 and ASASSN-18rg also showed double superoutburst-like phenomena (Isogai et al. in preparation).

5.2 Orbital-period modulations in the fading stage

The periods of the modulations in the fading stage are close to Porb (table 1). GW Lib, a typical H-rich WZ Sge-type DN, also showed such orbital-period modulations in the fading stage (see figure 33 in Kato et al. 2009). It is known that the pressure effect in the disk shortens $P_{SH}$ (Lubow 1992). If the pressure effect is amplified in the fading stage, $P_{SH}$ might match with P orb. The right panel of figure 2 shows the orbital-period modulations have a sine wave shape. The period and the profile may give us the impression that the bright spot was brightened in the fading stage, namely the mass transfer was en-
hanced. However, it is difficult to understand the reason why such orbital modulations become visible only in the fading stage.

5.3 Mass ratio and evolutionary channel

Three evolutionary channels (WD, helium-star and evolved-CV channels) have been proposed to form AM CVn stars, but the contribution of each channel is poorly understood. The secondaries of WD channel systems are fully-degenerate WDs. Whereas, those of helium-star and evolved-CV channel systems are initially semi-degenerate stars and gradually evolve into fully-degenerate ones (cf. Deloye et al. 2007). Thus, secondary masses help to reveal their evolutionary channels.

We can also use mass ratio \( q \), which is easier to obtain than donor mass. The empirical relation between \( q \), \( P_{\text{orb}} \) and \( P_{\text{SH}} \) of hydrogen-rich DNe has been widely known, e.g. Patterson et al. (2005). However, Roelofs et al. (2006b) confirmed that \( q \) from the empirical law is significantly different from their spectroscopic measurement. Furthermore, Pearson (2007) indicated that superhump periods are affected by the pressure effect in the disk and computed the pressure effect of AM CVn stars. According to his formulation, the pressure effect also depends on the mass-radius relation of the secondary. Because the mass-radius relation of AM CVn stars differs with the evolutionary scenarios, Pearson (2007) concluded that we should not use the empirical law for AM CVn stars. Osaki, Kato (2013) interpreted that \( P_{\text{SH}} \) of the growing (stage A) superhump corresponds to the dynamical precession rate at the 3:1 resonance radius based on the Kepler’s complete light curve. Kato, Osaki (2013) investigated \( P_{\text{SH}} \) and \( q \) of hydrogen-rich CVs and have established the \( q \) estimation method in a purely dynamical way. They confirmed that \( q \) from stage A are in good agreement with \( q \) from the eclipse measurement. Because this method does not depend on the disk composition and the secondary mass-radius relation, we can apply to other DN cousins. In fact, Ohnishi et al. (submitted) estimated \( q \) of the metal-poor (population II) system OV Boo by using \( P_{\text{SH}} \) in stage A and the early superhump period which is regarded as \( P_{\text{orb}} \). They succeeded in confirming that \( q \) from the stage A method is consistent with \( q \) from the eclipse measurement. The metal abundance significantly affects the mass-radius relation (Stehle et al. 1997) and the viscosity in the disk (Pojmanski 1986). Therefore, this result strongly suggests that we can also apply the stage A method to AM CVn stars. However, we need to confirm the orbital period and mass ratio via spectroscopies or eclipse observations. Kato, Osaki (2013) proposed that \( q \) can be estimated by using the fractional superhump excess \( e^* = 1 - P_{\text{orb}} / P_{\text{SH}} \) in stage A. On the basis of the theoretical equations in Kato, Osaki (2013) and \( e^* = 0.0174(8) \), we obtained \( q = 0.045(2) \).

Armstrong et al. (2012) derived the following evolutionary tracks from the Kepler’s third law, the secondary’s Roche lobe-filling condition (Faulkner et al. 1972), the mass-radius relation of fully-degenerate stars (Zapolsky, Salpeter 1969) and that of semi-degenerate stars (Savonije et al. 1986):

\[
M_2 = 1.43 \times 10^{-4} P_{\text{orb}}^{-1.22} \quad \text{for the fully-degenerate secondary}, (1)
\]

\[
M_2 = 3.18 \times 10^{-4} P_{\text{orb}}^{-1.27} \quad \text{for the semi-degenerate secondary}, (2)
\]

Figure 4 shows the above evolutionary tracks on the \( P_{\text{orb}} - q \) plane. The dashed and solid curves respectively mean semi and fully-degenerate secondaries assuming \( M_1 \). The value of NSV 1440 suggests that the object has a semi-degenerate secondary, and hence the object is an AM CVn star in a helium-star or evolved-CV channel.

![Fig. 4. Relation between \( q \) and \( P_{\text{orb}} \) with various primary masses. The dashed curve indicates semi-degenerate secondaries, and the solid curve indicates fully-degenerate secondaries. Top to bottom, three lines represent the \( q - P_{\text{orb}} \) relation, assuming \( M_1 = 0.60, 0.75, \) and 1.00 \( M_\odot \), respectively. The filled stars represent the measurements from stage A superhump (CR Boo: Isogai et al. 2016, J0902 = SDSS J090221.35+381941.9: Kato et al. 2014). The filled squares represent the measurements from Doppler tomography (Marsh, Horne 1988) (AM CVn: Roelofs et al. 2006b, V406 Hya: Roelofs et al. 2006a, J1240 = SDSS J124058.03-015919b: Roelofs et al. 2005, GP Com: Marsh 1999, V396 Hya: Solheim 2010). The filled circle represents the measurement from eclipse observations (J0926 = SDSS J092620.42+034542.3: Copperwheat et al. 2011, Gaia14aae: Green et al. 2018).](image-url)
5.5 Supercycle

As mentioned in section 2, the four outbursts have been detected: \( V = 13.544 \) in 2003, \( V = 13.492 \) in 2005, \( V = 13.8 \) in 2015, \( V = 13.0 \) in 2017. The complete light curves of ASAS-3 and ASAS-SN are shown in figure E2. Although there is no time-resolved data in 2003 and 2005, their outburst maxima suggest that they are superoutbursts. As you can see in figure 1, all superoutbursts are brighter than 14.0 mag, and all rebrightenings (normal outbursts) are fainter than 14.0 mag. These superoutburst intervals imply the supercycle of two years. If this inference is correct, we can calculate the averaged supercycle of \( 728(7) \) d. Levitan et al. (2015) empirically obtained the following relation between the outburst recurrence time \( \Delta T \) and \( P_{\text{orb}} \):

\[
\Delta T[^{\text{day}}] = 1.53 \times 10^{-9} P_{\text{orb}}[^{\text{min}}]^{3.35} + 24.7. \tag{3}
\]

This equation suggests that the supercycle of NSV 1440 is 474.6 d. This value is roughly consistent with our estimation. However, there is some uncertainty. Although ASAS-3 had observed around NSV 1440 for nine years, the detected outburst is only two. It might be caused by the shallow limiting magnitude of \( V \sim 14 \) (Pojmanski 2004) and/or some observation gaps. We should correct the supercycle by further observations.

6 Summary

The outbursts of NSV 1440 showed the following features, are known in H-rich WZ Sge-type DNe: (1) double superoutbursts; (2) early superhumps; (3) late-stage superhumps instead of stage C ones; (4) orbital-period modulations in the fading stage; (5) multiple rebrightenings.

Therefore, we interpreted NSV 1440 as the first WZ Sge-type DN in AM CVn stars and candidates. This discovery implies that many AM CVn stars also show WZ Sge-type superoutbursts. We should note that early and ordinary superhumps in WZ Sge-type superoutburst tell us the basic binary parameters (i.e., orbital period and mass ratio).

We obtained the early superhump period of 0.0252329(49) and the stage A superhump one of 0.025679(20) d from the 2015 outburst. On the basis of these periods and the method of Kato, Osaki (2013), we estimated \( q = 0.045(2) \). This value suggests that the object is an AM CVn star and has a semi-degenerate secondary. In other words, the object can be a helium-star or evolved-CV channel system. However, we should note that the validity of the \( q \) estimation method from stage A \( P_{\text{SH}} \) is not confirmed in AM CVn stars. Therefore, we need to compare \( q \) from stage A with \( q \) from other methods also in AM CVn stars.

Supplementary Material

The following supplementary data is available in the online article. figure E1–E2 and tables E1–E4.

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References

Armstrong, E., Patterson, J., & Kemp, J. 2012, MNRAS, 421, 2310
Bildsten, L., Townsley, D. M., Deloye, C. J., & Nelemans, G. 2006, ApJ, 640, 466
Cleveland, W. S. 1979, J. Amer. Statist. Assoc., 74, 829
Copperwheat, C. M., et al. 2011, MNRAS, 410, 1113
Deloye, C. J., Taam, R. E., Winisdoerffer, C., & Chabrier, G. 2007, MNRAS, 381, 525
Evans, D. W., et al. 2018, A&A, 616, A4
Faulkner, J., Flannery, B. P., & Warner, B. 1972, ApJ, 175, L79
Fernie, J. D. 1989, PASP, 101, 225
Gaia Collaboration, et al. 2018, A&A, 616, A1
Green, M. J., et al. 2016, A&A, 595, A1
Hirose, M., & Osaki, Y. 1990, PASJ, 42, 135
Ishioka, R., et al. 2002, A&A, 381, L41
Isogai, K., et al. 2016, PASJ, 68, 64
Kato, T. 2002, PASJ, 54, L11
Kato, T. 2015, PASJ, 67, 108
Kato, T., et al. 2009, PASJ, 61, S395
Kato, T., et al. 2010, PASJ, 62, 1525
Kato, T., et al. 2014, PASJ, 66, L7
Kato, T., & Osaki, Y. 2013, PASJ, 65, 115
Kato, T., Uemura, M., Ishioka, R., Nogami, D., Kunjaya, C., Baba, H., & Yamaoka, H. 2004, PASJ, 56, S1
Kimura, M., et al. 2016, PASJ, 68, 55
Kochanek, C. S., et al. 2017, PASP, 129, 104502
Kotko, I., Lasota, J.-P., Dubus, G., & Hameury, J.-M. 2012, A&A, 544, A13
Kukarkin, B. V., et al. 1982, New Catalogue of Suspected Variable Stars (Moscow: Nauka Publishing House)
Levitan, D., Groot, P. J., Prince, T. A., Kulkarni, S. R., Laher, R., Ofek, E. O., Sesar, B., & Surace, J. 2015, MNRAS, 446, 391
Lin, D. N. C., & Papaloizou, J. 1979, MNRAS, 186, 799
Lubow, S. H. 1991a, ApJ, 381, 259
Lubow, S. H. 1991b, ApJ, 381, 268
Lubow, S. H. 1992, ApJ, 401, 317
Marsh, T. R. 1999, MNRAS, 304, 443
Marsh, T. R., & Horne, K. 1988, MNRAS, 235, 269
Martin, D. C., et al. 2005, ApJ, 619, L1
Nelemans, G. 2005, in ASP Conf. Ser. 330, The Astrophysics of Cataclysmic Variables and Related Objects, ed. J.-M. Hameury, & J.-P. Lasota (San Francisco: ASP), p. 27
Nelemans, G., Portegies Zwart, S. F., Verbunt, F., & Yungelson, L. R. 2001, A&A, 368, 939
Nogami, D., Monard, B., Retter, A., Liu, A., Uemura, M., Ishioka, R., Imada, A., & Kato, T. 2004, PASJ, 56, L39
Osaki, Y. 1989, PASJ, 41, 1005
Osaki, Y., & Kato, T. 2013, PASJ, 65, 95
Osaki, Y., & Meyer, F. 2002, A&A, 383, 574
Osaki, Y., & Meyer, F. 2003, A&A, 401, 325
Patterson, J., Halpern, J., & Shambrook, A. 1993, ApJ, 419, 803
Patterson, J., et al. 2005, PASP, 117, 1204
Patterson, J., et al. 2002, PASP, 114, 721
Pearson, K. J. 2007, MNRAS, 379, 183
Pojmanski, G. 1986, Acta Astron., 36, 69
Pojmanski, G. 2002, Acta Astron., 52, 397
Pojmanski, G. 2004, arXiv Astrophysics e-prints
Ramsay, G., et al. 2018, A&A, 620, A141
Riello, M., et al. 2018, A&A, 616, A3
Roelofs, G. H. A., Groot, P. J., Marsh, T. R., Steeghs, D., Barros, S. C. C., & Nelemans, G. 2005, MNRAS, 361, 487
Roelofs, G. H. A., Groot, P. J., Marsh, T. R., Steeghs, D., & Nelemans, G. 2006a, MNRAS, 365, 1109
Roelofs, G. H. A., Groot, P. J., Nelemans, G., Marsh, T. R., & Steeghs, D. 2006b, MNRAS, 371, 1231
Savonije, G. J., de Kool, M., & van den Heuvel, E. P. J. 1986, A&A, 155, 51
Shappee, B. J., et al. 2014, ApJ, 788, 48
Solheim, J.-E. 2010, PASP, 122, 1133
Stehle, R., Kolb, U., & Ritter, H. 1997, A&A, 320, 136
Tsurugawa, M., & Osaki, Y. 1997, PASJ, 49, 75
Warner, B. 1995, Ap&SS, 225, 249
Warner, B. 2015, Mem. Soc. Astron. Ital., 86, 129
Whitehurst, R. 1988, MNRAS, 232, 35
Zapolsky, H. S., & Salpeter, E. E. 1969, ApJ, 158, 809
Fig. E1. Enlarged light curve of the 2015 outburst. The object showed multiple rebrightenings and "short rebrightenings". Circles and triangles represent our observations and the ASAS-SN $V$-band data, respectively. The date is defined to be $\text{BJD} - 2457346.751$. 
"V"-shapes represent the ASAS-3 data and its rough upper limits of V = 14, respectively. The blue crosses and yellow "V"-shapes represent ASAS-SN V-band data and its upper limits, respectively. The object has shown four major outbursts on BJD 2452929.74 (in 2003), 2453669.80 (in 2005), BJD 2457339.62 (in 2015) and BJD 2457987.27 (in 2017).
Table E1. Log of observations of NSV 1440 in 2015

| Start  * | End  * | Mag† | σ_Mag ‡ | N§ | Obs∥ |
|---------|-------|------|----------|----|------|
| 0.8898  | 1.0540 | 12.998 | 0.002 | 65 | HaC |
| 1.8870  | 2.0904 | 13.137 | 0.002 | 85 | HaC |
| 2.5267  | 2.7838 | 0.372  | 0.001 | 733 | MLF |
| 2.8842  | 3.0924 | 13.248 | 0.003 | 87 | HaC |
| 3.3320  | 3.4302 | 13.398 | 0.001 | 100 | SPET |
| 3.5174  | 3.6244 | 0.500  | 0.001 | 309 | MLF |
| 3.8813  | 4.0827 | 13.376 | 0.002 | 84  | HaC |
| 4.2724  | 4.3770 | 13.487 | 0.001 | 100 | SPET |
| 4.5354  | 4.7701 | 0.674  | 0.002 | 676 | MLF |
| 4.8785  | 5.0849 | 14.267 | 0.019 | 86  | HaC |
| 5.2262  | 5.3156 | 14.804 | 0.010 | 100 | COO |
| 5.2483  | 5.4314 | 15.262 | 0.012 | 154 | SPET |
| 5.8758  | 6.0843 | 13.685 | 0.048 | 86  | HaC |
| 6.8731  | 7.0832 | 16.084 | 0.022 | 70  | HaC |
| 7.5648  | 7.8429 | 0.836  | 0.005 | 802 | MLF |
| 7.8704  | 8.0834 | 13.465 | 0.004 | 115 | HaC |
| 8.5238  | 8.7154 | 0.604  | 0.002 | 552 | MLF |
| 8.8675  | 9.0839 | 13.481 | 0.004 | 118 | HaC |
| 10.0357 | 10.0840 | 13.665 | 0.005 | 29  | HaC |
| 10.5446 | 10.8418 | 0.916  | 0.001 | 855 | MLF |
| 11.8599 | 12.0832 | 13.959 | 0.003 | 120 | HaC |
| 12.2777 | 12.2777 | 14.153 | –     | 1   | SPET |
| 12.8571 | 13.0825 | 15.720 | 0.012 | 123 | HaC |
| 13.2295 | 13.3184 | 15.920 | 0.008 | 98  | COO |
| 13.5190 | 13.6784 | 3.160  | 0.005 | 401 | MLF |
| 13.8544 | 14.0833 | 16.084 | 0.008 | 125 | HaC |
| 14.1800 | 14.4771 | 16.225 | 0.003 | 315 | MGW |
| 14.2019 | 14.2837 | 16.082 | 0.006 | 93  | COO |
| 14.5276 | 14.7287 | 3.369  | 0.003 | 576 | MLF |
| 14.8515 | 15.0831 | 16.340 | 0.006 | 174 | HaC |
| 15.1737 | 15.4781 | 16.321 | 0.003 | 322 | MGW |
| 15.5221 | 15.6718 | 3.353  | 0.005 | 361 | MLF |
| 15.8489 | 16.0828 | 16.209 | 0.004 | 156 | HaC |
| 16.1631 | 16.4782 | 16.200 | 0.003 | 346 | MGW |
| 16.6098 | 16.8054 | 3.266  | 0.003 | 561 | MLF |
| 16.8461 | 17.0470 | 16.063 | 0.005 | 133 | HaC |
| 17.7688 | 17.8459 | 1.422  | 0.003 | 222 | MLF |

*BJD−2457346.751 (same as figure 1, 3 and E1
†Mean magnitude. All observations are no filter (clear).
‡Standard deviation of the observed magnitude.
§Number of observations.
∥Observer’s code: HaC(F.-J. Hambsch), MLF (B. Monard), MGW(G. Myers), SPET(P. Starr), COO(L. M. Cook)
Table E1. Log of observations of NSV 1440 in 2015 (continued)

| Start  | End   | Mag  | $\sigma_{\text{Mag}}$ | N$^8$ | Obs$^\dagger$ |
|--------|-------|------|----------------------|------|----------------|
| 17.8433 | 18.0439 | 14.546 | 0.011 | 122 | HaC |
| 18.8405 | 19.0404 | 16.448 | 0.009 | 124 | HaC |
| 19.8378 | 20.0388 | 16.529 | 0.007 | 125 | HaC |
| 20.2918 | 20.4782 | 16.484 | 0.003 | 214 | MGW |
| 20.5318 | 20.8392 | 3.514 | 0.002 | 878 | MLF |
| 20.8350 | 21.0360 | 16.455 | 0.006 | 125 | HaC |
| 21.8322 | 22.0319 | 16.607 | 0.007 | 120 | HaC |
| 22.2789 | 22.4782 | 16.564 | 0.004 | 244 | MGW |
| 22.8294 | 22.8473 | 16.599 | 0.026 | 9 | HaC |
| 23.2991 | 23.4568 | 16.440 | 0.003 | 164 | MGW |
| 23.8266 | 24.0277 | 16.414 | 0.009 | 123 | HaC |
| 24.2995 | 24.3904 | 16.324 | 0.004 | 115 | MGW |
| 24.5284 | 24.8259 | 2.061 | 0.025 | 827 | MLF |
| 24.8239 | 25.0247 | 14.368 | 0.009 | 123 | HaC |
| 25.5257 | 25.913 | 2.859 | 0.009 | 58 | MLF |
| 25.8211 | 26.0214 | 16.509 | 0.010 | 123 | HaC |
| 26.8183 | 27.0186 | 16.695 | 0.010 | 119 | HaC |
| 27.2992 | 27.4784 | 16.670 | 0.004 | 213 | MGW |
| 27.5710 | 27.8199 | 3.752 | 0.005 | 353 | MLF |
| 27.9891 | 28.0160 | 16.590 | 0.020 | 19 | HaC |
| 28.3005 | 28.4782 | 16.547 | 0.005 | 106 | MGW |
| 28.5371 | 28.8419 | 3.069 | 0.009 | 431 | MLF |
| 28.8133 | 29.0129 | 16.356 | 0.010 | 121 | HaC |
| 29.3037 | 29.4775 | 16.473 | 0.005 | 175 | MGW |
| 29.8105 | 30.0106 | 16.594 | 0.016 | 121 | HaC |
| 30.2989 | 30.4215 | 16.606 | 0.005 | 119 | MGW |
| 30.8084 | 31.0071 | 16.548 | 0.017 | 74 | HaC |
| 31.8051 | 32.0047 | 15.364 | 0.067 | 86 | HaC |
| 32.5268 | 32.8433 | 2.488 | 0.007 | 907 | MLF |
| 32.8383 | 33.0023 | 15.943 | 0.016 | 75 | HaC |
| 33.2758 | 33.3766 | 16.825 | 0.082 | 2 | SPET |
| 33.5329 | 33.7819 | 3.851 | 0.006 | 352 | MLF |
| 35.2284 | 35.2284 | 16.701 | 1 | SPET |
| 35.4451 | 35.4665 | 16.591 | 0.036 | 25 | COO |
| 36.5335 | 36.8398 | 3.123 | 0.012 | 433 | MLF |
| 37.6134 | 37.8440 | 3.639 | 0.005 | 326 | MLF |
| 38.2401 | 38.4775 | 16.884 | 0.008 | 280 | MGW |
| 38.2818 | 38.2818 | 16.755 | 1 | SPET |
| 38.7856 | 38.9860 | 16.601 | 0.016 | 76 | HaC |
| 39.3522 | 39.3522 | 16.674 | 1 | SPET |
| 39.4124 | 39.4778 | 16.637 | 0.007 | 81 | MGW |
| 39.7829 | 39.9810 | 15.389 | 0.080 | 63 | HaC |
| 40.2406 | 40.4519 | 14.697 | 0.010 | 225 | MGW |
Table E1. Log of observations of NSV 1440 in 2015 (continued)

| Start  | End   | Mag  | $\sigma_{\text{Mag}}$ | N   | Obs |
|--------|-------|------|------------------------|----|-----|
| 40.4201 | 40.4201 | 14.942 | 0.003                  | 2  | SPET |
| 40.7802 | 40.9804 | 15.923 | 0.018                  | 62 | HaC |
| 41.2516 | 41.4007 | 16.733 | 0.005                  | 161| MGW |
| 41.7775 | 41.9782 | 16.769 | 0.019                  | 55 | HaC |
| 42.7766 | 42.9778 | 16.769 | 0.017                  | 55 | HaC |
| 44.7712 | 44.9718 | 16.754 | 0.014                  | 55 | HaC |
| 45.7628 | 45.9666 | 16.805 | 0.011                  | 79 | HaC |
| 46.7644 | 46.9652 | 16.800 | 0.010                  | 77 | HaC |
| 47.7702 | 47.9638 | 16.640 | 0.013                  | 53 | HaC |
| 48.2146 | 48.4468 | 15.436 | 0.003                  | 282| MGW |
| 49.7638 | 49.9580 | 16.770 | 0.018                  | 56 | HaC |
| 50.2256 | 50.4782 | 16.856 | 0.004                  | 193| MGW |
| 53.2775 | 53.4783 | 16.896 | 0.003                  | 225| MGW |
| 57.1948 | 57.3692 | 16.562 | 0.004                  | 219| MGW |
| 58.1977 | 58.4472 | 15.420 | 0.010                  | 287| MGW |
| 64.1787 | 64.3493 | 16.731 | 0.005                  | 210| MGW |
### Table E2. Log of observations of NSV 1440 in 2017

| Start  *  | End   *  | Mag  †  | $\sigma_{\text{Mag}}$ †  | N§  | Obs  †  |
|---------|---------|---------|-----------------|-----|---------|
| 5.7946  | 5.8998  | 14.274  | 0.009           | 44  | HaC     |
| 6.7918  | 6.8995  | 15.416  | 0.011           | 45  | HaC     |
| 7.7885  | 7.8979  | 13.302  | 0.003           | 82  | HaC     |
| 8.7857  | 8.8978  | 13.393  | 0.003           | 84  | HaC     |
| 9.5052  | 9.6732  | 0.624   | 0.001           | 484 | MLF     |
| 9.7823  | 9.8979  | 13.538  | 0.003           | 103 | HaC     |
| 10.7800 | 10.8965 | 13.675  | 0.003           | 95  | HaC     |
| 11.3870 | 11.6694 | 0.918   | 0.001           | 807 | MLF     |
| 11.7772 | 11.8962 | 13.828  | 0.002           | 97  | HaC     |
| 12.7744 | 12.9023 | 14.108  | 0.007           | 105 | HaC     |
| 13.7716 | 13.9018 | 15.973  | 0.010           | 105 | HaC     |
| 14.7689 | 14.9003 | 16.184  | 0.010           | 98  | HaC     |
| 15.7663 | 15.9000 | 16.249  | 0.008           | 86  | HaC     |
| 16.7636 | 16.8988 | 16.222  | 0.007           | 87  | HaC     |
| 17.7608 | 17.8988 | 14.229  | 0.005           | 89  | HaC     |
| 19.7553 | 19.8975 | 16.566  | 0.013           | 92  | HaC     |
| 20.7246 | 20.8958 | 16.400  | 0.022           | 76  | HaC     |
| 21.7218 | 21.8959 | 16.457  | 0.012           | 77  | HaC     |
| 25.3862 | 25.6586 | 2.588   | 0.007           | 758 | MLF     |
| 25.7684 | 25.8820 | 16.065  | 0.012           | 64  | HaC     |
| 26.7656 | 26.8219 | 16.670  | 0.033           | 28  | HaC     |
| 28.7600 | 28.8910 | 16.515  | 0.009           | 77  | HaC     |
| 29.7573 | 29.8910 | 16.488  | 0.008           | 78  | HaC     |
| 32.9011 | 32.9018 | 15.777  | 0.176           | 2   | HaC     |
| 33.9004 | 33.9011 | 16.713  | 0.121           | 2   | HaC     |
| 34.8998 | 34.9006 | 16.710  | 0.049           | 2   | HaC     |
| 35.8990 | 35.8997 | 16.585  | 0.047           | 2   | HaC     |
| 36.8983 | 36.8991 | 16.733  | 0.199           | 2   | HaC     |
| 37.8976 | 37.8976 | 16.551  | –               | 1   | HaC     |
| 38.8970 | 38.8970 | 16.670  | –               | 1   | HaC     |
| 39.8944 | 39.8952 | 14.891  | 0.006           | 2   | HaC     |
| 40.8903 | 40.8910 | 15.913  | 0.046           | 2   | HaC     |
| 41.3925 | 41.5975 | 3.957   | 0.005           | 510 | MLF     |
| 41.8896 | 41.8903 | 16.777  | 0.171           | 2   | HaC     |
| 42.8889 | 42.8897 | 16.868  | 0.182           | 2   | HaC     |
| 43.8882 | 43.8889 | 16.759  | 0.015           | 2   | HaC     |
| 44.8875 | 44.8882 | 16.665  | 0.011           | 2   | HaC     |

* BJD − 2457982.000 (same as figure 1 and 3
† Mean magnitude. All observations are no filter (clear).
‡ Standard deviation of the observed magnitude.
§ Number of observations.
¶ Observer’s code: HaC(F.-J. Hambsch), MLF (B. Monard), MGW(G. Myers), SPET(P. Starr), COO(L. M. Cook)
Table E2. Log of observations of NSV 1440 in 2017 (continued)

| Start *  | End *  | Mag † | σ Mag ‡ | N§ | Obs∥ |
|----------|--------|-------|--------|----|------|
| 45.8868  | 45.8875| 16.726| 0.051  | 2  | HaC  |
| 46.8861  | 46.8869| 16.815| 0.023  | 2  | HaC  |
| 47.8854  | 47.8862| 16.697| 0.091  | 2  | HaC  |
| 48.8847  | 48.8855| 15.685| 0.068  | 2  | HaC  |
| 49.8840  | 49.8848| 15.976| 0.090  | 2  | HaC  |
| 50.8833  | 50.8841| 16.489| 0.012  | 2  | HaC  |
| 51.8826  | 51.8834| 16.604| 0.210  | 2  | HaC  |
| 52.8820  | 52.8827| 16.841| 0.125  | 2  | HaC  |
| 53.8812  | 53.8820| 16.546| 0.009  | 2  | HaC  |
| 54.8805  | 54.8813| 16.529| 0.086  | 2  | HaC  |
| 55.8799  | 55.8806| 16.531| 0.080  | 2  | HaC  |
| 56.8791  | 56.8799| 15.122| 0.008  | 2  | HaC  |
| 57.8793  | 57.8793| 17.926|  –     | 1  | HaC  |
| 58.8777  | 58.8785| 16.718| 0.190  | 2  | HaC  |
| 59.8771  | 59.8778| 16.812| 0.014  | 2  | HaC  |
| 60.8763  | 60.8771| 16.955| 0.163  | 2  | HaC  |
| 61.8757  | 61.8764| 16.825| 0.103  | 2  | HaC  |
| 62.8750  | 62.8757| 16.812| 0.166  | 2  | HaC  |
| 63.8743  | 63.8751| 16.824| 0.142  | 2  | HaC  |
| 64.8736  | 64.8743| 16.719| 0.020  | 2  | HaC  |
| 65.8728  | 65.8736| 16.655| 0.044  | 2  | HaC  |
| 66.8722  | 66.8730| 16.689| 0.090  | 2  | HaC  |
| 67.8715  | 67.8722| 14.906| 0.018  | 2  | HaC  |
| 68.8715  | 68.8722| 16.942| 0.140  | 2  | HaC  |
| 69.8708  | 69.8715| 16.970| 0.104  | 2  | HaC  |
| 70.8702  | 70.8709| 16.777| 0.082  | 2  | HaC  |
| 71.8694  | 71.8701| 17.052| 0.250  | 2  | HaC  |
| 72.8688  | 72.8695| 16.920| 0.139  | 2  | HaC  |
| 73.8680  | 73.8687| 16.940| 0.040  | 2  | HaC  |
| 74.8681  | 74.8688| 17.016| 0.088  | 2  | HaC  |
| 75.8674  | 75.8681| 16.809| 0.164  | 2  | HaC  |
| 76.8667  | 76.8674| 16.901| 0.113  | 2  | HaC  |
| 77.8659  | 77.8667| 16.988| 0.088  | 2  | HaC  |
| 78.8660  | 78.8667| 17.099| 0.495  | 2  | HaC  |
| 79.8653  | 79.8660| 15.047| 0.037  | 2  | HaC  |
| 80.8646  | 80.8653| 16.910| 0.030  | 2  | HaC  |
| 81.8639  | 81.8646| 16.958| 0.251  | 2  | HaC  |
| 82.6613  | 82.6621| 16.957| 0.113  | 2  | HaC  |
| 83.6586  | 83.6593| 16.945| 0.020  | 2  | HaC  |
| 84.6558  | 84.6566| 17.101| 0.173  | 2  | HaC  |
| 85.3592  | 85.4434| 4.394 | 0.011  | 193| MLF |
| 85.6530  | 85.6537| 17.335| 0.180  | 2  | HaC  |
| 86.6502  | 86.6509| 17.080| 0.033  | 2  | HaC  |
Table E2. Log of observations of NSV 1440 in 2017 (continued)

| Start  | End    | Mag   | \(\sigma_{\text{Mag}}\) | \(N\) | Obs  |
|--------|--------|-------|--------------------------|------|------|
| 87.6475 | 87.6482 | 17.247 | 0.049 | 2 | HaC |
| 88.6447 | 88.6454 | 17.172 | 0.326 | 2 | HaC |
| 89.6419 | 89.6426 | 17.245 | 0.222 | 2 | HaC |
| 90.6391 | 90.6398 | 17.017 | 0.034 | 2 | HaC |
| 91.6363 | 91.6371 | 17.209 | 0.118 | 2 | HaC |
| 92.6336 | 92.6343 | 17.052 | 0.060 | 2 | HaC |
| 93.6307 | 93.6314 | 17.212 | 0.247 | 2 | HaC |
| 94.6279 | 94.6287 | 17.276 | 0.096 | 2 | HaC |
| 95.6252 | 95.6259 | 17.181 | 0.044 | 2 | HaC |
| 96.6224 | 96.6231 | 17.173 | 0.156 | 2 | HaC |
| 97.6197 | 97.6204 | 17.237 | 0.164 | 2 | HaC |
| 98.6169 | 98.6176 | 17.326 | 0.055 | 2 | HaC |
| 99.6142 | 99.6149 | 17.835 | 0.132 | 2 | HaC |
| 100.6120 | 100.6128 | 17.216 | 0.039 | 2 | HaC |
| 101.6093 | 101.6100 | 17.221 | 0.070 | 2 | HaC |
| 102.6065 | 102.6072 | 17.676 | 0.175 | 2 | HaC |
| 103.6037 | 103.6044 | 17.229 | 0.058 | 2 | HaC |
| 104.6008 | 104.6016 | 17.435 | 0.461 | 2 | HaC |
| 105.5981 | 105.5988 | 17.258 | 0.250 | 2 | HaC |
| 106.5953 | 106.5960 | 17.167 | 0.210 | 2 | HaC |
| 107.5926 | 107.5933 | 17.446 | 0.021 | 2 | HaC |
| 108.5899 | 108.5906 | 17.193 | 0.002 | 2 | HaC |
| 109.5870 | 109.5877 | 16.945 | 0.241 | 2 | HaC |
| 111.5815 | 111.5822 | 17.725 | 0.234 | 2 | HaC |
| 113.5759 | 113.5767 | 17.968 | 0.194 | 2 | HaC |
| 114.5732 | 114.5739 | 18.137 | 0.137 | 2 | HaC |
| 115.5704 | 115.5711 | 17.611 | 0.060 | 2 | HaC |
| 116.5676 | 116.5684 | 18.074 | 0.186 | 2 | HaC |
| 117.5648 | 117.5655 | 17.839 | 0.136 | 2 | HaC |
| 118.5620 | 118.5628 | 18.186 | 0.224 | 2 | HaC |
| 119.5592 | 119.5600 | 18.203 | 0.189 | 2 | HaC |
| 120.5565 | 120.5572 | 18.481 | 0.097 | 2 | HaC |
| 121.5538 | 121.5545 | 18.453 | 0.254 | 2 | HaC |
| 122.5516 | 122.5524 | 18.795 | 0.265 | 2 | HaC |
| 125.5578 | 125.5586 | 18.803 | 0.426 | 2 | HaC |
| 126.5558 | 126.5565 | 18.530 | 0.096 | 2 | HaC |
| 127.5537 | 127.5537 | 18.328 | – | 1 | HaC |
| 128.5503 | 128.5510 | 18.204 | 0.139 | 2 | HaC |
| 131.5410 | 131.5410 | 18.045 | – | 1 | HaC |
| 133.5347 | 133.5347 | 18.407 | – | 1 | HaC |
| 137.5244 | 137.5244 | 17.673 | – | 1 | HaC |
| 142.5126 | 142.5126 | 18.037 | – | 1 | HaC |
Table E3. Timings of superhump maxima of NSV 1440 in 2015.

| E  | Maximum time | Error  | O − C† | N‡ |
|----|--------------|--------|--------|----|
| 0  | 7.03553      | 0.00068| -0.00798| 7  |
| 1  | 7.05998      | 0.00058| -0.00890| 7  |
| 21 | 7.57272      | 0.00061| -0.00330| 47 |
| 24 | 7.65045      | 0.00051| -0.00164| 60 |
| 25 | 7.67702      | 0.00050| -0.00044| 58 |
| 26 | 7.70118      | 0.00061| -0.00162| 58 |
| 27 | 7.72639      | 0.00042| -0.00178| 58 |
| 28 | 7.75210      | 0.00053| -0.00143| 59 |
| 29 | 7.78111      | 0.00097| 0.00223 | 58 |
| 30 | 7.80405      | 0.00046| -0.00019| 58 |
| 31 | 7.82826      | 0.00049| -0.00134| 59 |
| 38 | 8.00756      | 0.00106| 0.00046 | 12 |
| 59 | 8.54141      | 0.00019| 0.00180 | 58 |
| 60 | 8.56712      | 0.00016| 0.00215 | 58 |
| 61 | 8.59260      | 0.00018| 0.00227 | 58 |
| 62 | 8.61800      | 0.00022| 0.00232 | 59 |
| 63 | 8.64317      | 0.00019| 0.00214 | 59 |
| 64 | 8.66806      | 0.00021| 0.00166 | 58 |
| 65 | 8.69376      | 0.00019| 0.00201 | 58 |
| 73 | 8.89717      | 0.00082| 0.00255 | 12 |
| 76 | 8.97323      | 0.00037| 0.00254 | 11 |
| 79 | 9.04841      | 0.00064| 0.00165 | 11 |
| 139| 10.57123     | 0.00039| 0.00302 | 59 |
| 140| 10.59640     | 0.00034| 0.00283 | 59 |
| 141| 10.62099     | 0.00035| 0.00207 | 58 |
| 142| 10.64665     | 0.00024| 0.00237 | 59 |
| 143| 10.67219     | 0.00029| 0.00255 | 59 |
| 144| 10.69760     | 0.00021| 0.00260 | 58 |
| 145| 10.72232     | 0.00047| 0.00196 | 59 |
| 146| 10.74784     | 0.00035| 0.00212 | 59 |
| 147| 10.77259     | 0.00035| 0.00152 | 59 |
| 148| 10.79878     | 0.00035| 0.00235 | 58 |
| 149| 10.82362     | 0.00035| 0.00183 | 59 |
| 191| 11.88719     | 0.00078| 0.00038 | 12 |
| 192| 11.91419     | 0.00091| 0.00202 | 10 |
| 193| 11.93871     | 0.00061| 0.00119 | 10 |
| 194| 11.96480     | 0.00038| 0.00193 | 12 |
| 195| 11.98758     | 0.00089| -0.00066| 11 |
| 196| 12.01453     | 0.00089| 0.00093 | 12 |
| 197| 12.04180     | 0.00066| 0.00285 | 11 |
| 230| 12.88009     | 0.00088| 0.00434 | 9  |

*BJD−2457346.751 (same as figure 1 and 3).
†C = 2457353.794513 + 0.02535754750E.
‡Number of points used to determine the maximum.
Table E3. Timings of superhump maxima of NSV 1440 in 2015 (continued).

| E  | Maximum time* | Error  | O − C† | N‡ |
|----|---------------|--------|--------|----|
| 232| 12.92823      | 0.00084| 0.00176| 10 |
| 233| 12.95554      | 0.00054| 0.00371| 12 |
| 234| 12.98005      | 0.00064| 0.00287| 12 |
| 235| 13.00527      | 0.00053| 0.00274| 11 |
| 236| 13.03049      | 0.00094| 0.00260| 11 |
| 237| 13.05637      | 0.00049| 0.00312| 12 |
| 244| 13.23305      | 0.00053| 0.00230| 20 |
| 245| 13.25899      | 0.00040| 0.00288| 23 |
| 246| 13.28529      | 0.00100| 0.00382| 21 |
| 247| 13.30968      | 0.00105| 0.00285| 18 |
| 256| 13.53975      | 0.00047| 0.00470| 54 |
| 257| 13.56191      | 0.00041| 0.00151| 49 |
| 259| 13.60964      | 0.00101| -0.00148| 59 |
| 261| 13.66484      | 0.00060| 0.00301| 54 |
| 283| 14.21677      | 0.00040| -0.00293| 47 |
| 284| 14.24298      | 0.00040| -0.00208| 48 |
| 287| 14.31922      | 0.00309| -0.00191| 25 |
| 288| 14.34528      | 0.00112| -0.00121| 24 |
| 289| 14.37048      | 0.00112| -0.00137| 24 |
| 290| 14.39580      | 0.00122| -0.00140| 24 |
| 292| 14.44656      | 0.00078| -0.00136| 24 |
| 293| 14.47320      | 0.00098| -0.00007| 19 |
| 296| 14.54730      | 0.00130| -0.00205| 59 |
| 297| 14.57497      | 0.00094| 0.00026| 56 |
| 298| 14.59405      | 0.00087| -0.00601| 59 |
| 299| 14.61735      | 0.00086| -0.00807| 58 |
| 300| 14.64042      | 0.00641| -0.01036| 58 |
| 301| 14.67064      | 0.00067| -0.00550| 58 |
| 302| 14.70126      | 0.00134| -0.00024| 59 |
| 322| 15.20068      | 0.00060| -0.00796| 26 |
| 323| 15.22620      | 0.00109| -0.00780| 25 |
| 327| 15.32919      | 0.00099| -0.00624| 25 |
| 328| 15.35461      | 0.00168| -0.00618| 25 |
| 329| 15.37861      | 0.00232| -0.00754| 25 |
| 331| 15.43101      | 0.00057| -0.00585| 26 |
| 332| 15.45570      | 0.00080| -0.00652| 25 |
| 336| 15.55663      | 0.00082| -0.00702| 41 |
| 337| 15.58332      | 0.00096| -0.00569| 45 |
| 338| 15.60673      | 0.00106| -0.00763| 58 |
| 339| 15.63103      | 0.00064| -0.00869| 49 |
| 340| 15.65951      | 0.00096| -0.00557| 55 |
| 349| 15.88843      | 0.00106| -0.00487| 15 |
| 353| 15.98966      | 0.00082| -0.00507| 15 |
| 354| 16.01330      | 0.00078| -0.00679| 14 |
| $E$ | Maximum time $^c$ | Error  | $O - C^†$ | $N^‡$ |
|-----|------------------|--------|-----------|-------|
| 355 | 16.03913         | 0.00089| -0.00632  | 14    |
| 356 | 16.06652         | 0.00088| -0.00428  | 14    |
| 361 | 16.19323         | 0.00044| -0.00436  | 25    |
| 362 | 16.21864         | 0.00048| -0.00431  | 26    |
| 363 | 16.24375         | 0.00094| -0.00456  | 26    |
| 366 | 16.31962         | 0.00046| -0.00476  | 25    |
| 367 | 16.34620         | 0.00076| -0.00353  | 25    |
| 368 | 16.37098         | 0.00040| -0.00411  | 26    |
| 369 | 16.39607         | 0.00052| -0.00438  | 26    |
| 370 | 16.42090         | 0.00071| -0.00490  | 25    |
| 371 | 16.44703         | 0.00035| -0.00413  | 26    |
| 378 | 16.62417         | 0.00077| -0.00449  | 58    |
| 379 | 16.64643         | 0.00125| -0.00759  | 58    |
| 380 | 16.67116         | 0.00078| -0.00822  | 58    |
| 381 | 16.70058         | 0.00114| -0.00416  | 58    |
| 382 | 16.72708         | 0.00097| -0.00302  | 58    |
| 383 | 16.75134         | 0.00095| -0.00412  | 58    |
| 384 | 16.77798         | 0.00051| -0.00283  | 58    |
| 389 | 16.90430         | 0.00076| -0.00330  | 14    |
| 392 | 16.98097         | 0.00169| -0.00270  | 14    |
| 394 | 17.02965         | 0.00103| -0.00474  | 15    |
| 523 | 20.30808         | 0.00082| 0.00257   | 26    |
| 524 | 20.33344         | 0.00104| 0.00257   | 26    |
| 525 | 20.35825         | 0.00087| 0.00202   | 25    |
| 526 | 20.38164         | 0.00092| 0.00006   | 25    |
| 527 | 20.40691         | 0.00044| -0.00003  | 22    |
| 529 | 20.45956         | 0.00119| 0.00191   | 26    |
| 546 | 20.89078         | 0.00057| 0.00204   | 11    |
| 547 | 20.91461         | 0.00091| 0.00051   | 13    |
| 601 | 22.29049         | 0.00048| 0.00709   | 25    |
| 602 | 22.31738         | 0.00080| 0.00863   | 25    |
| 603 | 22.34062         | 0.00081| 0.00651   | 25    |
| 604 | 22.36770         | 0.00087| 0.00823   | 25    |
| 605 | 22.39283         | 0.00070| 0.00800   | 24    |
| 606 | 22.41751         | 0.00112| 0.00732   | 24    |
| 607 | 22.44401         | 0.00062| 0.00846   | 25    |
| 608 | 22.46759         | 0.00054| 0.00669   | 23    |
| 641 | 23.30594         | 0.00051| 0.00824   | 25    |
| 642 | 23.33218         | 0.00040| 0.00912   | 26    |
| 643 | 23.35865         | 0.00042| 0.01023   | 26    |
| 662 | 23.83888         | 0.00099| 0.00867   | 7     |
| 664 | 23.88559         | 0.00052| 0.00467   | 12    |
| 681 | 24.32273         | 0.00052| 0.01072   | 26    |
| 682 | 24.34793         | 0.00048| 0.01057   | 25    |
| $E$  | Maximum time | Error  | $O - C$ | $N$ |
|------|--------------|--------|---------|-----|
| 683  | 24.37235     | 0.00059 | 0.00963 | 25  |
| 799  | 27.32055     | 0.00052 | 0.01636 | 24  |
| 800  | 27.34656     | 0.00066 | 0.01701 | 24  |
| 801  | 27.37153     | 0.00043 | 0.01662 | 24  |
| 802  | 27.39701     | 0.00036 | 0.01674 | 24  |
| 803  | 27.42265     | 0.00041 | 0.01703 | 24  |
| 804  | 27.44837     | 0.00063 | 0.01738 | 23  |
| 805  | 27.47338     | 0.00069 | 0.01704 | 17  |
| 810  | 27.60095     | 0.00064 | 0.01782 | 29  |
| 811  | 27.62675     | 0.00085 | 0.01827 | 28  |
| 812  | 27.65198     | 0.00087 | 0.01814 | 29  |
| 813  | 27.67551     | 0.00065 | 0.01631 | 29  |
| 814  | 27.70230     | 0.00078 | 0.01774 | 29  |
| 815  | 27.72874     | 0.00110 | 0.01882 | 29  |
| 817  | 27.78457     | 0.00207 | 0.02394 | 29  |
| 818  | 27.80378     | 0.00056 | 0.01780 | 29  |
| 838  | 28.31031     | 0.00074 | 0.01717 | 22  |
| 843  | 28.43813     | 0.00058 | 0.01820 | 21  |
| 844  | 28.46245     | 0.00066 | 0.01716 | 22  |
| 855  | 28.73965     | 0.00085 | 0.01543 | 29  |
| 856  | 28.76774     | 0.00065 | 0.01816 | 29  |
| 857  | 28.79029     | 0.00120 | 0.01536 | 28  |
| 858  | 28.82008     | 0.00267 | 0.01979 | 35  |
| 878  | 29.32823     | 0.00090 | 0.02079 | 21  |
| 879  | 29.35354     | 0.00075 | 0.02074 | 21  |
| 880  | 29.37978     | 0.00061 | 0.02162 | 20  |
| 881  | 29.40311     | 0.00028 | 0.01960 | 21  |
| 882  | 29.42966     | 0.00076 | 0.02079 | 20  |
| 883  | 29.45506     | 0.00086 | 0.02083 | 19  |
| 898  | 29.83663     | 0.00365 | 0.02204 | 9   |
| 900  | 29.88182     | 0.00122 | 0.01651 | 12  |
| 902  | 29.93984     | 0.00141 | 0.02382 | 13  |
| 904  | 29.98983     | 0.00081 | 0.02310 | 13  |
| 917  | 30.31616     | 0.00072 | 0.01977 | 25  |
| 918  | 30.34502     | 0.00052 | 0.02328 | 25  |
| 919  | 30.36800     | 0.00051 | 0.02090 | 23  |
| 1006 | 32.57241     | 0.00047 | 0.01920 | 59  |
| 1007 | 32.59711     | 0.00076 | 0.01855 | 58  |
| 1008 | 32.62250     | 0.00069 | 0.01858 | 58  |
| 1009 | 32.65006     | 0.00115 | 0.02078 | 58  |
| 1010 | 32.67470     | 0.00085 | 0.02006 | 58  |
| 1011 | 32.70033     | 0.00052 | 0.02033 | 59  |
| 1012 | 32.72316     | 0.00106 | 0.01781 | 59  |
| 1013 | 32.74884     | 0.00058 | 0.01813 | 58  |
Table E3. Timings of superhump maxima of NSV 1440 in 2015 (continued).

| E  | Maximum time (s) | Error (s) | O − C (s) | N† |
|----|-----------------|-----------|-----------|----|
| 1014 | 32.77472        | 0.00089   | 0.01865   | 58 |
| 1015 | 32.80402        | 0.00089   | 0.02260   | 58 |
| 1016 | 32.82728        | 0.00088   | 0.02050   | 58 |
| 1162 | 36.54211        | 0.00108   | 0.03313   | 28 |
| 1163 | 36.56420        | 0.00149   | 0.02985   | 28 |
| 1164 | 36.59776        | 0.00303   | 0.03806   | 29 |
| 1165 | 36.61692        | 0.00094   | 0.03186   | 28 |
| 1166 | 36.63856        | 0.00146   | 0.02814   | 28 |
| 1167 | 36.66798        | 0.00182   | 0.03220   | 27 |
| 1168 | 36.68965        | 0.00060   | 0.02852   | 29 |
| 1169 | 36.71854        | 0.00090   | 0.03206   | 29 |
| 1170 | 36.74117        | 0.00090   | 0.02933   | 29 |
| 1205 | 37.63432        | 0.00070   | 0.03496   | 29 |
| 1206 | 37.65766        | 0.00085   | 0.03295   | 29 |
| 1207 | 37.68302        | 0.00108   | 0.03295   | 29 |
| 1208 | 37.70748        | 0.00031   | 0.03205   | 28 |
| 1209 | 37.73136        | 0.00199   | 0.03057   | 29 |
| 1210 | 37.75901        | 0.00093   | 0.03287   | 28 |
| 1211 | 37.78580        | 0.00176   | 0.03429   | 29 |
| 1212 | 37.81117        | 0.00129   | 0.03431   | 28 |
| 1213 | 37.83164        | 0.00124   | 0.02942   | 27 |
| 1236 | 38.41839        | 0.00139   | 0.03295   | 24 |
| 1237 | 38.44155        | 0.00092   | 0.03076   | 25 |
| 1238 | 38.46594        | 0.00271   | 0.02978   | 25 |
| 1309 | 40.26518        | 0.00105   | 0.02864   | 23 |
| 1311 | 40.31788        | 0.00129   | 0.03062   | 22 |
| 1312 | 40.34172        | 0.00192   | 0.02911   | 23 |
| 1315 | 40.42033        | 0.00103   | 0.03164   | 24 |
| 1348 | 41.25810        | 0.00064   | 0.03261   | 20 |
| 1349 | 41.28359        | 0.00076   | 0.03275   | 23 |
| 1350 | 41.31109        | 0.00149   | 0.03489   | 23 |
| 1351 | 41.33288        | 0.00085   | 0.03132   | 22 |
| 1352 | 41.36051        | 0.00101   | 0.03360   | 23 |
| 1353 | 41.38411        | 0.00060   | 0.03184   | 17 |
| 1526 | 45.77633        | 0.00303   | 0.03720   | 13 |
| 1625 | 48.29053        | 0.00140   | 0.04100   | 26 |
| 1626 | 48.31561        | 0.00139   | 0.04072   | 27 |
| 1627 | 48.34478        | 0.00124   | 0.04454   | 25 |
| 1823 | 53.32038        | 0.00067   | 0.05006   | 25 |
| 1824 | 53.34916        | 0.00064   | 0.05348   | 26 |
| 1828 | 53.44638        | 0.00080   | 0.04927   | 25 |
| 1978 | 57.24552        | 0.00083   | 0.04478   | 26 |
| 1979 | 57.27226        | 0.00265   | 0.04616   | 26 |
| 1980 | 57.29554        | 0.00070   | 0.04408   | 26 |
### Table E3. Timings of superhump maxima of NSV 1440 in 2015 (continued).

| Year | Maximum time | Error  | O – C | N  |
|------|--------------|--------|-------|----|
| 1981 | 57.32261     | 0.00171| 0.04580| 26 |
| 2016 | 58.21708     | 0.00049| 0.05275| 25 |
| 2017 | 58.24373     | 0.00136| 0.05404| 26 |
| 2018 | 58.26918     | 0.00102| 0.05414| 25 |
| 2019 | 58.29248     | 0.00037| 0.05207| 26 |
| 2020 | 58.31870     | 0.00034| 0.05294| 25 |
| 2021 | 58.34415     | 0.00047| 0.05303| 26 |
| 2022 | 58.36952     | 0.00042| 0.05305| 25 |
| 2023 | 58.39516     | 0.00059| 0.05333| 22 |
| 2251 | 64.18447     | 0.00064| 0.06112| 23 |
| 2252 | 64.20992     | 0.00117| 0.06121| 24 |
| 2255 | 64.28665     | 0.00140| 0.06187| 26 |
| 2256 | 64.31203     | 0.00118| 0.06189| 25 |
| 2257 | 64.33610     | 0.00119| 0.06060| 24 |
Table E4. Timings of superhump maxima of NSV 1440 in 2017.

| $E$ | Maximum time* | Error  | $O - C$† | N‡ |
|-----|----------------|--------|----------|-----|
| 30  | 7.79878        | 0.00067| -0.00532 | 16  |
| 31  | 7.82167        | 0.00071| -0.00778 | 15  |
| 32  | 7.84789        | 0.00070| -0.00693 | 15  |
| 33  | 7.87355        | 0.00048| -0.00662 | 15  |
| 34  | 7.89908        | 0.00098| -0.00645 | 9   |
| 70  | 8.81625        | 0.00050| -0.00215 | 15  |
| 71  | 8.84228        | 0.00070| -0.00148 | 15  |
| 72  | 8.86629        | 0.00098| -0.00283 | 15  |
| 73  | 8.89179        | 0.00044| -0.00268 | 15  |
| 98  | 9.52667        | 0.00029| -0.00174 | 58  |
| 99  | 9.55158        | 0.00026| -0.00219 | 58  |
| 100 | 9.57734        | 0.00032| -0.00179 | 58  |
| 101 | 9.60212        | 0.00025| -0.00237 | 58  |
| 102 | 9.62767        | 0.00023| -0.00217 | 58  |
| 103 | 9.65369        | 0.00027| -0.00151 | 58  |
| 109 | 9.80509        | 0.00118| -0.00226 | 17  |
| 110 | 9.83168        | 0.00108| -0.00103 | 18  |
| 111 | 9.85618        | 0.00080| -0.00189 | 18  |
| 112 | 9.88081        | 0.00048| -0.00261 | 17  |
| 149 | 10.82032       | 0.00119| -0.00133 | 17  |
| 150 | 10.84469       | 0.00049| -0.00231 | 16  |
| 151 | 10.87055       | 0.00044| -0.00181 | 15  |
| 172 | 11.40200       | 0.00034| -0.00288 | 58  |
| 173 | 11.42743       | 0.00038| -0.00280 | 56  |
| 174 | 11.45236       | 0.00034| -0.00323 | 59  |
| 175 | 11.47869       | 0.00048| -0.00226 | 57  |
| 176 | 11.50452       | 0.00029| -0.00178 | 58  |
| 177 | 11.52973       | 0.00052| -0.00193 | 58  |
| 178 | 11.55450       | 0.00048| -0.00252 | 59  |
| 179 | 11.57972       | 0.00034| -0.00265 | 57  |
| 180 | 11.60529       | 0.00038| -0.00244 | 58  |
| 181 | 11.63030       | 0.00030| -0.00278 | 58  |
| 182 | 11.65545       | 0.00047| -0.00300 | 57  |
| 187 | 11.78264       | 0.00052| -0.00260 | 15  |
| 188 | 11.80732       | 0.00054| -0.00327 | 18  |
| 189 | 11.83251       | 0.00052| -0.00344 | 15  |
| 190 | 11.86024       | 0.00121| -0.00106 | 16  |
| 191 | 11.88319       | 0.00112| -0.00347 | 15  |
| 227 | 12.79641       | 0.00056| -0.00313 | 19  |
| 228 | 12.82239       | 0.00036| -0.00250 | 16  |

*BJD−2457982.000 (same as figure 1 and 3).
†$C = 2457996.842150 + 0.02535754750E$.
‡Number of points used to determine the maximum.
Table E4. Timings of superhump maxima of NSV 1440 in 2017 (continued).

| $E$ | Maximum time $^*$ | Error | $O - C^{\dagger}$ | $N^{\ddagger}$ |
|-----|------------------|-------|-------------------|---------------|
| 229 | 12.84706         | 0.00050 | -0.00319          | 16            |
| 230 | 12.87103         | 0.00067 | -0.00458          | 16            |
| 231 | 12.89907         | 0.00047 | -0.00190          | 13            |
| 266 | 13.78420         | 0.00084 | -0.00428          | 19            |
| 267 | 13.81098         | 0.00090 | -0.00286          | 16            |
| 268 | 13.83904         | 0.00237 | -0.00015          | 15            |
| 269 | 13.86463         | 0.00101 | 0.00008           | 16            |
| 270 | 13.88976         | 0.00113 | -0.00015          | 15            |
| 346 | 15.80863         | 0.00226 | -0.00846          | 12            |
| 347 | 15.83535         | 0.00155 | -0.00709          | 12            |
| 724 | 25.40132         | 0.00057 | -0.00092          | 59            |
| 725 | 25.42540         | 0.00069 | -0.00219          | 59            |
| 726 | 25.44882         | 0.00167 | -0.00413          | 57            |
| 727 | 25.47992         | 0.00157 | 0.00161           | 59            |
| 728 | 25.50450         | 0.00089 | 0.00083           | 58            |
| 729 | 25.52809         | 0.00099 | -0.00094          | 59            |
| 730 | 25.55569         | 0.00116 | 0.00130           | 58            |
| 731 | 25.58045         | 0.00084 | 0.00071           | 58            |
| 739 | 25.78447         | 0.00196 | 0.00187           | 10            |
| 740 | 25.80980         | 0.00653 | 0.00184           | 9             |
| 741 | 25.83844         | 0.00077 | 0.00513           | 12            |
| 857 | 28.78673         | 0.00060 | 0.01194           | 10            |
| 858 | 28.81273         | 0.00085 | 0.01258           | 10            |
| 859 | 28.83715         | 0.00485 | 0.01164           | 13            |
| 860 | 28.86360         | 0.00104 | 0.01274           | 14            |
| 897 | 29.80434         | 0.00150 | 0.01525           | 10            |
| 898 | 29.82538         | 0.00281 | 0.01093           | 13            |
| 899 | 29.85278         | 0.00144 | 0.01297           | 13            |