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A Year-long Superoutburst from an Ultracompact White Dwarf Binary Reveals the Importance of Donor Star Irradiation

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Abstract

SDSS J080710+485259 is the longest-period outbursting ultracompact white dwarf binary. Its first-ever detected superoutburst started in 2018 November and lasted for a year, the longest detected so far for any short orbital period accreting white dwarf. Here we show the superoutburst duration of SDSS J080710+485259 exceeds the ∼2 month viscous time of its accretion disk by a factor of about 5. Consequently it follows that neither the empirical relation nor the theoretical relation between the orbital period and the superoutburst duration for AM CVn systems. Six months after the end of the superoutburst the binary remained 0.4 mag brighter than its quiescent level before the superoutburst. We detect a variable X-ray behavior during the post-outburst cooling phase, demonstrating changes in the mass accretion rate. We discuss how irradiation of the donor star, a scenario poorly explored so far and that ultimately can have important consequences for AM CVns as gravitational-wave sources, might explain the unusual observed features of the superoutburst.

Unified Astronomy Thesaurus concepts: White dwarf stars (1799); Compact binary stars (283); Stellar accretion disks (1579); Dwarf novae (418); Hydrogen deficient stars (769); Common envelope binary stars (2156); Interacting binary stars (801); Cataclysmic variable stars (203); Transient detection (1957); Stellar accretion (1578); Gravitational wave sources (677); AM Canum Venaticorum stars (31)

1. Introduction

AM CVns are rare ultracompact binary systems in which white dwarfs (WDs) accrete matter from He-rich stars. They are characterized by short orbital periods ($P_{\rm orb}$) in the range ∼5–68 minutes (e.g., Ramsay et al. 2018; Green et al. 2020). SDSS J080710+485259 (hereafter SDSS 0807) was recently discovered (Kong et al. 2018) as a member of the AM CVns due to its lack of H and abundance of He in its spectrum. In 2018, SDSS 0807 brightened above its quiescent level of 20.8 mag in G and began its first detected superoutburst. It became bright enough to be observed by small ground-based telescopes and thus a periodic signal of 53.3 ± 0.3 minutes was identified (Kupfer et al. 2019). That modulation likely corresponds to the "superhump" period ($P_{\rm sh}$), which is observed during superoutbursts and represents a beat between the orbit and a much longer precession period. Since $P_{\rm sh}$ is typically a few percent longer than $P_{\rm orb}$, it can be used as a proxy in the absence of $P_{\rm orb}$. In fact, for many members of the AM CVn family, only $P_{\rm sh}$ has been determined because these binaries are too faint in quiescence (<20 mag) to be observed by small telescopes in short exposures (e.g., Ramsay et al. 2018). In this Letter we present analysis of the light curve of SDSS 0807 during superoutburst and discuss effects that might explain its peculiar observed characteristics.

2. Observations and Data Analysis

2.1. Optical Data

We used public optical observations of SDSS 0807 taken with the Zwicky Transient Facility (ZTF) in the g and r filters (Masci et al. 2019). Data were obtained from 2018 March 27 to 2019 December 29 with a gap from 2019 May 14 to 2019 August 28 due to the object's occultation. Public data obtained with the Gaia observatory (Gaia Collaboration et al. 2016, 2018) in the G filter were also used for the light -curve analysis. The first Gaia measurement corresponds to 2016 April 8, which together with data from 2017 and early 2018 helped to establish the full quiescent level. The last Gaia data point was obtained on 2020 June 1 during the post-outburst cooling phase. The ZTF data are calibrated to the AB magnitude system and only the observations flagged as good quality measurements were used for the analysis.

We looked for indications of outbursts or superoutbursts of SDSS 0807 in databases such as the Catalina Sky Survey and Pan-STARRS over the last 10 yr, and no indications of such an event were found. The monitoring cadence of these surveys was not short enough to provide a tight constraint on the existence of these events, but a long superoutburst as the one here presented likely did not occur. SDSS 0807 was not observed by ASAS-SN or DASCH.

2.2. X-Ray and UV Data

The X-ray (0.3–10 keV) and UV data analyzed in this Letter were taken with the Neil Gehrels Swift Observatory (Swift) on 2020 April 15 and 2020 May 28. A total of 3300 s was obtained in both observations, which corresponds to 1700 s and 1600 s, respectively. Data were reprocessed and analyzed following the standard reduction threads,[1] which make use of XSPEC v12.11.0 (Arnaud 1996). To determine the X-ray flux we have assumed an absorbed power-law model (TBabs*pegpwrlw) to fit the X-ray spectrum obtained on 2020 April 20. We set the value of the neutral H column ($N_{\rm H}$) to the Galactic value toward the binary's position ($N_{\rm H} = 3.89 \times 10^{20}$ cm^{-2}). Given the small number of counts, we used C-statistics for the fit.

Observations in the optical and UV were obtained with UVOT, and the corresponding magnitudes and exposure times

[1] https://www.swift.ac.uk/analysis/xrt/ and https://www.swift.ac.uk/analysis/uvot/.

Table 1
UVOT Magnitudes Taken with the Swift Observatory

Date	Filter	AB Mag	Exp. Time (s)
2020 Apr 15	*V*	>20.13	131
“”	*B*	19.60 ± 0.30	132
“”	*U*	20.48 ± 0.31	132
“”	*UVW*1	20.03 ± 0.18	262
“”	*UVW*2	20.52 ± 0.16	526
“”	*UVM*2	20.51 ± 0.19	436
2020 May 28	*U*	20.87 ± 0.32	634
“”	*UVW*1	20.37 ± 0.21	439
“”	*UVW*2	20.47 ± 0.18	439

per observation are given in Table 1. For the UVOT measurements we used a circular region with a radius of 5″ centered on R.A. = 08:07:10.33, decl. = +48:52:59.6. A circular region with radius 30″ and located in a star-free region of the image close to the target was used for the background subtraction. Given the coordinates of SDSS 0807 it is difficult or not possible to observe it with ground- or space-based telescopes from mid-May to late August. But a few data points using Swift and Gaia were obtained during the post-outburst cooling period.

2.3. Spectral Analysis

We analyze public Sloan Digital Sky Survey (SDSS) spectra of SDSS 0807 and, for comparison purposes, data from SDSS J141118.31+481257.6 (hereafter SDSS 1411). The latter is another long-period ($P_{\rm orb} = 46$ minutes) AM CVn system that was also recently identified in superoutburst for the first time, with an amplitude of ∼7 mag in optical (Rivera Sandoval & Maccarone 2019). A total of four and three spectra were analyzed for SDSS 0807 and SDSS 1411, respectively. For SDSS 0807 the data consist of two pairs of spectra taken sequentially and divided in two observations. The first one observed on 2014 October 3 and the second one on 2014 October 5. A total exposure time of 3600 s was obtained for that binary. For SDSS 1411, the observations consist of one exposure of 1000 s and two observations of 800 s each taken sequentially on 2005 March 17. All spectra cover the range 3800–9200 Å with a resolution of 1500 at 3800 Å (the blue channel) and 2500 at 9000 Å (the red channel). For each source, SDSS 0807 and SDSS 1411, the full width at half maximum (FWHM) values were obtained from Gaussian fits to individual 5875 Å He I profiles. Continuum-rectified spectra were fitted in a window of 200 Å, centered on that He I line (Appendix A).

3. Results and Discussion

3.1. The Superoutburst of SDSS 0807

In Figure 1 we show the combined light curve of SDSS 0807. Gaia data were used as reference for the superoutburst parameters given the smaller photometric errors. The superoutburst was considered to start on 2018 November 7 when Gaia measurements showed a brightness increase of ∼0.2 mag above the quiescent level. Previous Gaia measurements (not plotted in Figure 1) are scattered around the marked quiescent level. The peak value was given by the brightest Gaia measurements. The recording of several data points, which are

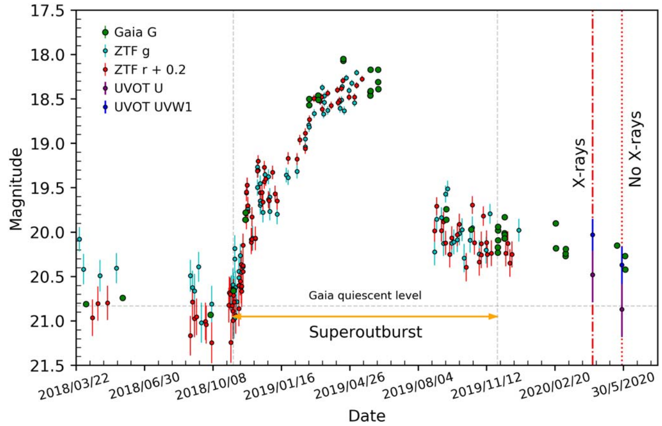

Figure 1. Light curve of SDSS 0807 with data from Gaia, ZTF, and Swift-UVOT. The average quiescent value is marked with a horizontal line. Additional Gaia points used to establish the quiescent level are not plotted. The duration of the superoutburst is indicated with an orange arrow. ZTF and UVOT magnitudes are given in the AB system. A constant to the magnitudes of ZTF-*r* has been added to match the quiescent level of the Gaia measurements. The detection ($10.1 \pm 2.7 \times 10^{-3}$ counts/s) and nondetection ($< 4.5 \times 10^{-3}$ counts/s) of X-rays in the 0.3–10 keV band are also marked with red vertical lines. Lack of data during the superoutburst is due to the binary's occultation.

consistent with each other, shows that the identified magnitude value was not due to systematics. The average magnitude of the several Gaia observations taken on 2019 November 28 was consistent with the one from observations on 2019 December 8 and thus defined the end of the superoutburst. Previous measurements were above that “stable level,” suggesting that the object's flux was still decreasing. To account for this uncertainty we have included a 10% error in the duration of the superoutburst (Figure 1). The event lasted ∼390 days, which is the longest accretion outburst ever observed for either an AM CVn or their cousins, the H-rich accreting WDs also known as cataclysmic variables (CVs). In fact, the long duration of the event excludes the possibility of a normal outburst (which lasts no more than a few days).

Superoutbursts in AM CVns are also characterized by amplitudes of several magnitudes. Indeed, for the period of SDSS 0807 an amplitude of ∼7 mag is expected (Levitan et al. 2015), which contrasts with the 2.7 mag observed (Figure 1). However, as in CVs with thick accretion disks and high inclinations where the luminosity can be reduced by 3.5 mag when observed at $i = 85°$ (Warner 1986, 1987), a similar situation is likely to have occurred in SDSS 0807. We measured the FWHM of the 5875 Å He I line that is prominent in AM CVns to estimate the radial velocity of the donor (K_2; see Appendix A for details on this calculation) and compared it to that of SDSS 1411. We found that SDSS 0807 has a larger average FWHM (and hence K_2) than SDSS 1411. Given its longer $P_{\rm orb}$, the broader He I line can only be explained if SDSS 0807 has a higher inclination angle, which, in turn, would explain the small observed amplitude of the superoutburst (Warner 1986, 1987). Note that the empirical relation between $P_{\rm orb}$ and the superoutburst amplitude found by Levitan et al. (2015) was determined for AM CVns with $P_{\rm orb} < 40$ minutes, which means that validity of the extrapolation to larger periods is not well established. In fact, inaccurate predictions have already been observed for other AM CVns systems in superoutburst such as SDSS 1411, which predicted the amplitude is 5.8 mag, but it showed a ∼7 mag

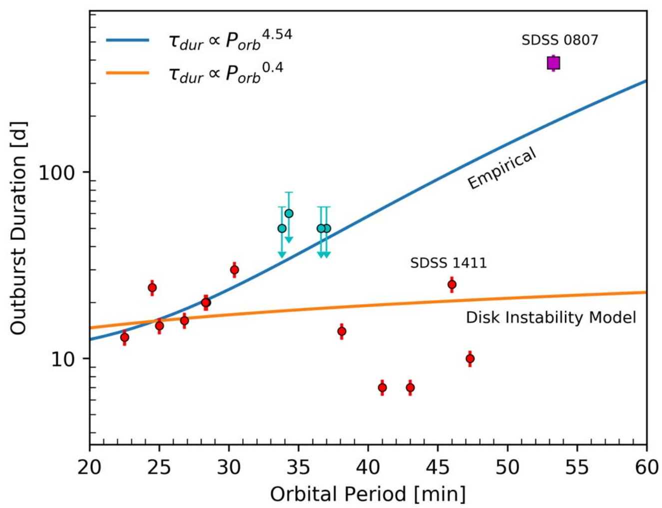

Figure 2. The orbital period ($P_{\rm orb}$) vs. outburst duration ($\tau_{\rm dur}$) relation for AM CVns. The red circles are known AM CVns with measured outburst duration (Cannizzo & Ramsay 2019, and references therein). The cyan circles indicate 75% of the upper limit values (i.e., 75% probability the object is fainter than such a value), which, considering the remaining 25% error and the values of the outburst duration at $P_{\rm orb} < 40$ minutes, give the empirical relation $\tau_{\rm dur} \propto P_{\rm orb}^{4.54}$ (Levitan et al. 2015). The relation $\tau_{\rm dur} \propto P_{\rm orb}^{0.4}$ was obtained considering the outburst duration of systems with $P_{\rm orb} < 50$ minutes and the DIM for He-dominated accretion disks (Cannizzo & Ramsay 2019). The observed $\tau_{\rm dur}$ for SDSS 0807 is well above the expected value of both relations. The aforementioned relations are actually valid for superoutbursts (most of these observational points and upper limits; Levitan et al. 2015; Cannizzo & Ramsay 2019), thus they are relevant for our data and discussion on SDSS 0807. We have considered a 10% error for the outburst duration for all systems that do not have an upper limit, as done by Levitan et al. (2015).

superoutburst (Rivera Sandoval & Maccarone 2019). This casts doubts whether the expected amplitude of SDSS 0807 is indeed ~7 mag. Also, if the WD accretor in SDSS 0807 is not a very massive one (e.g., $\sim 0.6\,M_\odot$), this would also affect the outburst amplitude as the accretion luminosity is directly and inversely proportional to the WD mass and radius, respectively. Furthermore, Kotko et al. (2012) have also shown that a larger metallicity substantially reduces the outburst amplitudes in AM CVns.

We also determined the rise and decline timescales of SDSS 0807 which are 60 day mag^{-1} and 115 day mag^{-1}, respectively. Both are remarkable because they are the slowest ever observed in any outbursting AM CVn or CV system. In fact, these rate values exceed by tens of times those expected for CVs (Bailey 1975), even if only long-duration outbursts or superoutbursts are considered (Otulakowska-Hypka et al. 2016), independently of their $P_{\rm orb}$. The viscous time sets the slow decay of superoutbursts, and for SDSS 0807, that is expected to be ~2 months (see Appendix B), which clearly contrasts with our observations (Figure 1).

From the Swift analysis we determined that on 2020 April 15 the object was clearly detected in X-rays with a count rate of $10.1 \pm 2.7 \times 10^{-3}$ counts s^{-1} (or $f_{\rm X} = 0.40^{+0.21}_{-0.14} \times 10^{-12}$ erg cm^{-2} s^{-1}), with a photon index $\Gamma = 2.46^{+0.83}_{-0.73}$. This indicates that the X-ray spectrum of SDSS 0807 is more dominated by lower-energy photons in that phase, perhaps due to a lower-mass WD or a more transparent boundary layer. On the other hand, the binary was not detected in X-rays on 2020 May 28, with an upper limit on the count rate of 4.5×10^{-3} counts s^{-1} at the 97.5% confidence level (corresponding to 2σ for a one-sided tail for a Gaussian distribution). The source thus clearly faded between the 2020 April and May observations, probably by a factor more than 2. Meanwhile, measurements in the U band for both dates correspond to 20.48 ± 0.31 mag and 20.87 ± 0.32 mag, respectively. The optical decline corresponds to a reduction in flux by a factor of 1.6, but given that a substantial fraction of the optical flux in these faint states comes from the radiative cooling of the WD itself, the accretion rate likely dropped by a larger factor. These measurements are in agreement within errors with those taken by the SDSS on 2000 April 25, when the object had a magnitude in u' of 20.4 ± 0.06 mag and was fully in quiescence. On the other hand, in the UV band UVW1 ($\lambda_c = 2600$ Å) the binary showed a slightly decrease in magnitude (0.4 mag) between both dates, suggesting a correlation with the X-ray emission decrease. Interestingly, Gaia measurements indicate that ~6 months after the event finished, the binary remained 0.4 mag brighter than its original quiescent level (Figure 1).

Enhanced emission in X-rays and UV at least 2 months after the end of an outburst has previously been observed in other AM CVns (Rivera Sandoval & Maccarone 2019), and the UV has been explained as heat released by the accreting WD, which was deposited on it during the intense accretion event (the superoutburst). The X-ray emission is explained as residual accretion, as the temperature of the accreting WD after the end of the superoutburst is not high enough to release X-rays (Godon et al. 2006). The Swift X-ray detection then shows that the binary was still accreting on 2020 April 15. On the other hand, the X-ray nondetection of SDSS 0807 on 2020 May 28 does not necessarily mean that the object reached its quiescent level, but it demonstrates that abrupt changes in the mass accretion rate occurred between 140 and 180 days after the end of the superoutburst. Note that the emission in the bluest UVOT band UVW2 ($\lambda_c = 1928$ Å) was consistent within errors during both UVOT observations and there was no flux increase in that band on 2020 May 28, when the binary was not detected in X-rays. This argues against the possibility of the boundary layer becoming optically thick (and thus reducing the X-ray emission) due to an episode of large accretion, as has been observed in CVs and AM CVns during (or near) the outburst peak (e.g., Wheatley et al. 2003; Ramsay et al. 2012b; Rivera Sandoval & Maccarone 2019).

3.2. Irradiation of the Donor

A commonly invoked scenario to explain the outbursts and superoutbursts in AM CVns is the disk instability model (DIM; e.g., Smak 1983; Lasota et al. 2008; Kotko et al. 2012; Cannizzo & Nelemans 2015; Cannizzo & Ramsay 2019), given that it reproduces the relations between $P_{\rm orb}$ and several outburst observables such as their duration ($\tau_{\rm dur}$), the recurrence time, and the mass transfer rate relatively well (Cannizzo & Nelemans 2015; Cannizzo & Ramsay 2019). It also predicts the threshold period for stable versus unstable accretion disks (Kotko et al. 2012). That model is an extension of the model applied to CVs, with the difference that the disks in AM CVns are dominated by He instead than by H, and their sizes are much smaller. The model assumes that the mass-transfer rate from the donor is constant and the value of the accretion rate onto the accreting WD determines the stability of the disk and therefore the existence of outbursts/superoutbursts. In the DIM for AM CVns the duration of the superoutburst increases with $P_{\rm orb}$ and follows the relation $\tau_{\rm dur} \propto P_{\rm orb}^{0.4}$ (Cannizzo & Ramsay 2019), implying that

SDSS 0807 should have had a superoutburst with a duration of 22 days, which contrasts with the ∼390 days observed. The observations presented here argue then against that model (Figure 2). Comparison between the superoutburst duration and the empirical relation derived by Levitan et al. (2015) is not well motivated as that relation was derived for systems with $P_{\mathrm{orb}} < 40$ minutes and for more than one detected superoutburst. Thus, we limit our discussion regarding the superoutburst duration to the DIM (Figure 2).

A poorly explored effect so far is the importance of irradiation of the donor by the accretor and its disk, which can enhance the mass transfer rates (Warner 1995; Hameury et al. 1997; Deloye et al. 2007; Kotko et al. 2012; Warner 2015). Given that the orbits in AM CVns have very short periods and the donors can be quite cold, this effect might be important in at least a fraction of the AM CVn systems. Irradiation could, in fact, explain the long superoutbursts such as in SDSS 0807, with longer rise and decline times due to changes in the mass transfer rate. Indeed, indications of changes in the mass transfer rates of other outbursting AM CVns have been observed (Patterson et al. 2000), as have anomalously long outbursts of a few months in duration (Ramsay et al. 2012a; Shears et al. 2012), suggesting that irradiation on the companion can be important and even relatively common. The extreme superoutburst characteristics of SDSS 0807 are the clearest and most extreme evidence of the action of this mechanism in AM CVns.

In fact, one can expect a significant effect on the structure of the donor star due to irradiation if the rate at which it absorbs heat from the accretor's radiative flux is comparable to the rate at which its internal energy is radiated. If we assume an initial mass of 0.2 $M_{\odot}$ and an initial temperature of 10^8 K for the donor WD (both likely higher than the typical initial values for the donors in AM CVn systems), and then follow the cooling of the donor star (Mestel 1952), taking into account that mass is lost during the evolution, then at $P_{\mathrm{orb}} \sim 53$ minutes, we expect the luminosity of the donor to be about 3.8×10^{29} erg s^{-1} and the temperature to be 2600 K. Using the same approach, we find that we expect $T = 1700$ K for a 68 minute orbital period, in reasonable agreement with the recent discovery of a $T \approx$ 1850 K excess in SDSS J1505+0659 (Green et al. 2020). The donor will occupy about 0.0025 of the solid angle seen from the source. Thus, if the superoutburst luminosity is $\gtrsim 10^{32}$ erg s^{-1}, the WD donor should heat substantially due to the outburst of the accretion disk, given that the albedo of a He star absorbing UV light should be low. Assuming a distance of at least 1 kpc (reasonable, given that the parallax to SDSS 0807 is not yet well constrained), the outburst does, indeed, reach this luminosity. The evolution of AM CVns indicates that they move from a short P_{orb} to a larger one as they evolve, with the donors significantly reducing their mass transfer rates and cooling as the orbit widens (Nelemans 2005). Thus, the long period of SDSS 0807 points toward an old, cold, and low-mass donor, which would be easy to heat during a superoutburst. These simple calculations show that the donor is susceptible to having irradiation affect it, but a more detailed quantification of the effects of donor irradiation is beyond the scope of this Letter given the complexity of the problem. However, Kotko et al. (2012) have shown that mass transfer enhancement does in fact substantially increase the duration of the outbursts in AM CVns besides affecting the shape of the light curves. Thus, the results of SDSS 0807 will certainly place constraints for a more detailed modeling of outbursts in these binaries.

The observations of SDSS 0807 then show that irradiation on the donor has to be considered in the evolution of AM CVns, as it can have important consequences for these binaries as gravitational-wave sources. If, for instance, enhanced mass transfer due to irradiation makes AM CVns evolve more quickly toward longer periods than currently predicted by models (which usually neglect this mechanism), then the number of ultracompact systems expected to be detected by LISA (Nelemans et al. 2004; Marsh 2011; Nissanke et al. 2012) will likely be smaller than currently thought; the LISA noise curve's shape will change as well, although this is likely to be dominated by detached double WDs. It is also possible that the abrupt changes in the mass transfer rates make the donor unstable, and therefore after the superoutburst (when the mass transfer rate will substantially drop), it will need to readjust its structure. This will likely make the recurrence times much longer than currently expected (either empirically or with the DIM; Levitan et al. 2015; Cannizzo & Ramsay 2019), therefore reducing the detection rate of these systems through their outbursts by all-sky variability surveys, directly influencing the density estimates. Detail modeling and further investigations on the accreting behavior of AM CVns is required in order to quantitatively assess how common this mechanism is on these binaries. Models will also help to investigate what are the causes that influence the donor's irradiation, among which could be the precession of a tilted/warped disk (e.g., Kotko et al. 2012, and references therein) and perhaps also the metallicity due to the type of donor (and hence the formation channel). Furthermore, to find these systems in deep quiescence new techniques should be developed.

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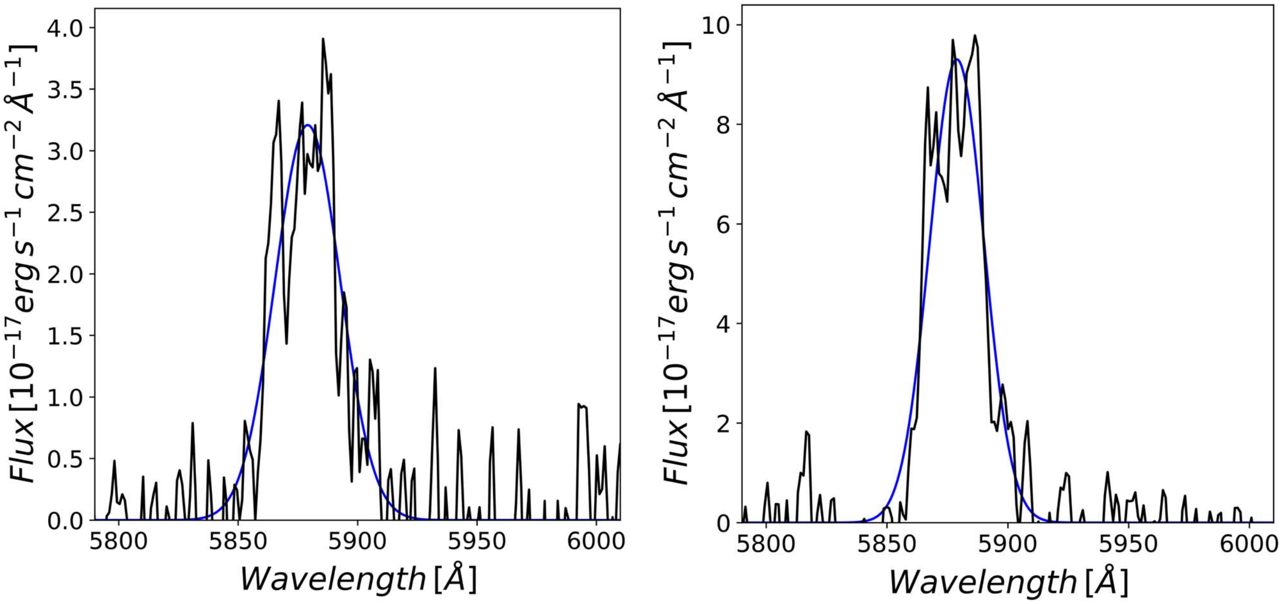

Figure A1. SDSS average spectra of the AM CVn systems SDSS 0807 (left) and SDSS 1411 (right) in the range 5800–6000 Å. The Gaussian fit to the 5875 Å He I emission line is shown in blue color. The average FWHMs are $\mathrm{FWHM}_{0807} = 1670 \pm 336$ km s^{-1} and $\mathrm{FWHM}_{1411} = 1350 \pm 85$ km s^{-1}, respectively.

Appendix A
Qualitative Estimation of K_2

We used the measured FWHM and the periods to estimate the difference in the inclination of the two sources, SDSS 0807 and SDSS 1411. We assumed that the FWHM of the 5875 Å He I line is correlated with K_2 in an analogous way to that found by Casares (2015) for black holes, where the FWHM is related to the radial velocity semi-amplitude of the donor star (K_2) as

$$\left(\frac{\mathrm{FWHM}}{2}\right)^2 = \frac{GM_1}{R_d}\sin^2 i$$

and

$$K_2^2 = \frac{GM_1^2}{a(M_1 + M_2)}\sin^2 i,$$

where R_d is the radius of the accretion disk, M_1 is the mass of the accretor, M_2 is the mass of the companion star, and i is the binary inclination angle. Assuming that the disk radius, $R_d = \alpha R_{L1}$, where $\alpha < 1$ and R_{L1} is the Roche lobe radius and can be computed from the Eggleton's relation (Eggleton 1983),

$$\frac{R_L}{a} = \frac{0.49q^{-2/3}}{0.6q^{-2/3} + \ln(1 + q^{-1/3})}.$$

We obtain K_2 as a function of α and the mass ratio $q = M_2/M_1$, i.e.,

$$\frac{K_2}{\mathrm{FWHM}} = \frac{\sqrt{\alpha f(q)}}{2},$$

where

$$f(q) = \frac{0.49(1 + q)^{-1}}{0.6 + q^{2/3}\ln(1 + q^{-1/3})}.$$

For AM CVns there are 17 systems with reported mass ratios ranging from 0.014 to 0.01 (Green et al. 2018a, 2020). This means that K_2 depends very modestly on q and for this range of mass ratios the term $\sqrt{f(q)}$ varies from 0.67 to 0.8. The constant number α has been reported for the eclipsing AM CVn Gaia14aae (Green et al. 2018b) to be 0.8.

The relationship between K_2 and the FWHM for black hole X-ray binaries (Casares 2015) has been found to be

$$K_2 = 0.233 \cdot \mathrm{FWHM}.$$

Similarly for AM CVns, we can then expect K_2 to be proportional to the FWHM, which together with P_{orb} can be used to determine their relative inclinations. SDSS 0807 has a P_{orb} close to the likely measured P_{sh} of 53.3 minutes, and SDSS 1411 has a $P_{\mathrm{orb}} = 46$ minutes. The average FWHMs using all the available spectra are $\mathrm{FWHM}_{0807} = 1670 \pm 336$ km s^{-1} and $\mathrm{FWHM}_{1411} = 1350 \pm 85$ km s^{-1}, respectively (Figure A1). Since K_2 is inversely proportional to $P_{\mathrm{orb}}^{1/3}$, for SDSS 0807, we would then expect a smaller FWHM than that of SDSS 1411. However, the observations indicate the contrary, suggesting that the larger FWHM of SDSS 0807 is then due to a larger inclination angle when compared to SDSS 1411. Note that here we do not give an explicit value of the constant that relates K_2 and the FWMH for AM CVns. At the present time there is insufficient data to calibrate these relations for AM CVns using the He I line, because the ionization structure of the disk affects the overall constant of proportionality differently for each emission line. Also note that from the photometric data presented in this Letter we cannot exclude the presence of an eclipse as in the case of Gaia14aae (Campbell et al. 2015), an AM CVn with $P_{\mathrm{orb}} \sim 50$ minutes that had a larger outburst amplitude (5 mag) than the one of SDSS 0807. However, Kupfer et al. (2019) did not mention the identification of such a characteristic in their light-curve analysis of SDSS 0807 using short-cadence observations. The result that SDSS 0807 is significantly more edge-on than SDSS 1411 is, nonetheless, robust.

Appendix B
Viscous Time

We have estimated the viscous time of SDSS 0807 by assuming a primary mass of $m_1 = 0.6\ M_\odot$ and a donor mass of $m_2 = 0.01\ M_\odot$. We considered $\dot{M} \gtrsim 7 \times 10^{-11}\ M_\odot\ \mathrm{yr}^{-1}$ that corresponds to at least 10 times (due to the superoutburst) the quiescent value of SDSS J1208, an AM CVn with a similar orbital period ($P_{\mathrm{orb}} = 53$ minutes for SDSS J1208; Ramsay et al. 2018) to that of SDSS 0807. We also considered $\alpha = 0.1$ and the following formula (Frank et al. 2002):

$$t_{\mathrm{visc}} \sim 3 \times 10^5 \alpha^{-4/5} \dot{M}_{16}^{-3/10} m_1^{1/4} R_{10}^{5/4}\ s,$$

where $R_{10} = R/10^{10}$ cm is the radius of the disk, considered here to be the tidal radius $R = 0.8a$, and $\dot{M}_{16} = \dot{M}/10^{16}\ \mathrm{g\ s}^{-1}$. We obtained a value $t_{\mathrm{visc}} \sim 66$ days.

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