ON THE ACCRETION RATES OF SW SEXTANTIS NOVA-LIKE VARIABLES

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ABSTRACT

We present accretion rates for selected samples of nova-like variables having IUE archival spectra and distances uniformly determined using an infrared method by Knigge. A comparison with accretion rates derived independently with a multiparametric optimization modeling approach by Puebla et al. is carried out. The accretion rates of SW Sextantis nova-like systems are compared with the accretion rates of non-SW Sextantis systems in the Puebla et al. sample and in our sample, which was selected in the orbital period range of three to four and a half hours, with all systems having distances using the method of Knigge. Based upon the two independent modeling approaches, we find no significant difference between the accretion rates of SW Sextantis systems and non-SW Sextantis nova-like systems insofar as optically thick disk models are appropriate. We find little evidence to suggest that the SW Sex stars have higher accretion rates than other nova-like cataclysmic variables (CVs) above the period gap within the same range of orbital periods.

Key words: accretion, accretion disks – novae, cataclysmic variables – stars: individual (white dwarfs)

1. INTRODUCTION

Cataclysmic variables (CVs) are short-period binaries in which a late-type, Roche-lobe-filling main-sequence dwarf transfers gas through an accretion disk onto a rotating, accretion-heated white dwarf (WD). The nova-like variables are a non-magnetic subclass of CVs in which the mass transfer rate tends to be high and the light of the system is typically dominated by a very bright accretion disk (Warner 1995). The spectra of nova-like variables resemble those of classical novae (CNe) that have settled back to quiescence. However, nova-like variables have never had a recorded CN outburst or any outburst. Hence their evolutionary status remains unknown. They could be close to having their next CN explosion, or they may have had an unrecorded explosion in the recent past. Their distribution of orbital periods reveals a large concentration of systems in the range between 3 and 4 hr, the former period being the upper boundary of the CV period gap in which very few CVs are found. Some nova-likes (classified as the VY Sculptoris systems) show the behavior of being in a very high optical brightness state for most of the time, but then, for no apparent reason, plummeting into a deep low optical brightness state with little or no ongoing accretion. Then, just as unpredictably, their optical brightness returns to the high state (cf. Honeycutt & Kafka 2004 and references therein). These precipitous drops in brightness are possibly related to the cessation of mass transfer from the K-M dwarf secondary star either by starspots that drift into position under the inner Lagrangian point, L1 (Livio & Pringle 1998), or irradiation feedback in which an inflated outer disk can modulate the mass transfer from the secondary by blocking its irradiation by the hot inner accretion disk region (Wu et al. 1995). Other nova-like systems, the UX UMa subclass, do not appear to exhibit low states but remain in a state of high outburst. It is widely assumed that the absence of dwarf novae outbursts in nova-likes is explained by their mass transfer rates being above a critical threshold where the accretion rates are so high that the accretion disk is largely ionized thus suppressing the viscous thermal instability (the disk instability mechanism or DIM) which drives dwarf nova limit cycles (Shafer et al. 1986).

Until recently, the accretion rates of nova-likes, including SW Sex stars (see below), have been reported for only a few individual systems from a variety of model analyses of their optical, FUV spectra or X-ray spectra. Optical determinations of the accretion rates in nova-likes are based upon estimates of their disk luminosity using distance estimates or clues (Patterson 1984). The absolute magnitudes of the accretion disks in nova-likes reveal that their accretion rates are similar to those derived for dwarf novae during their outbursts (Warner 1995). Unfortunately, the distances of nova-like variables remain uncertain due to the scarcity of trigonometric parallaxes and the absence of a reliable usable relation for nova-like variables between their absolute magnitude at maximum light versus orbital period similar to what exists for dwarf novae. A more systematic study of a larger number of systems is clearly needed in order to compare accretion rates among different subgroups of CVs. One recent statistical study (Puebla et al. 2007), utilizing a multiparametric optimization model fitting method, explored how well current optically thick accretion disk models fit the FUV spectra of nova-likes and old novae in a sample of 33 such systems. They found the average value of $\dot{M}$ for nova-like systems was $\sim 9.3 \times 10^{-9} M_{\odot} \text{yr}^{-1}$.

Among the nova-like variables is a subclass, the SW Sextantis stars, which displays a multitude of observational characteristics: orbital periods between 3 and 4 hr, up to one-half of the known SW Sex systems are non-eclipsing, and roughly one-half show deep eclipses of the WD by the secondary, thus requiring high inclination angles, single-peaked emission lines despite the high inclination, and high excitation spectral features including He ii (4686 Å) emission and strong Balmer emission on a blue continuum, high velocity emission S-waves with maximum blueshift near phase $\sim 0.5$, delay of emission line radial velocities relative to the motion of the WD, and central absorption dips in the emission lines around phase $\sim 0.4$–0.7 (Rodriguez-Gil et al. 2007a, 2007b; Hoard et al. 2003). The SW Sex stars appear to be intrinsically luminous as indicated by the apparent brightnesses of systems like DW UMa despite their being viewed at high orbital inclinations of 80$^\circ$ and higher (Rodriguez-Gil et al. 2007b). A picture of very high secular mass transfer rates is supported by the presence of very hot WDs in the rare SW Sex systems observed in a low...
state (e.g., DW UMa’s WD). The WDs in many, if not all, of these systems are suspected of being magnetic (Rodriguez-Gil et al. 2007b). However, the case for magnetic WDs in the SW Sex stars remains highly speculative and does not consistently account for the spectroscopic and photometric characteristics from system to system (see, for example, Hoard et al. 2003). It has also been asserted that the SW Sextantis subclass of nova-like variables have higher accretion rates than other nova-like systems (Rodriguez-Gil et al. 2007b). Indeed, 27 out of 35 SW Sex stars listed by Rodriguez-Gil et al. (2007b) have orbital periods concentrated in the range of 3–4.5 hr where nova-like systems tend to accumulate. As asserted in Rodriguez-Gil et al., either the SW Sex stars have “an average mass transfer rate well above that of their CV cousins” or another source of luminosity exists. Since these objects are found near the upper boundary of the period gap, their study is of critical importance to understanding CV evolution as they enter the period gap (Rodriguez-Gil et al. 2007b).

In the SW Sex systems (except those observed during low states), the accretion disk flux completely dominates the FUV wavelength range. The WD contribution is expected to be minimal in these systems because their disks are thick and luminous and because at high inclination the inner disk, boundary layer, and WD should be significantly obscured by vertical structure in the disk. Therefore, it is entirely reasonable that the analysis of a nova-like system in a high state be carried out with optically thick steady state accretion disk models in which the accretion rates are determined from fitting the continuum slopes and Lyman Alpha profiles with the fits constrained by the system distance, if known, and by parameters like the inclination angle and WD mass if reliably known. This is the same model fitting strategy that we employed to determine the accretion rates of 46 dwarf novae in outburst from disk modeling of their IUE archival FUV spectra (Hamilton et al. 2007).

An important question is whether or not the SW Sex systems really have higher than average accretion rates compared with other nova-like systems as asserted by Rodriguez-Gil et al. (2007b). If they do not have higher than average mass transfer rates, then what is the source of their higher luminosities? In order to test this assertion, we have determined accretion rates of SW Sex nova-likes and non-SW Sex nova-likes within approximately the same orbital period range.

2. SYSTEM PARAMETERS AND DISTANCES OF NOVA-LIKE VARIABLES

In order to constrain the synthetic spectral fitting and reduce the number of free parameters, we searched the published literature for the most accurately known system parameters. This included the compilations in Ritter & Kolb (2003) and the Goettingen CVCat Web site as well as publications documented in the SAO/NASA Astrophysics Data Service (ADS). The most critical parameter for the model fitting, the distance, is the least known. We conducted an exhaustive search of the literature for previous published distance estimates. There is only one nova-like, RW Tri, with a reliable trigonometric parallax measurement. Unlike dwarf novae where there exists a correlation between their absolute magnitude at maximum and their orbital period, there is no such relation for the nova-likes. However, a new method (Knigge 2006) utilizing Two Micron All Sky Survey (2MASS) JHK photometry and the observed properties of CV donor stars has proven useful for constraining nova-like distances. At present, this is the only reliable handle one has on nova-like distances (B. Warner 2008, private communication). For each system, we obtained the J, H, K apparent magnitudes from the 2MASS. For a given orbital period, Knigge (2006) provides absolute J, H, and K magnitudes based upon his semi-empirical donor sequence for CVs. If it is assumed that the donor provides 100% of the light in J, H, and K, then the distance is a strict lower limit. If the donor emits 33% of the light (the remaining being accretion light), then an approximate upper limit is obtained. The latter limit is a factor of 1.75 times the lower limit distance. For moderately bright CVs, interstellar reddening is expected to have a negligible effect on the IR photometry used to estimate the distances. The adopted distance ranges which are used as constraints in the synthetic spectral fitting procedure are given below (see Table 1).

For our comparative study, we selected all SW Sex and non-SW Sex nova-like variables within the orbital period range of 3–4.5 hr for which usable IUE archival spectra exist. This period range is where 77% of the known SW Sex stars are found. The SW Sex status was confirmed by a comparison of the census in Table 6 of Rodriguez-Gil et al. (2007b) with the latest census of membership in the SW Sex class given in D. W. Hoard’s Big List of SW Sex Stars.1

Within the 3–4.5 hr period range, the following objects are assigned “Definite” SW Sex membership status: V442 Oph, SW Sex, AH Men, WX Ari, BP Lyn, and UU Aqr. The systems HS Aqr and LN UMa are listed in D. W. Hoard’s Big List as “Probable” members while being listed in Rodriguez-Gil et al. (2007b) as bona fide SW Sex stars. We have retained these two objects as SW Sex members.

For the non-SW Sex nova-like systems within the same orbital period for which there are usable IUE archival spectra obtained during their high brightness state, we selected the following systems: LQ Peg, MV Lyn, TT Ari, VZ Scl, BZ Cam, and CM Del. We note that TT Ari and VZ Scl are listed in D. W. Hoard’s Big List as “Possible” SW Sex membership status. Therefore we compute the average accretion rates below with and without their inclusion.

In Table 1, we list the adopted parameters for the orbital period (hr), the apparent V magnitude, the inclination i (°), the WD mass (M⊙), the interstellar reddening, E(B−V), and the distance in parsecs. In our model fitting procedure, these published parameters are used as initial guesses but if the resulting fits are unsatisfactory then we allow the relevant parameters to vary in the model fitting.

3. FAR ULTRAVIOLET SPECTROSCOPIC OBSERVATIONS

All the spectral data were obtained from the Multimission Archive at Space Telescope (MAST) IUE archive, when the CVs were in high activity states. We restricted our selection to those systems with SWP spectra with a resolution of 5 Å and a spectral range of 1170–2000 Å. All spectra were taken through the large aperture at low dispersion. When more than one spectrum with adequate signal-to-noise ratio was available, the spectra were co-added or the two best spectra were analyzed. In Table 2, an observing log of the IUE archival spectra is presented in which the entries by column are (1) system name, (2) system subtype SW Sex or non-SW Sex, (3) the SWP spectrum number, (4) the exposure time in seconds, (5) dispersion, (6) aperture size, (7) the date and time of the observation, and (8) the brightness state.

1 See the Big List of SW Sextantis Stars at http://spider.ipac.caltech.edu/staff/hoard/biglist.html.
of the system. Transition refers to an intermediate state between the highest optical brightness state and the deepest low state.

In the case of those systems not covered by the AAVSO, their activity state was assessed based upon either mean photometric magnitudes taken from the Ritter & Kolb (2003) catalog or from IUE Fine Error Sensor (FES) measurements at the time of the IUE observation. In addition, the presence of P Cygni profiles, absorption lines, and a comparison with spectral data and flux levels of other systems during different activity states was used to ascertain the state of the system. The reddening of the systems was determined based upon all estimates listed in the literature. The three principal sources of reddening were the compilations of Verbunt (1987), LaDous (1991), and Bruch & Engel (1994).

The spectra were de-reddened with the IUERDAF IDL routine UNRED.

### 4. SYNTHETIC SPECTRAL FITTING MODELS

We adopted model accretion disks from the optically thick disk model grid of Wade & Hubeny (1998). In these accretion disk models, the innermost disk radius, \( R_{\text{in}} \), is fixed at a fractional WD radius of \( x = R_{\text{in}} / R_{\text{wd}} = 1.05 \). The outermost disk radius, \( R_{\text{out}} \), was chosen so that \( T_{\text{eff}}(R_{\text{out}}) \) is near 10,000 K since disk annuli beyond this point, which are cooler zones with larger radii, would provide only a very small contribution to the mid and far UV disk flux, particularly in the SWP FUV bandpass. The mass transfer rate is assumed to be the same for all radii. Thus, the run of disk temperature with radius is taken to be:

\[
T_{\text{eff}}(r) = T_e x^{-3/4}(1 - x^{-1/2})^{1/4}
\]

where \( x = r / R_{\text{wd}} \) and \( \sigma T_f^4 = 3 G M_{\text{wd}} M / 8 \pi R_{\text{wd}}^3 \).

Limb darkening of the disk is fully taken into account in the manner described by Diaz et al. (1996) involving the Eddington–Barbier relation, the increase of kinetic temperature with depth in the disk, and the wavelength and temperature dependence of the Planck function. The boundary layer contribution to the model flux is not included. However, the boundary layer is expected to contribute primarily in the extreme ultraviolet below the Lyman limit.

The disk is divided into a set of ring annuli. The vertical structure of each ring is computed with TLUSDISK (Hubeny 1990), which is a derivative of the stellar atmosphere program TLUSTY (Hubeny 1988). The spectrum synthesis program SYNTEX described by Hubeny & Lanz (1995) is used to solve the radiative transfer equation to compute the local, rest frame spectrum for each ring of the disk. In addition to detailed profiles of the H and He lines, the spectrum synthesis includes metal lines up to nickel (\( Z = 28 \)). The accretion disks are computed in LTE and the chemical composition of the accretion disk is kept fixed at solar values in our study.

Theoretical, high gravity, photospheric spectra were computed by first using the code TLUSTY version 200 (Hubeny 1988) to calculate the atmospheric structure and SYNTEX version 48 (Hubeny & Lanz 1995) to construct synthetic spectra. We compiled a library of photospheric spectra covering the temperature range from 15,000 K to 70,000 K in increments of 1000 K, and a surface gravity range, \( \log g = 7.0–9.0 \), in increments of 0.2 in \( \log g \).

After masking emission lines in the spectra, our normal procedure, in general, is to determine separately for each spectrum, the best-fitting WD-only model, the best-fitting accretion disk-only model, the best-fitting combination of a WD plus an accretion disk, and the best-fitting two-temperature WD (to include an accretion belt or ring). Using two \( \chi^2 \) minimization routines, either IUEFIT for disks alone and photospheres alone or DISKFIT for combining disks and photospheres or two-temperature WDs, \( \chi^2 \) values and a scale factor were computed for each model or combination of models. The scale factor, \( S \), normalized to a kiloparsec and solar radius, can be related to the WD radius \( R \) through: \( F_{\lambda \text{obs}} = SH_{\lambda \text{model}} \), where \( S = 4 \pi R^2 d^{-2} \), and \( d \) is the distance to the source. For the WD radii, we use the mass–radius relation from the evolutionary model grid of Wood (1995) for C–O cores. The best-fitting model or combination of models was chosen based not only upon the minimum \( \chi^2 \) value achieved, but the goodness of fit of the continuum slope, the goodness of fit to the observed Lyman Alpha region and consistency of the scale factor derived distance with the adopted Knigge (2006) distance for each system.

For a nonmagnetic nova-like variable during its high brightness state, it is reasonable to expect that a steady state optically thick accretion disk might provide a successful fit. Therefore, our modeling procedure is the same as the procedures carried out by Hamilton et al. (2007) for the entire IUE archive of 46 dwarf novae in outburst. For the nova-like variables during their high brightness states, we first try accretion disk models which satisfy both the continuum slope and Lyman Alpha line width in a single model. We use published parameters like the WD mass and inclination ONLY as an initial guess in searching for the best-fitting accretion disk models. If the parameters are

### Table 1

**Nova-Like System Parameters**

| System | Subtype | \( P_{\text{orb}} \) (hr) | \( V \) | \( M_{\text{wd}} \) (\( M_\odot \)) | \( i(\circ) \) | \( E(B-V) \) | \( d_{\text{kpc}} \) (pc) | \( d_{\text{lit}} \) (pc) |
|--------|--------|----------------|------|----------------|-----|--------|----------|---------|
| V442 Oph | VV,SW | 2.98 | 12.6 | ... | ... | 0.22 | 153–268 | 130 |
| SW Sex | UX,SW | 3.24 | 14.3 | 0.5 | > 75 | 0.0 | 243–426 | 450 |
| AH Men | SW | 3.05 | 13.2 | ... | ... | 0.12 | 91–160 | 120 |
| HL Aqr | SW | 3.25 | 13.3 | ... | ... | 0.05 | 174–304 | 213 |
| WX Ari | SW | 3.34 | 15.3 | ... | 72 | ... | 258.7–453 | 468 |
| LN Uma | SW | 3.46 | 14.6 | ... | ... | 0.05 | 349–610 | 405 |
| BP Lyn | SW | 3.67 | 14.5 | ... | ... | 251–440 | 344 |
| CU Aqr | SW | 3.93 | 13.3 | 0.67 ± 0.14 | 78 ± 2 | ... | 174–304 | 208 |
| LQ Peg | NSW | 2.99 | 14.4 | ... | ... | ... | 270–472 | 350 |
| MV Lyn | NSW | 3.18 | 11.8 | 0.73 ± 0.10 | 12 | ... | 431–754 | 442 |
| TT Ari | NSW | 3.30 | 9.5 | ... | ... | ... | 63–109 | 65 |
| VZ Scl | NSW | 3.47 | 15.6 | 1 | 90 | ... | 490–858 | 566 |
| BZ Cam | NSW | 3.69 | 12.0 | ... | ... | ... | 235–412 | 258 |
| CM Del | NSW | 3.89 | 13.4 | 0.48 ± 0.15 | 73 ± 47 | ... | 229–401 | 241 |
| VY Scl | NSW | 5.57 | 12.1 | 1.22 ± 0.22 | 30 ± 10 | ... | 196–343 | 337 |
published but not considered reliable or if they are entirely absent, then for each system’s spectrum we carry out fits for every combination of $M$, inclination, and WD mass in the Wade & Hubeny (1998) library. The values of $i$ are 18, 41, 60, 75, and 81°. The range of accretion rates covers $-10.5 < \log M_r < -8.0$ in steps of 0.5 in the log and five different values of the WD mass, namely 0.35, 0.55, 0.80, 1.03, and 1.2 $M_\odot$. The process is streamlined by a routine that compares each observed spectrum with the full 900 models using every combination of $i$, $M$, and $M_{WD}$, and provides the model-computed distance and $\chi^2$ value of each model fit. A good sense of the accuracy of our derived accretion rates for IUE FUV spectra of comparable quality is provided by a formal error analysis with contours discussed in Winter & Sion (2003). In general, we estimate that our accretion rates from these spectra are accurate to within a factor of 2–3.

5. ACCRETION RATES OF SW SEX NOVA-LIKES AND NON-SW SEX NOVA-LIKES

5.1. Accretion Rates from Multiparametric Optimization

The Puebla et al. (2007) sample contains ten SW Sex systems for which they derived accretion rates using a method different from ours, known as multiparametric optimization. Of the ten, three systems, RW Tri, RR Pic, and LX Ser, are listed as “Possible” SW Sex members on D. W. Hoard’s Big List while V347 Pup is listed as a “Probable” member. Since these systems are listed as members by Rodriguez-Gil et al. (2007a, 2007b), we have retained them in the following rough comparison with non-SW Sex nova-likes. For the latter systems, we have V592 Cas, CM Del, KR Aur, IX Vel, UX UMa, V794 Aql, V3885 Sgr, VY Scl, RW Sex, RZ Gru, and QU Car. If we take the comparison to be within approximately the orbital period range of 3–4.5 hr, then the average accretion rate of the SW Sex systems is $4 \times 10^{-9} M_\odot$ yr$^{-1}$ and non-SW Sex members have $M = 3 \times 10^{-9} M_\odot$ yr$^{-1}$.

If we average the SW Sex systems and non-SW Sex systems without regard to orbital period, then the 13 SW Sex systems have $M = 5 \times 10^{-9} M_\odot$ yr$^{-1}$ compared with 11 non-SW Sex nova-likes with $M = 1 \times 10^{-8} M_\odot$ yr$^{-1}$. One must caution that this comparison includes non-SW Sex systems having a mixed bag of distance methods, WD masses, and fitting methods with derived accretion rates from different groups.

Therefore, to facilitate a more uniform comparison between SW Sex and non-SW Sex nova-likes, we chose to (1) enlarge the sample size of SW Sex and non-SW Sex nova-likes from the IUE and Hubble Space Telescope (HST) archives, (2) restrict the comparison to the period range of the SW Sex stars, and (3) adopt distances determined uniformly with the same method. If we restrict our attention to the range of orbital periods between 3 and 4.5 hr where most nova-like variables appear to be concentrated, we can directly compare the accretion rates of non-SW Sex systems in that period range to the SW Sex systems in this same range of orbital period. For this experiment, the model fitting was carried out uniformly for all the systems, SW Sex and non-SW Sex, using the distances from the method of Knigge (2006) for which ideally the $P_{orb}$ versus $M$ relation would be expected to vary commensurately within this restricted period range.

5.2. Nova-Like Sample with $3 < P_{orb} < 4.5$ and Knigge Distances

In Table 3, we list the best-fitting parameters of our selected sample of SW Sex and non-SW Sex nova-likes (from Tables 1 and 2) where the entries by column are (1) the system name, (2) nova-like subclass, (3) WD mass, (4) inclination angle, (5) best-fitting model distance in pc, (6) accretion rate $(M_\odot$ yr$^{-1})$, and (7) $\chi^2$ value.

The best-fitting accretion disk model for each system is shown in the accompanying multipart figures where the systems are displayed in the same order as they are listed in Tables 1, 2,
and 3. We display in Figure 1(a) V442 Oph and (b) SW Sex. The WD model flux is denoted by a dotted line, the accretion disk model flux alone by a dashed line and the combined flux by the solid line.

1. **V442 Oph.** The observation of V442 Oph was made when its $V$ magnitude was 13.7 as indicated by the FES magnitude measured with *IUE*. This is 1.1 mag fainter than its visual magnitude in the high state and 0.3 mag brighter than its typical low state visual magnitude of 14.0 although it has been observed as faint as 15.5. Given this brighter low state, it may not be surprising that Puebla et al. (2007) predicted a WD flux contribution. With the system inclination and WD mass constrained by the range of values published in the literature (see Table 1) and the distance of 183 pc, the best fit (see Figure 1(a)) is a combination of an accretion disk model with $i = 75^\circ$, $M_{wd} = 0.4 M_\odot$ with an accretion rate $1 \times 10^{-8} M_\odot$ yr$^{-1}$ and a WD with $\log g = 7$, $T_{eff} = 23,000$ K but only a modest improvement in the fit over a disk alone. Puebla et al. (2007) derived a mass transfer rate of $3 \times 10^{-9} M_\odot$ yr$^{-1}$ for 130 pc. However, Shafter & Szkody (1983) derived $1.0 \times 10^{-8} M_\odot$ yr$^{-1}$ from three *IUE* spectra which had essentially the same flux level as SWP14731 and the same *IUE* FES magnitudes at the time their spectra were taken.

2. **SW Sex.** We co-added a closely spaced time series of three *IUE* spectra to improve the signal. Puebla et al. (2007) predicted a significant WD contribution. The co-added spectrum was best fitted by a combination of an accretion disk with $M_{wd} = 0.4 M_\odot$, $i = 75^\circ$, an accretion rate of $3 \times 10^{-9} M_\odot$ yr$^{-1}$ and a WD with $\log g = 7$, $T_{eff} = 21,000$ K for a distance of 357 pc and $\chi^2 = 9.86$. This combined fit (see Figure 1(a)) agrees with the accretion rate value derived by Puebla et al (2007).

3. **AH Men.** AH Men is normally at $V = 13.2$ but has been observed as faint as $V = 14$. There are several high state spectra and two low state spectra. Mouche et al. (1996) estimated the reddening to be $E(B-V) = 0.12$ and derived an accretion rate of $3 \times 10^{-9} M_\odot$ yr$^{-1}$ using standard black body accretion disk models. We modeled one of the highest flux level *IUE* spectra (SWP41399), displayed in Figure 2(a).

4. **HL Aqr.** This low inclination object, PHL227, is virtually a twin of V3885 Sgr in both the optical and the FUV (Hunger et al. 1985). The $H\alpha$ line of HL Aqr shows significant blueshifted absorption modulated at the orbital period. While the high inclination SW Sex stars are dominated by emission, HL Aqr and other low inclination SW Sex stars show dominant absorption. Our modeling with the Knigge distance yields an accretion rate of $1 \times 10^{-9} M_\odot$ yr$^{-1}$.

5. **WX Ari.** This is the first time that an accretion rate derived from the *IUE* spectrum has appeared for WX Ari, a definite SW Sex star in D. W. Hoard’s Big List. The inclination is uncertain. Our best fit favors $60^\circ$.

6. **LN UMa.** Listed as a “probable” SW Sex member. This is the first time the *IUE* spectrum and a derived accretion has been published for LN UMa. LN UMa was discovered, like many other nova-likes, as a thick disk CV in the Palomar-Green Survey.

7. **BP Lyn.** The continuum is very steeply rising toward shorter wavelengths. Many strong absorption features are present.

8. **MV Lyr.** The *IUE* archival spectrum was unfortunately not obtained during a high state of MV Lyr but instead an intermediate brightness state. Of ten *IUE* spectra, two were taken during intermediate states and eight during low states. Therefore, we have removed it from the non-SW Sex sample compared in the same orbital period range as the SW Sex stars. However, Linnell et al. (2005) modeled an *HST* spectrum of MV Lyr taken during a high state. They obtained an accretion rate $M = 3 \times 10^{-9} M_\odot$ yr$^{-1}$ for a distance of 505 pc, well within the Knigge et al. distance range. We have included the accretion rate derived from the *HST* STIS spectrum of MV Lyr in its high state in our comparison of SW Sex and non-SW Sex accretion rates.

9. **TT Ari.** There are numerous high state *IUE* archival spectra. TT Ari is listed as a “Possible” SW Sex member on
Figure 2. Flux density versus wavelength plots of IUE archival SWP spectra for (a) BP Lyn, (b) CM Del, (c) AH Men, (d) HL Aqr, (e) WX Ari, and (f) LN UMa. The best-fitting accretion disk model is shown with the thick solid line.

Figure 3. Same as Figure 2 except for (a) UU Aqr, (b) LQ Peg, (c) MV Lyr, (d) TT Ari, (e) VZ Scl, and (f) BZ Cam.

D. W. Hoard’s Big List. It has exhibited positive superhumps during high states and negative superhumps during low states. The WD temperature (39,000 K) is well determined from HST spectral data taken during a low state.

10. VZ Scl. Eclipsing system with optical spectra out of eclipse revealing strong emission lines of the Balmer series, He II and He I.

11. BZ Cam. This nova-like object has highly variable wind outflow, a bow shock nebula, strong, highly variable wind absorption with pronounced P Cygni profiles in C IV, Si IV, and very short timescale line profile variations. The origin of the bow shock nebula remains unclear.

12. CM Del. Puebla et al. obtained \( M = 4 \times 10^{-9} M_\odot \text{ yr}^{-1} \) but the spectrum they analyzed, SWP15280, was in a low to intermediate state with a flux level at 1350 Å of \( 5 \times 10^{-14} \text{ erg cm}^{-2} \text{ s}^{-1} \text{ Å}^{-1} \). They did not use the higher brightness state spectrum, SWP14707, which has a flux level at 1350 Å of \( 1 \times 10^{-13} \text{ erg cm}^{-2} \text{ s}^{-1} \text{ Å}^{-1} \). This is the spectrum we have modeled.
1. **VY Scl.** The orbital period remains uncertain. Puebla et al. (2007) and Hamilton & Sion (2008) derived accretion rates from high state IUE spectra of VY Scl.

The resulting accretion rates of the two groups of nova-likes are compared in Table 4, which shows the system name, orbital period in hours, and accretion rate in $M_\odot$ yr$^{-1}$ for the SW Sex (left three columns) and non-SW Sex (right three columns) systems.

First, we computed the average accretion rates of the 16 SW Sex systems and non-SW Sex systems in this paper within approximately the same orbital period range of 3–4.5 hr, the period range where 27 out 35 SW Sex stars reside (Rodriguez-Gil et al. 2007b). The average accretion rate for the SW Sex systems is $3 \times 10^{-9} M_\odot$ yr$^{-1}$ and for the non-SW Sex systems the average accretion rate is $4 \times 10^{-9} M_\odot$ yr$^{-1}$. Within the uncertainty of our accretion rates, there is no difference in the accretion rates of the two groups. Second, we added five additional nova-likes, two SW Sex systems and three non-SW Sex systems discussed elsewhere but whose accretion rates were determined with the same model grid as used in this paper and with Knigge (2006) distances. This amounted to 10 SW Sex systems and 11 non-SW Sex systems. Once again there is virtually no difference in the average accretion rates. In view of these results, we do not believe that SW Sex systems have higher secular accretion rates than other CVs, specifically the nova-like systems that do not exhibit the SW Sex spectroscopic characteristics and behavior.

### Table 4

| System       | $P_{\text{orb}}$(hr) | $M_\odot$ yr$^{-1}$ | System       | $P_{\text{orb}}$(hr) | $M_\odot$ yr$^{-1}$ |
|--------------|----------------------|---------------------|--------------|----------------------|---------------------|
| V442 Oph     | 2.88                 | $1 \times 10^{-8}$  | LQ Peg       | 2.9                  | $1 \times 10^{-9}$  |
| AH Men       | 3.05                 | $1 \times 10^{-9}$  | MV Lyr$^a$   | 3.19                 | $3 \times 10^{-9}$  |
| SW Sex       | 3.12                 | $3 \times 10^{-9}$  | TT Ari       | 3.3                  | $1 \times 10^{-8}$  |
| HL Aqr       | 3.25                 | $1 \times 10^{-9}$  | V751 Cyg$^b$| 3.47                 | $1 \times 10^{-9}$  |
| WX Ari       | 3.34                 | $1 \times 10^{-9}$  | VZ Scl       | 3.47                 | $5 \times 10^{-9}$  |
| DW UMa$^c$   | 3.65                 | $1 \times 10^{-8}$  | V794 Aql$^d$| 3.6                  | $3 \times 10^{-10}$ |
| LN UMa       | 3.47                 | $3 \times 10^{-10}$ | BZ Cam       | 3.68                 | $3 \times 10^{-9}$  |
| BP Lyn       | 3.67                 | $1 \times 10^{-8}$  | CM Del       | 3.88                 | $1 \times 10^{-8}$  |
| V380 Oph$^b$ | 3.79                 | $1 \times 10^{-9}$  | KR Aur$^d$   | 3.90                 | $7 \times 10^{-9}$  |
| UU Aqr       | 3.93                 | $1 \times 10^{-9}$  | VY Scl       | 3.99                 | $1 \times 10^{-9}$  |
|              |                      |                     | IX Vel$^f$  | 4.65                 | $5 \times 10^{-9}$  |

### References.

$^a$ Limnell et al. (2005).

$^b$ Zimmel et al. (2009).

$^c$ Puebla et al. (2007).

$^d$ Mizusawa et al. (2009).

$^e$ Limnell et al. (2007).

$^f$ Godon et al. (2007).

6. CONCLUSIONS

1. We have examined the accretion rates of nova-like systems of the SW Sex and non-SW Sex subclasses that were derived by the multiparametric optimization method of Puebla et al. (2007). If the two subclasses are compared in the same orbital period range of 3–4.5 hr, then the average accretion rates of the two subclasses are essentially the same, $4 \times 10^{-9} M_\odot$ yr$^{-1}$ for the SW Sex systems and $3 \times 10^{-9} M_\odot$ yr$^{-1}$ for the non-SW Sex systems. If the average accretion rates of the two groups are computed with no restriction on the orbital periods of the two groups, then the SW Sex systems have $M = 5 \times 10^{-9} M_\odot$ yr$^{-1}$ and the non-SW Sex systems have $M = 1 \times 10^{-8} M_\odot$ yr$^{-1}$. Using a different approach, we enlarged the sample of SW Sex and non-SW Sex stars, restricted attention to the orbital period range of 3–4.5 hr, used distances from the method of Knigge (2006), and applied a different methodology for determining accretion rates. We find that the non-SW Sex systems have an average accretion rate $M = 3 \times 10^{-9} M_\odot$ yr$^{-1}$ and the SW Sex systems in the sample also have $3 \times 10^{-9} M_\odot$ yr$^{-1}$. Therefore, based upon two independent methods of deriving accretion rates, that of Puebla et al. (2007) and the approach in this paper with Knigge (2006) distances, we find little evidence to support the suggestion that the SW Sex systems have higher average accretion rates among the nova-like systems, a possibility raised by Rodriguez-Gil et al (2007b). Therefore, it is likely that the SW Sextantis phenomenon, particularly their high optical luminosities, must be attributed to some other factor or characteristic of the systems than higher than average accretion rates. Among these possibilities are magnetic accretion and nuclear burning (Honeycutt 2001; Honeycutt & Kafka 2004). However, this conclusion applies only to the average accretion rates of the two groups. This does not rule out the possibility that the SW Sex phenomenon is exhibited when the accretion flow in a given system has undergone a temporary large increase at the time an observation of a nova-like is obtained, thus leading to the object being observed as an SW Sex star (Groot et al. 2004). We see little to suggest that SW Sex stars have persistently higher than average accretion rates than other nova-likes in the same range of orbital period.

2. Given the high average value of $M$ in nova-likes and the fact that their high states are generally longer in duration than their low states, the rate of accretion onto the underlying WD and hence a higher degree of compressional heating would be expected. Thus, the WD surface temperatures in nova-likes should be higher than in dwarf novae at the same orbital period. This should be true if one accepts a correlation between CV orbital period and $M$ such as shown by Patterson (1984). There is some preliminary evidence that this is the case when one compares the surface temperatures of WDs in nova-like variables to the WDs in dwarf novae (Hamilton & Sion 2008a; Godon et al. 2008a). However, these studies have relied upon the relatively rare situation when the nova-like drops into a deep low state and the WD is exposed to FUV spectroscopic observation. We point out that a number of SW Sex systems have lower orbital inclinations. In these systems, the upper hemisphere of the underlying WD and the inner boundary layer would not be obscured. Unfortunately, we are unable to reliably characterize the WD temperatures in the lower inclination SW Sex systems due to (1) the poor quality FUV spectra, (2) the overwhelming luminosity of the bright (high state) accretion disk, and (3) the lack of FUV spectra down to the Lyman limit (e.g., FUSE) where the flux contribution of a bright accretion disk and hot WD photosphere can be more easily disentangled.

Finally, given the small sample size of exposed WDs in nova-like systems, it is particularly important to catch more nova-like systems in their low states for both ground-based optical and space observations.

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