ABSTRACT. We present the results of a multicomponent synthetic spectral analysis of the archival far ultraviolet spectra of several key nova-like variables including members of the SW Sex, RW Tri, UX UMa, and VY Scl subclasses: KR Aur, RW Tri, V825 Her, V795 Her, BP Lyn, V425 Cas, and HL Aqr. Accretion rates as well as the possible flux contribution of the accreting white dwarf are included in our analysis. Except for RW Tri, which has a reliable trigonometric parallax, we computed the distances to the nova-like systems using the method of Knigge. Our analysis of seven archival IUE spectra of RW Tri at its parallax distance of 341 pc consistently indicates a low mass ($\sim 0.4 M_\odot$) white dwarf and an average accretion rate, $\dot{M} = 6.3 \times 10^{-9} M_\odot$ yr$^{-1}$. For KR Aur, we estimate that the white dwarf has $T_{\text{eff}} = 29,000 \pm 2000$ K, $\log g = 8.4$, and contributes 18% of the far-UV flux, while an accretion disk with accretion rate $\dot{M} = 3 \times 10^{-10} M_\odot$ yr$^{-1}$ at an inclination of 41° contributes the remainder. We find that an accretion disk dominates the far-UV spectrum of V425 Cas but a white dwarf contributes nonnegligibly with approximately 18% of the far-UV flux. For the two high state nova-likes, HL Aqr and V825 Her, their accretion disks totally dominate with $\dot{M} = 1 \times 10^{-9} M_\odot$ yr$^{-1}$ and $3 \times 10^{-9} M_\odot$ yr$^{-1}$, respectively. For BP Lyn we find $\dot{M} = 1 \times 10^{-8} M_\odot$ yr$^{-1}$ while for V795 Her, we find an accretion rate of $\dot{M} = 1 \times 10^{-10} M_\odot$ yr$^{-1}$. We discuss the implications of our results for the evolutionary status of nova-like variables.

1. INTRODUCTION

Nonmagnetic cataclysmic variables (CVs) are short-period binaries in which a late-type, Roche lobe-filling main-sequence dwarf transfers gas onto a rotating, accretion-heated white dwarf (WD). In a nonmagnetic system, the WD does not have a magnetic field strong enough to prevent the formation of an accretion disk. Hence, the gas carrying angular momentum is expected to accrete preferentially onto the equatorial latitudes of the WD and spread rapidly with latitude (Piro & Bildsten 2004; Balsara et al. 2009). For accretion rates below a critical threshold the accretion flow would be so high (hot) that the accretion disk would become fully ionized (Shafter et al. 1986). This critical threshold (Cannizzo et al. 1982; Cannizzo & Wheeler 1984) is given by

$$\dot{M}_{\text{crit}} = 1.38 \times 10^{16} r_1^{2.6} M_1^{0.87} \text{ g s}^{-1}.$$  

For a dwarf nova, a thermal-viscous instability in the disk leads to repetitive (limit cycle-like) disk accretion events in which gravitational energy is released (the dwarf nova outburst) in a few days followed by weeks to months of lower level...
accretion (dwarf nova quiescence) before the disk builds up to trigger the next outburst. If a CV WD accretes enough envelope mass, then every few thousand years to tens of thousands of years (depending upon the WD mass and average accretion rate), a thermonuclear explosion occurs in the WD’s accreted envelope that is identified as the classical nova (CN) outburst.

However, there is a subclass of CVs, known as the nova-like variables, in which the mass-transfer rate tends to be higher and the light of the system is typically dominated by a very bright accretion disk (Warner 1995). The spectra of nova-like variables generally resemble those of CNs that have settled back to quiescence. Yet the nova-like variables have never had a recorded CN outburst, dwarf nova outburst, or any outburst. Hence their evolutionary status is still unclear. 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 covers a broad range above the upper boundary of the CV period gap. Within the CV period gap between orbital periods of two and three hours, very few CVs are found.

The nova-like variables comprise a number of subclasses with differing photometric and spectroscopic behavior. The various subclasses of nova-like variables are defined in Warner (1995). Some nova-likes (classified as the VY Sculptoris systems) exhibit the behavior of being in a high optical brightness state for most of the time but unpredictably plummet 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 accretion, sometimes referred to as dwarf novas stuck in permanent outburst (Warner 1995). It is widely assumed that the absence of dwarf novas outbursts in nova-likes is explained by their mass-transfer rates being above the critical threshold where 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). However, in recent years, a number of authors (e.g., Borges & Baptista 2005; Baptista et al. 2007) have presented evidence questioning the validity of the DIM.

Still another nova-like subclass, this one spectroscopically defined, is the SW Sextantis stars, which display a multitude of observational characteristics: orbital periods between 3 and 4 hr, one third of the systems noneclipsing and two-thirds showing deep eclipses of the WD by the secondary, single-peaked emission lines despite the high inclination, high excitation spectral features including He II (4686) emission and strong Balmer emission on a blue continuum, high velocity emission S waves with maximum blueshift near phase \(-0.5\), delay of emission line radial velocities relative to the motion of the WD, and central absorption dips in the emission lines around phase \(-0.4–0.7\) (Rodríguez-Gil et al. 2007a; Hoard et al. 2003). The WDs in many, if not all, of these systems are suspected of being magnetic (Rodríguez-Gil et al. 2007b). Because 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 (Rodríguez-Gil et al. 2007b).

The time-averaged accretion rates of all subtypes of nova-like variables must be known in order to understand their secular evolution and to compare their accretion rates with each other and with the various classes of dwarf novas. These will in turn shed light on the evolutionary properties, including the possible relation to supersoft sources and Type Ia supernovas. In this article, we use synthetic spectra of accretion disks and WD photospheres to carry out analyses of the previously unmodeled far-UV spectra of seven nova-like variables with a special focus on determining their accretion rates. Two of the best-observed nova-likes, KR Aur and RW Tri, each have relatively good quality far-UV coverage. RW Tri in particular also has an accurate trigonometric parallax. These two objects together with V825 Her, V795 Her, BP Lyn, V425 Cas, and HL Aqr represent three different subclasses of nova-like systems. Four of the systems, BP Lyn, V795 Her, HL Aqr, and RW Tri, are also classified as SW Sextantis systems, while HL Aqr and RW Tri are also classified as UX UMa systems. Two of the nova-like systems, KR Aur and V425 Cas, are classified as VY Sculptoris systems. We briefly describe their presently known overall properties.

### 1.1. KR Aur

This nova-like system is classified as a VY Scl subtype with high states at magnitude 12.7 and the deepest low state being 17.9 (Ritter & Kolb 2003, edition 7.12). The system underwent a deep minimum during 1994–1995 when optical spectra revealed emission lines possibly indicative of a disk still being present (Antov et al. 1996). The minimum lasted eight months. However, usually the system brightness is magnitude 12–14 with 13.5 being the most typical brightness. KR Aur is one of six out of 23 VY Scl nova-likes that have negative superhumps. Negative superhumps may arise when a disk becomes tilted due to intense radiation from a very hot WD and thus could be an indirect indicator of nuclear burning (Kozhevnikov 2007). The other systems with negative superhumps are V442 Oph, DW UMa, TT Ari, and V751 Cyg. The orbital inclination is low with an upper limit of 38° and a lower limit of 10° (Ritter & Kolb 2003). The orbital period is 0.1628 days. The WD mass has been estimated to be in the range of 0.59–0.17 M\(_\odot\) (Ritter & Kolb 2003).
1.2. RW Tri

This very bright eclipsing nova-like variable \((V = 12.5)\) is classified as both an SW Sex star and a UX UMa system because it has never been observed to go into a low brightness state. It has an accurate Hubble FGS trigonometric parallax of \(341.98^\circ\) \([-38, -41]\) pc (McArthur 1999), and a moderately high orbital inclination of \(70.5 \pm 2.5^\circ\) (Sma\(k, 1995\)). The component masses given in Ritter & Kolb (2003, update 7.12) are \(M_{\text{wd}} = 0.45 \pm 0.15 M_\odot\) and a secondary mass of \(0.63 \pm 0.1 M_\odot\) while Poole et al. (2003) found \(M_{\text{wd}} = 0.55 \pm 0.15 M_\odot\) and \(M_2 = 0.35 \pm 0.05 M_\odot\).

1.3. V825 Her

This thick disk object, discovered as PG1717 + 413, is a luminous, nova-like CV classified as a UX UMa-type nova-like variable (Ferguson et al. 1984; Ringwald et al. 2005), as though it were a dwarf nova stuck in outburst continuously. There is no evidence of coherent optical pulsations expected for a magnetic accretor and only very weak He II, whereas He II is typically strong in magnetic CVs. No physical parameters were previously determined for V825 Her (Ritter & Kolb 2003). Its WD mass, orbital inclination, and accretion rate are unknown. Ringwald et al. (2005) reported no spectroscopic trace of the secondary star in their optical spectra thus suggesting relatively high luminosity and mass-transfer rate.

1.4. V795 Her

V795 Her is an SW Sex-subtype nova-like variable (Casares et al. 1996) that has an uncertain classification as an intermediate polar (it shows a coherent X-ray period that could be from a nonsynchronously spinning, magnetized WD and is a strong X-ray source). It exhibits a highly variable line spectrum with a periodicity seen in \(IUE\) spectra (4.8 hr) that was mistakenly identified with its orbital period and a continuum steeply rising toward short wavelengths. The correct orbital period appears to be 2.6 hr. Rosen et al. (1998) found the 2.6 hr orbital signature in the UV lines detected on \(HST\) FOS (\(Hubble Space Telescope\) Faint Object Spectrograph) time series spectra. Nevertheless, there is still some uncertainty associated with the origin of both detected periodicities. No eclipses have been observed. There is possibly a \(P\) Cygni profile at C IV.

1.5. BP Lyn

BP Lyn (PG0859 + 4150) is a low-inclination SW Sex-type nova-like variable where the WD primary is not eclipsed by the secondary star (Hoard & Szkody 1996). There is a shallow V-shaped eclipse suggesting an eclipse of a hot spot in the system around 0.9 phase. There are high excitation emission lines, and the high Balmer lines have broad absorption wings, characteristic of an optically thick accretion disk. The \(H\alpha\) emission line radial velocity lags the expected position for the location of the accretion disk at phase 0.4–0.5. Most of the radiation appears to emanate from the opposite side of the disk from the hot spot location. Hoard & Szkody (1996) invoke an enhanced thickness line absorption region at the edge of the disk at phases 0.6–0.9.

1.6. V425 Cas

V425 Cas is a VY Scl-type nova-like variable viewed at low inclination (Ritter & Kolb 2003). Its far-UV flux level and absence of \(P\) Cygni profiles indicate that V425 Cas was in an intermediate brightness state when it was observed with the \(IUE\) telescope (Szkody 1985). The \(IUE\) FES (fine error sensor) optical magnitude at the time of the \(IUE\) observation (see the following) was \(V = 16\) while in its deepest low state V425 Cas has \(V = 18\), thus confirming the intermediate state. Kato et al. (2001) discovered large amplitude oscillations with a 2.65 day period that they attribute to suppression of a disk instability by irradiation. If the variation were really due to a dwarf nova type instability, then this object could be transitional between a VY Scl system and an ultrashort outburst period dwarf nova. If that were the case, this would be the shortest recurrence time for dwarf nova outbursts ever seen in an H-rich CV (Hunger et al. 1985).

1.7. HL Aqr

HL Aqr (PHL227) is a UX UMa-type nova-like variable (Downes et al. 1995) with a highly variable optical spectrum and is also classified as an SW Sextantis member. It has a reddening value \(E(B - V) = 0.05\), but the WD mass and accretion rate are unknown. Rodríguez-Gil et al. (2007b) estimate that HL Aqr has an orbital inclination in the range \(19 < i < 27\), which is much lower than that of the emission-dominated, non-eclipsing SW Sex stars \((i \sim 60-70)\). This suggests the possibility of many low-inclination nova-likes actually being SW Sex stars but with a very different spectroscopic appearance as they show significant absorption rather than being emission line dominated (Rodríguez-Gil et al. 2007b). HL Aqr is a virtual spectroscopic twin of V3885 Sgr (Haefner & Schoembs 1987, and references therein). It shows pronounced irregular variations and coherent rapid oscillations with a period of 19.6 s.

In order to constrain the synthetic spectral fitting and try to reduce the number of free parameters, we carried out a thorough search of the published literature for the most accurately known system parameters. This included the compilations in Ritter & Kolb (2003) and the Goettingen CV Cat Web site, as well as publications documented in the Astrophysics Data Service. The most critical parameter for the model fitting, the distance, is one of the least known. Unlike dwarf novas, which reveal 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 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) although caution
should be exercised because for some nova-like systems
(e.g., TT Ari), the method appears to break down. For each sys-
tem, we obtained the $J$, $H$, and $K$ apparent magnitudes from
2MASS photometry. For a given orbital period, Knigge
(2006) provides absolute $J$, $H$, and $K$ magnitudes based upon
his semiempirical 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 remainder being accretion light), then an approximate
upper limit is obtained. The latter limit is a factor of 1.75 times
the lower limit distance. The adopted distances used as con-
straints in the synthetic spectral fitting procedure are given in
Table 1, where we list the adopted parameters for the orbital
period (hours), the apparent $V$ magnitude, the inclination $i$ (°), the WD mass ($M_\odot$), the interstellar reddening,
$E(B-V)$, and the distance or distance range in parsecs.

2. FAR ULTRAVIOLET SPECTROSCOPIC
OBSERVATIONS

All the spectral data obtained from the Multimission Archive
at Space Telescope (MAST) IUE archive are in a high activity
state, very near or at outburst. We restricted our selection to
those systems with SWP spectra, with 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 coadded or the two best spectra were analyzed.
In Table 2, an observing log of the IUE archival spectra is pre-
sented in which, by column, (1) lists the SWP spectrum number,
(2) the aperture diameter, (3) the exposure time in seconds, (4)
the date of the observation, (5) the continuum to background
counts, and (6) the brightness state of the system. Transition
refers to an intermediate state between the highest optical
brightness state and the deepest low state.

The activity state corresponding to each spectrum was deter-
mined by examining the AAVSO (American Association of Vari-
able Star Observers) light curves as well as the flux level of the
IUE spectrum that typically made it obvious that the spectrum
was obtained in a high state or an intermediate 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 FES
measurements at the time of the IUE observation. The FES
counts, when available, can be converted to optical magnitudes
to help ascertain the brightness state at the time of the IUE
observation. In addition, the presence of $P$-Cygni profiles,

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| Table 1: Nova-like System Parameters |
|--------------------------------------|
| System     | $P_{orb}$ (hours) | $V$ Range | $i$ (°) | $M_{bol}$ ($M_\odot$) | $E(B-V)$ | $d_{Knigge}$ (pc) |
| KR Aur     | 3.907             | 11.3–16.9 | 3.8 ± 10 | 0.59 ± 0.17 | 0.05     | 779–1362          |
| RW Tri     | 5.57              | 12.5–15.6 | 70.5 ± 2.5 | 0.55 ± 0.15 | 0.10     | 204–357           |
| V825 Her   | 4.944             | 14.1–     | —         | —           | —        | 380–665           |
| V795 Her   | 2.598             | 12.7–16.9 | —         | —           | —        | 115–202           |
| BP Lyn     | 3.741             | 14.5–17.2 | 79.8 ± 5  | —           | —        | 251–440           |
| V425 Cas   | 3.590             | 14.5–18   | 25 ± 9    | 0.86 ± 0.32 | —        | 282–494           |
| HL Aqr     | 3.25              | 13.4–13.6 | 18        | —           | 0.05     | 174–304           |

| Table 2: IUE Observing Log |
|----------------------------|
| System | SWP | $t_{exp}$ | Dispersion | Aperture | Date of Observation | State  |
|-----------------|-------|------------|------------|----------|---------------------|--------|
| KR Aur          | 13584 | 1920       | LOW        | Lg       | 1981 Mar 26         | High   |
| RW Tri          | 07915 | 9000       | LOW        | Lg       | 1980 Feb 11         | High   |
| RW Tri          | 10135 | 7500       | LOW        | Lg       | 1980 Sep 15         | High   |
| RW Tri          | 16037 | 5400       | LOW        | Lg       | 1982 Jan 13         | High   |
| RW Tri          | 16041 | 5000       | LOW        | Lg       | 1982 Jan 14         | High   |
| RW Tri          | 16064 | 7200       | LOW        | Lg       | 1982 Jan 18         | High   |
| RW Tri          | 17617 | 3000       | LOW        | Lg       | 1982 Aug 7          | High   |
| RW Tri          | 17621 | 3500       | LOW        | Lg       | 1982 Aug 7          | High   |
| V825 Her        | 17353 | 3600       | LOW        | Lg       | 1992 Aug 13         | High   |
| V795 Her        | 45334 | 3600       | LOW        | Lg       | 1988 Feb 18         | High   |
| BP Lyn          | 32940 | 7200       | LOW        | Lg       | 1988 Feb 18         | High   |
| V425 Cas        | 14735 | 6900       | LOW        | Lg       | 1981 Aug 12         | Intermediate |
| HL Aqr          | 23325 | 3600       | LOW        | Lg       | 1984 Jun 24         | High   |
absorption lines, and a comparison with spectral data and flux levels of other systems during different activity states were also used to ascertain or confirm the brightness state of the system. The reddening of the systems was taken from estimates listed in the literature, usually determined from the strength of the 2200 Å interstellar absorption feature if present. The three principal sources of reddening were the compilations of Verbunt (1987), LaDous (1991), and Bruch & Engel (1994). The IUE spectra were dereddened with the IUERDAF (International Ultraviolet Explorer Regional Data Analysis facility) IDL routine UNRED.

3. 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 because 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 the SWP far-UV bandpass. The mass-transfer rate is assumed to be the same for all radii.

Theoretical, high gravity, photospheric spectra were computed by first using the code TLUSTY (Hubeny 1988) to calculate the atmospheric structure and SYNSPEC (Hubeny & Lanz 1995) to construct synthetic spectra. We compiled a library of photospheric spectra covering the temperature range from 15,000–70,000 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, we determined separately for each spectrum, the best-fitting WD-only models and the best-fitting disk-only models using IUEFIT, a \( \chi^2 \) minimization routine. A \( \chi^2 \) value and a scale factor were computed for each model fit. The scale factor, \( S \), normalized to a kiloparsec and solar radius, can be related to the WD radius \( R \) through \( F_{\lambda(\text{obs})} = S H_{\lambda(\text{model})} \), 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. We combined WD models and accretion disk models using a \( \chi^2 \) minimization routine called DISKFIT. Using this method the best-fitting composite WD plus disk model is determined on the basis of the minimum \( \chi^2 \) value achieved, visual inspection of the model consistency with the continuum slope and Ly\( \alpha \) region, and consistency of the scale factor-derived distance with the adopted Knigge (2006) distance for each system. Based upon formal error analyses carried out on synthetic spectral fitting of IUE spectra having comparable quality to the spectra studied here (e.g., Winter & Sion 2003), we estimate that our accretion rates are accurate to within a factor of 2–3.

3.1. KR Aur

Its two far-UV spectra are dominated by absorption features due to metals with the strongest features due to N\( V \) (1240), Si\( III \) (1300), C\( II \) (1335), and Si\( IV \) (1400). Of the two SWP spectra, SWP 13584 has a slightly higher flux level and a better signal-to-noise ratio. At the time the IUE spectra were taken, the system had an FES visual magnitude of 13.3 that is close to its most typical optical brightness of 13.5 but fainter than its highest brightness state at 12.5. There are no \( P-Cygni \) profiles indicating wind outflow. We find that neither an accretion disk alone nor a WD photosphere alone provides a satisfactory fit to the observed continuum slope and absorption spectrum of KR Aur. However, we found that a statistically significant improvement (lower \( \chi^2 \)) in the fitting was evident when we combined an accretion disk model with a WD model. We find that the optimal combination for KR Aur consists of an accretion disk model with a WD mass of \( 0.55 \, M_\odot \), an inclination angle \( i = 41^\circ \), and an accretion rate of \( 3 \times 10^{-10} \, M_\odot \, \text{yr}^{-1} \) together with a WD photosphere model with \( T_{\text{eff}} = 29,000 \pm 2000 \, \text{K} \), \( \log g = 8 \), for a distance of 204 pc. This best combination fit to the IUE spectrum of KR Aur is displayed in Figure 1. In this fit, the accretion disk provides 82% of the far-UV flux and the WD contributes 18% of the flux.

3.2. RW Tri

Between February 1980 and August 1982, 12 far-UV SWP spectra were obtained with the IUE. These spectra can be characterized by prominent emission lines of Ly\( \alpha \), N\( V \) (1240),
Fig. 2.—The best-fitting accretion disk models to the IUE SWP spectra of the SW Sextantis-type nova-like system RW Tri during its high state. The seven panels from top to bottom are for spectra SWP07915, SWP10135, SWP16037, SWP16041, SWP16064, SWP17617, and SWP17621, respectively. The average accretion rate over the best disk model fits to the seven spectra corresponds to $M = 6.3 \times 10^{-9} \ M_\odot \ yr^{-1}$, $i = 75^\circ$, and $M_{\text{wd}} = 0.4 \ M_\odot$. 

2010 PASP, 122:299–308
Si IV (1400), and C IV (1550) with weaker emission components at C III (1175), O III (1590), and He II (1640). However, absorption features are also seen at Si II (1264), Si III (1303), Si IV (1393, 1402), C II (1721), and unidentified absorption features at 1655 Å, 1670 Å, and 1710 Å. The continuum flux level among the 12 spectra remains fairly constant. However, some of the spectra are quite noisy and thus unusable for our analysis. In Table 2, we list the IUE spectra suitable for our analysis, their exposure times, aperture size, dispersion, date of observation, and the brightness state of the system at the time the IUE spectrum was obtained. On the basis of the seven most suitable IUE spectra for model analysis, we have found the best-fitting accretion disk models for the parallax distance of 340 pc to have inclination angles ranging from 60° to 75° and in all seven spectra, a corresponding WD mass of 0.4 M☉. The accretion rate of RW Tri, averaged over the seven spectra, is 6 × 10⁻¹⁰ M☉ yr⁻¹. The best-fitting solution to each IUE spectrum is displayed in Figures 2a–2g for spectra SWP07915, SWP10135,
Moreover, the spectra, to our knowledge, have never been analyzed with actual disk and photosphere models. For our adopted distance of 159 pc, we found the best-fitting accretion disk model to have $M_{\text{wd}} = 0.8 \, M_\odot$, inclination $i = 41^\circ$, and $M = 10^{-10} \, M_\odot \, \text{yr}^{-1}$. This best-fit disk model is displayed in Figure 4.

### 3.5. BP Lyn

The IUE line spectrum is dominated by a strong C III (1175) emission line and markedly variable absorption features at N V (1240), Si III + O I (1300), C II (1335), possible O V (1371), Si IV (1393, 1402; both components resolved), C IV (1548, 1551, some spectra in P-Cygni structure; some spectra no C IV present), possible He II (1640), N IV (1718), and Al III (1854, 1862). The IUE spectrum itself (SWP32940) has a signal-to-noise ratio of about 3:1. In Figure 5, we display our best-fitting optically thick steady state accretion disk model to BP Lyn’s IUE spectrum and derive an accretion rate of $10^{-8} \, M_\odot \, \text{yr}^{-1}$ for our distance of 344 pc.

### 3.6. V425 Cas

The low flux level is consistent with an intermediate to low brightness state and definable continuum but the signal-to-noise ratio is insufficient to identify any lines with certainty. There is a strong emission feature at 1660 Å and a possible emission feature at C IV (1550) but no other line features are clearly identifiable. With our adopted distance of 278 pc, we find that the best-fitting accretion disk model corresponds to $M_{\text{wd}} = 0.8 \, M_\odot$, $i = 75^\circ$, and an accretion rate $M = 1 \times 10^{-10} \, M_\odot$. This best-fitting solution is displayed in Figure 6. Szkody (1985) using Williams & Ferguson (1982) models found $M = 1 \times 10^{-10} \, M_\odot \, \text{yr}^{-1}$ while the Patterson (1984) $P_{\text{orb}}$ versus $M$ relation yields $5 \times 10^{-10} \, M_\odot \, \text{yr}^{-1}$. Using the Hβ equivalent widths and Patterson’s relation, we get $M = 10^{-10} \, M_\odot \, \text{yr}^{-1}$, which is in agreement with our far-UV-derived value.

### 3.7. HL Aqr

The far-UV spectrum of this UX UMa system is characteristic of the UX UMa systems viewed at low orbital inclination. Strong wind absorption features of C IV (1550); in P-Cygni structure), Si IV (1400), and N V (1240) are seen along with

#### TABLE 3

| System   | $M_{\text{wd}}$ ($M_\odot$) | $i$ (°) | $d_{\text{disk}}$ (pc) | $M$ ($M_\odot \, \text{yr}^{-1}$) | $\chi^2$ |
|----------|-----------------------------|--------|------------------------|-------------------------------|---------|
| KR Aur   | 0.55                        | 41     | 204                    | $3 \times 10^{-10}$          | 7.65    |
| RW Tri   | 0.35                        | 75     | 341                    | $6.3 \times 10^{-9}$         | -       |
| V825 Her | 0.35                        | 18     | 500                    | $3 \times 10^{-9}$           | 1.87    |
| V795 Her | 0.80                        | 41     | 159                    | $1 \times 10^{-10}$          | 3.47    |
| BP Lyn   | 0.35                        | 75     | 344                    | $1 \times 10^{-8}$           | 2.81    |
| V425 Cas | 0.80                        | 75     | 278                    | $1 \times 10^{-10}$          | 4.29    |
| HL Aqr   | 0.35                        | 18     | 213                    | $1 \times 10^{-9}$           | 4.99    |
absorption due to C III (1175), Si III + O I (1300), C II (1335), and He II (1640). For the Knigge (2006) distance of 213 pc, our best-fitting disk model, shown in Figure 7, indicates a low mass WD ($\sim$0.4 M$_\odot$), a low disk inclination angle of 18°, and an accretion rate of $1 \times 10^{-9}$ M$_\odot$ yr$^{-1}$.

In Table 3, we summarize the best-fitting parameters of this selected sample of nova-like variables where the entries by column are (1) the system name, (2) WD mass, (3) inclination angle, (4) best-fitting model distance in parsec, (5) M (M$_\odot$ yr$^{-1}$), and (6) minimum $\chi^2$ value.

4. CONCLUSIONS

For the VY Sculptoris nova-like KR Aur, we find that combinations of models consisting of a hot WD and an optically thick accretion disk provides a significantly improved model fit to its far-UV spectrum compared with fits utilizing an accretion disk alone or a WD photosphere alone. The best-fitting model is a combination of a WD with $T_{\text{eff}} = 29,000 \pm 2000$ K, log $g = 8.4$, contributing 18% of the far-UV flux, and an accretion disk with accretion rate $M = 3 \times 10^{-10}$ M$_\odot$ yr$^{-1}$ at an inclination of 41°, contributing 82%. Our results are broadly consistent with the analysis of Puebla et al. (2007) who applied a multiparametric optimization fitting method to KR Aur. They explored a range of WD masses 0.4–0.8 M$_\odot$, inclinations $i = 30–50$, and an adopted Patterson (1984) distance of $d = 180$ pc. They found an accretion rate $M = 4.5 \times 10^{-10}$ M$_\odot$ yr$^{-1}$, which is atypically low for a VY Scl nova-like variable in its high state. Moreover, Puebla et al. (2007) found that KR Aur should have a significant flux contribution of a hot WD in addition to an accretion disk. Our results are not inconsistent with their reported analysis.

Further, the distance implied by our best-fitting model solution is similar to the Patterson (1984) distance used by Puebla et al. (2007). Thus, KR Aur represents a second case (TT Ari being the other) of a nova-like variable whose distance using Knigge’s method yields a large disagreement with existing distance estimates from other methods. Taking the temperature of the WD indicated by our solution at face value, then the WD temperature (29,000 K) would be cooler than other WDs of known temperature in VY Scl systems. For example, the WD in TT Ari has $T_{\text{eff}} = 39,000$ K, in MV Lyra 47,000 K, and in DW UMa, 49,000 K. It is unfortunate that a Far Ultraviolet Spectroscopic Explorer (FUSE) spectrum of KR Aur was not obtained because this would provide a definitive check on the WD temperature.

Our analysis of seven archival IUE spectra of the SW Sextantid nova-like-like RW Tri using its parallax distance consistently yields a low mass ($\sim$0.4 M$_\odot$) WD and an average accretion rate, $M = 6.3 \times 10^{-9}$ M$_\odot$ yr$^{-1}$. On the other hand, Puebla et al. (2007), using their statistical fitting solution, constrained the WD mass to be in the range 0.4–0.8 M$_\odot$, and the inclination angle between 60° and 80° for the fixed distance of 340 pc. Our modeling strongly favors a low mass WD ($M_{\text{wd}} < 0.6$ M$_\odot$). Our low WD mass also favors the low end of the most likely mass range (0.4–0.7 M$_\odot$) estimated by Poole et al. (2003). A comparison of our accretion rate with other derived accretion rates for RW Tri reveals it is lower than the value $10^{-8}$ M$_\odot$ yr$^{-1}$ determined by Groot et al. (2004) but agrees with the accretion rate of $4.7 \times 10^{-8}$ M$_\odot$ yr$^{-1}$ derived independently by Puebla et al. (2007). However, our accretion rate is a factor of 2 larger than the accretion rate published by Rutten et al. (1992) from eclipse mapping and a factor of 10 smaller than the accretion rate of Horne & Steining (1985), also derived from eclipse mapping.

Our model analysis of the UX UMa system V825 Her reveals an accretion rate of $3 \times 10^{-9}$ M$_\odot$ yr$^{-1}$ with a low-inclination angle (18°) and a low WD mass ($M_{\text{wd}} < 0.6$ M$_\odot$). For UX UMa systems, which are stuck in permanent outburst, this high accretion rate is not unreasonable. Likewise for HL Aqr, another UX UMa systems, our best-fit model indicates a low mass WD, a low-inclination angle but with an accretion rate $\times 10^{-9}$ M$_\odot$ yr$^{-1}$, a factor of 3 lower than V825 Her. Because HL Aqr is considered a spectroscopic twin of V3885 Sgr, we note that a likely FUSE + HST STIS (Space Telescope Imaging Spectrograph) detection of the hot accreting WD with $T_{\text{eff}} = 57,000$ K in the UX UMa system, V3885 Sgr, by Linnell et al. (2009), raises the possibility of an object with similar surface temperature being present in the UX UMa system HL Aqr.

For BP Lyn we find a high accretion $M = 1 \times 10^{-8}$ M$_\odot$ yr$^{-1}$. Hoard & Szkody (1996) commented that the continuum slope is consistent with that of an accretion disk-only although no detailed accretion disk model with vertical structure was applied to the data. It is clear from Hoard & Szkody (1996) that BP Lyn is a bona fide SW Sex member and appears to be a low-inclination analog of RW Tri (Still et al. 1995).

Finally, for V425 Cas, based upon a single IUE spectrum of this VY Scl system taken during an intermediate brightness state, we find that an accretion disk dominates its far-UV spectrum but with a nonnegligible contribution from a hot WD. Our derived accretion rate of $M = 1 \times 10^{-10}$ M$_\odot$ yr$^{-1}$ is lower than typical accretion rates of nova-like during high brightness states that appears consistent with V425 Cas being an intermediate brightness state. Szkody (1985) using Williams & Ferguson (1982) models found $M = 1 \times 10^{-9}$ M$_\odot$ yr$^{-1}$ while the Patterson (1984) $P_{\text{orb}}$ versus M relation yields $5 \times 10^{-10}$ M$_\odot$ yr$^{-1}$. Using the H$\beta$ equivalent widths and Patterson’s relation, $M = 10^{-10}$ M$_\odot$ yr$^{-1}$, this is in agreement with our far-UV-derived value.

Ballouz & Sion (2009) applied multicomponent modeling to the archival far-UV spectra of nova-like variables that are members of the SW Sextantid subclass and those that are not classified as members. They found no difference between the average derived accretion rates of SW Sex members and non-SW Sex members. The present study adds the modeling of 7 nova-like systems to the sample of 15 nova-like systems analyzed by Ballouz & Sion (2009), 23 nova-like systems analyzed by Puebla et al. (2007),

2010 PASP, 122:299–308
and 3 nova-likes analyzed by Zellem et al. (2009). The nova-like systems in the present study represent a mix of different sub-classes (UX UMa-type, VY Scl-type, and SW Sex-type) whose archival far-UV spectra have been compared, typically for the first time, with reasonably realistic models of accretion disks and photospheres. All but one had far-UV spectra taken in their high brightness states.

The accretion rates we have derived in this article are only as good as the distances we have adopted. The method of Knigge (2006) represents the best handle we presently have on the distances to nova-like variables. Because any derived accretion rates depend very sensitively upon distance, precision trigonometric parallaxes from the ground and from space (e.g., Gaia) are required to determine the most accurate accretion rates for the different subtypes of nova-like variables. In the meantime, more nova-like parallaxes are needed from the ground and with the fine guidance sensor (FGS) on HST.

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