A NEW, BRIGHT, SHORT-PERIOD, EMISSION LINE BINARY IN OPHIUCHUS

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ABSTRACT

The 11th magnitude star LS IV −08 3 has been classified previously as an OB star in the Luminous Stars survey, or alternatively as a hot subdwarf. It is actually a binary star. We present spectroscopy, spectroscopic orbital elements, and time-series photometry from observations made at the Kitt Peak National Observatory 2.1 m, Steward Observatory 2.3 m, MDM Observatory 1.3 m and 2.4 m, Hobby–Eberly 9.2 m, and Michigan State University 0.6 m telescopes. The star exhibits emission of varying strength in the cores of H and He i absorption lines. Emission is also present at 4686 Å (He ii) and near 4640/4650 Å (N iii/C iii). Time-series spectroscopy collected from 2005 July to 2007 June shows coherent, periodic radial velocity variations of the H α line, which we interpret as orbital motion with a period of 0.1952894(10) days. High-resolution spectra show that there are two emission components, one broad and one narrow, moving in antiphase, as might arise from an accretion disk and the irradiated face of the mass donor star. Less coherent, low-amplitude photometric variability is also present on a timescale similar to the orbital period. Diffuse interstellar bands indicate considerable reddening, which however is consistent with a distance of ∼100–200 pc. The star is the likely counterpart of a weak ROSAT X-ray source, whose properties are consistent with accretion in a cataclysmic variable (CV) binary system. We classify LS IV −08 3 as a new member of the UX UMa subclass of CV stars.

Key words: binaries: close – novae, cataclysmic variables – stars: emission-line, Be – stars: individual (LS IV-08 3) – stars: variables: other

Online-only material: color figure

1. INTRODUCTION

The star LS IV −08 3 has V = 11.475, (B − V) = +0.190 (Reed & Niemczak 2000), and was first classified “OB” in the Luminous Stars in the Northern Milky Way catalog (Nassau & Stephenson 1963). Later it was reclassified “sdB” by Kilkenny & Busse (1992) based on Reticon spectrograms and Strömgren photometry. Additional photometry of this object is available in the literature (Reed et al. 1998; Reed 1998; Reed & Niemczak 2000), but no additional spectroscopic observations have been reported. Astrometric and photometric data for this star, collected from the literature, are reported in Table 1.

We obtained spectra of LS IV −08 3 as part of our program on composite spectrum hot subdwarf stars (Stark & Wade 2003, 2005, 2006; Stark 2005), owing to its unusually red V − K s and J − K s colors as observed in the Two Micron All Sky Survey (2MASS; Skrutskie et al. 2006). We found that LS IV −08 3 exhibits broad absorption lines with core emission, which is variable in both strength and profile shape. We obtained time-series photometry and additional spectroscopy in order to correctly classify this star.

2. OBSERVATIONS

2.1. Low-Dispersion Spectra

2.1.1. Kitt Peak National Observatory 2.1 m Telescope

LS IV −08 3 was observed from the Kitt Peak National Observatory (KPNO) 2.1 m telescope using the GoldCam spectrograph during 2003 June and September. A journal of observations is given in Table 2. All exposures were between 5 and 20 min long. Two different spectrograph configurations were used, which covered approximately 4600–6750 Å and 6400–8900 Å at ∼1.3 Å pixel−1. The features observed in the GoldCam spectra include broad absorption lines with emission cores in Hα, Hβ, and He i 5875 Å; emission from He i 6678 Å, He ii 4685 Å, and N iii/C iii ∼4640/4650 Å. The emission components were observed to vary in both strength and profile in as little as ∼30 min (Figure 1; see also Section 2.2).

All GoldCam spectra were processed using standard IRAF7 routines. Unfavorable observing conditions prevented reliable flux calibrations on most nights, so we discuss only the normalized spectra. The continua were fitted by hand using splines. The equivalent widths (EWs) of features of interest were measured in each spectrum; the wavelength interval encompassed by each feature was determined by eye, noting where the line deviated from the continuum. For lines with broad absorption wings and

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7 IRAF is distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.
Table 1
Coordinates and Photometry of LS IV−08°3

| Datum | Value | Reference |
|-------|-------|-----------|
| R.A. (J2000) | 16:56:29.62 | 2MASS |
| Decl. (J2000) | −08:34:38.7 | 2MASS |
| μα cos δ (mas yr⁻¹) | −20.2 ± 2.3 | Høg et al. (2000) |
| μδ (mas yr⁻¹) | +8.6 ± 2.5 | Høg et al. (2000) |
| V_r | 11.564 ± 0.114 | Høg et al. (2000) |
| B_r | 11.771 ± 0.081 | Høg et al. (2000) |
| (B − V) | +0.207 ± 0.140 | Høg et al. (2000) |
| E(B − V) | +0.466 | Schlegel et al. (1998) |
| V | 11.475 | Reed & Niemczak (2000) |
| (B−V) | +0.190 | Reed & Niemczak (2000) |
| (V−B) | +0.161 | Reed & Niemczak (2000) |
| V_{sin} | 11.47 | see Section 2.1.4 |
| y | 11.51 | Kilkenny & Busse (1992) |
| (b−y) | +0.027 | Kilkenny & Busse (1992) |
| c1 | +0.072 | Kilkenny & Busse (1992) |
| J | 10.638 ± 0.039 | 2MASS |
| (J−H) | +0.175 ± 0.057 | 2MASS |
| (J−K_S) | +0.350 ± 0.052 | 2MASS |
| (H−K_S) | +0.175 ± 0.053 | 2MASS |

Notes.

a Skrutskie et al. (2006).
b LS IV−08°3 ≡ TYC 5642-627-1.
c Based on one measurement.
d Based on three measurements.

core emission, two EW measurements were made. The first is the total EW of the whole line (absorption and emission included). The second EW refers to just the emission component, measured above the point where the emission emerges from the absorption wings, giving a lower limit for the “true” emission EW. Reported in Table 3 are the average EWs and their formal errors (not including any systematic errors or accounting for variability). Also reported are the number of measurements, their standard deviation, minimum and maximum values, and the difference between the maximum and minimum. (Note that EW > 0 indicates absorption, while EW < 0 indicates emission.)

Significant reddening of this object is evidenced by strong interstellar NaI D lines and several diffuse interstellar bands (DIBs). Schlegel et al. (1998) report total galactic reddening of E(B−V) ≈ +0.48 along the line of sight to LS IV−08°3. The reddening and distance are discussed in Section 3.2.

Figure 1. KPNO 2.1 m Goldcam spectra of LS IV−08°3 showing the variable nature of the emission components at Hβ (top), He I 5875 Å partly blended with interstellar NaI D lines (middle), and Hα/He I 6678 Å (bottom). Dates and times are UT 2003; times correspond to mid-exposure and are heliocentric. Phases corresponding to the ephemeris in Section 2.1.4 are also indicated. Dates that are italicized in parentheses in the bottom panel do not have corresponding data for Hβ and He I 6678 Å. Dotted lines show the laboratory wavelengths of the labeled transitions; the spectra themselves are plotted using observed (topocentric) wavelengths. Several gaps in the spectra result from cosmic ray removal.

Table 2
Journal of GoldCam Observations

| UT date | Instrument setup | λλ range | Exp. time | S/N | λ for S/N |
|---------|-----------------|-----------|-----------|-----|-----------|
|         | Grating | Slit ("") | Filter | (s) | (Å) | (pix⁻¹) | (Å) |
| 2003 Jun 9 | #35... | 1.5 | OG570 | 6390−8930 | 900 | 83 | 7560 |
| 2003 Jun 11 | #35... | 1.5 | OG570 | 6390−8930 | 300 | 120 | 7560 |
| 2003 Jun 14 | #26new... | 1.3 | GG385 | 4600−6730 | 1200/1200 | 300/300 | 5665 |
| 2003 Sep 14 | #26new... | 1.3 | GG385 | 4600−6730 | 450 | 174 | 5665 |
| 2003 Sep 15 | #26new... | 1.3 | GG385 | 4600−6730 | 450 | 127 | 5665 |

Notes.

a Two exposures were taken. The mid-exposure times were separated by 76 min.
b Two exposures were taken. The mid-exposure times were separated by 25 min.
2.1.2. Steward Observatory 2.3 m Telescope

A flux-calibrated spectrum of LS IV−08·3, covering 3620–6895 Å at ~3 Å pixel$^{-1}$ dispersion (~9 Å resolution), was obtained on UT 2002 April 3 at the Bok 2.3 m telescope on Kitt Peak, AZ, using the B&C spectrograph with a thinned, back-illuminated 1200 × 800 Loral CCD. This “pre-discovery” spectrum is shown in Figure 2. It extends to shorter wavelengths than the GoldCam observations, including the Balmer lines up to the series limit. A second spectrum was obtained with the same instrument setup on UT 2007 May 8 and was flux-calibrated in a homogeneous way with the first; the overall spectral energy distribution is very similar, with the flux level differing by about 3%. The H emission lines were weaker in 2007, with the emission reversal in Hγ virtually disappearing and the height of Hα emission above the continuum diminishing by a factor of 2. Kilkenny & Busse (1992) classified LS IV−08·3 as “sdB” based on uvby photometry and 2 Å resolution Reticon spectroscopy covering 3900–4600 Å, so Hβ was not observed, and weak emission in the absorption core of Hγ might easily have been overlooked or even absent. The spectral energy distribution (SED) is quite blue, even despite the reddening evidenced by the DIBs. The SED is further discussed in Section 3.

2.1.3. MDM Observatory 1.3 m and 2.4 m Telescopes

Time-series spectra of LS IV−08·3 were obtained at the MDM Observatory on Kitt Peak, AZ. Table 4 gives a journal of observations. Most of the MDM spectra were obtained using the Mark III spectrograph and a SITE 1024$^2$ CCD detector mounted on the McGraw-Hill 1.3 m telescope. A 600 line mm$^{-1}$ grism gave ~2.3 Å pixel$^{-1}$ dispersion over the range 4660–6900 Å, with a full width half maximum (FWHM) resolution of 4.1 Å. All stellar exposures were bracketed with spectra of Hg, Ne, and Xe comparison lamps, in order to track the spectrograph flexure. (In 2004 June, an attempt was made to use the λ5577 night-sky emission feature to set the wavelength zero point; unfortunately, this did not work well, and those spectra are excluded from the present analysis.)

8 MDM Observatory is operated by a consortium consisting of Dartmouth College, Columbia University, Ohio State University, the University of Michigan, and Ohio University.
A few MDM spectra are from the Hiltner 2.4 m telescope and modular spectrograph, equipped with a SiTe 2048$^2$ CCD; this gave 2 Å pixel$^{-1}$ dispersion from 4300 to 7500 Å, with severe vignetting toward the ends of this range. The spectral resolution of this setup was slightly better than that of the Mark III. Some of these exposures were taken in bright twilight and bracketed with comparison exposures; for those taken away from twilight, the night-sky features were used to find the zero-point shift. Extensive internal checks show that this procedure worked well with this setup. Aliasing related to daily cycle count uncertainties was suppressed by pushing to large hour angles; the target’s brightness made it possible to obtain good signal-to-noise spectra even at large airmass.

Flux standard stars were observed to calibrate the instrument response, when the twilight sky was reasonably clear. Experience suggests that the zero point of the MDM spectra should be accurate to about 20%. Exposures of bright O and B stars were also obtained and used to map and correct for the telluric absorption features.

An average flux-calibrated spectrum was constructed from the 1.3 m data taken in 2005 June and July. Using the IRAF sbands task and the passband tabulated by Bessell (1990), we found a synthetic V magnitude of 11.47. The MDM 1.3 m average spectrum is very similar to the Steward 2.3 m spectrum from 2002 April in the wavelength region common to both, except the overall flux level is about 10% higher, and the emission lines are more evident (the Hβ emission reversal protrudes slightly above the continuum; the He I 6678 line is in emission at about 15% of the intensity of Hα).

### Table 4

| Date (UT) | N | HA start (hh:mm) | HA end (hh:mm) | Telescope |
|-----------|---|------------------|----------------|------------|
| 2005 Jul 2 | 2 | 1:41             | 1:04           | 1.3 m      |
| 2005 Jul 3 | 1 | 1:26             | 1:26           | 1.3 m      |
| 2005 Jul 7 | 5 | 1:35             | 1:14           | 1.3 m      |
| 2005 Jul 8 | 1 | 1:44             | 1:44           | 1.3 m      |
| 2005 Jul 9 | 1 | 1:40             | 1:40           | 1.3 m      |
| 2005 Jul 10 | 1 | 1:48             | 1:48           | 1.3 m      |
| 2005 Jul 11 | 9 | 1:46             | 3:11           | 1.3 m      |
| 2005 Jul 12 | 22 | 1:46             | 3:46           | 1.3 m      |
| 2005 Sep 3 | 5 | 1:27             | 3:29           | 1.3 m      |
| 2005 Sep 7 | 3 | 1:29             | 3:17           | 1.3 m      |
| 2005 Sep 8 | 2 | 1:39             | 3:35           | 1.3 m      |
| 2005 Sep 9 | 9 | 1:26             | 2:27           | 1.3 m      |
| 2005 Sep 12 | 2 | 1:27             | 1:34           | 1.3 m      |
| 2005 Sep 13 | 3 | 1:29             | 1:42           | 1.3 m      |
| 2005 Sep 15 | 4 | 1:38             | 1:57           | 1.3 m      |
| 2006 Jan 17 | 12 | 3:58             | 3:11           | 1.3 m      |
| 2006 Jan 18 | 11 | 3:47             | 3:01           | 1.3 m      |
| 2006 Jan 21 | 9 | 3:20             | 2:46           | 1.3 m      |
| 2006 Mar 16 | 13 | 2:43             | 1:49           | 1.3 m      |
| 2006 Mar 17 | 10 | 0:47             | 0:09           | 1.3 m      |
| 2005 Mar 19 | 1 | 1:21             | 1:21           | 2.4 m      |
| 2005 Jun 29 | 2 | 2:14             | 1:52           | 2.4 m      |
| 2005 Jun 30 | 1 | 2:26             | 2:26           | 2.4 m      |
| 2005 Jul 1 | 1 | 2:21             | 2:21           | 2.4 m      |
| 2005 Sep 3 | 1 | 2:34             | 2:34           | 2.4 m      |
| 2005 Sep 8 | 1 | 1:55             | 1:55           | 2.4 m      |
| 2006 Mar 17 | 1 | 3:13             | 3:13           | 2.4 m      |
| 2006 Jun 20 | 4 | 0:01             | 0:10           | 2.4 m      |
| 2006 Jun 22 | 1 | 1:16             | 1:16           | 2.4 m      |
| 2006 Jun 23 | 1 | 0:43             | 0:43           | 2.4 m      |
| 2006 Sep 1 | 1 | 2:30             | 2:30           | 2.4 m      |

Figure 3. Hα radial velocities used in the analysis, folded on the best-fitting period, with the sinusoidal fit superposed. Crosses: MDM velocities; filled squares: HET-HRS velocities. Two cycles are shown for continuity.

#### 2.1.4. Radial Velocity Variations

All of the MDM spectra show Hα emission. To measure the radial velocity (RV), we convolved the line profile with the derivative of a Gaussian and took the line center to be the zero of this convolution (Schneider & Young 1980). The width of the convolving function was optimized for a line with a FWHM of 11.5 Å, which is approximately the observed line width. We searched the velocity time series for periodicities using a “residual-gram” technique (Thorstensen et al. 1996), which is especially effective when the modulation is accurately sinusoidal. Because the data span hundreds of days, we were careful to use a sufficiently fine grid of trial frequencies. The period search yielded a single, uniquely-defined frequency near 5.12 cycle d$^{-1}$; a least-squares fit to the velocities of the form

$$v(t) = \gamma + K \sin \left( \frac{2\pi(t - T_0)}{P} \right)$$

then yielded a preliminary period of 0.195290 d, with a velocity semi-amplitude of 80 km s$^{-1}$.

Twenty-three additional RVs were used to extend the span of RV observations and to improve the precision of the ephemeris. These were measured using the same 11.5 Å FWHM Gaussian-derivative technique, applied to high-resolution spectra from the Hobby–Eberly Telescope (HET) obtained in 2004 and 2007 (see Section 2.2 below). The final heliocentric Hα RV ephemeris, based on 163 points, is given by

$$T_0 = \text{HJD} 2453628.6389 \pm 0.0016,$$

$$P = 0.1952894 \pm 0.0000010 \text{ d},$$

$$K = 77 \pm 4 \text{ km s}^{-1},$$

$$\gamma = -44 \pm 3 \text{ km s}^{-1}.$$
HET for about one hour per night as it is transiting from mid-April through mid-July. Queue observations of LS IV–08°3 were made with the HRS using 2′′ fibers (one object fiber and two sky fibers) and 2 x 3 on-chip binning, resulting in $R \equiv \lambda / \Delta \lambda \approx 30,000$, covering the wavelength region from Hβ to Hα. (Unfortunately, the λ5780 DIB falls into the gap between the “red” and “blue” CCDs with this setup.) Exposure durations were 10 min, with the exception of the first observation of 20 min duration and a few shortened exposures obtained as LS IV–08°3 approached the end of the HET track. Three or four separate exposures were obtained in quick succession on each of four nights in 2004 and three nights in 2007 (see Table 5 for a journal of observations). The typical signal-to-noise ratio was 100 at 5822 Å (range 75–120). Th–Ar lamps and flat field exposures were taken either before or after the sequence of exposures each night.

These spectra were processed with standard IRAF routines. At the dispersion of the HRS, the absorption components of the Balmer lines in the LS IV–08°3 spectrum are roughly as broad as a single spectral order. Thus, a pseudo-continuum was fitted to the broad H absorption profiles, and each spectrum was normalized using this fit. The data were then rebinned in uniform heliocentric wavelength bins. Figure 4 shows the normalized Hα core emission profiles at several key orbital phases. As the phase varies, the profile does not simply shift back and forth in velocity, but rather changes shape. To the eye, a decomposition into a broad component and a narrow component moving in anti-phase is suggested. This is made more evident in Figure 5, which gives a trailed-spectrogram representation of all the data.

The measured EW of the Hα emission (above the pseudo-continuum) was roughly constant at ~3.0 Å in 2004, but was lower in 2007, averaging 1.7, 2.1, and 1.8 Å on 2007 April 19, June 8, and June 22 respectively. To make Figures 4 and 5, we have “stretched” each spectrum to achieve a uniform emission EW of 3.0 Å, keeping the continuum level at unity. In the trailed spectrogram (Figure 5), each spectrum has then been made to fill a phase range of 0.05 cycles, centered on the phase bin (bin width = 0.01 cycles) nearest to the orbital phase at mid-observation. Note that data from 2004 and 2007 have been intermingled, and different orbital phases were observed in different years. The change in EW from one year to the other may signal a change in the behavior of the profile versus orbital phase.
phase; so we caution that quantitative conclusions about these distinct narrow and broad velocity components, based on these figures, are tentative. The phase of the broad component in the Hα emission profile is given by the RV ephemeris derived in Section 2.1.4, with the narrow component moving in anti-phase. Thus, the Gaussian-derivative method using FWHM = 11.5 Å described in Section 2.1.4 likely gives a "diluted" RV semi-amplitude for the broad component. Given the possible change in the profile behavior between 2004 and 2007 noted above, we did not attempt to decompose each observed profile or otherwise make formal two-component fits to the high-resolution data. A rough estimate gives FWHM ~ 8–10 and ~3 Å for the broad and narrow components. Estimates of the RV semi-amplitudes are \( K_{\text{broad}} \sim 120 \) and \( K_{\text{narrow}} \sim 90 \) km s\(^{-1}\), with errors of perhaps 20 km s\(^{-1}\).

We tentatively identify the broad emission as arising from an accretion disk around a compact object and the narrow emission as arising from the mass donating star in a cataclysmic binary. If the narrow emission arises on the hemisphere of the mass donor that faces the disk (see Section 3.1), one might expect the EW of the narrow component to vary, such that the emission EW is largest when the mass donor is at superior conjunction, which is orbital phase 0.5 in our convention. We searched for this effect using the low-resolution MDM spectra from the most extensive data set (2005 July), but did not find any firm indication of an EW variation with orbital phase. The limit on the variation in the total EW is 15–20% full amplitude. It is not possible to decompose these low-resolution spectra into separate components. The high-resolution HRS spectra are unfortunately not suitable for this test, since all data collected near orbital phase 0.5 come from the 2007 observations, and all data collected near orbital phase 0.0 come from 2004. While there is a tantalizing difference in total EW between these two observing seasons, we cannot know whether it is related to orbital phase; a more concentrated observing campaign is needed. We note that there need not be a large modulation of the EW of the narrow component, if the orbital inclination of the binary is moderate.

The H\(\beta\) emission line profile shows behavior similar to H\(\alpha\), with the narrow component being perhaps more pronounced (slightly higher intensity compared with the broad component). Similar behavior is also reflected in the He\(\iota\) \(\lambda 5876\) emission profile, although it is weaker.

### 2.3. Photometry

#### 2.3.1. Michigan State University 0.6 m Telescope

Differential V-band photometry of LS IV−08°3 was obtained using the Michigan State University 0.6 m telescope equipped with an Apogee Ap47p CCD camera. Aperture photometry for LS IV−08°3 was obtained relative to the star TYC 5642−00482−1, which has \( H = 12.389, \ V = 11.183 \). (This star is significantly redder than the program star, but there is no blue star of comparable brightness to the target within the CCD field of view.) Observations were made on twelve nights: UT 2004 July 26, 2004 August 1, 7, 9, 16, 22, 31; 2004 September 18; 2005 July 15, 20, 23; and 2006 May 27. Exposure times were typically 30 s, varying somewhat depending on observing conditions. Observing run lengths varied from as short as about 1 to 6.3 h on 2006 May 27, this being about the maximum run length possible at reasonable airmass from the latitude of the observatory. Calibrations were done using standard procedures and sky flats. Since observations were only taken in the V filter, no transformations to the standard system involving color terms could be attempted. The typical error of a single observation is ±0.02 mag.

The photometry shows LS IV−08°3 to be variable on both short (flickering) and long timescales, with no indication of eclipses. By itself, the photometry suggests no clear or consistent period of variation—folding the data on numerous trial periods showed many possible alias periods. Folding the data on the period derived from the RV observations (Section 2.1.4) does show weak modulations or waves, perhaps multi-periodic, in the brightness of LS IV−08°3 (Figure 6). The rapid modulation in \( \Delta V \) that is seen in the 2005 July 23 data, of amplitude ~0.03 mag and lasting several cycles over the phase interval ~0.2–0.6, is not seen in the photometric check stars; this may be simply an instance of strong flickering. The median light level is about ~0.06 mag brighter in 2005–2006 than in 2004. Additional time-series photometry, from a more southern site to permit longer nightly runs, would be desirable in characterizing the light curve and searching for persistent periodic signals.

#### 2.3.2. Northern Sky Variability Survey

LS IV−08°3 was detected as a variable star in the Northern Sky Variability Survey (NSVS; LS IV−08°3 ≡ NSVS 16408817; Woźniak et al. 2004). The NSVS record shows 92 observations of this star. The typical error of a single measure-
The SED of LS IV−08°3 is considerably redder than those of known single sdB stars. Dereddening by the equivalent of $E(B−V) \sim 0.6$ or more would be required to bring the Steward SED at optical wavelengths into agreement with sdBs that have $T_{\text{eff}}$ in the range 24,000−35,000 K. Likewise, the $E(B−V)$ needed to bring the 2MASS infrared colors into the range of single sdB stars is 0.6 mag or more.

On the other hand, LS IV−08°3 shares many properties with novalike variables of the UX UMa subclass. These systems show persistent broad Balmer absorption-line spectra. Ironically, these lines were once thought to indicate pressure-broadening in the atmosphere of a hot subdwarf or white dwarf—e.g., Walker & Herbig (1954)—and only later were reinterpreted as arising from an optically thick accretion disk, where they are (at least in part) kinematically broadened.

UX UMa stars also exhibit a wide range in strengths of the emission line components. Emission from combinations of H, He I, He II, Ne III, and C IV have all been observed at a variety of strengths in various UX UMa stars, or variable over time in a single star of the class. Emission is seen in all of these lines in LS IV−08°3, and the features are consistent with those observed in the UX UMa stars RW Sex and IX Vel (Beuermann et al. 1992; Beuermann & Thomas 1990, respectively). For UX UMa stars, the Balmer decrement in the emission components is steeper than in the absorption lines. This can result in a situation where Hα is purely in emission, while higher members show progressively stronger (less filled-in) absorption troughs. This effect is seen in LS IV−08°3 (Figure 2).

Narrow Balmer emission has been found in many UX UMa systems, superimposed on the broader emission from the disk. This narrow component is attributed to irradiation of the atmosphere of the secondary star, with reprocessing of the light to Balmer emission. As discussed in Section 2.2, the asymmetry and variations in the emission line profile shape (Figures 4 and 5) suggest the presence of such a component, moving in anti-phase to the broad component, as required for this interpretation.

The orbital period of $\sim0.195$ d ($\sim4.7$ h) determined for LS IV−08°3 is comparable to other UX UMa systems.

### 3. DISCUSSION

#### 3.1. Novalike CV Interpretation

We have already suggested (Section 2.1.2) that LS IV−08°3 could have been misclassified as a hot subdwarf (sdB) star, given only photometry and spectroscopy confined to wavelengths blueward of Hβ. Indeed, the dwarf nova FO Per (aliases: RL 92 and RWT 92) was classified by Chromey (1979) as an sdB star, when, unbeknownst to him, it must have been near maximum light in its outburst cycle. Two Steward Observatory 2.3 m spectra of FO Per, also near maximum light, obtained in 2004 December and 2006 December with a setup identical to that described in Section 2.1.2, show a spectrum that is almost indistinguishable from a somewhat reddened sdB star, except for emission cores in Hα, Hβ, and, very faintly, in the next few higher-order Balmer lines, i.e., at almost exactly the same level as seen in our 2005 May spectrum of LS IV−08°3.
If LS IV\textsuperscript{−08\,3} is assumed to be a UX UMa variable star, how far away is it, and is this consistent with the measured reddening? We adopt an overall magnitude $M_V \approx +5$ and a representative apparent magnitude $V = 11.50$ for LS IV\textsuperscript{−08\,3}. We use the standard relation $A_V = 3.1(E(B-V))$ to compute distance $d$ as a function of assumed $E(B-V)$. Values between 100 and 200 pc result for $E(B-V)$ in the range 0.0–0.5 mag, smaller distances corresponding to larger reddening. Ak et al. (2007) have put forward a calibration of $M_V$ for CVs, using as inputs the orbital period and the extinction-corrected 2MASS $J$ magnitude and $J - H, H - K_S$ colors. Again varying the assumed $E(B-V)$, we find $d$ in the range 140–180 pc by this method (minimum error at fixed reddening is 40%). Comparing the 2MASS colors of LS IV\textsuperscript{−08\,3} and IX Vel directly, we find a reasonable match if $E(B-V) \approx 0.10$ mag. We conclude that if $E(B-V)$ in the range 0.10–0.20 mag can be accommodated within distances of 100–200 pc, the colors and magnitudes of LS IV\textsuperscript{−08\,3} are consistent with those of a UX UMa variable. Such reddening values within such distances are plausible along the line of sight to LS IV\textsuperscript{−08\,3}, according to the maps of, e.g., Perry & Johnston (1982).

### 3.3. ROSAT X-ray Observations

A weak X-ray source detected in the ROSAT All-Sky Survey (RASS) appears to be coincident with LS IV\textsuperscript{−08\,3} (1 RXS J165630.2–083442; Voges et al. 1999). The count rate in the position sensitive proportional counter (PSPC) was 0.11 ± 0.02 s\(^{-1}\), yielding an estimated 0.1–2.4 keV flux of $1.5 \times 10^{-12}$ erg cm\(^{-2}\) s\(^{-1}\). Taking LS IV\textsuperscript{−08\,3} to be the optical counterpart, the X-ray/optical flux ratio is given by log $f_X/f_{opt} \approx -2.0$.

This source was also observed serendipitously by ROSAT (1WGA J1656.4–0834; White et al. 2000) during a pointed observation of another target. In this \textasciitilde 8000 s exposure, 150 net counts were collected, and the count rate was 0.02 ± 0.002 s\(^{-1}\) (five times lower than in the RASS), corresponding to $f_X \approx 3.0 \times 10^{-13}$ erg cm\(^{-2}\) s\(^{-1}\) and log $f_X/f_{opt} \approx -2.6$. A best-fitting blackbody spectrum has $kT \approx 0.2$ keV with an intervening hydrogen column density of $1.3 \times 10^{13}$ cm\(^{-2}\), corresponding to $E(B-V) \approx 0.2$. The unabsorbed flux is $F_{0.5–2}$ keV $\approx 2.7 \times 10^{-13}$ erg cm\(^{-2}\) s\(^{-1}\).

Using a bremsstrahlung or thermal plasma emission model would result in a similar $kT$ value, given the highly absorbed spectrum and the PSPC’s limited energy range and resolution. The inferred total X-ray flux is quite uncertain.

X-ray emission is not associated with sDB stars. On the other hand, CVs of all subclasses show X-ray emission. Verbunt et al. (1997) discuss the CVs detected in the RASS. A typical luminosity in the 0.5–2.5 keV band for a novalike variable is $L_X \approx 10^{31}$ erg s\(^{-1}\). The required distance for LS IV\textsuperscript{−08\,3} to have this $L_X$, given its modeled flux, is $d \approx 500$ pc. Using a 2 keV bremsstrahlung spectrum to model the ROSAT counts, Verbunt et al. (1997) find log $F_X/F_{UV, opt} < -2.5$ to be typical for novalikes. Given the uncertainties in the input spectrum and absorption column, we conclude that LS IV\textsuperscript{−08\,3} has X-ray properties consistent with membership in the UX UMa subclass of CVs.

### 4. SUMMARY

Given the many similarities between our observations and other UX UMa novalike variables, we propose that LS IV\textsuperscript{−08\,3} should be classified with the UX UMa stars. Evidence supporting this classification includes the presence of emission reversals in the Balmer absorption series, other emission lines including He\textsc{i}, He\textsc{ii}, and Ne\textsc{ii}/C\textsc{ii}, the variability of the emission line strengths, the intrinsically blue continuum, and the mild photometric variability. The key evidence in favor of a CV interpretation lies in the periodically modulated Doppler shifts and profiles of the emission lines, with a period of 4.7 h, consistent with a low-mass quasi-main sequence star that fills its Roche lobe and transfers mass to a luminous accretion disk around a white dwarf. The inner hemisphere of the donor star may be irradiated by the accretion disk. Reddening and distance estimates are consistent with the CV interpretation, from the standpoint of the expected luminosity of the system and the distribution of interstellar dust in the direction of LS IV\textsuperscript{−08\,3}. Finally, weak X-rays are apparently associated with the system, and the X-ray luminosity and X-ray/optical flux ratio are consistent with observations of other novalike CVs.

We refrain from deriving the dynamical mass ratio of the binary or individual masses of the stars in LS IV\textsuperscript{−08\,3} from any of the various RV semi-amplitudes that we have presented above, mainly because the HRS spectra on which such estimates would rely were obtained on widely separated dates, and the EW of the emission lines varied significantly among the various epochs. It is thus possible that one or both sites of the emission varied as well. Work aimed at determining the mass ratio is best undertaken with intensive time-series spectroscopy that can provide full orbital phase coverage in one or two nights, to minimize such variations. Likewise, we cannot offer a definitive interpretation of the photometric variability, given our present limited data. LS IV\textsuperscript{−08\,3} thus remains as an attractive and interesting target for further study.

Despite the apparent line-of-sight extinction to the source, LS IV\textsuperscript{−08\,3} is one of the brighter UX UMa stars so far discovered. Downes et al. (2001) list only three “UX UMa” systems (of two dozen catalogued) that are brighter: IX Vel, V3885 Sgr, and RW Sex. Only seven CVs of any “novalike” sub-type (89 systems total) are brighter than LS IV\textsuperscript{−08\,3} at their maximum light. Bright, relatively nearby systems are not only appropriate for follow-up studies, but contribute disproportionately to studies of the space density and kinematics of the various subclasses of CVs. Even though hundreds of thousands of stars that are much fainter have been observed spectroscopically by, e.g., the Sloan Digital Sky Survey, the sky has not been thoroughly explored at $V \sim 11$.

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