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THE X-RAY SELECTED CATACLYSMIC VARIABLES H0459+246 AND H0857−242

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ABSTRACT

We report the discovery of two cataclysmic variables located with the assistance of X-ray positions from the *HEAO 1* Modulation Collimator and the Large-Area Sky Survey. Each case is distinguished by evidence of two periodic modulations that appear to represent the orbital period and the spin period of the white dwarf, respectively. The first case, H0459+246, has been observed optically during faint states ($V \sim 16$), in which there are spectral features of both an accretion disk and a K star. The light curves in the V and I bands are consistent with ellipsoidal variations in the secondary stars with a binary period of 9.952 hr. X-ray observations with *EXOSAT* reveal a strong pulsation with a period ~62 minutes. This result confirms an "intermediate polar" classification for H0459+246. The pulsation is observed at 63.2 minutes in the optical I band. The long orbital period opens the possibility that H0459+246 is a relatively young intermediate polar that might evolve into a polar. The second case, H0857−242, shows radial velocity modulations at 1.78 hr along with photometric variations at a period ~49 minutes. The latter are observed only during the decay phase of dwarf nova outbursts ($13 < V < 17$), which apparently recur frequently. Given the lack of X-ray monitoring observations and the absence of proof that the 49 minute periodicity is coherent over long timescales, we regard H0857−242 as a *candidate* intermediate polar. Photographic records from the Harvard Observatory Plate Library further reveal superoutbursts for H0857−242 ($V \sim 11$). A bright X-ray source that is both an intermediate polar and a continually cycling dwarf nova may provide an effective means of measuring the time delay for the arrival of accreting matter at the white dwarf surface, relative to the onset of optical brightening.

Subject headings: binaries: spectroscopic — novae, cataclysmic variables — stars: individual (H0459+246, H0857−242) — X-rays: stars

1. INTRODUCTION

The majority of currently recognized cataclysmic variables (CVs) within the magnetic subclasses (viz., "polar" or "intermediate polar" types) have been discovered as X-ray sources detected in various all-sky surveys (see Ritter 1990 and references therein). This selection effect represents a qualitative confirmation of the accretion models that stress the importance of the white dwarf's magnetic field strength in the emission of X-rays from CVs (e.g., Lamb 1985). Radially directed accretion along magnetic field lines causes high stream velocities and shock-heated gas that emits thermal bremsstrahlung X-rays ($kT \sim 20$ keV) near the magnetic polar caps on the white dwarf surface. While detailed geometric models can account for much of the spectral and temporal behavior of these objects (Leibert & Stockman 1985), there are enigmatic examples among magnetic CVs (e.g., Silber et al. 1992), and many evolutionary questions remain unsolved (Lamb & Melia 1987).

In the polar subclass (also known as AM Herculis objects), the white dwarfs have a magnetic field strength that is strong enough to force the accreting matter to flow along magnetic field lines, preventing the formation of an accretion disk. The optical emission is characterized by strong circular polarization and these systems exhibit a high degree of synchronized spin/orbit rotation (Liebert and Stockman 1985). In the intermediate polar (often termed DQ Herculis stars; see Warner & Wickramasinghe 1991), the magnetic field disrupts only the inner accretion disk. The eventual focusing of accretion onto the magnetic poles of the white dwarf imposes a brightness modulation that represents (either directly or via beat frequencies) the spin period of the white dwarf (e.g., Hellier, Cropper, & Mason 1991). The spin period is seen to be coherent and the value is usually different from the orbital modulations typically deduced from radial velocities or from periodic increases in brightness caused by the changing aspect of the "hot spot," where the accretion stream intercepts the outer edge of the disk. Thus, intermediate polars are noted for their double periods, and the known cases exhibit spin periods that are faster than the orbital period.

This paper presents two new X-ray selected CVs that exhibit characteristics of intermediate polars, although in one case (H0875−242) the subclass assignment requires confirmation. The X-ray positions are provided by the *HEAO 1* Scanning Modulation Collimator (MC) (Gursky et al. 1978) and the Large-Area Sky Survey (LASS) (Wood et al. 1984). Our optical identification program is discussed by Remillard et al. (1986a).

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Briefly, the MC error diamonds that lie in or near the error boxes derived from the LASS and other X-ray surveys are used to select optical candidates that include bright stars and galaxies and objects that exhibit UV-excess or emission lines. The candidates in the latter two categories are derived from Schmidt photography of the field. All candidates are subsequently observed spectroscopically to assess their viability as X-ray counterparts. Magnetic CV classification resulting from this program of related research include the AM Herculis binaries H0538+608 (BY Cam) (Remillard et al. 1986b) and H1907+690 (Remillard et al. 1991), and the intermediate polars or candidates H0542−407 (TX Col) (Tuohy et al. 1986), 3A 1148+719 (YY Dra) (Patterson et al. 1992), H0534−581 (TW Pic) (Buckley & Tuohy 1990), and H0551−819 (Buckley et al. 1993).

2. X-RAY SOURCE IDENTIFICATIONS

The LASS catalog includes the X-ray detections, 1H 0459+248 and 1H 0857−242 (Wood et al. 1984), with respective X-rays fluxes of 1.7 and 2.1 × 10^{-11} ergs cm^{-2} s^{-1} at 2–10 keV assuming a Crab-like spectrum. The LASS observations were made during the first scan of each celestial region by the *HEAO 1* satellite, which occurred during 1977 September 7–12 and November 15–22, respectively. The analysis of observations by the *HEAO 1* MC provides further constraints on the positions of these X-ray sources. In the case of 1H 0459+248, the MC results are consistent with a spatially unresolved source; the detection significance is 2.6 σ (units are standard deviations in the fluctuations of the nonmodulated background) for the fine collimator, MC1 (30″ resolution), and 4.2 σ for the coarse collimator, MC2 (120″ resolution), using the full MC sensitivity range of 1–13 keV. The MC detection is derived from the sum of source crossings during the first and third (1978 September 6–11) scans of this region by *HEAO 1*. The addition of the second scan (1978 March 6–12) diminishes the MC results, implying reduced X-ray flux during this time period. The MC detection in the vicinity of 1H 0857−242 similarly utilizes the first and third *HEAO 1* scans (1977 November 15–22 and 1978 November 17–22), in the range of 1–6 keV. The MC detection is 4.1 σ for MC1 and 2.5 σ for MC2. The crossed lines of position for each MC unit produce a grid of parallelograms ("error diamonds") on the celestial tangent plane. The X-ray positions are displayed in Figure 1. A detection from the *Ariel 5* survey, 3A 0500+236 (McHardy et al. 1981), lies between the LASS sources 1H 0459+248 and 1H 0459+230 (unidentified). Thus, the *Ariel 5* detection may have received contributions from both LASS sources, resulting in the apparent position offset.

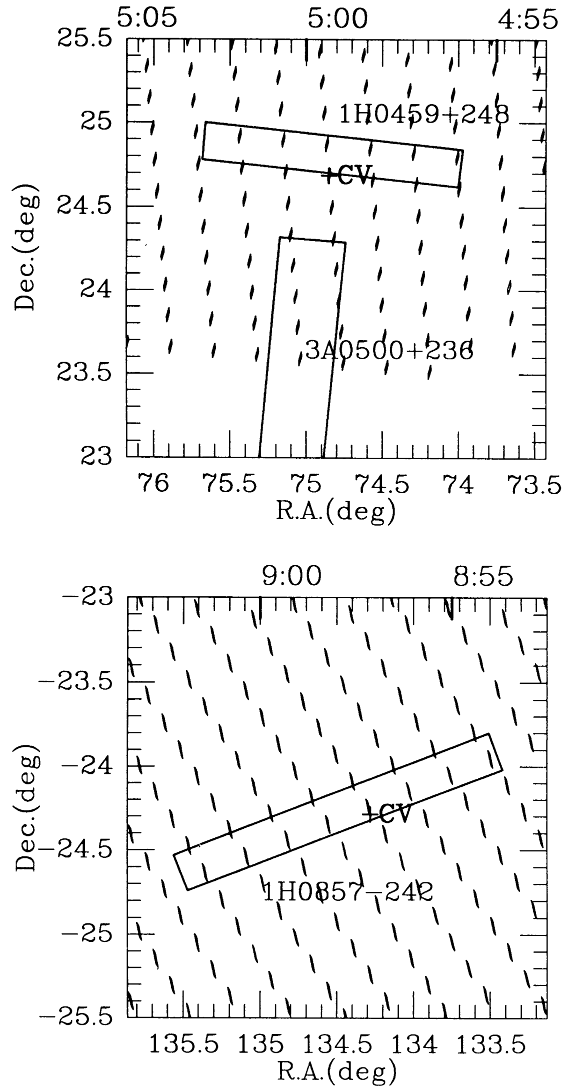

FIG. 1.—Allowed X-ray positions (B1950 coordinates) from the *HEAO 1* LASS ("1H"), Ariel V ("3A"), and the *HEAO 1* MC (grid of parallelograms).

Optical candidates with strong UV flux were located on photographic plates obtained with the Burrell Schmidt telescope at Kitt Peak National Observatory. The locations of these objects are marked "CV" in Figure 1. Finding charts are provided in Figure 2, and the celestial coordinates are given in the figure caption. In the paragraphs below we demonstrate that the objects are CVs and conclude that these CVs are the optical counterparts of the respective *HEAO 1* X-ray sources. In anticipation of these conclusions we designate names corresponding to the precise coordinates of the CVs and refer to them henceforth as H0459+246 and H0857−242, respectively.

Optical spectra from the 3.9 m Anglo-Australian Telescope (AAT) are displayed in Figures 3 and 4. These observations were made on 1988 February 22, using a double spectrograph consisting of the RGO/IPCS Instrument (3400–5400 Å at 7 Å resolution) and the Faint Object Red Spectrograph (5300–9000 Å at 20 Å resolution). A dichroic filter was used to split the incoming light to each spectrograph. For the latter instrument, the atmospheric absorption bands were corrected during the data reduction by using observations of "smooth spectrum" stars.

The spectrum of H0459−246 (Fig. 3) exhibits broadened emission lines from the Balmer series and He I (e.g., 4471 and 5876 Å), as well as strong He II λ4686 and C III–N III emission band at λλ4640–4650. These characteristics warrant a CV classification, and the strength of the He II lines indicates high-excitation emission that is common among magnetic and X-ray selected cases. In addition, Figure 3 also shows a red spectral component and absorption features that include the Mg I blend λ5175, Fe I λ5269, and some development of the TiO–CaOH band at 6230–6276 Å. These characteristics and the absence of other TiO bands exhibited by M stars leads to the conclusion that the spectrum of H0459+246 contains a spectral component from a late K star. The AAT observation

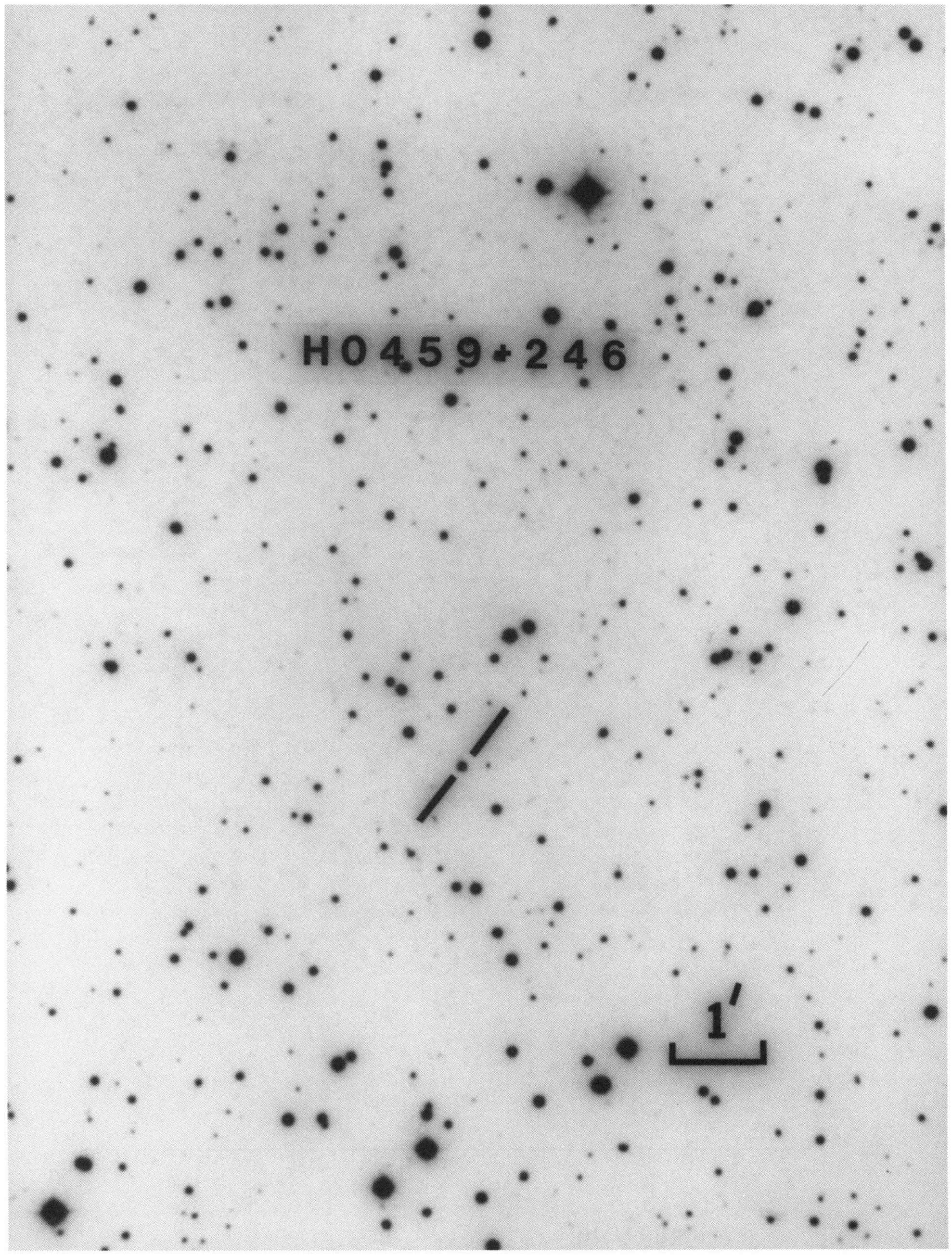

FIG. 2a

FIG. 2.—Optical finding charts for the cataclysmic variables proposed as the identifications of *HEAO 1* X-ray sources. North is toward the top, and east is to the left. The photographs are reproductions of the E prints from the Palomar Observatory Sky Survey (copyright National Geographic Society). The celestial coordinates (epoch B1950; ±2″) for H0459−246 are $\alpha = 04\ 59\ 24.0$, $\delta = +24\ 41\ 06$, with significant proper motion toward the south. Coordinates for H0857−242 are $\alpha = 08^h57^m07^s.7$, $\delta = -24°17'12''$.

appears to have caught H0459+246 in a relatively faint state, as subsequent spectroscopy (not shown) on 1989 October 28, 1990 February 20, and 1990 December 11 show brighter states [F_λ in the range of $(1.5–2.0) \times 10^{-15}$ at 5500 Å], with decreased visibility of the K-star component.

The optical spectrum of H0857−242 (Fig. 4) from the AAT also shows broadened emission lines of H, He I, and He II. The spectrum is similar to many optically selected CVs (e.g., Williams 1983). Compared to H0459+242, the He II/He I line ratios are weaker, while the continuum of H0857+242 does not exhibit evidence of the secondary star. Additional observations were made with the 1.3 m McGraw-Hill telescope at the Michigan-Dartmouth-MIT (MDM) Observatory.[8] Both the instrumentation and the data reduction techniques follow the description of Silber et al. (1992), except that the TI 4849 CCD was used in the present program. The MDM observation of

[8] Observations were carried out in part at the Michigan-Dartmouth-MIT (MDM) Observatory (Kitt Peak, AZ), which is operated by a consortium consisting of the University of Michigan, Dartmouth College, and MIT.

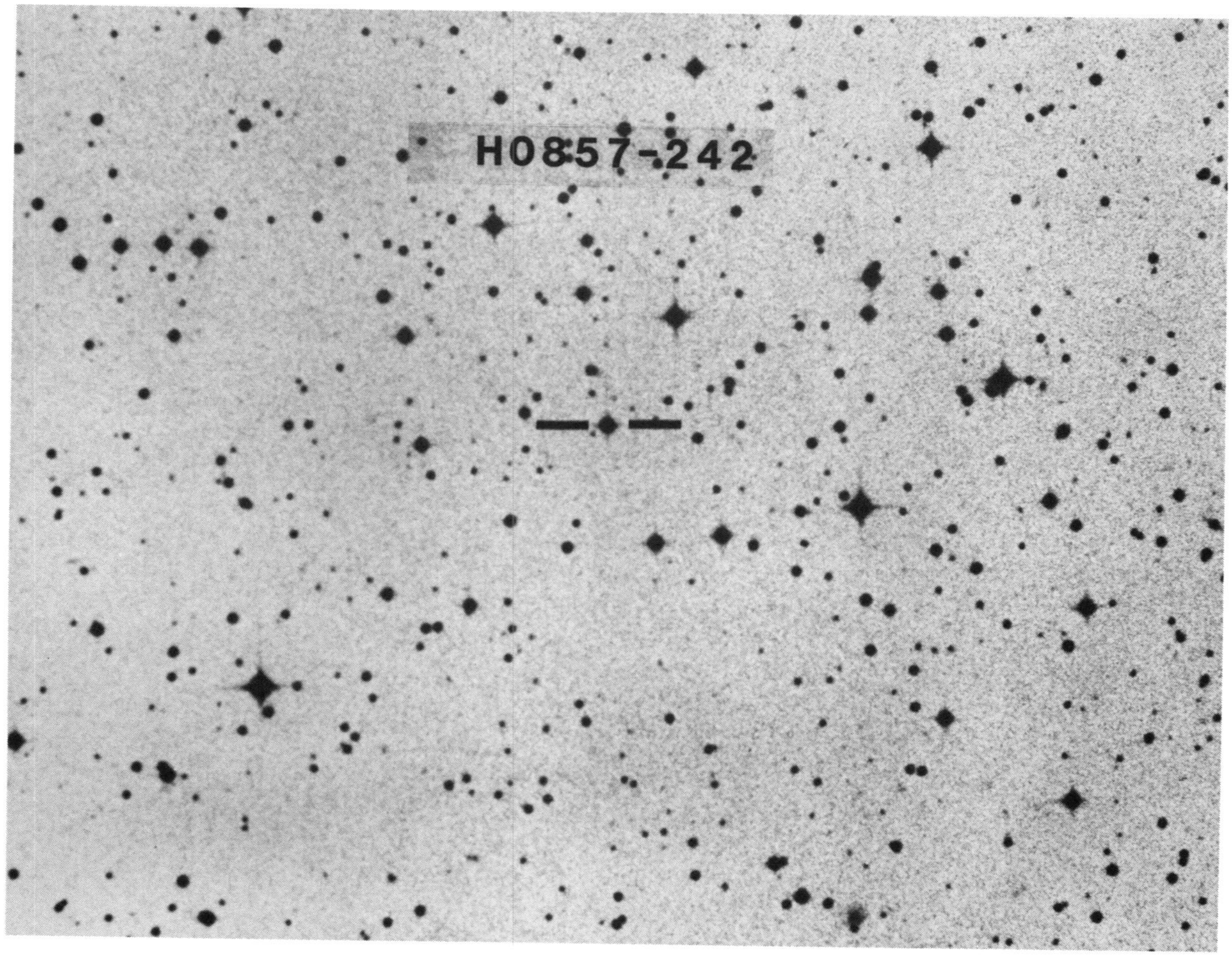

FIG. 2b

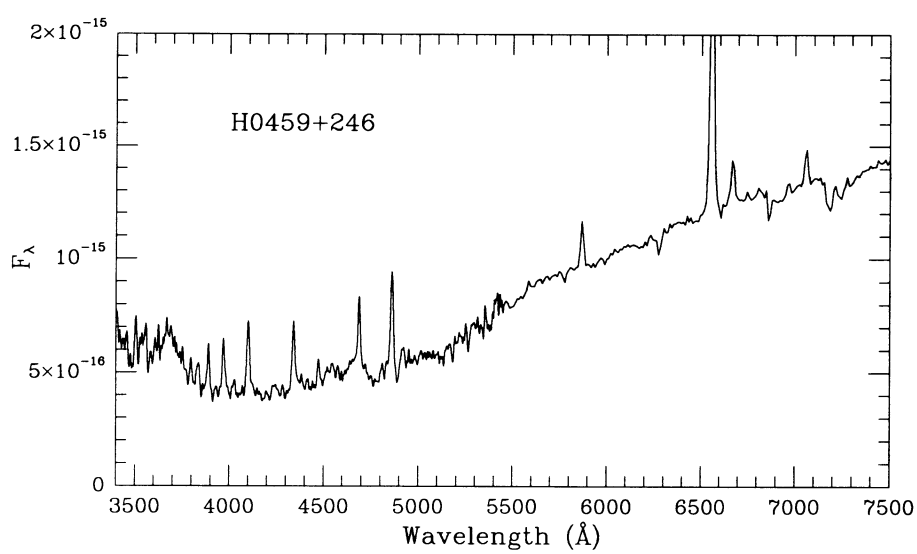

FIG. 3.—AAT spectrum of H0459 + 246, observed in a faint state. The spectrum exhibits a composite of the continuum and line features from both a cataclysmic variable and a K star.

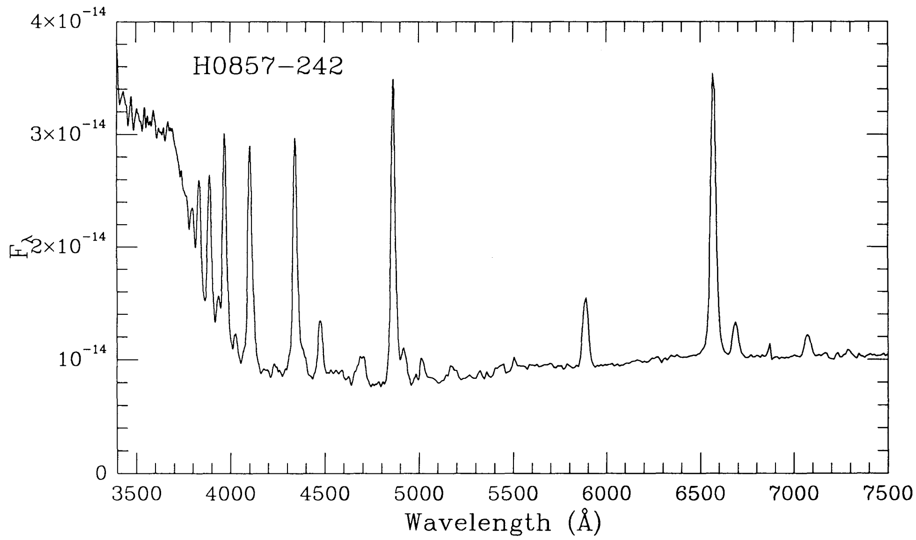

FIG. 4.—AAT spectrum of H0857−242. The emission lines of H, He I, and He II are fairly typical of CV spectra.

1991 November 18 is shown in Figure 5; H0857−242 was then in the midst of an outburst typical of the dwarf nova subclass of CVs. The increase in brightness and decrease in the equivalent widths of the emission lines (comparing Figs. 4 and 5) are typical spectral changes that signify a dwarf nova in outburst (e.g., Clarke, Capel, & Bowyer 1984; Szkody 1985).

The optical spectra presented above clearly support CV classifications for the two objects. As noted in previous publications (references in the last paragraph of § 1), the probability of finding CVs with $V < 16$ by chance within the allowed X-ray positions of the *HEAO 1* instruments is extremely small. We therefore conclude that the CVs presented above represent the optical counterparts of the respective *HEAO 1* X-ray sources. In the sections below we report additional observations that establish the orbital periods, provide evidence for the white dwarf spin periods, and investigate the outburst properties of H0459+246 and H0857−242.

3. *EXOSAT* OBSERVATIONS OF H0459+246

A pointed observation of H0459+246 with *EXOSAT* was made during 1985 October 12, after preliminary, low-resolution spectroscopy had indicated that the X-ray source was a CV. The data reductions were performed by one of us (I.R.T.), using the *EXOSAT* guest observers facility at ESTEC, located in Noordwijk, The Netherlands. The X-ray light curve from a ∼9 hr observation with the ME instrument (2–7 keV) is shown in Figure 6. The appearance of an X-ray pulsation at a period ∼1 hr was investigated by computing the variance statistic (Θ) of Stellingwerf (1978). In this method, the data are folded into a number of phase bins (e.g., 30) for a given trial

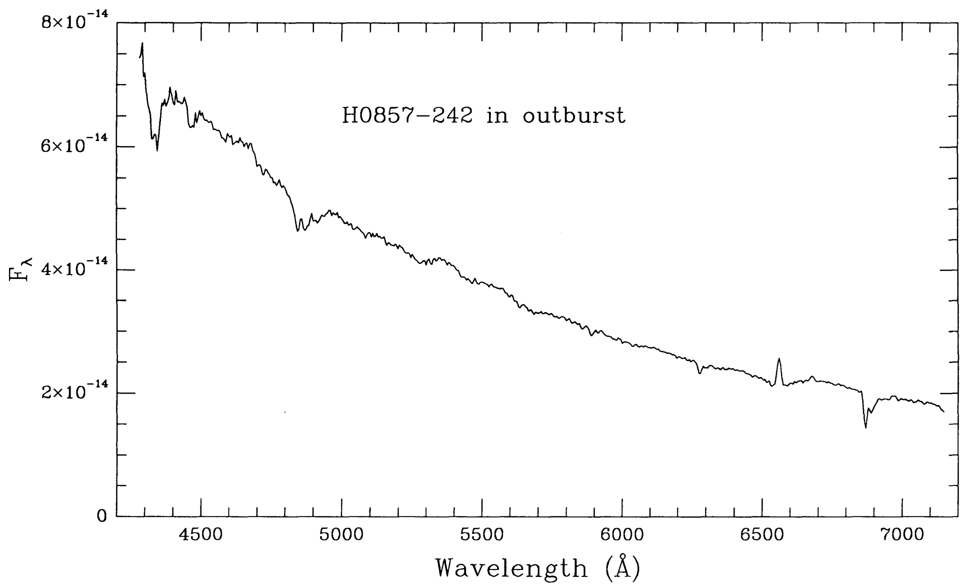

FIG. 5.—The outburst spectrum of H0857−242 recorded on 1991 November 18 at MDM Observatory. The spectral changes during outburst (see Fig. 4) and the outburst light curves (Fig. 6) clearly demonstrate that H0857−242 is a dwarf nova.

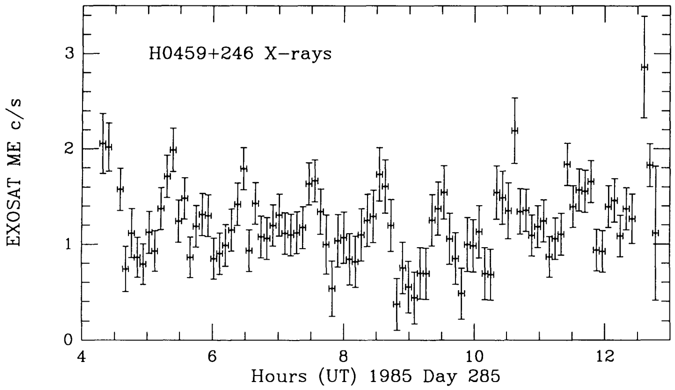

FIG. 6.—X-ray light curve of H0459+246 from the *EXOSAT* Medium-Energy (ME) Instrument, displayed with a time resolution ~5 minutes. Local maxima are evident every 62 minutes.

period. The variance is computed for the data points in each phase bin, and the average variance (e.g., of the 30 bins) is divided by the variance in the entire light curve. The result is called the "variance statistic," and this process is repeated for a large number of trial frequencies. Periodicities are seen as local minima in the variance statistic, since the measurements in every phase bin are highly correlated at the "true" period (or alias) but randomly reorganized ($\Theta \sim 1.0$) at other periods. This test is combined with a Monte Carlo technique for estimating period uncertainties, as described by Silber et al. (1992).

The variance statistic for X-ray frequencies in the range of 0.07 to 0.6 mHz (periods ~1 to 4 hr) is plotted in Figure 7 (top). The deep minimum corresponds to a period of 1.035 ± 0.010 hr, and the integral subharmonics are also evident. The folded X-ray light curve is shown in the lower panel of Figure 7. This pulsation is interpreted as the spin period of the white dwarf; an orbital period is reported below. The X-ray pulsations detected with *EXOSAT* establish membership for H0459+246 in the intermediate polar subclass.

The average X-ray spectrum of H0459+246, which is displayed in Figure 8, is best fitted by a power-law model ($\chi^2 = 22.5$ with 21 degrees of freedom), with a photon index of 0.97 ± 0.50, a column density of $5 \pm 2 \times 10^{21}$ cm^{-2}, and a normalization constant of 1.38×10^{-3} photons cm^{-2} s^{-1} keV^{-1}. This is a very flat X-ray spectrum for a CV, suggesting a high-temperature plasma. A thermal bremsstrahlung model suggests $kT \sim 20$ keV, but the model fit is substantially worse ($\chi^2 = 35$). The high value of the average column density suggests that the periodic X-ray modulation may be caused, at least in part, by variable amounts of obscuration along the line of sight to the X-ray emitting regions near the white dwarf's magnetic poles, as claimed for other intermediate polars by Hellier et al. (1991). A strongly modulated column density would shift the absorption profile during the pulsation period, and such an effect might explain the preference for a power-law model rather than a thermal model in the analysis of the average X-ray spectrum.

The implied X-ray flux at 2–6 keV is 0.64×10^{-11} ergs cm^{-2} s^{-1}. However, the intrinsic portion of the spectrum (using the power-law model and ignoring absorption) implies a flux of 1.86×10^{-11} ergs cm^{-2} s^{-1} at 2–10 keV, which is near the value deduced from *HEAO 1* observations (§ 2). Since the sensitivity range of the *HEAO* LASS extends to higher photon energies than the *EXOSAT* ME, the disparity between the

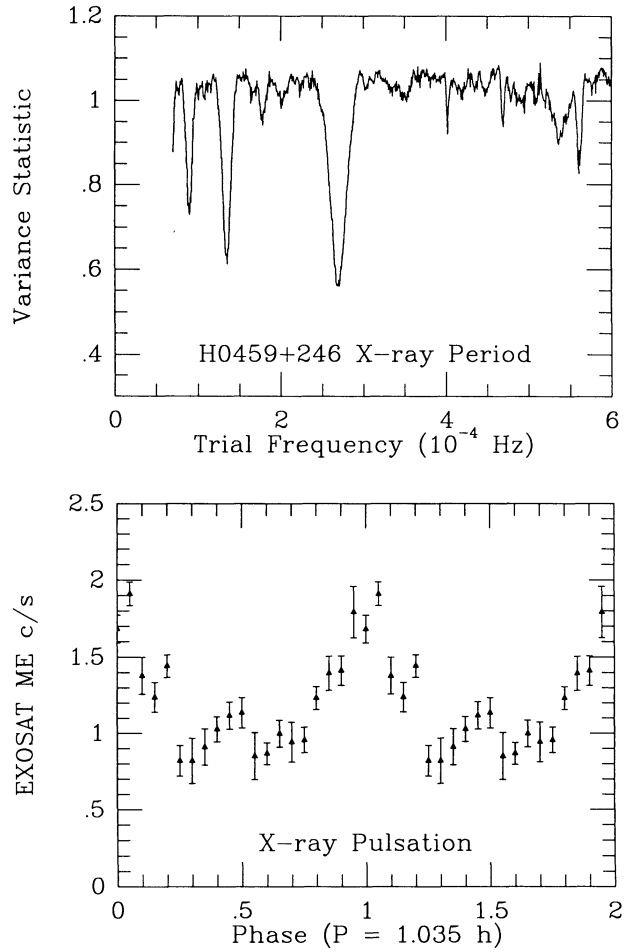

FIG. 7.—(*Top*) Variance analysis of the X-ray light curve of H0459+246. The results indicate an X-ray periodicity at 1.035 ± 0.015 hr. (*Bottom*) The X-ray light curve (2–7 keV) folded at a period of 1.035 hr and displayed in 20 phase bins. There is the suggestion of a secondary maximum near phase 0.5.

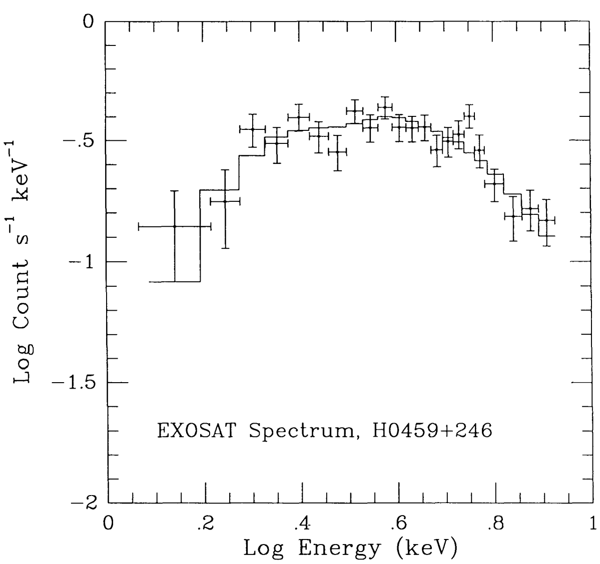

FIG. 8.—The *EXOSAT* ME spectrum of H0459+246 (2–7 keV), and the power-law model (histogram) described in the text.

HEAO 1 and *EXOSAT* photon flux measurements may be due to the X-ray spectral shape of H0459+246, and the conclusion of long-term X-ray variability is therefore not required.

The *EXOSAT* LE instrument (0.2 to 1.0 keV) detected 4 very weak sources after an exposure time of 24.1 ks. The measured fluxes are in the range of 1.4 to 3.8 LE counts per 1000 s, with signal-to-noise values in the range of 2 to 3. One of these (1.41 ± 0.58 LE counts per 1000 s) is within 7″ of the optical position of H0459+246. The low count rate of H0459+246 in the soft X-ray band is consistent with the high column density deduced from the ME spectral analysis.

4. OPTICAL PHOTOMETRY OF H0459+246

Time series of CCD images of H0459+246 were obtained with CCD instruments at MDM Observatory, using the 1.3 m McGraw-Hill telescope during 1988 November 27–30. The instrument and data reduction techniques follow the description of Remillard et al. (1991). Observations on the first two nights utilized an *I*-band filter (14.1 hr total exposure), and a *V* filter was used on the latter two nights (15.5 hr total exposure). The photometry was calibrated to the magnitude scale by observing standard stars of Landolt (1983). The average time resolution was ~2 minutes. The statistical uncertainty of individual measurements of H0459+246, judged empirically from the behavior of field stars of similar brightness, was in the range of 1%–2%.

The light curves of H0459+246 during each night are qualitatively very similar. Variations are confined to high-frequency flickering (~5% amplitude at a timescale of 2 minutes) and gradual changes of ~0.1 mag on timescales of several hours. When the variance statistic is computed for data sets that correspond to a given filter (i.e. two nights each in the *V* and *I* bands), a dip is seen near a trial period of 10 hr. Since the folded light curves in the *V* and *I* bands are similar, we combined all four nights into a single light curve (in linear intensity units), normalizing the data from each filter by the respective mean value. The variance statistic for this combined data set (*I* and *V*) is shown in Figure 9. A strong dip occurs at 0.279×10^{-4} Hz, corresponding to a period of 9.952 ± 0.074 hr. The folded light curves for each filter in calibrated magnitude units are shown in Figure 10. These curves are reminiscent of ellipsoidal variations in AE Aqr (9.9 hr period; see van Paradijs, Kraakman, & van Amerongen 1989) and also in

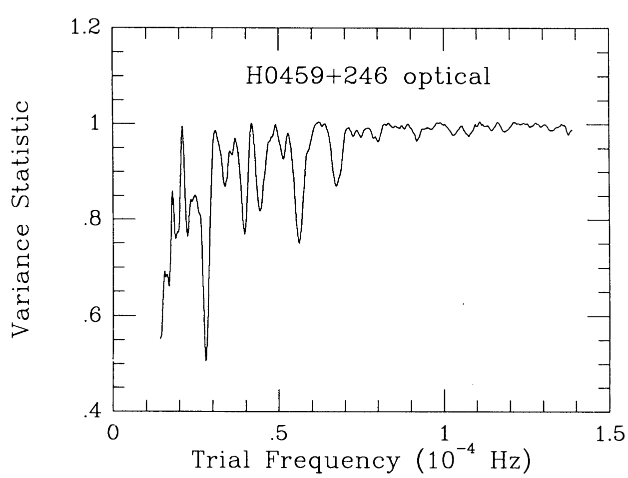

FIG. 9.—Variance analysis of the combined optical data set (normalized *V* and *I* filters) for H0459+246. The deep minimum signifies a period of 9.952 ± 0.074 hr.

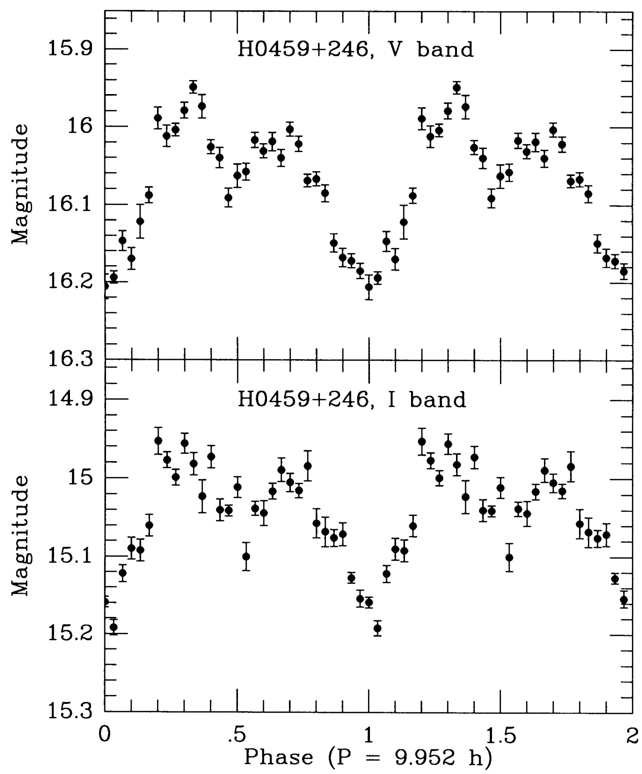

FIG. 10.—Folded light curves of H0459+246, shown separately in the *V* and *I* bands.

the light curves of quiescent X-ray novae such as the black hole binary A0620−00 (McClintock & Remillard 1986). This is not surprising, given the evidence for the K-star secondary in H0459+246 shown in Figure 3. The long orbital period, the absorption features in the "faint-state" spectrum, and the shape of the folded light curves all provide a consistent viewpoint that the secondary star in H0459+246 is of early spectral type than most CVs (Patterson 1984), and it contributes a significant portion of the optical radiation.

To explore the temporal variations of H0459+246 at shorter timescales, we computed residuals from the observed light curves after fitting the folded intensities in each filter with a Fourier series truncated to the first three harmonics. The residuals were then scaled by the mean intensity value for each filter band. The variance statistic was computed, and the results are shown in Figure 11. In the *I* band, the periodicity at ~1 hr (with subharmonics) is strongly evident. The best period is 1.054 ± 0.005 hr, and the heliocentric epoch of the intensity maximum is given in Table 1. The optical and X-ray pulsations are consistent to within 1.7 σ. The result is much weaker for the *V* band, with only a suggestion of the 1 hr modulation in the lower right-hand panel of Figure 11. Since the K star would be expected to contribute a greater fraction of the total light in the *I* band, as compared to the *V* band (Figs. 3 and 10), the weakness of the optical pulsation in the *V* band may be due to time variability of the pulsation amplitude (i.e., diminished on November 29–30).

5. RADIAL VELOCITY STUDY OF H0857−242

A series of radial velocity measurements were made on 1988 March 20 with the Dual Beam Spectrograph on the ANU 2.3 m telescope at Siding Spring Observatory. The observed wavelength range was 3500 to 7500 Å with ~2.5 Å resolution. The

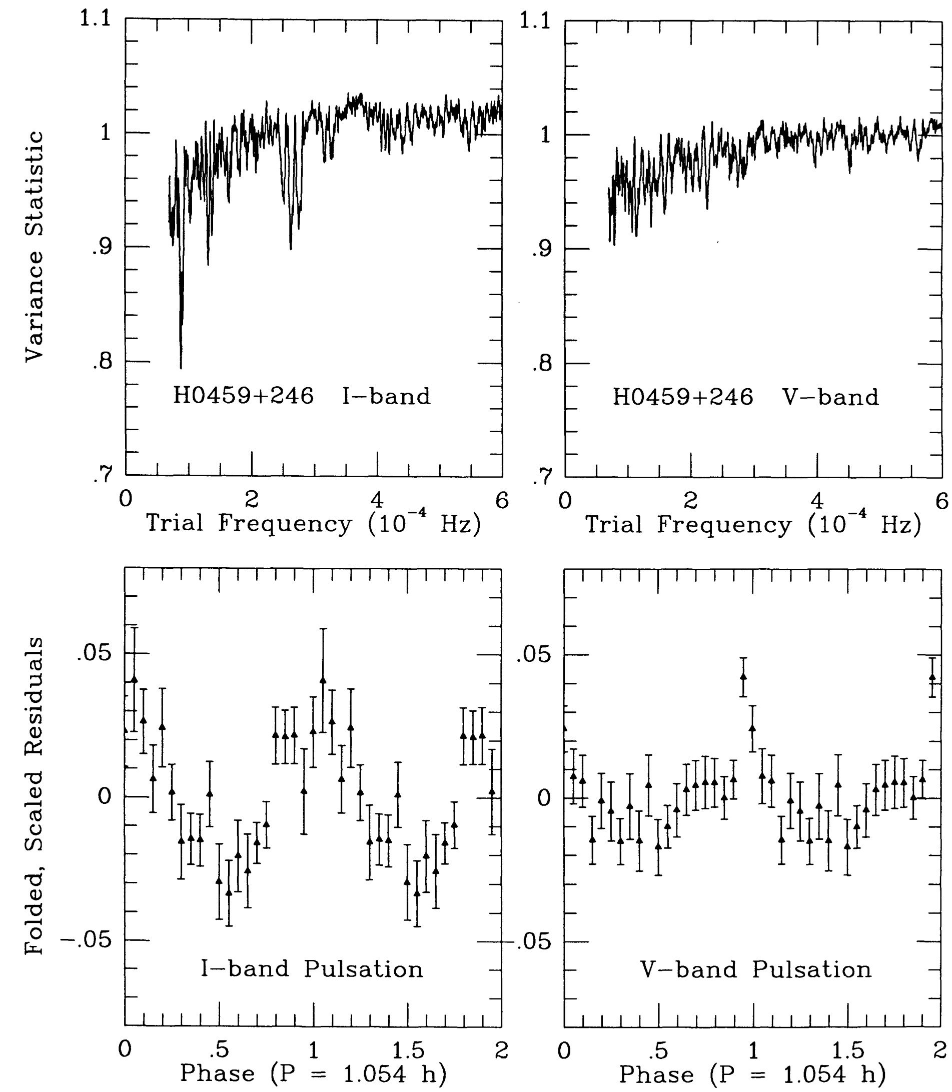

FIG. 11.—(*Top*) Variance analysis of the detrended *V* and *I* light curves of H0459+246. The minimum at 1.054 ± 0.005 in the *I*-band analysis occurs near the X-ray pulsation period. There is only a weak feature at this period in the results for the *V* band. (*Bottom*) The data in each band are shown folded at a period of 1.054 hr.

CV was in an optically low state with emission lines similar to those displayed in Figure 4. Radial velocity measurements were obtained by fitting selected Balmer lines (Hα to Hγ) with Gaussian functions in velocity space. The average FWHM at Hα was 1150 km s^{-1}, and the average equivalent width of Hα was 60 Å. The radial velocity curve is shown in Figure 12, and there is a clear velocity modulation with a sinusoidal appearance. Variance analysis yields a period of 1.78 ± 0.09 hr, which is assumed to represent the orbital period of H0857−242. The folded velocity curve was fitted to a sine wave with a half-amplitude of 40 km s^{-1} and a systemic velocity of 79 km s^{-1}. Since the inclination angle is unknown, and given the substantial problems associated with the analysis of the velocity amplitudes derived from CV emission lines, we refrain from interpretations beyond the 1.8 hr period signature.

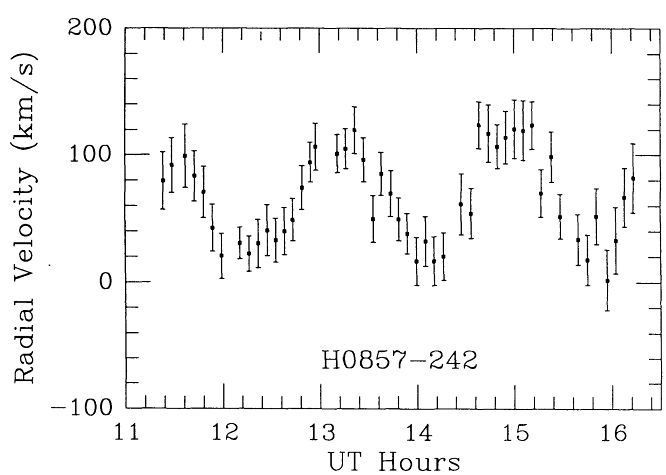

FIG. 12.—Time series of radial velocity measurements of the H emission lines of H0857+242. The data were obtained with the ANU 2.3 m telescope on 1988 March 20. Variance analysis indicates a period of 1.78 ± 0.09 hr.

6. OPTICAL PHOTOMETRY OF H0857−242

Photometric measurements of H0857−242 were made during three observing runs. The first set of observations (1988 November 27, 28, 30, and December 1) were made with the 1.3

TABLE 1

PERIODIC MODULATIONS IN H0459+246 AND H0857−242

Measurement Type	Period (hr)	Epoch Marker	Epoch (UT hr, date; HJD)[1]
		H0459+246	
Optical flux (*V*, *I*)	9.952 ± 0.074	Deep minimum	1.80 ± 0.25, 1988 November 29 HJD 7,494.586 ± 0.010
X-ray flux	1.035 ± 0.010	Maximum	6.41 ± 0.03, 1985 October 12 HJD 6,350.7702 ± 0.0013
Optical flux (*I* band)	1.054 ± 0.005	Maximum	4.85 ± 0.05, 1988 November 28 HJD 7,493.7077 ± 0.0021
		H0857−242	
Radial velocity	1.78 ± 0.09	Maximum	16.12 ± 0.12, 1988 March 20 HJD 7,241.1754 ± 0.0050
Optical flux[2] (*V*, *I*)	0.8124 ± 0.0021	Maximum	12.32 ± 0.08, 1988 November 30 HJD 7,496.0143 ± 0.0033
Optical flux[2] (*V* band)	0.8167 ± 0.0085	Maximum	0.76 ± 0.12, 1990 April 1 HJD 7,982.5346 ± 0.0050
Optical flux[2] (*V* band)	0.8086 ± 0.0030	Maximum	12.03 ± 0.08, 1990 May 26 HJD 8,038.0004 ± 0.0033

[1] Heliocentric Julian Date −2,440,000.0.

[2] In each case the periodicity was seen in the detrended data during the decay phase of dwarf nova outbursts. As the observations occurred, only the first night of data was excluded from the timing analysis performed for each observing run. The periods listed here are the best choice common to all three observing runs; 1 day aliases cannot be excluded as valid results, and precise values for these alternatives are given in the text.

m telescope at MDM Observatory after H0459+246 had set. The instrumental details and analysis follow the descriptions given in § 4. The CCD images were obtained with an I-band filter on every night except November 30, when a *V*-band filter was used.

The two other sets of observations (on a total of 7 nights) were obtained with the 1.0 m telescope at the South African Astronomical Observatory (SAAO) during 1990 March 29 to April 2 and 1990 May 25 to 29. The SAAO observations employed the University of Cape Town Photometer, a single-channel photoelectric instrument used with an Amperex 56 DVP (S-11) photomultiplier tube. The measurements were unfiltered, and the convolution of the CV spectrum and the phototube response reaches a maximum throughput in the *B* band. The time resolution was 5 s. Regular observations were taken of the sky background every 15–20 minutes, and a cubic spline fit to the sky measurements was subtracted from the data. Finally, the count rates for H0857−242 were corrected for atmospheric extinction. Additional *UBV*-filtered observations of H0857−242 were made at the start of each night. The results are given in Table 2; *V* magnitudes were in the range of 13.5 to 15.8.

The optical light curves of H0857−242 are displayed in Figure 13. The *I*-band count rates from the CCD instrument (*top*) have been normalized by the amplitude and profile of a local reference star (see Remillard et al. 1991). In the case of the SAAO data, a count rate of 8000 counts s^{-1} corresponds to a *B* magnitude of 13.6. The results shown in Figure 13 resemble the characteristic behavior of dwarf novae, with an outburst timescale ~5 days and a relatively short recurrence time.

TABLE 2

PHOTOMETRIC OBSERVATIONS OF H0857−242

HJD	*V* magnitudes	*B*−*V*	*U*−*B*
7981.2540......	13.520	−0.018	−0.770
7982.3497......	14.673	0.062	−0.912
7983.2940......	15.488	0.131	−1.020
7984.4142......	15.492	0.225	−1.076
8037.2280......	13.527	0.059	−0.513
8038.2100......	14.639	0.043	−0.802
8039.2718......	15.755	0.125	−1.110
8040.2510......	15.467	0.044	−1.145

In order to search for periodic modulations at short timescales, we investigated a number of data combinations and methods for removing the secular variations associated with dwarf nova outbursts. The most intriguing results were obtained by ignoring the night with the brightest optical flux, which happens to be the first night of each of the three observing runs. The remaining data was detrended by simply dividing the individual count rates by the mean value for a given night. The variance statistic was computed for these "selected, detrended" data sets for trial frequencies corresponding to periods between 0.1 and 6.0 hr. The results for the range of 0.1 to 2.0 hr are shown in Figure 14. For each observing run, there is evidence of a modulation near 3.4×10^{-4} Hz, or 0.8 hr, and its first subharmonic. The deepest minimum near 0.8 hr for the 1990 April data is aligned with variance minima in each of the panels, and the set of individual results implies a best period of 0.8120 ± 0.0017 hr. The observing runs are too far apart to permit a unique specification of cycle counts that would yield a single ephemeris for this optical pulsation. Alternative periods at 0.8383 and 0.7850 hr cannot be discounted, but the modulation amplitude in the folded light curves appears diminished at these periods for the data of 1990 April.

The folded light curves (at 0.8120 hr) for these selected, detrended data sets are shown in Figure 15. The modulations exhibit half-amplitudes in the range of 7%–10% of the average flux. We regard these results as tentative evidence for coherent modulations representative of the spin period of the white dwarf in H0857−242. In all three cases, the significance and amplitude of the ~49 minute pulsation is diminished if the "bright night" is included in the analysis.

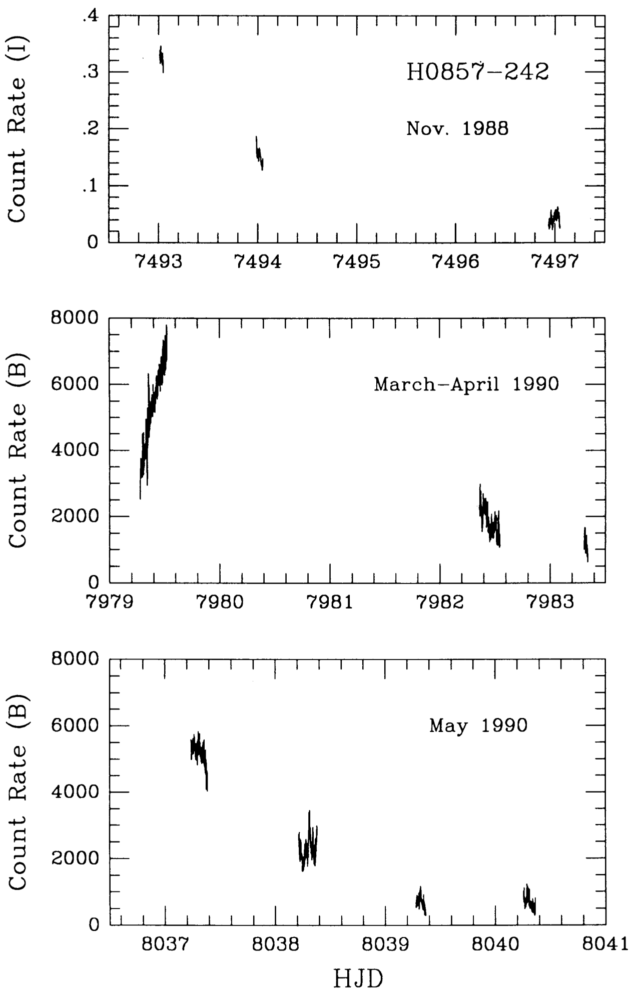

FIG. 13.—Photometric observations of H0857−242 during three observing runs. The displayed times are (Heliocentric Julian Date −2,440,000.0). In the top panel, a count rate of 0.1 corresponds to an I magnitude of 14.44 ($\pm$0.03), while 8000 counts s^{-1} in the lower panels corresponds to $B \sim 13.6$ although these observations were not made with a photometric filter. The results confirm a dwarf nova subclassification and suggest an outburst timescale of 4 to 5 days duration.

There appear to be additional minima in the variance statistic between 1.8 and 2.0 hr (especially at 1.98 $\pm$ 0.02 hr), that might be consistent with the radial velocity period; however, the period choice is not unique and variations in this range of timescales are blended with the subharmonic (and its aliases) of the 0.8 hr modulation. The remaining portion of the variance analysis, for trial frequencies corresponding to the range of 2 to 6 hr, is shown in Figure 16. There are additional, deep minima in the variance statistic. Most of these minima do not appear clearly in the 1990 April data set, but a minimum at 3.35 hr may be common to all three observing runs. However, the folded light curves at this period appear somewhat jagged and they do not resemble one another. The low frequency power in the detrended light curves of H0857−242 may therefore originate from noncoherent variability.

7. PHOTOGRAPHIC RECORDS FROM THE HARVARD PLATE LIBRARY

Both H0459+246 and H0857−242 were included in a historical study of X-ray selected CVs from the *HEAO 1* survey by Silber (1992), using the photographic plates from the Harvard Plate Library. In each case a sequence of 10 field stars was used to compare the CV brightness on a given plate, and the magnitudes of the field stars were calibrated using the Hubble Guide Star catalog. H0459+246 is visible on 12 of 121 plates, while the mean threshold for cases without detections is $B \sim 13.8$ (patrol plates). The detections are consistent with B mag in the range of 15.1 to 16.1, which is similar to the results reported in previous sections of this paper.

A much larger range in brightness is observed for H0857−242. This CV is seen on 72 of 152 plates, with B magnitudes distributed in the range of $11.2 \leq B \leq 15.5$, and a mean non-detection limit of $B \sim 14.5$. The brightest instances are seen on 1947 May 7 and May 14, when the CV appears at the level of the brightest star in Figure 2*b* (SE quadrant). These optical maxima are 2 mag above the common outburst levels ($B \sim 13$), leading to the conclusion that H0857−242 exhibits superoutbursts characteristic of the SU UMa type of dwarf novae (see Warner 1985). Very bright maxima were also recorded on 1933 March 29, 1934 May 18, 1944 March 17,

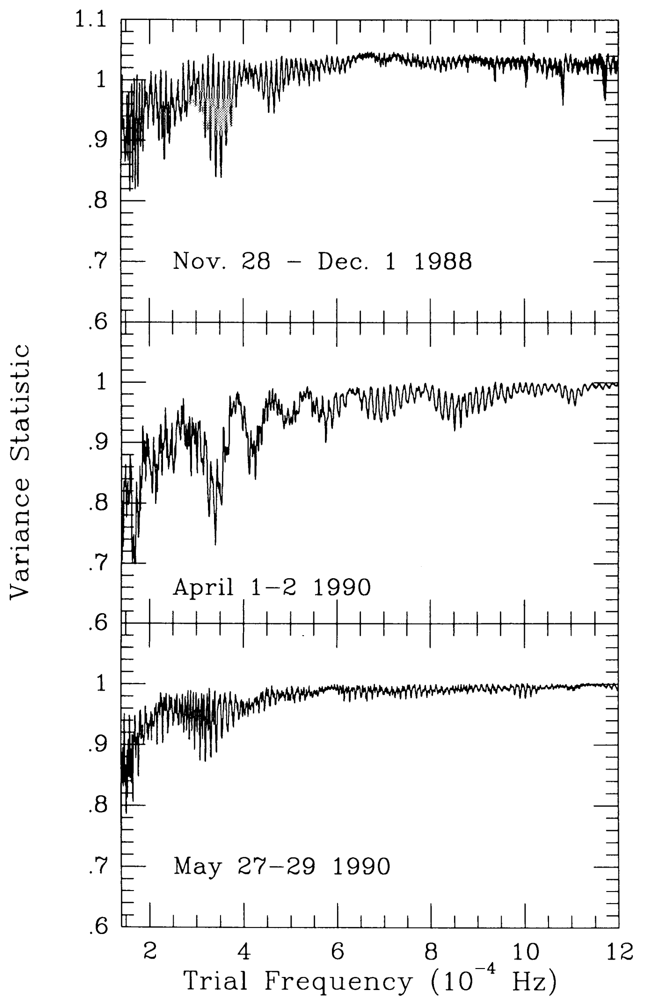

FIG. 14.—Variance analysis of the detrended photometric observations of H0857−242, excluding the single night with the brightest optical flux during each observing run. The deepest minimum near 3.4 × 10^{-4} Hz for 1990 April is consistent with minima in the other panels, suggesting a possible coherent period at 0.8120 $\pm$ 0.0017 hr during the decline phase of each dwarf nova outburst.

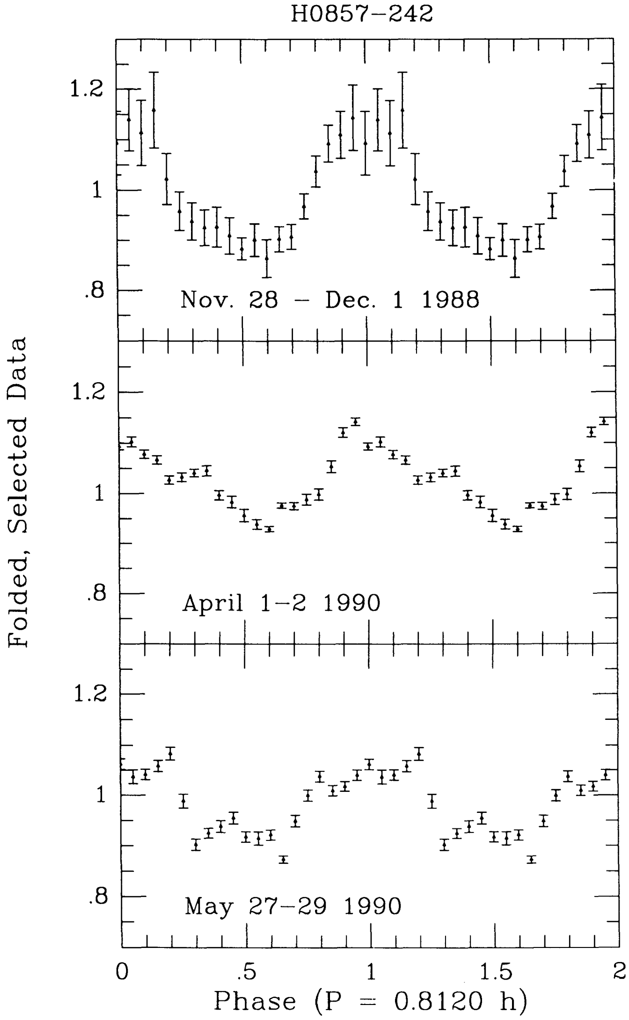

FIG. 15.—Detrended optical photometry, excluding the brightest night of each observing run. The data were scaled to the mean intensity value on each night of observations (see text) and then folded at a period of 0.812 hr.

1945 May 13, 1947 January 22, 1950 March 22, and 1987 November 20. We strongly advocate monitoring of H0857−242 to gain spectral and temporal measurements of superoutbursts that are expected to recur.

8. DISCUSSION

The CVs H0459+246 and H0857−242 provide a striking contrast in orbital period, spectral properties, and outburst behavior, despite the possibility that they may both be intermediate polars selected on the basis of hard X-ray emission. The evaluation of magnetic field strengths would be of great interest in both cases. A relatively large separation between the white dwarf and the secondary is expected for H0459+246, and a strong magnetic field could be accommodated without observational consequences. Thus, this case might harbor the pre–AM Her conditions hypothesized for intermediate polar stars by Hameury, King, & Lasota (1986). On the other hand, if H0857−242 is confirmed as an intermediate polar, its accretion disk and 1.8 hr period all but guarantee that its magnetic moment is significantly less than that of AM Her stars.

The case of H0857−242 is of further interest due to the possibility of combined magnetic and "normal" dwarf nova characteristics. A few CVs have shown evidence of both dwarf nova and intermediate polar classification (e.g., EX Hya and GK Per), but these examples tend to show irregular and peculiar dwarf nova characteristics (Cordova 1993; Ritter 1990, and references therein). In contrast, H0857−242 shows a normal outburst spectrum and a rapid recurrence timescale, while the intermediate polar classification is tentative.

Observations of a bright X-ray source that is both an intermediate polar and a *continually cycling* dwarf nova may provide an additional method for testing physical models of the outburst and superoutburst mechanisms. Multifrequency timing studies of "normal" dwarf novae have been applied to such models (Pringle, Verbunt, & Wade 1986; Pringle et al. 1987), but the results are not yet conclusive. There are time lags between the optical and UV components that are not understood, and the interpretation of X-ray emission is complicated by reprocessing effects and the development of a hot corona above the inner disk (Watson, King, & Heise 1985; van der Woerd & Heise 1987). Such investigations would profit from the provision of an X-ray modulation that would distinguish accretion flow onto the white dwarf surface, relative to the onset of optical and UV brightening. In practice, the utilization of this X-ray signature would also require favorable angles of binary inclination and magnetic pole colatitude, along a mag-

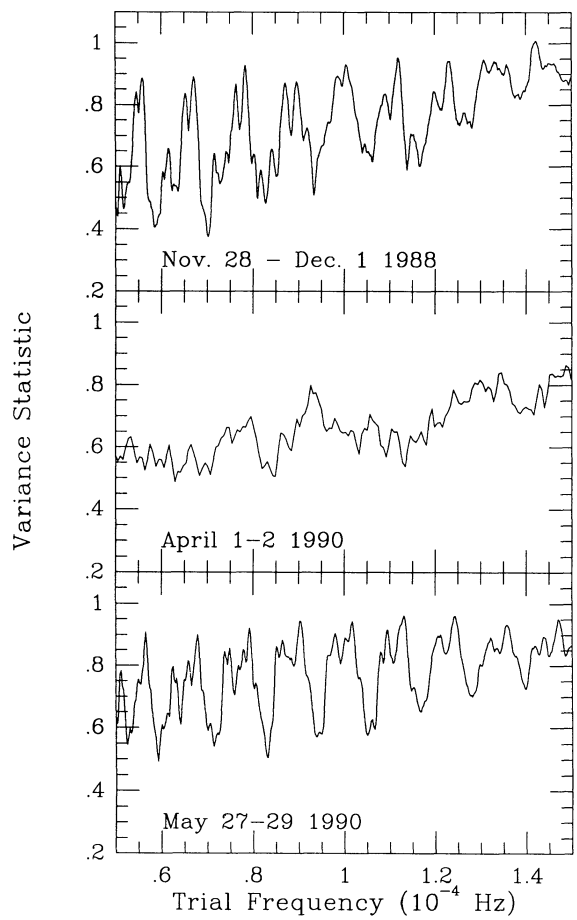

FIG. 16.—Variance analysis for trial periods in the range of 2.0 to 6.0 hr. As in Fig. 14, the computations were applied to the detrended photometric observations of H0857−242, excluding the single night with the brightest optical flux during each observing run.

netic field strength that is sufficient only to disrupt in innermost portion of the disk (see Angelini & Verbunt 1989).

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