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1H 0709−360: A CATACLYSMIC VARIABLE WITH AN ORBITAL PERIOD INSIDE THE "PERIOD GAP"

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ABSTRACT

We report the discovery of the second cataclysmic variable with a binary period lying well inside the nominal 2–3 hr period gap. The object, 1H 0709−360, is an X-ray source which has been identified on the basis of positional data from the instruments of the *HEAO 1* survey. The X-ray source was also detected by the *Uhuru* and *Ariel 5* surveys. Multicolor photometry has revealed eclipsing behavior at an orbital period of 2.444 hr. Radial velocity measurements show modulations at the same period, with an offset between the spectroscopic and photometric conjunctions. Both the eclipse profile and a clear rotational disturbance in the radial velocities of emission lines during eclipse provide unambiguous evidence for the existence of an accretion disk. Thus the object cannot be an AM Herculis variable, a conclusion supported by the absence of circular polarization. Instead, the evidence suggests that the object could be a DQ Herculis magnetic variable that is close to synchronism. We discuss the evolutionary implications of this rare object.

Subject headings: stars: dwarf novae — stars: eclipsing binaries — stars: individual (1H 0709−360) — X-rays: binaries

I. INTRODUCTION

The existence of a gap in the binary period distribution of cataclysmic variables (CV) has long been recognized as an important evolutionary characteristic of this class of interacting binaries. In a recent compilation of CVs with measured orbital periods, nearly all of the 116 objects have periods outside the nominal 2–3 hr gap (Ritter 1987). In the same compilation, the CVs closest to the gap are the dwarf novae TU Men (2.08 hr; Stolz and Schoembs 1984) and YZ Cnc (2.82 hr; Shafter and Hessman 1988). More recently, an AM Her type variable, EXO 033319−2554.2 (Osborne *et al.* 1988; Ferrario *et al.* 1989), redefined the short edge of the gap, with an eclipse period of 2.12 hr. Soon afterwards, Shafter and Abbott (1989) revealed the first example near the center of the period gap, with the observation of 2.57 hr eclipses displayed by the old nova, V Per. The gap may be eroded further by the detection of 2.78 hr modulations in the light curve of PG 1711+336 (Rosen *et al.* 1989), although the spin versus orbital interpretation of the latter case is still under debate.

The period gap is widely believed to represent a transition zone in the evolution of cataclysmic variables (e.g., Paczyński and Sienkiewicz 1983; Rappaport, Verbunt, and Joss 1983; Patterson 1984; Ritter 1986; Lamb and Melia 1987; King 1988). The most commonly described scenario is as follows. Above the gap, evolution of the binary system is driven by the loss of angular momentum via magnetic braking in the wind emanating from the secondary star. At $P \sim 3$ hr, the wind ceases abruptly as the secondary becomes fully convective. Thereafter, the binary evolution is governed by angular momentum losses due to gravitational radiation, and the Roche lobe around the secondary star shrinks much more slowly. The star, which had been driven out of thermal equilibrium during the binary evolution, then shrinks at the Kelvin-Helmholtz timescale and detaches from its Roche lobe. Eventually, the Roche lobe will again reach the surface of the star, at $P \sim 2$ hr, and mass transfer resumes with a significantly lower accretion rate. One possible difficulty with this explanation of the period gap is the apparent low space density of short-period binaries, unless a mechanism exists which destroys CVs on a time scale short compared to the age of the Galaxy (Patterson 1984). Nevertheless, the proposed evolutionary sequence provides a plausible and attractive explanation for the period gap, and implicitly predicts that CVs are not detectable inside the gap due to insufficient accretion luminosity.

In this paper we report the discovery of the second CV to have an orbital period lying well inside the period gap. The object, 1H 0709−360, is further distinguished by exhibiting partial eclipses of an accretion disk. Thus, 1H 0709−360 holds great promise in elucidating the nature of the enigmatic period gap, and in particular, the evolutionary status of systems inside the gap.

II. OBSERVATIONS AND RESULTS

a) Optical Identification and X-Ray Properties

We identified the CV, 1H 0709−360, as part of a major program directed toward the study of the fainter X-ray sources detected by instruments of the *HEAO 1* satellite. Our identification program is discussed in detail by Remillard *et al.* (1986; see also Bradt *et al.* 1988). X-ray positions are provided by the Scanning Modulation Collimator (MC) experiment on *HEAO 1* (Gursky *et al.* 1978). While the MC instrument produces multiple error "diamonds" for each X-ray source, the ambiguity in source location is significantly reduced by the superposition of a coarse error box measured contemporaneously by the Large Area Survey (LASS) experiment on *HEAO 1* (Wood *et al.* 1984). The MC error diamonds that lie in or near the error boxes derived from LASS and other X-ray surveys are then used to select optical candidates that show UV-excess,

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emission lines, or evidence of coronal activity. The candidates in the first two categories are derived from Schmidt photography of the field. All candidates are subsequently observed spectroscopically to assess their viability as X-ray counterparts.

The celestial region in the vicinity of 1H 0709 − 360, within 2° of R.A. = 7^h15^m and decl. = −37°.5, includes many detections from various X-ray surveys: three *HEAO*-LASS sources (1H 0709 − 360, 1H 0714 − 390, and 1H 0726 − 377; Wood *et al.* 1984), two sources from the *Uhuru* survey (4U 0711 − 38 and 4U 0729 − 37; Forman *et al.* 1978), and one *Ariel 5* detection (2A 0708 − 357; Cooke *et al.* 1978). Our analysis of data from the *HEAO*-MC experiment, in conjunction with our efforts to locate the optical counterparts of these X-ray sources, leads to the conclusion that the cataclysmic variable presented in this paper is the optical counterpart of 1H 0709 − 360, 2A 0708 − 357, and 4U 0711 − 38. The star HD 58111 (K0/1 V; SAO 197912), a chromospherically active star with evidence of weak Ca H, K emission (Houk 1982), is the optical counterpart of 1H 0714 − 390, while 1H 0726 − 377 (=4U 0729 − 37?) remains unidentified at the present time. Figure 1 shows the X-ray positions on the western side of this celestial region. Although the position for 4U 0711 − 38 is closer to the error box for 1H 0714 − 390, the locations of the proposed optical counterparts strongly favor the identification of the *Uhuru* source with the cataclysmic variable, which lies directly along the narrow dimension (i.e., the axis that is better determined) of the *Uhuru* error box. A finding chart and celestial coordinates for the cataclysmic variable are presented in Figure 2 (Plate 7).

The small, diamond-shaped error boxes in Figure 1 are the X-ray positions from the *HEAO*-MC for scanning observations processed in the vicinity of 1H 0709 − 360. The cataclysmic variable is located within one of these MC diamonds. The identification of HD 5811 with 1H 0714 − 390 is supported by the star's location with respect to a different set of MC diamonds (not shown in Fig. 1) for scanning observations in the vicinity of 1H 0714 − 390. The *HEAO*-MC detection of the cataclysmic variable arises from the superposition of data from the second and third celestial scans by *HEAO 1* (1978 April 15–22 and 1978 October 16–25). The MC results indicate that the average X-ray flux at those times was greater (by a factor ∼2) than the flux during the first *HEAO 1* scan (1977 October 15–25), which is the scan reported in the *HEAO*-LASS catalog (Wood *et al.* 1984). The MC detection is 3.3 σ for the fine collimator (30″ resolution) in the energy range of 1–3 keV, and 2.5 σ for the coarse collimator (120″ resolution) in the range of 1–13 keV.

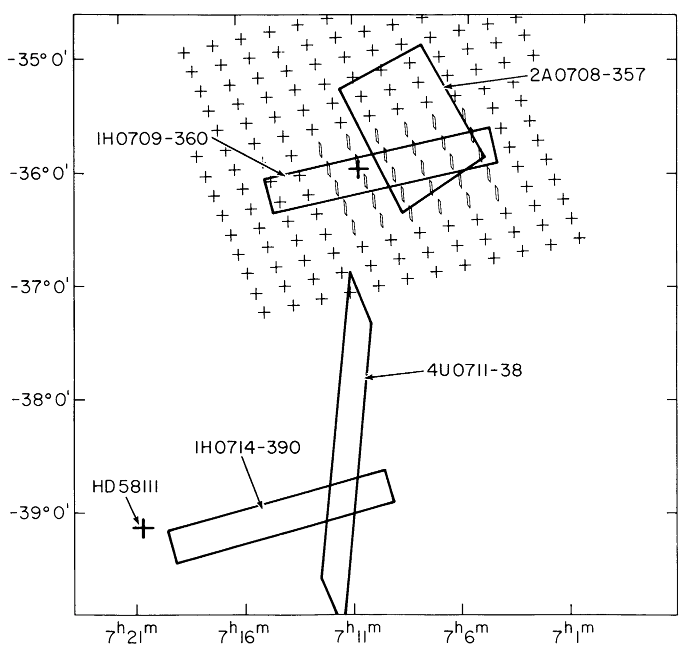

FIG. 1.—X-ray error boxes in the vicinity of the cataclysmic variable (CV) identified with 1H 0709 − 360. 1H denotes *HEAO*-LASS, 2A denotes Ariel-5, and 4U denotes *Uhuru*. The array of small "diamonds" is derived from the *HEAO*-MC instrument. The new CV is marked by a bold cross and lies inside an MC diamond within the *HEAO*-LASS error box. The CV lies close to the Ariel ("2A") position and is along the narrow dimension of the *Uhuru* error box. The object marked HD 5811 is a chromospherically active star believed to be the counterpart of 1H 0714 − 390 (as discussed in the text).

The X-ray detections from *each* of the most sensitive all-sky surveys imply that 1H 0709 − 360 is persistently bright at X-ray energies. The flux measurements, normalized to the range of 2–10 keV, vary between 2×10^{-11} ergs cm^{-2} s^{-1} (*HEAO*-LASS) and 6×10^{-11} ergs cm^{-2} s^{-1} (*Uhuru*), but some of the differences may be due to variations in instrumental response to X-ray temperature, which is unknown at present.

b) Optical Spectrum

An emission-line candidate for 1H 0709 − 360 was located on a photographic plate obtained with the 2° objective prism on the Curtis Schmidt telescope at Cerro Tololo Inter-American Observatory. Spectroscopy was undertaken on 1988 February 17 using the Dual Beam Spectrograph (DBS) of the ANU 2.3 m telescope at Siding Spring Observatory. The spectrum, acquired between 3500 and 8400 Å, immediately revealed emission features distinctive of a CV. Subsequently, on 1988 February 22, a broader spectrum was obtained using the Anglo-Australian Telescope (AAT) with a dichronic beam-splitter directing light to the RGO/IPCS Spectrograph (3400–5400 Å) and the Faint Object Red Spectrograph (FORS; 5300–10,000 Å). For the latter instrument, the atmospheric absorption bands were corrected during the data reduction by using observations of "smooth spectrum" stars. The average IPCS and FORS spectra are shown in Figure 3. The Balmer and Paschen series are evident, as well as intense and broad He II λ4686 and C III/N III emission between $\lambda\lambda$4640–4650. The strength of these latter high-excitation lines, relative to Hβ, suggests a magnetic system of the AM Herculis or DQ Herculis class (see, e.g., Watts 1985). We note that there is no evidence in the FORS spectrum for features which could be attributed to the secondary star (e.g., TiO bands).

c) Multicolor Photometry

Following the spectroscopic classification of 1H 0709 − 360, multicolor photometry was undertaken during the same observing run using the two-channel chopper (TCC; see Tuohy *et al.* 1986) of the 2.3 m telescope. Simultaneous *UBVRI* photometry of 1H 0709 − 360 was obtained on 1988 February 18 between 13.1–17.0 UT, and again on February 20 between 10.7–16.5 UT. On both occasions, distinct eclipse events separated by ∼2.4 hr were observed. These eclipses clearly reveal the binary period of the system and are illustrated in the calibrated *UBVRI* light curves for February 20 plotted in Figure 4.

A total of four well-defined eclipses were observed during the TCC photometry and their central heliocentric times are listed

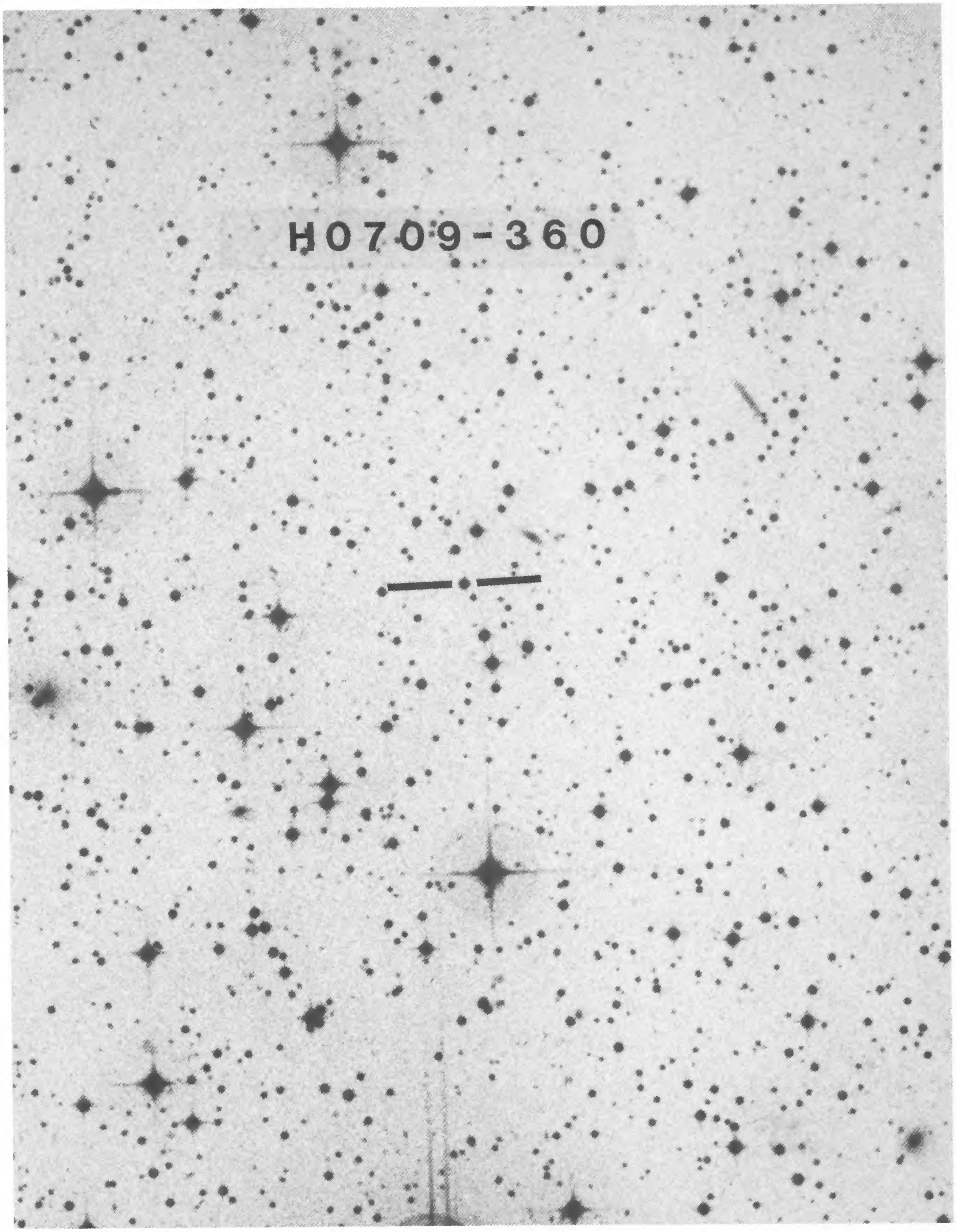

FIG. 2.—Finding chart for 1H 0709 − 360, with north to the top and east to the left. The coordinates (epoch 1950) for the CV are $\alpha = 07^h10^m45^s.4$, $\delta = -36°00'31''$.

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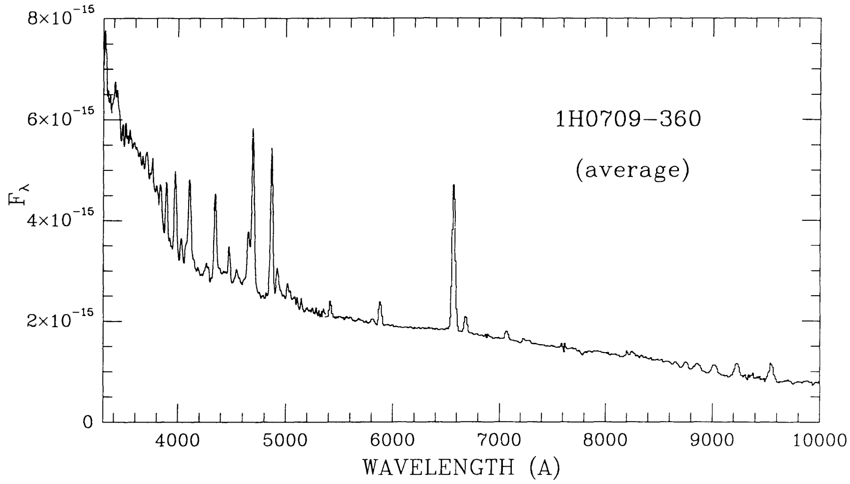

FIG. 3.—Optical spectrum of 1H 0708−360 measured with the AAT on 1988 February 22. The blue portion of the spectrum ($\lambda < 5400$ Å) is from the RGO/IPCS spectrograph, while the red spectrum is measured with the Faint Object Red Spectrograph. Atmospheric features at the A and B bands have been corrected using a smooth spectrum standard. Note the intense He II λ4686 and C III/N III $\lambda\lambda$4640, 4650 emission. The Paschen series of hydrogen is evident in the far red.

in Table 1, together with the times of two other eclipse centers derived from spectroscopic data presented below. A least-squares fit to the six times yields a best-fit period of 2.444161 ± 0.000014 hr and the following ephemeris for 1H 0709−360:

$$\phi_0 = \text{HJD } 2447210.12091 + (\text{N})0.1018401$$
$$(\pm 0.00007) \quad (\pm 0.0000006)\,.$$

This ephemeris predicts all observed times of minima to within 18 s, and is used throughout the paper to define phase zero.

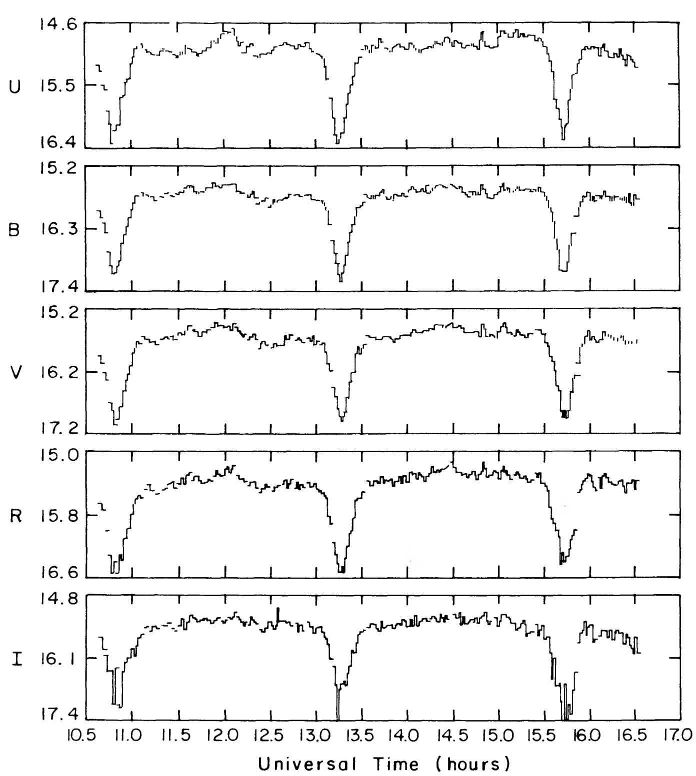

FIG. 4.—*UBVRI* light curves for 1H 0709−360 measured on 1988 February 20 using the ANU 2.3 m telescope. Three consecutive eclipses are evident at a separation of 2.44 hr.

Average *UBVRI* light curves for 1H 0709−36 derived by folding the two sets of TCC data at the best fit period are plotted in Figure 5 on a linear scale. The light curves are relatively flat-topped except for a small maximum in all bands centered near $\phi = 0.4$ (this maximum may not be present in every cycle, as is evident from Fig. 4). The depth of the eclipse ranges from ~66% between *U* and *V*, to ~55% between *R* and *I*. There appears to be a slight color dependence in the width of the eclipse, which has a FWHM of 13.8 minutes in the *U* and *B* bands, compared with 15.2 minutes in *R* and *I*. Both the duration of the eclipse and the relatively slow ingress and egress (4–5 minutes) are immediately indicative of an accretion disk; in particular, the eclipse profile contrasts markedly with the sharp transitions (10–40 s) observed in eclipsing AM Herculis variables (Ferrario *et al.* 1989; Biermann *et al.* 1985), for which the emission-arises from a magnetic accretion funnel and not an accretion disk.

d) Time Series Analysis

A time series analysis of the *UBVRI* photometry for February 18 and 20 was undertaken to investigate any additional periodicities in 1H 0709−360, and in particular, to search for an underlying white dwarf rotation period. Both epoch folding and Discrete Fourier Transform (DFT) techniques were applied to the non-uniformly sampled data (see Buckley and Tuohy 1989), with each procedure giving comparable results. Figure 6 shows a period versus chi squared plot derived from epoch folding over a range of trial periods between 1000–10,000 s. The 2.444 hr orbital periodicity and associated 2 day

TABLE 1

MID-ECLIPSE TIMES FOR 1H 0709−360[a]

Cycle	HJD	Residual
0	2,447,210.121125	−0.00021
18	2,447,211.954000	0.00003
19	2,447,212.055875	0.00000
20	2,447,212.157708	0.00000
38	2,447,213.990625	0.00021
294	2,447,240.061917	−0.00003

[a] Deducted orbital parameters are $P = 0.1018401$ (6) days and $\phi_0 = $ HJD 2447210.12091 (7).

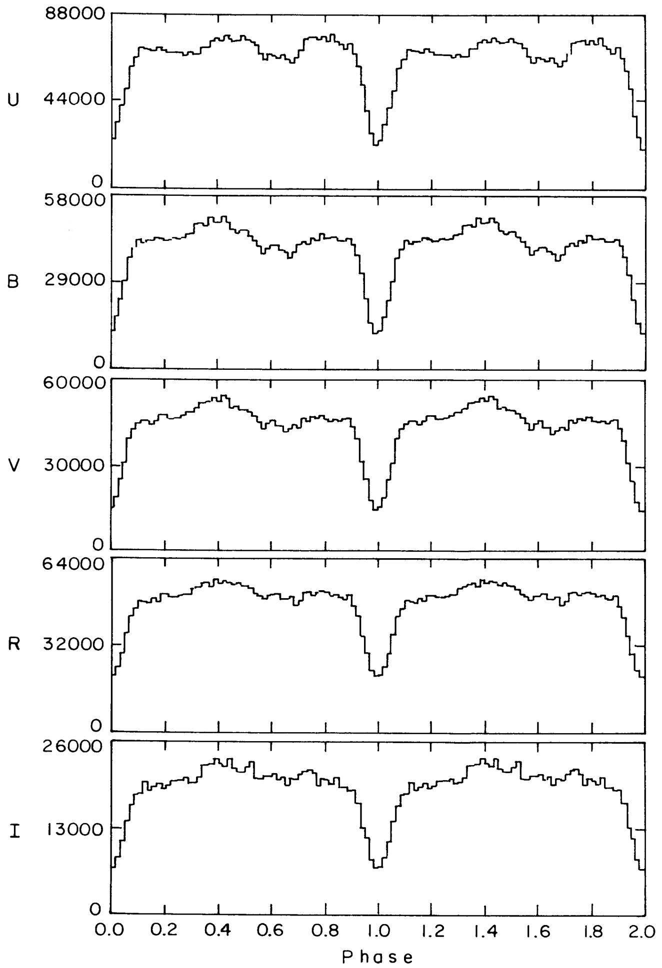

FIG. 5.—*UBVRI* light curves for 1H 0709−360 derived by folding the data for 1988 February 18 and 20 at a period of 2.444 hr according to the ephemeris given in the text. Two cycles are shown for clarity.

alias peaks dominate the plot in the vicinity of 8800 s. In addition, similar broad peaks and accompanying alias structure are apparent at the first to fourth harmonics of the orbital period.

Of particular interest in Figure 6 is the presence of a secondary peak (with alias structure) that is just resolved from the orbital period. The "window" power spectrum derived from our DFT analysis indicates that the multiple secondary peak structure is unlikely to be an artifact due to sampling. We have investigated the reality of this feature further by prewhitening the time series data (removing the fundamental periodicity) and repeating the analysis procedure. Two prominent chi-squared peaks are evident at $\sim$8555 s and $\sim$8980 s, both of comparable power and straddling the orbital period. Thus our data shows evidence for a second period in 1H 0709−360 which is close to being *synchronous* with the orbital period. Further observations over a longer time base are needed to confirm this result and to establish the correct value of the period.

e) AAT Eclipse Spectroscopy

A relatively short sequence of low-resolution spectroscopy of 1H 0709−360 was acquired during an AAT run on 1988 February 22. As noted above, the instruments used were the RGO/IPCS Spectrograph and the Faint Object Red Spectrograph (FORS), with a dichroic mirror splitting the beam at $\sim$5500 Å. The timing of the measurements was calculated to coincide with an eclipse using an ephemeris derived from the light curves measured 2 nights earlier. Fourteen pairs of spectra of duration 180 s were obtained between $\phi = 0.83$ through $\phi = 0.16$. We note that the average of these 14 measurements corresponds to the spectrum plotted in Figure 3. The spectra for both instruments were also binned in wavelength to produce a pair of light curves in which an eclipse is clearly present at the anticipated time; the central time of this event is included in Table 1. We have also isolated the two measurements obtained with the AAT during photometric minimum. The average of these spectra is shown in Figure 7. At minimum light, the spectrum is still dominated by the accretion disk, although a comparison between Figures 3 and 7 shows that the continuum is redder and the He II lines are slightly weaker in the latter case. We conclude that the photometric minima are eclipses of $\sim$70% of the accretion disk by the companion star, which remains invisible in Figure 7.

The radial velocity behavior of 1H 0709−360 through the eclipse has been investigated by Gaussian fitting of the Balmer and He II λ4686 lines in the individual spectra. The velocities and integrated fluxes for H (using the average velocities for Hβ, Hγ, and Hδ) and He II are shown in Figure 8. Both emission lines show a clear rotational disturbance in velocity during eclipse (a "*Z*-wave" as coined by Young, Schneider, and Schectman 1981). This behavior provides indisputable evidence for an accretion disk and is explained as follows. First, blueshifted material in the disk is progressively occulted by the companion star, and a peak in redshift occurs when the light is dominated by the bright redshifted material on the opposite side of the white dwarf. Soon after, the secondary's shadow moves over to the opposite side of the inner accretion disk, and the bright blueshifted region of the disk reappears, leading to the observed rapid reversal in velocity ($\sim$500 km s^{-1} in $\Delta\phi < 0.1$ for the Hβ–δ lines). As expected, the central time of the velocity reversal coincides with mid-eclipse. The *Z*-wave phenomenon has been observed in several other eclipsing cataclysmic variables (e.g., Young and Schneider 1980; Watts *et al.* 1986; Marsh, Horne, and Shipman 1987; Honeycutt, Kaitchuck, and Schlegel 1987).

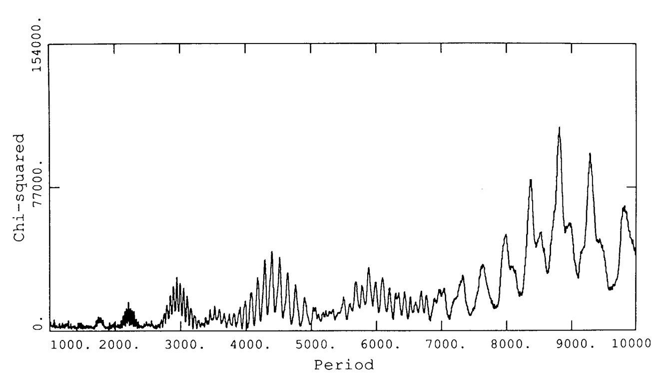

FIG. 6.—Period vs. chi-squared plot for 1H 0709−360 derived by folding the data for 1988 February 18 and 20 at trial periods between 1000 and 10,000 s. The dominant peak corresponding to the orbital period at 8798 s (2.444 hr) shows a clear subpeak, suggesting the presence of a secondary periodicity close to the fundamental. Alias peaks corresponding to the two day interval between the two data sets (February 18 and 20) are present, together with multiple peaks associated with the first to fourth harmonics.

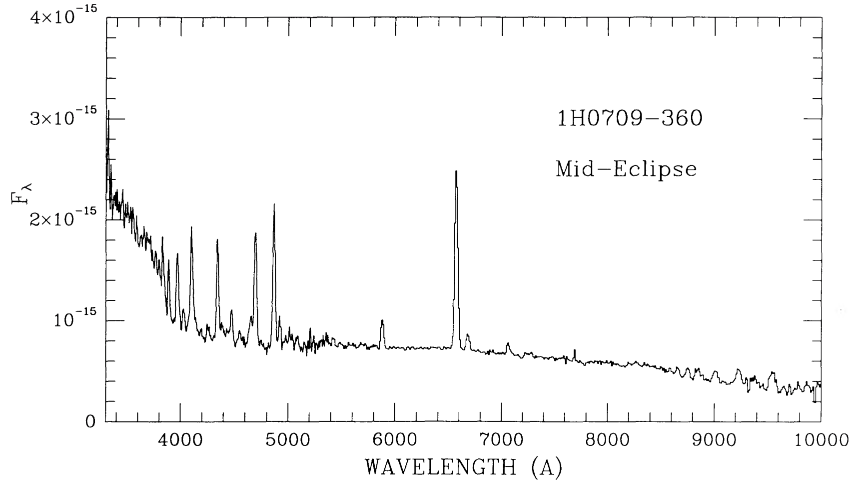

FIG. 7.—Optical spectrum of 1H 0709−360 measured with the AAT for 360 s during a photometric minimum on 1988 February 22. A comparison with Fig. 3 shows a slightly redder continuum with relatively weaker He II lines during the minimum, which is caused by a partial eclipse of the accretion disk.

We remark that the velocity and amplitude results for the individual Balmer lines (Hα through and Hε) are very similar, and their equivalent widths are anticorrelated with the flux amplitudes, indicating that the continuum is more severely occulted during the eclipse than are the emission lines. However, there are significant differences for He II, as can be seen from Figure 8. Most noticeable is a narrow velocity minimum in the He II profile at $\phi \sim 0.03$, just after eclipse. Second, the eclipse of the He II emitting region begins later and has a shorter duration than for the H lines; in particular, the widths of the minima in the amplitude curves are $\Delta\phi \sim 0.11$ and $\Delta\phi \sim 0.08$ FWHM, respectively. This behavior is consistent with the He II emission arising from a smaller volume closer to the white dwarf.

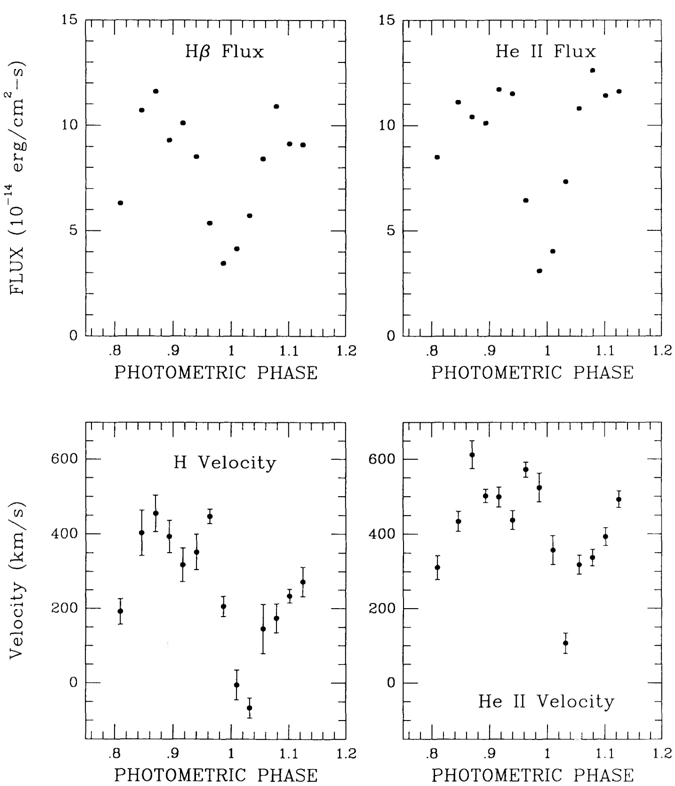

FIG. 8.—Radial velocity measurements obtained with the AAT during an eclipse on 1988 February 22 at 11.715 UT. The eclipse center defines photometric phase. 1.0. Radial velocities (*bottom panels*), and emission-line fluxes (*top panels*) are shown for Hβ (*left*) and He II λ4686 (*right*), respectively. Clear *Z*-wave behavior, due to the eclipse of an accretion disk, is present in both the Hβ and He II velocity curves.

f) 2.3 Meter Radial Velocity Measurements

A radial velocity study of 1H 0709−360 was undertaken on 1988 March 19 using the 2.3 m telescope and the DBS, set up to cover the wavelength range 3600–8200 Å with a typical resolution of ∼5 Å FWHM. Twenty-nine spectra of duration 300 s were acquired and span just over a full binary cycle. Again, a clear eclipse was detected and the time is included in Table 1. The emission lines were found to be adequately represented by single Gaussian profiles, although some spectra show evidence for velocity structure in the lines.

The radial velocity curves for Hα and He II are plotted in Figures 9*a* and 9*b*. Single sine curve fits with $P = 2.444$ hr are also shown; we note that the scatter in the data near $\phi \sim 0$ is due to the *Z*-wave effect discussed above (although the effect is less pronounced in the DBS data, which have lower time resolution and reduced statistics compared with the AAT eclipse spectroscopy). Least-squares parameters for both lines are summarized in Table 2. The only substantial difference in the radial velocity results for the two lines is the lower semi-amplitude (K) for He II.

TABLE 2

RADIAL VELOCITY PARAMETERS FOR 1H 0709−360

Emission Line	K Velocity (km s^{-1})	γ Velocity (km s^{-1})	Max Phase[a]
Hα	328 ± 20	99 ± 13	0.921 ± 0.008
He II	206 ± 17	45 ± 12	0.864 ± 0.012

[a] The photometric phase at which the velocity reaches a maximum. In other systems where there are eclipses of symmetric accretion disks, the maximum velocity (spectroscopic phase 0.0) occurs at a photometric phase of 0.75.

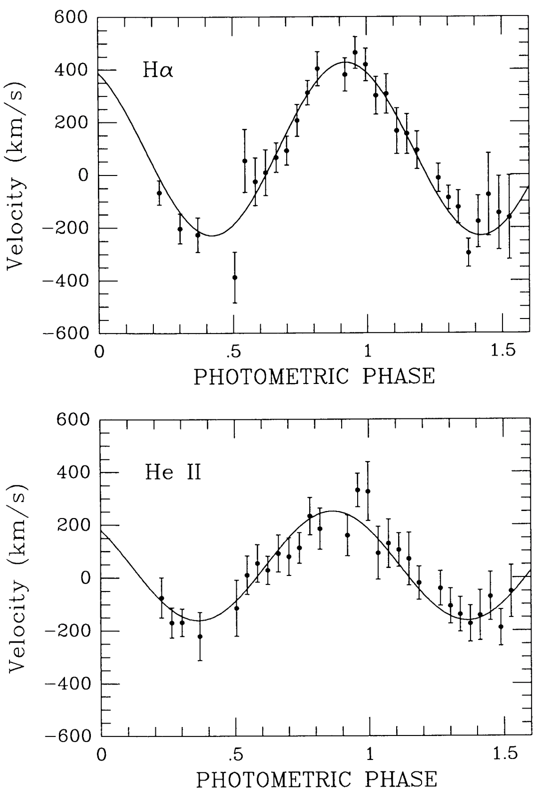

FIG. 9.—Radial velocity curves for 1H 0709 − 360 measured with the ANU 2.3 m telescope on 1988 March 19 between 11.5 and 14.8 hours UT. An eclipse at 13.443 UT defines photometric phase 1.0. Data are shown for Hα (*top panel*) and He II (*bottom panel*). The parameters for a least-squares fit to a sine curve are given in Table 2.

g) Circular Polarimetry

Circular polarimetric measurements of 1H 0709 − 360 were undertaken on 1988 March 27 (08:58–12:27 UT) and March 28 (12:22–13:47 UT using the AAT and Hatfield Polarimeter (Bailey 1988). Conditions on both nights were nonphotometric, but this did not significantly affect the polarimetry data, which span approximately two binary cycles.

No polarization was detected from 1H 0709 − 360. The results from averaging all of the data in two broad bands are as follows: $-0.09 \pm 0.11\%$ (3400–5300 Å) and $0.14 \pm 0.13\%$ (5500–8400 Å). Thus, the absence of strong polarization at wavelengths extending from the ultraviolet to the near-infrared argues strongly against an AM Her ("polar") classification for 1H 0709 − 360.

IV. DISCUSSION

The discovery of 1H 0709 − 360 marks only the second example of a cataclysmic variable that flagrantly contravenes the empirically determined 2–3 hr orbital period gap. The first example was recently demonstrated by Shafter and Abbott (1989) in the case of the classical nova, V Per. Shafter and Abbott discuss the idea that a low rate of mass transfer can delay or avoid the detachment of the secondary star from its Roche lobe, in cases where the magnetic braking had not been very strong. They then hypothesize a plausible scenario that V Per has historically had a low rate of mass transfer, leading to the nova outburst of 1887. The current state of enhanced accretion in V Per is interpreted as a result of the heating of the secondary star during the nova eruption, the affects of which may last for several hundred years.

In the case of 1H 0709 − 360, there is no immediate explanation for the location of its orbital period within the gap. The CV is relatively bright ($V \sim 15$), and the spectral properties (viz., He II strength and the X-ray: optical flux ratio) are very similar to many of the magnetic systems detected as hard X-ray sources by the *HEAO 1* survey. All of the evidence suggests robust accretion and our-time resolved spectroscopy during an eclipse minimum clearly shows the *Z*-wave signature of an accretion disk. Given the rarity of an orbital period of 2.44 hr, a precise determination of the subclass of 1H 0709 − 360 is of critical importance. While, the intensity of the high-excitation emission points strongly toward a magnetic variable (see Watts 1985), an AM Her classification (e.g., Liebert and Stockman 1985) is ruled out by the presence of an accretion disk, and by the absence of strong circular polarization. Instead, 1H 0709 − 360 is most probably a DQ Her magnetic variable (e.g., Warner 1983, 1985). The evidence favoring this classification, in addition to the intense He II emission and hard X-ray emission, is the possible existence of a second periodicity close to the orbital period, implying that the white dwarf is rotating in near-synchronism with the orbital period. This intriguing possibility, if confirmed, would provide convincing evidence that DQ Her systems can evolve into AM Her systems, with synchronism being achieved inside the period gap (e.g., Frank 1986; Lamb and Melia 1987; Hameury, King, and Lasota 1987). Synchronism could be attained via the "propeller mechanism" discussed by Schmidt, Stockman, and Grandi (1986). It has been suggested that DQ Her variables complete the transition to AM Her variables at $P \sim 2$ hours (e.g., Lamb and Melia 1987), at which time no accretion disk remains. A further implication of the probable classification of 1H 0709 − 360 as a DQ Her system concerns the indisputable evidence for the presence of an accretion disk. King (1985) and Hameury, King, and Lasota (1986) have argued that accretion disks are absent in DQ Her systems with $P < 5$ hours. Clearly, 1H 0709 − 360 would provide a counterargument to this assertion, if a DQ Her classification is confirmed.

The combination of an eclipsing light curve and radial velocity measurements of the emission lines offers the opportunity to derive limits for the inclination angle and the mass of the white dwarf in the binary system. However, in the present study, the difference between the spectroscopic and photometric phases is ~ 0.08, rather than the expected value of 0.25 (see Fig. 9 and note the similar high values of the emission-line velocities near the eclipse in Fig. 8). This contrasts strongly with other eclipsing CVs such as KPD 1911 + 1212 (Downes *et al.* 1986) and LB 1800 (Buckley *et al.* 1990), which exhibit eclipses precisely at the times that the radial velocities cross the mid-points from redshifted to blueshifted values. This suggests that there are significant azimuthal asymmetries in the accretion disk of 1H 0709 − 360, and the measured velocity amplitudes are likely to be affected by the Keplerian velocity of the asymmetric component(s). We conclude that we cannot interpret the radial velocity amplitude as the value of $V \sin i$ for the white dwarf in the binary system with the present data set.

A similar offset between the spectroscopic and photometric conjunctions was observed in the case of PG 1030 + 590 (DW Uma; Shafter, Hessman, and Zhang 1988). The latter CV is also an eclipsing system (3.28 hr) with very strong He II emission. The pre-eclipse UV hump in the light curve of PG 1030 + 590 may also be present in 1H 0709 − 360 (see Fig. 4), completing a very striking array of similarities between these two CVs.

A further sign of peculiarity in 1H 0709 − 360 is discussed by Bailey (1990). The eclipse duration is significantly longer than that of several other CVs on either side of the period gap. Bailey (1990) derives a mass ratio, $q > 0.6$, implying either a low-mass white dwarf or a secondary star with a mass-radius ratio that is larger than expected for a main-sequence companion. Thus, it is possible that the particular location of the "period gap" (i.e., the orbital parameters during the phase of binary detachment) may be offset for 1H 0709 − 360, compared to CVs that have binary components with more typical masses.

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