Publications of the Astronomical Society of the Pacific
106: 1141–1150, 1994 November

Superhumps in Cataclysmic Binaries. III. V795 Herculis

JOSEPH PATTERSON

Department of Astronomy, Columbia University, 538 West 120th Street, New York, New York 10027
Electronic mail: jop@carmen.phys.columbia.edu

DAVID R. SKILLMAN

Center for Basement Astrophysics, 9517 Washington Avenue, Laurel, Maryland 20723

Received 1994 July 1; accepted 1994 September 1

ABSTRACT. We report photometry of the cataclysmic variable V795 Herculis during 1990–1994. Comparison of recent with previously published data shows that the 2.78-hr periodicity has essentially disappeared; the amplitude has diminished by a factor of at least 10. In its place, there is a low-amplitude signal near the radial-velocity (orbital?) period of 2.60 hr. During 1983–1989, the star did show an obvious 2.78-hr signal. We study the published data on this signal, together with our own data under the (questionable) assumption that the signal still exists with an amplitude too small to survive the rigors of unbiased period detection. The data are really too sparse and too poorly distributed to decide the issue of phase stability. But since the photometric signal is transient and exceeds the likely orbital period by ~8%, the photometric waves are likely to be yet another example of "superhumps," the phenomenon made famous by dwarf novae in superoutburst. At high frequencies, the star shows a quasi-periodic signal with $P \sim 1160$ s, and possibly also a stable signal with $P = 1310.2$ s (or 1330.4 s, the one-day alias). The beat period between these signals could be the orbital period, or that of the vanished superhump.

1. INTRODUCTION

V795 Herculis is a noneruptive 13th-mag cataclysmic variable which has attracted considerable attention because of the bewildering variety of *periods* seen in the star. Thorstensen (1986) reported a most probable period of 14.6 hr from spectroscopic observations at Hα, but Shafter et al. (1990) found a period of 2.60 hr from radial velocities measured in the wings of Hα, Hβ, and He II λ4686. This seemed likely to be the true orbital period of the underlying binary. Mironov et al. (1983) found a photometric modulation of 2.8 hr, which has been confirmed by all subsequent studies, though with universal disagreement about the *exact* value of the period. Finally, as if we did not already have too many periods to deal with, Prinja and Rosen (1983) studied the UV emission lines and added another peculiar element to the broth: a very probable 4.86-hr period, not obviously related to any of the other periods observed.

The most recent photometric study, that of Zhang et al. (1991), derived a constant-period ephemeris alleged to be stable over a 6-yr baseline. This is an interesting result because high stability suggests that the underlying clock mechanism may involve some significant fraction of the total energy and angular momentum in the binary. In particular, Zhang et al. argued that such high stability at a period different from $P_{\rm orb}$ (presumed to be the 2.60 hr spectroscopic period) is only compatible with the rotation of a magnetic, accreting white dwarf.

This conclusion has been criticized (Prinja and Rosen 1993; Patterson et al. 1993a) on the grounds that the star basically fails to display the suite of characteristics we have come to expect from accreting magnetic white dwarfs: strong X-ray emission, polarization, broad line components moving with large velocity shifts at the rotation period. But whatever weight should be given to such arguments, it is also important simply to *verify* the claim of stability. Hence we embarked on a photometric observing program, spanning 148 hr over 39 nights during 1990–1994. Here we report the results of that program.

2. HISTORY OF THE 2.8-HR PERIODICITY

2.1 1983–1989

The 2.8-hr period was first reported by Mironov et al. (1983), based on data acquired in 1983. Additional photometry was published from 1984 (Baidak et al. 1985), 1984 and 1985 (Rosen et al. 1989), 1985 and 1986 (Shafter et al. 1990), 1988 (Kaluzny 1989), and 1989 (Ashoka et al. 1990). All of these published light curves show a conspicuous modulation, with an average full amplitude of 0.22 mag (peak-to-trough). Since most of the acquired light curves were presented in the published work, this is probably a realistic estimate of the actual mean amplitude.

Although some data were obtained during each observing season, the *distribution* of observations over each season was extremely unfavorable (when specified, it consisted usually of just *one* cluster of timings over an interval of ~4 d, followed by a gap of ~365 d). Such a distribution is highly inimical to the task of finding a precise period, but most authors gave it "the old college try," and produced the period estimates given in Table 1. The disagreement among these estimates is noteworthy, and augurs ill for the prospect that the 2.8-hr signal is truly a stable clock.

2.2 1990

Zhang et al. (1991) presented 1990 light curves, which they regarded as confirming the long-term phase stability of the 2.8-hr signal. However, it is clear from examining their light curves that the amplitude was vastly lower in 1990; we consider 0.07 mag (full amplitude) to be a firm upper limit, and in fact we do not see clear evidence in the light curves

TABLE 1
Period Estimates in 1983–1990

Years Spanned	Period (d)	Source
1983	0.115883	Mironov et al. 1983
1983-1985	0.114488	Baidak et al. 1985
1983-1985	0.1157550 or 0.1158807(6)	Rosen et al. 1989
1983-1988	0.1166728(5)	Kaluzny 1989
1983-1989	0.1164865(4)	Shafter et al. 1990
1983-1990	0.1164863 or 0.1164489(3)	Zhang et al. 1991

that the oscillation was present at all in 1990. Nevertheless, Zhang et al. made least-squares fits to light curves on five of seven nights, found that the estimated times of minima agreed with the ephemeris of Shafter et al. (1990), and concluded that the 2.8-hr signal is extremely stable. The fact that these timings on five nearly consecutive nights displayed very small scatter about a 0.1165-d period does tend to suggest that the photometric signal is still present, although much reduced in amplitude. Zhang et al. then went on to argue that such high phase stability requires that the 2.8-hr clock be seated in the rotation of a magnetic white dwarf.

2.3 Worries

Now we want to raise the question, *is the clock actually stable?* The best way to answer this question is to observe the star over a baseline long enough to reveal period drifts, but short enough to leave no uncertainty about the cycle count. Has this condition been met?

The answer appears to be no. The baselines used for period determination in each year were 1 d (1984), 105 d (1985), 5 d (1986), 4 d (1987), 6 d (1988), and 6 d (1990, assuming that the signal was in fact present). These are inadequate to specify the year-to-year cycle count, except perhaps for the 1985 data. But the 1985 data turn out to be not so useful either, because that year lacks suitably short baselines to specify with certainty the cycle count over 105 d (the only shorter baselines available that year are 1 d and 24 d). Even taking the 1985 data at face value, we calculate that the best-fit period that year was 0.11662(2) d, in poor agreement with all of the estimates in Table 1.

The 1990 data offer another baseline which might be long enough to be useful. Zhang et al. present a light curve on 1990 March 23, 68 d removed from their cluster of points in May. They do not present a timing for this night, although they do assert that the slow variation seen is due to the 2.8-hr signal. On this assumption, we estimate that minimum light was reached on HJD 2447973.921. Combining this with the cluster of timings in May 1990, we obtain a best-fit period of 0.11662 (3) d (together with aliases at 0.11642 and 0.11682 d, and possibly others).

In summary, throughout the interval 1983–1989, the amplitude was high and the observations were sufficiently dense over intervals of 1–6 d to specify an average period of 0.1166 (3) d. The 1985 season was consistent with a period of 0.11662 (2) d, but the data lack any segment sufficiently dense to prove that the signal was truly stable over the season. The 1990 season was also compatible with a period of 0.11662 d, but aliases at 0.11642 and 0.11682 d are possible, and the amplitude was so low (reduced by a factor >3) that we are not even sure that this "period determination" is fitting anything other than random variability.

3. NEW DATA IN 1990–1994

3.1 Data Acquisition and Reduction

To study this question of stability, we obtained photometric observations of V795 Her during 1990–1994, concentrating on time intervals (typically ~10–40 d) which previous studies have neglected (and thereby, we suspect, incurred uncertainty in cycle count). Some of the data were obtained in *B* light with a single-channel photoelectric photometer on the 61- and 91-cm Crossley reflectors at Lick Observatory, and reduced by subtracting the sky contribution and using a mean or measured extinction coefficient to convert to counts per second outside the atmosphere. Most of the light curves acquired on the 61-cm telescope were afflicted with thin clouds, so we edited these data heavily and assigned low weight to the final light curves. The light curves acquired with the 91-cm Crossley telescope were obtained under photometric conditions.

The single 1990 observation was obtained in *V* light with the CCD photometer described by Stover and Allen (1987), mounted on the 1.0-m Anna Nickel reflector at Lick Observatory. Data reduction was accomplished in the same manner as used for the photoelectric data, except that the CCD enabled point-by-point removal of the sky contribution.

The rest of the data was acquired through a clear filter (WG 280) with a CCD photometer on the 32- and 65-cm reflectors of the Center for Basement Astrophysics (CBA). The effective wavelength was estimated as ~5800 A. Observing conditions varied considerably, but we managed to subdue the effects of light clouds by performing point-for-point differential photometry with respect to a comparison star. Data taken through thick cloud were discarded. Details on the telescope, detector, and observing procedure have been given by Skillman (1981, 1993) and Skillman and Patterson (1993).

The complete log of observations is given in Table 2. For the Lick data, we obtained the mean *V* magnitude by measurement of nearby standard stars. For the 1993 CBA data, we took the mean delta magnitude for each night on the instrumental system, and then transformed to ΔV using Eq. (1) of Skillman and Patterson (1993). We then adopted $V=11.10$ for our principal comparison star (Kaluzny 1989, where our comparison star is referred to as the "check star"). A separate calibration is not available for the 1992 data, but we have noticed that all cataclysmic variables in our program average ~0.04–0.11 mag fainter in 1993 than in 1992. The latter effect could be due to a loss of quantum efficiency in the blue, since the comparison stars are much redder. Attempting to correct for this, we have added an extra 0.07 mag to the 1992 magnitudes.

3.2 1993 Light Curves and Periods

The 1993 data comprise a uniform and well-calibrated set, consisting of 55 hr distributed over 18 nights. Figure 1 shows

TABLE 2
Log of Observations

UT Date	Telescope	(HJD 2440000+) Start → End	Points	$\langle V \rangle$
23 Jul 1990	100 cm Lick	8095.68869 – .76323	322	12.67
13 Jul 1991	91 cm Lick	8450.71295 – .81793	886	12.78
21 May 1992	32 cm CBA	8763.79942 – .89248	133	12.82
26 May 1992	61 cm Lick	8768.78378 – .97615	...	...
28 May 1992	61 cm Lick	8770.77615 – .97684	...	...
29 May 1992	61 cm Lick	8771.85392 – .97406	...	...
31 May 1992	61 cm Lick	8773.74420 – .80948	...	...
2 Jun 1992	32 cm CBA	8775.61263 – .78972	227	12.90
2 Jun 1992	61 cm Lick	8775.74559 – .94767	...	...
3 Jun 1992	91 cm Lick	8776.75115 – .80364	443	12.96
4 Jun 1992	91 cm Lick	8777.71643 – .79487	662	12.91
5 Jun 1992	91 cm Lick	8778.70324 – .78168	662	12.84
10 Jun 1992	32 cm CBA	8783.77025 – .84803	109	12.88
12 Jun 1992	32 cm CBA	8785.72164 – .85220	179	12.97
13 Jun 1992	32 cm CBA	8786.69801 – .84245	206	12.86
22 Jun 1992	32 cm CBA	8795.66456 – .80899	199	12.73
3 Jul 1992	32 cm CBA	8806.57682 – .71709	180	12.93
25 Apr 1993	32 cm CBA	9102.68698 – .89463	240	12.76
22 May 1993	32 cm CBA	9129.66909 – .87639	308	12.76
23 May 1993	32 cm CBA	9130.66909 – .84670	342	13.04
30 May 1993	32 cm CBA	9137.62022 – .87795	480	12.89
31 May 1993	32 cm CBA	9138.73185 – .77179	106	13.01
24 Jun 1993	32 cm CBA	9162.66421 – .84859	352	12.97
25 Jun 1993	32 cm CBA	9163.66004 – .84703	319	12.98
26 Jun 1993	32 cm CBA	9164.68088 – .83349	292	12.93
28 Jun 1993	32 cm CBA	9166.65057 – .78079	239	12.76
5 Jul 1993	32 cm CBA	9173.62286 – .81451	368	13.09
7 Jul 1993	32 cm CBA	9175.55776 – .61298	105	13.02
8 Jul 1993	32 cm CBA	9176.56183 – .80767	463	12.88
10 Jul 1993	32 cm CBA	9178.62215 – .78205	295	13.12
14 Jul 1993	32 cm CBA	9182.64756 – .77882	145	13.05
18 Jul 1993	32 cm CBA	9186.55267 – .79174	435	12.86
21 Jul 1993	32 cm CBA	9189.56091 – .68487	238	12.94
23 Jul 1993	32 cm CBA	9191.55299 – .76290	366	12.81
24 Jul 1993	32 cm CBA	9192.55081 – .75655	368	12.92
15 Apr 1994	65 cm CBA	9457.70538 – .90990	471	12.91
17 Apr 1994	65 cm CBA	9459.69829 – .88990	252	12.86
26 Apr 1994	65 cm CBA	9468.67206 – .86026	527	12.82
13 May 1994	65 cm CBA	9485.68093 – .87676	274	12.88
14 May 1994	65 cm CBA	9486.65262 – .85315	288	12.88
22 May 1994	65 cm CBA	9494.69968 – .87051	222	12.79
23 May 1994	65 cm CBA	9495.59846 – .87173	670	12.74

a sampler of light curves, which show rapid flickering, slow trends on timescales of many hours, and no obvious sign of a period near 2.8 hr. This is in stark contrast to all the light curves acquired during the 1980s, which are dominated by an obvious 2.8-hr variation.

We calculated the power spectra of these light curves from the discrete Fourier transform. At very low frequencies, weak signals of ~0.10 mag semiamplitude were seen at 0.60 c day^{-1}, 0.831 c day^{-1}, and their one-day aliases. But because windowing effects severely corrupt this part of the power spectrum, we consider these detections to be doubtful, and only mention them for posterity's sake. A more densely spaced data set would provide a more reliable test.

In order to calculate the power spectrum at somewhat higher frequencies, we first removed long-term trends by subtracting the mean brightness for each night. The power spectrum of the resulting detrended light curve showed artificial peaks at 2, 3, and 4 cycles per sidereal day, and the mean light curve reached maximum brightness as V795 Her crossed the CBA meridian. This proves that the signal is artificial, and we believe that it is mostly due to the inevitable and uncorrected color dependence in the extinction (quite serious for us because the variable is much bluer than the comparison, causing extra extinction for the variable at large airmass). We had earlier estimated this effect at ~0.035 mag/airmass (Skillman and Patterson 1993), but the present data suggest an effect about twice as large. This is possible, since our earlier estimate was based on field stars much redder than cataclysmic variables. In any case, since the signal is obviously artificial, we subtracted it from the detrended light curve, and used the resultant "prewhitened" light curve for all subsequent spectral analysis.

The 1993 power spectrum at low frequencies is shown in the lower panel of Fig. 2. The only significant feature is a spike at $\nu=9.254(\pm0.004)$ c day^{-1}. The semiamplitude of this signal is 0.018 mag. The upper panel shows the power spectrum of a sinusoidal signal sampled exactly as the real data. Inspection of the upper panel shows most of the secondary features associated with the actual power spectrum, indicating an origin in aliasing; but some (e.g., the excess of power slightly "red-shifted" from the main signal) are not *exactly* reproduced, suggesting that the signal may be more complex than a sinusoid of constant frequency and amplitude.

The semiamplitude upper limit on any signal near the familiar 0.1164-d period (8.59 c day^{-1}, marked by the arrow at $\nu_{\rm old}$) is 0.008 mag; hence we conclude that this signal is reduced in amplitude, relative to the 1983–9 appearance, by a factor >10.

At still higher frequency, the power spectrum changed a lot from night to night. The weighted average of all 18 nights is shown in Fig. 3, and illustrates the possible presence of a high-frequency signal at $\nu=75\pm1$ c day^{-1} ($P=1166\pm14$ s). To study this feature further, we singled out all six pairs of consecutive nights, in order to insure that the aliasing in the power spectrum would be limited to the usual 1 c day^{-1} effects. After averaging these together, we obtained $P=1161\pm3$ s. To improve frequency resolution further, we then formed four separate time series consisting of segments with densely spaced data and lasting approximately one week. The average of these four power spectra is shown in Fig. 4, which illustrates the possible presence of a stable feature at $\nu=74.64\pm0.06$ c day^{-1} ($P=1157\pm1$ s).

To test this further, we calculated the power spectrum of the entire 1993 light curve in this frequency range, with the result shown in the lower panel of Fig. 5. A feature is evident near 74 c day^{-1}, but is too broad to arise from a signal with high phase stability. Thus it should be classified as a "quasi-periodic oscillation," and we so label it. The possibility that a stable signal lurks within it is not supported,[1] because the candidate periods corresponding to spikes in Fig. 5 do not agree with the period found in the densely spaced data sets (1157 s).

An equally interesting aspect of Fig. 5 is the spike seen at 65.943(3) c day^{-1} ($P=1310$ s). This feature has the width of a signal which maintains phase stability over the 90-day observing season, and is not surrounded by a broad bump in the power spectrum. It is statistically significant (~4σ) although that is not highly convincing since flickering in cataclysmic variables can mimic a stable signal. We are inclined to believe that this is a real detection of a stable signal, but it is certainly not beyond doubt. In the upper panel we show the power spectrum of an artificial light curve sampled ex-

---

[1] Nor is it *disproved*, of course. A nearby stable signal is allowed as long as its semiamplitude is less than 0.013 mag (2σ limit).

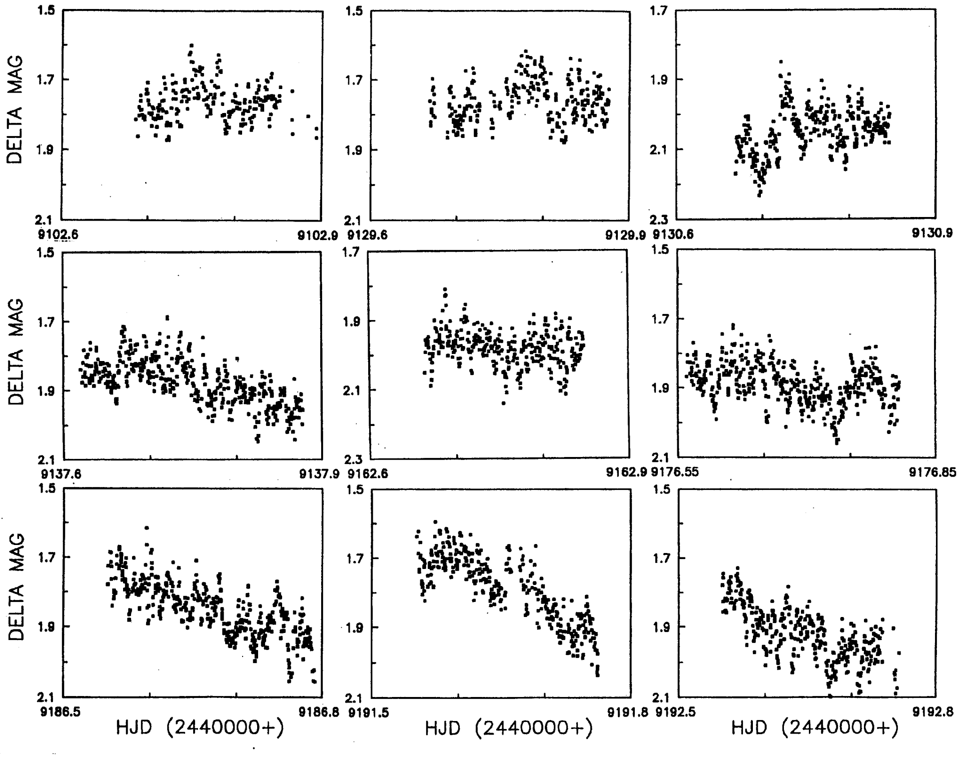

FIG. 1—Long light curves obtained during 1993, relative to the comparison star which has $V=11.10$. Magnitudes are left on the instrumental system. The familiar signal with $P=2.78$ hr is absent.

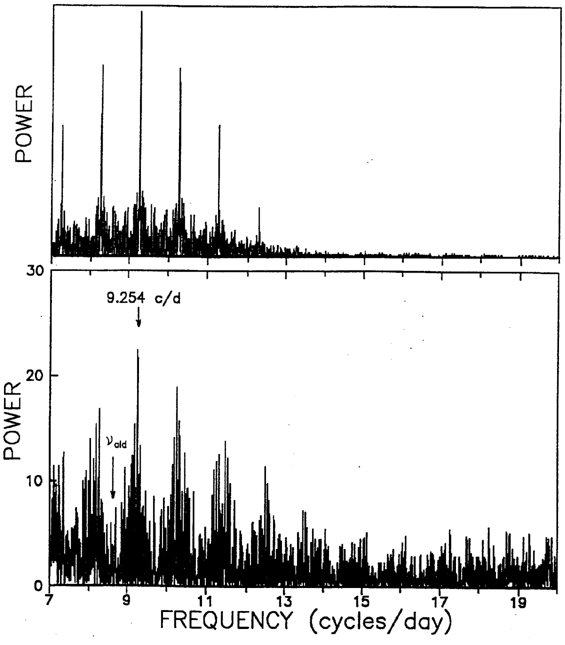

FIG. 2—Power spectrum of the entire 1993 light curve. The most significant peak occurs at $\nu=9.254$ c day^{-1}, and corresponds to a semiamplitude of 0.018 mag. The semiamplitude upper limit on any signal near the familiar superhump period ("$P_{\rm old}$") is 0.008 mag.

actly as the real data, but with periodicities at 1310 and 1160 s inserted. Comparison with the lower frame supports the conclusion that the 1310-s signal (if real) is very stable, but the 1160-s signal is not.

The semiamplitude of the 1310-s signal is 0.012 mag, and the ephemeris during 1993 was

$$\text{Maximum light}=\underset{(6)}{\text{HJD }2449102.6909}+\underset{(7)}{0.0151646E}. \tag{1}$$

Inspection of Fig. 5 shows that a 24-hr alias problem exists, and it is entirely possible that the correct frequency is 64.943 c day^{-1}.

The relationship between the QPO and the stable signal is of interest. Roughly speaking, they are separated by the known orbital (radial-velocity and photometric) frequency. A more exact relation is hard to specify. The QPO centroid is in the range 73.8–74.8 c day^{-1}, which gives a frequency difference of 7.86–8.86 c day^{-1}. This could possibly be the frequency of the vanished photometric signal (8.6 c day^{-1}). However, if the alias solution for the stable signal is adopted, then the frequency difference is 8.86–9.86 c day^{-1}, which is of special interest since it could be the orbital frequency.

Finally we should caution the reader that the 1310-s signal is only a probable detection; it was so weak that it required a full season's data, and thus did not give us the opportunity to confirm it with an independent data set of similar quality. We consider the QPO at 1160 s to be a secure

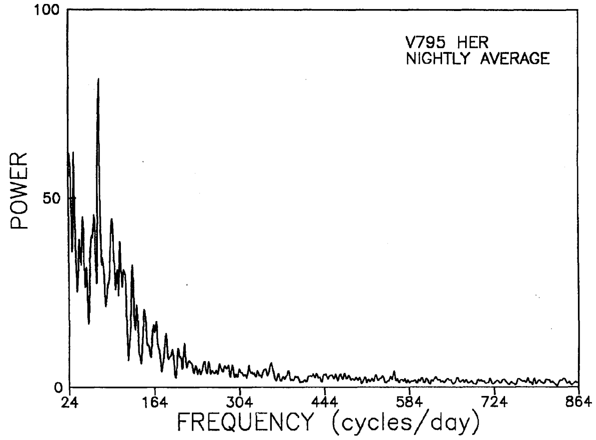

FIG. 3—Average power spectrum of 18 nights of long coverage. The rising power towards low frequency is characteristic of the flickering in cataclysmic variables; superimposed on that is a significant feature at ~75 c day^{-1}.

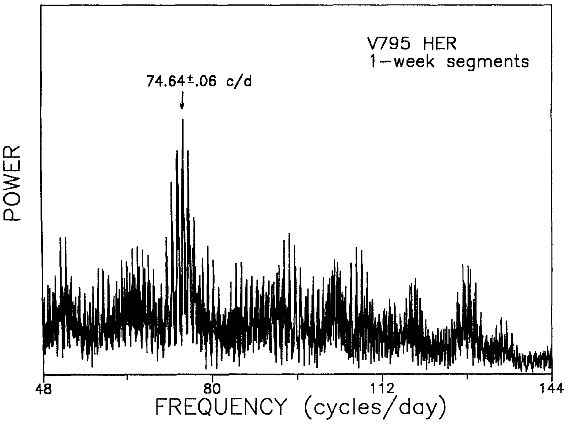

FIG. 4—Average power spectrum over four one-week intervals in which dense coverage was obtained. The data are consistent with the presence of a weak signal at 74.64 c d^{-1}, but the phase coherence of the signal is not known.

detection, since it is seen in all large subsets of the data. The claim of poor phase stability is also fairly secure, although one can fashion *complex* hypotheses which provide alternative ways of explaining the appearance in the power spectrum with good phase stability in the underlying clock (severe amplitude modulation; many closely spaced frequencies, each stable and of low amplitude; etc.).

3.3 Flickering

As a byproduct we have also studied the frequency dependence of the flickering, which is approximately given by

$$A(f)=0.0030\ \mathrm{mag}(f_{200})^{-0.66\pm0.10}, \qquad (2)$$

where A is the semiamplitude and $f_{200}=f/200$ c day^{-1}.

3.4 Light Curves and Periods in Other Years

Only isolated observations were obtained in 1990 and 1991, hence no period analysis is possible. Possible times of 2.8-hr minima are (HJD 2440000+) 8095.723 and 8451.722, although these should be regarded as of low weight since the light curves are brief.

In 1992, we obtained 55 hr of coverage on 14 nights, spanning a baseline of 43 d; and in 1994, we obtained 37 hr of coverage on seven nights, spanning 38 d. Although this coverage was comparable to that obtained in 1993, periodicity searches proved more troublesome, because joining the Lick and CBA data was difficult, and because the performance of the CCD photometer newly constructed in 1994 was not very well known. Nevertheless, we repeated the

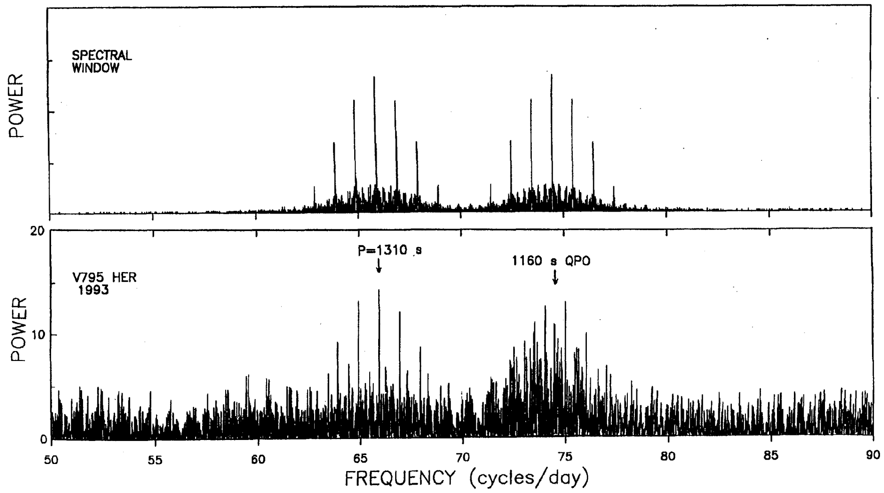

FIG. 5—Lower frame: power spectrum of the entire 1993 light curve. Weak periodic signals are seen with $P=1310$ and 1160 s. Upper frame: power spectrum of a light curve containing only artificial signals at these periods, and sampled exactly like the real light curve ("spectral window"). Comparison of the upper and lower frames establishes that the 1310-s signal could possess high phase stability, while the 1160-s signal definitely does not.

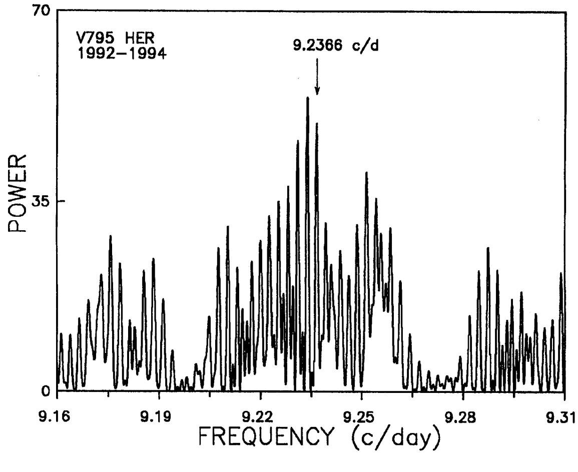

FIG. 6—Power spectrum of the entire 1992–1994 light curve, near the orbital frequency. Peaks at 9.254 and 9.251 c d^{-1} remain, but more power exists at slightly lower frequency, 9.2338 and 9.2366 c d^{-1}. However, the meaning is hard to assess, because none of these peaks agree with the radial-velocity frequency, and none pass unbiased tests for significance. See text for an even more inconclusive discussion.

analyses carried out for the 1993 data, with substantially similar results:

1. The 2.8-hr period was absent, to a comparable limit (semiamplitude <0.010 mag).
2. The "orbital" period was not definitely seen, but the upper limit was similar to the amplitude detected in 1993. The 1992 power spectrum did show a peak at 18.490±0.008 c day^{-1}, which could be a first harmonic.
3. A signal at ~1160 s was again seen, but with a higher noise level, not increasing the confidence of detection achieved from the 1993 data.
4. No signal at 1310 s was seen, with a semiamplitude upper limit ~0.015 mag.

3.4 The "Orbital" Period

There is some confusion regarding the observed photometric frequency of 9.254 (4) c day^{-1} in the 1993 data. The radial-velocity frequency was variously reported by Shafter et al. (1990) as 9.23661 or 9.23815 (3) c day^{-1}, either of which is significantly discrepant. To study this further, we recalculated the power spectrum including the 1992 and 1994 data (which have no independent detection). The region of interest is shown in Fig. 6. The strongest peaks now occur at 9.2338 (2) and its one-year alias 9.2366 (2) c day^{-1}; the latter agrees with one of Schafter et al.'s estimates to within 1 part in 10^5. This would seem to settle the matter, but now Schafter (1994) informs us that the other frequency (9.23815) is in fact the correct one![2]

How can we understand this? Consideration of the alias structure in the photometry and spectroscopy does not suggest any plausible reconciliation. The "agreement within one part in 10^5" could be spurious, since that detection is not of high significance (stronger peaks occur outside the frequency range shown in Fig. 6, due to the higher noise level in the data added from 1992 and 1994). But the 1993 signal at 9.254 c day^{-1} is very significant. Now we suspect that radial velocities are more likely to furnish a precise orbital-period estimator, because photometric observations are definitely contaminated by flickering (whereas $v_{\rm rad}$ observations only *might* be!). Also, the amplitude of the photometric signal is so low that conventional wisdom regarding origins of orbital modulations in CVs is not of much use here. One can imagine several sources in the binary producing signals, modulated at the orbital period, which might be important at this low level (e.g., hot spot at the outer disk, "wrong side" hot spot at the outer disk, hot spot at the inner disk, reflection effects from any of these, grazing eclipse, reflection from the secondary). Such signals occur at different orbital phases, and if their contributions vary slightly in amount, the phase of the photometric modulation could wander, producing the discrepancy.

Since our observed photometric frequency does not precisely agree with the spectroscopy, the absolute phasing of the signals probably signifies nothing. But in case a resolution to this puzzle is ever found, it may be helpful to give an ephemeris for the "orbital" signal in 1993:

$$\text{Maximum light} = \text{HJD } \underset{(5)}{2{,}449{,}102.753} + \underset{(5)}{0.10806}E. \qquad (3)$$

The variation is smooth with a peak-to-trough amplitude of 0.035 mag.

3.5 A Brightness Change?

A small brightness change may have coincided with the disappearance of the 2.8-hr signal. In 1983 Mironov et al. (1983) reported a mean brightness of $\langle V\rangle = 13.22$. Kaluzny (1989) reported $\langle B\rangle = 13.21$, $\langle V\rangle = 13.28$ in 1988. Table 2 shows that the mean V magnitude during 1992, 1993, and 1994 was close to 12.9. Although a systematic error of ~0.08 mag is possible in the V magnitudes derived from the CCD data, Table 2 still affirms that this is a significant difference. The isolated measures in 1990 and 1991 also tend to suggest that a small brightness increase and the disappearance of the 2.8-hr signal coincided in time, since the amplitude in 1990 was low.

4. PERIOD ANALYSIS

4.1 Looking for the Ghost of the Signal

The failure of the 2.8-hr signal to appear as a significant feature in power spectra is not conclusive proof that the signal has vanished. It is also possible that the signal is present but at too low an amplitude to survive the rigors of unbiased period detection. We have searched for traces of the 2.8-hr signal by synchronously summing long light curves on the period of Zhang et al. (1991), and measuring the waveform for minimum light. The results are: first half 1992, (HJD

---

[2] This confusion arose from a typographic error when two digits in the period were transposed (Shafter 1994).

2440000+) 8763.881; second half 1992, 8783.866; first half 1993, 9102.779; second half 1993, 9173.702; all 1994, 9457.746. The residuals from the Zhang et al. ephemeris are −0.13, 0.43, 0.21, 0.06, and 0.49 cycles, indicating no correlation with that ephemeris. We repeated this study for the other candidate periods in Table 1, and found no correlation for any of them.

4.2 Period Stability in Historical Data

The amplitude of the 2.8-hr signal is obviously variable by a factor >10. What about its *period*? Naturally we had hoped to resolve this issue with our own light curves, but have been thwarted by the disappearance of the signal. Hence we limit ourselves to published light curves and timings during 1983–90.

Previous authors have assumed or asserted that the period could be derived with sufficient accuracy to count cycles from year to year. But, as stated above, the distribution of timings of maxima/minima is very unfavorable for such a conclusion. The tabulation of Zhang et al. (1991) contains 30 timings; and if these timings were truly independent, their good-quality fit to a constant period would indeed be excellent evidence for a constant period. However, most of these timings are in closely spaced clusters (a few days), and thus strictly only rule out the possibility that the photometric clock loses coherence on a timescale less than a few days. If the clock wanders on a timescale of a few weeks to a few months (typical of the permanent superhumpers, see discussion below), then each tight cluster of points really amounts to just one independent timing, which makes the possibility of an *accidentally good fit* much higher.

We have taken the 30 timings of minima in Table 3 of Zhang et al. (1991), and averaged (with a period of 0.1165 d) those occurring within a week of each other; this collapses the 30 timings to nine independent timings. We could also consider four additional timings, likely to be somewhat less reliable: our two timings in 1990–1, the minimum of Baidak et al. (1985), and the minimum we have extracted from Fig. 3 of Zhang et al. (1991). Do these nine, or 13, timings favor the hypothesis of a single constant period?

We have tested this by fitting the timings to a period ranging from 0.11 to 0.12 d. We use 6000 trial periods through the period range, calculate the epoch which best fits the timings for each trial period, and record the rms residual for that ephemeris. The results for the nine timings are shown in the upper panel of Fig. 7.

The main lesson from this figure is that no particular period emerges as the preferred choice. About a dozen periods show a residual as low as 0.12 cycles. The lowest residual is 0.073 cycles at P=0.11881 d; but of course this period is much longer than any reasonable value (i.e., permitted by the cycle counting over *short* baselines), and therefore must be an accident. The second-lowest residual occurs at the period preferred by Zhang et al. Calculation outside this period range yielded similarly good fits, confirming that one can always find accidentally good fits to so sparse a data set.

We added the four extra timings and repeated the calculation, producing the lower panel of Fig. 7. The result was essentially unchanged: again no period emerges as the clear choice. The "best" choice, however, is 0.116450 d, the 1-yr alias of the period preferred by Zhang et al.

4.3 Summary

We conclude from all of this that:

(1) The signal really did vanish below detection limits during 1992–4.

(2) The signal is definitely phase stable on a timescale <20 d, but evidence of its stability on longer timescales is

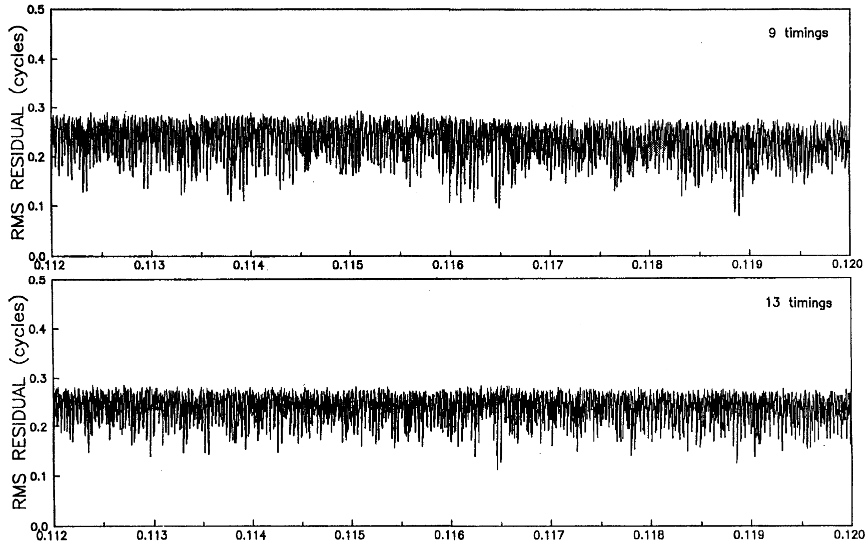

FIG. 7—Period searches among timings of 2.8-hr minima. Upper frame: result for nine most reliable timings. Lower frame: result after adding four other timings. The lack of any one period which gives markedly lower residuals leads us to conclude that the stability of the signal is unproven.

still lacking. It will take a large increase in the frequency of observation, and the return of the signal, to decide this matter.

5. INTERPRETATION OF THE 2.8-HR SIGNAL

The disappearance of the 2.8-hr signal, while somewhat remarkable, is not sufficient grounds for declining to explain it! Here we review the two candidate explanations which have been suggested.

5.1 A Rotating White Dwarf?

One possibility is that it arises from the rotation of a magnetic white dwarf; this was favored by Zhang et al. (1991) on grounds of high period stability. We think this gets low marks for plausibility. Accreting magnetic white dwarfs fall into two categories ("DQ Herculis" and "AM Herculis" stars) depending largely on the degree of *synchronism*, and V795 Her fails to display the suite of characteristics expected from synchronous or nearly synchronous stars (strong X rays, strong EUV/soft X-ray emission, polarization, broad emission lines moving with $P_{\rm rot}$, etc.). There is also some difficulty in understanding the physics by which $P_{\rm rot} > P_{\rm orb}$ can be maintained—or, alternatively in the case that 2.8 hr is considered an orbital sideband rather than the actual rotation period, the difficulty of understanding why the actual $P_{\rm rot}$ is not detected. We also do not concede that only rotation can provide the required stability, and believe that the observations are still too sparse to certify that stability.

5.2 Superhumps?

A much more promising possibility is that the 2.8-hr signal is a "permanent superhump." Superhumps are modulations in the light curve with a period a few percent displaced from, and usually exceeding, the orbital period. They are a well-known feature of dwarf novae in superoutburst (for a review see Warner 1985). Recent evidence indicates that many noneruptive stars also show this behavior (hence "permanent" superhumps; see Patterson et al. 1993a; Skillman and Patterson 1993).

The fractional period excess $\epsilon \equiv (P_{\rm sh} - P_{\rm orb})/P_{\rm orb} = 0.076$ is certainly consistent with this idea. Figure 17 of Patterson et al. (1993a) and Fig. 10 of Skillman and Patterson (1993) show that V795 Her fits in well with the known empirical relation between ϵ and $P_{\rm orb}$.

Superhump periods are known to be slightly unstable. Dwarf novae always show $|\dot{P}|$ near 5×10^{-5} (Patterson et al. 1993b). Data are available for only a few permanent superhumpers; the observed values of $|\dot{P}|$ are in the range 10^{-8}–5×10^{-6}. For V795 Her, the absence of data tracking the phase on timescales of weeks to months prevents a good estimate; coherence on a timescale >20 d establishes $|\dot{P}| < 2 \times 10^{-5}$, but $|\dot{P}|$ is as low as 4×10^{-9} if the phase is stable over six years. In either case, we consider these estimates to be broadly within the range shown by superhumping cataclysmic variables. Superhump amplitudes are also known to be unstable; excursions of at least a factor of 5 are known for AM Canum Venaticorum (Patterson et al. 1992), CP Puppis (O'Donoghue et al. 1989), and V603 Aquilae (Patterson et al. 1993a).

Finally, there is the issue of physical plausibility. Theoretical studies (Whitehurst 1988; Osaki 1989; Lubow 1991) suggest that accretion disks in binaries of low mass ratio ($q < 0.3$) should experience an eccentric instability, if the disks are large enough to make the tidal forces adequately strong. The short $P_{\rm orb}$ of V795 Her (assuming the radial-velocity period to be $P_{\rm orb}$) implies a low-mass secondary and hence a small q. We know from studies of disk size in dwarf novae (Smak 1984; O'Donoghue 1986; Anderson 1988) that the disks are largest when the stars are bright, and V795 Her is comparably bright to dwarf novae in eruption [$M_V \sim 5$, based on the $M_V - EW({\rm H}\beta)$ relation of Patterson (1984)]. Thus V795 Her is an excellent candidate to show superhumps.

In summary, the empirical properties of the 2.8-hr signal are consistent with the hypothesis of a superhump origin, which is plausible on physical grounds. The star should be classified as a permanent superhumper, although the label of permanence is meant to convey "long-lived and without obvious dependence on eruption state" rather than "everlasting."

6. A DQ HERCULIS STAR?

Magnetically channeled accretion seems to us a much better hypothesis for the signal(s) near 1200 s, not the vanished 2.8-hr signal. This would assign the star to the "DQ Her" class, in which the white dwarf rotates faster than synchronous. For example, if the white dwarf rotates retrograde with $P = 1330$ s, then the searchlight beam sweeps across structures fixed in the binary frame with $P \sim 1160$ s. The coherence of the reprocessed signal might be somewhat low if the contributions of these structures is variable (since they are located at different azimuthal angles around the disk). Alternatively, prograde rotation with $P = 1160$ s is possible, as long as there exists some mechanism to hide the regular pulses within the QPO. Several DQ Her stars do in fact show such behavior when in states of high accretion (Patterson 1994).

Certification of membership in this class requires proof that at least one of the high-frequency signals is very stable, which we have not established. X-ray observations may shed light on this important point.

7. SPECULATIONS CONCERNING THE SPECTROSCOPIC BEHAVIOR

Haswell et al. (1994) report an "s-wave" moving with very large amplitude ($K \sim 1700$ km s^{-1}), at a period very close to the orbital period. This is especially surprising because the velocity is too large to be characteristic of the outer disk, which is the portion of the disk usually regarded as linked to the orbiting secondary star. We think that this sort of "super-s-wave" is more likely to come from a direct linking of the *inner* disk to the secondary. Thus we envision V795 Her to look something like the following:

(1) A gas stream leads from the secondary and strikes the outer disk, leading to a normal s-wave of amplitude 400 km s^{-1} (Shafter et al. 1990).

(2) Part of the stream skims above the disk (perhaps as discussed by Lubow 1989) and continues to fall until it strikes some inner region, which might be a magnetosphere. The observed 1700 km s^{-1} then arises from either the stream infall velocity or the local Keplerian velocity at that point. The observed photometric signal(s) near 1160 s provides some extra evidence for the possible importance of magnetism.

(3) Finally, we suppose the outer part of the disk to be quasielliptical and precessing. We expect that the spectroscopic line profiles should show a distortion wave with a period of

$$P_{\rm prec}=(P_{\rm orb}^{-1}-P_{\rm sh}^{-1})^{-1},$$

(see Patterson, Halpern, and Shambrook 1993). Depending on the adopted value of $P_{\rm sh}$, this should be in the range 1.53–1.62 d. We note with much interest that the Hα observations of Thorstensen (1986) have already indicated a wave periodic with $P=0.62$ or 1.6 d. Haswell et al. (1994) presented a much more extensive data set which did not show this effect, but this may be misleading since the photometric superhumps were known to be absent at that time (May 1993).

8. THE UNWANTED 4.86-HR PERIOD

Prinja and Rosen (1993) presented evidence for a 4.86-hr period in the fluxes of UV emission lines, based primarily on two 5-day segments of data separated by ~1 yr. We consider the allegation that this is a "coherent" signal impossible to accept as proven; it founders on the same reef which sunk the many claims for the optical photometry: the great difficulty of knowing the cycle count in a very sparse data set. Nevertheless, the star clearly displays large variations in emission-line strength on a timescale ~4.9 hr, which is puzzling because this is a timescale not seen elsewhere in the star, and not characteristic of the region most likely to be responsible for the ultraviolet lines (inner disk and boundary layer). Our photometry in visible light gives an upper limit of ~0.015 mag semiamplitude for any persistent signal at this period.

We cannot resist indulging in some numerology with these periods. The radial-velocity frequency is 9.238 c $\rm day^{-1}$, and the best estimate of large-amplitude photometric frequency is 8.585 (10) c $\rm day^{-1}$. Prinja and Rosen (1993) estimate the UV lines to be modulated at 4.95 c $\rm day^{-1}$. Thus it appears that to within measurement accuracy (1 part in ~500),

$$\omega_{\rm rv}=2\,\omega_{\rm UV}-\Omega$$

and

$$\omega_{\rm phot}=2\,\omega_{\rm UV}-2\Omega,$$

where Ω is a constant. This is particularly interesting because relationships like this arise naturally in precessing-disk models. For example, we could account for this in the following manner:

(1) Let the orbital frequency $\omega_{\rm orb}$ be the UV frequency, and Ω be the disk precession frequency.

(2) Then the fundamental superhump frequency is $\omega_{\rm orb}-\Omega$ as usual, but for some reason most of the power in the photometric signal appears at the first harmonic (as occasionally seen in superhumping CVs).

(3) Suppose that the observed radial velocities are dominated not by true dynamical motions of the star, but by one of the s-waves (the normal s-wave usually thought to be associated with stream impact at the outer edge of the disk, or the super s-wave discovered by Haswell et al. 1994). If the relevant s-wave has two locations of enhanced emission, and if those locations are affected by the orientation of the elliptical disk, then the radial velocities could repeat with $2\omega_{\rm orb}-\Omega$.

Admittedly, (3) requires a large puff of smoke and mirrors, and requires us to surrender something hitherto considered a very reliable clue among CVs: that radial velocities usually do give the correct orbital period. It would be more conventional and comfortable to adopt $P_{\rm orb}=2.60$ hr and interpret the UV frequency as 0.5 $(\omega_{\rm orb}+\Omega)$. Some sort of excuse for the occurrence of the upper sideband could be found, but we have been unable to think of any periodic process occurring at *half* the natural clock frequency!

Thus we leave the matter as an unsolved problem.

9. SUMMARY

(1) We report a set of new visible-light photometry of V795 Her, mostly in 1992–4. The familiar 2.8-hr variation is absent, with its amplitude reduced by a factor >10. It seems that this disappearance coincided with a small (0.3 mag) increase in the star's brightness.

(2) We expend much analysis and many words to study the stability of the 2.8-hr clock, with only a very weak conclusion: it is stable on timescales <20 d. We think that the scarcity and unfavorable distribution of timings render the long-term cycle count uncertain, and therefore disagree with the conclusion of Zhang et al. (1991) that the clock is certifiably very stable. If it is stable, however, it is probably at one of the two periods favored by Zhang et al. An extensive observing campaign over a single season would probably resolve this matter, assuming that the signal returns with adequate strength.

(3) Largely independent of the stability issue, we consider it likely that the photometric signal arises from the accretion disk, not the white dwarf. The value of the fractional period excess $[(P_{\rm phot}-P_{\rm orb})/P_{\rm orb}=0.08]$, the probable low-mass ratio, and the observed instabilities of the photometric signal (certainly in amplitude, possibly in period) suggest a strong resemblance to the superhumps of dwarf novae in superoutburst.

(4) We detect a photometric signal at 2.59 hr, very close to the known radial-velocity period. The semiamplitude was 0.018 mag, low enough to hide unnoticed in previously published light curves.

(5) We detect a QPO at ~1160 s, of ~0.015 mag semiamplitude and possessing low phase coherence. We also detect a signal at 1310.22 (or 1330.40) s which does maintain

good phase coherence but is sufficiently weak that we consider its persistence to be only probable, not certain. This is an important point to study in future work. If it is persistent, then its high phase stability indicates a likely origin in the rapid rotation of the white dwarf. The QPO frequency is "blue-shifted" from that of the stable signal by approximately the orbital frequency, which might indicate retrograde rotation.

(6) We make a brief effort to incorporate the unexpected and newly discovered features in this star (the 4.86-hr UV period, and the super s-wave) into a model, but do not get beyond numerology. Weaving all these elements together into a convincing model will require greater vision than we have achieved here!

We thank Gino Thomas and Gretchen Kail for assistance with data acquisition and analysis; and Carole Haswell and Jules Halpern for discussions. This work was supported in part by NASA grant NAGW-2565 and NSF grant AST93-14567.

REFERENCES

Anderson, N. 1988, ApJ, 325, 266

Ashoka, B. N. et al. 1990, in Accretion-Powered Compact Binaries, ed. C. W. Mauche (Cambridge, Cambridge University Press), p. 243

Baidak, A. V., Lipunova, N. A., Shugarov, S. Yu., Moshkalev, V. G., and Volkov, I. M. 1985, Inf. Bull. Var. Stars, No. 2676

Haswell, C. A., Horne, K., Thomas, G., Patterson, J., and Thorstensen, J. R. 1994, in Interacting Binary Stars, ed. A. W. Shafter, ASP Conf. Ser. 56, p. 268

Kaluzny, J. 1989, Acta Astron., 39, 235

Lubow, S. 1989, ApJ, 340, 1064

Lubow, S. 1991, ApJ, 381, 268

Mironov, A. V., Moshkalev, A. G., and Shugarov, S. Yu. 1983, Inf. Bull. Var. Stars, No. 2438

O'Donoghue, D. 1986, MNRAS, 220, 23p

O'Donoghue, D., Warner, B., Wargau, W., and Grauer, A. D. 1989, MNRAS, 240, 41

Osaki, Y. 1989, PASJ, 41, 1005

Patterson, J. 1984, ApJS, 54, 443

Patterson, J. 1994, PASP, 106, 209

Patterson, J., Sterner, E., Halpern, J. P., and Raymond, J. C. 1992, ApJ, 384, 234

Patterson, J., Thomas, G., Skillman, D. R., and Diaz, M. P. 1993a, ApJS, 86, 235

Patterson, J., Bond, H. E., Grauer, A. D., Shafter, A. W., and Mattei, J. A. 1993b, PASP, 105, 69

Patterson, J., Halpern, J. P., and Shambrook, A. A. 1993, ApJ, 419, 803

Prinja, S. K., and Rosen, S. R. 1993, MNRAS, 262, L37

Rosen, S. R., Branduardi-Raymont, G., Mason, K. O., and Murdin, P. G. 1989, MNRAS, 237, 1037

Shafter, A. W. 1994, private communication

Shafter, A. W., Robinson, E. L., Crampton, D., Warner, B., and Prestage, R. M. 1990, ApJ, 354, 708

Skillman, D. R. 1981, S&T, 61, 71

Skillman, D. R. 1993, S&T, 85, 83

Skillman, D. R., and Patterson, J. 1993, ApJ, 417, 298

Smak, J. 1984, Acta Astron., 34, 93

Stover, R. J., and Allen, S. L. 1987, PASP, 99, 877

Thorstensen, J. R. 1986, AJ, 90, 940

Warner, B. 1985, in Interacting Binaries, ed. P. P. Eggleton and J. E. Pringle (Dordrecht, Reidel), p. 367

Whitehurst, R. 1988, MNRAS, 232, 35

Zhang, E., Robinson, E. L., Ramseyer, T. F., and Shetrone, M. D. 1991, ApJ, 381, 534