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Superhumps in Cataclysmic Binaries. XXI. HP Librae (=EC 15330−1403)

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ABSTRACT. We report photometry of the helium-dominated cataclysmic variable HP Librae during 1995–2001. The main photometric signal varies between 1118.89 and 1119.14 s, on a timescale of a few years, and displays a waveform characteristic of "superhumps." After subtracting the main signal, we found a weak residual signal at 1102.70 ± 0.05 s, which we interpret as the underlying orbital period of the binary. The full amplitude of this putative orbital variation is just 0.005 mag, the weakest orbital signal yet found in a cataclysmic variable (CV). The 1119 s signal of HP Lib is a superb match to the well-studied 1051 s superhump of AM CVn, the "mother of all helium CVs." The superhump shows no change in amplitude or waveform on any timescale and no essential change in period on timescales shorter than ∼3000 cycles. Such great stability makes the star a promising test case for detailed studies of the underlying spiral structure in the disk, the likely cause of superhumps. Comparison of orbital and superhump periods for the family of AM CVn stars supplies evidence that these stars are evolving toward longer orbital period.

1. INTRODUCTION

O'Donoghue et al. (1994) reported the discovery of EC 15330−1403, an interesting new cataclysmic variable in the Edinburgh-Cape survey for blue stars. The star showed broad, shallow He I absorption lines and a photometric period of 1119 s and maintained a nearly constant mean brightness near $V = 13.7$. These properties made the star an apparent close cousin of the famous AM Canum Venaticorum, the prototype of the interacting binary/white dwarf (IBWD) subclass of cataclysmic variables (CVs).

During each of the last 7 yr, we have carried out photometric observing campaigns on this star, recently renamed HP Librae. The results are fully consistent with the conclusions of O'Donoghue's initial study; in particular, the photometric signal is an excellent match to the well-studied "superhump" of AM CVn. The remarkable stability of the superhump in HP Lib enables us to count cycles uniquely over each observing season, and thus to study the signal over very long baselines (10^4–10^5 cycles). We also found a weak signal at a slightly shorter period (1102.70 ± 0.05 s), which is very likely to be the true orbital period of the binary. Here we report the results of this study.

2. OBSERVATIONS, LIGHT CURVES, PERIODS

The observations consisted of nightly time-series photometry from many telescopes in the network of the Center for Backyard Astrophysics (CBA; Skillman & Patterson 1993), supplemented by contributions from larger telescopes. In all, the observations covered 720 hr over 185 nights, detailed in Table 1. We obtained

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TABLE 1
Summary of HP Lib Observations, 1995–2001

Telescope	Observer	Nights/Hours
CBA-Tucson 0.35 m	Harvey	27/139
CBA-Braeside 0.41 m	Fried	22/120
MDM 1.3 m	Kemp/Halpern	35/106
CBA-Nelson 0.35 m	Rea	16/102
CBA-Maryland 0.63 m	Skillman	16/55
CTIO 1.0 m	Patterson/Kemp	22/54
CBA-Pakuranga 0.35 m	McCormick/Velthuis	8/42
CBA-Townsville 0.3 m	Butterworth	8/31
SAAO 1.0 m/0.75 m	O'Donoghue/Patterson	10/27
CBA-Illinois 0.2 m	Gunn	4/14
CBA-Awanui 0.25 m	Walker	5/12
Wise 1.0 m	Retter/Lipkin	5/12
CBA-Concord 0.44 m	Cook	3/9
CBA-Belgium 0.24 m	Vanmunster	2/6
CBA-Blenheim 0.25 m	Allen	1/6
CBA-Adelaide 0.35 m	McGee	2/5
CBA-Connecticut 0.2 m	Hannon	1/3
CBA-Moscow 0.6 m	Shugarov	1/3

a wide range in terrestrial longitude (with observations from the United States, New Zealand, Chile, South Africa, and Israel) in order to resolve ambiguities in daily cycle count, and a wide distribution over each observing season in order to define the precise period without cycle-count ambiguity on longer timescales (weeks to months). The data was predominantly differential CCD photometry with respect to a nearby star, most commonly GSC 5608−294, located about 100″ northwest of the variable and with $V = 12.93 \pm 0.02$. We generally used a V filter (or rotated filters) with the larger telescopes and white light with the smaller telescopes. On several occasions we verified that the periodic signal displayed no color dependence, so the data could be merged with no great loss of integrity. This was quite important because our program of accurate period measurement over very long baselines always requires merging data from disparate sources.

We were tremendously impressed with the stability of HP Lib. The star's mean brightness was always close to $V = 13.70 \pm 0.04$; we did not see any certifiable departures that exceeded 0.10 mag and did not see any low-frequency (0.1–5.0 cycles day^{-1}) periodic signals exceeding a full amplitude of 0.04 mag. These upper limits for variation in a long observing record are quite remarkable for a CV. Nor did the properties of the superhump, reported below, show much variation at all. High stability was also noted in the earlier study (O'Donoghue et al. 1994, hereafter O94).

After finding no significant change in the nightly means, we decided to assign $V = 13.70$ to every night by fiat. This simplified the time-series analysis and is a convenient normalization for displaying our results. Readers interested in absolute calibration should remember, however, that there is a zero-point uncertainty of ∼0.05 mag.

The upper panel of Figure 1 displays a sample light curve of HP Lib, with its characteristic 0.06 mag variation. Essentially all nights look alike. The lower panel shows the mean nightly power spectrum, formed by averaging the 28 nights of long coverage (>5 hr). The dominant signal at 77.2 cycles day^{-1} appears, along with the four lowest harmonics. By examining longer episodes (∼5–10 days) with particularly dense coverage, we were able to study these frequencies more closely and verify that all are exact integer multiples of 77.20 ± 0.02 cycles day^{-1}. This is explored more carefully in the next section.

Another point worth noting is the broad weak feature in the range 280–320 cycles day^{-1}. This was seen on many individual nights, but does not appear any more strongly in the aggregate since the peaks moved from night to night. This quasi-periodic oscillation (QPO) at $P \sim 5$ minutes is a real feature in the star, but we have learned nothing about it and will not comment further on it.

3. PERIOD ANALYSIS

During 4 years (1995, 1998, 2000, 2001), we had coverage sufficient to study fine-structure effects in the power spectrum. One of the better segments occurred in 2001, with coverage from New Zealand (R. Rea, J. McCormick, F. Velthuis) and Arizona (J. Halpern) in the most critical time window (JD 2,452,055–2,452,064). The raw power spectrum in the upper left panel of Figure 2 shows the powerful fundamental signal and establishes that it is easy to identify and thus reject aliased frequencies. The remaining panels of Figure 2 show the critical regions of this 9 night power spectrum, with significant detections marked by arrows and labeled with their frequencies (to ± 0.02 cycles day^{-1}). The power spectrum has been "cleaned" by removing the aliased frequencies. Aside from the obvious main signal and its harmonics, the interesting features are the signals at 78.35 and 155.57 cycles day^{-1}.

An alternate version of the most interesting part of Figure 2 is shown in Figure 3. Here we have cleaned the power spectra for the superhump only and have included the entire season's data, not just the densest portion of data. This gives a slightly noisier result (mainly because we remove only the mean superhump period, which is slightly variable) but a more accurate estimate of any stable period that may be present in the residuals. The two seasons with good detections yield $\omega = 78.353 \pm 0.004$ cycles day^{-1}.

Aside from all the obvious resemblances to AM CVn noted by O94, this structure of the power spectrum is yet another analogy. In particular, in the terminology used by Skillman et al. (1999), the orbital frequency ω should be identified as 78.35, and the fundamental superhump frequency $\omega - \Omega$ should be identified as 77.20. The remaining detections occur at $n(\omega - \Omega)$ for $n = 2$–5, and at $2\omega - \Omega$. The waveforms of the two relevant signals are shown in Figure 4. Especially noteworthy is the very low amplitude of the putative orbital signal, a mere

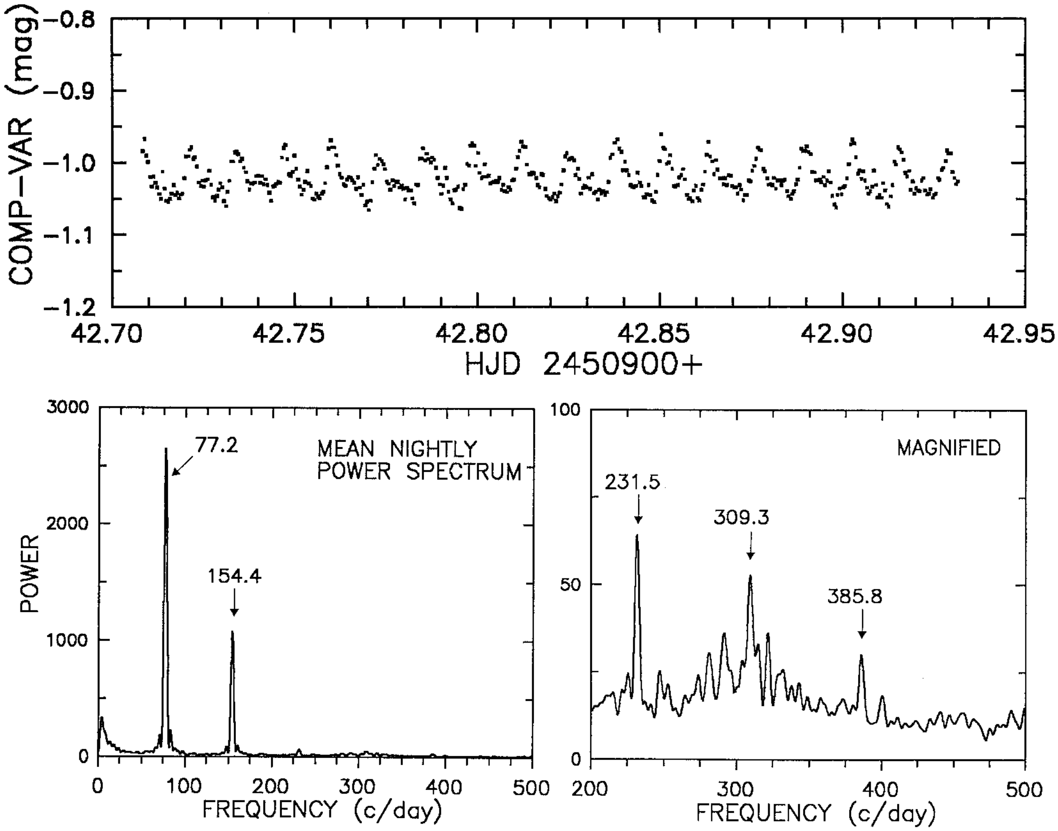

FIG. 1.—*Top:* Light curve of HP Lib in *V* light on 1998 May 9. *Bottom:* Mean nightly power spectrum, formed by averaging the 28 nights with long (>5 hr) time series. Significant features are marked with their frequencies in cycles day^{-1} ($\pm$0.5). A "QPO" is also evident as the broad excess of power near 300 cycles day^{-1}.

0.0048 ± 0.0005 mag at full amplitude. This is the weakest orbital signal ever seen in a cataclysmic variable; indeed, it is about 10 times smaller than the typical upper limit for CVs that *lack* orbital modulations in photometry!

The ascription of the 78.35 cycles day^{-1} signal to an orbital origin is indicated by its evidence for stability, the detailed analogy to AM CVn, and the (almost equally detailed) analogy to many superhumpers, which show similar $n\omega - m\Omega$ signals. Thus, we will here refer to it as an orbital signal, despite some doubt that must linger as long as compelling evidence for long-term stability is lacking. Additional evidence for or against an orbital origin is highly desirable to obtain.

It was straightforward—though tedious because of the signal's weakness—to obtain timings of the orbital signal during the observations. Table 2 shows all the detections, along with frequency measurements of both signals. The single-season estimate for $P_{\rm orb}$ is 0.0127627(6) days = 1102.70(5) s. Unfortunately the error in $P_{\rm orb}$ is still somewhat too large to permit unambiguous cycle count from year to year, but we give mean timings for orbital minimum light, which should eventually yield a precise ephemeris spanning many years. The most likely precise period is 0.01276282(1) days, with the other viable candidates at 0.01276326 and 0.01276227 days.

4. TRACKING THE SUPERHUMP

Since the superhump signal dominates the light curve, it is easy to extract a mean timing of maximum light for each night's observation. Indeed, with the mean brightness, power spectrum, and waveform essentially nonvariable, this is practically the entire information content from each night! The full set of 165 pulse timings during 1995–2001 is given in Table 3 and reduced to $O-C$ diagrams (relative to a test period of 0.0129511 days) in the yearly panels of Figure 5. The high density of coverage, coupled with the relatively high coherence of the signal, enables us to track the signal continuously during each observing season (without ambiguity in cycle count, except possibly for one or two lonely points at the beginning or end of a few seasons). The slope changes in Figure 5 show that the signal changes period from year to year, from 0.0129501(2) to 0.0129526(3) days. The timescale for changes is in the range 1–3 yr. A few wiggles suggest much faster period changes, but these are of

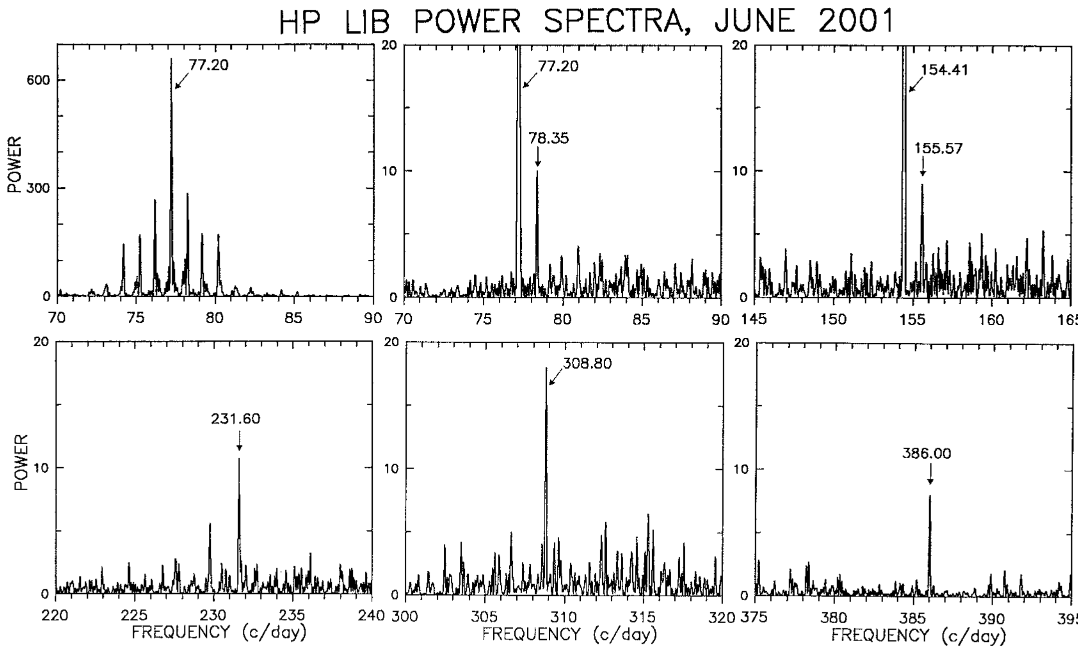

FIG. 2.—Power spectrum of HP Lib during JD 2,452,055–2,452,064, with significant features marked with their frequencies in cycles day^{-1} (± 0.02). The upper left panel shows the powerful fundamental and establishes that the coverage in terrestrial longitude is sufficient to identify and thus reject aliases. The remaining panels show the "cleaned" power spectrum, with aliases removed. The strong peaks at 77.20 and 154.41 rise to a power of 680 and 260 and correspond to a full amplitude of 0.044 and 0.026 mag, respectively. The weak features with a power near 10 correspond to a full amplitude near 0.004 mag.

quite short duration (∼1 month). These characteristics are an excellent match to the long-term timing properties of the famous 1051 s superhump of AM CVn (compare Fig. 5 here with Fig. 2 of Skillman et al. 1999).

We studied the yearly $O-C$ diagrams to see whether there might be a strict period (in the range 1–5 yr) that explains these long upward and downward ramps. There were a few candidates, and we show one in the last panel of Figure 5. However, since we do not actually know the cycle count between years, we have little real evidence on this point and do not discuss it further.

5. DISCUSSION

This study fully supports the interpretation of O94—that HP Lib is an IBWD which appears to be a very good match to AM CVn. Thus, we can appeal to the richly detailed studies of that famous star (Ostriker & Hesser 1968; Faulkner, Flannery, & Warner 1972; Smak 1975; Solheim et al. 1984; Patterson et al. 1992; Provencal et al. 1995; Harvey et al. 1998; Skillman et al. 1999). The orbital periods are very short and similar (1102 vs. 1028 s), the He I absorption-line spectra are similar, the magnitude history is similar (virtual constancy), and the broadband colors are very blue and similar ($B-V \sim -0.2$, $U-B \sim -1.2$). The orbital modulations are very weak, both less than 0.012 mag full amplitude. In addition, the detailed properties of the dominant photometric period in the light curve—the superhump—are similar, with virtually constant amplitude and harmonic structure, and complex sideband frequencies (slightly displaced from the exact superhump harmonics, according to $n\omega - m\Omega$ with $m < n$).

There are some differences, too, which emerge from these long time-series studies. HP Lib has a fractional period excess (of superhump over orbital period) of 0.0148, compared to 0.0219 in AM CVn. HP Lib has much more power in the fundamental (0.045 mag full amplitude, compared to 0.006 mag) and much less power in the harmonics. Eventually it may be possible to use these numbers—which really are stable properties of the two stars, not merely accidents of the observing window—to infer details about the structure of the underlying accretion disks. At present we confine ourselves to just one property, the value of the fractional period excess ϵ.

The origin of superhumps is now known to be in the apsidal precession of the accretion disk in binaries of extreme mass ratio (Whitehurst 1988; Hirose & Osaki 1990; Lubow 1991). The displacement of the superhump period $P_{\rm sh}$ from the orbital period $P_{\rm ort}$ reveals the precession period $P_{\rm prec}$ through

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

or equivalently

$$P_{\rm prec} = P_{\rm sh}/\epsilon.$$

Since ϵ and $P_{\rm sh}$ can be very accurately measured, this yields a

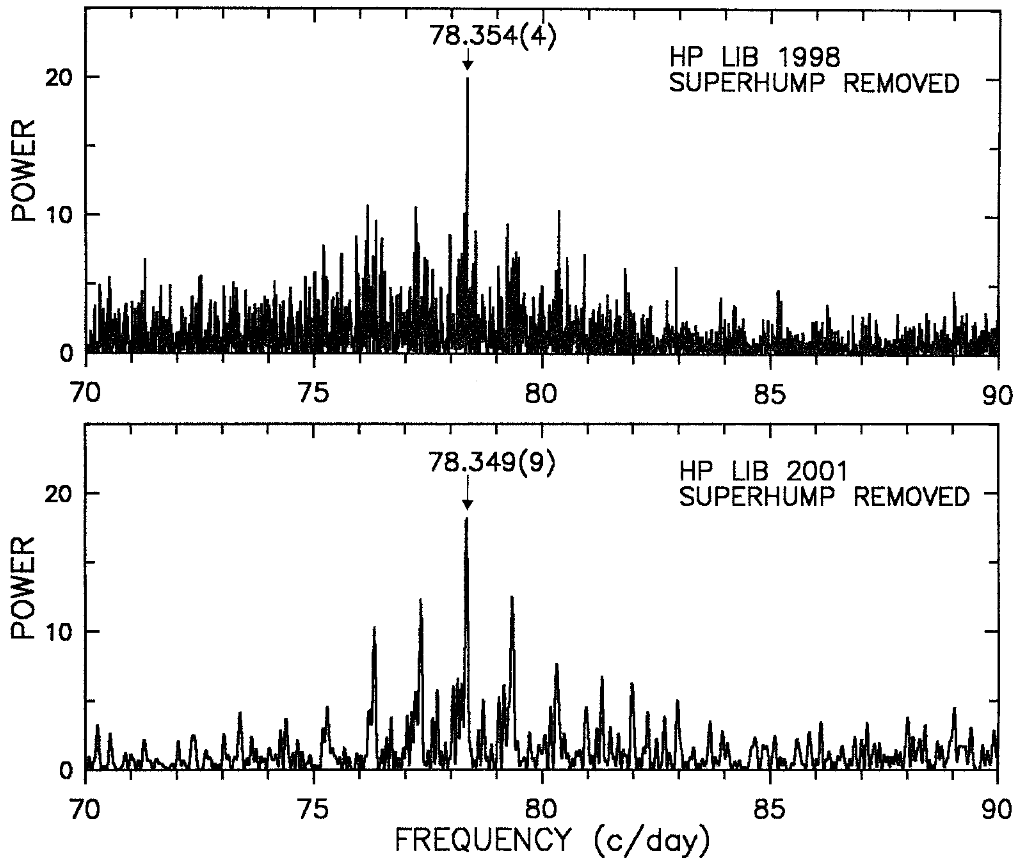

FIG. 3.—Power spectra for the entire 1998 and 2001 observing seasons, suggesting a stable signal with $\omega = 78.353(4)$ cycles day^{-1}. Here we have cleaned for the mean 77.20 cycles day^{-1} superhump only, preserving the noise and alias structure so the reader may judge the significance.

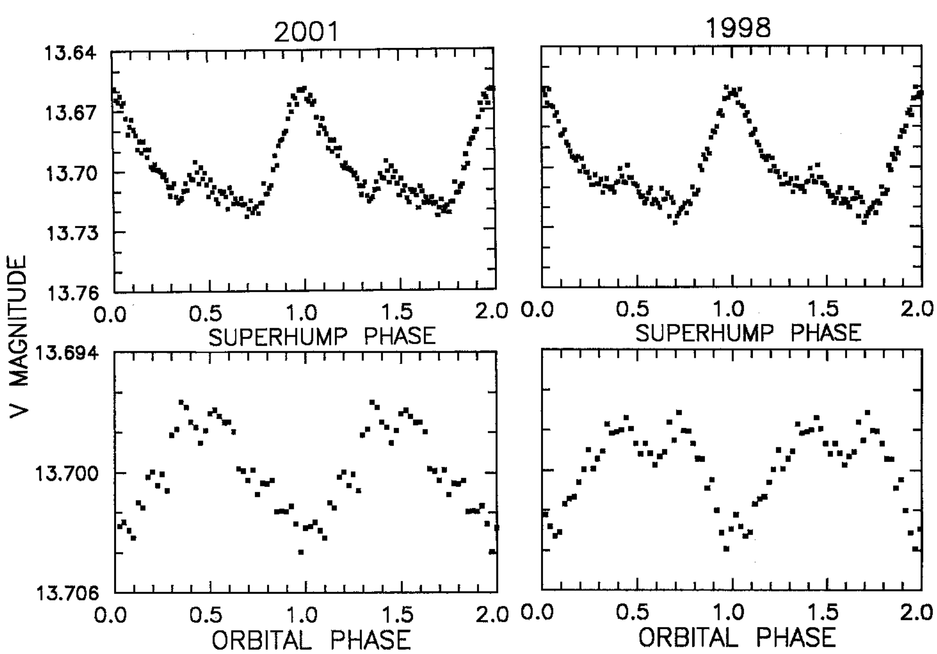

FIG. 4.—Mean light curves of the superhump ($\omega - \Omega$) and putative orbital (ω) signals in 1998 and 2001.

TABLE 2
FREQUENCIES AND EPOCHS IN HP LIB

YEAR	FREQUENCIES (cycles day^{-1}) Superhump	Orbital	ORBITAL MINIMUM (HJD [±0.0007])
1995	77.214(1)	...	...
1996	77.213(1)	...	...
1997	77.208(1)	...	...
1998	77.2165(8)	78.354(4)	2450906.4217
1998	JD 906–916 segment		2450906.4218
1998	JD 920–927 segment		2450920.4342
1998	JD 937–942 segment		2450937.3328
1998	JD 951–966 segment		2450951.6914
1999	77.220(2)	...	(2451328.8233)
2000	77.216(2)	78.350(10)	2451684.7630
2001	77.205(1)	78.349(9)	2452055.9693

NOTE.—The superhump is unstable, so a seasonal epoch is meaningless. The nightly epochs are given in Table 3. The 1999 orbital timing is uncertain. We measured four independent timings in 1998, which may help in long-term cycle counts.

firm value for $P_{\rm prec}$, namely, 0.875 ± 0.016 days. This should be directly, though not necessarily easily, measurable as a period in the star's absorption-line profiles (Patterson, Halpern, & Shambrook 1993).

Since precession arises from a perturbation on the disk from the orbiting secondary, the precession rate reveals the size of the perturbation and thus the underlying mass ratio of the binary. The problem arises in *calibrating* this relation. A recent calibration suggests $\epsilon = 0.216 \pm 0.018q$ (Patterson 2001, 1998), although Murray (2000) rejects this and gives an alternative discussion. Adopting this relation, we estimate $q = 0.068 \pm 0.007$.

There are now five AM CVn stars with precise measures of $P_{\rm orb}$ and $P_{\rm sh}$; this is sufficient to teach us something about superhumps (definitely) and something about helium secondaries (maybe). On the former, the lesson is simple: that *the helium binaries participate in roughly the same type of superhump behavior as their* H-*rich cousins*, with similar amplitudes, waveforms, and correlations with high/low states. This is fairly well evinced by the detailed studies of individual stars, especially the helium dwarf novae (CR Boo, V803 Cen, CP Eri; see references in Table 4).

Now let us see what can be learned about the helium secondaries. Kepler's third law in Roche geometry constrains the secondary to obey a period-density relation

$$P_{\rm orb}[\rm hr] = 8.75(M_2/R_2^3)^{-1/2},$$

with M_2 and R_2 in solar units. A cold low-mass white dwarf

TABLE 3
TIMES OF 1119 s MAXIMUM LIGHT

Maximum Light (HJD 2,400,000+)					
49,860.6413	50,221.8145	50,873.2407	50,942.7085	51,331.6488	51,697.9003
49,861.6512	50,232.7582	50,874.1861	50,947.8758	51,332.6459	51,698.7543
49,862.6617	50,273.6320	50,880.8554	50,949.9217	51,334.6664	51,699.6744
49,863.6584	50,274.6419	50,892.0191	50,951.6956	51,335.8576	51,700.6597
49,864.7077	50,275.6263	50,896.9143	50,952.7191	51,355.5807	51,702.7309
49,867.6689	50,279.6809	50,906.4206	50,952.9006	51,359.6724	51,705.6829
49,886.5174	50,303.4993	50,907.3788	50,955.6718	51,361.6672	51,705.7476
49,887.4755	50,312.5021	50,907.9873	50,956.7211	51,396.6337	51,706.8099
49,888.4727	50,467.8422	50,908.3502	50,957.7181	51,427.6091	51,719.5786
49,889.4829	50,534.8306	50,908.8162	50,958.7154	51,622.9459	51,935.0239
49,890.4799	50,541.7612	50,909.3860	50,961.7070	51,650.9159	52,010.6673
49,891.4772	50,564.7396	50,909.7354	50,962.6007	51,657.9476	52,043.0858
49,893.4721	50,568.7289	50,909.8005	50,966.6152	51,675.6758	52,044.0706
49,896.5285	50,570.7240	50,910.3573	50,976.2625	51,680.9856	52,045.0682
49,904.5194	50,592.6113	50,910.7587	50,982.6598	51,681.9699	52,046.0656
49,905.4779	50,594.6971	50,910.7717	50,987.6585	51,684.7676	52,055.9621
49,907.4855	50,608.6843	50,911.8207	51,029.9042	51,684.8971	52,056.9591
49,908.4831	50,616.5711	50,912.7922	51,032.5458	51,687.9277	52,057.9697
49,925.6559	50,619.6927	50,913.9704	51,041.8055	51,688.8474	52,058.9671
50,134.8851	50,622.6713	50,914.7996	51,061.8667	51,689.8330	52,059.9773
50,135.8827	50,623.6427	50,915.7192	51,220.0077	51,690.9582	52,060.9748
50,136.8798	50,625.6881	50,916.7424	51,252.9155	51,691.8907	52,062.9564
50,195.8348	50,626.6862	50,920.4333	51,266.9148	51,692.8626	52,063.8766
50,196.8061	50,628.6806	50,937.3342	51,305.3608	51,692.9009	52,063.9547
50,208.6952	50,630.6623	50,938.7718	51,320.8358	51,696.6695	52,066.9718
50,209.7439	50,866.9593	50,939.8336	51,328.8260	51,697.7189	

NOTE.—The typical error for timing maximum light is ±0.0004 days.

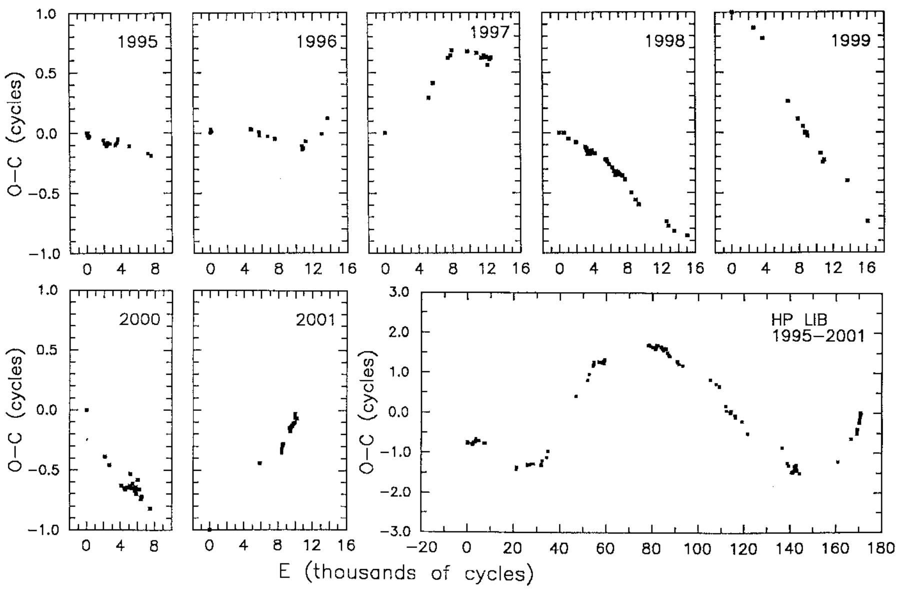

FIG. 5.—The yearly $O-C$ diagrams show the superhump's departure from a test period of 0.0129511 days. The first timing of each year is taken as the epoch for that year, though occasionally assigned $O-C=+1$ or -1 as needed for illustration. The cycle count is essentially well determined during each year. The changes in slope show the obvious period changes. However, the changes are sufficiently large that the cycle count between years is not securely known. One possible choice for the complete 7 yr cycle count is given in the last panel.

should approximately obey Chandrasekhar's (1939) relation

$$R_{\rm Ch} = 0.0126(1+X)^{5/3}M_2^{-1/3},$$

with $X=0$ here since the helium spectrum attests to a nearly pure helium composition. Coulomb corrections are important for secondaries of very low mass, so we use instead the models of Zapolsky & Salpeter (1969). Interpolation in their tables gives a power-law relation, accurate to 4% over the range 0.01–0.30 $M_\odot$:

$$R_{\rm ZS} = 0.0155M_2^{-0.212},$$

still in solar units. We adopt $R_2 = \alpha R_{\rm ZS}$ to allow for the possibility that the secondary may be slightly larger (since the degeneracy is not extremely high in these low-mass white dwarfs). Arithmetic then yields

$$M_2 = (0.0069/P_{\rm orb}^{1.22})\alpha^{1.83}, \quad (1)$$

which for $\alpha = 1$ implies $M_2 = 0.029$ in HP Lib. The superhump $\epsilon(q)$ relation then suggests $M_1 = 0.43 \pm 0.07$ in HP Lib. More generally, we expect the AM CVn stars to lie along a locus in ϵ-$P_{\rm orb}$ space given by

$$\epsilon = 0.216q = 1.5(2)\times 10^{-3}P_{\rm orb}^{-1.22}\alpha^{1.83}(M_1/0.7)^{-1.0}, \quad (2)$$

TABLE 4
ORBITAL AND SUPERHUMP PERIODS IN AM CVN STARS

Star	V	$P_{\rm orb}$ (s)	$P_{\rm sh}$ (s)	ϵ	q	References
AM CVn	14.2	1028.7332(2)	1051.2(2)	0.0218(2)	0.101(8)	1, 2
HP Lib	13.7	1102.70(6)	1119.0(1)	0.0148(2)	0.068(6)	3, 4
CR Boo	13–17	1471.3(3)	1487(3)	0.011(2)	0.051(9)	5, 6
V803 Cen	13–17	1612.0(5)	1618.3(8)	0.0041(8)	0.019(5)	7, 8, 9
CP Eri	15–18	1701.2(3)	1715.9(9)	0.0087(4)	0.040(5)	8, 10
GP Com	16.5	2794.05(20)	None	...	0.02*	11, 12
CE-315	17.5	3906(42)	None	...	0.02*	13

NOTE.—Asterisks indicate mass ratios that were estimated from spectroscopy (small radial-velocity wiggles in emission lines). The others were estimated from the empirical $\epsilon(q)$ relation.

REFERENCES.—(1) Skillman et al. 1999; (2) Provencal et al. 1995; (3) O94; (4) this paper; (5) Patterson et al. 1997; (6) Provencal et al. 1997; (7) O'Donoghue et al. 1990; (8) Patterson 2001; (9) Patterson et al. 2000; (10) Abbott et al. 1992; (11) Nather, Robinson, & Stover 1981; (12) Marsh 1999; (13) Ruiz et al. 2001.

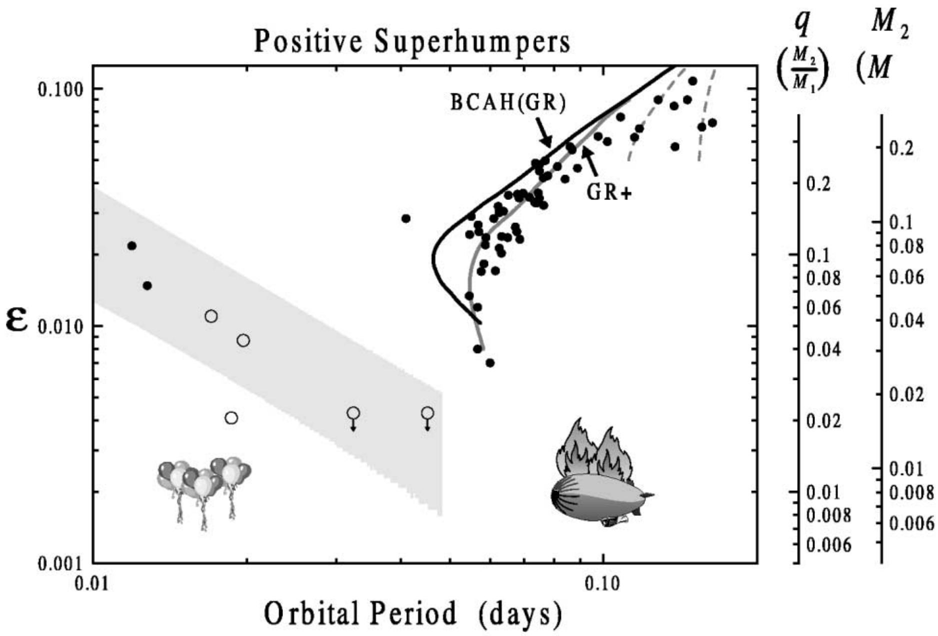

FIG. 6.—ϵ vs. $P_{\rm orb}$ for CVs with positive (apsidal) superhumps. H-rich CVs, mainly dwarf novae, are the family at upper right; the curves through these points are the evolutionary models favored in a previous discussion (GR and "enhanced" GR; Patterson 2001). He-rich CVs are the family at lower left; the lower boundary of the shaded region is the predicted locus (eq. [2] with $\alpha = 1$) if the secondaries are cold white dwarfs and $M_1 = 0.7\ M_\odot$. See text for discussion of the upper boundary. The scale at right gives estimates of q and M_2; this is moderately well calibrated in the range $0.05 < q < 0.2$ but extrapolated outside that range.

with the error set by the uncertainty in $\epsilon(q)$. [The actual scatter in $\epsilon(P_{\rm orb})$ will be greater, owing to the inevitable dispersion in M_1.]

How well does this prediction compare to the observational data? This is shown in Figure 6, an empirical plot of ϵ versus $P_{\rm orb}$. The H-rich stars are the cluster at right, discussed in detail previously (Patterson 1998, 2001). Helium CVs are the family at lower left, with the stars' individual properties given in Table 4. The line at lower left shows the predicted locus for cold white dwarf secondaries (eq. [2] with $\alpha = 1$). The upper envelope defines the locus for slightly larger secondaries, in particular the "semidegenerate" helium stars calculated by Savonije, de Kool, & van den Heuvel (1986), assuming that mass loss is rapid enough to drive the secondaries out of thermal equilibrium. The latter stars correspond approximately to $\alpha = 1.5$.

Also listed in Table 4, and appearing in Figure 6 as open circles, are the two helium CVs that do not show superhumps. They do, however, have limits on q available from spectroscopy. Thus, we have a reasonable constraint on q for all seven stars. Inspection of Table 4 and Figure 6 shows that *q appears to decline with increasing $P_{\rm orb}$*.

That is extremely interesting, because declining q almost surely means declining M_2 (any increases in M_1 can be neglected once M_2 has shrunk to these low values). *And the arrow of declining M_2 must be the arrow of evolution* because CVs must always evolve in the direction of decreasing M_2. The earliest theoretical studies of helium CVs (Paczyński 1967; Faulkner et al. 1972) suggested this—that the binaries probably evolve toward longer $P_{\rm orb}$—but it has been a long wait to find some actual evidence of this.

6. SUMMARY

1. Our main goal was to secure a detailed record of the rapid variability in HP Lib. The 1119 s signal is a very good match to the famous 1051 s superhump of AM CVn, which is now fairly well understood as the result of apsidal precession of the accretion disk in an IBWD. Like AM CVn, the HP Lib superhump keeps perfect time from night to night, but the period wanders slightly on a timescale of a few months to a few years. The period ranges from 1118.89 to 1119.14 s with $Q = 1/|\dot{P}| \sim 10^8$. The changes illustrated by Figure 5 seem to be erratic, although this can be usefully tested by future timings over long baselines. The amplitude and waveform of the signal are remarkably constant.

2. Episodes of dense photometric coverage reveal a weak signal at a period slightly shorter than that of the dominant superhump. The best estimate is $P = 1102.70 \pm 0.05$ s, with a full amplitude of 0.0047 ± 0.0005 mag. This is consistent with interpretation as the orbital period. The corresponding detection at 1028.733 s in AM CVn is *certifiable* as $P_{\rm orb}$, because it is demonstrably phase stable over a timescale of years, and

consistent with a periodic motion in the He I emission lines (Harvey et al. 1998; Skillman et al. 1999; Nelemans, Steeghs, & Groat 2001). A simile proof is desirable for HP Lib but will require similar evidence from additional photometry or spectroscopy. Times of minimum light from Table 2 should eventually supply a period of ephemeris quality.

3. The superhump has $\epsilon = 0.0148 \pm 0.0002$, which implies an accretion-disk precession period of 0.875 ± 0.016 days. This period might be directly detected in a study of the absorption-line profiles over a baseline of a few days. A recent $\epsilon(q)$ calibration suggests $q = 0.07 \pm 0.01$, or $M_2 \sim 0.05\ M_\odot$ if the accreting star is a garden-variety white dwarf with $M_1 \sim 0.7\ M_\odot$. Alternatively, enforcement of the *M-R* relation appropriate to cold white dwarfs implies $M_2 = 0.041(4)\ M_\odot$ and $M_1 = 0.60(8)\ M_\odot$.

4. There are now five AM CVn stars with measured values of superhump period excess. These show a trend of lower ϵ with longer $P_{\rm orb}$, happily consistent with the idea that IBWDs really do evolve toward longer period.

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