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ERUPTIONS AND SUPERHUMPS IN DWARF NOVAE

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ABSTRACT

The existence of two distinct eruption types in dwarf novae is considered. A small subclass of dwarf novae, the SU Ursae Majoris stars, show occasional very bright and long eruptions ("supermaxima"), and during supermaxima, large-amplitude photometric variations ("superhumps") at a period related to the orbital period are seen. Two new stars showing these effects, AY Lyrae and YZ Cancri, are reported. A third star, WZ Sagittae, is probably also a member of the class. Models for the superhumps are reviewed and found to be unsatisfactory. Observational constraints on a successful model are discussed.

I. INTRODUCTION

Among the dwarf novae, there is a small subclass of stars (the SU UMa stars) which show anomalously bright and long eruptions ("supermaxima") in addition to their more frequent normal eruptions. Photometric studies of these stars during supermaximum have revealed, in all cases, large amplitude variations ("superhumps") at a period related to the orbital period of the binary system (VW Hyi: Vogt 1974, Warner 1975a; V436 Cen: Warner 1975b; WX Hyi: Walker, Marino, and Freeth 1976). The origins of both the supermaxima and the superhumps are unknown.

We have observed the dwarf novae AY Lyrae and YZ Cancri during supermaxima, established their membership in the SU UMa class, and discovered periodic superhumps in their eruption light curves. This brings the number of SU UMa stars examined photometrically during supermaximum to 6, and every one of them has shown periodic superhumps. Furthermore, periodic superhumps have not been found in any dwarf nova other than the SU UMa stars, and are not found in *any* star during normal eruptions. This remarkable fact demonstrates conclusively that the source of the superhumps is the source of the supermaxima, and suggests that supermaxima and normal maxima arise from entirely different mechanisms.

In this paper we review existing observational evidence on the nature of the superhumps, and attempt to identify their origin. None of the published models are satisfactory, although a magnetic rotator model similar to that proposed by Papaloizou and Pringle (1978) remains viable. We conclude by listing the important observational constraints on a successful model.

II. ERUPTIONS OF AY LYRAE AND YZ CANCRI

a) *Visual Data*

The eruption light curves of AY Lyr and YZ Cnc, based on the visual observations of the AAVSO, are shown in Fig. 1. For each star, one supermaximum and one normal maximum are displayed. The normal maximum shown is a typical but well-observed one drawn from AAVSO files. The filled circles and upper limits are the visual observations, while our photoelectric measurements are shown by open circles. The supermaxima are seen to be ~1 mag brighter than normal maxima, and last ~5 times longer. These are typical values for certified SU UMa stars.

The extensive data published in the AAVSO *Circulars* have been utilized to determine mean outburst periods for AY Lyr, YZ Cnc, and the prototype SU UMa. The results are shown in Table I, which includes all available data for known and suspected SU UMa stars. The case of WZ Sge is special and will be discussed below. As Warner (1976a) noted, there seems to be some preference for short recurrence times between normal outbursts; in fact, the quoted recurrence times for our three stars are the three shortest known among the ~50 well-studied U Gem stars.

For YZ Cnc, AAVSO data are sufficiently extensive to warrant a detailed study of the relationship between eruption type and recurrence time. Figure 2 shows the relationship between maximum brightness and "days elapsed since last eruption." The dots are normal maxima preceded by normal maxima; the recurrence time is 10.3 ± 2.5 days.* Supermaxima preceded by normal maxima are indicated by triangles, and tend to occur 11.5 ± 3 days later. The crosses are normal maxima preceded by supermaxima, and they tend to occur 23 ±

* The distribution of dots also appears to be bimodal, with a lack of points between 10 and 15 days. This *may* indicate a dichotomy of "normal" eruptions in YZ Cnc. Since the normal eruptions of dwarf novae other than SU UMa stars often show a dichotomy with respect to the *duration* of an eruption (the "long/short" division), it may be possible to interpret this as a manifestation of long/short behavior. Unfortunately, this is difficult to verify directly because YZ Cnc's eruptions are so short-lived that the durations are very ill-determined by the visual data. We will not consider this point further.

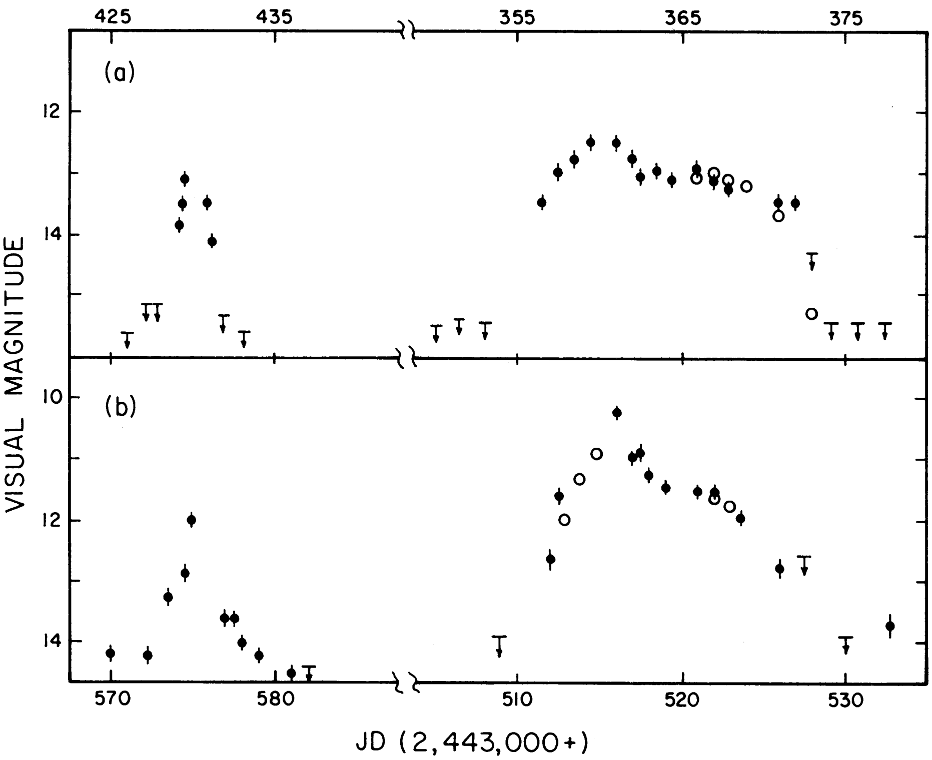

FIG. 1. Eruption light curves for (a) AY Lyr and (b) YZ Cnc. A typical short eruption (at left) is shown, together with the long eruption in which superhumps were found. Filled circles and upper limits are visual data; open circles are photoelectric data.

5 days later. In other words, if the mean outburst period is P_0, then supermaxima follow the last normal maximum by $\sim P_0$ but precede the next normal maximum by $\sim 2P_0$. Various interpretations of this result are possible, but perhaps the simplest is that normal maxima may occur during supermaxima but are not observed due to the brighter background.

TABLE I. Basic data for SU UMa stars.

star	Recurrence times: short maxima	Recurrence times: long maxima	Superhump period (min)	Source
YZ Cnc	10.3 ± 2.5 d	134 ± 19 d	133.2	1
AY Lyr	~12	196 ± 11	107.8	1, 3
SU UMa	13.2 ± 1.5 d	160 ± 40		1, 2
WX Hyi	13.7	195	112.4	6, 7
VW Hyi	28.7	180 ± 12	110.4	4, 5
V436 Cen	25	~630, scattered	92.2	4, 8
Z Cha	96	313	111.2	4, 9, 11
AT Ara	70	~500, scattered		4
CU Vel	139	scattered		4
OY Car	188	~300		4
WZ Sge?	none	32.5 yr	82.44	10

Sources:
1. this work
2. Isles (1976)
3. Howarth (1977a, 1977b)
4. Warner (1976a)
5. Vogt (1974)
6. Bateson (1976)
7. Walker, Marino, and Freeth (1976)
8. Warner (1975a, 1975b)
9. Warner (1974)
10. unpublished data
11. Vogt (1978)

b) *Photoelectric Data*

The photoelectric observations were obtained at the Cassegrain focus of the 76-cm, 92-cm, and 2.1-m reflecting telescopes of McDonald Observatory. Detailed information is contained in the observing log in Table II. The photometer used was the two-star, pulse-counting, high-speed photometer described by Nather (1973). A blue-sensitive RCA 8850 photomultiplier tube was used in the primary channel.

The observing technique consisted of continuous 2- or 3-s integrations on the star in unfiltered light, with occasional measures of sky and comparison star. Simultaneous measurement of a nearby star in the second channel provided a continuous monitor of extinction. When photometric conditions prevailed throughout an observing run, the data were reduced by subtracting the sky contribution and using a mean extinction coefficient to convert to counts per second outside the atmosphere.

The reduction technique differed when the second channel revealed the presence of thin clouds. To remove the extinction to first order, the counts in the primary channel were compared point-for-point to the counts in the second channel. An appropriate normalization factor then converted the data to counts per second outside the atmosphere. Experience has shown that this procedure increases the noise band by a factor of about 3, depending on the nature of the extinction. Some long-time-scale effects arising from differential tube drift, nongray extinction changes, etc., are not removed by this technique

TABLE II. Journal of observations.

Run	Date (UT)	Start	Duration	Telescope (m)	Brightness	Comments
a) AY Lyrae						
1911	10 Aug. 1977	3:16:15	$2^h 49^m$	2.1 m	$B \sim 13.1$	supermaximum
1913	11 Aug.	3:09:21	1 35	2.1	$B \sim 13.0$	supermaximum
1914	11 Aug.	5:16:39	0 34	2.1		
1915	11 Aug.	6:54:05	2 10	2.1		
1918	12 Aug.	3:01:11	1 26	2.1	$B \sim 13.1$	supermaximum
1919	12 Aug.	5:10:36	0 31	2.1		
1920	12 Aug.	6:57:46	2 17	2.1		
1922	13 Aug.	2:51:31	2 15	2.1	$B \sim 13.2$	supermaximum
···	15 Aug.	3:00	···	2.1	$V = 13.70, B - V = 0.15, U - B = -0.76$	supermaximum
1929	17 Aug.	8:25:11	···	0.76	$V = 15.30, B - V = 0.15, U - B = -0.76$	falling from supermaximum
2147	14 Apr. 1978	10:22:11	0 53	2.1	$B \sim 18.4$	minimum light
2234	29 Jul.	2:42:20	1 16	2.1	$V = 13.41, B - V = -0.04, U - B = -0.81$	normal maximum
b) YZ Cancri						
1567A	7 Jan. 1975	5:45:48	2 53	0.92	$B \sim 12.1$	falling from supermaximum
1567B	8 Jan.	5:55:09	2 20	0.92	$B \sim 12.4$	falling from supermaximum
1570	9 Jan.	4:17:42	2 51	0.92	$B \sim 12.7$	falling from supermaximum
2036	4 Dec. 1977	12:09:00	0 37	0.76	$B \sim 11.8$	maximum
2063	4 Jan. 1978	7:21:00	2 6	0.76	$V = 12.0, B - V = -0.13, U - B = -0.87$	rising to supermaximum
2065	5 Jan.	6:32:57	6 33	0.76	$V = 11.3, B - V = -0.11, U - B = -0.78$	supermaximum
2069	6 Jan.	4:13:40	5 0	0.76	$V = 11.0, B - V = -0.11, U - B = -0.90$	supermaximum
2074	13 Jan.	4:16:21	3 1	2.1	$B \sim 11.7$	falling from supermaximum
2077	14 Jan.	4:35:09	0 57	2.1	$B \sim 11.9$	falling from supermaximum
2084	7 Mar.	4:22:40	2 25	0.76	$V = 12.5, B - V = -0.05, U - B = -0.63$	rising
2090	8 Mar.	3:23:50	1 6	0.76	$V = 12.1, B - V = -0.08, U - B = -0.79$	maximum
2096	9 Mar.	3:10:30	1 26	0.76	$V = 12.7, B - V = -0.14, U - B = -1.03$	falling
2101	10 Mar.	2:53:40	5 31	0.76	$V = 14.1, B - V = -0.15, U - B = -1.01$	near minimum
2159	8 May	2:28:30	1 8	0.92	$B \sim 12.0$	maximum

and render precision photometry impossible. However, with some restraint in the use of this technique (such as avoiding moonlight and large air masses), many hours unsuitable for precision photometry may be redeemed, when lower quality data can be accepted. In particular, the timings of the light curve in the present study do not require high precision, and the two-star reduction technique was found to be satisfactory.

i) Supermaxima

The light curves obtained for AY Lyr and YZ Cnc during supermaximum are shown in Fig. 3. The superhumps are clearly evident, and the arrows show the scheduled moment of maximum light, according to the ephemerides (UT):

$$\text{AY Lyr, 10.185 August} + 0.07552\ E.$$
$$\text{YZ Cnc, 5.350 January} + 0.09204\ E.$$

The superhumps in AY Lyr are strictly periodic over the 4 days of observation. Those of YZ Cnc show a period change over the 10 days of observation. The timings are best satisfied by a period decreasing from 0.0920 days on 5–6 January to 0.0905 days on 13–14 January.

In addition, *UBV* measurements were obtained oc-

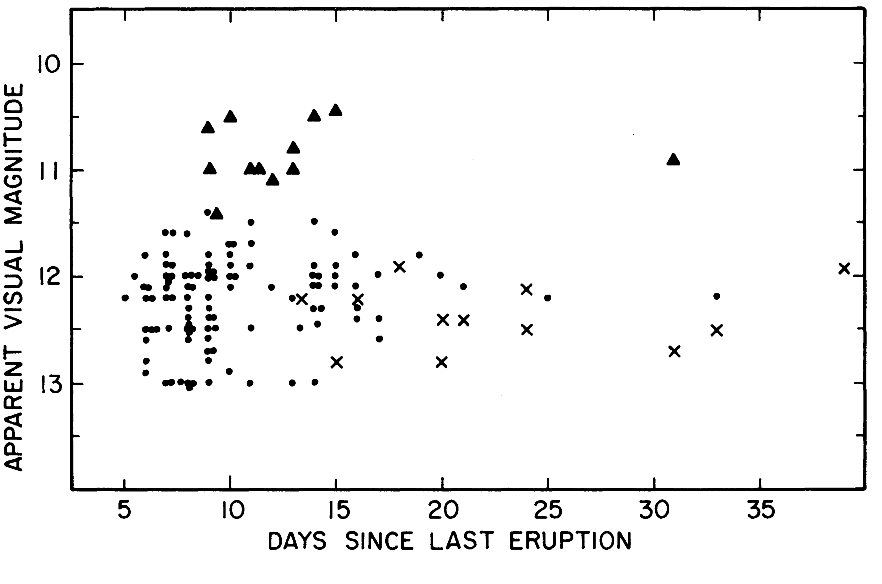

FIG. 2. The correlation between the peak visual magnitude of an eruption and the number of days elapsed since the last eruption for YZ Cnc, 1971–1978. Dots refer to normal eruptions preceded by normal eruptions; triangles refer to long eruptions preceded by normal eruptions; crosses refer to normal eruptions preceded by long eruptions.

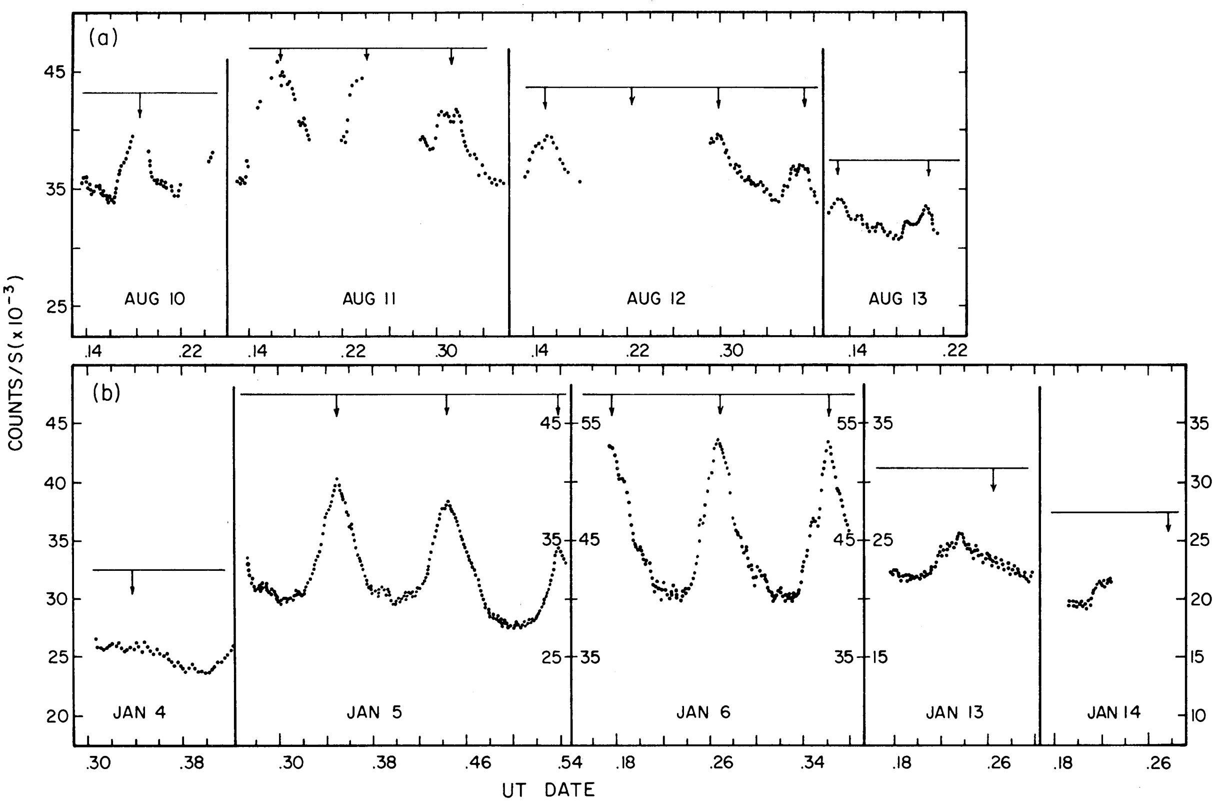

FIG. 3. (a) Light curve for AY Lyr in August 1977. Arrows indicate scheduled moments of maximum light. (b) Light curve for YZ Cnc in January 1978. Arrows indicate scheduled moments of maximum light. The count rates for 13 and 14 January have been converted to the corresponding count rates on the 76-cm telescope.

casionally for YZ Cnc, and no appreciable color changes through the superhump cycle were found.

ii) Normal maxima and minimum light

Some limited photometry has been obtained during normal eruptions and at minimum light. These data are also included in Table II. No superhumps were observed during normal eruptions.

In the case of YZ Cnc, a search was made for periodic humps at minimum light; no periodic hump is present with a recurrence period of less than 5 h. This is noteworthy because YZ Cnc shows very strong flickering, suggesting an active hot spot at a sufficiently low inclination that it remains visible throughout the binary orbit.

In the case of AY Lyr, the published "minimum light" value is $m_v = 16$ (Elvey and Babcock 1943, Kukarkin *et al.* 1969), but the star was found to be fainter than 18th magnitude. A 1-h observation at minimum light showed strong flickering (~0.2 mag), but was too short to reveal any periodic humps. In view of the discrepant "minimum light" magnitudes and the "G-type" spectrum reported by Elvey and Babcock, it is likely that AY Lyr has not been correctly identified at minimum light until now. However, the finding chart published by Vorobyeva (1960) is correct.

iii) Search for periodicities

All of the data were subjected to power spectrum analysis (Robinson and Warner 1972) to search for rapid periodicities, which are often seen in erupting dwarf novae. No periodicities were found.

III. DISCUSSION

a) The Supermaxima of SU UMa Stars

The existence of anomalously bright and long maxima is the defining characteristic of SU UMa stars. The recent statistical studies of the British Astronomical Association (e.g., Isles 1976; Howarth 1977a, 1977b) suggest that *most* U Gem stars show a division into "long" and "short" eruptions. It is possible that this is just a weaker manifestation of the SU UMa phenomenon, but for simplicity we restrict ourselves to certified SU UMa stars, and summarize the points of similarity and difference between normal and supermaxima.

The similarities are as follows. (1) The broad-band colors of the system are similar (Vogt 1974, this work). (2) Transient coherent oscillations are occasionally seen in both classes of eruption (Warner and Brickhill 1978; Haefner, Schoembs, and Vogt 1978). (3) Humps and eclipses seen at minimum light due to the luminosity of the hot spot at the outer edge of the disk are absent in both classes of eruption (Vogt 1974). (4) The excess light in both classes of eruption comes from the accretion disk (Warner 1974, Bateson 1978). (5) Averaged over years, the energy radiated is about the same for the two classes of eruption (Warner 1976a).

The points of difference are as follows. (1) The duration of outburst differs by a factor of 2–10. The distribution of the durations is typically a double Gaussian with no overlap (e.g., see Isles 1976 for SU UMa). (2) Light variations with a period related to the orbital period are seen during supermaxima—but never during normal maxima. (3) There is considerable evidence that the outburst clocks that regulate the two types of eruption are independent. Figure 3 of Warner (1976b) demonstrates that in VW Hyi a supermaximum may begin while a short maximum is in progress. The interpretation of our Fig. 2 suggests that in YZ Cnc a short maximum may occur while a supermaximum is in progress. From an extensive study of visual data for Z Cha, Bateson (1978) also found that the outburst clocks were independent, in the sense that supermaxima could occur at any time in the normal outburst cycle. (4) Warner (1976a) has claimed that the recurrence times between supermaxima are more regular than for normal maxima.

b) *The Superhumps*

The most striking and unique feature of supermaxima is the presence of superhumps in the light curve. Remarkably, all six certified SU UMa stars studied during supermaximum have shown these humps. This provides powerful evidence that the source of the superhumps is the source of the supermaximum and that the underlying mechanism does not depend critically on the inclination of the binary system.

i) *VW Hyi*

By good fortune, the brightest southern hemisphere dwarf nova, VW Hyi, is an SU UMa star, and has been well studied. Periodic humps at minimum light are seen, probably due to the brightness of the shock front ("hot spot") where the stream of transferred matter strikes the accretion disk. From these humps the orbital period is known to be 106.950 min (Haefner, Schoembs, and Vogt 1978). During supermaxima in 1972 and 1973, periodic superhumps were found by Marino and Walker (1974), Vogt (1974), and Warner (1975a). In 1972, humps were seen over 9 days, with a period that decreased from 110.8 to 110.1 min. In 1973, humps were seen over 11 days, with a period that decreased from 111.0 to 110.2 min. Periodic superhumps were also found in December 1974 by Haefner, Schoembs, and Vogt (1978). The period decreased from 110.8 to 110.0 min over 11 days. All of these studies have shown that the superhump behavior of VW Hyi is faithfully repeated during each supermaximum. The mean periods are identical to the limits of measurement: 110.38, 110.41, and 110.42 (±0.07) minutes for the supermaxima of 1972, 1973, and 1974, respectively.

The most puzzling feature of the superhumps is certainly the relationship of their period to the known orbital period. Unfortunately, the observational data are not sufficient to specify the nature of the problem. It is possible that the superhump period of VW Hyi is "bumped" from the orbital period to a value 3% greater, then slowly returns to the orbital period. It is also possible that the superhump period is always a few percent greater than the orbital period, and drifts by some smaller amount. Models of the first kind are more intuitive, but since the observed *mean* superhump period is stable to $\lesssim 0.1\%$, while differing from the orbital period by 3.2%, models of the second kind may be preferred. In fact, the VW Hyi superhumps can be represented with a totally stable period of 110.4 min, plus "phase drift" which does not exceed 0.15 cycles. Such a phase drift has been observed in other cataclysmic variables [e.g., in the 3.3-h variation of V1500 Cyg (Patterson 1979), and in the timings of the "minimum light" hump in VW Hyi itself (Haefner, Schoembs, and Vogt 1978)]. In any case, these observational uncertainties greatly complicate the problem of interpreting the period changes.

ii) *WZ Sagittae*

Recurrent humps have been found in the outburst light curve of WZ Sagittae (unpublished data; Targan 1979). Inspection of the unreduced data shows that during the interval 10–28 December 1978 the period was 0.05725 ± 0.00002 days and stable. This period is 1% greater than the known orbital period. A full discussion of these results will appear in a later publication on the outburst. In view of this result and the weight of other evidence that WZ Sge is in fact a dwarf nova (Patterson *et al.* 1978), it seems reasonable to classify the star as an SU UMa star that happens to lack normal eruptions. This classification is tentative, however, until the period is found to return to its preoutburst value.

iii) *Z Cha*

Superhumps in Z Cha were suspected by Warner (1975a), and have been confirmed by Vogt (1978). The period found by Vogt was 111.2 min, 3.6% longer than the known orbital period (Warner 1974). The existence of deep eclipses in Z Cha leads to the possibility that eclipse timings may specify the spatial origin of the excess luminosity in the system. As we shall see in Sec. III*d*, this possibility appears to be realized.

iv) *Other stars*

Information on the other four superhump stars is fragmentary, but suggests that the behavior of VW Hyi is typical of the class. Only YZ Cnc shows clear evidence

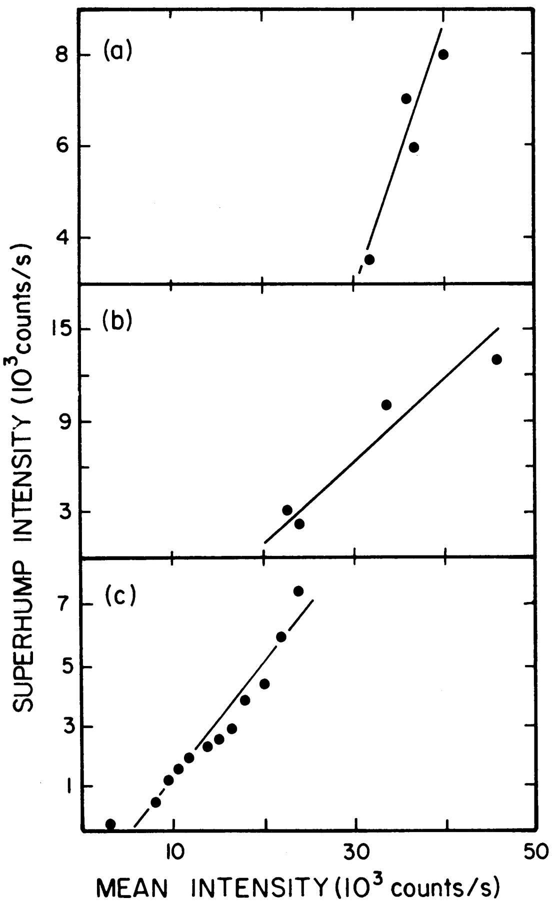

FIG. 4. The correlation between the amplitude of the superhump and the mean brightness of the star for (a) AY Lyr, (b) YZ Cnc, and (c) VW Hyi. VW Hyi data is taken from Haefner, Schoembs, and Vogt (1978). The count rates for each star are left on an instrumental system, and are not calibrated with each other.

of period changes, but that may be due to the fact that its observations span the longest baseline (10 days). A period change of the magnitude seen in VW Hyi requires a baseline of $\gtrsim 6$ days for detection.

For AY Lyr, YZ Cnc, and VW Hyi, the observations are sufficiently extensive to study the dependence of superhump amplitude on the mean light intensity of the star. This is shown in Fig. 4. Data for VW Hyi are taken from Haefner, Schoembs, and Vogt (1978). The linear dependence of superhump amplitude on mean intensity strongly suggests that the superhumps arise from the principal light source of the system. We shall see presently that this can only be the accretion disk or the white dwarf.

c) *Correlations with Outburst Period and Orbital Period*

Warner (1976a) has pointed out that the SU UMa phenomenon appears to be most prevalent among dwarf novae with short outburst periods and short orbital periods. These would be valuable clues to the origin of the supermaxima, but unfortunately both propositions are seriously troubled by selection effects. A star with a short outburst period will have many maxima observed, which permits better statistical analysis and easier identification of supermaxima. [UV Per is a case in point. The light curves shown by Petit (1958) and Glasby (1970) suggest that it is an SU UMa star, but because the normal eruptions are so infrequent (P = 360 days according to Kukarkin *et al.* 1969), the data are very sparse and the identification uncertain.] In addition, if the interval between supermaxima is roughly proportional to the interval between normal maxima, then few supermaxima will be produced by stars with long outburst periods. Thus, the significance of the tendency of SU UMa stars to have short outburst periods is open to doubt.

A different selection effect confounds the association with short orbital periods. Orbital periods are known only for VW Hyi, Z Cha, and WZ Sge, although the superhump periods of V436 Cen, WX Hyi, AY Lyr, and YZ Cnc are probably close to the orbital period (or *half* the orbital period). The difficulty is that all of these periods have been found by photometric observation. This technique is very unlikely to reveal variations with a period longer than the length of the observation, which seldom exceeds 4 h. Therefore, this may not be a representative sample of the class. We note that spectroscopic features of the late-type star have been reported in AT Ara (Vogt 1976). These features are found only in dwarf novae with orbital periods $\gtrsim 6$ h (Robinson 1976). Therefore, the requirement that SU UMa stars must have short orbital periods is still unproven, although it seems likely that some preference for short orbital periods exists.

d) *Models*

We now examine possible origins of the superhump and supermaximum. If one accepts that all supermaxima are similar and share a common origin with the superhumps, then an unambiguous constraint is provided by the eclipse light curve of Z Cha. Warner's (1974) observations during a supermaximum showed that the luminosity originates from the inner parts of the accretion disk. While his data do not show pronounced superhumps, this may be due to the fact that the observations were obtained rather late in the eruption; the superhumps of VW Hyi appear to fade somewhat more quickly than the unmodulated light (Warner 1975a). As mentioned above, superhumps have been found by Vogt (1978), whose eclipse timings agree with those of Warner. The visual data for Z Cha reported by Bateson (1978) extend this result considerably. Deep eclipses are observed throughout all phases of normal and supermaxima, and the eclipse timings prove that the same light source—the accretion disk—is always eclipsed. (The timings are not yet sufficiently accurate, however, to cleanly separate the contributions of white dwarf, disk proper, and mass-transfer hot spot.)

Even without the example of Z Cha, many observations suggest that the excess luminosity originates in the accretion disk for all dwarf nova eruptions. These include: the radial-velocity observations of SS Cyg (Walker and Chincarini 1968, Walker and Reagan 1971), which showed that the light of a normal maximum was centered on the white dwarf; the disappearance during eruption of humps and eclipses due to the contribution of the hot spot at the outer edge of the disk; spectra of VW Hyi during supermaximum, which show broad absorption lines from the disk (Vogt 1976); and the existence during all types of eruptions of coherent periodicities as short as 10 s (Patterson, Robinson, and Kiplinger 1978), which must come from the white dwarf or inner disk. Thus, it appears that we need consider only the white dwarf and disk as possible sites for the excess light in all dwarf nova eruptions.

A very different approach has been taken by Schoembs (1977), Vogt (1977), and Haefner, Schoembs, and Vogt (1978). These authors attribute the superhumps to bright spots on the surface of the red star. By hypothesizing that the star's synchronous rotation is disturbed by the eruption and that differential rotation is present as the bright spot is transported to lower latitudes, they can account for the period changes observed in VW Hyi. We believe that this model is incorrect, for the following reasons.

(1) Accretion onto the red star is $\sim 10^2$ times less efficient than accretion onto the white dwarf. Even if the mechanics for the formation of the bright spot can be understood, it is very doubtful that the red star can produce a luminosity comparable to that of the accretion disk and white dwarf.

(2) The *mean* superhump period in VW Hyi is constant to within 0.1%, although differing from the orbital period by 3.2%. This constancy is fortuitous in the proposed model.

(3) All of the evidence cited above indicates an origin in the white dwarf or inner disk. The eclipses of Z Cha show *decisively* that this is the principal light source. (The observations also permit some contribution from a mass-transfer hot spot, but no significant contribution from the red star.)

Papaloizou and Pringle (1978) suggest a model for VW Hyi in which the variations at *minimum* light arise from an "almost synchronous" rotating white dwarf, sufficiently magnetized to channel accreting matter onto its poles. The longer period seen at supermaximum is interpreted as the true orbital period, which manifests itself through a mass-transfer hot spot. This model is certainly untenable for WZ Sge and Z Cha, since the superhump period is known to be greater than the orbital period in these eclipsing systems. (The existence of eclipses leaves no doubt as to which is the true orbital period.) Thus we should expect that the shorter period is the orbital period—as is generally supposed.

A variant of this model, in which the longer period is identified as the white dwarf rotation period, may be considered. This can account for most of the observed features, and may explain the dichotomy of eruption types in a natural way, if the magnetic field disrupts the inner disk. The period changes are difficult to understand, but may alternatively be interpreted as a phase drift of ~ 0.2 cycles, as discussed in III*a*. Katz, Rappaport, and Joss (1979) have discussed the possibility of slow drifts from exact synchronism in AM Her stars.

IV. CONCLUSION

We can now list the critical observational constraints on a successful model for the superhumps.

(1) A model must produce a period slightly longer than the orbital period.

(2) A model should account for the ubiquity of the superhumps. Specifically, it should not rely heavily on binary inclination to produce a modulation, since at least one star—YZ Cnc—can produce respectable superhumps yet fails to produce normal humps at minimum light.

(3) A model must account for the lack of humps or superhumps during normal eruptions.

(4) The principal light source in the system must be modulated. This is supported by Fig. 4 and by the lack of color variations through the superhump cycle.

(5) The eclipse timings of Z Cha demonstrate that the luminous regions must be at least approximately centered on the white dwarf.

(6) A model must be able to reproduce the "pulsar-like" waveforms of Fig. 3. This suggests an aspect effect rather than an eclipse.

(7) A model should account for the broad absorption lines, generally considered to originate in the accretion disk.

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