OBSERVATIONAL EVIDENCE FOR THE TWO TYPES OF DWARF NOVA OUTBURSTS

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ABSTRACT. Observed characteristics of outbursts of eight dwarf novae are compared with those predicted for the two types of outbursts by the disk instability theory. OY Car, U Gem, VW Hyi, and WX Hyi are identified as Type A, while RX And, SS Cyg, AH Her, and CN Ori - as Type B.

1. INTRODUCTION

Time dependent models of accretion disks in dwarf novae, including the effects of thermal instability due to ionization of hydrogen (cf. recent reviews by Smak 1984a and Meyer 1985), predict two types of outbursts: Type A, when the instability begins in the *outer* parts of the disk, and Type B, when the instability first occurs in the *inner* parts. In Type A the instability propagates inward, while in Type B - inward *and* outward. Nearly all observable characteristics of the two types of outbursts, as predicted by model calculations, differ considerably. A preliminary comparison with the observational data available three years ago showed (Smak 1984a,c) that such two types of outbursts can, indeed, be identified. The purpose of the present communication is to discuss the results of another such comparison, based on more extensive data now available.

2. DIRECT PHOTOMETRIC EFFECTS

In the case of an eclipsing system it is possible to determine the surface brightness distribution of the disk. In particular, from an analysis of the eclipses at the onset of an outburst, it is possible - in principle - to determine which part of the disk brightens first. Such a direct evidence is now available for two systems: U Gem (Smak 1971) and OY Car (Vogt 1983). In both cases the original brightening occurs in the outer parts of the disk and then propagates inward, which implies Type A outbursts.

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3. EXPANSION OF THE DISK

In Type A outbursts the sudden accretion of some of the material of the outer ring requires that the remaining material absorbs the excess angular momentum, so that the outer radius of the disk expands during early rise. In Type B outbursts this can occur much later and only if the instability propagating outward reaches the outer edge of the disk. So far, U Gem remains the only system with adequate coverage of the disk-radius variations (Smak 1984b) and shows the expansion of the disk during early rise, as predicted for Type A.

4. THE DELAY BETWEEN THE VISUAL AND ULTRAVIOLET LIGHT CURVES

In Type A, the outburst begins with the heating up and brightening of the outer parts of the disk. The increasing viscosity causes the material to flow inward and this prevents any excessive heating. The area involved is relatively large, however, and even the moderate initial heating is sufficient to show up as a major visual brightening. At shorter wavelengths, no comparable brightening occurs until the accre-

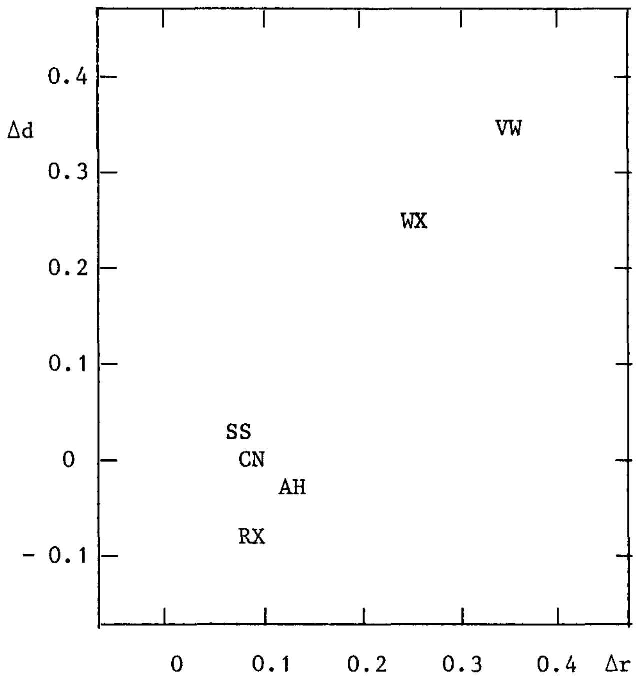

Figure 1. Relative delays between the visual and uv light curves. Δr corresponds to the rising branch, and Δd - to the declining branch, their values being positive when the ultraviolet is delayed with respect to the visual flux. Objects are identified in Table I.

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ting material reaches the inner parts of the disk, what leads to a considerable increase of their temperature. In Type B outbursts, no significant global brightening can be observed, due to the relatively small area of the central parts, until they become fairly hot. Hence, the outburst begins *almost* simultaneously at all wavelengths, with a *small delay* between the uv and visual flux. Calculations show that a similar difference in delays between the two types of outbursts exists also for the declining branch. Before going further, we must clarify two misunderstandings. First, the difference between Type A and Type B lies not in the *presence* or *absence* of a delay but rather in the *amount* of that delay. Secondly, the observed delay should be related to some characteristic time scale of the outburst. Accordingly, we shall define the *relative* delays Δr (or Δd) between the rising (or declining) branches of the uv and visual light curves: $\Delta r = \Delta R/W$ (or $\Delta d = \Delta D/W$), where ΔR (or ΔD) is the observed delay and W is the outburst duration.

The relative delays Δr and Δd have been estimated from simultaneous visual and uv observations available for the following systems: RX And (Szkody 1981,1982, Verbunt *et al.* 1984), SS Cyg (Cannizzo *et al.* 1986), AH Her (Verbunt *et al.* 1984), VW Hyi (Hassall *et al.* 1983, Schwarzenberg-Czerny *et al.* 1985), WX Hyi (Hassall *et al.* 1985), and CN Ori (Pringle *et al.* 1986). For the uv we used the monochromatic light curves at λ = 1350 A (except for SS Cyg, with λ = 1050 A). The results are shown in Fig.1. As can be seen, two objects - VW Hyi and WX Hyi - show very large delays, indicative of Type A. The remaining four systems, with much smaller delays, must be identified with Type B. We note, in passing, that Δd appears to be as useful as Δr.

5. THE LOOPS IN THE COLOR-MAGNITUDE DIAGRAM

The difference between the spectral behavior of the two types can also be studied in the color-magnitude diagram: Type A produces wide loops, while Type B - much narrower loops. The BV photometry of SS Cyg, AH Her, and VW Hyi was already discussed elsewhere (Smak 1984b). Sufficient data are now also available for RX And (Echevarria 1984) and OY Car (Vogt 1983); they indicate Type B and Type A, respectively.

6. SUMMARY AND DISCUSSION

All identifications of the previous sections are listed in Table I. We can summarize them as follows:

1. For six objects we have identifications based on two different types of evidence. They all agree.

2. All three ultra-short-period systems (OY Car, VW Hyi, WX Hyi) are identified with Type A.

3. All three Z Cam systems (RX And, AH Her, CN Ori) are identified with Type B. This requires further comments. Z Cam systems are known to represent a transition case between stationary and dwarf nova behavior (Meyer and Meyer-Hofmeister 1983). Their *mean* accretion rates are just below the critical level for the dwarf nova instability. Model calcul-

TABLE I

Evidence	RX And	OY Car	SS Cyg	U Gem	AH Her	VW Hyi	WX Hyi	CN Ori
phot.effects		A		A				
exp. of disk				A				
Δr and Δd	B		B		B	A	A	B
C-M diagram	B	A	B		B	A		

ations predict that Type A outbursts occur at higher accretion rates, while Type B - at lower rates. Our Type B identifications for the three Z Cam systems may thus seem inconsistent with these predictions. If we recall, however, that the *true* accretion rate during the dwarf nova phase is *lower* than the *mean* rate, our result may simply imply that it is *much* lower, i.e. low enough to produce Type B.

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