RECURRENCE BEHAVIOUR OF OUTBURSTS IN VW HYI

H. VAN DER WOERD[1] and J. VAN PARADIJS[2]
[1]Laboratory for Space Research Utrecht,
Utrecht, The Netherlands
[2]Astronomical Institute 'Anton Pannekoek',
University of Amsterdam, Amsterdam, The Netherlands

ABSTRACT.

The recurrence behaviour of normal- and super-outbursts in the SU Uma system VW Hyi is consistent with the idea that every superoutburst is triggered by a normal outburst. A simple description with a constant relaxation period of 170 days for the recurrence of superoutbursts, together with a randomly occurring trigger (the normal outbursts) is presented.

1. INTRODUCTION

The SU Uma type dwarf nova VW Hyi shows two kinds of outbursts: 'normal' outbursts (mean recurrence time of 28 days, duration 3-5 days, and maximum visual magnitude V ≈9.5), and the 'superoutbursts' (recurrence time ≈180 days, maximum magnitude V ≈8.6, and duration 10 to 14 days); see Bateson (1977). The outbursts reflect an increased mass transport through the disc (Bath et al., 1974). There is no agreement about the origin of this increase. Proposed explanations are variations

Paper presented at the IAU Colloquium No. 93 on 'Cataclysmic Variables. Recent Multi-Frequency Observations and Theoretical Developments', held at Dr. Remeis-Sternwarte Bamberg, F.R.G., 16–19 June, 1986.

Astrophysics and Space Science **130** (1987) 135–142.

in the viscosity in the accretion disc (see Smak, 1984), and an instability in the mass-transfer from the companion star (see Bath and Pringle, 1981). We here study on the connection between normal- and super-outbursts, which may help to reveal the origin of both phenomena.

2. NORMAL OUTBURSTS AT THE ONSET OF SUPEROUTBURSTS

Based on the similarity of normal outburst profiles to those observed during the initial rise and temporary decline at the onset of about 20 % of the superoutbursts, Bateson (1977) suggested that in some cases a superoutburst starts as a normal outburst. Marino and Walker (1979) proposed that this is the case for all superoutbursts: in the other 80 % the delay between the normal outburst and the bulk of the superoutburst is too short to be observable. This idea is strengthened by recent multi-wavelength observations of a superoutburst of VW Hyi, which showed no significant drop in the visual flux after the initial rise. In the EUV and X-ray bands a well-observed precursor decayed about 1.5 magnitude, before the final rise of the superoutburst started, and had a profile which is indistinguishable from that of a normal outburst (Polidan and Holberg, 1986; van der Woerd and Heise, 1986).

3. DESCRIPTION OF THE RECURRENCE OF SUPEROUTBURSTS

The idea that a superoutburst starts with, and may be triggered by, a normal outburst provides a qualitative framework for an understanding of at least some aspects of their recurrence behaviour. Without an explicit specification of which physical parameters are involved, we will assume that the superoutburst behaviour is governed by a parameter X, which is temporarily increased when a normal outburst occurs (see Fig. 1). We demand that this increase of the parameter X is positively

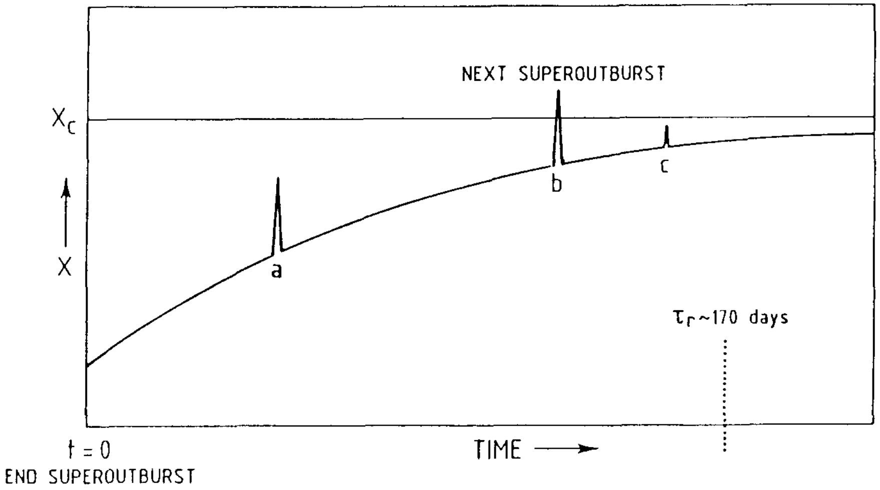

Fig. 1. The recurrence of superoutbursts in VW Hyi can be described by a gradual increasing parameter X, which can temporarily be increased by a normal outburst. When the value of X exceeds a critical level X_c a superoutburst will be initiated. The point t=0 denotes the end of the previous superoutburst.

correlated with the strength of the normal outburst. A superoutburst is triggered when X exceeds a critical value X_c. In the beginning of a supercycle X is so far from its critical value that no normal outburst (e.g. outburst a) is sufficiently strong to trigger a superoutburst. Later in a supercycle the stronger normal outbursts (compare outburst b and c) manage to trigger a superoutburst. After a "relaxation period" X is sufficiently close to its critical value that all normal outbursts give rise to a superoutburst. This model is based on a statistical analysis of observations of 44 superoutbursts and 257 normal outburst (Bateson, 1977), which is descibed in more detail by van der Woerd and van Paradijs (1986).

4. RECURRENCE BEHAVIOUR OF SUPEROUTBURSTS

Normal outbursts remain near maximum for only a brief period (≈1.3 days), and therefore the determination of the outburst energy depends strongly on the quality of the observations. Smak (1985) found that the strength of a normal outburst is correlated with the time interval since the previous outburst (see also van der Woerd and van Paradijs, 1986). We will therefore use the well defined length of the preceding normal cycle as a measure of the strength of a normal outburst.

In Fig. 2 we have plotted the time since the previous normal outbursts versus the time since the previous superoutburst, for the last normal outburst in a supercycle. Our qualitative model accounts for the fact that the last normal outburst in a supercycle always occurs before ≈170 days, which we identify with the "relaxation period". Only before this time interval is there a finite chance that a normal outburst is not strong enough to trigger a superoutburst. For longer time intervals every normal outburst will trigger a superoutburst (and will not be observed as a normal outburst).

Figure 2 shows that the length of the normal cycle, preceding the last normal outburst in a supercycle, is correlated with the time after superoutburst ($r= -0.65$, significance > 99.9 %). This correlation is a selection effect: those normal outbursts which occur just before the relaxation period, and have a long preceding normal cycle, are energetic enough to trigger a superoutburst, and therefore are not any more the last normal outburst in a cycle.

In Fig. 3 we have plotted the time since the previous normal outburst versus the time since the previous superoutburst, for the onset of the superoutburst. In our model the length of this preceding normal cycle is a measure of the strength of the normal outburst which manages to trigger the superoutburst. The mean length of supercycles is not dependent on the length of the preceding normal cycle. However, the spread in length is larger for supercycles with a longer preceding normal cycle. This is partly due to the fact that a strong normal outburst can trigger a superoutburst sooner after the previous superoutburst than a weak normal outburst (Fig. 1). Furthermore weak outbursts have a short recurrence time, and are therefore likely to occur near the relaxation period.

A comparison between Figs. 2 and 3 shows that, at a given time since the previous superoutburst, the normal cycles before a superoutburst are on average larger than the normal cycles before the last normal outburst in a supercycle. This fits our model: the normal outbursts which, at a given time after the last superoutburst, manage to trigger a superoutburst, are stronger than the normal outbursts which fail to do so.

Finally we note that the length of the supercycle before a superoutbursts with a clearly separated precursor in the visual is always shorter than 175 days.

5. DISCUSSION

The recurrence behaviour of superoutbursts in VW Hyi is consistent with the idea that every superoutburst is triggered by a normal outburst. An interpretation of these results is not obvious.

A particular model which fits the qualitative description of the relation between normal outbursts and superoutbursts is that proposed by

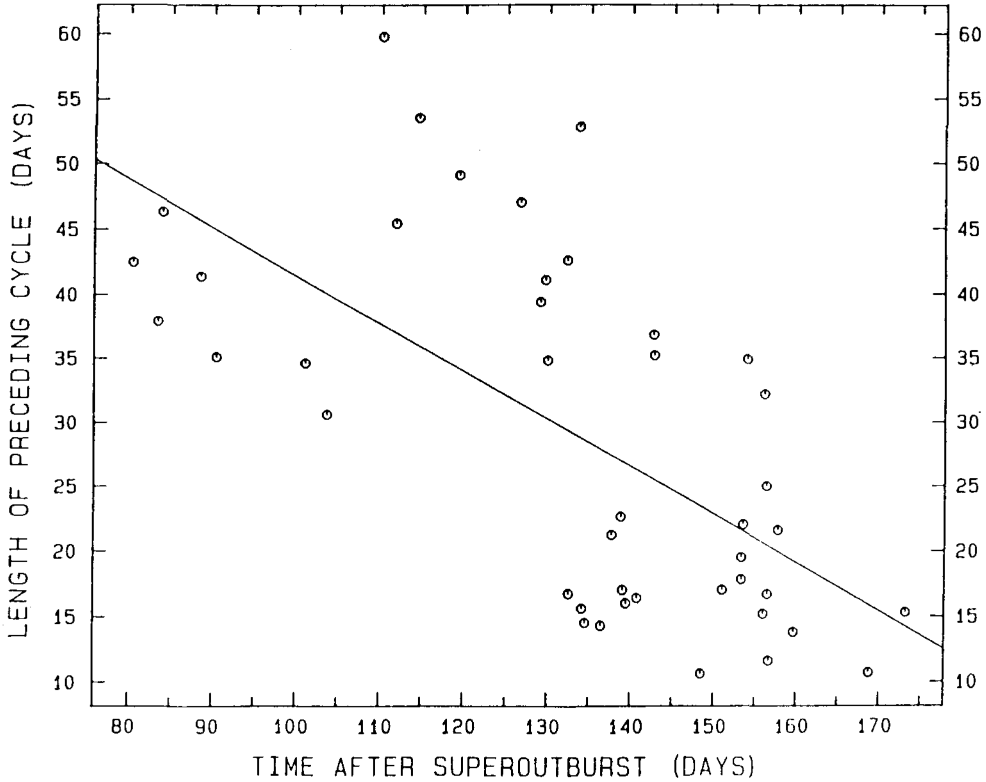

Fig. 2. *The length of the normal cycle, preceding the last normal outburst in a supercycle, versus the time after superoutburst. The correlation coefficient equals -0.65. A best fit is drawn.*

Osaki (1985). In his model the superoutbursts are due to enhanced mass transfer from the secondary, induced by X-ray irradiation from the white dwarf during a normal outburst. The model parameter X would in this model describe the susceptibility of the outer layer of the secondary to enhanced mass transfer due to X-ray irradiation. However, during outburst the X-ray emission is predominantly at wavelengths above 170 Å (van der Woerd and Heise, 1986), which makes it doubtful whether this

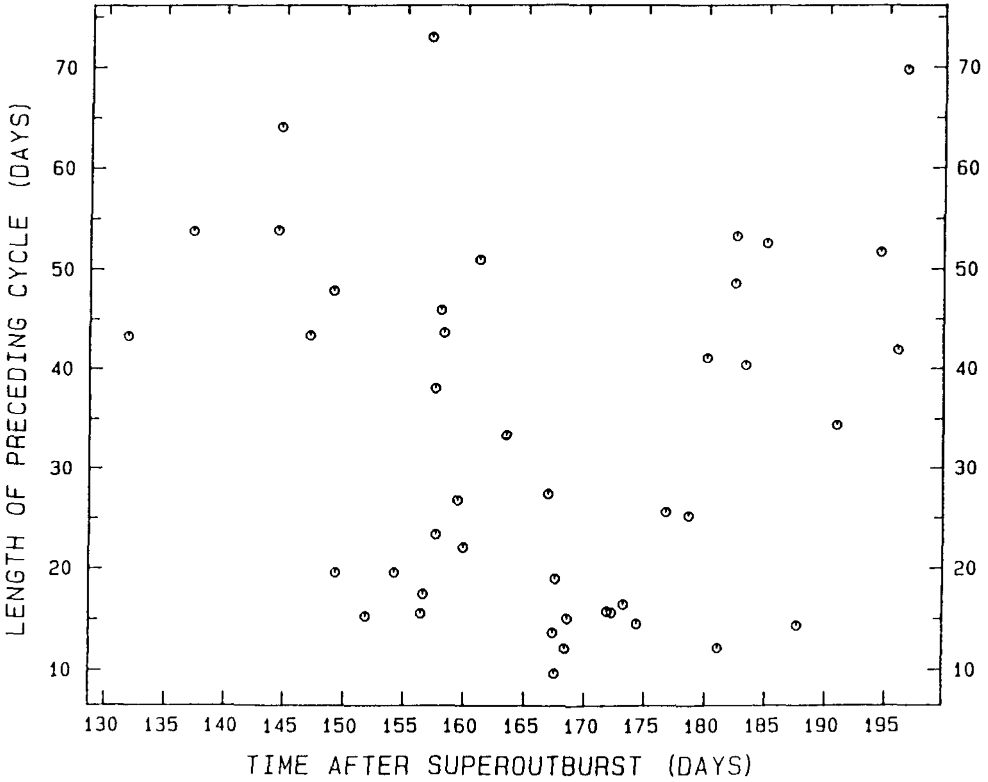

Fig. 3. The length of the last normal cycle in a supercycle versus the length of the supercycle. The distribution of the length of supercycles reflects the distribution of the length of the preceding cycle, i.e. the distribution of the energy of the triggering normal outbursts.

mechanism works (Hameury et al., 1985). The fact that some superoutbursts show a clear precursor in the visual and some do not (Marino and Walker, 1979), suggests that the trigger may not work instantaneously.

VW Hyi is the only SU Uma system which in the visual sometimes shows a precursor at the onset of a superoutburst (Bateson, 1986).

Neither is a precursor observed near the onset of wide outbursts in dwarf novae above the period gap, which may be perhaps similar to the superoutbursts (van Paradijs, 1983). Perhaps short-wavelength observations of the onset of these outbursts can decide whether there are no triggering outbursts, or whether the trigger joins smoothly with the wide outburst.

REFERENCES

Bateson, F.M.: 1977, New Zealand J. of Sci. **20**, 73

Bateson, F.M.: 1986, private communication

Bath, G.T., Evans, D.W., Papaloizou, J., Pringle, J.E.: 1974, Mon. Not. R. astr. Soc. **169**, 447

Bath, G.T., Pringle, J.E.: 1981, Mon. Not. R. astr. Soc. **194**, 967

Hameury, J.M., King, A.R., Lasota, J.P.: 1985, in "Recent results on Cataclysmic Variables", ESA SP-236, p. 167

Marino, B.F., Walker, W.S.G.: 1979, in Proc. I.A.U. Coll. No. 46, ed. J. Smak, p. 29

Osaki, Y.: 1985, Astron. Astrophys. **144**, 369

Polidan R.S., Holberg J.B.: 1986, Mon. Not. R. astr. Soc., submitted.

Smak, J.: 1984, Publ. Astron. Soc. Pacific. **96**,5

Smak, J.: 1985, Acta Astron. **35**, 357

van der Woerd, H., Heise, J.: 1986, Mon. Not. R. astr. Soc. submitted

van der Woerd, H., van Paradijs, J.: 1986, Mon. Not. R. astr. Soc. in press

van Paradijs, J.: 1983, Astron. Astrophys. **125**, L16