Detection of Short Fading Episodes in Two Dwarf Novae from VSNET Observations

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Abstract

From the observations reported to VSNET, we detected short fading episodes in two dwarf novae, RX And (orbital period 5.0 hr) and SU UMa (orbital period 1.8 hr). The episodes in RX And can be naturally explained as the response to a short-term reduction of the mass-transfer rate. A qualitative comparison with VY Scl-type fadings is also discussed. In SU UMa, the same explanation is expected to be more difficult to apply. The viable, but still poorly understood, possibilities include the temporary reduction of quiescent disk viscosity and the temporary reduction of mass-transfer rate. If the latter possibility is confirmed, we probably need a different mechanism from that of VY Scl-type stars.

Key words: accretion, accretion disks — stars: dwarf novae — stars: individual (RX Andromedae, SU Ursae Majoris) — stars: novae, cataclysmic variables

1. Introduction

Cataclysmic variables (CVs) are close binary systems consisting of a white dwarf and a red-dwarf secondary transferring matter via the Roche lobe overflow. Among CVs, there exist a group of objects called VY Scii-type stars or anti-dwarf novae (Warner 1995). In VY Scii-type stars, the mass-transfer from the secondary is occasionally reduced, or possible even stops (Robinson et al. 1981). Well-described examples of typical VY Scii-type stars can be found in Robinson et al. 1981; Wenzel, Fuhrmann 1983; Fuhrmann 1985; Greiner 1998; Kato et al. 2002c. Fading episodes (low states) similar to those of VY Scii-type stars are known to appear in various kinds of CVs: intermediate polars (Garnavich, Szkody 1988); some dwarf novae (Sion et al. 2001; Kato et al. 2002d; Schreiber et al. 2002). Polars and soft X-ray source are also known to show low states (Hessman 2000), but they are likely to have different origin (for supersoft X-ray source, see e.g. Hachisu, Kato 2003). Past studies of temporary reduction of mass-transfer rates in CVs mostly focused on episodes with long time scales (usually $\geq 100$ d). We here report the detection of much shorter (tens of days) fading episodes, at least some of which are likely arising from temporary reduction of mass-transfer rates, in two dwarf novae RX And and SU UMa. The analyzed data are from visual observations reported to VSNET.

2. RX Andromedae

RX And is one of the prototypical Z Cam-type dwarf novae which show standstills in addition to ordinary dwarf nova outbursts see e.g. Hellier 2001 Sect. 5.4; see also Warner, van Citters 1974; Meyer, Meyer-Hofmeister 1983; Oppenheimer et al. 1998). Most recently, RX And has been shown to be an unique Z Cam-type dwarf nova which also exhibits occasional “low states” (Sion et al. 2001; Kato et al. 2002d; Schreiber et al. 2002). Schreiber et al. (2002) even suggested that RX And is a transitional object between Z Cam-type dwarf novae and VY Scii-type stars (cf. Warner, van Citters 1974; Warner 1995; Greiner 1998), although Kato et al. (2002d) reported difference between fadings in RX And and in VY Scii-type stars.

Schreiber et al. (2002) examined the historical light curve of RX And and reported that typical fadings of RX And lasted for $\sim 100$ d.2

Here we report on the detection of an unusually short fading episode in 2002. The upper panel of figure 1 shows the light curve covering this event starting at around JD 2452570. The errors of visual observations are usually less than 0.3 mag, which do not affect the discussion. About 3–4 d after reaching a temporary minimum, the object underwent a short, small brightening (JD 2452582). This behavior is remarkably similar to what is expected for a thermally stable accretion disk suffering from a sudden decrease of the mass-transfer rate (Honeycutt et al. 1994; King, Cannizzo 1998). We therefore identify the 2002 phenomenon as an extremely short fading episode. The recovery from this fading took less than 30 d (figure 1, upper panel). No similarly short fading episode was identified in

2 Before the discovery of the 1996 fading episode, RX And in deep quiescence (or in low state) may have been confused with the nearby star. Because of the ambiguity in interpreting the historical data, both Kato et al. (2002d) and apparently Schreiber et al. (2002) ascribed “intervals without outbursts” to historical fading episodes.
Fig. 1. (Upper:) Light curve of RX And in 2002. While the object initially showed regular dwarf nova outbursts, it entered a short faint state starting at around JD 2452570. (Lower:) Long fading episode in 1996. The object entered a faint state at around JD 2450310, after the initial state of a standstill. An occurrence of a short, faint brightening just following the start of the fading episode is remarkably similar on both occasions, although the duration of the fading is very different. The large and small dots represent positive and upper limit visual observations reported to VSNET. The open squares represent CCD V-band observations from Kato et al. (2002d).

3. **SU Ursae Majoris**

SU UMa is the well-known prototype of the SU UMa-type dwarf novae (Udalski 1990). Although some irregularities in the long-term light variation has been reported (e.g. Rosenzweig et al. 2000; Kato 2002), past studies mainly pointed out the irregularities in the supercycle (or occurrence of superoutbursts) and the occasional absence of normal outbursts. From the VSNET observation, we report on the detection of short fades, which may be analogous to that of RX And (section 2). Figure 2 shows the long-term (1994–2003) light curve of SU UMa. Although the object spends most of its quiescence at around $V=14.0$, there are at least two instances [marked with the arrows: around JD 2450600 (1997 May) and JD 2452680 (2003 February)] when the object was transiently observed below $V \sim 15.0$. During these phases, the number of outbursts was remarkably reduced (figure 3). After the 1997 May fading, the object underwent a superoutburst.

4. **Discussion**

In most VY Scl-type stars, the fading episodes (low states) usually take much longer durations (cf. Greiner 1998; Kato et al. 2002c). This difference may be a result of a stronger heating effect on the accretion disk in VY Scl-type stars (Leach et al. 1999).

Following the calculation by Leach et al. (1999), very short events of the reduced mass-transfer in VY Scl-type stars, if any, may not appear as prominent fades since a heating can thermally stabilize the accretion disk. Leach et al. (1999) reported that a white dwarf temperature of $4 \times 10^4$ K produces ionized inner disk, thereby preventing dwarf nova-type disk instability from occurring at low mass-transfer rates, and preventing the system from immediately reaching a deep, low state. We can expect that...
Fig. 2. Long-term light curve of SU UMa from VSNET observations. The large and small filled squares represent positive and negative (upper limit) observations. Two short fading episodes are shown with the thick arrows.
in the range $3 \, \text{hr} \leq P_{\text{orb}} \leq 4 \, \text{hr}$ (see Livio, Pringle 1994 for the full explanation). The location of RX And ($P_{\text{orb}} = 5.0 \, \text{hr}$) is just above this region, and the proposed mechanism would reasonably work. The long-period dwarf novae with occasional low states include WW Cet ($P_{\text{orb}} = 4.2 \, \text{hr}$, Ringwald et al. 1996), although it is not clear whether these low states actually correspond to reduced mass-transfer phenomena.

This explanation, however, is more difficult to apply to SU UMa (section 3). Since SU UMa is an object with $P_{\text{orb}} = 1.8 \, \text{hr}$, the secondary star is expected to become fully convective and we can not canonically expect a high magnetic activity (Verbunt, Zwaan 1981; Rappaport et al. 1982; Rappaport et al. 1983; Verbunt 1984; Rappaport, Joss 1984; Ritter 1985). The first fading episode (1997 May) might have a different origin. This episode was followed by a superoutburst, suggesting that the large amount of mass must have stored (Osaki 1989) even during this fading. During this fading, the low quiescent brightness may have been a temporary reduction of disk viscosity which also suppressed normal outbursts (Kato 2002), but once the thermal instability occurs, this would lead to a larger outburst (the extreme effect would be best seen in WZ Sge-type stars: Osaki 1995, Osaki, Meyer 2003). The second fading (2003 February) was not associated with similar occurrence of a superoutburst. This phenomenon may have been an episode with a true reduction of mass-transfer. If this possibility of mass-transfer reduction is confirmed, we probably need a different mechanism from that of VY ScI-type stars.

We must also note that some objects with $P_{\text{orb}}$ similar to SU UMa are claimed to have “low states” (e.g. HT Cas: $P_{\text{orb}} = 1.8 \, \text{hr}$, Zhang et al. 1986; Wood et al. 1995; Robertson, Honeycutt 1996 and IR Com: $P_{\text{orb}} = 2.1 \, \text{hr}$, Richter, Greiner 1995; Kato et al. 2002a). There are also SU UMa-type dwarf novae with long-term variation of outburst properties (V1159 Ori: Kato 2001; V503 Cyg: Kato et al. 2002d; DM Lyr: Nogami et al. 2003a; MN Dra = Var73 Dra: Nogami et al. 2003b). It is not still certain whether or not variable mass-transfer rate is responsible for these phenomena in these short-$P_{\text{orb}}$ dwarf novae.

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