1993 Superoutburst of LL Andromedae

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Abstract

We present time-resolved CCD photometry of LL And during its 1993 outburst. The observation revealed the presence of superhumps with a period of 0.05697(3) d. This period is one of the smallest among the hydrogen-rich dwarf novae. Although LL And has been proposed to be a WZ Sge-type dwarf nova based on its low outburst frequency, our new analysis indicates that the outburst amplitude (∼5 mag) and outburst duration (9±2 d) are much smaller and shorter than in typical WZ Sge-type dwarf novae.

We suspect that the unusual outburst properties of LL And might be explained by assuming a “leaky disk” in quiescence, which was originally proposed to explain the prototypical WZ Sge-type outbursts. By combination with the recent suggestion of the orbital period, the fractional superhump excess is found to be 3.5(1) %, which is unusually large for this short-period system. LL And may be an object filling the gap in the evolutionary track, which has recently been proposed to explain the unusual ultracompact binaries with an evolved mass donor.

Key words: accretion, accretion disks — stars: dwarf novae — stars: individual (LL Andromedae) — stars: novae, cataclysmic variables

1. Introduction

WZ Sge-type dwarf novae are a class of SU UMa-type dwarf novae [for recent summaries of dwarf novae and SU UMa-type dwarf novae, see Osaki (1996) and Warner (1995b), respectively], characterized by a long (∼10 yr) outburst recurrence time and a large (∼8 mag) outburst amplitude (cf. Bailey 1979; Downes, Margon 1981; Patterson et al. 1981; O’Donoghue et al. 1991; Kato et al. 2001). WZ Sge-type dwarf novae are considered to be systems close to the terminal evolution of cataclysmic variables (CVs). Since the expected mass of the mass-donor secondary stars in such systems is close to the lower limit of normal low-mass stars, WZ Sge-type dwarf novae are recently regarded as promising candidates for binaries containing brown dwarfs (Howell et al. 1997; Politano et al. 1998; Ciardi et al. 1998; Patterson 2001; Howell, Ciardi 2001; Mennickent, Diaz 2002; Littlefair et al. 2003).

LL And, being known as a hydrogen-rich dwarf nova with one of the shortest periods, has been nominated as a promising candidate harboring a brown dwarf secondary (Howell, Ciardi 2001).

LL And is an eruptive object discovered in 1979 (Wild 1979). Since the only approximate position was announced at the time of the discovery, we examined the Palomar Observatory Sky Survey (POSS) I prints and identified a blue object close to the reported position (T. Kato, 1990, unpublished). This supposed identification, which was later confirmed by the detection of a new outburst in 1993, of a relatively bright (∼19 mag) quiescent counterpart naturally suggested the dwarf nova-type classification. This information was quickly relayed to observers through the international alert networks (e.g. VSNET: Kato et al. 2003b), and the object has been continuously monitored since then. The long-awaited next outburst finally occurred in 1993.

2. Observation

The CCD photometric observation was performed using a CCD camera (Thomson TH 7882, 576 × 384 pixels, on-chip 2 × 2 binning adopted) attached to the Cassegrain focus of the 60-cm reflector (focal length = 4.8 m) at Ouda Station, Kyoto University (Ohtani et al. 1992). The frames were first corrected for standard de-biasing and flat fielding, and were then processed by a microcomputer-based photometry package developed by the author. The log of observations is listed in table 1.

The observations used GSC 1741.858 (V = 13.87) as the comparison star, and GSC 1741.301 (V = 14.58) and GSC 1741.441 (V = 14.62) as the check stars. The magnitudes of the comparison stars were taken from Henden, Honeycutt (1997). The VSNET chart on this magnitude system (showing LL And in outburst) is available at ⟨ftp://vsnet.kusastro.kyoto-u.ac.jp/pub/vsnet/charts/LLAnd.ps⟩. The GSC magnitudes, which were used at the time of the 1993 outburst, are confirmed to be ∼0.4 mag too bright, which explains the discrepancy between the present CCD V measurements and the visual observations published on the 1993 outburst occasion (Howell, Hurst 1994). We thereby added a correction of 0.4 mag to the visual observations described in (Howell, Hurst 1994). We also obtained a few snapshot quiescent observations which are also listed in table 1.

Heliocentric corrections to the observed times were ap-
Table 1. Journal of CCD photometry.

| Date       | Start–End  | Filter | Exp(s) | N | Mean mag | Error |
|------------|------------|--------|--------|---|----------|-------|
| 1990 December 30 | 48255.992–48255.993 | V | 60–120 | 2 | 18.0     | ⋯     |
| 1991 July 19 | 48457.212–48457.217 | I_c | 120    | 3 | 18.0     | ⋯     |
| August 21  | 48490.208–48490.215 | I_c | 180    | 4 | 18.8     | 0.5   |
| 1993 December 9 | 49330.863–49331.096 | V | 120–240 | 96 | 14.54    | 0.01  |
| 11         | 49332.904–49333.060 | V | 120    | 69 | 14.62    | 0.01  |
| 12         | 49333.877–49334.116 | V | 120    | 147| 14.65    | 0.01  |
| 19         | 49340.948–49341.063 | V | 120–240 | 25 | 17.63    | 0.04  |
| 1994 January 1 | 49353.882–49353.964 | V | 60–480 | 20 | 18.07    | 0.05  |
| 2          | 49354.905–49355.001 | V | 60–360 | 22 | 18.33    | 0.04  |

*JD−2400000.

Fig. 1. Light curve of the 1993 outburst of LL And. The large filled circles and open circles represent our CCD V-band and visual observations (corrected for the 0.4 mag zero-point error in the comparison stars), respectively. The small dots represent upper limit observations.

Fig. 2. Superhumps in LL And. The errors of individual observations are smaller than the size of the marks.

3. Results

3.1. Outburst Light Curve

The resultant outburst light curve is presented in figure 1. The object was first detected in outburst by T. Vanmunster on 1993 December 7.906 UT. The object was not detected in outburst 0.34 d (M. Moriyama), 1.03 d (P. Schmeer), 18.00 d (G. Poyner) before this detection, respectively. It was thus less likely that the object underwent a missed brighter maximum before Vanmunster’s initial detection. Following a slow decline at least until December 15, the object entered the rapid decline stage sometime before December 19. The most likely duration of the outburst was 9±2 d.

3.2. Superhumps

On December 9, 11, and 12, our time-resolved CCD photometry revealed the presence of superhumps. This information, relayed through the alert network system (Kato et al. 2003b), was announced by Howell, Hurst (1994). The nightly light curves of the superhumps are shown in figure 2.
4. Discussion

4.1. Outburst Properties

Howell, Hurst (1994), Howell, Hurst (1996) suggested, from the available material at these times, that LL And belongs to a class of dwarf novae with large outburst amplitudes. This identification, however, becomes dubious upon closer examination of the present material.

Firstly, Howell, Hurst (1994) used the maximum outburst magnitude of $m_{\text{vis}} = 13.8$, which is clearly an overestimated caused by an incorrect zero point. The present observation, calibrated on the modern $V$ scale, suggests a much fainter outburst maximum of $V = 14.3-14.5$. The bright magnitude quoted by Wild (1979) needs to be treated with special caution, because the observation probably used blue-sensitive plates (hence would not adequately represent visual magnitudes), and because the published magnitudes were very likely only preliminary measurements with probable errors of $\sim 1$ mag.

Secondly, the quiescent magnitude in Howell, Hurst (1994), Howell, Hurst (1996) was likely underestimated. The object is already readily recognized on paper reproduction of POSS I red and blue prints (section 1), which suggests a significantly brighter magnitude than $V \approx 20$. The modern magnitude estimates (USNO B1.0: Monet et al. 2003) give red and blue magnitudes of 19.26 and 19.59–19.78, respectively. These measurements are in line with the author’s estimate on POSS I paper prints. The USNO B1.0 magnitude correspond to $V = 19.4$.

The inferred outburst amplitude from these new estimates is $\sim 5.0$ mag, which is no longer an exceptionally large value for SU UMa-type dwarf novae (e.g. Nogami et al. 1997b).

The outburst frequency looks like to be small. The only recorded outbursts up to now were in 1979 September (Wild 1979) and in 1993 December (this work). In spite of intensive monitoring mainly by the VSNET (Kato et al. 2003b) members, no definite outburst has been recorded up to 2003. Even considering the unavoidable seasonal observational gaps, the detected outbursts are much less frequent than in most dwarf novae, and may be comparable to those of the WZ Sge-type dwarf novae.

4.2. Fractional Superhump Excess

Very recently, Patterson et al. (2003) reported the detection of photometric periodicity of 0.055053(6) d. Assuming that this periodicity represents the orbital period ($P_{\text{orb}}$), the fractional superhump excess $\epsilon = P_{\text{SH}}/P_{\text{orb}} - 1$ amounts to 3.5(1) %. This value is exceptionally large for an SU UMa-type system with $P_{\text{SH}} = 0.05697$ d (cf. Patterson 2001). This conclusion seems

One should be, however, careful in interpreting quiescent periodicity. The well-known WZ Sge-type object AL Com showed seemingly coherent variations whose period is clearly different from the supposed orbital period (Abbott et al. 1992). We assume $P = 0.055053(6)$ d to likely represent $P_{\text{orb}}$ because of its proximity to what would be expected from the superhump period using the known relation (Stolz, Schoembs 1984).
to further support the presence of a rather massive secondary star (Patterson et al. 2003), and is likely incompatible with the earlier claim of a brown-dwarf secondary (Howell, Ciardi 2001).2

4.3. Comparison with Other Unusual Dwarf Novae

As shown in subsection 4.1, the outburst cycle length of LL And is likely comparable to rarely outbursting WZ Sge-type dwarf novae. The short superhump period (0.05697 d) is also comparable to those of WZ Sge-type dwarf novae (Kato et al. 2001). The object, however, shows remarkable difference from typical WZ Sge-type dwarf novae in its small (~5 mag) outburst amplitude (compared to ~8 mag for WZ Sge-type dwarf novae), short (9±2 d) duration of the superoutburst (compared to >20 d for WZ Sge-type dwarf novae, cf. Ishioka et al. 2002; Patterson et al. 1996; Nogami et al. 1997a; Kato et al. 2002b).

The combination of long outburst cycle length, low outburst amplitude, and short duration of a superoutburst resembles that of an unusual SU UMa-type dwarf nova GO Com (A. Imada et al., in preparation). In GO Com, the small scale of the recorded outburst, in spite of the long preceding quiescence, is interpreted as the possible consequence of the exclusion of disk mass (e.g. via evaporation) during quiescence (A. Imada et al., in preparation). This scenario was initially proposed by Lasota et al. (1995) to explain the long outburst intervals in systems resembling WZ Sge-type stars, but now looks more applicable to systems such as GO Com and LL And [see also discussions by Osaki (1995); Osaki (1998) on the difficulty of reproducing WZ Sge-like outbursts with a “leaky” accretion disk, as in Lasota et al. (1995)].

By adopting the large fractional superhump excess (subsection 4.2), the secondary star of LL And is likely slightly too massive for this period (figure 5). We know at least two well-established examples of such short-period dwarf novae with unusually massive or luminous secondaries (El Psc: Uemura et al. 2002; Thorstensen et al. 2002b; Skillman et al. 2002 and QZ Ser: Thorstensen et al. 2002a). Both objects have low outburst frequencies than would be expected from their binary parameters. Uemura et al. (2002) and Thorstensen et al. (2002b) suggested that El Psc may be the first identified object following the hypothetical evolutionary track (Podsiadlowski et al. 2003) containing an mass donor having an evolved core. LL And may be an object filling the evolutionary missing link between QZ Ser and El Psc (see also figure 4 in Thorstensen et al. 2002a), and finally to the double-degenerate AM CVn stars (Warner 1995a; Solheim 1995). Further spectroscopic determination of the orbital parameters is encouraged.

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Fig. 5. Relation between orbital period ($P_{\text{orb}}$) and fractional superhump period excess ($\epsilon$). The basic data were mainly taken from Patterson (1998); Patterson (2001); Thorstensen et al. 2002c; Patterson et al. 2003, supplemented and refined with Uemura et al. (2002); Kato et al. (2002a); Kato et al. (2003a). The small filled and open squares represent ordinary SU UMa-type dwarf novae, and unusual hydrogen-rich ultracompact binaries (EI Psc and V485 Cen), respectively. The location of LL And is marked with a open circle.

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