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THE OUTBURST HISTORY OF AW SGE

Christopher Lloyd

Open University, Milton Keynes MK7 6AA, UK, C.Lloyd@open.ac.uk

Abstract: A review of the outbursts of AW Sge suggest that the outburst interval is 286±28 days, which is much shorter than previously thought. The normal outbursts last less than 3 days and usually reach magnitude 14.5. The superoutbursts are about half a magnitude brighter and last about 8 days. A previously unrecognised superoutburst has been identified from 1961.

Introduction

AW Sge is a faint and poorly observed dwarf nova and is considered to have rare outbursts. In recent times these have occurred every two years but as they reach only magnitude 14 - 15 it is likely that some have been missed. Apart from the 2006 November superoutburst very little has been published on this star and most of the analysis, comments and observations are scattered through sources on the Internet, some of which are no longer accessible.

AW Sge was first suspected of being a CV on the basis of its blue colour and variability, and was included in Vogt and Bateson's (1982) atlas of southern and equatorial dwarf novae, and later in the Downes and Shara (1993) and subsequent catalogues. Wolf and Wolf (1906) first reported AW Sge as a variable star and found the star visible at magnitude 13 and 15, on two plates out of seven, taken between 1900 and 1905. The first recognisable outburst was reported by Meinunger (1965) from Sonneberg plates in 1961 October, but this event seems to have passed largely unnoticed. Unlike the earlier outbursts, which were seen on single plates, the whole of this outburst was observed. It lasted for about 9 days and reached magnitude 14.4pg at maximum. Systematic visual observations did not begin until the early 1990s.

The first outburst in recent times was discovered in 1996 by Pietz visually at around magnitude 15 and faded very rapidly (Pietz 1996, Vanmunster 1996, see also Kato 2000a). The 2000 outburst was discovered visually by Stubbings (2000) at magnitude 14.0 and showed superhumps for the first time establishing AW Sge as an UGSU system (Masi and Tosti 2000, Masi 2000). This outburst

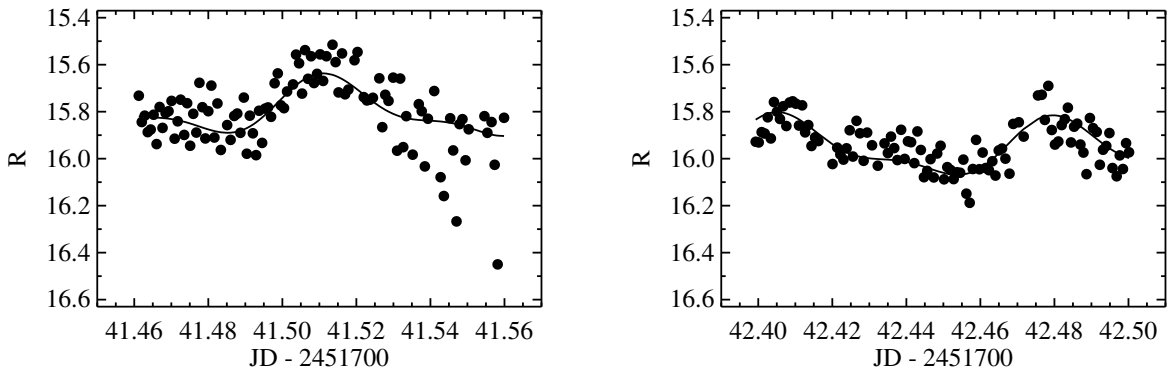

Figure 1: The unfiltered data of Masi & Tosti from the 2000 superoutburst calibrated as R with the Fourier fit over-plotted.

Table 1: Timing data for all the outbursts of AW Sge

Year	JD	Cycle number	O-C (days)	Duration (days)	Magnitude	Reference
1901	2415258.5	-	-	-	13pg	Wolf & Wolf 1906
1905	2416990.5	-	-	-	15pg	Wolf & Wolf 1906
1961	2437578.5	-	-	9	14.9/14.4pg	Meinunger 1965
1996	2450344.4	0	25	1	15.0Vis	Pietz 1996
2000	2451737.1	5	-10	8	14.0Vis	Stubbings 2000
2002	2452578.5	8	-27	3	14.4Vis	Simonsen (Kato 2002)
2004	2453147.9	10	-28	-	14.8CR	Schmeer (Kato 2004)
2006	2454056.3	13	23	7	14.8C	Shears (2008)
2007	2454337.4	14	18	3	15.3/15.0V	Pickard (2007)

lasted considerably longer than the previous one at about 8 days (Kato 2000b). The 2002 outburst was discovered by Simonsen (see Vanmunster 2002, Kato 2002) at magnitude 14.4Vis and was initially thought to be a possible superoutburst, but it faded rapidly, at 0.9 mag/day, and was seen for about 3 days. Vanmunster (2002) reported irregular variations of ~ 0.3 magnitude but these were clearly not superhumps. There was one observation that suggested a re-brightening but this was not confirmed (see Kato 2002). The 2004 outburst was very poorly observed and there seems to have been just the one positive discovery observation by Schmeer at magnitude 14.8C, with observations the previous day putting the system at quiescence. After four days the magnitude was $>$ 15.0Vis and five days $>$ 17.8C (AFOEV archive, Vanmunster 2004, Kato 2004). The most recent superoutburst, in 2006 November, was discovered by Shears at magnitude 14.8C and faded to magnitude 16.5C after seven days. Common superhumps were seen with the same period as the 2000 superoutburst (Shears et al. 2008). The most recent outburst was discovered in 2007 August by Pickard (2007) at magnitude 15.3V. It brightened briefly and then faded rapidly to magnitude 17.1C after 3 days (Poyner 2007). All the outbursts are listed in Table 1 with their discovery/maximum magnitude and duration.

The superoutbursts

It is clear that the normal outbursts of AW Sge are short, probably lasting less than 3 days, with the system fading very rapidly, at nearly a magnitude per day, from a day or so after detection. The normal outbursts peak at about magnitude 14.5. Three of the outbursts lasted much longer, at 7 - 9 days, and two of these are confirmed to have superhumps. The third one was the 1961 outburst and this was caught on the rise at magnitude 14.9pg and stayed near 14.4pg for about 6 days before fading to 15.2pg after 9 days. Despite the minimal amount of photometry this was clearly a superoutburst.

The behaviour during the 2000 superoutburst was similar with the system remaining at about magnitude 14.5Vis for the first 3 or 4 days then fading increasing rapidly over the next 4 days, reaching magnitude 15.3V after 8 days. The first time series photometry was reported by Masi and Tosti (2000) on two nights, four and five days after discovery, and while this photometry has never been formally published a superhump period has been reported by Kato et al. (2003).

These data have been analysed again here. The first night shows increased scatter towards the end and is generally poorer than the second night. The two nights have been analysed individually and in combination by fitting a 2nd order Fourier curve and linear trend. The combined data give a superhump period, $P_{sh} = 0.0745(2)$, which is identical to that of the 2006 superoutburst, and a decline rate of 0.18 mag/day, which is also similar to the 2006 superoutburst. The second night

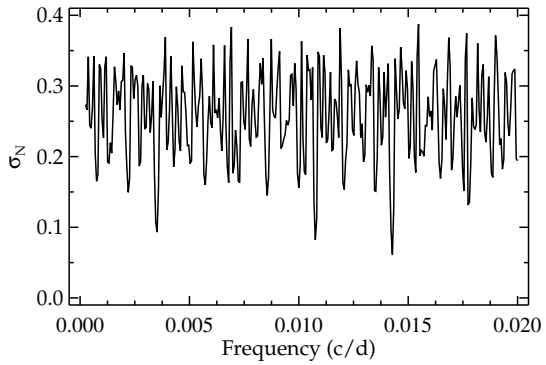

Figure 2: Periodogram of the outburst timings.

shows a bump on the decending part of the light curve, which is often seen towards the end of superoutbursts. The light curves are shown in Figure 1 with the fit plotted. The photometry is unfiltered and the magnitudes are given relative to GSC 1616-0277, which corresponds to star 2 of Henden's (1999) sequence, and has $V = 11.98$ and $B - V = 0.29$. The likely value of $V - R$ for this star is 0.3 so it probably has $R \sim 12.3$, and this is adopted as the zero point of Masi and Tosti's photometry. .

The 2006 superoutburst has been discussed in detail by Shears et al. (2008). The system faded from magnitude 14.8C at discovery at 0.12 mag/day over the first four days and 0.38 mag/day thereafter, reaching magnitude 16.5C after 7 days. Common superhumps with a period of 0.0745(2) days were visible for the first four days. Compared to the other superoutbursts this one was perhaps half a magnitude fainter at maximum and had a slightly shorter duration.

The outburst time scale

Prior to the most recent outburst the intervals between outbursts from 1996 were 1393, 841, 569 and 908 days, which in terms of the shortest one are 2.45, 1.48, 1.00 and 1.59 respectively. As the fractions are all close to a half it suggests that the outburst interval might be about half 569 days, or 284 days. Also, the interval between the two outbursts in 1901 and 1905 is 1732 days, which is 3.04 x 569. A period analysis based on the standard deviation of the $O - C$ residuals for also supports this period, and is shown in Figure 2. The quantity $\sigma_{\rm N}$ is the standard deviation of

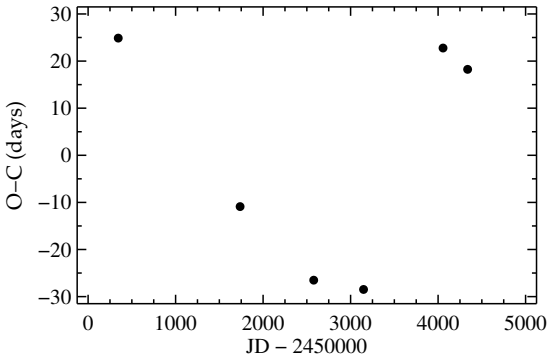

Figure 3: O-C diagram of the recent outbursts.

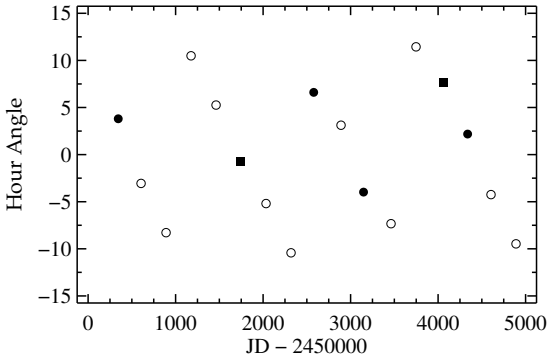

Figure 4: Visibility of the outbursts suggested by the ephemeris (open circle) and normal (filled circle) and superoutbursts (filled square).

the $O-C$ residuals at each frequency, divided by that period, for the outbursts from 1996. The longest period that shows a significant reduction in the residuals is 286 days ($f = 0.0035$ c/d) but there are also features at $3f$ and $4f$, which are not unexpected. However these correspond to much shorter outburst intervals, 95 and 71 days, and at present it seems unlikely that the period is this short. On this basis an outburst was predicted to occur during July or August 2007 (Lloyd 2007) and the system duly obliged on August 25 (Pickard 2007), 281 days after the 2006 November superoutburst. The $O-C$ diagram is shown in Figure 3 and the residuals are given in Table 1. The outburst ephemeris for the data from 1996 is

$$JD = 2450320 + 286 \times E$$

and for all the data is

$$JD = 2450333 + 285 \times E$$

Given that the outburst interval is less than a year it is perhaps surprising that so few outbursts have been detected, however, that has to be set against the faintness of the system in outburst and their very short duration. Shears et al. made a thorough search of the AAVSO archive but could not identify any other outbursts that had been previously missed. Using the ephemeris it is possible to examine the visibility of the expected outbursts and compare them with those actually seen. Figure 4 shows the visibility of the outbursts in terms of the local hour angle of AW Sge at midnight at the expected (and observed) times of the outbursts. Not surprisingly most of the outbursts that occurred within 3 months of opposition were seen but equally some, like the 2006 superoutburst, were seen a long way from opposition. However, some that might reasonably have been expected to be seen were not.

The identification of AW Sge

While there has never been any real doubt about the position of AW Sge, spectroscopy by Mason and Howell (2003) showed a G-type star at the position given by Downes et al. (2001). However, the position has been measured on many occasions in outburst by Wolf and Wolf (1906), Kato (1996), Masi and Tosti (2000), Oksanen (2002) and in quiescence by Bruch et al. (1992) and Henden (1999) and all the recent values are consistent to within an arc second. The position given by Downes et al. (2001), 19 58 37.10 +16 41 28.6 (2000) corresponds to the identification on the finding chart, and the star identified by Vogt and Bateson (1982) is also correct. Possible confusion arises over the comment in the change list of the Downes et al. catalogue, “AW Sge updated identification

and coordinates (02/23/01)". However, the change to the position is only about 1 arc second as that given in the Downes et al. (1997) version is the same but with the seconds of time and arc truncated to integer values, and the same star is identified. The most likely conclusion is that Mason and Howell picked up a nearby star.

Conclusion

An examination of the outburst history and most of the available photometry of AW Sge has shown that the normal outbursts are very short, less than three days, and reach about magnitude 14.5 at maximum. The superoutbursts are about half a magnitude brighter and last 7 - 9 days. In addition to the superoutbursts seen in 2000 and 2006 another one has been identified in 1961. The outburst interval is around 286 days and is relatively stable, with the scatter at the 10% level. The next outburst should occur within a month of 2008 May 18.

Acknowledgements

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