# The Superoutburst Period of KV Draconis

**Jeremy Shears**
*"Pemberton," School Lane, Bunbury, Tarporley, Cheshire CW6 9NR, England*

*Received April 27, 2009; revised June 5, 2009; accepted June 5, 2009*

**Abstract** Analysis of observations of KV Dra between May 2000 and June 2009 has revealed nine superoutbursts. Assuming a linear ephemeris, the superoutburst period is 301 days, with a standard deviation of 28 days.

## 1. Introduction

KV Dra (= RXJ1450.5+6403 and HS 1449+6415) is an SU UMa-type dwarf nova having an orbital period, $P_{orb} = 0.05898$ day. The first known superoutburst of this system was observed in May 2000 and was intensively studied (Vanmunster *et al.* 2000; Nogami *et al.* 2000). The current paper reports the analysis of observations of KV Dra, mainly from the AAVSO International Database, with the aim of determining the interval between superoutbursts, often referred to as the superoutburst period or supercycle.

## 2. Observations of KV Dra

The AAVSO International Database contains more than 3,200 observations of KV Dra between May 2000 and June 2009. These observations, supplemented with data from Nogami *et al.* (2000), the BAA Variable Star Section's Recurrent Objects Programme (Poyner 1996), and VSNET, are shown in Figure 1, where negative ("fainter than") observations have been omitted for clarity. It is apparent from this plot that the number of observations of KV Dra has increased with time as more observers began to monitor the star. Moreover, the detection limit has improved as more CCD observations are contributed. If we assume that any observation where the magnitude was 17 or fainter is during quiescence, then the average magnitude of KV Dra at minimum is 17.5. At it is brightest it reaches 13.1, which suggests an outburst amplitude of 4.4 magnitudes.

## 3. Analysis of superoutbursts

In order to identify possible outbursts in the data, we noted when the star was brighter than 16.0. Table 1 shows that twenty-two such possible outbursts have been recorded. It is clear from the outburst durations listed that there are two categories of outburst exhibited by KV Dra. Thirteen of the outbursts were short, lasting less than five days. The remaining nine were longer, lasting more than seven days. Literature references and time-resolved photometry from the AAVSO International Database confirm that six of these longer outbursts showed superhumps, modulations in the light curve that are diagnostic of superoutbursts (unfortunately, time-resolved photometry for the remaining three long outbursts is not available). Thus we interpret the category of short outbursts as "normal" outbursts and the longer outbursts as superoutbursts. The superoutbursts typically last twelve to thirteen days and the normal outbursts are typically less than four days.

The intervals, ΔT, between each of the nine superoutbursts are shown in Table 2. The mean outburst interval is 411 days and the median 330 days. Two of the outburst intervals were considerably longer than the median (545 and 838 days) suggesting that they may be multiples of the superoutburst period. It is entirely possible that further superoutbursts have been missed due to incomplete coverage. Kato *et al.* (2003) suggested a possible superoutburst period of 840 days based on the interval between the 2000 and 2002 outbursts, which corresponds to our 838-day interval. A preliminary superoutburst cycle number was assigned to each observed superoutburst, assuming the ΔT = 545-day interval contains two supercycles and ΔT = 838 days contains three supercycles. A linear ephemeris was calculated from the superoutburst times:

$$JD_{max} = 2451641(18) + 301(8) \times E \tag{1}$$

This suggests a superoutburst period of 301 ± 8 days. The corresponding O–C diagram is shown in Figure 2. The O–C residuals range over about ± 38 days, or about 13% of the proposed superoutburst period. The standard deviation of the residuals is 28 days and this value probably gives a more realistic idea of when a superoutburst might be seen, rather than the formal error on the superoutburst period (Shears *et al.* 2009). Thus the adopted superoutburst period is 301 ± 28 days.

In another approach to investigate the potential superoutburst periods, the Date Compensated Discrete Fourier Transform (DCDFT) power spectrum of the positive observations of KV Dra was constructed using the PERANSO software (Vanmunster 2007) and is shown in Figure 3. The strongest signal lies at 302 ± 28 days, which is consistent with the superoutburst period determined from the linear analysis of superoutburst times.

## 4. Discussion

The linear analysis of the superoutbursts, described above, suggests that three superoutbursts may have been missed: two between May 2000 and August 2002 and one between December 2006 and June 2008. During the first interval there are 255 separate observations in the AAVSO International Database, but the gaps between observations are sufficiently large that superoutbursts could have been missed. The longest gap is 54 days, but there are twenty-seven instances of gaps of more than 7 days. By contrast, the later interval corresponds to a period when there were much more frequent observations. In the period covering two standard deviations either side of the superoutburst time predicted by the linear ephemeris (Equation 1) there were 109 observations. The longest gap was 7 days, but the median and mean were both 1 day. One outburst was detected during this period. The relative faintness ($V = 14.7$) and short duration (< 7 days) suggests it was not a superoutburst, although this cannot be ruled out. Had it been a superoutburst, it occurred only 25 days before the time predicted by Equation 1. Thus, although we cannot completely rule out a superoutburst during this interval, we consider such an event unlikely.

Superoutbursts are thought to be triggered by normal outbursts when sufficient mass transfer of material from the secondary star into the accretion disc has occurred to expand the outer part of the disc into a region where it becomes unstable (Hellier 2001). At this point, the disc then becomes elliptical and starts to precess, resulting in superhumps in the light curve. Normally the mass-transfer rate in SU UMa systems is thought to be constant, resulting in regular spacing of superoutbursts (Hellier 2001). Thus our observation that a superoutburst of KV Dra may actually be "missing" is surprising. Further close monitoring of this object should continue to improve the statistics on the superoutburst period and show whether KV Dra does in fact "miss" some superoutbursts.

We have tried to compare the superoutburst period of KV Dra with that of other SU UMa stars of similar $P_{orb}$ listed in Kato *et al.* (2003). However, this is complicated by that fact two sub-types of SU UMa systems with extreme superoutburst behavior have similar $P_{orb}$ values. The WZ Sge stars have exceptionally long superoutburst periods measured in years; WZ Sge itself has $P_{orb} = 0.057$ day and a superoutburst period of around 30 years. By contrast, the ER UMa stars have exceptionally short superoutburst periods of a few days or weeks, e.g., RZ LMi has $P_{orb} = 0.059$ day and a superoutburst period of 19 days. The more conventional SU UMa system PU CMa has $P_{orb} = 0.058$ day and a superoutburst period of 362 to 391 days.

## 5. Conclusion

Examination of observations of KV Dra between May 2000 and June 2009 has revealed nine likely superoutbursts, although gaps in the data mean that further superoutbursts could have been missed. Analysis of the superoutburst times, assuming a linear ephemeris and allowing for possible missed outbursts, results in a superoutburst period of 301 days, with a standard deviation of 28 days. Further observations are required to refine the ephemeris and to confirm whether some superoutbursts predicted by the ephemeris were not in fact triggered. All observers are encouraged to monitor this star regularly.

**6. Acknowledgements**

The author gratefully acknowledges the use in this research of observations from the AAVSO International Database contributed by observers worldwide, as well as observations contributed to VSNET relating to the “missing” outburst in 2007 (kindly highlighted to the author by Wolfgang Renz) and to the BAA Variable Star Section’s Recurrent Objects Programme, which were provided by the programme co-ordinator, Gary Poyner.

**References**

Hellier, C. 2001, *Cataclysmic Variable Stars: How and Why They Vary*, Springer-Verlag, New York.

Kato, T., Nogami, D., Moilanen, M., and Yamaoka, H. 2003, *Publ. Astron. Soc. Japan*, **55**, 989.

Kato, T., *et al.* 2009, *Publ. Astron. Soc. Japan*, submitted, pre-print available at http://arxiv.org/abs/0905.1757

Kato, T. 2009, vsnet-alert 11249, http://ooruri.kusastro.kyoto- u.ac.jp/pipermail/vsnet-alert/2009-May/002855.html

Nogami, D., Engels, D., Gänsicke, B. T., Pavlenko, E. P., Novak, R., and Reinsch, K. 2000, *Astron. Astrophys.*, **364**, 701.

Poyner, G. 1996, *J. Brit. Astron. Assoc.*, **106**, 155.

Shears, J., *et al.* 2009, *J. Brit. Astron. Assoc.*, **119**, 31.

Vanmunster, T., Skillman, D. R., Fried, R. E., Kemp, J., and Novak, R. 2000, *Inf. Bull. Var. Stars*, No. 4940.

Vanmunster, T. 2007, PERANSO period analysis software, http://www.peranso.com

Table 1. Outbursts of KV Dra between May 2000 and June 2009.

| *Detection date* | *JD* | *Magnitude at maximum*[a] | *Outburst duration (d)*[b] | *Superhumps detected?* |
|---|---|---|---|---|
| 2000 May 14 | 2451679.4 | 13.4v | 14 * | Y 1 |
| 2000 Jun 25 | 2451721.3 | 15.2R | 3 | |
| 2000 Sep 17 | 2451805.3 | 15.7v | <3 | |
| 2000 Sep 25 | 2451813.3 | 14.6v | <5 | |
| 2002 Aug 31 | 2452517.6 | 13.1C | 13 * | Y 2, 3 |
| 2003 Jun 20 | 2452811.4 | 14.1V | >7 * | |
| 2004 Apr 4 | 2453100.4 | 14.1v | <4 | |
| 2004 Apr 22 | 2453118.4 | 13.9v | >5 * | Y 2, 3 |
| 2004 Sep 14 | 2453263.3 | 15.4v | <3 | |
| 2005 Apr 2 | 2453462.5 | 13.6v | >10 * | Y 3 |
| 2005 Apr 18 | 2453479.4 | 15.9C | <4 | |
| 2006 Jan 17 | 2453752.8 | 15.2C | <4 | |
| 2006 Jan 26 | 2453762.4 | 14.3C | 12 * | Y 2 |
| 2006 Apr 14 | 2453840.4 | 15.0C | <3 | |
| 2006 Jun 19 | 2453905.6 | 14.2v | <3 | |
| 2006 Jul 13 | 2453930.4 | 15.4v | <3 | |
| 2006 Dec 9 | 2454079.4 | 14.4C | 12 * | |
| 2007 Mar 9 | 2454168.8 | 14.6v | <3 | |
| 2007 Jun 11 | 2454262.6 | 15.2V | <3 | |
| 2007 Aug 12 | 2454325.4 | 14.7v | <3 | |
| 2008 Jun 7 | 2454624.7 | 14.2V | 13 * | |
| 2009 May 18 | 2454970.3 | 13.6v | 13 * | Y 4 |

[a] *v = visual, R = CCD + Johnson* R *filter, C = unfiltered CCD, V = CCD + Johnson* V *filter.*

*1 Vanmunster* et al. *(2000) and Nogami* et al. *(2000); 2 AAVSO International Database; 3 Kato* et al. *(2009); 4 Kato (2009).*

[b] Probable superoutbursts are marked with an asterisk.

Table 2. Superoutbursts of KV Dra.

| *Detection date* | *JD* | *ΔT (d)* |
|---|---|---|
| 2000 May 14 | 2451679.4 | |
| 2002 Aug 31 | 2452517.6 | 838.2 |
| 2003 Jun 20 | 2452811.4 | 293.8 |
| 2004 Apr 22 | 2453118.4 | 307.0 |
| 2005 Apr 2 | 2453462.5 | 344.1 |
| 2006 Jan 27 | 2453762.4 | 299.9 |
| 2006 Dec 9 | 2454079.4 | 317.0 |
| 2008 Jun 7 | 2454624.7 | 545.3 |
| 2009 May 18 | 2454970.3 | 345.6 |

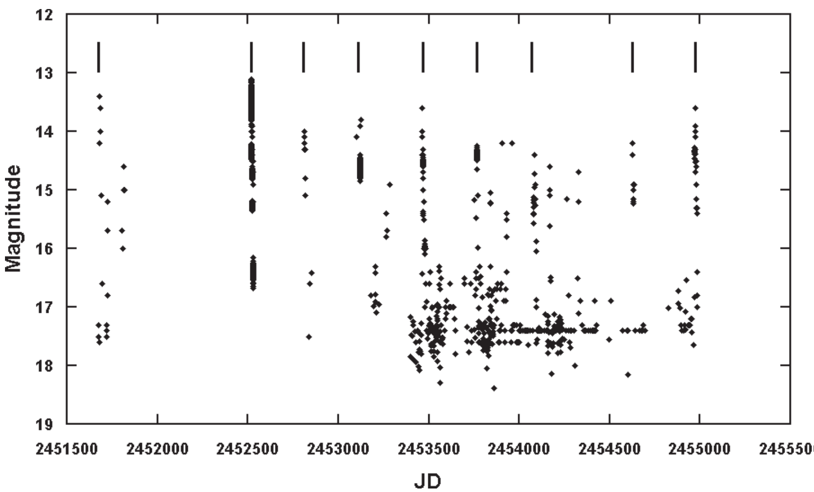


Figure 1. Observations of KV Dra. Superoutbursts are indicated by a bar.

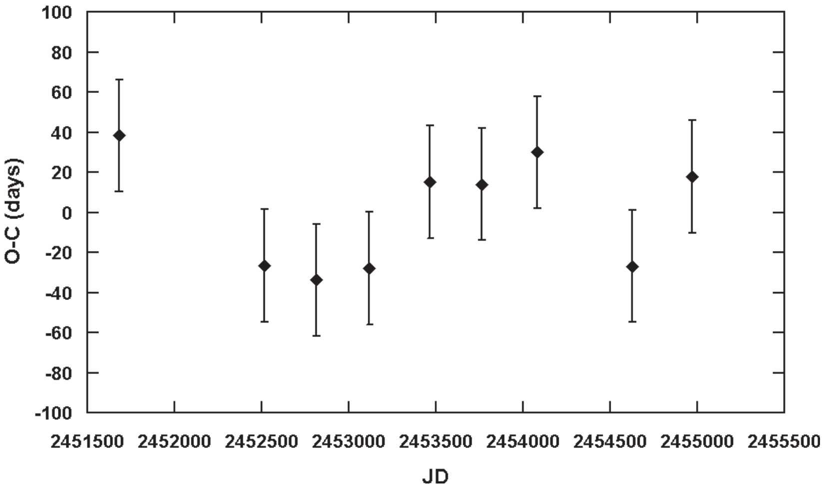


Figure 2. O–C diagram of superoutbursts of KV Dra. Error bars represent the standard deviation of the O–C residuals (28 days).

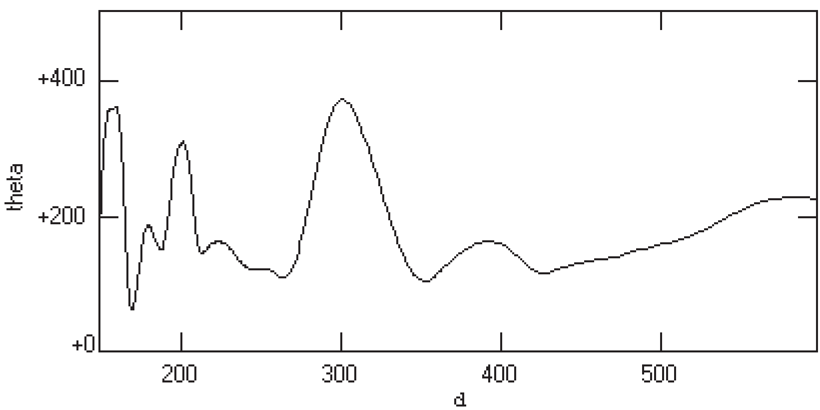


Figure 3. DCDFT power spectrum of the positive observations of KV Dra.