V1432 AQL: 5 MORE YEARS OF OBSERVATIONS

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Abstract: Photometry observations of the asynchronous polar V1432 Aql are presented. Ephemerides for the orbital motion and for the spin are derived and are compared with previous ephemerides. For the spin, there is some evidence for a secondary derivative of the period.

Introduction

V1432 Aql is a cataclysmic system, which is a binary with an accreting white dwarf. It has eclipses and the orbital period is 3.37 h. It is a bright X-ray source and the white dwarf is strongly magnetized.

It is a polar: there is no accretion disk and the accreted material is funneled by the magnetic field. Usually, with such systems, the white dwarf shows the same side to its donor star, i.e. its rotation (or spin) period is equal to the orbital period. But with V1432 Aql the rotation period is slightly different from the orbital one (it is larger): this is an asynchronous polar. There are only 4 such systems known.

Here 5 years of obtaining of light curves, spanning from 2007 to 2011, are presented and are compared to ephemerides.

Observations

The observations were carried out with a 203 mm Schmidt-Cassegrain telescope, a Clear filter, and a SBIG ST7E camera (KAF401E CCD). The exposure duration for each image was 200 s (sometimes 60 s for the first image of a session). For the differential photometry, the comparison star is GSC 5728-00410. Figure 1 is an example of a light curve; Table 1 is a summary of the observations.

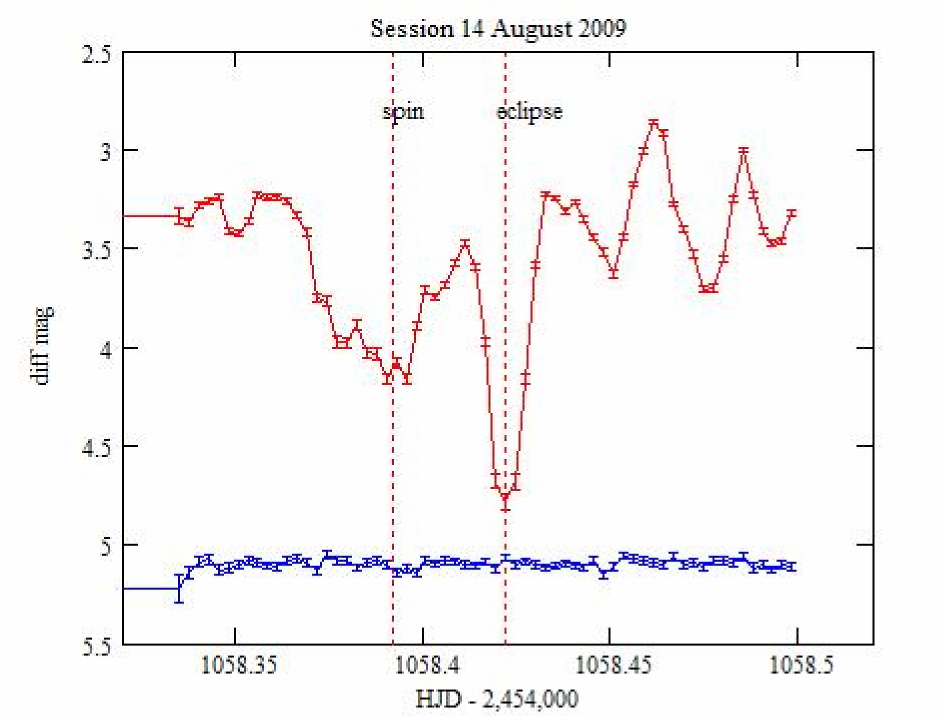

Figure 1: An example of a light curve showing a spin minimum and an eclipse. Red: V1432 Aql, Blue: a check star (actually GSC 5728-01558, shifted by +2.5 mag). The error bars are +/- the 1-sigma statistical uncertainties.

Season	Number of sessions	Number of images	Number of eclipses	Number of spin minima
2007	9	345	9	2
2008	4	202	4	3
2009	4	184	3	4
2010	6	372	8	6
2011	5	276	5	3
Total	28	1379	29	18

Table 1: Summary of the observations.

With the sharp eclipses, the times of the minima are determined by interpolating from the ingress and the egress. The spin modulations are localized using the available ephemerides, and the times of the minima are taken at the bottoms of the modulations; because of other variations superposed on the modulations, the uncertainties are fairly large.

The 29 eclipses I observed are listed in Table 2, and the 18 spin minima are in Table 3. (In 2007 I was not able to observe many spin minima because they happened to be in phase with the eclipses).

Season	Eclipse minimum HJD – 2,454,000	Uncertainty
2007	289.5127	0.0002
	294.5605	0.0002
	295.4013	0.0003
	296.3845	0.0003
	296.5250	0.0003
	297.506	0.001
	318.544	0.002
	349.3934	0.0002
	359.3520	0.0003
2008	646.5522	0.0002
	670.3920	0.0002
	685.3966	0.0002
	709.3773	0.0002
2009	1007.5162	0.0002
	1032.4770	0.0003
	1058.4220	0.0002
2010	1339.5915	0.0004
	1353.4757	0.0002
	1353.6160	0.0002
	1355.5800	0.0004
	1426.3972	0.0002
	1477.3020	0.0003
	1478.2840	0.0003
	1506.3290	0.0003
2011	1787.5022	0.0002
	1794.5142	0.0003
	1795.3550	0.0003
	1804.4700	0.0004
	1810.3576	0.0002

Table 2: List of the 29 eclipses.

Season	Spin minimum HJD – 2,454,000	Uncertainty
2007	296.478	0.002
	297.600	0.005
2008	646.514	0.006
	670.418	0.003
	709.344	0.002
2009	979.5375	0.0025
	1007.503	0.005
	1032.395	0.001
	1058.392	0.005
2010	1352.598	0.010
	1353.588	0.004
	1355.550	0.012
	1477.283	0.003
	1478.265	0.004
	1506.247	0.002
2011	1787.493	0.003
	1804.362	0.003
	1810.420	0.005

Table 3: List of the 18 spin minima.

O – C analysis of the eclipses

The eclipses may be fitted with the ephemeris t(e) = T + P.e. A first mean squares fit, weighted with the uncertainties, of the 29 eclipses I observed, yields:

T_1 = 2,454,289.513,45 ± 0.000,27 HJD
P_1 = 0.140,234,8179 ± 0.000,000,0016 (0.0001 s) d

P_1 is in agreement with the period of Patterson et al., 1995 (within their fairly large error box), it differs from the one of Mukai et al., 2003 by twice their error box of 0.004 s, and is way off from the one of Andronov et al., 2006 (hereafter A2006) by 80 times their error box.

32 eclipses were also reported by Patterson et al., 1995 and 31 more by A2006. This gives the O-C diagram of Figure 2.

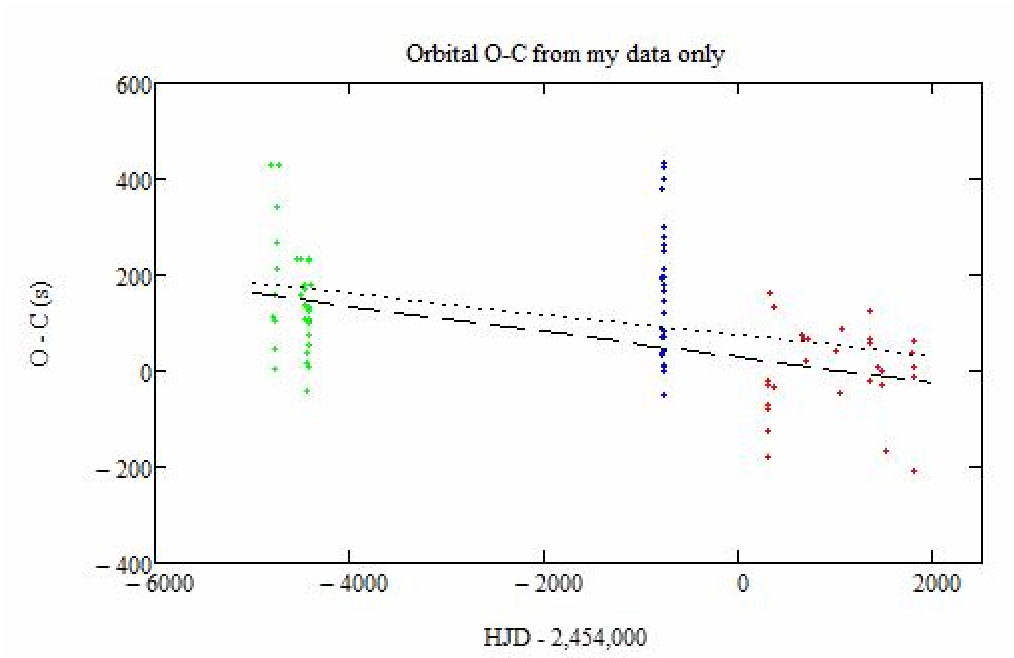

Figure 2: Green: the O-C from the data of Patterson et al., 1995), Blue: from the data of A2006, Red: from my data. The ephemeris used is derived from my measurements only. Black dot line: a linear fit using all the data, Black dash line: excluding the A2006 data.

Another ephemeris may be derived from the Patterson et al., 1995 data and my data (a total of 32+29=61 eclipses). Patterson et al., 1995 gives the times with 4 decimal digits but no uncertainty, so I assumed that the uncertainties on their measurements are 0.0001 day. Then, a second mean squares fit, weighted with the uncertainties, yields:

T_2 = 2,454,289.513,66 ± 0.000,24 HJD
P_2 = 0.140,234,7733 ± 00.000,000,0039 (0.0003 s) d

This is within the error boxes of Patterson et al (1995) and of Mukai et al (2003), but again way off the ephemeris of A2006. Figure 3 is the corresponding O-C diagram.

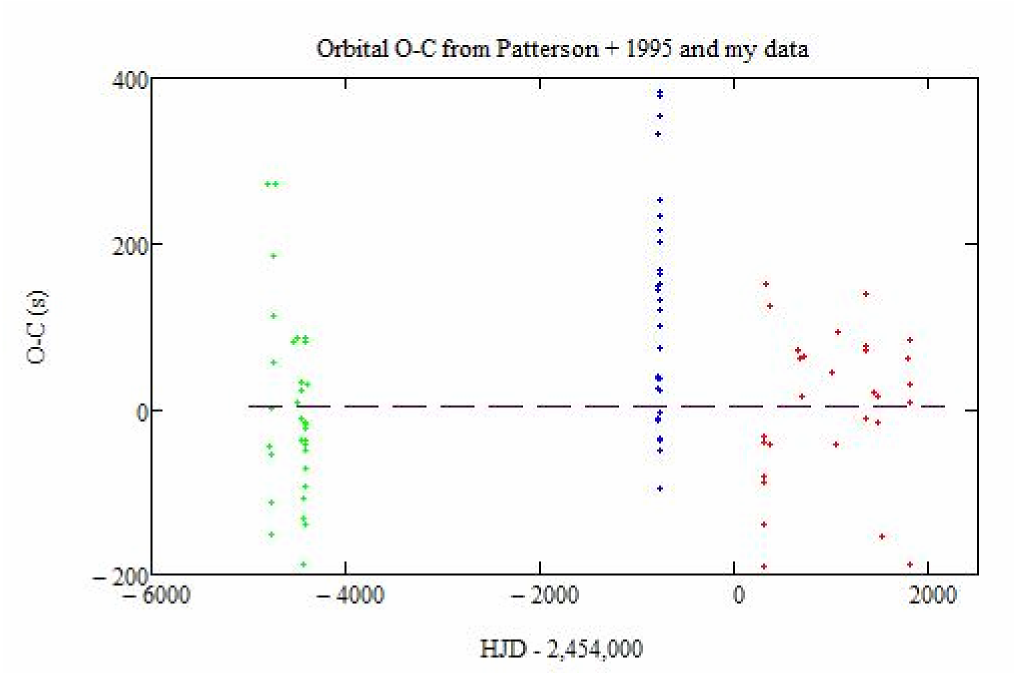

Figure 3: The same as in Figure 2 but with the ephemeris derived from the data of Patterson et al., 1995 and my data.

With the above ephemeris, the data from A2006 do not fit. To fit them and all the other data (92 eclipses), a third term is used in the ephemeris: $t(e) = T + P.e + \beta.e^2$. This yields:

T = 2,454,289.514,63 ± 0.000,15 HJD
P = 0.140,234,6828 ± 0.000,000,0125 (0.0011 s) d
$\beta = (-3.4 \pm 0.3).10^{-12}$ d

This gives the derivative of the period:

$$P' = \frac{dP}{dt} = \frac{2.\beta}{P} = -4.9.10^{-11}$$

and the time scale:

$$\frac{1}{2}.\frac{P}{|P'|} = 3.9 \text{ Myr}$$

which is extraordinarily short for an orbital phenomenon (unless there is a third body). Figure 4 is the resulting O-C diagram.

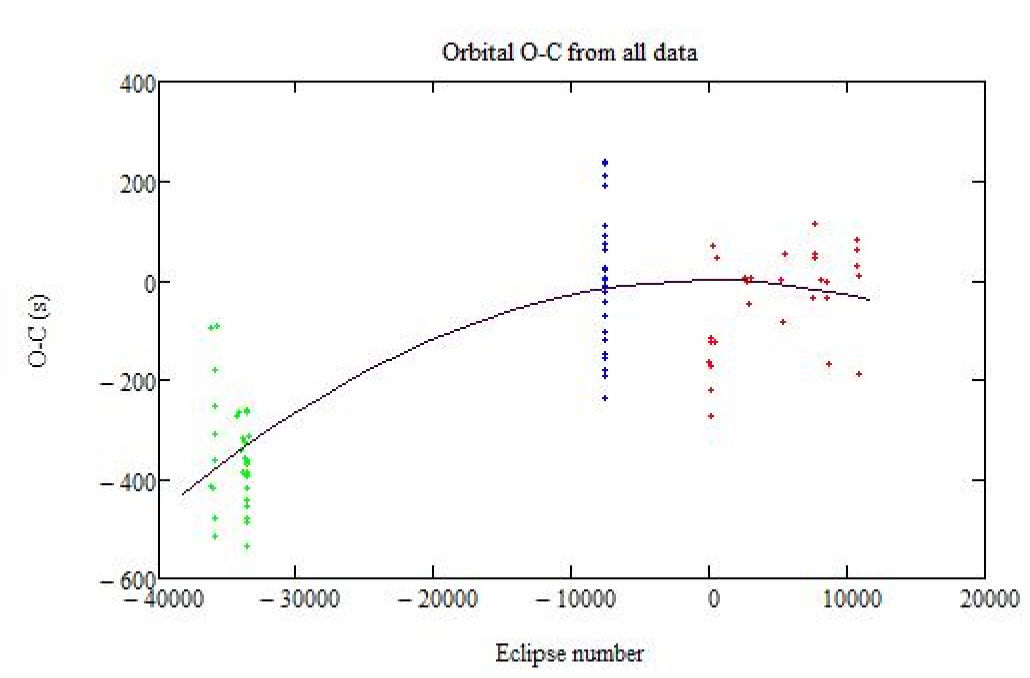

Figure 4: The same as in Figure 2 but with the ephemeris derived from all the available eclipses measurements. The solid line is the $\beta.e^2$ function.

O - C analysis of the spin minima

The following spin minima are also used along with my 18 measurements:

- 33 minima from 1992 to 1997, compiled by Staubert et al., 2003;
- 9 minima from 1993 to 2002 by Mukai et al., 2003. No uncertainties are reported so I use an uncertainty of 1 on the last digit of each measurement;
- 16 minima ("spin-1") in 2004 by A2006.

That is a total of 76 minima spanning 20 years.

These minima are fitted with the ephemeris $t(E) = T_s + P_s.E + \beta_s.E^2$, using the mean squares method, weighted by the uncertainties. The result is:

T_s = 2,449,638.3282 ± 0.0020 HJD
P_s = 0.140,627,35 ± 0.000,000,23 (0.02 s) d
$\beta_s = (-7.56 \pm 0.06).10^{-10}$ d

That is a derivative of the period of:

$$P_s' = \frac{dP_s}{dt} = \frac{2.\beta_s}{P_s} = -1.075.10^{-8}$$

The average residual is:

average(O - C) = 110 ± 494 s (the ± is the standard deviation)

At this rate, the spin period will be equal to the orbital period in 2094.

This ephemeris looks very much like the one obtained by A2006 although with a slightly shorter period and a slightly lower period decrease. Figure 5 is the O-C diagram and Figure 6 shows the residuals.

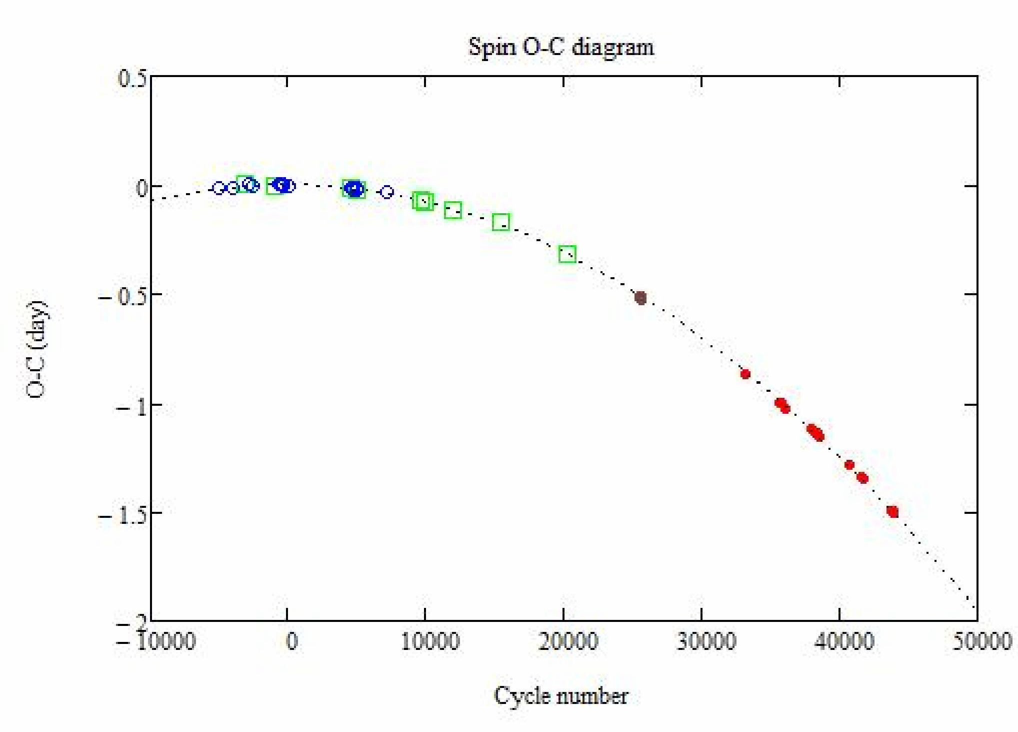

Figure 5: Blue open circles: the data of Staubert et al., 2003, Green open squares: Mukai et al., 2003, Brown dots: A2006, Red dots: my data, Black dot line: the $\beta_s .E^2$ function.

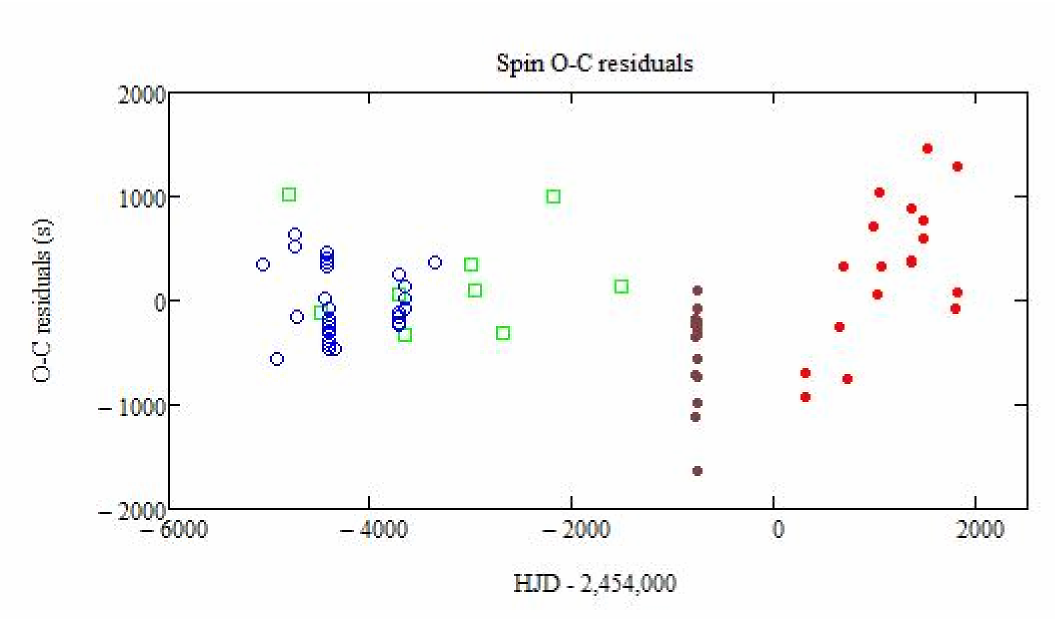

Figure 6: The same as Figure 5 but for the residuals.

Actually, the minima may be fitted with a secondary derivative of the period, that is with the ephemeris $t(E) = T_s + P_s.E + \beta_s.E^2 + \gamma_s.E^3$. The result is:

T_s = 2,449,638.3278 ± 0.0020 HJD
P_s = 0.140,628,49 ± 0.000,000,06 (0.005 s) d
$\beta_s = (-8.31 \pm 0.05).10^{-10}$ d
$\gamma_s = (1.2 \pm 0.2).10^{-15}$ d

This gives for the derivatives of the period:

$P_s' = -1.182.10^{-8}$

$$P_s'' = \frac{d^2P_s}{dt_2} = \frac{6.\gamma_s}{P_s^2}$$

$$\frac{P_s.P_s''}{P_s'^2} = 368$$

The average residual is then:

average(O - C) = 48 ± 467 s

A minimum of the period is then reached in 2083, but this minimum is still larger than the orbital period. Figure 7 is the O-C diagram with the new ephemeris and Figure 8 shows the residuals.

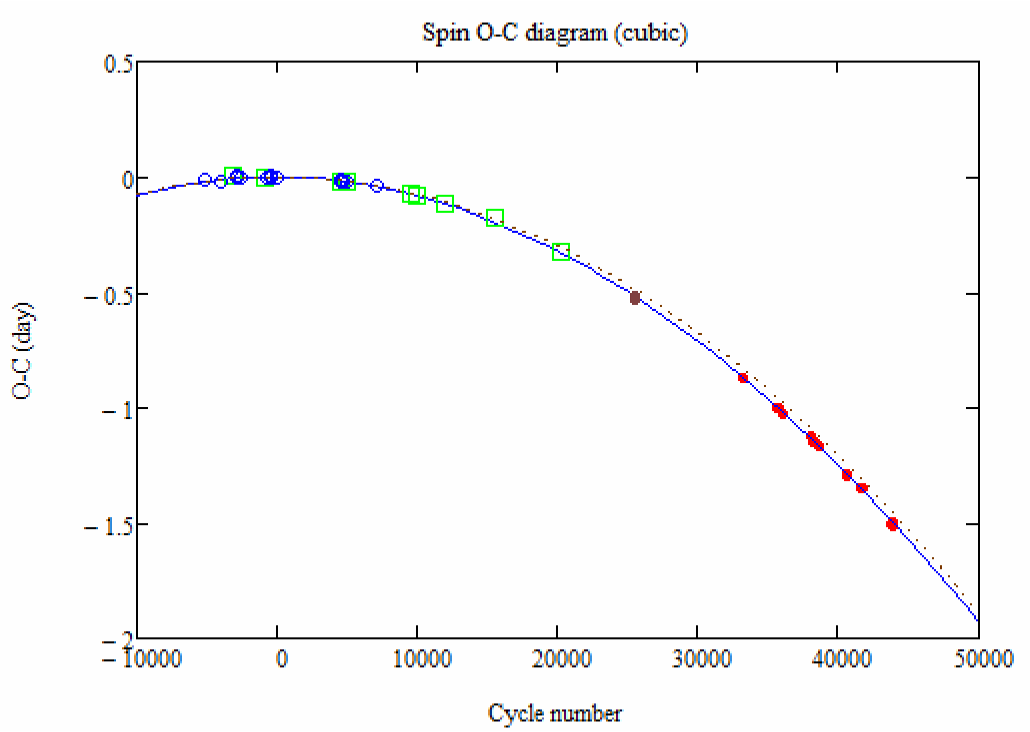

Figure 7: the same as in Figure 5 with the Blue line for the new $\beta_s.E^2 + \gamma_s.E^3$ function.

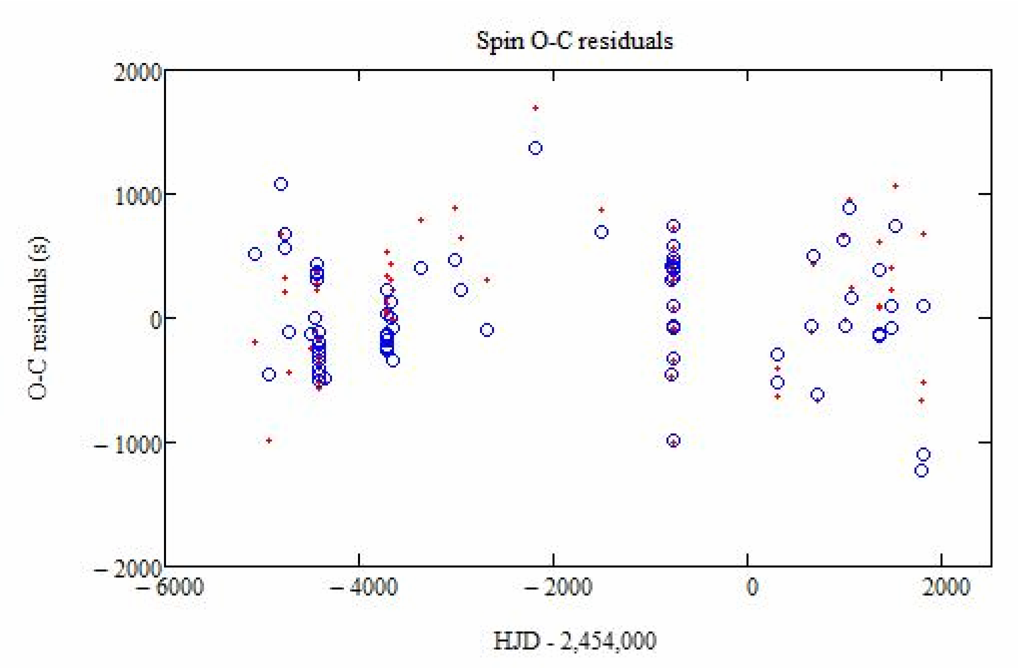

Figure 8: Red dots: the residuals computed with the ephemeris using the first derivative of the period only (the same as in Figure 6), Blue circles: using the secondary derivative of the period.

Conclusions

The eclipse observations of Patterson et al., 1995, Mukai et al., 2003 and the ones presented here lead to a constant orbital period. But with those of A2006, there is evidence for a variation on a short time scale. This is to be confirmed with more observations. However, according to Pavlenko and Shugarov, 2005b, V1500 Cyg, another asynchronous polar, may have a similar orbital variation.

The system is observed with a spin period slightly greater than the orbital period and to be spinning up. With my data there is evidence that this spin up is smoothly slowing down. According to Pavlenko and Shugarov, 2005a, the derivative of the rotation period of V1500 Cyg also varies, but on a discontinuous way.

References

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