DISK PRECESSION OF V603 AQL IN 2001-2002

V.F. Suleimanov[1], I.F. Bikmaev[1], C.V. Belyakov[1], N.A. Sakhibullin[1], G.V. Zhukov[1], Z. Aslan[2], U. Kizilogly[2], I. Khamitov[2]

[1] Department of Astronomy, Kazan State University
Kremlevskaya str. 18, Kazan 420008 Russia, *vals@ksu.ru*
[2] TUBITAK National Observatory
Antalya, Turkey

ABSTRACT. The rezults of the novalike variable V603 Aql photometric observations performed by Russian-Turkish telescope RTT150 during 11 nights of 2001 – 2002 are presented. It is shown the star was in the state with "positive" superhumps and photometric period $0.^d144$ – $0.^d145$ was longer than orbital one.

The conclusion that disc precession period depends on the accretion rate has been made. It is found that V603 Aql in the state with "negative" superhumps is brighter by $0.^m2$ – $0.^m3$ than in the state with "positive" superhumps. It is suggested that transition between these states is also caused by accretion rate changing.

Quasiperiodic oscillations (QPO) of the brightness with typical periods 9 – 70 min are found for the each night.

Key words: Stars: binary: cataclysmic; stars: individual: V603 Aql.

1. Introduction

Nova Aquilae 1918, named now V603 Aql, was one of the brightness nova with peak visual magnitude of about -1^m. Now this is a close binary with accretion disk around white dwarf. The orbital period of the system ($P_{orb} = 0^d.138$) was found by Kraft (1964) and then was obtained with better accuracy ($P_{orb} = 0^d.1385$) by Arenas et al. (2000). Haefner and Metz (1985) found that this system has a photometric brightness variations with amplitude $0^m.2$ - $0^m.3$ and with period longer ($0.^d1449$) than spectroscopic one. Patterson et al (1993) showed that this period changed on a time scale of months in the range $0^d.1449$ - $0^d.1466$. Furthermore, Patterson et al. (1997) found that photometric period was smaller than the spectroscopic period in 1992-1994. Systems with such photometric behaviour have been refered to as "permanent superhump" systems.

The currently accepted model explaining superhumps is that which results from tidal stressing of the disk by the secondary star (Whitehurst 1988, Lubow 1991). For systems that have high mass transfer rates and low mass ratios $q=M_2/M_1 < 0.3$ the outer disk can expand to the radius near the 3:1 eccentric inner Linblad resonance. As a result the accretion disk becomes eccentric and precessing (the line of apsides is slowly precessing in the prograte direction with period P_{prec}). Therefore, the secondary meets up with the line of apsides on a period slightly longer than the orbital period. This period is *positive* superhump period P_{pos} and these two periods are related by the orbital period as:

$$P_{prec}^{-1} = P_{orb}^{-1} - P_{pos}^{-1}. \qquad (1)$$

The model of *negative* superhumps (a photometric period is less than orbital period) invokes the retrograde precession of the line of nodes in an accretion disk tilted with respect to the orbital plane (Barrett et al. 1988).

Here we present the results of the observations of V603 Aql and discuss the relation between observed properties of superhumps and physical properties of the accretion disk.

2. Observations

Photometric observations of V603 Aql in V band were obtained in June and August 2001, and July 2002. The observations were carried out with 1.5-m Russian-Turkish telescope RTT150. The telescope was equipped with CCD ST-8E. Duration of individual runs were 2-5 hours. Integration time was 10 s in all cases. Reduction of the observations and differential aperture photometry were performed in MIDAS package. Log of observations is given in Table 1. The obtained light curves are shown in Fig.1 and 2.

We also used the observations of V603 Aql, which were obtained in October 1994. These observations were carried out with the 60-cm reflector of Special Astrophysical Observatory (Suleimanov et al 1998).

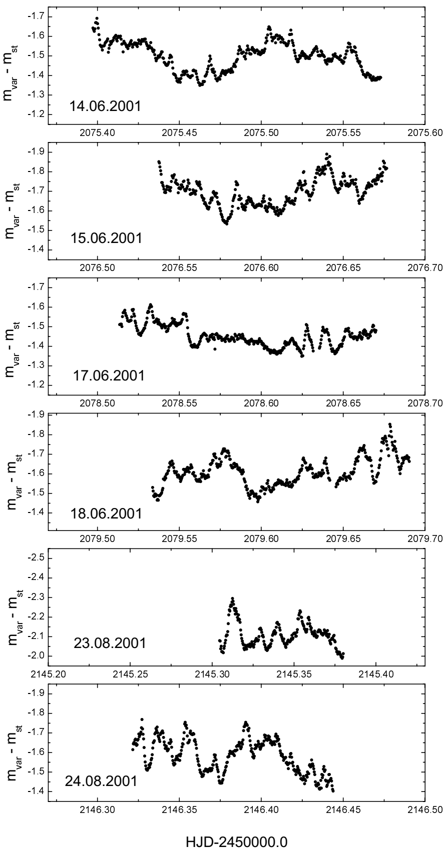

Figure 1: Light curves of V603 Aql in 2001.

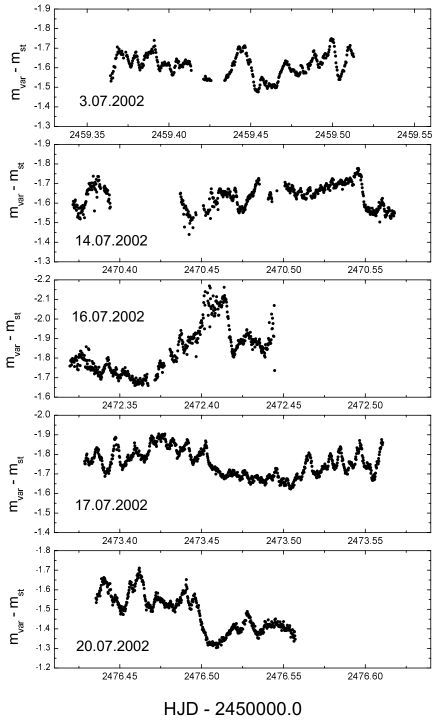

Figure 2: Light curves of V603 Aql in 2002.

Table 1: Log of observations

Data	Begin-End JD 2400000.0+	Number of points	<V>
07.10.1994	49633.1771-0.2929	570	11.76
08.10.1994	49634.1759-0.2976	609	11.76
09.10.1994	49635.1984-0.3111	579	11.62
14.06.2001	52075.3973-0.5730	429	12.10
15.06.2001	52076.5376-0.6767	399	11.90
17.06.2001	52078.5136-0.6701	440	12.15
18.06.2001	52079.5337-0.6905	441	11.99
23.08.2001	52145.3047-0.3801	228	12.07
24.08.2001	52146.3217-0.4440	372	12.02
03.07.2002	52459.3644-0.5129	378	11.99
14.07.2002	52470.3715-0.5679	562	11.97
16.07.2002	52472.3196-0.4446	496	11.77
17.07.2002	52473.3785-0.5607	777	11.85
20.07.2002	52476.4355-0.5572	523	12.12

Table 2: Obtained photometric periods close to orbital one. P_1 - main period, P_2 - possible additional periods.

Epohe	Number of nights	P_1	P_2
10.1994	3	$0.^{d}135$	$0.^{d}13$
			$0.^{d}139$
07.2001	4	$0.^{d}1442$	$0.^{d}1360$
			$0.^{d}13$ (?)
08.2001	2	$0.^{d}145$	
07.2002	5	$0.^{d}1449$	$0.^{d}13$
			$0.^{d}139$

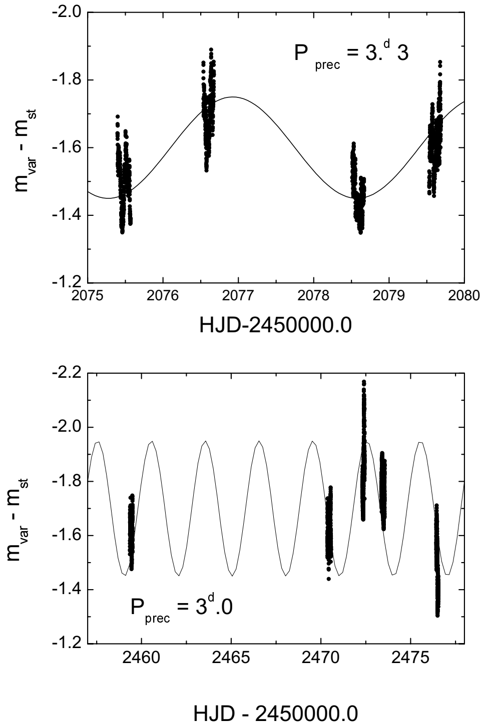

Figure 3: Disc precession periods of V603 Aql in June 2001 and July 2002.

3. Period analysis

The periodogram analysis was carried out using the code L2, written by Yu. Kolpakov (SAI, Moscow) and code EFFECT, written by V. Goransky (SAI, Moscow).

The search of photometric periods close to the orbital period were performed separately for October 1994, June 2001, August 2001 and July 2002. The obtained periods are summed in Table 2. It is obvious that V603 Aql had a negative superhumps in 1994 ($P_{neg} = 0^d.135$) and a positive superhumps in 2001-2002 (P_{pos}=$0.^d144$-$0^d.145$). We also found the brightness changes from night to night (see Fig. 3). Periods of these changes are of about 3^d in according with expected accretion disc precession period (see Eq.(1)).

4. Discussion and conclusions

Obtained photometric periods have shown that main dynamical process in V603 Aql accretion disk was the line of apsides precession. Our periods agree with the relation between positive superhumps periods and mean brightness of V603 Aql, which was found by Patterson et al. (1993) (see Fig.4a):

$$dP_{pos}/dm = 0.009 \pm 0.0016. \qquad (2)$$

As P_{pos} is changed, therefore P_{prec} is changed too (1). Disk precession period depends on outer disk radius (Osaki 1985). Murray (2000) derived a more accuarcy (than Osaki (1985)) analytical formula for the precession rate of the accretion disk:

$$P_{prec}^{-1} = b(r)\frac{q}{\sqrt{1+q}}P_{orb}^{-1}, \qquad (3)$$

where q is the mass ratio equal 0.24$\pm$ 0.05 for V603 Aql (Arenas et al. 2000) and r is an outer disk radius in units of the binary separation a. $b(r)$ is the function of a Laplace coefficient from celestial mechanics and it is plotted in Fig.1 of Murray (2000) paper.

We have evaluated from (3) that a change of P_{pos} from $0^d.1442$ to $0^d.1466$ (Patterson et al. (1993) data) corresponds to a change of outer disk radius from $0.345^{+0.04}_{-0.025}$ to $0.4^{+0.04}_{-0.025}$ in units a. Therefore, the brightness increasing by $0^m.3$ gives the outer disk radius increasing by 0.055 a.

Such brightness and outer disk radius increasing can be caused by the accretion rate increasing at an outer disk radius constant effective temperature $T_{out} = const$. In this case the relation between brightness and outer disk radius is:

$$\Delta m = -2.5\log\frac{R_{out}^2}{(R'_{out})^2}. \qquad (4)$$

This relation gives Δm close to observed brightness increasing by $0^m.32$ due to the outer disk radius increasing by $0.055a$.

We also found that V603 Aql is brighter by $0^m.2$–$0^m.3$ during negative superhumps state than during positive superhamps state (see Table 1 and Patterson et al. (1993,1997) data). This brightnes increasing can be also caused by the accretion rate increasing and follow outer disk radius increasing. In this case the disk inclination to orbital plane can depend on disk radius (see Fig. 4b). It may be caused by magnetic field of the secondary star (Murray et al. 2002).

Acknowledgements. We thank Dr. V. Goransky for his EFFECT software and we also thank Yu. Kolpakov for his L2 software. The VS,IB, CB, and NS are grateful to the Russian Foundation for Basic Research (project no. 02-02-17174) and President of Russian Federation grant on leading scientific scool support (project no. NSH-1789.2003.2) for financial support.

References

Arenas J., Catalan M., Augusteijn T., Retter A.: 2000, *MNRAS*, **311**, 135.

Barrett P., O'Donoghue D., Warner B.: 1988, *MNRAS*, **233**, 759.

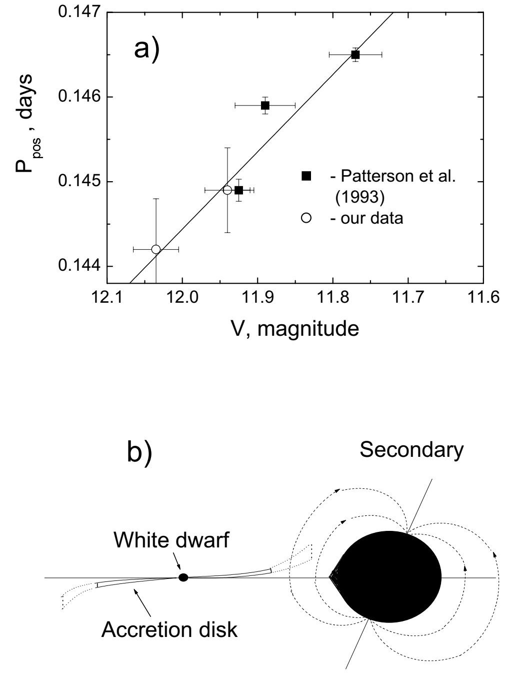

Figure 4: a) Photometric period - brightness dependence. b) Scheme of the dependence of accretion disc inclination on disc radius.

Haefner R., Metz K.: 1985, *Astron. Astrophys.*, **145**, 311.
Kraft R.: 1964, *Astrophys.J.*, **139**, 457.
Lubow S.: 1992, *Astrophys.J.*, **398**, 525.
Murray J.R.: 2000, *MNRAS*, **314**, L1.
Murray J.R., Chakrabarty D., Wynn G., Kramer L.: 2002, *MNRAS*, **335**, 247.
Osaki Y.: 1985, *Astron. Astrophys.*, **144**, 369.
Patterson J., Thomas G., Skillman D., Diaz M.: 1993, *Astrophys.J. Suppl. Ser.*, **86**, 235.
Patterson J., Kemp J., Saad J. et al.: 1997, *PASP*, **109**, 468.
Suleimanov V., Zhukov G., Senio D.: 1998, *Astr. Astrophys. Trans.*, **15**, 117.
Whitehurst R.: 1988, *MNRAS*, **232**, 35.