Simultaneous $UBVR_cI_c$ observations of the cataclysmic variable V794 Aquilae: Flickering source parameters ⋆

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Abstract. We report simultaneous observations in 5 bands $UBVR_cI_c$ of the flickering variability of the cataclysmic variable V794 Aql. The observations are obtained with the Rozhen NAO and Belogradchik AO telescopes on 2009 July 23 and on 2010 August 13. V794 Aql has flickering source with average $(U-B)_0 = -0.75 \pm 0.20$, $(B-V)_0 = +0.02 \pm 0.10$, $(V-R)_0 = 0.15 \pm 0.05$. We find for the flickering source parameters: $T_{fl} = 10900 \pm 600$ K, $\bar{R}_{fl} = 0.10 \pm 0.05$ $R_\odot$, and $\bar{L}_{fl} = 0.11 \pm 0.02$ $L_\odot$ (using a distance of $d = 690 \pm 105$ pc).
Key words: stars: individual: V794 Aql – binaries: novae, cataclysmic variables

Синхронни $UBVR_cI_c$ наблюдения на катаклизмичната променлива V794 Aql: Параметри на източника на фликеринг

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Представени са резултатите от 5-цветните ($UBVR_cI_c$) синхронни наблюдения на фликеринга на катаклизмичната променлива V794 Aql, проведени на 23 юли 2009 и 13 август 2010 с телескопите на НАО Рожен и АО Белоградчик. Получените средни цветове на източника на фликеринг са като следва $(U-B)_0 = -0.75 \pm 0.20$, $(B-V)_0 = +0.02 \pm 0.10$, $(V-R)_0 = 0.15 \pm 0.05$. За параметрите на източника на фликеринг, при разстояние $d = 690$ pc, получаваме $T_{fl} = 10900 \pm 600$ K, $\bar{R}_{fl} = 0.10 \pm 0.05$ R $_\odot$ и $\bar{L}_{fl} = 0.11 \pm 0.02$ L$_\odot$.

1 Introduction

V794 Aql is a nova-like cataclysmic variable star. It has been discovered as a variable star by Hoffmeister in 1936. Szkody et al. (1981) classified it as cataclysmic variable. It consists of an accreting white dwarf and red dwarf mass donor with orbital period $P_{orb} = 3.68$ hours (Honeycutt & Robertson 1998). This system is a VY Sculptoris subtype. The orbital periods of VY Sculptoris nova-likes are in the e.g. orbital period gap – between 3-4 hours.

On the base of spectral observations, Godon et al. (2007) derived mass of the white dwarf $M_{\rm wd} \sim 0.9$ M$_\odot$, mass accretion rate in high state $10^{-8.5}-10^{-8}$ M$_\odot$ yr^{-1}, inclination of the system $i \sim 60^0$, an extinction value $E_{B-V} = 0.2$, and distance $d = 690 \pm 105$ pc. Using $M_{\rm wd} \sim 0.9$ M$_\odot$ and mass-radius relation

⋆ Based on data collected with Rozhen NAO and Belogradchik AO telescopes

for white dwarfs (Madej et al. 2004), we calculate for the white dwarf radius $R_{\rm wd} = 7000$ km.

The flickering (stochastic light variations on timescales of a few minutes with amplitude of a few×0.1 magnitudes) is a variability observed in the three main types of binaries that contain white dwarfs accreting material from a companion mass-donor star: cataclysmic variables (CVs), supersoft X-ray binaries, and symbiotic stars (Sokoloski 2003).

The flickering of V794 Aql has been detected by Meinunger (1979). Using high speed photometer, Warner (1982) observed brightness variations of up to 0.5 mag on a timescale of minutes with smaller variations on timescales of tens of seconds.

2 Observations

On the nights of 2009 July 23 and 2010 August 13, we observed V794 Aql simultaneously with four telescopes equipped with CCD cameras. The 2m RCC telescope of the National Astronomical Observatory Rozhen equipped with a dual channel focal reducer (FoReRo2) observed in U and V bands.

Table 1. Journal of observations of V794 Aql. In the table are given as follows: the telescope, band, UT-start and UT-end of the run, exposure time, number of CCD images obtained, minimum – maximum magnitudes in each band, average magnitude in the corresponding band, standard deviation of the mean, typical observational error.

Telescope	band	UT start-end	exp-time [sec]	N_{pts}	min-max [mag]-[mag]	average [mag]	stdev [mag]	err [mag]
2009 July 23		JD2455036						
2.0 m Rozhen	U	0:16-1:15	240	14	15.129 – 15.458	15.264	0.089	0.07
50/70 cm Schmidt	B	0:04-1:32	180	28	15.973 – 16.542	16.254	0.130	0.06
2.0 m Rozhen	V	0:18-1:19	60	54	15.835 – 16.270	15.992	0.099	0.02
60 cm Belogr	R	0:38-1:42	60	59	15.356 – 15.756	15.519	0.084	0.05
60 cm Rozhen	I	0:31-1:19	90	32	15.001 – 15.396	15.134	0.087	0.03
2010 August 13		JD2455422						
2.0 m Rozhen	U	19:06-21:23	300	24	14.407 – 14.675	14.547	0.091	0.035
50/70 cm Schmidt	B	19:44-21:26	180	34	15.120 – 15.440	15.286	0.084	0.025
2.0 m Rozhen	V	19:11-21:26	60/90	100	14.920 – 15.193	15.044	0.069	0.010
60 cm Belogr	R	19:32-21:28	120	58	14.493 – 14.773	14.651	0.069	0.021
60 cm Rozhen	I	19:07-21:28	120	70	14.390 – 14.620	14.494	0.058	0.025

In the U band a Photometrics CCD (1024 x 1024 px) has been used, and in the V band a VersArray (512 x 512, 7.5' x 7.5'). The 60 cm Rozhen telescope observed in the I band (equipped with a FLI PL09000 CCD with 3056 x 3056 pixels and 18' x 18'); the 50/70 cm Schmidt telescope of NAO Rozhen in the B band (SBIG STL11000M CCD, 4008 x 2672 px), and the 60 cm

telescope of the Belogradchick Astronomical Observatory in the R band (FLI PL09000 CCD with 3056 x 3056 pixels and 18' x 18'). All of the CCD images have been bias subtracted, flat fielded, and standard aperture photometry has been performed. The data reduction and aperture photometry are done with standard packages and tasks in IRAF and have been checked with alternative software packages. The comparison star number two from Henden and Honeycutt (1995) has been used: $B = 14.358 \pm 0.008$, $V = 13.736 \pm 0.003$, $U = 14.51 \pm 0.02$, $R = 13.22 \pm 0.01$ and $I = 12.89 \pm 0.01$.

The results of our observations are summarized in Table 1 and plotted in Fig.1 and 2. For each run we measure the minimum, maximum, and average brightness in the corresponding band, plus the standard deviation of the run.

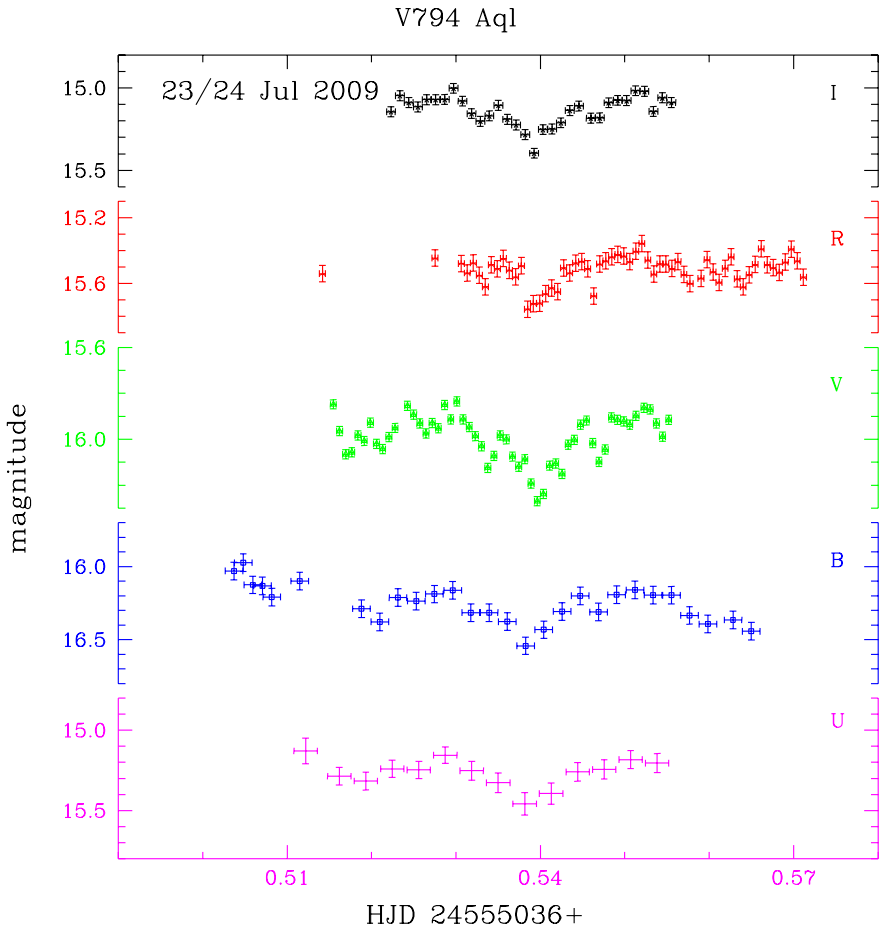

Fig. 1. Variability of V794 Aql in the UBVRI bands on 2009 July 23.

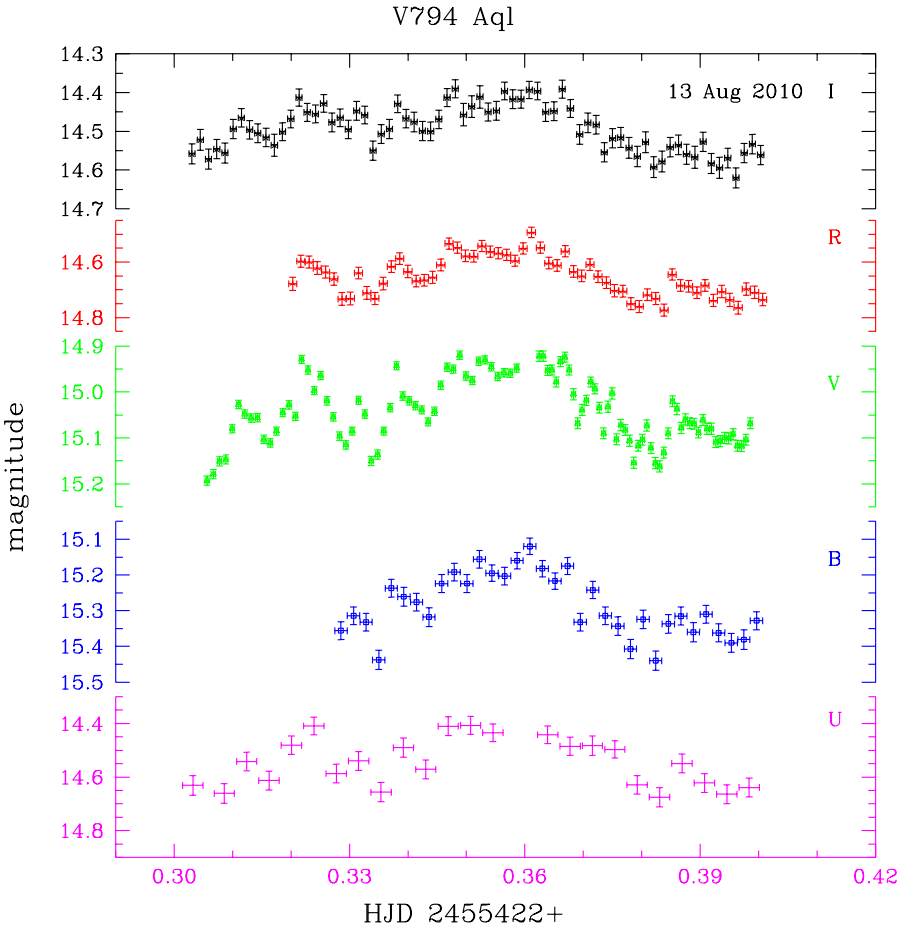

Fig. 2. Variability of V794 Aql in the UBVRI bands on 2010 August 13.

3 Flickering source parameters

As can be seen in Figs 1, 2 and Table 1, during our observations V794 Aql exhibited flickerig variability on a short time scale of 1-5 minutes. For the U, B, V, R, I-band amplitudes we obtain: ΔU=0.33, ΔB=0.57, ΔV = 0.44, ΔR=0.40 and ΔI=0.39 respectively (2009 July 23); ΔU=0.27, ΔB=0.32, ΔV=0.27, ΔR=0.28 and ΔI=0.23 (2010 August 13).

Bruch (1992) proposed that the light curve (for the run) of CVs can be separated into two parts – constant and variable (flickering) component. We assume that all the variability is due to flickering. In this case the flickering

light source is considered 100% modulated. Given these assumptions, we can calculate the flux of the flickering light source as $F_{fl} = F_{av} - F_{min}$, where F_{av} is the average flux during the run and F_{min} is the minimum flux during the run (corrected for the typical error of the observations). F_{fl} has been calculated for each band, using the values given in Table 1 and Bessel (1979) calibration for the fluxes of a zero magnitude star. Using the Pogson formula we estimate the magnitudes and colors of the flickering source (corrected for interstellar extinction):

2009 July 23 : $U = 16.224$, $B = 16.999$, $V = 16.971$,$R = 16.755$, $I = 16.400$, $(U-B)_0 = -0.775$, $(B-V)_0 = 0.028$, $(V-R)_0 = 0.216$, $(R-I)_0 = 0.355$ mag.

2010 August 13 : $U = 15.926$, $B = 16.653$, $V = 16.638$,$R = 16.552$, $I = 16.489$, $(U-B)_0 = -0.727$, $(B-V)_0 = 0.015$, $(V-R)_0 = 0.086$, $(R-I)_0 = 0.063$ mag.

The range of errors is 5–15%.

In Fig.3 we plot the flickering source flux versus the wavelength. The data are approximated with a black body fit in IRAF ($nfit1d$ task). Using $d = 690 \pm 105pc$ (Godon et al. 2007) we calculate the flickering source parameters (temperature, size and luminosity):

2009 July 23 : $T_{fl} = 10340 \pm 200$ K; $R_{fl} = 0.098 \pm 0.005$ $R_\odot$; $L_{fl} \sim 0.09$ $L_\odot$.

2010 Aug 13 : $T_{fl} = 10760 \pm 200$ K; $R_{fl} = 0.105 \pm 0.005$ $R_\odot$; $L_{fl} \sim 0.13$ $L_\odot$. Using all data normalized to V band (Fig.4) we estimate $T_{fl} = 10900 \pm 600$ K.

On August 13, 2010 the average magnitude in V-band is about 15 mag which is very close to the magnitude in high photometric state ($V = 14.8$ mag). On July 23, 2009 the V-magnitude is about 16 mag with variations. In other words, the brightness in V is about 2.5 times weaker.

We adopt that in high state the accretion rate is $10^{-8.5}$ $M_\odot$ yr^{-1} (Godon et al. 2007). The total accretion luminosity, L_{acc}, is :

$$L_{acc} = GM_{\rm wd}\dot{M}_a R_{\rm wd}^{-1}, \quad (1)$$

where $M_{\rm wd} \sim 0.9$ $M_\odot$ and $R_{\rm wd} = 7000$ km s^{-1} (see Sect.1).

We calculate $L_{acc} = 3.52$ $L_\odot$, and for the ratio $L_{fl}/L_{acc} \sim 0.025$ (July 23, 2009), and $L_{acc} = 8.8$ $L_\odot$ and $L_{fl}/L_{acc} \sim 0.014$ (August 13, 2010). The flickering source contributes about 2% of the total accretion luminosity.

4 Time interval between nova eruptions

At accretion of hydrogen rich material on the white dwarf surface the pressure in the base of envelope increase. When the pressure at the base of the envelope (P_{base}) exceeds a certain critical value $P_{crit} \approx 2 \times 10^{19}$ dyne cm^{-2} under sufficiently degenerate conditions an ignition does occur, resulting in high temperatures and velocities and leading to a nova eruption phenomena (Livio

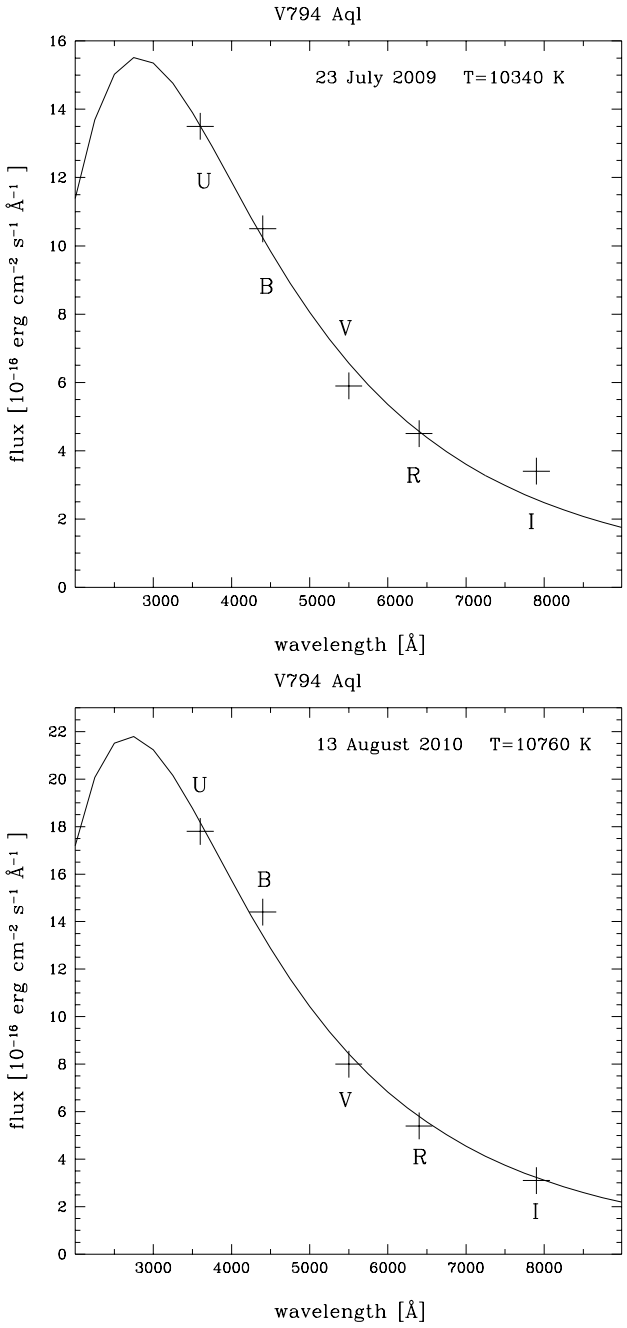

Fig. 3. Dereddened fluxes of the flickering source of V794 Aql.

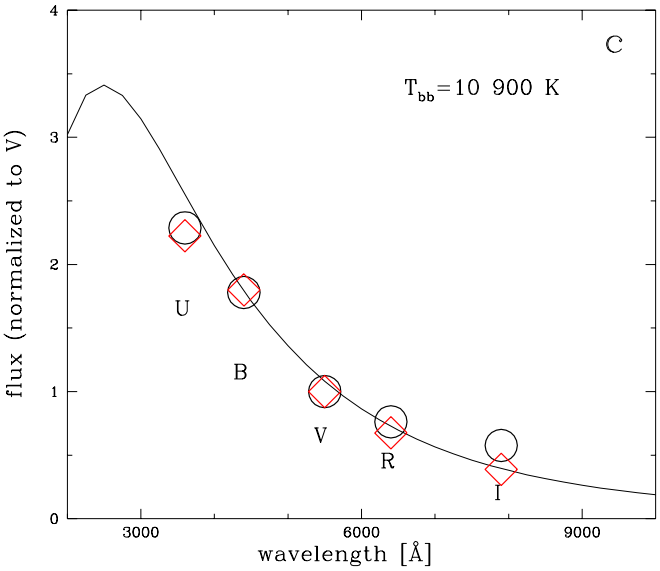

Fig. 4. All data normalized to V band and plotted together. The fit is $T_{bb} = 10900$ K.

1983). The pressure at the base of the envelope increases as:

$$P_{base} = \frac{GM_{\rm wd}\Delta M}{4\pi R^4_{\rm wd}}, \tag{2}$$

where $M_{\rm wd}$ and $R_{\rm wd}$ are the white dwarf mass and radius respectively, ΔM is the mass of the accreted material and G is the gravitational constant. The mass of the envelope increases in the time as:

$$\Delta M = \dot{M}_a\, t \tag{3}$$

Using these two formulas and adopting average $\dot{M}_{acc} = 10^{-8.5} - 10^{-9.5}$ $M_\odot$ yr^{-1}, we estimate the time interval between nova eruptions of V794 Aql of about $8 \times 10^4 - 8 \times 10^5$ yr.

5 Conclusions

We report our CCD observations of the flickering variability of the nova-like variable V794 Aql. The observations are performed simultaneously with 4 telescopes in the UBVRI bands. Our calculations show that:

(1) V794 Aql has a flickering source with average colors $(U-B)_0 = -0.75$, $(B-V)_0 = 0.02$, $(V-R)_0 = 0.15$ and $(R-I)_0 = 0.21$ mag.

(2) For the flickering light source in V794 Aql, we estimate $T_{eff} = 10900 \pm 600$ K, which is similar to the temperature of the bright spot in CVs;

(3) Using a distance of d = 690 pc, we find average size $\bar{R}_{fl} = 0.10 \pm 0.05$ $R_\odot$, and luminosity $\bar{L}_{fl} = 0.11 \pm 0.02$ $L_\odot$ of the flickering source.

(4) In addition, we also estimate radius of the white dwarf $R_{\rm wd} \approx 7000$ km and time between nova eruptions $\sim 10^5$ yr.

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