High-mass X-ray Binaries: Illuminating the Passage from Massive Binaries to Merging Compact Objects
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Optical and X-ray study of *V*404 *Cyg* during its activity in the Summer 2015

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Abstract. The black hole X-ray binary *V*404 *Cyg* was studied during of the 2015 outburst. Optical photometry and spectroscopy were performed by using 1.5-meter Russian-Turkish telescope (RTT-150) facilities at the TUBITAK National Observatory (Antalya, Turkey). From June 22 to June 28, 2015, shell expansion velocity decreased from 650 to 400 km s^{-1} as measured by Hα and Hβ lines and from 450 to 330 km s^{-1} as measured by HeI and HeII lines. Thus, the shell expansion occurred with deceleration, where the hydrogen and helium line formation regions are at different radial distances from the center of the star. The correlation of flow variability in the optical and X-ray ranges is caused by fluctuations in the rate of accretion near a compact source where X-ray photons are generated.

Keywords. *V*404 *Cyg*, low-mass X-ray binary

1. Introduction

We have observed optical outburst of the black hole X-ray binary *V*404 *Cyg* during its X-ray activity (Barthelmy *et al.* 2015, Negoro *et al.* 2015) in Summer 2015 by using 1.5-meter Russian-Turkish optical telescope (RTT-150) equipped with TFOSC instrument. We performed photometry, polarimetry and middle resolution (5 Å) spectroscopy during the period June 20-28, 2015. Optical spectra dominated by strong broad emission signatures from HI, HeI and HeII. It associated to a nova-like nebula formed by the cooling remnant of strong accretion disc winds (Rahoui *et al.* 2017).

2. Overview

The velocity of shell expansion was measured based on the FWHM of the hydrogen and helium lines. From June 22 to June 28, 2015, shell expansion velocity decreased from 650 to 400 km s^{-1} as measured by Hα and Hβ lines, from 450 to 330 km s^{-1} as measured by lines of HeI 6678 Å, 7065 Å and HeII 4685 Åline Table 1. Thus, we suppose that the shell expansion occurred with deceleration in the indicated period. We found also the asymmetry of the profiles of the hydrogen lines (Fig. 1), which may be associated with an uneven decrease in the rate of expansion of the shell in the different directions.

We performed polarimetric observations in June 23-24, 2015, and found that V-band emission of the source is polarized with $P \sim 8 \pm 0.5\%$. Our polarization degree value is in agreement with the published values (Panapoulou *et al.* 2015, Blau *et al.* 2015, Itoh *et al.* 2015). This suggests that the polarization might be of interstellar origin or occurred by dust scattering on the rings and diffuse structure (found by SWIFT XRT observations,

Table 1. Line profile's parameters.

date	HJD	λ_{peak}, Å	W, Å	FWHM/2, km s^{-1}
		Hα		
22.06.2015	2457196.56524933	6564.8	-70.8	667
24.06.2015	2457198.49295458	6563.8	-82.0	545
26.06.2015	2457200.57518956	6563.3	-233.8	533
27.06.2015	2457201.55512845	6563.9	-671.2	443
28.06.2015	2457202.55643330	6562.2	-22.3	401
		Hβ		
22.06.2015	2457196.56524933	4863.0	-16.8	557
24.06.2015	2457198.49295458	4861.6	-12.7	384
26.06.2015	2457200.57518956	4861.7	-22.7	425
27.06.2015	2457201.55512845	4862.1	-15.4	490
		HeI (7065 Å)		
22.06.2015	2457196.56524933	7067.9	-6.5	487
24.06.2015	2457198.49295458	7065.3	-6.9	319
26.06.2015	2457200.57518956	7065.5	-14.2	343
		HeI (6678 Å)		
22.06.2015	2457196.56524933	6680.0	-6.3	446
24.06.2015	2457198.49295458	6678.1	-7.4	290
26.06.2015	2457200.57518956	6678.3	-14.0	321
		HeII (4686 Å)		
22.06.2015	2457196.56524933	4685.8	-7.9	468
24.06.2015	2457198.49295458	4684.9	-12.5	297
26.06.2015	2457200.57518956	4685.1	-7.3	328

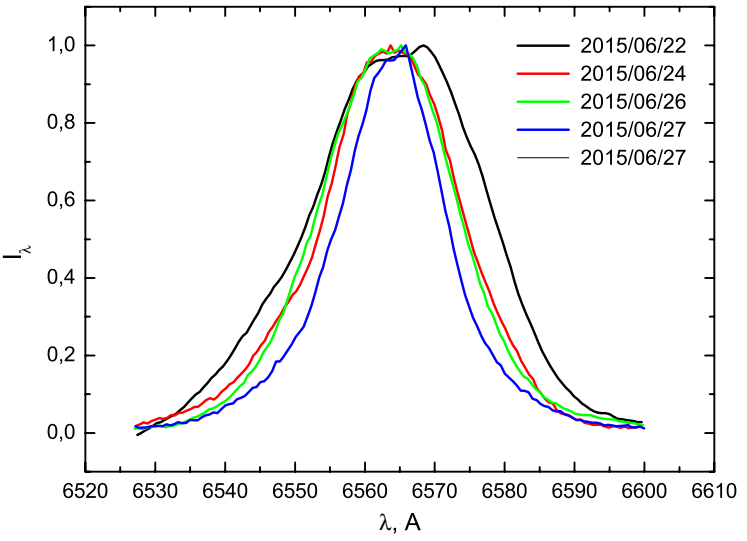

Figure 1. Changing of Hα Line Profiles.

Beardmore *et al.* 2015). These rings could be associated with previous flaring episodes from the central binary system.

The X-ray light curve of *V*404 *Cyg* was analysed during its flare activity in June and December 2015 using the open public XRT data of the SWIFT orbital observatory. RTT-150 optical observations made during the period from June 20 to June 28, 2015 in V, B, R and I filters (Fig. 2).

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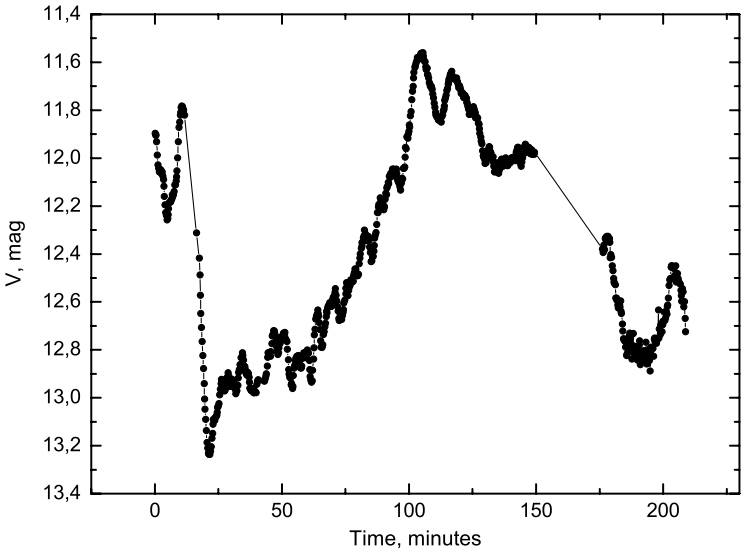

Figure 2. V-band light curve in June 20, 2015.

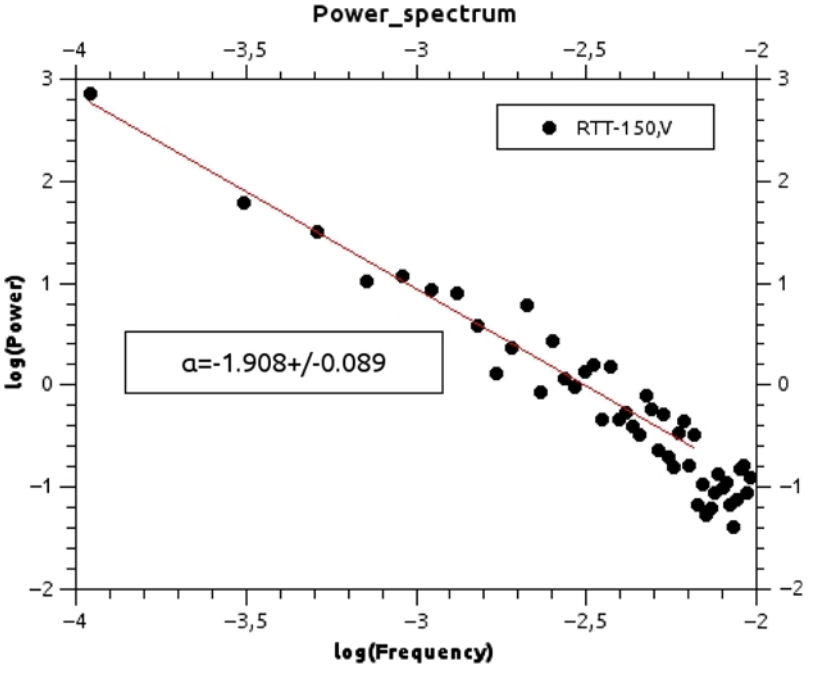

Figure 3. X-ray Power spectrum of $V404\,Cyg$.

LS-spectra (Least-Square) were constructed for the analysis of X-ray and optical data by the Lomb-Scargle method (Fig. 3, 4). Those power spectra show the same slope within the error limits: -1.9 ± 0.09 in the optical range and -1.85 ± 0.06 in the X-ray range. Within the frequency range from 0.002 Hz and below the X-ray power spectrum shows a "flat area". The X-ray power spectrum exhibits possible QPO at the frequency of 0.0137 Hz, which nature remains unknown (Fig. 5).

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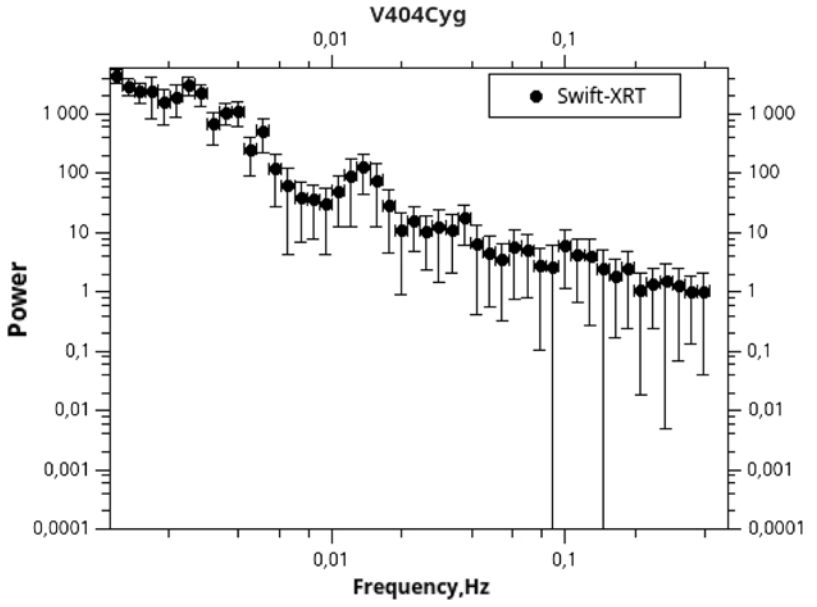

Figure 4. Optical Power spectrum of $V404\,Cyg$.

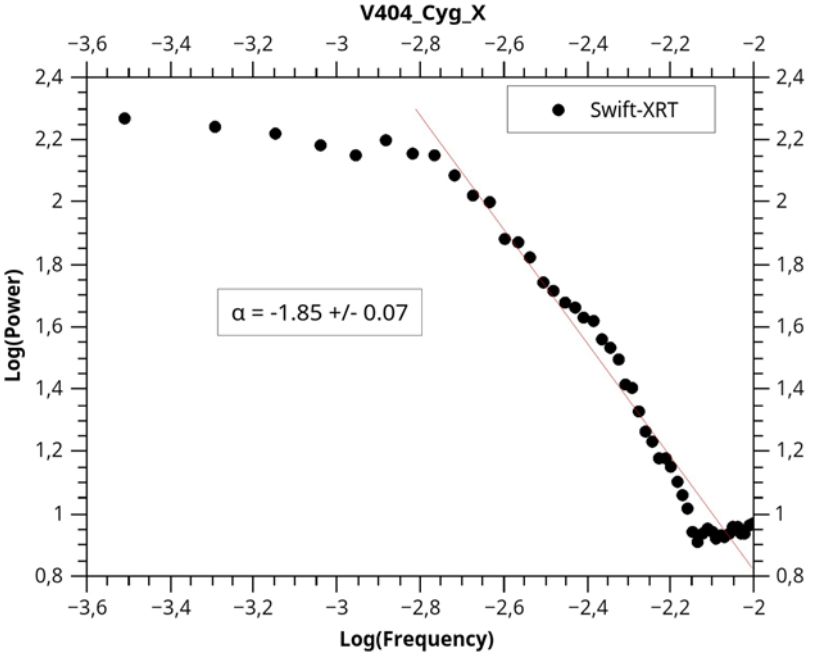

Figure 5. Possible QPO on 0.0137 Hz detected on X-ray power spectrum.

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