BG Tri an example of a low inclination RW Sex-type novalike

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ABSTRACT
We analyse a wealth of optical spectroscopic and photometric observations of the bright (V = 11.9) cataclysmic variable BG Tri. The Gaia DR2 parallax gives a distance d = 334(8) pc to the source, making the object one of the intrinsically brightest nova-like variables seen under a low orbital inclination angle. Time-resolved spectroscopic observations revealed the orbital period of P orb = 3h 00m 28s (24). Its spectroscopic characteristics resemble RW Sex and similar nova-like variables. We disentangled the Hα emission line into two components, and show that one component forms on the irradiated face of the secondary star. We suggest that the other one originates at a disc outflow area adjacent to the L3 point.

Key words: cataclysmic variables, dwarf novae, white dwarf, stars: individual: BG Tri

1 INTRODUCTION
Cataclysmic variables (CVs) are close binary systems comprised of a white dwarf (WD) and a low-mass star losing matter in a Roche-lobe overflow regime, usually creating an accretion disc around the accreting WD (Warner 1995). CVs show diverse observational characteristics depending on fundamental physical properties, including their orbital period, mass transfer rate; and strength of the magnetic field of the WD. Their diversity is also in part due to the viewing angle (Howell & Mason 2018). In non- or weakly-magnetic systems, the accretion flow takes place in a fully-developed accretion disc. At high mass transfer rates (≥ 10−9 M⊙ yr−1), these are hot, steady-state discs (Baptista et al. 1996). Therefore, the disc thermal instability that triggers dwarf nova outbursts is prevented (Shafter et al. 1986; Shafter 1992; Lasota 2001). These high mass transfer rate systems are known as nova-like variables (NLs), because it was initially argued that they might potentially exhibit or have undergone undetected nova eruptions (Vorontsov-Velyaminov 1934). No known NL has ever been seen to erupt as a nova. However, some NLs may resemble nova when the nova returns to a quiescent state after the eruption (Warner 1995). They constitute a small fraction of the entire CV population (~15 percent in Ritter & Kolb 2003a,b), which might be result of an observational bias. The vast majority of NLs have orbital periods above the so-called "period gap" (Rappaport et al. 1983; Kolb et al. 1998; Zorotovic et al. 2016; Abril et al. 2020). We exclude CVs with moderately or highly magnetic WDs, which historically were also accounted for as NLs.

There is a visible differentiation between NLs and dwarf novae in terms of their orbital periods and colours (Abril et al. 2020). It is noticeable that NLs dominate the orbital period range 3-4h, where very few dwarf novae are observed (Kniige et al. 2011). However, in absolute numbers, the amount and the distribution of NLs and dwarf novae right above the period gap are comparable (Kniige et al. 2011). There is no good understanding why the two populations of NL and dwarf novae overlap in some period ranges, but not in others. NLs have accretion rates that are higher than "normal" CVs both at longer and shorter periods. They are intrinsically very bright, and their WDs tend to be hotter (Townsley & Gänsicke 2009).

The spectra of some NL variables display persistent broad Balmer absorption lines, indicative of optically thick discs. However, NLs themselves come in different flavours. A fraction of NLs, known as VY ScI stars, show occasional states of low mass transfer rates, i.e. they become significantly fainter for prolonged periods of time (months to years, Warner & van Citters 1974; Rodríguez-Gil et al. 2020). However, the physical cause of these low mass transfer states is still uncertain (Livio & Pringle 1994; King & Cannizzo 1998; Schmidtobreick et al. 2018).

SW Sex stars form a class of NL variables with distinctive spectro-
The secondary facing the disc. The wide component is formed in an extended, low-velocity region in the outskirts of the opposite side of the accretion disc, with respect to the collision point of the accretion stream and the disc. Recently, Subeckova et al. (2020) claim, that this property is observed in RW Tri. They compiled a current list of similar NLs with orbital periods ≥4 hours. At least four of them, the components of Hz emission closely resemble those seen in RW Sex.

Other interpretations of line provenance (including absorption features frequently flanking emission lines) in such NL systems have been put forward. Notably, the disc overflow model by Hellier (1996) and disc wind interpretations and models (e.g. Patterson et al. 1996; Murray & Chiang 1996) are worth mentioning.

BG Tri is a bright object reported by Woźniak et al. (2004); Khruslov (2008) to show an irregular, low-amplitude variability and tentatively identified as a CV, citing ROTSEI, TYC2 and ROSAT detections. Accordingly, the object is also catalogued as TYC 2298 01538 and 1RXS J014444.4+323320. Makarov (2017) confirms its NL identification based on a distance estimate by Gaia (Gaia Collaboration et al. 2018) in combination with Galaxy Evolution Explorer (GALEX) UV magnitudes (Martin et al. 2003). However, BG Tri has not been studied in detail until now. We report the results of the spectroscopic study of the object on the backdrop of the long term photometry collected by the Catalina Real-time Transient Survey and the All Sky Automated Surveys (ASAS).

### 2 OBSERVATIONS AND REDUCTION

We present an extensive set of multi-wavelength observations of BG Tri obtained by us as well as a variety of data collected in surveys.

#### 2.1 Photometry

The data from the Catalina Real-Time Transient Survey (CRTS) (Drake et al. 2009) and the All-Sky Automated Survey for Supernovae (ASAS SN) (Shappee et al. 2014; Kochanek et al. 2017) were used to produce the light curve (Figure 1) of the object. The data were obtained in V- and g-bands. The difference between filters g and V is not significant and the average colour index was g − V ≈ 0.0. Most of the time BG Tri is bright (≈12 mag, one of the brightest CVs in apparent magnitude) and nearly constant with non-regular, small amplitude variability. The average magnitude in a time stretch HJD 2456524.01 to HJD 2457668.08 is V = 11.91, with a deviation of ±0.06 magnitudes. The light curve shows one occasion of a large flux drop (~2.5 mag), with a duration of 176 days. The initial descent from the average V = 11.9 +13.6 magnitude lasts about 40 days at a rate of 0.04 mag day−1. Following a stand-still at that magnitude that last one month, the brightness briefly falls further (on HJD 2458337), reaching V = 14.3 mag. From there, the luminosity starts to recover with a slower rate of 0.026 mag day−1. This low state episode, detailed in the upper panel of Figure 1, is fairly common among NLs, classifying BG Tri as a YY Sco star. There is also an episode of a sudden jump of brightness detected between HJD 2457669.88 and HJD 2457797.72 before the anti-dwarf nova episode when the average brightness of the object reaches V ≈ 11.7.

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**Table 1. Log of spectroscopic observations**

| Date       | JD* | Range (Å) | No. of Spectra | Exp. time (s) | Comments |
|------------|-----|-----------|----------------|---------------|----------|
| 2002 Aug. 21 | 2507 | 3341-7546 | 2              | 200           | INT      |
| 2002 Aug. 23 | 2510 | 3341-7546 | 24             | 340           | INT      |
| 2002 Aug. 25 | 2512 | 3341-7546 | 15             | 120           | INT      |
| 2002 Aug. 31 | 2518 | 3341-7546 | 8              | 120           | INT      |
| 2002 Sep. 02 | 2520 | 3341-7546 | 4              | 120           | INT      |
| 2002 Sep. 03 | 2521 | 3341-7546 | 6              | 120           | INT      |
| 2003 Oct 19  | 2932 | 3784-9063 | 2              | 60            | ISIS B&R |
| 2003 Dec. 13 | 2987 | 4257-8318 | 4              | 120           | CA       |
| 2003 Dec. 14 | 2988 | 4257-8318 | 9              | 60            | CA       |
| 2003 Dec. 15 | 2989 | 4257-8318 | 2              | 60            | CA       |
| 2003 Dec. 16 | 2990 | 4257-8318 | 10             | 60            | CA       |
| 2003 Dec. 17 | 2991 | 4257-8318 | 10             | 60, 120       | CA       |
| 2003 Dec. 17 | 2991 | 3775-6840 | 7              | 120           | NOT      |
| 2003 Dec. 23 | 2997 | 4257-8318 | 6              | 60            | CA       |
| 2003 Dec. 24 | 2998 | 4257-8318 | 6              | 60            | CA       |
| 2003 Dec. 25 | 2999 | 4257-8318 | 2              | 60            | CA       |
| 2003 Dec. 26 | 3000 | 4257-8318 | 4              | 60            | CA       |
| 2003 Dec. 27 | 3001 | 4257-8318 | 2              | 60            | CA       |
| 2004 Aug. 09 | 3226 | 4257-8318 | 2              | 180           | CA       |
| 2004 Aug. 10 | 3227 | 4257-8318 | 2              | 180           | CA       |
| 2004 Aug. 11 | 3228 | 4257-8318 | 2              | 180           | CA       |
| 2004 Aug. 12 | 3229 | 4257-8318 | 2              | 180           | CA       |
| 2004 Oct. 21 | 3300 | 4257-8318 | 2              | 120           | CA       |
| 2004 Oct. 23 | 3302 | 4257-8318 | 2              | 120           | CA       |
| 2004 Oct. 24 | 3303 | 4257-8318 | 2              | 120           | CA       |
| 2004 Oct. 26 | 3305 | 4257-8318 | 2              | 120           | CA       |
| 2004 Sep. 10 | 3623 | 4257-8318 | 2              | 120           | CA       |
| 2004 Nov. 04 | 3314 | 3775-6840 | 2              | 120           | NOT      |
| 2005 Jan. 01 | 3372 | 3784-9063 | 2              | 200           | ISIS B&R |
| 2005 Jan. 04 | 3375 | 3784-9063 | 2              | 200           | ISIS B&R |
| 2005 Jan. 05 | 3376 | 3784-9063 | 2              | 200           | ISIS B&R |
| 2005 Jan. 06 | 3377 | 3784-9063 | 2              | 200           | ISIS B&R |
| 2005 Jan. 07 | 3378 | 3784-9063 | 2              | 200           | ISIS B&R |
| 2005 Sep. 10 | 3623 | 4257-8318 | 2              | 120           | CA       |

* 2450000+ JD is given at beginning of the observing night.

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The spectroscopic behaviour (Thorsten et al. 1991). They mostly cluster in the 3-4 h orbital period range (Rodríguez-Gil et al. 2007b), Baptista et al. (1996), Dhillon et al. (2013), and Tommissan et al. (2014) proposed an extended hot spot as the predominant source of emission lines from the optically and physically thick disc. However, such interpretation is challenged by Rodríguez-Gil et al. (2007, 2015). A search for non-eclipsing SW Sex in the 3-4 h period range revealed systems with two-component emission lines (Rodríguez-Gil et al. 2007a), but they were inconclusive whether these are low-inclination SW Sex objects. Conversely, two-component emission lines recently have been observed, in a couple of the UX UMa-type NLs (which are the primary concern of this paper). For example, Hernandez et al. (2017), based on high-resolution spectroscopy, demonstrated that NLs RW Sex and RXS J064434.5+334451 show at least two components in the profiles of the Balmer emission lines. The narrow component with a low radial-velocity amplitude originates from the irradiated surface of the primary, while the secondary facing the disc. The wide component is formed in an extended, low-velocity region in the outskirts of the opposite side of the accretion disc, with respect to the collision point of the accretion stream and the disc. Recently, Subeckova et al. (2020) claim, that this property is observed in RW Tri. They compiled a current list of similar NLs with orbital periods ≥4 hours. At least four of them, the components of Hz emission closely resemble those seen in RW Sex.
in all cases. The pixel-wavelength correspondence for each target spectrum was obtained by interpolating between the two nearest arc spectra. The preliminary reduction steps for all low-resolution spectra were performed with the standard packages for long-slit spectra within IRAF\footnote{IRAF is distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.}, while wavelength calibration and most of the subsequent analyses made use of Tom Marsh’s MOLLY\footnote{MOLLY is available at Tom Marsh’ web page: http://deneb.astro.warwick.ac.uk/phsaap/software/} package.

No flux calibration is available for the low-resolution spectra, hence we present in Figure 2 normalized spectrum obtained by combining data at different epochs with different telescopes/instruments. The low-resolution spectra failed to reveal significant radial velocity (RV) variation.

The overall spectral behaviour of BG Tri does not change significantly from epoch to epoch. The spectra indicate a steep blue continuum with Balmer lines showing emission features embedded in broader absorption lines. The higher members of the Balmer series appear to have more intense absorption, while towards the lowest numbers the emission component dominates. Helium lines are also present in the spectrum. The neutral helium lines have complex profiles, especially at $\lambda 4447$ Å. Also visible are He II and Ca II lines. The spectra are typical of NL variables with an optically thick disc and low inclination.

2.2.2 High-resolution spectroscopy

The high-resolution observations were obtained with the echelle REOSC spectrograph (Levine & Chakrabarty 1995), attached to the 2.1m Telescope of the Observatorio Astronómico Nacional at San Pedro Mártir, during several nights of 2017 and 2018. The CCD 2048 × 2048 detector was used to obtain a spectral resolution of $R \sim 18,000$. All observations were carried out with the 300 l mm$^{-1}$ cross-dispersor, which has a blaze angle at around 5500 Å. The spectral coverage was about 3600–7300 Å. The exposure time for each spectrum was 1200 s. Th-Ar lamp was used for wavelength calibration. The spectra were reduced using the echelle package in IRAF. Standard procedures, including bias subtraction, cosmic-ray removal, and wavelength calibration, were carried out. No flat-field correction and flux calibration was attempted; instead, the normalised spectra were used for measurements and visualisation. The log of all spectroscopic observations is shown in Table 1.

3 THE PHENOMENOLOGY OF BG TRI

Khruslov (2008) in a discovery note, points out that BG Tri is a variable star, probably a CV. Presented here, the long term light curve and spectra leave no doubt that the first assessment was correct. However, CVs comprised of a WD and a late red or brown dwarf secondary stars come in different flavours depending on their orbital periods (or separation), mass accretion rate, and strength of the magnetic field of the WD. Absence of nova or dwarf nova outbursts in a period of time over 5000 days indicates that this is an NL variable. Moreover, an anti-dwarf nova occurrence registered in the light curve is another characteristic of bright NLs, which occasionally undergo a fall in brightness by more than one magnitude (Warner 1995).

Low-resolution spectra confirm the CV identification of BG Tri, which exhibits a standard set of hydrogen and helium lines, with
higher numbers of the Balmer series showing wide absorptions with embedded, relatively narrow emissions. In Figure 2, an averaged and combined spectrum obtained at different epochs is plotted. All significant spectral features are marked. A combination of emission and absorption features of Balmer lines usually occurs either in dwarf novae near period minimum where the WD becomes dominant, or, in NLs with optically thick discs.

Using the *Gaia* distance $d=334(8)$ pc to BG Tri, we calculate the absolute magnitude of the object $M_V = 4.26$. Such high luminosity enlists BG Tri among the brightest CVs, making it only the second after the infamous RW Sex (Hewitt et al. 2020). The derived absolute magnitude is consistent with the low inclination angle (Warner 1986, 1987). We will detail spectral energy distribution (SED) and luminosity of the accretion disc further in the paper. Nevertheless, based
only on the derived absolute magnitude, we can state that this object is not a low accretion rate WZ Sge type, near the period minimum.

In NLs, the bulk of the accretion disc is optically thick (hot and dense), producing absorption lines. The emission lines are formed either in the separate parts of the disc or by the gas in its vicinity (Warner 1976; Beuermann et al. 1992). Figure 3 displays a set of H and He line profiles from averaged, and normalised high-resolution echelle spectra (with low-resolution profiles in the background), illustrating the composition of lines. In the averaged spectra, the emission profile of the Balmer lines is rather symmetric. The absorption is much wider, visually slightly blue-shifted in regard to the emission peak. Measuring this shift in spectra not corrected for the instrumental sensitivity is complicated since the continuum is not well defined.

H$_r$ looks like it has a P Cyg profile with a blue-shifted absorption from a material rapidly expanding in the direction of the observer. However, it is just a contrast effect, particularly in the case of the low-resolution spectra. The emission feature is the strongest among the Balmer lines, hence the symmetry of the underlying absorption line is visually distorted. However, the composition of the line is similar to the rest of the Balmer lines; an emission peak is embedded in a wider absorption line. Helium lines show a more complicated structure comparison with Balmer lines, discussed below.

In general, BG Tri's spectrum looks like a replica of RW Sex (Hernandez et al. 2017) or IPHASX J210204.7+471015 (Guerrero et al. 2018). Hence, our approach to interpreting BG Tri builds on the assumption that it is a low inclination NL system.

4 RADIAL VELOCITIES AND PERIOD DETERMINATION

Low-resolution spectra did not provide information on the orbital motion of emission lines. This supports our assumption of a low orbital inclination. Hence, we obtained higher resolution echelle spectra to reveal the orbital period of the object. Fitting H$_r$ emission with a single Gaussian produced a large scatter but no definite periodic pattern. However, measuring H/$\beta$ with a single Gaussian produced a time series which allowed us to determine a possible period and its closest one-day alias. The power spectrum calculated using a discrete Fourier transformation provided by Period 04 (Lenz & Breger 2014, 2005) indicated that the orbital frequency was either $~5.3$ cycles-per-day (c/d) or $~6.3$ c/d (see the bottom panel of Figure 4). It was clear that the complications related to the period determination were due to lines that are composed of two or more components, as evident from the study of similar objects (Hernandez et al. 2017; Guerrero et al. 2018).

Now that we have an estimate of the orbital period, we further improve the obtained result by measuring individual components of the lines. In the high-resolution spectra, the H$_r$ line is the strongest feature. It is also the least affected by the absorption accompanying all H emission lines. In general, it looks like one peak line, but with variable wings. We applied line de-blending splot-procedure in IRAF to separate the line into components. We fit the profile with two Gaussians with unrestricted parameters. The details of the method are provided in Tovmssian et al. (2018).

We seek a periodic sinusoidal pattern in the RV/time-space by eye, and assign measurements of RVs to one or more component(s), in all cases when they are clearly distinct. Sometimes just one component stands out. We determine a more accurate orbital period by subjecting the first emerging periodic pattern to the Fourier analysis. Period-04 was used to determine the best choice of the orbital period. We refine RVs by fitting a sin-curve to the measurements of the better-defined component and perform another round of deblending, by fixing the central wavelength of this component. As a result, we improve the determination of the second component, which can be used to measure the orbital period. The difference in values of the orbital period from two components is rather small. The higher velocity amplitude component (HVC) power spectrum peaks at 6.3.114 c/d, while the lower velocity amplitude component (LVC) has a frequency of 6.33794 c/d. The spread of measurements remains high. The residuals (RMS) of the fit of HVC are 36 km s$^{-1}$ with the amplitude of variation 121 km s$^{-1}$. The LVC has an amplitude of 78 km s$^{-1}$ and RMS of 25 km s$^{-1}$. They reconcile better at the period determined from the HVC, which we adopted as the orbital period of $P_{\text{orb}} = 3.8028(24)$ h $= 0.15845(10)$ d. The power spectra obtained from RVs of H/$\beta$ and two components of H$_r$ are presented in Figure 4. Obviously, the power of H/$\beta$ as a whole is much smaller than the power of separate components of H$_r$, but they all are consistent with one another.

The RV curves of H/$\beta$ and H$_r$ components along the measurements folded with the determined orbital period are presented in the two middle panels of Figure 5, respectively. We assigned phase zero at the negative to positive crossing of the LVC. Plots are flanked by trailed spectra of corresponding lines on both sides. In the upper panel of Figure 6 Gaussian profiles of individual components, their sum, and the observed line profiles in four different orbital phases are presented to illustrate the result of the separation of the line into two components. Residual spectra of individual components, as well as residuals after subtraction of both components, are displayed in the bottom panel. H/$\beta$ is probably also multi-component, but dismantling it into components is rather difficult. There is a stronger absorption
Figure 5. RV curves of Hβ and components of Hα folded with the orbital period are in the left and right panels respectively. RV of Hβ line was first measured by fitting a single Gaussian, which enabled determination of the orbital period. Hα was separated into two components; by fitting two Gaussians (see the text for the description). The RV measurements corresponding to the high-velocity component of Hα are marked by red symbols and the fit to them with 121 km s$^{-1}$ semi-amplitude as a red line. Respectively, the low-velocity component is plotted in blue. The semi-amplitude of the best fit curve is 74 km s$^{-1}$.

Figure 6. The line profile phase-evolution of Hα. Four orbital phases (marked in the upper right corner of each panel) are displayed. In the upper panels the grey line are the observed spectra. Two Gaussians obtained as a result of de-blending are plotted by red and blue curves. Their sum is plotted by a black line as a fit to the observed profile. In the bottom panels by the red and blue lines the residuals of subtraction of the counterpart Gaussian are plotted, while the gray line is after subtraction of both Gaussians.

undermining the wings of the emission components. One component (the HVC) dominates, as evident from Figure 5. The amplitude of fitted sin$^2$-curve to single-Gaussian measurements of the line is only 24 km s$^{-1}$, decreasing to 22 km s$^{-1}$ if the adopted 0.15845 d period is used to fit the data. The RMS is 16 km s$^{-1}$.

Armed with a set of two components comprising Hα, we may try to figure out their origin. We compare our spectroscopic observation with a small sample of similar objects published recently (Hernández Santisteban et al. 2017; Hernandez et al. 2017), which show similar two-component emission lines. RW Sex and 1RXS J064434.5+334451 (Hernandez et al. 2017) and RW Tri (Subebekova et al. 2020) were all observed with the same instrumental settings as BG Tri, so the measurements are uniform, and the comparison is straightforward. All three objects show two distinct components varying with the respective orbital periods in almost counter-phase, relative to one another. One component is usually wider. Another, the narrow one, is firmly linked to the irradiated face of the secondary by two eclipsing objects in the sample, for which the zero phases were known precisely. The wide component is also regularly the higher velocity component in other NLs. In case of BG Tri, the difference in widths of components is insignificant, but still, the HVC is slightly broader than LVC (average FWHM = 5.7(8) Å vs 5.3(4) Å, respectively).

Assuming that the secondary star emits the LVC, in analogy with the above-mentioned NLs (Hernandez et al. 2017; Subebekova et al. 2020), we determine the orbital phase zero ($\phi = 0$) of the system as the moment when the RV of LVC changes sign from negative to positive, i.e. when the secondary star is in the inferior conjunction. In which case, the ephemeris of BG Tri can be expressed as

$$HJD_{\phi=0} = 2458053.45490(60) + (t_115845(10) \times E).$$  \hspace{1cm} (1)

All phases used in this paper were calculated with this ephemeris.

4.1 Doppler tomography

A customary way to illustrate the emission line behaviour is via trailed spectra and Doppler tomography (Marsh & Horne 1988). It is worth mentioning that the Doppler tomography works best if the emitting particles are in the orbital plane, and the inclination of the system’s orbital plane is high (Marsh 2005). In order to construct trailed spectra and Doppler maps, we used the phase zero as defined above, stemming from the assumption that the LVC is the component originating from the irradiated face of the secondary. With this premise, the Doppler tomograms presented in Figures 7 and 8
were constructed (Spruit 1998). Echelle high-resolution spectra were used for this purpose. The Doppler map of the Hα line without separation into two components was calculated, but is not presented here because it is less informative. Tomograms of unaltered lines were presented by Hernandez et al. (2017); Guerrero et al. (2018). Instead, we split the Hα line into components, as demonstrated in the bottom panel of Figure 6, and made a tomogram of each component separately.

In the bottom panels of Figure 7 trailed spectra (and their reconstructed counterparts) of Hα’s HVC and LVC are presented side by side. Together, they form the trailed spectra of Hα shown at the right side of Figure 5. Meanwhile, in the upper panels, the velocity maps resulting from the Doppler tomography are shown. Locations of the stellar components are marked by “×”, the centre of the masses by “+”. The Roche lobe of the secondary star and the ballistic trajectory of mass transfer flow are over-plotted, as well as a ring corresponding to the outer radius of the disc. To calculate them, we selected the mass of the WD, $M_{WD} = 0.8 M_\odot$, and the mass ratio, $q = 0.4$ as statistically average values for a $P_{\text{orb}} = 3.8\,h$ nova-like CV (Knigge et al. 2011; Zorotovic et al. 2011). The orbital inclination angle was fixed at $i = 25^\circ$ (see Section 5 for justification of these parameters).

The LVC produces a spot converging with the position of the secondary in the velocity map. Apparently, this is a result of our phase allocation. Usually, when the irradiated secondary star forms the emission, the line is narrower (3.8 Å in the eclipsing RW Tri (Subebekova et al. 2020) against 5.3 Å in BG Tri), and the compact spot is concentrated at the hemisphere facing the WD. The reason for such a diffuse spot is not clear, but a low orbital inclination of the system probably contributes to it. Meanwhile, the HVC produces another diffuse and elongated concentration (upper left panel), at a region which is clearly evading identification with either the stellar component of the binary, the accretion disc, or the mass transfer stream; including impact area of the stream with the disc. Detection of this Hα component and its corresponding location in the velocity maps has become common for RW Sex-type NLs. Among a few possible explanations cited by Hernandez et al. (2017) and Subebekova et al. (2020), we prefer the model in which the outflow from the disc takes places in the orbital plane, instead of the wind perpendicular to the plane direction. Three-dimensional numerical simulations of the gas dynamics show that such outflows are viable through the vicinity of the Lagrange L₃ point (Sytov et al. 2007). BG Tri provides a good argument in favour of this hypothesis: firstly, the object shows meagre emission from He I line, even though we observe it almost face-on, hence it is difficult to argue that a disc wind is significant enough to produce an intense enough emission spectrum (e.g. Matthews et al. 2015) to overcome the bright accretion disc. Generally, P Cygni-like profiles for NLs are observed in UV, and quite successfully modelled for recombination emission (Long & Knigge 2002), where the lines of low inclination systems exhibit the characteristic imprint. However, reproducing it in the optical range is a challenging task; it produces some double-peaked emission line contribution only in a high inclination ($i > 60^\circ$) systems. Matthews (2016) attempted to

![Figure 7](image-url)}
We revised the available data, since some indicate a simple accretion disc spectrum as a \( \lambda \text{He} \) \( L \) (Subebekova et al.\(^8\)). For simplicity, we adopted \( M_{\text{WD}} = 0.8 M_{\odot} \). Taking into account the semi-empiric relation of secondary vs orbital period, we expect a secondary with a mass of \( M_2 \approx 0.3 M_{\odot} \), and spectral type of M3V-M4V (Knigge 2006). The expected mass ratio and separations are \( q \equiv M_2/M_{\text{WD}} \approx 0.4 \) and \( a = 1.23 R_{\odot} \), respectively. The accretion disc truncation radius\(^4\) is \( r_{\text{disc}}^{\text{out}} = 0.52 R_{\odot} \). Corresponding primary, secondary, and \( L_1 \) orbital velocities are 117 km s\(^{-1}\), 292 km s\(^{-1}\), and 129 km s\(^{-1}\), respectively (see Figure 9).

There are numerous flux measurements of BW Tri available in the public domain. We fetched all available data from VizieR\(^5\) (Ochsenbein et al. 2000). We revised the available data, since some measurements are erroneous (e.g. the SDSS data are not correct because the object is too bright), and compiled those which passed the scrutiny in Table 2. Selected data are plotted using circles in the bottom panel of Figure 9, after the interstellar reddening correction of \( E(B-V) = 0.03 \) (Green et al. 2015). Using the \textit{Gaia} distance of \( d = 334(8) \) pc, we can calculate the luminosity of different components. In particular, even a hot 50 kK white dwarf will have a negligible contribution to the optical flux. A secondary M3-4.5 V Roche lobe filling star has some insignificant influence in the IR. The comparison of the observed fluxes with those expected from different components confirms that the flux in the entire wavelength range is formed mostly by the accretion disc. The dashed lines in the bottom panel of Figure 10 indicate a simple accretion disc spectrum as a composition of multiple black-bodies; from concentric rings with a corresponding distribution of temperatures throughout the stationary, optically thick disc (La Dous 1989). Since the observed flux would depend on the aspect of the disc, we fitted the observed SED as a function of the mass transfer rate \( M \), and the system inclination.

The UV points were excluded from consideration because it is well known that accretion disc models do not reproduce the observed spectrum shape of BW Tri in the wide range including the UV (Puebla et al. 2007).

For the fit’s robustness, we added a spectrum of M3V-type stars from the empirical template library of the Sloan Digital Sky Survey

\( ^4 \) equation 2.61 from Warner (1995)  
\( ^5 \) http://vizier.unistra.fr/vizier/sed/
stellar spectra (Kesseli et al. 2017), which was extended to the IR range using spectral templates from Rayner et al. (2009). The star spectrum was scaled to the object’s distance. For each band listed in Table 2 (except FUV and NUV) the flux $m_{\text{calc}}$ was calculated as a sum of the disc model and the secondary. The result of the best fit of function $\chi^2 = \Sigma(m_{\text{obs}} - m_{\text{calc}})/\Delta m_{\text{obs}}$ is presented as a long dashed line in the lower panel of Figure 10. In the upper panel of Figure 10, the goodness-of-fit is presented as an intensity scale diagram. Following the assumption that the LVC is emitted from the heated hemisphere of the companion star, the expected LVC velocity is located in the range of $v_{\text{LVC}} \in [130 \sin(i), 290 \sin(i) \text{ km s}^{-1}]$ (see Figure 9), which allow us to estimate limits on the orbit inclination from the dynamical constrains. The observed value of LVC is $78 \text{ km s}^{-1}$, which defines the limits marked by the vertical dashed lines in Figure 10, top. The line at the right side of the plot indicates the observed LVC, which is consistent with the L1 point, and another corresponds to the center of mass of the secondary (at the left side). In other words, the inclination angle and mass accretion rate would be highest if the LVC is emitted just from the L1 point, and accordingly, lowest if the entire surface of the secondary is heated. Of course, neither assumption is correct, so we introduced some parameter which reflects the increasing cross-section of the secondary, with decreasing temperature. According to which, the best fit is achieved at $i = 25(5)$ degree and $M = 8.0(1.0) \times 10^{-9} \text{M}_\odot \text{ year}^{-1}$.

Given all uncertainties of adopted assumptions, the fit is remarkably good. The values of mass accretion rate are within the range of estimates for a number of other NLs (e.g. Figure 2 of Hameury 2019). The mass transfer $M$ depends slightly on the mass of the WD. For a $0.6 \text{M}_\odot$ WD, the mass transfer rate increases to $10^{-8} \text{M}_\odot \text{ year}^{-1}$. On the down side, $M$ is $\sim 4.0 \times 10^{-9} \text{M}_\odot \text{ year}^{-1}$ for a massive $\geq 1.0 \text{M}_\odot$ WD.

The LVC velocity corrected for a system inclination of $i = 25^\circ$ is $v_{\text{LVC}} = 185 \text{ km s}^{-1}$. As we showed earlier, the corrected HVC velocity is $\approx 300 \text{ km s}^{-1}$, it corresponds to the orbital velocity at the edge of the disc on the opposing side of the system relative to the secondary. The location of the HVC on Doppler maps of all similar NLs is related to the Lagrangean L1 point. According to some hydrodynamic models (Sytov et al. 2007; Lukin et al. 2017) an outflow of matter from the disc in to the orbital plane takes place from this area (marked green area in Figure 9). The concentration of gas in that area might be responsible for HVC or wide component of emission lines in these objects.

6 CONCLUSIONS
We studied BG Tri, one of the brightest CVs at $V = 11.9$, which somehow escaped attention until now. We determined its orbital period to be 0.15845 d or 3.8028 h. We show that it is a NL system, identified by its characteristic blue spectrum containing a set of H$\alpha$ and H$\beta$ lines, comprised of wide absorption features containing strong emission peaks. The orbital period and the spectrum, combined with the SED, indicate the presence of a bright accretion disc in a high density and temperature state, proper to NLs. The long term
Figure 10. The plot of spectral energy distribution of BG Tri in the bottom panel. Circles represent the fluxes from Table 2. They were corrected for the interstellar extinction E(B − V)=0.03. The dashed line through the observed data in the optical-IR range represents the spectrum of accretion disc. The red points represent a spectrum of a M3V star scaled to a 337 pc distance. The solid line is a combination of fluxes from the accretion disc and the secondary. The outermost left two points correspond to UV data. In the upper panel the best fit parameters (mass accretion rate vs. inclination angle) of the accretion disc model to the data are presented in the form of intensity map. The extreme boundaries of i corresponding to the secondary mass center and I1 point are marked by vertical lines. Preferred values of M and i (blue strip) are also function of increasing surface and decreasing temperature along latitude.

Table 2. VizieR photometric data of BG Tri

| λ (μm) | Flux (×10^3 Jy) | 1σ Flux ×10^-3 | Band | Source | Ref. |
|--------|----------------|----------------|------|--------|------|
| 0.153  | 32.1           | 0.2            | FUV  | GALEX  | 1    |
| 0.231  | 19.3           | 0.1            | NUV  | GALEX  | 1    |
| 0.444  | 64.2           | 11.6           | B    | AVSO   | 2    |
| 0.477  | 79.0           | g              | PAN-STARRS | 3     |
| 0.482  | 64.6           | 9.3            | g'   | AVSO   | 2    |
| 0.502  | 65.7           | 0.9            | Gbp  | GAI2   | 4    |
| 0.554  | 64.1           | 9.6            | V    | AVSO   | 2    |
| 0.613  | 63.2           | r              | PAN-STARRS | 3     |
| 0.623  | 58.9           | 0.3            | G    | GAI2   | 4    |
| 0.625  | 58.7           | 7.7            | r'   | AVSO   | 2    |
| 0.748  | 51.6           | i              | PAN-STARRS | 3     |
| 0.763  | 51.5           | 7.6            | i'   | AVSO   | 2    |
| 0.772  | 49.6           | 0.7            | Gr p | GAI2   | 4    |
| 0.865  | 44.2           | z              | PAN-STARRS | 3     |
| 0.960  | 36.5           | 0.8            | y    | PAN-STARRS: | 3     |
| 1.24   | 29.9           | 0.6            | J    | 2MASS  | 5    |
| 1.65   | 20.6           | 0.4            | H    | 2MASS  | 5    |
| 2.16   | 14.0           | 0.2            | Ks   | 2MASS  | 5    |
| 3.35   | 6.85           | 0.15           | W1   | WISE   | 6    |
| 4.60   | 4.19           | 0.08           | W2   | WISE   | 6    |
| 1.16   | 0.89           | 0.09           | W3   | WISE   | 6    |

1 - Bianchi et al. (2017)  
2 - Henden et al. (2015)  
3 - Chambers et al. (2016)  
4 - Gaia Collaboration et al. (2018)  
5 - Cutri et al. (2003)  
6 - Cutri & et al. (2012)

light curve of BG Tri, obtained by ASAS SN and CRTS sky surveys, shows the absence of dwarf nova style outbursts, but reveals an instance of low luminosity state often detected in NLs, also known as the VY ScI phenomenon.

Absorption lines originate from the optically thick accretion disc, while emission forms elsewhere. We demonstrate that the Balmer emission lines are complex and we are able to separate Hα into two components. We identify the LVC with the heated surface of the secondary star facing the luminous disc. We associate the HVC with the disc outflow region situated on the opposite from the secondary and the hot-spot, side of the disc. A similar occurrence is also common for mentioned NLs, which we may call RWSx type systems, all of which are concentrated in a 3-6h range of orbital periods (Subebekova et al. 2020). An HVC velocity, corrected for the inclination angle, of ~300 km sec⁻¹, is very definite in all studied objects, regardless of their orientation. That, in our opinion, argues against the disc wind origin of the HVC component. However, it is not evidence of the absence of wind, just a rationalisation that emission lines in the optical range are not formed in the wind.

The SED of BG Tri confirms that stellar components contribution is negligible and that most of the flux from UV to near-IR is emitted by the disc. The energy balance favours that we observe the system nearly face-on, and the deduced inclination angle validates the value fetched from the dynamical considerations.

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DATA AVAILABILITY

The data underlying this article will be shared on reasonable request to the corresponding author.

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