SRGe J214919.3+673634—a Candidate for AM Her Variables Discovered by the eROSITA Telescope onboard the Spectrum–Roentgen–Gamma Orbital Observatory

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Abstract—We present the results of the optical identification, classification, and analysis of our photometric and spectroscopic observations of the X-ray transient SRGe J214919.3+673634 discovered by the eROSITA telescope onboard the Spectrum–Roentgen–Gamma orbital observatory in the summer of 2021 during the fourth sky survey. The photometric observations of the optical counterpart of SRGe J214919.3+673634 performed at the 6-m BTA telescope of SAO RAS, the 1.5-m Russian–Turkish telescope RTT-150, and the 2.5-m telescope of CMO SAI MSU as well as the archival data from the 48-inch ZTF telescope have shown that the source is a cataclysmic variable with an orbital period \( P = 8.5 \pm 0.4 \) min and exhibits a long-term photometric variability from \( 23.5 \) m (low state) to \( 20 \) m (high state). We show that the light curves in the high state are consistent with the model of an accreting magnetized white dwarf and suggest that SRGe J214919.3+673634 belongs to the AM Her variables. The spectra of the optical counterpart taken in the low state at BTA are consistent with the spectral energy distribution of a white dwarf with a temperature \( \sim 24000 \) K.

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INTRODUCTION

The SRG X-ray observatory (Sunyaev et al. 2021) launched on July 13, 2019, successfully operates in an orbit around the Lagrange point L\(_2\) of the Sun–Earth system. The main goal of the observatory is an all-sky survey in a wide energy range, 0.3–30 keV. Four full sky surveys had been completed by mid-December 2021. The observatory incorporates two X-ray telescopes with grazing-incidence optics: SRG/eROSITA operating in the 0.3–10 keV energy band (Predehl et al. 2020) and Mikhail Pavlinsky SRG/ART-XC operating in the 5–30 keV energy band (Pavlinsky et al. 2021). As a result of the four sky surveys, SRG/eROSITA detected more than two million X-ray sources in the half of the sky for the data processing in which the Russian Scientists are responsible. The overwhelming majority of the detected sources are active galactic nuclei (AGNs) and quasars. Apart from the persistent sources detected in all four scans, in the period from 2019 to 2022 SRG/eROSITA also detected variable X-ray sources the flux from which changed by more than a factor of 7
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between the scans or they were detected only in one of the scans. The tidal disruption events in the vicinity of AGNs discovered by SRG/eROSITA are among such variable sources (Sazonov et al. 2021).

In several cases, as a result of their optical observations, the variable X-ray sources were identified with cataclysmic variable stars discovered in the period of their X-ray brightening. SRGe J214919.3+673634 being studied here is among such sources. SRGe J214919.3+673634 was discovered in the fourth SRG/eROSITA scan in July 2021. According to the archival data from the CatWISE2020 Catalog (Marocco et al. 2021), there is an infrared source, J214918.91+673633.3, in the 98% SRG/eROSITA X-ray position error circle of radius $R_{98} = 5.5''$. On July 12, 2021, the ZTF survey (Masci et al. 2018) revealed a candidate for optical transients, ZTF21ablohh, with RA = 327.32858° and DEC = +67.609050° at a distance of 0.3'' from the infrared source. This transient had an apparent magnitude $r = 20.1 \pm 0.2$.

The search photometry performed at BTA in the SDSS $i$ filter revealed an optical counterpart coincident in position with ZTF21ablohh in the position error circle. Figure 1 shows the position of the source found. The source’s brightness clearly changed between the neighboring exposures. Long photometric series showing signatures of photometric variability typical for cataclysmic variables were obtained at RTT-150. To determine the parameters of this optical candidate SRGe J214919.3+673634 (hereafter designated as SRGe J214919.3+673634 for short), we carried out a series of photometric and spectroscopic observations at the 1.5-m telescope RTT-150, the 2.5-m telescope of the Caucasus Mountain Observatory (CMO) of SAO MSU, and the 6-m BTA telescope of SAO RAS. The results of these observations are analyzed in this paper.

Cataclysmic variables are close binary systems consisting of an accreting white dwarf (primary component) and a main-sequence star (secondary component) filling its Roche lobe and losing material through the vicinity of the Lagrange point L1 (Warner 1995). The orbital periods of these systems lie in the range from $\approx 82$ min (Knigge et al. 2011) to several hours.

**Fig. 1.** The image of the source’s vicinity in the $i$ filter obtained by averaging the RTT-150 images. The blue circle of radius $5.5''$ indicates the 98% position error circle of the X-ray source. The center of the circle corresponds to the position of the X-ray source with RA = 327.33046° and DEC = +67.60941°. The arrow indicates the probable optical counterpart with coordinates RA = 327.32866° and DEC = +67.60914° for the epoch J2000. The red circles mark the comparison stars used during our photometry.
Accretion in cataclysmic variables depends on the white dwarf magnetic field strength. An accretion disk is formed in systems with weak white dwarf magnetization ($B \lesssim 0.1$ MG). Many of the representatives of such systems exhibit periodic outbursts with an amplitude $\Delta V = 2-6''$ and are called dwarf novae. The outbursts occur due to the thermal accretion disk instability arising at low accretion rates ($\dot{M} \lesssim 10^{-9} M_\odot$ yr$^{-1}$). The outbursts of dwarf novae last from several days to several months and can recur on time scales from weeks to decades. Nova-like stars that exhibit no outburst activity are another type of cataclysmic variables. These systems are believed to have a high accretion rate ($\dot{M} \gtrsim 10^{-9} M_\odot$ yr$^{-1}$) at which the disk is stable. AM CVn stars with degenerate donors (Solheim 2010) are related to cataclysmic variables. They are characterized by short orbital periods ($P_{\text{orb}} = 5-65$ min) and the absence of hydrogen lines in their optical spectra.

In the case of strong white dwarf magnetization ($B \sim 10-200$ MG), no accretion disk is formed. The ionized gas of the accretion stream rapidly reaches the Alfvén radius and, having no time to turn around the white dwarf, flows along magnetic field lines toward the magnetic poles. The systems of this type are called AM Her variables or polars. A strong magnetic field in polars causes the white dwarf spin to be synchronized with the orbital motion ($P_{\text{spin}} = P_{\text{orb}}$). The material falling to the accretor forms hot ($T \sim 10-50$ keV) accretion spots on the white dwarf surface that are the sources of X-ray emission and optical cyclotron emission. For a more detailed introduction to AM Her systems, see the review by Cropper (1990). Systems with weaker white dwarf magnetic fields ($B \sim 0.1-10$ MG) are classified as DQ Her ones or intermediate polars (Patterson 1994). Accretion disks that are destroyed by the white dwarf magnetic field from the inside can be formed in them. In contrast to polars, there is no synchronization of the spin and orbital motion of the white dwarf in intermediate polars (the average spin-to-orbital period ratio is $P_{\text{spin}}/P_{\text{orb}} \approx 0.1$).

**SRG/eROSITA X-RAY OBSERVATIONS**

The source SRGe J214919.3+673634 was discovered by SRG/eROSITA in the fourth sky survey and was observed in scans in the period from July 16 to 19, 2021. The X-ray coordinates of the source are RA = 327.33046° and DEC = 67.60941°; the positional error of the X-ray source is $R_{98} = 5.5''$. In the fourth survey 44 X-ray photons were recorded from the source in the 0.3–2.2 keV energy band. The mean flux from the source in the fourth survey is $(11.2 \pm 2) \times 10^{-14}$ erg s$^{-1}$ cm$^{-2}$. Interestingly, eROSITA observed the source’s region only four days after its bright optical outburst ZTF21ablobhh and discovered a bright source already in the X-ray band at this location.

The source was not detected in the previous SRG/eROSITA sky surveys. The upper limit from the sum of the three previous eROSITA surveys is $0.6 \times 10^{-14}$ erg s$^{-1}$ cm$^{-2}$ (0.3–2.2 keV). The upper limit on the X-ray flux in the third sky survey is $1.4 \times 10^{-14}$ erg s$^{-1}$ cm$^{-2}$. Thus, the source became brighter in X-rays by more than a factor of 8 between the third and fourth surveys. Such a significant semiannual variability allows one to assign the source to the eROSITA sample of X-ray transients and to carry out more detailed multiwavelength studies of the source for its classification.

**OBSERVATIONS AND DATA REDUCTION**

**Photometry**

Within our research on the optical identification of SRGs J214919.3+673634, the first images were obtained in the SDSS $i$ filter at the 6-m BTA telescope of SAO RAS using the multimode SCORPIO-2 focal reducer (Afanasiev and Moiseev 2011) on October 10, 2021. The E2V CCD261-84 detector in the 2 $\times$ 2 binning mode provided a 6.8' field of view with discreteness of 0.4'' per pixel. Six exposures with a duration of 15 s were taken. An optical counterpart whose brightness changed from 23 to 21 mag was discovered within R98. To understand the nature of the source, we decided to obtain long-term photometry and to perform spectroscopy for the source.

The photometric observations of SRGs 2149 were carried out at the 1.5-m Russian–Turkish telescope RTT-150 (Turkish TÜBITAK National Observatory) from October 14 to November 16, 2021, and on October 2–4, 2022. The TFOSC instrument and the SDSS $i$ filter were used. The detector was an Andor iKon-L 936 BEX2-DD-9ZQ 2048 $\times$ 2048 pixel CCD camera. The seeing was 1.5''–2'' in different observing periods; therefore, the observations with $2 \times 2$ binning and an image scale of 0.65 arcsec/pixel were used. Additional photometric observations were performed on November 5, 2021, at the 2.5-m telescope of CMO SAI MSU in the SDSS $r$ band simultaneously with the spectroscopic observations at the 6-m BTA telescope. The measurements were carried out with the liquid-nitrogen-cooled NBI CCD photometer1 (with a 4096 $\times$ 4096 pixel chip and an image scale of 0.155 arcsec/pixel) mounted at the Cassegrain focus of the telescope. The object was

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1 More detailed information about the detector is accessible at https://obs.sai.msu.ru/cmo/sai25/wh/.
Table 1. Log of photometric observations of SRGe J214919.3+673634

| Telescope | Date            | Observing period, HJD-2459000 | \(N\) | Filter | \(\Delta t_{\text{exp}}, \text{s}\) | \(\Delta T, \text{h}\) | \(\langle m \rangle, \text{m}\) |
|-----------|----------------|--------------------------------|-------|--------|----------------|----------------|----------------|
| RTT-150   | Oct. 14/15, 2021 | 502.32845–502.43391            | 19    | \(i\)  | 300            | 2.5            | 21.6           |
| RTT-150   | Oct. 18/19, 2021 | 506.36633–506.47173            | 28    | \(i\)  | 300            | 2.4            | 21.8           |
| RTT-150   | Oct. 19/20, 2021 | 507.21642–507.53612            | 60    | \(i\)  | 300            | 8              | 21.9           |
| RTT-150   | Oct. 20/21, 2021 | 508.21643–508.63550            | 111   | \(i\)  | 300            | 10.6           | 22.1           |
| RTT-150   | Oct. 28/29, 2021 | 516.23887–516.29336            | 14    | \(i\)  | 180, 300       | 1.7            | 22.8           |
| RTT-150   | Nov. 5/6, 2021   | 524.20206–524.22764            | 4     | \(i\)  | 600            | 0.7            | 23.7           |
| RTT-150   | Nov. 5/6, 2021   | 524.23487–524.36515            | 19    | C      | 600            | 3.1            | 23.7           |
| 2.5-m CMO | Nov. 5/6, 2021   | 524.23724–524.34754            | 22    | \(r\)  | 300            | 3              | 23.5           |
| RTT-150   | Nov. 16/17, 2021 | 535.22147–535.26842            | 7     | C      | 600            | 1.1            | 23.2           |
| RTT-150   | Oct. 2/3, 2022   | 855.31460–855.35774            | 12    | \(i\)  | 300            | 1.0            | 21.8           |
| RTT-150   | Oct. 3/4, 2022   | 856.20068–856.33360            | 36    | \(i\)  | 300            | 3.1            | 22.0           |
| RTT-150   | Oct. 4/5, 2022   | 857.32003–857.37078            | 11    | \(i\)  | 300            | 1.2            | 21.9           |

The telescopes and the photometers involved in the observations, the observing nights, the observing period in heliocentric Julian dates, the number of images obtained (\(N\)), the filters used (C— the observations without a filter), the duration of single exposures (\(\Delta t_{\text{exp}}\)), the total duration of the observations in hours (\(\Delta T\)), and the mean magnitude \(\langle m \rangle\) are listed.

The data obtained were reduced using the standard tools of the IRAF package. Bias frames were subtracted from the images, the images were corrected for multiplicative errors based on flat-field frames, and the images were cleaned of cosmic-ray particle hits using the LaCosmic algorithm (van Dokkum 2001). We searched for star-like sources in the images with the DAOFIND algorithm. Aperture photometry for SRGe 2149+6736 was performed using several comparison stars shown in Fig. 1. An analysis of their brightnesses relative to the check star did not reveal their variability over the entire observing period. The choice of an optimal aperture was made by minimizing the standard deviation of the brightness of check stars comparable in brightness to SRGe 2149.

Spectroscopy

The spectroscopic observations of SRGe 2149+6736 were performed at the 6-m BTA telescope of SAO RAS using the multimode SCORPIO-2 focal reducer in the mode of long-slit spectroscopy (Afanasiev and Moiseev 2011). The observations were carried out on the night from November 5 to 6, 2021, in good astroclimatic conditions (seeing ≈1″). A VPHG1200@540 grism and a 1.5″-wide slit, which provide spectra in the range \(\lambda = 3650–7250\ \text{Å} \) with an effective spectral resolution \(\Delta \lambda \approx 6.5\ \text{Å} \), were used to obtain the spectra. The slit length is 6.8′′ for a scale of 0.4 arcsec/pixel. Unfortunately, by the time of our observations of SRGe 2149 at the 6-m telescope its apparent brightness declined to \(i \approx 23.5\text{m} \). A total of five exposures with a total duration of 6000 s were taken.
The data obtained were reduced using the software package in the IDL environment developed at SAO RAS to reduce the long-slit spectra taken with SCORPIO-2. The main reduction steps are described in a number of papers (see, e.g., Egorov and Moiseev 2019). However, in contrast to the standard technique, cosmic-ray particle hits were cleaned on individual frames already after the transformation of the spectra to the wavelength scale and the subtraction of the nightglow spectrum. This technique is determined by the relatively large sizes of cosmic-ray particle hits in the observations with the E2V CCD261-84 detector (Afanasiev et al. 2022).

We performed the spectrophotometric calibration based on the spectrum of the standard star BD+28°4655 observed on the same night before the observations of SRGe 2149 at a close zenith distance. The spectrum of SRGe 2149 was extracted in a rectangular 5′′-wide aperture.

ANALYSIS OF OUR PHOTOMETRY

During the photometric observations the mean brightness of SRGe 2149 underwent big changes. The light curve of SRGe 2149 constructed from all of the RTT-150 observations in 2021 is presented in Fig. 2. It can be seen that in October 14–20, 2021, the mean brightness of the object was \( \langle i \rangle = 21.4 - 21.8 \) m and then dropped to \( \langle i \rangle \approx 23.5 \) m recorded on November 5, 2021. On October 28 SRGe 2149+6736 was observed in an intermediate state with a mean brightness \( \langle i \rangle \approx 22.8 \) m. It can be seen from Table 1 that on October 2–4, 2022, the source was again in a high state with a mean brightness \( \langle i \rangle \approx 21.9 \) m. Apart from the long-term variability, the object exhibits short-period brightness variations on a time scale \( \sim 1 \) h.

The short-period brightness variations in SRGe 2149+6736 were analyzed by the Lomb–Scargle method (VanderPlas 2018). To construct the periodograms, we used the observations obtained when the object was in its high and intermediate brightness states (October 14–28, 2021). The mean brightness level was subtracted from the light curves of individual nights, while the observations with a poor detection were excluded from consideration. An analysis of the variability based on one harmonic \( (\cos(\omega t)) \) gave a significant power peak corresponding to a period \( P \approx 42.5 \) min (Fig. 3). However, a more reliable period is distinguished when using two or more harmonics. Figure 3 presents the Lomb–Scargle periodogram constructed with four harmonics \( (\cos(i\omega t), i = 1, \ldots, 4) \), which provide a satisfactory (within the error limits) description of the phase light curve. The power peak corresponds to \( P = 85.0 \pm 0.4 \) min.

There are also physical constraints suggesting that the last period is true. The first period \( (P \approx \text{...}) \)
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Fig. 3. The upper panel shows the Lomb–Scargle periodograms of SRGe J214919.3+673634 in its high and intermediate brightness states (October 14–28, 2021). The black curve is the power spectrum obtained with one harmonic; the red curve is the power spectrum obtained with four harmonics. The lower panel presents the high-state light curve of SRGe J214919.3+673634 constructed at the phases of the photometric period according to the ephemeris (1). The dashed line is the fit by a trigonometric polynomial with four harmonics.

The period found is close to the limit $P_{\text{min}}$ and, on the other hand, is close to the most probable orbital period of a cataclysmic variable (i.e., corresponds to the peak of the observed distribution of cataclysmic variables (Gänsicke et al. 2009)). The light curve of SRGe 2149+6736 folded with it is presented in Fig. 3. It has a complex shape with two minima differing in shape and depth. The ephemeris of the primary brightness minimum for SRGe 2149+6736 is

$$BJD_{\text{min}} = 2459502.3339(6) + 0.0590(2)E.$$  (1)
Let us consider in more detail the light curve in Fig. 3. The center of the primary minimum located at phase $\varphi = 0$ is narrower ($\Delta \varphi \approx 0.2$) and has a sharp ingress and egress. The secondary minimum located at phase $\varphi \approx 0.5$ is less deep and is distinguished by a smooth ingress and egress. The change of the light curve for SRGe 2149 during our observations is presented in Fig. 4. A decrease in the brightness amplitude with decreasing mean brightness of the object is obvious. The observations on October 14–20 demonstrate the largest amplitude ($\Delta i \approx 1.5–2^m$) at a mean brightness $i \approx 21.7^m$ (Fig. 2). Then, on October 28 the brightness of the star declined by $\approx 1^m$ and the amplitude dropped to $\Delta i \approx 1^m$. In the low brightness state on November 5 the observations of the variability of SRGe 2149+6736 at RTT-150 were possible only without using any photometric filters. No brightness variations are distinguished in the derived light curve and constraints can be imposed on the amplitude, $\Delta m \lesssim 0.5^m$. On the same night SRGe 2149+6736 was observed at the 2.5-m CMO SAI MSU telescope in the SDSS $r$ filter. In contrast to the behavior of the brightness in its high state in the $i$ band, the derived light curve is a single-humped one with an amplitude $\Delta r \approx 0.5^m$. Note that in view of the error in the period found, the November 5 light curves may be shifted in phase by $\Delta \varphi \approx 0.5$.

The high-state light curve of SRGe 2149 resembles the behavior of the brightness of some polars. The polars BS Tri (Kolbin et al. 2022), EP Dra (Schwope, and Mengel 1997), and V379 Vir (Debes et al. 2006) can serve as examples. The brightness minimum in them stems from the fact that the accretion spot goes behind the stellar disk, while during the spot passage across the stellar disk a double-hump maximum is formed. The cyclotron emission is responsible for the double-humped structure of the light curve. Under some physical conditions of the emitting medium its intensity is maximal at angles between the magnetic field line and the line of sight $\theta \sim 90^\circ$ and drops with decreasing $\theta$. A similar scenario is probably realized in SRGe 2149, but it differs from the presented examples by a narrower minimum. The latter can be associated with a smaller inclination of the white dwarf rotation axis to the line of sight and, as a consequence, a shorter duration of the stay of the accretion spot behind the stellar disk (provided that the spot is located near the rotation pole facing the observer). In the low brightness state the accretion rate in the system is probably reduced. This leads to a reduced accretion spot brightness with a corresponding decrease in the brightness amplitude.

Unfortunately, the low brightness of SRGe 2149 in the period of its spectroscopic observations ($i \approx 23.5^m$) did not allow us to obtain data suitable for estimating the system’s parameters (the component masses, the orbital inclination) and the white dwarf magnetic field strength. Knowing these parameters would allow us to model the light curves with the determination of the magnetic dipole orientation and the accretion spot position. In this paper we will restrict ourselves only to the interpretation of the light curve for SRGe 2149 in its high state within the model of an accreting magnetized white dwarf with a dominance of the accretion spot emission in the optical band. To do this, we used the code for computing and fitting the light curves of polars described in Kolbin and...
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Borisov (2020). This code uses a simple white dwarf model with a dipole magnetic field. The accretion spot is assumed to be geometrically thin and to be drawn on the stellar surface by the magnetic field lines crossing the ballistic trajectory of the accretion stream. The accretion spot is deemed uniform in temperature and density. The intensity of its emission is calculated under the assumption of a high Faraday rotation that reduces the calculation of the Stokes parameters to two independent equations for the ordinary and extraordinary waves. The main contribution to the accretion spot emission in the optical band belongs to the cyclotron emission. To calculate its intensity, we used the absorption coefficients calculated by the method of Chanmugam and Dulk (1981). The accretion spot was assumed to be a point-like plane-parallel source, i.e., the spot depth along the line of sight $\ell$ behaves as $\ell \sim 1/\cos \gamma$, where $\gamma$ is the angle between the normal to the stellar surface and the line of sight.

Using the described approach, we modeled the light curve of SRGe 149 obtained on October 20, 2021. To compute the ballistic trajectory, the code of Kolbin and Borisov (2020) requires the binary component masses. The white dwarf mass was assumed to be 0.83 $M_\odot$, i.e., the mean mass of the accretor in cataclysmic systems (Zorotovic et al. 2011). The mass of the secondary component was taken to be 0.07 $M_\odot$ (Knigge et al. 2011). The orbital inclination was fixed at $i = 60^\circ$. The intensity of the cyclotron emission drops rapidly after a frequency $\approx 10\omega_c$, where $\omega_c = eB/m_c$ is the cyclotron frequency (Wada et al. 1980). This makes it possible to impose a constraint on the magnetic field strength $B \gtrsim 10$ MG, since the variability due to the cyclotron emission source is observed in the $i$ band. In our modeling we used the magnetic field strength $B = 20$ MG. The accretion spot temperature was taken to be 20 keV. The plasma parameter $\Lambda = \omega_p^2 H/\omega_c$, where $\omega_p$ is the plasma frequency and $H$ is the spot depth, is also required to calculate the intensity of the spot emission. This parameter was fixed at $\Lambda = 10^3$ typical for polars. The orientation of the magnetic dipole and the position of the stagnation region (i.e.,

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**Fig. 5.** Comparison of the observed (dots with photometric error bars) and theoretical (solid line) light curves of SRGe J214919.3+673634. The light curves are presented in the scale of orbital phases for the model of SRGe J214919.3+673634 ($\phi_{\text{orb}} = 0$ corresponds to the greatest distance of the white dwarf from the observer).

**Fig. 6.** The model of SRGe J214919.3+673634 seen from the observer at two orbital phases. The red line indicates the ballistic trajectory of the accretion stream flowing from the Roche-lobe filling donor. It passes into the magnetic trajectory (blue line) that ends on the white dwarf surface. The orbital phases $\phi_{\text{orb}}$ and the photometric phases $\phi$ at which $\phi = 0$ corresponds to the middle of the primary minimum in the light curve are indicated.
the transition region from the ballistic trajectory to the magnetic one) determining the spot coordinates were found by fitting the light curve by the least-squares method. To minimize $\chi^2$, we used a genetic algorithm (see, e.g., Charbonneau 1980). As a result, we obtained the magnetic dipole orientation parameters $\beta = 22^\circ$ and $\psi = 70^\circ$, where $\beta$ is the inclination of the dipole axis to the rotation axis and $\psi$ is the longitude of the magnetic pole measured from the direction toward the secondary component in the direction of orbital motion. The stagnation region was located at the azimuthal angle $\alpha = 30^\circ$ measured from the direction toward the secondary component. The theoretical light curve is compared with the observed one in Fig. 5. The observations are described with $\chi^2 \approx 11$, while the deviation of $\chi^2$ from unity is due to the variability of the light curve shape during the observations and the possible rapid brightness fluctuations (flickering). The three-dimensional model of the system seen at two orbital phases is presented in Fig. 6. Although the presented model may also be far from the real picture in view of the large number of assumptions used, this example shows that the light curve shape can be interpreted by the model of a magnetized white dwarf with a cyclotron emission source and reinforces our assumption that the object belongs to the AM Her systems.

**Fig. 7.** The observed spectrum of SRGe J214919.3+673634 (black line), the model spectrum of a white dwarf at $T_{\text{eff}} = 24,000$ K (red line), and their ratio (blue line).

### ANALYSIS OF OUR SPECTRA

The averaged spectrum of SRGe 2149 is shown in Fig. 7. To reduce the influence of noise, it was smoothed by a Gaussian with a width of 10 Å. In addition, the fluxes were corrected for interstellar extinction $E(B-V) = 0.57$ toward the source SRGe 2149+6736. The derived spectral energy distribution has a monotonic redward slope ($dF/d\lambda \approx -2.6 \times 10^{-5}$ erg cm$^2$/Å$^2$/s). Emission is observed in the Hα line, while the high noise level does not allow any absorption features to be distinguished in the spectrum. An emission peak whose intensity exceeds the noise level in its vicinity by a factor of 3.7 and the half-width $\Delta \lambda \approx 10$ Å corresponds to the spectral resolution is distinguished at $\lambda = 6561.1$ Å. This emission is probably the Hα line with a Doppler shift for the radial velocity $V_r \approx -80$ km s$^{-1}$.

The observed flux distribution qualitatively corresponds to the thermal one at a temperature of the emitting object above $T_{\text{eff}} = 20,000$ K. Therefore, we described it by the theoretical spectra of white dwarfs with different $T_{\text{eff}}$. To compute the model spectra, we used the $\text{STAR}$ code (Menzhevitski et al. 2014) and the plane-parallel white dwarf model atmospheres with radiative and convective transfer constructed by Mitrofanova et al. (2014). The abundances of all the elements, except for hydrogen, were taken to be zero, while the Balmer H I line profiles were modeled.
using the VCS theory (Vidal et al. 1973). The spectra were computed for a set of white dwarf atmospheres with $T_{\text{eff}} = 20000$–$40000$ K at fixed surface gravity $\log g = 8.3$ roughly corresponding to the mass $M = 0.8\ M_\odot$. The theoretical spectra were convolved with the point spread function of the spectrograph and were compared with the observed one by calculating the root-mean-square (rms) deviation of the flux ratios:

$$\sigma = \sqrt{\frac{1}{\lambda_2 - \lambda_1} \int_{\lambda_1}^{\lambda_2} \left( \frac{F_{\text{obs}}^\lambda}{F_{\text{mod}}^\lambda} - 1 \right)^2 \, d\lambda},$$

where $F_{\text{obs}}^\lambda$ and $F_{\text{mod}}^\lambda$ are the fluxes in the observed and theoretical spectra. In our comparison we used the range $\lambda \lambda = 4400$–$6700$ Å with a lower noise level by excluding the H$\alpha$ and H$\beta$ line regions with a width $\Delta \lambda = 50$ Å each on both sides of their laboratory wavelengths. These exclusions were made to remove the possible influence of emissions, the uncertainty in choosing $\log g$, and the possible Zeeman splitting. The dependence of $\sigma$ on the effective temperature is presented in Fig. 8, while the model and observed spectra at $T_{\text{eff}} = 24000$ K are compared in Fig. 7.

The mean signal-to-noise ratio in the smoothed spectrum is $S/N \approx 4.1$ and determines $\sigma_{\text{lim}} = 0.244$ for the absolutely accurate modeling of the observed $F_\lambda$ distribution. A comparison of the minimum $\sigma = 0.257$ at $T_{\text{eff}} = 24000$ K with $\sigma_{\text{lim}}$ shows that, in this case, the error in the model description of the $F_\lambda$ distribution is 8%. The range of possible white dwarf temperature variations $T_{\text{eff}} = 21000$–$35000$ K is defined by the condition for the difference of the deviations $\sigma$ and $\sigma_{\text{lim}}$ to double compared to the minimum. The distribution of the observed-to-model flux ratio in $\lambda$, which qualitatively illustrates the possible emission features in the spectrum of SRGe 2149, is presented in the lower part of Fig. 7. Apart from the emission in the H$\alpha$ line noted above, similar features appeared in the remaining Balmer lines. Their observed intensities decrease from H$\alpha$ to H$\delta$, which is typical for the accreting structures in cataclysmic variables. However, the high noise level in the blue range does not allow an effective analysis of these emissions to be performed. On the whole, we concluded that the spectrum of SRGe 2149 observed in its low state could be properly represented by the spectrum of a white dwarf with a temperature $T_{\text{eff}} = 24000$ K with an additional emission in the H$\delta$ emission features probably forming in the accreting structure.

**CONCLUSIONS**

In this paper we performed optical studies of the X-ray source SRGe J214919.3+673634 discovered by eROSITA in the fourth scan during the X-ray sky survey by the SRG orbital observatory. Two brightness states differing by $\Delta i \approx 2^m$ were detected during our photometric observations of SRGe J214919.3+673634. In the high state the object had double-peaked light curves with an amplitude $\Delta i = 1.5$–$2^m$. In the low state the light curves have a smaller amplitude ($\Delta r \approx 0.5^m$), while the spectra show a blue continuum and exhibit the H$\alpha$ emission line ($EW = 18 \pm 5$ Å). The photometric period was found to be $P = 85.0 \pm 0.4$ min, i.e., close to the limiting orbital period $P_{\text{min}} \approx 82$ min for cataclysmic variables (Knigge et al. 2011). On the other hand, periods close to $P_{\text{min}}$ are not rare among the cataclysmic variables and, moreover, correspond to the maximum of their distribution (Gänsicke et al. 2009).
Based on the listed observational features, it can be assumed that SRGe J214919.3+673634 is a representative of the magnetic cataclysmic AM Her variables (or polars). The fast brightness state switching of several magnitudes in the long-term light curves of such systems is associated with the change in the rate of mass transfer through the Lagrange point L1 probably attributable to the magnetic activity of the donor (King and Cannizzo 1998). We showed that the double-humped shape of the light curves for SRGe J214919.3+673634 in its high state could be described by the model of a white dwarf with a cyclotron emission source (accretion spot). A high brightness amplitude $1.5 - 2^m$ is also typical of polars with the dominant contribution of the accretion spot to the optical emission. In its low state the spectrum of SRGe J214919.3+673634 is consistent with the spectrum of a white dwarf with a temperature $T_{\text{eff}} = 24000$ K, which would have been expected at a low accretion rate. SRGe J214919.3+673634 can be unambiguously classified as a polar based on its polarimetric observations or its spectroscopic observations with the detection of cyclotron line harmonics.

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REFERENCES

1. V. L. Afanasiev and A. V. Moiseev, Baltic Astron. 20, 363 (2011).
2. I. Afanasieva, V. Ardilanov, V. Murzin, N. Ivaschenko, M. Pritynchenko, A. Moiseev, E. Shablovinskaya, and E. Malygin, Exp. Astron. (2023, submitted).
3. G. Channugam and G. A. Dulk, Astrophys. J. 244, 569 (1981).
4. P. Charbonneau, Astrophys. J. Suppl. Ser. 101, 309 (1995).
5. M. Cropper, Space Sci. Rev. 54, 195 (1990).
6. J. H. Debes, M. Lép Moreno, A. Z. Bonanos, and A. J. Weinberger, Astrophys. J. 647, 147 (2006).
7. P. G. van Dokkum, Publ. Astron. Soc. Pacif. 113, 1420 (2001).
8. O. V. Egorov and A. V. Moiseev, Mon. Not. R. Astron. Soc. 260, 363 (2011).
9. B. T. Gänsicke, M. Dillon, J. Southworth, J. R. Thorstensen, P. Rodríguez-Gil, A. Hungwerojwit, T. R. Marsh, P. Szkody, et al., Mon. Not. R. Astron. Soc. 397, 2170 (2009).
10. A. R. King and J. K. Cannizzo, Astrophys. J. 499, 348 (1998).
11. S. Knigge, I. Baraffe, and J. Patterson, Astrophys. J. Suppl. Ser. 194, 28 (2011).
12. A. I. Kolbin and N. V. Borisov, Astron. Lett. 46, 812 (2020).
13. A. I. Kolbin, N. V. Borisov, N. A. Serebriakova, V. V. Shimansky, N. A. Katysheva, M. M. Gabdeev, and S. Yu. Shugarov, Mon. Not. R. Astron. Soc. 511, 20 (2022).
14. F. Marocco, P. Eisenhardt, J. Fowler, J. Kirkpatrick, A. Meisner, E. Schlably, S. Stanford, N. Garcia, et al., Astrophys. J. Suppl. Ser. 253, 8 (2021).
15. F. Masci, R. LaHe, B. Rusholme, D. L. Shupe, S. Groom, J. Surace, E. Jackson, S. Monkewitz, et al., Publ. Astron. Soc. Pacif. 131, 995 (2018).
16. V. S. Mennshtnikova, N. N. Shimanskaya, V. V. Shimansky, and D. O. Kudryavtsev, Astrophys. Bull. 69, 169 (2014).
17. A. A. Mitrofanova, N. V. Borisov, and V. V. Shimansky, Astrophys. Bull. 69, 82 (2014).
18. J. Patterson, Publ. Astron. Soc. Pacif. 106, 209 (1994).
19. M. Pavlinsky, A. Tkachenko, V. Levin, N. Alexandrovich, V. Areﬁev, V. Babushkin, O. Batanov, Yu. Bodnar, et al., Astron. Astrophys. 650, A42 (2021).
20. J. T. van der Plas, Astrophys. J. Suppl. Ser. 236, 16 (2018).
21. P. Predehl, R. Andritschke, V. Areﬁev, V. Babushkin, O. Batanov, W. Becker, H. Becker, H. Boehringer, et al., Astron. Astrophys. 647, A1 (2021).
22. S. Sazonov, M. Gilfanov, P. Medvedev, Y. Yao, G. Khorunzhev, A. Semena, R. Sunyaev, R. Burenin, et al., Mon. Not. R. Astron. Soc. 508, 3820 (2021).
23. A. D. Schwope, and S. Mengel, Astron. Nachr. 318, 25 (1997).
24. J.-E. Solheim, Publ. Astron. Soc. Pacif. 122, 1133 (2010).
25. R. Sunyaev, V. Areﬁev, V. Babyshkin, et al., Astron. Astrophys. 656, A132 (2021).
26. C. R. Vidal, J. Cooper, and E. W. Smith, Astrophys. J. Suppl. Ser. 25, 37 (1973).
27. T. Wada, A. Shimizu, M. Suzuki, M. Kato, and R. Hoshi, Prog. Theor. Phys. 64, 1986 (1980).
28. B. Warner, Cataclysmic Variable Stars (Cambridge Univ. Press, Cambridge, 1995).
29. M. Zorotovic, M. R. Schreiber, and B. T. Gansicke, Astron. Astrophys. 536, 42 (2011).