Optical Identification of Candidates for Active Galactic Nuclei Detected by the Mikhail Pavlinsky ART-XC Telescope Onboard the SRG Observatory during an All-Sky X-ray Survey

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Abstract—We present the results of our identification of eight objects from the preliminary catalogue of X-ray sources detected in the 4–12 keV energy band by the Mikhail Pavlinsky ART-XC telescope onboard the SRG observatory during the first all-sky survey. Three of them (SRGA J005751.0+210846, SRGA J014157.0−032915, SRGA J232446.8+440756) have been discovered by the ART-XC telescope, while five have already been known previously as X-ray sources, but their nature has remained unestablished. The last five sources have also been detected in soft X-rays by the eROSITA telescope of the SRG observatory. Our optical observations have been carried out at the 1.6-m AZT-33IK telescope of the Sayan Observatory and the 1.5-m Russian–Turkish telescope (RTT-150). All of the investigated objects have turned out to be active galactic nuclei (AGNs) at redshifts from 0.019 to 0.283. Six of them are Seyfert 2 galaxies (including one Seyfert 1.9 galaxy), one (SRGA J005751.0+210846) is a “hidden” AGN (in an edge-on galaxy), and one (SRGA J224125.9+760343) is a narrow-line Seyfert 1 galaxy. The latter object is characterized by a high X-ray luminosity ($\sim 2\times 10^{44}$ erg s$^{-1}$ in the 4–12 keV band) and, according to our black hole mass estimate ($\sim 2\times 10^7$ $M_\odot$), an accretion rate close to the Eddington limit. All three AGNs discovered by the ART-XC telescope (which are not detected by the eROSITA telescope) are characterized by a high absorption column density ($N_H \gtrsim 3\times 10^{23}$ cm$^{-2}$). The results obtained confirm the expectations that the ART-XC telescope is an efficient instrument in searching for heavily obscured and other interesting AGNs in the nearby ($z \lesssim 0.3$) Universe. The SRG sky survey will last for another 3 years or more, which must allow many such objects to be discovered.

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INTRODUCTION

The Russian Mikhail Pavlinsky ART-XC telescope (Pavlinsky et al. 2021) onboard the Russian SRG orbital observatory (Sunyaev et al. 2021) has conducted an all-sky X-ray survey at energies from 4 to 30 keV since December 2019. Mirrors operating on the principle of grazing X-ray incidence and semiconductor detectors based on cadmium telluride crystals are used in the telescope, providing unique characteristics for this energy range: a wide field of view (36 arcmin) and a good angular resolution (better than 1 arcmin in the sky scanning mode). Because of this, during a four-year survey we expect to obtain an all-sky map unique in depth and sharpness at energies 4–12 keV and, in particular, to detect at least 5000 active galactic nuclei (AGNs), which is more than we have managed to find at such energies in previous all-sky surveys by several times.

In June 2020 the SRG observatory completed the first (of the planned eight) sky scanning, and a preliminary catalogue of detected sources (more than 600 objects in total) was produced from the ART-XC

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data obtained. This catalogue was correlated with: (1) the catalogues of sources detected in previous X-ray sky survey; (2) the preliminary catalogue of sources detected on one half of the celestial sphere $0^\circ < |l| < 180^\circ$ in the soft X-ray energy band during the first SRG/eROSITA survey; (3) the catalogues of astrophysical objects in other wavelength ranges (from radio to ultraviolet). As a result, a list of objects consisting of the sources discovered by the ART-XC telescope and previously known X-ray sources of an unestablished nature was compiled. Some of these objects were also detected by the eROSITA telescope (Predehl et al. 2020) of the SRG observatory.

Spectroscopic observations are carried out at Russian optical telescopes to identify these potentially interesting ART-XC sources. The first results of this observational campaign are presented in our paper. The eight ART-XC sources to be discussed below have turned out to be type 1 or 2 AGNs, including objects with a strong internal absorption. The latter was revealed by analyzing the X-ray spectra constructed from the ART-XC and eROSITA data.

The presented luminosity estimates are based on the model of a flat Universe with parameters $H_0 = 70$ and $\Omega_m = 0.3$.

THE SAMPLE OF OBJECTS

The objects being studied (see Table 1) were selected among the point X-ray sources detected by the ART-XC telescope during the first sky survey (December 12, 2019–June 10, 2020) with a signal-to-noise ratio of no less than 4.5 in the 4–12 keV energy band. Based on the ART-XC data, we measured the positions of the sources in the sky and their fluxes in this energy band. The typical position error (at 95% confidence) is 30 arcsec.

For these objects, based on the eROSITA data, we obtained the fluxes or upper limits on the flux in three energy bands: 0.3–2, 2–6, and 4–9 keV. Out of the eight sources detected by the ART-XC telescope, 5 were also detected by the eROSITA telescope either in all three or in the first two of these bands. For them, based on the eROSITA data, we managed to improve the source position in the sky. The remaining three objects are not detected by the eROSITA telescope.

For all our objects Table 1 gives: the coordinates of the ART-XC source, the coordinates of the putative optical counterpart, the distance between the position of the optical counterpart and the positions of the X-ray source from the ART-XC and eROSITA data (if available), and the X-ray observatory that first discovered the X-ray source.

X-RAY OBSERVATIONS

The X-ray radiation from AGNs can experience photoabsorption in the gas–dust torus around the supermassive black hole (SMBH) and in the interstellar medium of the host galaxy. One of the goals of this study was to estimate the column density of neutral (or weakly ionized) matter $N_H$ for the objects being discussed. Although the number of X-ray photons detected by the ART-XC and eROSITA telescopes (in the short source scanning time during the SRG sky survey) is insufficient to perform a detailed spectral analysis, these data nevertheless allow sufficiently reliable constraints on $N_H$ to be obtained in most cases.

We fitted the X-ray spectra in the range 0.3–12 keV using the XSPEC v12.9.0n code jointly based on the ART-XC and eROSITA data. The eROSITA spectra were first binned into spectral bins 0.3–0.5, 0.5–0.7, 0.7–1, 1–1.5, 1.5–2, 2–4, 4–6, and 6–9 keV.

We assumed the AGN X-ray spectrum to be fitted by a power law with a fixed slope $\Gamma = 1.8$ (a typical value for Seyfert galaxies) and a low-energy cutoff as a result of photoabsorption in the Galaxy and the object itself. Thus, we used the following model in XSPEC:

$$\text{phabs(zphabs(powerlaw))},$$

where phabs is the absorption in the Galaxy from HI4PI survey data (Ben Bekhti et al. 2016) and zphabs is the absorption at the AGN redshift $z$ (measured from the object’s optical spectrum). A satisfactory quality of the fit was achieved for all of the sources.

The X-ray spectra obtained are presented on the graphs below in units of $F_E(E)$. A power-law model with a slope $\Gamma = 1.8$ was used to convert the counts on the detector to photons. It should be kept in mind that such figures should not be used to obtain accurate fluxes.

OPTICAL OBSERVATIONS

Our spectroscopy for the objects was performed at the 1.6-m AZT-33IK telescope of the Sayan Observatory using the low- and medium-resolution ADAM spectrograph (Afanasiev et al. 2016; Burenin et al. 2016) and the 1.5-m Russian–Turkish telescope (RTT-150) using the TFOSC$^3$ spectrograph. A set of long slits is used at both spectrographs to obtain the spectra.

We used volume phase holographic gratings (VPHG), 600 lines per millimeter, to obtain the

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$^1$ Russian scientists are responsible for processing the data from the eROSITA telescope (Germany) in this part of the sky.

$^2$ http://heasarc.gsfc.nasa.gov/xanadu/xspec/.

$^3$ http://hea.i.ki.rssi.ru/rtt150/en/index.php?page=tfosc.
optical counterparts. After each series of spectroscopic images, we used a 2"-wide slit. The spectrograph slit position angle is 90°. Before and after obtaining the series of spectroscopic images for each object, we obtained the images of a lamp with a continuum spectrum and the line spectrum of a Fe–Ar lamp.

All our observations were carried out at dark moonless time. Before obtaining the spectroscopic images, we tried to place the galactic nucleus at the center of the spectrograph slit as accurately as possible. After each exposure, we changed the object’s position along the slit by 10–15″ in a random direction upward or downward using a photoguide. On each night at both telescopes we took the spectra of spectrophotometric standards from the ESO4

4 https://www.eso.org/sci/observing/tools/standards/spectra/stanlis.html.

Table 1. List of objects for our spectroscopic observations

| ART-XC source          | Optical coordinates | r (ART-XC) | r (eROSITA) | Discovered by |
|------------------------|---------------------|------------|-------------|---------------|
| SRGA J005751.0+210846  | 00 57 52.1          | +21 08 46  | 15.4″       | –             | SRG          |
| SRGA J014157.0−032915  | 01 41 59.4          | −03 29 34  | 40.6″       | –             | SRG          |
| SRGA J043209.6+354917  | 04 32 08.0          | +35 49 29  | 22.9″       | 2.3″          | ROSAT        |
| SRGA J045049.8+301449  | 04 50 48.0          | +30 15 03  | 27.2″       | 3.2″          | Swift        |
| SRGA J152102.3+320418  | 15 21 01.8          | +32 04 14  | 7.5″        | 2.9″          | Swift        |
| SRGA J200431.6+610211  | 20 04 32.4          | +61 02 31  | 20.8″       | 5.3″          | ROSAT        |
| SRGA J224125.9+760343  | 22 41 25.8          | +76 03 53  | 10.0″       | 4.6″          | ROSAT        |
| SRGA J232446.8+440756  | 23 24 48.4          | +44 07 57  | 17.3″       | –             | SRG          |

Column 1: the source name in the preliminary ART-XC catalogue (the coordinates of the X-ray sources used in the names are given for epoch J2000.0). Columns 2 and 3: the coordinates of the putative optical counterpart. Column 4: the distance between the ART-XC source position and the optical counterpart position. Column 5: the separation between the eROSITA source position and the optical counterpart position (the dash means that a given source is not detected by the eROSITA telescope). Column 6: the X-ray observatory that discovered the source.

Table 2. Spectral features of SRGA J005751.0+210846 = LEDA 1643776

| Line          | Wavelength, Å | Flux, 10^{-16} erg s^{-1} cm^{-2} | Eq. width, Å | FWHM, km s^{-1} |
|---------------|---------------|----------------------------------|--------------|-----------------|
| Hα            | 6880          | 9.9 ± 6.0                         | −5.0 ± 3.0   | (3.6 ± 0.3) × 10^2 |
| [N II]λ6584   | 6901          | 8.8 ± 5.0                         | −4.4 ± 2.5   | (3.8 ± 0.2) × 10^2 |

1 Negative values correspond to emission lines.

spectra at the ADAM spectrograph. As a dispersive element we used VPHG600G for the spectral range 3650–7250 Å with a resolution of 4.3 Å and VPHG600R for the spectral range 6460–10 050 Å with a resolution of 6.1 Å. When using VPHG600R, we set the OS11 filter, which removes the second interference order from the image. A thick e2v CCD30-11 array produced by the deep depletion technology is installed at the spectrograph. This allows the spectral images to be obtained at a wavelength of 1 μm without interference on the thin CCD substrate. A set of slits is available at the spectrograph; we used a 2″-wide slit to obtain the spectroscopic images. All our observations were performed with zero slit position angle. After each series of spectroscopic images for each object, we obtained the calibration images of a lamp with a continuum spectrum and the line spectrum of a He–Ne–Ar lamp.

Transmitting diffraction grating no. 15 with the spectral range 3700–8700 Å, which provides a spectral resolution of 12 Å, was used at the TFOSC spectrograph as a dispersive element. This grating allows bright Balmer lines to be obtained in the spectral images for galaxies up to z = 0.32. To obtain the spectroscopic images, we used a 2″-wide slit. The spectrograph slit position angle is 90°. Before and after obtaining the series of spectroscopic images for each object, we obtained the images of a lamp with a continuum spectrum and the line spectrum of a Fe–Ar lamp.
list for all the sets of diffraction gratings and slits being used. The data reduction was performed using IRAF\textsuperscript{5} software package and our own software.

To estimate the broadening of emission lines, their profiles were fitted by a Gaussian, with the background having been fitted by a polynomial. The line width was defined as $\text{FWHM} = \sqrt{\text{FWHM}_{\text{mes}}^2 - \text{FWHM}_{\text{res}}^2}$, where $\text{FWHM}_{\text{mes}}$ is the measured line width and $\text{FWHM}_{\text{res}}$ is the spectral broadening of the instrument whose values were given above for each dispersive element being used.

We classified the Seyfert galaxies based on their optical spectra in a standard way (Osterbrock 1981; Véron-Cetty et al. 2001).

RESULTS OF OBSERVATIONS

Below we present the details of our optical and X-ray observations and the results obtained for each object from the sample.

SRGA J005751.0+210846. This X-ray source was discovered in the 4–12 keV band by the ART-XC telescope of the SRG observatory and, at the same time, was not detected in softer X-rays by the eROSITA telescope of the same observatory.

A probable optical counterpart of the X-ray source is the galaxy LEDA 1643776 that falls into the ART-XC position error circle (Fig. 1). The galaxy is oriented edge-on to the observer. Previously, a spectrum

\textsuperscript{5}http://iraf.noao.edu/.
has already been obtained for it during the Sloan Digital Sky Survey (release 12, SDSS Collaboration 2015), from which its redshift was measured ($z = 0.04798 \pm 0.00002$). However, this spectrum does not allow the object to be reliably classified as an AGN.

Our optical observations of the object were carried out on October 22, 2020, at the AZT-33IK telescope with VPHG600G. Six spectral images with an exposure time of 300 s each were obtained; the total exposure time was 30 min.

Our spectrum of the galaxy is shown in Fig. 1. Narrow Hα, [N II]λ6584, and sulfur doublet emission lines are seen in it. The Hβ, [O III]λ4959, and [O III]λ5007 lines are absent. The 2σ upper boundary of the intensity maximum in these lines is $5.5 \times 10^{-17}$ erg s$^{-1}$ cm$^{-2}$ Å$^{-1}$. Table 2 presents the characteristics of the two brightest lines. From these two lines we measured the object’s redshift, $z = 0.04795 \pm 0.00005$, consistent with the measured SDSS redshift within the error limits.

Because of the absence of the Hβ line and the [O III] doublet in the spectrum, it is impossible to establish the position of the galaxy LEDA 1643776 on the standard BPT diagram (Baldwin et al. 1981, see Fig. 9) and, consequently, its optical type. Nevertheless, a high X-ray luminosity ($\sim 5 \times 10^{43}$ erg s$^{-1}$ in the 4–12 keV band from the ART-XC data) of the object leaves no doubt that this is an AGN. The weakness of the observed lines probably stems from the fact that we observe the galaxy LEDA 1643776 edge-on, so that the optical radiation from the active nucleus (and, in particular, from the narrow-line region) is almost completely absorbed in the interstellar gas of the galaxy.

The non-detection by the eROSITA telescope in combination with the 4–12 keV flux measured by the ART-XC telescope (Fig. 1) allows a lower limit (at 90% confidence) to be placed on the absorption column density: $N_H > 10^{24}$ cm$^{-2}$. Much of this absorption may arise in the interstellar gas of the galaxy.
Table 3. Spectral features of SRGA J014157.0−032915 = LEDA 1070544

| Line          | Wavelength, Å | Flux, 10^{-16} erg s^{-1} cm^{-2} | Eq. width, Å | FWHM, km s^{-1} |
|---------------|---------------|-----------------------------------|--------------|-----------------|
| Hβ           | 4954          | 27 ± 5                            | −17.8 ± 3.0  | (6.0 ± 0.7) × 10^2 |
| [O III]λ4960  | 5054          | 31 ± 3                            | −14.5 ± 1.5  | (5.0 ± 0.7) × 10^2 |
| [O III]λ5007  | 5102          | 84 ± 9                            | −38 ± 4      | (4.9 ± 0.7) × 10^2 |
| Hα           | 6689          | 88 ± 8                            | −50 ± 5      | (3.9 ± 0.5) × 10^2 |
| [N II]λ6584   | 6709          | <12                               | >−7.3        | −               |

Table 4. Spectral features of SRGA J043209.6+354917 = 2MASX J04320796+3549287

| Line          | Wavelength, Å | Flux, 10^{-16} erg s^{-1} cm^{-2} | Eq. width, Å | FWHM, km s^{-1} |
|---------------|---------------|-----------------------------------|--------------|-----------------|
| Hβ, narrow    | 5112          | <2                                | >−4.3        | −               |
| Hβ, broad     | 5112          | 28 ± 7                            | −64 ± 16     | (5.8 ± 0.6) × 10^3 |
| [O III]λ4960  | −             | <3                                | >−6.5        | −               |
| [O III]λ5007  | 5260          | 12 ± 2                            | −27 ± 5      | (6.4 ± 1.2) × 10^2 |
| [N II]λ6548   | 6854          | 2 ± 2                             | −2 ± 2       | (5.8 ± 0.9) × 10^2 |
| Hα, narrow    | 6893          | 9 ± 2                             | −9 ± 2       | (5.8 ± 0.9) × 10^2 |
| Hα, broad     | 6893          | 282 ± 8                           | −278 ± 8     | (6.0 ± 0.2) × 10^3 |
| [N II]λ6584   | 6919          | 14 ± 2                            | −14 ± 2      | (5.8 ± 0.9) × 10^2 |

galaxy and not in the gas–dust torus surrounding the SMBH.

SRGA J014157.0−032915. This X-ray source was discovered in the 4–12 keV band by the ART-XC telescope of the SRG observatory and, at the same time, was not detected in softer X-rays by the eROSITA telescope.

A probable optical counterpart is the galaxy LEDA 1070544 (Fig. 2). Although its center is at a distance of about 40″ from the position of the X-ray source (Table 1), such position errors can occur in the case of sources at the ART-XC detection threshold.

Our optical observations were carried out on October 13, 2020, at the AZT-33IK telescope using VPHG600G. Three spectral images with an exposure time of 600 s each were obtained; the total exposure time was 30 min.

The Hβ, [O III]λ4959, [O III]λ5007, Hα, and [S II] doublet emission lines are seen in our spectrum (Fig. 2). The [N II]λ6584 line is difficult to separate from the Hα line. Table 3 gives the characteristics of the emission lines. They are all narrow. The redshift determined from four lines is $z = 0.01878 ± 0.00003$.

The absence of broad lines in the spectrum and a fairly high X-ray luminosity ($\sim 3 \times 10^{42}$ erg s$^{-1}$ in the 4–12 keV band from the ART-XC data) suggest that this is a Seyfert 2 galaxy. However, according to the measured line flux ratios $\log([O III] λ5007/H β) = 0.49 ± 0.09$ and $\log([N II] λ6584/H α) < -0.86$, the object lies in the region of star-forming galaxies on the BPT diagram (Fig. 9), though near (within three standard deviations) the region of Seyfert galaxies. Most likely, we are dealing with a galaxy in which, apart from SMBH activity, there is active star formation.

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SRGA J043209.6+354917. This X-ray source is first mentioned under the name 1WGA J0432.1+3549
in the catalogue of sources discovered in the soft X-ray energy band during the ROSAT pointed observations (White et al. 2000). It is also present in the catalogue of sources detected during the XMM-Newton slew observations (The XMM-Newton Survey Science Centre 2018). However, the nature of this object so far has remained unknown. The source was reliably detected by both ART-XC and eROSITA telescopes of the SRG observatory.

The X-ray source is reliably identified with the galaxy 2MASX J04320796+3549287 = WISEA J043207.95+354928.8 (Fig. 3), whose colors in the near infrared \((W1 – W2 = 0.68)\) (Wright et al. 2010) point to the presence of an active nucleus.

Our optical observations were carried out on September 15, 2020, at RTT-150. Five spectral images with an exposure of 900 s each were obtained; the total exposure time was 75 min.

Balmer hydrogen and forbidden oxygen and nitrogen emission lines are seen in the object’s spectrum (Fig. 3). Table 4 gives the characteristics of the emission lines. The redshift was determined from three lines, H\(\alpha\), [O III]\(\lambda\)5007, and [N II]\(\lambda\)6584, and is \(z = 0.0506 \pm 0.0010\). The H\(\alpha\) and H\(\beta\) lines have a broad component; only an upper limit can be placed on the flux in the narrow H\(\beta\) component. The object is classified from the ratios \(\log([\text{O III}]\lambda5007/H\beta) > 0.77\) and \(\log([\text{N II}]\lambda6584/H\alpha) = 0.19 \pm 0.11\) (Fig. 9) and the fluxes in the broad and narrow H\(\alpha\) and H\(\beta\) components as a Seyfert 1 galaxy.

A slight absorption is detected in the object’s X-ray spectrum (Fig. 3): \(N_{\text{H}} \sim 3 \times 10^{21} \text{ cm}^{-2}\).

SRGA J045049.8+301449. This object was discovered in hard X-rays (the source SWIFT J0450.6+3015) by the BAT instrument of the Neil Gehrels Swift observatory (Oh et al. 2018) and is present in the catalogue of point X-ray sources.

**Fig. 3.** Same as Fig. 1, but for SRGA J043209.6+354917. In the pointing picture the blue and red circumferences indicate the ART-XC and eROSITA position error circles, respectively.
detected by the XRT telescope of the same observatory (Evans et al. 2020). However, its nature so far has remained unknown. The source was reliably detected by both ART-XC and eROSITA telescopes of the SRG observatory.

The X-ray source is reliably identified (Fig. 4) with the galaxy LEDA 1896296 = WISEA J045048.00+301502.8 ($W1 - W2 = 0.38$).

Our optical observations were carried out on October 22, 2020, at the AZT-33IK telescope using VPHG600G. Four spectral images with an exposure time of 600 s each were obtained near the object’s culmination; the total exposure time was 40 min.

The $\lambda 4960$, $\lambda 5007$, $\lambda 6584$, and sulfur doublet emission lines are seen in the object’s spectrum (Fig. 4). The $H\beta$ line is unseen. The upper limit on the ratio log($\lambda 5007/H\beta$) > 0.92. The upper limit on the ratio log($\lambda 6584/H\alpha$) = $-0.04 \pm 0.16$. All these lines are narrow, except $H\alpha$ in which a broad component can be distinguished.

The characteristics of the emission lines are given in Table 5. The object’s redshift was measured from six emission lines: $z = 0.03308 \pm 0.00004$. From the position on the BPT diagram (Fig. 9) and the presence of a broad component only in the Balmer $H\alpha$ line, the object can be classified as a Seyfert 1.9 galaxy.

An appreciable absorption is detected in the object’s X-ray spectrum (Fig. 4): $N_H \sim 4 \times 10^{22}$ cm$^{-2}$.

SRGA J152102.3+320418. This X-ray source is present in the catalogue of point X-ray sources detected by the XRT telescope of the Neil Gehrels Swift observatory (Evans et al. 2020), but its nature so far has remained unknown. The source was reliably detected by both ART-XC and eROSITA telescopes of the SRG observatory.

The X-ray source is reliably identified (Fig. 5) with the galaxy (SDSS data) WISEA J152101.83+320414.6, whose infrared color ($W1 - W2 = 1.20$) points to the possible presence of an active nucleus.
Table 5. Spectral features of SRGA J045049.8+301449 = LEDA 1896296

| Line         | Wavelength, Å | Flux, 10^{-16} erg s^{-1} cm^{-2} | Eq. width, Å  | FWHM, km s^{-1} |
|--------------|---------------|-----------------------------------|----------------|-----------------|
| Hβ           | 5037          | <2                                | >-1.3          | -               |
| [O III]λ4960 | 5124          | 5.9 ± 0.8                         | -3.7 ± 0.5     | (6.5 ± 0.6) × 10^2 |
| [O III]λ5007 | 5173          | 17 ± 2                            | -10.3 ± 1.2    | (6.8 ± 0.6) × 10^2 |
| Hα, narrow   | 6781          | 24 ± 8                            | -7 ± 2         | (4.7 ± 0.5) × 10^2 |
| Hα, broad    | 6781          | 25 ± 4                            | -7.1 ± 1.2     | (2.8 ± 0.4) × 10^3 |
| [N II]λ6584  | 6803          | 22 ± 3                            | -6.7 ± 0.9     | (4.8 ± 0.5) × 10^2 |
| [S II]λ6718  | 6940          | 15 ± 2                            | -4.2 ± 0.6     | (5.2 ± 0.8) × 10^2 |
| [S II]λ6732  | 6956          | 10 ± 2                            | -2.7 ± 0.6     | (4.8 ± 0.8) × 10^2 |

Table 6. Spectral features of SRGA J152102.3+320418 = WISEA J152101.83+320414.6

| Line         | Wavelength, Å | Flux, 10^{-16} erg s^{-1} cm^{-2} | Eq. width, Å  | FWHM, km s^{-1} |
|--------------|---------------|-----------------------------------|----------------|-----------------|
| [O II]λ3729  | 4155          | 112 ± 7                           | (-1.8^{+1.7}_{-0.8}) × 10^2 | (6.8 ± 0.8) × 10^2 |
| [He I]λ3889  | 4312          | 33 ± 7                            | -9^{+9}_{-4}   | (6.2 ± 0.8) × 10^2 |
| Hδ           | 4573          | <11                               | -27            | -               |
| Hγ           | 4837          | 14 ± 2                            | -31^{+12}_{-6} | (6.7 ± 0.7) × 10^2 |
| [O III]λ4364 | 4863          | 7.1 ± 1.5                         | -15.4^{+1.2}_{-2.7} | (6.3 ± 0.7) × 10^2 |
| Hβ           | 5418          | 30 ± 3                            | -67^{+24}_{-13} | (5.7 ± 0.6) × 10^2 |
| [O III]λ4960 | 5527          | 75 ± 3                            | (-1.23^{+0.45}_{-0.11}) × 10^2 | (6.1 ± 0.6) × 10^2 |
| [O III]λ5007 | 5580          | (2.3 ± 0.1) × 10^2                | (-3.6 ± 0.4) × 10^2 | (6.3 ± 0.6) × 10^2 |
| [O I]λ6302   | 7022          | 14.9 ± 0.7                        | -41^{+8}_{-7}  | (6.1 ± 0.5) × 10^2 |
| [O I]λ6365   | 7086          | <7                                | -7.6           | -               |
| [N II]λ6548  | 7298          | <20                               | -22            | -               |
| Hα           | 7316          | (3.0 ± 0.1) × 10^2                | (-2.4^{+0.8}_{-0.7}) × 10^2 | (5.6 ± 0.4) × 10^2 |
| [N II]λ6584  | 7339          | 73 ± 4                            | -56^{+20}_{-28} | (7.2 ± 0.8) × 10^2 |
| [S II]λ6718  | 7487          | 62 ± 7                            | -58 ± 8        | (5.9 ± 0.4) × 10^2 |
| [S II]λ6732  | 7504          | 53 ± 7                            | -50 ± 8        | (5.8 ± 0.4) × 10^2 |
Our optical observations were carried out on February 27 and April 24, 2020, at the AZT-33IK telescope. Five spectral images with an exposure time of 600 s each were obtained on February 27, 2020, the total exposure time was 50 min; on April 24, 2020, we obtained two spectral images with an exposure time of 1200 s each in VPHG600G and three spectral images with an exposure time of 1200 s each in VPHG600R, the total exposure time was 100 min.

Fourteen narrow hydrogen, oxygen, nitrogen, sulfur, and helium emission lines are seen in our spectrum (Fig. 5). Information on these lines is collected in Table 6. The redshift of the galaxy determined from these 14 lines is $z = 0.11425 \pm 0.00031$. The ratios $\log([\text{N II}]\lambda 6584/\text{H}\alpha) = -0.61 \pm 0.03$ and $\log([\text{O III}]\lambda 5007/\text{H}\beta) = 0.88 \pm 0.05$. From the position on the BPT diagram (Fig. 9) and the absence of broad lines, the object is classified as a Seyfert 2 galaxy.

An appreciable absorption is detected in the object’s X-ray spectrum (Fig. 5): $N_{\text{H}} \sim 2.5 \times 10^{22} \text{cm}^{-2}$.

SRGA J200431.6+610211. This X-ray source was discovered during the ROSAT all-sky survey: 2RXS J200433.8+610235 (Boller et al. 2016). However, its nature so far has remained unknown. The source was detected by both ART-XC and eROSITA telescopes of the SRG observatory.

The X-ray source is reliably identified (Fig. 6) with the galaxy 2MASX J20043237+6102311 = WISEA J200432.40+610230.8, whose infrared color $(W1 – W2 = 0.89)$ points to the possible presence of an active nucleus.

Our optical observations were carried out on October 22, 2020, at the AZR-33IK telescope using VPHG600G. Five spectral images with an exposure time of 300 s each were obtained; the total exposure time was 25 min.

Narrow H$\beta$, [O III] $\lambda$4959, [O III] $\lambda$5007, H$\alpha$, [N II] $\lambda$6584, and sulfur doublet emission lines are seen in our spectrum (Fig. 6). The line characteristics are given in Table 7. The redshift was determined from seven lines: $z = 0.05866 \pm 0.00013$. 

Fig. 5. Same as Fig. 3, but for SRGA J152102.3+320418. The optical spectrum is shown on the two lower panels: the spectrum taken in VPGH600G (left) and VPHG600R (right).
The ratios log([O III]λ5007/Hβ) = 1.04 ± 0.03 and log([N II]λ6584/Hα) = 0.00 ± 0.06. From the position on the BPT diagram (Fig. 9) and the absence of broad lines, the object can be classified as a Seyfert 2 galaxy.

A slight absorption is detected in the object’s X-ray spectrum (Fig. 6): N_H ~ 5 × 10^{21} cm^{-2}.

SRGA J224125.9+760343. This X-ray source was discovered during the ROSAT all-sky survey: 2RXS J224124.5+760346 (Boller et al. 2016), but its nature so far has remained unknown. The source was detected by both ART-XC and eROSITA telescopes of the SRG observatory.

The X-ray source is reliably identified (Fig. 7) with the infrared source WISEA J224125.79+760353.8, whose infrared color (W1 – W2 = 0.97) points to the possible presence of an active nucleus.

Our optical observations were carried out on June 21, 2020, at RTT-150. Three spectral images with an exposure time of 1800 s each were obtained; the total exposure time was 90 min.

The Balmer Hα, Hβ, Hγ, and Hδ emission lines with narrow and broad components are seen in our spectrum (Fig. 7). The Hα line merged with the [N II]λ6548 and [N II]λ6584 lines. Obviously, for this reason, the measured FWHM of the broad Hα component slightly exceeds the FWHM of the corresponding Hβ component. The [O III]λ4960, [O III]λ5007 emission lines and the complex of [Fe II]λ4570 (λ4434–λ4684) lines are also present in the spectrum. The characteristics of all lines are presented in Table 8. The redshift determined from six emission lines is z = 0.2834 ± 0.0003. The narrow-line flux ratio is log([O III]λ5007/Hβ) = 0.66, while the ratio log([N II]λ6584/Hα) is difficult to estimate due to the line merging. The relative narrowness of the broad Balmer line components (FWHM (Hβ) < 2000 km s^{-1}) and the presence of a noticeable
### Table 7. Spectral features of SRGA J200431.6+610211 = 2MASX J20043237+6102311

| Line       | Wavelength, Å | Flux, 10^{-16} erg s^{-1} cm^{-2} | Eq. width, Å | FWHM, km s^{-1} |
|------------|---------------|-----------------------------------|---------------|-----------------|
| Hβ         | 5147          | 18.0 ± 1.2                        | −6.7 ± 0.5    | (4.7 ± 0.7) × 10^2 |
| [O III]λ4959 | 5250        | 57 ± 5                           | −19 ± 4       | (4.8 ± 0.7) × 10^2 |
| [O III]λ5007 | 5302        | 196 ± 7                          | −59 ± 3       | (4.8 ± 0.7) × 10^2 |
| Hα         | 6950          | 110 ± 11                         | −23 ± 2       | (4.7 ± 0.5) × 10^2 |
| [N II]λ6584 | 6972        | 111 ± 11                         | −23 ± 2       | (5.0 ± 0.5) × 10^2 |
| [S II]λ6718 | 7113        | 31 ± 3                           | −7.7 ± 0.6    | (5.5 ± 0.4) × 10^2 |
| [S II]λ6732 | 7129        | 31 ± 3                           | −7.7 ± 0.6    | (5.2 ± 0.4) × 10^2 |

### Table 8. Spectral features of SRGA J224125.9+760343 = WISEA J224125.79+760353.8

| Line       | Wavelength, Å | Flux, 10^{-16} erg s^{-1} cm^{-2} | Eq. width    | FWHM, km s^{-1} |
|------------|---------------|-----------------------------------|--------------|-----------------|
| Hγ, narrow | 5579          | <0.8                              | >−1.2        | −               |
| Hγ, broad  | 5579          | 17.4 ± 0.8                        | −26 ± 1      | (2.1 ± 0.2) × 10^3 |
| [Fe II]λ4570 | 5982       | 18.6 ± 1.3                        | −            | −               |
| Hβ, narrow | 6239          | 4.4 ± 0.3                         | −6.4 ± 0.4   | (3.8 ± 0.9) × 10^2 |
| Hβ, broad  | 6239          | 51 ± 1                            | −35 ± 2      | (1.5 ± 0.2) × 10^3 |
| [O III]λ4959 | 6365       | 7.7 ± 0.2                         | −11.3 ± 0.3  | (3.7 ± 0.9) × 10^2 |
| [O III]λ5007 | 6428        | 20.1 ± 0.3                        | −29 ± 1      | (3.7 ± 0.9) × 10^2 |
| Hα, narrow | 8429          | 6.0 ± 0.9                         | −8.8 ± 1.3   | (2.8 ± 0.7) × 10^2 |
| Hα, broad  | 8429          | 197 ± 3                           | −288 ± 5     | (2.3 ± 0.1) × 10^3 |

### Table 9. Spectral features of SRGA J232446.8+440756 = 2MASX J23244834+4407564

| Line       | Wavelength, Å | Flux, 10^{-16} erg s^{-1} cm^{-2} | Eq. width, Å | FWHM, km s^{-1} |
|------------|---------------|-----------------------------------|---------------|-----------------|
| Hβ         | 5087          | 27 ± 4                            | −12 ± 3       | (7.4 ± 1.0) × 10^2 |
| [O III]λ4959 | 5189        | 74 ± 9                            | −42 ± 9       | (6.8 ± 1.0) × 10^2 |
| [O III]λ5007 | 5239        | 196 ± 12                          | −102 ± 17     | (7.3 ± 1.0) × 10^2 |
| Hα         | 6865          | 134 ± 9                           | −41 ± 6       | (5.3 ± 0.8) × 10^2 |
| [N II]λ6584 | 6887        | 46 ± 7                            | −17 ± 3       | (1.5^{+3.7}_{−1.5}) × 10^2 |
Fe II emission suggest that this object is a narrow-line Seyfert 1 galaxy.

There is no evidence of an additional absorption in the object’s X-ray spectrum (Fig. 7), except for the absorption in our Galaxy. At a fixed slope of the power-law spectrum $\Gamma = 1.8$ we obtain a strict upper limit on the internal absorption: $N_H < 4 \times 10^{20} \text{cm}^{-2}$.

SRGA J232446.8+440756. This X-ray source was discovered in the 4–12 keV band by the ART-XC telescope of the SRG observatory and, at the same time, was not detected in softer X-rays by the eROSITA telescope.

The X-ray source can be identified with the irregular galaxy 2MASX J23244834+4407564 = WISEA J232448.36+440756.5 (Fig. 8). Its redshift is known: $z = 0.04634$ (Huchra et al. 2012), while its infrared color ($W_1 - W_2 = 0.83$) points to the presence of an active nucleus. However, the galaxy has not yet been classified as an AGN from optical spectroscopy.

Our optical observations were carried out on June 10, 2020, at RTT-150. Nine spectral images with an exposure of 600 s each were obtained; the total exposure time was 90 min.

Narrow Hα, Hβ, [O III]λ4959, λ5007, and [N II]λ6584 emission lines and the [S II] doublet are seen in our spectrum (Fig. 8). The line characteristics are given in Table 9. The redshift was determined from five emission lines and is $z = 0.04624 \pm 0.00020$, consistent with the previously measured value by Huchra et al. (2012). The ratios $\log([\text{N II}]\lambda6584/\text{H}\alpha) = -0.46 \pm 0.07$ and $\log([\text{O III}]\lambda5007/\text{H}\beta) = 0.86 \pm 0.07$. From the position on the BPT diagram (Fig. 9) and the absence of broad lines, the object can be classified as a Seyfert 2 galaxy.
The non-detection by the eROSITA telescope in combination with the 4–12 keV flux measured by the ART-XC telescope (Fig. 8) allows a strict upper limit to be placed on the absorption column density: $N_H > 3 \times 10^{23} \text{ cm}^{-2}$.

**PROPERTIES OF THE DETECTED AGNs**

Table 10 presents the main properties of the AGNs that we managed to identify in this study. Apart from the redshift and the optical type, the estimated column density of cold matter inside the object $N_H$ and its X-ray luminosity $L_X$ in the 4–12 keV energy band are given for each object.

We estimated the X-ray luminosity based on the flux in the 4–12 keV energy band measured by the ART-XC telescope of the SRG observatory and the photometric distance to the object calculated from its redshift. The presented values of $L_X$ neglect the $k$ corrections and were not corrected for the line-of-sight absorption. The first of these corrections should not be significant, given the low redshifts of the objects and that the slope of the AGN X-ray spectra does not differ greatly from $\Gamma = 2$. As regards the absorption correction, although it may turn out to be large for three objects from the sample with a high column density ($N_H > 10^{23} \text{ cm}^{-2}$), it is virtually impossible to reliably take into account based on the existing ART-XC and eROSITA data (there are too few detected photons). Therefore, it should be kept in mind that the true luminosity of these heavily obscured AGNs can be greater than that given in the table by several times.

As can be seen from Table 10, most of the objects being discussed are Seyfert galaxies with a luminosity $L_X \sim 10^{42} - 10^{44} \text{ erg s}^{-1}$ in the nearby Universe ($z < 0.1$), except for the source SRGA J224125.9+760343 at $z = 0.28$ with a luminosity $L_X \sim 10^{45} \text{ erg s}^{-1}$ that, using the traditional terminology, may be attributed to quasars.
Almost all of the investigated objects fall into the region of Seyfert galaxies on the standard BPT diagram (Fig. 9) of the [O III]λ5007/Hβ and [N II]λ6584/Hα flux ratios. SRGA J005751.0+210846 was not placed on this diagram, because the required information about the emission lines cannot be obtained from the available optical spectra. In this case, we are dealing with a galaxy (LEDA 1643776) seen edge-on, so that the line emission regions in its active nucleus can be completely hidden from the observer. SRGA J224125.9+760343 did not fall on the BPT diagram either, because the broad Hα component merged with the [N II]λ6584 line and, for this reason, it is impossible to estimate the line parameters. Undoubtedly, both objects are AGNs, because they are characterized by a high X-ray luminosity. As has already been discussed above, the object SRGA J014157.0−032915 is located on the BPT diagram in the region of star-forming galaxies, but near the region of Seyfert galaxies. The narrow emission lines in its spectrum probably result not only from the accretion of matter onto the SMBH in the galactic nucleus, but also from intense star formation in the galaxy.

Six of the eight investigated objects (if SRGA J005751.0+210846 seen edge-on is included) turned out to be Seyfert 2 or intermediate-type (1.9) galaxies. The detection of an appreciable absorption in their X-ray spectra is quite expectable.

One of the objects (SRGA J224125.9+760343) turned out to be a narrow-line Seyfert 2 galaxy. We can estimate the SMBH mass in this object from the formula (Vestergaard and Peterson 2006)

$$\log M_{\text{BH}} = \log \left[ \frac{(\text{FWHM}(H\beta))^2}{1000 \text{ km s}^{-1}} \left( \frac{L(H\beta)}{10^{42} \text{ erg s}^{-1}} \right)^{0.63} \right] + 6.67.$$ 

In our case, FWHM(Hβ) = (1.5 ± 0.2) × 10^3 km s^{-1} and the line flux is $F(H\beta) = (1.30 ± 0.02) \times 10^{-14}$ erg s^{-1} cm^{-2} (see Table 8), which allows the line luminosity to be estimated at $z = 0.2834$, $L(H\beta) \approx 3.3 \times 10^{42}$ erg s^{-1}. As a result, we find $M_{\text{BH}} \approx 2.3 \times 10^7 M_\odot$.

For such a relatively small black hole the critical Eddington luminosity is $L_{\text{Edd}} \approx 3 \times 10^{45}$ erg s^{-1}. At the same time, the measured luminosity of the source SRGA J224125.9+760343 in the X-ray energy band (4−12 keV) is $L_X \sim (2−13) \times 10^{44}$ erg s^{-1}. Since the bolometric luminosity $L_{\text{bol}}$ of an AGN usually exceeds the X-ray luminosity at least by several times (see, e.g., Sazonov et al. 2004), we conclude that $L_{\text{bol}} \sim L_{\text{Edd}}$ for SRGA J224125.9+760343. This corresponds to the universally accepted paradigm (see, e.g., Mathur 2000) that in narrow-line Seyfert 1 galaxies the accretion of matter occurs at a rate close to the critical one.

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### Table 10. Properties of the AGNs

| Object                  | Optical type | $z$               | $N_H^2$ | $\log L_X^3$ |
|-------------------------|--------------|-------------------|---------|--------------|
| SRGA J005751.0+210846   | Sy2$^4$      | 0.0479 ± 0.00002  | >1 × 10^3 | 43.7 ± 0.2   |
| SRGA J014157.0−032915   | Sy2          | 0.01878 ± 0.00003 | >3 × 10^2 | 42.5 ± 0.3   |
| SRGA J043209.6+354917   | Sy1          | 0.0506 ± 0.0010   | 3.0 ± 0.8 | 43.8 ± 0.2   |
| SRGA J045049.8+301449   | Sy1.9        | 0.03308 ± 0.00004 | 38 ± 11  | 43.4 ± 0.3   |
| SRGA J152102.3+320418   | Sy2          | 0.1143 ± 0.0003   | 25 ± 6   | 44.1 ± 0.2   |
| SRGA J200431.6+610211   | Sy2          | 0.05866 ± 0.00013 | 4.7 ± 2.2 | 43.6 ± 0.3   |
| SRGA J224125.9+760343   | NLSy1        | 0.2834 ± 0.0004   | <0.4     | 44.9 ± 0.2   |
| SRGA J232446.8+440756   | Sy2          | 0.0462 ± 0.0002   | >3 × 10^2 | 43.5 ± 0.2   |

1. Sy1, Sy1.9, and Sy2 are Seyfert 1, 1.9, and 2 galaxies, respectively, NLSy1 is a narrow-line Seyfert 1 galaxy.
2. In units of 10^{20} cm^{-2}, the errors and limits correspond to the 90% confidence level, while the 68% confidence level is presented for the source SRGA J014157.0−032915.
3. The luminosity uncorrected for absorption in the observed 4−12 keV energy band in units of erg s^{-1}.
4. The classification is arbitrary, because the galaxy is seen edge-on.
CONCLUSIONS

We managed to identify eight new AGNs among the X-ray sources detected during the first sky survey with the ART-XC telescope of the SRG observatory. We measured the redshifts of these objects and studied their optical and X-ray properties. Most of the objects turned out to be Seyfert 2 galaxies, with an appreciable absorption in the X-ray spectrum. For three AGNs the absorption column density exceeds $3 \times 10^{23}$ cm$^{-2}$. For this reason, they are detected only in fairly hard X-rays with the ART-XC telescope and are not detected in softer X-rays with the eROSITA telescope. In one of these objects (SRGA J005751.0+210846) the absorption may be associated mainly with the interstellar gas in the host galaxy seen edge-on. One of the objects (SRGA J224125.9+760343) turned out to be a narrow-line Seyfert 1 galaxy with a luminosity close to the Eddington limit.

The results of our study confirm the expectations that the ART-XC telescope is an efficient instrument in searching for heavily obscured and other interesting AGNs in the relatively nearby ($z \lesssim 0.3$) Universe. The SRG sky survey will last for another three years or more, which must allow a lot of such objects to be discovered.

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Fig. 9. Positions of the AGNs under study (red dots and limits) on the BPT diagram (Baldwin et al. 1981) constructed from SDSS data (release 7, SDSS Collaboration 2009). The demarcation lines between different classes of galaxies were taken from Kauffmann et al. (2003)—the dashed line, Kewley et al. (2001)—the thin line, and Schawinski et al. (2007)—the thick line. Only the six objects for which we managed to determine the parameters of the required lines are shown. The diagram was constructed with the help of the site http://wwwmpa.mpa-garching.mpg.de/SDSS/DR7/Data/gal_line_dr7_v5_2.fit.gz.
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