New nearby AGNs from all sky surveys of INTEGRAL and RXTE observatories

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We present first results of a campaign of optical identifications of X-ray sources discovered by RXTE and INTEGRAL observatories during their all sky surveys. In this work we study six newly discovered nearby active galactic nuclei at \(z < 0.1\).

INTRODUCTION

During last decade a significant progress in understanding the properties of active galactic nuclei (AGNs) and their evolution was achieved. In particular, it was shown that the rise of volume density of low luminosity AGNs occurred at much lower redshifts than that of high luminosity AGNs (see e.g., Steffen et al. 2003; Ueda et al. 2003). Observations show that a large fraction of cosmic X-ray background is contributed by AGNs with high intrinsic photoabsorption (see e.g., Hasinger 2004), while fraction of absorbed AGNs rises with the decrease of their X-ray luminosity (Ueda et al. 2003; Sazonov & Revnivtsev 2004).

In frames of widely accepted “unification scheme” of AGNs (see e.g., Antonucci & Miller 1983; Krolik & Begelman 1988; Setti & Walter 1999; Antonucci 1993) the absorption observed in X-ray and optical spectra of AGNs is explained as a result of obscuration by molecular torus around the central black hole of AGN. In order to probe different theories of X-ray and optical absorption (i.e., theories of AGN unification) and in order to obtain accurate estimates of AGN volume density in local Universe \((z < 0.1)\) one need to study large sample of redshift AGNs. Unfortunately, it is not possible to obtain this sample in deep surveys of extragalactic fields, which were done recently with last generation X-ray telescopes (e.g. Brandt et al. 2001; Hasinger et al. 2001), due to their small sky coverage.

It is very hard for X-ray telescopes to cover a large fraction of the sky due to their small fields of view. Until recently practically the only available X-ray survey at the energies above 2 keV was HEAO1/A2 all sky survey (Piccinotti et al. 1982). Recently completed all sky survey of RXTE observatory (XSS - RXTE Slew Survey, Revnivtsev et al. 2004) allowed to improve the sensitivity and considerably increased the X-ray sample of local AGNs (Sazonov & Revnivtsev 2004). However, due to not very hard energy band of the RXTE survey (3–20 keV) its sensitivity to highly absorbed AGNs \(\log(N_{\text{H}L}) > 23\) is low, which introduce a considerable bias in the sample.

Large solid angle surveys in hard X-rays of INTEGRAL and SWIFT observatories (Revnivtsev et al. 2006, in preparation; Gehrels et al. 2004; Markwardt et al. 2005) allow one to avoid this bias.

At the present time observations of INTEGRAL satellite (Winkler et al. 2003) covered a significant part of the whole sky and allowed one to discover a set of AGN candidates (see e.g. Sazonov et al. 2005; Revnivtsev et al. 2006, in preparation). Optical identifications of these AGN candidates are complicated in many cases because of insufficiently accurate positions of these sources provided by INTEGRAL telescopes (typically 2–3′). It is especially difficult to identify sources which have no counterparts in other catalogs which have more accurate positions, e.g. ROSAT all sky survey catalog (Voges et al. 1999).

The number of nearby \((z < 0.1)\) X-ray bright \((L_x > 10^{42–43} \text{ erg/s})\) AGNs is not very large. For example, the most sensitive up to date all sky X-ray survey (XSS) contains only \(~75\) AGNs with redshifts \(z < 0.1\). Therefore, even few nearby AGNs added to this sample are of value.

Recently we (in collaboration with S.Sazonov, E.Churazov and A. Vikhlinin) initiated a campaign of optical identification of sources from RXTE and INTEGRAL all sky surveys. In this Letter we present first results obtained during this project. The optical data were obtained with Russian-Turkish 1.5-m Telescope (RTT150, TÜBİTAK National Observatory, Antalya, Turkey).
Turkey). For the first series of observations we selected only sources with relatively accurate positions, determined with ROSAT, EINSTEIN, SWIFT or CHANDRA (Sazonov et al. 2005) observatories. Six studied XSS and IGR sources were identified with AGNs in nearby galaxies.

DATA ANALYSIS

As a first set of X-ray sources we have selected RXTE and INTEGRAL objects of the northern sky (Dec > −30°) which have the best localization accuracy because of observations of EINSTEIN, ROSAT, CHANDRA or SWIFT satellites. List of studied sources is presented in Table 1.

Observations were performed with RTT150 during August 8–13, Sept. 5–10 and Oct. 4–9, 2005 using low resolution spectrometer TFOSC and CCD-photometer.

Spectrometer TFOSC

The TÜBİTAK Faint Object Spectrograph and Camera1 (TFOSC) is a direct imaging and low-to-medium resolution spectrometer, similar to DFOSC and other instruments of this series, build at Copenhagen University Observatory. It was build and delivered to RTT150 telescope only recently. In this Letter we present first scientific results from spectrometric data obtained with this instrument.

In order to minimize the losses of light we have selected the slit width 100 μm (corresponding to 2.6′′ angular size on the sky). For this study we used the grism #15, which provides the maximal light efficiency and the widest spectral range (3300–9000 Å). Obtained spectral resolution is 12–15 Å (600–800 km/s)

Grism #7 (spectral range 3900–6750 Å) provides better spectral resolution (∼7 Å), but for objects with redshifts z > 0.03 important part of the spectrum with group of lines Hα and [NII], λλ6548, 6584 Å would be lost which will require additional observations with grism #8 (5800–8000 Å). Spectra with higher spectral resolution (grisms #7 and #8) of some objects will be presented in separate paper.

Since studied objects are not too faint (see Table 1), during our observations we used 5–10 min exposures, depending on a source brightness. For every object we obtained 2–6 individual spectra. Inside series of spectral images the calibration spectra of neon and helium calibration lamps were taken. Every night we also obtained spectra of spectrophotometric standards at corresponding zenith angles.

Analysis of obtained spectral data was done with modified version of DECH package [Galazutdinov 1992]. Overall accuracy of absolute wavelengths calibration is ∼1 Å. For subsequent photometric calibration of obtained spectra we used our observations of spectrophotometric standards. Additional correction for interstellar reddening was done using the neutral hydrogen map of Dickey & Lockman 1990.

RESULTS

We have obtained deep (limiting magnitude Rc 23.5 mag) images of localization regions of AGN candidates (see Fig. 1). Circles on Fig. 1 show different localizations of these sources obtained by RXTE, ROSAT, CHANDRA, INTEGRAL and SWIFT satellites. In some cases localization accuracy was high enough to assure unambiguous identification of optical counterpart of the X-ray source. If more than one relatively bright (Rc < 16) optical object was found within localization uncertainty radius we obtained optical spectra of several optical objects. These objects are marked with numbers in Fig. 1.

For all these X-ray sources we found optical objects with bright emission lines of Hα and O[III] with redshifts z > 0 which clearly indicates the presence of nearby galaxies.

Width of hydrogen lines and ratio of fluxes of lines Hα, Hβ, O[III] and N[II] reveal the presence of an active nucleus in the galaxies (shown by arrows in Fig. 1). Some parameters of obtained spectra are presented in Tables 1 and 2. Spectra, normalized on continuum flux are presented in Fig. 2.

Study of deep images of AGNs showed that in all cases we detected extended object around the AGN — their host galaxies. Angular sizes of galaxies at the sensitivity limit of images are ∼10–20′′ which correspond to linear sizes of the galaxies ∼10–20 kpc.

In Fig. 3 we present correlation between X-ray luminosity and luminosity of AGN in O[III]λ5007. As it was shown by different authors (see e.g., Heckman et al. 2005) these two quantities are well correlated.

Our measurement of AGN luminosities in X-rays and oxygen line are consistent with these results, taking into account possible variability of AGN luminosity on time scales of months and years between our X-ray and optical measurements.

CONCLUSION

We have performed series of observations of AGN candidates discovered by RXTE and INTEGRAL observatories with RTT150 telescope. Using low resolution spectrometer TFOSC we obtained a number of spectra within localization regions of these X-ray sources. In all cases we have discovered relatively bright (Rc < 17) optical objects with redshifted emission lines, typical for AGNs. We present redshifts of these AGNs and main parameters of their emission lines, which allowed us to classify them as Seyfert 1 or Seyfert 2. Six newly identified AGNs in local Universe is a significant contribution to the existing samples of nearby AGNs. Therefore, further continuation of our campaign of identification of RXTE and INTEGRAL AGN candidates in optical is an important task which will

1 http://astroa.physics.metu.edu.tr/tug/tfosc.html
Table 1. List of identified AGNs and their main parameters.

| Source Name         | R.A.       | Dec.       | R_c | z      | log L_{O[III]} | log L_x | FWHM_{H_2} | km/s | Type  | Comment        |
|---------------------|------------|------------|-----|--------|----------------|--------|-------------|------|-------|----------------|
| XSS J0505−2348      | 05 05 45.7 | −23 51 14  | 14.6| 0.0351(2)| 41.1           | 43.6   | < 685       |      | Sy2   | 2MASX J05054575−2351139 |
| XSS J1615−0943      | 16 15 19.1 | −09 36 14  | 14.8| 0.0650(2)| 42.0           | 43.9   | 1600        |      | Sy1   | IRXS J161519.2−093618 |
| IGR J18559+1535     | 18 56 06.6 | +15 37 58  | 16.6| 0.0838(2)| 42.2           | 44.7   | 3200        |      | Sy1   | 2E 1853.7+1534 |
| IGR J19473+4452     | 19 47 19.4 | +44 49 43  | 17.2| 0.0532(2)| 41.4           | 43.5   | < 685       |      | Sy2   | 2MASX J19471938+4449425 |
| IGR J21277+5656     | 21 27 44.4 | +56 56 35  | 16.6| 0.0144(2)| 41.6           | 43.2   | 1600        |      | Sy1   | IRXS J212746.7+565606 |
| XSS J21354−2720     | 21 34 45.1 | −27 25 56  | 15.8| 0.0670(2)| 41.9           | 43.8   | 1190        |      | Sy1.5?| 1RXS J213445.2−27251 |

X-ray fluxes were calculated for 2-10 keV energy band, assuming power law shapes of AGN spectra (Γ = 1.8). Observed fluxes were taken from RXTE survey (3–20 keV, Revnivtsev et al. 2004) or measured with CHANDRA (2–10 keV, Sazonov et al. 2005) or INTEGRAL (17–60 keV, Revnivtsev et al. 2006, in preparation).

Table 2. Parameters of some lines in AGN spectra

| Source Name        | H_α, λ4340 | H_β, λ4861 | O_[III], λ4959/λ5007 | H_α, λ6563 |
|-------------------|-------------|-------------|-----------------------|-------------|
| XSS J0505−2348     | 10 18       | < 15 15     | 34/102                | < 15 80     |
| XSS J1615−0943     | 26 30       | 33 94       | 16/52                 | 35 398      |
| IGR J18559+1535    | –           | 69 115      | 16/47                 | 70 542      |
| IGR J19473+4452    | < 10 4      | < 14 7      | 24/69                 | < 15 32     |
| IGR J21277+5656    | 20 52       | 37 169      | 28/77                 | 35 515      |
| XSS J21354−2720    | 12 18       | 17 40       | 35/107                | 26 160      |

Spectral resolution in these observations was Δλ ∼ 15Å. Widths of hydrogen lines are given with corrections to instrumental widening. Accuracy of determination of lines equivalent widths (EW) ∼10-15%.

help to improve our knowledge of demography of supermassive black holes in local Universe.

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NOTE: When paper was already accepted we have noticed that one AGN of our sample (IGR J18559+1535) was also identified by the group of Masetti et al. (2005)

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Fig. 3. Correlation of optical luminosity of AGNs in emission line O[III]λ5007 with X-ray luminosity. Open circles show type 2 Seyferts, filled circles — type 1 Seyferts. Dashed line shows linear correlation with $\log L_x/L_{\text{O[III]}} \sim 2$. 
Fig. 1. RTT150 images of the sky in $R_c$ filter around unidentified X-ray sources of RXTE and INTEGRAL all sky survey.
Fig. 2. Normalized spectra of identified AGNs.