X-RAY SPECTRAL PROPERTIES OF THE ISOLATED AGNs: NGC 1050, NGC 2989, ESO 317-038, ESO 438-009

I.B. Vavilova, A.A. Vasylenko, Iu.V. Babyk, N.G. Pulatova

Main Astronomical Observatory of the NAS of Ukraine,
27 Akademika Zabolotnogo St., Kyiv, MSP 03680, Ukraine, *irivav@mao.kiev.ua*

ABSTRACT. We have analyzed the spectral data obtained by XMM-Newton, Swift, Chandra, and INTEG-RAL space observatories for several isolated AGNs from 2MIG catalogue, for which the available X-ray data were accessed. Among these objects were CGCG 179-005, NGC 6300, NGC 1050, NGC 2989, WKK 3050, ESO 438-009, and ESO 317-038. We determined corresponding spectral models and values of their parameters (spectral index, intrinsic absorption etc.). X-ray spectra for bright galaxies, NGC 6300 and Circinus, were analyzed up to 250 keV and their characteristics of emission features were determined in 6-7 keV range.

We present the results for NGC 1050, NGC 2989, ESO 317-038, and ESO 438-009, for which their spectral parameters were obtained for the first time.

Keywords: Active galaxy nuclei – X-ray; Objects: NGC 1050, NGC 2989, ESO 317-038, ESO 438-009

1. Introduction

The most galaxies with active nuclei (AGNs) in the Local Universe are in a low-luminosity state (Ptak et al., 2000; Ho et al., 2009; Maia et al., 2003; Pulatova et al., 2015). In this sense, the principal question is why this state is related also to X-ray activity of the isolated galaxies with active nuclei (AGNs). The answer will be helpful to explain the AGN's paradigm in detail as well as to get a response to the internal evolution of galaxy activity as well as to investigate the influence of halo matter (baryonic/dark) on the formation and productivity of AGN's engine.

With this goal we have analyzed the data obtained by XMM-Newton, Swift, Chandra, and INTEG-RAL X-ray observatories to find the X-ray spectra of a good quality for several isolated AGNs from 2MIG catalogue (Karachentseva et al., 2010). We have selected such objects as CGCG 179-005, NGC 6300, NGC 1050, NGC 2989, WKK 3050, ESO 438-009, and ESO 317-038 and determined their main spectral properties. In this paper we describe briefly our results for NGC 1050, NGC 2989, ESO 438-009, and ESO 317-038, for which their spectral parameters were not previously studied.

2. Data processing

The Swift/BAT spectra were derived from the 70-month hard X-ray Survey (Baumgartner et al. 2013). The reduced Swift /XRT products were taken by using the XRT products generator (http://www.swift.ac.uk/user_objects/) (Evans et al. 2007, 2009, 2010) with HEASOFT 6.15.1 software package in UKSSDC (UK Swift Science Data Centre) archive. We only used the data taken in the photon counting (PC) mode in such a manner that we were able to identify the precise locations of our targets without any contamination. Only events with energy in the range of 0.3–10 keV with grades 0–12 were included.

The XMM-Newton MOS and PN data were pro-cessed using the standard software packages XMM SAS ver. 11.0 (Science Analysis Software) according to the guidelines of XMM-Newton User's Manual. Because of its higher sensitivity, we use the EPIC/PN spectrum for the analysis of NGC 1050, although duration of exposure for EPIC/MOS has been slightly longer (but it has less data as compared to PN). Only patterns corresponding to single and double events (pattern ≤4) were taken into account for the PN camera. Filter FLAG=0 was applied to exclude bad pixels and events that are at the edge of a CCD. The ARFGEN and RMFGEN tasks were used to create ancillary and response files. Spectra were binned according to the luminosity of each source.

The XMM-Newton/XRT and BAT spectra were treated together and analyzed using XSpec ver.12.6 software. Since observations for each instrument are not simultaneous, a cross-calibration constants C have been introduced in our models. In order to derive the luminosities we used the standard ΛCDM cosmological model with parameters H_0 =70 (km·s)/Mpc, Λ=0.73, Ω_{m}=0.27 (Bennett, 2003) as well as the Galactic absorption (see Table 1) has already been taken into account in the fitting.

The Chandra data was analyzed with CIAO software package (Chandra Interactive Analysis of Observations, version 4.7 (Fruscione et al. 2006) and the latest realize of calibration files. The standard reprocessing and screening routines to create new level=2 event files were made using *chandra repro* script. To extract the source and background spectra with ARF and RMF files we have used *specextract* script. The XSpec environment version 12.6.0 was used to model all spectra with absorbed power law model. The errors of best-fit parameters correspond of 1σ confidence level.

3. Results

The main spectral parameters of NGC 1050, NGC 2989, ESO 317-038 and ESO 438-009 are given in Table 1, namely, Column (1): Object name; Column (2): Right Ascension from NASA/IPAC Extragalactic Data base (NED); Column (3): Declination (NED); Column (4): Redshift (NED); Column (5): X-ray Observatory/ Instrument; Column (6): Observation exposures in ks; Column (7): Galactic absorption in units of 10^{20} cm^{-2} (by Kalberla

Table 1. The main spectral parameters of NGC 1050, NGC 2989, ESO 317-038 and ESO 438-009 for the absorbed power law fits to the data

(1) Object (Type)	(2) RA (deg) (J2000)	(3) Dec. (deg) (J2000)	(4) z	(5) Instrument	(6) Exposure (ks)	(7) N_H 10^{20} cm^{-2}	(8) L, 10^{40} erg/s	(9) N_H	(10) Phot. index
NGC 1050 (Sy2)	40.648	34.764	0.013	XMM-Newton/ EPIC PN	9.507*	5.67	2.15±0.23 (0,5-2 keV)	47.43±0.81 (10^{22} cm^{-2})	2.0 (fixed)
NGC 2989 (AGN)	146.355	-18.374	0.014	Swift/ XRT	27.8*	4.34	2.19 (0,5-2 keV)	$5.07^{+0.10}_{-0.05}$ (10^{20} cm^{-2})	1.69±0.68
ESO 317-038 (AGN)	157.440	-38.349	0.015	Swift/ XRT+BAT	14.4*+8482	6.0	27.1	$17.05^{+32.59}_{-14.12}$ (10^{22} cm^{-2})	1.7 (fixed)
ESO 438-009 (Sy1.5)	167.700	-28.501	0.024	Swift/ XRT+BAT	17.4*+7242	5.26	357	$4.61^{+4.76}_{-3.40}$ (10^{21} cm^{-2})	1.89±0.08
* Exposure time in ks (EPIC PN/Swift XRT) after the data screening									

et al. 2005 (LAB map)); Column (8): Luminosity, L, in units of 10^{40} erg/s in 2-10 кeV range; Column (9): Intrinsic absorption in units of 10^{22} cm^{-2}; Column (10): Photon Index.

NGC 1050 has been observed by XMM-Newton (2013-02-27, ID 0693540201). X-ray spectrum has a bad quality and the data beyond ~5 keV are absent. It was fitted by the model *phabs*(zbbody+zpo)*, where *tbabs* corresponds to the Galactic absorption. Because of a lack of data in the middle range, we have fixed a value of the photon index as $\Gamma = 2.0$. We determined the values of flux in 0.5-2.0 keV as $(5.64±0.59) \cdot 10^{14}$ ergs/cm^2/s and black-

body model as $kT = 189±23$ eV (χ^2/dof = 15.41/11 = 1.4). Other parameters are summarized in Table 1 and the best fitting spectrum is presented in Figure 1 (left panel).

X-ray observational data for NGC 1050 are presented for the first time.

NGC 2989 has been observed twice by Swift/ XRT (2008-10-06/08), duration of exposure in XRT/PC mode was 14125 s та 13672 s. A lower limit of spectrum was 2.5 keV. We fitted it by the model *phabs* zphbs*zpo*, where *phabs* corresponds to the Galactic absorption. A value of the photon index was determined as Γ=1.69±0.68, χ^2/dof = 9.06/9. The main parameters are summarized in Table 1 and its spectrum is presented in Figure 1 (left panel). The errors are caused by the poor quality of the XRT data.

ESO 317-038 has been observed six times by Swift/XRT from 2011-02-24 to 2011-03-20, duration of exposure in XRT/PC mode was 623 ÷ 4909 s. A spectral analysis was conducted altogether with the Swift/BAT observational data and allowed us to enlarge a spectral range till 195 keV. A lower limit of spectrum was also 2.5 keV. We fitted its spectrum by the model *phabs*zphbs* cutoffpl*, where *phabs* corresponds to the Galactic absorption. We fixed a value of the photon index as Γ=1.7 and energy as $E_{cut-off}$= 500 keV. Luminosity is $2.71 \cdot 10^{41}$ ergs/s in 2.0-10 keV, $6.31 \cdot 10^{42}$ ergs/s in 14-195 keV (Swift BAT 70-Month Hard X-ray Survey). The main parameters are

summarized in Table 1 and its spectrum is presented in Figure 1 (right panel). The errors are caused by the poor quality of the XRT data.

ESO 438-009 has been observed three times by Swift/XRT from 2010-11-02 to 2010-11-08, duration of exposure in the XRT/PC mode is 1172÷6429 s. A spectral analysis was conducted altogether with the Swift/BAT observational data and allowed us to enlarge a spectral range till 195 keV. A lower limit of spectrum is 0.5 keV. We fitted its spectrum by the model phabs*zxicpf*cut offpl, where *zxipcf* corresponds to the absorption by the ionized matter with the overlap factor C (we fixed C=1). We determined the photon index as Γ=1.86±0.06, cut-off energy was fixed as $E_{cut-off}$ = 500 keV. Intrinsic ionized absorption is N_H= $4.61^{+4.76}_{-3.40}$ 10^{21} cm^{-2} and ionization rate log ξ = $2.35^{-0.44}_{+0.68}$; χ^2/dof=134.51/116. Luminosity is L_x=2.73 10^{42} ergs/s in 0.5-2.0 keV, $4.94 \cdot 10^{41}$ ergs/s in 2.0-10 keV, $1.24 \cdot 10^{43}$ ergs/s in 14-195 keV (Swift BAT 70-Month Hard X-ray Survey). The main parameters are summarized in Table 1 and its spectrum is presented in Figure 1 (right panel).

4. Brief discussion

One can see, the studied galaxies are of low activity (X-ray luminosity is less than 10^{42} ergs/s) that is consistent with our previous research (Pulatova et al., 2015), where we found that isolated AGNs in the Local Universe are mostly faint in X-ray. Altogether with these new data, a mean luminosity for 17 the 2MIG isolated AGNs without companions is L_x ~1.9·10^{42} ergs/s in the soft 2-10 keV range (see, for comparison, results by Halderson (2001). The same estimations were derived by Anderson et al. (2013) for subsets of 2MIG galaxies: the average luminosity L_X within 50 kpc is 1.0·10^{40} ergs/s. They found also that that 1/2 of the total emission is extended and about 1/3 of the extended emission comes from hot gas.
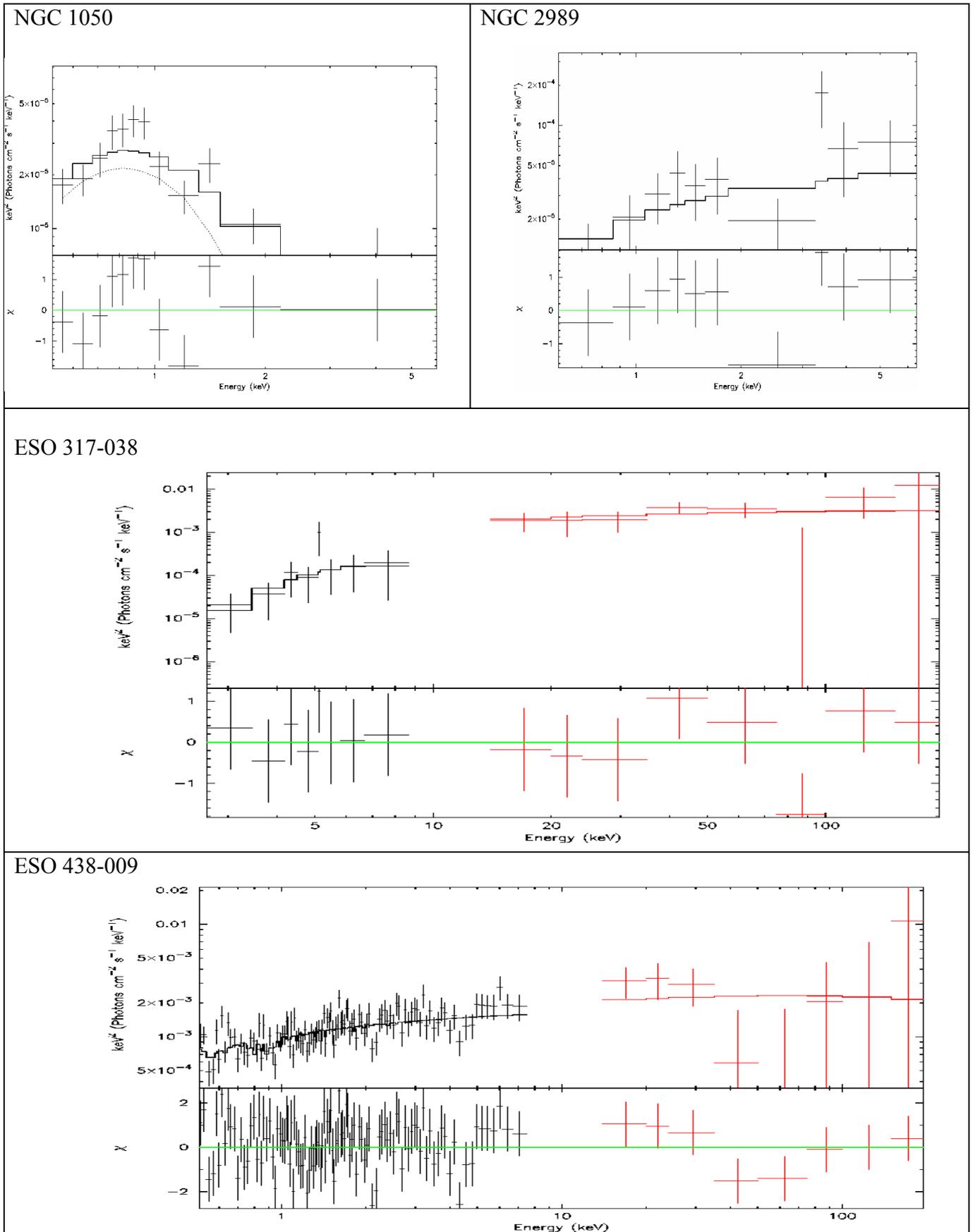
Figure 1: Unfolded spectrum of the isolated galaxies with active nuclei (their parameters are in Table 1).
Top: NGC 1050 and NGC 2989; the spectra were obtained in 0,5-10 keV range with XMM-Newton/XRT/BAT (best fitting spectra) and Swift respectively. *Down*: ESO 317-038 and ESO 438-009; the broad-band spectra were obtained in 0,5-150 keV range with Swift and INTEGRAL (red)

The authors (Melnyk et al., 2013) in their research with two selected samples XMM-LSS field (X-ray galaxies and AGNs) have studied an environment effect and found that AGNs, including soft X-ray AGNs, when comparing to X-ray galaxies, prefer to be located in lower galaxy overdensities. It is in a good agreement with our estimations on the influence of choice of isolation criteria for spatial analysis and physical/morphological properties of host galaxies (Vavilova, 2009; Elyiv, 2009). At the same time, we do not confirm the conclusion that the softest AGNs are of Sy1 type.

We noted in our research (Pulatova et al., 2015) that Sy 1 type galaxies appear to be more luminous that of Sy 2 type. Some AGNs of our sample have the spectral energy distribution almost flat from the infrared to X-ray part of spectrum, as result the spectral index is ~ 1, although it is usually steeper.

The stronger X-ray flux, than X-ray continuum is produced by lower energy photons. These photons are scattered to higher energies by relativistic electrons using Compton scattering. The fraction of the power emitted in the X-ray flux is almost four times bigger in AGNs than in normal galaxies. Using such property, we conclude that X-ray soft emission from the studied objects is in favor of the presence of AGN's engine. Additional evidences are the normalized excess variances (variability amplitudes) that anti-correlate with black hole masses. Our preliminary estimations point out (Chesnok et al., 2010) that the isolated AGNs in the Local Universe posses a low-mass black holes (intermediate values, 10^5-10^6 M_{Sun}) being closer to their primordial mass (Ludlam et al., 2015).

To investigate the correlation between photon index of power law model and X-ray flux for each AGNs we have used additional data of XMM-Newton and Chandra observatories. Figure 2 shows the distribution of slopes of spectra of the isolated AGNs over X-ray flux. It was found a clear correlation between these values: the slope is 1.3. At the same time, we did not find correlation between the photon index and luminosity of the studied X-ray isolated AGNs.
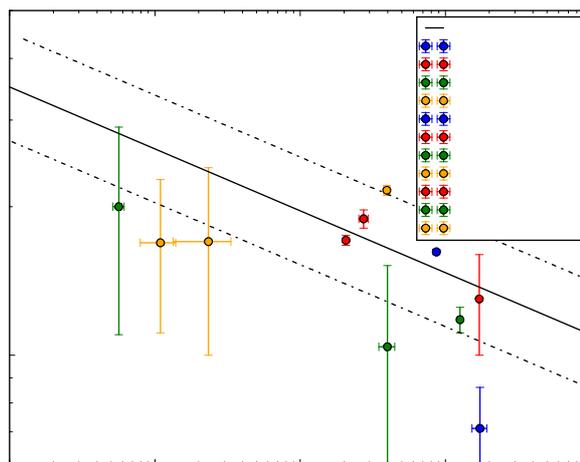
Figure 2: The Flux - Photon Index relation for X-ray sample of the isolated AGNs. The solid line corresponds to the simple power law model with slope 1.3, while two dotted lines correspond to the standard deviation.

References

Anderson M.E. et al.: 2013, *ApJ*, **762**, Is. 2, article id. 106.
Baumgartner W. H. et al.: 2013, *ApJSS*, **207**, 19.
Bennett C.L. et al.: 2003, *ApJSS*, **148**, 1.
Chesnok et al.: 2009, *Kinemat. Phys. Celest. Bodies*, **25**, issue 2, 107.
Chesnok N. et al.: 2010, *AIP Conf. Series.*, **1206**, 328.
Elyiv A.A. et al.: 2009, *MNRAS*, **394**, Is. 3, 1409.
Evans P. A. et al.: 2007, *A&A*, **469**, 379.
Evans P. A. et al.: 2009, *MNRAS*, **397**, 1177.
Evans P. A. et al.: 2010, *A&A*, **519**, A102.
Fruscione et al.: 2006, SPIE Proc. 6270, 62701V, D.R. Silvia & R.E. Doxsey, eds.
Halderson E.L. et al.: 2001, *AJ*, **122**, 637.
Ho L.C.: 2009, *ApJ*, **699**, 626.
Hwang H.S. et al.: 2012, *A&A*, **538**, A15.
Kalberla P. M. et al.: 2005, *A&A*, **440**, 775.
Karachentseva V.E. et al.: 2010, *Astrophys. Bull.*, **65**, 1.
Ludlam R.M. et al.: 2015, *MNRAS*, **447**, 2112.
Maia M.A.G. et al.: 2003, *ApJ*, **126**, 1750.
Melnyk O.V. et al.: 2013, *A&A*, **557**, id. A81.
Ptak A. et al.: 1999, *ApJSS*, **120**, 179.
Pulatova N.G.et al.: 2015, *MNRAS*, **44**7, 2209.
Vasylenko A.A. et al.: 2015, *Ap&SS*, DOI: 10.1007/s10509-015-2585-z
Vavilova I. B. et al: 2009, *Astron. Nachr.*, **330**, 1004.
Vol'vach A.E. et al.: 2011, *Astron. Reports*, **55**, 608.