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Classification of unidentified AGNs detected with Swit/BAT

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Through an optical campaign performed at 5 telescopes located in the Northern and the Southern Hemisphere, plus archival data from two on-line sky surveys, we have obtained optical spectroscopy for 17 counterparts of suspected or poorly studied hard X-ray emitting Active Galactic Nuclei (AGNs) detected with Swift/BAT and selected from the Swift/BAT AGN surveys of Tueller et al. (2009), Ajello et al. (2008) and Winter et al. (2008) in order to determine or better classify their nature. We find that 7 sources of our sample are Type 1 AGNs, 9 are Type 2 AGNs and 1 object is an X-ray Bright Optically Normal Galaxy (XBONG); the redshifts of these objects lie in a range between 0.012 and 0.286. For all these sources an X-ray data analysis has also been performed in order to estimate their absorption and to search for possible Compton thick candidates. Among type 2 objects, we found no clear Compton thick AGN but at least 6 out of 9 objects resulted to be highly absorbed ($N_H > 10^{23}$ cm^{-2}), while there is one which does not require intrinsic absorption, i.e. it seems to be a naked Seyfert 2 galaxy.

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1. Introduction

The *Swift* mission was designed to study cosmic gamma-ray bursts (GRBs) in a multiwavelength context (Gehrels et al. 2004), but with its unique repointing capabilities it is able to study and monitor other types of X-ray emitting objects. Through its payload, consisting of three instruments, i.e. the burst alert telescope (BAT; Barthelmy, 2004), the X-Ray telescope (XRT; Burrows et al. 2004) and the ultraviolet/optical telescope (UVOT; Roming et al. 2004), *Swift* can detect and follow X-ray emitting objects up over a wide range of wavelengths.

Observations performed below 10 keV with other satellites, such as *ASCA*, *BeppoSAX* (Matt et al. 2000, Ueda et al. 1999), *Chandra*, *XMM*, and *Suzaku* (Ueda et al. 2007, Guainazzi et al. 2005), have revealed a population of absorbed AGNs with a hydrogen column density along the line-of-sight higher than 10^{23} cm^{-2}, which obscures the nuclei at optical and soft (0.2-10 keV) X-ray bands. Now a number of surveys at energies higher than 10 keV is available to study this class of objects. In this work we have selected from the *Swift*/BAT AGN surveys of Tueller et al. (2009), Ajello et al. (2008) and Winter et al. (2008) those objects (17 in total) either without optical identification, or not well studied or without published optical spectra. Following the method applied by Masetti et al. (2004, 2006a,b, 2008, 2009) for the optical spectroscopic follow-up of unidentified *INTEGRAL* sources, we determine the nature of these 17 selected objects.

In the following sections we show the optical spectroscopic results and the X-ray data analysis for all of our sources, divided in Type 1 and Type 2 AGNs. Results are reported in Table 1. A complete treatment of the data presented here is available in Parisi et al. (2009)

2. Observations and data analysis

The following telescopes were used for the optical spectroscopic study presented here:

- the 1.5m telescope at the Cerro Tololo Interamerican Observatory (CTIO), Chile;
- the 1.52m "Cassini" telescope of the Astronomical Observatory of Bologna, in Loiano, Italy;
- the 1.8m "Copernicus" telescope at the Astrophysical Observatory of Asiago, in Asiago, Italy;
- the 2.1m telescope of the Observatorio Astrónomico Nacional in San Pedro Martir, Mexico;
- the 3.58m telescope "Telescopio Nazionale Galileo" (TNG) at the Observatorio of the la Roque de Los Muchachos (Canary Islands, Spain);

plus archival spectra from 6dF[1] and SDSS[2].
The data reduction was performed with the standard procedure using IRAF.

The X-ray data analysis were performed using Swift/XRT for 13 out of 17 objects, while for the remaining ones archival XMM-*Newton* and *Chandra* observations have been considered. Due to the low statistics available, we chose for each source the best energy range for the spectral

[1] `http://www.aao.gov.au/local/www/6dF`
[2] `http://www.sdss.org`

Table 1: Main results obtained from the analysis of the optical and X-ray spectra of the 17 AGNs of the present sample

Object	Class	z	Opt. telescope	N_H Gal $\times 10^{22}$cm^{-2}	N_H AGN $\times 10^{22}$cm^{-2}	Γ^{+}	$F_{(2-10)keV}$ $\times 10^{-12}$erg s^{-1} cm^{-2}	X-ray telescope
Swift J0059.4+3150	Sy1.2	0.015	SPM	0.055	–	$1.67^{+0.03}_{-0.03}$	7.3	Swift/XRT
Swift J0134.1−3625	Sy2	0.029	CTIO	0.019	75^{+34}_{-21}	[1.8]	1.9	Swift/XRT
Swift J0342.0−2115	Sy1	0.0139	AAT+6dF	0.023	–	$1.94^{+0.05}_{-0.05}$	23.8	Swift/XRT
Swift J0350.1−5019	Sy2	0.035	CTIO	0.012	17^{+9}_{-7}	[1.8]	3.1	Swift/XRT
Swift J0505.7−2348	Sy2	0.036	SPM	0.021	$6^{+0.5}_{-0.5}$	$1.4^{-0.4}_{+0.3}$	15.5	Swift/XRT
Swift J0501.9−3239	Sy2	0.0126	AAT+6dF	0.018	–	$1.45^{+0.05}_{-0.05}$	13.6	Swift/XRT
Swift J0640.1−4328	Sy2	0.061	CTIO	0.025	$11.7^{+4.5}_{-3.6}$	[1.8]	2.2	Swift/XRT
Swift J0727.5−2406	Sy1.9	0.123	TNG	0.650	–	–	0.6	Chandra
Swift J0739.6−3144	Sy2	0.026	SPM	0.431	47^{+13}_{-12} $14^{+2.3}_{-1.9}$	$1.77^{+0.07}_{-0.09}$	0.9	XMM/EPIC
Swift J0743.0−2543	Sy1.2	0.023	CTIO	0.581	–	–	14.7	XMM/EPIC
Swift J0811.5+0937	XBONG	0.286	TNG	0.024	–	–	0.1	Chandra
Swift J0902.0+6007	Sy2	0.012	Asiago	0.043	$8^{+8.6}_{-4.0}$	[1.8]	1.1	Swift/XRT
Swift J0904.3+5538	Sy1.5	0.0374	SDSS	0.022	–	$1.44^{+0.07}_{-0.07}$	4.9	Swift/XRT
Swift J0911.2+4533	Sy2	0.0269	SDSS	0.012	$30^{+9.5}_{-7}$	[1.8]	2.0	Swift/XRT
Swift J0917.2−6221	Sy1.2	0.057	CTIO	0.158	$0.7^{+0.3}_{-0.3}$	$1.67^{+0.2}_{-0.2}$	16.0	Swift/XRT
Swift J0923.7+2255	NLSy1	0.034	SPM	0.031	–	$1.95^{+0.05}_{-0.05}$	11.8	Swift/XRT
Swift J1049.4+2258	Sy2	0.033	Loiano	0.019	20^{+5}_{-3}	[1.8]	0.7	Swift7XRT

The typical error on the redshift measurement is ± 0.001 but for the SDSS and 6dFGS spectra, for which an uncertainty of ± 0.0003 can be assumed.
$^{+}$ The square brackets in the Γ column indicate that we used a fixed value

analysis and we employed a simple power law (often fixing the photon index to a canonical value of 1.8), absorbed by both the Galactic (Dickey & Lockman 1990) and the intrinsic neutral hydrogen column density when required as our baseline model.

3. Type 1 AGNs

The seven Type 1 AGNs (see Fig. 1 for few examples of our spectra) of our sample could be recognized as they show broad H_α+[N II] complex in emission, H_β emission line and the [O III]5007 forbidden narrow emission line. These enable us to calculate the redshifts of these objects that lie in a range between 0.014 and 0.123. For 6 Type 1AGNs of our sample, the H_β emission flux, corrected for the Galactic color excess (Schlegel et al. 1998), and the corresponding line width were used to estimate the central black hole mass (see Table. 2). We could not estimate the mass of the central black hole of Swift J0727.5-2406 because only the narrow component of the H_β line is detected for this source, so no BLR gas velocity could be derived.

Table 2: BLR gas velocities and central black hole masses for 6 Seyfert 1 AGNs.

Object	$v_{\rm BLR}$ (km s^{-1})	$M_{\rm BH}$ ($10^7\ M_\odot$)
Swift J0059.4+3150	3500	4.5
Swift J0342.0−2115	4150	8.3
Swift J0743.0−2543	2510	2.6
Swift J0904.3+5538	2910	3.3
Swift J0917.2−6221	3460	7.0
Swift J0923.7+2255	1820	6.4

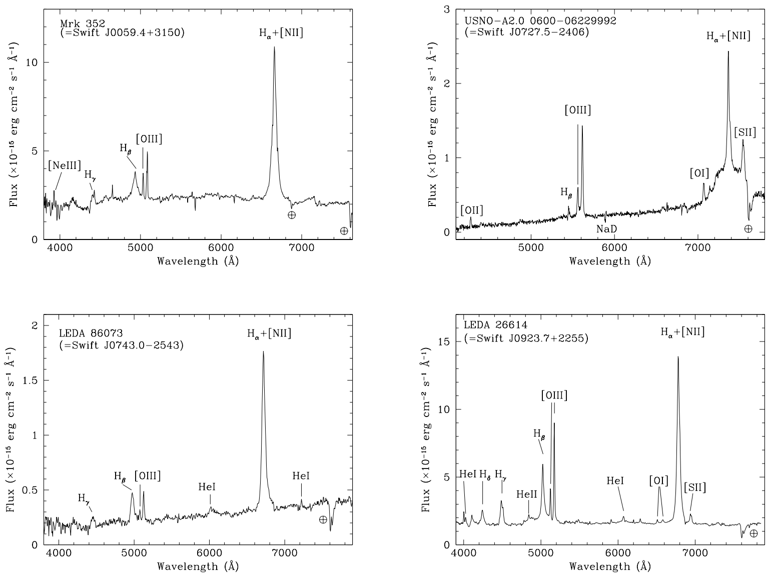

Figure 1: Spectra (not corrected for the intervening Galactic absorption) of the optical counterpart of Type 1 AGNs Swift J0059.4+3150, Swift J0727.5−2406, Swift J0743.0−2543 and Swift J0923.7+2255.

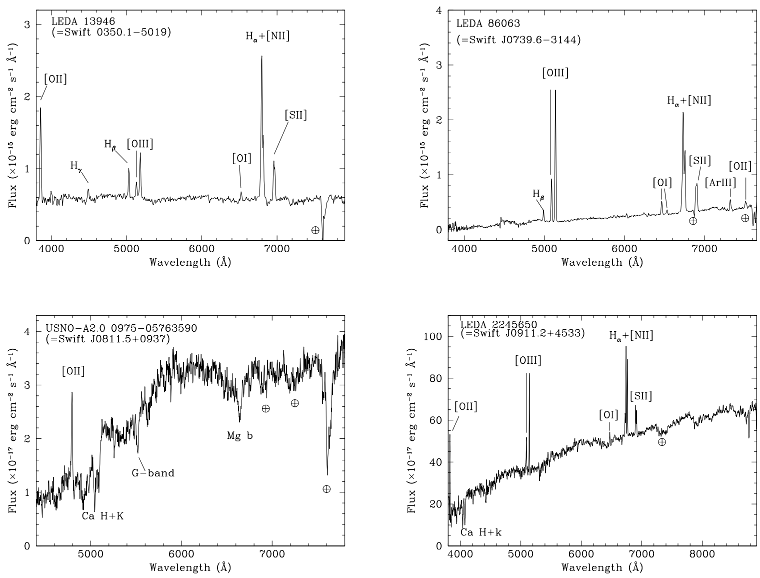

Figure 2: Spectra (not corrected for the intervening Galactic absorption) of the optical counterpart of Type 2 AGNs Swift J0350.1−5019, Swift J0739.6−3144, Swift J0811.5+0937 and Swift J0911.2+4533.

4. Type 2 AGNs

The spectra of nine type 2 sources (see Fig. 2 for few examples) of our sample show a very narrow emission H_α+[NII] complex with H_β permitted narrow emission line. Most of them show [OI]6300, [OIII]5007 and [OII]3727 forbidden narrow emission lines. From these lines we estimated the source redshifts, which lie between 0.012 and 0.061. It is worth noting the case of Swift J0501.9-3239 which is a possible naked Seyfert 2 AGN. Indeed, from our XRT data analysis, no absorption intrinsic to the source has been measured. Its softness ratio (F2-10 keV/F14-195 keV$\sim$ 0.26) is not particularly low, therefore it is unlikely to be a Compton thick AGN. However higher X-ray data quality are needed to assess if it is a real unabsorbed Seyfert 2 galaxy.

Another object of interest of our sample is Swift J0739.6-3144. For this source XMM-Newton EPIC-pn (Struder at al. 2001) data have been analyzed. We fit the X-ray spectrum using an absorbed power law model. The addition of a mekal and of the Kα iron fluorescence emission line improves the fit: the energy of the line is found to be at 6.41$\pm$0.04 keV with an equivalent width EW of $0.5^{+0.12}_{-0.13}$ keV. As recently found by Malizia et al. (2009) studying the Compton thick source IGR J16351-5806 a complex absorption is used to fit our data. In the present case this model best fits the data and provides a canonical value of power law continuum of $\Gamma = 1.77^{+0.07}_{-0.09}$ and the absorption in forms of two columns of $N_{H_1} \sim 5 \times 10^{23}$ cm^{-2} and $N_{H_2} \sim 1.5 \times 10^{23}$ cm^{-2} both covering 70-90% of the source (see Table 1).

5. Swift J0811.5+0937: an XBONG

The spectrum of this object shows a forbidden [OII] narrow emission line and absorption features. Following the method of Laurent-Muehleisen et al. (1998), for this source we have calculated the Ca II break contrast at 4000 Å (Br_{4000}), as defined by Dressler & Shectman (1987), and its value is ∼ 45%; the presence of other absorption features, such as the G band, the Mg I and the Ca II H+K doublet and the lack of strong Balmer absorption lines, enables us to state that this source is a normal galaxy. This peculiar object is thus an XBONG with redshift of 0.286±0.001.

6. Conclusions

In this work we have either given for the first time, or confirmed, or corrected, the optical spectroscopic identification of 17 Swift AGNs. This was achieved through a multisite observational campaign in Europe, Central and South America. We found that our sample is composed of 16 AGNs (7 of Type 1 and 9 of Type 2) and 1 XBONG. The softness ratio parameter has been calculated for all the AGNs, to find possible Compton candidates among Seyfert 2. For all our sources the X-ray data analysis has been performed in order to evaluate their main spectral parameters. Moreover, we searched for possible Compton thick candidates. Our Seyfert 2 objects turn out to be highly absorbed ($N_H \sim 10^{23}$ cm^{-2}), but none of them result to be Compton thick. Finally, we have estimated the central black hole masses for 6 out of 7 Seyfert 1.

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