X-ray AGM activity classes based on SDSS spectra

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Abstract

Sources of X-ray radiation are very interesting and at the same time little studied. Their class mainly includes objects that exhibit a certain activity, such as AGNs, cataclysmic variable stars, white dwarfs, pulsars, etc. Identification of X-ray sources is a rather difficult task, and it is not always possible to detect an optical object. In this work, we tried to carry out a spectral classification of X-ray AGNs and identify activity classes, taking as a basis the ROSAT BSC/FSC catalog of X-ray AGNs, compiled on the basis of low-dispersion spectral plates of the first Byurakan survey. We identified these objects with the SDSS spectral catalog and tried, by carefully studying the spectra, to find out their activity classes, as well as to understand which activity class is more common in these sources.

Keywords: active galactic nuclei, radio source, quasar, X-ray, ROSAT

1. Introduction

ROSAT data are mainly listed in two catalogs: ROSAT Bright Source Catalogue (BSC) (Voges 1999) and ROSAT Faint Source Catalogue (FSC) (Voges 2000). They are clearly distinguished from each other by X-ray flux expressed in count-rate (CR; the number of particles registered by the receiver per unit time, namely per 1 sec).
Among the identification works, the ROSAT Bright Sources (RBS,Schwope 2000) is well-known. 2012 BSC sources with CR ≥ 0.20 and $|b| > 30^o$ have been optically identified. However, most of the identified sources come from the Hamburg Quasar Survey (HQS, Hagen 1995), which was used as a basis for optical identifications.

Three main projects have been carried out: Hamburg-ROSAT Catalogue (HRC, Zickgraf 2003), Byurakan-Hamburg-ROSAT Catalogue (BHRC, Mickaelian 2006) and HRC/BHRC catalouge (Paronyan 2021). HRC is based on ROSAT-BSC and BHRC is based on ROSAT-FSC fainter sources (down to CR=0.04 to have confident X-ray sources) at $|b| > 20^o$ and $\delta > 0^o$ area.

Table 1. Source of combine catalogue

Tupe	Number	Percent
GAL	492	6.0
AGN	4253	53.0
STAR	1800	22.4
Ukn	1495	18.6
Total	8037	100.0

We combined these two Catalogues and created a new homogeneous and complete catalogue of X-ray selected AGN, which covers all the northern sky limited by high galactic latitudes ($\delta > 0^o$, $|b| > 20^o$), and

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with CR > 0.04 (Paronyan 2021). After some checks from various available catalogs, we have excluded a number of objects and included some missed AGN and finally it contained 4253 AGN or their candidates.

Out of the 4253 HRC-BHRC objects, 3369 sources were confirmed as AGN by means of optical spectral classifications; the main criteria in VCV-13 and BZCAT (Veron-Cetty 2010, Massaro 2012), 173 in (Paronyan 2019), 198 in (Paronyan 2020).

2. Observing material

These 3369 objects have been cross-correlated with GALEX (Bianchi 2011), SDSS, 2MASS (Skrutskie 2006) NIR, All WISE (Cutri 2013) , IRAS PSC (Beichman 1988) and FSC (Moshir 1992), NVSS (Condon 1988), FIRST (Becker 1997) catalogues.

Table 2. Cross-correlated catalogues

Gamma-ray	**X-ray**	**UV**	**Optical**	**IR**	**Radio**	**Catalog**
FERMI	INTEGRAL	GALEX	APM	2MASS	NVSS	RC3
INTEGRAL	ROSAT		USNO-B1.0	WISE	FIRST	VCV-13
			GSC 2.3.2	IRAS		Roma Blazar
			SDSS	AKARI		

Asobserving material wehad 1426 spectra of HRC-BHRC objects from SDSS DR10-16 (Ahn 2014, Alam 2015, Albaretti 2017, Abolfathi 2018, Ahumada 2020). Spectroscopic redshifts, intensities (assigned as "heights") and equivalent widths of spectral lines for 123 of them from SDSS DR10-DR16 are available.

Very often SDSS measurements from their spectra are based on very low-quality lines at the level of noise. These automatic measurements give some artificial numbers that indicate non-real data. So, one needs to carefully check the spectra along all wavelengths and decide which measurements should be used for further studies. Especially important are those, which are being used in the diagnostic diagrams (Hβ, [OIII] 5007$\AA$, [OI] 6300$\AA$, Hα, [NII] 6583$\AA$, and [SII] 6716+6731$\AA$) (Veilleuxand 1987).

3. Classification Principles

We have used several methods for classification of our spectra

- By eye examination (taking into account all features and effects)
- By diagnostic diagram using [OIII]/Hβ and [OI]/Hα ratios
- By diagnostic diagram using [OIII]/Hβ and [NII]/Hα ratios
- By diagnostic diagram using [OIII]/Hβ and [SII]/Hα ratios

Classification by eye has been done to compare with the classification by diagnostic diagrams and because not all objects appeared on them. Besides, the broad emission line component is not taken into account on the diagnostic diagrams, and this may be crucial for the classification of Seyfert 1.2-1.9 subclasses. Roughly, we distinguish Seyferts from LINERs by the criteria: [OIII]/Hβ > 4, and AGN from HII by [NII]/Hα > 2/3, [OI]/Hα > 0.1 criteria.

4. Results of Study of Spectra and Classification

We started studying spectra with identifications of spectral lines. We have used only lines having intensities 3σ over the noise level. Hβ also appears in absorption on most of these spectra.We studied the

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FERMI 5	10-100 Gev	SDSS i	7480 A	IRAS	100 μm
FERMI 4	3-10 Gev	DSS I(N)	8060 A	AKARI	140 μm
FERMI 3	1-3 Gev	SDSS z	8932 A	AKARI	160 μm
FERMI 2	300-1000 Mev	2MASS J	1.235 μm	NVSS	21 cm
FERMI 1	100-300 Mev	2MASS H	1.662 μm	FIRST	21 cm
INTEGRAL	60 kev	2MASS K	2.159 μm		
INTEGRAL	30 kev	WISE 1	3.35 μm		
INTEGRAL	10 kev	WISE 2	4.6 μm		
ROSAT	1.25 kev	AKARI	9 μm		
GALEX FUV	1550 A	WISE 3	11.6 μm		
GALEX NUV	2275 A	IRAS	12 μm		
SDSS u	3551 A	AKARI	18 μm		
DSS B(O)	4450 A	WISE 4	22.1 μm		
SDSS g	4686 A	IRAS	25 μm		
DSS V	5510 A	IRAS	60 μm		
SDSS r	6166 A	AKARI	65 μm		
DSS R(E)	6580 A	AKARI	90 μm		

Figure 1. Filters from which we received data.

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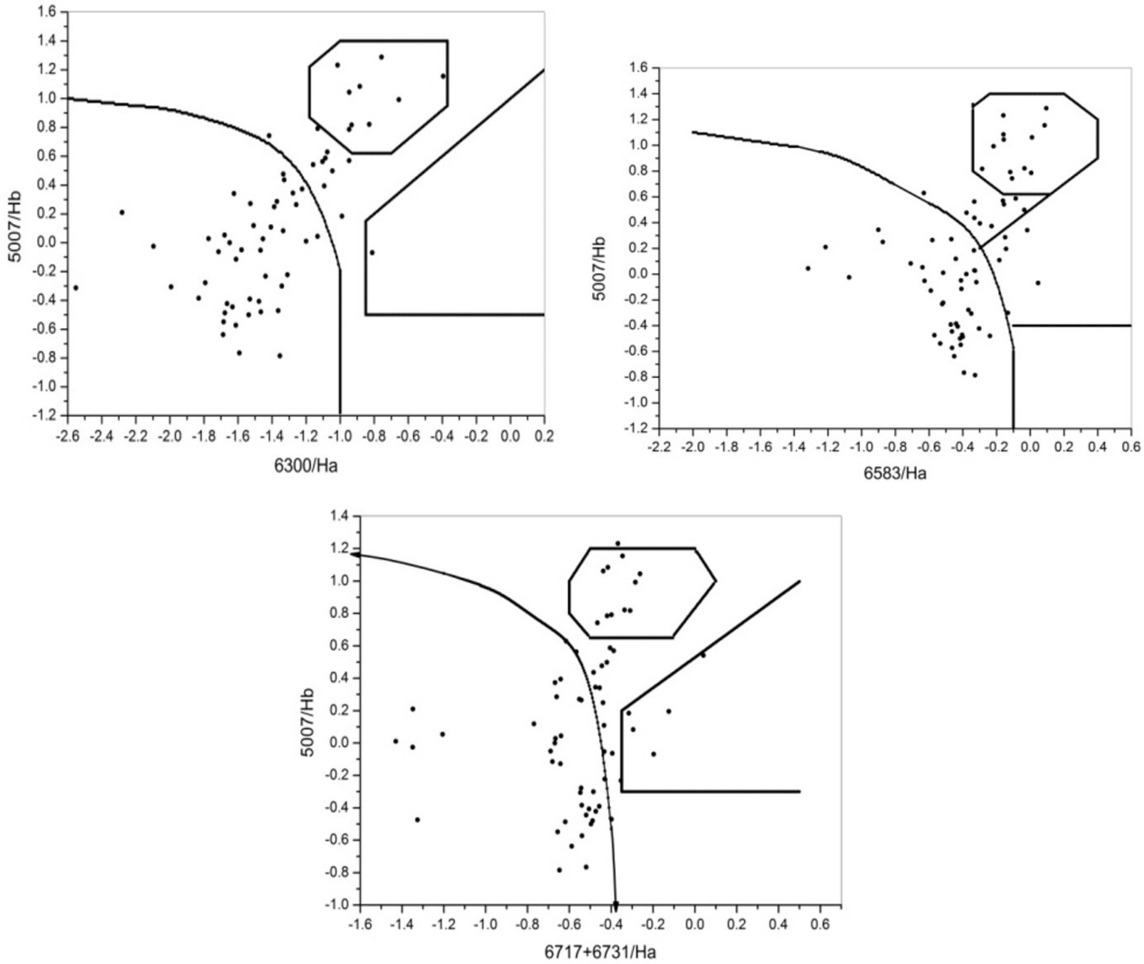

Figure 2. Diagnostic diagrams

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influence of Hβ absorption component on the emission one, which is important for using of the numerical data given in SDSS tables. After identifications of the emission lines we decided which of them should be used to build diagnostic diagrams (Veilleuxand 1987).

On diagnostic diagrams the narrow-line AGN are separated into 3 main groups (HII, Sy, LINER). In addition, there are objects in intermediate areas, which have been classified as Composites (Veilleuxand 1987) having both AGN and HII features.

Table 3. Source of combine catalogue

Type	**Percent**	**Type**	**Percent**
QSO	2.5	H II	14.5
Sy1.0 & nSy1.0	1	ELG	10
Sy1.5 & nSy1.5	3.5	Comp	4
Sy1.8 & nSy1.8	12.7	Galaxy	47
Sy1.9 & nSy1.9	7	WD, CV, C star	1.7
LINER	0.6	Uc Cl	4.5

5. Summary and Conclusion

We have created sample of X-ray selected AGN candidates and carried out spectroscopic investigation for those objects having SDSS spectra. 1426 objects appear in this list and we have classified them by activity types using three diagnostic diagrams and eye examination of the spectra (to be complete in classification of broad line AGN). Many Seyferts, LINERs, Composites and Starburst have been revealed. We

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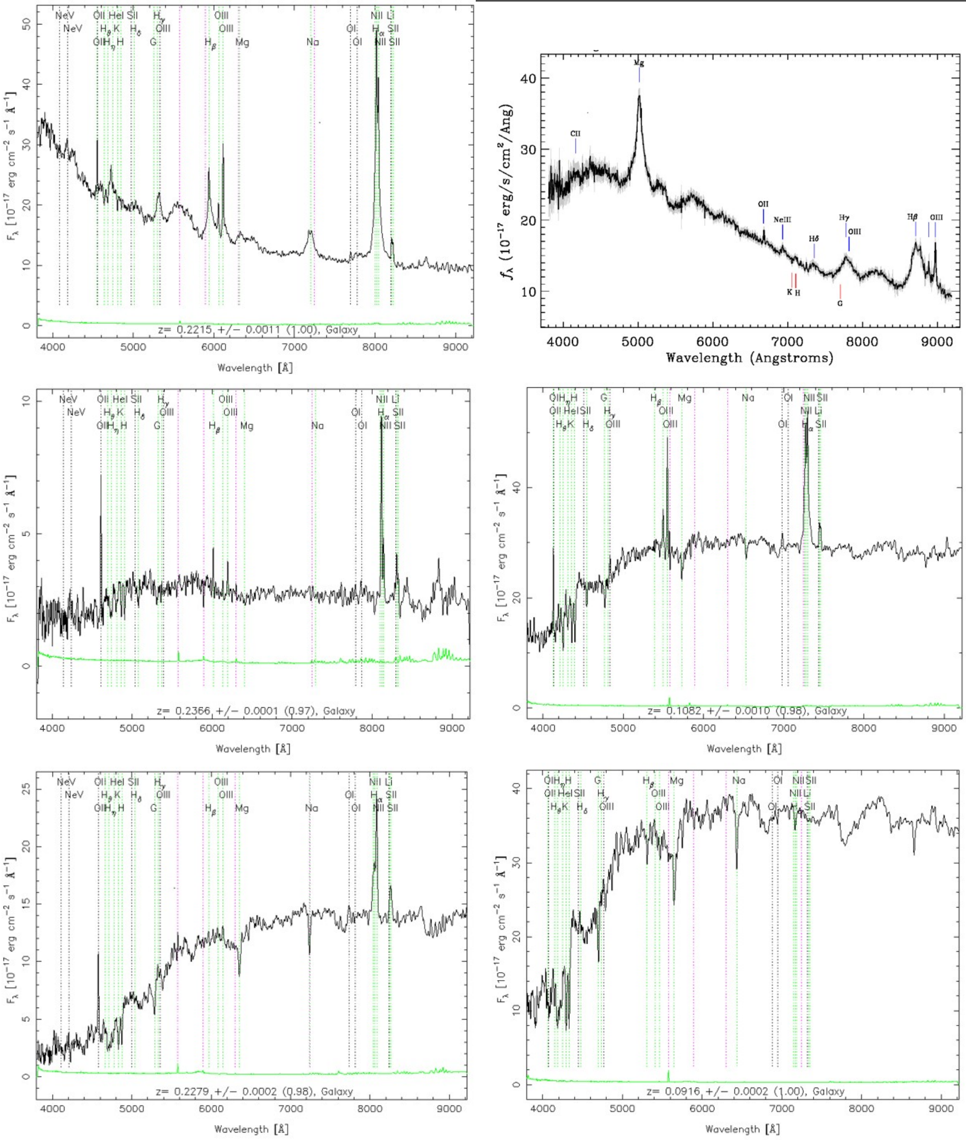

Figure 3. Classified spectra

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have applied all possible parameters for fine classification to distinguish between narrow and classical broad line Seyferts, and to identify all details related to Seyfert subtypes depending on the strength of their broad components. We have introduced subtypes of NLS1, namely NLS1.0, NLS1.2, NLS1,5 and NLS1.8 giving more importance to these details (Osterbrock 1980, Winkler1992, Osterbrock 1985, Heckman 1980, Ho 1997, Weedman 1977, Veron 1997). Further accumulation of statistics may provide possibilities to understand the physical differences.

These 3369 objects have been cross-correlated with GALEX (Bianchi 2011), SDSS, 2MASS (Skrutskie 2006) NIR, All WISE (Cutri 2013) , IRAS PSC (Beichman 1988) and FSC (Moshir 1992), NVSS (Condon 1988), FIRST (Becker 1997) catalogues.

We have calculated all possible physical parameters of the studied objects: radial velocities, distances, absolute magnitudes, luminosities, etc.

One of the most intriguing class of objects among the X-ray sources are absorption line galaxies. The brightest ones may just appear in this sample due to their integral high luminosity, however we find that many such objects have low luminosity and still appear to be strong X-ray sources. We consider these objects as possible hidden AGN (We have 543 possible hidden AGNs). The optical spectra do not show any signatures of emission.

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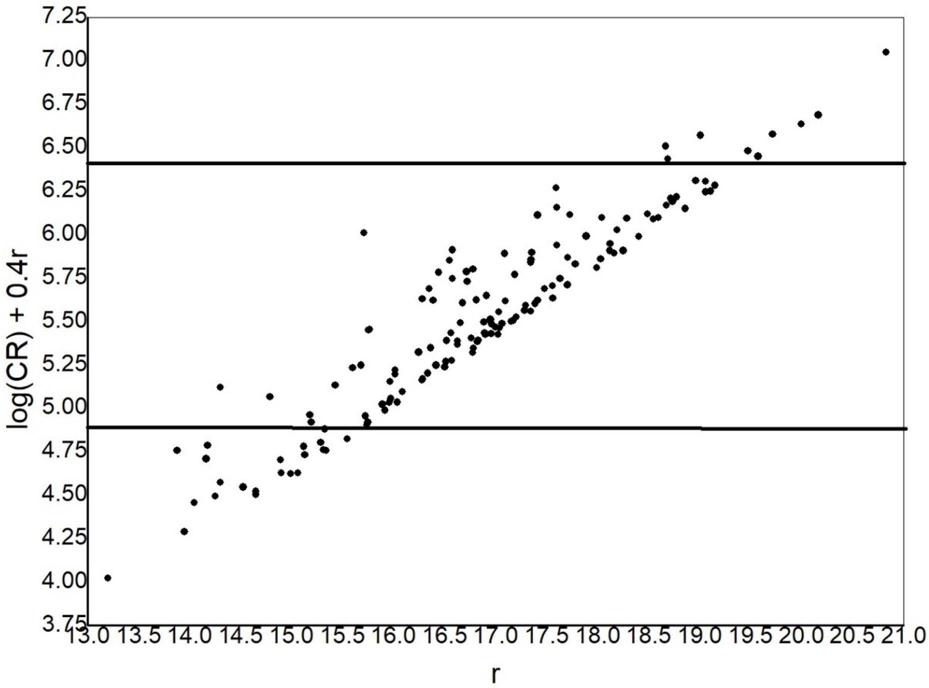

Figure 4. Possible hidden AGNs.

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