

Study of a homogeneous X-ray selected AGN sample

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Abstract. Based on optical identifications of ROSAT sources, we have created a large homogeneous catalog of X-ray selected AGN. The Hamburg-RASS Catalog (HRC) and Byurakan-Hamburg-RASS Catalog (BHRC) made up on the basis of optical identification of X-ray sources from ROSAT Bright Source (BSC) and Faint Source (FSC) catalogues, respectively, have been used. These identifications were based on low-dispersion spectra of Hamburg Quasar Survey (HQS). As a result, a new large sample of X-ray selected AGN has been compiled containing 4253 sources with photon count rate $CR > 0.04$ ct/s in the area with galactic latitudes $|b| > 20$ and declinations $\delta > 0$. All these sources are classified as AGN or candidate AGN. We have carried out multiwavelength studies in several wavelength ranges (X-ray, optical, radio). Catalogues that more or less guarantee the completeness condition (all-sky or large area surveys) were used. A number of erroneous classifications were found (some AGN had been classified as stars or galaxies); 1024 and 59 from HRC and BHRC, respectively. Out of 4253 sources, 3352 are spectroscopically confirmed AGN (given in Veron-Cetty & Veron and Roma Blazar catalogs), and the rest 901 are candidate AGN. For 210 of them spectra are available in SDSS DR9, and the results of their classification are given in another paper. We calculated absolute magnitudes, fluxes, improved coordinates and redshifts. An attempt is made to find a connection between the radiation fluxes in different bands for different types of sources, and identify their typical characteristics, thus confirming candidate AGN and in some cases finding new ones.

Keywords. surveys, X-ray: AGN, radio: AGN, IR: AGN, UV: AGN, AGN candidates

ROSAT catalogs contain thousands of interesting objects, and even though a number of recent X-ray missions have been conducted, ROSAT so far remains the only all-sky enough deep survey. ROSAT sources are listed in two main catalogs: Bright Source Catalogue (BSC, Voges *et al.* 1999) and Faint Source Catalogue (FSC, Voges *et al.* 2000) containing 18,811 and 105,924 sources, respectively in the 0.1–2.4 keV energy range. However, only $\sim 10,000$ optically identified. Among the identification works, the ROSAT Bright Sources (RBS, Schwope *et al.* 2000) is well-known (2012 BSC sources with $CR \geq 0.20$ and $|b| > 30$ have been optically identified. However, most of the identified sources come from the Hamburg Quasar Survey (HQS, Hagen *et al.* 1995). Its low-dispersion spectra allow a preliminary classification of objects into a number of types, giving possibility to make up subsamples of objects for further studies. Two main projects have been carried out: Hamburg ROSAT Catalogue (HRC, Zickgraf *et al.* 2003) and Byurakan-Hamburg ROSAT Catalogue (BHRC, Mickaelian *et al.* 2006). HRC is based on ROSAT BSC and contains 5341 sources at $|b| > 20$ and $\delta > 0$, while BHRC is based on ROSAT FSC and contains 2791 fainter sources (down to $CR = 0.04$) in the same area (3297 objects found).

A Joint HRC/BHRC Catalogue has been created by merging HRC and BHRC, altogether 8132 sources. Together with combining data from the two catalogues, we have checked and added many new ones, as well as corrected many errors and misidentifications. The distribution of identified objects by types in the Joint HRC/BHRC catalogue is as follows: 4253 AGN, 492 galaxies, 1800 stars, and 1587 spectroscopically

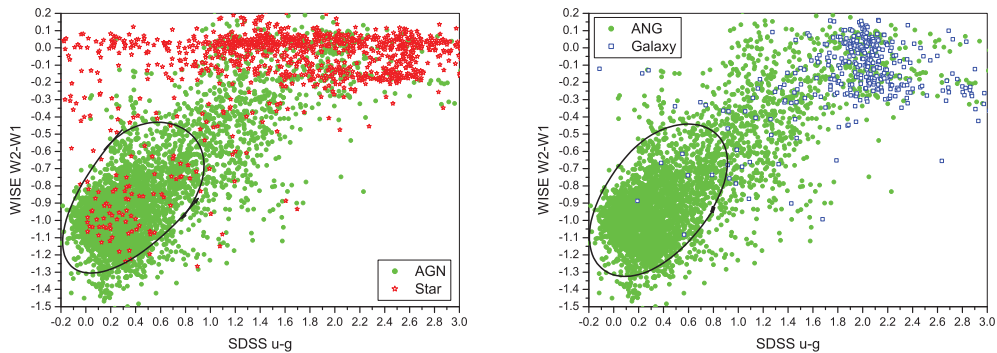


Figure 1. WISE w_2-w_1 vs. SDSS $u-g$ color-color diagram for AGN and stars (left) and AGN and galaxies (right).

unidentified objects. Out of 4253 X-ray selected AGN, 3352 are confirmed ones in Veron-Cetty & Veron 2010 (13th version, hereafter VCV-13) and Massaro *et al.* 2009 (Roma Blazar Catalogue) catalogues and 901 are AGN candidates. Multiwavelength (MW) data have been retrieved by cross-correlations with all-sky or large area catalogues from gamma-rays to radio: FERMI (Nolan *et al.* 2012), INTEGRAL (Bird *et al.* 2010), GALEX (Bianchi *et al.* 2011), APM (McMahon *et al.* 2000), USNO-B1.0 (Monet *et al.* 2003), GSC 2.3.2 (Lasker *et al.* 2008), SDSS DR9 photometric and spectroscopic (Adelman-McCarthy *et al.* 2012), 2MASS (Cutri *et al.* 2003), WISE (Cutri *et al.* 2012), IRAS (Moshir *et al.* 1992), NVSS (Condon *et al.* 1998), and FIRST (Becker *et al.* 1999).

In order to confirm candidate AGN and to find new ones we have built diagrams that give the dependence between the different fluxes and colors. To begin, we have built all diagrams by dividing the sources into three groups: stars, galaxies and AGN (including QSOs). This grouping was done in order to distinguish QSOs and other AGN from other classes of objects. We have built many color-magnitude and color-color diagrams using these MW data and investigated the distribution of objects to find either candidates for the known types among the spectroscopically unidentified objects or find extreme objects by their characteristics.

Fig. 1 shows the WISE w_2-w_1 vs. SDSS $u-g$ color-color diagram for AGN and stars (left) and AGN and galaxies (right). Stars are typically located in WISE w_2-w_1 from -0.2 to 0.1 and in a large area by SDSS $u-g$ from -0.2 to 3 . However, there is a group of stars that occupies the same region as AGN. These might be AGN candidates. By the distribution of objects we claim that almost all candidate AGN are genuine ones. Galaxies continue their distribution to larger w_2-w_1 and $u-g$ values and seem to have the same nature as AGN. Most probably they might also be hidden AGN (the same picture is repeated in other MW diagrams). This is one of the most important questions that we have achieved: are all ROSAT galaxies hidden AGN?

Cross-correlation with the SDSS allows us obtain homogeneous optical magnitudes in 5 bands (u, g, r, i, z) and colors for the optical counterparts, as well as improve absolute magnitudes and redshifts.

The main results of our study may be given as follows:

- We have built a joint catalogue of optical identifications of ROSAT sources ($CR \geq 0.04$) based on HRC and BHRC, altogether 8132 sources in the Joint HRC/BHRC. The catalog covers the entire northern sky at high galactic latitudes, $\delta \geq 0^\circ$, $|b| \geq 20^\circ$;

- We have found out 1024 incorrectly classified sources in HRC catalog, and 59 in BHRC. The corresponding corrections were done and most of these sources were reclassified as AGN;
- The Joint HRC/BHRC contains 4253 objects that are given as AGN or their candidates, 492 galaxies, 1800 stars and 1587 spectroscopically unidentified objects;
- Out of 4253 sources, 3352 are confirmed AGN and the rest 901 are candidate AGN;
- We have cross-correlated the AGN sample with MW catalogues and found many associations, including almost all objects in GALEX, APM, USNO-B1.0, SDSS, 2MASS, and WISE and many others in other catalogues;
- We have built many color-magnitude and color-color diagrams using these MW data and by the distribution of objects we claim that almost all candidate AGN are genuine ones;
- We claim that almost all galaxies identified in ROSAT catalogues are hidden AGN and need further studies.

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