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Investigation of Blazars in UV and in radio

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Abstract

Blazars are the most energetic sources in the Universe, but have not been thoroughly and homogeneously investigated in all spectral ranges, particularly in UV. We carried out cross-correlations of BZCAT v.5 Catalogue with UV (GALEX) and radio catalogues, in order to find a connection between the fluxes in UV with optical and radio ranges. BZCAT v.5 catalogue includes 3561 objects. For these objects, we found 1841 associations from the GALEX catalogue (providing Far UV – FUV and Near UV – NUV), from which 999 associations from FIRST (providing fluxes at 1400 MHz) and 855 associations from SDSS (providing photometry at ugriz bands and medium dispersion spectroscopy for limited number of objects). Our main task is to understand which type of blazars (BZB, BZG, BZQ, and BZU) are more powerful sources in the UV range. We calculated UV/radio and UV/opt flux ratios and analyzed them to understand possible connections between radio, optical, and UV ranges. Having our new optical classification of blazars by activity types, we also analyzed the UV/radio/optical properties of the sample across their activity types.

Keywords: *Blazars, Quasars, Active Galactic Nuclei, Catalogues*

Introduction

Our main task is to understand which type of blazars are the most powerful sources in the UV range. Blazars catalogue, which is given by Massaro in 2014 includes all known blazars in the sky. For our work, we used the following catalogues:

- The Galaxy Evolution Explorer (GALEX) catalogue, which is an all sky survey and have information in a far-ultraviolet (FUV, 1350–1750 Å) channel and a near-ultraviolet (NUV, 1750–2800 Å) channel (Bianchi et al., 2017),
- The VLA FIRST Survey catalogue (FIRST), which covers 10,575 square degrees in the north cap in 1.4 MHz (Bianchi et al. (2017)),
- The SDSS Photometric Catalog, which covers 14,555 square degree in the northern cap and partially in the southern cap (Almeida et al. (2023)).

Having information from GALEX, FIRST and SDSS we try to understand possible connections between radio, optical and UV ranges.

Observational data

For our investigation, we use BZCAT v.5 (Massaro et al. (2015)), which includes 3561 blazars in all sky. In BZCAT, blazars have 4 types: BZB, BZG, BZQ and BZU.
In the first step, we cross-corelated these objects with GALEX. In the second step having objects which have GALEX identification we cross-corelated with FIRST. Most of the objects are identified within approximately 2.2 arcseconds for GALEX and within approximately 1.2 arcseconds for FIRST (Figure 1).

In the last step, objects which have GALEX identification were cross-corelated with SDSS. In Table 1 we give all information from GALEX, FIRST, and SDSS.

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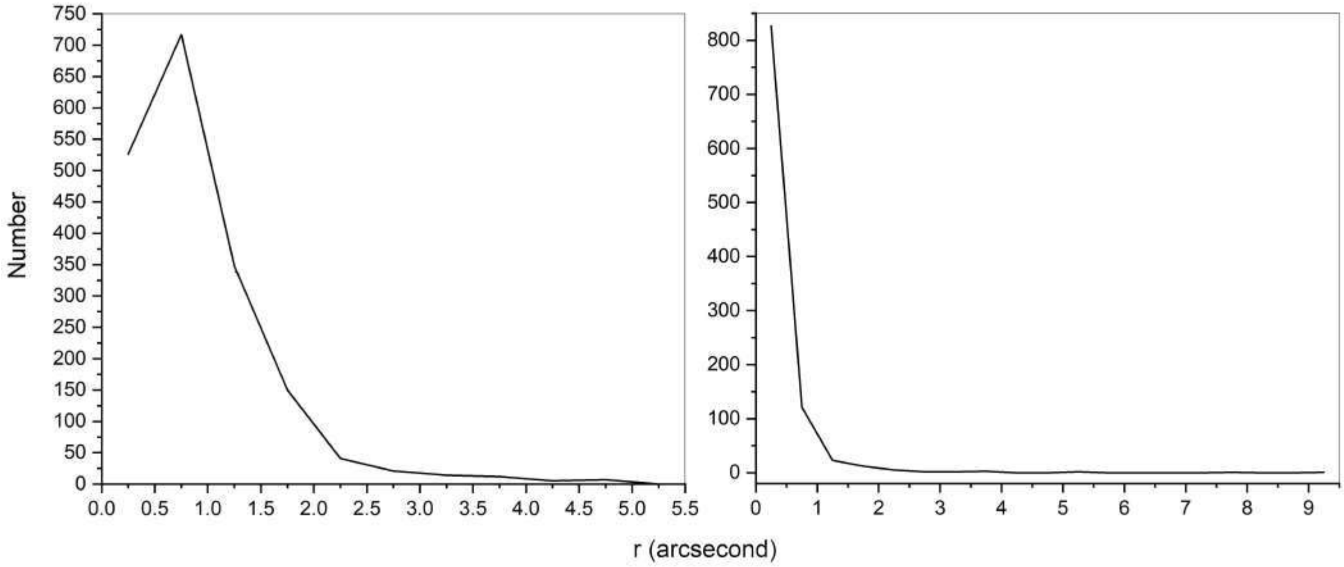

Figure 1. Distribution radius for identified objects from GALEX (left) and FIRST (right).

Type	BZCAT	GALEX	FIRST	SDSS
BL Lac (BZB)	1151	500	236	373
Galaxies (BZG)	274	256	207	88
Quasars (BZQ)	1909	937	459	369
Unclassified (BZU)	227	148	97	25
All Types	3561	1841	999	855

Table 1. Number of sources by type and their matches in GALEX, FIRST, and SDSS surveys.

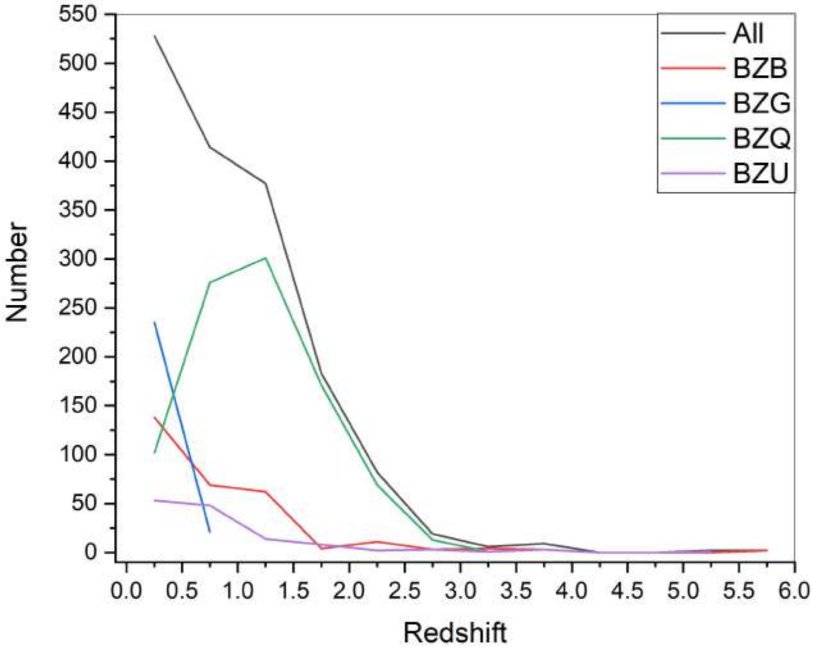

Figure 2. Distribution redshift for Blazars which have GALEX identification.

Most of our objects have information for redshift from SDSS catalogue. Having that and having information for redshift from BZCAT (for objects that have not information of redshift from SDSS) we built a distribution for redshift, which you can see in Figure 2. Most of the objects have redshift within 2.5.

In Figure 3 we give color-magnitude diagrams for NUV and FUV magnitude. In diagrams, we can see that different types of Blazars (in particular BZQ and BZG) are concentrated and distributed in different ways.

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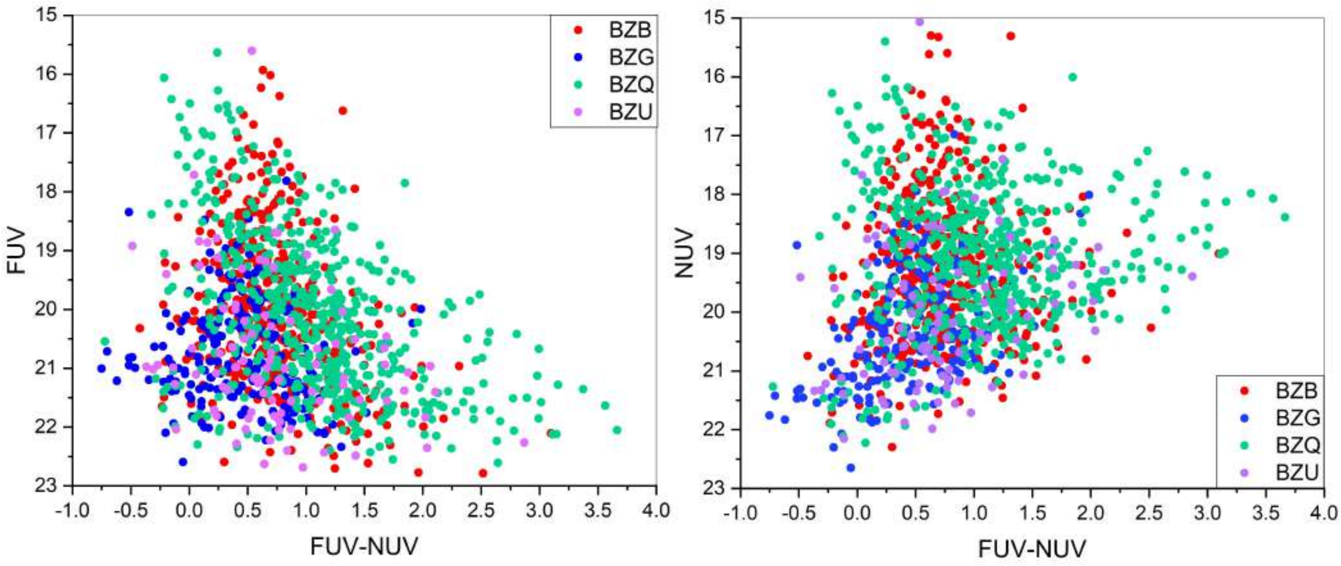

Figure 3. Color-magnitude diagrams for Blazars.

GALEX/FIRST flux ratio

For understanding definition of blazars, it is very important to understand which UV/radio and UV/opt flux ratio have different types of blazars and try to find possible connections between radio, optical and UV ranges.

So, in the UV/radio flux ratio, for GALEX FUV and NUV we converted the magnitudes to mJy by the following formula (Morrissey et al. (2007)).

$$m_{\mathrm{UV}} = m_{0\mathrm{UV}} - 2.5\log_{10}(f_{\mathrm{UV}})$$

when $m_{0\mathrm{FUV}}$=18.81, $m_{0\mathrm{NUV}}$=20.08.

Type	GALEX/FIRST (FUV)			GALEX/FIRST (NUV)		
	Number	Range	Average	Number	Range	Average
BZB	191	$6.266 \times 10^{-5} \div 3.625 \times 10^{-1}$	1.959×10^{-2}	236	$3.940 \times 10^{-4} \div 2.455$	9.928×10^{-2}
BZG	174	$2.824 \times 10^{-5} \div 7.998 \times 10^{-2}$	9.294×10^{-3}	207	$2.152 \times 10^{-5} \div 3.043 \times 10^{-1}$	3.515×10^{-2}
BZQ	279	$3.486 \times 10^{-5} \div 2.951 \times 10^{-1}$	9.261×10^{-3}	459	$1.194 \times 10^{-4} \div 1.401$	4.118×10^{-2}
BZU	55	$1.101 \times 10^{-4} \div 1.811 \times 10^{-1}$	1.511×10^{-2}	97	$1.997 \times 10^{-4} \div 8.343 \times 10^{-1}$	5.788×10^{-2}
All	699	$2.824 \times 10^{-5} \div 3.625 \times 10^{-1}$	1.311×10^{-2}	999	$2.152 \times 10^{-5} \div 2.455$	5.837×10^{-2}

Table 2. GALEX / FIRST (int.) flux ratio

This Table 2 and Figure 4 presents the GALEX / FIRST (int.) flux ratio for NUV and FUV.

GALEX/SDSS flux

The same method, which we applied for GALEX and FIRST, for SDSS (r band) we converted the magnitude to mJy and counted the GALEX/SDSS flux ratio for NUV and FUV.

This Table 3 and Figure 5 presents the GALEX / SDSS flux ratio for NUV and FUV.

Summary and Results

In this work, we aimed to understand which type of blazars (BZB, BZG, BZQ and BZU) are the most powerful sources in UV range. We calculated UV/radio and UV/opt flux (Tables 2 and 3, Figures 3 and 5).

The main results are as follows:

- GALEX FUV / FIRST (integrated) flux ratio (average): 1.311×10^{-2}

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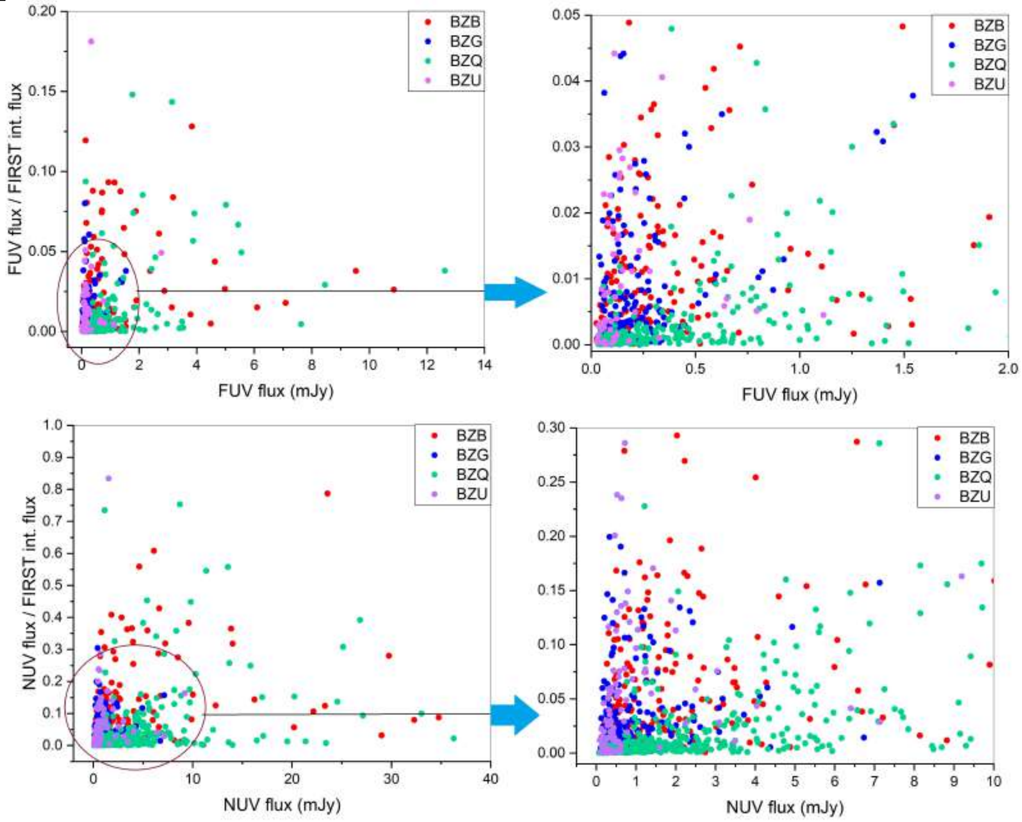

Figure 4. Connection of NUV and FUV fluxes with NUV/FIRST and FUV/FIRST flux ratios.

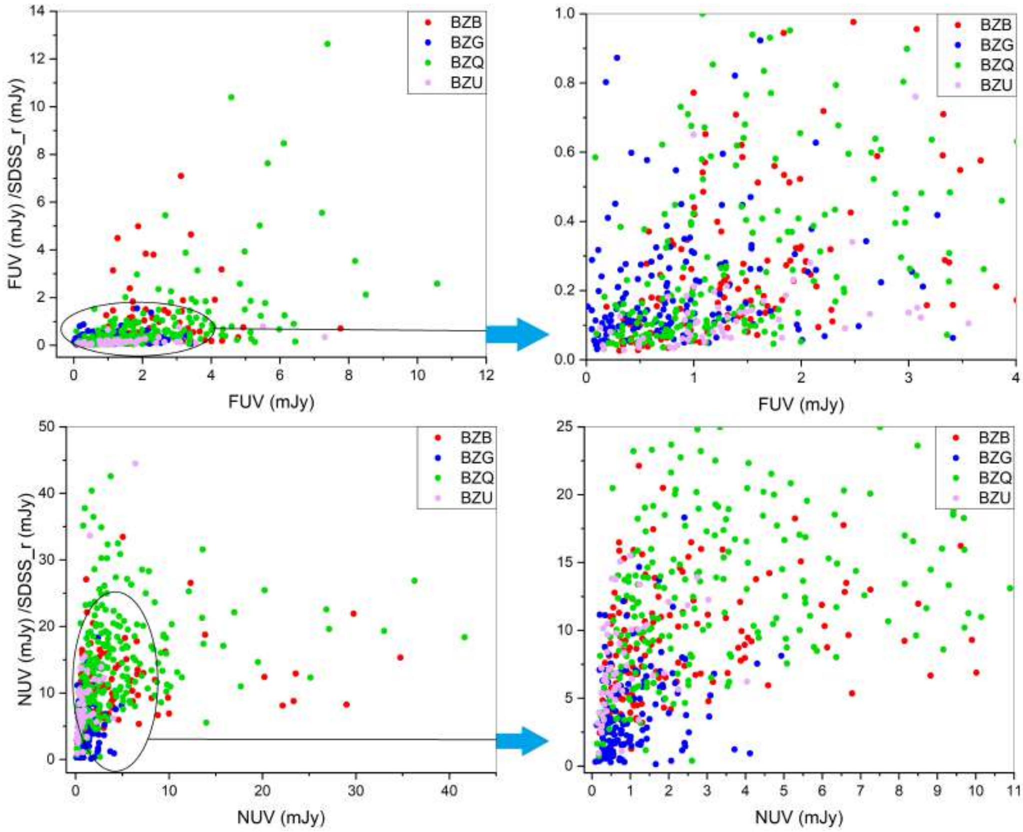

Figure 5. GALEX/SDSS flux ratio

- GALEX NUV / FIRST (integrated) flux ratio (average): 5.837×10^{-2}
- GALEX FUV / SDSS flux ratio (average): 1.529
- GALEX NUV / SDSS flux ratio (average): 8.325

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Type	GALEX / SDSS Flux Ratio (FUV)			GALEX / SDSS Flux Ratio (NUV)		
	Number	Range	Average	Number	Range	Average
BZB	146	0.188 ÷ 7.769	1.692	180	1.258 ÷ 33.448	9.421
BZG	159	0.012 ÷ 3.413	0.865	188	0.127 ÷ 18.313	3.828
BZQ	250	0.085 ÷ 10.577	2.006	390	0.379 ÷ 67.479	12.164
BZU	57	0.0131 ÷ 7.304	1.497	97	0.771 ÷ 44.501	7.889
All	612	0.012 ÷ 10.577	1.529	855	0.127 ÷ 67.479	8.325

Table 3. Flux ratio between GALEX (FUV/NUV) and SDSS fluxes for different blazar types.

Thus, in average, Blazars are more powerful in radio range and less powerful in optical range.

- Our goal is to provide a simple definition of blazars, a class of objects that is still under active investigation.
- By analyzing the radio emission, our main objective is to determine a cutoff value that can be used to identify quasars.

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