Classification of Blazars by Activity Types

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Abstract

We have carried out a spectral classification by the Activity Types for all sample of Blazars from the BZCAT v.5 Catalogue, namely the BZB, BZG, BZQ and BZU type objects. The classification is based on the Sloan Digital Sky Survey (SDSS) homogeneous medium-resolution optical spectroscopy and along with the standard BPT-type diagnostic diagrams, we have applied our newly introduced fine classification scheme with subtypes of AGN and considering many more features. Out of 3561 BZCAT objects, 1363 (38.3 %) having SDSS spectra were classified. After the new classification, 749 (54.9 %) of 1363 objects have changed their optical class.

Keywords: *blazar, quasar: active galactic nuclei, optical spectral classification, activity types, BL Lac objects, Flat Spectrum Radio Quasars*

1. Introduction

Blazars are considered to be the most energetic sources in the Universe. BL Lac was discovered by Hoffmeister (Hoffmeister (1929)). The originally discovered source was considered to be a variable star. Later, a thorough study of this source showed that it was extragalactic radio source. Discovered source was a radio source which had optical variability. Nowadays 3,561 blazars are known. The revealed sources have been published by Massaro et al. (2015) as a general list. In this catalog, Massaro grouped all blazars in four main classes: BZB (BL Lacs), BZQ (Flat Spectrum Radio Quasars, FSRQ), BZG (Blazar-like Galaxies) and BZU (Unclassified candidate objects). According to the definition, blazars should be radio sources and have optical variability. But information about variability is not complete in this catalogue. Information for optical variability of blazars is given by Abrahamyan et al. (2019b).

From BZCAT catalog, we cannot understand which sources are called Blazars. Using this catalogue, we plan to derive the definition of blazars. But in the first step we must understand properties of different types of Blazars. To summarize different physical properties of blazars we must understand which properties show different types of blazars (BZU, BZB, BZG and BZU).

2. Observational data

For our investigation we use BZCAT v.5 (Massaro et al. (2015)), which includes 3561 blazars. In BZCAT, blazars have 4 types (table 1).

We have done optical classification of those Blazars (38.3 %), which have optical spectra from SDSS catalogue (Abdurro'uf et al. (2022)).

3. Classification Method

Mickaelian et al. in 2022 and in 2024 (Mickaelian et al. (2022), Mickaelian et al. (2024c)) have introduced a new optical classification scheme (https://www.bao.am/activities/projects/21AG-1C053/mickaelian/). In this paper we have carried out optical classification using this method. To guarantee the

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Table 1. Distribution of the types of blazars from BZCAT catalogue.

N	Type		Number of objects		Number of objects with spectra in SDSS	
			Number	%	Number	%
1	BZB	BL Lac	1151	32.3	552	47.9
2	BZG	Galaxies	274	7.7	150	54.8
3	BZQ	Quasars	1909	53.6	618	32.4
4	BZU	Unclassified	227	6.4	43	18.9
All			**3561**	**100.0**	**1363**	**38.3**

best accuracy and consider all possible details, we classify the objects in several ways and then consider all obtained types and subtypes:

- By the 1st diagnostic diagram (DD1) using line intensity ratios [OIII]/H_β vs. [OI]/H_α
- By the 2nd diagnostic diagram (DD2) using line intensity ratios [OIII]/H_β vs. [NII]/H_α
- By the 3rd diagnostic diagram (DD3) using line intensity ratios [OIII]/H_β vs. [SII]/H_α
- By comparison and using the 1st, 2nd and 3rd diagnostic diagrams simultaneously
- By eye (considering all features and effects). Very often, the diagnostic diagrams do not give full understanding for all objects and only eye can reveal some details.

For many objects, the lines H_α and H_β were mainly absent in the spectra (due to high redshifts), so we

4. Classification of Blazars by Activity Types

4.1. BZU (Unclassified)

In table 1 we can see 227 objects out of 3561 have uncertain types of blazars. For our investigation we take these 227 BZU objects (Abrahamyan et al. (2019a)). In the First step we cross-corelated these objects with SDSS (Abdurro'uf et al. (2022)). As a results, we have 81 identification from which 43 have spectra. In Figure 1, we give redshift distribution of BZU and distribution of 43 objects, which have spectra in SDSS. In figure 1 BZU source mainly have 0 to 2.2 redshift and our studied sources have 0 to 1.75 redshift. For these 43 sources we have carried out classification using SDSS spectra.

Using our classification method (Mickaelian et al. (2022) and Mickaelian et al. (2024c)) we have carried out classification of 43 sources which have uncertain type.
As a result, 37 BZU objects out of 43 changed their classification to BZQ, BZG and BZG. In table 2 (for 10 objects, the whole list is given in Abrahamyan et al. (2019a)) we give the new classification and redshifts from SDSS.

So, having optical spectra of 43 BZU, we reclassified these objects. As the main results we have:

- 37 (86 %) objects from 43 changed classification (table 3).
- For 5 objects these numbers are different (5BZUJ0933+0003, 5BZUJ1051+4644, 5BZUJ1058+0133, 5BZUJ1302+5748, 5BZUJ2156-0037).
  We checked and corrected redshift and for 4 (5BZUJ0933+0003, 5BZUJ1051+4644, 5BZUJ1302+5748, 5BZUJ2156-0037) sources is given by SDSS and for 1 (5BZUJ1058+0133) source is given by BZCAT.

4.2. BZG (Galaxies)

In table 1 we can see 274 objects out of 3561 have galaxy types of blazars. For our investigation we take these 274 BZG objects (Abrahamyan et al. (2023)). In the First step we cross-corelated these objects with SDSS (Abdurro'uf et al. (2022)). As a result, 150 of the 274 BZG objects have optical spectra in the SDSS

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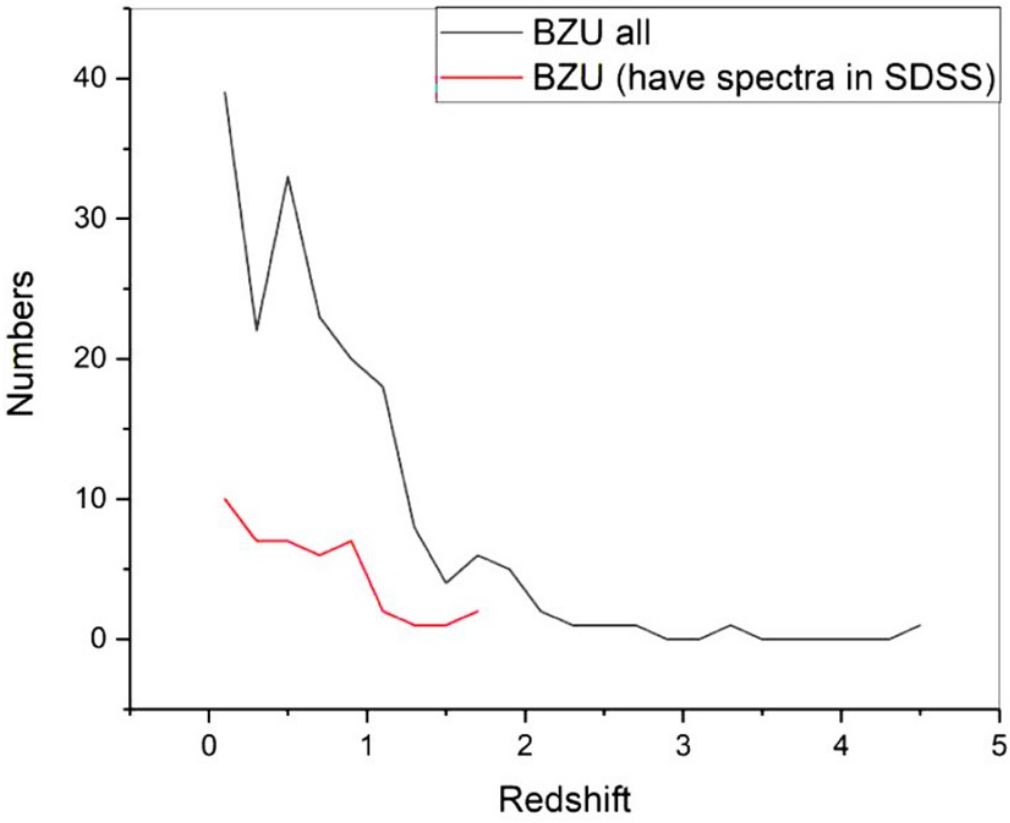

Figure 1. Redshift distribution of BZU objects.

Table 2. New classification of BZU objects.

BZCAT v.5		**Our classifaction**		**Redshift**		
Source name	Type			BZCAT	NED	SDSS
5BZUJ0217-0820	BZU	NLQSO	BZQ	0.607	0.606538	0.60654
5BZUJ0304+0002	BZU	QSO1.2	BZQ	0.564	0.56417	0.56366
5BZUJ0742+3744	BZU	QSO1.5	BZQ	0.806	0.806274	0.80574
5BZUJ0840+1312	BZU	QSO1.2	BZQ	0.681	0.6808	0.68037
5BZUJ0849+5108	BZU	QSO	BZQ	0.583	0.584701	0.58345
5BZUJ0856+0140	BZU	Unknown	BZU	0.448	0.448184	0.44807
5BZUJ0909+4253	BZU	QSO	BZQ	0.670	0.669915	0.67041
5BZUJ0933+0003	BZU	Unknown	BZU	0		0.71107
5BZUJ0954+5719	BZU	QSO	BZQ	0.981	0.981193	0.98121
5BZUJ1000+2233	BZU	Sy2.0	BZG	0.419	0.418732	0.41874

Table 3. New classification of BZU.

N	**Old**	**New**	**Numbers**
1	BZU	BZB	1 (2 %)
2	BZU	BZG	14 (33 %)
3	BZU	BZQ	22 (51 %)
4	BZU	BZU	6 (14 %)
All			43 (100 %)

catalog.

Using our classification method (Mickaelian et al. (2022) and Mickaelian et al. (2024c)) we classified all 150 objects.

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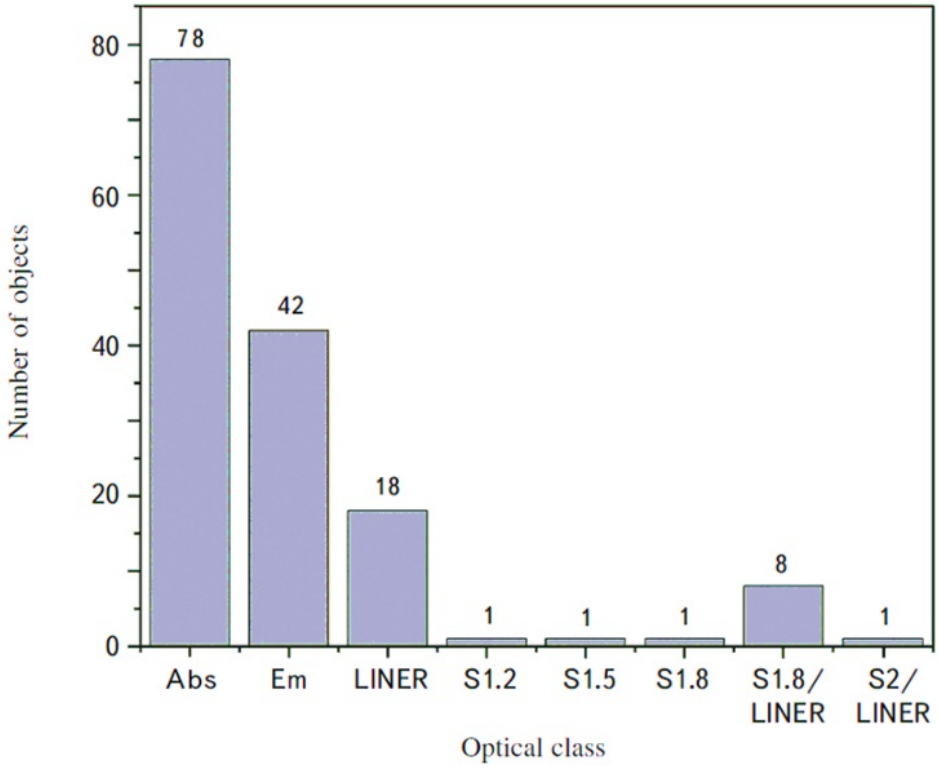

Figure 2. The new classification of the BZG objects using the SDSS spectra.

Table 4. New classification of BZG.

N	Old	New	Numbers
1	BZG	BZB	0 (0 %)
2	BZG	BZG	150 (100 %)
3	BZG	BZQ	0 (0 %)
4	BZG	BZU	0 (0 %)
All			150 (100 %)

In Table 4 and in Fig. 2 we show our spectral classification for 150 BZG objects using the SDSS spectra. We provided a new detailed spectral classification for 149 of the objects and only one object remained with its previous classification as a LINER.

Figure 2 shows that of the the 150 objects, 78 have Abs spectra, although they are presented as BZG objects in the BZCAT catalog. Our detailed radio and optical study of these objects showed that in them the radio fluxes (1400 MHz, FIRST) form a fraction of 0.16 of the optical flux ($SDSS_r$). And also, of the 78 objects, 66 are x-ray sources. This again confirms our assumption that these objects may be hidden AGN.

4.3. BZQ (Quasars)

In table 1 we can see 1909 objects out of 3561 have galaxy types of blazars. For our investigation we take these 1909 BZQ objects (Mickaelian et al. (2024a)). In the First step we cross-corelated these objects with SDSS (Abdurro'uf et al. (2022)). In results e 618 of the 1909 BZQ objects have optical spectra in the SDSS catalog. Using our classification method (Mickaelian et al. (2022) and Mickaelian et al. (2024c)) we classified all 150 objects.

Using our classification method (Mickaelian et al. (2022) and Mickaelian et al. (2024c)) we classified all 618 objects.

In Table 5 and in Fig. 3 we show our spectral classification for 618 BZQ objects using the SDSS spectra. It is clear from Table 5 and Fig. 3 that these objects are mostly classical QSOs (about 56.31 %) and other QSO subtypes (almost 17.8%).

After our new classification, 327 (52.91 %) of 618 have not changed their optical class, and 291 (47.0 %) of

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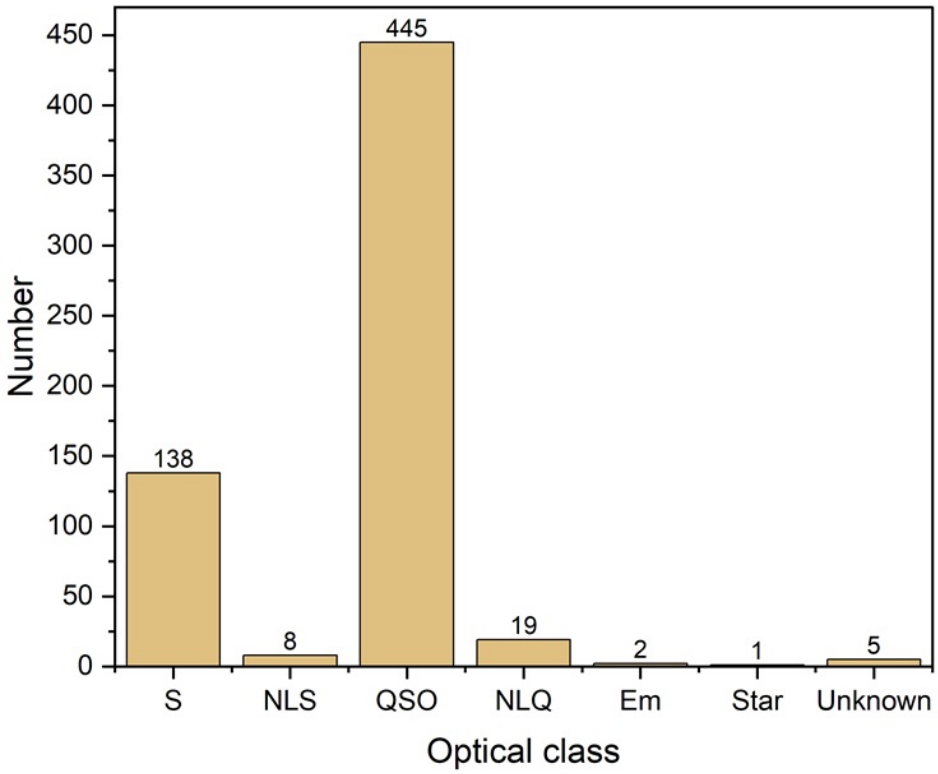

Figure 3. The new classification of the BZQ objects using the SDSS spectra.

Table 5. New classification of BZQ.

N	Old	New	Numbers
1	BZQ	BZB	0 (0 %)
2	BZQ	BZG	6 (1 %)
3	BZQ	BZQ	606 (98 %)
4	BZQ	BZU	6 (1 %)
All			618 (100 %)

these objects have changed their optical class.

4.4. BZB (BL Lac)

We have picked out 1151 BL Lac candidates from table 1, which make up our investigation data. 552 out of the 1151 BZB objects have optical spectra in the SDSS (Mickaelian et al. (2024b)). For these objects we have carried out a detailed classification using the SDSS spectra.

In figure 4 we give distribution of BZB objects by redshift; this information is taken from SDSS. Most of these objects have redshift smaller than 1.5 (the average is 0.95).
Using our classification method (Mickaelian et al. (2022) and Mickaelian et al. (2024c)) we classified all 552 objects.

Table 6. New classification of BZB.

N	Old	New	Numbers
1	BZB	BZB	259 (46.9 %)
2	BZB	BZG	130 (23.6 %)
3	BZB	BZQ	18 (3.3 %)
4	BZB	BZU	145 (26.3 %)
All			552 (100 %)

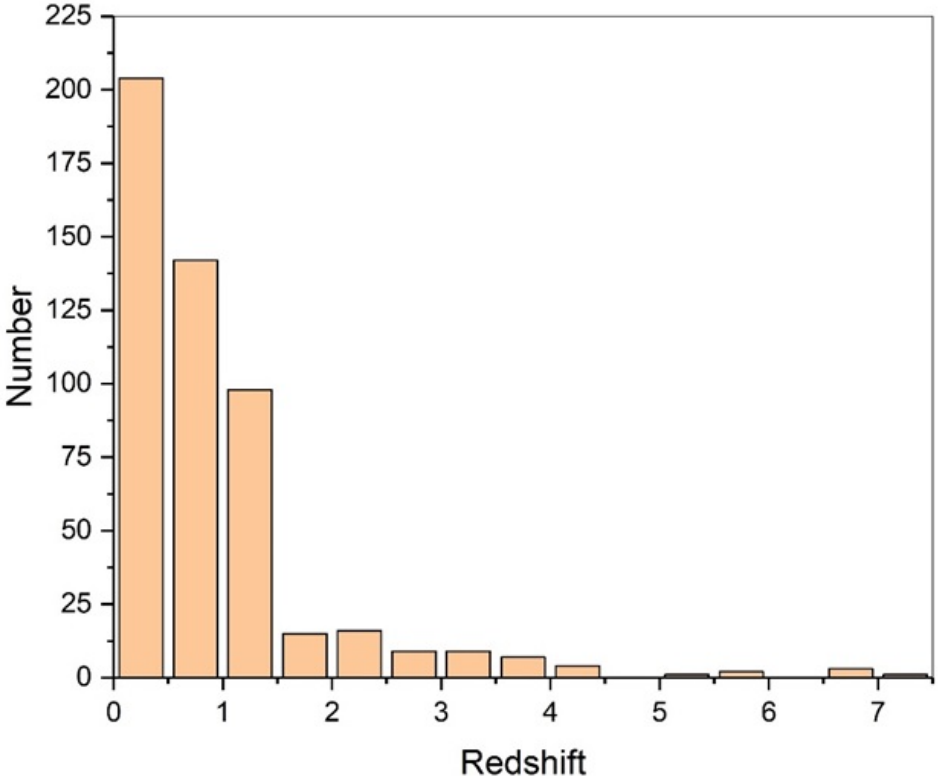

Figure 4. The distribution of BZB objects by redshift.

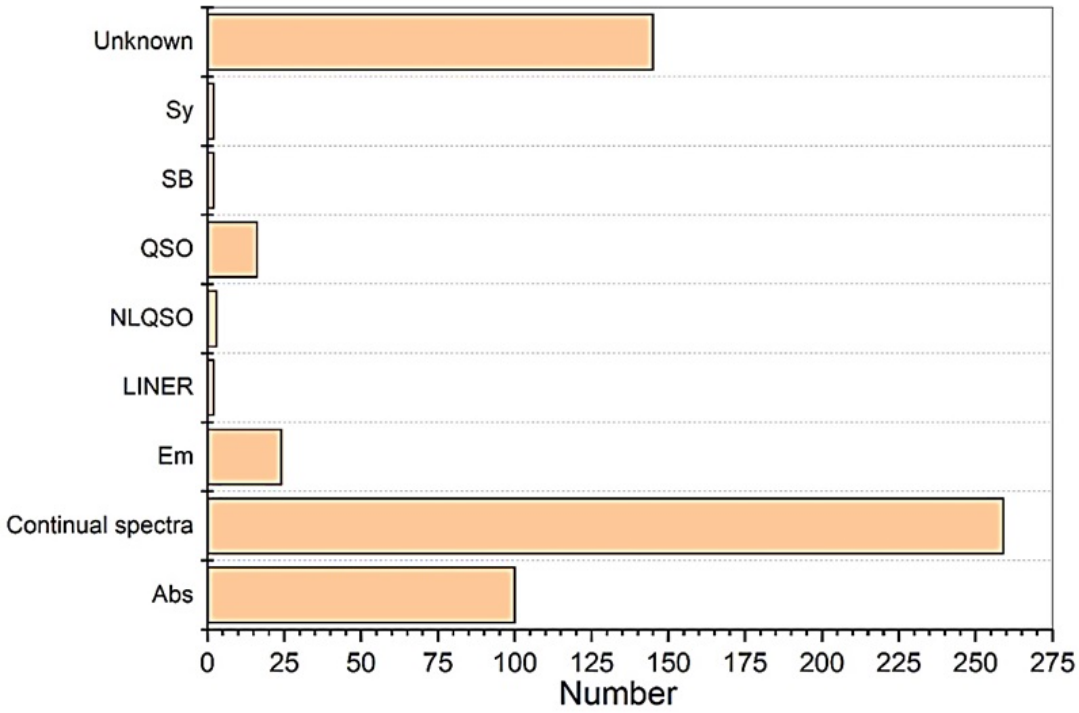

Figure 5. The new classification of the BZB objects using the SDSS spectra.

In Table 6 and in Fig. 5 we show our spectral classification for 552 BZB objects using the SDSS spectra. It is clear from Table 6 and Fig. 5 that these objects mostly have "Continual spectra", which dominated BZB objects (about 46.82 %).

After our new classification, 259 (46.1 %) out of 552 have not changed their optical class, and 293 (53.1 %) out of these objects have changed their optical class.

5. Summary of the Results

As a result, out of 3561 BZCAT objects, 1363 (38.3 %) having SDSS spectra were classified. After the new classification, 749 (54.9 %) of 1363 objects have changed their optical class:

- 293 (53%) BZB objects from 552 changed classification,
- 149 (99%) BZG objects from 150 changed classification,
- 270 (44%) BZQ objects from 618 changed classification,
- 37 (86%) BZU objects from 43 changed classification.

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