Classification of Blazars by Activity Types

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Abstract

Blazars are the most energetic sources in the Universe. They unify two major types of objects: BL Lac objects and Flat Spectrum Radio Quasars (FSRQ). So far, 3561 blazars are known from BZCAT v.5 catalogue. However, in BZCAT v.5 all blazars are grouped into four main classes, where extended radio sources and some unknown objects are added: BZB (BL Lac objects), BZQ (FSR Quasars), BZG (Blazar-like (BZQ-like) Galaxies) and BZU (Blazars of Unknown subtypes). There is no information about optical classification of these sources. We have accomplished optical classification for BZU and BZG sources, which have optical spectra from SDSS catalogue. Most of these sources had no optical class before or have changed their optical classification after our work. For some blazars, we obtained optical classes for the first time. In the current work we have done an overall optical investigation for all classes of blazars (BZB, BZQ, BZG and BZU). After the optical classification, some BZU sources, which have SDSS spectra, have changed to QSO (BZQ) or Galaxies (BZG). This way we give a better understanding of objects included in BZCAT v.5.

Keywords: *Blazar, Quasar, Active Galactic Nuclei, optical classification.*

Introduction

Blazars are considered to be the most energetic sources in the Universe. BLL 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. At present 3,561 blazars are known. The disclosed 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, BZQ, BZG and BZU. 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).

The blazar category includes BL Lac objects and Optically Violently Variable (OVV) quasars. The generally accepted theory is that BL Lac objects are intrinsically low-power radio galaxies while OVV quasars are intrinsically powerful radio-loud quasars. The name "blazar" was coined in 1978 by Edward Spiegel to denote the combination of these two classes.

So, summarize different physical properties of blazars we must understand which properties show different types of blazars (table 1).

Classification method

We have used several methods for classification of the SDSS spectra (Mickaelian et al., 2022);

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Table 1. Distribution of types of objects in BZCAT.

N	Type	Numbers
1	BZB	1151
2	BZG	274
3	BZQ	1909
4	BZU	227
All		**3561**

- By eye (taking into account all features and effects)
- By diagnostic diagram using [OIII]/H_β and [NII]/H_α ratios (Reines et al., 2013),
- By diagnostic diagram using [OIII]/H_β and [SII]/H_α ratios (Reines et al., 2013),
- By diagnostic diagram using [OIII]/H_β and [OI]/H_α ratios (Reines et al., 2013).

Classification of BZCAT objects having uncertain types

For optical classification of BZCAT objects having uncertain types (Abrahamyan et al., 2019a), in the first step we cross-corelated these objects with SDSS (Abdurro'uf et al., 2022). As results we have 81 identification from which 43 have spectra. Our work is dedicated to these 43 objects. For a better understanding of the properties of BZU objects we cross-correlated with VCV-13 (Véron-Cetty & Véron, 2010), SDSS and NED.

Using information from VCV-13, SDSS and NED we can conclude the following:

- In SDSS: 13 objects are "galaxies" (extended objects) and 30 are "stars" (point-like objects),
- In VCV-13: 6 objects are BL or BL?, 2 objects are HP (HPQ), 6 objects are Sy1, 1 object is Sy1.2, 3 objects are Sy1.5, 1 object is Sy1n (Narrow Line Seyfert 1), 5 objects are Sy2, and for 19 objects we do not have any information,
- In NED: 13 objects are galaxies, 26 objects are quasars and 4 objects are RadioS (radio sources). Among these objects we have 4 BL Lac, 18 FSS (Flat-Spectrum Radio Source), 1 CSS (Compact Steep Spectrum), 1 Sy1, 1 Sy1.2, and 1 Sy 1.5,
- In NED we have radio morphology: 4 objects have radio jets, 1 object is FRII and 1 object is core-dominated radio object.

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

1) 37 (86%) objects from 43 changed classification (table 3).

Table 2. 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%)**

2) Using the information on redshift from BZCAT, SDSS and NED, 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) sources is given by BZCAT.

Table 3. Spectral classification using SDSS spectra

Activity Type	Numbers
Abs	1
BLL	1
Em	4
LINER	2
NLQSO	1
QSO	17
QSO 1.2	3
QSO 1.5	1
Sy 1.2	1
Sy 1.5	2
Sy 1.8	1
Sy 2.0	3
Unknown	6
Total	43

3) Using SDSS spectra we have carried out classification in optical range. In table 3 we give information for this classification.

   In VCV–13 catalogue, if the absolute magnitude is more than -22.25 then the sources are classified as quasars in Véron-Cetty & Véron (2010). So, using that, among our sources we had classification QSO 1.2 and QSO 1.5. If these sources have absolute magnitude less than -22.25, we classify them as Sy1.2 and Sy1.5.
   QSO 1.2 and QSO 1.5 have the same properties which have Sy 1.2 and Sy1.5, and according to VCV catalogue there is only absolute magnitude limit -22.25.

Classification of BZCAT objects having BZG types

BZG objects from the BZCAT catalog were selected for study (Abrahamyan et al. (2023)). It is clear from Table 1 that we have 274 galaxies. 150 of the 274 BZG objects have optical spectra in the SDSS spectroscopic catalog. For these objects we have carried out a detailed classification using the SDSS spectra (table 1).

Using the data from various catalogs and the data bases VCV-13, NASA/IPAC Extragalactic Database (NED) and SDSS, we have clarified the optical classification of these sources prior to our classification. Table 2 lists these data. As it can be seen from Table 4, these objects do not have a detailed optical classification. They were classified as galaxies because in the optical range (in optical images) they have an extended shape.

Table 4. Classification of BZG Objects from VCV-13, NED, and SDSS

Classification	SDSS spectra	VCV-13	NASA/IPAC
S1	-	8	5
S2	-	4	1
S3 (LINER)	-	2	-
S?	-	1	-
BL	-	54	49
BL?	-	33	6
QSO	7	2	-
AGN	-	2	-
Galaxy	143	-	-
FSS source	-	-	21
Total	**150**	**106**	**82**

Figure 1 shows optical images of two of these extended blazars. The measurements of the SDSS spectra

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are very often based on lines at the noise level and of low quality.

As a result, automatic measurements lead to some unreal results. Thus, it is necessary to carefully check the spectra at all wavelengths and to decide which measurements should be used for further study.

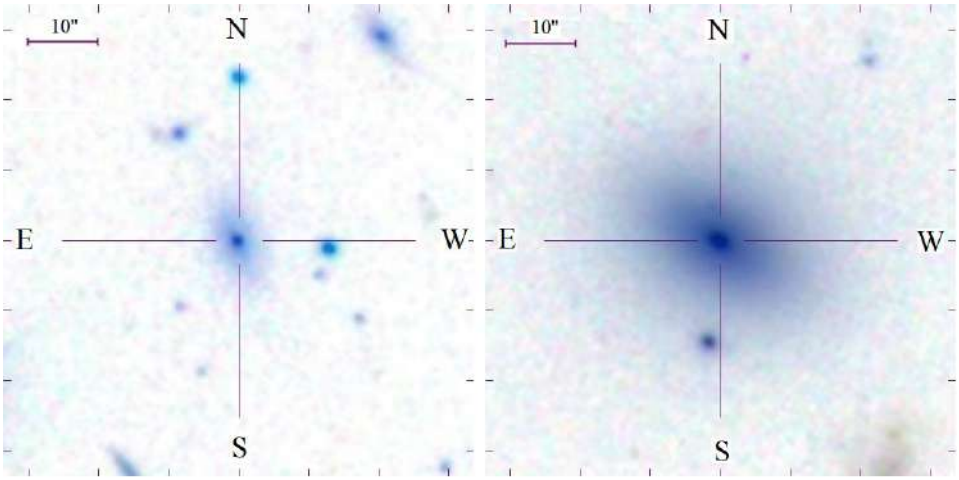

Figure 1. Optical images of the extended blazars 5BZG J0850+4036 and 5BZG 5BZG J0906+4124 from SDSS.

In Table 5 and in Fig. 2 we show our spectral classification for 150 BZG objects using the SDSS spectra. It is clear from Table 3 and Fig. 2 that these objects are mostly Em and Abs (about 80%) galaxies and had not been classified prior to us. 30 (20%) of the objects (S, LINER, and Composite) had no optical classification or changed class; only the blazar 5BZG J1532+3020 was classified as a LINER and remained as a LINER. Thus, it may be concluded that we are providing a detailed optical classification for essentially all the 150 objects.

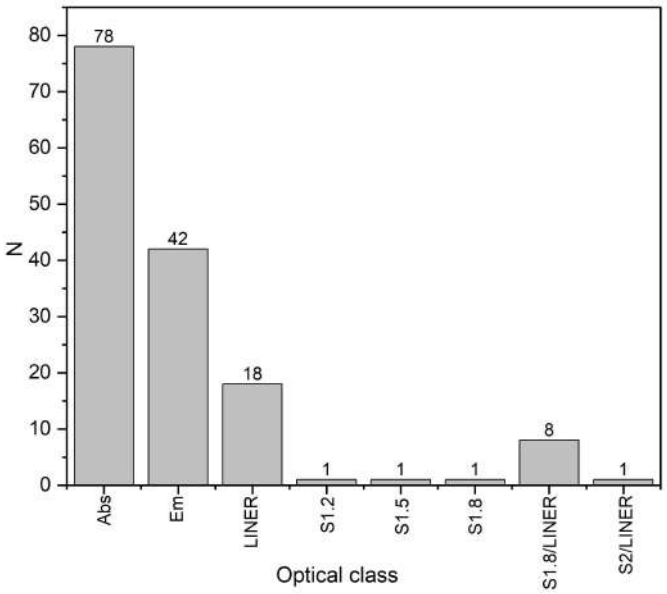

Figure 2. The new classification of the BZG objects using the SDSS spectra.

In order to clarify the optical nature of the extended blazars we have chosen BZG objects from the BZCAT catalog. Optical spectra from the SDSS catalog for 150 of the 274 BZG objects were used for a detailed spectral classification. Table 5 and Fig. 2 show that out of 150 objects, 30 (20%) have high quality optical 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.

Table 5. Classification of BZG Objects Ising the SDSS Spectra

S1.2	1 (0.7%)
S1.5	1 (0.7%)
S1.8	1 (0.7%)
LINER	18 (12%)
S1.8/LINER	8 (5.2%)
S2.0/LINER	1 (0.7%)
Em	42 (28%)
Abs	78 (52%)
All	**150 (100%)**

Summary and Results

So, having optical spectra of 43 BZU, we reclassified these objects. As the main results we have: 1) 37 (86%) objects from 43 changed classification, 2) For 5 objects that 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.

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In the future, we plan to carry out optical classification of BZCAT objects having BZQ and BZB types.

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