Classification of BZCAT objects having uncertain types

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Abstract

In this work we try to understand some optical properties of blazars having uncertain types (BZU) in BZCAT vs. 5 Catalogue. Cross-correlation with SDSS reveals 43 BZU out of 227 that have spectra in SDSS. We have carried out spectral reclassification for these 43 blazar candidates (BZU) for activity types. As a result, 37 (86%) objects out of 43 changed their previous type.

Keywords: *blazar, active galactic nuclei.*

1. Introduction

Blazars are considered to be the most energetic sources in the Universe. BLL Lac was discovered by the 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 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. (2019).

From BZCAT catalog, we cannot understand which sources are called Blazars. Using this catalogue we plan to take out definition of blazars. But in the first step we must understand properties of different types of Blazars. The most important and very interesting sources are blazars, which are classified as uncertain type (BZU). In this type included sources which have not good spectra, or have united properties which have other types of blazars. So, for better understanding of Blazars we must carry out investigations of all types of Blazars and take out united properties.

For summarize different physical properties of blazars we must understand which properties show different types of blazars (BZU, BZB, BZG and BZU).
This work is dedicated to classification of 43 blazars having uncertain type (BZU) in BZCAT catalogue v.5 (Massaro et al., 2015).

2. Observational data

For our investigation we take BZCAT v.5 (Massaro et al., 2015), which includes 3561 blazars. In BZCAT blazars have 4 types (table 1). In table 1 we can see 227 objects out of 3561 have uncertain

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DOI: 10.52526/25792776-2019.66.1-1

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**

types of blazars. For our investigation we take these 227 BZU objects.

In the First step we cross-corelated these objects with SDSS (Fan et al., 1999). In 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 (table 2).

Table 2. The list of BZU objects with their activity types and radio morphology.

BZCAT name	SDSS	VCV	NED		
		Sp.	Object	Radio Morphology	Activity Type
			Type	Homogenized Classification	Homogenized Classification
5BZUJ0217-0820	Star	BL	QSO		BL Lac
5BZUJ0304+0002	Star		QSO		QSO
5BZUJ0742+3744	Star		QSO		QSO
5BZUJ0840+1312	Star	S1.2	QSO	FR II	Sy 1.2
5BZUJ0849+5108	Star	S1n	QSO		Flat-Spectrum Radio Source
5BZUJ0856+0140	Star	BL	G		BL Lac
5BZUJ0909+4253	Star	S2	QSO	Core-Dominated	CSS
5BZUJ0933+0003	Galaxy	BL?	RadioS		
5BZUJ0954+5719	Star		QSO		QSO
5BZUJ1000+2233	Star	S2	QSO		
5BZUJ1021+4523	Star		G	radio jet	Flat-Spectrum Radio Source
5BZUJ1030+3102	Galaxy	S1.5	G	radio jet	Flat-Spectrum Radio Source
5BZUJ1033+0711	Galaxy		RadioS		Flat-Spectrum Radio Source
5BZUJ1051+4644	Star		QSO		Flat-Spectrum Radio Source
5BZUJ1058+0133	Star	HP	QSO	radio jet	BL Lac
5BZUJ1059+4051	Star		RadioS		
5BZUJ1153+5831	Galaxy	S1.5	QSO		Sy 1.5
5BZUJ1208+6121	Galaxy	BL?	G		BL Lac
5BZUJ1225+4834	Star		QSO		QSO
5BZUJ1238+5325	Star	S1	G		Sy 1
5BZUJ1257+0024	Star		QSO		QSO
5BZUJ1302+5748	Star		QSO		Flat-Spectrum Radio Source
5BZUJ1310+3220	Star	HP	QSO		Flat-Spectrum Radio Source
5BZUJ1345+4125	Star		QSO		
5BZUJ1345+5332	Galaxy	S1	G		
5BZUJ1347+3012	Star		QSO		QSO
5BZUJ1353+0443	Star		QSO		Flat-Spectrum Radio Source
5BZUJ1431-0052	Star		QSO		QSO
5BZUJ1435+2021	Star	BL?	G		Flat-Spectrum Radio Source
5BZUJ1448+0402	Star	S2	G		Flat-Spectrum Radio Source
5BZUJ1449+4221	Galaxy	S2	QSO		Flat-Spectrum Radio Source
5BZUJ1458+0416	Star		QSO		Flat-Spectrum Radio Source
5BZUJ1511+0518	Galaxy	S1	G		Flat-Spectrum Radio Source
5BZUJ1536+3742	Galaxy		G		
5BZUJ1550+1120	Star	S1.5	QSO		Flat-Spectrum Radio Source
5BZUJ1557+3304	Star		QSO	radio jet	QSO
5BZUJ1602+2646	Galaxy	S2	G		Flat-Spectrum Radio Source
5BZUJ1603+1554	Galaxy		G		Flat-Spectrum Radio Source
5BZUJ1618+2159	Star	S1	QSO		
5BZUJ1633+2112	Galaxy	S1	QSO		
5BZUJ1706+3214	Star		RadioS		
5BZUJ2156-0037	Star	BL	QSO		Flat-Spectrum Radio Source
5BZUJ2327+1524	Galaxy	S1	G		Flat-Spectrum Radio Source

Using table 2 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.

In Figure 1, we give redshift distribution of BZU and distribution of 43 objects, which have spectra in SDSS.

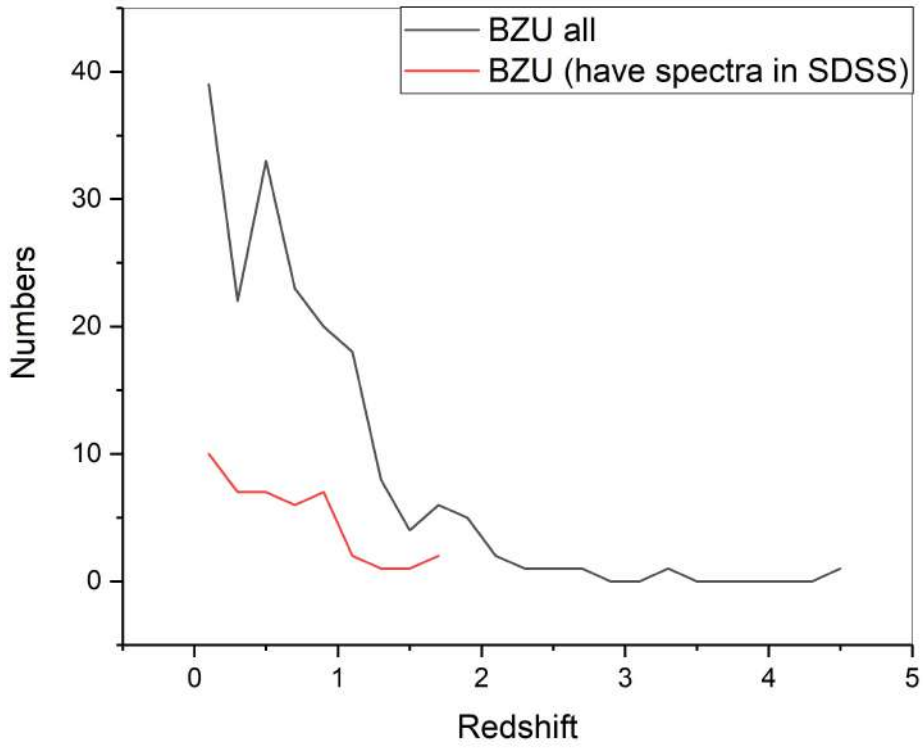

Figure 1. Redshift distribution of BZU objects.

In figure 1 BZU source mainly have 0 until 2.2 redshift and our studied sources have 0 until 1.75 redshift. For these 43 sources we have done classification using SDSS spectra.

For understanding some physical properties of blazars we use the paper Abrahamyan et al. (2019). In this paper calculated absolute magnitude for all blazars. In Figure 2, we give graphs of the absolute magnitude versus redshift.

In Figure 2 our investigated sources have -21 to -25 absolute magnitudes.

So, using 43 SDSS spectra for our sources, we have carried out optical classification.

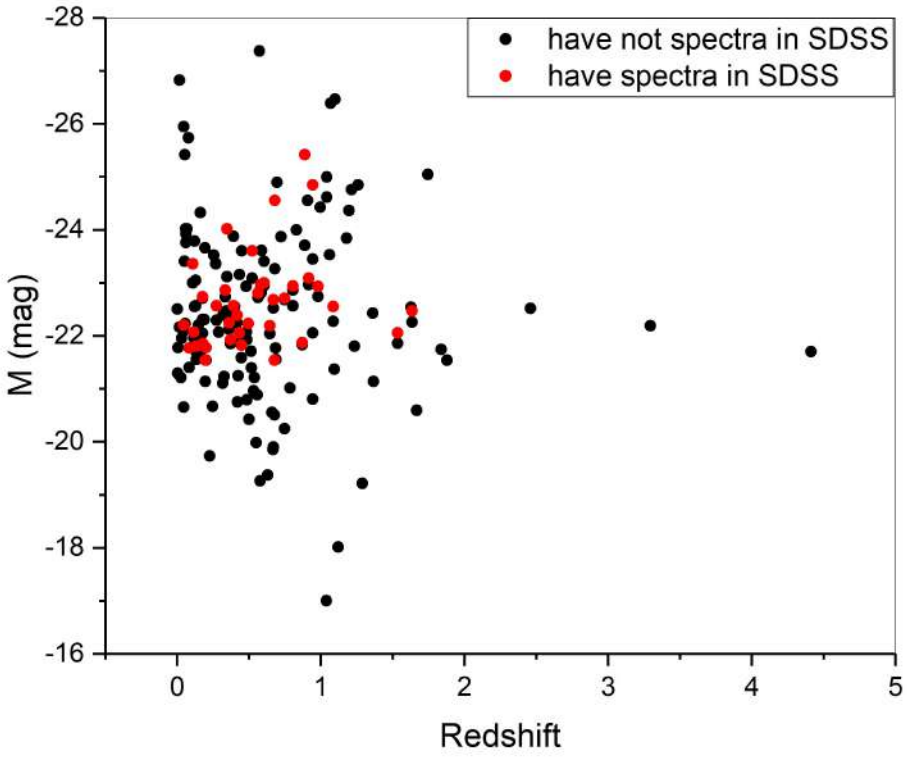

Figure 2. Absolute magnitude vs. redshift.

3. Classification method and results

We have used several methods for classification of our spectra (Mickaelian et al., 2018);

- 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),

We have done classification only by eye, because we have not enough information for diagnostic diagrams from the spectra.

We started the studying of spectra with identifications of spectral lines. We have used only lines having intensities 3 sigma over the noise level.

In Figure 3 we give 4 spectra out of 43 our investigated blazars.

In order to do classification, we need to consider the classification Massaro et al. (2015):

- **BZB**: BL Lac objects, used for AGNs with a featureless optical spectrum, or having only absorption lines of galactic origin and weak and narrow emission lines (Massaro et al., 2015);
- **BZG** objects, usually reported as BL Lac objects in the literature, but having a spectral energy distribution (SED) with a significant dominance of the galactic emission over the nuclear one (Massaro et al., 2015);

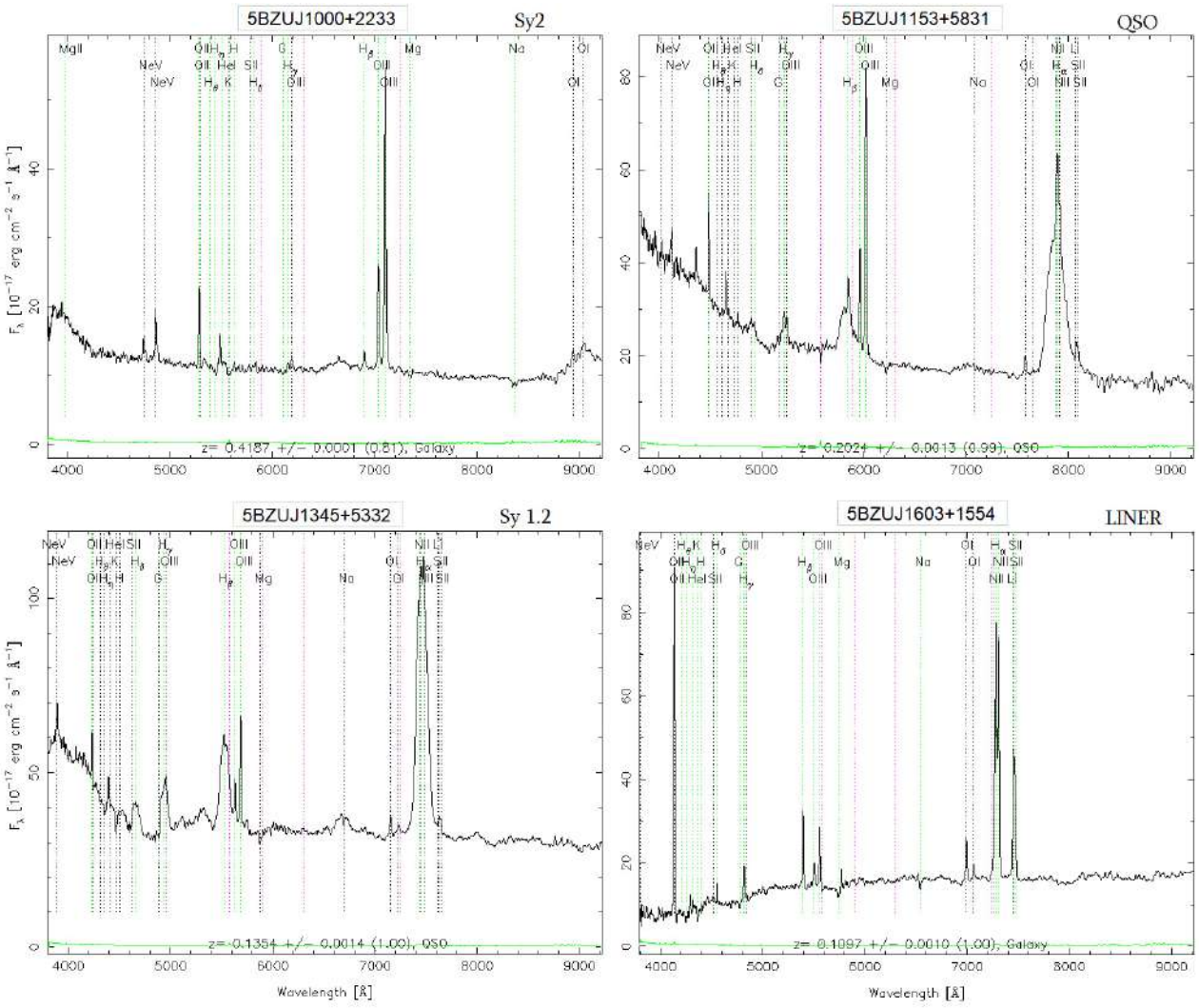

Figure 3. Examples of spectra.

- **BZQ**: Flat Spectrum Radio Quasars, with an optical spectrum showing broad emission lines and dominant blazar characteristics (Massaro et al., 2015).

Using classification of BZCAT given in Massaro et al. (2015). we have carried out classification of 43 sources which have uncertain type.
So, 37 BZU objects from 43 changed their classification to BZQ, BZG and BZG. In table 3 we give the new classification and redshifts from SDSS.

In table 3 we give old and new classification, and give activity type using SDSS spectra. And we give redshift form catalogue BZCAT v. 5, NED and SDSS. For 5 sources we checked and corrected redshift and for 4 sources is given by SDSS and for 1 source is given by BZCAT.

4. Conclusion

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 4).

2) In table 3 we give information of redshift from BZCAT, SDSS and NED. 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) sources is given by BZCAT.

Table 3. 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^b		0.71107^a
5BZUJ0954+5719	BZU	QSO	BZQ	0.981	0.981193	0.98121
5BZUJ1000+2233	BZU	Sy2.0	BZG	0.419	0.418732	0.41874
5BZUJ1021+4523	BZU	QSO	BZQ	0.364	0.36388	0.36437
5BZUJ1030+3102	BZU	QSO	BZQ	0.178	0.1782	0.17815
5BZUJ1033+0711	BZU	Unknown	BZU	1.535		1.52948
5BZUJ1051+4644	BZU	Unknown	BZU	0^b	1.419418^b	0.00005^a
5BZUJ1058+0133	BZU	BLL	BLB	0.890^a	0.89^a	0.3823^b
5BZUJ1059+4051	BZU	QSO	BZQ	1.746		1.75049
5BZUJ1153+5831	BZU	QSO	BZQ	0.202	0.202439	0.2024
5BZUJ1208+6121	BZU	Abs	BZG	0.275	0.274783	0.27479
5BZUJ1225+4834	BZU	QSO	BZQ	0.647	0.646553	0.64687
5BZUJ1238+5325	BZU	QSO1.2	BZQ	0.348	0.347506	0.34684
5BZUJ1257+0024	BZU	QSO	BZQ	1.259	1.260971	1.25808
5BZUJ1302+5748	BZU	Unknown	BZU	1.088^b	1.088^b	0.83066^a
5BZUJ1310+3220	BZU	QSO	BZQ	0.997	0.998007	0.99725
5BZUJ1345+4125	BZU	QSO	BZQ	0.916	0.916932	0.91654
5BZUJ1345+5332	BZU	Sy1.2	BZG	0.135	0.135406	0.13537
5BZUJ1347+3012	BZU	Sy1.5	BZG	0.118	0.11785	0.11784
5BZUJ1353+0443	BZU	QSO	BZQ	0.523	0.522821	0.5234
5BZUJ1431-0052	BZU	QSO	BZQ	1.635	1.633083	1.63687
5BZUJ1435+2021	BZU	Em	BZG	0.748	0.748	0.74768
5BZUJ1448+0402	BZU	Em	BZG	0.871	0.8712	0.8712
5BZUJ1449+4221	BZU	Sy2.0	BZG	0.179	0.1783	0.17867
5BZUJ1458+0416	BZU	Em	BZG	0.392	0.391547	0.39154
5BZUJ1511+0518	BZU	Sy2.0	BZG	0.084	0.084	0.08452
5BZUJ1536+3742	BZU	Em	BZG	0.679	0.679211	0.67911
5BZUJ1550+1120	BZU	Sy1.5	BZG	0.436	0.43598	0.43567
5BZUJ1557+3304	BZU	QSO	BZQ	0.943	0.944472	0.94962
5BZUJ1602+2646	BZU	LINER	BZG	0.372	0.371657	0.37171
5BZUJ1603+1554	BZU	LINER	BZG	0.110	0.109866	0.10971
5BZUJ1618+2159	BZU	QSO	BZQ	0.336	0.334828	0.3348
5BZUJ1633+2112	BZU	Sy1.8	BZG	0.198	0.198156	0.1982
5BZUJ1706+3214	BZU	QSO	BZQ	1.070		1.06979
5BZUJ2156-0037	BZU	Unknown	BZU	$0.495?^b$	0.495^b	2.23931^a
5BZUJ2327+1524	BZU	QSO	BZQ	0.046	0.045717	0.04581

(a) Right measurement.
(b) Wrong measurement.

3) Using SDSS spectra we have carried out classification in optical range. In table 5 we give

Table 4. 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%)**

information for this classification.

Table 5. 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

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.

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