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CLASSIFICATION OF BLL BLAZARS BY OPTICAL ACTIVITY TYPES

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We have carried out a spectral classification by the Activity Types for a subsample of Blazars from the BZCAT v.5 Catalogue, namely the BL Lac (BLL, Lacertids) candidates, designated in the Catalogue as BZB subtype 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 Quasars and considering many more features. Out of 1151 BZB objects, 552 having SDSS spectra were classified. After new classification, 259 (46.1%) of 552 have not changed their optical class, and 293 (53.1%) of these objects have changed their optical class. Having this new information on the optical classification we suggest to change the classification of some objects in BZCAT: for 130 BZB objects to BZG, for 18 BZB objects to BZQ and for 145 BZB objects to BZU.

Keywords: *blazars: BL Lac objects: quasars: radio sources: activity type: classification*

1. *Introduction*. Among the Active Galactic Nuclei (AGN), the most interesting are blazars with combination of two subtypes: a) BL Lac (BLL) objects and b) special types of quasars (QSO): Optically Violent Variable (OVV) and Highly Polarized Quasars (HPQ). A blazar is characterized as a very compact quasar, associated with a presumed Super Massive Black Hole (SMBH) at the center of an active giant elliptical galaxy. Blazars are the most energetic objects in the Universe [1]. The object BL Lac was originally discovered by Hoffmeister [2] as a variable star, and later it was identified by Schmitt [3] as an extragalactic source, and BL Lac type objects were assigned as one of the AGN types. They are characterized by significant optical variability, optical continuous spectrum without or with very weak absorption or emission lines, and they have radio emission, which is typically also variable and polarized.

Massaro et al. [1] presented the blazar catalog BZCAT v.5, where the objects are divided into 4 types: BZB (Lacertids, BL Lac or BLL), BZQ (Quasars, namely Flat Spectrum Radio Quasars, FSRQ), BZG (Galaxies), and BZU (Undetermined class). Table 1 shows the distribution of the types of blazars from the BZCAT catalog.

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

In our earlier papers we studied and classified BZU, BZG and BZQ objects [4-6]. This paper is devoted to detailed spectral classification of the largest group BZB blazars from the BZCAT catalog. We aim at classifying all objects by activity types, as well as rearranging BZCAT types to have more homogeneous grouping.

2. *Studied data*. For our investigation, we have selected BZB (BL Lac) objects from BZCAT catalog. 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 [7]. For these objects we have carried out a detailed classification using the SDSS spectra.

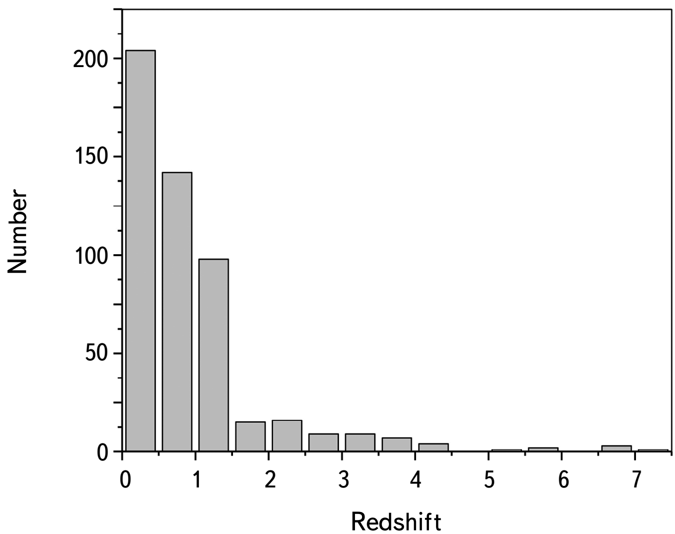

Fig.1. The distribution of BZB objects by redshift.

Table 2

DISTRIBUTION OF TYPES OF OPTICALLY CLASSIFIED BZB (BL Lac) OBJECTS FROM BZCAT CATALOGUE

Classes/Subclasses	SDSS images	VCV-13	NED
BL Lac	-	417	-
QSO	-	28	262
AGN	-	7	-
Galaxy	139	-	145
GClstr	-	-	2
Star	413	-	3
UvES	-	-	3
UvS	-	-	2
VisS	-	-	19
IrS	-	-	7
RadioS	-	-	9
Total	552	452	452

In Fig.1 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 the data from various catalogs and data bases VCV-13 [8], NASA/IPAC Extragalactic Database (NED) and SDSS [7], we have clarified the optical classification of these objects prior to our classification. We list these data in Table 2.

As it can be seen from Table 2, some objects do not have detailed optical classification. In this table information on optical classification for all BZB objects from SDSS, VCV-13 catalogues and NED database is given.

The measurements of the SDSS spectra are very often based on lines at the noise level and of low quality. As a result, automatic measurements lead to some misclassification. Thus, it is necessary to carefully check the spectra at all wavelengths and to decide which measurements should be used for further study. The lines which are used in the diagnostic diagrams are especially important ($H\beta$, [OIII] 5007 Å , [OI] 6300 Å , $H\alpha$, [NII] 6583 Å , and [SII] 6716+6731 Å) [9].

3. *Optical classification for activity types*. Diagnostic diagrams are useful tools for the galaxies classification based on the emission lines ratio [10-12]. Mickaelian et al. in [10,11] 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 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 $[OIII]/H\beta$ vs. $[OI]/H\alpha$.
- By the 2nd diagnostic diagram (DD2) using line intensity ratios $[OIII]/H\beta$ vs. $[NII]/H\alpha$.
- By the 3rd diagnostic diagram (DD3) using line intensity ratios $[OIII]/H\beta$ vs. $[SII]/H\alpha$.

Table 3

CLASSIFICATION OF BZB OBJECTS USING THE SDSS SPECTRA

Classification		Number	%
Abs (Absorption galaxy)		100	18.11
BZB	Continual spectra with z	22	3.97
	Continual spectra without z	237	42.85
Em		24	4.32
LINER		2	0.36
NLQ1		1	0.18
NLQ1.5		2	0.36
QSO		16	2.90
SB		2	0.36
Sy2		2	0.36
Unknown		145	26.23
Total		552	100

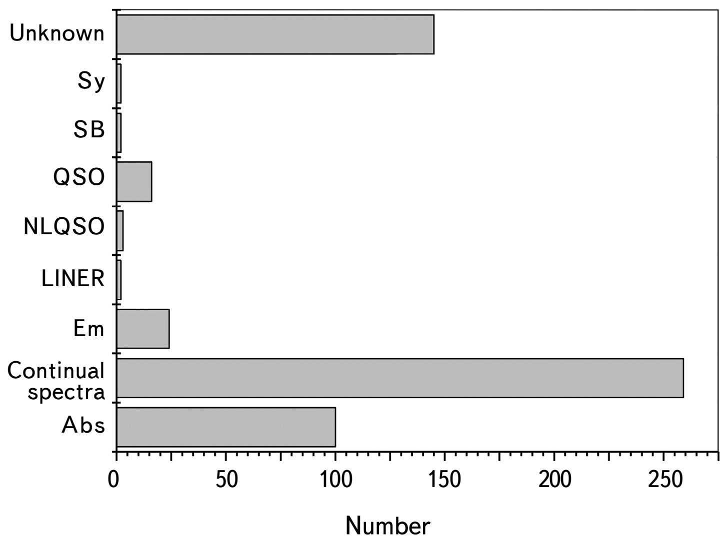

Fig.2. The new classification of the BZB objects using the SDSS spectra.

- 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 these objects in the spectra, the lines Hα and Hβ were mainly absent (due to redshifts), so we made a classification only by the visual method.

In Table 3 and in Fig.2 we show our spectral classification for 552 BZB objects using the SDSS spectra. It is clear from Table 3 and Fig.2 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.

Table 4 shows our detailed classification of the 10 BZB objects using the SDSS spectra (the full list will be available in electronic form in VizieR). Having this new information on the optical classification we suggest to change the classification of some objects in BZCAT between the groups, given by Massaro et al. [1]: for 130 BZB objects to BZG, for 18 BZB objects to BZQ and for 145 BZB objects to BZU.

Table 4

LIST OF 10 BZB OBJECTS CLASSIFIED USING THE SDSS SPECTRA

BZCAT name	Old class				New class		M	L
	BZCAT	SDSS	VCV-13	NED	Activity type	BZCAT class	SDSS r	$\times 10^{43} L_{\odot}$
5BZB J0110-0415	BL Lac	Star			NLQSO1	BZQ	-22.76	41.82
5BZB J0832+4913	BL Lac	Star	B	QSO	Sy2	BZG	-21.82	17.51
5BZB J1058+4304	BL Lac	Star	B	QSO	QSO	BZQ	-22.96	50.12
5BZB J1337+0035	BL Lac	Galaxy	B	G	LINER	BZG	-21.76	16.52
5BZB J1402+1559	BL Lac	Star	B	QSO	LINER	BZG	-22.02	21.08
5BZB J1417+2543	BL Lac	Galaxy	B	RadioS	Em	BZG	-22.70	39.59
5BZB J1437+3002	BL Lac	Star			QSO	BZQ	-22.88	46.38
5BZB J1617+4106	BL Lac	Galaxy	B	QSO	Sy2	BZG	-22.14	23.51
5BZB J1714+3036	BL Lac	Star	B	G	QSO	BZQ	-22.54	34.03
5BZB J2219+2120	BL Lac	Star			NLQSO1.5	BZQ	-21.83	17.73

4. *Absolute magnitudes and luminosities*. Having information on magnitudes from SDSS, we have calculated absolute magnitudes for BZB objects using Eq. (1).

$$M = m + 5 - 5\log L - f(z) + \Delta m(z), \quad (1)$$

$$L = \frac{c(1+z)}{H_0}\int_0^z \left[(1+z)^3\Omega_M + \Omega_\Lambda\right]^{-0.5} dz \quad (2)$$

where L is the luminosity distance as defined by Riess et al. [13], z is the redshift, $f = 2.5(1-z)^{1-\alpha}$ the k correction, $\Delta m(z)$ is a correction to k considering that the spectrum of quasars is not strictly a power law of the form $S \propto \nu^{-\alpha}$ ($\alpha = -0.3$, [8]).

The following values were taken for the cosmological constants in the calculations:

$$\Omega_M = 0.29, \quad \Omega_\Lambda = 0.71, \quad H_0 = 71\ \mathrm{km\,s^{-1}Mpc}.$$

Having absolute magnitude, we counted luminosities for BZB objects from Blazars catalogue using Eq. (3).

$$L = 2.512^{M_\odot - M} L_\odot \tag{3}$$

where $L_\odot$ and $M_\odot$ are the luminosity and the absolute magnitude of the Sun ($L_\odot = 3.83 \cdot 10^{33}$ erg/s, $M_\odot = 4.83$). Data on absolute magnitude and luminosity can be found in Table 4.

After the optical classification and change of the subtypes of some objects (for 130 BZB objects to BZG, for 18 BZB objects to BZQ and for 145 BZB objects

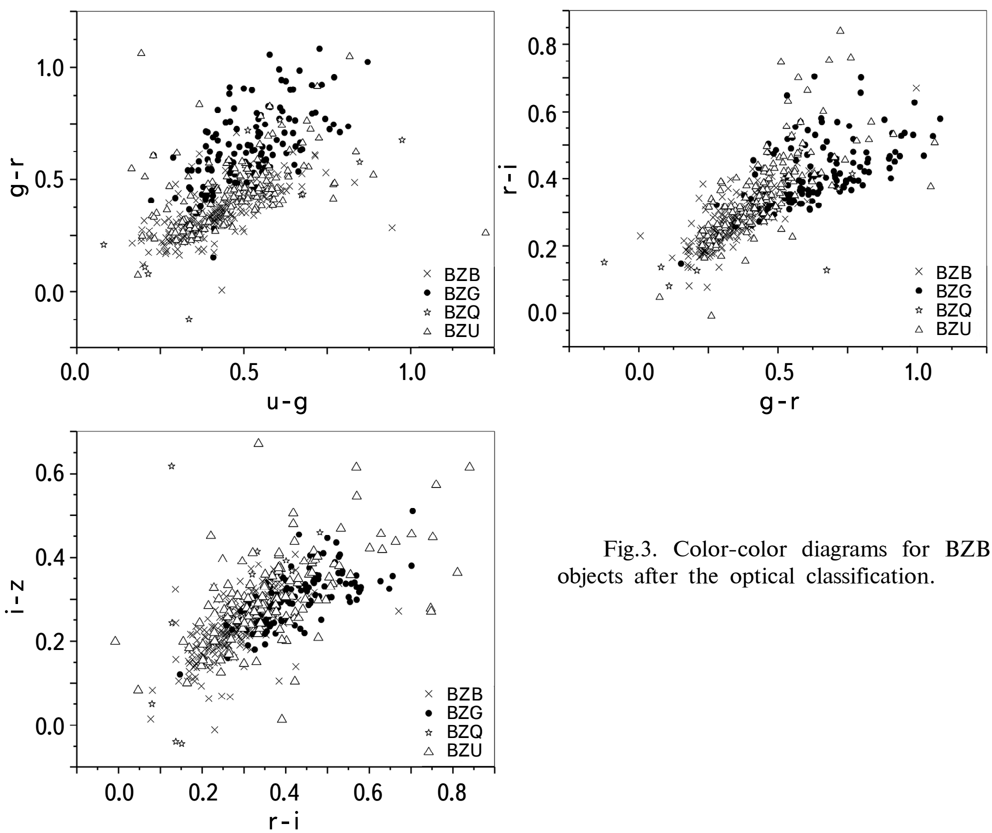

Fig.3. Color-color diagrams for BZB objects after the optical classification.

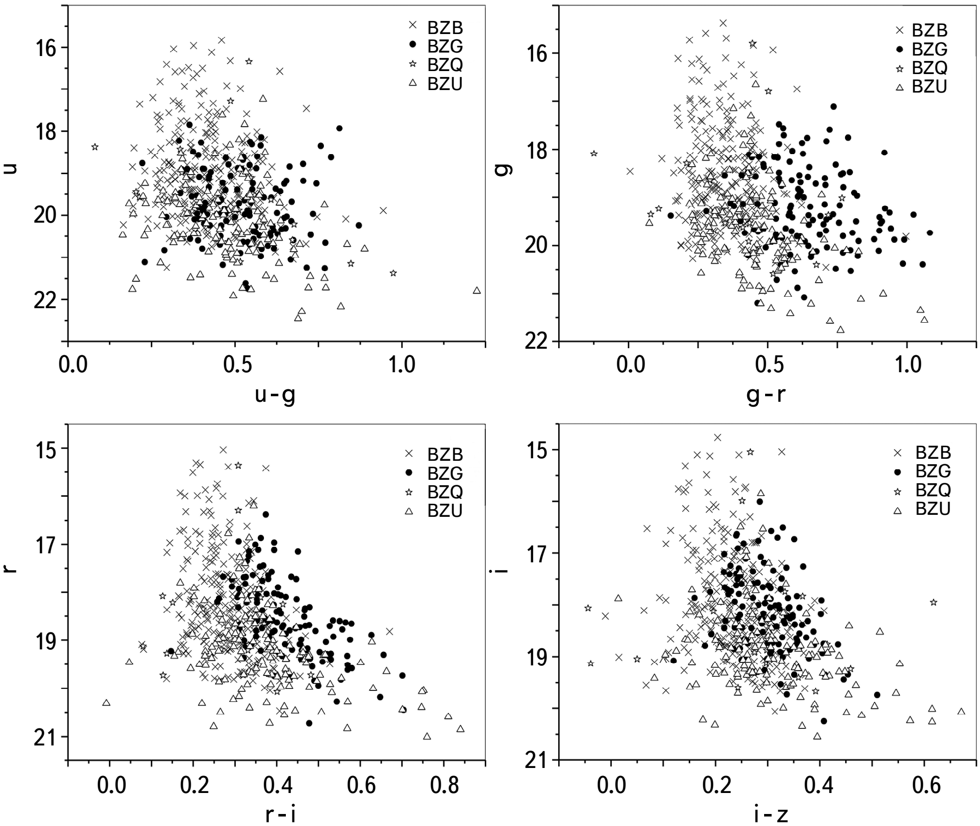

Fig.4. Color-magnitude diagrams for BZB objects after the optical classification.

to BZU), we built color-color and color-magnitude diagram for BL Lac objects (Fig.3 and 4). In most of graphs blazars subtypes are scattered in all area. In color-color and color-magnitude diagrams distribution of BZG objects have a shift from other blazars distribution and is different from others. In color-magnitude diagrams the weakest objects are mainly BZU subtype objects.

5. *Results*. We selected BZB objects from BZCAT catalog (Table 1). 552 of the 1151 BZB objects have optical spectra in the SDSS. For these objects we have carried out a detailed classification using the SDSS spectra. In this paper we have carried out optical classification using method given by Mickaelian et al. in [10,11]. Our optical classification results are given in Table 3 and 4.

In Table 3 and in Fig.2 we show our spectral classification for 552 BZB objects using the SDSS spectra. It is clear from Table 3 and Fig.2 that these objects are mostly have "Continual spectra", which dominated BZB objects (about 46.82%). After our new classification, 259 (46.1%) of 552 have not changed their optical class, and 293 (53.1%) of these objects have changed their optical class.

Having this new information on the optical classification we suggest to change the classification of some objects in BZCAT between the groups, given by Massaro et al. [1]: for 130 BZB objects to BZG, for 18 BZB objects to BZQ and for 145 BZQ objects to BZU.

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КЛАССИФИКАЦИЯ БЛАЗАРОВ BLL ПО ТИПАМ ОПТИЧЕСКОЙ АКТИВНОСТИ

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Проведена спектральная классификация по типам активности для подвыборки блазаров из каталога BZCAT v.5, конкретно для кандидатов в BL Lac (BLL, Лацертиды), обозначенные в каталоге как объекты подтипа BZB. Классификация основана на оптической спектроскопии среднего разрешения Слоановского цифрового обзора неба (SDSS), и наряду со стандартными диагностическими диаграммами BPT-типа применена недавно введенная авторами схема тонкой классификации с подтипами квазаров и учетом многих других особенностей. Из 1151 BZB объектов классифицированы 552, которые имеют спектры SDSS. После новой классификации 259 (46.1%) из 552 не изменили свой подтип, а 293 (53.1%) из этих объектов изменили подтип. Имея эту новую информацию об оптической классификации, мы предлагаем изменить классификацию некоторых объектов в BZCAT: для 130 объектов BZB на BZG, для 18 объектов BZB на BZQ и для 145 объектов BZB на BZU.

Ключевые слова: *блазары: объекты BL Lac: квазары: радиоисточники: тип активности: классификация*

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