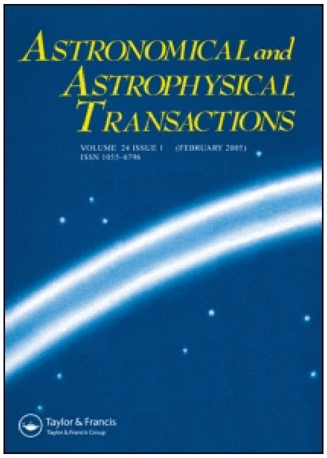

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BLUE STELLAR OBJECTS OF THE FIRST BYURAKAN SURVEY

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The second part of the First Byurakan Survey is devoted to the search and investigation of blue stellar objects, hot subdwarfs, white dwarfs, HBB stars, cataclysmic variables, quasars, compact Seyfert galaxies. 1103 object were selected on a surface of 4009 square degrees at high Galactic latitudes, 716 of which are new. Many of these objects are being investigated with spectral and polarimetric methods, and photometric estimates of objects are being made. An analysis of the sample of blue stellar objects is made and subsamples of different types of objects within this sample are separated for further study.

KEY WORDS Blue stellar objects, surveys

1 INTRODUCTION

In 1965–1980 Markarian *et al.* (1981) in Byurakan carried out the First Byurakan Survey (FBS). More than 2000 photographic plates were obtained with the 1 m Schmidt telescope and 1.5° objective prism. A surface of more than 17 000 square degrees was covered at high galactic latitudes ($|b| > 15°$) at $\delta > -15°$. As a result, 1500 galaxies with UV excess were selected, which are known at present as Markarian galaxies. Later these objects were investigated in more detail and appeared to be Seyfert galaxies, LINERs, QSOs, BL Lacertae objects, starburst galaxies, extragalactic HII regions, other emission-line galaxies, sources of X-Ray, radio- and infrared radiation, and others. Full data for Markarian objects are given in the catalogue of Markarian *et al.* (1989).

In 1987 the Second part of the FBS began (Abrahamian *et al.*, 1990a). It includes the selection of blue stellar objects on the basis of the FBS observational material, as well as their spectral classification and further investigation. Blue stellar objects (BSOs) are interesting because they represent white dwarfs, hot subdwarfs, cataclysmic variables, as well as extragalactic objects: QSOs, Seyferts and others. Some objects of these types found on the plates of the FBS have already been described (Markarian *et al.*, 1987; Stepanian, 1982; Lipovetski and Stepanian, 1981, etc).

2 THE SELECTION OF THE BLUE STELLAR OBJECTS

2.1 The Observational Material

At present the survey for the blue stellar objects has been carried out in 11 zones ($+33° < \delta < +45°$ and $+61° < \delta < +90°$) of the FBS with a total surface of 4009 square degrees. The observational material consists of 438 mainly Eastman Kodak IIAF, IIaF, 103aF and IIF photographic plates obtained in 278 4×4 degree fields. The magnitude limits are estimated by the author as 16.1–19.3 with a mean value of 17.8. It should be mentioned that the stellar objects may be selected up to the limit of the plate and the completeness of the survey is higher than that of the survey of galaxies. Each plate contains about 15 000–20 000 low-dispersion spectral images, which have been examined by means of $7\times$ and $15\times$ lenses with the goal of selection of stellar objects with UV excess. The dispersion of 1800 A/mm near H-alpha allows as to distinguish some important absorption and emission lines, estimate the colour of the objects and follow the energy distribution in the spectra.

2.2 Selection of Objects and Criteria of Classification

In general the selection of the BSOs is being carried out in two ways – colorimetric and spectral methods. The most famous colorimetric survey is the Palomar–Green survey (PG) carried out by Green *et al.* (1986). The Case objective prism survey (Pesch and Sanduleak, 1983) and the Second Byurakan Survey (Stepanian, 1994) are the most efficient among the spectral surveys. Nevertheless, FBS is greater in its surface and includes many uninvestigated regions. The presence of the UV excess which allows one to select objects during the surveying of the plates without measuring the colour, the possibility of noticing peculiarities in the energy distribution, and some spectral lines (Balmer absorption lines and some others for white dwarfs and subdwarfs and emission lines for quasars) are the advantages of the spectral method. All these types of objects have long blue-UV parts in the low-dispersion spectra in comparison with other objects (mainly A–K type stars).

Markarian (1967) has suggested criteria for classification of low-dispersion spectra. In Paper 1 (Abrahamian *et al.*, 1990a) we have discussed these criteria and our new principles of BSO classification. The presence of the green gap in objective-prism spectra obtained on panchromatic emulsion allows us to select and classify them by the intensity and length correlation of the two divided parts (conditionally, blue and red).

It may be recalled here that in our classification the B-type designates objects which have the blue part of the spectra more intense than the red one, and the N type designates objects which have equal intensities of both blue and red parts. The indices 1, 2 and 3 show the ratio of the lengths of the blue and red parts of the spectrum in decreasing order. The indices 'a' and 'e' show the presence of absorption and emission lines in low-dispersion spectra, respectively. A colon denotes the cases of uncertainty of these data. Thus, the bluest objects with the strongest UV excess

Table 1. Results of the second part of the FBS

No. of lists	*Year of survey*	δ	α	*Surface (sq. deg)*	*Number of fields*	*Number of selected objects*	*Number of new objects*
I	1987	+37–+41	00^h00^m–13^h30^m	505	33	100	61
II	1987	+37–+41	13 30–24 00	334	22	103	59
III	1988	+41–+45	00 00–13 30	490	33	120	74
IV	1988	+41–+45	13 30–24 00	344	24	106	61
V	1989	+33–+37	00 00–13 30	504	32	111	65
VI	1989	+33–+37	13 30–24 00	345	22	98	52
VII	1991	+61–+65	05 30–18 40	356	23	119	71
VIII	1991	+65–+69	05 15–18 05	298	19	98	73
IX	1993	+69–+73	03 50–18 10	280	19	84	64
X	1995	+73–+80	03 30–18 30	353	30	100	80
XI	1996	+80–+90	02 08–20 15	200	21	64	56
Total	1987 1996	+33–+45 +61–+90	All α except the Milky Way	4009	278	1103	716

are classified as B1. On the other hand, many quasars have flat spectra and are classified as N (especially N1).

The identification of our objects with BSOs from other catalogues and surveys, as well as our spectral observations, showed that these criteria of selection allow us to find the following types of objects: early-type main sequence stars (O–B5), horizontal branch stars (HBB), hot subdwarfs of sdO and sdB classes, white dwarfs at DO, DB, DA, DC and DZ classes, planetary nebulae nuclei (PNN), cataclysmic variables (CV), binaries (Bin), red dwarfs in the flare stage (dMe), as well as extragalactic objects: QSO candidates, Seyfert galaxies with star-like images, BL Lac objects, compact galaxies (BCDG-s as well), other emission-line and UV excess galaxies and other peculiar objects.

2.3 Results of the Survey

At present 11 lists of BSOs have been published with the results of surveying of 11 zones (Abrahamian *et al.*, 1990a [Paper 1]; 1990b [Paper 2]; 1990c [Paper 3]; 1991 [Paper 4]; Abrahamian and Mickaelian, 1993a [Paper 5]; 1993b [Paper 6]; 1994a [Paper 7]; 1994b [Paper 8]; 1994c [Paper 9]; 1995 [Paper 10]; 1996 [Paper 11]). These lists contain 1103 objects (the mean surface density is 0.28 object per square degree whereas the same parameter of the Palomar–Green survey (Green *et al.*, 1986) is 0.17), 716 of which have been discovered for the first time. Other objects are identified with blue stellar objects of analogous surveys, which allows us to carry out a comparison in the completeness of the sample, in the frequency of selection of various objects, as well as in the accuracy of the coordinates and magnitude. Such a comparison was fulfilled in Paper 2 and Paper 4.

Table 1 presents data on all the regions of the survey and results on the discovery of BSOs. The columns present: number of the lists, year of investigation, δ (4°

strips), limits of α, surface of the investigated region, number of 4×4 degree fields, selected UV excess objects, and number of objects selected for the first time.

The accuracy of the equatorial coordinates, determined from the POSS charts, is 1 s (for the right ascension) and 10″ (declination). The accuracy of the V magnitudes and colour indices, derived from the estimated m_O and m_E magnitudes on the POSS charts by means of the relation 'image diameter – magnitude' (King and Raff, 1977), is iR about $0^m.3$. The lists with the objects contain the IAU designations and survey numbers, equatorial coordinates for the epoch 1950.0, m_{pg} and m_v (close to V) magnitudes, colour indices (close to $B - V$), survey types (preliminary classification of the low-dispersion spectra), estimation of the class for the part of the objects (DA, DB, PNN, CV, Bin, QSO, Sy, Gal, in all for 202 objects) and references (identification with known BSOs from other surveys or catalagues, in all for 387 objects).

3 INVESTIGATION OF THE OBJECTS

3.1 Spectral Investigations

The spectral observations were carried out in 1987–91 at the Cassegrain focus of the Byurakan 2.6 m telescope by means of the UAGS spectrograph and image tube UMK-91B. The linear dispersion is 101 Å/mm and the spectral range is 3300–6800 Å. Eastman Kodak IIa-0 and 103a-0 films were used.

451 slit spectra for 396 FBS objects with a total effective exposure of 20 359 min were obtained. 422 of them are for 368 new objects. The slit spectra were recorded with the PDS-1010A microdensitometer and processed with the ADA system. The resulting spectral resolution is 4–5 Å. The errors of determination of FWHM and FWOI, as well as equivalent widths, are 20–30%.

Palomar–Green criteria were mainly used for the spectral classification. In all there are 24 classes and subclasses. All the 396 objects have been provisionally classified. 58 objects were investigated in details (Abrahamian and Mickaelian, 1991). The composition at the sample is the following: 56% are hot subdwarfs (sdB, sdB-O, sdOA, sdOB, sdOC, sdOD, sdO classes), 16% are white dwarfs (DA, DB, DBA, DZ, DAZ, DBZ, DC, DO or PNN classes), 8% are main sequence blue stars and HBB stars, 4% are extragalactic objects (QSO, Sy, Gal), 2% are CVs, 1% are binaries; 8% have continuous spectra and may appear to be QSOs, BL Lac objects, DCs, sometimes CVs, and 5% cannot be classified. It is to be mentioned that this is the distribution of relatively bright objects. The faintest object remain unobserved and the percentage of the extragalactic ones will increase with our observations and classification. The composition of our sample will be clear after the full spectral investigation.

In 1996 five more FBS objects are observed at the 6 m telescope with the UAGS spectrograph and CCD. At present the results are being processed (Balayan, 1996).

Table 2. List of objects with linear polarization

FBS	*b*	*r (max)*	*m(V)*	*Filters*	*P (%)*	*θ*	*Comments*
1559 + 369	+49.1	70	14.2	*B*	3.5–3.9	180	magn. WD
1654 + 351	+37.8	350	12.7	*B, U*	0.7	85	
1704 + 347	+35.7	1200	15.4	*B*	0.5–6.0	16	var., polar
1815 + 381	+22.7	400	13.0	*B*	2.5–4.4	178	var., magn. WD
1850 + 443	+18.4	160	11.0	*B*	2.0–3.3	135	var.

3.2 Polarimetric Observations

The polarimetric observations were carried out in 1990–91 at the Cassegrain focus of the Byurakan 2.6 m telescope by means of an electropolarimeter, working in the regime of direct measuring of continuous current. An EMI-9789QB photomultiplier was used as a receiver. The accuracy of measurements of the percentage of polarization is about 0.5–1.0%, depending on the brightness of the objects, and the position angle of the polarization, about 5°.

The goal of the polarimetric observations was the polarimetric investigation of the sample, revealing the intrinsic polarization of new objects and the discovery of new objects of definite types: magnetic white dwarfs and other magnetic stars, polars, highly polarized QSOs; etc. 35 objects were observed, four of which thrice, 10 twice and 21 once (Mickaelian *et al.*, 1991; Eritsian and Mickaelian, 1993). Five objects show linear polarization and their high Galactic latitudes and relative proximity suggest an intrinsic (or environmental) origin of the observed polarization. Table 2 presents the results of polarimetric observation of these objects. The following data are given in the columns: FBS name of the observed object, Galactic latitude, maximum distance estimated by the upper limit of the absolute magnitudes, visiual magnitude, filters used, percentage of linear polarization, position angle of polarization, and comments on the nature of the objects. .

The object FBS 1850 + 443 was observed also at the 6 m telescope by S. N. Fabrika and V. G. Stol in 1993 (Fabrika, 1993) and the presence of the linear polarization was confirmed. The polarimetric investigation of the FBS objects will be continued.

4 ANALYSIS OF THE SAMPLE

4.1 Comparison with Other Surveys

A comparison was made for the first 9 lists, where 939 objects were selected by us in 1987–93 on a surface of 3456 square degrees, and 580 of which are new. Table 3 shows a comparison of the results of the fulfilled part of our survey with other analogous surveys in the overlapped surface. The columns present: designation of the surveys, overlapped surface with the FBS, total number of objects in the

Table 3. Comparison of the surveys of blue stellar objects

Survey	*Overlapped surface*	*Total number of objects*	*Number of objects discovered in FBS*	*Total Number of FBS objects*	*Number of new objects*
Ton	390	375	31	82	51
PB	92	2068	24	41	17
KUV	430	399	61	103	42
US	48	956	8	16	8
Case	575	809	94	141	47
PG	1965	313	261	585	324

common surface, number of these objects discovered in the FBS too, total number of the FBS objects discovered in the common surface, and number of new objects of the FBS. The designation of the surveys are the following: Ton denotes the Tonanzintla survey (Iriarte and Chavira, 1957; Chavira, 1959), PB – the Palomar–Berger survey (Berger and Fringant, 1977), KUV – the Kiso UV excess objects (Noguchi *et al.*, 1980; Kondo *et al.*, 1984), US – the Usher survey (Usher, 1981), Case – the Case low-dispersion survey (Pesch and Sanduleak, 1983; 1986; 1989) and PG – the Palomar–Green survey (Green *et al.*, 1986).

The total overlapping surface is 2065 square degrees (taking into account also other surveys, not presented in the table). In all 359 objects are identified (60% of all the FBS objects (609) on this surface). This means that on this surface we have discovered 250 more new BSOs. Besides, as was mentioned, 330 new BSOs are discovered in new regions.

It is to be mentioned that some of the other surveys do not have strong criteria and may contain (and it is shown by other investigations) sdA and sdF subdwarfs, main sequence A and F stars, etc. In order to be strict, we shall take into account only the bluest objects (such as PB objects). In this case we can estimate the completeness (ratio of the number of objects discovered to the estimated total number of objects) of the Second part of the FBS, as well as the completeness of all the other surveys up to a definite magnitude (e.g 16.5) and definite colour criteria ($U - B < -0.5$),

This is shown in Table 4, where the completeness is determined, taking into account that the total number of BSOs is estimated by the formula

$$N = \frac{N_1 N_2}{N_{12}},$$

where N_1 and N_2 are the numbers of BSOs in the common surface of the given survey and the FBS, respectively, and N_{12} is the number of the common objects, discovered in both of the surveys. N is the total number of UV excess objects in the common surface of the two surveys. The columns of the table present the following data: designation of the surveys (the same as in Table 3), total number of objects with $m < 16.5$ and $U - B < -0.5$, surface density in degree^{-2}, number of objects discovered in the FBS too, total number of FBS objects with $m < 16.5$ and $U - B < -0.5$, completeness of the given survey with respect to the total number

Table 4. Comparison of the FBS, PG, Case and Kiso surveys for objects with $m < 16.5$ and $U - B < -0.5$

Survey	*Total number of objects*	*Surface density*	*Number of objects discovered in FBS*	*Total Number of FBS objects*	*Completeness of: given survey*	*FB*
KUV	106	0.247	50	94	53	47
Case	133	0.231	79	132	60	59
PG	290	0.148	258	472	55	89

of objects estimated by the above formula, and completeness of the FBS survey in respect to the same total number of objects.

So the completeness of the FBS BSO survey up to 16.5 and for objects with $U - B < -0.5$ is estimated as about $50 - 60\%$. (the PG is not complete up to this magnitude, so the percentage is artificially higher if estimated on the basis of it).

4.2 Distribution of Objects with respect to Galactic Latitude

The surface density of the FBS BSO is 0.275 object per square degree and is nearly identical at all galactic latitudes. One could conclude that the distribution of our objects corresponds to a spherical subsystem. But in our case this conclusion is wrong because our sample does not consist of objects of the same nature. The presence of various types of objects demands that we carry out an investigation of them separately. But the problem is that we do not know which object is of what kind.

In Paper 4 we have shown that quasars make up 40% of N-type objects, while 90% of B-type objects are subdwarfs and white dwarfs. White dwarfs often display absorption features on low-dispersion spectra and are classified mainly as B1a, B2a or B3a. Conditionally we can call N-objects quasars; B-objects with absorption, white dwarfs; and B-objects without absorption, subdwarfs. Now we can examine the galactic distribution of each group separately. The dependence of the surface density of B- and N-type objects of our survey on Galactic latitude is shown in Figure 1. It contains data for all 1103 objects selected up to now.

Evidently, the density of B-objects decreases with the Galactic latitude. This is natural for galactic stars (which are mainly subdwarfs and white dwarfs in our sample), whereas the density of N-type objects increases. This fact confirms the presence of a significant percentage of extragalactic objects among them.

Thus, without having the spectral classes of all FBS objects, we studied their nature statistically.

4.3 Subsamples of Separate Types of Objects

The difference of the distribution of the Galactic and extragalactic objects by their Galactic latitude is not all the information which can be obtained from the preliminary types. On the basis of the spectral classes of the 264 rediscovered known

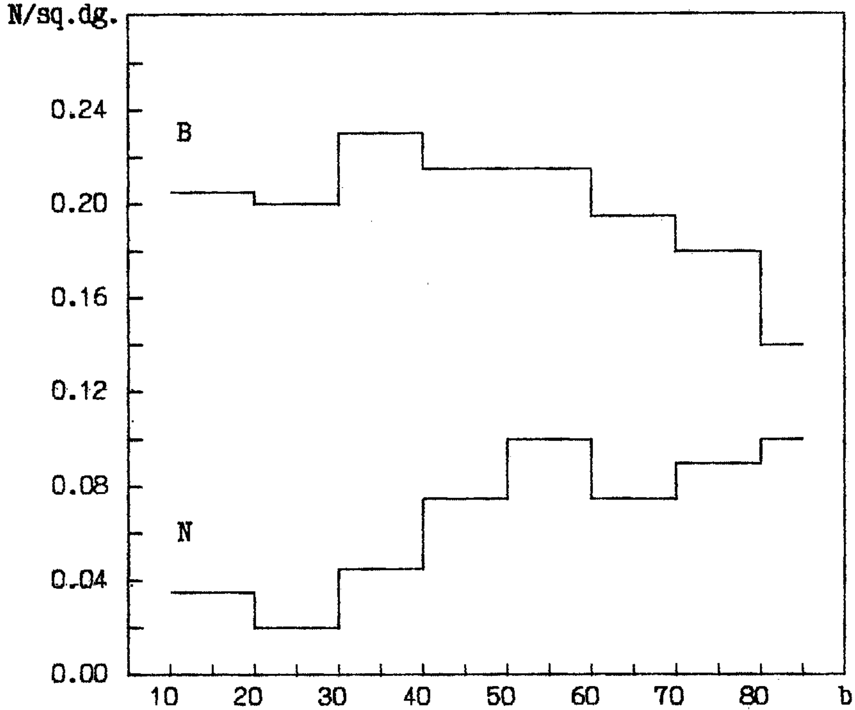

Figure 1 Dependence of the surface density of B- and N-type blue stellar objects on galactic latitude.

objects of other surveys and our spectral observations for 396 FBS objects (in all for 660 objects) we have compared the spectral classes with the preliminary types of the low-dispersion spectra. Comparison shows that each type of object has low-dispersion spectra mainly of definite types. For example, quasars include 35% percent of N-type objects and only 2% of B-type ones. It means that one must search quasars among the N-type, especially N1 type (45% of them are QSOs).

On the contrary, white dwarfs make up 77% of B objects with absorption features and 34% of B objects without the absorption features (it is difficult to distinguish absorption lines for many faint WDs on low-dispersion spectra). So one must search white dwarfs among the B type, especially among the B type spectra with absorption lines (Ba).

Half of the B-type without absorption are subdwarfs. At present we can say about PNN, CV and Sy only that they show emission lines on low-dispersion spectra and one must search them among any type of the preliminary classification (B1, B2, B3, N1, N2, N3) with the sign 'e'. Because of the low number of these objects, as well as HBBs and binaries, they cannot be studied enough.

So subsamples of QSO, white dwarf and subdwarf candidates can be made up on the basis of the low-dispersion spectra types. The main idea of making such subsamples is to select candidates for the most interesting types of objects for further investigations.

We can estimate the expected number of objects of different types among the new FBS objects, based on their preliminary types. Together with the known objects the whole sample will contain about 540 hot subdwarfs, 270 white dwarfs, 80 main sequence and HBB stars, 80 extragalactic objects, and 35 cataclysmic variables.

5 CONCLUDING REMARKS

The results of the fulfilled part of the FBS BSO survey confirm the importance of its continuation and termination by obtaining a complete sample of such objects on a large surface of 17 000 square degrees. By means of the worked out criteria of the recognition of QSOs and white dwarfs on the base of the analysis of low-dispersion spectra it is expected to increase the efficiency of their discovery.

With the continuation of the survey, a transition to automatic methods will be made. Input of the FBS plates by scanner or their full record by PDS or another scanning machine will allow us to select the objects automatically according to worked out criteria. Nevertheless, the selected objects are to be scanned also by eye in order to match the automatic selection with the previous eye selection. All the parameters of the objects will be determined automatically. The selected spectra will be recorded by the PDS machine and classified by worked out principles.

It is expected to continue the spectral observations on the 6 m and other telescopes (mainly the subsamples of the most interesting objects). The polarimetric observations will also be continued for the confirmation of the polarization of the five objects, the study of the variability of their polarization and the discovery of new objects with polarization. It is desirable also to study the space distribution of white dwarfs and subdwarfs with the goal of estimation of their Galactic altitude (mean distance from the Galactic plane) and Galactic subsystem.

With the termination of the survey a complete catalogue of BSOs will be published, containing all the data on more than 4500 selected and investigated objects.

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