АСТРОФИЗИКА

ТОМ 45 ФЕВРАЛЬ, 2002 ВЫПУСК 1

УДК: 524.337

SEARCH FOR NEW INTERESTING OBJECTS IN THE SECOND PART OF THE FBS

A.M.MICKAELIAN[1], H.V.ABRAHAMIAN[1], J.GUIBERT[2], R.CHESNEL[2]

Received 11 May 2001
Accepted 23 November 2001

We present the results of study of the FBS blue stellar objects with a goal of discovery of new interesting objects. 47 FBS objects have been observed with the Byurakan Observatory 2.6m telescope in 1987-1991 and scanned with the MAMA scanning machine at Observatoire de Paris in 1997-1999. 5 QSOs/Syls, 4 emission-line stars, 5 white dwarfs, and a number of continuous spectra objects (possible BL Lacs and DC white dwarfs) have been revealed.

1. *Introduction*. The First Byurakan Survey (FBS) [1] provides numerous objects for follow-up study and discovery of new QSOs and other interesting objects. The second part of this survey [2-4] revealed a few dozens of new candidate QSOs, which have to be studied in detail to understand their real nature. On the other hand, because of the low signal-to-noise and spectral resolution many objects display continuous spectra even after photographic spectral follow-up observations; these are candidates BL Lac objects (BLLs), DC white dwarfs, etc. To study these objects and understand their physical nature one needs high-contrast investigation of the obtained photographic spectra and new CCD observations. One of the most interesting subsamples in the FBS are bright QSOs.

The surface density of bright QSOs is still poorly known. The BQS sample [5] appeared to be ~50% complete, as shown in [6]. A new, more complete sample of QSOs brighter than 16.1 V magnitude has been constructed in that work. Our spectroscopic observations revealed several new objects. However, there may be a few new bright QSOs in the studied area and the sample may be complemented.

2. *Observations*. A spectral study of the FBS blue stellar objects has been started [7] in order to classify them and investigate the more interesting ones in detail. More than 400 photographic spectra of the FBS blue stellar objects have been obtained. A rough classification has been made for all these spectra [8]. However, the nature of a number of them remained unclear, as the spectra have low contrast and many emission and/or absorption lines are unnoticeable.

The observations have been carried out from August 1987 to October 1991

at the Cassegrain focus of the Byurakan Observatory 2.6m telescope using the UAGS spectrograph with a three-stage UMK-91V image converter tube [9]. A grating with a dispersion of 101 A/mm was used at an angle of 33 degree to obtain the blue part of the spectrum. The observations have been done in the spectral range λλ 3300-6100 A. The spectra were photographed,using Eastman Kodak IIa-O and 103a-O films. The spectral resolution was 3-4 A.

During our observations the seeing was 1-3 arcsec and the limiting magnitude varied over the range 16^m-$17^m.5$. The longest exposures were 2 hours. All objects were observed within $z < 20°$, and corrections were unnecessary, since they were small.

3. *Scanning*. For scanning of the 2.6-m photographic spectra, the Byurakan Observatory PDS machine was first used [7]. However, a number of our spectra have rather low signal-to-noise ratio (S/N) and the PDS could not give the needed photometric accuracy for their analysis. To understand the nature of the low-contrast photographic spectra for further observations with CCDs, we have selected 47 spectra being mainly continuous for scanning with the MAMA scanning machine[1] at Observatoire de Paris. The main aim was to reveal new QSOs, BLLs, cataclysmic variables, etc. The high photometric accuracy of MAMA would resolve the low-contrast spectral lines of these objects.

The dynamics of the MAMA machine is 3 densities and the positional accuracy close to 1 mm. Photographic densities are coded on 12 bits (i.e. 4096 linear levels) [10].

The spectra were scanned with a pixel size of 10μm x 10μm, in the form of 2,000 adjacent lines covering the range λλ 3450-5450 A. Each line, perpendicular to the dispersion, was 1024 pixels (i.e. 10.24 mm) long, and one pixel (i.e. 10 mm) wide (which corresponds to a wavelength step of 1A).

4. *Reduction*. The reduction has been carried out under MIDAS using the standard reduction procedure for astronomical spectra: extraction of the spectrum, wavelength calibration, flux calibration. Feige 25 ($12^m.5$), BD+28°4211 ($9^m.7$), and Feige 34 ($10^m.4$) have been observed as standard stars. The accuracy of the conversion to wavelengths is better than 0.5 A. The S/N is about 10:1 for the good spectra and drops down to 2:1 for the poor ones. The error in determining the full width of the lines at half maximum (FWHM) and the full width of the lines at the zero-intensity level, i.e. at the level of the continuous spectrum (FW0I) ranged up to 30%, which reflects the impossibility (in the majority of cases) of securing an accurate continuous spectrum.

Note that at the limits of the spectral range ($\lambda < 3600$ A and $\lambda > 5400$ A) data reduction was not always perfectly done, as a result of which these parts

[1] *MAMA (Machine Automatique a Mesurer pour l'Astronomie, http://dsmama.obspm.fr) is developed and operated by INSU/CNRS and Observatoire de Paris*

of the spectra were almost not taken into account for classification purposes. The range $\lambda\lambda$ 3800-5200 A was mostly used. Our aim was to obtain the real spectral energy distribution (SED) and to find any spectral lines allowing the separation of stars from possible extragalactic objects, and to select good candidates for further CCD observations.

5. *Results*. Table 1 gives the list of objects selected for search of QSOs and BL Lacs with the observational data and classification. The columns are as follows: 1 - designations of the objects, 2 - FBS numbers, 3 - *V* magnitudes determined from the POSS charts [11], 4 - approximate spectral type, determined from the low-dispersion spectra, 5 - journal number of the 2.6m spectrum, 6 - date of observation, 7 - exposure time in minutes, 8 - spectral

Table 1

LIST OF THE FBS BLUE STELLAR OBJECTS OBSERVED AT 2.6-m TELESCOPE AND SCANNED WITH MAMA

Object	FBS No	*V* magn.	Spectral type	2.6-m No	Date of Observation	Exp. (min)	Class
1	2	3	4	5	6	7	8
0019+402	1	16.0	Cont:	2199	15-09-1988	80	sd:
0028+435	208	14.5	QSO:	2176	13-09-1988	40	sd:/cont?
0047+347	442	16.5	QSO:	4202	15-09-1991	90	?
0051+418	215	16.5	Cont	2184	14-09-1988	35	sd:
0058+431	216	15.0	Cont	2212	16-09-1988	15	Sd
0125+351	454	16.3	Cont:	4197	14-09-1991	120	?
0125+386	13	15.0	WD:	1342	02-09-1987	60	Sd
				1606	26-11-1987	60	sd
				1724	16-12-1987	20	em:
0127+408	14	17.0	Cont	1595	25-11-1987	60	?
0156+439	224	14.0		1607	26-11-1987	50	sd
				1725	16-12-1987	40	DA:
			QSO	2234	18-09-1988	50	Sd
0212+385	25	14.5	cont	1447	15-09-1987	15	DC:
0217+343	461	15.4	QSO:	4208	17-09-1991	90	?
0228+447	227	15.5	cont	2203	15-09-1988	60	sd:
0255+379	29	14.5	cont	1448	15-09-1987	20	sd
0706+407	41	13.5	QSO:	1598	25-11-1987	15	DA
0732+395	46	16.0	Sy:	1840	15-03-1988	60	QSO/Sy
0743+337	484	17.0	QSO:	4095	09-02-1991	90	cont
0848+438	256	15.0	cont	4069	08-02-1991	90	sd
0850+394	56	17.0	sd:	1835	14-03-1988	60	sd
0906+368	493	15.8	cont	3383	24-02-1990	90	cont:
0931+437	260	16.0	cont	2671	26-02-1989	60	QSO
0935+396	63	17.0	CV:	4107	10-02-1991	100	cont
0938+375	65	17.0	cont	1836	14-03-1988	40	sd
0938+447	265	16.0	cont:	2707	05-03-1989	50	sd
0946+362	498	15.5	sd:	4111	14-02-1991	90	em:
1007+417	274	16.0	QSO	2686	02-03-1989	40	QSO
1102+347	510	16.2	cont:	4116	15-03-1991	60	QSO:
1141+407	84	16.5	cont	1852	17-03-1988	20	cont

Table 1 (the end)

1	2	3	4	5	6	7	8
1204+399	86	16.0	cont	4102	09-02-1991	80	sd:
1219+353	524	16.1	cont:	4133	19-04-1991	70	cont:/em:
1229+383	90	17.0	cont	1839	14-03-1988	90	nonstellar:
1249+433	315	15.5	cont	3410	27-02-1990	50	nonstellar:
1339+421	326	17.0	cont	3411	27-02-1990	90	cont
1352+386	102	17.5	QSO	1829	26-02-1988	80	
				1845	15-03-1988	60	cont/em:
1402+437a	332	15.0	QSO	2718	05-03-1989	35	QSO
1640+362	580	13.5	cont	4139	03-07-1991	30	DA:
1648+407	147	16.5	cont	1871	20-05-1988	80	DA:
1712+410	935	15.0	gal	1470	19-09-1987	70	sd:
1724+372	600	14.2	cont	3464	27-06-1990	30	sd
1743+441	385	16.0	cont	2854	27-06-1989	15	cont:
				2855	27-06-1989	35	cont
1744+421	386	13.0	cont	2181	14-09-1988	90	cont:
1755+394	164	16.0	cont	1278	20-08-1987	40	cont:
1756+442	389	13.5	cont	2004	19-08-1988	50	sd
1812+425	393	13.5	cont	2010	20-08-1988	40	sd
1816+349	610	15.7	cont	4163	13-08-1991	80	?
				4164	13-08-1991	40	?
				4191	14-09-1991	90	?
2248+447	411	16.0	WD:	1998	16-08-1988	30	CV:
2302+428	416	16.0	cont	2025	21-08-1988	50	sd:
2340+423	427	15.0	cont	2197	15-09-1988	20	sd:
				3149	11-04-1989	40	sd

Comments to some objects of Table 1:

FBS 0228+447 - the object was observed also at the Byurakan Observatory 2.6-m telescope with ByuFOSC focal reducer on 25.11.1998 [2].

FBS 0732+395 - observed also at the Observatoire de Haute-Provence 1.93m telescope with the CARELEC spectrograph on 28.10.1997 [13]. The spectrum shows a typical emission lines of Syl at $z = 0.1186$. The 2.6-m telescope spectrum revealed the H_γ line, and the 1.93m spectrum, the H_β and [OIII] λλ 4959/5007 lines with the same redshift.

FBS 0931+437 - PG 0931+437 [12] = US 737 [14]. The object is present in the Catalog of Quasars and Active Galaxies: a QSO with $z = 0.456$ [15].

FBS 1007+417 - KUV 10074+4147 [16] = 4C 41.21 [17]. A QSO with $z = 0.613$ [15].

FBS 1102+347 - Ton 1329 [18] = CSO 314 [19]. A QSO with $z = 0.510$ [15].

FBS 1249+433 - 4C 43.25 [17]. The spectrum shows evidence of a nonstellar object, probably Sy galaxy. Absent in [15].

FBS 1402+437a - CSO 409 [19] = PB 1309 [20] = IRAS 14026+4341 [21]. Present in [15] and the catalog of Seyfert galaxies [22]. A QSO with $z = 0.320$.

classification. It should be noted that during 1990-1991, the observations had been carried out on old Kodak films with decreased sensitivity and the exposures were in average longer for objects of the same magnitudes.

The spectra have been scanned with MAMA on 10.11.1997 (2 spectra), 7.01.1999 (48 spectra) and 11.02.1999 (5 spectra). As the spectra are mainly of low S/N, the final classification gives mostly the rough classes (nature of

objects): sd (subdwarfs of sdB or sdA subtypes), DA, DC, CV, em (emission lines are revealed, probable CVs), QSO, Sy, cont, nonstellar. The latter type is for FBS 1229+383 and FBS 1249+433, which show nonstellar SEDs, however without any spectral lines. 7 spectra (5 objects) are of rather poor quality to be classified.

The objects have been classified according to generally accepted criteria. As mentioned in [7], on account of instrumental and atmospheric effects there are some differences between our spectra and those of the Palomar Green Survey [12]. Most of the spectra had been classified as continuous. These spectra do not exhibit spectral lines more than 10% above the continuum level; the SED allows us to classify them either as DC white dwarfs, or candidate QSOs and BLLs. The reliability of classification for individual objects also varies, depending on the S/N ratio for the given spectrum.

Fig.1 gives the spectra of FBS 0732+395, a newly revealed QSO/Sy, and the continuous spectrum of FBS 1744+421.

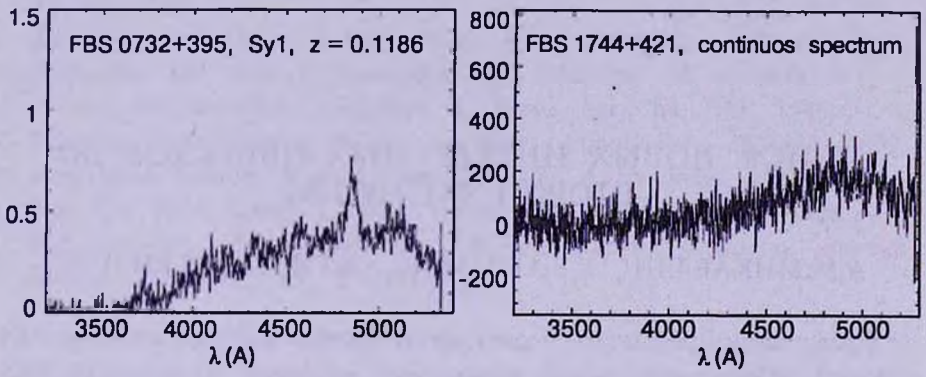

Fig.1. The 2.6-m spectrum of FBS 0732+395, a newly revealed QSO/Sy, and FBS 1744+421, an object with continuous spectrum.

6. *Conclusions*. We have obtained with the 2.6-m telescope and scanned with the MAMA machine 47 photographic spectra to find out new QSOs, BLLs, as well as cataclysmic variables and other types of objects with low contrast of emission lines. 5 QSOs have been revealed, however 4 were known already. FBS 0732+395 is a new bright QSO/Sy which was observed also in 1997 at the Observatoire de Haute-Provence 1.93-m telescope [13]. However, the 2.6-m photographic spectrum complements our CCD observations to the shorter wavelengths range. The spectrum shows a typical emission lines of Sy1. In the 2.6-m spectrum, Hγ is observed at $\lambda = 4855$ A, corresponding to $z = 0.1186$, the same as from the CCD observations. Another possible new QSO or BLL is FBS 1249+433. It is a radio source and its FBS spectrum shows a UV excess. The other types are distributed as follows: DA - 4, DC - 1, CV - 1, em and em/cont - 3, nonstellar - 2, cont and sd/cont - 9, sd - 17, and unknown - 5. The continuous spectra objects are candidates for DC white dwarfs, QSOs or

BLLs. The revealed white dwarfs and cataclysmic variables are interesting as well.

We plan to carry out new CCD observations at the Byurakan Observatory 2.6-m telescope for the continuous spectrum objects to make more accurate classification. Additionally, the observations will give a new wavelength range for these spectra (as in the case of the FBS 0732+395) and combination of the data may reveal the nature of these objects. The emission-line stars are interesting targets for further studies as well.

The authors are grateful to P.Veron and M.P.Veron-Cetty (Observatoire de Haute-Provence, France) for useful discussions. This research has made use of the NASA/IPAC Extragalactic Database (NED) which is operated by the Jet Propulsion Laboratory, Caltech, under contract with the National Aeronautics and Space Administration.

[1] V.A. Ambartsumian Byurakan Astrophysical Observatory, Armenia
[2] Observatoire de Paris, CNRS, France

ПОИСК НОВЫХ ИНТЕРЕСНЫХ ОБЪЕКТОВ ВО ВТОРОЙ ЧАСТИ FBS

А.М.МИКАЕЛЯН[1], Г.В.АБРАМЯН[1], Ж.ГИБЕР[2], Р.ШЕНЕЛ[2]

Представлены результаты исследования голубых звездных объектов FBS с целью обнаружения новых интересных объектов. 47 объектов FBS наблюдались на 2.6-м телескопе Бюраканской обсерватории в 1987-1991гг. и были сканированы на сканирующей машине Парижской обсерватории MAMA в 1997-1999гг. Выявлено 5 квазаров и Сейфертов, 4 эмиссионных звезды, 5 белых карликов и ряд объектов с континуальным спектром (возможных объектов BL Lac и белых карликов DC).

REFERENCES

1. *B.E.Markarian, V.A.Lipovetski, J.A.Stepanian, L.K.Erastova, A.I.Shapovalova*, Commun. Special Astrophys. Observ., **62**, 5, 1989.
2. *H.V.Abrahamian, V.A.Lipovetski, J.A.Stepanian*, Astrophysics, **32**, 14, 1990.
3. *H.V.Abrahamian, A.M.Mickaelian*, Astrophysics, **39**, 315, 1996.
4. *A.M.Mickaelian*, Astron. Astrophys. Transactions, **18**, 557, 2000.

5. *M.Schmidt*, *R.F.Green*, Astrophys. J., **269**, 352, 1983.
6. *A.M.Mickaelian*, *A.C.Gonçalves*, *M.P.Véron-Cetty*, *P.Véron*, Astrophysics, **44**, 14, 2001.
7. *H.V.Abrahamian*, *A.M.Mickaelian*, Astrophysics, **35**, 363, 1991.
8. *A.M.Mickaelian*, Discovery and Investigation of the FBS Blue Stellar Objects, Ph.D. thesis, Byurakan, 1994, p.384.
9. *G.I.Bryukhnevich*, *L.V.Gyavgyanen*, *E.I.Zak et al.*, Astrofizika, **21**, 379, 1984.
10. *J.Berger*, *J.-P.Cordoni*, *A.M.Fringant*, *J.Guibert*, *O.Moreau*, *H.Reboul*, *C.Vanderriest*, Astron. Astrophys., Suppl. Ser. **87**, 389, 1991.
11. *I.R.King*, *M.J.Raff*, Publ. Astron. Soc. Pacif., **89**, 120, 1977.
12. *R.F.Green*, *M.Schmidt*, *J.Liebert*, Astrophys. J. Suppl. Ser., **61**, 305, 1986.
13. *A.M.Mickaelian*, *A.C.Goncalves*, *M.P.Veron-Cetty*, *P.Veron*, Astrophysics, **42**, 1, 1999.
14. *P.D.Usher*, Astrophys. J. Suppl. Ser., **46**, 117, 1981.
15. *M.P.Veron-Cetty*, *P.Veron*, ESO Scientific Report No.19, 2000.
16. *T.Noguchi*, *H.Maehara*, *M.Kondo*, Ann. Tokyo Astron. Obs., 2nd Ser., **18**, 55, 1980.
17. *J.F.R.Gower*, *P.F.Scott*, *D.Wills*, Mem. Roy. Astron. Soc., **71**, 49, 1967.
18. *E.Chavira*, Bol. Observ. Tonantzintla y Tacubaya, **18**, 3, 1959.
19. *P.Pesch*, *N.Sanduleak*, Astrophys. J. Suppl. Ser., **60**, 543, 1986.
20. *J.Berger*, *A.-M.Fringant*, Astron. Astrophys. Suppl. Ser., **28**, 123, 1977.
21. Joint IRAS Science Working Group. Infrared Astronomical Satellite Catalogs, The Point Source Catalog, Version 2.0, NASA RP-1190, 1988.
22. *V.A.Lipovetski*, *S.N.Neizvestnyi*, *O.M.Neizvestnaya*, Commun. Special Astrophys. Observ., **55**, 5, 1987.