The Digitized First Byurakan Survey on ArmCluster

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Abstract

The Digitized First Byurakan Survey (DFBS) is the digitized version of the famous Markarian Survey, also known as the First Byurakan Survey (FBS). It is the largest low dispersion spectroscopic survey of the sky covering 17,000 square degrees at galactic latitudes |b|>15. DFBS provides the astronomical community with images and extracted spectra for all objects present in the FBS plates. Some 1800 plates have been scanned and stored and programs were developed to compute the astrometric solution, extract the spectra, and apply wavelength and photometric calibration for the objects. The DFBS database and catalog have been assembled containing data for nearly 20,000,000 objects. A classification scheme for the DFBS spectra is being developed. DFBS has been installed on dedicated servers at "La Sapienza" Università di Roma (Italy) and at present on the ArmCluster at the Institute of Informatics and Automation Problems (Armenia). A work is active on making the DFBS available through the Virtual Observatory standards and access to spectroscopic data. From the point of view of VO, the DFBS is a new database needing both image and spectra access tools and an interchange between these two standards. Algorithms, tools, and facilities needed for efficient use of the DFBS are discussed, in particular the spectra extraction, visualization, and analysis tools. New scientific projects as well as existing surveys will benefit by the digitized images and the ready-to-use extracted spectra which will allow an efficient computer-based analysis of the dataset. The Armenian Virtual Observatory (ArVO) is based on the DFBS database and other large-area surveys and catalogue data and is a part of the International Virtual Observatory Alliance (IVOA).

Keywords: Astronomical Surveys, Computer science, Information technology, Virtual Observatories.

The Digitized First Byurakan Survey (DFBS). The First Byurakan Survey (FBS) has been carried out by B.E. Markarian, V.A. Lipovetski and J.A. Stepanian in 1965-1980 on the Byurakan Observatory 102/132/213cm (40″/52″/84″) Schmidt telescope with 1.5° prism (Markarian et al. 1989). 2050 Kodak IIAF, IIaF, IIF, and 103aF photographic plates in 1133 fields (4°×4° each, the size being 16cm×16cm) have been taken. FBS covers 17,000 deg^2 of all the Northern Sky and part of the Southern Sky (δ>-15°) at high galactic latitudes (|b|>15°) and is the largest spectroscopic survey in the world. In some regions, it even goes down up to δ=-19° and |b|=10°. The limiting magnitude on different plates changes in the range of 16.5^m-19.5^m in V, however for the majority it is 17.5^m-18^m. The scale is 96.8 ″/mm and the dispersion is 1800 Å/mm near Hγ and 2500 Å/mm near Hβ (mean spectral resolution being about 50 Å). Low-dispersion spectra cover the range 3400-6900 Å, and there is a sensitivity gap near 5300 Å, dividing the spectra into red and blue parts. It is possible to compare the red and blue parts of the spectrum (easily separating red and blue objects), follow the spectral energy distribution, notice some emission and absorption lines (such as broad Balmer lines, molecular bands, He, N_1+N_2 lines, broad emission lines of QSOs and Seyferts, etc.), thus making up some understanding about the nature of the objects. The FBS is made up of zones (strips), each covering 4° in declination and all right ascensions except the Galactic plane regions. In all there are 28 zones, which are named by their central declination (ex. zone +27° covers +25°<δ<+29°, zone +63° has +61°<δ<+65°, etc). The zones and the neighboring plates in right ascension overlap about 0.1 degree, as the exact size of a plate is 4.1°×4.1°, thus making the whole area

complete. Each FBS plate contains low-dispersion spectra of some 15,000-20,000 objects, and there are some 20,000,000 objects in the whole survey having some 40,000,000 spectra. New surveys for blue stellar objects (BSOs) and late-type stars were carried out in 1990s using the FBS plates and thousands of new objects were discovered thus proving the value of this observational material. Moreover, such spectroscopic data provide the best opportunity for making optical identifications of X-ray, IR, and radio sources and a large project of identifications of IRAS point sources was accomplished as well.

The DFBS (Mickaelian et al. 2005, 2006, 2007) is the digitized version of the Markarian survey or the FBS. It was accomplished in frame of collaboration between the Byurakan Astrophysical Observatory (Armenia), Cornell University (USA), and "La Sapienza" Università di Roma (Italy). The project was carried out in 2001-2006 and consisted of the following tasks:

- scanning of the plates
- archiving on DVDs and HDDs
- astrometric plate solution
- extraction of low-dispersion spectra
- wavelength calibration
- density and flux calibration
- multiband (UBVR and O/E) photometry
- making up template spectra
- numerical classification
- creation of the DFBS catalog and database
- creation of the web page and user interface

1874 DFBS plates in 1139 fields were digitized and stored on DVDs and HDDs using EPSON Expression 1680 Pro scanner with 1600 dpi resolution and 16μ pixel size (1.542″). Astrometric solution was applied for all plates and gave better than 1″ accuracy. A dedicated extraction and reduction software *bSpec* was written by one of the authors (GC) and was applied to all plates resulting on a catalog of all DFBS objects with their positional and photometric data and preliminary classification.

The DFBS web portal. All spectra extracted with *bSpec* were assembled in a database which contains for each object the one-dimensional spectrum plus additional information including an identification label in the coordinates *hhmmss+ddmmss*, the coordinates RA, DEC at equinox 2000, the position of the red head in plate in pixels, B and R magnitudes from the extracted spectra obtained as described above, the local background value, and a quality flag computed on the basis of the brightness of the object and the possible blending with other stars (before the spectral classification, it will serve as a rough one).

The DFBS database containing the extracted spectra was first stored on a dedicated PC at the "La Sapienza" University in Rome and can be accessed through the web interface *http://byurakan.phys.uniroma1.it/*. A web page and user interface allow access to the DFBS database for the astronomical community. Beside the Rome University, the DFBS webpage is open in Armenia (*http://aras.am/dfbs.html*). The list of all FBS plates is also available in the Wide-Field Plate Database (WFPDB) at *http://draco.skyarchive.org/search test/*, as well as at CDS (catalogue No. VI/116) at *http://cdsweb.ustrasbg.fr/viz-bin/Cat?VI/116* (Mickaelian et al. 2005).

The DFBS database (v1.0) can be queried online at the Rome webpage. Several palettes give general information on the FBS and DFBS, the main characteristics of the observational material, and the main results obtained from the plates. In particular, the keys sky – coverage and platelist contain detailed information on individual plates, such as type of emulsion, observation date, observer, and accurate central coordinates from the plate center computed after application of the astrometric solution.

It is possible to retrieve a list of DFBS plates with given limitations on observing dates, sky area, emulsion types, and observers. The digitization and reduction procedures are also described in detail, including the scanning, astrometric solution, extraction, density and wavelength calibration.

The user interface has a menu type structure. In the explore menu portion, the images are visualized and a spectroscopic DFBS plate can be compared with the corresponding direct plates from the Digital Sky Survey (DSS1 and DSS2). There is an easy access to the database and to portions of the digitized plates. The extracted spectra of individual objects can also be displayed and stored to be downloaded later. However, users cannot run the bSpec software on a remote machine to create a personal database, but they may download portions of the plates in FITS format and perform their own analysis of the images.

The DFBS on the ArmCluster. Using the experience of the DFBS web portal at the University of Rome, we have created a copy on the ArmCluster (Astsatryan et al. 2004a, 2004b). The same database was installed online from the University of Rome. The user interface presently allows the following operations to the guest user:

a) Sky coverage: in a RA, DEC rectangular interactive sky map shows the position on the sky of each plate; plates already processed are color-coded. Basic data about each plate are available by clicking on the corresponding plate.

b) Plate list: the list of the plates is shown; it can be sorted by several parameters (e.g. plate numbers, RA or DEC, emulsion types, observers) and downloaded. Each plate number is also clickable, so that it is possible to check all data concerning any plate.

c) Explore: allows the display of a portion of plate around a given central RA, DEC position, comparison with the same portion of the DSS1 or DSS2 (blue, red, or IR), interactive selection of one or more spectra present in the database, their collection (saving in a list) and downloading (ASCII files) to the guest computer. This option is useful for studies of definite fields.

d) Get image: allows users to select a portion (presently up to 1024×1024 pixels) of a plate in FITS format and all the spectra of this portion present in the database for downloading (spectra are ASCII files), as well as downloading of the whole selected field in FITS format. This option is useful for downloading portions of DFBS.

e) Get spectra: allows downloading all the spectra in the database in a needed field (within a given distance from a selected central position); the query may be either interactive, with the RA, DEC position, or made by uploading an ASCII file containing one or more RA, DEC positions (one per line). Objects may be selected by B, R or B-R values. This option displays also an interactive ("clickable") table of the selected objects, which allows looking at each object individually (both 1D and 2D spectra) for a quick evaluation of the data.

Future Developments. The DFBS project has achieved significant success with its large datasets provided to the astronomical community. At present the DFBS presents the main data in frame of the Armenian Virtual Observatory (ArVO). VO standards SIA (simple image access) and SSA (simple spectra access) are being developed for the DFBS images and spectra. At present one of the important points is the classification of the DFBS spectra, which will give understanding on the nature of each object (QSOs, white dwarfs, cataclysmic variables, planetary nebulae, carbon stars, etc., as well as the spectral type of each star).

From the point of view of VO, the DFBS is a new database needing both image and spectra access tools and an interchange between these two standards. Algorithms, tools, and facilities needed for efficient use of the DFBS are being developed too, in particular a better spectra extraction, visualization, and analysis tool. The DFBS will be accessible through all VO tools, such as ALADIN, VOSpec, VOSED, etc. New scientific projects as well as existing surveys will benefit by the digitized images and the ready-to-use extracted spectra which will allow an efficient computer-based analysis of the dataset.

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