

# Revised and Updated Catalogue of the First Byurakan Survey Late-Type Stars. 2nd Edition

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## Abstract

Eighteen lists of late-type stars (LTSs) have been published between 1990 and 2016. These LTSs have been found in the low-dispersion spectroscopic plates of the First Byurakan Survey (FBS). The systematic search and selection was carried out on a surface  $\sim 16000 \text{ deg}^2$  on almost the whole area of the FBS. As a result, “Revised And Updated Catalogue Of The First Byurakan Survey Of Late-Type Stars” was generated (LTSs, first version). Since 2007, all FBS low-resolution spectral plates are digitized, and Digitized First Byurakan Survey (DFBS) database and second catalog of objects has been assembled. All DFBS spectral plates are analysed with the help of standard image analysis softwares (FITSView and SAO Image ds9) and numerous of comparatively faint LTSs were discovered. We present the 2nd version of the FBS catalogue of LTSs with new data. We have made cross-correlation with the Digitized First Byurakan Survey (DFBS), the United State Naval Observatory-B1.0 Catalogue, the Two Micron All-Sky Survey (2MASS), the Wide-Field Infrared Survey Explorer (new version-ALLWISE) catalogue, the Infrared Astronomical Satellite Point Source Catalogue/Faint Source Catalogue, the AKARI catalogue, the ROSAT Bright Source Catalogue/Faint Source Catalogue, the General Catalogue of Variable Stars, Sloan Digital Sky Survey (SDSS) photometric catalogue. We have added updated SIMBAD data for the objects. For numerous of the new detected objects we present accurate Digitized Sky Survey 2 positions, approximate spectral subtypes refined from the DFBS low-dispersion spectra, luminosity classes estimated from 2MASS colours, and available proper motions for 1471 FBS LTSs. 2nd Version of the Revised and Updated Catalogue lists a large number of completely new objects, which promise to extend very significantly the census of M giants, faint N-type Asymptotic Giant Branch (AGB) carbon stars, CH-type carbon giants at high Galactic latitudes, also M dwarfs in the vicinity of the Sun up to 16.0-17.0 mag. in visual. We present also some important data from the Gaia DR2 data base for FBS LTSs. Some supplementary spectra obtained with

the Byurakan Observatory 2.6 m telescope and LAMOST telescope are shown.

**Keywords:** *astronomical data bases: miscellaneous - catalogues - surveys - stars: carbon - stars: late-type.*

## 1. Introduction

The First Byurakan Survey (FBS), known also as the Markarian Survey, was the first systematic objective-prism survey of the extragalactic sky. This survey was conducted by B. E. Markarian, V. A. Lipovetski and J. A. Stepanian from 1965 to 1980. The Photographic plates were obtained using the 1m Schmidt telescope at the Byurakan Astrophysical Observatory (BAO), which was equipped with a  $1.5^\circ$  prism giving a reciprocal dispersion of 1800 Å/mm near  $H_\gamma$  throughout a useful field of  $4^\circ \times 4^\circ$ . The FBS is the largest area low-resolution spectral survey and covers a total of 17 000  $\text{deg}^2$ , segmented in 28 parallel zones of all the Northern sky and part of the Southern sky at high Galactic latitudes by  $\delta > -15^\circ$  and  $|b| > 15^\circ$ . Later, several other projects based on the FBS were conducted, which resulted in the discovery of various important objects, such as FBS blue stellar objects (BSOs) and late-type stars (LTSs) and in the identification of Infrared Astronomical Satellite (IRAS) sources.

We present in this paper the 2nd updated version of the FBS LTSs Catalogue at high Galactic latitudes, which is a comprehensive list of 1471 objects.

## 2. The Second Part of the FBS and Late-Type Stars

The second part of the FBS (which started in 1980s) was devoted to the discovery and study of BSOs (Abrahamian & Mickaelian, 1996, and reference therein). The main goal of the second part of the FBS was the discovery of new bright quasi-stellar objects (QSOs), Seyferts, white dwarfs (WDs), subdwarfs (sds), planetary nebula nucleus (PNNs), cataclysmic variables (CVs), and other interesting objects. The results of the investigations of the new FBS of BSOs are summarized and presented by Mickaelian (2008) in the “Revised and Updated Catalogue of the First Byurakan Survey of Blue Stellar Objects”, which contains data for 1103 objects.

The second part of the FBS includes also selection, listing and investigation of faint LTSs at high Galactic latitudes. The large spectral range of the FBS is also suited to identify cool M-type or carbon (C)-type stars. The visual inspection (with help of the eye-piece, with magnification of  $15\times$ ) was used for selecting slitless spectra showing pronounced absorption bands. C stars can be identified through the presence of the Swan bands of

the  $C_2$  molecule at 4737, 5165, and 5636  $\text{\AA}$  (N-type C stars). Several objects showing the bandhead at 4382 $\text{\AA}$  are early-type C stars (R or CH-type stars). M-type spectra can easily be distinguished because of the titanium oxide (TiO) molecule absorption bands at 4584, 4762, 4954, 5167, 5500, 6200 and 6700 $\text{\AA}$  (the same criteries of selection that used to select the LTSs on objective-prism plates taken with the Burrell Schmidt telescope at Kitt Peak (Stephenson 1986; Sanduleak & Pesch 1988). In practice, the limiting magnitude of the FBS for LTSs is estimated to be 16.0-17.0 in the V-band (Gigoyan et al 2001).

### 3. Optical Spectroscopy and Classification of FBS LTSs

For FBS LTSs a medium-resolution spectrum was obtained on different epochs with the Byurakan Observatory 2.6-m telescope (UAGS, ByuFOSC2 and SCORPIO spectrographs; Abrahamyan & Gigoyan 1993, Abrahamyan, Hambaryan & Gigoyan 1994; Gigoyan, Mickaelian & Mauron 2006). Medium and high-resolution CCD spectra for FBS C stars were also obtained with the Observatory de Haute-Provence (OHP, France) 1.93-m telescope (CARELEC spectrograph; Gigoyan et al., 2001, Mauron 2008). Moderate-resolution CCD spectra for FBS C stars also were obtained at the 1.83-m Cima-Ekar telescope of the Padova Astronomical Observatory (Italy) equipped with the Asiago faint Objects Spectrometer and Camera (AFOSC) and with the 1.52-m Cassini telescope of the Bologna Astronomical Observatory at Loiano (Italy) equipped with the Bologna Faint Objects Spectrometer and Camera (BFOSC; Gigoyan et al., 2008 ). All CCD observations, confirms reliability of our preliminary low-resolution spectral class determinations on the FBS plates.

Figure 1 presents 2.6 m Byurakan Astrophysical Observatory telescope moderate-resolution CCD spectra for some objects.

### 4. LAMOST Spectra

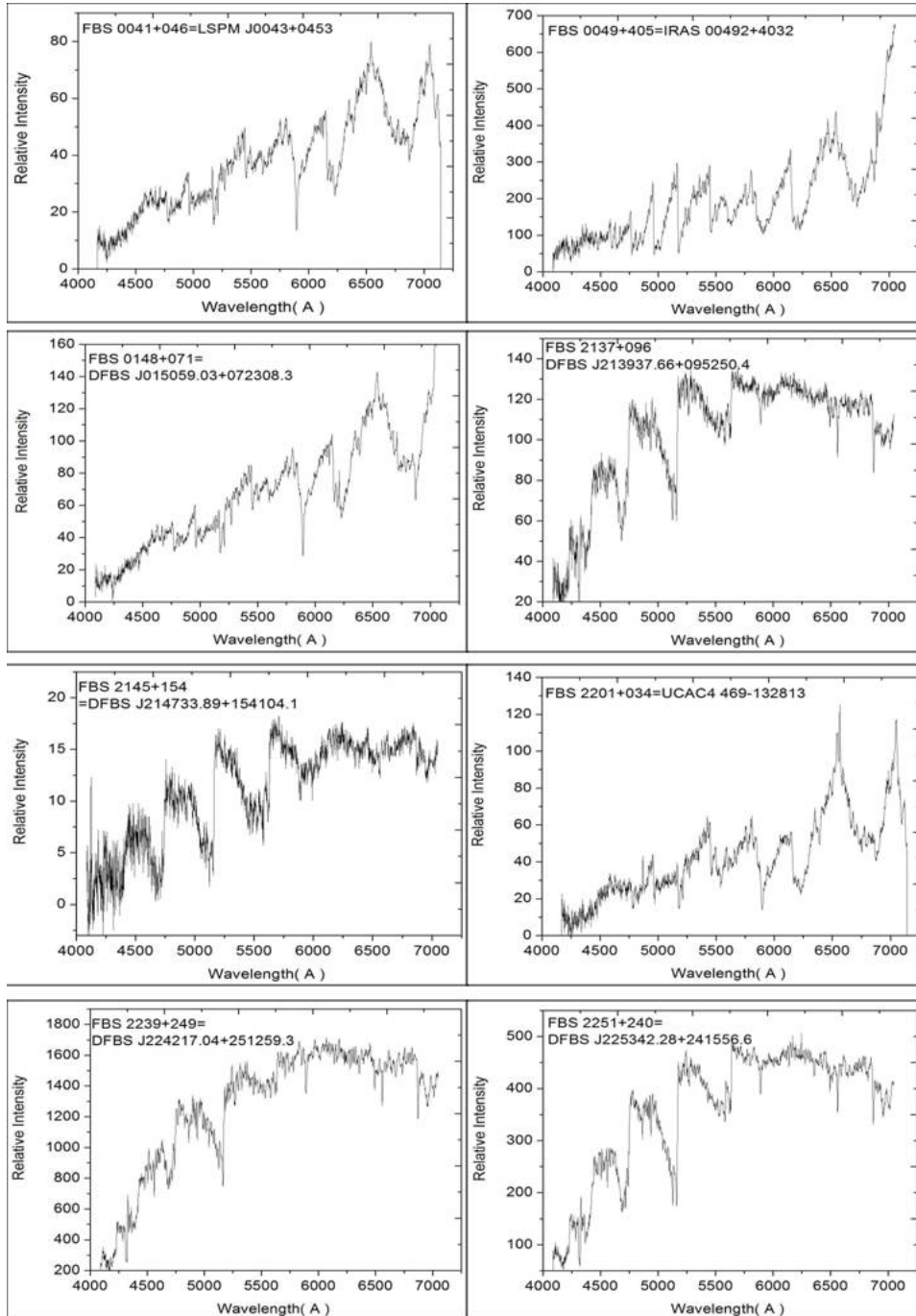
For 179 FBS LTSs moderate-resolution spectra is available in LAMOST (Large Sky Area Multi-Objects Fiber Spectroscopic Telescope) DR2 data base (Luo et al, 2016, CDS VizieR catalog V/149dr2, wavelength coverage 4000-9100 $\text{\AA}$ ).

## 5. Summary

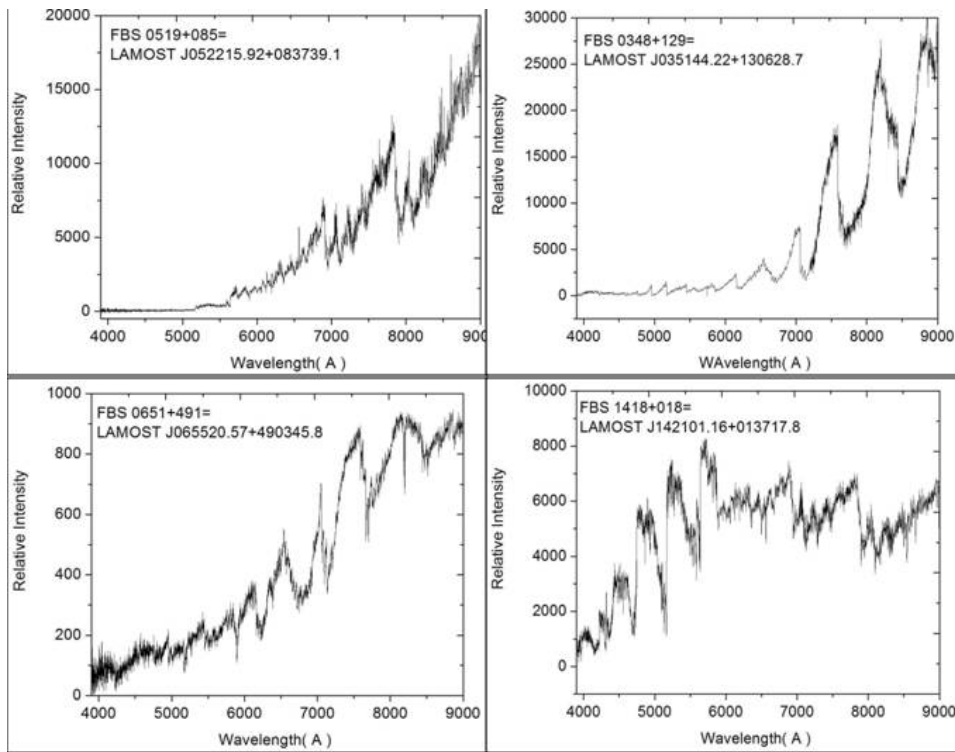
All Digitized First Byurakan Survey (DFBS) spectral plates are analysed with the help of standard image analysis softwares (FITSView and SAO Image ds9) on the base of present of the absorption bands of C<sub>2</sub> and TiO molecule in the low-resolution spectrum of the objects. We revised, updated and generated the new version of the FBS LTSs catalogue. The second version of the catalogue contains main available data for 1471 objects. In revised catalogue we present DSS1/DSS2 accurate positions, USNO-B1.0 catalogue optical photometry and proper motions, WISE IR photometry, et al. for 1471 objects. Among 1471 objects, 127 are carbon stars of the early and late classes. Remaining objects are M giants and dwarfs. Large number of the FBS LTSs are completely new objects, which promise to expand the census of M giants and M dwarfs in the vicinity of the Sun. In combination with new Gaia DR2 data with the existing photometric and spectroscopic data, further studies is needed to clarify the nature of the FBS LTSs, particularly the origin of the high radial velocity M-giants, N-type AGB C stars, and CH-type faint C stars at high Galactic latitudes and in Galactic Halo.

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**Figure 1:** 2.6 m BAO telescope moderate-resolution CCD spectra for some objects.



**Figure 2:** LAMOST moderate-resolution spectra for some sample of FBS LTSs.