THE DIGITIZED FIRST BYURAKAN SURVEY DATABASE LATE-TYPE STARS CANDIDATES. NEW CONFIRMATIONS. II

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Three new carbon C stars was confirmed among the sample of the Late-Type Stars candidates, selected on the Digitized First Byurakan Survey (DFBS) spectral plates. The DFBS is the digitized version of the First Byurakan Survey (FBS, or Markarian survey). The FBS was the first systematic survey of the extragalactic sky. This objective-prism survey was carried out in 1965-1980 by B.E.Markarian and his colleagues using the 1 m Schmidt telescope of the Byurakan Astrophysical Observatory and resulted in discovery of 1517 UV-excess (Markarian) galaxies. FBS spectral plates have been used long period to search and study faint LTS (C-type and M-type stars) at high Galactic latitudes. In this work we present Gaia DR3 photometric data, spectra, light curves, distances, high above/below Galactic plane, radial velocities (RV), and other important physical characteristics from the modern astronomical catalogues for three new confirmed DFBS C stars. The confirmation is based on Gaia DR3 BP/RP low-resolution spectral database. In our previous studies of the DFBS plates, these objects were presented as LTS candidates. One of the new confirmed objects is N-type C star, which is a Mira-type variable. Two remaining objects, are early CH-type giants at high Galactic latitudes. Most probably they present binary systems.

Keywords: *catalogs-stars: carbon stars: surveys: Gaia data*

1. *Introduction*. The First Byurakan Survey (FBS, or Markarian survey), was the first systematic survey of the extragalactic sky. This objective-prism (op) low-resolution (lr) survey was carried out in 1965-1980 by Markarian and collaborators using the 1 m Schmidt telescope of the Byurakan Astrophysical Observatory (BAO, Armenia) and resulted in discovery of 1517 UV-galaxies [1]. FBS spectral plates have been used for a long time to search and study faint Late-Type Stars (LTS, M-type and C (carbon) stars) at high Galactic latitudes [2]. All FBS spectral plates have now been digitized, resulting in the creation of the Digitized First Byurakan Survey (DFBS) database [3]. Its images and spectra are available on the web portal in Trieste (on-line at https://www.ia2-byurakan.oats.inaf.it). All DFBS plates are analyzed with help of analysis softwares FITSView and SAOImage ds9. A Second Version of the "Revised and Updated Catalogue of the First Byurakan Survey of Late-Type Stars", containing data for 1471 M and C stars was generated [4] (CDS VizieR Catalogue J/MNRAS/489/2030/catv2). This

visualization allows to detect very red and faint C and M stars candidates close to the detection limit in each plate [5]. Candidates of N-type (Asymptotic Giant Branch-AGB) C stars and M-type giants, for which very short spectra is visible on the DFBS plate, no C_2 and TiO molecule absorption bands are detectable. Moderate-resolution slit spectroscopy was carried out for thirteen candidates, confirming the C-rich nature of them [6]. Several of such candidates could be M dwarfs also [5].

Meanwhile, a huge amount of such faint candidates detected on the DFBS plates, remained to be confirmation of spectral types [5]. To classify LTS candidates, we use Gaia DR3 BP/RP lr spectroscopic database, which allows us to confirm the spectral types for candidates very easily. In our previous paper (first in this series [7]), we present some very important data for newly confirmed CH-type, N-type stars, and M giants. We also report on a large number of new M dwarfs confirmed in the Gaia DR3 database. In this paper (second in this series) we present data for three additional LTS candidates, confirmed C stars in Gaia DR3 spectroscopic database.

This paper is structured as follows: Section 2 introduces the Gaia DR3 spectra for three new confirmed DFBS C stars. Section 3 present Gaia DR3 important data for these objects. Phase dependence light curves for new objects is presented in Section 4. Section 5 recalls the main results obtained for objects and provide concluding remarks and future works.

2. *Gaia DR3 Spectra*. The European Space Agency (ESA) mission Gaia (Gaia Collaboration [8]), has already released three catalogues to the astronomical community, of increasing richness in terms of content, precision, and accuracy. Researchers from many branches of astrophysics have shown great interest in the published data, leading to the publication of more than 6000 papers based on Gaia data. With respect to previous Gaia Early Data Release 3 (EDR3) [9], Gaia Data Release 3 (Gaia DR3 [10]) introduces a number of new data products based on the same source catalogue, including a total of 1.8 billion objects based on a period of 34 month of satellite operations. Blue (BP) and Red (RP) photometer lr spectral data are one of the exciting new products in Gaia DR3 (CDS VizieR Catalog I/355/gaiadr3). Time-averaged mean spectra covering the optical to near-infrared (NIR) wavelength range $\lambda 3300 - 10500\,\text{Å}$ are published for approximately 220 million objects (Catalog I/355/spectra). Most of these objects are brighter than $G = 17.65\,\text{mag}$ [11]. M-type stars can be detected very easily in the Gaia DR3 lr spectral database by the presence of the broad absorption bands of the TiO molecules in the range 6500-7000 Å , 7000-7500 Å , and 8000-8500 Å , and C stars display strong Swan bands at 4383, 4737, 5165, and 5636 Å of C_2 molecule [7]. Table 1 presents three DFBS candidates confirmed as C stars, it gives the DFBS

Number, the Gaia I/355/gaiadr3 source name, other association in SIMBAD database, and our spectral type determination (C-N or C-CH-type). Fig.1 presents Gaia DR3 Catalogue BP/RP lr spectra for objects of Table 1.

Table 1

DFBS LTS CANDIDATES CONFIRMED CARBON STARS

DFBS number	Gaia DR3 source name	Other associations in SIMBAD database	Sp. type
J055944.18+473700.8	198083449311963392	NSVS 4490482*	C-N
J174725.28+301231.5	4597258364288414976		C-CH
J182708.82+274303.9	4585675254107197440		C-CH

Note to Table 1: The object DFBS J055944.18+473700.8 as variable object, were included in Catalogue NSVS (Northern Sky Variability Survey [12], SIMBAD CDS Catalog II/287/ skydot/). In Extended catalog of NSVS Red AGB Variable Stars, found in the NSVS Database [13], CDS Catalog J/other/OEJV/87/catalog), this object classified as Mira-type variable.
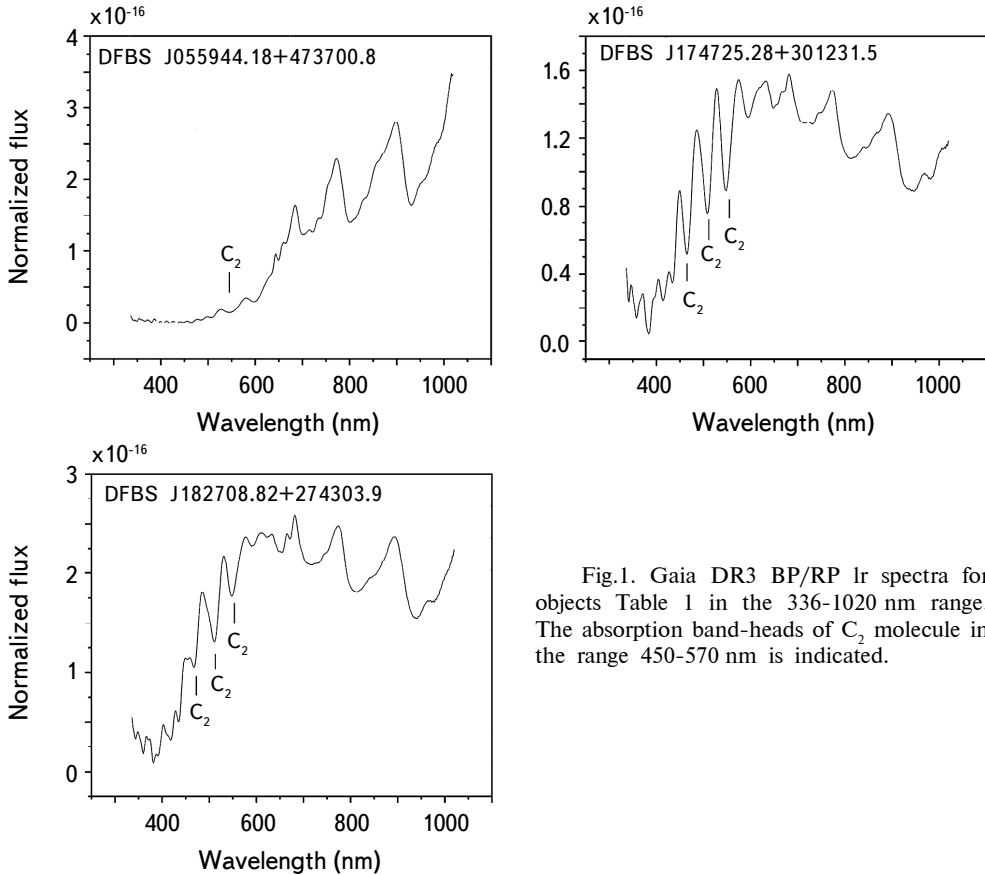

Fig.1. Gaia DR3 BP/RP lr spectra for objects Table 1 in the 336-1020 nm range. The absorption band-heads of C_2 molecule in the range 450-570 nm is indicated.

3. *Gaia DR3 photometric data. Distances and absolute magnitudes.* Table 2 presents Gaia DR3 catalogue key data for new confirmed C stars and their hight above/below the Galactic plane. The distance estimation is based on Gaia DR3 trigonometric parallaxes (absolutely the same value of parallaxes, as presented in Gaia EDR3 catalogue). Therefore, we used the distance information from Gaia EDR3 by Bailer-Jones et al. [14].

Table 2

SOME IMPORTANT GAIA DR3 DATA FOR THREE NEW
CONFIRMED C STARS

DFBS Number	G-band mag	BP-RP Color	RV (km/s)	r (pc)	M (G) mag	Z (pc)
J055944.18+473700.8	13.45	3.03	-33.70($\pm$0.99)	9170.0($\pm$900)	-1.40($\pm$0.5)	1857($\pm$200)
J174725.28+301231.5	13.30	1.44	-351.18($\pm$0.92)	6690.0($\pm$400)	-0.80($\pm$0.02)	2953($\pm$300)
J182708.82+274303.9	12.77	1.49	-130.77($\pm$0.38)	7541.0($\pm$600)	-1.61($\pm$0.02)	2309($\pm$90)

4. *Variability.* The object DFBS J055944.18+473700.8 is classified as Mira-type variable by Usatov & Nosulchik [13]). Phase dependent light curve for this object is available in "ASAS-SN Variable Star Database" [15,16] (on-line at https://asas-sn.osu.edu/variables/, DFBS J055944.18 + 473700.8 = ASASSN-V J055944.17+473700.7, $V_{mean}=14.98$ mag, $P=296.6646$ d). Fig.2 shows ZTF (Zwicky Transient Facility) [17] light curve for N-type C star DFBS J055944.18+473700.8.
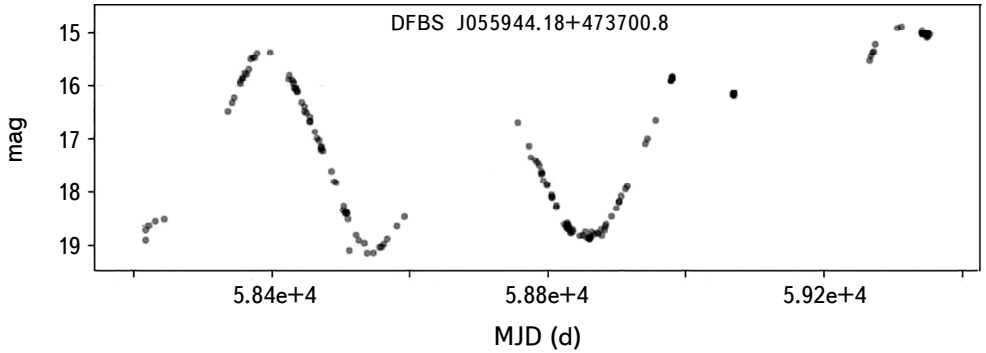

Fig.2. Zwicky Transient Facility light curve for DFBS J055944.18+473700.8 (available on-line at https://irsa.ipac.caltech.edu?missions/ztf.html). X-axis presents the period in Julian Data and Y-axis presents ZTF g-band magnitude. The observational identifier is 745107100000050 ($P \approx 307$ d).

Fig.3 shows ZTF light curves for DFBS J174725.28+301231.5 and DFB J182708.82+274303.9.
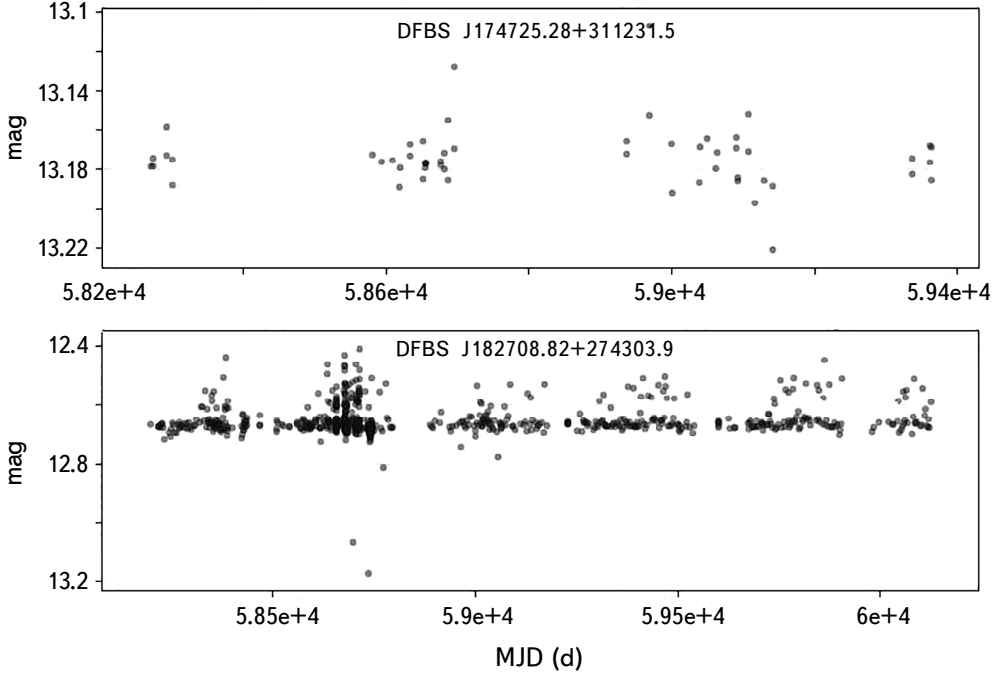Gaia DR3 and Transiting Exoplanet Survey Satellite (TESS) Input Catalog-

Fig.3. ZTF phased light curves in R-band for DFBS J174725.28+301231.5 (Obs. id is 1680211300008908) and for DFBS J182708.82+274303.9 (Obs. id is 63721100007586). For DFBS J182708.82+274303.9 the variability in r-band with amplitude $\Delta m \approx 0.3$ mag is evident.

V8.2(TIC-8.2,[18], VizieR CDS Catalog IV/39/tic82) indicates 2 objects in the 5 arcsec search radius around DFBS J182708.82+274303.9. In Table 3 most important TIC-8.2 catalog data are presented for objects of Table 1.

In Gaia DR3 database very close object to DFBS J182708.82+274303.9 is Source 4585675254107401984, for which $G = 18.76$ mag. TIC-8.2 catalogue identifier for this faint object is 1686925212, $T = 18.06$ mag. If this object is gravitationally bound, i.e. it is a physical companion of DFBS J182708.82+274303.9 at the same distances, its G-band absolute magnitude can be estimated $M(G) = +4.4$. Such magnitudes characterized dwarfs late F-subclasses. In Gaia DR3 database no

Table 3

SOME IMPORTANT TIC-8.2 CATALOG DATA FOR THREE
NEW DFBS C STARS

DFBS Number	TIC Number	T mag	T_{eff} (K)	Radius (R_{Sun})	Lum. Class
J055944.18+473700.8	440391815	11.94	3379.0	84.277	Giant
J174725.28+301231.5	18637876	12.59	4447.0	29.253	Giant
J182708.82+274303.9	235769793	12.03	4435.0	38.959	Giant

BP-RP color information is available for this object, to predict spectral type. High-angular-resolution CCD observations is required to resolve the faint, close companion.

5. *Summary and future works*. Carbon stars are peculiar and rare objects compared with normal stellar objects, and they are excellent kinematic tracers of the Galaxy [19]. They can be used as distance indicators. Rotation curve of the Milky Way has been studied based on C stars with radial velocities in many literature [20]. In this paper, we just focus on Gaia DR3 BP/RP spectral confirmation and studying LTS candidates, detected on DFBS spectral plates. We have demonstrated the power and excellent opportunity of the Gaia DR3 spectral database for this task. We report the belonging of the three LTS candidates to the group of C stars and we present Gaia DR3 low-resolution spectra in the range 3360-10200 Å . DFBS J174725.28 + 301231.5 and DFBS J182708.82 + 274303.9 are CH-type C stars, with large radial velocities (RV = -351.18 km/s and RV = -130.77 km/s) at high Galactic latitudes. A most of the CH stars are known to be binary systems [21,22]. High-angular-resolution CCD observations is required to resolve the faint close companions, also study in more detail, particularly kinematic study, and their location in the galactocentric XYZ system, will allow to understand the origin of such high velocity CH stars at high latitudes. The object DFBS J055944.18+473700.8 is Mira-type variable with period $P \approx 307$ day. The list of all Gaia DR3 spectroscopically confirmed new DFBS LTS candidates, reported as supplementary (value-added) catalog to the Second Edition of the "Revised And Updated Catalogue of The First Byurakan Survey of Late-Type Stars" [4], will be presented in SIMBAD VizieR database very soon.

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ОЦИФРОВАННЫЙ ПЕРВЫЙ БЮРАКАНСКИЙ ОБЗОР НЕБА. ЗВЕЗДЫ КАНДИДАТЫ ПОЗДНИХ СПЕКТРАЛЬНЫХ КЛАССОВ. НОВЫЕ ПОДТВЕРЖДЕНИЯ. II

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Три новые углеродные С звезды были подтверждены среди кандидатов звезд поздних спектральных классов, отобранных на оцифрованных пластинках Первого Бюраканского Обзора (DFBS). DFBS - это оцифрованная версия Первого Бюраканского Обзора (FBS) или Маркаряновского обзора. FBS является первым систематическим внегалактическим обзором. Он был осуществлен Маркаряном и его коллегами в 1965-1980гг. с объективной призмой с использованием 1-м телескопа Шмидта Бюраканской астрофизической обсерватории (БАО) и увенчался открытием 1517 галактик с UV-избытком, названных галактиками Маркаряна. Пластинки обзора FBS длительное время использовались для поиска и изучения слабых звезд поздних спектральных типов (LTS, M и С (углеродные)) на высоких галактических широтах. В данной работе мы приводим Gaia DR3 фотометрические данные, спектры, кривые блеска, расстояния, радиальные скорости (RV) и другие важные физические характеристики из современных астрономических каталогов для трех новых DFBS С звезд. Подтверждение основано на Gaia DR3 BP/RP спектральных базах данных. В наших предыдущих исследованиях эти объекты были представлены как кандидаты в LTS. Одним из новых подтвержденных объектов, это С звезда типа N. Два оставшихся объекта являются СН гигантами в высоких галактических широтах. Скорее всего, они представляют двойные системы.

Ключевые слова: *каталоги-звезды: углеродные звезды: обзоры: данные Gaia*

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