K. S. Gigoyan, K. K. Gigoyan, Alain Sarkissian, G. R. Kostandyan, E. Karapetyan, Mustapha Meftah, N. Azatyan, F. Zamkotsian

First Byurakan Spectral Survey. Late-Type Stars. Dwarfs

K. S. Gigoyan *[1], K. K. Gigoyan[1], A. Sarkissian[2], G. R. Kostandyan[1], E. Karapetyan[3], M. Meftah[2], N. Azatyan[1], and F. Zamkotsian[4]

[1]INAS RA V. Ambartsumian Byurakan Astrophysical Observatory (BAO), Byurakan 0213, Aragatzotn Province, Armenia
[2]Universite de Versailles Saint -Quentin, CNRS/INSU, LATMOS-IPSL, France
[3]Yerevan State University, Astronomy Department, 0025, Alex Manoogian 1, Yerevan, Armenia
[4]Laboratoire d Astrophysique de Marseille, CNRS-AMU, 13388, Marseille Cedex 13, France

Abstract

A total of 18 lists of the First Byurakan Survey of Late-Type Stars (FBS LTS) were published between 1990 and 2016. The stars were found on FBS low-dispersion spectral plates. A systematic search and selection were carried out on a surface of ∼16 000 deg^2 on almost the whole area of the FBS. Since 2007, all FBS low-resolution spectral plates have been digitized. The second version of the "Revised And Updated Catalogue of the First Byurakan Survey of Late-Type Stars", containing data for 1471 M and C (carbon) stars (130 C-type giants, 1105 M – giants, and 236 M dwarfs) was generated. Among the 236 M dwarfs selected, 176 are new discoveries. The *Gaia* EDR3 G broad-band magnitudes are in the range $11.3 < G < 17.1$. New distance information by Bailer-Jones et al. (2021), which is based on the EDR3 parallaxes are used to estimate the G-band absolute magnitudes for M dwarfs. 9 FBS M dwarfs (out of 176 new discovered) lie within 25 pc of the Sun. The object FBS 0909-082 is more distant (r = 780pc) M dwarf among the sample considered, for which G-band absolute magnitude M(G) = 9.18, M = 0.59 M_{Sun}, L = 0.13597 L_{Sun}, and T_{eff} = 3844 K. This object can be classified as M1-M2 subtype dwarf. The nearest object is FBS 0250+167, a M7 subtype dwarf with very high proper motion (5.13 arcsec/yr) and is located at 3.83 pc from the Sun. The TESS estimated masses lie in the range $0.095\,(\pm 0.02)\,M_\odot \leq M \leq 0.7\,(\pm 0.1)\,M_\odot$ and T_{eff} in the range $4000K < T_{eff} < 2790K$ for FBS M dwarfs. Color-absolute magnitude (CaMD) diagrams are constructed for the FBS M dwarfs based on Gaia EDR3 and TESS data.

Keywords: *surveys-stars: late-type -stars, dwarf M stars, TESS and Gaia data*

1. Introduction

More than 75% of all stars within our Galaxy are M dwarfs (Henry et al., 2006, 2018), dominating the stellar populations by number, having a very low mass range $0.075\,M_\odot \div 0.50\,M_\odot$ and effective temperature (T_{eff}) less than 4000 K (Delfosse et al., 2000). M dwarfs are main-sequence stars whose spectra display bands of TiO and other molecules such as CaH, CaOH, VO, FeH, and CrH (Johnson et al., 1986, Kirkpatrick et al., 1993).

The great majority of the M dwarfs discoveries was based on the study of the proper motion catalogues, such as Lowell Observatory Proper Motion (Giclas et al., 1971), proper motion "Catalogue of Nearby Stars, 3rd edition- CNS3" (Gliese & Jahreiss, 1991), the "New Luyten Two Tenths"(NLTT) catalogue of Luyten (1979-80), which includes 58 845 stars with proper motions larger than 0.18 arcsec/yr. Numerous of the M dwarfs was confirmed among the proper motion objects in the catalogue by Lépine & Shara (2005).

Spectra of M dwarfs increases dramatically with the development of modern astronomical facilities. West et al. (2011) presented the spectroscopic catalog of 70841 M dwarfs from Sloan Digital Sky Survey (SDSS) Data Release 7. Zhong et al. (2019) presented catalog of M dwarfs from the LAMOST (Large Sky Area Multi-Objects Fiber Spectroscopic Telescope, (Cui et al., 2012), Data Release 5).

M dwarfs are in the focus of many astronomers in the recent two decades for their application to exoplanet research (Tarter et al., 2007). The small radii, low mass, low luminosity facilitate the discovery of orbiting low-mass planets via radial velocity (RV) and transiting photometry (Mann et al., 2018, Martinez et al., 2017, Muirhead et al., 2012). Recently, the Calar Alto High-Resolution search for M dwarfs with Exoearth

*kgigoyan@bao.sci.am, Corresponding author

doi:https://doi.org/10.52526/25792776-22.69.2-207

with Near-infrared and optical Echelle Spectrog- raph (CARMENES; Quirrenbach et al., 2014), and HARPS (Astudillo-Defru et al., 2017) surveys is searching for planets around M dwarfs (Alonso-Floriano et al., 2015, Cifuentes et al., 2020, Espinoza et al., 2022). CARMENES is a high-resolution, double-channel spectrograph at the 3.5 m Calar Alto telescope, which is monitoring M dwarfs to detect exoplanets with the RV method.

The main goal of the present paper is the characterization of a Galactic M dwarfs sample selected on First Byurakan Survey (FBS) plates (Gigoyan et al., 2019), using modern astronomical data bases, such as *Gaia* EDR3 (Brown et al., 2021) and TESS (Transiting Exoplanet Survey Satellite, Stassun et al. (2019). In this paper we present some important parameters for FBS M dwarfs and is structures as follows: First, we introduce the FBS for late-type stars (LTSs) and its digitized version, we characterize our sample of 236 M dwarfs. In Section 3, for selected M dwarfs we present spectroscopic observations. Cross-correlations with Gaia EDR3, TESS, GALEX, and ROSAT catalogues, color-absolute magnitude diagrams (CaMD) of FBS M dwarfs are considered in Section 4, giving a special attention on star FBS 025+167. In Section 5 we discuss possible multiplicity and companions around M dwarfs. Finally, in Section 6, we discuss the results obtained for the FBS M dwarfs, and we provide concluding remarks.

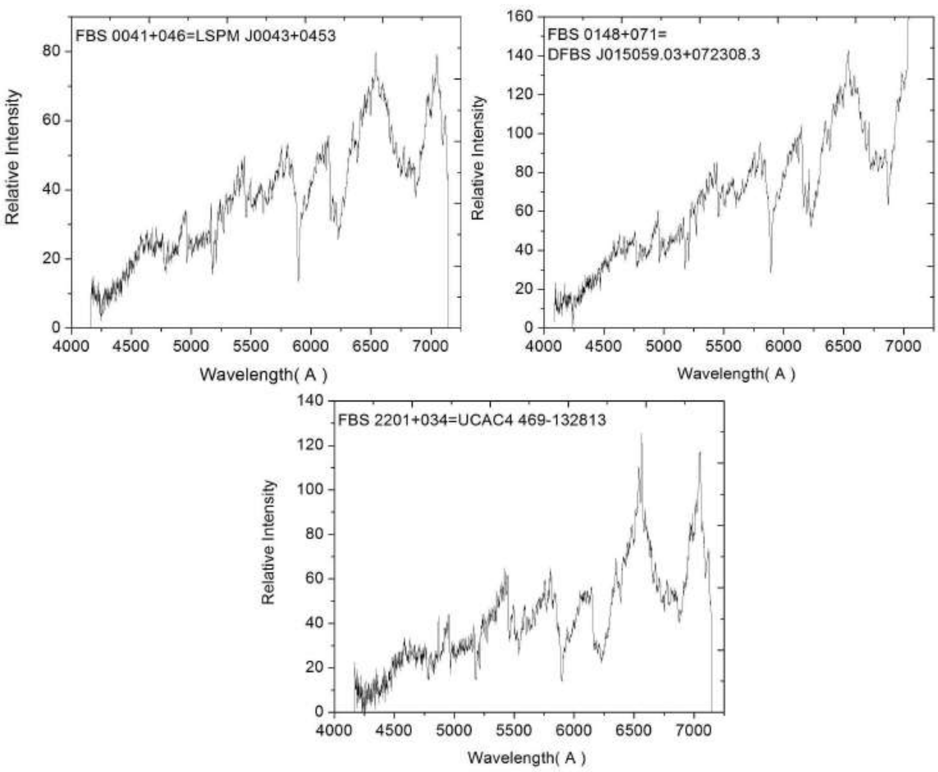

Figure 1. BAO 2.6-m telescope spectra for three FBS M dwarfs, obtained on September 8/9 2018 with the SCORPIO spectrograph, using a 600 line/mm grism and CCD EEV 42-40 in spectral range λ4000-7000 Å (pixel size 13.5 μm, resolution ~6 Å).

2. FBS Late-Type Stars Catalog

All M dwarfs analyzed in this paper are presented in "The Second Revised and Updated Version of the FBS Late-Type Stars (LTSs) Catalogue", which is a comprehensive list of 1471 objects (130 C (carbon) giants, 1105 M giants, and 236 M dwarfs, Gigoyan et al. (2019), CDS VizieR Catalogue J/MNRAS/489/2030). LTSs are selected on the Digitized First Byurakan Survey (DFBS)(its spectra are available on the DFBS web portal in Trieste https://www.ia2-byurakan.oats.inaf.it/ plates, which is a digitized version of the FBS (Markarian et al., 1989). From the 236 M dwarfs, 176 are new discoveries. 60 M dwarfs are proper motion objects, known mainly from the NLTT catalogue (CDS VizieR Catalog I/98A), and from Catalogue by Lépine & Shara (LSPM; 2005). Spectral types as M dwarfs for a large number of these 60 known proper motion objects was reported also by Gigoyan et al. (2019).

doi:https://doi.org/10.52526/25792776-22.69.2-207

Table 1. CAFOS spectral types for 6 FBS M dwarfs

FBS Number	“Karmn” Number	SIMBAD association	J mag	Sp. type	Data
0444-113	J04468-112AB	1RXS J044652.0-111658	8.14	M4.9V	2013-02-14
0928+026	J09308+024	1RXS J093051.2+022741	9.42	M4.0V	2012-01-04
1040-089	J10430-092AB	WT1827	9.67	M5.5V	2012-01-09
1527+469	J1529.0+4646	1RXS J152902.1+464627	9.94	M4.5V	2012-02-09
1652+631	J16528+610	LSPM J1652+6304	9.59	M6.0V	2012-08-06
2201+034	J22035+036AB	1RXS J220330.8+034001	9.74	M4.0V	2012-01-04

3. Spectroscopy

For FBS LTSs, medium-resolution CCD spectra were obtained at different epochs with the Byurakan Astrophysical Observatory (BAO, Armenia) 2.6-m telescope. Figure 1 present optical spectra for three FBS M dwarfs obtained with the SCORPIO spectrograph and an EEV 42-40 2048 × 2048 pixel CCD as examples.

Moderate-resolution CCD spectra for 44 FBS M dwarfs (out of 236, presented by Gigoyan et al. (2019) was secured by LAMOST (Large Sky Area Multi-Object Fiber Spectroscopic Telescope) observations Luo et al. (2019), LAMOST DR7, spectra available on-line at http://dr7.lamost.org/search/.

Spectra for 12 M dwarfs were secured also with Calar Alto Focal Reductor and Spectrograph (CAFOS) mounted on the Ritchey-Chretien focus of the Zeiss 2.2 m Calar Alto telescope (wavelength range of $\lambda 4200-8300 \mathring{A}$, CDS Vizier Catalogue J/A+A/577/A128/Mstars/).We list in Table 1 CAFOS observations of 6 FBS M dwarfs (out of the 12 stars observed).

Table 1 presents FBS name, CARMENCITA identifier follows the nomenclature format “Karmn” (CARMENCITA CARMENES Cool dwarf Information and data Archive, (Alonso-Floriano et al., 2015), other associations in SIMBAD database, 2MASS (Two Micron All-Sky Survey, Skrutskie et al. (2006) J magnitude, spectral subclasses estimated and data of observations.

4. Photometric Data

4.1. Gaia EDR3 Data

Gaia EDR3 (Gaia Collaboration; Brown et al., 2021) provides high-precision astrometry, three-band photometry, effective temperatures, and information on astrophysical parameters for about 1.8 billion sources over the full sky brighter than G = 21.0 magnitude. All FBS M dwarfs were cross-matched with the Gaia EDR3 catalogue source. These objects are relatively bright, so that G-band brightnesses were in the range $11.3 < G < 17.1$.

4.2. TESS Observations

NASA’s Transiting Exoplanet Survey Satellite (TESS) is an all-sky space-based mission designed to search for planets transiting around nearby M dwarfs (Ricker et al., 2014). We have cross-matched our list of 236 M dwarfs with the TESS Input Catalog (TIC), Version 8.2, Paegert et al. (2021), CDS VizieR catalogue IV/39/tic82, Stassun et al. (2018). This catalogue includes numerous of important physical parameters for stars, parallaxes, proper motions, TESS (T) magnitudes, temperatures, masses and luminosities in solar units, etc.

4.3. GALEX Ultraviolet Detection

We have cross-correlated the FBS M dwarfs against the GR6+7 data release of the GALEX. To match with the FBS M dwarf sample we queried GALEX (VizieR Catalogue II/335/galex-ais, Bianchi et al., 2017) data to identify UV sources within 5 arcsec. We found GALEX counterparts for 43 FBS M dwarfs (out of 176 new discovered) using 5” search radius.

doi:https://doi.org/10.52526/25792776-22.69.2-207

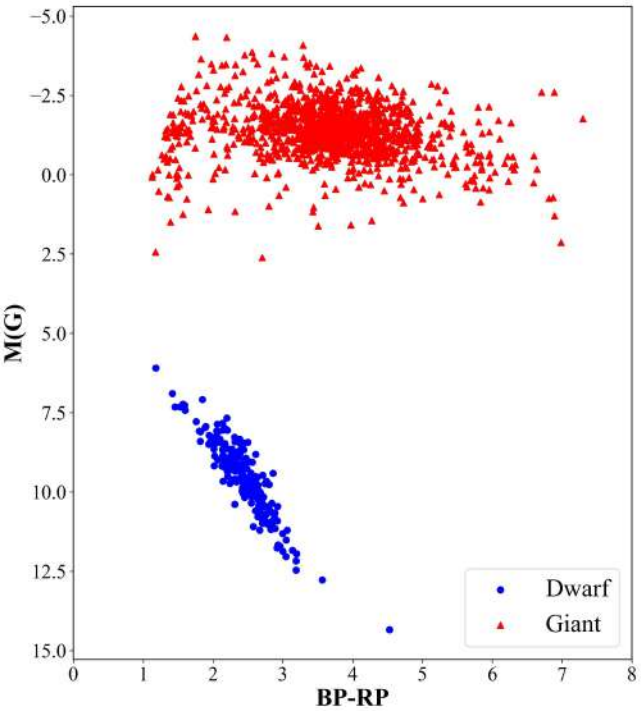

Figure 2. *Gaia* EDR3 absolute magnitude M(G) vs. BP-RP color for FBS M dwarfs (blue circles) and giants (M and N giants – red triangles) for comparison. The faintest object among the sample is M dwarf FBS 0250+167 (M(G) = 14.35).

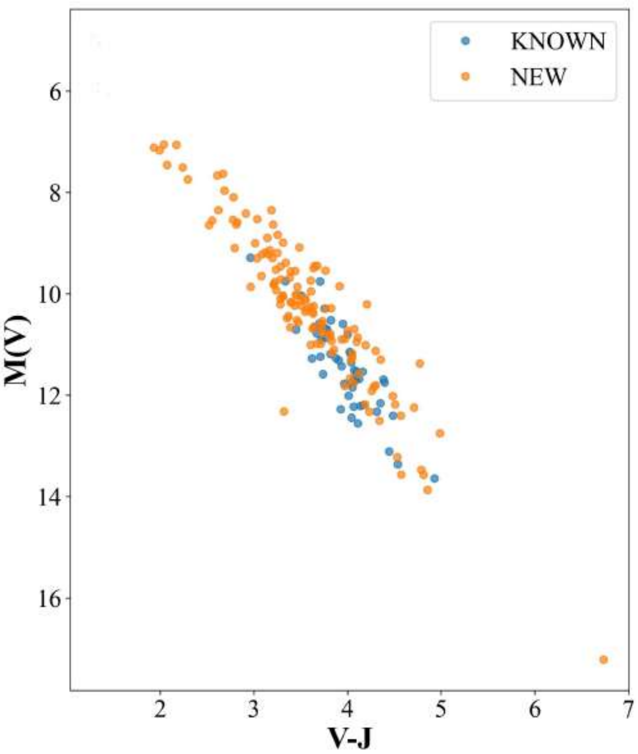

Figure 3. Observational HR diagram for FBS M dwarfs (M_V vs. V-J and V-K color based on TIC catalogue data with measured trigonometric parallaxes). Symbols are: orange dots-FBS M dwarfs (NEW), blue dots–M dwarfs KNOWN.

doi:https://doi.org/10.52526/25792776-22.69.2-207

4.4. ROSAT Data

Our list of all FBS M dwarfs was cross-correlated also with both the ROSAT All-Sky Survey Faint Source Catalog (Voges et al., 2000) and the Second ROSAT All-Sky Survey (2RXS) Source Catalog (Boller et al., 2016). We used a search radius of 15 arcsec, which is on the order of the astrometric precision of the ROSAT catalog. Our search identified 20 M dwarfs with the X-ray counterparts.

4.5. 2MASS Data

The 2MASS J-H versus H-Ks color-color plots for all 1471 FBS M-and C-type stars are presented in paper by Gigoyan et al. (2019). A special interest among all FBS M dwarfs present the extremely high proper motion star FBS 0250+167 (2MASS 02530084+1652532, J – H = 0.511, H – Ks = 0.298). In our XIV – th list of the LTSs, we present this object as M7-M8 subtype star (Gigoyan et al., 2003). The finder chart and the direction of the motion of this object is presented in Figures 9 and 10 by Gigoyan (2022, in press).

As part of CARMENES search for exoplanets around M dwarfs, Zechmeister et al. (2019) obtained more than 245 RV measurements for FBS 0250+167 and analyzed them for planetary signals. Authors find periodic variability in the RV and evident for two planet candidates, orbiting at periods of 4.91 and 11.4 d, respectively. TIC v8.2 catalogue gives the following data for FBS 0250+167, TIC Identifier is 257870150, M = 0.095M_{Sun}, L = 0.00077L_{Sun}, T_{eff} = 2790 K, and V = 15.13 mag.

4.6. Color-Absolute Magnitude (CaMD) diagrams based on *Gaia* DR3 and TESS

Figure 2 present the observational Gaia absolute magnitude (M(G)) versus BP-RP color, or Hertzsrung-Russell Diagram-HRD) for all FBS detected M dwarfs. For comparison on the same diagram we present FBS M and C giants (Gigoyan et al., 2019) also.

We used the distance information derived from *Gaia* EDR3 by Bailer-Jones et al. (2021). We estimate the absolute G-band magnitude via the usual equation:

$$M(G) = G - 5Logr + 5 - A(G) \tag{1}$$

We assume that A(G) is very low for our objects, because they are at high Galactic latitudes.

Figure 3 shows the absolute M(V) magnitude vs. optical-to-infrared V-J color diagrams for FBS M dwarfs (J and K magnitudes are from the 2MASS) based on TIC catalog data.

5. Possible Companions. Multiplicity

Stellar multiplicity among low-mass stars within 15 pc is presented by Ward-Duong et al. (2015). Winters et al. (2019), surveyed a volume-limited sample of 1120 M dwarfs within 25 pc. In many studies, authors explored the regions around M dwarfs in search of different types of objects at different separation from the star to study substellar companions. Finding and characterizing M dwarf multiples is useful for studying transiting exoplanets, and multiplicity trends among them can yield insight into stellar formation and evolution (Lamman et al., 2020).

There are no direct and high-angular-resolution CCD imaging observations to search companions around FBS sample of the new detected M dwarfs. This type of observations is required to resolve the faint and close companions. Therefore, for a preliminary information about companions around FBS sample of the new detected M dwarfs, we used high accuracy photometric data mainly from the Gaia EDR3 and TESS (TIC) catalogues. We search also possible data for multiplicity in the Gaia Catalogue of Nearby Stars (GCNS) for FBS M dwarfs up to 100 pc distances. As a supplement information, we check visually POSS II I-band direct images for FBS M dwarfs in STScI Digitized Sky Survey database (on-line via `https://stdatu.stsci.edu:cgi-bin/dss-form`).

5.1. Gaia EDR3 Search

Gaia DR3 has the potential for extensive multiplicity studies. Gaia can resolve most companions down to 1 arcsec. at magnitude contrast as large as six; closer systems are not resolved, regardless of secondary brightness (Lamman et al., 2020, Ziegler et al., 2018). From 176 of our cross-matched FBS new M dwarf

doi:https://doi.org/10.52526/25792776-22.69.2-207

Table 2. Some Important *Gaia* ERD3 Catalogue Data For Three FBS M Dwarfs

FBS Number	*Gaia* EDR3 Number	G mag	BP-RP mag	r (pc)
0041+046	(bright) 2554308108533636992	13.68	2.44	56.04
	(faint) 2554308108534379264	20.57	1.58	
0820+035	(bright) 3092033444148132224	13.48	2.68	49.23
	(faint) 3092030489210218240	20.83	1.66	
0828-087	(bright) 5752169164602798336	12.37	2.50	61.30
	(faint) 5752169160308040960	16.92	0.46	

Table 3. Some Important TESS Catalog Data For Three FBS M Dwarfs

FBS Number	TESS Input Catalog Identifier	TESS T mag	T_{eff} K	Mass ($M_\odot$)	Lumonosity ($L_\odot$)
0041+046	(bright) 336565415	12.52	3464.0	0.366 (0.020)	0.01847(0.00448)
	(faint) 610931424	18.99			
0820+035	(bright) 455236039	12.23	3340.0	0.386(0.020)	0.01751(0.00437)
	(faint) 804051355	19.76			
0828-087	(bright) 51039965	11.18	3433.0	0.641(0.021)	0.05586(0.01311)
	(faint) 51039966	16.70			

targets, 27 had second Gaia EDR3 object within 5 arcsecond search radius. In 19 cases from 27, Gaia EDR3 database gives nearly equal-magnitudes in G-band. Three objects, mainly FBS 0041+046, FBS 0820+035, and FBS 0828-087 deserve a special attention. There are very close to primary M star and extremely faint in G-band second object (see detail below).

5.2. TESS Catalog Search

TESS Input Catalog-v8.2 gives data for two objects in search radius 5 arcsec around position for 27 FBS M dwarfs also, from which in 12 cases this catalogue comprises two objects with nearly-equal T magnitudes (Stassun et al., 2019). In this catalogue also three objects noted above, are exceptional, having the bright primary star, and very faint secondary object.

In Tables 2 and 3 consequently, *Gaia* EDR3 and TESS catalogue important data are presented for three FBS M dwarfs and for very close and faint companions in 5" search radius around them.

There are no distance information (only positional data) about the very faint and very close objects around these M dwarfs in Gaia EDR3 and TESS databases. If these objects are gravitationally bound, i. e. they are physical companions at the same distances, therefore absolute magnitudes can be obtained M (G) = 16.83, 17.37 and 13.00 for FBS 0041+046, FBS 0820+035, and for FBS 0828-087 consequently. Such BP-RP colors and absolute G-band magnitudes placed them on White Dwarfs (WD) sequence on HRD (for detail see Fig. 13 by Babusiaux et al., 2018).

Table 4. GCNS Data For Three New FBS M Dwarfs As A Binary Systems

FBS Number	*Gaia* EDR3 Identifier	G mag.	G mag. diff	BP-RP color	Angul. sep.(arcsec.)	Proj. sep. (AU)
1009+350A	753259752444224000	14.28	2.62	2.41	3.431	249.95
B	753259748150042752	16.91		3.08		
1107+350A	761700565771564416	11.54	2.03	1.68	3.170	190.000
B	761700565771564032	13.58		2.34		
1136-082A	3591834837013732096	12.73	3.00	3.00	4.250	192.411
B	3591834871372295040	15.74		2.69		

doi:https://doi.org/10.52526/25792776-22.69.2-207

5.3. Gaia Catalogue of Nearby Stars Search

To search companions around new discovered FBS M dwarfs we have cross-matched with the Gaia Catalogue of Nearby Stars (GCNS, Gaia Collaboration; Smart et al., 2019). This catalogue gives information about 19176 resolved multiple systems.

Table 4 present data for three FBS M dwarfs, which are presented as resolved binary systems in the GCNS data base. These table present FBS Name (A, B) for the bright, primary source and B for the secondary component, Gaia EDR3 source identifier, Gaia EDR3 G –band magnitude, BP-RP color, G-band magnitude differences, angular separation of both objects, projected separation in AU.

Figure 4 illustrates secondary physical components around three FBS M dwarfs on DSS2 I charts according to GCNS database.

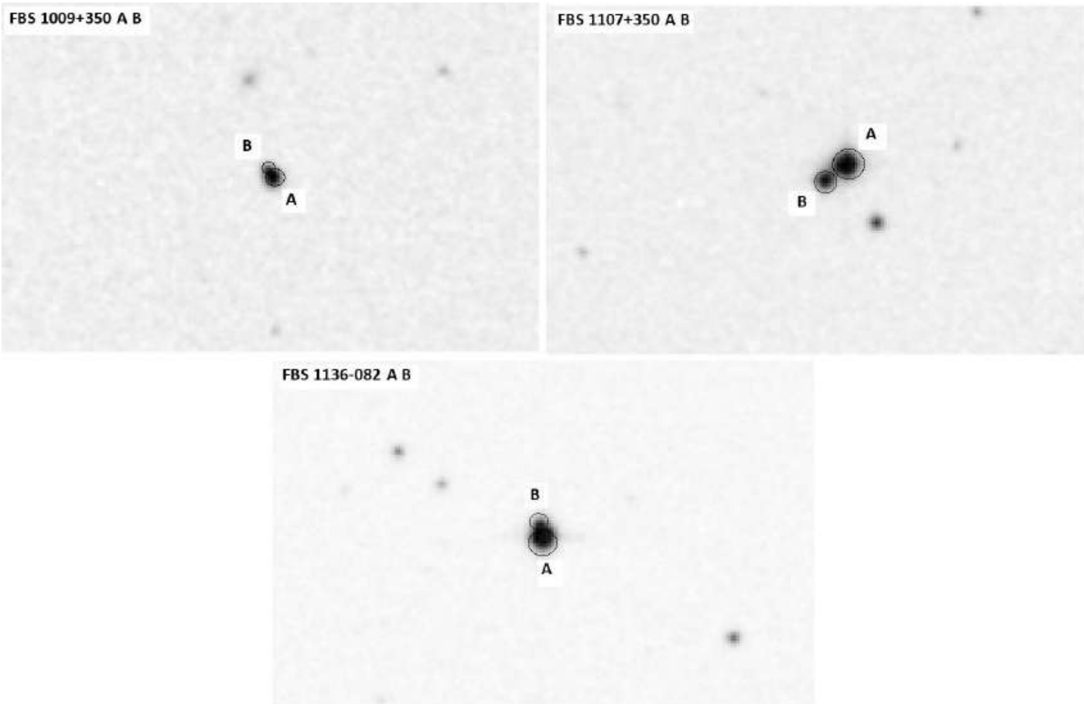

Figure 4. POSS2 I images for three FBS M dwarfs, which are included in GCNS catalogue as a binary systems. Physical components are circled and noted as B. They all are within 100 pc from the Sun. Very important note, the *Gaia* BP-RP colors for all components are typical for dwarf M stars. Field is 15 arcmin × 15 arcmin.

5.4. Washington Visual Double Star Catalog

We have cross-matched also all FBS M dwarfs with the "Washington Visual Double Star Catalogue" (WDS) objects (SIMBAD VizieR Catalog B/wds/wds, Mason et al., 2001) to find publications with information on multiple systems. Four objects out of 236, namely FBS 0115-095, FBS 0913-103, FBS 1345+796, and FBS 1513+796, are associated with the visual doubles. FBS 1345+796, is EA type eclipsing binary.

5.5. Visual Inspection of the POSS2 I Images

With help of the data visualization software SAOImage ds9, we search the POSS2 I-band images for new detected FBS M dwarfs, aiming to look companions around these objects. Such visualization allowed to detect very close and comparatively bright possible physical companions around dwarfs FBS 0756+234, FBS 1010+205, FBS 1016+142, FBS 1340-049, FBS 1412-058, and FBS 1719+829. Only in case of FBS 0756+234 we have very good matched Gaia EDR3 catalogue distances (Bailer-Jones et al., 2021) for primary M dwarf star and for very close companion. For the remaining FBS M dwarfs above noted, the distance values for the faint close objects and primary star are very different.

In Figure 5 we illustrate the POSS2 I - band image and second companion around M dwarf star FBS 0756+234. Spectra in the range 3900-9100 A for this object was secured by LAMOST telescope and classified as dM4 type star (identifier is LAMOST J075935.66+232039.5).

doi:https://doi.org/10.52526/25792776-22.69.2-207

Table 5. *Gaia* EDR3 and TESS Catalogue Data For Dwarf M Star FBS 0756+234

FBS Number	*Gaia* EDR3 Identifier	G mag	BP-RP color	*Gaia* EDR3 distance(pc)	TIC Number	Mass ($M_\odot$)	Lum ($L_\odot$)	TESS T_{eff} (K)
0756+234A	680421917468548608	13.09	2.49	44.8166	54233548	0.389(±0.021)	0.01992(±0.004888)	3437.0
B	680421917468548480	14.58	2.82	44.7298	54233549	0.224(±0.02)	0.00658(±0.00167)	3267.0

Table 5 include Gaia EDR3 and TESS data for dwarf M star FBS 0756+234 and for very close companion. The BP-RP color and Teff of the second and very close object is also typical for M dwarfs, therefore most probably, we have pair of M dwarfs. High-angular-resolution CCD is required to resolve very well the second component of FBS 0756+234 and faint companions around FBS M dwarfs in general.

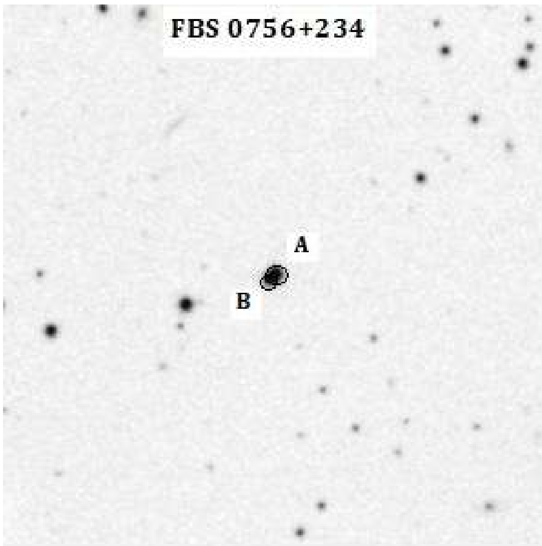

Figure 5. POSS2 I image of dwarf M star FBS 0756+234 (primary star-A), which we present as a binary system (companion-B). Angular separation is 1.74´ arcsec on I-image. Field is 5´ × 5´.

6. Summary And Future Works

In an effort to characterize the new M dwarfs found in the FBS, we used Gaia EDR3 and TESS monitored data to search M dwarfs and their possible multiplicity. These objects are relatively bright, 2MASS Ks magnitude lie in range between 7.3 and 14.4. For this purpose, we search visually POSS II I-images, also cross-matched all M dwarfs with the GCNS and with the Washington Visual Double Star Catalogue. The Gaia EDR3 G broad-band magnitudes are in the range $11.3 < G < 17.1$. The TESS estimated masses lie in the range 0.095 (± 0.02) $M_\odot$ ≤ M ≤ 0.7 (± 0.1) $M_\odot$ and T_{eff} in the range $4000K > T_{eff} < 2790K$ for FBS M dwarfs. For 27 FBS M dwarfs Gaia EDR3 and TESS catalogues gives two objects in 5 arcsec search radius. Three objects, namely FBS 0041+046, FBS 0820+035, and FBS 0828-087 most probably are binaries, having the second companion White Dwarf. Four objects FBS 0115-095, FBS 0913-103, FBS 1345+796, and FBS 1513+796 are included in Washington Visual Double Star Catalogue. FBS 1345+796, is EA type eclipsing binary. According to Gaia EDR3 and TESS photometric data, most probably FBS 0756+234 is a close binary. Gaia EDR3 BP-RP color for both objects are typic 0909-082 is a more distant M dwarf (r=780 pc), or which G-wide band absolute magnitude M(G) = 9.18, M = 0.59 $M_\odot$, L = 0.13597 $L_\odot$, and T_{eff} = 3844 K. This object can be classified as M1-M2 subtype dwarf. The nearest object is FBS 0250+167, a M7 subtype dwarf with extremely high proper motion (5.13 arcs./yr) and is located at 3.83 pc from the Sun. As part of CARMENES search for exoplanets around M dwarfs, two exoplanets was found around this high proper motion object.

In the future, high-angular-resolution CCD observations are necessary for higher-significance detections of the close companions around FBS M dwarfs and their reliable photometry to know more about multiplicity of FBS M dwarfs. Also we plan to download and analyze the TESS light curves for all FBS new detected M dwarfs from the Mikulski Archive for Space Telescopes (MAST-https://mast.stsci.edu/portal/Mashup/

doi:https://doi.org/10.52526/25792776-22.69.2-207

Clients/Mast/Portal.html).

Finally, for the first time we estimate the detection range of survey FBS for early and late-subclasses of M dwarfs adopting the limiting magnitude 17.5-18.0 in V-band. Adopting Mv = 8.0 for early-type M0 dwarfs (Reid et al., 2004), one can estimate the detection range up to $\sim 1000pc$, and adopting Mv = 19.0-20.0 for M8-M9 dwarfs, the detection range can be estimated up to 25 pc for survey FBS.

Acknowledgements

This work is supported by ERASMUS+2019-1-FRO-KA107-061818. KSG and KKG are grateful to Administration of OVSQ Observatory and LATMOS Laboratory (France) for organizing their visit. This research has made use of results from the SAO/NASA Astrophysics Data System Bibliographic Services, as well as the SIMBAD and VizieR databases, operated at CDS, Strasbourg, France, and Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center, funded by NASA and NSF. This research was made possible using the ASAS-SN and Catalina Sky Survey variability data bases. We used LAMOST telescope spectra. The LAMOST is a National Major Scientific project build by the Chinee Academy of Sciences. This work has made use of data from the European Space Agency (ESA) mission *Gaia* (https://cosmos.esa.int/gaia), processed by Gaia Data Processing and Analysis Consortium (DPAC, https://www.cosmos.esa.int/web/gaia.dpac.consortium). This paper includes data collected by the TESS mission, which are publicly available from the Mikulski Archive for Space Telescopes (MAST). This research has made use of the Washington Double Star Catalog maintained at the U.S. Naval Observatory.

References

Alonso-Floriano F. J., et al., 2015, Astron. Astrophys. , 577, A128

Astudillo-Defru N., et al., 2017, Astron. Astrophys. , 602, A88

Babusiaux C., van Leeuwen F., Barstow M. A., Jordi C., Zucker S., Zurbach C., Zwitter T., 2018, Astron. Astrophys. , 616, A10

Bailer-Jones C. A. L., Rybizki J., Fouesneau M., Demleitner M., Andrae R., 2021, Astron. J. , 161, 147

Bianchi L., Shiao B., Thilker D., 2017, Astrophys. J. Suppl. Ser. , 230, 24

Boller T., Freyberg M. J., Trümper J., Haberl F., Voges W., Nandra K., 2016, Astron. Astrophys. , 588, A103

Brown et al., 2021, Astron. Astrophys. , 650, C3

Cifuentes C., et al., 2020, Astron. Astrophys. , 642, A115

Cruz K. L., Núñez A., Burgasser A. J., Abrahams E., Rice E. L., Reid I. N., Looper D., 2018, Astron. J. , 155, 34

Cui X.-Q., et al., 2012, Research in Astronomy and Astrophysics, 12, 1197

Delfosse X., Forveille T., Ségransan D., Beuzit J. L., Udry S., Perrier C., Mayor M., 2000, Astron. Astrophys. , 364, 217

Espinoza N., et al., 2022, Astron. J. , 163, 133

Giclas H. L., Burnham R., Thomas N. G., 1971, Lowell proper motion survey Northern Hemisphere. The G numbered stars. 8991 stars fainter than magnitude 8 with motions ¿ 0".26/year

Gigoyan K. S., Abrahamyan H. V., Azzopardi M., Mauron N., Russeil D., Sinamyan P., 2003, Astrophysics, 46, 475

Gigoyan K. S., Mickaelian A. M., Kostandyan G. R., 2019, Mon. Not. R. Astron. Soc. , 489, 2030

Gliese W., Jahreiss H., 1991, NASA STI/Recon Technical Report A, 224, 161

Guerrero N. M., et al., 2021, Astrophys. J. Suppl. Ser. , 254, 39

Henry G. W., Fekel F. C., Sowell J. R., Gearhart J. S., 2006, Astron. J. , 132, 2489

Henry T. J., et al., 2018, Astron. J. , 155, 265

Jayasinghe T., et al., 2018, Mon. Not. R. Astron. Soc. , 477, 3145

Johnson H. R., Querci F. R., Jordan S., Thomas R., Goldberg L., Pecker J.-C., 1986, The M-type stars

Kirkpatrick J. D., Kelly D. M., Rieke G. H., Liebert J., Allard F., Wehrse R., 1993, Astrophys. J. , 402, 643

Lamman C., et al., 2020, Astron. J. , 159, 139

Lépine S., Shara M. M., 2005, Astron. J. , 129, 1483

Luo A. L., Zhao Y. H., Zhao G., et al. 2019, VizieR Online Data Catalog, p. V/164

Mann A. W., et al., 2018, Astron. J. , 155, 4

Markarian B. E., Lipovetsky V. A., Stepanian J. A., Erastova L. K., Shapovalova A. I., 1989, Soobshcheniya Spetsial'noj Astrofizicheskoj Observatorii, 62, 5

Martinez A. O., et al., 2017, Astrophys. J. , 837, 72

doi:https://doi.org/10.52526/25792776-22.69.2-207

Mason B. D., Wycoff G. L., Hartkopf W. I., Douglass G. G., Worley C. E., 2001, Astron. J. , 122, 3466

Muirhead P. S., et al., 2012, Astrophys. J. , 747, 144

Paegert M., Stassun K. G., Collins K. A., Pepper J., Torres G., Jenkins J., Twicken J. D., Latham D. W., 2021, arXiv e-prints, p. arXiv:2108.04778

Quirrenbach A., et al., 2014, in Ramsay S. K., McLean I. S., Takami H., eds, Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series Vol. 9147, Ground-based and Airborne Instrumentation for Astronomy V. p. 91471F, doi:10.1117/12.2056453

Reid I. N., et al., 2004, Astron. J. , 128, 463

Ricker G. R., et al., 2014, in Oschmann Jacobus M. J., Clampin M., Fazio G. G., MacEwen H. A., eds, Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series Vol. 9143, Space Telescopes and Instrumentation 2014: Optical, Infrared, and Millimeter Wave. p. 914320 (arXiv:1406.0151), doi:10.1117/12.2063489

Skrutskie M. F., et al., 2006, Astron. J. , 131, 1163

Smart R. L., Marocco F., Sarro L. M., Barrado D., Beamín J. C., Caballero J. A., Jones H. R. A., 2019, Mon. Not. R. Astron. Soc. , 485, 4423

Stassun K. G., et al., 2018, Astron. J. , 156, 102

Stassun K. G., et al., 2019, Astron. J. , 158, 138

Tarter J. C., et al., 2007, Astrobiology, 7, 30

Voges W., et al., 2000, , 7432, 3

Ward-Duong K., et al., 2015, Mon. Not. R. Astron. Soc. , 449, 2618

West A. A., et al., 2011, Astron. J. , 141, 97

Winters J. G., et al., 2019, Astron. J. , 157, 216

Zechmeister M., et al., 2019, Astron. Astrophys. , 627, A49

Zhong J., Li J., Carlin J. L., Chen L., Mendez R. A., Hou J., 2019, Astrophys. J. Suppl. Ser. , 244, 8

Ziegler C., et al., 2018, Astron. J. , 156, 259

doi:https://doi.org/10.52526/25792776-22.69.2-207