АСТРОФИЗИКА

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Notes

FBS 2213+421, AN EXTREMELY RED OBJECT WITH C - RICH CHARACTERISTICS

1. *Introduction.* We turned our attention again to late-type star FBS 2213+421 [1], after revision all possible data existing in modern astronomical catalogues for this object. We have detected this object on the First Byurakan Survey (FBS) [2] plate and estimated it as a star of M5-M6 subclass, according to the energy distribution in low-resolution (lr) FBS spectrum (~1800A/mm near Hγ, see more details in the paper [3] and Digitized First Byurakan Survey - DFBS database at http://www.aras.am for FBS lr spectral characteristics for various type of objects).

Finding charts from the DSS database, optical and near - infrared photometric data from USNO-B1.0 [4] and the 2MASS Point Source Catalogue (PSC), are presented in our previous paper [1], devoted to Extremely Red Object (ERO) FBS 2213+421.

2. *Spectroscopy.* Two spectra in the range λ4500 – 7250Å were obtained on 17.XI.2008 (exp. time 40 min for each spectra, $m \approx 17^{m}.5 - 18^{m}.0$ in visual) at the 2.6m telescope of the V.A.Ambartsumian Byurakan Astrophysical Observatory (BAO) equipped with the ByuFOSC2 spectrograph with 600 g/mm grating. The detector is a Lick 3 2063×2058 CCD with 15μm×15μm pixels. The resulting dispersion is 1.9 Å/pixel (spectral resolution ~8 Å). The wavelength calibration and data reduction were performed with the ESO-MIDAS software.

Fig.1 presents the BAO 2.6m telescope spectra of FBS 2213+421 with strongly rising continuum. In this spectra (the signal-to-noise ratio is not so high, because of the faintness of object) it is easy to found the (0, 0) λ5165Å, (0, 1) λ5636Å, (0, 2) λ6192Å absorption bands of C_2 molecule (Swan system), CN(3, 0) λ6950Å and CN (4, 1) λ7100Å absorbtion bands, also absorption bands at λ4871Å and λ4982Å of SiC_2 molecule (Merill-Sanford bands), typical for carbon stars [5] and are proving the carbon (C) - rich nature of object FBS 2213+421. But the most intense lines are the absorption lines of Na I D and Hα. The intense line of sodium doublet indicates the latest N-subclass of this object.

Spectra of FBS 2213+421 are very similar to the spectra of many ERO's,

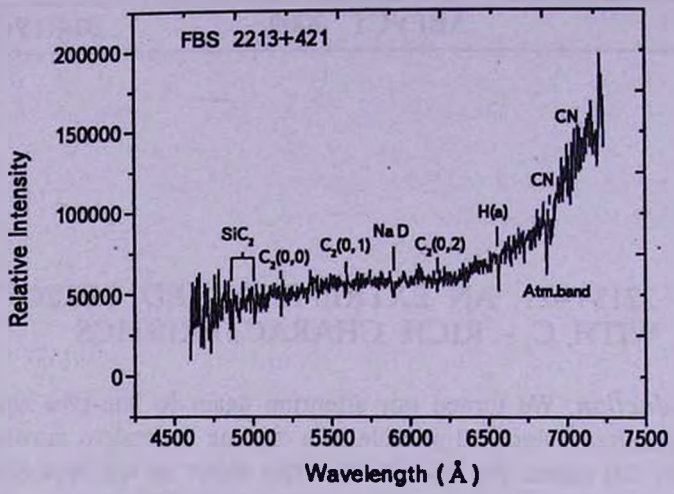

Fig.1. The 2.6m BAO telescope ByuFOSC2 spectrograph spectrum for FBS 2213+421 in the range $\lambda 4500 - 7250$Å. The Y-axis is intensity in relative units.

especially to spectra of heavily obscured carbon stars CRL 1235 [6], GL 971 and IRC+10216 [7], which are Long-Period Mira-type variables.

3. *Near-Infrared Colours.* Fig.2 presents 2MASS $J-H$ *vs.* $H-K_s$ colour-colour diagram of about 100 carbon stars presented in papers [6,8-12],

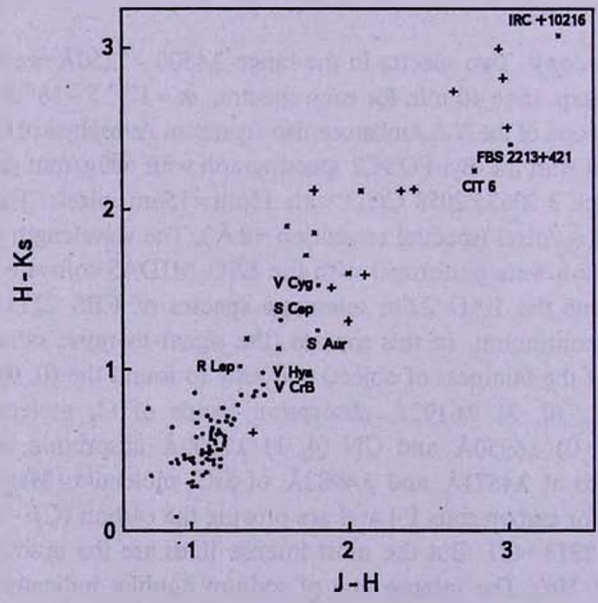

Fig.2. 2MASS $J-H$ and $H-K_s$ colour-colour diagram near 100 carbon stars from papers [6,8-12]. Symbols: dots - carbon stars from papers [8-10], crosses - IRC objects [11,12] and plus sign - AFGL objects [6].

where the position of FBS 2213+421 is indicated with a filled square. On this diagram, all objects having $J-H>2.5$ mag and $H-K_s>2.0$ mag are Extreme Carbon Stars (ECS), which are post-AGB (or pre-planetary nebula phase objects) Long-Period Mira-type variables with high mass-loss rate. On this diagram we present the locus of the well studied ECS IRC +10216 (CW Leo-Peanut Nebula) and CIT6 (RW LMi) also, which have a dense envelope and are investigated in many molecular lines [13]. It is known also, that IRC +10216 and CIT6 show variability in the near-infrared *JHK* bands [14].

4. *Variability*. The USNO-B1.0 catalogue *B* and *R* magnitude differences (*R2-R1*=6.86 mag, and *B2-B1*=2.38 mag) between two epochs (POSS I and POSS II) presented in our previous paper [1] for ERO FBS 2213+421, indicate the confident variability for this object.

In order to study the variability of FBS 2213+421, we considered the Northern Sky Variability Survey (NSVS) database [15].

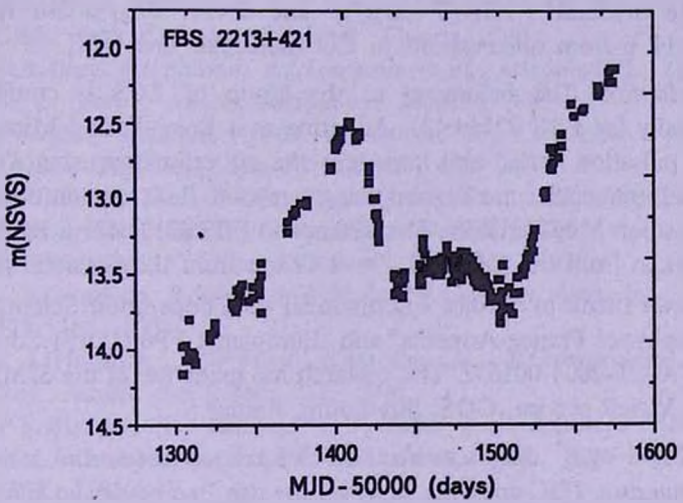

Fig.3. NSVS phase dependence light curve for FBS 2213+421 (identif. No 6089551, $R_{max}=13^m.457$, number good points is 257). X-axis present the period in Julian Data, and Y-axis present the NSVS magnitude.

On Fig.3 is presented phase dependence light curve for FBS 2213+421. The object show unusual light curve. According to NSVS data, it is evident that after decreasing of the brightness from 12.5 mag by ~1.0 mag, it remains around 13.5 mag about 100 days. This is probably caused by the presence of the faint companion around FBS 2213+421.

5. *Possible parameters estimation*. Assuming, that the ECS FBS 2213+421 is a Long-Period Mira-type variable, we used the *K*- [12] colour (as a function of period, derived for Galactic and LMC C - rich Miras presented in paper [14]) to estimate the pulsation period. It is found a period

of the order $P \sim 630$ days. Therefore, using revised Period-Luminosity (PL) relations for Galactic carbon Miras, presented in paper [16], we found $M_{bol.} = -5^m.23 (L/L_\odot \sim 8300)$ and $M_K = -8^m.80$. We note, that $M_{bol.} = -5^m.23$ and $M_{bol.} = -5^m.25$ consequently for IRC +10216 and CIT 6 [17]. Apparent bolometric magnitude is calculated for FBS 2213+421 also, using formulae:

$$m_{bol.} = m(K) + \mathrm{BC}(K) \qquad (1)$$

where $\mathrm{BC}(K)$ is the bolometric correction at K band. Adopting $\mathrm{BC}(K) = 1^m.3$ (see B(C) vs. K - [12] colour in paper [14] for more details) we obtain $m_{bol} = +9^m.0$. Distance to FBS 2213+421 is calculated from the apparent bolometric magnitude and absolute magnitude, which is based on the $M_{bol} - P$ relation ($R = 7.2$ kpc from the Sun and $Z = -1.47$ kpc from the Galactic plane). As a very good indicator of the optical depth of the circumstellar dust shell [14] we use the K-[12] colour to estimate the mass-loss rate for FBS 2213+421 also. The total mass-loss rate is estimated $\sim 10^{-5} M_\odot$/yr. We note, that the mass-loss rate is found $\sim 1.5 \times 10^{-5} M_\odot$/yr and $5 \times 10^{-6} M_\odot$/yr for IRC + 10216 and CIT 6 from observations in CO molecular lines [18].

6. *Conclusion.* The belonging to the group of ECS is confirmed spectroscopically for FBS 2213+421. Adopting as a Long-Period Mira-type variable, the pulsation period and mass-loss rate are estimated using K-[12] colour index. Luminosities are derived using a revised P-L relation obtained for Galactic carbon Mira-variables. The distance to FBS 2213+421 is estimated to be $R = 7.2$ kpc from the Sun and $Z = -1.47$ kpc from the Galactic plane.

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FBS 2213+421, Экстремально красный объект с С - характеристиками. ПЗС-спектры, полученные для Экстремально красного объекта FBS 2213+421, подтвердили его принадлежность к группе углеродных С-звезд. Используя показатель цвета K-[12] и принимая, что объект является долгопериодической Миридой, оценили период пульсации и потерю массы. Светимости оценены из соотношения период-светимость для галактических углеродных Мирид. FBS 2213+421 расположен приблизительно на 7.2 кпк от Солнца и $Z = -1.47$ кпк от плоскости Галактики.

Ключевые слова: *Переменные типа Миры Кита: FBS 2213+421*

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