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SPECTROSCOPIC MONITORING OF THE B[E] OBJECTS FS CMA AND MO CAM

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ABSTRACT. Objects with the B[e] phenomenon exhibit permitted and forbidden emission lines due to the presence of circumstellar ionized gas and large infrared excesses due to processing of the stellar radiation by circumstellar dust. There are five groups of stars that show this phenomenon (pre-main-sequence Herbig Ae/Be stars, symbiotic systems, proto-planetary nebulae, some supergiant, and FS CMa type objects). The latter group is the most recently discovered and the least explored. The leading hypothesis about the group nature implies that they are mostly intermediate-mass binary systems, whose circumstellar medium was created during a strong mass-transfer phase due to a Roche lobe overflow of the more massive star in the system. We have been conducting a large program of spectroscopic and photometric observations of many objects and candidates to this group. The current report is devoted to the preliminary results of our ongoing study of two objects with similar underlying early B-type stars, FS CMa (the group prototype) and MO Cam. The objects show different emission-line profiles and infrared excesses which are most likely due to different tilt angles of their non-spherical envelopes with respect to the line of sight. Variability of spectral lines is discussed here.

Key words: Stars: emission-line, Be - Stars: evolution - Stars: circumstellar matter - Stars: binaries: general.

АНОТАЦІЯ Об'єкти з феноменом B[e] демонструють дозволені та заборонені емісійні лінії завдяки присутності навколозоряого іонізованого газу та великого інфрачервоного надлишку завдяки перевипромінюванню навколозоряним пилом. Існують п'ять груп зір, які показують цей феномен (перед-ГП Ae/Be зорі типу Гербіга, сімбіотичні системи, протопланетарні туманності, деякі надгіганти та об'єкти типу FS CMa). Остання група є зовсім недавно відкритою та найменш дослідженною. Головна гіпотеза щодо природи цієї групи полягає в тому, що вони у більшості є подвійними системами проміжних мас, чиє навколозоряне середовище створюється на протязі фази сильного переносу маси завдяки перетіканню у порожнину Роша речовини з більш масивної зорі у системі. Ми маємо виконати велику програму спектроскопічних та фотометричних спостережень багатьох об'єктів та кандидатів до цієї групи. Це повідомлення присвячено попереднім результатам нашого інтенсивного вивчення двох о'бєктів зі схожими головними ранніми зорями B-типу, – FS CMa (прототип групи) та MO Cam. Ці об'єкти показують різні профілі емісійних

ліній та інфрачервоного надлишку, але які є найбільш схожими завдяки різним кутам нахилу їх несферичних оболонок до лінії спостереження. В роботі обговорено змінність спектральних ліній цих об'єктів.

Ключові слова: B[e]-зорі, еволюція B[e]-зір, оболонки B[e]-зорь, подвійні зорі.

1. Introduction

The B[e] phenomenon is the presence of line emission (e.g., H I and Fe II) and large IR excesses due to dust in the spectra of B–type stars (Allen & Swings 1976). It is found in five stellar groups (Lamers et al. 1998): pre-main-sequence stars, symbiotic binaries, compact Proto-Planetary Nebulae, some supergiants, and FS CMa objects. Classification and determination of fundamental parameters of many objects with the B[e] phenomenon is difficult due veiling of stellar features by circumstellar material.

The group of FS CMa objects was defined with the following criteria (Miroshnichenko 2007). Observational: A hot star continuum with emission lines of H I, Fe I, O I, [Fe II], [O I], Ca II; a large IR excess peaking at $\lambda = 10 - 30\mu$m and sharply decreasing at longer wavelengths; location outside star-forming regions; and a secondary companion (if revealed) typically either fainter and cooler or degenerate. Physical: Hot star has a spectral type between O9 and A2 and a luminosity range log $L/L_\odot$ between ∼2.0 and ∼4.5.

Most FS CMa objects show very strong emission-line spectra inconsistent with mass–loss from single stars. Our studies show that they are not pre-main-sequence stars or proto-planetary nebulae due to lack of cold circumstellar dust. They are thought to be binary systems after a strong mass-transfer stage, when large amounts of gas and dust were formed in the circumstellar envelope. However, only ∼30% of the ∼70 group members and candidates have been confirmed to be binary systems mostly due to a lack of data.

2. Observations

Optical spectroscopic observations of the group prototype FS CMa and MO Cam were obtained with échelle spectrographs (resolving power R ∼12000–65000) at the following telescopes: 3.6 m Canada–France–Hawaii Telescope (CFHT, USA), 2.7 m Harlan J. Smith telescope (McDonald Observatory, USA), 2.1 m telescope of the Observatorio Astronómico Nacional San Pedro Martir (Mexico), 11.4×9.8 m South African Large Telescope, 2 m Himalayan Chandra Telescope (HCT, India), and 0.81 m telescope of the Three College Observatory (USA, FS CMa only). Photometric observations were obtained with a 1 m telescope of the Tien-Shan Astronomical Observatory (Kazakhstan) in BVR filters in 2014–2016. We have also collected V–band light curves from the ASAS SN all-sky survey (Kochanek et al. 2017) for both objects. The latter are shown in Fig. 1 (left panel).

3. The objects description

FS CMa. A peculiar spectrum of FS CMa was discovered over 120 years ago (Pickering et al. 1898) and classified as that of a Be star (Merill et al. 1925). Later a large IR excess due to radiation of circumstellar dust was found, and it became a prototype of objects with the B[e] phenomenon (Allen & Swings 1976). It was also considered a Herbig Ae/Be star (e.g., Sitko et al. 1995), but it belongs to no star forming region. Miroshnichenko (2007) included it in the B[e] subgroup of FS CMa objects, which are thought to be post mass-transfer binary systems. Its binarity has been suspected from spectro-astrometric data (Baines et al. 2006) but unconfirmed by other techniques. FS CMa shows long-term brightness variations, which are large in the visual range (V=6.9–8.8 mag, Miroshnichenko 1998) and much smaller in the near-IR.

MO Cam. The Hα emission in the spectrum of MO Cam (also known as AS 78) was discovered by Merill & Burwell (1933). Its large IR excess was identified in the IRAS data by Dong & Hu (1991). Initial study was done by Miroshnichenko et al. (2000), who detected brightness variations of $\Delta V \sim 0.3$ mag and P Cygni type Balmer line profiles, found the object's spectral type to be B3, and spectroscopically estimated its distance to be ∼2.9 kpc from the Sun.

4. Results

FS CMa shows fast brightness and line profile variations on a timescale of several days. Blue peaks of double-peaked emission-line profiles vary stronger than red peaks indicating an active mass loss from the B–type star. Small emission peaks near the centers of the Balmer lines may arise in the material near the center of mass of the binary (Fig. 1, right panel). Absorption lines of He I have variable positions, which may be due to a variable contribution from the circumstellar disk.

Line profile and brightness variations of MO Cam are not as fast and not as strong as in FS CMa. Absorption components of the P Cyg type profiles in Balmer lines vary in shapes, indicating changes in the velocity of the circumstellar material in front of the B–type star (Fig. 1, right panel).

5. Conclusions

Both photometric and spectroscopic data show that FS CMa is a highly variable object, while variations of MO Cam are much smaller (Fig. 1, left panel). Brightness variations of both objects contain no periodic component. There is no clear evidence for secondary companions in the properties of both objects, but the properties are very unusual for single stars. FS CMa may undergo a strong mass transfer phase, while MO Cam might have already finished this phase. A more frequent monitoring at timescales of days to weeks may help understanding the reasons for the objects' variability. Spectroscopic distances to both objects are consistent GAIA parallaxes (0.62±0.02 kpc for FS CMa and 3.0±0.3 kpc for MO Cam, GAIA DR2, 2018).

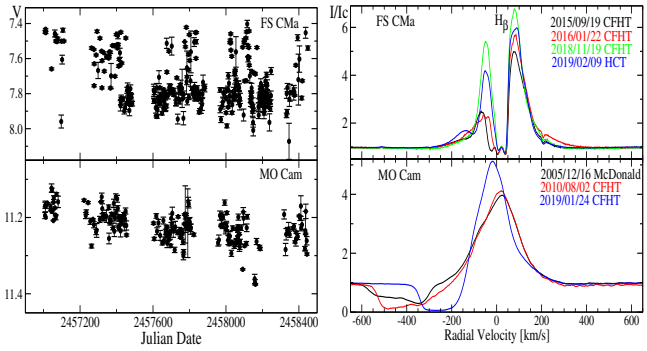

Figure 1: **Left panel.** *V*–band light curves of FS CMa and MO Cam from the ASAS SN survey in 2012–2018 (Kochanek et al. 2017). **Right panel.** Hβ line variations in the objects' spectra. Only high-resolution data from CFHT, McDonald Observatory, and HCT are shown. Intensity normalized to the local continuum is plotted against heliocentric radial velocity.

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