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Mystery of lithium in FS CMa stars*

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Abstract. FS CMa type stars are B-type emission-line stars, whose effective temperatures (from 9 000 to 30 000 K) are too high for neutral lithium with a low ionization threshold of 5.39 eV to exist in their atmospheres. However, about half of stars from the FS CMa group shows the Li I doublet 6708 Å. The presence of lithium lines has been considered a proof of binarity. Here we discuss spectral properties of FS CMa stars that show a slight indication of a possibility that lithium lines may be formed in the circumstellar disk.

Key words. Stars: circumstellar matter – Stars: emission line, Be – Stars: mass loss – Binaries: spectroscopic – Cosmology: observations – Cosmology: primordial nucleosynthesis

1. Introduction

FS CMa stars (Miroshnichenko 2007) are a group of peculiar hot B-type stars named after its prototype, the variable star FS Canis Majoris. The main feature, which distinguishes them from other stars, is forbidden emission lines in their spectra, such as [O I] and [Fe II]. They also have large infrared excesses attributed to the presence of circumstellar dust. Unusually strong Balmer emission of hydrogen is another typical feature of FS CMa stars. For example, the maximum intensity of the Hα

* Based on data from Perek 2 m telescope, Ondřejov, Czech Republic.

Based on observations obtained at the Canada-France-Hawaii Telescope (CFHT) which is operated by the National Research Council of Canada, the Institut National des Sciences de l'Univers of the Centre National de la Recherche Scientique of France, and the University of Hawaii. The observations at the Canada-France-Hawaii Telescope were performed with care and respect from the summit of Maunakea which is a significant cultural and historic site.

Table 1. FS CMa stars with high-resolution spectra

Li I detection

IRAS ID	other ID	6708 Å
00470+6429		1)
03421+2935	MWC 728	2)
07455-3143	AS 174	2)
08307-3748	FX Vel	2)
17175-3757	AS 225	3)
19545+3058	MWC 623	strong 3)
22248+6058	V669 Cep	weak 3)
candidate objects		
20493+4849	AS 446	weak 3)

Li I not detected

IRAS ID	other ID	notes
06259-1301	FS CMa	3)
6491-0654	HD 50138	3)
07370-2438	AS 160	3)
17449+2320	StHa 145	3)
18316-0028	SS 170	3),⋆
20212+3920	MWC 342	3)
22407+6008	MWC 657	3)
candidate objects		
06158+1517	MWC 137	probably a B[e] supergiant 4),5)

(1) Miroshnichenko et al. (2009); (2) Miroshnichenko et al. (2007); (3) Korčáková et al. (2020, in prep.); (4) Kraus et al. (2017); (5) Alimardanova et al. (2017); ⋆ composite spectrum with a cool component – the line identification is not unique.

line can reach hundred times the one in the nearby continuum in some of these stars. In the UV spectral region, their spectra are full of absorption lines of the iron-group elements. This phenomenon called *"iron curtain"* may be responsible for a large number of permitted emission lines of metals in the visible and near-IR spectral regions. All these properties suggest a huge amount of circumstellar matter that extends to a few hundreds of stellar radii.

So much circumstellar material can not be produced by a single intermediate-mass star, which is still located near the main sequence. Since FS CMa stars do not show of being at the post-AGB evolutionary stage, the main hypothesis about the origin of their circumstellar matter has been mass-transfer in a binary system. However, only a small number of binaries have been discovered among the group members. The circumstellar matter, intrinsic variability of a star, as well as a lack of observations complicates the measurements and analysis of radial velocities (RV). The brightness of most group stars is too low for interferometry. Spectroastrometry can be used for fainter stars to prove binarity. However, both methods are better for discovering distant secondaries, which can hardly affect the properties of the primary B-type star. Therefore FS CMa stars remain the last stellar group whose evolutionary status is still unexplained. Lithium can play a crucial role in this enigma.

Neutral lithium should not be present in B-type stars. The temperature range of these stars is too high for the low ionisation threshold of Li I of 5.39 eV. However lithium has been observed in nearly half of FS CMa stars. The presence of Li I lines is therefore taken as a proof of binarity.

2. Observations of Li in FS CMa stars

Only the Li I doublet 6708 Å has been detected in FS CMa stars. The left panel of Table 1 shows the list of stars with detected lithium lines. We also summarise there the stars for which high-resolution and high S/N spectra are at the disposal, however, no lithium lines has been found up to now.

The strongest Li I 6708 Å doublet has been found in the spectrum of MWC 623 (Fig. 1, left panel). The position of this line is about $+10\ \mathrm{km s^{-1}}$ shifted from the position of the [O I] doublet $\lambda\lambda$ 6300, 6364 Å, which is located at about a zero heliocentric RV. The former position corresponds to the RVs of narrow weak absorption lines (Polster et al. 2012), which Zickgraf (2001) determined as a spectrum of a K2Ib-II component. These phenomena really point out to a binary nature of MWC 623. However, note that RVs were almost constant

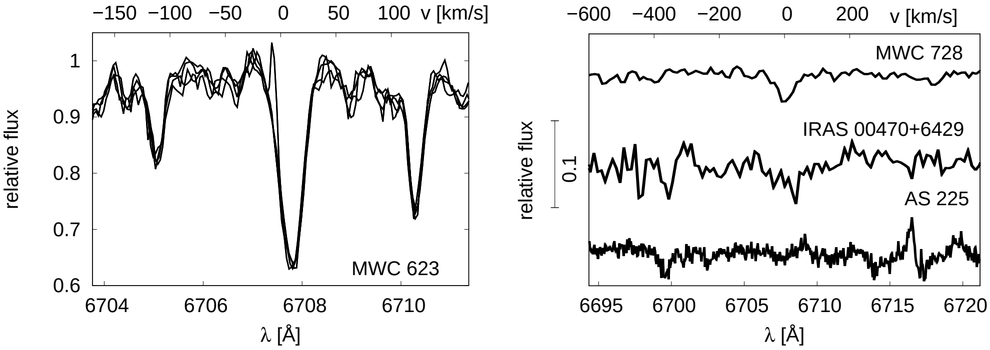

Fig. 1. Li I doublet 6708 Å. The zero velocity corresponds to the position of [O I] doublet $\lambda\lambda$ 6300, 6364 Å. *Left panel:* The strong Li doublet in MWC 623. Plotted ELODIE spectra were taken on 20 November 1994, 11 and 23 August 1995, and 28 July 1996. *Right panel:* Li weak lines. MWC 728 and IRAS 00470+6429 spectrum are a composition of 11, 4 spectra (respectively) from the Ondřejov 2m telescope. AS 225 is ESO/UVES spectrum from 19 April 2009.

during a period of nearly 3 years shown in Fig. 1, because it might be a long-period binary (Polster et al. 2012).

Fig. 1, right panel, shows the Li I 6708 Å doublet in MWC 728, IRAS 00470+6429, and AS 225. Unfortunately, the low S/N do not allow measurements of the line positions in individual spectra of MWC 728 and IRAS 00470+6429, and we can only see the average of 11, and 4 spectra (respectively).

3. Discussion and conclusion remarks

We have seen that the lithium lines in some FS CMa stars come from a cool companion of a B-type primary. However, could there be another explanation for their presence? RVs of the Li I 6708 Å doublet in MWC 623 agree with the RVs of a cool K-type component, which are the same as the bisector RVs of the Hα wings (Polster et al. 2012). The broad Hα emission wings can hardly be formed in a slowly rotating cool star. Modelling of the Hα bisector variability (Polster et al. 2018) suggests a possibility that the absorption component is formed in the circumstellar disk.

There are two other important observed phenomena: *i)* Li lines were always observed in absorption, and *ii)* stars with Li lines have very sharp central absorption in the He I 5876 Å line. In particular, a very sharp absorption in He lines points to the line formation in the pseudo-atmosphere of a circumstellar disk.

If the Li lines are really formed in the circumstellar disk, it offers another way to resolve the lithium problem. Up to now, there have only been two possibilities to determine the primordial Li abundance: old metal-poor dwarfs and interstellar matter (ISM). Both methods suffer from serious problems. Cool stars have convective atmospheres whose description requires 3D convective models. On the other hand, observation of the ISM lithium is very difficult, see the talk of C. Howk at this conference.

Both difficulties could be avoided thanks to FS CMa stars. Radiative transfer calculations in a disk are simpler than those in a convective atmosphere and also observation of these objects is easy to be done. Moreover, the atmospheres of hot stars are not lithium depleted during star formation. Unfortunately, FS CMa stars cannot offer a straightforward answer to the lithium problem, because they belong to the disk population. Therefore the composition of their star-forming clouds has already been changed by the nucleosynthesis in the previous stellar generation. Despite this, observations and analysis of these objects could help with a better description of the lithium story.

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References

Alimardanova, F., Miroshnichenko, A. S., Zharikov, S. V., et al. 2017, in The B[e] Phenomenon: Forty Years of Studies, Miroshnichenko, A. et al. eds. (ASP, San Francisco), ASP Conf. Ser., 508, 355

Kraus, M., Liimets, T., Cappa, C. E., et al. 2017, AJ, 154, 186

Miroshnichenko, A. S. 2007, ApJ, 667, 497

Miroshnichenko, A. S., Chentsov, E. L., Klochkova, V. G., et al. 2009, ApJ, 700, 209

Miroshnichenko, A. S., Manset, N., Kusakin, A. V., et al. 2007, ApJ, 671, 828

Polster, J., Korčáková, D., Votruba, V., et al. 2012, A&A, 542, A57

Polster, J., Korčáková, D., Manset, N. 2018, A&A, 617, A79

Zickgraf, F. J. 2001, A&A, 375, 122