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The nature of FS CMa stars as revealed by host young clusters

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Abstract

The nature and evolutionary state of the diverse objects displaying the B[e] phenomenon are reasonably known, except for a rare subtype named FS CMa stars. These are surrounded by compact disks of warm dust whose origin is unclear. Although the luminosity of these objects corresponds to main-sequence stars, mass loss rates derived from emission lines are 2 orders of magnitude larger than predicted by wind theory. Hitherto, FS CMa stars have been only found in isolation, which hinders the study of their nature. In this contribution, we present the discovery of FS CMa stars in two young Galactic clusters, which host Wolf-Rayet stars and OB supergiants. Membership to these coeval populations allows us to constrain the luminosity, circumstellar extinction and age of FS CMa stars in an unprecedented way. Due to their relatively low brightness when compared with coeval evolved massive stars, a high number of these objects may remain unnoticed in young clusters.

1 Introduction

Among the so-called Be stars (early-type emission-line stars), there is a fraction displaying the B[e] phenomenon, which is defined as the simultaneous presence of forbidden lines of low-ionization metals and a strong infrared excess. As argued by [11], the B[e] phenomenon is shown by objects of diverse evolutionary states, namely: pre-main sequence B[e] stars, B[e] supergiants, symbiotic B[e] stars and compact planetary nebulae. Additionally, these authors established the UnclB[e] (unclassified B[e] stars) subclass in order to include objects of uncertain evolutionary state. Although subsequent research (see e.g. [1]) demonstrated

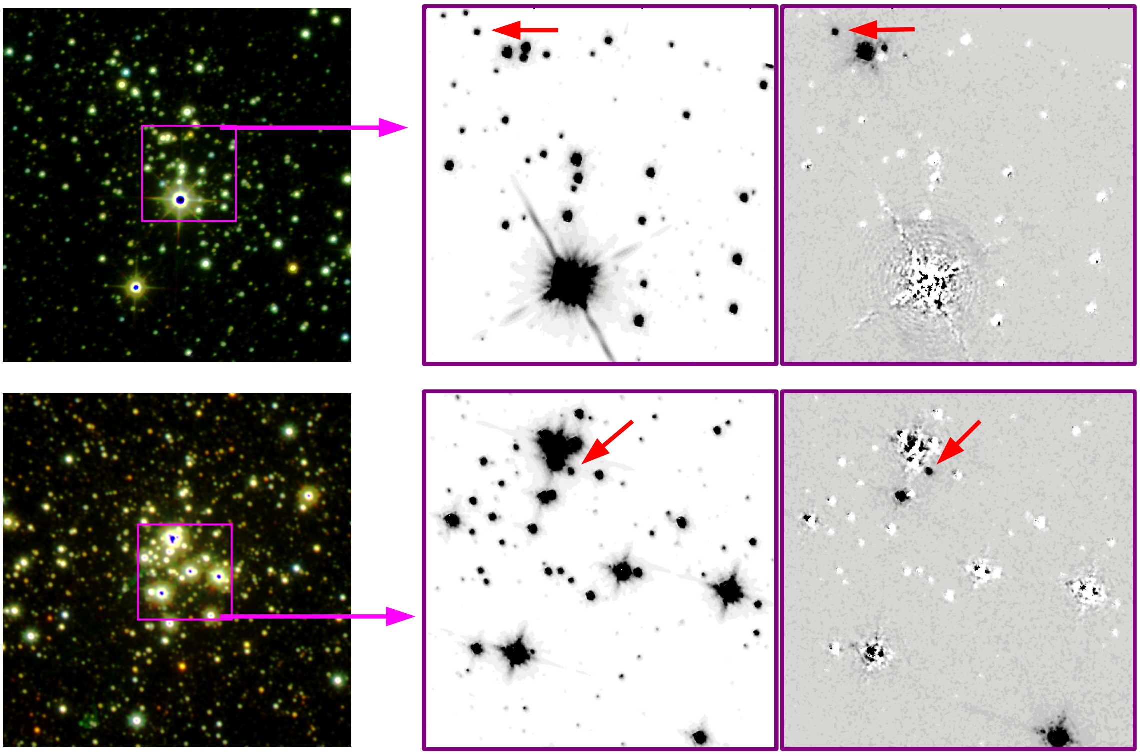

Figure 1: Near-infrared images of Mc20 (top) and Mc70 (bottom), where stars showing the B[e] phenomenon are marked with red arrows. The wide-field views on the left are $2' \times 2'$ RGB (=KHJ) images from the UKIDSS (for Mc20) and VVV (for Mc70) public surveys. The close-up views are the NICMOS/HST observations; the central pannels are F222M images and the right pannels show the F187N − F190N subtraction. For all the images, north is up and east is left.

that several UnclB[e] stars were actually misclassified, part of them turned out to have well-determined specifical features, suggesting that these objects form a separate B[e] subgroup ([14]). The distinguishing features consisted of a sharp decrease of the mid-infrared flux above $\sim 20\mu m$ (indicating the existence of a compact disk of warm dust) and a luminosity range $2.5 \leq log(L/L_{\odot}) \leq 4.5$, which corresponds to the main sequence or slightly above. Extensively studied members of this subgroup (e.g. FS CMa, [10, 5]) also showed rapid, irregular photometric and spectroscopic variability. Taking the aforementioned star as the prototype, [14] named these objects FS CMa stars.

FS CMa stars are very puzzling objects. Derived mass-loss rates of members of this group ([15, 2]) are at least 2 orders of magnitude higher than predicted by wind theory for such low-luminosity stars. Also, the evolutionary state of these rare objects remain unknown, as well as the origin of the circumstellar dusty disk ([16, 2, 17]). Progress on these questions has been hampered by the paucity of confirmed FS CMa stars and the fact that none of them is known to be part of a coeval population.

2 Cluster observations and detection of B[e] objects

Clusters were observed using broad- and narrow-band filters of the NICMOS camera onboard the Hubble Space Telescope (program #11545). These observations were initially aimed at finding hot luminous evolved stars (specifically, Wolf-Rayet stars, Luminous blue variables, and Of supergiants) through their characteristic Paschen-α excess, in the same way as [12, 3]. After subtracting the adjacent continuum (F190N) from the narrow-band filter situated at Paschen-α (F187N), several strong line emitters were highlighted (Fig. 1) in the clusters Mercer 20 and Mercer 70 (hereafter Mc20, Mc70). Surprisingly, two of the strongest line-emission objects (one in each field) appeared significantly fainter at the broad-band images than expected for the aforementioned evolved stars.

Emission-line objects of Mc20 and Mc70, as well as other bright stars, were selected for spectroscopic follow-up. H- and K-band data of the low-luminosity line emitters Mc20-16 and Mc70-14, taken with the ISAAC spectrometer (Very Large Telescope, program ID: 087.D-0957) are shown in Fig. 2. The presence of strong H I and He I lines, along with the absence of He II features, are indicative of early-B spectral types, while the double-peaked emission profiles point at the existence of rotating disks with high inclination angles ([9]). On the other hand, the presence of the B[e] phenomenon in both stars is revealed by forbidden iron lines.

3 Characterization

In this section, we intend to present preliminary results of the study of Mc20-16 and Mc70-14 through the host clusters; details will be thoroughly discussed in a forthcoming paper ([4]).

3.1 The host clusters

Apart from the B[e] stars, these clusters comprise the following spectroscopically confirmed members ([13, 4]).

- Mc20: Two Carbon-rich Wolf-Rayet stars (WC), one yellow supergiant (G0-2 I), and thirteen OB stars.
- Mc70: One WC star, one “Slash” star (Ofpe/WN), and eight OB stars.

These spectral types provide us strong constraints on the ages of the clusters, based on state-of-the-art evolutionary tracks and isochrones ([7, 8]). These age results, along with spectrophotometric distances, radial velocities and average color excesses of the clusters (due to extinction, i.e. excluding stars with suspected circumstellar contribution) are presented in Table 1.

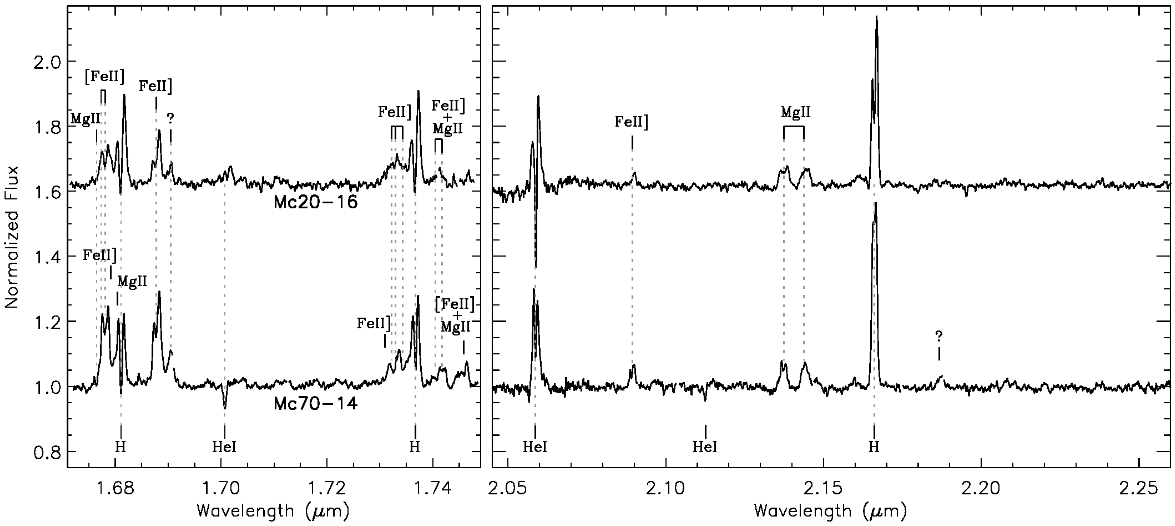

Figure 2: ISAAC/VLT spectra of the newly-discovered B[e] objects.

Table 1: Inferred parameters of the clusters and the FS CMa stars. Distances and ages of FS CMa stars are taken from the corresponding cluster values.

Object	$v_r(km/s)$	$d(kpc)$	Age (Myr)	E(F160W−F222M)
Mercer 20	43 ± 4	8.2 ± 1.3	[5.0, 6.5]	0.93 ± 0.12
Mc20-16	45 ± 6	8.2 ± 1.3	[5.0, 6.5]	1.37 ± 0.05
Mercer 70	-95 ± 6	7.0 ± 0.9	[3.5, 5.4]	0.79 ± 0.16
Mc70-14	-98 ± 11	7.0 ± 0.9	[3.5, 5.4]	1.06 ± 0.05

3.2 FS CMa stars as cluster members

The measured color excesses and radial velocities of the new B[e] objects are also presented in Table 1. The consistency with the radial velocity values of Mc20 and Mc70, along with the locations of Mc20-16 and Mc70-14 in the central regions of the clusters, ensure that these stars are cluster members. Therefore, we can directly apply the distances and ages of the clusters to their B[e] components, assuming coevality. The resulting age range allow us to discard pre- and post-main sequence evolutionary states for these early-B stars. Since the spectra do not show signs of cool evolved companions (which would be the major contributors by far in the K band), these objects cannot be symbiotic B[e] stars. The only remaining possibility is a FS CMa classification for Mc20-16 and Mc70-14.

From the NICMOS K-band photometry ([19, 4]) and the cluster results for interstellar extinction and distance, we obtain the following absolute magnitudes: $M_K^{Mc20-16} = -3.8 \pm 0.5$ and $M_K^{Mc20-16} = -3.4 \pm 0.4$. These results are only corrected for interstellar reddening, however both circumstellar extinction and disk flux are still included, causing additional reddening effects. Although these contributions are hard to separate, comparison of color excesses of these FS CMa stars and the host clusters (see Table 1) allows us to estimate the overall non-stellar contribution; after subtracting it, the final result is $M_K^{stellar} \sim -2.5$ for both underlying stars. Taking the intrinsic colors of early-B stellar types from [6], this is consistent with the luminosity of main-sequence stars ([18]).

4 Conclusions and future work

We have confirmed the presence of FS CMa stars in clusters for the first time. This discovery has led us to constrain some of their properties in an unprecedented way, through the corresponding coeval populations. Specifically, spectrophotometric distances and ages of the clusters have been directly applied to each FS CMa star in order to constrain their luminosities and evolutionary states. As a result, Mc20-16 and Mc70-14 are apparently main-sequence stars surrounded by disks. Additionally, cluster membership has allowed us to separate the circumstellar contribution to the color excess from the interstellar extinction.

Interestingly, the discovery process has been very enlightening in itself. We noticed the unexpected presence of low-luminosity emission-line stars thanks to Paschen-α photometry, which can be only accomplished from space. Otherwise we would not have selected these objects for spectroscopic follow-up, due to their relative faintness. This fact prompt us to argue that Paschen-α photometry could constitute a very effective method for systematical searches of FS CMa stars in young clusters like Mc20 and Mc70. Successful outcome of such searches is crucial to find out how numerous are FS CMa stars in clusters. If Mc20-16 and Mc70-14 are the tip of the iceberg of a hidden population of FS CMa stars, we would wonder if clustered environments are somehow triggering the formation of FS CMa stars. Finally, it is worth to study how much these objects contribute to dust feedback in regions of recent star formation.

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