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The enigmatic open cluster NGC 7419*

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Abstract: We determine the distance and the age of the open cluster NGC 7419 using accurate photometry and spectroscopy. We analyze spectra for a great number of members; concluding that NGC 7419 has one of the highest Be fractions among Galactic open clusters. We also confirm that the cluster contains five red supergiants but there are no blue supergiants. Both effects may be related to fast rotation, but high Be content and high RSG content do not always go together.

1 Introduction

The heavily reddened young open cluster NGC 7419 could hold the key to our understanding of the effects of rotation on the evolution of massive stars, as it is claimed to present several unusual characteristics.

Based on photometric searching techniques, Pigulski & Kopacki (2000) determined a Be fraction of $36 \pm 7\%$, which would be the highest for any Galactic open cluster. In addition, the cluster contains five red supergiants (Beauchamp, Moffat & Drissen 1994), though no blue object looks bright enough to be a supergiant. The red to blue supergiant ratio of $5/0$ is very different from expectations from current theoretical models and the observed ratios in other Galactic clusters. The very high fraction of Be stars and extremely low ratio of blue to red supergiants are predicted by current theoretical models to occur only in very low metallicity environments. Three previous photometric studies of NGC 7419 have used UBV photometry. The U magnitudes show average differences of several tenths of magnitude between the different works, rendering the parameters determined very insecure.

Here, we present Strömgren photometry and multi-epoch spectroscopy of NGC 7419. We are able to confirm the extremely high fraction of Be stars and the absence of any blue supergiant. Our extended dataset, which includes for the first time accurate spectral types for the brightest members, will allow a better determination of the extinction law and cluster parameters.

2 Observations

Observations of NGC 7419 were conducted with the 2.6-m Nordic Optical Telescope (La Palma, Spain), on 2004 October 2^{nd} to 4^{th} (poor weather), and again on 2005 October 3^{rd} to 5^{th} (photometric weather). The telescope was equipped with the imager and spectrograph ALFOSC. We obtained

*Partially based on observations collected at the Nordic Optical Telescope and the William Herschel Telesope (La Palma, Spain) and at the 1.93-m telescope at Haut Provence Observatory (France)

uvby observations of the cluster with a field of view of $6.3\,' \times 6.3\,'$ and secondary stars in several open clusters (Marco & Bernabeu 2001). We also took intermediate resolution spectra of the brightest early-type cluster members with ALFOSC grism #16 and low resolution spectra of other objects with grisms #7 and #14. We also obtained slitless spectroscopy of the field, by combining the low resolution grism #4 with the Bessell *R*-band filter. Slitless fields were taken at three different orientations, in order to minimise source overlapping. These observations were complemented by low resolution spectroscopy of some of the brightest Be candidates taken in July 2001 with the 1.93-m telescope at Haute Provence Observatory (France) and the Carelec spectrograph, and spectra of the red supergiants taken with William Herschel Telescope and ISIS. A preliminary report on the observations from 2001 and 2004 was presented in Negueruela et al. (2007).

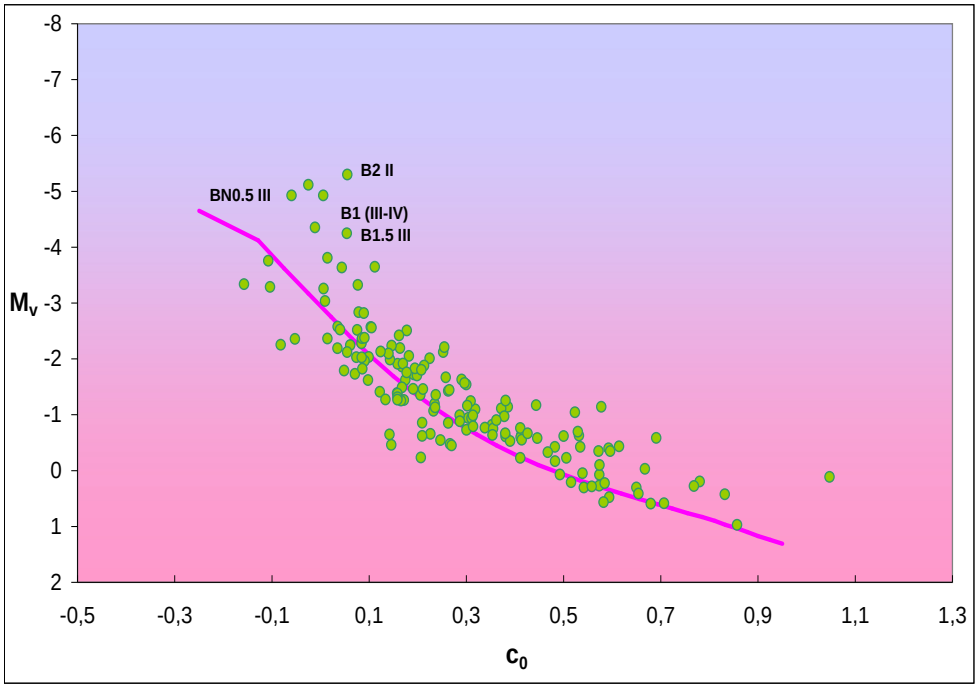

Figure 1: Observational HR diagram for the open cluster NGC 7419 based on our Strömgren photometry.

3 Results

We have carried a complete photometric and spectroscopic study of the open cluster NGC 7419. We have used Strömgren photometry for building the HR diagram. The use of this photometry which allows a more accurate determination of the parameters of the cluster, has never been tried at high reddenings. In spite of the $A_V \approx 5$ for NGC 7419, the transformation to the standard system seems to have worked. The M_V/c_0 diagram (Figure1) shows the expected shape and values. There is very good agreement between spectral types and position in the HR diagram. Objects close to the main-sequence turn-off have spectral types B1IV-V, suggesting an age in the $10-15$ Myr range. This is also

in good agreement with the determination of 14 ± 2 Myr by Beauchamp et al. (1994). The spectral types, however, are too early for the age of 22.5 ± 3.0 Myr given by Joshi et al. (2008). The fit of the ZAMS to our data gives a value of the distance modulus of 13.0 ± 0.2. In Figure 2 we display spectra of the brightest blue cluster members. The spectral types are in rather good agreement with those estimated by Caron et al. (2003) from *I*-band spectra. The most luminous stars have spectral types B2 II and BN0.5 III (this is likely a blue straggler).

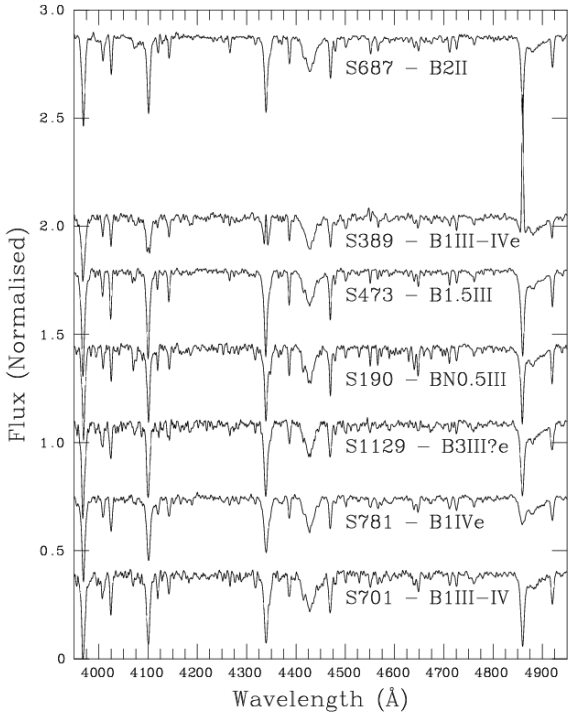

Figure 2: Classification spectra of the brightest blue cluster members. Nomenclature is taken from Beauchamp et al. (1994).

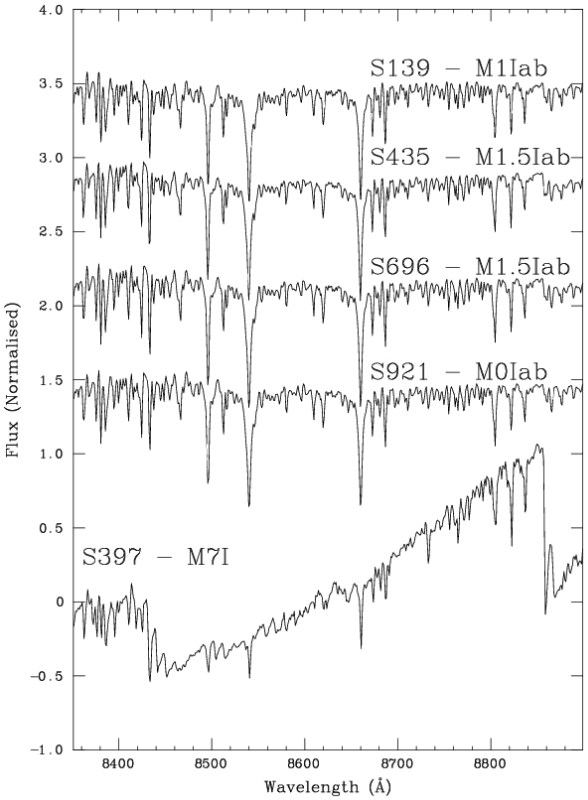

Figure 3: Spectra of the five red supergiants in NGC 7419, in the region of the Ca II triplet.

These values confirm that there are no blue supergiants in NGC 7419. Given the small number of blue stars above the main sequence turn-off, the presence of 5 red supergiants (Figure 3) represents a puzzle for evolutionary models, as the RSG phase is believed to be short.

We have detected 18 Be stars in NGC 7419. Among the photometric candidates of Pigulski & Kopacki (2000), we observe definitely in absorption two Be stars (one of them was losing its envelope in 2001). For the faintest candidates, we cannot confirm nor dismiss their Be status. These results confirm that NGC 7419 has one of the highest Be fractions among Galactic open clusters. We detect clear variability in the emission characteristics of several Be stars. In Figure 4, we show the spectra taken in different epochs for one Be star. This variability confirms that these objects are classical Be stars and not Herbig Be stars, as speculated by Subramaniam et al. (2006).

NGC 7419 is definitively younger ($10 - 15$ Myr) than the other two well known Be-rich clusters in the Galaxy, NGC 663 and NGC 3766, which are both 25 Myr old.

Several spectra seem to show evidence of nitrogen enhancement. This could be related to fast rotation. Unfortunately, our spectra lack resolution for model atmosphere fits and abundance determination. The high Be fraction may also be related to fast rotation. However, high Be content and high RSG content do not always go together. NGC 663 has five blue supergiants and no RSGs in its core.

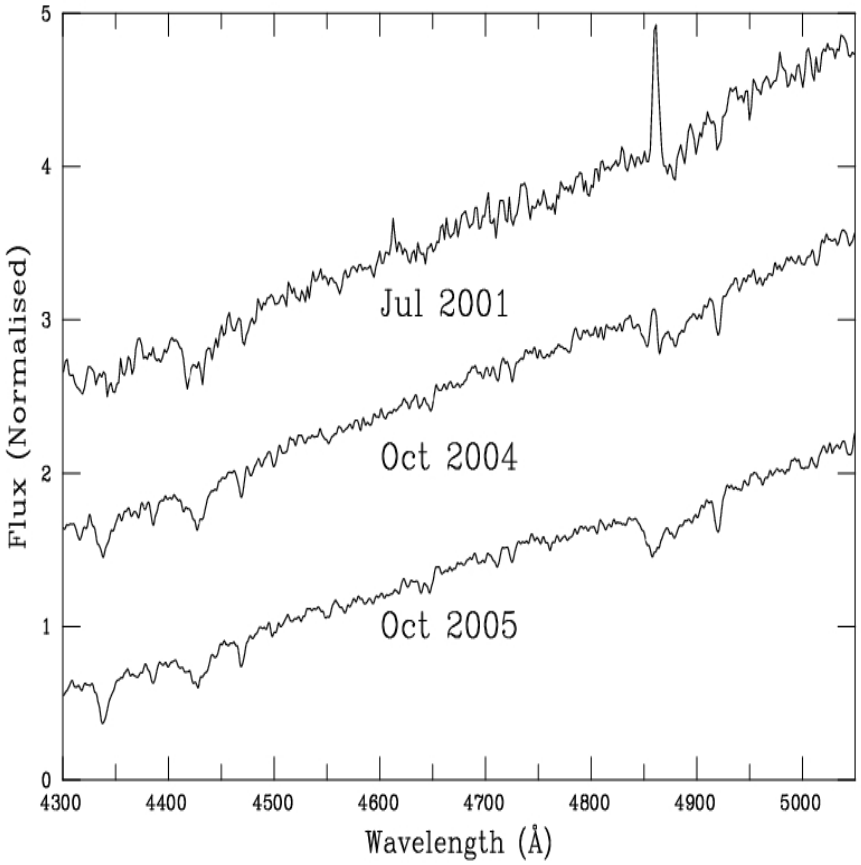

Figure 4: Spectra of the Be star S781 taken at different epochs and showing the progressive disappearence of emission characteristics.

Acknowledgements

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