

NGC 7419: An open cluster rich in Be stars

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Abstract. The results of our CCD photometric H α observations of NGC 7419 are presented. The observations resulted in a discovery of 17 new Be stars and two other emission-line objects. In consequence, the number of known Be stars in this young cluster increased more than twofold and equals now to 31. This is at present the largest number of Be stars known in any galactic open cluster. Moreover, we estimate that these 31 Be stars constitute $36 \pm 7\%$ of all cluster B-type stars brighter than $R_C = 16.1$ mag. This locates NGC 7419 among these open clusters which are richest in Be stars such as galactic NGC 663, NGC 330 in SMC, and NGC 1818A in LMC.

Key words: stars: emission-line, Be — open clusters and associations: individual: NGC 7419

1. Introduction

In a debate on the fraction of Be stars in young open clusters it is often forgotten that, in fact, a relatively small number of clusters has been deeply searched for the presence of Be stars. The objective-prism spectroscopic surveys which led to the discovery of the most of known Be stars are magnitude-limited and ineffective in crowded regions. In consequence, our knowledge of Be star fraction in clusters is usually confined to the brightest, that is, the early B-type stars. It is therefore possible that clusters with large number of Be stars could still be discovered. The use of CCD detectors and the H α filters opens a convenient way to fill in this gap, allowing both the crowded-field photometry and the detection of H α emission even in late B-type stars. With a moderate-size telescope even Magallanic Clouds clusters are within reach (Grebel 1997; Keller et al. 1999).

Among the galactic open clusters there are three that are usually mentioned as those which contain large number of Be stars. These are χ Persei, NGC 3766, and

NGC 663 (Mermilliod 1982; Slettebak 1985). Of these, NGC 663 is the richest in Be stars since about 35% of its B stars show H α emission (Maeder et al. 1999). In the percentage of Be stars, NGC 663 is surpassed only by such Magallanic Clouds clusters as NGC 330 and NGC 1818A (Keller et al. 1999).

In the present paper we report results of our CCD H α photometry of the highly reddened galactic cluster NGC 7419. We find in the cluster a large number of previously unknown Be stars.

2. Observations and reductions

All photometric observations of NGC 7419 were carried out at the Białków Observatory of the Wrocław University using the 60-cm reflecting telescope equipped with a 576×384 pixels CCD camera covering a $6' \times 4'$ field of view. In order to detect emission in the H α line, we used two interference filters centred on this line with the full width at half maximum of 20 and 3 nm for wide and narrow H α filter, respectively.

The H α observations of NGC 7419 were carried out on a single night of November 15, 1999. We took 11 frames in the wide H α filter and 8 frames in the narrow one with the total integration time of 6 600 and 18 500 s, respectively. The H α observations were supplemented by observations of the same field through Cousins R_C and I_C filters made on November 15, 1999 (R_C , a single 600-s frame) and September 17, 1999 and January 6, 2000 (I_C , twenty 120-s frames). These observations were transformed to the standard system using the photometry of Bhatt et al. (1993), tied to the Landolt (1983) standards. We do not give here the details of transformations and present the photometry in the graphical form only. They are, however, available from the authors upon request. The resulting colour-magnitude diagram (CMD) shown in Fig. 4 is used for distinguishing some of the non-members. All stars which were detected both in the R_C and I_C -filter frames are shown in Fig. 1.

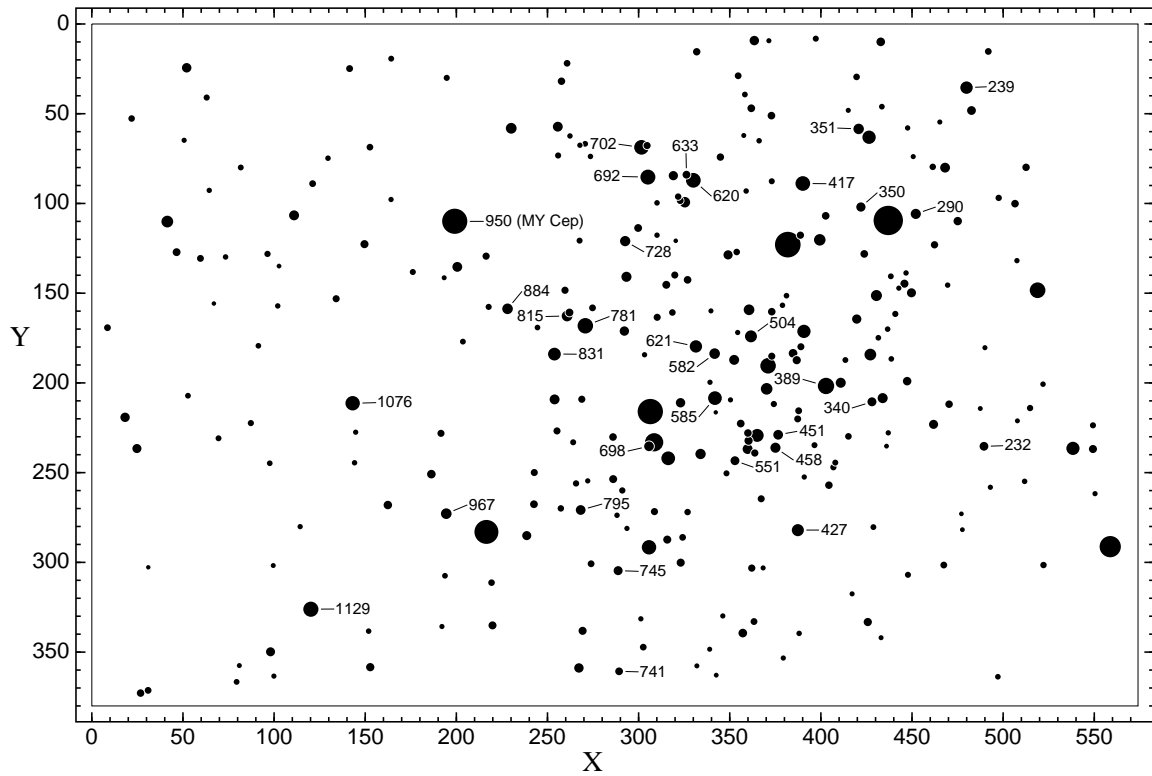


Fig. 1. Schematic view of our $6' \times 4'$ field in NGC 7419. The diameters of the circles were chosen to resemble the cluster appearance as seen through the R_C filter. All emission-line objects listed in Table 1 are labeled with numbers from B94. North is up, east to the left

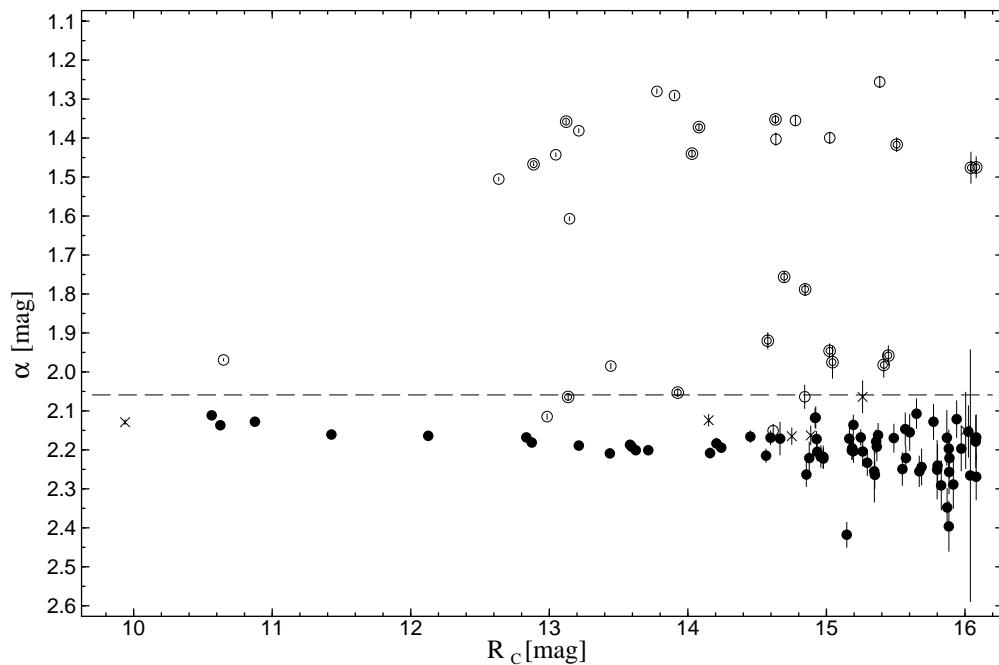


Fig. 2. The α index (in mag) for 107 stars brighter than $R_C = 16.1$ mag, plotted as a function of R_C . Non-members are shown with crosses, cluster members showing $H\alpha$ emission, with open circles (the circles are double for new Be stars), remaining stars, with filled circles. The dashed line corresponds to the expected value of α for zero equivalent width of the $H\alpha$ line

Table 1. Stars in NGC 7419 showing H α emission. The columns are: (1): Beauchamp et al. (1994) number, (2): Bhatt et al. (1993) number, E precedes the number of a star in the eastern region of the cluster, W, a star in the western region, (3): Kohoutek & Wehmeyer (1997) number, (4) and (5): X and Y coordinate in Fig. 1, (6): right ascension (epoch 2000.0, in hours, minutes, and seconds), (7): declination (epoch 2000.0, in degrees, arcmin and arcsec), (8): R_C magnitude (in mag), (9): $(R - I)_C$ colour index (in mag), (10): α index (in mag), (11): remarks

BMD	BPMM	HBH	X	Y	Right Asc.	Decl.	R_C	$(R - I)_C$	α	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
232	W12	—	489.5	235.4	22 54 07.10	+60 48 17.3	15.51	1.33	1.417 \pm 0.019	new
239	W14	6206-14	479.9	35.5	22 54 07.55	+60 50 22.7	13.90	1.31	1.291 \pm 0.008	
290	W23	—	452.0	105.8	22 54 10.05	+60 49 38.9	14.84	1.18	2.064 \pm 0.031	D 22-117:
340	W33	—	428.1	210.6	22 54 12.29	+60 48 33.6	15.41	1.20	1.982 \pm 0.033	new
351	W37	—	420.8	58.5	22 54 12.63	+60 50 09.0	14.70	1.15	1.756 \pm 0.015	new
389	W45	6206-13	402.8	201.7	22 54 14.42	+60 48 39.5	12.64	1.14	1.505 \pm 0.005	B1-2 I:e (B94)
417	—	—	390.1	88.9	22 54 15.30	+60 49 50.4	13.14	1.06	2.064 \pm 0.008	new
427	W54	—	387.4	282.0	22 54 15.89	+60 47 49.4	14.03	1.23	1.440 \pm 0.008	new
451	W58	—	376.6	228.9	22 54 16.71	+60 48 22.8	15.02	1.08	1.946 \pm 0.019	new
458	W60	—	375.0	236.1	22 54 16.85	+60 48 18.3	14.85	1.12	1.788 \pm 0.016	new
504	E10	—	361.6	174.0	22 54 17.88	+60 48 57.4	14.08	1.11	1.372 \pm 0.008	new
551	E20	—	352.9	243.3	22 54 18.75	+60 48 14.1	15.45	1.08	1.958 \pm 0.026	new
582	E25	—	341.7	183.7	22 54 19.59	+60 48 51.6	14.63	1.02	1.352 \pm 0.011	new
585	E26	6206-12	341.9	208.4	22 54 19.62	+60 48 36.1	13.44	1.02	1.985 \pm 0.008	
620	E30	—	330.1	87.1	22 54 20.41	+60 49 52.3	13.12	1.14	1.358 \pm 0.006	new
621	E31	—	331.4	179.7	22 54 20.46	+60 48 54.3	13.93	1.12	2.053 \pm 0.010	new
633	—	—	326.3	84.0	22 54 20.73	+60 49 54.3	16.04	1.10	1.476 \pm 0.041	new
692	E50	6206-11	305.1	85.3	22 54 22.54	+60 49 53.7	13.05	1.15	1.443 \pm 0.006	
698	—	—	305.7	235.3	22 54 22.76	+60 48 19.7	15.04	1.04	1.975 \pm 0.042	new
702	E53	6206-18	301.6	68.8	22 54 22.81	+60 50 04.1	13.15	1.13	1.607 \pm 0.006	
728	E57	6206-15	292.6	121.0	22 54 23.67	+60 49 31.5	14.78	1.01	1.355 \pm 0.013	
741	—	—	289.3	360.7	22 54 24.37	+60 47 01.3	16.08	1.21	1.475 \pm 0.028	new
745	E61	6206-10	288.7	304.6	22 54 24.32	+60 47 36.5	15.39	1.18	1.256 \pm 0.014	
781	E68	—	270.8	168.2	22 54 25.61	+60 49 02.3	12.89	1.09	1.467 \pm 0.005	new, B1-2 I: (B94)
795	E71	6206-09	268.3	270.9	22 54 26.01	+60 47 57.9	15.02	1.17	1.399 \pm 0.015	
815	E75	—	260.7	162.7	22 54 26.46	+60 49 05.8	14.58	1.02	1.920 \pm 0.022	new
831	E82	6206-08	253.8	183.9	22 54 27.08	+60 48 52.6	13.78	1.03	1.280 \pm 0.007	
884	E90	6206-07	228.1	158.8	22 54 29.24	+60 49 08.7	14.64	1.07	1.403 \pm 0.017	
967	E100	6206-16	194.5	272.9	22 54 32.30	+60 47 57.6	14.62	1.07	2.151 \pm 0.018	
1076	—	6206-17	143.1	211.4	22 54 36.56	+60 48 36.9	13.21	1.15	1.381 \pm 0.006	D 22-124
1129	—	—	120.2	326.1	22 54 38.72	+60 47 25.3	12.98	1.06	2.115 \pm 0.008	D 22-125
950	E96	—	199.1	110.0	22 54 31.62	+60 49 39.7	10.65	2.95	1.969 \pm 0.004	MY Cep
350	W36	—	422.0	101.9	22 54 12.60	+60 49 41.8	15.26	1.73	2.064 \pm 0.042	non-member

3. The cluster

NGC 7419 (C 2252+605) is a small, young open cluster in Cepheus, known mainly for its five M-type supergiants (Blanco et al. 1955; Fawley & Cohen 1974; Beauchamp et al. 1994, henceforth B94). The coolest of them is MY Cephei = IRAS 22525+6033, an Lb or SRc-type variable of spectral type M7.5 I, known also to be an H₂O maser (Dickinson et al. 1978) and an OH/IR source (Alcolea et al. 1990). The age of NGC 7419 was estimated by Bhatt et al. (1993) as smaller than 40 Myr, while B94 derived that it is equal to 14 ± 2 Myr. The average reddening, in terms of $E(B - V)$, amounts to about 2.0 mag, but a differential effect of the order of 0.4 mag is also

observed (B94). The average total absorption in the V band, as estimated by the same authors, amounts to about 6.7 mag.

4. Be stars in NGC 7419

The first two Be stars in NGC 7419 were discovered by González & González (1956) and designated in their list as stars Nos. 112 and 113. Dolidze (1959) increased this number to seven. These seven stars appear also in his later compilation (Dolidze 1975). Unfortunately, finding charts in the above-mentioned papers are not detailed enough, so that only two out of the seven stars, D 22-124 and D 22-125 (Dolidze 1975), can be unambiguously identified.

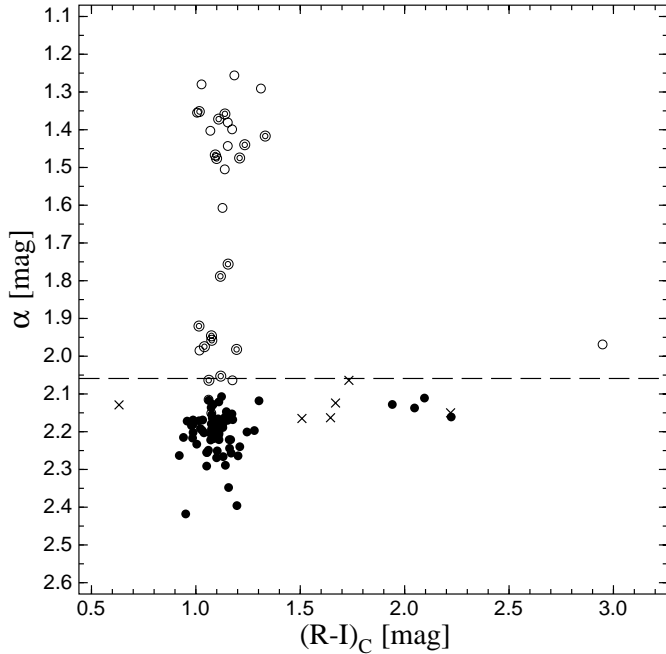


Fig. 3. The same as in Fig. 2 but plotted as a function of $(R - I)_C$ colour. Symbols and the dashed line have the same meaning as in Fig. 2. For clarity, the error bars were omitted here

B94 found emission in one of the five brightest blue members, BMD 389 (we shall use the numbering system of B94 preceding their number by “BMD”). Recently, Kohoutek & Wehmeyer (1997) detected 12 Be stars in the cluster, but list also two others. Altogether, 14 Be stars were known in NGC 7419 prior to our study.

Our discovery of stars showing emission in $H\alpha$ line was made by means of the α index defined by two $H\alpha$ filters described in Sect. 2, in analogy to the well-known photometric β index, namely:

$$\alpha = m_{\text{narrow}} - m_{\text{wide}} + C, \quad (1)$$

where m_{narrow} and m_{wide} denote the magnitude of a star as seen through the narrow and wide $H\alpha$ filter, respectively. The constant C takes into account the differences in the exposure times and differences in zero points between frames.

The α index is shown in Fig. 2 for 107 brightest stars in the field down to magnitude $R_C = 16.1$. Only one of the previously known 14 Be stars, BMD 967 = HBH 6206-16, shows no or only weak emission. A weakening of the emission was observed in many Be stars, and this could be such a case. Remaining 13 stars stand clearly above the sequence of non-emission stars (see Fig. 2). In order to be able better recognize emission stars, especially those of late type, the α index was also plotted as a function of colour index $(R - I)_C$ (Fig. 3).

In addition to the 14 emission-line objects in NGC 7419 listed by Kohoutek & Wehmeyer (1997), 19 stars showing emission were found. Out of them, two are of late type.

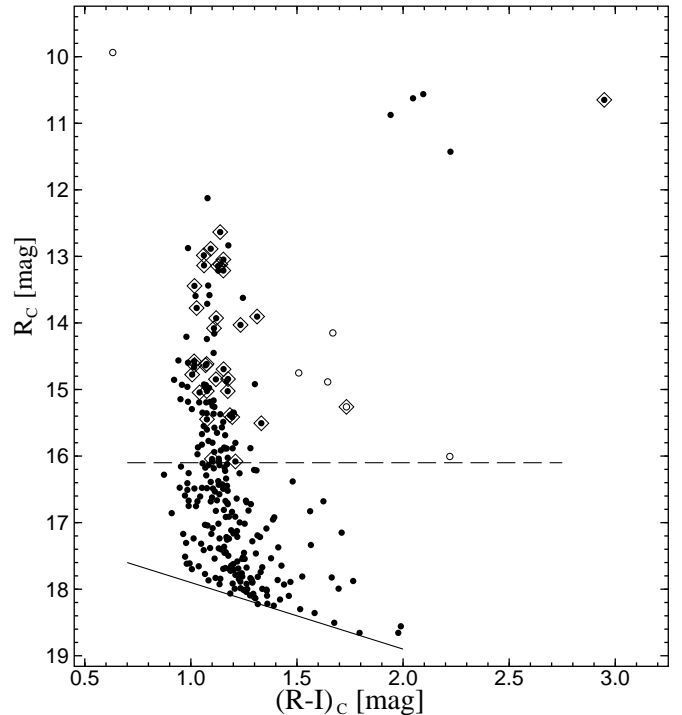


Fig. 4. CMD for NGC 7419. Open circles denote stars brighter than $R_C = 16.1$ mag which are too red or too blue to be members. Diamonds are used to indicate the emission-line objects. The solid line shows the limit of our $(RI)_C$ photometry while the dashed one, that of the $H\alpha$ photometry

The first one is MY Cep = BMD 950 mentioned in Sect. 3. The other one, BMD 350, probably also of late type, is not a member as can be judged from its position in the cluster CMD (Fig. 4). Thus, there are now 31 stars in the observed field which are very likely cluster Be stars.

The data for all 33 stars in the observed field showing $H\alpha$ emission are given in Table 1. The typical error of R_C magnitude given in Table 1 equals to 0.004 and 0.011 mag for a star with $R_C = 13$ and 16 mag, respectively. The corresponding errors of colour indexes for such stars are 0.007 and 0.035 mag. The coordinates of stars were derived using the positions of 10 stars in the field from the NASA Guide Star Catalog, v. 1.1. They are accurate to within $0.5''$.

As can be seen in the cluster CMD (Fig. 4), the Be stars are 0.1 – 0.2 mag redder in $(R - I)_C$ than non-emission stars of the same magnitude. This is a well-known effect observed in many open clusters with Be stars.

5. Fraction of Be stars

Maeder et al. (1999) compare fractions of Be stars in clusters of similar age in three different intervals of M_V . The widest interval, $-5 < M_V < -1.4$, includes all stars of type B3 and earlier. Taking $V - M_V = 18.5$ mag for NGC 7419 (B94) and adopting average $V - R_C \approx 1.0$ mag

for the cluster upper main-sequence estimated from photometry of Bhatt et al. (1993), we find that this interval of M_V corresponds roughly to $12.5 < R_C < 16.1$. There are 100 stars in our field falling within this interval, of which 31 are Be stars. It is rather unlikely that any of the Be stars is a non-member, but the total number of stars in the interval is certainly affected by contamination by field stars.

In order to estimate the number of field stars in the above-mentioned interval of R_C , four fields, situated about $7'$ north, east, south and west of the cluster were observed on June 8, 2000 through the R_C and I_C filters. In total, 52 stars having $12.5 < R_C < 16.1$ were found in these fields. Hence, in the vicinity of NGC 7419 there are $52/4 = 13$ stars in this interval and in a $6' \times 4'$ field of view. All of them are probably foreground and/or background stars, because at a distance of $7'$ from the centre of NGC 7419 the percentage of cluster stars is negligible. The final estimate of the fraction of Be stars in NGC 7419 is therefore $31/(100 - 13) \approx 36 \pm 7\%$, where the error was calculated assuming Poisson statistics. If we split the above interval into two parts, i.e. $12.5 < R_C < 14.3$ and $14.3 < R_C < 16.1$, the fractions of Be stars are equal to $61 \pm 21\%$ and $27 \pm 7\%$, respectively.

We note that owing to the intermittency of the Be phenomenon and the fact that weak emission cannot be detected photometrically, the above estimated fraction of Be stars in NGC 7419 represents a lower limit. Since the age of NGC 7419 is similar to the ages of clusters investigated by Maeder et al. (1999), the fraction of Be stars we derived can be directly compared with their numbers. This comparison locates NGC 7419 among the clusters with largest known

fractions of Be stars, such as the galactic NGC 663 ($34 \pm 11\%$), NGC 330 in SMC ($39 \pm 7\%$), and NGC 1818A in LMC ($36 \pm 7\%$).

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