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On the normal helium abundance in globular cluster stars

A. N. Gerashchenko, Z. I. Kadla, N. V. Yablokova

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Address: Sternberg, State Astronomical Institute, USSR Academy of Sciences, Moscow, USSR

Thanks to the observations (Greenstein and Munch, 1966; Sargent, 1967; Rogers, 1972) there is a prevailing opinion among astronomers that the atmospheres of horizontal-branch (HB) stars in globular clusters — representatives of the oldest population in the Galaxy — have a considerable helium deficiency. At the same time, from the theory of stellar evolution and stellar pulsations it follows that the helium abundance in the atmospheres of these stars does not differ from that of the Sun. Besides, the residual background emission is interpreted as a proof of a high initial helium abundance. Therefore, to explain the helium deficiency in the atmospheres of the HB stars, the theory of gravity segregation of elements (Greenstein et al., 1967) was proposed.

The low brightness even of the brightest members of globular clusters, the red giants and, still more, that of the horizontal-branch stars imposes a strong restriction on the possibilities of obtaining a great number of high-quality spectroscopic data. This explains the fact that till now the spectra of only 10 HB stars in globular clusters have been obtained. Table 1 lists the observations of HB stars in globular clusters in whose spectra He lines have been searched for. The first two columns contain the names of the globular clusters and the stars in them. The next two columns list the different values of the stellar magnitudes and colour indices of the stars. The fifth column lists the colour excess used by the author of the paper where the helium abundance is estimated and the last column contains the references. The sixth column lists the colour excess according to the Catalogue of Globular Clusters (Alkaino, 1979). Here attention should be paid on the non-homogeneity of the data for the colours and the colour excesses adopted by the different authors. The column before the last shows the dispersions of the spectrograms. It is obvious from the table that the major part of the spectra have been obtained at low enough dispersions where the most intensive He I 4026 and 4471 Å lines are observed.

Table 1

Cluster NGC M	Star	V	B-V	E_{B-V}	E_{B-V}	Dispers-ion, Å/mm	Reference
	1403	15^{m}42	0^{m}09				
		15,45	0,14				
5139				0^{m}11	0^{m}10	100	Rogers, 1972
	1853	15,51	0,01				
		16,63	—0,01				
5904 M5	I-6	16,06	—0,25	0,00	0,03	190	Greenstein and Munch, 1966
6205	II-25	15,82	—0,16	0,09	0,02	200	Sargent, 1967
M13	AJ 63	16,48	—0,19	0,00		190	Greenstein and Munch, 1966
6341	II-40	15,86	—0,08	0,00	0,03	190	Greenstein and Munch, 1966
M92	III-27	16,15	—0,12	0,00		200	Sargent, 1967
	661	13,35	—0,03	0,10		86	Sargent and Searle, 1968
6397		13,36	0,18	0,20		140, 180	Newell et al., 1969
	659	13,96	0,07	0,20	0,11	140,180	Newell et al., 1969
7078 M15	I-70	16,84	—0,09	0,12	0,08	200	Sargent, 1967

In all these papers the estimate of the helium abundance is based on a qualitative comparison of the intensity of the helium lines in the spectra of HB stars in globular clusters and of stars of Population I. In stars of Population I these lines are found at dispersions shown in Table 1 only in spectra of stars later than B5, that is when $(B\text{-}V)_0 \leqslant -0^m,16$. From this point of view the only stars from Table 1 where the He lines are to be searched for and by the intensities of which it would be possible to judge on the helium abundance are the stars in the clusters M5, M13 and M15. With reference to the star in M5 it must be noted that the indicated colour is probably incorrect because of incorrect reduction of the magnitudes m_{pg} and m_{pv} in the B, V system.

According to Geenstein et al. (1966) and Sargent (1967), the He lines in the stars in the globular cluster M13 II-25 and AJ63, though present, are very weak and the helium abundance estimated with regard to their intensity is 1/5÷1/10 from that of the Sun.

For a more detailed study of the problem, the observational programme on the 6-m telescope involved globular cluster stars of $(B\text{-}V)_0 < -0^m,10$, stars from Table 1 and stars above the horizontal branch which, according to Stoeckly and Greenstein (1968), Strom and Strom (1970), have a normal helium abundance (Table 2). In Table 2 the photoelectrically determined stellar magnitudes and colours are listed for all the stars except for II-25 (M13). For the last star, the U and B magnitudes are determined by the authors of this communication by plates taken on the 6-m telescope.

The stars II-57, II-25, B29 and III-27 are members of the respective clusters in terms of the criterion of radial velocities. The stars AJ110 and II-40 are probably also members of the cluster since the line shift in their spectra is similar to that in stars in the respective clusters with known radial velocity.

The spectra of the stars were obtained with the 500-channel photon counter in combination with the UAGS fast spectrograph in the range of 3900-4400 and 4400-4900 Å. The spectral resolution was 2,5 Å for all the stars except for AJ110 where it was 3,5 Å. Besides, the spectrum of the latter star was obtained in the range of 3900-4400 Å only, and its quality is not very high. The methods of obser-

Table 2

Cluster	Star	V	$(B-V)_0$	$(U-V)_0$	V_r	Δt, min
M3	II-57	14^m93	-0^m30	-1^m41	—153	40
	B 29	12,98	—0,16	—1,02	—244	60
M13	AJ 110	17,33	—0,22	—1,00	—	60
	II-25	15,82	—0,18	—0,76	—244	40
M92	III-27	16,15	—0,15	—0,52	—104	90
	II-40	15,86	—0,11	—0,41	—	60

vations and processing are analogous to those employed at the Special Astrophysical Observatory of the USSR Academy of Sciences (N e b e l i t s k y et al., 1983).

For the investigated HB stars the parameters of the atmospheres T_e and g were found by comparing the measured widths of the H_γ and H_δ hydrogen lines for a given level with Kurucz's models (K u r u c z, 1979). The T_e and g thus obtained are in good agreement with the parameters determined by the empirical dependences (Table 3), in particular with the T_e values obtained by the dependences (θ_e, Q) where $\theta_e=5040/T_e$ and $Q=(U-B) - 0{,}72\ (B-V)$ for Population I (S c h i l d et al., 1971). We have therefore the right to compare the He line intensities in globular cluster stars and in Population I stars of one and the same colour.

Fig. 1 illustrates the spectra of all the stars from Table 2 in the spectral range of 3900-4400 Å. The He lines are absent in the cluster M92 but they can be observed in the hotter stars in M13. The measured equivalent widths of the 4026 and 4471 Å He lines in the spectra of globular cluster stars are listed in Table 4. The equivalent widths of the He lines in the spectra of the stars of the same colour of the luminosity class by data of K o p y l o v (1958, 1960) are also given in the table. On our spectra only lines with $W>0{,}60$ Å are definitely identified by the line intensity in the stars B29 (M13) and II-57 (M3) (S t o e c k l y and G r e e n s t e i n, 1968; S t r o m and S t r o m, 1970). As can be seen from Table 4, the absence of

Table 3

Cluster M	Star	θ_e		log g	
		H	Q	H	$g\theta_e^4=C$ (N e w e l l et al., 1969)
M13	AJ110	0,245	0,26	4,6	4,5
	II-25	0,33	0,32	3,8	4,1
M92	III-27	0,39	0,39	3,8	3,8
	II-40	0,43	0,42	3,5	3,7

Table 4

Cluster M	Star	$(U-V)_0$	W_{4026}		W_{4471}	
			Cluster	Population I	Cluster	Population I
M13	AJ 110	-1^m00	1,1	1,3	—	—
	II-25	—0,76	1,0	1,1	0,9	1,0
M92	III-27	—0,52	0,6	0,6	0,6	0,6
	II-40	—0,41	0,6	0,4	0,6	0,3

He lines in the spectra of the stars in the cluster M92 is the reason not to speak of deficiency in the atmospheres of these stars. The indefiniteness of the mean values of the equivalent widths by data of K o p y l o v (1958, 1960) is of the order of 0,2 Å. The intensities of the He lines in the stars in M13 are within the errors

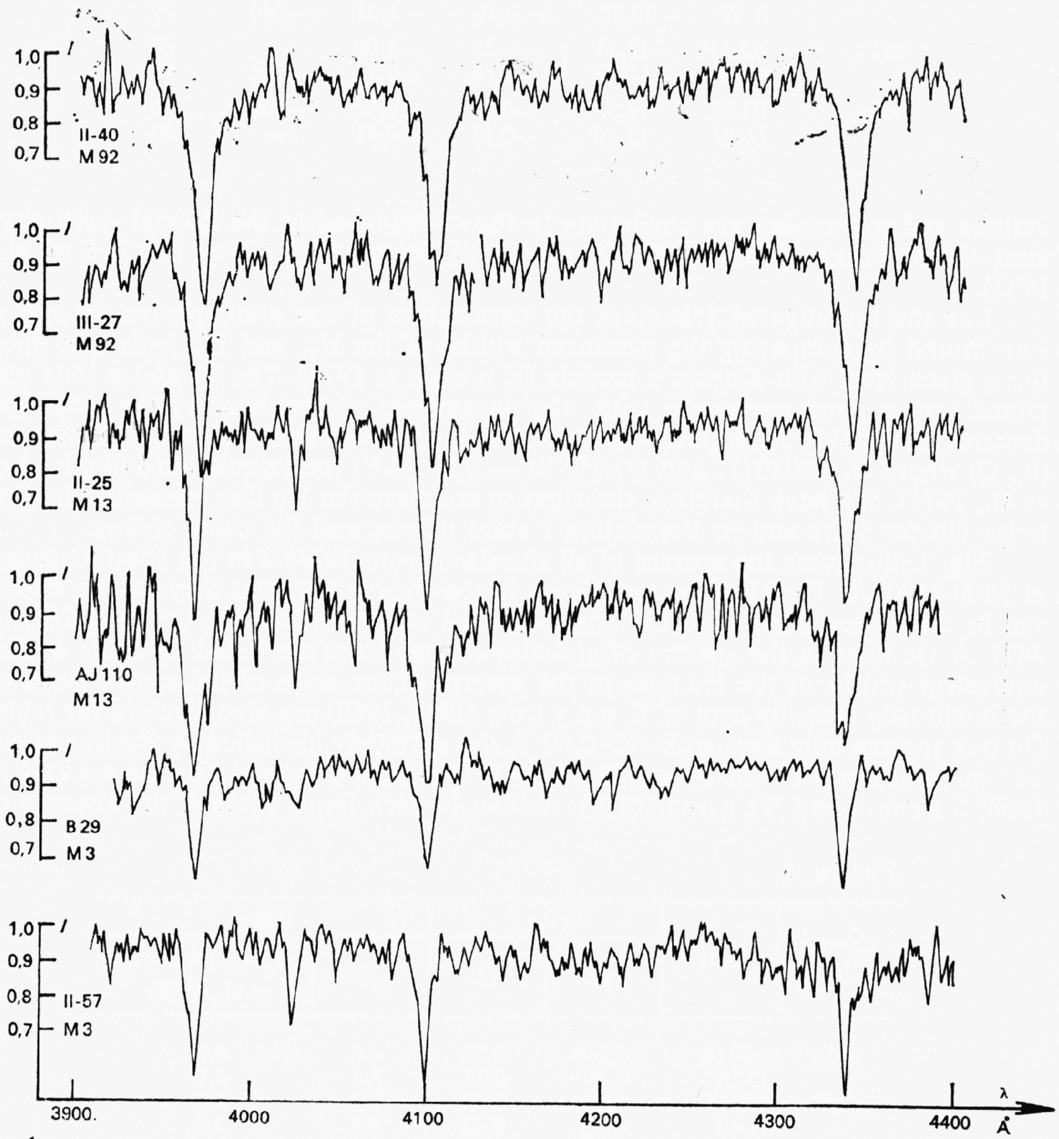

Fig. 1

of the line intensities corresponding to a helium abundance equal to 0,1 by the number of atoms. Anyway, we cannot speak of any helium deficiency of the order of 5-10 times. In fact, according to theoretical calculations (S h i p m a n and S t r o m, 1970), by varying the He abundance n times, the intensity of the lines under consideration varies $\sqrt{n}$ times, that is at a He deficiency of 5-10 times, the He lines in our spectra of the star II-25 are not to be seen.

Thus, our observations brought the conclusion about the decreased He abundance in the atmospheres of the stars of Population II in question.

At the last IAU symposium of Globular Clusters (Crocker and Rood, 1986) it was reported that in the spectra of the HB stars in the cluster NGC 6752 intensive helium lines testifying to normal helium abundance in their atmospheres were observed, as well. It is worth noting that the two clusters refer to subtype II B according to Oosterhoff characterized with relatively small number of variable stars of the RR Lyrae type. Obviously, further investigations of blue stars in other globular clusters are necessary.

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