ON THE FAINT WHITE STARS IN LOW GALACTIC LATITUDES

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1. When considering the nearest stars the attention is attracted to the fact that within a sphere of 5 parsecs radius there is only one star absolutely brighter than $+1^m,5$ (Sirius), while within the same sphere there are known three white dwarfs (Sirius B, o_2 Eridani and van Maanen's star), as much as the number of the dwarfs of type G. It seems to be certain that within this sphere there are no more giants, whereas the further discovery of the white dwarfs is not excluded. Therefore in our neighbourhood the space density of white dwarfs surpasses that of giants of all types taken together. Unless this is due to a chance we must conclude that the number of white dwarfs in the galactic system surpasses the number of all giants. The discovery of four new white dwarfs in the last years [1, 2] confirms the view that the space density of white dwarfs is really considerable. The confirmation of this suggestion by more observational data will emphasize the importance of all the theoretical and practical problems connected with the white dwarfs. On the other hand, the presence in Russell diagram of a peculiar branch of white dwarfs, more rich than the giant branch, must throw a new light on the nature of this diagram itself.

There are known two ways for the discovery of white dwarfs, the determination of spectrum or color of the components of double stars and the determination of spectrum or color of faint stars with large proper motion. Even if the parallax of a double star is unknown, the observation of spectra of both components allows in many cases to estimate the luminosity of the companion. In general, if the brighter component is not a dwarf of late type, the companion — the white dwarf — may be observed in systems with large Δm. But in this case the determination of spectrum or color of companion becomes difficult. Up to now this way did not give new results, with exception perhaps of o Ceti, where the companion was suggested to be a white dwarf of type B of absolute magnitude about $+5$.

The observations of spectrum or color of faint stars with large proper motion cannot lead to rapid increase of white dwarfs since in the overwhelming majority the stars with considerable proper motion are red dwarfs. In addition to this, if the absolute magnitude of white dwarfs is of the order $+10$ and fainter, they may be observed more or less often among the stars of 15—17 apparent magnitude, while the limiting magnitude of stars in the catalogues of proper motions is usually much higher. Some statistical results with respect to white dwarfs we may hope to obtain from the counts of stars of different colors in high galactic latitudes. Owing to the small depth of galactic system the normal white stars will be rapidly exhausted when approaching the apparently fainter stars and on the contrary the white dwarfs must begin to encounter. It is known that the function $A(m)$ giving the number of stars of apparent magnitude between $m - \frac{1}{2}$ and $m + \frac{1}{2}$, has a maximum for the stars of type B and A in high galactic latitudes. If the luminosity function of white stars has, owing to the presence of white dwarfs, a second maximum about $+10^m$ (more rich than that of normal white stars about $+1^m$) the function $A(m)$ is to be expected to have also a second maximum, more rich than the former, apart from it approximately on 9 magnitudes. For instance, the counts of stars of type A in galactic latitude about 50° by van Rhijn and Schwassmann lead to a maximum of $A(m)$ about $m=11$ [3]. It follows then that the second maximum must be observed about $m=20$. In reality, probably beginning already from $m=17$, a second ascent of the curve $A(m)$ must be manifested. Unfortunately there are no observational data to test this consequence connected with the hypothesis of abundance of white dwarfs. It is obvious that the observations of C. I. of faint stars in high galactic latitudes are highly desirable.

There may be offered however another, probably a more effective way, which may lead to the discovery of white dwarfs. Let, the stars, the color of which we have observed be situated in the direction where the sensible interstellar selective absorption was found. Then with respect to every faint white star, for instance, 15^m or fainter we shall have an alternative: either this star is normal white star at the distance of many thousands parsecs, or this is a white dwarf. But the first hypothesis is to be rejected since at such a distance the color excess is large and the star cannot be white. Therefore the faint white stars, observed in the direction, where the space reddening is firmly established, should be probably white dwarfs. The limiting apparent magnitude for a normal white star in the region under consideration depends on the value of color excess on 1000 parsecs.

2. The observational data which may be tested with this purpose are few. We shall consider mainly C. I. of stars in Scutum observed by Krieger (six fields in the region between $18^h38^m,1$ and $18^h56^m,1$ in α, and $-6°20'$ and $-9°42'$ in δ [4]. We have the following evidences in favour of an appreciable selective absorption in the region under consideration.

1) In Stebbin's and Huffer's catalogue of B stars [5] we find the

HD	l	b	C. E.	Distance
167 971	345°	1°,5	0,44	870
169 033	346	0,5	0,04	150
169 454	345	−0,8	0,52	630
169 753	349	1,0	0,35	520
170 714	353	1,5	0,21	300
170 740	348	−0,8	0,23	210
176 162	349	−7,8	0,01	140
179 406	355	−9,0	0,13	170

following stars in this region. Reducing the color-excess to the distance 1000 parsecs we have the selective absorption to be equal in the mean $+0^m,61$. Stebbins and Huffer give $+0,67$ for the longitude 350° and $+0^m,22$ for $l=10°$.

The longitude of the region in question is approximately within the limits 352—356°.

2) Trümpler in his investigation on star clusters [6], using Shapley's C. I. of 46 stars of type $B8-A2$ in M. 11 for which he observed the spectra, gives the color-excess $+0,65$ or on 1000 parsecs $+0,48$. However we must keep in mind that Shapley's C. I. of stars in galactic clouds are generally in disagreement with selective absorption since the observed C. I. decrease with the increasing magnitude of stars [7].

3) Basing on Krieger's C. I. of 20 brighter stars of type A0 we were able to derive the coefficient of selective absorption γ from the equation C. I. $=$ (C. I.) $+\gamma R$, where C. I. is observed color-indexs for each star, (C. I.)— the color-index unaffected by selective absorption, R — distance in kiloparsecs. We have found $\gamma = 0,45 \pm 0,13$ in Krieger's system C. I., or 0,35 in Mt. Wilson one. Notwithstanding the agreement with preceding results, it must

be emphasized that the above value of γ is determined from a very small number of stars.

4) When there is an appreciable selective absorption the system of C. I. based on the distant stars must evidently differ from that derived for near stars. One of the consequences of this is the displacement of the upper limit of C. I. to the larger values. Below in Table 1 (identical with Krieger's Table 21) there are given the numbers of stars on 0,1 square degree, corrected for the dispersion due to the observational errors of C. I.

This magnitude — color diagram resembles the Hertzsprung-Russell's diagram with well developed main sequence and the faint giant one as it has to be expected for a limited volume of space. If we assume that the stars belong in overwhelming majority to the cloud at the distance about 1500 parsecs (Trümpler, Krieger), we shall find the absolute magnitude of stars of 16—18 apparent magnitude to be 5—7^m, (the dwarfs of type G — K). The number of late type giants projected on this region is evidently very small. In fact it is known that the space density of normal A type stars is not less than of giants of type G and K. For this reason with a large percentage of late type giants not a minor number of A type stars should be expected at the same apparent magnitude. In the present case the number of A type stars (as judging by color) is very small, and therefore the faint red stars are the dwarfs of type G—K in overwhelming majority.

Krieger's C. I. for the dwarfs dG0, dG5 and dK0, are + 0,75, + 1,02 and + 1,38 respectively. Further, it is known that generally C. I. of the stars of type M differs but little from that of K (in several systems of C. I. even decreases for M type). From the Table 1 (which is corrected for dispersion due to be the observational error of C. I.) follows that there is a large number of dwarfs with a considerable color-excess. Here we have about 17 per cent of stars with C. I. > 1,65 among 15—18^m. Accounting even for the real dispersion in C. I. for a given spectral class and allowing a small influence of late type giants (C. I. of gK0 = 1,91), we must conclude that the displacement of the upper limit of C. I. is real. Roughly the selective absorption for red stars may be estimated as $0^m,5$. This is of interest from that point of view that the evidences in favour of selective absorption are based generally up to now mainly on the stars of type B. Owing to the peculiarities of color temperatures of these stars this seems to be to same degree an incomplete evidence. If the displacement in question for the faint red stars may be considered as real, we have here an independent evidence in favour of the selective absorption. The same displacement of the upper limit of C. I. is also manifested in other series of observations of C. I. For instance Seares and Ioyner found an excess of faint red stars with anomalous C. I. in S. A. 40 [8]. Seares assumes the faint stars of his table to be dwarfs of type G and K, for which C. I. in Mt. Wilson system are + 0,99 and + 1,48 respectively. The number of stars with C. I. > 1,8 among the stars of 14—16 apparent magnitude reaches about 30 per cent. In addition the normal maximum in M. Wilson system of C. I. is equal about + 1,9, and that observed by Seares for S. A. 40 surpasses 2,8 or at least 2,6. It then follows that the color excess about 0,7 for the red faint stars of 14—16 apparent magnitude may be ascribed to the selective absorption. Seares' result seems to be more convincing since here we are guaranted against the sensible error in the scale and in the zero point for the faint stars.

The same effect bring out also the observations of C. I. by L. Slocum [9]. Among the faint stars there is a considerable number with C. I. > 2,5. While C. I. for dG0 and dK0 is + 1,09 and + 1,54, we have among the stars of 14,5—15,5, 15,5—16,5, 16,5—17,5 and > 17,5 apparent magnitude 11, 18, 26 and 28 per cent of stars with C. I. > 1,75 respectively. In these counts we have used Slocum's tables Va, Vb (l. c.) already corrected for the dispersion due to the errors of observation of C. I. All these data taken together give a good evidence in favour of the reddening of the faint red stars due to the selective absorption.

5) The region embracing Krieger's and Slocum observations enter into the Hubble's zone of avoidance of the extragalactic nebulae. On the plate which centre $l = 350^\circ$ and $b = -5^\circ$ Hubble found no extragalactic nebulae.

6) The galactic latitude of Krieger's area *A* is -3° (on this area is mainly based Krieger's counts). Almost at the same longitude -6° there is situated the faint globular cluster NGC 6712 with C. E. about $+0{,}30$. It seems to be improbable that for a smaller latitude (-3°) the color-excess decreases or even remains constant. For this reason for the distant stars in the area *A* a color-excess larger than 0,30 is to be expected.

As to the observations by Slocum it is to be noted that in addition to the evidences in favour of selective absorption mentioned above, there is a computation of the coefficient of selective absorption by Slocum based on the stars of type *A* and *F* (in the Mt. Wilson system of C. I. $\gamma = 0{,}34 \pm 0{,}03$).

Further for the areas under considerations we are able to derive [1] from the work of Stebbins and Huffer the following values for the selective absorption S.A.64: $+0{,}19$, S.A.18: $+0{,}31$, S.A.19: $+0{,}40$, S.A.8: $+0{,}43$ and S.A.9: $+0{,}43$.

3. All the evidences considered above do not leave doubt that in the directions under investigation there is really a sensible space reddening, and therefore here we may try to apply the method of finding of white dwarfs mentioned in the introduction. In this respect it may seem to be suggestive a small isolated group of faint white stars in the lower left corner of Table 1, based on Krieger's observations. Below are given the faint stars not brighter than $13^m{,}5$ with negative C. I. larger than $-0{,}10$.

Krieger

N	m_{phot}	C. I.
A2009	17,21	$-0{,}40$
A2057	16,98	$-0{,}28$
A2177	16,28	$-0{,}34$
A2497	16,98	$-0{,}29$
B8	13,59	$-0{,}69$
B20	14,30	$-0{,}14$
B38	14,39	$-0{,}51$
B83	14,30	$-0{,}16$
E46	14,50	$-0{,}21$

Slocum

N	m_{phot}	C. I.
Area 18.M.W.123	17,61	<0
" 518	15,80	$-0{,}17$
" 530	16,31	$-0{,}59$
" 667	16,65	$-0{,}21$
" 733	14,49	$-0{,}49$

The S.A.40 (discussed by Seares and Joyner [8]) is evidently free from the faint white stars with the exception of two stars between 13,0 and 13,5 with C. I. about $+0{,}3$. Unfortunately the limiting magnitude of stars under consideration is $15^m{,}7$. Not overstimating the accuracy of C. I. of faint stars and allowing for the possibility of large accidental errors (notwithstanding the double measurement for the majority of stars) the peculiar character of Table 1 or of Krieger's Tables 12—21 is to be emphasized. The isolated position of faint white stars in the magnitude — color diagram, uncorrected as well as corrected for the dispersion due to observational errors seems to resemble the position of white dwarfs in the Hertzsprung-Russell diagram. If the stars in the lower left corner are normal stars of type A0—A5($M = +1$), — their distance must be of order 15000 parsecs. In this case it is very difficult to understand, how could they have maintained the negative C. I. If they are near stars not affected seriously by selective absorption the conclusion about their dwarf nature is inevitable, and at the distance of 100, 250 and 500 parsecs their absolute magnitude must be of the order 12, 10 and 8,5 respectively. Among the white stars also few ones of

13^m are observed. Even in this case the color-excess for normal white stars must be considerable. If we are dealing here with white dwarfs their distance is smaller than 100 parsecs, unless they are absolutely brighter than 8^m.

Krieger' and Slocum observational data for the stars with known spectrum allow to determine the dispersion of C. I. for a given spectral subdivision. This consists of real dispersion and of dispersion due to the error of observation. Not dividing these constituents we derive for Krieger's C. I. the mean square error of one observation for A0 $\pm$ 0,19, A2 $\pm$ 0,15 and A5 $\pm$ 0,23 or in the mean $\pm$ 0,19. Assuming the normal law of distribution for the residuals, we can compute the probability that out of 17 stars with C. I. between + 0,15 and + 0,40 (see Krieger's Table 18, l. c.) 4 stars will acquire the negative C. I. between — 0,10 and — 0,60. This probability is less than 0,001. Assuming the mean square error to be $\pm 0^m,28$ (1,5 of the observed value) we find the probability in question to be less than 0,01. But the dispersion in the observed values of C. I. is not only due to the errors of observations, and in such a case the law for residuals probably differs from the normal law of errors. For this reason the computed probability may be disputed. However there remains the very considerable probability that the accumulation of the faint white stars in the lower left corner of Table 1 is not due to a chance.

The mean square error for Slocum C. I., is somewhat larger, namely $\pm$ 0,27 and the probability that the observed negative C. I. are due to a chance is larger than above, but it is still small.

In order to explain the presence of faint white stars in the

Table 1

m \ C. I.	< − 0,60	− 0,60 to − 0,35	− 0,35 to − 0,10	− 0,10 to + 0,15	+ 0,15 to + 0,40	+ 0,40 to + 0,65	+ 0,65 to + 0,90	+ 0,90 to + 1,15	+ 1,15 to + 1,40	+ 1,40 to + 1,65	+ 1,65 to + 1,90	+ 1,90 to + 2,15	+ 2,15 to + 2,40	> 2,40
< 10,0		0,2					0,2		0,2					
10—11	0,2		0,6	0,8		0,4		0,6	0,4	0,3				
11—12			0,5	1,2	1,3	0,8					0,2	0,2		
12—13	0,2		1,4	3,0	2,8	1,9	1,0	0,1	0,4	0,4	0,2			
13—14	0,7		0,9	6,0	9,2	8,5	3,3	1,9	1,4	2,5	0,3		0,4	0,4
14—15				4,3	33,3	41,6	15,7	7,0	13,3	8,7	7,3	2,6	1,1	
15—16				2,0	9,7	28,6	75,1	74,8	13,5	37,6	31,1	21,4		
16—17		(6)	(17)		2,0	25	275	202	8	24	39	22	29	23
17—18						24	303	323	260	32	54	56	38	30

regions under considerations two hypotheses may be offered. Either the observed white stars of apparent magnitudes 16—18 are white dwarfs, or the selectively absorbing medium in the direction of Scutum and the other areas under consideration ends at the distance of 1500—2000 parsecs and for this reason C. E. do not increase by the transition from 11—12 to the apparently fainter stars. Krieger's system of C. I. for white stars was derived for the stars at the distance about 1000—1500 parsecs, and for this reason in the case of the latter hypothesis the C. I. of the distant stars behind the cloud may be very small. But this is generally not applicable to Slocum's stars, since her system of C. I. is free or almost free from the effect of selective absorption. But the presence of many negative C. I. in Table 1 is in favour of the former hypothesis since the white dwarfs of type A—F in the Krieger's system of C. I., affected by absorption, being comparatively not distant must have namely the negative C. I. But if these stars are really white dwarfs there arises another difficulty: the presence of a too large number of them in the observed region. Basing on these counts we get too great space density of white dwarfs. Not fixing the absolute magnitude of these stars it is difficult to estimate the space density, but it is probably not less than ten times larger than the density of white dwarfs in our neighbourhood. It is true that probably not all white dwarfs in our neighbourhood are known.

As to the second hypothesis we are not able to overthrow it. However it is to be noted that if the space behind the Scutum cloud would be transparent from 1500 to 15 000 parsecs the number of white stars brighter than $m = 18$ on the square degree would amount to several thousands or still more, since it is difficult to adopt, that in the direction so near to the direction to the galactic centre the space density of stars greatly decreases with the increasing distance from the Sun. Therefore in this direction there is undoubtedly a considerable general absorption at least, and this is in the agreement with the coincidence of the region under consideration with the Hubble's zone of avoidance of extra-galactic nebulae. The second hypothesis may be altered in such a sense, that to a distance about 1500 parsecs there is a general and selective absorption and behind the cloud there remains only a considerable general absorption, without a trace of selective one. But this supposition seems to be too artificial.

At last a possibility is not excluded that the white stars are seen in the small areas, where the space reddening reaches a minimum (oppenings or breacks in the absorbing cloud). The unevenness of the absorption favours to this point of view. So at the longitude in question (about 350) and at the latitude $-5°$ there is no extragalactic nebulae, while at the latitude $-6°$ a distant globular cluster NGC6712 is observed (it is true only, with C. E. $+0{,}30$). But it is difficult to think that such breacks are frequent at the latitude $-3°$.

However only the measurements of the proper motions and the verification of negative values of C. I. of the stars in question will ch ck without any ambiguity the hypothesis of white dwarfs. It is obvious in general that the study of faint white stars in low galactic latitudes affords the very valuable information on the nature of the stars thems lves as well as on the distribution of absorbing medium in space.

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О СЛАБЫХ БЕЛЫХ ЗВЕЗДАХ В НИЗКИХ ГАЛАКТИЧЕСКИХ ШИРОТАХ

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В настоящей заметке указано, что наблюдение цветов звезд в тех направлениях, в которых имеется заметное селективное междузвездное поглощение, может служить методом открытия белых карликов. Действительно, пусть в этих направлениях мы наблюдаем слабые белые звезды. Если допустить, что это нормальные звезды типов В и А, т. е. звезды с большой абсолютной яркостью, то их нужно считать очень далекими, что противоречит их неокрашенности. Остается допустить, что это белые звезды с низкой светимостью, т. е. белые карлики.

С этой точки зрения подвергнуты дискуссии измерения колориндексов, произведенные Кригером в Scutum Cloud и Слокумом в площадях Каптейна. Установлено наличие признаков селективного поглощения в этих направлениях. Одновременно в этих направлениях имеется целый ряд белых звезд 15—16-й величины. Либо эти звезды являются белыми карликами, либо же облако, производящее селективное поглощение, совершенно прекращается на расстоянии около 2 тыс. парсек, и дальше поглощение становится совершенно неселективным. Нужно думать, что последнее предположение несколько искусственно.