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λ 5200 Å depression intensity variation in magnetic SiSrCrEu stars with age

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Abstract.
Variation of Z parameter of Geneva photometry in SiSrCrEu type magnetic peculiar stars as they evolve across the main sequence strip is investigated. It is found that Z parameter varies in accordance with the dependence of Z on the surface magnetic field, which, as it is well known, diminishes due to the evolutionary change of radius of stars. The shape of the obtained dependence confirms the opinion that CP stars of SiSrCrEu type acquire chemical anomalies "before the main sequence".

Key words: stars: magnetic stars – evolution: peculiar stars – magnetic field

Klochkova and Kopylov (1985) showed that the chemical composition of magnetic CP stars is anomalous by the moment they evolve to the main sequence, and that chemical anomalies arise in the evolutionary period of stars "before the main sequence". In accordance with the results of Mishaud (1980) the time necessary for accumulation of chemical anomalies in the upper layers of CP stars' atmospheres is of the order of 10^6 years. However, massive CP stars evolve to the main sequence at the age of about 10^5 years, which is why it is possible to suggest that the accumulation of chemical anomalies in He–r type stars must take place on the main sequence. Glagolevskij et al. (1991) and Zboril et al. (1994) presented the data supporting this assumption. In these papers it is shown that the helium abundance in the stars grows as they evolve across the main sequence strip. An attempt was made to find such dependences for other chemical elements but reliable results were not obtained because of inadequate amounts of observational data. In this work we tried to study the intensity variation of the depression λ5200Å in SiSrCrEu type stars as they evolve across the main sequence strip, i.e. with age. A number of authors suggest that this depression arises due to autoionisation of SiII, but if this is the case then we are actually trying to search for silicon abundance variation with age. As a measure of the depression intensity we used Z parameter of multicolour photometry. The values of Z were calculated by the formula

$$Z = -0.4572 + 0.0255U - 0.1740B1 + 0.4696B2 - 1.1205V1 + 0.7994G.$$

The colour indices U, B1, B2, V1 and G are taken from the catalogue of Rufener (1988). The temperatures of stars are taken from Glagolevskij (1995a). In the cases when the temperature value was absent we determined it by the same method as in the aforementioned paper, by the parameter X (or (B2 — G) if $T_e < 10500K$). Besides, the relative radii R/R_0 (R is the radius of a star at the present time, and R_0 is its radius on the zero-age sequence ($R/R_0 \sim \lg g$) were calculated by the method presented by Glagolevskij (1988a), and the ages of stars were calculated by the known evolutionary tracks of Iben (1967). For estimation of the surface magnetic field $B_s(Z)$ we constructed the relationship between Z parameter and B_s using the data from Glagolevskij (1988b). The values of the average surface magnetic fields in this work are estimated by the Stibbs–Preston method from the curves of effective magnetic field variations. The obtained dependence is virtually linear up to $Z \approx$ -0.060 and $B_s \approx$ 5 kGs, then it becomes constant for any value of B_s parameter. The linear section can be represented as

$$Z = 0.20 - 0.009 \cdot B_s.$$

Fig. 1a presents Z parameters versus R/R_0 value. It shows how Z varies with age as stars evolve across the main sequence. The scatter of points is large as a result of great difference in the degree of anomaly of chemical composition of magnetic CP stars. Therefore in order to better reveal the sought dependence we averaged Z values in the narrow limits of R/R_0 values and the average values we marked on the diagram with circles. It is clearly seen that as CP stars

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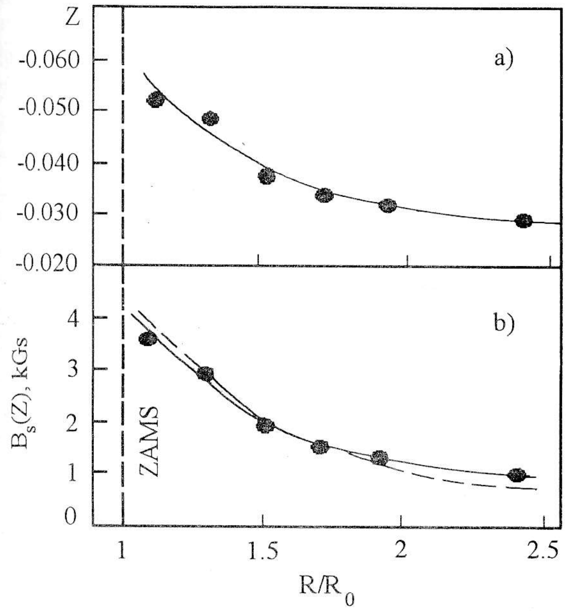

Figure 1: *a) Photometric parameter Z versus relative radius for stars of SiSrCrEu type. b) Average magnetic field as a function of relative radius for stars of SiSrCrEu type.*

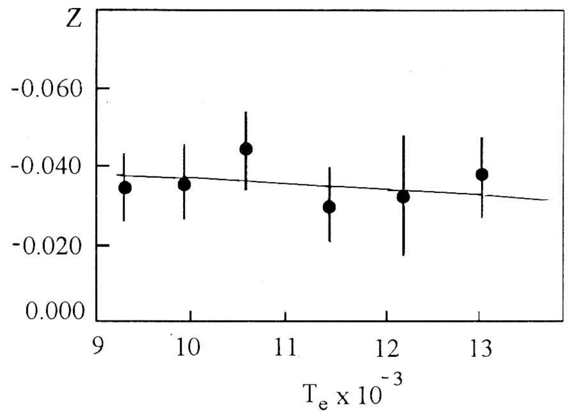

Figure 2: *Average Z value against temperature for stars of SiSrCrEu type.*

evolve across the main sequence strip, Z parameter decreases. This is consistent, probably, to a decrease of chemical anomalies in general. Fig. 1b shows the relation between $B_s(Z)$ and R/R_0, where $B_s(Z)$ values were estimated from the mean Z values from Fig. 1a. From Figs. 1a,b it is clear that the intensity of depression $\lambda5200$Å and the magnetic field decrease with the age of stars as they evolve across the main sequence strip. The second conclusion is that SiSrCrEu type stars evolve to the main sequence being already chemically peculiar, and no rise in the intensity of the depression near $R/R_0 \approx 1$ is perceptible, which would point out to the presence of Si accumulation process at the beginning of life on the main sequence. This problem has already been discussed by Glagolevskij (1988a) as applied to all investigated CP stars, but here it is confirmed again through the data for stars of one type of peculiarity (SiSrCrEu).

Fig. 1 confirms the assumption that chemical anomalies in CP stars (except He–r and possibly He–w (Glagolevskij and Kopylova, 1990)) arise at early stages of evolution, probably "before the main sequence". The diffuse process creates the observed chemical anomalies for the time t $\approx 10^6$ years, and the age of SiSrCrEu type stars on the initial main sequence is the same.

Our task consists in trying to explain the behaviour of Z versus relative radius. Why the intensity of the depression $\lambda5200$Å and, hence, the concentration of silicon (and possibly other anomalous chemical elements) fall as stars evolve across the main sequence strip. Consider Fig.1b. The relationship $B_s(Z) \sim R^{-2}$ is shown by the dashed line. This occurs if the magnetic flux remains constant with time, but the average surface field varies with increasing radius of a star. This problem was discussed by Glagolevskij (1988a). It was shown that the surface fields of all magnetic stars are reduced according to this law. In this case the existence of the relation $B_s \sim R^{-2}$ is confirmed particularly for SiSrCrEu type stars. On the other hand, in the paper by Glagolevskij (1995b) it was shown that the concentration of peculiar chemical elements is dependent on the surface magnetic field strength. This, probably, happens because the magnetic field suppresses the turbulence which hinders the diffusion of chemical elements to the surface under the action of light pressure. At $B_s \approx 5$ kGs the turbulence is fully suppressed and further strengthening of the field does not cause acceleration of diffusion and growth of concentration of chemical elements. Therefore, Z is linearly dependent on (B_s) only up to the above value. Therefore, the curve in Fig. 1a is nothing but the display of dependence of the concentration of chemical elements on the surface field, which is reduced as a result of enlargement of the stars radius. This may occur only under permanent "feeding" of the regions of concentration of chemical elements. Their content "traces" the varying surface magnetic field strength. This suggests that certain processes exist, probably horizontal diffusion, which constantly "blur" the regions of concentration of elements. These regions are constantly renewed by vertical diffusion processes under the action of light pressure. It may be supposed that the trend of the relationship between Z and R/R_0 is distorted by temperature effect, since with evolution of stars across the main sequence strip their temperature falls. If Z

Table 1:

HD	$B_s(Z)$	B_s	Star	$B_s(Z)$	B_s
3773	4.3		112381	3.9	
8855	3.3		119419	>5	
9393	>5		122525	4.2	
24212	3.5		133029	4.3	7.4
27404	3.5		142823	3.8	
32633	>5	13.6	147010	>5	13.0
35548	>5		149822	3.8	
44738	4.5		157751	>5	
50540	4.2		161596	2.7	
52539	3.2		164429	3.1	
60431	>5		165605	2.6	
64698	3.8		168108	2.9	
66188	4.6		170973	2.9	
67951	3.8		174581	>5	
83266	2.9		176519	3.1	
90044	3.3		187128	2.7	
92534	>5		187474	2.7	
93507	4.8		190068	>5	
94274	2.7		193382	3.8	
94660	>5		208340	2.8	
96910	3.9		220147	3.6	

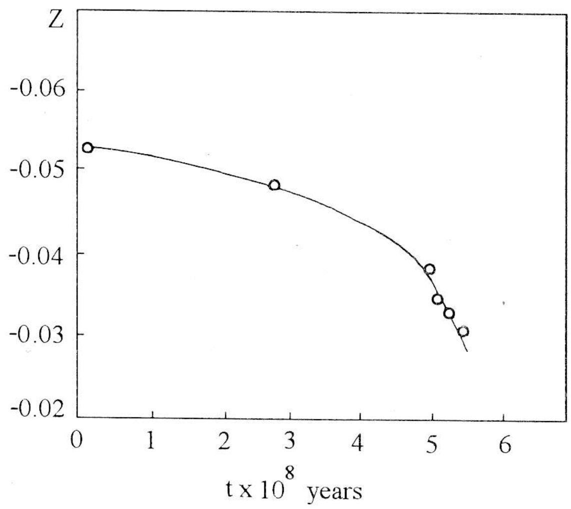

Figure 3: *Variation of average Z parameter with age of stars of SiSrCrEu type.*

parameter depends on the temperature, then its influence must be taken into account. However Fig. 2 shows that within the limits of temperatures of the stars under investigation there is no noticeable dependence of Z on temperature. Therefore, in a first approximation, it can be considered that the dependence in Fig. 1 is not affected by temperature.

It is extremely interesting to examine the behaviour of the Z with time. We estimated the time t for average values of Z using the evolutionary tracks of Iben (1967), and the sought relationship is shown in Fig 3. It is clearly seen that most of the time the intensity of the depression changes slightly and only at the end of the period it begins to reduce rapidly. In the end, the value of Z approaches the normal value and the star evolves from the main sequence. It may be supposed that at this moment the value of the surface magnetic field strength decreases to a value of several Gauss. Probably it partly dissipates in a turbulent atmosphere of a supergiant. Besides, the surface field value decreases proportionally with R^{-2}. Thus, in conclusion, a number of stars should be noted in which the value of Z exceeds the values of the linear portion of the relationship $B_s(Z)$, i.e. they correspond to the fields $B_s > 4 - 5$ kGs. The list of such stars is presented in Table 1. Their magnetic fields should be measured for extreme magnetic stars to be found. The third column cites the already known values (Glagolevskij, 1988b) of average surface B_s magnetic fields.

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