On the evolution of chemical abundance of CP stars with age

Yu.V. Glagolevskij

Special Astrophysical Observatory of the Russian AS, Nizhnij Arkhyz 357147, Russia

Abstract. Evidence for a gradual change of chemical anomalies in magnetic CP stars with age is presented. At the end of the period of stay of CP stars on the main sequence the anomalies disappear rapidly because of increasing star radius, which results in reduction of the surface magnetic field.

The chemical elemental abundance evolution of magnetic CP stars has already been treated in the works of Kopylov, Klochkova (1975), Glagolevskij, Kopylova (1990), Zboril et al. (1994) and Glagolevskij (1995). In the last three of them are presented relationships between the helium abundance and the relative radius R/R_z, where R is the present-time star radius, while R_z is the radius on the zero-age main sequence (ZAMS). The values of R/R_z are proportional to lg$g$ and well characterize the star position on the main sequence.

The behaviour of the helium abundance with R/R_z for He-rich stars plotted from data of Glagolevskij, Kopylova (1990), Glagolevskij et al. (1992), and Zboril et al. (1994) is presented in Fig.la. For a better clearness individual values of He/H are averaged by the boxcar average method. It is seen that the abundance of helium decreases with age. On the ZAMS the abundance of helium is normal or it is slightly overabundant, which may indicate that diffusion was initiated near the moment the stars evolved to the main sequence, when accretion terminated and the star reached a stationary state.

The preliminary data on the behaviour of He-weak stars are presented in the paper by Glagolevskij, Kopylova (1990), where He/H is plotted as a function of R/R_z (Fig.lb) (the data are obtained by the boxcar average method). Based on this relationship the helium abundance on the ZAMS can be assumed to be close to normal. Then it is reduced and its anomaly is a maximum at the moment the stars stay on the line occupied by normal stars of luminosity class V. After that the helium abundance is apparently gradually normalized as the star evolves to the upper part of the main sequence band. There are no stars with He/H = 0.05-0.1 because of the observational selection.

In order to investigate chemical abundance of stars of other types of peculiarity it would be necessary to organize spectral observations for a large number of CP stars, but these would take many years. As the first step in this direction we have investigated the variation of two parameters with age — the parameter Z of Geneva photometry and Δa, which characterize the intensity of the depression λ5200 Å (Cramer, Maeder, 1979; Hauck, 1978). This depression arises as a result of absorption by Si II autoionization. Therefore the value of these parameters represents the abundance of one of the chemical elements typical of magnetic stars. It is known that the depression intensity has a correlation with the abundance of europium (Lebedev, 1986) and other elements. In the paper (Zboril et al., 1993) it is shown that the depression λ5200 Å can arise as a consequence of overlapping of the Fe II spectral lines. In the normal stars this parameter is close to zero.

We made the next step in the investigation of abundance evolution having examined the dependence of Z and Δa upon age for CP stars of different types of peculiarity, namely, for Si- and

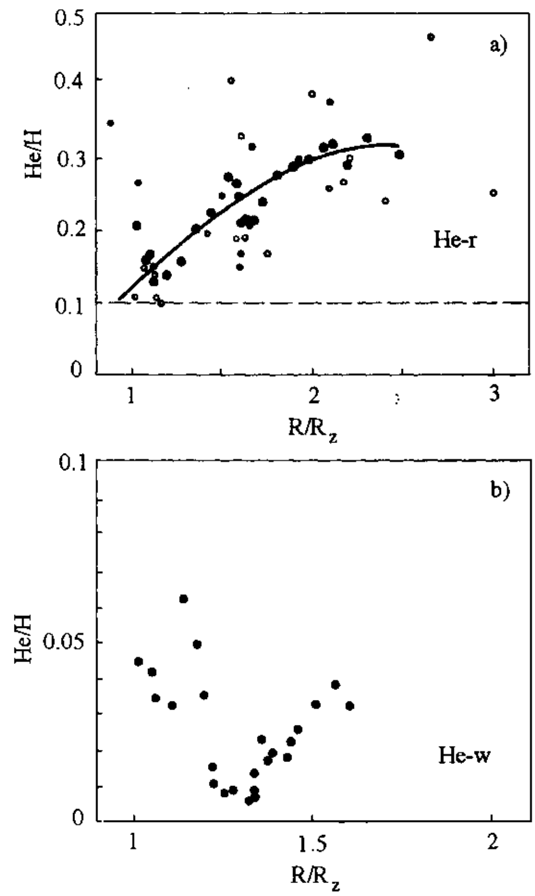

Figure 1: The dependence of the helium abundance on the relative radius for magnetic CP stars. Open circles — measurements of individual stars; filled circles — average values, calculated by the boxcar average method.

SrCrEu-stars. The parameters for calculation of Z were taken from (Rufener, 1988) and the parameters Δa were taken from (Lebedev, 1986). The parameters R/R_z calculated from the absolute bolometric magnitudes are determined from the parameter β with the use of the Crowford (1979) calibration.

It should be kept in mind that the number of stars having the known Δa values is several times smaller than the number of stars with the known Z, therefore the relations in which Z parameters are used are much more reliable. On the other hand the parameter Z depends not only on the depression λ5200 Å intensity but also on the intensity of other spectral lines located in the regions of the used photometric bands.

It appeared that the most marked dependences occurred in the cases where stars were taken in the narrow range of temperatures between the evolutionary tracks. In Figs.2 and 3 are presented these relationships, the temperature boundaries correspond to the intersection of the evolutionary track with the ZAMS. The boundaries were chosen so that in the first case Si-stars fell in the region between the tracks. The first remarkable thing is the presence of a maximum near $R/R_z \cong 1.5$— 1.7 on the relationship for Δa. On the relationship for Z this maximum is observable only in the SrCrEu-

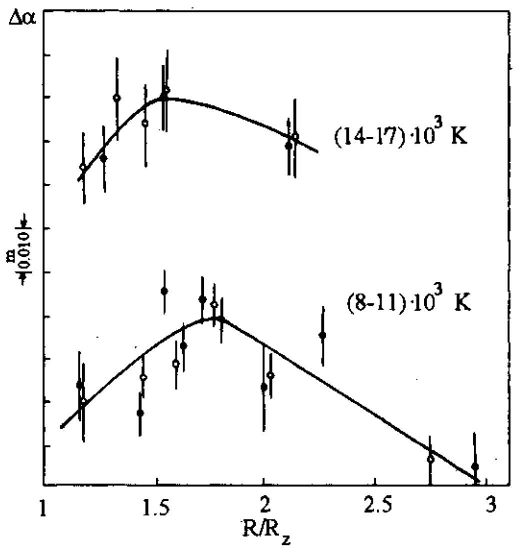

Figure 2: The relationship between intensity of the depression λ5200 Å and the relative radius. Upper diagram: open circles — 14000–15500 K, filled circles — 15500–17000 K. Lower diagram: open circles — 8000–9500 K, filled circles — 9500–11000 K.

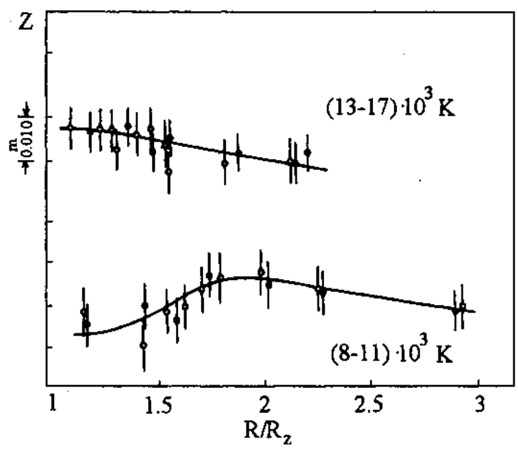

Figure 3: Z parameter against relative radius. Upper diagram: open circles – 13000–14500 K, filled circles – 14500–16000 K, open triangles – 16000–17000 K. Lower diagram: open circles 8000–9500 K, filled circles – 9500–11000 K.

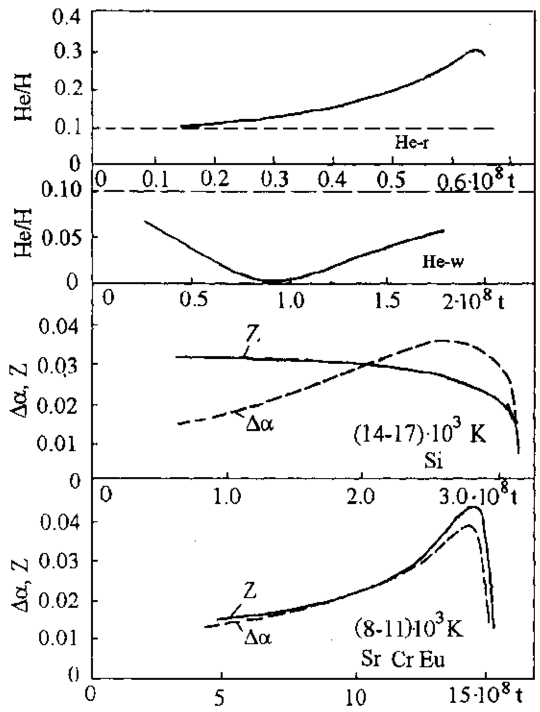

Figure 4: The relationship between He/H and intensity of the depression $\lambda 5200$ Å and age t for He-rich, He-weak, Si- and SrCrEu-type stars.

type stars. The stars of Si-type are likely to have the maximum around the ZAMS. Anyway the intensity of the depression $\lambda 5200$ Å varies with time. The different shape of the relationships for Δa and Z may be caused by the fact that the Z parameter is affected, as has been mentioned, by the abnormal intensities of spectral lines.

In Figs.2 and 3 the points are the average values in the narrow intervals of R/R_z. The bars indicate the average quadratic dispersion of the individual points, but not the errors. The distribution of the points is not Poisson because it is conditioned by the abundance scatter and by the dependence of the abundance upon magnetic field (Glagolevskij, 1994). In consequence of observational selection there is lack of stars with weak chemical anomalies which exist at the beginning and at the end of their stay on the main sequence.

The stars having temperatures of 11000-14000 K do not show any changes in the plot of Δa and Z against R/R_z. It is possible that the depression $\lambda 5200$ Å arises because of absorption of two or more chemical elements, which changes in different manner in different temperature ranges. For example, in the paper (Zboril et al., 1992) the depression is suggested to be due to the absorption of Si and Fe.

It is very interesting to see how the parameters Δa and Z vary on time scale t. To convert R/R_z into we have used the evolution tracks from the paper (Iben, 1965). Fig.4 shows such dependences on the t scale. It is remarkable that all of them, but for $Z(t)$ for Si stars, show a slow rise during all the time they stay on the main sequence and a rapid drop at the end of being on it. In the paper of Glagolevskij (1995) we have shown that the fast decrease in the chemical element abundance is probably due to the radius growth and to the surface magnetic field decrease, upon which the abundance depends.

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