THE EFFECT OF PECULIARITY IN THE ATMOSPHERES OF MAGNETIC CP STARS

S. G. Aliev [a*], ***V. M. Khalilov*** [a]

[a] *Shamakhy Astrophysical Observatory named after Nasireddin Tusi of the Azerbaijan National Academy of Sciences*

The paper presents the results of a study of the role of the peculiarity effect - the influence of chemical anomalies and a strong magnetic field in the atmospheres of about 30 different magnetic stars, which are located in the spectral range of B4-F0. To this end, extremal phases were determined for each star corresponding to the spotted and (relatively) normal region on the surface of the star. The role of the chemical anomaly and the magnetic field separately and their combined actions are analyzed in detail. The role of anomalies in the chemical composition leads to the appearance of an additional source of opacity - a coating effect in the atmosphere of CP stars. The magnetic field changes the structure along with the height of the atmosphere and strengthens the spectral lines and depression in the continuum, which manifests itself at different depths of the atmosphere of the stars under study. Extra-atmospheric observations also indicate that the distribution of the chemical anomaly over the height of the atmosphere is not monotonic, but is stratified - stepwise. In peculiar areas, depending on their types of peculiarity, magnetic field intensity and temperature, several depressions are found in the continuum (e.g., λ1400, λ1600, λ2500, λ3700, λ4100, λ5200 AA, etc.).
It is concluded that, due to the peculiarity effect in the region of spots, the atmospheric structure of magnetic CP stars has a stratification - layered character.

Keywords: magnetic CP stars–chemical abundance–magnetic fields– variability

1. INTRODUCTION

The concept of the peculiarity effect was previously used as the spotting effect [1, 2]. Unlike sunspots, the size of the spotted region on the surface of magnetic SR (MCP) stars is approximately 15-20% of the star's surface. According to [3,4], in magnetic stars, the spot temperature is on average 500-1500 K and the content

* E-mail: sabirshao5@gmail.com

of peculiar elements is 2-4 orders of magnitude higher than the surrounding region of the star's atmosphere. To distinguish stellar spots from sunspots, instead of the spotting effect, it is advisable to use the term "peculiarity effect". The peculiarity effect arises due to a strong anomaly in the chemical composition and powerful magnetic field, which are characteristic in the spotted region on the surface of MCP stars. For the study, about 30 different magnetic stars were selected, which are located in the spectral range of B4-F0. For each star, extreme phases were determined to correspond to the spotted and (relatively) normal region on the surface of the star.

2. THE EFFECT OF ANOMALIES IN CHEMICAL COMPOSITION

It has been established that excesses in the content of peculiar chemical elements (Si, Mn, Cr, Sr, Eu, etc.) in magnetic stars are approximately 2-5 orders of magnitude. As a result of collective energy absorption by the lines of these elements in the peculiar regions of stars, the coefficient of the coating effect (CE) reaches about 15–20% [5, 6]. As a result, the structure of the atmosphere and the distribution of energy in the spectrum change. Due to additional PE, the chemical anomaly has a significant effect on the atmospheric structure of magnetic superlattices. In other words, a chemical anomaly leads to the appearance of an additional source of opacity in the atmosphere of these stars. As a result of increased energy absorption by lines of peculiar elements in the underlying layers, the density of radiant energy, respectively, and temperature increases, and the upper layers of the atmosphere are cooled. Due to the chemical anomaly in the peculiar regions, the temperature is 500–1500 K higher than the normal atmospheric region of these stars [3, 4]. In addition to the reasons that lead to a change in the structure of the atmosphere and physical conditions, they can also be associated with a change in the absorption coefficient in the peculiar regions of the atmosphere of magnetic stars. The continuous absorption coefficient for the stars B0-F0 can be represented as follows

$$K\lambda = K\lambda(H, He) + K\lambda(M) + K\lambda(e) \quad (1)$$

Where Kλ(H, He) is the absorption coefficient of hydrogen and helium, Kλ(M) is the absorption coefficient of metals, Kλ (e) is the scattering coefficient on free electrons. The main contribution to continuous absorption comes from helium and hydrogen. In the work of Leushin [7], it was noted that the electron densities for MCP stars obtained from the last number of hydrogen lines of the Balmer series, which refers to the upper layers of the atmosphere $\tau \leq 0.1$, slightly differ from normal values. This is due to the fact that due to PE in the upper atmosphere, the temperature and electron densities in the normal and spotted regions are almost the same. However, in the lower atmosphere ($\tau \leq$ 0.1-0.7), where the continuous spectrum and the first members of the Balmer series (Hα - Hγ) are effectively formed, which determine the electron densities (Unsold method), the calculated electron densities in the spot region are 2 -3 times more than in the normal atmosphere of MCP stars [8]. Based on these facts, we can conclude that, due to an increase in temperature, the electron concentration and the coefficient of continuous absorption increase. In this regard, the role of the main absorbing element, hydrogen, decreases and the structure of the atmosphere in the peculiar regions of the studied stars changes.

In addition, due to an anomaly in the chemical composition and the associated increase in Kλ a change occurs in the redistribution of the flux over wavelengths in peculiar regions, which partially "fills" the Balmer jump, decreasing its magnitude. Thus, we can conclude that the change in Kλ, the Balmer jump, photometric ($\Delta\alpha$, Z) and spectral indices (P(E)) of peculiarity are mainly associated with anomalies of chemical composition. Change of these parameters and structure of the atmosphere are also associated with a magnetic field, which enhances the anomaly of the chemical composition itself.

3. THE ROLE OF THE MAGNETIC FIELD IN THE ATMOSPHERES OF MCP - STARS

It is known that magnetic CP stars have strong magnetic fields (34 Kg). Therefore, of particular interest is the question of the influence of such a strong magnetic field on the structure of the atmosphere and the spectra of these stars. A magnetic field can affect the atmosphere of a star in two ways:

1. A change in the magnetic field with the height of the atmosphere leads to a change in hydrostatic equilibrium in the peculiar regions of the star's atmosphere.
2. The magnetic field through the Zeeman splitting of numerous lines, especially lines with a large Lande factor, increases the opacity of the star's atmosphere.

Let's consider each fact separately. According to [9], the measured differences in the magnetic field before and after the Balmer jump indicate the existence of changes in the magnetic field along with the height of the atmosphere, i.e. there is a radial gradient of the magnetic field. In the monograph by Sakhibulin [10], it is indicated that at the same temperature in magnetic stars the gas pressure is less than that of non-magnetic stars. A magnetic field suppresses convection and additionally supports atmospheric layers in peculiar regions.

However, in the direction of the magnetic field, the microturbulent velocities νt increase according to [11] according to the formula $\nu_t = 1,4 \times 10^{-4} \lambda$ Z Bs, where Z is the Lande factor, and Bs is the surface magnetic field.

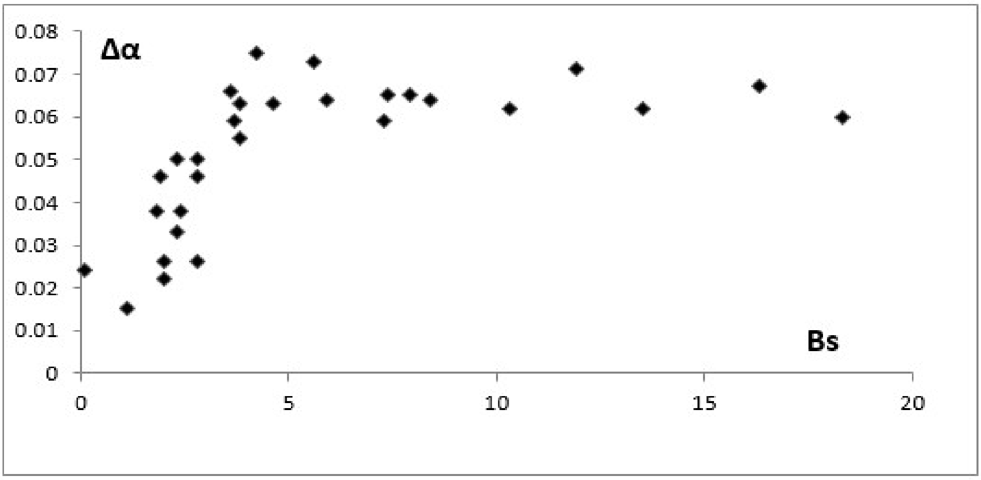

Fig. 1. Dependense of $\Delta\alpha$ on the magnet field.

Simultaneously with the change in the gas pressure Pg, the concentration of free electrons [8, 12] and the temperature (blanketing effect) also change with the height of the star's atmosphere. Thus, the existence of a radial gradient of the magnetic field leads to a change in the distribution of pressure (P = Prg+Pe), temperature and electron density with a depth of the atmosphere; those. the atmospheric structure in the peculiar regions of MCP stars changes [13]. In [14], it was found that the content of iron-type elements near the photosphere is 3-4 orders of magnitude higher than in the upper atmosphere. It was also noted there that rare-earth elements are concentrated mainly in the upper atmosphere, which also indicates the stratification character of the atmosphere of MCP stars, i.e. the atmospheric anomaly of these stars is not monotonic, but "layered" in nature. The above facts indicate that, due to the existence of a radial gradient of the magnetic field, the distribution of physical parameters (P, Te and ne) and anomalies of the chemical composition are not monotonic, but layered. The results of spectral and photometric observations of a large number of MCP stars (about 25 stars) show that the magnetic field enhances the spectral (P) and photometric indices (Δ α, Z) of peculiarity. As an example, Fig.1 shows the dependences of the degree of peculiarity (P) on the magnetic field. The values of the degree of peculiarity were taken from [15] and [16]. These values were averaged for all studied chemical elements. The mean values (P) for Cr, Si, Sr and rare earth were estimated. The values of the surface magnetic field (Bs) were taken from [17]. Figure 2 shows the dependence of $\Delta\alpha$ on the magnetic field Bs. As can be seen from Fig.2, as the magnetic field grows, so does $\Delta\alpha$. Thus, with an increase in Bs, the intensity of depression increases and reaches a maximum (Bs ≈ 4.5KG), then remains constant (saturation occurs).

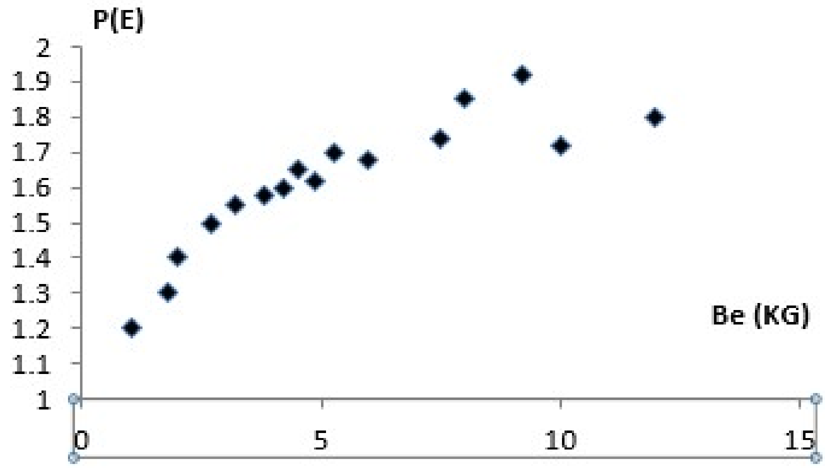

Fig. 2. Dependence of P(E) on the magnetic field

REFERENCES

1. Khokhlova V.L., Aliev S.G., Rudenko V.M. (1969). Investigation of the spectra of peculiar A-stars of the manganese group. Izv. KrAO, Vol.40, pp.65-71.

2. Kopylov I.M., Kumaigorodskaya R.N. (1973). Spectrophotometric study of the magnetically variable star α^2 CVN from high-resolution spectrograms. Astrophys. Issled., Vol.5, pp.37-51.

3. Glagolevskij Yu. V. (2002). A new list effective temperature of chemically peculiar stars. Bull. Spec. Astrophys. Obs., Vol.53, pp.33-46.

4. Aliev S.G. (2010). Determination of the effective temperatures of magnetic stars, taking into account the inhomogeneity of the atmosphere of magnetic stars, Transactions of National Academy Sciences of Azerbaijan, XXXV, No.2, pp.173-178.

5. Iliev I.Kh.(1983). On a single mechanism of spectral and photometric variability of peculiar A stars. Reports of CAO, No.39, pp.3-39.

6. Aliev S.G. (1986). Study of the effect of the integumentary effect on photometric variability of peculiar A-stars. Astron. Circular RAS, No.1450, pp.6-8.

7. Leushin V.V. (1973). Hydrogen lines in the spectra of peculiar stars. Astrophysics. Issled. (Izv. SAO), Vol.5, pp.70-80.

8. Aliev S.G. (1999). Study of chemically peculiar CP stars I. ShAO Circular., No.97, pp.17-20.

9. Romanyuk I.I. (1984). On some manifestations of magnetic amplification of absorption lines in the spectra of peculiar stars. Astrophysics. Issled. (Izv. SAO), Vol.18, pp.37-56.

10. Sakhibullin N.A. (1997). Modelling Methods in Astrophysics. Kazan FEN, pp.1-315.

11. Adelman S.J. (1973). A study of twenty-one sharp-lined cool peculiar stars. Astrophys. J., Vol.183, pp.95-101.

12. Kopylov I.M. (1961). Electron densities in the atmospheres of hot stars II. Izv. KrAO, Vol.35, pp.21-33.

13. Romanyuk I.I. (1980). On the existence of a radial field gradient in the atmospheres of magnetic stars. Astrophys. Issled. (Izv. SAO), Vol.12, pp.3-9.

14. Ryabchikova T.A. (1980). Chemical structure of atmospheres of magnetic peculiar stars. PhD Thesis, Moscow 2014.

15. Kopylov I.M. (1987). Quantitative spectral indices of a peculiarity of CP - stars of the upper part of the main Astrophysics sequence. Issled. (Izv. SAO), No.24, pp.44-67.

16. Aliev S.G., Khalilov V.M. (2012). Determining the degree of a peculiarity of magnetic CP stars B6-F0. Int. Conf. Modern Problems of Physics, pp.305-307.

17. Glagolevsky Yu.V., et al. (1986). Magnetic fields and other parameters of chemically peculiar stars. I. Astrophys. Issled. (Izv. SAO), Vol.23, pp.37-57.