Cosmic Magnetic Fields:
From Planets, to Stars and Galaxies
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First magnetic stars

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Abstract. This contribution dedicated to the analysis of the magnetism of chemically peculiar (CP) stars of the upper Main Sequence. We use our own measurements and published data to compile a catalog of magnetic CP stars containing a total of 326 objects with confidently detected magnetic fields and 29 stars which are very likely to possess magnetic field. Our analysis shows that the number of magnetic CP stars decreases with increasing field strength in accordance with exponential law, hotter and faster rotating stars have stronger fields. Intensity of depressions in the continua correlates with the magnetic field strength.

Keywords. Stars: magnetic field – stars: chemically peculiar

1. Introduction

First (after the Sun) astronomical objects with measured magnetic fields were CP stars (Babcock 1947). The technique proposed by Babcock allowed only large-scale regular magnetic fields with simple structure to be studied. The first catalog of magnetic stars was published by Babcock (Babcock 1958). It contains the results of his own studies. He found a total of 89 magnetic stars, majority of which were Ap/Bp stars.

2. The catalog

In the last 10 years more than 200 new magnetic stars were found. Now there are more then 350 stars known to be magnetic CP ones (see our catalog (Romanyuk and Kudryavtsev 2008)), it is the most numerous group of stars with measured magnetic fields. The data of magnetism of 300 stars are based on measurements of longitudinal field component B_e, and the surface field is measured from split Zeeman components only for 50 of these stars. Thus present-day concepts of magnetism of CP stars are based on results of measurements of longitudinal field component.

It was shown that the greatest number of the magnetic observations were performed by H. Babcock, G. Preston and their co-authors, J. Landstreet and his coauthors (E. Borra, I. Thompson, D. Bohlender, G. Wade and others), G. Mathys and his coauthors, S. Hubrig *et al.*, new teams (S. Bagnulo and his co-authors, M. Auriere and his co-authors), and also by a team of researchers from the Special Astrophysical Observatory working on the 6-m telescope of the Russian Academy of Sciences (Yu.V. Glagolevskij, I.I. Romanyuk, V.G. Elkin, D.O. Kudryavtsev, G.A. Chountonov, E.A. Semenko *et al.*).

Absolute majority of CP stars have magnetic field of simple dipole configuration and only 3% of these objects have more complex field.

The longitudinal component B_e averaged over the entire surface of the star varies with the phase of star's rotation. Its extreme value $B_e(extr)$ (in the case of the simplest dipole configuration of the field) is, on the average, equal to 1/3 of the surface field B_s and thus quantitatively is a quite adequate measure of the actual field strength at the surface of the CP stars. However, $B_e(extr)$ can be correctly inferred only for the objects for which the curve of variations of B_e phased with rotation period is known.

If observational data are scare and/or the period of star's rotation is unknown then its magnetic field must be estimated using an average parameter – the so-called root-mean square field (Bohlender *et al.* 1993).

3. Discussion

The number of magnetic CP stars decrease with increasing field strength with exponential law (in the $B_e(extr)$ interval from 0.7 to 5 kG):

$$N = \exp(5.2 - 0.0008 B_e(extr))$$

with the correlation coefficient 0.988.

It is easy to understand why exponential dependence breaks is not valid the interval mentioned above: 1) not all magnetic CP stars with $B_e(extr)$ smaller 600-700 G have been discovered (and hence not all such stars were included into our list) and therefore fall of the histogram in the domain of weak fields can be explained by observational selection and 2) there too few objects in the domain of strong (greater than 5 kG) fields and hence statistical approach cannot be applied in this case.

Our data show that the extreme field strength B_e exceeds 4 kG only in 6% of all magnetic CP stars. We can thus estimate that at least 90% of all magnetic CP stars in our list (Romanyuk and Kudryavtsev 2008)) have average surface field $B_s$weaker than or equal to 10 kG. We find only a few objects with stronger fields (with B_s greater than 20 kG) in our list. It appears that at the level of several tens of kG the threshold lies beyond which stronger large-scale fields cannot form in the atmospheres of Main Sequence stars.

There's a weak dependence: hotter and faster rotating stars have stronger fields. Nevertheless, strong fields (about 1 kG strength) are observed in very slow rotators, with rotation period of tens of years. The observational data give an evidence on the relic nature of the magnetic field of these objects.

Depressions in the continua of chemically peculiar stars are observed, intensity of depressions correlates with the magnetic field strength. Chemical composition is anomalous, the distribution of elements over the surface is non-uniform. Recently, first reliable observational data on the connection between location of spots of chemical elements and magnetic field configuration were obtained; that confirmed efficiency of magnetic field separation mechanism in the atmospheres of CP stars.

There is large number of nearly and bright stars among these objects so high quality observations with high S/N ratio is possible to obtain for them. Detail study of Zeeman effect using such spectra gives us new possibilities for searching the inaccessible before fine features in physical processes taking place in the atmospheres of stars with strong magnetic fields.

References

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