Magnetic stars, 2004, 212-215

Averaged stellar effective magnetic fields. A catalog

Bychkov V.D.[1,2], Bychkova L.V.[1], Madej J.[3]

[1] Special Astrophysical Observatory of the Russian AS, Nizhnij Arkhyz 369167, Russia,
[2] Isaac Newton Institute of Chile, SAO Branch, Nizhnij Arkhyz, 369167 Russia
[3] Warsaw University Observatory, Al. Ujazdowskie 4, 00-478 Warsaw, Poland

Abstract. This paper presents a description of a catalog containing averaged quadratic effective magnetic fields $\langle B_e \rangle$ for 596 main sequence and giant stars. The catalog is based on 12076 measurements of the stellar effective (or mean longitudinal) magnetic field strengths B_e, which were compiled from the available literature.

1 Introduction

Research on stellar magnetic fields is among the most important issues in both observational and theoretical astrophysics. The first measurements of magnetic fields in stars were made more than 50 years ago (Babcock & Burd 1952). Since that time, both the number of magnetic field measurements and the number of investigated stars have grown enormously. Therefore we decided to collect and present in some homogeneous form all the published magnetic field measurements.

Similar efforts were made previously, but they were based on much less numerous sets of measurements (Brown et al. 1981; Borra et al. 1983; Glagolevskij et al. 1986; Bychkov 1990, Bychkov et al. 1990). The above compilations have been essential for our understanding of the magnetic field strength and structure in stellar atmospheres, and their generation and time evolution in stellar interiors. Taking into account the large increase in the accumulated observational material, we believe that new research of this kind is necessary and fully justified.

The catalog presented below does not include either isolated degenerate stars (cooling neutron stars and most white dwarfs), or degenerate stars in interacting binaries. Only a few of the brightest white dwarfs are present in the catalog.

2 Stellar effective magnetic fields

The differential contribution dB_e to the effective magnetic field of a star is defined as the area-weighted projection of the local vector of the magnetic field $\mathbf{B}_{loc}$ onto the line of sight. The local monochromatic intensity I_ν of outgoing radiation is also a weighting factor in that projection. The effective (or mean longitudinal) magnetic field B_e is the weighted mean value, integrated over the visible stellar disc

$$B_e = \frac{\int_0^{2\pi} \int_0^{\pi/2} B_{loc} \cos\gamma \, I_\nu(\theta) \sin\theta \cos\theta \, d\theta \, d\varphi}{\int_0^{2\pi} \int_0^{\pi/2} I_\nu(\theta) \sin\theta \cos\theta \, d\theta \, d\varphi} \, , \qquad (1)$$

where γ denotes the angle between the local vector $\mathbf{B}_{loc}$ and the direction towards the observer. The variable θ denotes the colatitude angle, and φ stands for the azimuthal angle of the angular integration. The above definition assumes a simplified situation, in which the B_e is determined at a single discrete frequency only (Madej 1983).

In general, the specific intensity of radiation $I_\nu(\theta)$ depends strongly on the frequency of radiation ν, and exhibits various limb-darkening relations for different ν. Therefore the value of the effective magnetic field B_e

is also a frequency dependent quantity, when measured for the given magnetic field configuration of a star. Dependence of B_e on frequency ν was always ignored in previous papers.

In most magnetic stars the values of B_e change periodically with the rotational phase of the star. Values of B_e can be either positive or negative. Moreover, it is possible that a star with strong magnetic field can momentarily exhibit $B_e = 0$, depending on the aspect. Therefore it is useful to characterize the magnetic properties of various stars by the averaged quadratic effective magnetic field $\langle B_e \rangle$, which is always positive (Borra et al. 1983).

3 Averaging procedure

For a series of B_e measurements, we define

$$\langle B_e \rangle = \left(\frac{1}{n} \sum_{i=1}^{n} B_{ei}^2 \right)^{1/2} , \tag{2}$$

$$\langle \sigma_e \rangle = \left(\frac{1}{n} \sum_{i=1}^{n} \sigma_{ei}^2 \right)^{1/2} , \tag{3}$$

where B_{ei} denotes the i-th measurement of the effective magnetic field, and n is the total number of observations for a given star. The variable σ_{ei} is the standard error of B_{ei}, and $\langle \sigma_e \rangle$ is the rms standard error of $\langle B_e \rangle$.

The value of χ^2/n (given per single degree of freedom) allows one to judge whether a series of B_{ei} for a given star represents a reliable detection of a nonzero effective magnetic field, or whether this series is rather the result of random noise

$$\chi^2/n = \frac{1}{n} \sum_{i=1}^{n} \frac{B_{ei}^2}{\sigma_{ei}^2} . \tag{4}$$

This method for averaging the individual B_e measurements of a magnetic star was introduced by Borra et al. (1983) to study magnetic properties of He-weak stars. This evaluation of $\langle B_e \rangle$ is particularly useful to study stars with low or high noise B_e observations, where full magnetic curves cannot yet be constructed.

Borra et al. (1983) have pointed out that the value of $\langle B_e \rangle$ gives an estimate of the amplitude of the B_e variations of a given star, provided that this amplitude is substantially larger than $\langle \sigma_e \rangle$.

4 The catalog

The basic and most extensive Table A.1 presents the full catalog of stars for which we performed computations of the quadratic $\langle B_e \rangle$ averages. For convenience, these stars are ordered according to their HD number. Successive rows of Table A.1 give: HD number (or BD number in case of faint stars), spectral type, number N of magnetic observations, value of $\langle B_e \rangle$ in G, standard deviation σ in G, value of χ^2/n, method of B_e determination (abbreviations are explained at the bottom of Table A.1), and numbers referring to papers where we found the original magnetic field measurements. Cross-references between these numbers and the original papers are also given at the bottom of Table A.1.

Table A.1 contains magnetic data on a total of 596 stars of various spectral types. One can easily see that in the case of many stars listed there, the value of $\langle B_e \rangle$ is approximately equal or smaller than $\langle \sigma_e \rangle$, which usually means that detection of the magnetic field itself is highly uncertain.

Unfortunately, the extensive set of available B_e is not satisfactory. It exhibits very strong selection effects, since during the recent 50 years observers were mostly interested in measuring strong stellar magnetic fields exhibited by many hot chemically peculiar stars on the upper main sequence (dwarfs of B-A-F type). Existing measurements of B_e fields in stars of other spectral classes are much more scarce.

Both figures convincingly imply that during the recent 50 years efforts of observers measuring stellar magnetic fields were very strongly concentrated on investigation of chemically peculiar A stars.

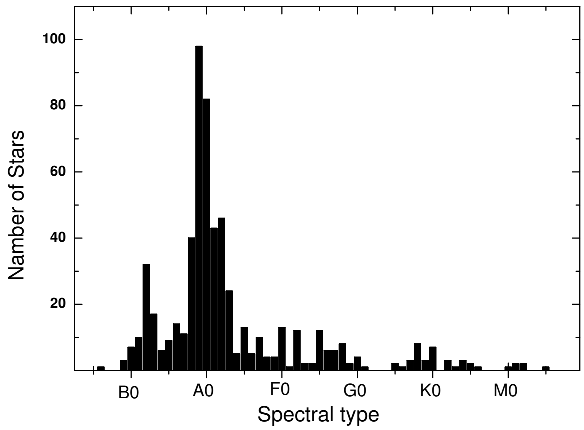

Figure 1: *Number of stars which have magnetic field B_e measured vs. spectral type.*

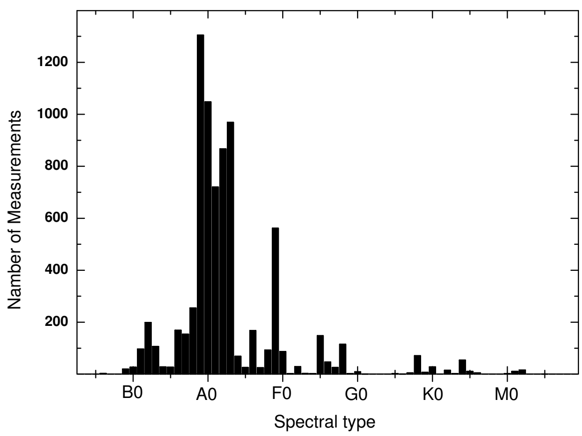

Figure 2: *Total number of published B_e measurements vs. spectral type for all stars collected in our catalog.*

5 Summary

We present an extensive list of the averaged quadratic effective magnetic fields $\langle B_e \rangle$ for main sequence and giant stars. Individual B_e observations were compiled from the available literature, and were further processed to obtain a homogeneous set of averaged effective magnetic fields.

We consider our averaged values of $\langle B_e \rangle$ as a reasonable representative measure of the field strength in the atmosphere of a given star. This is because the value of $\langle B_e \rangle$ results directly from the observed effective magnetic field strengths B_e and is a strictly model-independent quantity. Parameter $\langle B_e \rangle$ is a single scalar parameter which describes the magnetic field of a star also if the number of individual B_e is low or the B_e observations are noisy.

Acknowledgements. We are grateful to J.D. Landstreet, the referee, for his criticism and numerous suggestions which helped us to improve this paper. Our research is based on data compiled and posted in the SIMBAD, ADS, and CDS databases. We acknowledge support from the Polish Committee for Scientific Research, grant No. 2 P03D 021 22.

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The catalog has been published in Astron. Astrophys. **407**, pp.631-642 (2003). Table A.1 and its references are available only in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/407/631 .