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Magnetic fields of stars

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This paper reports on the description of the accumulated observation material about magnetics fields of stars. The upper limits of observed variability of magnetic fields of stars are presented.

Keywords: Stars: magnetic fields – stars

1 Introduction

Research into stellar magnetic fields is one of the most important issues in both observational and theoretical astrophysics. The first measurements of magnetic fields in stars were done more than 70 years ago (Babcock and Burd 1952). We will look at the perceptions of effective (or mean longitudinal) magnetic fields obtained so far.

2 Observations data

During the whole time about 50 thousand estimates of observation were received effective magnetic field (MF) measurements for 2,727 stars. Figure 1 shows the distribution of the number of MF estimates received by year.

We see clearly from Fig. 1 that the situation with magnetic measurements changed significantly in around 2004. Since then, the number of measurements has increased significantly. From 2004 to the present more than 30 thousand MF measurements have been received. The highest number of new measurements have been taken in recent years on the ESPaDOnS CFHT (Canada–France–Hawaii Telescope 3.6 m) – 38.5%, FORS1/2 (ESO, 8 m, telescopes UT1, UT2, UT3) – 23.1%, NARVAL TBL (Telescope Bernard Lyot, 2 m) – 17.7%, HARPS (ESO, 3.6 m) – 7.4%, MMS or NES (SAO RAS, 6 m) – 6.3%, MuSiCoS (TBL 2 m, Isaac Newton Telescope 2.5 m, South

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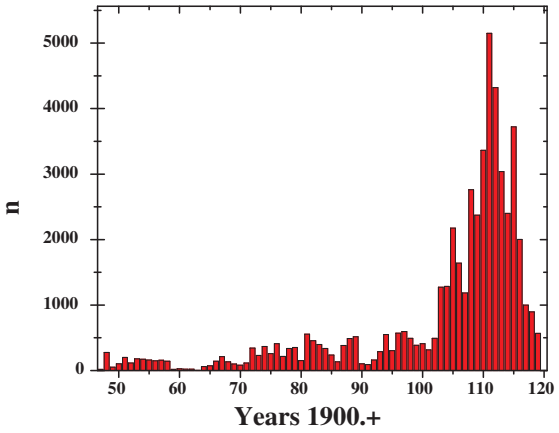


Figure 1 The distribution of the number of magnetic field estimates received by year.

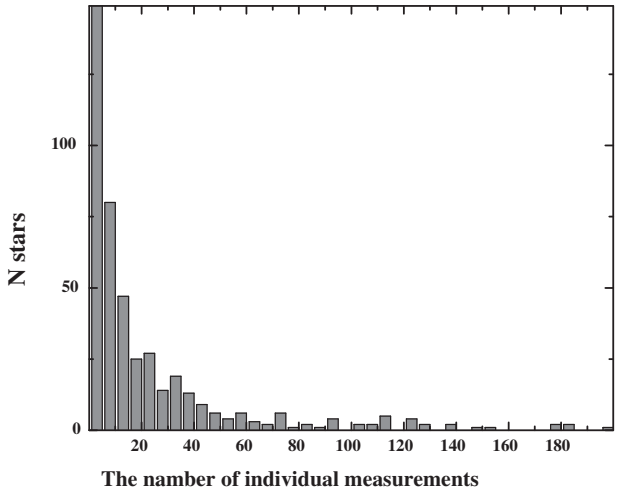


Figure 2 The number of CP stars in a single bin versus the number of individual B_l determinations for a single star. The width of bins is equal to 5. The leftmost bin (1–5 B_l measurements for a star) includes 1776 stars and has been cut to fit in the above figure.

African Astronomical Observatory 1.9 m) – 3.1%. The remaining measurements are obtained from a number of other instruments, but each contribution does not exceed one per cent. FORS1/2 is mainly designed for overview tasks, receiving estimates for weak objects or with high time resolution, but in some cases it allows to obtain MF estimates with sufficient high accuracy. This shows only the condition for 2019. It is necessary to note a significant increase in the accuracy of measurements. This gives a wide application of LSD (Donati et al. 1997), WLSD (Wade et al. 2000) and other methods. We do not consider the results of surface mapping of magnetic fields obtained with the ZDI (Semel 1989) and other methods and we will devote a separate

work to this. The decrease in the number of MP estimates after 2016 is due to the fact that not all MF measurements have been published. Figure 2 shows the degree of magnetic investigation of stars. Nearly 65% of stars have from 1 to 5 magnetic field estimates.

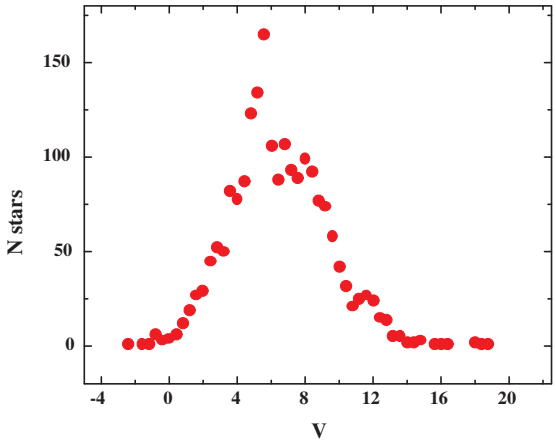


Figure 3 The distribution of stars by the apparent magnitude of m_V.

Figure 3 shows the distribution of stars by the apparent magnitude of m_V. Figure 4 shows distribution by spectral types of stars for which MF measurements were taken.

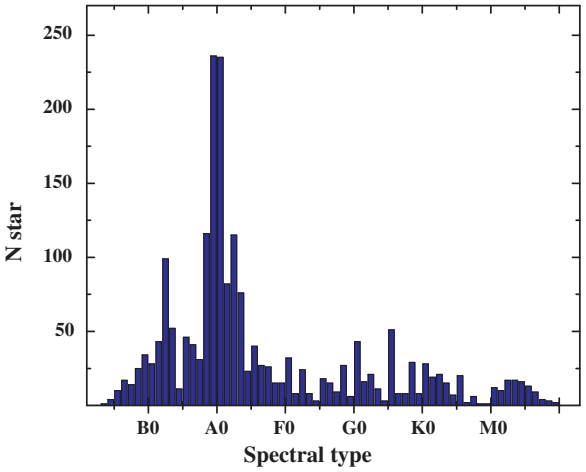


Figure 4 The distribution by spectral types of stars for which MF measurements were taken.

Figure 4 shows that Ap/Bp stars are the most studied. These stars are divided into groups by chemical anomalies of the atmospheres. The relative magnetization of

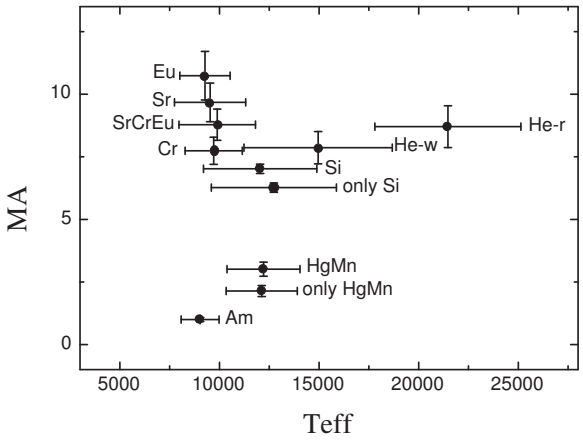


Figure 5 MA for various subclasses of CP stars. Bars define the range of $T_{\rm eff}$ and MA occupied by a given subclass. MA, relative coefficient of atmosphere magnetization.

Table 1 Maximum values of the half-amplitudes B_1 and B_2 for various types of stars.

Type of star	n stars with simple wave	B_1 max G	n stars with double sinusoid	B_1 max G	B_2 max G
Ap/Bp	147	3000	49	5000	1200
Var. β Cep type	14	500			
Slowly pulsating B stars	6	350			
High proper motion stars	2	10	5	200	50
Var. δ Cep type	1	80			
Multiple stars	11	1050	3	5000	750
Pulsating stars	2	650			
Var. BY Dra	3	10	4	35	15
Var. Ori type	2	870			
Rotationally var. star	5	2900	3	3500	350
Stars hosting planets	7	10	1	3	2
Normal chemical comp. stars	4	1350	1	50	40
Be stars	5	750	1	650	170
Var. δ Sct type	1	3000			
Semi-regular var. pulsating	2	10			
Flare stars	10	400	5	700	150
Ae/Be Herbig stars	6	450	2	650	170
T Tau stars	3	330	1	300	80
Pre-main sequence	1	150	1	20	10
EB Algol type			1	35	10
Stars in open clusters	5	850	2	3300	1000

the atmospheres of these stars were studied in Bychkov et al. (2009) and is shown in Fig. 5.

The magnetic fields of stars are variable. By this we can fully judge the magnetic field of the star after the magnetic field variability has been studied. To date, MF

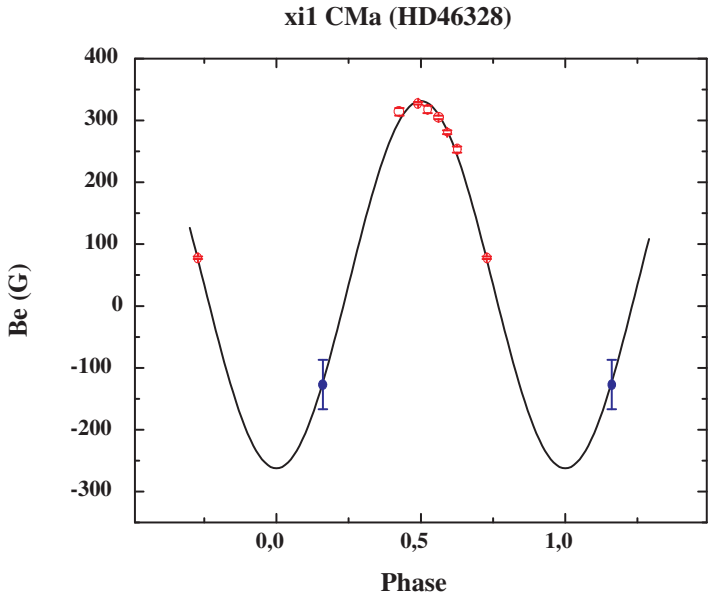


Figure 6 The curve shows the least-squares sinusoidal fit to the annual mean measurements over a 30 year period.

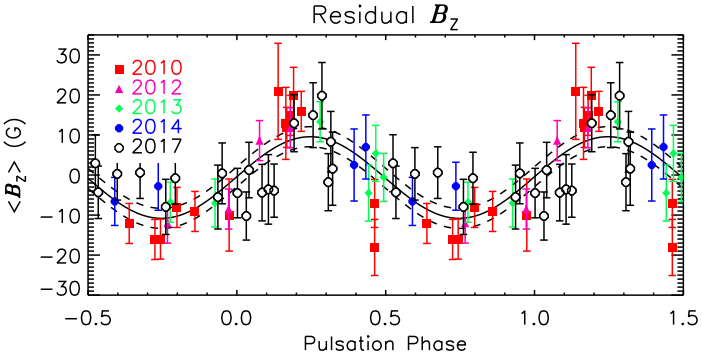


Figure 7 Residual ESPaDOnS B_l measurements, after subtraction of the mean B_l at each epoch, phased with the pulsation period.

variability has been studied in approximately 340 stars. The upper limits of MF variability are given in Table 1 (Bychkov et al. (2019) for different types of stars.

Average magnetic phase curves can be found for part of the stars in the catalog (Bychkov et al. 2005). A second version of the catalog is currently being prepared for publication. Let us give one interesting example of magnetic field variability in the pulsating star ξ^1 Per (HD46328) type β Cep. The star pulsates with the main period of $P_0 = 0.2095763(1)$ days (see Fig. 7) while slowly rotating with a period of about 30 years (Shultz et al. 2017) (see Fig. 6).

3 Conclusions

Magnetic fields of various configurations are probably present in all stars. Increasingly accurate measurements are needed to detect and investigate them.

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