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Observations of magnetic white dwarfs in the Special Astrophysical Observatory of the Russian Academy of Sciences

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Abstract. Studies of magnetic white dwarfs in the Special Astrophysical Observatory of the Russian Academy of Sciences (SAO RAS) have been carried out since 1990 with the 6-m telescope using various spectrographs and with the 1-m Zeiss-1000 telescope using the Multi-Mode Photometer-Polarimeter (MMPP). As a result, we have derived direct estimates of the longitudinal magnetic field obtained with spectropolarimetric observations and circular polarization values in the photometric mode. We observed both well-known magnetic white dwarfs and objects with no data about magnetic field. Among well-known magnetic objects, there were white dwarfs with an extremely strong magnetic field of up to hundreds megagauss and weak magnetic white dwarfs with a field of several tens kilogauss. The use of these data and the data obtained by other authors allowed time series of the observations of these objects to be several decades. Analyzing these time series, we estimated the lower limits of the evolution times of the magnetic fields of white dwarfs.

Keywords: stars: white dwarfs, magnetic field, evolution

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1 Introduction

SAO RAS astronomers have been conducting a program to search for global (regular) magnetic field of white dwarfs (WDs) since 1990. The main goal of this program is to search for magnetic white dwarfs (MWDs) with a field smaller than a megagauss and to study their distribution by magnetic fields. Analysis of this distribution can provide an answer to the question about the physical nature of these objects, in particular, whether MWDs make a specific subtype of white dwarfs with unique evolutionary features or if MWDs are objects with the strongest magnetic fields in the distribution of magnetic fields of all WDs. In this paper, we again analyze these studies combined with new results of other authors.

Observations for these programs were carried out on the 6-m and 1-m telescopes of the SAO RAS, on the ESO telescopes and on the 3.6-m telescope of the Franco-Hawaiian Observatory (Fabrika et al. 1997; Valyavin et al. 2005, 2006, 2008, 2014; Landstreet et al. 2012, 2016, 2017; Aitov et al. 2022).

2 Estimates of the magnetosphere stability time of white dwarfs

The time series of observations of magnetic objects ranged from several to almost 50 years within the above programs and using the data by other authors. Comparing the results of magnetometric and polarization observations at these time intervals, we obtained lower estimates of the stability time of the MWD magnetospheres. For the stars with known rotation periods, we obtained the amplitudes from sinusoid approximation for different sections of the time series (spaced by years). Then we obtained estimates of the characteristic evolution times using the linear model of the magnetic field secular evolution and the derived amplitudes. For the objects without any data on their rotation, all points were approximated linearly.

Table 1 presents the results. The magnetospheres of these stars remain stable for periods from several decades (for WD 2359−434) to hundreds or more (for GRW +708247 and WD 1312+098) years. First, this confirms the hypothesis of the fossil origin and slow dissipation of magnetic field (Wendell et al. 1987). Second, these MWDs can be used as the circular polarization standards, because their magnetic fields remain stable for periods of decades or more years. So far, there has been no list of such standards.

Table 1. Estimates of evolution time.

Star	Estimates of evolution time, years
WD 0009+501	80
WD 1953−011	100
WD 2047+372	140
WD 2359−434	40
GRW +708247	$\gg 100$
WD 1312+098	$\gg 100$

3 Distribution of white dwarfs' magnetic field

The objects discussed above have magnetic field strengths of several tens of kilogauss and greater. However, most white dwarfs do not show any magnetic properties. The solution to this problem should be sought in the distribution of white dwarfs by their magnetic field strengths.

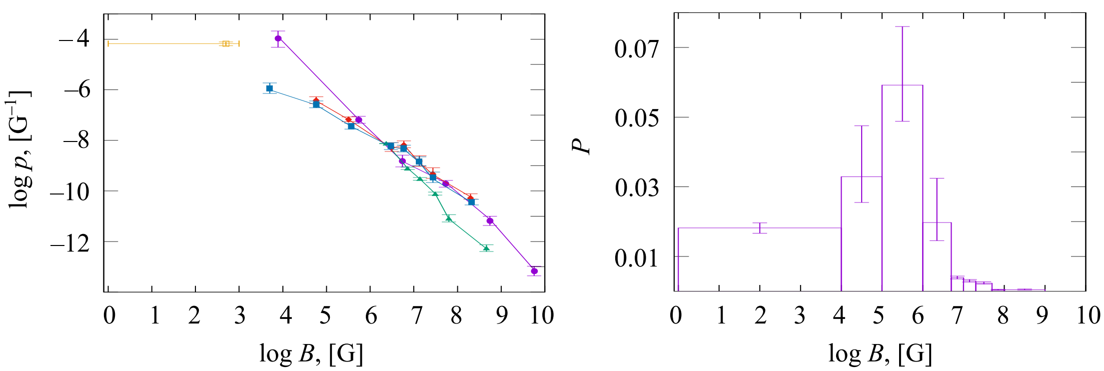

Fig. 1. Left panel: The function of the magnetic field of white dwarfs (MFF, the dependence of the probability density p of detecting the MWD with the set magnetic field strength) according to different authors. The purple circles signs represent the function given in Fabrika & Valyavin (1999), the green triangles represent the function according to Kepler et al. (2013), the red diamonds represent the function according to Bagnulo & Landstreet (2021), the blue solid squares represent the function according to Holberg et al. (2016) with additions from Bagnulo & Landstreet (2021) and Valyavin et al. (2006). The orange open square represents the lower limit of the MFF according to Bagnulo & Landstreet (2021) for the objects in which no magnetic field was detected and the 3σ criterion for which the field was smaller than 1 kG (in the paper, the accuracy of 1σ is indicated). Right panel: Probability P of detecting the MWD with the strength. The figure is drawn according to Kepler et al. (2013) for the objects with strong magnetic fields and according to Bagnulo & Landstreet (2021) for the objects with weak magnetic fields.

For the first time, this distribution (Magnetic Field Function, MFF) was constructed by (Fabrika & Valyavin 1999). We have built new MFFs based on modern reviews; they are shown in Fig. 1 in the left panel. All functions show power dependence. However, the dependence is broken in the area below 100 kilogauss and demonstrates a "fall" that illustrated in the right panel of Fig. 1. Our explanation of this phenomenon is that the symmetry of the magnetic field is caused by dynamic processes in the surface layers of white dwarfs. Therefore, the search for magnetic fields in this region by polarimetric methods becomes ineffective.

4 Conclusion

Estimates of the stability time of the magnetospheres of six MWDs are obtained. They range from several decades to hundreds or more years. This fact makes it possible to use these objects as circular polarization standards.

The MWD distribution by magnetic fields is constructed. A selection "fall" is found in the distribution of the magnetic field strengths below 100 kG. The reason for this phenomenon is the destruction of the global symmetry of the magnetic field by the processes in the surface layers of the MWD.

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