MAGNETISM OF WHITE DWARFS
(intermediate results of a survey for kilogauss magnetic fields in white dwarfs)

G. Valyavin [1],[2], S. Bagnulo[3], S. Fabrika[2], A. Reisenegger[4], G.A. Wade[5], Inwoo Han[1], D. Monin[6]

[1] Korea Astronomy and Space Science Institute, 61-1, Whaam-Dong, Youseong-Gu, Taejeon, Republic of Korea 305-348
[2] Special Astrophysical Observatory,Russian Academy of Sciences, Nizhnii Arkhyz, Karachai Cherkess Republic, 357147, Russia
[3] European Southern Observatory,Alonso de Córdova 3107, Santiago, Chile
[4] Departamento de Astronomía y Astrofísica, Pontificia Universidad Católica de Chile, Casilla 306, Santiago 22
[5] Physics Department, Roual Military College of Canada, Kingston, Ontario, Canada
[6] Dominion Astrophysical Observatory, 5071, West Saanich Road, Victoria, British Columbia, V9E 2E7,Canada

ABSTRACT. We shortly present intermidiate results of a survey for weak magnetic fields among degenerate stars (white dwarfs and hot subdwarf stars). Kilogauss upper limits of longitudinal magnetic fields are presented for several brightest DA white dwarfs and new candidates to magnetic degenerates are found. We discuss our findings in the frame of 25% fractional incidence of white dwarf magnetism in the kilogauss region. The complete version of this presentation will be published in the **Astrophysical Journal**.

Key words: Stars: white dwarfs: subdwarfs: magnetic stars; stars: individual: WD1036+433, WD1647+591, WD1105-048.

1. Introduction

The investigation of white dwarf stars (WDs) is of fundamental importance for the understanding of stellar and galactic evolution, as WDs represent the final evolutionary stage of more than 90% of all stars. Nowadays we believe that the general properties and evolution of white dwarfs are fairly well understood. However, there are several important problems that still need to be properly addressed, especially those connected with the origin of the group of about one hundreed isolated magnetic white dwarfs (MWDs, Liebert & Sion, 1979; Angel, et al., 1981; Putney, 1999; Liebert, et al., 2003). Latest conclusions about progenitors of the MWDs (Liebert et al., 2003; Wickramasinghe & Ferrario, 2005) or about evolution of their magnetic fields which is likely seen in observations (Liebert & Sion, 1979; Valyavin & Fabrika, 1999; Liebert et al., 2003) form two main problems to be studied in the frame of stellar magnetism. The first problem is related to the origin of the MWDs. Earlier studies (Angel, et al., 1981) suggested that MWDs are descendants of magnetic Ap/Bp stars. More recent studies, however, have suggested that the progenitors are not restricted to this class (Liebert et a., 2003; Wickramasinghe & Ferrario, 2005). The second problem is associated with the evolution of a global magnetic field during a WD's life: it has been shown (Liebert & Sion, 1979; Valyavin & Fabrika, 1999; Liebert et al., 2003) that the magnetic field exhibits some peculiar features during the WD life time. One of them is that WDs with strong fields show a tendency to increase in fractional incidence with age, in contradiction to the hypothesis that WD magnetic fields decay with time.

The implications of the above studies are extremely significant. Unfortunately, *they are based on a highly biased and limited sample of strongly magnetic WDs*, and therefore they are still controversial and require better statistics. It appears quite likely that the fraction of MWDs (as compared to the total population of known WDs) will increase significantly if high-precision spectropolarimetric surveys are conducted. For the better understanding of the WD magnetic field origin, it is also important to extend the observations to a group of pre-WD hot subdwarf stars (Elkin, 1996), the magnetic nature of which is still not well studied.

The required accuracy of magnetic field measurements is about 1 kG or better. For these reasons, we are carrying out an observational program with the 6 m and 8 m Russian and European telescopes. Here, we present some new results from our survey (Valyavin et al., 2003) for kilogauss magnetic fields among isolated degenerate stars.

2. Observational strategy

Our observations are aimed at studying a random sample of WDs in a limited space volume with an accuracy of magnetic field measurements of about 1-2 kG and better. To answer the question of *whether WD magnetic field evolution can be detected in observations*, it is important to extend field measurements with uniform accuracy to the whole range of WD masses and temperatures. All types from the hottest (youngest) WDs to the coolest (oldest) degenerates of DA8-9 spectral classes are present in our list, in order to provide the survey with appropriate statistics.

With the aid of the 6 m telescope (BTA), we searched for circular polarization in cores of the hydrogen lines of the brightest ($V < 14$ mag) northern hot (young) WDs and WDs of intermediate temperatures. The cooler (and older) WDs, however, can not be studied well with this telescope. These stars are intrinsically fainter and have weaker Balmer absorption features that make it difficult to study them polarimetrically with the necessary field measurement accuracy. In order to minimize this observational bias, we have extended our list toward observations with the VLT of a random sample of southern WDs with $T_{\rm eff} < 9000\ K$. These observations, when completed, will make it possible to determine the fractional incidence of magnetism in the low-field regime among WDs of different ages. Our full list consists of 40 isolated WDs of different masses and temperatures. In this paper, we report observations of the 8 brightest WDs in our target list for the 6 m telescope.

3. Observations and data reduction

The observations were carried out at the 6 m Russian telescope from 2003 to 2005 in the course of about 9 observing nights shared with other observational programs. The observations are now obtained using the updated prime-focus spectrograph-polarimeter UAGS (R $\sim$ 2000, Hα region). The instrument and observational technique are described in detail by Naydenov et al. (2002).

In polarimetric observations of each star, we obtain series of short, consecutive exposures at two orthogonal orientations of the quarter-wave plate (the sequence of its position angles is $+45°, -45°, -45°, +45°$). Assuming *a priori* that the time-scale of possible variability of the longitudinal magnetic field could be as short as a few minutes, we usually set the integration time of each exposure to 60-300 s, depending on stellar magnitude and sky conditions.

For longitudinal magnetic field measurements, we initially use cross-correlation analysis of the displacement between positions of the Hα line in spectra of opposite circular polarizations (see Valyavin et al., 2005 and references therein). Applying this method to the series of short time exposures, we then analyze rows of the longitudinal field values to rule out a possible variability of the magnetic field on longer time scales (tens of minutes and longer). After the determination of these scales for each star, we combine spectra of equal orientations of the quarter-wave plate into longer equivalent exposures and build Stokes I and V profiles as described by Valyavin et al. (2005). Finally, we obtain the longitudinal field determinations from the Stokes I and V profiles through the weak-field approximation, as described by Bagnulo et al. (2002).

4. Results

Results of longitudinal magnetic field measurements are summarized in Table 1, where column 1 is the name of the WD, column 2 is the spectral class, column 3 is the Julian Date of the midpoint of the observation, column 4 is the exposure time, and columns 5-6 report the measurements and uncertainties of the longitudinal magnetic fields as obtained using the weak-field approximation.

Six targets of our list (WD0009+501, WD0644+375, WD0713+584, WD1105-048, WD1134+300, WD1647+591) have already been observed by Schmidt & Smith (1995); Valyavin et al. (2003); Aznar Cuadrado et al. (2004). In order to minimize the probability to observe a possible zero crossover of the longitudinal magnetic field due to rotation, we repeated the observations of these WDs.

Two targets in our list (WD1105-048 and WD1036+433) showed longitudinal magnetic fields by the presence of weak circular polarization in the Hα cores of their spectra. **WD1036+433** is the brightest ($V = 11.22$) weak-lined hot subdwarf star. In three observations of this degenerate in different nights, the longitudinal magnetic field was detected once at more than the 3σ level (see Table 1). **WD1105-048** is, in comparison, a well-studied, ordinary DA3 WD discovered recently as magnetic by Aznar Cuadrado et al. (2004). The longitudinal magnetic field of this star was found to be variable, varying from about -1 to -4.6 kG. In this study, we confirm the magnetic nature of this degenerate star.

Table 1: Determination of the mean longitudinal field obtained as explained in § 3.

Name	SP	JD	Exp	B_l	σ
WD		-2400000	sec	*kG*	*kG*
0501+527	DA1	53004.49	3600	-3.9	2.8
0644+375	DA2	53004.59	4020	+1.9	1.8
0713+584	DA4	53003.53	7100	+0.6	0.8
		53003.61	7100	+0.8	1.0
		AVER		+0.7	0.6
1036+433	sdO	53005.49	6000	+9.6	2.6
		53005.63	5000	+5.9	2.8
		53422.34	5500	-1.1	3.2
		AVER		+5.5	1.6
1105-048	DA3	53006.54	3600	-7.9	2.6
		53007.55	7200	-4.8	2.3
		53007.64	3100	+0.1	2.7
		AVER		-4.4	1.4
1134+300	DA3	53004.64	1800	+8.9	4.5
		53006.62	3600	+3.5	2.7
		AVER		+4.9	2.3
1647+591	DAv4	53194.47	3600	−2.9	3.4
		53195.46	3600	-8.7	3.2
		53422.59	5100	-0.5	2.8
		AVER		-3.8	1.7

5. Discussion

We have presented new observations of kilogauss longitudinal magnetic fields in 6 WDs and 1 hot subdwarf. We confirm the magnetic nature of WD1105-048 and find a new candidate weak-field magnetic hot subdwarf, WD1036+433. Kilogauss upper limits are presented for the other 5 WDs. Here, we formally estimate the fraction of kilogauss MWDs as 17% (1/6) that is consistent with the estimate of Aznar Cuadrado et al. (2004) (25%). Note, that practically the same estimate of the frequency of kilogauss MWDs has been done using the magnetic field function technique (Fabrika & Valyavin, 1999). Based on these results, one might speculate that the MWDs are not a unique class of degenerate stars, but rather represent the strong-field tail of a continuous distribution of field intensities.

The 10 % fraction of megagauss MWDs (Liebert et al., 2003), in comparison to 25 % for kilogauss fields, supports this idea. This conclusion, however, could be more definite if framed in terms of surface magnetic fields (mean field modulus, B_s) since our study is based on observations of only the longitudinal component B_l of the field, which is smaller than B_s in all cases. In case of a dipolar geometry, the difference may be as much as 3 times and higher, depending on the orientation of the dipole to the line of sight. Furthermore, the large-scale magnetic field structure of the weak-field MWDs may be different from dipolar, giving a very strong observational bias to the underestimation of the incidence of WD magnetism in the polarimetric observations. Therefore, the above conclusion about the incidence of magnetism below 1 kG can only be considered as a lower limit.

Acknowledgements. GV is grateful to the Korean MOST (grant M1-022-00-0005) and KOFST for providing him an opportunity to work at the KAO through Brain Pool program. GAW acknowledges Discovery Grant support from the Natural Sciences and Engineering Research Council of Canada. AR acknowledges FONDECYT (grant 1020840).

References

Angel J.R.P., Borra E.F., Landstreet J.D.: 1981, *ApJ Supplement*, **45**, 457.

Aznar Cuadrado R., Jordan S., Napiwotzki R., Schmid H.M., Solanki S.K., Mathys G.: 2004, *A&A*, **423**, 1081.

Bagnulo S., Szeifert T., Wade G.A., Landstreet J.D., Mathys G. 2002, *A. & A*, **389**, 191.

Elkin V.: 1996, *A&A*, **312L**, 5.

Fabrika S.N., Valyavin G., : 1999, *11th. European Workhop on White Dwarfs, ASP Conf. Series*, **196**, 214. J.E. Solheim, E.G. Meistas ed.

Liebert J., Sion E.M.: 1979, *Astrophysical Letters*, 20, 53.

Liebert J., Bergeron P., Holberg J.B.: 2003, *A. J.*, **125**, 348.

Naydenov I.D., Valyavin G.G., Fabrika S.N., et al.: 2002, *Bull. Spec. Astrophys. Obs.*, **53**, 124.

Putney A.: 1999, *11th. European Workhop on White Dwarfs, ASP Conf. Series*, **196**, 195. J.E. Solheim, E.G. Meistas ed.

Schmidt G.D., Smith P.S.: 1995, *Ap. J.*, **448**, 305.

Schmidt G.D., Grauer A.D.: 1997, *Ap. J.*, **488**, 827.

Valyavin G., Fabrika S.N.: 1999, *11th. European Workhop on White Dwarfs, ASP Conf. Series*, **196**, 206. J.E. Solheim, E.G. Meistas ed.

Valyavin G.G., Burlakova T.E., Fabrika S.N, Monin D.N.: 2003, *Astronomy Reports*, **47**, 589.

Valyavin G., Bagnulo S., Monin D., Fabrika S., Lee B.-C., Galazutdinov G., Wade G., Burlakova T.: 2005, *A.& A.* , **439**, 1099.

Wickramasinghe D.T., Ferrario Lilia: 2005, *MNRAS*, **356**, 1576.