PROGRESS IN MODELING MAGNETIC WHITE DWARFS

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1. Introduction

The analysis of magnetic white dwarfs has made considerable progress since the last white dwarf workshop: 1. It could be shown that neither the magnetic white dwarf Grw +70°8247 (Jordan & Friedrich, 2001) nor LP 790–29 (Jordan & Friedrich 2002, Beuermann et al. 2002) are fast rotators (P < 10 min) but are rotating slowly (P > 20 years). 2. Automatic fitting procedures have been developed which can be used to derive the geometries of complex magnetic fields for rotating white dwarfs (see Euchner et al. 2002, Euchner et al., these proceedings, Gänscicke et al, these proceedings). 3. First models with consistent energy values and oscillator strengths for neutral helium in strong magnetic fields have been calculated and can be compared to observed spectra and polarization data.

Grw +70°8247 the first white dwarf in which a magnetic field has been detected, turned out to be a long standing challenge for the modeling, since the polarization could not be fitted, while the flux spectrum could be well reproduced by centered dipole models. Now, a possible solution could be found. First models with consistent energy values and oscillator strengths for neutral helium in strong magnetic fields have been calculated and can be compared to observed spectra and polarization data. Such calculation were applied to the DAP GD 229.

2. Analysis of Grw +70°8247

Fits to the flux spectrum of Grw +70°8247 have been published by Wickramasinghe & Ferrario (1988), Jordan (1988), Jordan (1989), and Jordan (1992). The result was a pure dipole models with a polar field strength of about 320 MG. However, one mystery of this well studied object still remained: the detailed wavelength dependence of the circular and linear
polarization predicted by the dipole model strongly deviated from the observation.

Since the fitting procedure has very much improved since than, I have repeated the analysis with a method developed by Jordan and Rahn. The code is similar to the one described by (Euchner et al., 2002) but uses a genetic algorithm instead of an evolutionary strategy.

The best fit of the spectrum to a pure magnetic dipole model resulted in a polar field strength of 347 MG and an angle $i = 56^\circ$ between the dipole axis and the observer. However, the model cannot fit the observed polarization (see. Fig. 1). The situation does not change if one allows for offsets of the dipole relative to the center of the star. The fitting of the spectrum resulted in dipole offsets smaller than 0.005 stellar radii.

The next step was an expansion of the surface magnetic fields into spherical harmonics

$$B_r = -\sum_{l=1}^{\infty} \sum_{m=0}^{l}(l + 1)(g_l^m \cos m\phi + h_l^m \sin m\phi) P_l^m(\cos \theta)$$

$$B_\theta = +\sum_{l=1}^{\infty} \sum_{m=0}^{l}(g_l^m \cos m\phi + h_l^m \sin m\phi) \frac{dP_l^m(\cos \theta)}{d\theta}$$

$$B_\phi = -\sum_{l=1}^{\infty} \sum_{m=0}^{l} m(g_l^m \cos m\phi + h_l^m \sin m\phi) \frac{dP_l^m(\cos \theta)}{d\sin \theta}$$

with the associated Legendre polynomials $P_l^m$. The components are given in spherical coordinates $r, \theta,$ and $\phi$. For this paper we limited ourselves to $l \leq 4$, i.e. to 24 free parameters; an additional parameter is the angle $i$ between the arbitrary magnetic axis and the observer.

The best fit parameters were

$i = 75.9^\circ$

$g_{10} = 183.00 \quad g_{11} = +0.71 \quad h_{11} = +0.36$

$g_{20} = -40.58 \quad g_{21} = +16.16 \quad h_{21} = -16.38 \quad g_{22} = +0.02 \quad h_{22} = +0.16$

$g_{30} = +1.39 \quad g_{31} = -1.51 \quad h_{31} = +6.16 \quad g_{32} = -0.46 \quad h_{32} = -0.38$

$g_{33} = -0.22 \quad h_{33} = +0.55$

$g_{40} = +1.45 \quad g_{41} = -5.41 \quad h_{41} = +7.41 \quad g_{42} = -0.49 \quad h_{42} = -0.37$

$g_{43} = +0.53 \quad h_{43} = +0.56 \quad g_{44} = +0.11 \quad h_{44} = -0.48$

Fig. 1 shows the improvement: While the fit to the flux spectrum remained virtually unchanged, the main features of the wavelength dependent circular polarization can now be well reproduced by the model. The change is mainly due to a different distribution of the magnetic field component towards the observer. Due to the large number of free parameters it is clear that this solution is not unique and that other models could fit the flux and polarization spectrum well. However, this is the first time that the circular
Figure 1. Left: Synthetic spectra and circular polarization compared to the observation of Grw +70°8247 (black). The light grey curve corresponds to the best fit pure magnetic dipole model, while the best fit for an expansion into spherical harmonics ($l \leq 4$) is presented in dark grey. Right: Distribution of the absolute value of the magnetic field (left) and of the component towards the observer (right) for the expansion into spherical harmonics polarization of the most famous magnetic white dwarf Grw +70°8247 could be explained by any model.
3. Modeling of GD 229

For a long time modeling of magnetic white dwarfs was limited to pure hydrogen. However, as in the case of non-magnetic white dwarfs some of the objects posses helium rich atmospheres. However, wavelengths for helium components were not available before 1998 when Jordan et al. could identify most of the absorption features in the spectrum of GD 229 with stationary line components. In the meantime the data sets have been enlarged (see Jordan et al. (2001)).

Radiative transfer calculations had to wait until data for oscillator strengths were calculated by Schmelcher and Becken. Now a first application to GD 229 with consistent line data for helium in a magnetic field is presented here.

Fig. 2 shows the best fit to the spectrum of GD 229 with an offset dipole model ($i = 30^\circ$, dipole strength 497 MG, offset in dipole direction $-0.25$ stellar radii, offsets in other directions $< 0.004$ stellar radii) and several features, in particular the main feature at 4200 Å, are well reproduced. However, several other parts of the spectrum lack resemblance with the observaion. There is also no agreement of the model prediction with circular polarization. Therefore, the fitting is not satisfactory at the moment and has to be continued.
References

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