Magnetic field geometries of Ap and Bp stars using the 6 m telescope

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Abstract.
We report on a long-term observational programme, making substantial use of the 6 metre telescope, aimed at establishing a firm observational understanding of the basic systematics of magnetism in Ap and Bp stars.

Key words: magnetic fields, Ap and Bp stars

1. Introduction

The strength, structure and variability of the magnetic fields of middle main sequence stars are both qualitatively and quantitatively different from those exhibited by late-type stars, wherein magnetohydrodynamic (MHD) dynamos are invoked as the source of magnetic activity (e.g. Krause, 1993). It is clear that fundamentally different physical processes are responsible for the magnetism of hot stars: MHD dynamo models seated in the convective cores of A and B stars (e.g. Moss, 1989) are unable to produce strong fields sufficiently quickly to be consistent with the youngest observed magnetic hot stars. While a fossil (or relic) origin is more generally accepted, the apparent absence of strong magnetic fields in some 90%-95% of main sequence A and B type stars, the often wildly different magnetic characteristics of magnetic stars which presumably formed under similar conditions (stars in binary systems, associations and open clusters), and the apparent lack of ordered magnetic fields in the direct precursors of main sequence A and B stars (the Her big Ae/Be stars (Glagolevskij, Chountonov, 1998)) represent critical issues that remain to be addressed. Thus the origin or source of magnetic fields in hot stars remains essentially unknown.

Whatever their ultimate source, the magnetic fields of these stars must presently result from currents operating deep with their envelopes or interiors. Therefore any magnetic field will evolve over time due to, for example, field advection by internal circulation currents, ohmic decay, and changes in hydrostatic equilibrium of the star resulting from stellar evolution. Such evolution has the potential to provide us with information about both the physical state of the stellar interior and about the source of the magnetic field.

2. Goals, method and targets

The goal of this study is to establish a firm observational understanding of the basic systematics of magnetism in Ap and Bp stars so as to direct and motivate future theory in this area. By way of conventional Zeeman observations (mean longitudinal magnetic field; mean magnetic field modulus; net broadband linear polarisation) and simple numerical modeling, we are constructing quantitative models of the global-scale magnetic configurations of a large sample of Ap and Bp stars with a variety of ages, effective temperatures and rotation rates, both inside and outside binary systems (e.g. Wade et al., 1996abc, 1997ab, 1998, 1999, 2000; Wade, 1998). When complete, this sample should comprise some 30 stars, more than doubling the number of stars for which reliable models exist. Many of these stars have accurate **HIPPARCOS** parallaxes, allowing us to locate them on the HR diagram and to explore the evolution of the magnetic field as the star evolves (e.g. Wade, 1997).

3. First results

As of the writing of this paper, we have developed models for 10 stars using various kinds of data, and we have 18 additional stars for which observing is ongoing. The sample for which modeling is complete is strongly biased toward stars with short rotational periods (i.e. of order 1 month or shorter). However, the range of rotational periods is sufficiently large so as to confirm the recent discovery of Landstreet,

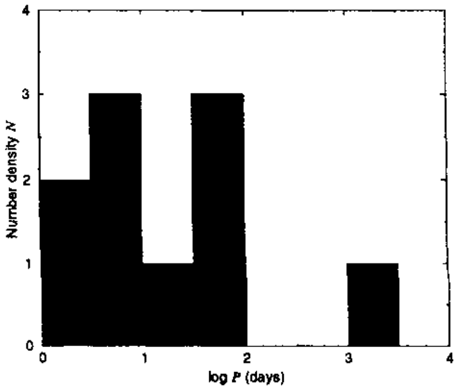

Figure 1: *Distribution of rotational periods inferred for the 10 stars already examined in this study. The sample is strongly biased toward shorter-period stars. Half of the sample rotate in under 10 days, while 9 stars rotate in under 100 days. Only one star (HD 59435) has a rotational period longer than 100 days.*

Mathys (1999): magnetic Ap stars with rotational periods longer than 25 or 30 days exhibit magnetic axis inclinations $\beta < 30^\circ$, suggesting that the magnetic and rotational axes of slowly rotating Ap stars are essentially aligned. They suggest that the same physical processes which resulted in the near total loss of rotational angular momentum in these stars also resulted in their present magnetic orientations, implying field evolution. Another possibility is that the fields of slowly rotating stars have remained essentially unchanged since their arrival on the main sequence, implying that angular momentum is more efficiently lost from those stars with aligned magnetic orientations. The distribution of rotational periods for the stars already examined in this study is shown in Fig. 1.

Examples of the observational data and model fits for two programme stars, HD 200311 and HD 12288, are shown in Fig. 2.

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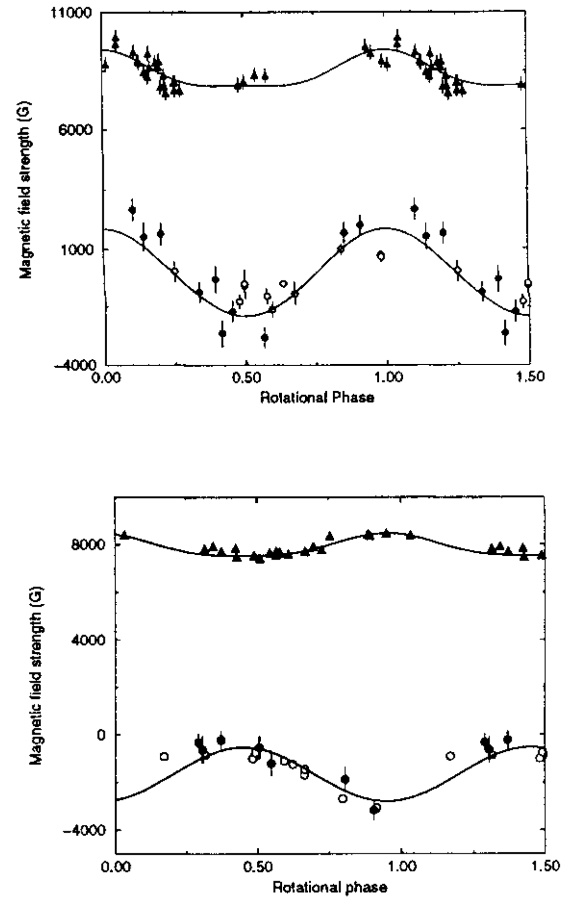

Figure 2: *Observed and computed mean longitudinal magnetic field and mean magnetic field modulus variations of the B9p Si star HD 200311 (upper frame; Wade et al., 1997) and the A2p CrSi star HD 12288 (lower frame; Wade et al., 1999).* Filled circles – *UWO longitudinal magnetic field data.* Open circles – *SAO longitudinal magnetic field data.* Filled triangles – *mean magnetic field modulus data (Mathys et al., 1997). The curves are decentred dipole magnetic field model predictions with:* $i = 90 \pm 8^\circ, \beta = 28 \pm 8^\circ, B_d = 12.8 \pm 1$ kG, and $a = +0.09 \pm 0.04\ R_*$ *(HD 200311), and* $i = 119 \pm 6^\circ, \beta = 21 \pm 6^\circ, B_d = -11.8 \pm 0.5$ kG, and $a = +0.01 \pm 0.04\ R_*$ *(HD 12288).*

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