*Physics of Magnetic Stars, 2007, pp. 98–101*

# Monitoring magnetic fields of sharp-lined and slowly-rotating Ap stars with the 6m telescope

**G.A. Wade[1], I.I. Romanyuk[2], D. Kudryavtsev[2], S. Smolkin[1], J. Flood[1]**

[1] Royal Military College of Canada, Canada
[2] Special Astrophysical Observatory of the Russian AS, Nizhnij Arkhyz 369167, Russia

**Abstract.** We are conducting a long-term monitoring of the longitudinal magnetic fields of a sample of sharp-lined Ap stars, using spectropolarimetric instrumentation at the 6m telescope of the Russian Academy of Sciences. This short article provides an update on this very long-term project.

**Key words:** stars: chemically peculiar – stars: magnetic fields – stars: rotation

## 1 Introduction

It is well known that the magnetic Ap stars rotate significantly more slowly than normal stars of similar spectral type (e.g. Abt & Morrell 1995), with mean projected rotational velocity less than one-fifth that of chemically normal A stars. Among the Ap stars, there exists a remarkable group of stars for which very long rotational periods are inferred (months – years – tens of years; see, e.g., Landstreet & Mathys 2000). As discussed by Landstreet & Mathys (2000), these extreme slow rotators are preferentially stars of lower mass, and are too numerous to be the long-period tail of a single distribution of periods of all magnetic intermediate-mass stars. They also showed that the magnetic and rotational axes axes of these stars are nearly aligned, in contrast to more rapidly-rotating Ap stars, which show significant magnetic obliquity.

As proposed by Stępień (2000), the general slow rotation of Ap stars can be explained by angular momentum loss at the pre-main sequence (PMS) phase, taking into account accretion of matter along the magnetic field lines, the stellar field-disc interaction and a magnetised stellar wind. Stępień (2000) and Stępień & Landstreet (2002) also confirmed that under special circumstances a magnetised star can indeed reach an exceptionally long rotation period of several years (and in fact up to 100 years in the most extreme cases). This requires a long PMS life time (satisfied only for lower-mass stars), the existence of a disc for only a part of the PMS phase, and the wind and the strong magnetic field existing for the rest of the PMS life. They also showed that rotational braking is most efficient for stars with nearly-aligned magnetic and rotation axes.

The model of Stępień (2000) therefore provides a reasonable explanation for the principal rotational characteristics of the Ap stars. Because of its sensitivity to the accretion, disc, wind and magnetic field properties of pre-Ap stars at the PMS phase, it is potentially a powerful tool for understanding the formation of intermediate-mass stars in the presence of a strong magnetic field. However, the number of Ap stars with very long rotational periods is relatively small. For many of these stars the rotational period is known only approximately (many are apparent lower limits), and for most of these stars the magnetic field geometry has not been modeled. Continued monitoring of this group of stars is therefore clearly required.

## 2 Observations

In order to explore the rotational and magnetic properties of extreme slowly rotating Ap stars, we are conducting a long-term monitoring of the longitudinal magnetic fields of a sample of sharp-lined Ap stars, using spectropolarimetric instrumentation at the 6m telescope of the Russian Academy of Sciences. SAO is essentially the only facility worldwide where this monitoring can be carried out, for three reasons. First, the 6m telescope provides the necessary spectropolarimetric instrumentation to perform Zeeman circular spectropolarimetry, and to measure the longitudinal magnetic field. Secondly, the 6m telescope can effectively access the full magnitude range of our targets, from about $V = 4$ to $V = 10$. Finally, and most importantly, the SAO has demonstrated a commitment to this effort by providing consistent allocation of observing time with stable instrumentation over the very long timescale needed to complete this project. This combination of instrumentation and long-term dedication is available at no other facility in the world.

Since 1996, we have obtained 369 longitudinal field measurements of 31 sharp-lined Ap stars. We have already published a few papers based on these data, mostly for stars with shorter rotational periods for which we have already obtained unambiguous rotational periods and complete phase coverage (Wade et al. 1996a, 1997, 2000a, 2000b, Elkin et al. 2005). We have continued to monitor the magnetic fields of the remaining stars, in order to refine periods for some shorter-period stars, and to place lower limits on periods for long-period stars. A implicit goal is to identify shorter-period Ap stars with small variability amplitudes, which may appear to have very long periods. The existence of such objects in this sample is a genuine concern due to the expectation of aligned magnetic and rotational axes.

In this paper, we report results for some of the remaining stars in our sample, consisting of 24 stars mainly with suspected periods > 200 days.

## 3 Results

### 3.1 Stars with newly-determined periods

For a few stars, we are able to tentatively assign new rotational periods based on our longitudinal field data, in combination with published mean magnetic field modulus measurements (e.g. Mathys et al. 1997). In some cases, Hipparcos photometry has been used to constrain possible shorter-period variations.

In Fig. 1 we show phased longitudinal field and field modulus data for two slowly-rotating stars with tentative new periods, HD 18078 and HD 59435b. HD 18078 is a poorly-studied cool Ap star for which we have obtained 20 longitudinal magnetic field measurement. A few field modulus measurements have also been published (Mathys et al. 1997). Although analysis of this star is hampered by lower precision of the earliest measurements obtained from photographic spectra, we tentatively adopt a rotational period of 1480 d (4.1 y). However, in order to fit the field modulus measurements with this period, a double-wave field modulus variation is required. Such a variation would imply that we see both magnetic hemispheres as the star rotates, implying a significant magnetic obliquity. Although the relative phasing of the inferred longitudinal field and field modulus curves is reasonable, further data are clearly necessary to confirm the period of this star.

HD 59435b is a member of an SB2 system, in which the secondary is a cool giant. Based on field modulus and photometric measurements, Wade et al. (1996b, 1999) reported a rotational period of 1360 d for this star. However, based on our new longitudinal field measurements and the field modulus measurements of Wade et al. (1996b, 1999), we find that a period of 1150 d (3.2 y) provides a better fit to all of the magnetic data. The relative phasing of the inferred field modulus and longitudinal field variations is reasonable. We also point out that the new period is nearly exactly twice as long as one of the photometric periods reported by Wade et al. (1999; 576 d).

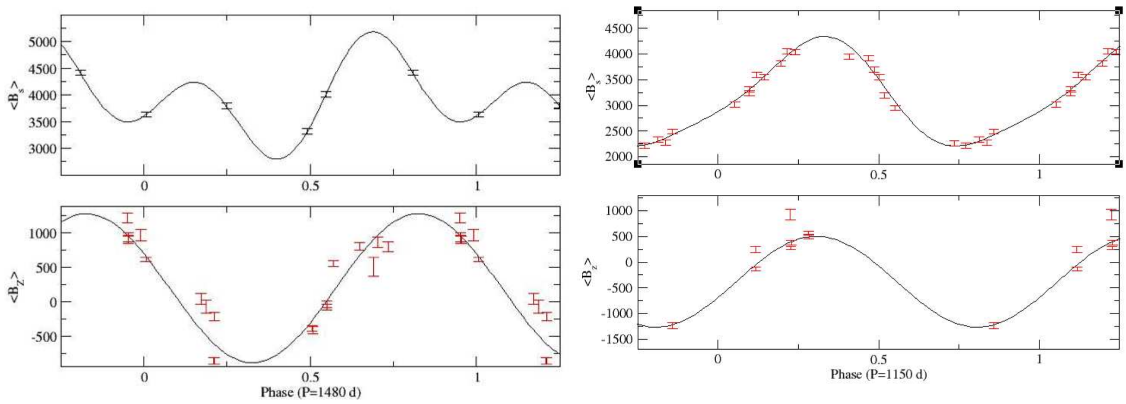


Figure 1: HD 18078 (left) and HD 59435 (right) are two slowly-rotating stars for which we tentatively determine rotational periods of 1480 d and 1150 d, respectively.

Preliminary models of the magnetic field geometries of these two stars are currently in preparation.

### 3.2 Stars with very long, and yet unknown, periods

For many of the stars in our sample, we are unable to unambiguously determine the rotational period based on the data currently available. Two examples of such stars are HD 965 and HD 9996.

Although HD 965 is a cool Ap star showing physical and spectroscopic properties similar to the roAp stars, it does not show detectable photometric or radial velocity variability (Kurtz et al. 2003, Elkin et al. 2005). As illustrated in Fig. 2, we observe a clear, systematic change in the longitudinal field, including a change of sign, over the time covered by our observations. This star is therefore a long-period variable, with a rotational period of at least 1900 d (5.2 y), and probably at least twice that long.

HD 9996 is an unusual example of a hot (B9p) extreme slow rotator. Four observations reported by Babcock (1958) around 2432878-2433256 are all around -1 kG. A single measurement obtained by him 1200 d later yielded a field of +0.14 kG, and 15 more measurements obtained from 2439334-2439776 are clustered around +0.25 kG. Scholz (1984) reported 6 measurements obtained from 2443477-2445220, which appear to increase from -0.25 kG to +0.3 kG. Our 12 new measurements, obtained since 2451482, cluster around +0.6 kG. Bychkov et al. (2005) estimate a rotational period for HD 9996 of 7692 days (21 y), although the long-term trend in longitudinal field evident in Fig. 2 could be interpreted as due to a much longer period. Additional data is needed in order to resolve this ambiguity.

## 4 Conclusions

Since 1996 we have monitored the longitudinal magnetic fields of a sample of 31 sharp-lined and slowly-rotating magnetic Ap stars.

Nearly all are of these slow rotators are cool, low-mass Ap stars, with a mass distribution which is substantially different from the incidence distribution of Ap stars in the solar neighbourhood (Power et al., these proceedings). However, a few are inferred to have higher masses.

Some of these stars have relatively short periods but are seen near their rotational pole, resulting in small projected rotational velocity. For some of these stars with large variability amplitudes we

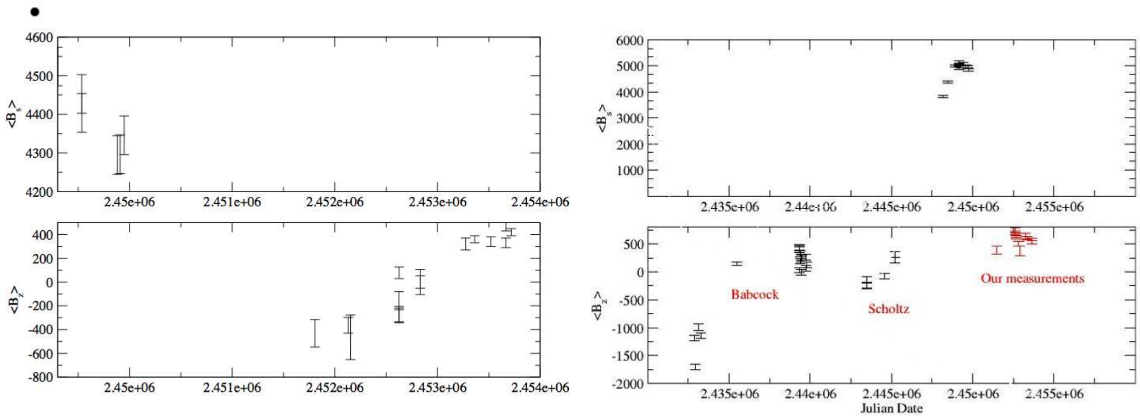


Figure 2: HD 965 (left) and HD 9996 (right) are two slowly-rotating stars for which we are not yet able to identify rotational periods.

have already published papers reporting the derived rotational periods and magnetic field geometries.

From the remaining sample, we are attempting to differentiate true extreme slow rotators and shorter-period stars with small variability amplitudes. In the present paper, we discuss several stars for which we consider extreme slow rotation to be well established. For some of these stars, we are able to tentatively identify new rotational periods.

The publication of a compendium of all data and period analysis to date is expected during the next semester.

**Acknowledgements.** This research has been partially funded by the Natural Sciences and Engineering Research Council of Canada (NSERC) and Russian Foundation for Basic Research (RFBR grant no. 06-02-16110a).

## References

Abt H.A. & Morrell N.I., 1995, ApJS, **99**, 135
Babcock H.W., 1958, ApJS, **3**, 141
Bychkov V. D., Bychkova L. V., Madej J., 2005, Astron. Astrophys., **430**, 1143
Elkin V. G., Kurtz D. W., Mathys G., Wade G. A., Romanyuk I. I., Kudryavtsev D. O., Smolkin S., MNRAS, **358**, 1100
Kurtz D. W., Dolez N., Chevreton M., 2003, Astron. Astrophys., **398**, 1117
Landstreet J.D. & Mathys G., 2000, Astron. Astrophys., **359**, 213
Mathys G., Hubrig S., Landstreet J. D., Lanz T., Manfroid J., 1997, A&AS, **123**, 353
Scholz G., 1984, AN, **305**, 325
Stępień K., 2000, Astron. Astrophys., **353**, 227
Stępień K. & Landstreet J.D., 2002, Astron. Astrophys., **384**, 554
Wade G.A., Elkin V.G., Landstreet J.D., Leroy J.-L., Mathys G. and Romanyuk I.I., 1996a, Astron. Astrophys., **313**, 209
Wade G.A., Mathys G., North P., Hubrig S., 1996b, Astron. Astrophys., **314**, 491
Wade G.A., Elkin V.G., Landstreet J.D., Romanyuk I.I., 1997, MNRAS, **292**, 748
Wade G. A., Mathys G., North P., 1999, Astron. Astrophys., **347**, 164
Wade G.A., Debernardi Y., Bohlender D.A., Hill G.M., Landstreet J.D., Mathys G., Elkin V.G., 2000a, Astron. Astrophys., **361**, 991
Wade G.A., Kudryavtsev D., Romanyuk, I.I., Landstreet J.D., Mathys G., 2000b, Astron. Astrophys., **355**, 1080