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Zeeman split lines in CP stars: a discovery of low-contrast fields in slow rotators?

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Abstract. We show that high-resolution observations of resolved Zeeman split lines can be used to obtain new constraints on the stellar magnetic field geometry. In particular, the contrast of the field strength distribution over the stellar surface can be deduced from differential measurement of the second moment of the π and σ Zeeman components. Our analysis of the triplet lines in slowly rotating cool magnetic CP stars uncovers a surprisingly homogeneous field structure, inconsistent with any low-order multipolar geometry.

Key words: stars: atmospheres – stars: chemically peculiar – stars: magnetic fields – stars: individual: HD 47103, HD 154708

1. Introduction

A number of slowly rotating magnetic A and B stars have surface magnetic fields strong enough to produce observable Zeeman splitting of line profiles in high-resolution spectroscopic observations. This effect is routinely used to diagnose the surface magnetic field strength (e.g. Mathys *et al.*, 1997). But, at the same time, information provided by the shapes of the resolved π and σ components is largely neglected. Here we propose a novel technique to measure the *relative widths* of the resolved Zeeman components and infer an important global field characteristic from the resulting new magnetic observable.

2. Mean field scatter

At each point on the magnetic star surface the local line profiles are split according to the magnetic field strength. The π component of a triplet line coincides with the laboratory wavelength, whereas the shift of σ components is proportional to the field modulus and therefore varies over the stellar surface together with the field strength. Consequently, the σ components are broader than π components. Thus, the width of the σ components relative to that of π components provides a measure of *the contrast of the field strength distribution* over the stellar disk.

Neglecting stellar rotation and using assumptions similar to the derivation of common magnetic observables (e.g., Mathys, 1995), we can quantify the difference in width of the resolved Zeeman components of a triplet line using

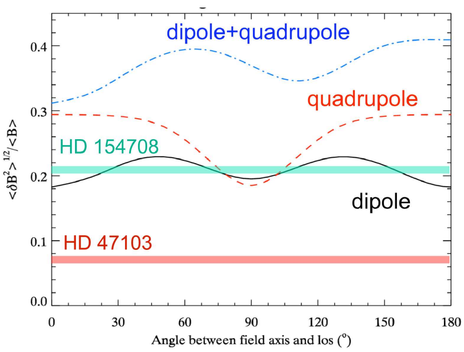

Figure 1. Measurements of the mean field scatter in HD 47103 and HD 154708 (shaded regions) are compared with the $\langle\delta B^2\rangle/\langle B\rangle$ ratio expected for multipolar field geometries viewed from different angle α between the field axis and the line of sight.

measurement of their second moments, $M^{(2)}_{\pi,\sigma}$, computed with respect to the center-of-gravity of each component:

$$M^{(2)}_{\sigma} - M^{(2)}_{\pi} = \left(\frac{e\lambda_0^2}{4\pi m_e c^2}\right)^2 \bar{g}^2\langle\delta B^2\rangle, \qquad (1)$$

where $\bar{g}$ is the mean Landé factor and other variables have their usual meaning. $\langle\delta B^2\rangle$ is a new magnetic observable, the *mean field scatter*. It is primarily sensitive to the field strength contrast and weakly sensitive to the field orientation.

3. Low-contrast fields in cool Ap stars

We studied Zeeman split triplet lines in the UVES spectra of the cool Ap stars HD 47103 and HD 154708. Results of the $\langle\delta B^2\rangle$ measurements for these stars are summarized in Fig. 1. It is evident that the large width of the σ components in HD 154708 is consistent with a dipolar field geometry, but the σ components are unexpectedly narrow in HD 47103. Some other strong-field Ap stars also exhibit narrow σ components. Fig. 1 shows that this observation cannot be reconciled with *any* low-order multipolar field configuration.

Thus, some slowly rotating cool Ap stars host surprisingly homogeneous surface magnetic field topologies. This finding might have an important implication for the theories of formation and evolution of magnetic fields in these stars.

References

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