Magnetic field distribution and element concentration on the CP2 star CU Virginis

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Abstract. We search for a relation between the published distributions of different elements and the calculated magnetic field structure, following from a dipole-quadrupole configuration, of the CP2 star CU Vir. The highest concentration of individual chemical elements on the stellar surface coincides obviously with the regions of the highest values of the magnetic field strength.

Key words: stars: chemically peculiar stars - magnetic fields - element abundances

1. Introduction

The B9pSi star CU Vir (HD 124224, $P_{\rm rot} = 0\overset{\rm d}{.}52$, e.g. Weiss et al. 1976), has an amplitude of the effective magnetic field curve of about 1000 gauss and shows very large spectral variations of helium and silicon. Relations between the structure of the magnetic field and the distribution of some chemical elements on the stellar surface should exist according to, e.g., Michaud (1970), Glagolevskij (1994), and Hatzes (1997). For our investigation we use the values of the longitudinal magnetic field, $B_{\rm eff}$, measured photoelectrically by Borra and Landstreet (1980) and the distribution of He, Si, and Mg over the stellar surface derived by Goncharskij et al. (1983), Hiesberger et al. (1995), Kuschnig et al. (1997), and Hatzes (1997).

2. Magnetic model of CU Vir

The magnetic field structure has been calculated on the assumption that the variation of the $B_{\rm eff}$ values observed is caused by a dipole-quadrupole configuration of the magnetic field and the model of the oblique rotator. Fig. 1 represents the observations (dots) of CU Vir versus the rotational phase. The points differ distinctly from a sinusoidal curve, which would exist for a dipole field. For the

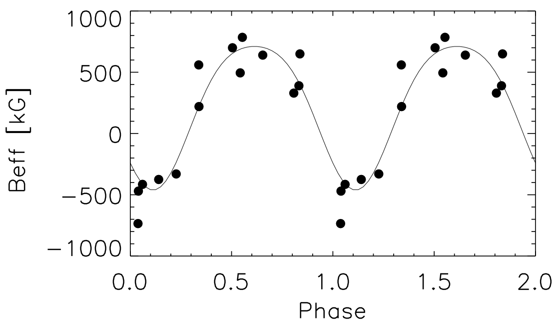

Figure 1. Variation of the longitudinal magnetic field after Borra & Landstreet (dots) and our model (curve)

magnetic field modelling we take the angle $i = 60°$ between the rotation axis and the line of sight and we set the angle $\beta = 65°$, describing the inclination between the rotation axis and the dipole axis. The magnetic sources are located at $R_* = 0.1$ from the centre and produce at the stellar surface the magnetic field strengths of the dipole of +1.5 and −1.5 kG and of the quadrupole of +3.1, −3.1, +3.1, and −3.1 kG. The calculated variation of $B_{\rm eff}$ is represented in Fig. 1.

3. Magnetic structure and surface maps

3.1. He

We have taken the distribution of He over the stellar surface from Hiesberger et al. (1995) and Kuschnig et al. (1997). The He spots obviously coincide with the regions of the maximal field strength. Differences between the distribution maps quoted above occur especially in the region of the broad positive magnetic maximum. The solution of Hiesberger et al. appears to be closer to the magnetic field structure derived from our model. In the vicinity of the maximal negative pole only a weak He spot exists. An explanation could be that we observe only the edge of a large spot, but this spot is practically invisible because of the large inclination of the star.

3.2. Si, Mg

To search for a relation between the magnetic field and the element Si we use the Si map distributions of Goncharskij et al. (1983), Kuschnig et al. (1997), and Hatzes (1997). Only a general tendency can be seen: the Si abundance is lower in the region of the broad positive maximum, whereas in the region of the negative magnetic field extremum the abundance seems to be higher.

Alécian and Vauclair (1981) and Mégessier (1984) have shown the importance of the horizontal component of the diffusion velocity in magnetic Ap stars. They postulated an overabundance of Si in these regions. To test these suggestions we calculated the isolines of the horizontal magnetic field lines from our dipole-quadrupole model. Comparing with Hatzes Si map a concentration of this element in the areas with the horizontal direction of the magnetic field lines seems possible.
The behaviour of Mg, of which only the distribution map of Goncharskij et al. is known, is obviously quite similar to that of Si.

4. Discussion

Our dipole-quadrupole model yields two maxima at the positive halfwave of the magnetic field and a very satisfactory agreement between the calculated and the observed behaviour of $B_{\rm eff}$. We are not able to fit the strong anharmonic variation of $B_{\rm eff}$ by a decentred dipole field. The two observed He spots seem to support the assumption of a dipole-quadrupole configuration.
The maps proposed for Si allow to explain the element distribution over the surface by a concentration of the element at the magnetic poles as well as in the regions where the magnetic field lines have a horizontal direction. To overcome the existing discrepancies, more accurate observations are necessary.

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