Doppler Mapping of CP-star Surfaces with Weak and Strong Magnetic Fields

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A code for Doppler mapping of the distribution of chemical elements on stellar surfaces (Goncharskij *et al.*, 1977, 1982) has been used during the past decade to make maps for several CP-stars. The code is based on Tikhonov's method of solution of so-called ill-posed inverse problems and on an analytical expression of local line profiles in the form of the Milne-Eddington solution of the radiative transfer equation. This code takes into account the atmospheric model of the star through an assumed central depth of very strong and saturated lines, and through limb-darkening coefficients. As a solution one gets local line profiles and hence local equivalent widths.

Recently some more sophisticated codes were developed by Piskunov (1985) and Vogt *et al.* (1987) which use the results of the numerical solution of the transfer equation directly for local profiles and are thus able accurately to take into account an appropriate atmospheric model. In these codes the results of solution are local abundances of an element. Only Piskunov's code provides a simultaneous solution for all Stoke's parameters (I,V,U) if observed polarization profiles are available. Up to now only in one case, namely α^2 CVn, have phase variations of I and V been observed and Doppler mapping of some elements as well as Doppler-Zeeman mapping [1] of magnetic field made (Glagolevskij *et al.*, 1985).

The original code by Goncharskij *et al.* (1982) was modified in two respects:

a) An additional block has been written to convert local equivalent widths into abundances using a theoretical curve of growth.
b) Straight introduction of input data (observed profiles) was made. This prevents loss of precision through intermediate calculations.

We note some advantages of this code as compared with more sophisticated ones in spite (or may be because) of its simplicity. First, it permits the use of lines for which $\log gf$ values are unknown and the construction of maps of local equivalent widths. It is also easy to make averages of abundance maps, obtained from different lines of the same element, and later to introduce necessary linear corrections when new improved $\log gf$ values are available, without time consuming

[1] The apt terms "Doppler imaging" and "Doppler-Zeeman imaging" were proposed for these procedures by Vogt (1984) and Donati *et al.* (1990).

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recalculations. Secondly, it permits the use of less powerful computers (such as PC AT286).

During the past decade seven CP stars, over a wide range of T_e and surface magnetic field strengths, have been mapped (see Table).

Table

star	T_e K	B_e Gauss	elements	Reference
CU Vir	12000	$+700/-500$	Si	(1)
χ Ser	9500	<300	Fe, Sr	(1)
α^2 CVn	12000	$+1000/-1300$	Ti, Cr, Fe	(2)
ε UMa	9500	< 200	Si, Cr, Fe, Eu	(3)
				(4)
θ Aur	10000	$+360/-240$	Si, Ti, Cr, Fe	(5)
σ OriE	22500	> 3000	He, Si	(6)
HD 32633	12500	$+3000/-5000$	Ti, Fe	(7)

References: (1) Goncharskij *et al.*, 1983, (2) Khoklova and Pavlova, 1984 (3) Wehlau *et al.*, 1990, (4) Totochava and Khokholova, 1990 (5) Khokhlova *et al.*, 1986, (6) Khokhlova *et al.*, 1990 (7) Landstreet *et al.*, 1991

Some useful remarks on the basis of the experience of using the code follow: as the only Stokes parameter I is used to obtain the distribution of an element, choice of stars and lines should be suitably chosen so as to avoid the distortion of results by a magnetic field (by Zeeman splitting and/or by magnetic intensification of lines).

Having chosen unblended lines for the analysis, further criteria should be taken into account. The first one is obvious and requires that rotational broadening must be larger than magnetic splitting of a line. The second requirement is that the thermal Doppler width should be larger than the magnetic Zeeman splitting over the whole surface of a star. In that case the influence of magnetic intensification is not important. This requirement is undoubtedly fulfilled for light elements such as He, C, Mg, Si, or for lines with zero or small Landé factors, or for hot stars (such as σOriE) or for stars with weak magnetic fields (such as HD124224, HD140160, θAur, ϵUMa). The star HD32633 is a limit case for this requirements and needs special consideration.

Some conclusions may be made using our experience and looking at the results obtained up to now.

1. Large chemical inhomogeneities on the surface of CP-stars correlate neither with temperature nor with magnetic field strength.
2. There is a hint that rapid rotators have a simpler surface chemical structure than slow rotators (fewer small features, larger spots).

3. It is very difficult (if not impossible) to obtain with the method of Doppler mapping a map of the major part of a stellar surface; only in the strip within 40° of the "subsolar line" is described satisfactorily. The situation is demonstrated in Fig. 1 where the results obtained with different initial approximations are shown. The solution is more or less independent of the initial approximation only within this strip. So any conclusions about the real structure of inhomogeneities outside of this strip are not very reliable.

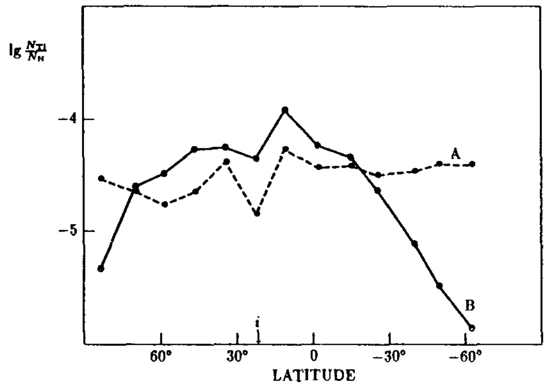

Fig. 1. Abundance of Ti along a meridian on the surface of HD 32633. A – an initial approximation of lg $\frac{N_{Ti}}{N_H} = -4.2$. B – an initial approximation of lg $\frac{N_{Ti}}{N_H} = -6.0$.

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