

MAGNETIC FIELD AND SILICON DIFFUSION IN Bp-Si STARS

C. Mégessier¹, T. Lanz², J.D. Landstreet³

¹Observatoire de Paris-Meudon, place J.Janssen
92195 Meudon France

²Institut d'Astronomie de l'Université de Lausanne
CH-1290 Chavannes-des-Bois, Switzerland

³Department of Astronomy University of Western Ontario
London, Ontario, Canada N6A 3K7

ABSTRACT. SiIII lines of magnetic Bp-Si stars in open clusters have been observed with the CAT (ESO) in order to get a mapping of the Silicon abundance distribution over the stellar surface, in the frame of the oblique rotator model. We point out the influence of the Zeeman splitting and of the abundance inhomogeneities on the line profiles.

1. THE ASTROPHYSICAL CONTEXT

The main sequence Bp-Ap Si stars are remarkable by their strong magnetic field (some kilo-Gauss) and their silicon overabundance which is not constant over the stellar surface. Theoretical works on the diffusion in the stellar atmosphere, in the presence of a magnetic field, predicts that the amount of the silicon overabundance is tied to the magnetic field geometry (Michaud et al., 1981). Moreover the silicon overabundance is expected to move from the magnetic equator to the magnetic pole in times shorter or comparable to the main sequence stage of these stars. Accordingly the geometry of the silicon overabundance would depend on the stellar age (Mégessier, 1984).

Observed silicon lines, effective magnetic field and photometric variations occur with the same period, which is the rotational period of the star. These variations arise from the inclination of the magnetic axis to the rotational one, and from the inhomogeneous silicon distribution over the stellar surface.

To get a mapping of the silicon over the stellar surface it is necessary to determine the abundance at several phases distributed over the stellar rotational period. However the Zeeman splitting due to the strong magnetic field affects the line profiles. This effect has to be taken into account to get a correct value of the abundance. Accordingly spectra with a high signal-to-noise ratio are required to enable us to get the shape of the lines.

2. THE OBSERVATIONS

We selected stars in open clusters so that their age is known. Three Bp-Si stars, the magnetic field of which was measured by Landstreet, has been observed in March 1987 with the CES at the CAT (ESO). We chose the SiII multiplet $\lambda 6347-6371 \text{ \AA}$ which is in the region of high sensitivity of the receptor. Simultaneous photometric observations have been performed in the Geneva photometric system to determine the stellar rotational period and the phase of the spectroscopic and magnetic data.

Here we present the preliminary results for HD 92664 which has a moderate magnetic field ($-1200 < B_e < -200 \text{ Gauss}$) and which $v_e \sin i$ is 66 km/s and for HD 147010 which magnetic field is very strong ($-5800 < B_e < -3200 \text{ Gauss}$) but which $v_e \sin i$ is small (less than 20 km/s or even less than 10 km/s).

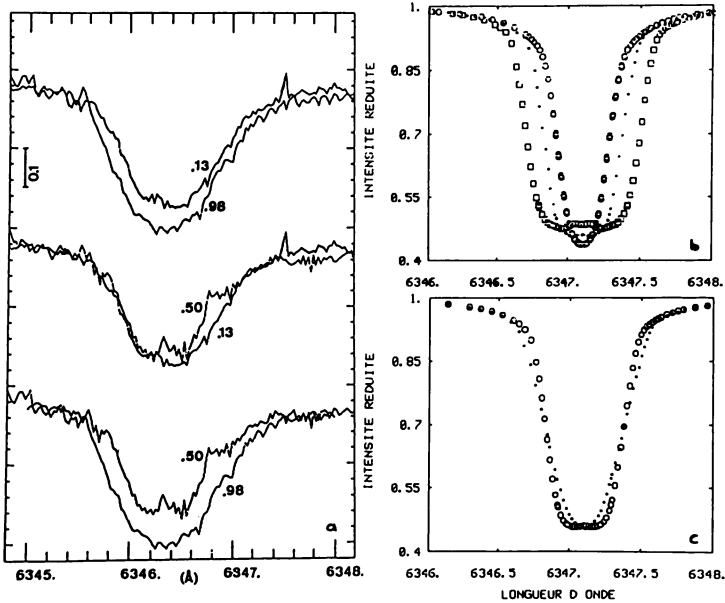


Figure 1 a) Variations of the SiII line $\lambda 6347$ (mult. 2) for HD 147010. The spectra are normalized to unity. The phase is indicated near each spectrum. The SiII line has a remarkable box shape. b) LTE spectrum synthesis of the $\lambda 6347$ SiII line for $v_e \sin i = 5 \text{ km/s}$ and for three values of the mean local magnetic field 3 kGauss (o), 6 kGauss (.) and 10 kGauss (□).

c) When convoluted by a rotational profile the line profile has no more a box shape. Open circles: $B_e = 6 \text{ kGauss}$ and $v_e \sin i = 5 \text{ km/s}$, dots: $B_e = 6 \text{ kGauss}$ and $v_e \sin i = 10 \text{ km/s}$

3. MAGNETIC FIELD INTENSITY AND ROTATIONAL VELOCITY EFFECT ON THE LINE PROFILES.

SiII lines have been calculated with a Kurucz model ($T_{\text{eff}} = 11700^\circ \text{K}$, $\log g = 4$, $\text{metal} = 10 \times \theta$). The Zeeman pattern of the transition was taken into account. Three values of the mean local magnetic field: 3, 6 and 10 kilo-

Gauss, have been considered. Then the spectra have been convoluted by a rotational profile. In case of a small rotational velocity (5 km/s) (Fig 1b) the line becomes square shaped and with a 10 kilo-Gauss field it is splitted into two components. The equivalent width of the line increases with the field intensity. The SiIII line is saturated but a large field allows a desaturation via the Zeeman splitting. With a somewhat larger rotational velocity (10 km/s) (Fig 1c) the line is no more square shaped but its width is larger than in the absence of a field.

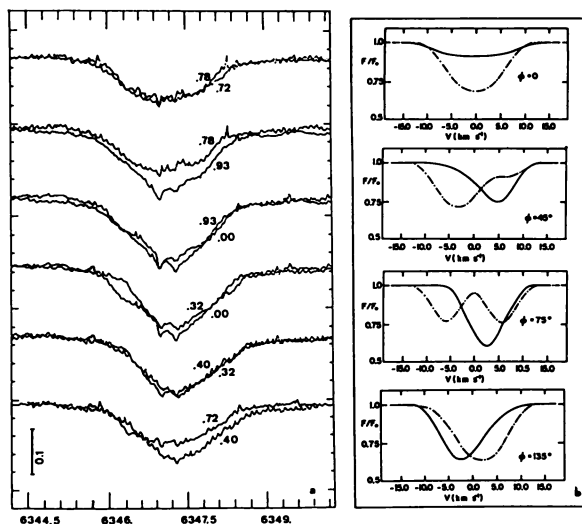


Figure 2 a) Variations of the SiIII line $\lambda 6347$ for HD 92664. The line shapes are dominated by a rotational profile, and not by the Zeeman splitting. b) Predicted variations and asymmetries of the lines (from Michaud et al., 1981) for a concentration of elements at the magnetic poles (point dash line) or in a ring (full line)

4. THE OBSERVED LINE PROFILES AND THEIR VARIATIONS.

The profile of the SiIII lines in the spectra of HD 147010 has the box shape which arises from the Zeeman splitting (Fig 1a). It also implies a slow rotational velocity (< 10 km/s). The main changes in the line profiles at different phases affect the line width rather than its symmetry. These spectral variations originate then from different sights over the magnetic field geometry during the rotational period.

In the case of HD 92664 (Fig 2a) the line shapes are dominated by a rotational profile, and not by the Zeeman splitting. Asymmetries are clearly present at several phases. So the variations are primary due to the inhomogeneous distribution of the Silicon. Fig 2b shows the predicted variations and asymmetries (from Michaud et al., 1981) for a concentration of elements at the magnetic poles (point dash line) or in a ring (full

line) where the field is horizontal (around the magnetic equator for a pure dipolar field). A comparison between these theoretical predictions and the observed variations suggests that Silicon is concentrated near the magnetic equator of HD 92664.

5. CONCLUSION

Line profiles allow to determine the Silicon overabundance geometry on the stellar surface better than the only line intensities. A spectral resolution as high as possible is required to separate the geometric effects from the magnetic field effects on the lines. We could point out these two effects in our spectra, although their signal-to-noise ratio are rather limited. This limitation arise from the necessary temporal resolution compared to the rotational period.

Both high spectral resolution and high signal-to-noise ratio are necessary to map these stars and then better understood the link between the magnetic field and the local overabundances.

REFERENCES.

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 Michaud, G., Mégessier, C., Charland, Y.: 1981, *Astron. Astrophys.* 103, 244

DISCUSSION

ANDERSEN I should like to see theoretical diffusion calculations trying to reproduce the element distribution on a few specific well-observed stars (preferably of different types). In the field of close binary evolution, models could produce Algol or Sirius-type systems in a general way very early, but as soon as it was attempted to model specific well-observed systems, the difficulties became exposed and the theoretical limitations became apparent (non-conservative mass transfer, etc..). I suspect that the situation with respect to the diffusion models is somewhat analogous.

MEGESSIER Before to be able to reproduce theoretically the element distribution on specific stars, we need more observational constraints. In the present state of the available observations, we may say that the diffusion computations do reproduce the observed features, since these latter give a crude representation only of the star. We need to know the magnetic field geometry and its local intensity and direction, the local element overabundances on the stellar surface with a better accuracy and a better confidence. In that respect several problems are still to be solved. This only will allow to constraint more the parameters to be introduced in the diffusion computations for specific stars.