PROBE OF THE NEARBY INTERSTELLAR MEDIUM
BY THE VACANT LINE OF SIGHT TO β CMa

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ABSTRACT

The line of sight to βCMa has been probed by Copernicus observations. This particular line of sight is remarkable for the low mean densities. We find $\bar{n}_H \sim .002\ cm^{-3}$. However we can distinguish two separate regions:

1) A local nearby HI region extends over a few parsecs from the sun with a density of the order of $0.1\ cm^{-3}$ and a temperature of 11000 to 12500 K.

2) An HII region lies somewhere beyond the HI region and is spread over about 60pc. Its total hydrogen mean density is of the same order as the HI region, i.e. of $\sim 0.1\ cm^{-3}$ and it contains only elements in low ionization state. All the data are coherent with the picture of a cloud in ionization equilibrium at T $\sim$ 23 000° K.

INTRODUCTION

Interstellar lines in all bright unreddened B stars within 150-200 pc have been observed with Copernicus to study the distribution of the various phases of the warm interstellar gas. This paper presents the results for βCMa, the line of sight to which is remarkable for the low mean densities ($\bar{n}_{HI} \sim 0.002\ cm^{-3}$).

THE STAR AND ITS LOCATION

βCMa is a 1.98 magnitude star, of type B1 II-III. It is situated at a distance of 200pc, with galactic coordinates of $l \sim 226°$, $b \sim -14°$. Figure 1 shows its position on the galactic plane together with a few nearby stars to the direction of which the neutral hydrogen abundance is known.

THE OBSERVATIONS

Measurements of UV resonance lines of 10 elements (listed in Table 1) were made with the Copernicus spectrograph at high resolution (0.045 Å). The analysis of the UV lines was performed through line profile fitting (method described in Vidal-Madjar et al., 1977).

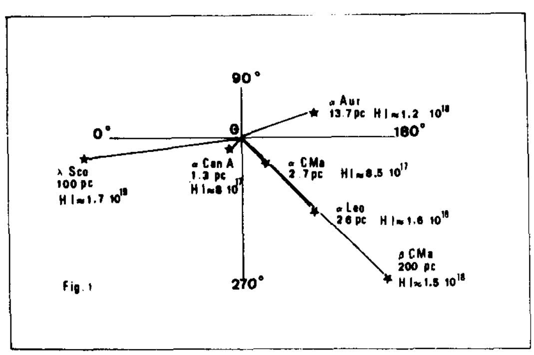

Fig. 1

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Velocity analysis

The fitting program can include a large number of velocity components but in the case of this line of sight the best fits were obtained for a unique component. There is however a systematic shift of about 5 km/s in velocity between the neutral and the ionised species with an intermediate velocity for the strongest NI line, suggesting the presence of 2 components: one containing almost all the neutral gas at about 1.5 km/s, the other one being almost entirely ionised and moving at a slightly different velocity of 6.5 km/s.

Abundances

HI and DI: The low hydrogen abundance is evidenced by the shape of the Lyman β line which shows no damping wings (see Figure 2). Independently of the assumed stellar line, the acceptable fits imply N(HI) to be in the range 1 to 2.2 10^{18} cm^{-2}, with a b-value of 13.5 to 14.3 km/s.
The deuterium line was fitted together with the hydrogen line, leading to the ratio D/H = 0.7-2.3$10^{-5}$.

Other species: Examples of fits of the different lines are shown on Figure 3. The results of the fits are summarized in the first columns of Table 1. More precise abundances are obtained for NI and SII which were derived with 4 and 3 lines, respectively. OVI was not detected but an upper limit could be set.

DISCUSSION: STRUCTURE OF THE LINE OF SIGHT

Neutral region

Considering that the neutral hydrogen absorption comes from a unique component, the data give directly its column density (1 to 2.2 10^{18} cm^{-2}) and its temperature (11000 to 12500K). This latter is derived from the b-value which, being much higher than those found for the heavier species (see Table 1), indicates thermal broadening. On the other hand, the comparison with shorter lines of sight containing approximately the same amount of neutral matter shows that the neutral region can not be much extended. In particular, the line of sight to βCMa passes as close as 0.3 pc to the star αCMa in the direction of which the interstellar gas density is about 0.1 cm^{-3} (UV observations; Bruhweiler and Kondo 1982).

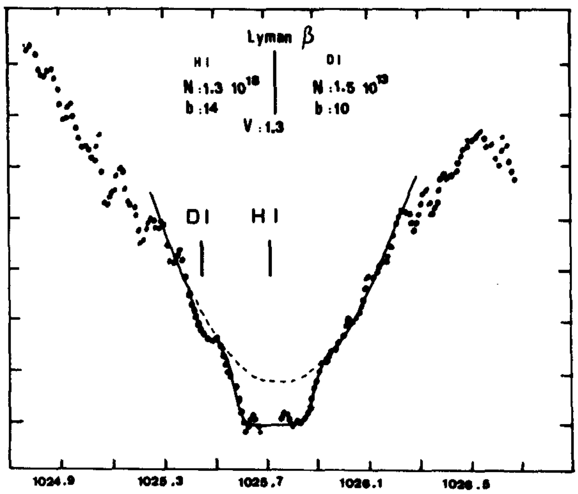

Fig 2

H and D Lyman profiles(...) observed, (—): theoretical. The IS absorption is superimposed on the stellar line(---).

The HI contribution in the spectrum of βCMa thus evidences the existence of a nearby neutral cloud of density 0.1 cm^{-3}, temperature 12000 K, extending over a few parsecs (less than 8 pc), the density of neutral gas dropping off by at least a factor of 100 beyond this cloud.
The contribution of this neutral region to the absorption profiles of other elements have been calculated on the assumptions of mean interstellar abundances (as given by Spitzer and Jenkins 1975; Ferlet, 1981; York et al.,

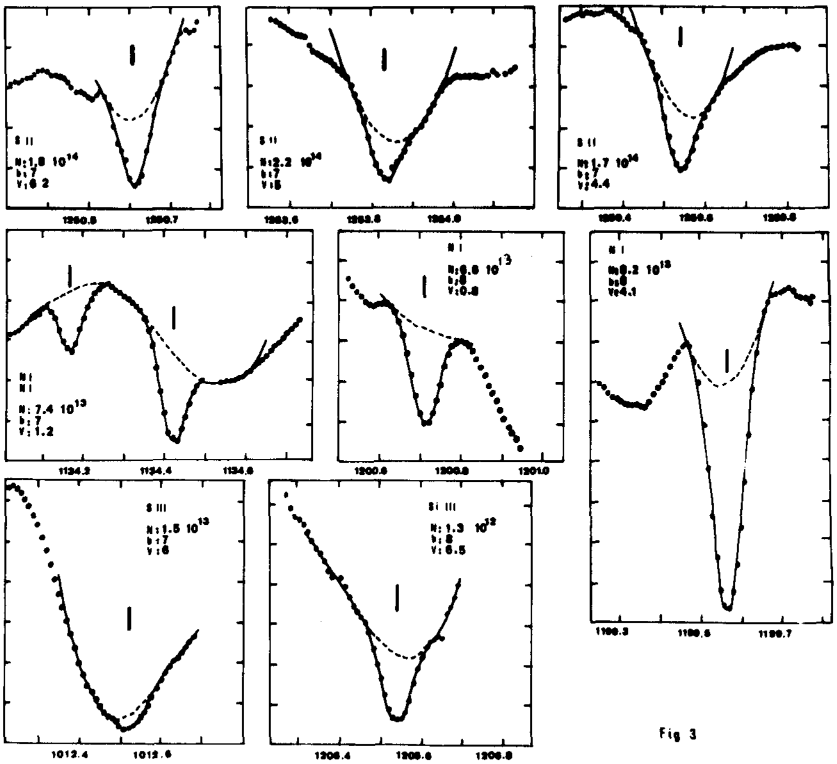

Figure 3: Observed (dots) and theoretical (continuous line) profiles of some of the lines studied here. The fits are performed with only one component having the characteristics indicated on each plot.

SPECIES	observations N (cm^{-2})	b (km/s)	V (km/s)	N (cm^{-2}) as expected in the HI region
HI	$1 - 2.2\ 10^{18}$	13.5 - 14.3	0.5 - 2.5	—
DI	$1.5 - 2.3\ 10^{13}$	9 - 12	0.5 - 2.5	—
NI	$6 - 8.2\ 10^{13}$	6.5 - 8	0.6 - 4.3	$5 - 14\ 10^{13}$
SII	$1.7 - 2.2\ 10^{14}$	6 - 8	4.4 - 6.2	$< 2.9\ 10^{13}$
SIII	$0.9 - 1.6\ 10^{13}$	7 - 8	5 - 8	$< 7\ 10^{7}$
SiIII	$1.2 - 1.7\ 10^{12}$	7 - 8	5 - 8	$< 4\ 10^{10}$
NII	$1 - 50\ 10^{14}$	7 - 8	5 - 8	
OI	$3.8 - 16.8\ 10^{14}$	6 - 8	3.2 - 4.5	$5.7 - 14.5\ 10^{14}$
CII*	$0.8 - 1.3\ 10^{13}$	7 - 8	5 - 7	
OVI	$< 5\ 10^{11}$			

Table 1: Column 1,2,3 : column densities, b-values and velocities derived by fitting the profiles. column 4 : predicted abundances in the HI region deduced from the HI column density, a temperature of 11000 to 12500 K and the asumption of solar abundances.

1983) and thermal equilibrium ionisation fractions (as calculated by Shull and Van Steenberg, 1982), and are displayed also in Table 1.
From the comparison of the 1st and 4th columns of Table 1, it is clear that the neutral region contributes to part or all of the neutral species (NI and OI) column densities, but can not account for the abundances of the ionised species as SII, SIII, SiIII: an ionised region must lies beyond the HI cloud.

Ionised region

Since H/S and C/S can be assumed to be solar for this unreddened line of sight, we find $N(H^+) \sim 1.6 - 2\ 10^{19}$ cm^{-2} and $N(CII) \sim 3.7 - 5\ 10^{15}\ cm^{-2}$. From Table 1, $N(CII^*) \sim 0.8 - 1.3\ 10^{13}$, thus $N(CII^*)/N(CII) = 1.6\ 10^{-3} - 3.5\ 10^{-3}$. From Table 4 of York and Kinahan (1979), this implies collisional excitation of the ground term of CII by electron in a medium with density $n_{H+} = n_e = 0.07 - 0.14\ cm^{-3}$. Thus, the HII region is density bounded and extended over 40 to 90 pc.
It is unlikely that the ionisation is due to the UV flux of βCMa, as to get rise to such an abundance of H^+, the density in the Stromgren sphere of this star should be higher than $0.7\ cm^{-3}$.
Alternatively, a unique temperature (T = 22500 - 25000 K) can account for all observed line intensities ratios in the asumption of collisional ionisation equilibrium (again the ionisation ratios given by Shull and van Steenberg (1982) were used).
Finally two more remarks can be made after this study: First the non-detection of OVI shows that there is no coronal gas in this direction within 200 pc. Second, the presence in the distant line of sight to λSco (see Figure 1) of a component presenting abundances and characteristics very similar to those of the HII component discussed here (York, 1983), could suggest that these 2 components arise from a same hot (22500K-25000K), diffuse ($N_H \sim 0.1\ cm^{-3}$) cloud surrounding the nearby HI regions.

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