The Line of Sight of ϵ Canis Majoris: Depletion and Extent of the Local Cloud

Cécile Gry[1,2] and Olivier Dupin[1]

[1] Laboratoire d'Astronomie Spatiale, CNRS, BP 8, F-13376 Marseille Cedex 12
[2] ISO Science Operation Center, PO Box 50727, E-28080 Madrid

Abstract. With new high resolution UV spectra of ϵ CMa we show that the gas column density in this sight-line is less than 4 10^{17} cm^{-2}, that the neutral gas density is less than 10^{-5} cm^{-3} after the first 3 parsecs, and that the Local Cloud seems to be almost undepleted and to extend to no more than 0.6 pc in this direction.

1 Introduction

The two lines of sight toward the early type stars ϵ Canis Majoris (l=240°,b=-11°) and β Canis Majoris (l=226°, b=-14°), located at respectively 132 pc and 153 pc (Hipparcos catalogue), are ideal to study diffuse clouds in the Local Bubble environment because of the very small amount of absorbing material they present relative to their length. In particular the early spectral type of ϵ CMa gives the unique opportunity to perform a complete study of the small cloud in which the Sun is embedded (LIC - Lallement and Bertin 1992), including all UV atomic lines, seldom observable toward the other (cooler) stars where the LIC is detected.
With the GHRS on board HST we have obtained high resolution Ech A ($\Delta\lambda/\lambda \sim 100\,000$) spectra of lines in the range 1180 Å- 1600 Å, that complete the pre-existing high resolution Ech B spectra at higher wavelengths (Gry et al. 1995). We will give here a rapid overview of the line of sight to ϵ CMa as studied from these new observations and we will focus on the description of the LIC.
The line of sight also includes an ionized component (C3) presenting interesting depletion and ionization patterns typical of previously shocked gas. It is discussed together with the β CMa sight-line in the accompanying paper by Dupin and Gry (this volume).

2 The Structure of the Line of Sight Toward ϵ CMa

Figures 1 and 2 show examples of the absorption profiles in the spectrum of ϵ CMa together with the best fit that allowed the determination of column densities, velocities and b-values for the considered species. In Figure 1, we show the strongest SiII line. It is not saturated, fact which demonstrates the extraordinarily low column densities. The two components marked LIC and

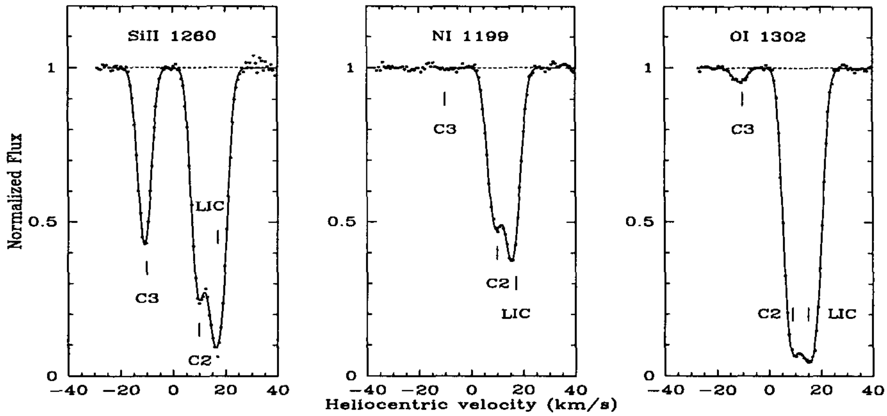

Fig. 1. Interstellar profiles in the GHRS-EchA spectra (dots) of ϵ CMa with their best fit. The strong SiII, NI and OI lines illustrate the weakness of the absorption in the sight-line and the low neutral gas content in C3.

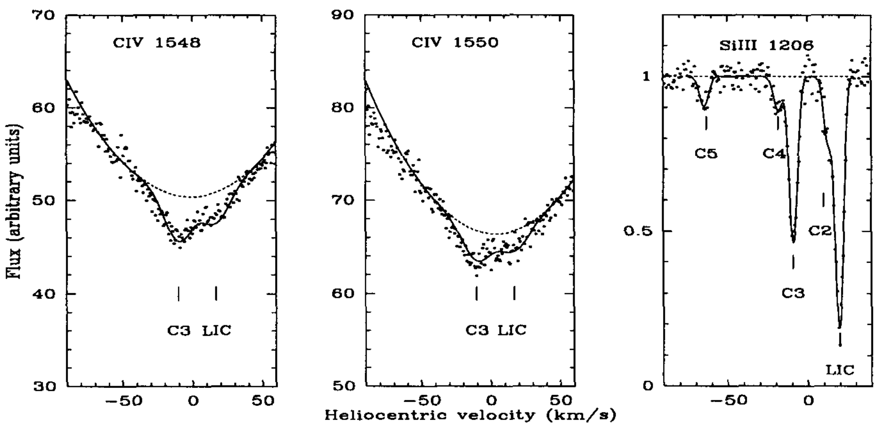

Fig. 2. High ionization species in the line of sight of ϵ CMa. The detection of CIV absorption at the velocity of the LIC and C3 suggests that we are observing an interface between the clouds and the hot bubble gas.

C2 are detected in MgII and FeII with very similar characteristics (Lallement et al. 1994 and Gry et al. 1995) in the spectrum of α CMa, located only 2.7 pc away from the Sun, and are therefore most probably very local. Apart from these local clouds another weak component -marked C3- is present in the ion absorption profiles. However, component 3 is not detected in any of the NI lines and shows a weak absorption feature in the strong OI line. This together with the most constraining depletion assumption implies that in component 3 the neutral gas column density is less than 5 $10^{15}\,cm^{-2}$, and that in the

130 parsecs beyond the distance of Sirius, the mean neutral gas density is less than 1.2 $10^{-5}\,cm^{-3}$.

Another feature of this line of sight is illustrated in Figure 2 : the presence of highly ionized species. In SiIII the detection is clear, showing the same structure and b-value as the other less ionized species (C4 is only detected in the strongest lines and C5 only in SiIII and HI, where it is blended with the deuterium line). For CIV, the detection is also clear, with two absorption components detected in both doublet lines at the velocities of LIC and C3, with a temperature of about 150 000 K. However, they occur at the bottom of the broad and asymetric stellar line, and we cannot rule out at this stage that they could be due to features arising in the stellar wind of the star. In SiIV, there is only a 2-σ feature at the velocity of the LIC. The SiIV and CIV column densities and temperature derived from the fit of these features (see Table 1) are compatible with the prediction of Slavin (1989) model for the conduction layer between the Local Cloud and the hot gas supposed to fill the Bubble.

3 The Local Interstellar Cloud (LIC)

	log N at cm^{-2} (1)	log H derived with warm ISM depletion (2)	log H derived with minimum depletion (3)	ionization potential (eV) (4)
SII	$\leq$ 12.6	$\leq$17.3	$\leq$17.3	23.3
SIII	$\leq$12.3	$\leq$17.0	$\leq$17.0	34.8
NI	13.20	17.4	17.15	14.5
OI	14.15	17.5	17.2	13.6
MgII	12.48	17.55	17.23	15.0
FeII	12.13	17.97	17.18	16.2
SiII	12.64	17.73	17.28	16.3
SiIII	12.26	17.35	16.90	33.1
SiIV	11.0(2σ)	16.1	15.6	45.1
CIV	12.3	15.7	15.7	77.4

Table 1 column 1 lists the column densities derived for the Local Cloud from the fit of most available atomic lines in the spectrum of ϵ Canis Majoris. SII is a key element because its ionization potential makes it a tracer of both neutral and ionized gas and because, as it is usually observed with solar abundance in the ISM, it is traditionally considered to be undepleted. A very weak SII absorption feature is observed for the LIC, with a column density of 3 $10^{12}\,cm^{-2}$ given by the best fit and a strict upper limit of 4 $10^{12}\,cm^{-2}$. We can thus derive an upper limit for the total hydrogen column density in the LIC with this value and the sulfur solar abundance, -4.73 dex (Anders and Grevesse 1989). This gives $\log N(H) \leq 17.3$ cm^{-2}.

Similarly, we derive the hydrogen column density traced by the other species from their measured column densities and adopting the *mean depletion values in the warm ISM* (Jenkins, Savage and Spitzer (1986) for iron and magnesium, with the correction recommended by Fitzpatrick (1997) for magnesium, idem for silicon, Ferlet (1981) for nitrogen and Keenan (1985) for oxygen). OI, NI, SiII, MgII and FeII have ionization potentials lower than SII so they can not trace more gas than SII. The results are listed in column 2 of Table 1 and it is apparent that the above elements show no consistency when these depletion values are used, with a difference of almost a factor of 5 in the case of iron. This inconsistency could suggest that sulfur is somewhat depleted, but depetion in sulfur has never been observed to be larger than -.15 dex, so this depletion would have to be accompanied by a lower depletion of the other elements to have them all agree. Alternatively, if we consider the *minimum depletion* observed in the ISM for every species, i.e. no depletion for sulfur, nitrogen and oxygen and the minimum depletion values observed in the halo high velocity clouds and given by Fitzpatrick (1996) for magnesium, iron and silicon, we find (column 3) that the derived hydrogen column densities for all elements agree with each other to within 30 %. This suggests that the Local Cloud is only slightly depleted, implying that most species usually locked in the dust grains have been returned to the gas phase by some dust sputtering process.

With these depletion values we derive an HI column density of less than $2\,10^{17}$ cm^{-2} for the Local Cloud in the line of sight of ϵ Canis Majoris . With the approximate density $n_{HI} \sim 0.1$cm^{-3}, this implies that the extent of the Local Cloud in this direction is of the order of or less than 0.6 pc.

The second implication is that, adding the contribution of component 2, the total HI column density in the line of sight is less than $4\ 10^{17}$ cm^{-2}, considerably smaller than that derived from the study of the Extreme UV spectrum of the star (Cassinelli et al. 1995).

References

Anders E. and Grevesse N. (1989) : Geochim. Cosmochim. Acta, 53, 197.
Cassinelli J.P., Cohen D.P., MacFarlane J.J., et al. (1995) : ApJ. 438, 932.
Ferlet R. (1981) : A&A 98, L1
Fitzpatrick E.L. (1996) : ApJ 473, L55
Fitzpatrick E.L. (1997) : ApJ. in press
Gry C., Lemonon L., Vidal-Madjar A., et al. (1995) : A&A 302, 497.
Jenkins E.B., Savage B.D., and Spitzer L., (1986) : ApJ 301, 355.
Keenan F.P., Hibbert A., Dufton P.L. (1985) : A&A 147, 89.
Lallement R. and Bertin P. (1992) : A&A 266, 479.
Lallement R., Bertin P., Ferlet R., et al. (1994) : A&A 286, 898.
Slavin J. (1989) : ApJ 346, 718.