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IUE OBSERVATIONS OF INTERSTELLAR HYDROGEN AND DEUTERIUM TOWARD ALPHA CENTAURI B

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ABSTRACT

We present a profile of the Lyα emission line of α Cen B (K1 V, $d = 1.3$ pc), obtained by addition of two *IUE* small-aperture, high-dispersion images. The use of the small aperture has largely eliminated contamination from diffuse geocoronal and interplanetary Lyα. The square-well–shaped interstellar H I absorption profile shows excellent agreement with that previously observed in the Lyα emission of α Cen A. This agreement provides evidence that the Lyα emission lines of both stars are free from gross asymmetries that could confuse interpretation of the H I absorption. Modeling of the data has yielded improved limits on the heliocentric bulk velocity ($v_{\rm H\,I} = -15.5 \pm 1.9$ km s^{-1}), the average number density ($n_{\rm H\,I} < 0.21$ cm^{-3}), and the velocity dispersion ($b_{\rm H\,I} > 13.8$ km s^{-1}) of the neutral gas along the α Cen sightline. The lower limit on the velocity dispersion, together with the upper limit ($b_{\rm H\,I} < 12$ km s^{-1}) previously observed toward Capella ($d = 13.2$ pc), points to an inhomogeneity in the structure of the neutral gas in the local interstellar medium.

An asymmetry between the blue and red wings of the Lyα emission is attributed to absorption by interstellar deuterium, and a lower limit of $n_{\rm D\,I}/n_{\rm H\,I} > 1.1 \times 10^{-5}$ is set on the deuterium-to-hydrogen number ratio.

Subject headings: interstellar: abundances — stars: individual — stars: visual multiples — ultraviolet: spectra

I. INTRODUCTION

Neutral hydrogen and deuterium in the local (<25 pc) interstellar medium can be detected as absorption features superposed on the chromospheric Lyα emission of nearby late-type stars. High-dispersion Lyα profiles have been obtained for a handful of late-type stars, including α Cen A (Landsman *et al.* 1984*a*), HR 1099 (Anderson and Weiler 1979), Procyon (Anderson *et al.* 1978), and Capella (McClintock *et al.* 1978*a*). These data have been modeled to provide information on the average density $n_{\rm H\,I}$, velocity dispersion $b_{\rm H\,I}$, and bulk velocity of the intervening gas. The derived parameter ranges are consistent with a picture of the local interstellar medium in which the Sun is near the edge of a low-density ($n_{\rm H\,I} \approx 0.1$ cm^{-3}) interstellar cloud with a total column density of (1–2) × 10^{19} cm^{-2} toward $l = 0°$, but less than 10^{18} cm^{-2} toward $l = 180°$ (Bruhweiler 1984).

The α Cen system (G2 V + K1 V, $d = 1.3$ pc, $l = 316°$, $b = -1°$) provides a unique probe of the local interstellar medium. Its proximity to the Sun means that one can observe an interstellar column that is spatially averaged over only 1.3 pc. This may be especially significant because the maps of Bruhweiler (1982) and Frisch and York (1983) suggest that the Sun is in a transition zone between neutral gas and much hotter material. The proximity of α Cen to the Sun also allows the best comparison with the properties of the neutral gas observed entering the solar system by the resonant scattering of solar Lyα and He I (584 Å) (Bertaux 1984). In addition, because the chromospheric emission spectrum of α Cen A is similar to that of the Sun (Ayres and Linsky 1980), one has greater confidence that chromospheric and interstellar effects in the observed Lyα profile can be properly disentangled. Finally, the α Cen system contains two components of large apparent brightness, which allows independent confirmation of the entire modeling procedure.

Landsman *et al.* (1984*a*, hereafter Paper I) have discussed all the existing high dispersion observations of the Lyα emission of α Cen A. These consist of *Copernicus* observations obtained in 1976 and 1978, and a sequence of 10 large-aperture *IUE* images in 1979. The reduced spectra showed good overall agreement, although the interstellar deuterium feature appeared somewhat stronger in the 1978 *Copernicus* spectrum. A broad range ($0.03 < n_{\rm H\,I} < 0.17$ cm^{-3}) of H I densities was found to be consistent with the square-well–shaped interstellar H I profile, and a lower limit was set on the velocity dispersion of $b_{\rm H\,I} > 11$ km s^{-1}. An asymmetry between the blue and red wings of the Lyα profile was identified as being due to interstellar D I absorption, and a lower limit was set on the ratio of deuterium to hydrogen of $n_{\rm D\,I}/n_{\rm H\,I} > 0.8 \times 10^{-5}$. It was also found that a much better model fit could be obtained to both the *IUE* and *Copernicus* data if the bulk velocity of the inter-

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stellar D I feature was blueshifted 8 km s^{-1} from that determined from the H I absorption profile. It was thus suggested that the sightline to α Cen contains multiple velocity components, which cannot be individually identified in the broad, saturated H I absorption.

In this paper, we present the first high-dispersion profile of the Lyα emission of α Cen B. (A previous *IUE* high-dispersion spectrum [SWP 9036] of α Cen B, discussed by Ayres *et al.* (1982) was badly overexposed at Lyα.) The observed profile and the derived interstellar parameters will be compared with those previously determined toward α Cen A.

II. OBSERVATIONS AND DATA REDUCTION

Small-aperture, high-dispersion images of α Cen B were obtained in 1984 June and 1984 September. Details of the observations are given in Table 1. The dates were chosen so as to place diffuse geocoronal Lyα emission in the center of the interstellar Lyα absorption. Acquisition of α Cen in the small aperture requires a blind offset, because the fine error sensor (FES), normally used for target acquisition, will seek the center of light of the binary system. Precise coordinates of a 15′ distant, 12th mag offset star needed to acquire α Cen B in the small aperture were obtained from Kamper and Wesselink (1978). The star was probably not as well-centered in the small aperture during the June observation, as the observed flux was less than half of that received during the September observation. The spectrum obtained in September had seven data points whose fluxes exceeded the highest calibrated levels of the intensity transfer function (ITF). However, the raw data values do not exceed 235 DN, and the fluxes obtained using the extrapolated ITF provided by the *IUE Observatory* were given full weight in our modeling procedure. The September image was sufficiently well-exposed that data could also be extracted from the secondary echelle order ($m = 114$) containing Lyα. No attempt was made to absolutely calibrate the data, due to the uncertain throughput of the small aperture.

The range of interstellar parameters allowed by our modeling procedures depend on the uncertainties assumed for the observed spectra. Fixed pattern noise, and uncertainties in the ITF, make it difficult to quantify the errors associated with an *IUE* line profile. Following Paper I, we have tried to conservatively estimate our uncertainties, by combining the signal-to-noise ratio properties typically observed in SWP spectra with the RMS fluctuations measured in a flux-free region near 1218 Å. Well-exposed SWP spectra of bright, hot stars, processed with the current high-dispersion software, have a typical signal-to-noise ratio of 12:1 (Sonneborn 1985). Table 1 gives the signal-to-noise ratio (and hence, relative weighting) derived at the peak of the Lyα emission for each of our spectra. When co-adding the spectra, fixed pattern noise was assumed to be uncorrelated, as the velocity separation of the June and September spectra (11 km s^{-1}) exceeded the separation of independent data points (5.5 km s^{-1}).

TABLE 1

OBSERVING LOG

Image	Date (1984)	Exposure Time (minutes)	Echelle Order	Peak Signal-to-Noise Ratio
SWP 23287.........	Jun 19	305	113	7
SWP 23900.........	Sep 7	320	113	11.5
			114	10

Our modeling procedure remains unchanged from Paper I. Theoretical spectra were constructed using either a three-parameter Gaussian or a five-parameter solar-type profile to model the intrinsic stellar emission. Voigt absorption profiles for interstellar H I and D I were then computed, initially assuming a uniform, thermally broadened medium. The free interstellar parameters were the density, velocity dispersion, and bulk velocity of H I, and the density of D I. To compare with the *IUE* data, the theoretical spectra were convolved with a Gaussian instrumental profile with a FWHM of 0.1 Å (Evans 1984).

III. RESULTS

Figure 1 shows the co-added *IUE* spectrum of the Lyα emission of α Cen B. Superposed, and normalized at the peak of the red emission wing, is the Lyα profile of α Cen A obtained in Paper I. The α Cen B spectrum shows weak emission from diffuse geocoronal/interplanetary Lyα within the core of the interstellar H I absorption. These points were deleted from consideration when modeling the data.

As expected from the Wilson-Bappu relation for Lyα (McClintock *et al.* 1975), the emission from α Cen A is broader than that of the less luminous secondary. Modeling with a solar-type profile yielded FWHM, respectively, of 0.86 Å and 0.77 Å for the primary and secondary. The previous suggestion of Ayres *et al.* (1982), that the α Cen system may violate the Wilson-Bappu relation, was based on a very overexposed Lyα profile of α Cen B. Due to the strong interstellar absorption, our models could provide no information on the nature of any self-reversal in the two stars. It is notable, however, that a better model-fit could be obtained to the α Cen B data by using a Gaussian, rather than a solar-type, emission profile. The reverse had been true when modeling the α Cen A data.

Despite the difference in the Lyα emission line widths, the interstellar H I absorption profiles observed toward the two stars show excellent agreement with each other. This agreement is borne out quantitatively when modeling the data to obtain the H I bulk velocity. The interstellar bulk velocity is found to be 3.6 ± 1.9 km s^{-1} with respect to the emission center of α Cen B. In Paper I, the interstellar bulk velocity was determined to be 10 ± 3 km s^{-1} with respect to the emission center of α Cen A. These values must be corrected for stellar radial velocities, which, from the orbit given by Heintz (1982) was -19.1 km s^{-1} for α Cen B, and -24.7 km s^{-1} for α Cen A, on the respective observation dates. Very similar values of -15.5 ± 1.9 km s^{-1} for α Cen B, and -14.7 ± 3 km s^{-1} for α Cen A, are then derived for the heliocentric interstellar bulk velocity. It should be noted that this method of deriving the bulk velocity does not require use of the *IUE* absolute wavelength scale.

While the square-well shape of the H I absorption profile is useful for defining the bulk velocity, it also indicates that the absorption is not in the damping region of the curve of growth and thus does not uniquely specify the density $n_{\rm H\,I}$, or the velocity dispersion $b_{\rm H\,I}$. Figure 2 shows a contour plot of allowed values in the $n_{\rm H\,I}$-$b_{\rm H\,I}$ plane. This contour plot is derived from a grid of χ^2 values according to the method of Lampton, Margon, and Bowyer (1976). There is a large range of values for which the two parameters can trade off with each other to give an acceptable fit. However, the 90% contour gives a lower limit on the velocity dispersion of $b_{\rm H\,I} > 13.8$ km

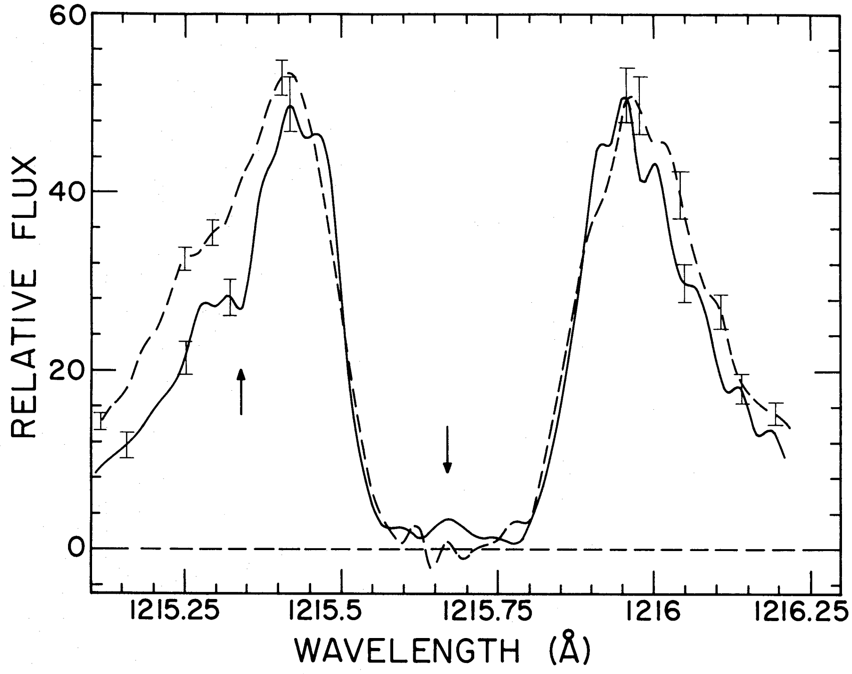

FIG. 1.—The reduced, co-added *IUE* spectrum of α Cen B (*solid line*) is compared with the *IUE* Lyα profile of α Cen A obtained in Paper I (*dashed line*). The data have been normalized at the red emission peak. Selected error bars are shown. The derivations of these error bars, and caveats concerning their interpretation, are given in the text. The downward arrow, in the center of the interstellar core, points to weak emission from geocoronal/interplanetary Lyα. The upward arrow points to the predicted position of the interstellar deuterium feature, as determined from the H I bulk velocity. The Lyα emission of the primary star is clearly broader than that of the secondary, but the interstellar H I absorption profiles observed toward the two stars are in close agreement.

s^{-1}, and an upper limit on the average density of $n_{\rm H\,I} < 0.21$ $\rm cm^{-3}$. The need for a large velocity dispersion may be inferred, more directly, from the failure to see damping wings in the H I absorption. The condition that Doppler broadening dominate a Voigt profile at a velocity shift u from the line center may be written (Mihalas 1978)

$$\exp -(u^2/b_{\rm H\,I}{}^2) > (\gamma/\pi^{1/2})(b_{\rm H\,I}/u^2), \quad (1)$$

where $\gamma = 6.046 \times 10^{-3}$ km s^{-1} is the damping coefficient for Lyα. The absorption line wings begin at a shift of 32 km s^{-1} (0.13 Å) from the line center, so equation (1) gives the approximate result $b_{\rm H\,I} > 10$ km s^{-1}. Our modeling procedure gives the stronger lower limit on $b_{\rm H\,I}$ since it fits the entire absorption wing, taking into account the instrumental profile, and observational uncertainties.

When comparing the interstellar parameters derived toward the two components of α Cen, it is important to note the differences in the way the data were obtained. The *IUE* images of

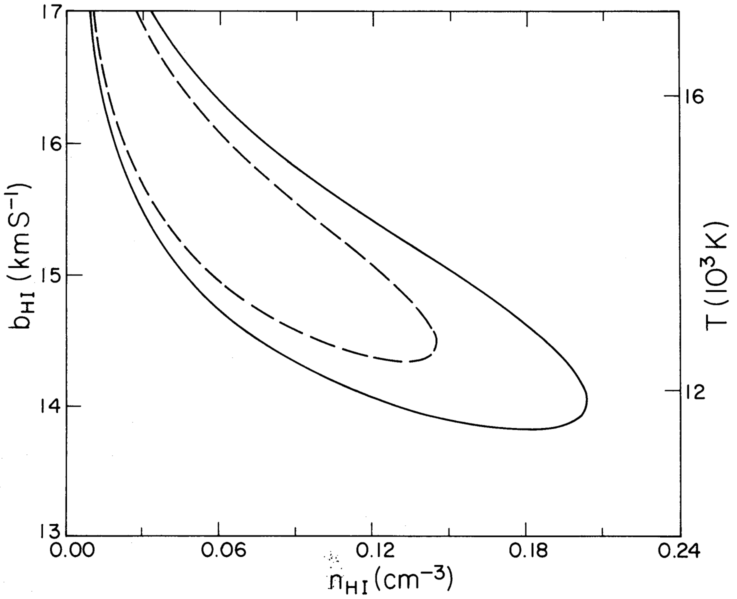

FIG. 2.—The 50% (*dotted line*) and 90% (*solid line*) confidence contours for allowed values in the $n_{\rm H\,I}$-$b_{\rm H\,I}$ plane

α Cen A discussed in Paper I were all obtained with the large aperture and required a substantial correction for diffuse Lyα contamination. Thus, the limits obtained here on $n_{\mathrm{H\,I}}$ and $b_{\mathrm{H\,I}}$ are tighter than those found in Paper I. Hower, the interstellar D I feature in Paper I was *not* contaminated by diffuse Lyα. Furthermore, a total of 10 *IUE* images (and two *Copernicus* spectra) were obtained of α Cen A, while only two *IUE* images have been obtained of α Cen B. Therefore, the interstellar D I profile discussed in this work is not as well defined as in Paper I.

The detection of D I absorption is made difficult by its low column density, by the relatively coarse *IUE* spectral resolution, and by the sloping continuum. The last difficulty may be partially overcome by reflecting the red wing of the Lyα emission onto the blue, to use as a pseudocontinuum (Fig. 3). A discrepancy between the line wings is seen near the expected interstellar D I feature at 1215.33 Å. This effect was also observed in Paper I, when analyzing the broader Lyα emission of α Cen A. Thus, the asymmetry is likely due to interstellar D I absorption, rather than to being an intrinsic property of the stellar emission. Modeling the data with a symmetric stellar emission then allows an estimate of the D I column density needed to fit the observed asymmetry. Figure 4 shows the allowed contours in the $n_{\mathrm{H\,I}}$-$n_{\mathrm{D\,I/H\,I}}$ plane. A lower limit of $n_{\mathrm{D\,I}}/n_{\mathrm{H\,I}} > 1.1 \times 10^{-5}$ is found at a 90% confidence level. Much larger values of $n_{\mathrm{D\,I}}/n_{\mathrm{H\,I}}$ are possible at low values of $n_{\mathrm{H\,I}}$.

In Paper I, it was found that a much better fit could be obtained to the α Cen A data if the deuterium feature were blueshifted 8 km s^{-1} from the bulk velocity determined by the H I absorption. In contrast, the model fits to the α Cen B data were insensitive to the bulk velocity assumed for deuterium. The D I bulk velocity may be blueshifted up to 9 km s^{-1} relative to H I, while only marginally affecting the χ^2 of the fit. As noted above, a partial explanation for this is the poorer signal-to-noise ratio, in the α Cen B data, near the interstellar D I feature. In addition, none of our uniform, thermally broadened models are able to satisfactorily fit the "ledge" which is observed near 1215.32 Å (see Fig. 3). A slightly reduced χ^2 can be achieved by relaxing the assumption of thermal broadening. For example, a satisfactory fit to the ledge can be made, without shifting the D I feature, by using a model with $n_{\mathrm{H\,I}} = 0.1$ cm^{-3}, $b_{\mathrm{H\,I}} = 15$ km s^{-1}, $n_{\mathrm{D\,I}}/n_{\mathrm{H\,I}} = 3 \times 10^{-5}$, and $b_{\mathrm{D\,I}} = 5$ km s^{-1}. Thus, a uniform, thermally broadened interstellar medium may not adequately describe the α Cen sightline, but the limited quality and resolution of the present data precludes a further analysis.

Table 2 summarizes the parameters derived toward the α Cen components in this work and in Paper I.

IV. DISCUSSION AND CONCLUSIONS

We have shown that contamination from diffuse geocoronal/interplanetary Lyα may be largely eliminated in *IUE* spectra by the use of the small aperture. A program is currently underway to apply this observing technique to several other late-type stars in the solar neighborhood.

The interstellar H I absorption profile observed toward α Cen B shows excellent agreement with that observed toward α Cen A. This is true despite the different Lyα emission widths observed for the two stars, and the different chromospheric structure expected for G2 and K1 dwarfs. This indicates that the derived interstellar H I parameters are probably not very sensitive to the profile assumed for the unknown intrinsic stellar emission. This conclusion can probably be generalized to all late-type dwarfs, where strong line asymmetries due to

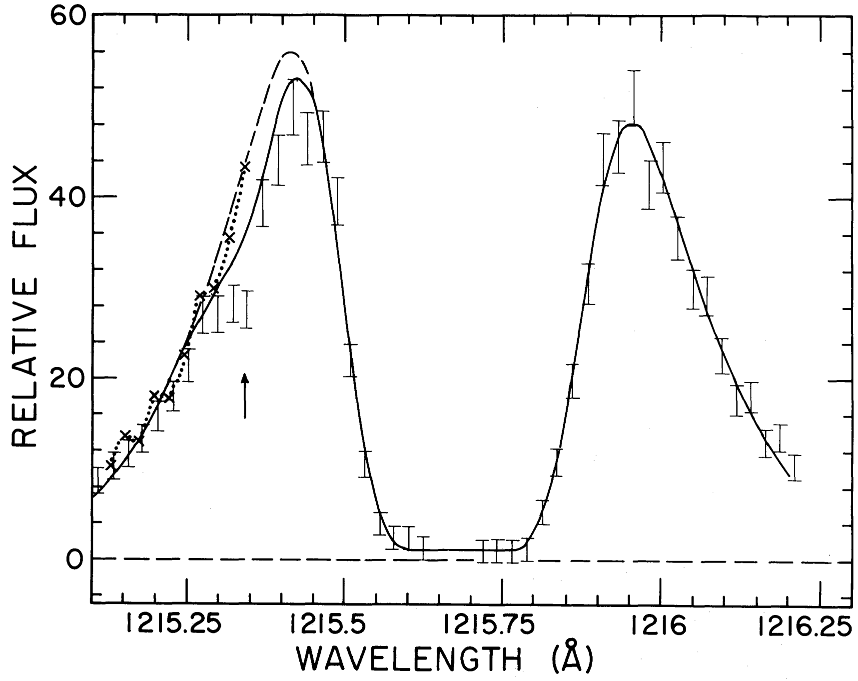

FIG. 3.—The solid line shows a best-fit model to the α Cen B data, assuming $n_{\mathrm{H\,I}} = 0.1$ cm^{-3}. Other parameter values in this model are $n_{\mathrm{D\,I}}/n_{\mathrm{H\,I}} = 2.3 \times 10^{-5}$ and $b_{\mathrm{H\,I}} = 14$ km s^{-1}. The arrow points to the predicted position of the interstellar deuterium feature as determined from the H I bulk velocity. The dashed line has the same parameters as the solid line fit, but with D I absorption removed from the model. The crosses connected by the dotted line show the red wing of the Lyα profile reflected through the center of symmetry (as defined by the far wings) into the blue.

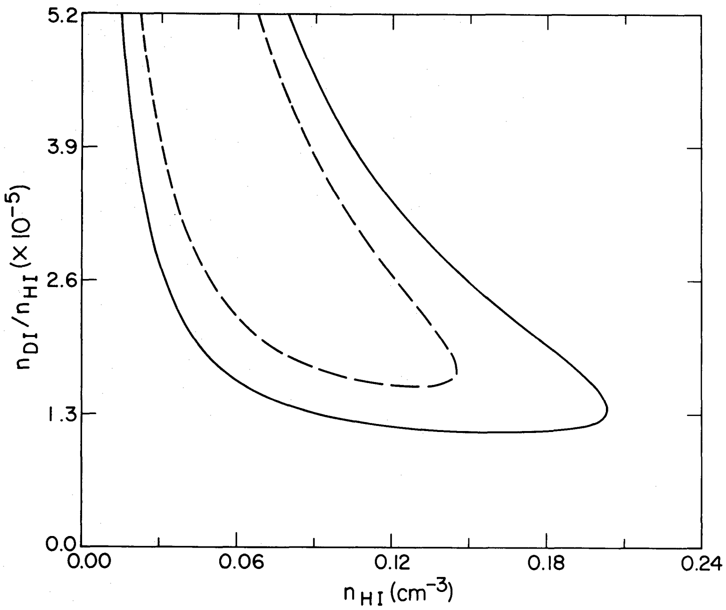

FIG. 4.—The 50% (*dashed line*) and 90% (*solid line*) confidence contours for allowed values in the $n_{\rm H\,I}$-$n_{\rm D\,I}/n_{\rm H\,I}$ plane

stellar winds have not been seen.[4] Interpretation of the Lyα profiles of late-type giants (McClintock *et al.* 1978*b*) remains problematic, because, in giants with $V-R > 0.8$, chromospheric gas is observed to participate in the stellar wind (Stencel and Mullan 1980).

The heliocentric bulk velocity of the interstellar gas toward α Cen B was determined to be -15.5 ± 1.9 km s^{-1}, in good agreement with the velocity previously determined toward α Cen A. The projection of the interstellar wind velocity along the α Cen sightline is expected to be -16.5 km s^{-1} using the velocity parameters derived from He I (584 Å) photometry by Weller and Meier (1981), or -13.2 km s^{-1} from the velocity parameters derived from Lyα absorption cell photometry by Bertaux (1984). The projection toward α Cen of the local interstellar medium velocity determined by Crutcher (1982), from optical interstellar absorption lines of stars more than 50 pc from the Sun, is -9.7 km s^{-1}. These values suggest that the gas observed toward α Cen, and in the interstellar wind, may be distinct from more distant gas in the local interstellar medium. The bulk velocity determination toward α Cen may not be valid, however, if (as discussed below) the sightline contains more than one interstellar component.

TABLE 2

SUMMARY OF DERIVED PARAMETERS

Parameter	α Cen A (Paper I)	α Cen B (This work)
$n_{\rm H\,I}$ (cm^{-3})	0.03–0.27	<0.21
$n_{\rm D\,I}/n_{\rm H\,I}$	$>8 \times 10^{-6}$	$>1.1 \times 10^{-5}$
$b_{\rm H\,I}$ (km s^{-1})	>11	>13.8
$v_{\rm H\,I}$[a] (km s^{-1})	-14.7 ± 3	-15.5 ± 1.9
$n_{\rm D\,I}/n_{\rm H\,I}$[b]	$(0.8\text{–}2.7) \times 10^{-5}$	$(1.2\text{–}4.1) \times 10^{-5}$
$b_{\rm H\,I}$[b] (km s^{-1})	13–15	14.2–15.6

[a] Heliocentric bulk velocity.
[b] Assuming $n_{\rm H\,I} = 0.1$ cm^{-3}.

The square-well–shaped H I absorption profile does not allow a unique determination of parameters in the $n_{\rm H\,I}$-$b_{\rm H\,I}$ plane, and the H I column density toward α Cen remains very uncertain. Our models do give a 90% confidence upper limit of $n_{\rm H\,I} < 0.21$ cm^{-3}, and lower limit on the velocity dispersion of $b_{\rm H\,I} > 13.8$ km s^{-1}. The lower limit on the velocity dispersion is interesting, in view of the upper limit of $b_{\rm H\,I} < 12$ km s^{-1} (McClintock *et al.* 1978*a*) found toward Capella ($d = 13.2$ pc). The D I velocity dispersion observed toward Capella ($b_{\rm D\,I} < 9$ km s^{-1}), is consistent with the ratio, $b_{\rm D\,I}/b_{\rm H\,I} = 1/2^{1/2}$, expected for thermal broadening. If this is the case, then the Capella sightline contains gas cooler than 8700 K, while the α Cen sightline contains gas warmer than 11,500 K. For comparison, the temperature of the interstellar wind observed entering the solar system has been determined to be 8000 ± 1000 K from Lyα photometry (Bertaux 1984), and 16,000 ± 5000 K from He I (584 Å) photometry (Dalaudier *et al.* 1984). The higher temperature obtained from He I (584 Å) photometry may be partially due to interaction of the helium atoms with the solar wind (Fahr, Nass, and Rucinski 1985).

Alternatively, the large velocity dispersion observed toward α Cen may indicate large-scale turbulence, or perhaps multiple velocity components. Observations of the D I feature with the High-Resolution Spectrograph aboard the Hubble Space Telescope, can be used to discriminate among these possibilities.

Fitting the observed asymmetry between the blue and red wings of the Lyα emission, has yielded a lower limit of $n_{\rm D\,I}/n_{\rm H\,I} > 1.1 \times 10^{-5}$. This result is not as secure as that found toward the four late-type stars mentioned in the introduction, where good quality *Copernicus* data could better resolve the D I absorption profile. Nevertheless, it is of interest that all these late-type stars yield values of $n_{\rm D\,I}/n_{\rm H\,I} > 10^{-5}$, whereas observations of the higher Lyman lines of more distant early-type stars suggest that $n_{\rm D\,I}/n_{\rm H\,I} < 10^{-5}$ (Vidal-Madjar *et al.*

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[4] Brown and Jordan (1981) did suggest that the Lyα emission of Procyon (F5 IV–V) contains an enhanced blue wing, and that the interstellar parameters derived toward this star should therefore be considered poorly determined. However, these authors misidentified the substantial contamination from diffuse geocoronal/interplanetary Lyα present in their large-aperture *IUE* image. After removing the diffuse Lyα component, Landsman *et al.* (1984*b*) found that an excellent fit could be made to the Procyon data, by assuming a symmetric stellar emission, and a uniform interstellar medium.

1983; Ferlet, Gry, and Vidal-Madjar 1984). It remains to be seen whether real variations exist in the local D/H abundances, or if one of the analysis methods is still subject to systematic errors.

Finally, the D I bulk velocity toward α Cen B is poorly determined and cannot be used to address the reality of the 8 km s^{-1} shift between the bulk velocities of H I and D I towards α Cen A, which was derived in Paper I. However, the peculiarity of the D I feature does suggest that a uniform, thermally broadened interstellar medium may not adequately describe the α Cen sightline.

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REFERENCES

Anderson, R. C., Henry, R. C., Moos, H. W., and Linsky, J. L. 1978, *Ap. J.*, **226**, 883.
Anderson, R. C., and Weiler, E. J. 1979, *Pub. A.S.P.*, **91**, 431.
Ayres, T. R., and Linsky, J. L. 1980, *Ap. J.*, **235**, 76.
Ayres, T. R., Linsky, J. L., Basri, G. S., Landsman, W. B., Henry, R. C., Moos, H. W., and Stencel, R. E. 1982, *Ap. J.*, **256**, 550.
Bertaux, J. 1984, in *Local Interstellar Medium*, ed. Y. Kondo, F. C. Bruhweiler, and B. D. Savage (NASA CP-2345), p. 3.
Brown, A., and Jordan, C. 1981, *M.N.R.A.S.*, **196**, 757.
Bruhweiler, F. C. 1982, in *Four Years of IUE Research*, ed. Y. Kondo, J. M. Mead, and R. D. Chapman (NASA CP-2238), p. 125.
———. 1984, in *Local Interstellar Medium*, ed. Y. Kondo, F. C. Bruhweiler, and B. D. Savage (NASA CP-2345), p. 39.
Crutcher, R. M. 1982, *Ap. J.*, **254**, 82.
Dalaudier, F., Bertaux, J. L., Kurt, V. G., and Mironova, E. N. 1984, *Astr. Ap.*, **134**, 171.
Evans, N. R. 1984, in *Minutes of the International Ultraviolet Explorer Users Committee* (CSC/TM-84/6109), Appendix P.
Fahr, H. J., Nass, H. U., and Rucinski, D. 1985, *Astr. Ap.*, **142**, 476.
Ferlet, R., Gry, C., and Vidal-Madjar, A. 1984, in *Local Interstellar Medium*, ed. Y. Kondo, F. C. Bruhweiler, and B. D. Savage (NASA CP-2345), p. 84.
Frisch, P. C., and York, D. G. 1983, *Ap. J.* (*Letters*), **271**, L59.
Heintz, W. D. 1982, *Observatory*, **102**, 42.
Kamper, K. W., and Wesselink A. J. 1978, *A.J.*, **83**, 1653.
Lampton, M., Margon, B., and Bowyer, S. 1976, *Ap. J.*, **208**, 177.
Landsman, W. B., Henry, R. C., Moos, H. W., and Linsky, J. L. 1984*a*, *Ap. J.*, **285**, 801 (Paper I).
———. 1984*b*, in *Local Interstellar Medium*, ed. Y. Kondo, F. C. Bruhweiler, and B. D. Savage (NASA CP-2345), p. 60.
McClintock, W., Henry, R. C., Linsky, J. L., and Moos, H. W. 1975, *Ap. J.*, **202**, 733.
———. 1978*a*, *Ap. J.*, **225**, 465.
McClintock, W., Moos, H. W., Henry, R. C., Linsky, J. L., and Barker, E. S. 1978*b*, *Ap. J. Suppl.*, **37**, 223.
Mihalas, D. 1978, *Stellar Atmospheres* (San Francisco: W. H. Freeman).
Stencel, R. E., and Mullan, D. 1980, *Ap. J.*, **238**, 221.
Sonneborn, G. 1985, personal communication.
Vidal-Madjar, A., Laurent, C., Gry, C., Bruston, P., Ferlet, R., and York, D. G. 1983, *Astr. Ap.*, **120**, 58.
Weller, C. S., and Meier, R. R. 1981, *Ap. J.*, **246**, 386.

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