IUE STUDY OF THE VERY LOCAL INTERSTELLAR MEDIUM

R. C. Henry* J. Murthy* H. W. Moos W. B. Landsman**
J. L. Linsky† A. Vidal-Madjar†† C. Gry†††

*The Johns Hopkins University †JILA, U of Colorado, & NBS †††ESA, Madrid
**SASC, GSFC, NASA ††Institut d’Astrophysique, Paris

ABSTRACT

IUE and Copernicus results are compared, for studies of the very local interstellar medium. Despite its lower resolution, IUE produces results of comparable quality, giving important confirmation of Copernicus results on the density, temperature, turbulence, and deuterium-to-hydrogen ratio in the region within ∼10 pc of the sun. The stars observed are in a very low-density quarter of the galaxy: multi-component structure seen in other directions may not be present in the direction of most of our observed stars. The exceedingly low densities observed in certain directions encourages the idea that BUV (λ <912 Å) studies of certain normal stars may be possible.

Keywords: Interstellar Medium, Late-Type Stars, Hydrogen, Deuterium, Procyon, HR 1099, Capella, Rub 'al Khālī

1. INTRODUCTION

Murthy et al. (Ref. 1) are reporting new high-dispersion IUE observations of the interstellar hydrogen and deuterium Ly α absorption profiles toward the late-type stars η Per (3.3 pc), Procyon (3.5 pc), Altair (5.1 pc), Capella (13.2 pc), and HR 1099 (33 pc). Preliminary line profiles are given by Landsman et al. (Ref. 2). In the present paper, we do two things: 1) we place the observations in the context of recent information on the multi-component nature of the local interstellar medium, and 2) we discuss each star in comparison with previous Copernicus observations.

2. THE VERY LOCAL ISM

Figure 1 shows the location in the galactic plane of the stars that we have observed with IUE. The position of α Cen, which we have observed previously (Refs. 3,4), is also marked. (Note that the direction of the galactic center is to the right).

Our observations are of the interstellar medium: each star is used as a light source at Ly α, and interstellar hydrogen and deuterium are observed in absorption against the chromospheric stellar emission. Our results are rather insensitive to the exact original stellar profile that is assumed. This is demonstrated by our observations of α Cen, where our results for the interstellar parameters are in good agreement, comparing results from α Cen A (Ref. 3) and α Cen B (Ref. 4).

The "b" value which we obtain from our analysis could be due to temperature effects, or to turbulence, or to a combination of these. The densities which we obtain are sensitive to the number of components ("interstellar clouds") along the line of sight. A recent paper by Lallement, Vidal-Madjar, and Perlet (Ref. 5) gives valuable information on the number of clouds in various directions, from high resolution and high signal-to-noise ground-based observations of CIII interstellar absorption lines toward various nearby stars. In addition to the Very Local Interstellar Medium (VLISM), they identify four components, or clouds, which they name Asterix, Obelix, Panoramix, and Idefix. The number of components which Lallement et al. observe in each direction is plotted at the location of each star in Figure 1. The only star we have in common is Altair (λ =48°, d=5.1 pc). In the direction of Altair, we find that b, lies in the range 20 to 35 km s⁻¹ (Ref. 1), which is very high. The fact that Lallement et al. find at least three interstellar components toward Altair (with heliocentric velocities of -17.4, -21.4, and -26 km s⁻¹) suggests an explanation for our result: if these components are also present in HI, they could be blended together by the finite spectral resolution of IUE to form a broad absorption profile, simulating a velocity dispersion much higher than that of any of the individual clouds.

The three solid lines in Figure 1 are neutral hydrogen density contours from Parese (Ref. 6). They are labelled with the neutral hydrogen column density to that distance. It has become apparent in recent years, and Parese's paper shows particularly clearly, that there is an "empty quarter" in the sky, the region from galactic longitude 180° to 270°. The vast sandy empty quarter (Rub 'al Khālī) of Saudi Arabia provides a name for this quarter of the galaxy.
There is clearly some tendency, in Figure 1, for larger numbers of components to be present in the direction of larger HI column density, as might be expected. Apart from Altair, all of the stars that we have observed with IUE are located in or on the edge of the Rub' al Khālī, and only the very local interstellar medium itself should be observed! It appears that our lines-of-sight should be as simple as it is possible to get. Even in the shortest line of sight available, that to α Centauri, however, there is some evidence (Ref. 3) for a multi-component medium.

2. INDIVIDUAL STARS

2.1 HR 1099

This star is particularly important, as it is a relatively long way away (33 pc), yet it has an extraordinarily low column density of HI, as discovered by Anderson and Weiler (Refs. 7, 8).

Our observations for $n_T$ and $b$ are compared in Figure 2 with those of Anderson and Weiler (Ref. 8). In this and in all subsequent figures, dashed contours represent 50% confidence, while solid contours represent 90% confidence. Murthy et al. (Ref. 1) detail why the present result might be preferred to that of Refs. 7, 8. The column density of $\sim 0.01 \times 33 \times 3.09 \times 10^{19} = 1.02 \times 10^{18}$ cm$^{-2}$ may be compared with the HI $10^{19}$ and $10^{20}$ cm$^{-2}$ contours of Figure 1.

2.2 ε Eri

This star does not have very strong La emission, and uncertainties are fairly large for both IUE and Copernicus: this is shown in Figure 3. The results from the two spacecraft are mutually consistent, however, and indicate that the density of interstellar matter must drop substantially beyond ε Eri in the direction of HR 1099 (compare with Figures 1 and 2).

The center of the galaxy is to the right, in this map showing the location of the stars we have observed with IUE. The empty quarter (Rub’ al Khali), almost devoid of neutral interstellar matter, lies in the sector 180° to 270°. Plotted numbers represent numbers of interstellar components, or clouds, in that direction, to that distance, as reported by Lallemand et al. (Ref. 5).
Figure 2. Contour plots of $b_H$ versus $n_H$ for HR 1099, from IUE (cross, Ref. 17) and from Copernicus (solid dot, Ref. 8). The column density is only $10^{-7}$ cm$^{-2}$ to this star.

Figure 3. ε Eri observations (September 1975, Ref. 10) from Copernicus (solid dot), compared with our IUE results (cross, Ref. 1). Uncertainties are fairly large because the stellar flux is weak.

Figure 4. Capella (α Aur) observed with Copernicus (solid dot) and with IUE (cross). The average density in this direction is a factor three larger than in the direction of HR 1099 (see Figure 1).

Figure 5. Procyon (α C Mi) observed with Copernicus (solid dot, Ref. 11) and IUE (cross, Ref. 1). The parameters of the interstellar matter in this direction agree well with those in the direction of ε Eri (Figure 3), but are much better determined.

2.3 α Aur

Capella is a spectroscopic binary with strong Lα emission. The Copernicus observations of McClintock et al. (Ref. 9) were reanalyzed by Anderson (Ref. 10), and are plotted as a solid dot in Figure 4. Our IUE data (cross in Figure 4) may be more reliable, because the Copernicus profile did not include the entire stellar emission line.

2.4 α C Mi

Figures 5 and 6 give information on the interstellar medium in the direction of Procyon, as determined with IUE (Ref. 1) and Copernicus (Ref. 11). The data are of much higher quality than in the case of ε Eri, but the result is the same: Figure 5 and Figure 3 show that in the general direction of HR 1099 (see Figure 1), the density is $\approx 0.1$ cm$^{-3}$ for $\approx 3.5$ pc, and is about 1/10 that density or less for the next 30 parsecs.

Figure 6 addresses a different topic, the cosmologically important deuterium-to-hydrogen ratio. Landman et al. (Ref. 2) emphasize that the D/H ratio for Procyon is the most reliable that has been measured toward a late-type star. Figure 6 shows that in this case the IUE data do more than simply confirm the Copernicus result of Ref. 11, by substantially increasing confidence that the interstellar D/H ratio in this direction lies in the range $1.0 - 2.5 \times 10^{-5}$.

3. CONCLUSION

Data from IUE are presented that tend to confirm an emerging picture of the very local interstellar medium.

4. REFERENCES


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