High-resolution Na I Observations of the Local Interstellar Medium

Barry Y. Welsh, Peter W. Vedder and John V. Vallerga, Center for EUV Astrophysics, University of California, Berkeley CA 94720, USA

Abstract: We present high-resolution absorption measurements (R ~ 150 000) of the interstellar Na I D-lines at 5890 Å observed towards 46 early-type stars. The distance to these stars ranges from 20–200 pc, allowing a probe of the local interstellar medium (LISM). The velocity structure, velocity dispersions and column densities of the various cloud components have been derived using an absorption line-fitting analysis. Sodium column densities have been determined for 23 of the 46 target stars. No sodium absorption was detected towards any of the stars with distances < 43 pc. Such null results imply a corresponding hydrogen column density limit, N(H), of ~ 2.5 x 10^{18} cm^{-2} in many directions in the LISM. For three exceptionally vacant lines of sight (to β CMa, 36 Lyn and η Hya) this limit of low hydrogen column density can be placed out to a much further distance of > 150 pc.

We have plotted the distribution of sodium column density in the LISM for a total of 118 stars in the form of three galactic maps. These maps qualitatively show that the present picture of the LISM, in which the first 50 pc is essentially free of dense clumps of neutral gas, is correct. Our map of sodium columns for stars with distances > 100 pc shows that the region within the galactic quadrant defined by 200° < l < 270° shows a conspicuous absence of any significant concentration of neutral gas. This region will be a prime direction of study for forthcoming soft X-ray and extreme ultraviolet satellite experiments.

1. Introduction

We use the interstellar sodium D-lines at 5890 Å as tracers of neutral gas in the local interstellar medium (LISM). Using extremely high-resolution spectroscopy (R ~ 150 000) on the 3-metre Shane telescope at the Lick Observatory in California, we have observed 46 early-type stars with distances ranging from 20–200 pc. Following the procedures outlined in Welsh et al. (1990) we have determined sodium column densities towards 23 of our target stars and have used an absorption line-fitting analysis to fit the observed absorption profiles.

In addition to our own observations, we have included results of sodium absorption recorded at similarly high resolution by several authors in the literature for a further 72 stars with dis-
tances < 200 pc. Thus, in combination we present maps of the space distribution of sodium (and hence the neutral interstellar gas) observed towards a total of 118 stars in the LISM.

2. Results
We plot the distribution of neutral sodium gas in the following three galactic maps. The main results of this survey are as follows:

(a) Only two stars closer than 50 pc show any appreciable sodium absorption (i.e., 2 And and δ Cyg). We therefore conclude that in at least 90% of the directions so far viewed in the LISM, there exists a distinct paucity of neutral gas to 50 pc. Thus, the Local Bubble is uniformly empty of dense neutral interstellar gas clouds.

(b) From the previous result we can place an upper limit to the neutral sodium column density of $N(\text{Na I}) < 10^{10}$ cm$^{-2}$ for the majority of stars closer than 50 pc. Using the relationship given by Ferlet et al. (1985) this implies a corresponding upper limit of $N(\text{H}) < 2.5 \times 10^{18}$ cm$^{-2}$ in the Local Bubble.

(c) Of the 18 stars with distances 40–70 pc, only six have measurable sodium absorption. This indicates that the Local Bubble extends farther than 60 pc in many directions. In the 70–90 pc range, over 60% of the stars have measurable sodium and for stars with distances > 90 pc, over 90% of the stars have appreciable sodium absorption.

(d) Three particularly low density lines of sight have been observed towards the distant stars β CMA (203 pc), 36 Lyn (150 pc) and η Hya (160 pc). Since neutral interstellar hydrogen seems to be deficient in these lines of sight, these will be prime regions of interest to extreme ultraviolet observations by NASA's Extreme Ultraviolet Explorer satellite.

Acknowledgement
This work was supported by NASA contract NASS–30180.