The David Dunlap Observatory IVC Distance Project: First Results

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Abstract.

We present distance estimates to a set of high-latitude intermediate-velocity HI clouds. We explore some of the physical parameters that can be determined from these results, such as cloud mass, infall velocity and height above the Galactic plane. We also briefly describe some astrophysical applications of these data and explore future work.

1. Intermediate Velocity Clouds

Clouds of neutral hydrogen at high galactic latitudes are detected as discrete velocity structures in 21cm line emission. The population of intermediate velocity clouds (IVCs) has $|V_{LSR}| < 70$ km s$^{-1}$. The nature of the clouds remains unknown, although several scenarios for their origin have been proposed (see Wakker & van Woerden [1997] for a review). In order to understand the origins and dynamics of these clouds, it is necessary to have accurate distance estimates to them.

We have undertaken a project to measure the distances to high-latitude intermediate velocity clouds selected from the Heiles, Reach & Koo (1988) sample. We observe a set of target stars along the lines of sight to the clouds and use interstellar absorption features to determine if the stars are behind or in front of the clouds. From spectral classification, we deduce the distances to these foreground and background stars and hence bracket the distances to the clouds. In this paper, we explore some potential applications of our data.

2. Some Applications of Distance Measurements

We have upper and lower distance estimates for 9 clouds and lower limits only for another 2 clouds (Gladders et al., 1998a,b; Burns et al., 1999; see Table I). These distances allow us to calculate a number of physical parameters of the clouds. For instance, we can calculate the infall velocity ($v_{\perp}$) and cloud distance above the Galactic plane ($z$) as shown in Figure I. These perpendicular velocities can be compared to theoretical predictions of ballistic infall models and terminal velocity models, and appear to be consistent with the latter.
Figure 1. Velocity perpendicular to the Galactic plane plotted as a function of cloud height above the plane. The connected symbols indicate the upper and lower brackets computed from the line of sight distance estimates. Perpendicular velocities were calculated assuming that the clouds’ motions are directed vertically (in the co-rotating Galactic frame), and include corrections for the differential Galactic rotation. Note that, in general, the higher clouds are falling faster. The dotted lines correspond to the predictions of the terminal velocity models of Benjamin & Danly (1997); top to bottom lines correspond to cloud densities of $10^{20}$, $3 \times 10^{19}$ and $10^{19}$ cm$^{-2}$ in their warm HII + HI + hot halo model. Our data appear to be consistent with these terminal velocity infall models.

Distance estimates also enable us to calculate the cloud mass. Table 1 shows the cloud HI mass estimates obtained by combining our distance brackets with the HI column densities from Heiles, Reach & Koo (1988) and angular sizes from IRAS 100 $\mu$m dust images.

3. Future Work

We are currently extending our project to include more intermediate velocity clouds. We are also refining (where possible) the above cloud distances by observing more stars and by obtaining spectroscopic classification for those stars which currently have only colour-based distances.

Future high resolution observations of several strong interstellar absorption line features in background stars will allow us to constrain cloud metallicities. The metallicity will be relevant to the question of the origin of the clouds (i.e., whether they are Galactic ejecta or primordial gas).
Table 1.  IVC distance brackets and HI mass estimates.

| CLOUD(S)                      | V_{LSR} \(^1\) (km/sec) | d (pc) | M_{HI} (M_\odot) |
|-------------------------------|---------------------------|--------|-----------------|
| G163.9+59.7                   | −19.0                     | 300–2380 | 5–250            |
| G139.6+47.6 & G141.1+48.0     | −12.1 & −12.9             | 120–420 | 10–110           |
| G135.5+51.3                   | −47.2                     | 310–1900 | 100–3560         |
| G149.9+67.4                   | −6.3                      | 260–660 | 5–20             |
| G249.0+73.7                   | −0.6                      | ≥180    | ≥60              |
| G124.1+71.6                   | −11.4                     | 240–2020 | 50–3430         |
| G107.4+70.9 & G99.3+68.0      | −29.9 & −26.6             | 530–1220 | 220–1170        |
| G86.5+59.6                    | −39.0                     | ≥430    | ≥380             |
| G90.0+38.8 & G94.8+37.6 (Draco)\(^2\) | −23.9 & −23.3            | 330–860 | 190–1340        |
| G81.2+39.2                    | +3.5                      | 320–1260 | 270–4180       |
| G86.0+38.3                    | −43.4                     | 640–3560 | 130–4070        |

\(^1\)Heiles, Reach and Koo (1988)

\(^2\)Presented in detail in Gladders et al., 1998a

IVC distances can also be used to constrain the nature of the soft X-ray background radiation (Kerp, 1996). The origin of this emission is considered to be from either the local interstellar medium or from the galactic halo. The detection of an “X-ray shadow” toward the Draco cloud (Snowden et al., 1990) provided evidence that at least some of the emission is from large distances. Further soft X-ray shadowing measurements toward more clouds with distance brackets will provide insight into the origin of this emission.

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