Cold Galactic H I in the First and Second Quadrants

S. J. Gibson *(NAIC)*, **J. M. Stil, A. R. Taylor** *(U. Calgary)*, **C. M. Brunt** *(U. Exeter)*, **D. W. Kavars** *(U. Minnesota)* , **& J. M. Dickey** *(U. Tasmania)*

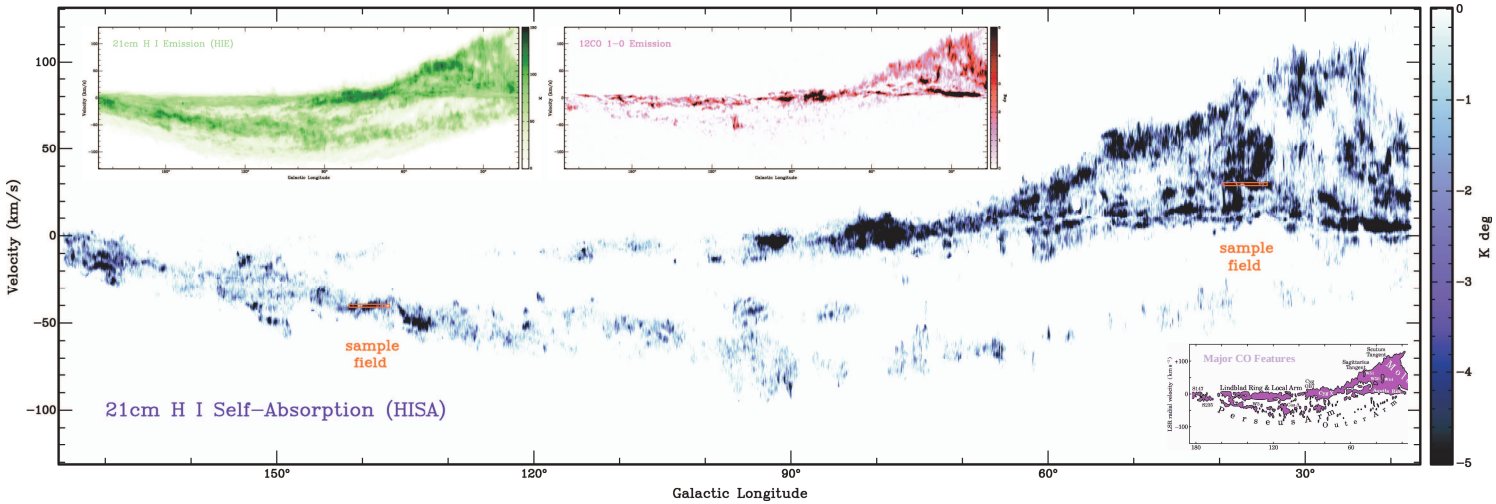

Figure 1. Longitude-velocity projections of gas near the Galactic plane. Main plot (blue): HI self-absorption extracted from the Canadian and VLA Galactic Plane Surveys (Taylor et al. 2003; Stil et al. 2006), integrated over latitude; the red boxes mark longitude-latitude sample areas shown in Fig. 2. Green inset: maximum HI emission brightness temperature over $|b|<10^0$ for the same area, from the Leiden/Argentine/Bonn (LAB) HI Sky Survey (Kalberla et al. 2005). Pink inset: 12CO J=1-0 emission integrated over latitude, from the CfA Composite CO Survey (Dame et al. 2001). Purple inset: matching portion of schematic from Dame et al. (2001) identifying spiral arms and other major features.

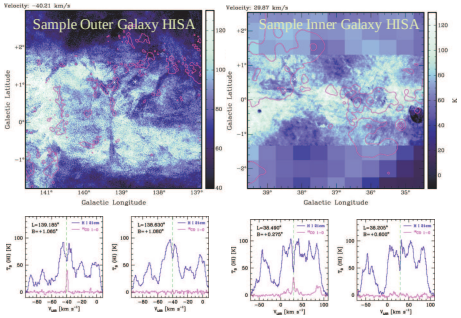

Figure 2. Channel maps and spectra of sample HISA features (blue) marked in Fig. 1 with CO comparison data (pink) from Heyer et al. (1998), Clemens et al. (1986), and Dame et al. (2001). White asterisks mark the spectral sightlines. The VGPS image on the right is padded with LAB data for $|b| > 1.3^0$; HISA is much more visible at arcminute resolution (the dark feature at l=34.5^0 is W44). HISA is found with and without CO in both locations, but the degree of CO association is higher in the inner Galaxy.

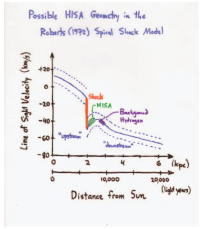

Figure 3. Simple Galactic rotation implies one distance per velocity channel in the outer Galaxy, which cannot explain HISA. Roberts' (1972) spiral shock model yields a natural HI emission background for HISA immediately downstream of the shock, where cold atomic gas may be forming molecular clouds prior to new star formation. The velocity departure just after the shock is marked in Fig. 6.

Mapping the Coldest HI with HISA

Cold atomic gas is an important interstellar constituent that is hard to map directly. HI self-absorption (HISA) against warmer background HI emission at the same velocity allows a detailed mapping of the cold atomic medium as well as a probe of the Galactic velocity field over large distances. We have extended a prior HISA census of the Phase I Canadian Galactic Plane Survey (Gibson et al. 2005) with CGPS II and VLA Galactic Plane Survey data covering most of the first and second quadrants. Weak HISA is widespread and may arise from turbulent fluctuations in the ambient ISM. Strong HISA is concentrated in cloudlike features along the Perseus and Outer spiral arms at $v < 0$ km/s and in much of the inner Galaxy at $v > 0$ km/s.

HISA vs. CO

Although HISA gas has temperatures of only a few times 10 K, most outer-Galaxy HISA has little apparent CO emission. HISA-CO agreement is stronger for $l < 90^0$, $v > 0$ km/s, where Galactic far-side HI emission illuminates trace cold HI in CO clouds as HISA.

Spiral Structure

Spiral density waves are required to explain strong, organized HISA in the outer Galaxy. The Roberts (1972) spiral shock model is consistent with observed Perseus arm HISA, given the lumpiness of the real ISM. This HISA gas may be premolecular, accounting for the poor CO correspondence. A similar situation is likely for the Outer arm in the first quadrant. HISA may also trace spiral shocks in the inner Galaxy; efforts to untangle the arm geometry in this region are ongoing.

References

Clemens, D. P., Sanders, D. B., Scoville, N. Z., & Solomon, P. M. 1986, ApJS, 60, 297

Dame, T. M., Hartmann, D., & Thaddeus, P. 2001, ApJ, 547, 792

Gibson, S. J., Taylor, A. R., Higgs, L. A., Brunt, C. M., & Dewdney, P. E. 2005, ApJ, 626, 195

Heyer, M. H., Brunt, C. M., Snell, R. L., Howe, J. E., Schloerb, F. P., & Carpenter, J. M. 1998, ApJS, 115, 241

Kalberla, P. M. W., Burton, W. B., Hartmann, D., Arnal, E. M., Bajaja, E., Morras, R., & Pöppel, W. G. L. 2005, A&A, 440, 775

Roberts, W. W. 1972, ApJ, 173, 259

Stil, J. M., Taylor, A. R., Dickey, J. M., Kavars, D. A., Martin, P. G., Rothwell, T. A., Boothroyd, A., Lockman, F. J., McClure-Griffiths, N. M. 2006, AJ, in prep

Taylor, A. R., Gibson, S. J., Peracaula, M., Martin, P. G., Landecker, T. L., Brunt, C. M., Dewdney, P. E., Dougherty, S. M., Gray, A. D., Higgs, L. A., Kerton, C. R., Knee, L. B. G., Kothes, R., Purton, C. R., Uyaniker, B., Wallace, B. J., Willis, A. J., & Durand, D. 2003, AJ, 125, 3145

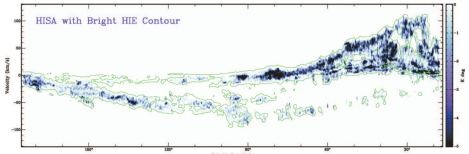

Figure 4. HISA *l-v* projection with HI emission T_max = 70 K contour marking the area where the emission background is sufficient for HISA detection. Faint HISA is found in most areas where it can occur. Strong HISA tends to be concentrated in organized complexes.

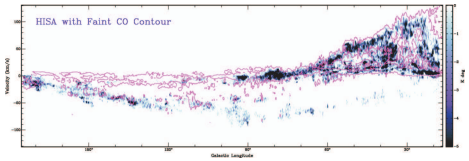

Figure 5. HISA with integrated CO contour of 0.5 K deg. As with the examples of Fig. 2, CO associates more strongly with HISA in the inner Galaxy than in the outer Galaxy.

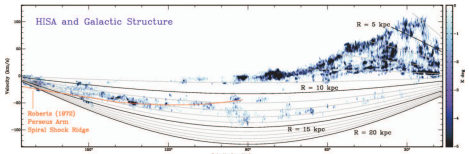

Figure 6. HISA with Roberts (1972) Perseus arm spiral shock ridge locus (red) and curves of constant Galactocentric radius (gray, black) assuming simple circular rotation with R_o=8.5 kpc and V_o=220 km/s.

Support was provided by a grant from NSERC in Canada and by NAIC and Cornell University under Cooperative Agreement with the NSF.

For more details, please see www.naic.edu/~gibson/hisa