Constraining the Physical Properties of Interstellar Gas Clouds

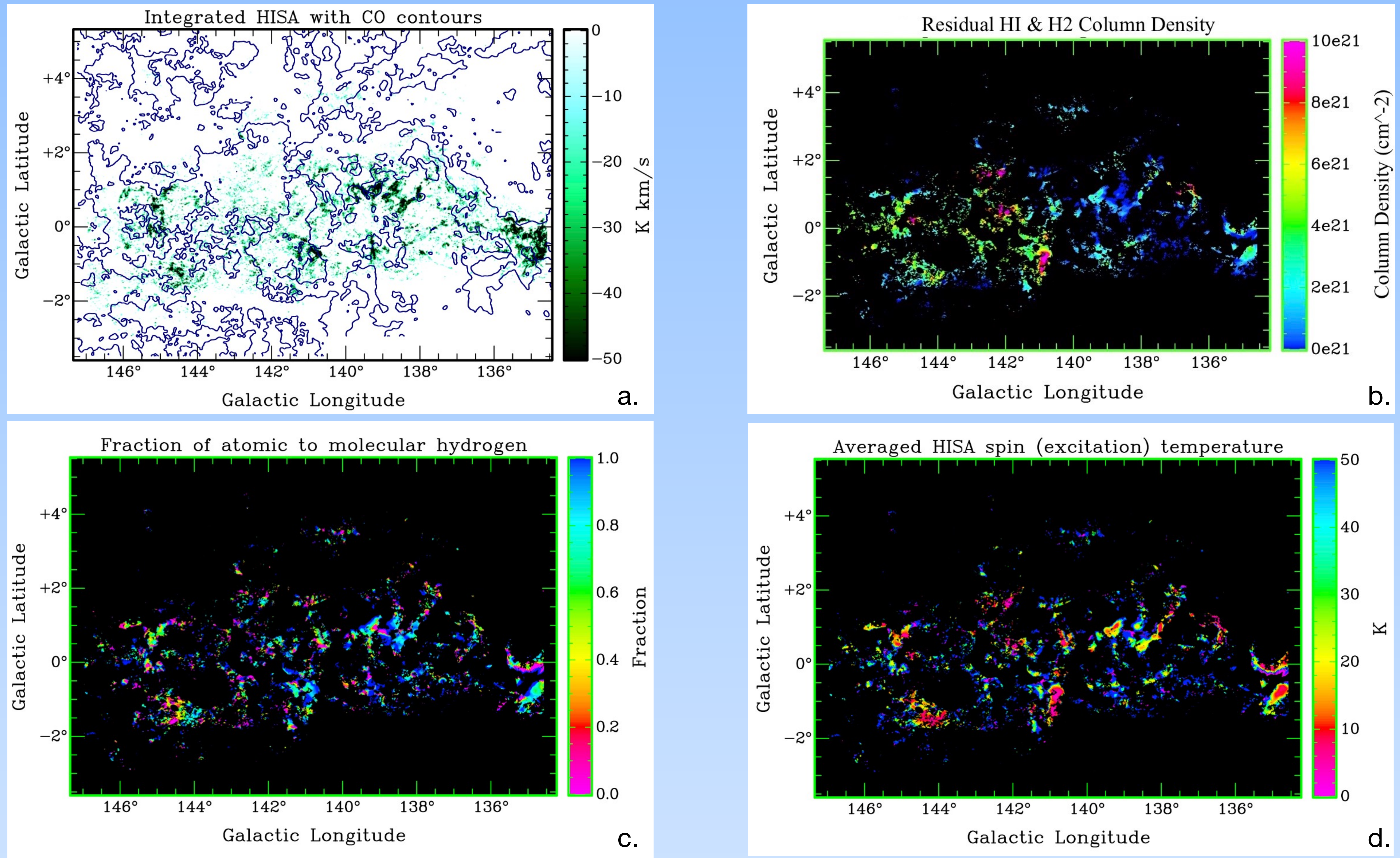
Mary Spraggs, Steven Gibson
Western Kentucky University

Background Information

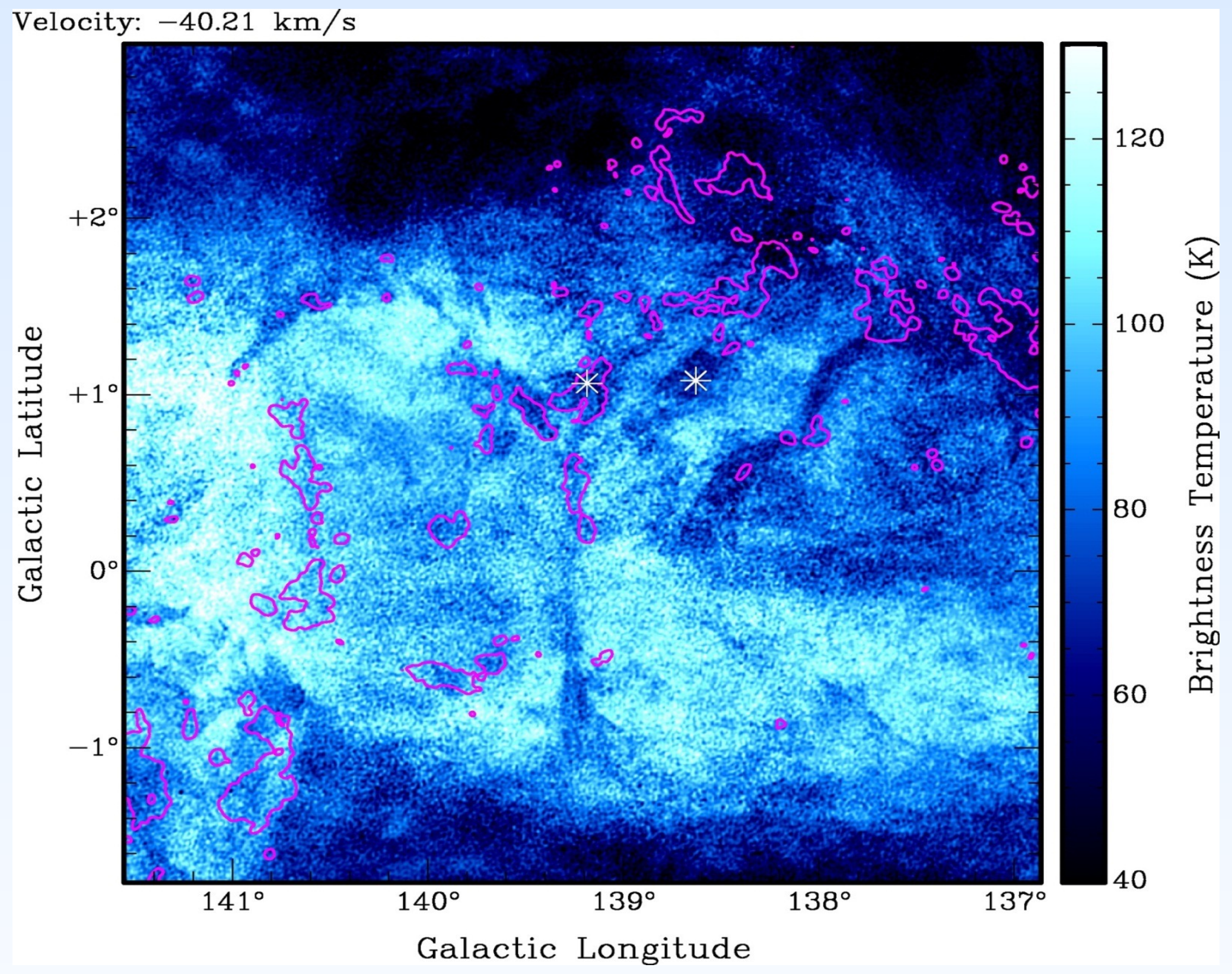
Since the interstellar medium (ISM) plays an integral role in star formation and galactic structure, it is important to understand the evolution of clouds over time, including the process of cooling and condensing that in turn forms new stars. This work aims to constrain and better understand the physical properties of the cold ISM by utilizing large surveys of neutral atomic hydrogen (HI) 21cm spectral line emission and absorption, carbon monoxide (CO) 2.6mm line emission, and multi-band infrared dust thermal continuum emission. We are developing an algorithm that identifies areas where the gas may be cooling and forming molecules using HI self-absorption (HISA), in which cold foreground HI clouds absorbs radiation from warmer background HI emission, and analyzes the HI spectral line in parallel with the CO and infrared data. From these inputs, we can determine the gas temperature, density, molecular abundance, and other properties as functions of position. The products of the algorithm are *property maps* that allow us to visualize the variation of the property values throughout HISA clouds and any dependencies with galactic location.

Analysis

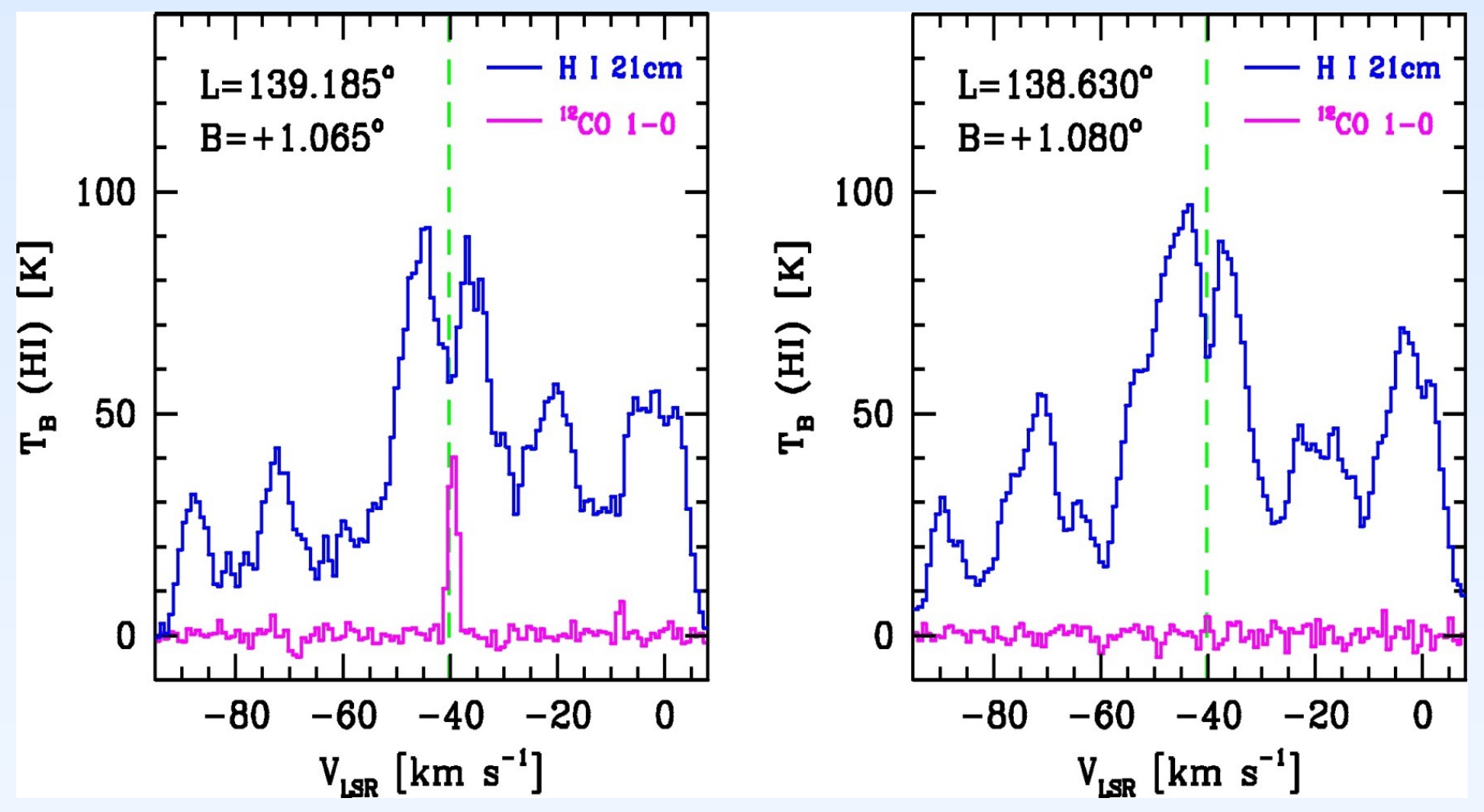
Our selected region contains several large HISA features within the Perseus spiral arm. HISA gas properties are not easy to constrain from the HI data alone, but by comparing the HISA to CO and dust, we are able to measure the fraction of atomic gas in the cloud and the spin temperature, among other physical properties. Using *Planck* dust as a proxy for total gas content, we subtract the H_2 column traced by CO emission from this, leaving only a residual column of dark HI plus H_2 gas. If we assume the dark column outside the HISA boundaries is all molecular, this allows us to separate the dark HI plus H_2 column density components. The atomic gas fraction thus obtained is sufficiently precise to allow good constraints on other gas properties like temperature and density obtained via ideal gas relationships (e.g. Gibson et al. 2000).



Maps of the area under investigation: (a) HISA ON-OFF brightness differences tracing cold, dark HI (from Gibson et al. 2005), smoothed to the *Planck* resolution and integrated over velocity, with similarly smoothed ^{12}CO J=1-0 emission line-integral contours tracing "visible" H_2 content (Heyer et al. 1998) at a level of 4 K km/s ~ 1.4×10^{21} H-atoms cm^{-2} (using the conversion factor of Dame et al. 2001); (b) total H-atom gas column traced by Planck dust (converted from E(B-V) with $X_{EBV} = 5.8 \times 10^{22}$ H atoms cm^{-2} / mag, after Bohlin et al. 1978) with HI and CO emission subtracted to show $N_{H,\, H2,\, dark}$, the column density of all hydrogen (atomic and molecular) not directly observed; (c) fractional abundance of atomic gas $f_{HI} = n_{HI} / (n_{HI} + n_{H2})$ in the studied area, limited to locations that satisfied the model assumptions of a larger column ON the HISA than OFF and more column in the Planck dust than in other tracers; (d) HISA spin (excitation) temperature, derived from ideal gas conditions and the fractional abundance map. At the adopted distance of 2.3 kpc, 0.1 degree = 4.0 pc.



A channel map of HI 21cm line emission (CGPS; Taylor et al. 2003), showing cold atomic gas as dark blue HI self-absorption shadows (HISA; Gibson et al. 2000). Magenta contours show H_2 traced by CO (Heyer et al. 1998).



HI and CO spectra taken from positions marked with two white asterisks in the map to the left. The cloud on the left side of this map has a CO spike corresponding with a HISA dip, indicating cold atoms and molecules are both present. The cloud on the right has HISA without CO, so it may be in a less-developed state. There are many such clouds throughout the Galaxy (Gibson 2010).

Results & Future Work

We have shown that our analysis using HI self-absorption, CO, and dust emission can provide reasonable constraints on both the atomic/molecular content and gas properties of clouds where dark H_2 is actively forming. This algorithm is still a work in progress and can be improved by examining conditions in areas where the model fails. Afterward, the algorithm will be run on a larger section of the Galaxy, enabling a thorough investigation of both the influence of internal properties on where H_2 forms within clouds and that of Galactic environment on where such clouds are most likely to arise, and what physical mechanisms (shocks, spiral density waves, etc.) may be responsible for their development.

References

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