A Multi-wavelength Analysis of Cold Evolving Interstellar Clouds

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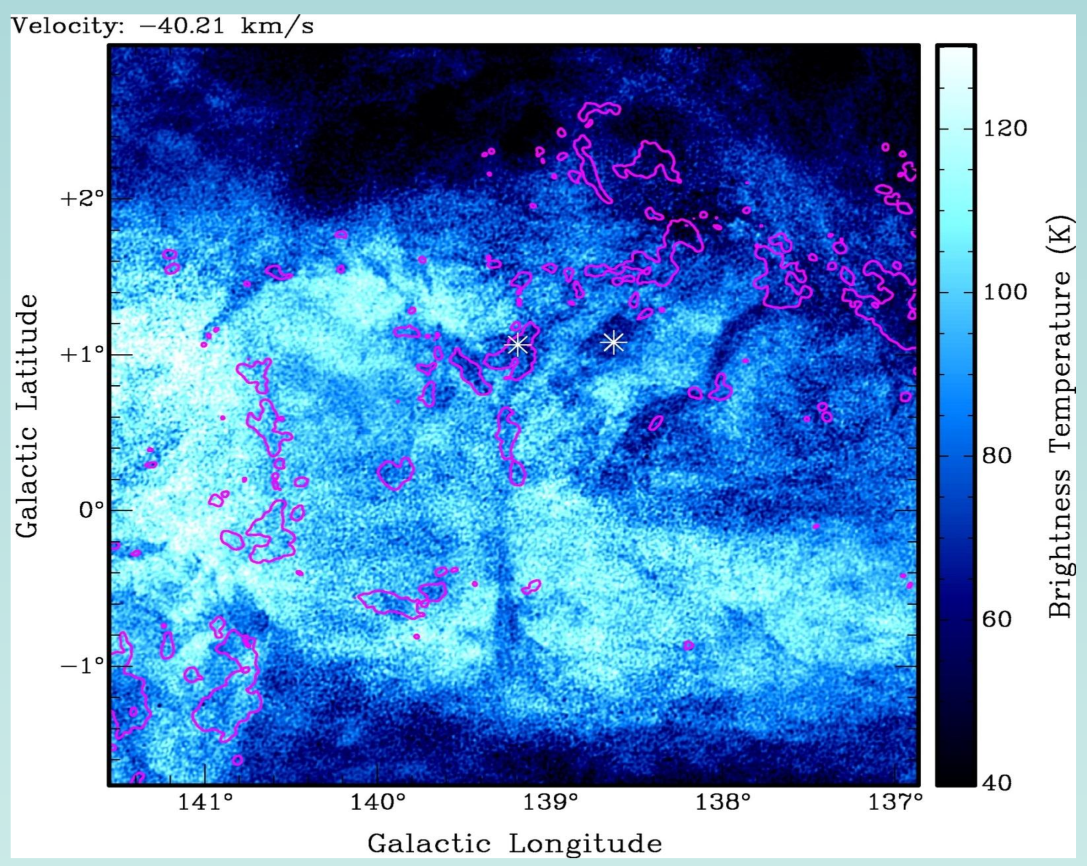
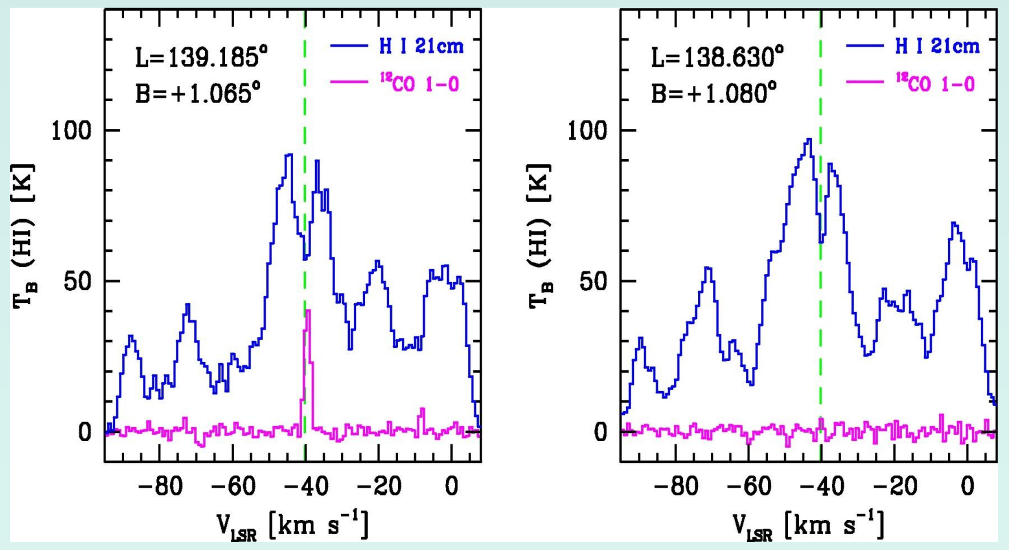
Background Information

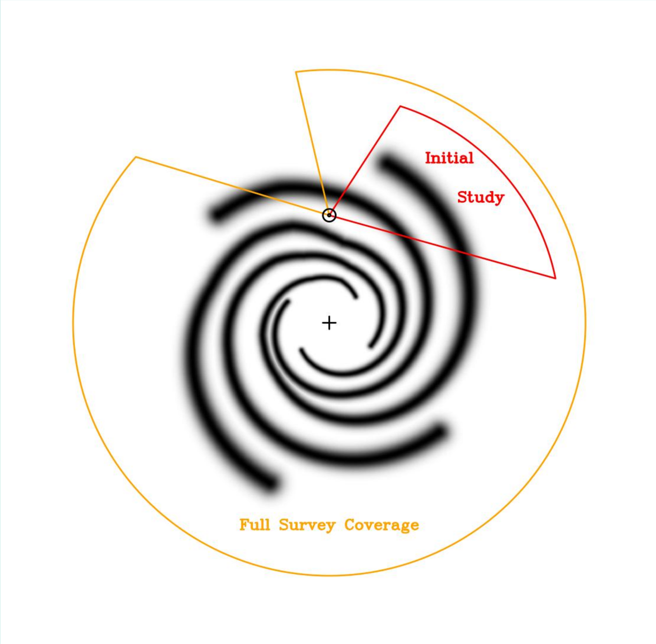
The ambient interstellar medium (ISM) is too tenuous for clouds to collapse on their own, but the formation of molecular hydrogen (H_2) aids this process by shielding the cloud interior from UV radiation, allowing the cloud to cool and contract. We are interested in finding areas in the Milky Way where H_2 is forming and studying their physical properties and environment to determine what conditions are responsible for triggering H_2 formation. We measure the neutral atomic hydrogen (HI) content and properties with HI self-absorption (HISA) and the H_2 content with CO emission plus *Planck* dust column density to detect ``dark'' H_2. HISA is a known tracer of the coldest HI, where H_2 formation is most likely to occur, so we target HISA clouds in our study.



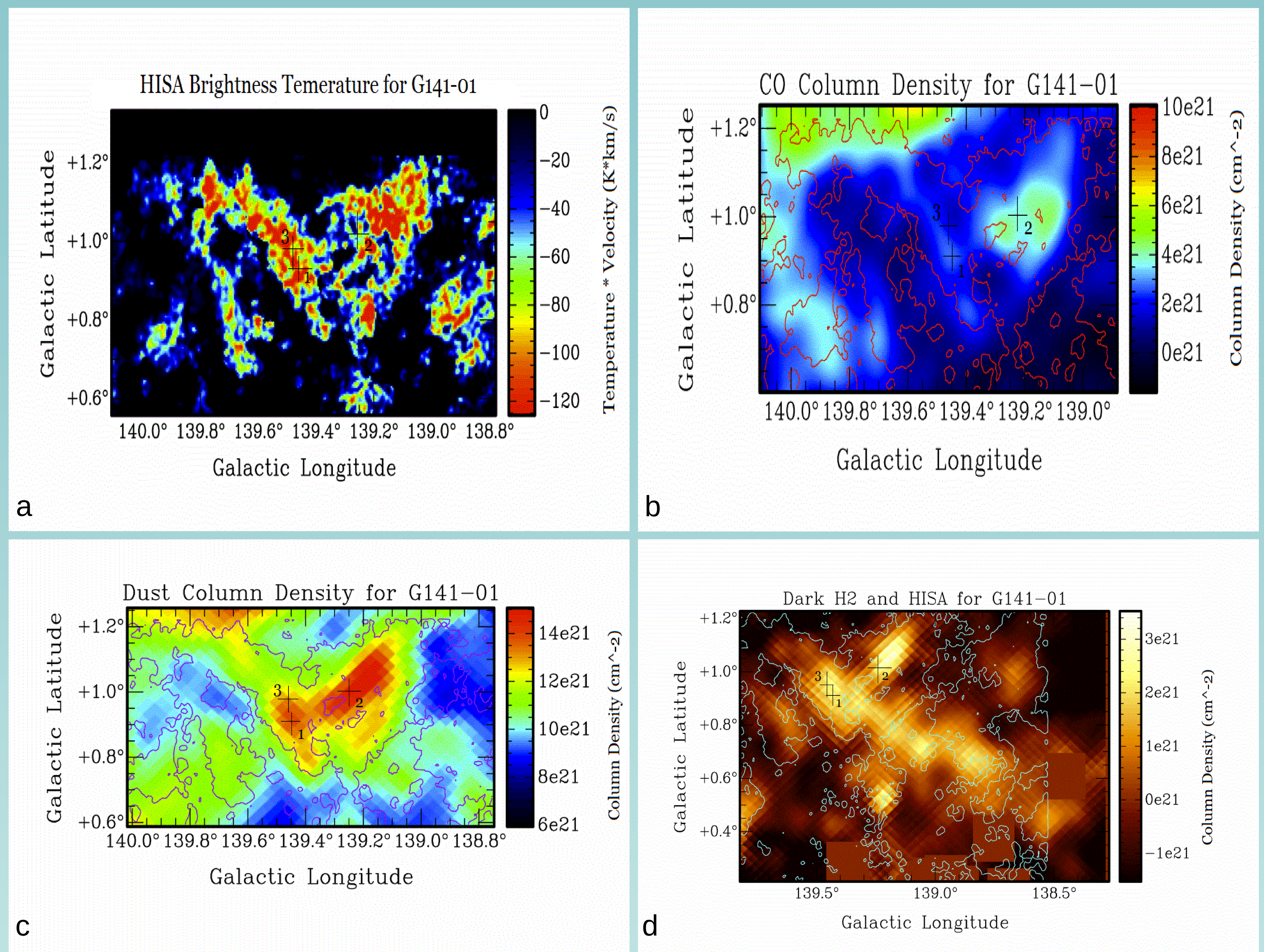
A channel map of HI 21cm line emission (CGPS; Taylor et al. 2003), showing cold atomic gas as dark blue HI self-absorption shadows (HISA; Gibson et al. 2000). Magenta contours show H_2 traced by CO (Heyer et al. 1998).



HI and CO spectra taken from positions marked with two white asterisks in the map above. The cloud on the left 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).



A schematic plan view map showing the CGPS Phase 1 area (red) and the larger coverage of the International Galactic Plane Survey area (yellow) that we plan to analyze in the future.



•Maps of the cloud under investigation: (a) HISA channel map near the line peak showing the ON-OFF brightness difference (from Gibson et al. 2005); (b) ^{12}CO *J*=1-0 emission tracing "visible" H_2 content (Heyer et al.1998), smoothed to the *Planck* resolution, integrated over velocity, and scaled by 2 $X_{CO} = 3.6 \times 10^{20}$ cm^{-2} (K km/s)$^{-1}$ for H-atom column density (Dame et al. 2001), with HISA contours overlaid; (c) *Planck* dust reddening (*Planck* Consortium 2013), scaled to H-atom column density (Bohlin et al. 1978), with HISA contours; and (d) *Planck* dust column with HI emission and CO subtracted to show "dark" HI + H_2 column density, with HISA contours. Crosses in all panels mark target positions, for which results are tabulated. At the adopted distance of 2.3 kpc, 0.1 degree = 4 pc.

Results and Future Work

We have successfully demonstrated that a combined analysis of HI self-absorption plus CO and dust emission provides reasonable constraints on both the atomic/molecular content and gas properties of clouds where dark H_2 is actively forming. Our next goal is to develop an automated method of applying this analysis to large areas of the Galaxy using HI, CO, and dust survey data sets. This will enable us to thoroughly investigate 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.

Analysis

We have selected a prominent HISA cloud in the Perseus spiral arm for our initial investigation. 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. Using the *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 (Gibson et al. 2000).

Quantity	Point 1	Point 2	Point 3	Units
$N_{H, dust}$	38.2	52.2	32.3	10^{20} cm^{-2}
$N_{H, H2, CO}$	21.6	30.7	14.4	10^{20} cm^{-2}
$N_{H, H2, dark}$	0.00–3.47	0.00–3.47	0.00–3.47	10^{20} cm^{-2}
$N_{H, HISA}$	13.1–16.6	18.1–21.6	14.4–17.9	10^{20} cm^{-2}
$f_{n, HI}$	0.511–0.605	0.515-0.585	0.617-0.713	
n_{total}	207-221	284-298	188-202	cm^{-3}
$T_{S, HISA}$	13.6-14.5	10.1-10.6	14.8-15.9	K
$\tau_{, HISA}$	0.412-0.417	0.392-0.395	0.250-0.254	

References

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