SURP Research Summary: Mapping the thermal condensation of diffuse HI in the intermediate velocity (IVC) gas towards Ursa Major.

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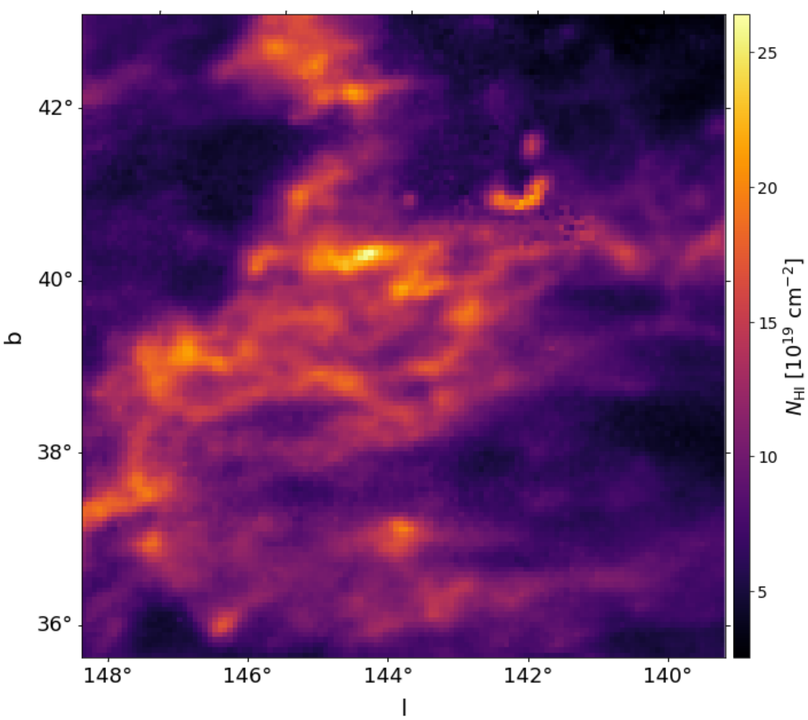
Hydrogen is the most abundant gas in the universe, and the Interstellar Medium (ISM) is mainly comprised of neutral atomic hydrogen (HI). HI can be found in multiple thermal phases, namely the Cold Neutral Medium (CNM) and the Warm Neutral Medium (WNM), which have a kinetic temperature about Tk =100 K, and Tk = 8000 K, respectively. In the Solar neighborhood, these thermal phases have been found to coexist in pressure equilibrium with the denser CNM condensations typically surrounded by the hotter and more diffuse WNM. A potential explanation for the production of CNM structures is the thermal condensation of the WNM through a combination of compression events (e.g., turbulence, colliding flows, SN explosions) and thermal instability. It is believed that the gravitational collapse of large, over-dense structures found in molecular clouds (of which CNM structures are the precursors) is what leads to the formation of stars. However, we are still unsure of the physical process that leads to the formation of these structures. Here, we explore this process for the particular case of Intermediate Velocity (IVC) gas, part of the intermediate latitude infalling Galactic fountain, using data from the GHIGLS 21cm line survey in the direction of Ursa Major (UMA).



The figure above is of the total integrated HI column density of the IVC toward UMA, in a velocity range of approximately -82 km/s < v < -27 km/s. The gas is located approximately 3 kpc above the Galactic plane, and the typical peak IVC emission is at -57 km/s relative to the local standard of rest.

The main analysis tool that enabled us to distinguish the thermal phases was ROHSA, which is a regularized optimization algorithm that decomposes spectra in emission-line cubes into a sum of

Gaussians. We fit the velocity dispersion of the spectral features and related this back to the temperature of the gas being modelled, since the kinetic motions of HI (along with turbulent motions) broadens the 21cm emission line through Doppler broadening. This allows us to estimate the temperature associated with each thermal phase, the colder CNM corresponding to a narrow Gaussian component, and the warmer WNM corresponding to a broad Gaussian component. Six Gaussians were used to model the emission spectra. This number was determined by an initial one Gaussian decomposition and then increasing the number of Gaussians until we achieved a noise-dominated reduced chi squared map.

Using this solution, we were able to separate the thermal phases of the IVC by classifying the Gaussians used to model the data based on their velocity dispersions. We computed properties of each phase independently. The more diffuse WNM has an approximate kinetic temperature of 4000 K, whereas the clumpy CNM is cooler than 400 K. We found that the two phases were clearly spatially coherent, and that the CNM has clumpy, almost filamentary structure inside of the more diffuse WNM envelope. The filamentary structure, especially along the edges of the envelope, could be further shaped by the fact that the gas is moving down towards the Galactic disk, which in the image above is from the top right corner to the bottom left corner. This bulk movement through the gas of the Galactic halo produces turbulence, especially in instabilities along the sides of the envelope. This turbulence could also contribute to the broadening of the 21cm line in our data, making the gas appear to be hotter than it is.

Finally, we analyzed absorption data from the DHIGLS 1’ survey of the same region, which has a significantly finer spatial resolution than that of GHIGLS (beam size of 9.4’). We found that there was cold gas absorbing against the synchrotron continuum of a known radio galaxy in the background. Since cold gas absorbs much more efficiently (inversely as the temperature), this allowed us to probe the CNM directly. We took an average of the emission spectra around the absorption source, fit the resulting spectrum with a single Gaussian, and combined this amplitude with the depth of absorption and the continuum brightness temperature to estimate a spin temperature of T = 82 K.

Our future plans for this project involve using the absorption data in DHIGLS to estimate the turbulent line width and Mach number of that line of sight, which could provide insight into the turbulent nature of the IVC. We would also like to compare the findings of our GHIGLS decomposition to a decomposition of DHIGLS data to explore how spatial resolution effects the CNM mass fraction and the power spectra. We will also use the results of a DHIGLS decomposition to study the effects of “beam smearing” at various spatial resolutions.

In conclusion, based on the results of the CNM mass fraction map, power spectrum, and results of the analysis of the absorption data, there is strong evidence that WNM in the IVC has undergone a thermal phase transition due to turbulence-related compression and resulting thermal instability and has condensed into cooler CNM clumps and filaments.