Emission Spectra of H I Clouds in the Interstellar Medium

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Clouds in the Interstellar Medium

Interstellar clouds may collapse to form new stars with clouds of cold, dense molecular gas being most susceptible to this process. The details of stars forming from these clouds are unfortunately not well understood and can be challenging to study. One such poorly understood area is where and how these clouds assemble from the interstellar medium. Looking out into the interstellar medium, we can find many structures that appear to be forming these clouds.

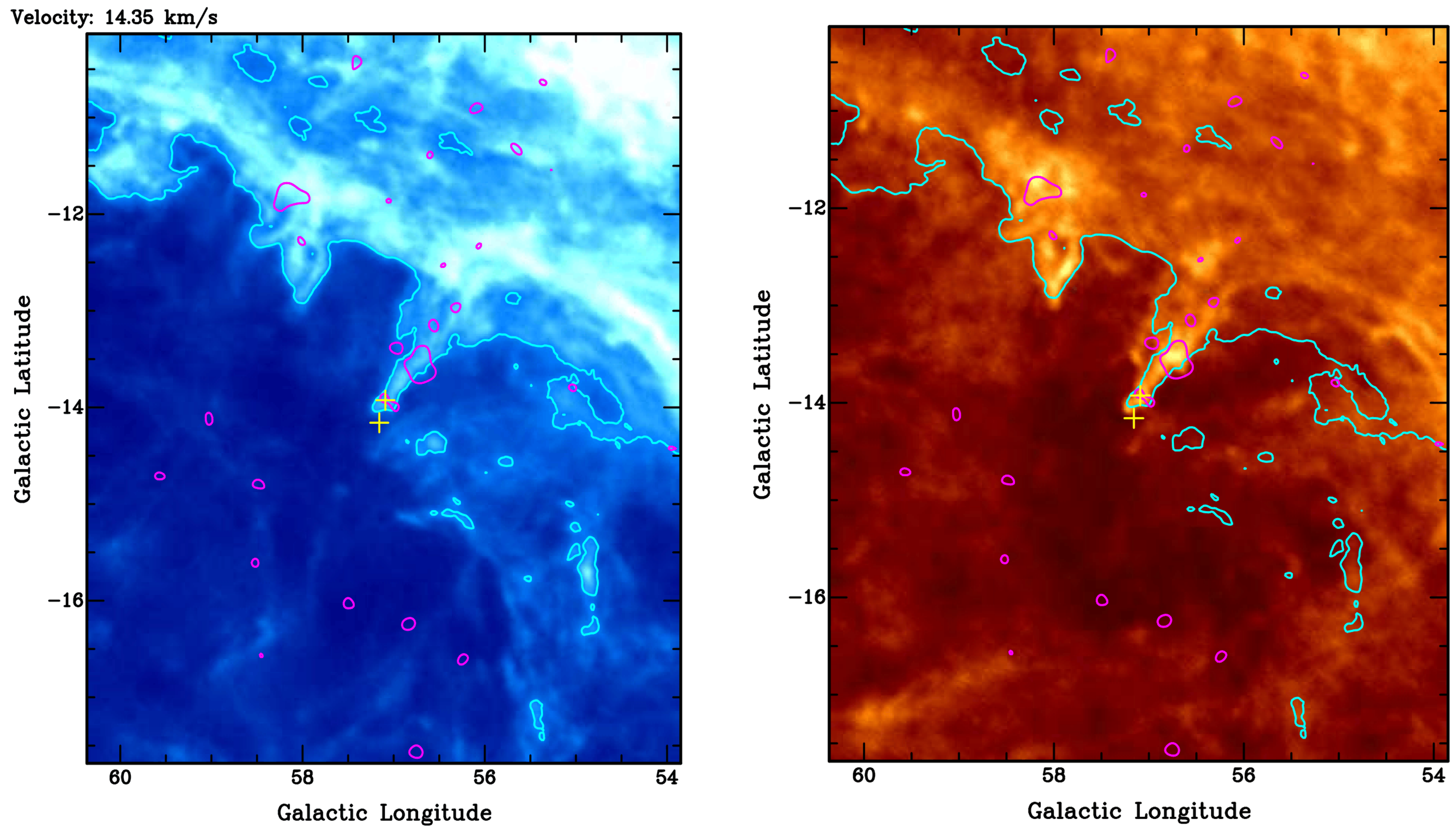
What We Do

Since we can find some clouds that are condensing, we are able to investigate their properties. We examine their cold gas content primarily with narrow 21-cm emission lines of neutral atomic hydrogen (H I) obtained with Arecibo GALFA-HI survey, a large data set with high sensitivity. These data are supplemented with 2.6-mm line emission from carbon monoxide molecules (CO) in CfA and Planck surveys, and thermal continuum radiation from dust grains mixed with the gas, detected by multiple infrared space telescope missions. Comparing these different emission spectra allows for the parameters we are investigating to be found more precisely.

Methods

To investigate these emission lines, we model the spectra. For this initial analysis, we subtract the OFF spectrum from the ON spectrum and fit the ON-OFF emission with a simple 1-component model, with parameters for the line-center optical depth τ_0, excitation temperature T_s, line center v_0 and line width Δv_{FWHM}. The cloud's ON-OFF brightness is modeled as $T_B(v) = T_s\,[1 - \exp(-\tau(v))]$. We assume a Gaussian optical depth profile $\tau(v) = \tau_0 * \exp(-0.5(v-v_0)^2/\sigma^2)$ where $\sigma = \Delta v_{FWHM}/(8\ \ln(2))^{1/2}$. The figure of merit for our least-squares fit is $\chi^2 = \Sigma\,[(T_{b,obs} - T_{b,mod})^2\ /\ T_{noise}^2]$ where $T_{noise} \sim 0.3$ K in empty H I channels. We use a brute-force fit that steps over a 4-D grid of parameter values, identifying the minimum χ^2, then zooming in on a grid half the size and repeating this process until χ^2 stops decreasing significantly.

Figure 1: Images of the Cloud

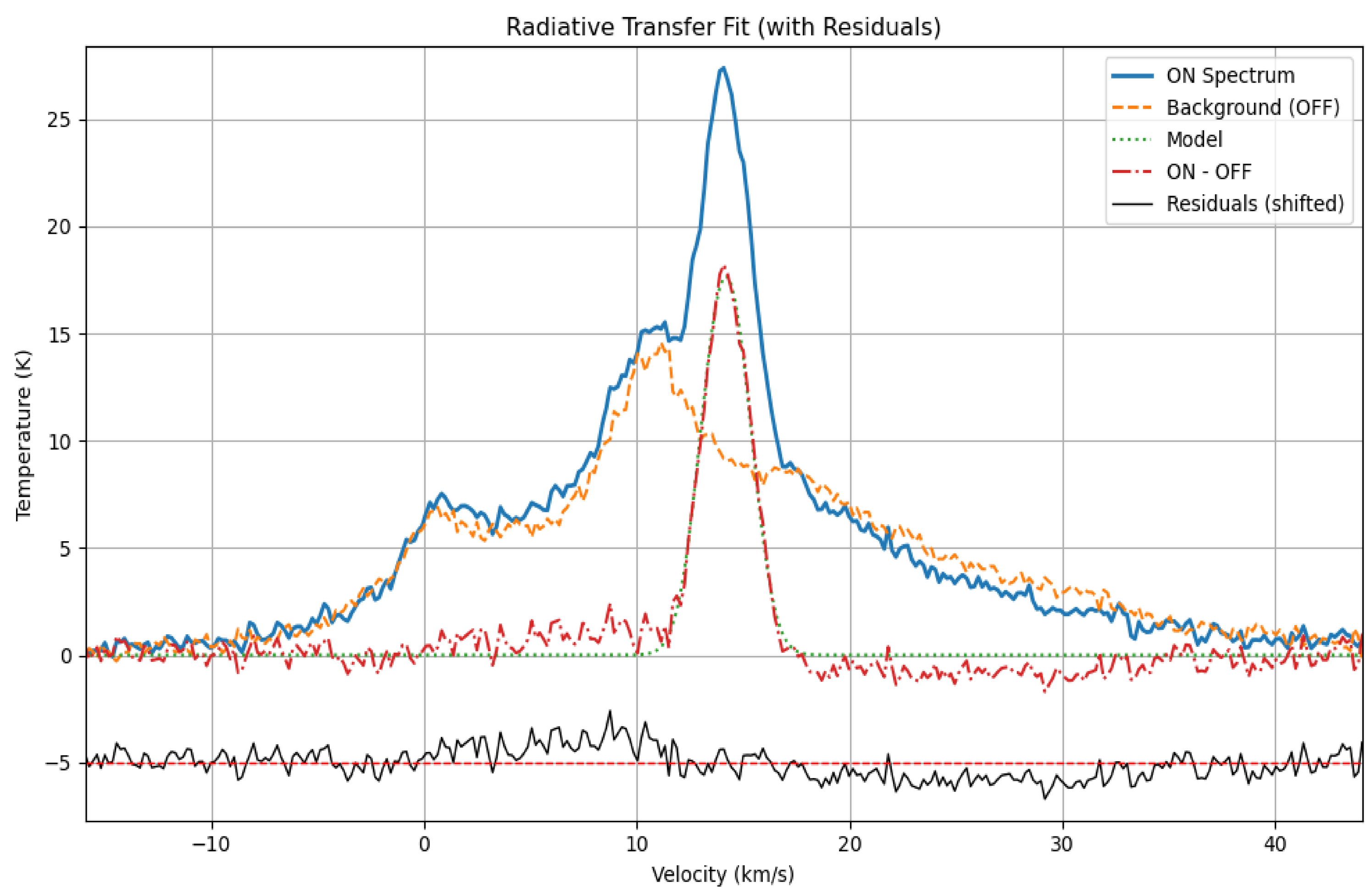


Left: Arecibo HI channel map of our target narrow-line emission cloud.
Right: Planck dust column map.
Crosses show points on and off the feature used to obtain HI spectra for analysis. Blue contours mark HI emission; purple contours show CO emission.

Results and Future Prospects

We fit the difference between the H I spectra at the ON and OFF positions in Figure 1 with the model described at the left. Results are shown in Figure 2. Our best fit results imply v_0 = 14.18 km/s, T_s = 46.07 K, τ_0 = 0.48, Δv_{FWHM} = 2.53 km/s, and an H I column density of 1.04 x 10^{20} cm^{-2}. The dust column at this position is consistent with a total gas column density of N_H >~ 1.1 x 10^{21} cm^{-2}, most of which is likely H_2. Since CO emission is not detected at this location or in many other parts of the cloud, most of this H_2 gas is CO-dark, perhaps because the CO is still forming. We are beginning to analyze our fit uncertainties in detail, after which we will adapt our method to fit spectra in each map pixel to explore property variations within a cloud. Subsequently, we plan to expand our analysis into other clouds for a population study.

Figure 2: HI spectra with model fit



The graph to the left shows an example of the modeling done on the cloud shown in Figure 1. The residuals line is from the difference between the target minus the background and the model. It is shifted down for clarity.

References

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