MAPPING THE THERMAL CONDENSATION OF DIFFUSE HI IN INTERMEDIATE VELOCITY GAS TOWARD URSA MAJOR

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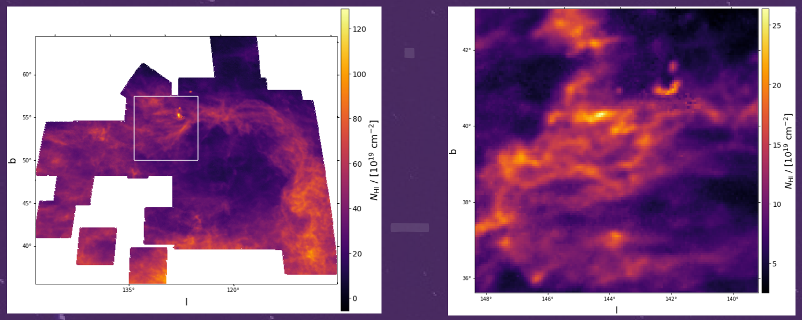
INTRODUCTION

WE MAPPED THE THERMAL CONDENSATION OF DIFFUSE HI IN INTERMEDIATE VELOCITY GAS (IVC) TOWARDS URSA MAJOR (UMA) TO UNDERSTAND THE UNDERLYING MECHANISMS OF THERMAL PHASE TRANSITIONS OF NEUTRAL HI, ALONG WITH THE TURBULENT PROPERTIES OF THE IVC GAS.

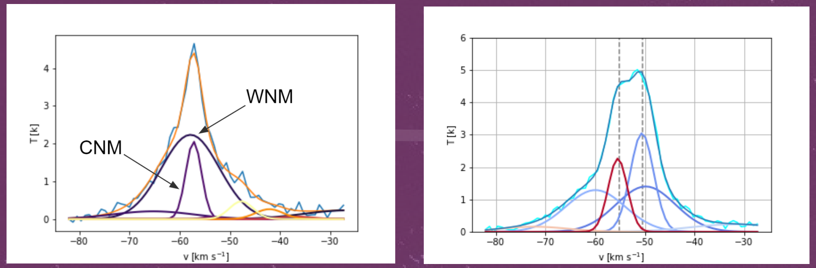


(LEFT) TOTAL INTEGRATED COLUMN DENSITY OF THE ENTIRE NORTH CELESTIAL POLE LOOP FROM THE GHIGLS 21CM LINE SURVEY (MARTIN ET AL. 2015) . THE WHITE BOX INDICATES THE REGION OF INTEREST FOR THIS PROJECT, WHICH IS DIRECTED AT URSA MAJOR (UMA). (RIGHT) TOTAL INTEGRATED COLUMN DENSITY UMA FIELD IN THE IVC VELOCITY RANGE OF -82 KM/S TO -27 KM/S.

THE IVC IS MADE UP OF TWO DISTINCT THERMAL PHASES: THE WARM NEUTRAL MEDIUM (WNM), WHICH IS WARMER AND MORE DIFFUSE, AND THE COLD NEUTRAL MEDIUM (CNM), WHICH IS DENSER AND COLDER. THIS IVC IS LOCATED ABOVE THE GALACTIC PLANE AND IS APPROXIMATELY 3 KPC ABOVE THE GALACTIC PLANE, AND THE PEAK OF THE AVERAGE IVC EMISSION IS LOCATED AROUND -57 KM/S RELATIVE TO THE LOCAL STANDARD OF REST.

ANALYSIS TOOL: ROHSA

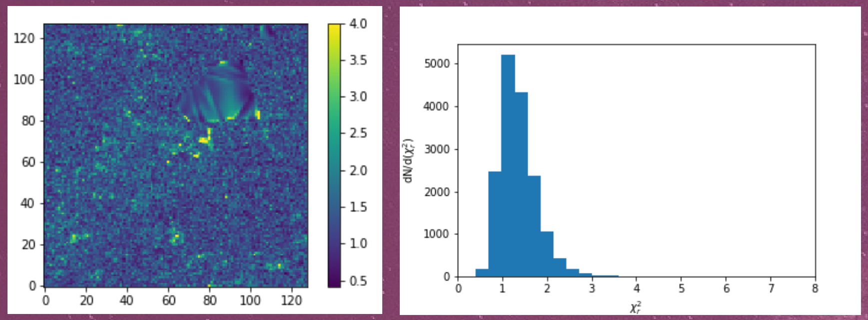
THE SPECTRUM OF EACH PIXEL ALONG THE LINE OF SIGHT WAS MODELLED USING ROHSA, WHICH IS A REGULARIZED OPTIMIZATION ALGORITHM THAT DECOMPOSES EMISSION CUBES INTO A SUM OF GAUSSIANS. THIS ALLOWS US TO FIT THE FEATURES OF THE SPECTRA AND RELATE THEM BACK TO THE TEMPERATURE OF THE GAS BEING MODELLED. THIS IS BECAUSE THE 21CM LINE IS BROADENED DUE TO A COMBINATION OF THERMAL AND TURBULENT MOTION IN THE PROCESS KNOWN AS DOPPLER BROADENING. THE END GOAL OF THESE DECOMPOSITIONS IS TO BE ABLE TO SEPARATE THE CNM AND WNM COMPONENTS IN ORDER TO EXAMINE EACH THERMAL PHASE INDEPENDENTLY .



ABOVE ARE TWO EXAMPLES OF SPECTRA DECOMPOSED BY ROHSA. AS YOU CAN SEE IN THE PLOT ON THE LEFT, THE COLD CNM GAS CORRESPONDS TO THE NARROW GAUSSIAN COMPONENT, WHEREAS THE WNM CORRESPONDS TO THE BROADER COMPONENT. THE PLOT ON THE RIGHT DEMONSTRATES THE NEED FOR MULTIPLE GAUSSIAN COMPONENTS IN ORDER TO PROPERLY MODEL THE EMISSION SPECTRA.

DATA MODELING

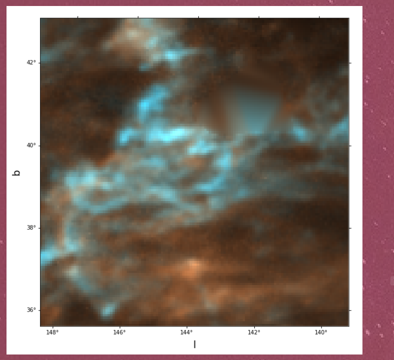
TO PROPERLY MODEL THE EMISSION DATA, WE NEEDED TO FINE TUNE VARIOUS PARAMETERS WITHIN ROHSA , NAMELY THE NUMBER OF GAUSSIANS AND THE HYPER PARAMETERS CONTROLLING THE SMOOTHNESS OF THE SOLUTION. WE STARTED WITH A 2 GAUSSIAN DECOMPOSITION, AND RAISED THE NUMBER OF GAUSSIANS UNTIL WE ACHIEVED A NOISE DOMINATED REDUCED CHI SQUARED MAP. SIX GAUSSIANS YIELDED A GOOD FIT FOR THE DATA IN OUR FIELD WITHOUT OVER FITTING ANY ELEMENTS OF THE SPECTRA.



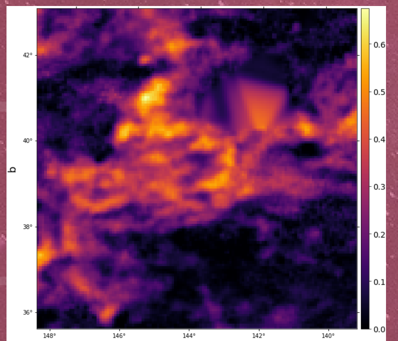
(LEFT) MAP OF REDUCED CHI SQUARE VALUES IN THE FIELD. THE MAP IS NOISE DOMINATED, AND DOES NOT HAVE ANY LARGE STRUCTURES WITHIN IT, INDICATING THAT WE HAVE MODELLED ALL FEATURES FROM THE EMISSION CUBE. (RIGHT) CORRESPONDING REDUCED CHI SQUARED DISTRIBUTION THAT PEAKS AT 1.2.

THERMAL PHASE SEPARATION

WE SEPARATED THE CNM AND WNM COMPONENTS OF THE IVC BASED ON THE WIDTH OF THE GAUSSIAN COMPONENTS USED TO MODEL THE DATA. THIS ALLOWED US TO DIRECTLY COMPUTE PROPERTIES OF EACH PHASE INDEPENDENTLY AND ANALYZE HOW THEY INTERACT WITH ONE ANOTHER.



TWO PHASES SUPERIMPOSED, WHERE THE CLUE REPRESENTS THE CNM, AND THE BROWN/ORANGE REPRESENTS THE WNM. THE CNM IS CLEARLY MORE CLUMPY, WITH FILAMENTARY STRUCTURE, WHEREAS THE SURROUNDING WNM ENVELOPE IS MORE DIFFUSE.

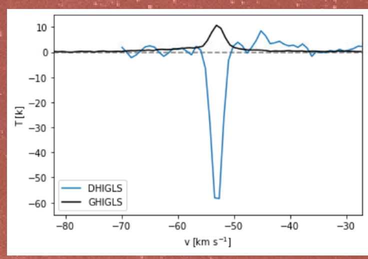


CNM MASS FRACTION. THERE ARE CLUMPS OF VERY HIGH CNM MASS FRACTION WITHIN THE LARGER WNM ENVELOPE.

CNM MASS FRACTION

THE CNM MASS FRACTION (PLOT ON THE RIGHT ABOVE) IS A POWERFUL TOOL THAT ALLOWS US TO EVALUATE THE RATIO OF CNM TO WNM IN THE FIELD. THERE ARE CLEARLY CLUMPS OF VERY HIGH CNM MASS FRACTION INSIDE THE ENVELOPE, INDICATING THAT WE HAVE SEEN THE WARM DIFFUSE WNM CONDENSE INTO THE COLD DENSE CNM.

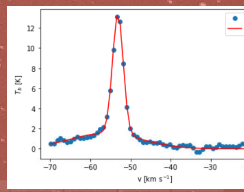
FURTHER EVIDENCE FOR COLD GAS



ANOTHER WAY THAT WE CAN VERIFY THE EXISTENCE OF COLD GAS IN THIS FIELD IS BY USING THE ABSORPTION DATA WE GET FROM THE DHIGLS 1' SURVEY (BLAGRAVE ET AL. 2016). SINCE WE HAVE A KNOWN RADIO GALAXY (J094912 + 66145) IN OUR FIELD, THIS HIGHER RESOLUTION SURVEY ALLOWS US TO MEASURE ABSORPTION AT THIS POINT. SINCE WE KNOW THAT ONLY COLD GAS ABSORBS LIGHT, WE CAN CONCLUDE THAT THERE IS COLD GAS PRESENT IN THIS IVC. THE ABSORPTION FROM THE DHIGLS SURVEY AND THE EMISSION FROM THE CORRESPONDING PIXEL IN THE GHIGLS SURVEY CAN BE SEEN IN THE PLOT ON THE LEFT.

THE EQUATION ON THE RIGHT ALLOWS US TO CALCULATE THE SPIN TEMPERATURE T_S FROM THE BRIGHTNESS TEMPERATURE OF THE CONTINUUM T_C, AND THE BRIGHTNESS TEMPERATURE AT THE PEAK OF ABSORPTION T_N WHICH ARE ALL KNOWN VALUES FROM BLAGRAVE ET AL. 2017. T_B WAS CALCULATED BY TAKING AN ANNULUS AROUND THE ABSORPTION SOURCE AND AVERAGING THE SPECTRA. NEXT WE FIT A SUM OF TWO GAUSSIANS TO THE SPECTRUM AS CAN BE SEEN ON THE RIGHT, AND THE RESULTING PEAK OF THE CNM COMPONENT WAS DETERMINED TO BE T_B = 12 K.

$$T_s = T_c/(1 - T_n/T_b)$$



T_s = 75 K

FUTURE RESEARCH

- USING THE FIT OF THE SPECTRUM IN THE PREVIOUS SECTION TO ESTIMATE THE TURBULENT LINE WIDTH AND MACH NUMBER FOR THAT LINE OF SIGHT

- COMPARING THE FINDINGS OF THE GHIGLS DECOMPOSITION TO THE DECOMPOSITION OF THE DHIGLS SURVEY TO EXAMINE HOW SPATIAL RESOLUTION CHANGES THE CNM MASS FRACTION

- STUDYING THE EFFECTS OF "BEAM SMEARING" BY COMPARING THE GHIGLS AND DHIGLS DECOMPOSITIONS

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