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AST425 MID-TERM PROGRESS REPORT: WHAT LOCAL MAGNETIC FIELDS CAN TEACH US ABOUT A POSSIBLE SUPERNOVA REMNANT (G182.5-4.0)

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1. RESEARCH GOAL

This proposed study focuses on classifying a currently unknown object which we refer to as G182.5-4.0 as seen in Fig. 1a. In this figure, we display G182.5-4.0 through the Stokes I parameter, which in this case, displays this object's shape very well (compared to the other Stokes parameters). It is believed that this object possibly falls into one of two categories; an old single supernova remnant (SNR) or filaments in the interstellar medium produced by multiple SNRs that have retained their shape due to an interstellar magnetic field (West et al., 2020). Although these possibilities exist, G182.5-4.0 may be something entirely different. We say that the object is a possible SNR because of its highly unusual shape that does not comply with any current and commonly known geometries of SNRs. We believe that the unusual filamentary shape is connected and can be explained by the properties of the interstellar magnetic field that permeates the object, and the surrounding neutral hydrogen (HI) fibers. HI fibers are known to align with interstellar magnetic fields in the cold neutral medium where HI is found (Clark et al., 2014). We propose that if a connection can be made between the magnetic field orientation in multiple mediums (i.e. cold neutral - HI, relativistic - total intensity as displayed by Fig. 1a, and polarized) this can then provide strong evidence to classify G182.5-4.0.

The goal of this project is to do this in two ways; using the Rolling Hough Transform (RHT) and using Rotation Measure (RM)-Synthesis. The RHT provides connections between G182.5-4.0 and HI filament/magnetic field orientations in the neutral and relativistic mediums, while RM-Synthesis provides connections between G182.5-4.0 and the magnetic field orientations in the relativistic and polarized mediums. If there are connections between the magnetic field orientations between these mediums, then we will be able to determine if the magnetic field has played an important role in shaping this object. Through this project, we can learn more about the role that magnetic fields have on large scale structures such as those within galaxies. We can also apply the procedures which we employ for this project to study the magnetic fields of galaxies as a whole and the spaces in between, and determine what kind of a role they play on these structures as well.

2. UNDERSTANDING & MANIPULATING DATA

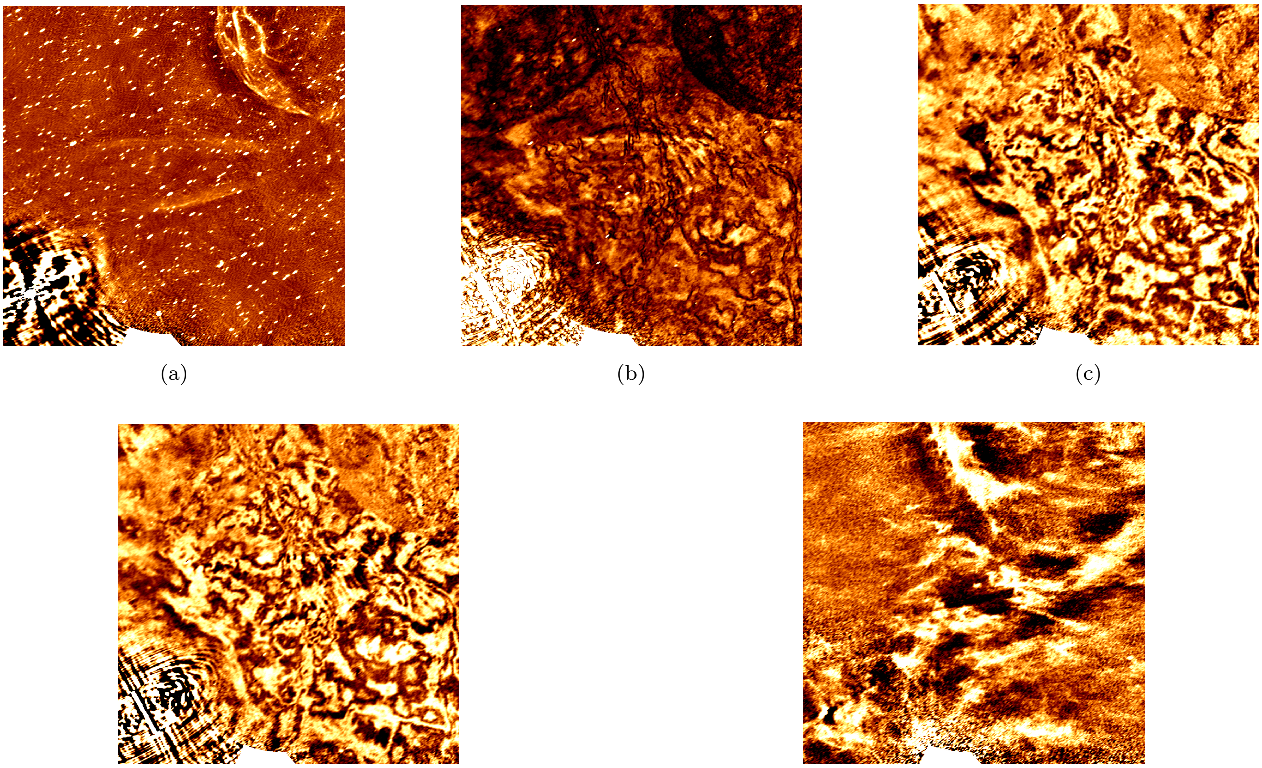
The first set of data that we used for this project was from the Dominion Radio Astrophysical Observatory - Synthesis Telescope (DRAO-ST), collected at a frequency of 1.4 GHz. Time was spent understanding the various data sets that were available. These include the Stokes I (Total Intensity), PI (Polarized Intensity), Q, and U (Polarized Intensity Components) parameters (Fig. 1a-1d), as well as a 3-D HI cube data set (Fig. 1e). The 3-D HI data was sliced into its constituent 2-D data sets as the RHT can only be employed for 2-D data structures. The last step in this process was to convert units of pixel to angular units.

3. DETERMINING PARAMETERS FOR THE RHT

The RHT requires two parameters, a window length (WLEN) and a smoothing radius (SMR). Briefly, these parameters control the width and length of the filamentary structures which are quantified by the RHT. For instance, if low values of WLEN and SMR are given, the RHT will quantify filaments that are thinner and shorter in length. The chosen parameters must display the filamentary structure we are interested in clearly. This was simply done by varying a range of these parameters in the RHT for a single 2-D HI slice and determining which of these parameters produce the best results. An example of this is shown in Fig. 2 where the RHT parameters were varied for a single HI velocity channel slice, each producing unique results.

4. RUNNING THE RHT

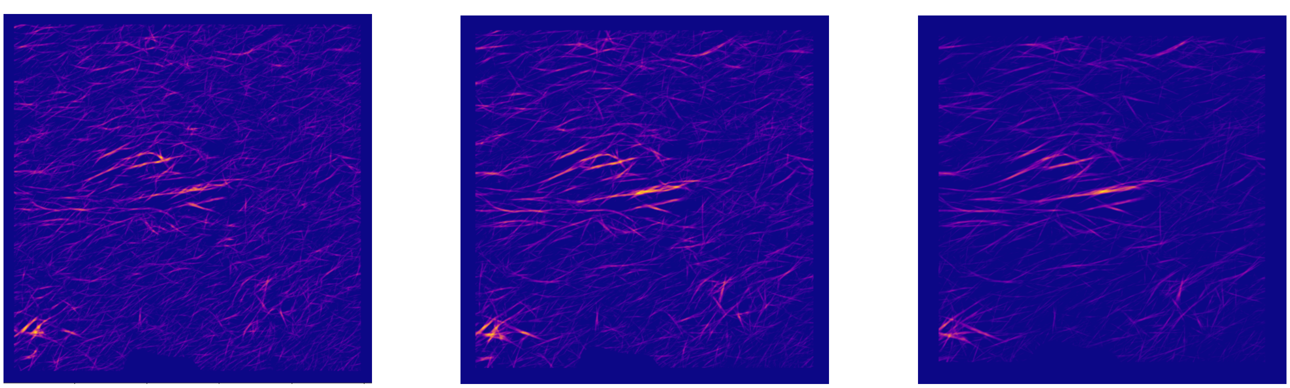
Once the parameters for the RHT were determined, the RHT was applied to each individual 2-D HI slices as well as to Stokes I. An example is shown in Fig. 3 where a result of applying the RHT (right) to a certain HI velocity channel slice (left) was determined, and hence we are able to view the filamentary structure for this particular HI velocity channel. It was determined that certain HI velocities provide well matching orientations



(a) (b) (c)

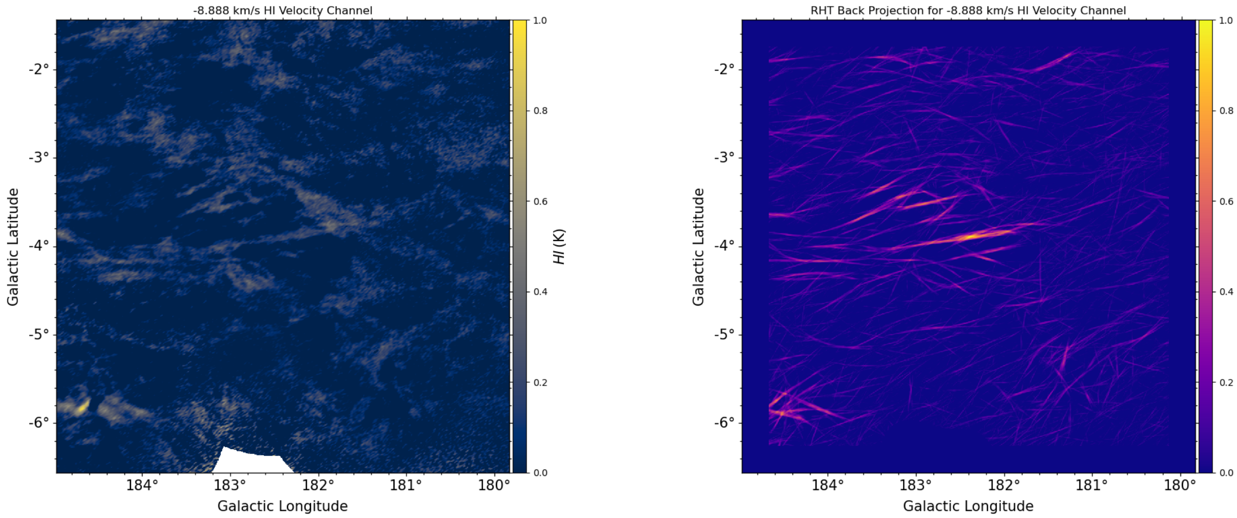
(d) (e)

Figure 1. The Stokes parameters captured by DRAO-ST. (a) & (b) represent the I and PI Stokes parameters respectfully. (c) & (d) represent the Q and U Stokes parameters respectfully. (e) represents one velocity channel slice of the HI data cube. In general, the HI data cube contains multiple 2-D data sets. All of the images (a)-(e) were captured at a frequency of 1.4 GHz and a resolution of 1'.



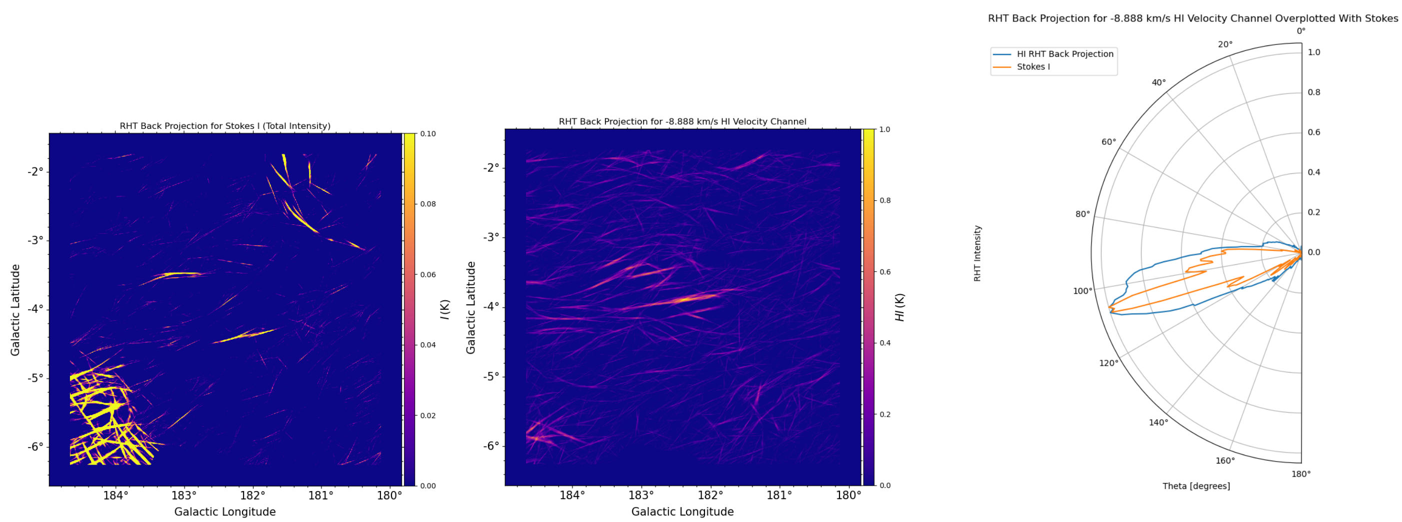
(a) (b) (c)

Figure 2. Varying the parameters for the RHT for a single HI velocity channel. The RHT parameters used here are (a) SMR=8 and WLEN=51, (b) SMR=10 and WLEN=71, (c) SMR=11. and WLEN=101.



(a) (b)

Figure 3. The results of the RHT (b) being employed on the -8.888 km/s HI velocity channel (a).



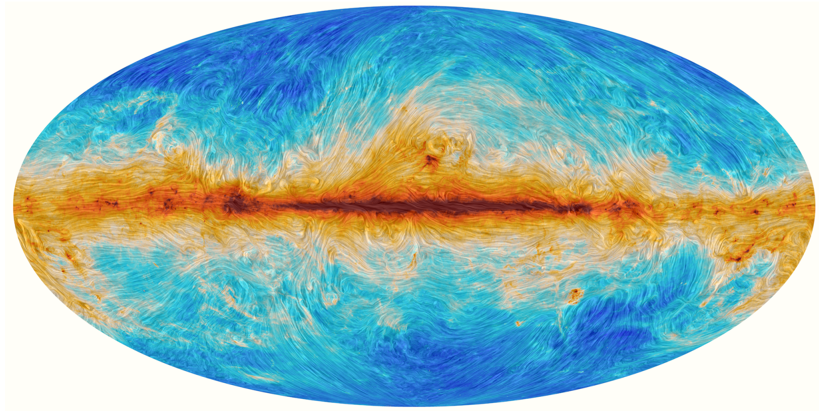
(a) (b) (c)

Figure 4. Generated polar plot (c) for the Stokes I RHT back projection (a) and the -8.888 km/s HI velocity channel (b)

to G182.5-4.0. This suggests that the orientation of the magnetic field in question plays a role in the unusual shape of the object.

5. GENERATING POLAR PLOTS

With the RHT being employed, polar plots were generated for each individual 2-D HI velocity slices as well for Stokes I. Polar plots are able to display orientations of data. In Fig. 4, we can see such a plot that was generated for a particular RHT result (Fig. 4b) that displays the integrated (average) orientations of the detected filaments (Fig. 4c). Also plotted in this image is the integrated orientation of Stokes I from Fig. 1a. In this case, the polar plot displays the integrated orientation of the filamentary structure which was generated through the RHT. One orientation refers to G182.5-4.0 as seen in Stokes I while the other refers to a specific HI velocity slice. This way, we can clearly see that for this particular HI velocity channel there is a clear overlap in orientations.



(a)

Figure 5. The structure of the Milky Way's magnetic field along with a coloured magtitude scale. Credit: ESA and the Planck Collaboration

6. FUTURE RESEARCH PLAN

For the first part of this project, the RHT was employed which quantifies and displays prominent filamentary structures from some starting data set. The results of the RHT are displayed in this report. For the second part of this project, we plan to employ an algorithm known as RM-Synthesis. To do this, we will study data from the G-ALFA Continuum Transit Survey – Arecibo Telescope (GALFACTS) at a frequency range of 1.37 GHz – 1.52 GHz of the same object. The major difference between the DRAO-ST data and the GALFACTS data is that the GALFACTS data was collected using a range of frequencies while the DRAO-ST data was collected at a single frequency. Another important differences is that the GALFACTS data was collected using a single dish telescope while the DRAO-ST data was collected using an array of telescopes. This is very important because in order to perform RM-Synthesis, data from a range of frequencies is required. The ultimate goal is to generate plots such as the one shown in Fig. 5. In this figure, we can visualize the magnetic field of the Milky Way galaxies through over plotted magnetic field orientations. The goal is to generate a plot that contains G182.5-4.0 and the visual overlay of the magnetic field orientation in the polarized medium. Once this is done, we will have multiple separate results for the magnetic field orientation. We will then be able to compare this result with the previous RHT result and draw conclusions whether the magnetic field ultimately has played a role in shaping G182.5-4.0, which is the ultimate goal of this research project.

REFERENCES

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