# Investigating the Structure of the Cygnus Loop using Radio Wavelength Observations


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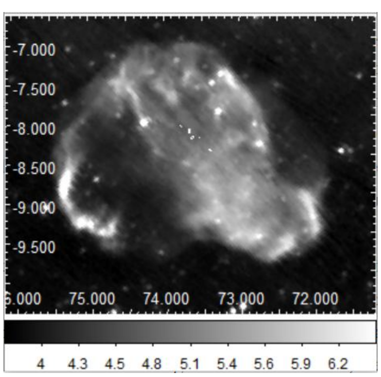
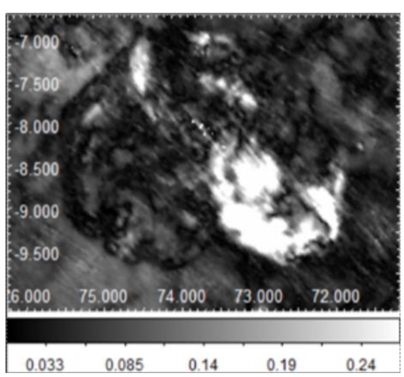
This summer, my research project focused on studying a supernova remnant called the Cygnus Loop in greater detail using radio wavelength observations. Our interest in this object is motivated by its unusual structure that can be seen in Figure 1 with two regions: a circular explosion in the north, as well as what appears to be an outburst to the south. The two hypotheses for this are that it is the result of a blowout region into a low-density area or that it is two supernova remnants. In these structures, the high energy cosmic rays or relativistic electrons embedded in the magnetic field will emit polarized synchrotron radiation. The brightness of the synchrotron emission varies according to the frequency at which we measure it, dominating at radio wavelengths. Thus, the datasets being used are from the Galactic Arecibo L-band Feed Array Continuum Transit Survey (GALFACTS) with a frequency range of 1.37 - 1.52GHz, the Dominion Radio Astrophysical Observatory (DRAO) at 1420MHz and the Low Frequency Array (LOFAR) at 143.65MHz. To provide indirect clues about the magnetic field structure and its properties in different locations, we look at Rotation Measure and the spectral index.



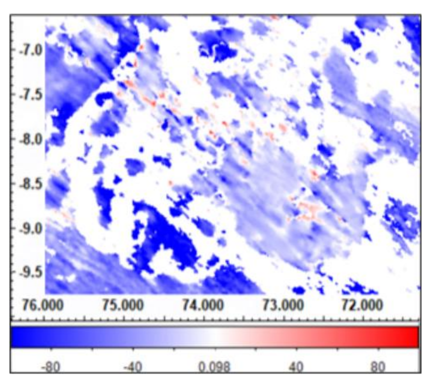




Figure 1 (Left): Total Intensity of GALFACTS data, units of Kelvin. Galactic coordinate axes.
Figure 2 (Middle): Polarized Intensity of GALFACTS data, units of Kelvin.
Figure 3 (Right): Rotation Measure map generated from GALFACTS data, units of rad/m$^2$, with low polarized intensity areas masked to reduce noise and artifacts.

Comparing Figures 1 & 2, there is a clear distinction in the distribution of the polarized emission between the north and south regions, which could indicate a significant difference in their magnetic field configurations and mechanisms. This polarized emission is rotated by the Faraday Effect as it passes through the medium as a function of frequency according to the Rotation Measure (RM), which is related to the electron density and line-of-sight component of the magnetic field. Figure 3 was made using RM Synthesis with the Python package RM-Tools. We compare this pattern to features seen in other data. In addition, we can now discern a feature extending out from the southern region that has not been seen in previous observations.
We also perform RM-synthesis on low frequency data from the LOFAR telescope. We find a region of polarized emission near the southern region. This result is quite exciting because of how unusual it is to detect coherent polarization from synchrotron radiation at such a low frequency. We'd like to continue identifying and characterizing these features, as they both support the idea that the Cygnus Loop has a different structure than previously thought.

Next, our goal was to compare spectral indices from different regions by using Temperature-Temperature (or TT) plots between LOFAR and DRAO data. To do this, we did point source removal on the LOFAR data using the Python package AegeanTools and convolved the LOFAR data to match DRAO's resolution, adjusting the units and scale using Montage to reproject it. Significant progress was made on this task, but we were not able to complete a set of corrected TT-plots due to challenges with the data. We hope to continue this work and compare the spectral index values to those in the literature.

In conclusion, our goal for this project was to investigate and provide further evidence supporting either possibility by studying how the polarization within the Cygnus Loop changes over a range of frequencies. While definite results remain uncertain, we have made good progress exploring the polarization, morphology and spectral properties and we will be following up on these promising developments in the future.