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A Comparison of Magnetic Field Tracers in the Warm Ionized and Cold Neutral Phases of the ISM

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Motivation

The Galactic magnetic field (GMF) plays a crucial role in many astrophysical processes. However, magnetic field tracers often probe different phases of the interstellar medium (ISM) while providing only one- or two-dimensional projections of the full magnetic field vector. As a result, very little is understood about how the GMF threads the multi-phase ISM.

This Work

We searched for evidence of a common GMF geometry shared between the **warm ionized (WIM)** and **cold neutral medium (CNM**) by comparing polarization gradients and HI emission using 1.4 GHz Arecibo data from the Galactic Arecibo L-Band Feed Array Continuum Survey (GALFACTS) and Galactic ALFA HI (GALFA-HI) survey.

Magnetized WIM

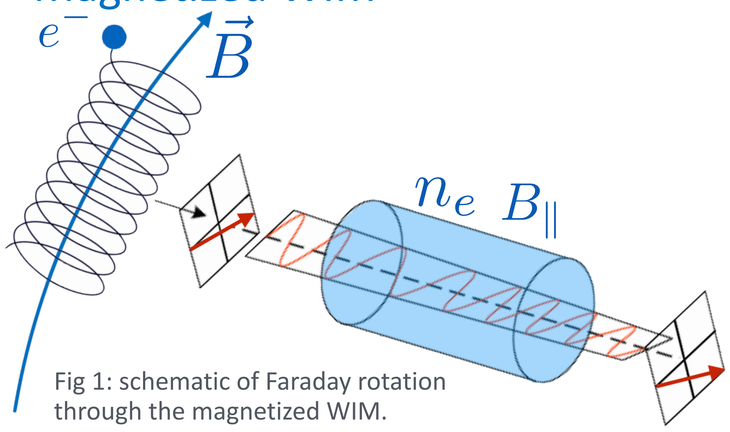


Fig 1: schematic of Faraday rotation through the magnetized WIM.

As polarized synchrotron radiation passes through the magnetized WIM, the thermal electron density n_e and line-of-sight magnetic field strength $B_\parallel$ rotate the polarization angle quantified by the **rotation measure** (RM):

$$\mathrm{RM} = -0.81 \int_{\text{source}}^{\text{observer}} n_e B_\parallel \mathrm{d}\ell \, [\mathrm{rad\,m^{-2}}].$$

The **polarization gradient** $|\nabla \mathbf{P}|$ is the spatial gradient of the polarization vector and highlights discontinuities in the RM.

Magnetized CNM

Linear HI structures in narrow velocity channels, sometimes called **HI fibers**, are density structures that trace the CNM. The orientation of these structures are spatially correlated with the plane-of-sky magnetic field direction using both starlight and dust polarization data.

Comparison of Polarization Gradient and Narrow HI Structures

We identified a <u>single region</u> in the high-latitude sky containing filaments in $|\nabla \mathbf{P}|$ that are aligned with narrow HI structures.

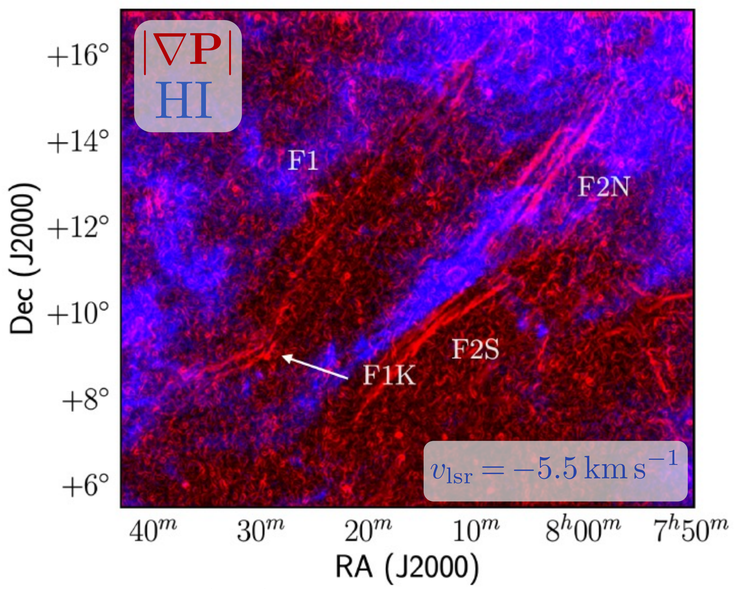


Fig 2: GALFACTS $|\nabla \mathbf{P}|$ (red) and GALFA-HI velocity channel map at -5.5 km/s (blue).

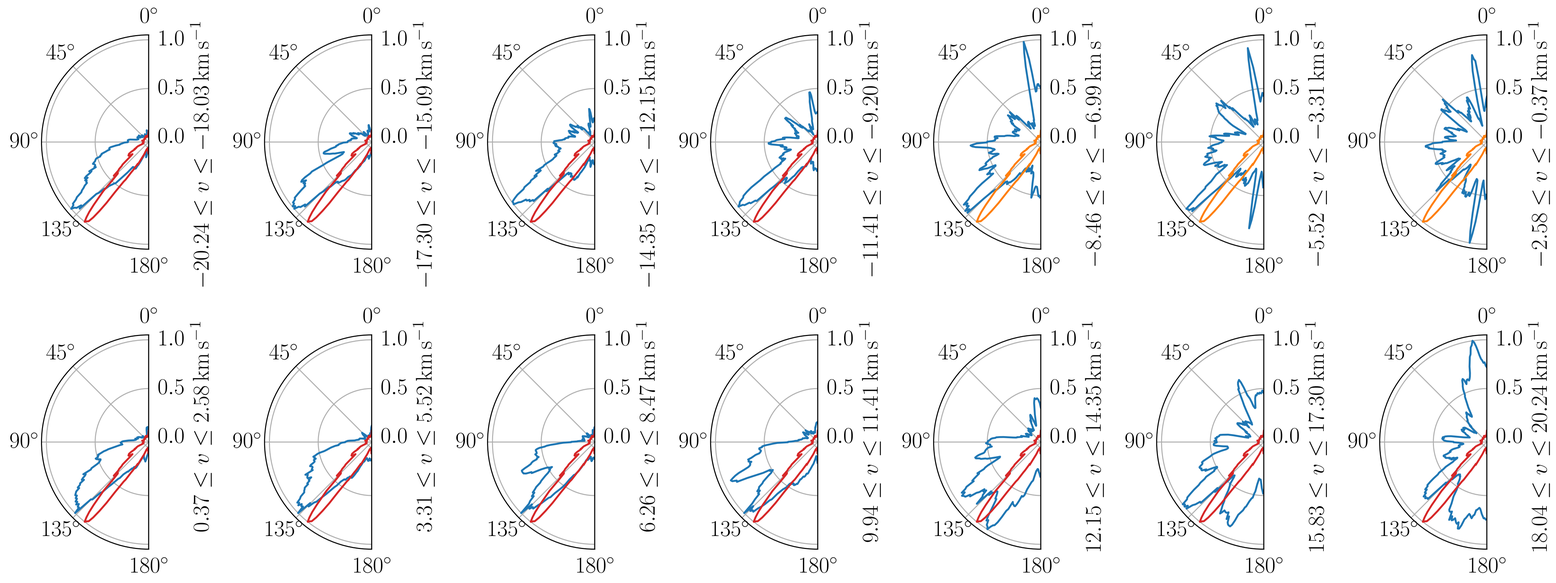


Fig 3: Distributions of structures in GALFACTS polarization gradient (red) and GALFA-HI velocity channel maps from -20 km/s (top left) to +20 km/s (bottom right). The histograms have been rotated such that an angle of 0° corresponds to vertical in the image plane.

Magnetic Field Alignment Between the WIM and CNM

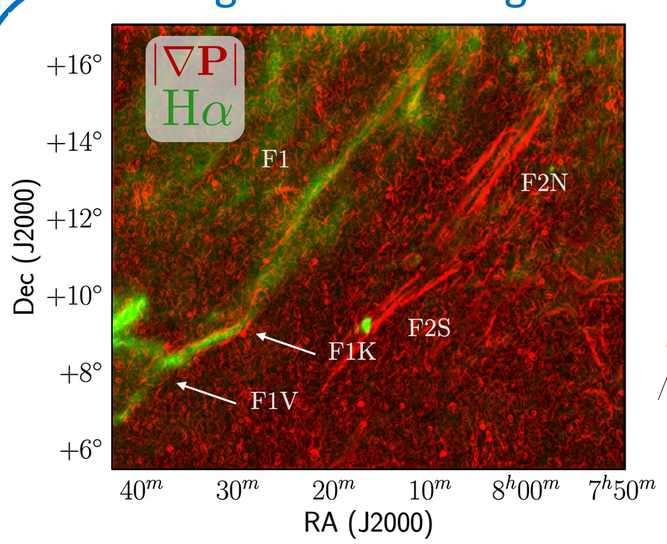
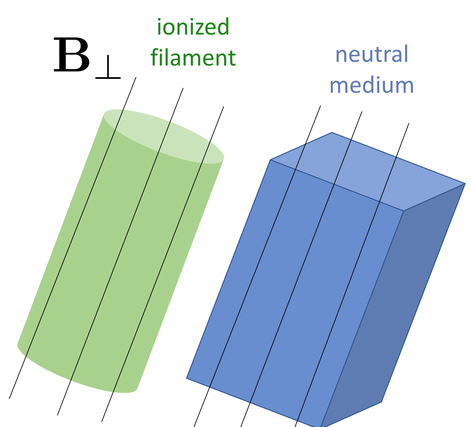


Fig 4: GALFACTS $|\nabla \mathbf{P}|$ (red) and VTSS Hα emission (green).



$B_\parallel = 6 \pm 4 \mu\mathrm{G}$

$\beta = 0.4^{+0.5}_{-0.4}$

We find a small-scale Hα filament that is spatially correlated with a $|\nabla \mathbf{P}|$ filament. This structure is an ionized filament with a magnetically-dominated pressure and a magnetic field that likely runs parallel to the filament. This supports our interpretation of a GMF alignment between the WIM and CNM.

Open Questions

Our work raises the question of why alignments between multi-phase magnetic field tracers are not more widespread. While we find no strong evidence for an associated HI shell, this region may reflect an unusual circumstance within the magnetized ISM, such as a shock-induced phase transition.

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