Cold H I Filamentary Structure and Magnetic Fields near the Galactic Plane

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Overview

The cold neutral atomic gas from which molecular clouds form has abundant filamentary structure in H I 21cm line maps. This structure is more apparent at higher angular resolution and often displays a distinct affinity for magnetic field structure traced by interstellar optical starlight polarization. Clark et al. (2014; CPP) recently developed a method of automatically identifying and measuring H I "fibers" and used this to quantify H I - B-field alignments in high-latitude fields from Arecibo and Parkes and an ATCA Galactic-center field. Using a similar approach, we have mapped H I fibers in the DRAO Canadian Galactic Plane Survey (CGPS) and Arecibo Inner-Galaxy ALFA survey (I-GALFA). We find conspicuous H I alignments with both optical polarization and first-look Planck sub-mm polarimetry. These occur predominantly in local-velocity gas with minimal sight line confusion and track the global B-field geometric variation vs. Galactic longitude. Where measurable, typical aligned H I structures have narrow line widths, indicating that cold atomic gas, despite its low ionization fraction, either influences or is influenced by the magnetic field.

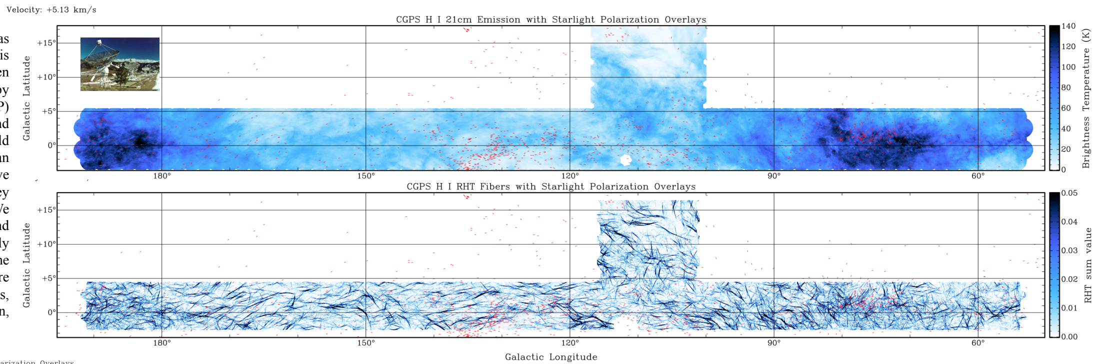

Figure 1. CGPS H I data (*top panel*; Taylor et al. 2003), which have a variable resolution of ~ 1.0' - 3.3', were smoothed to a 3.3' uniform circular beam, and then large-scale structure was removed by subtracting a second version of the data smoothed to 10' resolution. Filamentary emission structures on scales as long as 100' were then identified using the Rolling Hough Transform (RHT) described by CPP, essentially by counting the numbers of pixels above some threshold in each direction from each pixel in the map, and recording counts above a second threshold. This generates maps of H I "fibers" (*second panel*), along with their position angles and other statistics, for each H I velocity channel. At local velocities, the fibers are prominent throughout the CGPS, with a conspicuous degree of organization and frequent agreement with starlight polarization angles (red annotations; Heiles 2000). The coherence of the structures also appears to track the geometry of the Galactic magnetic field, being end-on in the Cygnus tangent region and side-on elsewhere, although confusion is added by overlapping structures in areas of distance ambiguity, like the anticenter and low-latitude inner Galaxy.

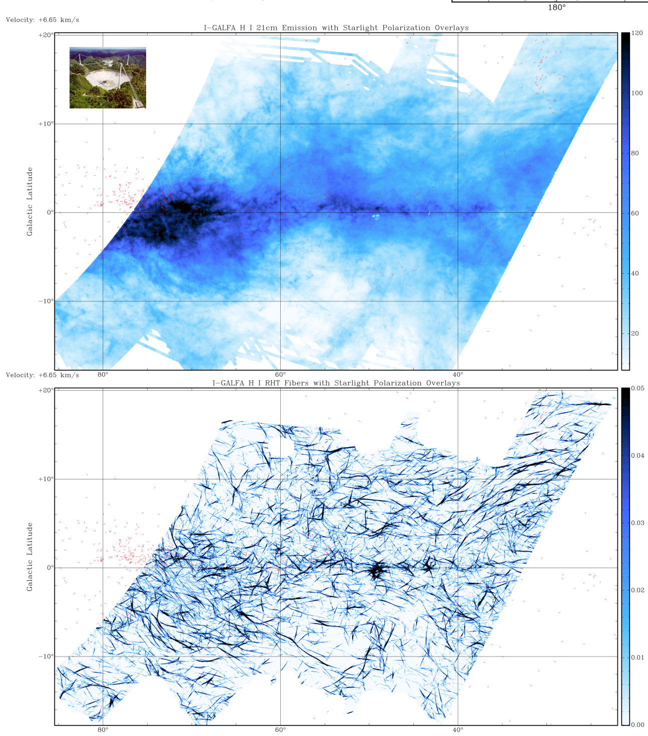

Figure 2. I-GALFA H I data (*top left*; Koo et al. 2010; Gibson et al. 2012), which have 4' resolution, were also spatially filtered at the 10' scale and processed with the same RHT algorithm. These data sample a wide variety of structure on and off the Galactic plane, especially at local velocities (*bottom left*). Here, as in the CGPS, many long filaments mix chaotically in the Cygnus tangent area, while many others lie nearly parallel to the Galactic plane. Especially intriguing is an organized collection of fibers in the northeast corner of I-GALFA, which aligns with optical polarization angles and appears to be part of a large H I plume extending diagonally away from the plane and the Aquila Rift molecular complex (e.g., see Dame et al. 1987). We have only just begun to explore the rich I-GALFA data set in a few of its thousands of spectral channels.

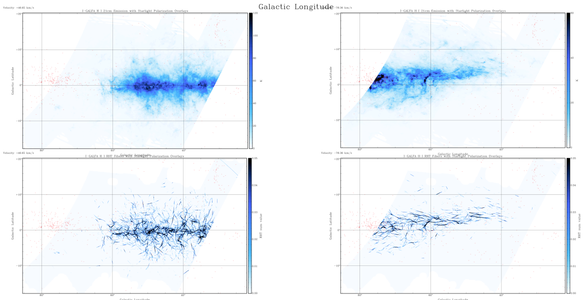

Figure 3. Two non-local I-GALFA velocity channels are shown below: an inner-Galaxy velocity (*far left*, +48 km/s) and a far-outer-Galaxy velocity (*near left*, -78 km/s). The RHT algorithm easily detects the significant vertical structure in the first case, which may trace H I "worms" between chimneys caused by massive star formation, and the predominantly horizontal structure in the second case, indicating relatively little star-forming activity in the outer reaches of the Galactic disk (Park et al. 2011).

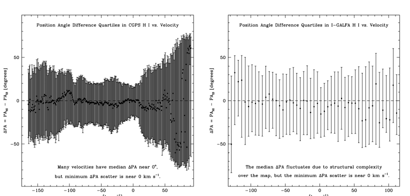

Figure 4. How organized are the H I fibers? And how well do their position angles match starlight polarization? Inspired by CPP's analysis, we find quartiles of the set of position angle differences between the two within 30' of each optical polarization sight line and plot the 1st quartile, median, and 3rd quartile vs. radial velocity. Despite being averaged over a very large Galactic longitude range, the CGPS statistics (*above left*) show a fair amount of agreement at many velocities, but a clearly reduced scatter of angles at local velocities, consistent with visual inspection and distance selection biases for optical starlight polarimetry. The I-GALFA statistics (*above right*) hint at a similar local-velocity match, but this result may be buried under the "noise" of many different structures visible over the area of that survey. Investigation of this issue is ongoing.

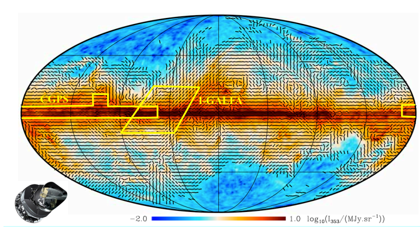

Figure 5. *Planck* all-sky dust thermal emission map, with interstellar magnetic field orientation inferred from dust polarimetry (Planck Consortium 2014). The position angles are generally consistent with the H I fibers found in the CGPS and I-GALFA survey areas. A detailed comparison is planned when the Planck data become public.

Acknowledgements

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