Galactic Magnetic Fields

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A review of Galactic magnetic fields is presented, with attention for the use of wide-band spectro-polarimetry as a tool to investigate the magneto-ionic interstellar medium.

Magnetic fields are arguably a major wild card in the astrophysics of galaxies. They influence a variety of phases of the interstellar medium, from the collapse of individual cloud cores, to the formation of giant molecular clouds, to the retention of the products of stellar nucleosynthesis, cosmic rays and hot plasma in the disk. In return, stellar feedback shapes the magnetic field as supernovae and stellar winds inject matter, energy and momentum into the interstellar medium. Interaction between the magnetic field and the interstellar medium spans at least 4 orders of magnitude in scale, from parsec scales up to the large-scale magnetic field in the disks of spiral galaxies. Magnetic fields are important on sub-parsec scales as is evident from magnetic activity of stars, stellar remnants and protostellar objects, and in situ measurements in the solar system.

Despite its significance for the evolution of the interstellar medium, neutral and ionized, measurements of the magnetic field are difficult and can leave significant room for interpretation. In the Milky Way, magnetic field structure can be studied by Zeeman splitting, dust grain alignment giving rise to polarization-dependent emission or interstellar extinction, polarization of synchrotron emission, and Faraday rotation of the plane of polarization of synchrotron emission as it travels through a magnetized plasma. These different observational techniques each reveal a piece of a larger puzzle. Some are sensitive to the component of the magnetic field along the line of sight, some trace the magnetic field component perpendicular to the line of sight. Depending on the situation, they may reveal magnetic field direction or strength averaged over the line of sight, or in a particular object. Rarely can they be applied to mutually re-inforce each other, because of the different physical conditions that give rise to these effects, and practical limitations of probing certain angular scales or certain regions of the Galaxy. Looking away from the Galactic plane where the line of sight through the Galaxy is short, provides the best opportunity to combine different tracers of the magnetic field. When applied to other galaxies, polarimetry of cm wavelength radio waves is the most versatile probe of magnetic fields.

The ongoing development of hardware and software allowing wide-band polarimetric radio astronomical observations brings new opportunities and new challenges to this field. Faraday synthesis using a wide range of frequencies allows us to investigate the turbulent and regular magnetic field along the line of sight. Faraday rotation is as much a tracer of the magnetic field as it is a tracer for subtle differences in plasma density that cannot be observed otherwise. The spatial structure in images made by Faraday synthesis, and its association with observable tracers of the interstellar medium, or other tracers of the magnetic field, can assist in the interpretation of these rich data sets. New algorithms are being developed for the interpretation of wide-band spectro-polarimetric data. Their application to current and future surveys like GMIMS, GALFACTS, and POSSUM will cast a new light on the role of the magneto-ionic medium in relation to star formation and stellar feedback in galaxies. The Square Kilometre Array will extend this to galaxies at a wide range of redshifts and allow us to observe magnetic fields in the context of galaxy evolution.

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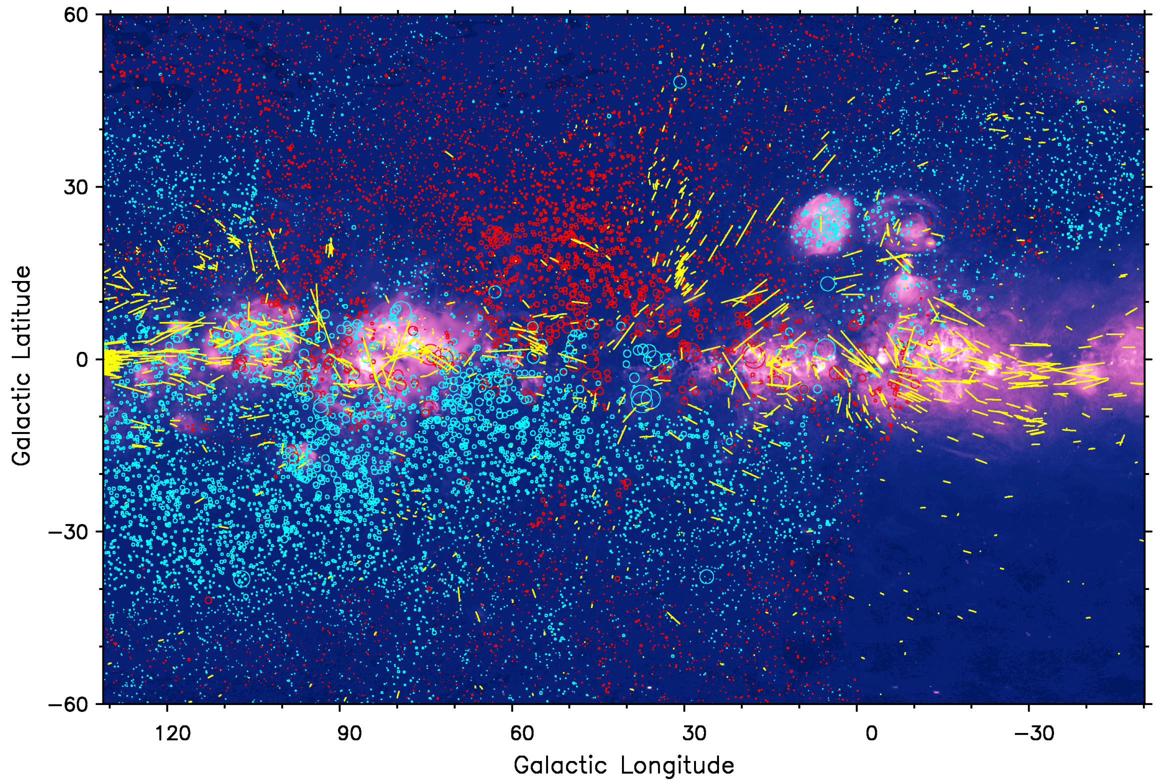

Figure 1. Section of the Galaxy showing in the background Hα intensity from [1], with rotation measures from [2] represented by red (positive) and blue (negative) circles with diameter that scales with |RM|, and polarization of light from stars within 900 pc from the Sun from [3] as yellow polarization vectors. The extended regions of positive and negative RM have no counterpart in Hα intensity, while the HII region around the star ζ Oph also shows significant Faraday rotation. It is tempting to associate patterns in the polarization of star light with patterns in RM, but it should be kept in mind that the stellar polarization data provides only sparse sampling of the high-latitude field. The arc-like structure of positive RM in the upper left of the figure coincides with a section of an intermediate-velocity HI structure called the IV Arch.

References

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