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Diagnose interstellar plasma with radio polarization observations

Xiaohui Sun
[1] Department of Astronomy, Yunnan University
e-mail (speaker): xhsun@ynu.edu.cn

The interstellar medium (ISM) in the Milky Way Galaxy is a tenuous plasma, which is in multi-phase, magnetized, and turbulent. The important astrophysical processes such as star formation occur in ISM with both magnetic fields and turbulence playing key roles. ISM also determines the observational appearance of the Galaxy and influences its evolution. It is therefore essential to understand ISM.

Radio polarization observations provide a unique probe of the properties of the interstellar plasma. The linearly polarized emission originates from the synchrotron radiation caused by relativistic electrons spiraling around the magnetic fields. A linearly polarized wave propagating through magnetoionic medium experiences Faraday rotation. The rotation of the polarization angle is proportional to the wavelength squared and the coefficient for this linear relation is called rotation measure (RM) which depends on the line-of-sight magnetic field and thermal electron density. Because of fluctuation of the electron density and magnetic field in the ISM, polarized emission from different positions along the line of sight or within the telescope beams has its polarization angles varying differently, resulting in complex morphologies in the polarization images of the Galaxy (Fig. 1).

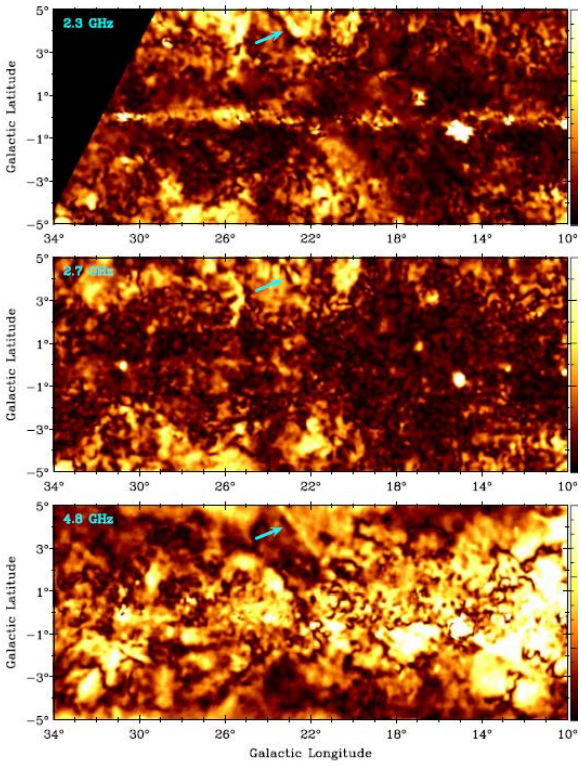

Fig. 1. Polarized intensity at 2.3 GHz, 2.7 GH, and 4.8 GHz [1].

The diffuse polarized emission from the Galaxy carries out information on the interstellar plasma. Several all-sky polarization surveys have been completed recently producing images in wide frequency ranges divided into many fine channels. This will allow us to recover the detailed structures of the ISM using algorithms such as RM synthesis and QU-fitting[5]. The polarized intensity at 230 MHz by applying RM synthesis to the data from the Murchison Widefield Array is shown in Fig.2.

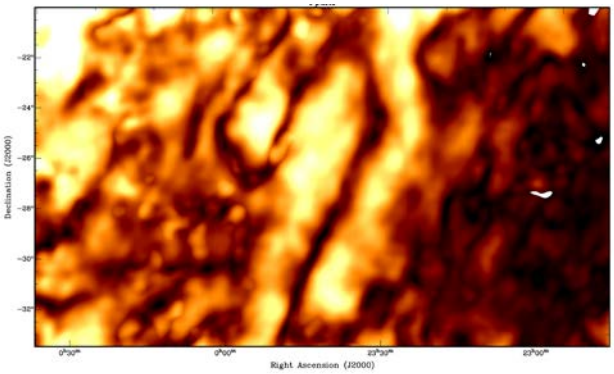

Fig. 2. Polarized intensity from at 230 MHz from the Murchison Widefield Array (Sun et al. in prep.).

RMs of extragalactic radio sources are mainly contributed by the ISM along the line of sight from the observer throughout the Galaxy. Therefore a grid of RMs allows us to study turbulent properties of the plasma with methods such as structure function[2]. The density of the current RM grid is about 1 source per square degree primarily from the NVSS RM catalogue[3]. Future surveys with Square Kilometre Array (SKA) and its precursors aim to increase the density by several orders of magnitude, so that small-scale turbulence of the Galactic ISM can be studied[4].

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