Cosmic Magnetic Fields:
From Planets, to Stars and Galaxies
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Detecting magnetic fields in large-scale structure with radio polarization

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Abstract. We present our attempts to detect magnetic fields in filamentary large-scale structure (LSS) by observing polarized synchrotron emission emitted by structure formation shocks. Little is known about the strength and order of magnetic fields beyond the largest clusters of galaxies, and synchrotron emission holds enormous promise as a means of probing magnetic fields in these low density regions. We report on observations taken at the Green Bank Telescope which reveal a possible Mpc extension to the Coma cluster relic. We also highlight the major obstacle that diffuse galactic foreground emission poses for any search for large-scale, low surface-brightness extragalactic emission. Finally we explore cross-correlation of diffuse radio emission with optical tracers of LSS as a means to statistically detecting magnetic fields in the presence of this confounding foreground emission.

Keywords. Magnetic fields – polarization – radiation mechanisms: nonthermal

1. Introduction

One of the goals of the next generation(s) of radio telescopes (LOFAR, MWA, EVLA, SKA) will be to determine the origin of cosmic magnetism. As noted by Donnert *et al.* (2008), the large amplification of fields to several μG in rich galaxy cluster cores largely erases the signatures of their origins, whereas the 0.1μG fields expected in filaments can retain indicators of their origins. Thus, it is critical to study the strength and structure of filament fields. Radio synchrotron emission is a powerful means of detecting magnetic fields in these regions, and shocks from infall into and along the filamentary structures between clusters are now widely expected to generate relativistic plasmas (e.g., Ryu *et al.* 2008, Skillman *et al.* 2008). We are searching for the synchrotron signatures of these shocks.

2. Results

The Coma cluster's radio relic is evidence of shock activity due to infall from a smaller cluster. We performed 1.4 GHz observations of this cluster with the Green Bank Telescope (GBT). Fig. 1 shows a Stokes I image of the Coma region after subtracting point sources and applying a $20'$ median weight filter. Diffuse emission, both polarized (not shown) and unpolarized, extends a full 2 Mpc aligned with the relic. It is unclear if this is all related to the shock/filament, though the fact that it is polarized is consistent with shock compression. We are currently analyzing 350 MHz RM-Synthesis (Brentjens & de Bruyn 2005) data from the WSRT which could resolve the ambiguity.

We have also identified high galactic-latitude "Faraday screens" as a significant source of confusion for low frequency polarization studies (Brown, Rudnick, & Farnsworth in prep). These Faraday rotating clouds modulate the smooth galactic background to produce polarized power in an interferometer that has no total-intensity counterpart (Fig. 1). These features will likely be ubiquitous at frequencies < 200 MHz, and will present a foreground contamination to extragalactic studies. Intrinsic angle changes in galactic

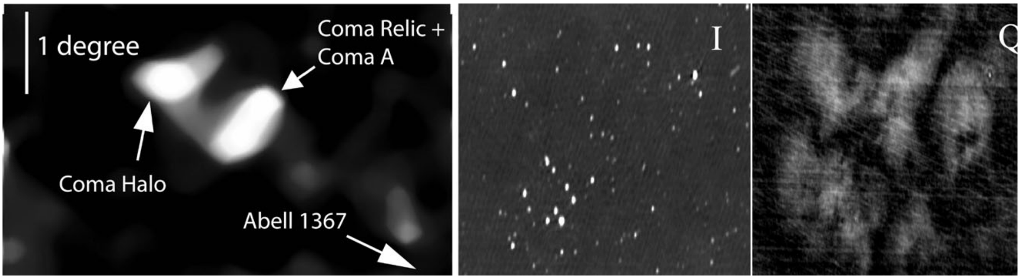

Figure 1. Left: GBT Stokes I image of Coma cluster; Center/right: Westerbork Synthesis Radio Telescope (WSRT) Stokes I/Q images of field north of Coma cluster where Kronberg *et al.* (2007) report diffuse source "B". We do not confirm this source in I, although Faraday modulated Q and U patches are seen in this region.

emission, independent of Faraday rotation, will also add polarized power into an interferometer while the total intensity remains invisible because it is smooth on large scales.

Motivated by these foreground issues, we are exploring cross-correlation methods for detecting synchrotron emission in filamentary LSS. Similar to detections of the Integrated Sachs-Wolfe effect (ISW), we cross-correlate large FOV radio maps with optical/IR tracers of LSS. As a first step, we performed a zero-shift cross correlation of a 34×34 degree area of the 1.4 GHz Bonn survey with the corresponding distribution of 2MASS galaxies ($0.03 < z < 0.04$). To assess the significance of a positive correlation, we also correlated the 2MASS galaxies with 24 random fields of the same size from the rest of the Bonn survey. Though we obtained a null result (as expected), we found that adding a signal weighted by the 2MASS image with a mean surface brightness of $\sim$1 mK was sufficient to produce a 3σ positive correlation. This injected signal is below the rms noise of the Bonn survey and demonstrates the power of this technique.

3. Conclusions

Measuring the weak magnetic fields within filaments of galaxies is critical to determining the origins of cosmic magnetism, and synchrotron radio emission can be a powerful tracer of magnetic fields in these regions. Diffuse Galactic synchrotron emission and Faraday rotating plasma will present a significant foreground problem for upcoming low-frequency surveys, particularly in polarization. We demonstrate that cross-correlation of synchrotron maps and tracers of large-scale structure provides a powerful method for detecting faint emission in filaments.

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