Cosmic Magnetic Fields:
From Planets, to Stars and Galaxies
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Cosmic magnetic fields in galaxies, groups and clusters

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Abstract. The distribution of the Faraday depth induced by galaxies, groups and clusters on a patch of sky is investigated. For instance, we utilise a halo model approach to obtain synthetic Faraday skies. Moreover, our modelling includes cluster physical as well as cosmological aspects. A SKA sky survey will provide a large sample of rotation measures of polarised sources. Hence, we examine to what extent statistics of rotation measures of these sources can yield information about cosmic magnetic fields and cosmology.

Keywords. Galaxies: clusters: general – galaxies: magnetic fields – magnetic fields – radio continuum: galaxies – polarization – methods: data analysis

1. Faraday sky simulations

The origin and evolution of magnetic fields in the Universe is still little understood. Generally, it is assumed that seed magnetic fields are amplified by dynamo mechanisms. These seed fields, which can later be fostered by dynamo actions, might be generated by Weibel instabilities or the Biermann battery mechanism. A powerful tool for studying magnetic fields in a variety of environments is to use Faraday rotation against background and embedded polarised sources. New and up-coming instruments, such as the SKA and its pathfinders, will allow for the first time to perform detailed studies of the magnetic Universe via Faraday rotation measure (RM) techniques. In the presented work, we investigate which insights can be gained on magnetic field evolution from observations by these instruments on the basis of cosmological simulations of magnetic fields and electron gas distributions in large scale structures (LSS), such as clusters, groups and galaxies. In particular, our Faraday sky simulations build on a halo model approach. We employ N-body simulations as well as Lagrangian perturbation theory in order to derive the spatial distribution of halos within chosen mass and redshift ranges. Further halo properties, which can not be directly derived from these simulations of gravitational growth of LSS, are obtained via scaling relations. For example, we assume different scalings between central halo mean magnetic field amplitudes and halo masses and also alter their redshift evolutions. These scalings and their evolutions are physically and/or observationally motivated. The structure of the magnetic field inside clusters is realised by a power-law power spectrum of the magnetic field vector components and our modelling ensures that the vector field is divergence free. Furthermore, we scale the cluster magnetic field strength by a profile so that it decreases radially outwards. Note that our applied magnetic field modelling is backed by observations (see e.g. Murgia *et al.* 2004). The electron gas density profile is derived from the distribution of dark matter in the halo, which is modelled by a NFW profile, by assuming hydrostatic equilibrium. Figure 1 shows Faraday sky patches for different lower halo mass limits and different slopes of the cluster magnetic field power spectra.

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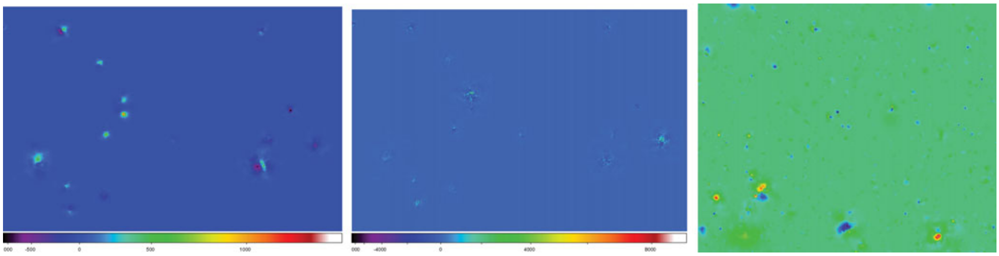

Figure 1. Faraday sky realisations: The left and mid panel show the projected Faraday depth obtained from massive cluster sized halos on a patch of sky assuming different power-law power spectrum slopes of the magnetic field structure inside clusters (colour bar units: rad/m^2). The Faraday sky patch on the right includes galaxy and group sized halos.

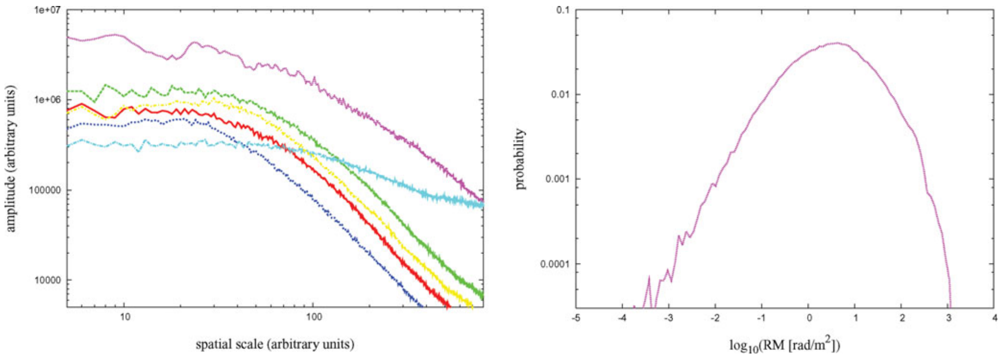

Figure 2. (a) Faraday sky power spectra for different halo mass cuts, magnetic field evolutions, magnetic field amplitude to halo mass scalings and cosmologies (σ_8). (b) Probability distribution of LSS background source RMs for a 'high' σ_8 simulation including galaxy and group halos.

2. Studying the magnetic Universe

Future radio telescopes (especially the SKA) will yield large samples of RMs of polarised extragalactic sources (for a discussion of RM grids and RM synthesis techniques see Geisbuesch & Alexander (2009) (this volume)). RM distributions are sensitive to the evolution of the magnetic field and baryon densities in the LSS and also dependent on cosmology. Especially, the normalisation of the matter power spectrum, σ_8, has an impact on RM statistics. Note further that also the total number of detectable polarised sources, their redshift distribution and spatial correlations depend besides on the integration time on cosmology and LSS physics. Moreover, the variation of the RM distribution for sources at different redshifts is as well dependent on the cosmological evolution of structures and their embedded magnetic fields (see e.g. Kronberg *et al.* (2008) for a recent study of the 'RM-redshift' variation). In Figure 2a we show the power spectra of the line-of-sight projected Faraday depth of generated sample patches. The realisations assume different scaling relations and magnetic field and cosmological evolutions. The Faraday depth distribution can be probed by the polarised background source population, which is spatially uncorrelated with the Faraday foreground. The probability distribution of RMs for lines of sight to high redshift LSS background sources is shown in Figure 2b.

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