Measuring Magnetism in the Milky Way with the SKA

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Why measure B fields in the MW?

- **Big Question**: What is the origin and evolution of interstellar magnetic fields? (see talks by R. Beck, G. Heald)

- **Milky Way as the ideal testbed**:
  - identification of large-scale field reversals
  - B fields of discrete objects (e.g. SNRs, HII regions)
  - probe turbulent power spectrum down to small scales
  - excellent observations of the multi-phase ISM
  - MW is a significant foreground to cosmological experiments: CMB polarization, epoch of reionization, propagation of UHECRs
Why is the SKA a game changer?

Tools:
• extragalactic RM grid (~ 1 source/deg$^2$)
• pulsar RM (~ current # 679)
• diffuse pol. synchrotron emission
• Zeeman splitting (T. Robishaw’s talk)

Major Improvements the SKA will provide:
✓ much denser extragalactic RM grid
✓ much denser pulsar grid with reliable distances
✓ high spatial and FD resolution Faraday tomography

This talk:
• global magnetic field configuration
• turbulent magneto-ionic medium
• other exciting topics
Global Magnetic Field Configuration: Current Understanding

$B_{\text{disk}}$: • 1 confirmed large-scale reversal

• symmetric across mid-plane

van Eck et al. 2011
Global Magnetic Field Configuration: Current Understanding

$B_{\text{halo}}$: • dipolar toroidal? spiral?

• X-shape fields?

+ve RM in Q1 $b>0^\circ$ likely produced by a local magnetized bubble
Global Magnetic Field Configuration: Testing Dynamo Models

• measure global B field configuration → test dynamo models

• dynamo predicts:
  – axisymmetric quadrupolar disk field
  – dipolar halo field

• a bisymmetric halo field: could suggest a primordial origin

• disk and halo fields of different parities can co-exist
Global Magnetic Field Configuration: What the SKA will bring

**Pulsars:**
SKA1: ~ 10,000 normal pulsars
SKA2: parallax distances out to 30 kpc
✓ improve $n_e$ distribution model
✓ many more sightlines w/RMs: wavelet analysis

**Extragalactic sources:**
SKA1-SURVEY: up to $x10^3$ denser RM grid
✓ identify sightlines affected by local structures

**Diffuse Polarized Emission**
SKA-low + SURVEY: Faraday tomography
✓ Faraday-thick structures + superb FD resolution
✓ estimate RM contributions from local structures

Kramer & Stepanov et al. 2002
Magnetized Turbulence: RM Structure Functions

- slope of the power spectrum
- energy injection scale

Interarm $\sim 100$ pc

Arm $\sim$ few pc

Armstrong+ 1995

Haverkorn+ 2008
Magnetized Turbulence: Polarization Gradient

New Diagnostic: Gradient of the polarization vector

Gaensler et al 2011
Magnetized Turbulence: Polarization Gradient

Burkhart et al 2012, see also Iacobelli et al. 2014
Magnetize Turbulence: What the SKA will bring

**Extragalactic sources:**
SKA1-SURVEY: up to $x10^3$ denser precise RM grid

- reliably probe SF down to arcmin scales
  - obtain slope & outer-scale for the whole sky

**Diffuse Polarized Emission**
SKA-low+SURVEY:
- high resolution and sensitivity Faraday tomography
  - apply polarization gradient technique to map Mach number everywhere in the Galaxy

Stil et al. 2011
Other Exciting Topics

- Magnetized Jets from Massive Stars
  - Carrasco-Gonzalez et al. 2010

- Supernova Remnants
  - Landecker et al. 2010

- The Galactic Center
  - LaRosa et al. 2000

- HII regions
  - Harvey-Smith et al. 2011
## Summary

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<thead>
<tr>
<th>Galactic magnetic field component</th>
<th>CURRENT</th>
<th>SKA</th>
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<tr>
<td>Global Field Configuration</td>
<td>one confirmed reversal some vertical components?</td>
<td>direct comparison to dynamo models/simulations</td>
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<tr>
<td>Magnetized Turbulence</td>
<td>Energy injection scale: few pc in arm regions 100 pc in interarm regions</td>
<td>Map outer scales → turbulence injection mechanisms</td>
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<tr>
<td></td>
<td>transonic turbulence in selected regions</td>
<td>Map Mach number throughout the Galaxy</td>
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<td>Others</td>
<td>2 YSO jets Handful of SNRs Large angular extent HII regions Galactic center “checkerboard” pattern?</td>
<td>• Increase the statistics of measurement of B field in discrete objects • Connect the GC field to the overall global field</td>
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