Study of Large-Scale Galactic Magnetic Fields at Low Frequencies

Jana Köhler - MPIfR -
How to measure Magnetic Fields ??
How to measure Galactic Magnetic Field?

- Linear Polarization of Starlight
  - product by mostly coherent alignment of spinning dust grains
- Zeeman Splitting
  - 21 cm line get splitted into three levels by the influence of an external magnetic field

- Polarized synchrotron emission
  - product of acceleration of relativistic electrons in a magnetic field
- WMAP (23 – 94 GHz)
How to Measure the Galactic Magnetic Field?

- Faraday Rotation
  \[ \chi = \chi_0 + \text{RM} \times \lambda^2 \quad \text{with} \quad \text{RM} = 0.81 \int n_e B \cdot dl \]

- RM from extragalactic sources
- Pulsar RMs
  \[ \Rightarrow \text{electron density can be measured by } DM = \int n_e \, dl \]
  \[ \Rightarrow < B_{||} > = 1.232 \, \text{RM} / \text{DM} \]

- Diffuse Synchrotron Emission
  \[ \Rightarrow \text{Rotation Measure Synthesis} \]
What is known up to now ???
All-Sky Surveys at Low Frequencies

45 MHz
MU Radar & Maipu Array

408 MHz
Jodrell Bank & Effelsberg & Parkes

150 MHz
Parkes

1420 MHz
Stockert & Villa Elisa
Polarized Intensity

22 GHz
- at low frequencies
  - strongest polarisation at Fan region and Northern Spur
- at lower frequencies
  - patchy structure in the Galactic plane

1.4 GHz
- more depolarisation at lower frequencies
RM Map

- larger RM values near the Galactic disc
- antisymmetric structure

Oppermann et al., 2012

- RM > 0: magn. field pointing towards the observer
- RM < 0: magn. field pointing away from observer
Magnetic Fields

Zweibel & Heiles, 1997

WMAP

Zweibel & Heiles, 1997
Magnetic Field Strength

- Magnetic Field in the vicinity of the Sun is about 5 μG
- total field is stronger in the arm regions (mainly random fields)
- regular fields are stronger in interarm regions; mostly in a range of 1~2 μG
- field strength probably increases towards the Galactic center

Han, 2001
Magnetic Field Studies at Low Frequencies

- Low frequencies for measuring low RM
  - Necessary for studying weak magnetic fields
  - Ideal to study fields in the galactic outer disc and halo and in the intergalactic medium

- RM in Galactic Disk: ~ few 100 rad/m²
- RM in Galactic Halo: ~ few 10 rad/m²
What I want to do ...
What I want to do …

- Map of the large scale total and polarized intensity of the entire Northern Sky at low frequencies
- using RM Synthesis for measuring the polarized emission
- having a closer look at the polarization properties of the Milky Way
  → especially polarization properties of the cosmic rays in the disk and halo
  → studying the structure of the ISM of the Milky Way and turbulences
- properties of special targets like CasA, CygA, TauA
... and how to get there

- using LOFAR for studies for low frequencies (< 250 MHz)
  → large scale structures only visible in Single Station mode
- using RM synthesis for measuring the polarized emission
  → good frequency resolution needed for not running into bandwidth depolarisation
  → therefore using raw uncorrelated TBB data
- at these low frequencies good calibration of the ionosphere is needed
- Dipole Beam correction is needed
- simultaneous pulsare observations for polarization calibration
- (for a lot of the Single Stations locale RFI is a big problem for the calibration)
Using TBB Data
( Transient Buffer Boards )

PRO

- good frequency resolution
- all sky within one measurement
- simultaneous pulsar observations possible

CON

- small integration time for one measurement (1.3 sec)
- big datasets (100GB raw data)
- long writing time (10 ~15 min)

Self written correlator, where frequency resolution can be chosen freely
Calibration

- Correlation of TBB dataset
- Phase calibration with CasA and CygA
  → for subbands with strong RFI also use the RFI as Calibrator source

- Self Amplitude-Phase Calibration
  → search for sources in the field (also RFI) and use them for the calibration

- use gains for calculating delays
  → maybe creating own CalTables
Measuring the Entire Northern Sky

- 2 x 24 h observations (with different stations)
- gap of half a year in between
  - combine to measure to hole (northern) sky
  - better sensitivity
  - RFI and Sun will get averaged out

- also useful/helpful to study:
  - behaviour of the ionosphere
  - beam model
Combination of Skymaps

49 MHz – total intensity
1.3 sec integration time
200 kHz bandwidth

22. August 2011, 20:00

11. August 2011; 19:00

3. April 2012; 12:00
Galactic Coordinates – 49 MHz
Galactic Coordinates – 36 MHz
Galactic Coordinates – 62 MHz
Thank you