

# Cosmic Magnetism Commissioning and Preparation

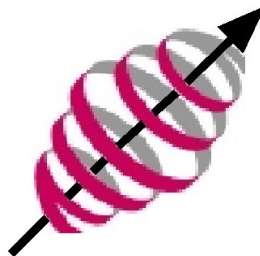
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**On behalf of LOFAR  
and the MKSP**

**(although so far it has mostly just been Ger and myself, we at  
least are starting to include the larger MKSP community in the  
discussions :)**

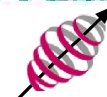
Max-Planck-Institut  
für Radioastronomie



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# Cosmic Magnetism Overview

- Magnetic fields in the universe
  - Primarily from polarization measurements, although can also get information on magnetic fields from Stokes I
- Main topics (by observing time?)
  - Milky Way
  - Nearby galaxies
- Additional topics
  - Pulsars, radio galaxies (AGN), stellar jets
- Data algorithms and data products
  - Full Stokes (I,Q,U,V) calibration and imaging
  - Ionospheric Faraday rotation calibration
  - Rotation measure (RM) synthesis

# Where Are We Trying to Go in 2009?

- Find first polarization
- Find first polarization calibrators
- Test polarization calibration
- Test RM synthesis
- Test instrument performance
  - Beams, sensitivity,
  - Polarization leakage
  - Dynamic range in I, P (and Q,U,V), RM synthesis
  - And so on
- Prepare for major polarized-calibrator search as part of MS<sup>3</sup> using long baselines

# Detecting Polarization With LOFAR

- Find some polarized stuff with LOFAR!

# RM Synthesis Testing

- Algorithm, code, and instrument testing
- Dynamic range testing
- Testing models of galaxies, Milky Way, and so on
  - Test model performance, results
  - Show astronomers what to expect from LOFAR data
- Can use data from other instruments for some testing
- Need to test actual performance using LOFAR observations
  - Include actual instrument response
  - RMSF sensitive to source emission characteristics, so need to test on real sources in LOFAR frequency range

# Single Station Imaging

- Short baselines and total power measurements necessary for Milky Way and large nearby galaxies (M31) observations
- Explore modes of operations for single stations and **superterp** observations
  - Single-station full-sky imaging with station correlator
  - Beamforming total power measurements
    - Use multiple beams to scan across sky, feed measurements into existing single-dish software
    - Requires extra operational control capability (rapid beam repointing, scanning beam across sky)
  - Superterp interferometry and/or tied-array beams
  - TBB interferometry mode
- Lots of interest from international partners, which we need to harness

# Γ Factors

- Reams of beams for LOFAR teams
  - Element/antenna beam
  - Tile beam
  - Station beam
  - Interferometer (single baseline) beam
  - Synthesized beam
  - Tied-array beam
- Model and measure E-Jones gains for directional dependence of beams for proper (full polarization) calibration

# Short Baseline Calibration

- Big G Galactic polarized sources
  - Start with the Fan region
- Need sufficient number of short baseline stations
  - Do we need to wait for the superterp?
- Use existing Westerbork LFFE measurements for calibration
- Commission calibration software
  - Well, need to write the polarization calibration software first
  - Many different possibilities for calibrating using spatially complicated sources with complicated RM structure
- Commission instrument performance



# Pulsar Observations

- Pulsars should often be bright and highly polarized
- MKSP will use pulsars for polarization calibration on intermediate baseline lengths
- **Need to make a pulsar calibrator list**
  - **Observe candidate pulsars**
    - Westerbork LFFE project
    - Need to transfer over to LOFAR observations, full 10—240 MHz
  - **Single-station observations useful, also need interferometry**
  - **Calibrator properties**
    - Brightness, polarization fraction as function of frequency
    - Time to stable polarization (how many pulses to integrate over)

# Long Baseline Observations

- Long baselines critical to many aspects of MKSP
  - High resolution observations for specific projects
  - Probably required for polarization calibration
- Need different sources for calibration on long baselines
  - Galactic emission resolved out
  - Pulsars expected to be scatter broadened by ISM
    - Low frequency VLBI results from 1970's
- Need to get LOFAR long baselines working
- Initial Stokes I calibrator survey
- Check really bright sources for polarized emission
  - Observe AGNs (radio galaxies, etc.) with small enough synthesized beams to hopefully avoid beam depolarization
- Begin calibrator and instrument performance tests



# Ionosphere

- Ionospheric calibration critical for MKSP
- Ionospheric Faraday rotation calibration far more challenging than simple ionospheric delay calibration
  - Depends on absolute TEC, not relative
  - Polarized emission 10—100 times weaker than Stokes I
- Study ionospheric behavior on all baseline lengths
- Commission calibration software

# Calibration Software

- Basics of polarization calibration are already in place
  - MeqTrees and BBS are fully complex matrix-based calibration
- But huge number of details need to be filled in
  - Ionosphere
  - Dealing with rotation measure of calibrators
    - Frequency dependence
    - Doppler shift important in calibration process
    - At LOFAR frequencies, expect few calibrators with single RM
  - Extended sources
  - $(u,v)$  or image plane information
- Lots of things to commission

# Dynamic Range

- Want to go down to very low noise levels, and hence dynamic range
  - $10^4$ — $10^5$
  - Dynamic range requirements perhaps less stringent than total intensity, but still really tough
- Very worried about leakage from Stokes I into polarization
- Need to test early on, and continue as more stations, (u,v) coverage, software improvements come on-line

# Weird Stuff

- Jupiter
  - Stokes V polarization
- Thinking about transient preparation
- Polarized RFI
- ???

# Busy Week

- Ger and I talked a while ago about scheduling a polarization busy week for late June, early July
- Right now my schedule depends on Effelsberg roll-out schedule
- **Need to set up Doodle page**

# MS<sup>3</sup>

- Need full sky polarized calibrator list
  - Propose to get this by using long baseline observations as part of MS<sup>3</sup> to search for polarized emission from all bright sources in all beams across LOFAR sky
- Want  $\geq 4$  International stations available
- Do not expect LOFAR polarization calibration, imaging, or RM software to be working properly by the start of MS<sup>3</sup>
  - So we have to store visibilities to come back and reprocess MS<sup>3</sup> data with improved software
  - MS<sup>3</sup> data including long baselines with reasonable time/frequency averaging will take up 700—1000 TB
  - Planning to use Juelich archive for storage
- Long way to go...



# Not The End...