



# Report from the event supported by RadioNet

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**TITLE** *THE POWER OF FARADAY TOMOGRAPHY:  
TOWARDS 3D MAPPING OF COSMIC MAGNETIC FIELDS*

**DATE:** *28 MAY 2018 - 2 JUNE 2018*

**LOCATION:** *MIYAZAKI, JAPAN*

**MEETING WEBPAGE:** *[http://ska-jp.org/ws/SKAJP\\_MAGWS2018/](http://ska-jp.org/ws/SKAJP_MAGWS2018/)*

**HOST INSTITUTE:** *SKA-JP / KYUSHU UNIVERSITY*

**RADIONET  
BENEFICIARY / NO:** *OSO / 7*

# Report:

## 1. SCIENTIFIC SUMMARY

The workshop aimed to get together scientists with an interest in cosmic magnetic fields, and in particular the astronomical technique of Faraday Tomography to study the field. Especially with the onset of low-frequency spectro-polarimetry with telescopes such as LOFAR, this technique has great promise for the study of Galactic, extragalactic and intergalactic magnetism.

The workshop was divided into seven sessions:

1. Faraday Tomography
2. Cosmology, Large-Scale Structure and Galaxy Clusters
3. High Energy Magnetism Messengers from Space
4. Galaxies and AGN
5. Magnetic Fields in the Milky Way
6. Amazing Magnetism Projects
7. Tutorials of CASA/AIPS and Faraday Tomography

The program also contained room for an open meeting of the ASKAP project POSSUM.

The goals of the workshop were to bring together experts of Faraday Tomography with experts in observational, numerical and theoretical cosmic magnetism studies, and to provide training in radio astronomy and cosmic magnetism studies for young astronomers. The latter is evidenced by the tutorial sessions given, the review talks at every session, and the large number of young astronomers attending. For the youngest students, an informal tutorial on scientific writing was held, followed by proceedings-writing sessions, in the evenings.

Every new session started with a review talk by an eminent scientist in the field, as an introduction into the more specific presentations in each session. The first session on Faraday Tomography was introduced in an excellent review by Shinsuke Ideguchi, which was followed by contributions comparing the method of Faraday Tomography to other methods for radio spectro-polarimetric calibration and analysis.

LOFAR, one of the RadioNet infrastructures, plays a large role in the topic of this conference. Most pioneering low-frequency spectro-polarimetric studies of diffuse plasmas in the Universe have been done with LOFAR (e.g., Iacobelli et al 2013, Jelic et al 2014, 2015, Van Eck et al 2017). Cameron Van Eck presented his work on understanding the diffuse polarized foreground emission as observed with LOFAR, discovering new correlations between magnetic fields and other components of the interstellar medium. The outlook to SKA has led to development of advanced methods to study cosmic magnetism at ever higher redshifts with current and next-generation interferometers (e.g. Vacca et al 2016, Akahori et al 2016), with the goal of deciphering the evolution of the Universe's magnetism over time. Invited speaker Valentina Vacca presented her observations of the polarized extragalactic Universe with the Sardinia Radio Telescope (see Figure 1), and presented numerical simulations that suggested that intergalactic magnetic fields would become observable with SKA1. Also with current and future radio facilities in mind, Takuya Akahori discussed which radio frequencies and bandwidths would be required to make an intergalactic magnetic field observable. These studies were accompanied by theory presentations about possible sources for magnetic fields in the early Universe, from dynamos driven by the chiral magnetic effect in the first second of the Universe's existence (Jennifer Schober) to magnetic field generation at the Epoch of Reionization (Matthieu Langer).

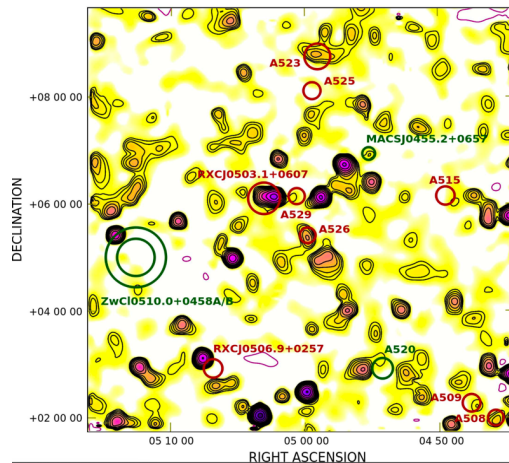


Figure 1: Radio polarimetric observations of the new Sardinia Radio Telescope, giving evidence for a new class of weakly magnetized galaxy cluster halos, as presented by Valentina Vacca.

Local Japanese groups have vast expertise in magneto-hydrodynamical simulations and presented their results on galaxies (Mami Machida), galaxy clusters (Soongyoung Roh), AGN (Yuki Kudo, Tomohisa Kawashima, Hiroyuki Takahashi), and protostellar jets (Haruka Sakemi.). These results complemented the observational results discussed.

One special session was dedicated to "Amazing Magnetism Projects", which contained contributions about many of the exciting big radio-polarimetric projects going on around the globe. Bryan Gaensler discussed the polarimetry survey with ASKAP, named POSSUM. Tessa Vernstrom introduced the MWA, after which George Heald discussed the polarimetry efforts within the MWA-GLEAM survey. George Heald also presented the LOFAR Multifrequency Snapshot Sky Survey (MSSS). Jamie Farnes introduced the work being done on an integration prototype for SKA's Science Data Processor, but also presented exciting initial results of the new pipeline for the MAPS project, which processes the polarization products of the LOFAR MSSS survey introduced by George Heald (see Figure 2).

One of the main goals of this workshop was dissemination of knowledge regarding Faraday Tomography and the use of low-frequency radiopolarimetry in general, and training of the next generation of radio astronomers. The many young scientists at the workshop were very actively involved, in the scientific and social aspects of the workshop. My impression was that many new contacts were made, and I know that new collaborations have been set up at this workshop. Therefore, this workshop has contributed to building and broadening the LOFAR/SKA user base.

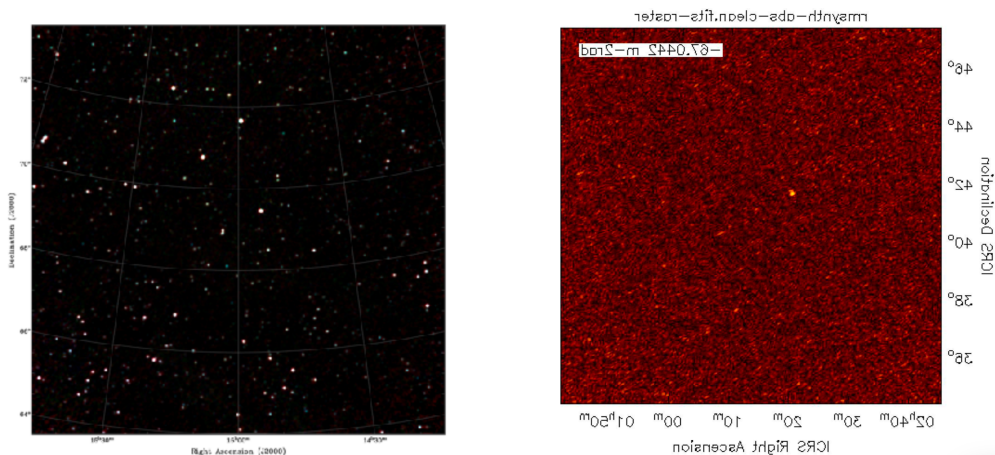


Figure 2: Presented results from LOFAR's Multifrequency Snapshot Sky Survey (MSSS). Left: the verification field in total intensity, as presented by George Heald. Right: initial results from the LOFAR-MAPS project, investigating polarized sources in the MSSS survey, as presented by Jamie Farnes.

## 2. AGENDA OF THE EVENT

### 28 May 2018

- 9:00-9:20 Opening Remarks SOC and LOC
- Session 1: Faraday Tomography** (chair: Keitaro Takahashi)
- 9:20-10:00 The Power of Faraday Tomography: Basics and Applications to Cosmic Magnetism Study (Shinsuke Ideguchi)
- 10:00-10:20 Modelling Faraday Active Spectra for POSSUM Early Science (Cormac Purcell)
- 10:20-10:40 New Generation Radio Telescopes: Challenges in Instrumental Calibration (Wasim Raja)
- 10:40-11:20 Coffee/Tea Break
- 11:20-11:40 Performance test of QU-fit in cosmic magnetism study (Yoshimitsu Miyashita)
- 11:40-12:00 RESOLVE -- Latest Developments (Philipp Arras)
- 12:00-12:20 Optimum Frequency for Studying the IGMF with Faraday Tomography (Takuya Akahori)
- 12:20-12:40 Discussion on Session 1
- 12:40-13:40 Lunch
- Session 2: Cosmology, Large-scale Structure, and Galaxy clusters** (chair: Motokazu Takizawa)
- 13:40-14:20 Cosmic Magnetic Fields: A Theorist View of the Nature and Origin (Dongsu Ryu)
- 14:20-14:40 Magnetizing the Cosmic Web during Reionization (Mathieu Langer)
- 14:40-15:00 Thermal Sunyaev-Zel'dovich effect in the IGM due to the primordial magnetic fields (Teppei Minoda)
- 15:00-15:20 Poster Presentations (poster presenters)
- 15:20-16:00 Coffee/Tea Break
- 16:00-16:20 Chiral dynamos and the origin of cosmic magnetic fields (Jennifer Schober)
- 16:20-16:40 Tracing primordial magnetic fields with 21 cm line observations (Kerstin Kunze)
- 16:40-17:00 Towards Exascale simulations of the ICM dynamo with Wombat (Julius Donnert)
- 17:00-17:20 Magnetic fields in clusters of galaxies: a simulation study (Soonyoung Roh)
- 17:20-17:40 Simulations of the polarized sky of the SKA: how to constrain intracluster magnetic fields (Francesca Loi)
- 17:40-18:00 Wavelet RM synthesis versus fitting parametric models for reconstruction magnetic field structure (Dmitry Sokoloff)
- 18:00 --- Dinner + Discussion/Social gathering

### 29 May 2018

- Session 2: Cosmology, Large-scale Structure, and Galaxy clusters** (chair: Hiroyuki Nakanishi)
- 9:00-9:40 Magnetic fields in Galaxy Clusters and in the Large-Scale Structure of the Universe (Valentina Vacca)
- 9:40-10:00 Synergy between X-ray and low-frequency radio telescopes on particle accelerations in galaxy clusters (Hiroki Akamatsu)
- 10:00-10:20 X-ray and radio observations of the radio relic galaxy clusters 1RXS J0603.3+4214 and RXC J1053.7+5453 (Motokazu Takizawa)
- 10:20-10:40 The Toothbrush Radio Relic: Filaments and Polarisation (Matthias Hoeft)
- 10:40-11:20 Coffee/Tea Break
- Session 3: High Energy Magnetism Messengers from Space** (chair: Hiroki Akamatsu)
- 11:20-12:00 Fast Radio Burst tomography of the circum- and inter-galactic medium (Vikram Ravi)
- 12:00-12:20 Limits on cosmic magnetic fields from recent cosmic-ray results (Justin Bray)
- 12:20-12:40 Discussion on Session 2 and 3
- 12:40-13:40 Lunch
- Session 4: Galaxies and AGN** (chair: Jamie Farnes)
- 13:40-14:20 Untangling cosmic magnetic fields: Applications of broadband radio spectro-polarimetry (Shane O'Sullivan)
- 14:20-14:40 The structure of magnetised thermal plasma in the lobes of Fornax A and Centaurus A (Craig Anderson)
- 14:40-15:00 Broadband Investigation of NVSS High Rotation Measure Extragalactic Radio Sources (Yik Ki Ma)
- 15:00-15:20 Broad-band spectropolarimetric observation of high-RM AGN (Alice Pasetto)
- 15:20-16:00 Coffee/Tea Break
- 16:00-16:20 3D Magnetohydrodynamic Simulations of AGN Torus (Yuki Kudo)
- 16:20-16:40 Faraday depolarization effects of the spiral galaxies (Mami Machida)

- 16:40-17:00 Magnetic fields in the halo of spiral galaxies seen edge-on -- as deduced from CHANG-ES (Marita Krause)  
 17:00-17:20 Magnetic field vector maps of nearby spiral galaxies (Hiroyuki Nakanishi)  
 17:20-17:40 Revealing the nature of anomalous arms in NGC 4258 using Faraday Tomography (Sarrvesh Seethapuram Sridhar)

30 May 2018

**Session 4: Galaxies and AGN** (continued) (chair: Mami Machida)

- 9:00-9:20 On a spin signature in black hole shadow of M87 (Tomohisa Kawashima)  
 9:20-9:40 Numerical Study of Supercritical Accretion onto Black Holes and Neutron Stars (Hiroyuki Takahashi)  
 9:40-10:00 Discussion on Session 4

**Session 5: Magnetic Fields in the Milky Way** (chair: Mami Machida)

- 10:00-10:40 The Power of Low-Frequencies: Faraday Tomography with LOFAR (Cameron Van Eck)  
 10:40-11:20 Coffee/Tea Break  
 11:20-11:40 Faraday tomography of the Milky Way ISM with GMIMS (Alex Hill)  
 11:40-12:00 Magnetic field of Milky Way by near-infrared polarimetry of Cepheids (Tetsuya Zenko)  
 12:00-12:20 Searching for helical magnetic fields in the Milky Way (Jennifer West)  
 12:20-12:40 The Local Bubble: a magnetic veil to our Galaxy (Marta Alves)  
 12:40-13:40 Lunch

**Session 5: Magnetic Fields in the Milky Way (Continued)** (chair: Marijke Haverkorn)

- 13:40-14:00 The Power of Zeeman: Mapping Magnetic fields in our Galaxy through masers (Jimi Green)  
 14:00-14:20 Structure of electron density and magnetic field in the Milkyway Galaxy (Osamu Kameya)  
 14:20-14:40 Uniform fields in Hii regions revealed by GMIMS (Alec Thomson)  
 14:40-15:00 Analytic growth rate of gravitational instability in self-gravitating planar polytropes (Jean-Baptiste Durrive)  
 15:00-15:40 Coffee/Tea Break  
 15:40-16:00 H-alpha Polarization Measurements of Tycho's Eastern Limb with the Subaru FOCAS (Satoru Katsuda)  
 16:00-16:20 On Measuring the Turbulent Magnetic Energy Spectrum in Supernova Remnant by Correlation Analysis of Radio Synchrotron Intensity (Jiro Shimoda)  
 16:20-16:40 Propagation and Structure of Astrophysical Jets by Two-temperature Magnetohydrodynamics (Takumi Omura)  
 16:40-17:00 Faraday Tomography of the SS433 Jet Terminal Region (Haruka Sakemi)  
 17:00-17:20 Magnetohydrodynamic Simulations of a Plunging Black Hole into a Molecular Cloud (Mariko Nomura)  
 17:20-17:40 Discussion on Session 5  
 17:40 --- Dinner + Discussion/Social Gathering

31 May 2018

- 9:00-9:40 POSSUM: First Results from Wide Field Polarisation Surveys (Bryan Gaensler)  
 9:40-10:20 The Murchison Widefield Array: Overview and Recent Results (Tessa Vernstrom)  
 10:20-11:00 Coffee/Tea Break  
 11:00-11:40 LOFAR MSSS (George Heald)  
 11:40-12:00 The Square Kilometre Array (SKA) Science Data Processor Integration Prototype (Jamie Farnes)  
 12:00-12:40 Summary and Discussion (Takuya and Jamie)  
 12:40-14:00 Lunch

POSSUM Users meeting - Early POSSUM data (Survey Group 4: George Heald & Naomi McClure-Griffiths)

- 14:00-14:30 Overview of ASKAP polarisation observations taken so far  
 14:30-15:00 Discussion of data requirements and science outcomes for Early Science  
 15:00-15:30 Discussion of early science papers: process, topics, authors  
 15:30-16:00 Coffee/Tea break

POSSUM Users meeting - Source-finding in polarisation surveys (Survey Group 2: Jamie Farnes)

- 16:00-16:30 Source-finding tools and simulations  
 16:30-17:00 Source-finding data challenge and next steps

POSSUM Users meeting - Commissioning tasks for POSSUM (Survey Group 4: Wasim Raja)



17:00-17:20 Introduction to POSSUM Memo 66  
17:20-18:00 Discussion on tests to be performed during commissioning  
18:00 -- Dinner + Discussion/Social Gathering

### 1 June 2018

POSSUM Meeting - POSSUM pipelines, quality control and RM determination (Survey Groups 5 & 8: Cormac Purcell & Jennifer West)

9:00-9:30 Overview of the POSSUM data-processing pipeline  
9:30-10:00 Data validation metrics for polarisation  
10:00-10:30 Coffee/Tea break  
10:30-11:30 Parallel sessions  
1: Incorporating ideas from this conference on QU-fitting and RM determination (Cormac Purcell)  
2: Tutorial on analysing ASKAP data (Craig Anderson & Wasim Raja?)  
3: Survey strategy (Survey Group 3: Craig Anderson)  
11:30-12:00 Plans for survey tiers leading up to full survey  
12:00-12:30 Refreshing the science case and plans for full POSSUM  
12:30-12:40 Summary and synthesis (Bryan Gaensler)  
12:40-14:00 Lunch  
14:00-18:00 Tomography Tutorial  
18:00 -- Japanese BBQ + Karaoke

### 2 June 2018

9:00-12:40 AIPS & CASA Tutorial

## 3. PARTICIPANTS

The workshop had 64 participants. The biggest group of these were Japanese (24), there were 19 from Europe (6 Germany, 4 Netherlands, 4 Italy, 2 UK, 1 France, 1 Spain), 8 from North America (5 Canada, 3 US), 8 from Australia, and 4 from Asia other than Japan (2 South-Korea, 1 Russia, 1 India).

A relatively large part of these were young researchers: 28 postdocs, 12 PhD students and 2 MSc students.

We invited 8 experts to give review presentations. Originally, these were 3 women and 5 men. However, 2 female and 1 male invitee could not accept the invitation, so in the end we had 6 male invited speakers and 2 female invited speakers. Of the participants, 16 were women and 48 men, which means that 25% of our participants are female. This was mostly due to the large fraction of men in the Japanese contingent (21 out of 24). Not counting the Japanese participants, there were 13 women and 27 men (almost 50% female).

An attendance list is added to this document, electronically signed by Marijke Haverkorn, co-chair of the Scientific Organizing Committee.



#### 4. RADIONET FINANCIAL CONTRIBUTION

The RadioNet financial contribution was used to enable Dr Jamie Farnes (Oxford University) to attend the conference. Jamie is one of the initiators and main organizers of this workshop.

Jamie Farnes is an expert in cosmic magnetism and has expertise in many aspects of this: from the calibration and imaging techniques, to interpretation of magnetism measurements in a wide variety of objects, from nearby supernova remnants to the high-redshift Universe.

Jamie plays a large role in the LOFAR community. He is the initiator and co-PI of a LOFAR legacy survey derived from the pioneering Multi-frequency Snapshot Sky Survey (MSSS) called MAPS (see above and Figure 2). The MAPS survey uses the polarized emission from the MSSS survey to shed light on a range of science topics, including Galactic magnetism, interstellar medium, Rotation Measure grids, searches for low-frequency polarization calibrators, depolarization of radio galaxies, and searches for pulsars and brown dwarfs.

In addition to this, he has used LOFAR for individual projects such as characterization of the supernova remnant W51 (Farnes et al 2017, MNRAS, 467, 4777) and has devised a new method for source finding in linear polarization for LOFAR (Farnes et al 2018, MNRAS, 474, 3280). He was a co-author on numerous other LOFAR papers.

Jamie is using his expertise built up with (amongst others) LOFAR to help preparing for the construction of the SKA, and gave an excellent presentation about the Science Data Processor Integration Prototype for the SKA.

The presence of Jamie in this workshop was important in many ways: firstly, through the presentation he gave at the conference, and his active involvement in discussions. Secondly, Jamie was organizing the tutorial session on the AIPS and CASA data processing packages, for the attending students. Gaining familiarity with general radio data processing techniques will be an important first step for these students to becoming involved in radio astronomy, and possibly LOFAR. Thirdly, I fully expect that the scientific exchanges he had with colleagues at the conference, will turn out useful for the progress of his own LOFAR work and that of others. And last but not least, he kept the whole community posted of what was happening at the workshop via Twitter.

The SOC of this workshop is very grateful indeed that RadioNet funding made it possible for Jamie to actively attend this workshop.

## 5. PUBLICATIONS

The proceedings of this workshop will be published as a Special Issue of the peer-reviewed journal *Galaxies*. RadioNet support will be acknowledged in at least two of the proceedings contributions: the paper by Jamie Farnes, and the conference summary paper, written by Mami Machida and Marijke Haverkorn.