POSSUM Newsletter 2

June 2012

From the PIs

Two face-to-face meetings were held last month in Sydney: a one-day science workshop on polarisation and magnetic fields on 7 May 2012, followed by a two-day POSSUM meeting over 8-9 May 2012.

The science workshop featured more than 30 attendees, with talks covering diverse topics including interstellar turbulence, magnetic fields in planets, molecular clouds and supernova remnants, polarisation of galaxies, quasars and clusters, and polarisation source counts and statistics. Amongst the presentations were several talks from overseas given by phone or videoconference. The program and presentation slides are available at http://askap.org/possum/Meetings/SydneyMagneticFieldWorkshop2012.

The POSSUM meeting was a much-needed opportunity to discuss and debate a variety of technical issues relating to our ongoing ASKAP design study. Substantial progress was made on developing RM synthesis and RMCLEAN, understanding ionospheric correction, defining catalogues and data products, planning the overall POSSUM software pipeline, and preparing for commissioning with BETA and ASKAP-12. The convenor of each session has been asked to write a one-page report that will summarise the discussion and identify key action items going forward. The meeting program, presentation slides and additional notes are all available at http://askap.org/possum/Meetings/SydneyPossumWorkshop2012.

Many thanks to everyone who participated in these meetings, both in person and remotely. Apart from a few minor hiccups, the video system worked well and we hope to use it again for further discussions.

The feedback received from the students who participated is that their heads were spinning afterwards, which is a good sign that we accomplished a great deal! We'd like to particularly thank Cormac Purcell, Xiaohui Sun, Shane O'Sullivan, Joanne Daniels, Jane Kaczmarek, Craig Anderson, Niloofar Gheissari and everyone else who helped organise this event. We also thank those who made the long trip to Australia to participate - your presence added a lot!

In this newsletter you can read updates on RM synthesis and on the POSSUM pipeline, summaries of new papers on detection thresholds in Faraday depth spectra and on recognising magnetic field structures using wavelets, and an interview with POSSUM researcher Shane O'Sullivan.

Bryan Gaensler, Tom Landecker and Russ Taylor

POSSUM Activities

Recovering complex Faraday depth spectra

Xiaohui Sun

Complex Faraday depth spectra are very important for many scientific investigations. However, it has already been shown that RM synthesis and RMCLEAN are not sufficient for properly reconstructing complex spectra. Other methods such as compressive sampling and sparse RM synthesis have been developed to treat complex spectra. These methods are yet to be robustly tested. How POSSUM should proceed in tackling these spectra was one of the issues discussed extensively during the POSSUM workshop. A data challenge is being developed by Craig Anderson, Larry Rudnick, Jeroen Stil and Xiaohui Sun, consisting of four different scenarios that each needs to be reconstructed from incomplete λ^2 observations

- 1 Faraday thin component
- 2 Faraday thin components with different spectral indices, amplitudes and phases, separated by a non-negligible Faraday depth
- 1 Faraday thick component
- 1 Faraday thin component plus 1 Faraday thick component

A proposal for the data challenge will be circulated soon to all groups that are developing RM deconvolution algorithms. After comment and discussion, a final data challenge will be developed. The methods that optimally resolve this data challenge will be recommended for POSSUM.

Update on POSSUM pipeline

Cormac Purcell

The POSSUM pipeline has now been successfully ported to Python from the initial IDL implementation developed by Tim Robishaw. A general control script now integrates the modules into a cohesive whole. Figure 1 shows a simulated Stokes *I* image (left) of a field seen by ASKAP BETA (courtesy of Tony Willis). The new RM synthesis code has been run on the frequency data-cube to test the code's viability and performance. The panels on the right zoom in to a bright polarised source showing the peak RM across the emitting region (top) and the dirty Faraday depth spectrum (bottom). Performance of RM synthesis using the "numpy" array modules is relatively fast, although the processing time is limited by the large size of the simulated data. Currently we are testing the RMCLEAN module and incorporating the changes suggested at the recent POSSUM workshop. In the near future the ASKAP software team will implement RM synthesis in the ASKAPSOFT processing pipeline, while the POSSUM team will be responsible for performing RMCLEAN on the Faraday depth spectra. We also plan to investigate the possibility of using Mike Bell's new Faraday synthesis technique.

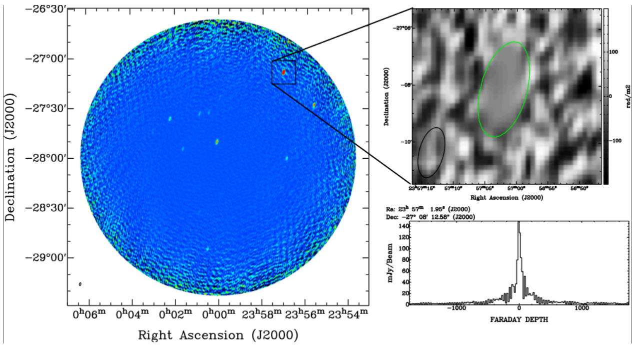

Figure 1. Preliminary RM synthesis results from the POSSUM pipeline.

Analytic detection thresholds for measurements of linearly polarised intensity using rotation measure synthesis

Chris Hales, Bryan Gaensler, Ray Norris, Enno Middelberg

We extend the analytic formalism for standard linear polarisation, namely that describing measurements of the quadrature sum of Stokes *Q* and *U* intensities, to the rotation measure synthesis environment. We derive the probability density function and expectation value for Faraday-space polarisation measurements for both the case where true underlying polarised emission is present within unresolved Faraday components, and for the limiting case where no such emission is present. We then derive relationships to quantify the statistical significance of linear polarisation measurements (L_{RM}) in terms of standard Gaussian statistics (G). The formalism developed in this work (Figure 2) will be useful for setting signal-to-noise ratio detection thresholds for measurements of linear polarisation, for the analysis of polarised sources potentially exhibiting multiple Faraday components, and for the development of polarization de-biasing schemes. For example, with the number of independent samples in Faraday depth spectra M=30, a detection threshold of L_{RM}/σ_{RM}=6.0 is required to ensure equivalent Gaussian significance in excess of $\pm 5.0\sigma_{RM}$.

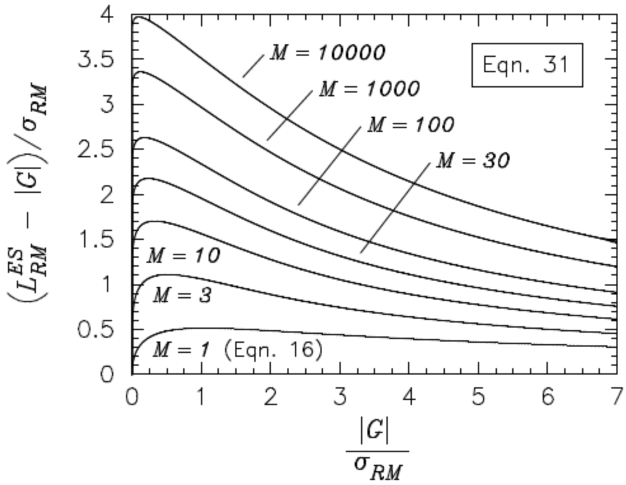

Figure 2. Detection thresholds for L_{RM} that exhibit equivalent false positive error rates to those of standard Gaussian detections, G.

We also show that Gaussian fitting routines may not be appropriate for source extraction in images of linear polarisation, unless low signal-to-noise ratio wings are excluded from the fitting process (e.g. by imposing a signal-to-noise ratio cut-off threshold for fitting). Additionally, the non-Gaussian distribution of pixel intensities about the mean profiles will likely cause a systematic positive bias in extracted flux densities, particularly for low SNR sources.

Hales et al. 2012, MNRAS, in press (arXiv: 1205.5310)

Recognising magnetic structures by present and future radio telescopes with RM synthesis

Rainer Beck, Peter Frick, Rodion Stepanov, Dmitry Sokoloff

We investigate the possibilities of wavelet-based RM synthesis for the recognition of structures of regular and turbulent magnetic fields in extended magnetised objects like galaxies and galaxy clusters. We present observational tests to recognise regular magnetic fields with and without one or two reversals along the line of sight and also with imprints of turbulent magnetic fields. A region with a regular magnetic field generates a broad "disk" in Faraday space, with

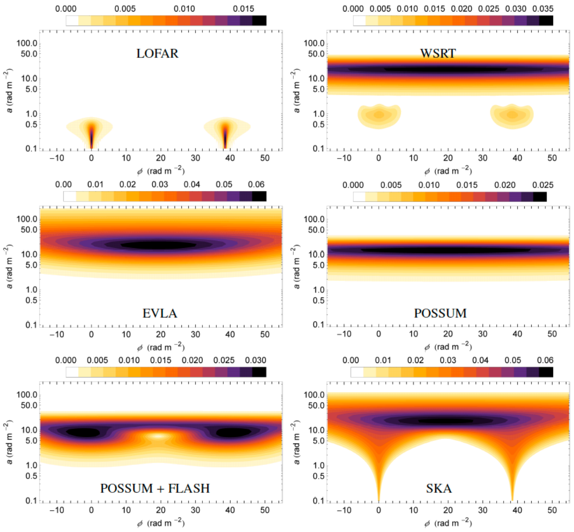

Figure 3. Wavelet planes for the magnetic field with Gaussian profiled and the same scale heights of thermal and CRE electrons. The vertical axes show the scale of the reconstructed structure, and the colour corresponds to the amplitude of wavelet transform.

two "horns" if the distribution of cosmic-ray electrons is broader than that of the thermal electrons. Each field reversal generates one asymmetric "horn" on top of the "disk". A region with a turbulent field can be recognised by many components. As shown in Figure 3 for a regular field, both the disk and horn structures can be seen with the SKA. Observations of ASKAP will be especially insightful in this regard if we are able to combine λ^2-coverage from both POSSUM and FLASH.

Table 1: Spectral ranges of various radio telescopes and parameters crucial for wavelet-based RM synthesis.

Telescope	λ m	$\Delta\lambda^2$ m^2	$\lvert\delta\phi\rvert$ rad/m^2	$\lvert\Delta\phi_{max}\rvert$ rad/m^2	$(\lambda_{max}/\lambda_{min})^2$
LOFAR HBA	1.25–2.73	5.9	0.59	2.8	4.8
WSRT	0.17–0.23 + 0.77–0.97	0.91[1]	3.8	110	33
GMRT	0.21–0.30 + 0.47–0.52 + 0.87–0.98	0.92[1]	3.8	71	22
DRAO, Parkes, Effelsberg (GMIMS)	0.17–0.23 + 0.33–1.0	0.97	3.6	110	35
Parkes (S-PASS)	0.12–0.14	0.004	870	220	1.4
Arecibo (GALFACTS)	0.20–0.24	0.021	165	79	1.4
EVLA	0.025–0.30	0.089	39	5000	144
ATCA	0.03–0.27	0.072	48	3500	81
ASKAP (POSSUM)	0.21–0.27	0.026	130	71	1.6
(POSSUM + FLASH)	0.21–0.42	0.14	25	71	4.0
SKA phase 1	0.10–4.3	18	0.19	310	1850
SKA phase 2	0.03–4.3	18	0.19	3500	20500

We argue that the ratio of maximum to minimum wavelengths (Table 1) is an important parameter because it determines the range of scales that can be identified in Faraday space. The combination of data from the POSSUM and FLASH surveys will be able to improve the recognition of structures at intermediate scales.

Beck et al. 2012, A&A, in press (arXiv: 1204.5694)

Profile – Shane O'Sullivan

Shane is currently an OCE Postdoctoral Fellow at CSIRO Astronomy and Space Science. He obtained his PhD from University College Cork, Ireland, in 2010, for his studies on magnetic field properties of parsec-scale AGN jets. Shane will be moving to the University of Sydney to take up an ARC Super Science Fellow in October 2012, where he will continue his work on POSSUM.

What are your main research interests?

Radio galaxies and magnetic fields.

What excites you about POSSUM?

The technical and scientific challenges that a successful POSSUM survey is forcing us to address.

What tasks are you undertaking for POSSUM?

Assessing candidate polarisation calibrators and investigating the effect of the ionosphere on our RM measurements.

What are the main challenges for your current tasks?

Finding a polarised radio source whose polarisation is stable with time and whose RM we fully understand.

What papers are you working on?

Faraday rotation and polarisation analysis of the giant lobes of the radio galaxy Centaurus A. Anaylysis of the polarisation and RM structure of spatially unresolved AGN using ultrawide bandwidth observations

What do you enjoy outside work?

Getting some fresh air and exercise! Watching and playing any number of sports.

Other Related Science Results

A new model of the Galactic magnetic field

Ronnie Jansson and Glennys R. Farrar

A new, much improved model of the Galactic Magnetic Field (GMF) is presented. We use the WMAP7 Galactic Synchrotron Emission map and more than forty thousand extragalactic rotation measures to constrain the parameters of the GMF model, which is substantially generalised compared to earlier work to now include an out-of-plane component (as suggested by observations of external galaxies) and striated-random fields (motivated by theoretical considerations). The new model provides a greatly improved fit to observations (Figure 4). Consistent with our earlier analyses, the best-fit model has a disk field and an extended halo field. Our new analysis reveals the presence of a large, out-of-plane component of the GMF; as a result, the polarised synchrotron emission of our Galaxy seen by an edge-on observer is predicted to look intriguingly similar to what has been observed in external edge-on galaxies. We find evidence that the cosmic ray electron density is significantly larger than given by GALPROP, or else that there is a widespread striated component to the GMF.

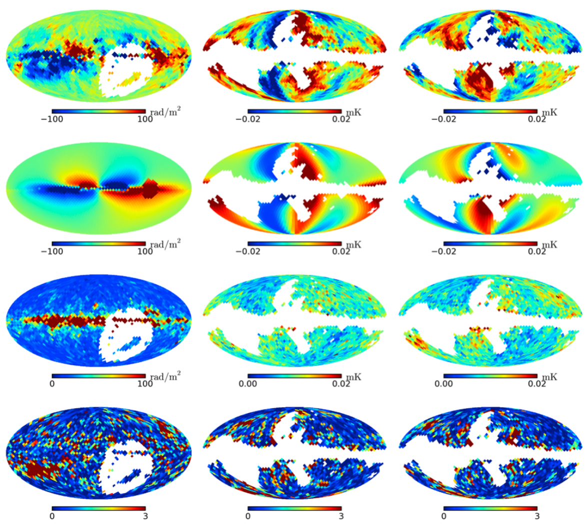

Figure 4: Left to right: RM, WMAP Stokes *Q* and *U*. Top to bottom: data, models, errors of the data and contribution of each pixel to chi-squared.

Jansson & Farrar, 2012, ApJ submitted (arXiv: 1204.3662)

On the reliability of polarisation estimation using rotation measure synthesis

J.-P. Macquart, R. D. Ekers, I. Feain, M. Johnston-Hollitt

We benchmark the reliability of the RM synthesis algorithm using the 1005 Centaurus A field sources. There is no systematic difference in the polarisation amplitude recovered by RM synthesis compared to a least-squares fitting approach as a function of signal to noise ratio (SNR). We derive the statistical properties of the polarisation amplitude associated with RM synthesis in presence of noise. Even the measured SNR is low, there is a nonzero probability that RM synthesis deduces the correct Faraday depth (Figure 5). Polarisation bias should not be subtracted from the derived polarisation amplitudes when analysing polarisation source counts. We also derive the criteria for the likelihood for the detection of a second RM component as,

$$\frac{P_2^2}{\Sigma^2} \approx \frac{1}{3}\left[\chi_2^2(2N_{\rm chan}-6) - \chi_1^2(2N_{\rm chan}-3)\right]$$

where P_2 is the amplitude of the second component, Σ is the band averaged noise, and $N_{\rm chan}$ is the number of channels.

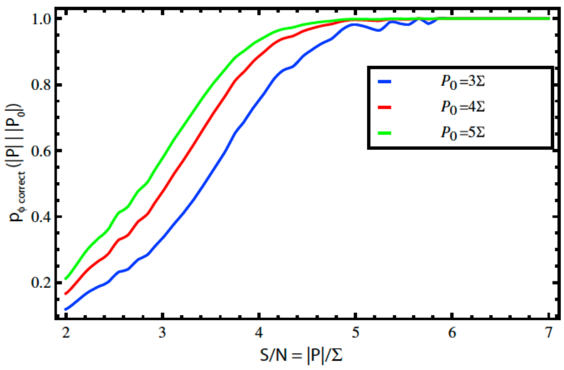

Figure 5: Probability that RM synthesis correctly identifies the Faraday depth as a function of the measured SNR. The intrinsic polarisation amplitude is P_0.

Macquart et al. 2012, ApJ, 750: 139

Upcoming meetings

The XXVIII IAU general assembly

Beijing, China, August 20-31, 2012

http://www.astronomy2012.org