POSSUM REPORT 3: DRAFT DATA VERIFICATION PLAN

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Introduction

This report describes the data verification process for the ASKAP POSSUM survey, which is the responsibility of POSSUM WG5. Members of the POSSUM working groups are currently developing and testing algorithms for source finding and polarization debiasing (WG2), and RM synthesis and RM CLEAN (WG8). These algorithms will form the basis for the RM data pipeline (described in POSSUM report 5), which will be implemented by the ASKAP computing team. The POSSUM survey will have two outputs: the first being the POSSUM Polarization Catalogue (PPC) describing the polarization properties of each Stokes-I source identified in the EMU survey. The second is the more comprehensive POSSUM Polarization Atlas (PPA), which will include the properties of all polarized sources found in the $P = \sqrt{Q^2 + U^2}$ image plane. These data products are described in the POSSUM Data Format and Access document.

In this report we describe the steps that will be carried out to verify the POSSUM survey. In Section 1 we describe tests for the algorithms that make up the software pipeline, to be carried out using simulated data. Section 2 contains a discussion of the data verification steps planned during the BETA test phase. In Section 3 we outline the design of an automated process, to be run on-the-fly within the RM pipeline, that will test the results destined for the data catalogue and atlas. Here we primarily discuss the PPC, as the generation and verification of this catalogue is our immediate focus leading up to the project review to be held in November 2011. Although we give some consideration to the PPA, a detailed description of the data verification steps for the PPA is beyond the scope of this report.

1. Testing the POSSUM data pipeline using ASKAP simulations

Before ASKAP data are available, we will test the POSSUM data pipeline using a simulated sky. Current and planned ASKAP simulations include polarized sources, but for a robust test of the final pipeline the simulations must be sufficiently sophisticated to handle sources with multiple RM components, extended/complex polarized sources and polarized transient sources. Simulations that are not covered in the ASKAP simulations will be produced by the POSSUM simulations and

imaging group (WG1). In this Draft Data Verification Plan we outline the tests to be carried out on the PPC. POSSUM Report 23 (due date 15th June 2011) will provide a full description of automated tests to apply to simulated data, including algorithms.

1.1. **Per-source testing of RM pipeline modules.** The POSSUM RM pipeline (described in POSSUM Report 5) will take the pixel with the brightest Stokes-I flux density from each EMU source and perform RM synthesis. The RM spectrum will be searched for a polarized source (see POSSUM Report 1) and if one is present, the spectrum will be RM-CLEANed (see POSSUM Report 24). The clean RM spectrum will then undergo assessment as to whether it is simple (containing a single RM) or complex (containing multiple RM components). In the PPC, complex sources will have a flag in the RM column and simple sources will have an RM entry. For the PPA, multiple RMs will be catalogued.

Specific types of test to be carried out on the algorithms using simulated data will include but not be limited to those listed in Table 1.

Simulated Scenario	Output to PPC
Polarized point source with a single RM	P, $\%P$, RM correct within uncertainties
EMU source with no polarized counterpart	$\%P = 0$, P upper limit, 'no source' flag
Polarized source with multiple RM components	'complex source' flag
Polarized source, single RM, many channels removed	RM correct within uncertainties
Polarized source, multiple RMs, many channels removed	'complex source' flag

TABLE 1. End-to-end tests to be carried out on simulated data to ensure the robustness of the pipeline and to verify the results.

The POSSUM RM pipeline should recover the input RMs within the quoted uncertainties, where the polarized flux density is more than $10\sigma_{RMS}$. If the polarized flux density is greater than $5\sigma_{RMS}$ but less than $10\sigma_{RMS}$, only the polarization properties will enter the PPC and a flag will be applied to the columns relating to the RM information. The pipeline must be sufficiently robust to cope well with sources for which several channels have been removed or have low signal-to-noise ratios due to flagged data (e.g. due to the presence of RFI). Algorithm testing for the PPA is likely to be considerably more sophisticated than the PPC case, as this will include verifying the RM CLEAN process and checking the identification of multiple RMs.

1.2. **Global tests of the RM pipeline using simulated data.** When the pseudo-PPC has been generated using simulated data, the output source statistics will be tested against the input source statistics. The input and output should agree within the quoted uncertainties. A simple way to test this is to plot a

difference histogram (input minus output source statistics). For each ASKAP field, suitable histograms would include:

- Number of polarized sources in intervals of P
- Number of polarized sources in intervals of $\%P$
- Number of polarized sources in intervals of polarization position angle
- Number of polarized sources in intervals of RM

The histogram representing the difference between input and output statistics will be run through a spectral 'source finder', similar to that used on the RM spectra. Where a difference histogram has a peak greater than $5\sigma_{RMS}$, a flag will be applied to denote significant deviation of the pipeline from expected behaviour. This will enable us to investigate the cause of the discrepancy, which is a vital part of the process of algorithm testing and refinement before the November 2011 review of end-to-end simulations.

When considering outputs to the PPA, additional tests such as comparisons of angular size will be carried out. This step from PPC to PPA verification will likely require only superficial additions to the data verification software for checking catalogue-wide results during the simulations stage.

2. BETA: tests using the first data releases

ASKAP will be amongst the first generation of telescope to employ PAFs, which utilise wide sampling of the focal plane and digital beamforming to produce multiple overlapping beams on the sky and thereby sample a wide field of view. The performance of the CSIRO PAFs, in particular their gain variations and polarization leakage across the 30 square degree field, are not well understood. Characterising the performance of PAFs will be a vital element of the ASKAP SSPs during BETA operations. Characterisation of the off-axis polarization response of ASKAP lies with POSSUM WG4b.

During BETA operations a number of test observations will be carried out. The data from BETA will be run through the RM pipeline and subjected to the same data verification processes as the full POSSUM survey, which are described in the following section.

3. Verification of the POSSUM survey data products

In this section we outline the data verification tests that will be carried out on POSSUM data produced by the ASKAP data pipeline. These processes will need to be fully automated, owing to the enormous volumes of data involved. There are two main aspects to data verification. The first is comparison of trusted RM, P, %P with the corresponding results in our catalogue, which will yield agreement if our systems and software are functioning correctly. The second is a check for catalogue entries that are impossible, improbable or unexpected (where a flag is

added to the data). We finish by discussing some addition issues that will affect data verification of the PPA alone.

3.1. **Comparison of ASKAP data with existing catalogues.** POSSUM will be the deepest and most comprehensive survey of the rotation measure sky to date. Even so, it is possible to test the RM and polarization information gathered by POSSUM using comparisons with existing RM catalogues. One option is to use RMs from the NVSS catalogue (Taylor, Stil and Sunstrum 2009), although this is limited to declinations greater than $-40°$, it provides only 1 polarized source per square degree and individual RMs may not be reliable (see e.g. Battye et al. 2008, Mao et al. 2010). To improve this situation, dedicated observations of two ASKAP 30 deg^2 fields using ATCA will shortly be carried out using the ATCA (Feain et al). Work is also underway by members of the POSSUM team (O'Sullivan et al.) to image 10 deg^2 of the ASKAP sky (yielding $\sim$100 polarized sources with a source density of 10 deg^{-2}). Although these data will be useful in testing the RM pipeline during the ASKAP design study phase, it would be beneficial to extend this work before full ASKAP operations commence to ensure that every 30 deg^2 ASKAP field has at least one independently verified RM (a 'polarized verification source') for data verification purposes. Plans are afoot to compile a more comprehensive all-sky database of RMs, which may be available by commencement of BETA operations (Ensslin et al. *in prep.*).

3.2. **POSSUM data checks.** To automatically verify the entries in the PPC we will carry out a series of automated tests. Data that fail these tests will be flagged. Note that for our purposes a flag is not the same as deleting data - it simply means applying a marker to a data column against a data product. By doing this, unusual or unexpected results are visible for investigation and error. As the survey progresses through the simulations and BETA phases, we will learn what limits are appropriate for actual deletion or disregarding of data. The tests to be applied to the PPC include:

- Flag upper limits to polarized intensity (where P $< 5\sigma_{RMS}$, quote upper limit).
- Flag $\%P >$80% and $\%P <$0%.
- Flag values of P above 5000 Jy.
- Flag sources where Stokes V $> 5\ \sigma_{RMS}$.
- Flag values of |Q| or |U| $>$ 5000 Jy.
- Flag entries where |RM| is greater than maximum value that can be measured.
- Flag sources where bmaj or bmin $<$ synthesised beam size
- Flag sources where polarization position angle $> 180°$ or $< 0°$.
- Flag sources where P/I or V/I is less than error in instrumental polarization.

- Flag sources where position does not match central pixel of the corresponding postage stamp (tolerance = 1 pixel width).
- Flag sources where peak and/or integrated flux do not match peak/integrated flux from the corresponding postage stamp (tolerance to be determined).
- Flag sources where errors (in P, RM, polarization position angle) differ from theoretical estimates (tolerance to be determined).
- Flag sources where change in Q,U across band differs from expectation. For simple sources in the PPC, Q,U $\propto \lambda^2$.
- Flag sources where the polarization leakage terms are greater than -25dB.
- Verify that the bias correction has been calculated and applied correctly. WG2 are currently investigating debiasing and once the results are known they will be incorporated into our data verification plan.

A full and final description of these tests (including tolerances) will be given in POSSUM report 23 (deadline June 15th 2011).

In addition to these checks on individual catalogue entries, we will also check some global properties of the PPC. For each 30 square degree field, we will generate a histogram of polarization position angle. As the survey progresses, we will create a running sum of these histograms (following Battye et al. 2008) with the purpose of detecting any systematic effects. We will also run tests (methods to be decided) to ensure that the polarization leakage, after calibration, remains within the POSSUM specifications.

3.3. **Towards data verification of the PPA.** The PPA will contain information on every polarized source found in the ASKAP survey field. Verification of the PPA will require additional stages to that of the PPC, including checking of the source-finding algorithms, image fitting and identification of multiple RM components. For the images of polarized intensity, data verification will include measurement of noise levels and the presence of spurious signals due to sidelobes.

- Check that P at central RA, Dec of the image matches P of catalogue source.
- Check whether S/N of polarized intensity postage stamp image corresponds correctly to the quoted error in RM (tolerance to be determined).
- Flag entries where secondary peaks in a cleaned RM spectrum lie in sidelobes of the rotation measure transfer function (criteria to be determined).