POSSUM Report 24: Constructing the PPC

1 Introduction

This report is a specification of the steps to be carried out in order to produce the POSSUM Polarization Catalogue (PPC), and identifies who is responsible for delivering the algorithms to compute catalogue values. This process is handled by modules 2.6, 2.7, and 2.3 (as seen in Fig. 1, which outlines the flow of data through the POSSUM pipeline), though some entries will originate in other modules.

Table 1 lists the relevant PPC entries, where the quantities will be calculated in the pipeline, and who will develop the algorithms. In §2, we outline the relationship between the three relevant working groups. In §3, for each catalogue entry, we will describe the current default method of calculating this quantity, summarise what more needs to be done, and what PR will describe the outcomes of these investigations. In §4, we give a brief description of the PRs listed in Table 1.

2 Coordination of WGs 2, 5, & 8

The source-finding (WG 2) and RM-Synthesis (WG 8) working groups are primarily responsible for developing the algorithms to calculate the entries in the PPC. The first person listed in column *d* of Table 1 will lead the algorithm development and testing, in collaboration with the others listed. The chairs of WGs 2 (Stil) and 8 (Gaensler) are responsible for insuring the quality and appropriateness of the algorithms, while it is the responsibility of the WG 5 chair (Harvey-Smith) to coordinate the timely production of the PPC algorithms in general, and the writing of the subsequent PRs in particular.

Catalogue Entry[a]	Module[b]	Report[c]	Person[d]
emu_id	EMU catalogue	NA	NA
emu_comp	EMU catalogue	NA	NA
e^e	EMU catalogue	NA	NA
$\mathcal{I}, \mathcal{Q}, \mathcal{U}, \mathcal{V}$	2.1	51	Banfield
$\delta\mathcal{I}, \delta\mathcal{Q}, \delta\mathcal{U}, \delta\mathcal{V}$	2.1	51	Banfield
$P(\lambda^2)$, $\delta P(\lambda^2)$	2.6, 2.7	61	Sun
$\mathbf{P}_C(\phi)$, $\delta\mathbf{P}_C(\phi)$, $\mathbf{P}_{C,ann}(\phi)$	2.6	52	Sun/Gaensler
RM_0, $\delta\mathrm{RM}_0$	2.6	52	Sun/Gaensler
θ_0, $\delta\theta_0$	2.6	52	Sun
P, δP	2.6, 2.7	61	Sun
P^+	2.3	55	Stil
V, δV	2.6, 2.7	61	Sun
V^+	2.3	55	Stil
f, δf	2.6, 2.7	61	Sun
f^+	2.3	55	Stil
s	2.4	58	Brown
r_1	2.6	56	Harvey-Smith/Purcell
r_2	2.7	56	Harvey-Smith/Purcell

Table 1: a) Symbol for the PPC entry, described in detail in POSSUM Report #7; b) The module where the entry will be calculated (see Fig. 1); c) The POSSUM Report number where the algorithm will be described; for #24, it will outline the time line and report numbers in which each of these algorithms will be provided; d) The primary person(s) responsible for leading the development of the algorithm; e) e is a flag from the EMU catalogue indicating whether a source is extended or not. The horizontal line delineates spectral quantities which are functions of channel or rotation-measure (above) from those that have a single band-averaged quantity (below).

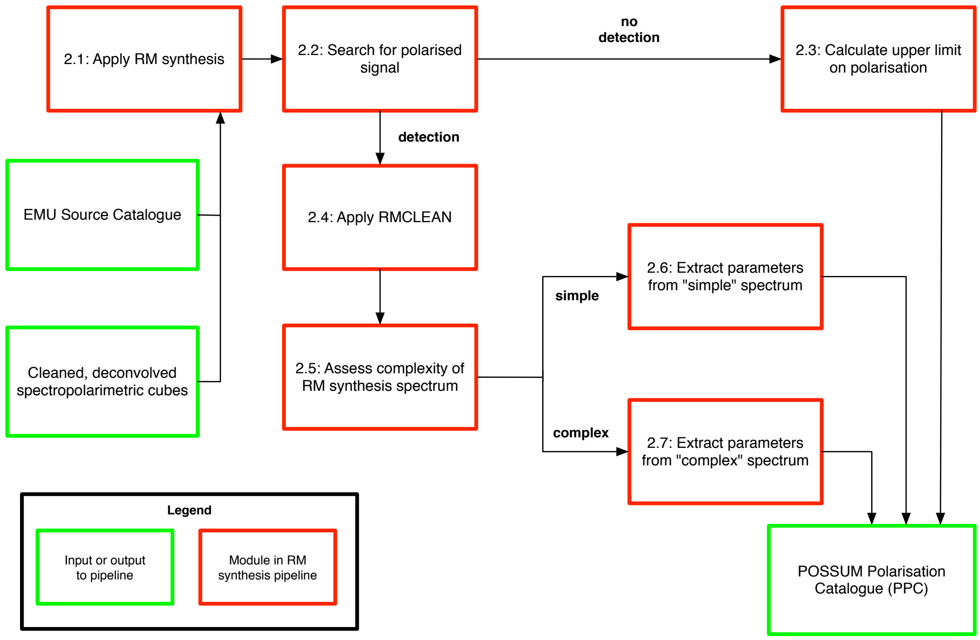

Figure 1: A flowchart for the POSSUM RM pipeline, reproduced from POSSUM Reports #5 & #7.

3 Constructing the Catalogue

3.1 Calculation of $\mathcal{I}, \mathcal{Q}, \mathcal{U}, \mathcal{V}$

These are postage stamp cutouts of all of the sources. The exact size of the postage stamps will be determined at a later date, and presented in PR #51.

3.2 Calculation of $\delta\mathcal{I}, \delta\mathcal{Q}, \delta\mathcal{U}, \delta\mathcal{V}$

These are noise maps associated with the postage stamp images, and will be produced from the residual images after cleaning of the individual channel maps. These will allow noise weighted averages of the spectral data. The exact specification of these images will be outlined in PR #51.

3.3 Calculation of $I(\lambda^2), Q(\lambda^2), U(\lambda^2), V(\lambda^2)$

These are one-dimensional spectra of the EMU source produced by a weighted sum of the 5×5 pixel grid centred on the peak EMU pixel (see PR #14).

3.4 Calculation of $\mathbf{RM}_0$, $\delta\mathbf{RM}_0$

As per PR #7, RM_0 is the dominant rotation measure of the polarized source. The current default method to calculate RM_0 (outlined in PR #1 with modifications outlined in PR #14) is to 1) apply RM-synthesis on the 5×5 pixel summed spectrum (see PR #14) centred around the peak of the EMU source, 2) deconvolve and restore this spectrum using RM-Clean (see P.R. #41), then 3) if the spectrum is determined to be simple (see PR #9), fit a parabola to the peak of the cleaned spectrum and find its location ($\phi_{peak} \equiv \mathrm{RM}_0$). The uncertainty in RM_0 is calculated using the formula of Brentjens & de Bruyn (2005);

$$\delta RM_0 = \frac{\sigma_\chi}{\sigma_{\lambda^2}\sqrt{N-1}} \tag{1}$$

where N is the number of channels, σ_χ is the uncertainty in the polarization angel given by

$$\sigma_\chi = \frac{\sqrt{Q^2\sigma_Q^2 + U^2\sigma_U^2}}{2|P|^2} \tag{2}$$

and σ_{λ^2} is the dispersion in the λ^2 coverage. In theory σ_{λ^2} will be a fixed number for POSSUM, though the flagging of channels due to RFI will alter the distribution as a function of time.

We are also exploring alternative methods of calculating RM_0, including compressive sampling (Li et al. 2011) and maximum likelihood methods (O'Sullivan et al. in prep.). Our final specification for calculation of RM_0 will be presented in PR #52.

3.5 Calculation of $\mathbf{P}(\phi)$, $\delta\mathbf{P}_C(\phi)$, and $\mathbf{P}_{C,ann}(\phi)$

$\mathbf{P}_C(\phi)$ and $\delta\mathbf{P}_C(\phi)$ are the Faraday spectrum and corresponding uncertainties for the 5×5 pixel sum centred on the EMU source, and $\mathbf{P}_{C,ann}(\phi)$ is a "background" Faraday spectrum averaged over an annulus around the source.

See P.R. #1 for a description of RM-Synthesis. These spectra will be deconvolved and restored, and the deconvolution process will be described in P.R. #52.

3.6 Calculation of θ_0, $\delta\theta_0$

These are the polarization angle at $\lambda^2 = 0$ and its uncertainty for the 5×5 pixel sum centred on the EMU source. Once the RM_0 and the polarization angle within the POSSUM band is calculated (θ_{λ^2}), then the we get

$$\theta_0 = \theta_{\lambda^2} - RM_0\lambda^2. \tag{3}$$

The final specification for how (θ_0, $\delta\theta_0$) will be calculated will be outlined in PR #52.

3.7 Calculation of f, δf

As the RM-synthesis will be performed on $(q, u) \equiv (Q/I, U/I)$, the peak value found by fitting $F(\phi)$ will be the band-averaged fractional polarization of the source, $f_{peak} \equiv F(RM_0)$. We must first correct for any variation in the background, so $f = f_{peak} - F_{ann}(RM_0)$. The uncertainty, δf will be calculated using ... The final specification for how this will be calculated with be outlined in PR #61.

3.8 Calculation of P, δP

Once f is calculated, P is found by multiplication, $P = fI$, where I is the band averaged value of the 5×5 pixel sum of $I(\lambda^2)$. The final specification for how this will be calculated with be outlined in PR #61.

3.9 Calculation of V and δV

This is simply the bad-averaged value of the $V(\lambda^2)$ and its uncertainty is calculated as $\delta V =$. The final specification for how this will be calculated with be outlined in PR #61.

3.10 Calculation of P^+, V^+ and f^+

Upper limits on the polarized intensity P^+, Stokes V V^+, and fractional polarization f^+ will be described in PR #55.

3.11 Calculation of s

The calculation of the complexity parameter s is described in PR #9. The value of $s = 0$ means that the source is simple, and other values will describe the degree and/or type of complexity. These other values, as well as the method for calculating the threshold at which sources are considered complex, will be outlined in PR #58.

3.12 Calculation of r_1 and r_2

These are tables of quality codes for the key PPC parameters (RM_0, θ_0, P, f, S) and their errors; r_1 is for simple sources and r_2 is for complex sources (and thus only for P, f, and S). $r_i = 0$ for acceptable values, while $r_i > 0$ indicates problems; these values will be outlined in PR #56.

4 Outline of Future POSSUM Reports

4.1 PR #51: Specification of Postage-Stamp images and Residuals

This report will outline how large the postage stamps need to be, and how the residual noise images should be produced.

4.2 PR #52: The Optimum Rotation-Measure Synthesis

This report will specify our choice of algorithm to produce the Faraday spectrum of the source, including deconvolution, weighting and other issues that affect the determination of RM_0 and its derivative products. *This is the first workhorse memo of the series!*

4.3 PR #55: Specification of calculation of upper limit on Stokes parameters

This report will specify the calculation of upper limits of P^+, V^+ and f^+. This will require the injection of fake sources into the POSSUM pipeline and finding the minimum detectable signal.

4.4 PR #56: Determining Data Quality Flags

This report will outline how we will determine which products are of good quality and which are not; in particular, the detailed accounting of what the values of r_1 and r_2 mean.

4.5 PR #58: The Threshold for Complexity

This report will calculate the threshold on $\delta\phi_M$ above which we consider a source complex (see PR #9).

4.6 PR #61: Calculating Source Stokes Parameters

This report will outline our calculation of all the Stokes parameters for the EMU sources, including derivative products such as θ_0. This report also specifies how upper limits on the Stokes parameters will be calculated. *This is the second workhorse memo of the series! Modeling will need to be done.*