Mapping of difficult 3C sources

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Summary. Maps have been made by hand of some sources that were slow to converge using the automatic mapper written by Marinus Israel, and two that failed to converge. The purpose was to find out whether they could be made to converge, and if so what major-loop algorithm was optimal. Convergence was achieved in each case using four loops; two of phase-only selfcalibration and two of amplitude selfcalibration.

Objects mapped. The sample of objects selected were those which had been found to be problematic for the `autocal` script (typically with >20 iterations of selfcal/cleaning: 3C69, 3C431, 3C452) and those which failed to converge in the automapper: 3C35 and 3C58. The data considered were measurement sets of about 6h long which had been carried out as part of multiple-beam observations. They had previously been demixed to remove A-team sources by Marinus Israel.

Objects were mapped by hand in Difmap. Major cycles were performed using either phase or amplitude selfcalibration. This typically took about 0.3-0.5 seconds per selfcalibration. It was impractical to run these tests in BBS, due to the factor >100 longer processing time needed for each selfcal.

Starting models were generated using VLSS. These consisted of either one or two point components. The fluxes of these point components were, however, adjusted by hand to correspond roughly to the visibilities in the measurement sets.

Method and results. All datasets converged to satisfactory results using essentially the same algorithm, involving four major cycles. This proceeded as follows:

1. Data were read into uvfits and the XX polarization selected for analysis, together with the VLSS model.

2. Data were edited to remove international baselines. They were also edited to remove data on short baselines, in cases where external sources were obviously present. For some sources (3C452) this entailed removal of only baselines shorter than a few hundred metres; for others in which CasA is still a problem (3C35, 3C58) data on baselines shorter than a few km were deleted.

3. An initial phase-only selfcalibration using the VLSS model was done. Data were inverted and an initial clean was done based on the brightest one or two peaks in the residual map.

4. A second phase-only selfcalibration was done.

5. A second clean was done, with windows set so as to avoid any component which was a mirror reflection of any other component.

6. Two more loops of cleaning and selfcal were done. These selfcalibrations consisted of one phase+amplitude selfcal with a long solution interval (typically 60 min) and one with a shorter interval (10-20 minutes). Any component significantly above the noise was windowed in the clean before the second amplitude selfcal. Cleaning was done with uniform weighting.

Results. The final maps are shown in figure 1. They typically have dynamic ranges (peak:rms) of about a hundred. All seem to have converged satisfactorily, and where other low-frequency maps are available the structures agree.

To do. It may be worth while to attempt to implement this algorithm in BBS, so that it can run through automatically. The difficult bit is likely to be the implementation of the CLEAN windowing in between the selfcalibrations; if an erroneous component is included in the model in the first amplitude selfcal it is very difficult to get it out again. **Opinion**: if mirrored components are excluded before the first three of the four selfcalibrations this should avoid such problems. This is particularly the case in 3C69 where a mirrored component appears in the residual map. **Opinion from previous experience rather than these tests**: exclusion of real components which are in the position of mirror reflections of others, during the first three major loops, should not cause them to disappear from the model, provided that the array has more than 6-10 elements.

Opinion: I think we do have to consider the approach to be adopted in the quasi-linear regime (A-team previously removed by demixing; dominant source in the centre of the field; better model of this dominant source required before later application of this model to further investigation of the field). The reason is simply speed, and in particular the factor of >100 difference in the selfcalibration part of the loop[1]. Mapping a subband by hand takes about 5 minutes, including the conversion to FITS. CLEAN components from the bright source can then be written back into BBS for further analysis.

Software available: I wrote a script for generating Difmap model files from the VLSS catalogue, which is available on `/home/jackson/vlss_out.py`. It also needs the VLSS catalogue (available from the VLSS website), together with `/home/jackson/modconvert.py` and the `astLib` library. It generates a BBS skymodel as well as the difmap model file.

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[1]For the 3C452 data, selfcalibrating to a model with 2 components and with the differential gain switched off, BBS takes 36 minutes on an otherwise empty 2-GHz cluster node using max-iter=200, or 12 minutes with max-iter=20. The same data in Difmap on my 2-GHz laptop with no other processes takes about 1.3s for the data edited in the same way for 1 polarization, so 5s for all polarizations (factor 120-430 difference, depending on number of iterations)
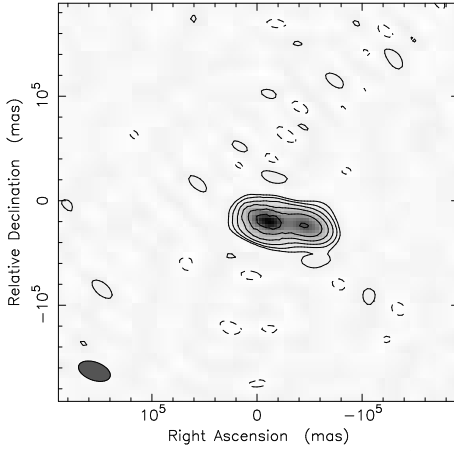
3C69

Clean XX map. Array: LOFAR
BEAM_30 at 0.058 GHz 2011 May 21
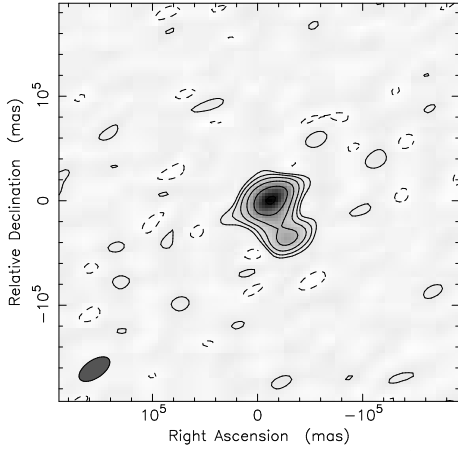
Map center: RA: 02 38 04.080, Dec: +59 11 56.400 (2000.0)
Map peak: 0.0171 Jy/beam
Contours: 0.0005 Jy/beam x (−1 1 2 4 8 16 32)
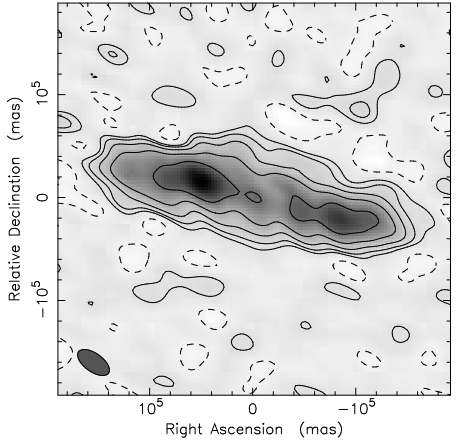Beam FWHM: 3.35e+04 x 1.71e+04 (mas) at −55.9°

3C431

Clean XX map. Array: LOFAR
BEAM_19 at 0.058 GHz 2011 May 21

Map center: RA: 21 18 53.588, Dec: +49 37 19.199 (2000.0)
Map peak: 0.0246 Jy/beam
Contours: 0.0005 Jy/beam x (−1 1 2 4 8 16 32)
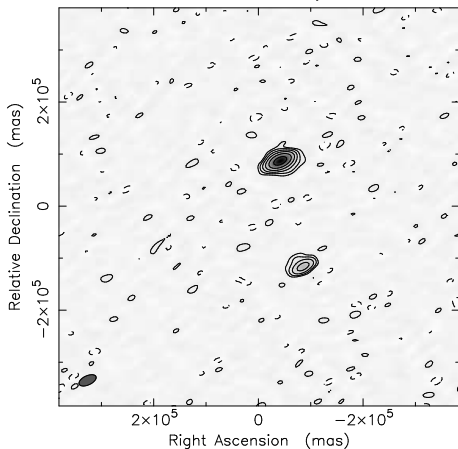Beam FWHM: 3.17e+04 x 1.73e+04 (mas) at 69.8°

3C452

Clean XX map. Array: LOFAR
BEAM_2 at 0.058 GHz 2011 Apr 30

Map center: RA: 22 45 48.800, Dec: +39 41 16.000 (2000.0)
Map peak: 0.0152 Jy/beam
Contours: 0.0005 Jy/beam x (−1 1 2 4 8 16)
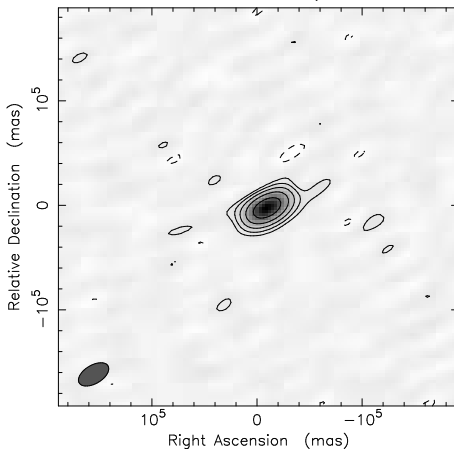Beam FWHM: 3.58e+04 x 1.79e+04 (mas) at 54.5°

3C35

Clean XX map. Array: LOFAR
BEAM_16 at 0.058 GHz 2011 May 21

Map center: RA: 01 12 04.320, Dec: +49 26 13.200 (2000.0)
Map peak: 0.0138 Jy/beam
Contours: 0.0003 Jy/beam x (−1 1 2 4 8 16 32)
Beam FWHM: 3.52e+04 x 1.77e+04 (mas) at −65°

3C58

Clean XX map. Array: LOFAR
BEAM_17 at 0.058 GHz 2011 May 21

Map center: RA: 02 05 33.870, Dec: +64 49 44.192 (2000.0)
Map peak: 0.0132 Jy/beam
Contours: 0.0005 Jy/beam x (−1 1 2 4 8 16)
Beam FWHM: 3.2e+04 x 1.76e+04 (mas) at −59.1°

Figure 1: Maps of the 3C objects analysed.