MERLIN – A PHASE-STABLE 'VLBI' ARRAY

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Abstract. The recent upgrading of MERLIN has resulted in a much improved array with both increased sensitivity and higher angular resolution. At L-band and higher frequencies the array is now operated in a manner similar to the VLA with routine phase calibration every few minutes using a nearby compact source. An automatic data analysis "pipeline" has been developed using AIPS software. This enables MERLIN data to be routinely processed to produce images in all Stokes parameters and with positional accuracy much better than the size of the restoring beam.

Key words: MERLIN – Phase-stable Array – Automated Data Processing

1. Upgraded MERLIN

MERLIN has recently been upgraded with the addition of a new 32m antenna at Cambridge together with improved low-noise receivers and wide-band μ-wave radio links. This has increased the angular resolution of MERLIN with baselines now extended to 220 kms. The new wide-band radio links now return both hands of circular polarization from the outstation antennas; each with a bandwidth of 16MHz. Over the past year the enhanced array has been commissioned and is now in full operation at 5GHz. Typically an imaging run of around 15 hours will yield RMS noise levels around 50-60μJy beam^{-1} with angular resolution around 50 mas.

2. Phase-stable Operation

At radio frequencies of 1.4GHz and above MERLIN now operates in a manner similar to the VLA with routine phase calibration every few minutes using a nearby compact source. In addition, the outstation receiver local oscillators are all phase-locked to Jodrell Bank via a two-way L-Band link along the same physical path as the returning μ-waves; thus link-path phase changes are measured and corrected online (Thomasson 1986). The phase stability of MERLIN is limited by atmospheric and ionospheric path length fluctuations. At 5GHz tropospheric activity is the dominant cause of phase instability. At elevations above 15 degrees such phase excursions can be routinely removed by phase calibration with a nearby compact source with typical cycle times of 10 minutes (8 on the target and 2 on the phase calibrator). Experience over the last year indicates that phase calibration is successful for in excess of 90% of the observing time. The situation deteriorates with decreasing elevation and for very low declination objects close phase calibrators (within 2 - 3 degrees) and shorter cycle times are required. Successfully phase calibrated images have dynamic ranges (peak to RMS) of between 100 and 200:1.

The northern sky has been searched for suitable phase calibrators for MERLIN and a list of several thousand has been established such that any target should lie within about 3 degrees of a suitable phase calibrator (Patnaik *et al* 1992a).Such calibrators do not have to be points but must contain compact structure (unresolved to Cambridge) at a few tens of mJy.

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The correction of instrumental polarization leakage is routinely performed with standard AIPS procedures using the phase calibrator - provided it contains compact structure stronger than 200 mJy. Such corrections are stable on timescales of days and may thus be carried across from adjoining observations should a particular phase calibrator prove too weak. After correction, leakage terms on a baseline are around 0.5% resulting in spurious polarization structure in test images at the 0.1-0.2% level.

3. Data Processing

In addition to hardware improvements, much effort has been made to ease the use of MERLIN by external observers. After an initial interactive calibration and data flagging pass the data are converted to disk FITS files which are then accessed by an automated 'Pipeline' procedure in AIPS.

The MERLIN AIPS 'Pipeline' runs from a complex runfile generated by a short interactive programme. It accesses FITS files generated from the initial procedure on the target, phase calibrator, point source calibrator and polarization position angle calibrator all of which will have been scheduled with your observations. 'Pipeline' performs the following: It assembles all the data into a single multifile. It performs final calibration corrections derived from the point source calibrator. It maps the phase calibrator from a point source performing 3 passes of phase and a single pass of gain selfcalibration. It solves for the polarization instrumental residuals. It calibrates the position angle of polarization. It calibrates and maps the target source. It performs up to 10 cycles of subsequent selfcalibration on the target if requested. Also, of order 50 intermediate and final contoured maps and solution plots are automatically produced.

The full procedure takes typically 5 hours to run on an empty Sun Sparc 10 workstation. An example automated run is shown here for the gravitational lens 1422+231 (Patnaik *et al* 1992b). The run is an amalgamation of two observations separated by 3 days; the first curtailed early by system failure, the second missing Cambridge for the last 6 hours. It is not a carefully selected 'best case' example and still contains poor data missed in the initial flagging pass. Figure 1 shows the final phase solutions found from the phase calibrator 1424+240 for the first and second days respectively. Telescope gain corrections were around +/- 10% during both runs. The gap around 18:00 on each day is a calibration scan. Figure 2 shows the final selfcalibration phase solution on the target for the second day. This illustrates the phase errors still present in the data after phase calibration. Note that errors increase at low elevation at each end of the run on the more distant antennas (1, 2, and 3). Phase corrections on Cambridge shortly before failure are indicative of impending system problems. Figure 3 shows the phase calibrated image with a dynamic range around 100:1. Figure 4 is the image after 10 subsequent cycles of selfcalibration. Figure 5 shows the polarized image with detected ratios of 0.9%, 0.9%, and 0.8% for the three bright images running NE to SW. The fourth image is only 3.74 mJy in total intensity and thus lies below the detection threshold in the polarized image. Figure 6 shows the position angles are very similar but not exactly the same with measured values of -52, -55, and -49 degrees respectively.

References

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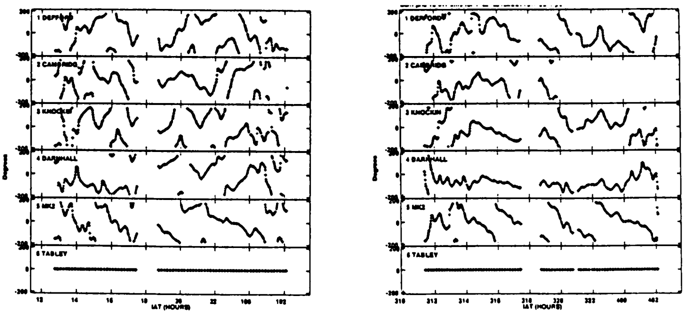

Fig. 1. Phase Solutions For Both Days Derived From 1424+240

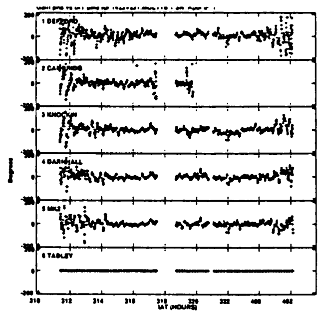

Fig. 2. Final Selfcalibration Phase Solution For Day 2 On 1422+231

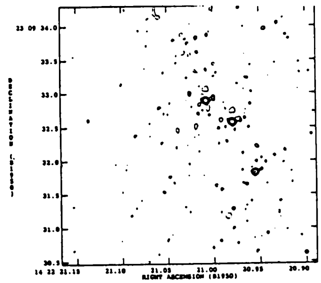

Fig. 3. Phase Calibrated Image of 1422+231

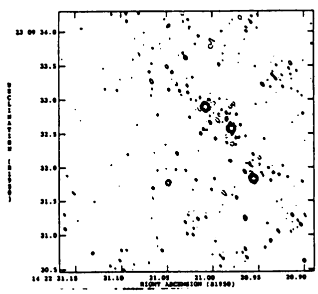

Fig. 4. Final Image of 1422+231 After 10 Cycles Of Phase Selfcalibration

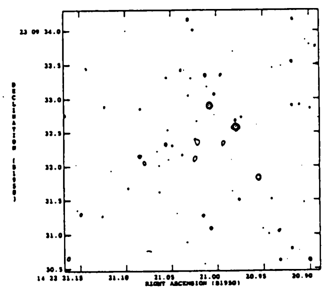

Fig. 5. Image of 1422+231 In Polarized Flux Density

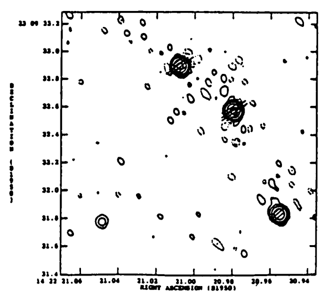

Fig. 6. Map Of 1422+231 In Total Intensity With Polarized Intensity Marked As Vectors