Imaging VLBI polarimetry data for Active Galactic Nuclei using the Maximum Entropy Method

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Abstract

Mapping the relativistic jets emanating from AGN requires the use of a deconvolution algorithm to account for the effects of missing visibilities and thermal noise. The CLEAN algorithm is the most commonly used algorithm in VLBI imaging. The Maximum Entropy Method (MEM) is a relatively little-used alternative with some advantages over CLEAN, including better spatial resolution and a more rigorous and unbiased approach to deconvolution. We have developed a MEM code suitable for deconvolving VLBI polarimetry data. Some results of its application to real multi-wavelength VLBI polarimetry data are presented.

The Maximum Entropy Method (MEM)

Consider the function

$$J = H(I_m, P_m) - \alpha\chi^2(V_{Im}, V_d) - \beta\chi^2(V_{Pm}, V_d) - conditions$$

where H is the entropy of a model map of the source [1] and χ^2 is a measure of the difference between the model and observed visibilities (there are two χ^2 terms, one for intensity and a second for polarisation). α and β are Lagrange parameters and other conditions are also included which represent additional constraints, such as positivity of the Stokes I component [1-3].

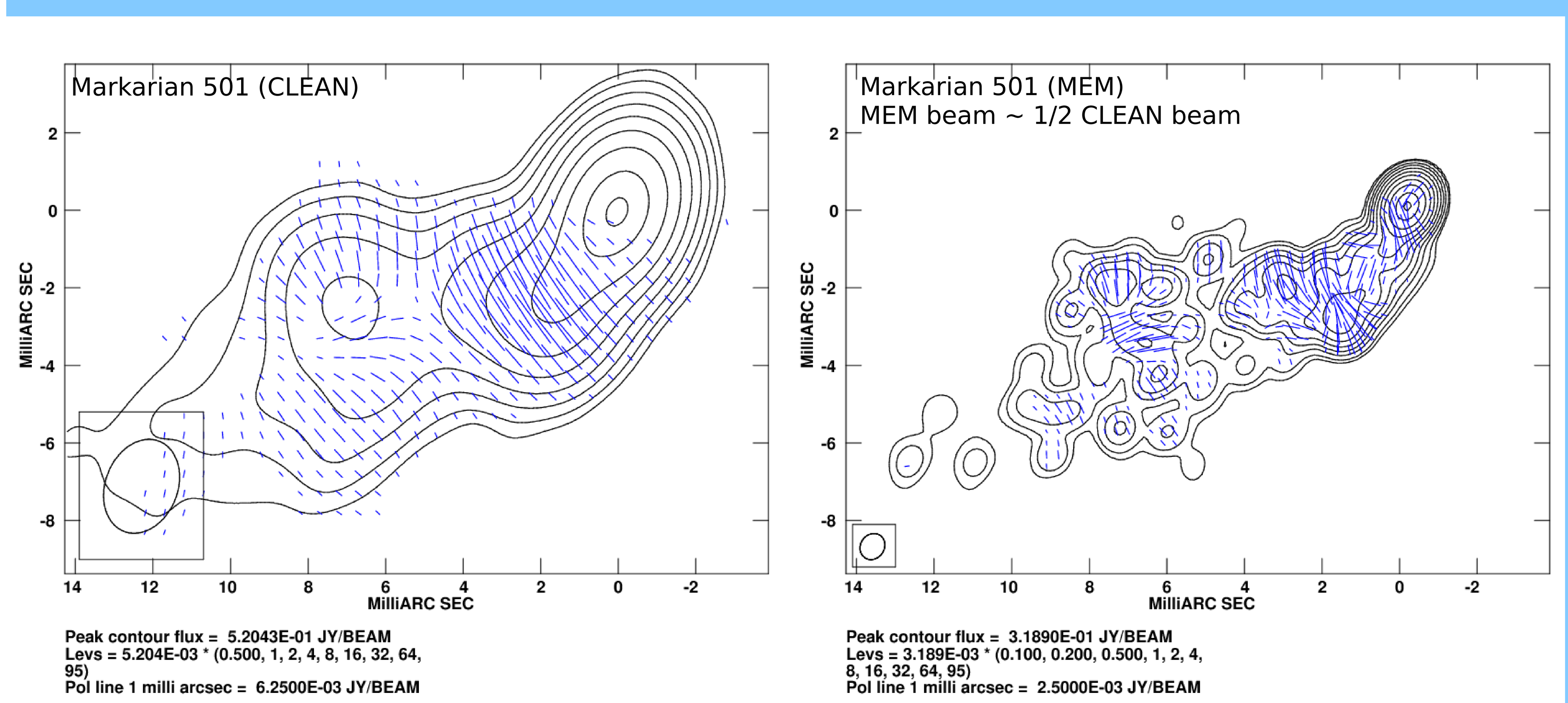
A model of the source is developed to maximise the function J. This results in a balance between entropy (representing noise, and the effect of unsampled visibilities) and fidelity to observed data.

Unlike the standard CLEAN algorithm, MEM does not model the source as a series of delta functions. This increases the effective resolution of MEM as it is not necessary to convolve the MEM model with the full CLEAN beam. This means that the resolution of MEM is the Nyquist sampling limit for the observation, although thermal and systematic noise may prevent drawing useful information at such small scales.

Monte Carlo Simulations

A C++ program based on the AIPS task “VTESS” and the MIRIAD task “PMOSMEM” was written to perform a MEM deconvolution of VLBI polarisation data. To ensure that the code was operating correctly and characterise the behvaiour of the MEM based deconvolution, Monte Carlo simulations of the deconvolution of simulated sources were performed. The code performed well in deconvolving small Gaussian sources: the MEM model map recovered the correct FWHM of the model Gaussian map.

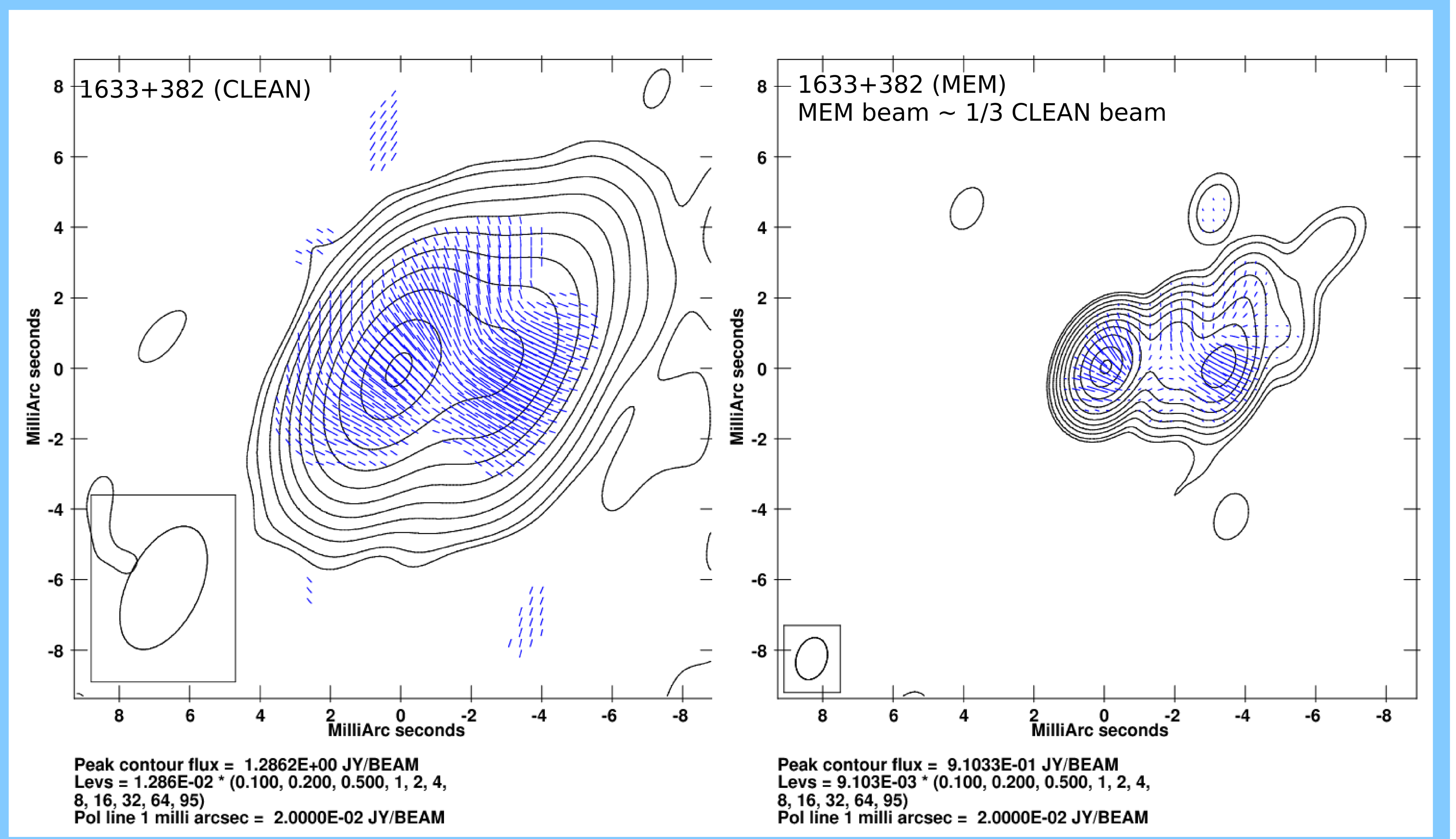
Results - Markarian 501



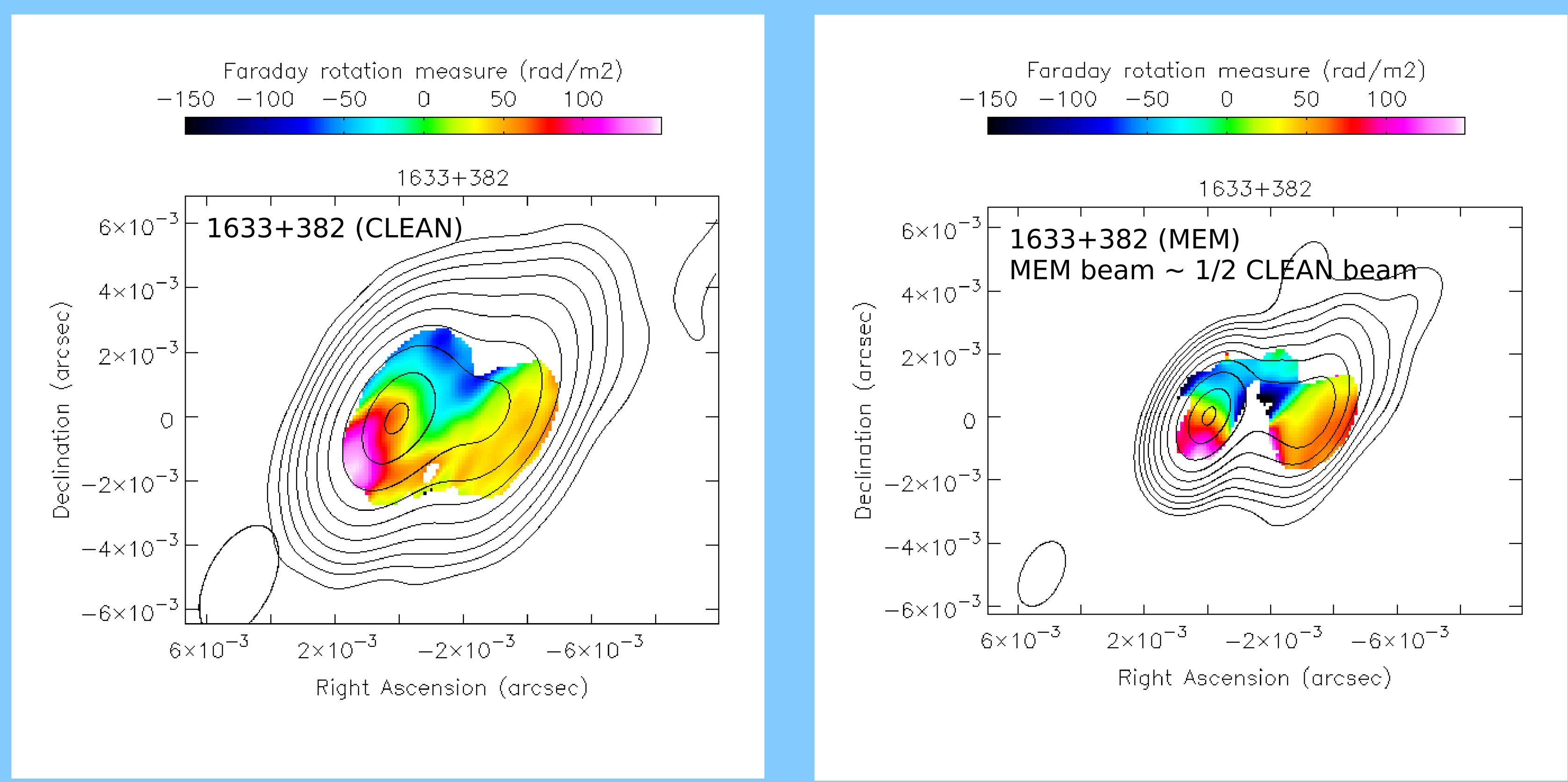
Markarian 501 has an extended, bent jet with a “spine-sheath” polarisation structure visible in some places (see above, and [5]), which was fitted using a helical magnetic-field model in [4]. The MEM map shows this spine-sheath polarisation structure about 8 mas from the core more clearly, and also reveals the polarisation structure of the inner jet in much more detail.

Results - 1633+382

This jet also shows transverse polarisation structure, but the available CLEAN resolution is not sufficient to discern its nature (below left). The higher resolution offered by MEM shows the polarisation structure more clearly, in particular, the presence of orthogonal polarisation (longitudinal B field) along the top half of the jet and longitudinal polarisation (orthogonal B field) along the botton half of the jet 1.5-2 mas from the core (below right).



The CLEAN Fardaday rotation measure (RM) map constructed using VLBA data at 2-6cm provided evidence for a transverse RM gradient across the jet, possibly due to a helical B field [6]. The higher-resolution MEM RM map confirms this transverse RM structure, with a clear sign change in the RM from the Northern to the Southern part of the jet.



Summary

Software to implement a MEM-based deconvolution of VLBI polarimetry data has been written and tested with Monte Carlo simulations. Some first results demonstrating its enhanced resolution over CLEAN have already been achieved. Future work will include multi-wavelength studies of sources with interesting polarisation structure at 2-6cm and 18-22cm.

References

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