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First Results of 1.4–5.0 GHz VLBA observations of the MOJAVE–II AGNs

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We are in the process of obtaining and analysing VLBA polarisation data for the 191 Active Galactic Nuclei (AGNs) in the MOJAVE-II sample at 5.0, 2.3, 1.7 and 1.4 GHz (6, 13, 18, 21 cm) obtained in Summer 2017 – Spring 2018. This is the first set of simultaneous observations in this frequency range for a large sample of AGNs, and will enable studies of the evolution of the intensity and magnetic-field structures of these AGN jets as they propagate from parsec to kiloparsec scales. This frequency range was chosen especially to enable sensitive and detailed spectral and Faraday-rotation mapping on scales out to tens to hundreds of parsec from the core at the typical distances of AGNs. The individual-pixel uncertainties in the Faraday rotation measure provided by these observations are typically less than 2–3 rad/m^2 — about a factor of 3–5 lower than 1.4–1.7 GHz RM images and a factor of 50–100 lower than 8–15 GHz RM images previously published in the framework of the MOJAVE project. Some first results from this new project are presented, highlighting the high sensitivity of the data to intensity, polarization and Faraday rotation on a wide range of scales.

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1. Introduction

In the standard theoretical model, AGN jets are electromagnetically launched and carry helical magnetic (**B**) fields, which come about due to the rotation of the black hole and accretion disk plus the jet outflow "winding up" the longitudinal component of an ambient seed field (e.g., [1]). Observations of Faraday Rotation — a change in the observed polarisation angle χ_{obs} when an electromagnetic wave propagates through a region with plasma and magnetic field — can be used to search for evidence of this predicted helical jet **B** field. Since the Faraday rotation measure (RM) depends on the line-of-sight component of the magnetic field in the region of Faraday rotation, the RM can trace the systematic change in the line-of-sight **B** field across the jet, manifest as a corresponding monotonic gradient in the RM. Maps of the RM can be produced using aligned sets of radio polarization images at multiple wavelengths, with the RM determined for each pixel by fitting a linear relationship to the dependence of χ_{obs} on the wavelength squared, λ^2: $\chi_{obs} = \chi_o + RM\lambda^2$ for external Faraday rotation, where χ_o is the emitted polarization angle.

2. Our New Observations

We are in the process of obtaining and analysing observations of the 191 AGNs in the MOJAVE-II sample [2] with the Very Long Baseline Array (VLBA) at 5.0, 2.3, 1.7 and 1.4 GHz. One of the main goals of this project is Faraday-rotation image of the jets of these AGN, but these observations will also provide a wealth of information about the morphology and spectral distributions of these jets on scales out to tens, or in some cases, hundreds, of parsec from the core.

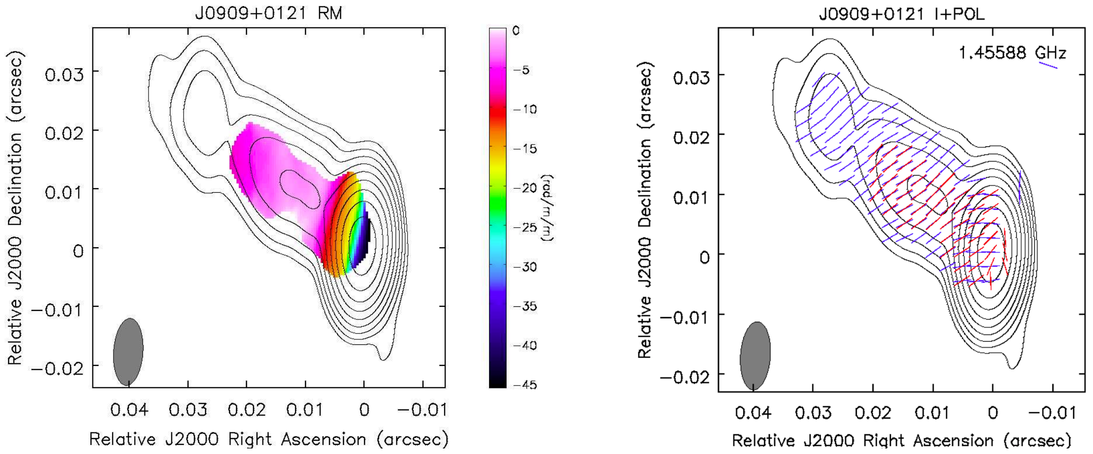

Figure 1: **Left:** RM map of J0909+0121 with 1.46 GHz intensity contours superposed. **Right:** Same 1.46 GHz contours overlaid with observed (blue) and Faraday-rotation corrected (red) 1.46 GHz polarisation angles.

These new observations were obtained in a series of short VLBA runs during Summer 2017 – Spring 2018. Each source was observed in a snapshot mode, with 10 scans of duration 115 seconds, at an aggregate bit rate of 2048 Mbits/s. All the calibration and imaging for the results presented here was done in AIPS using standard techniques, apart from the RM fitting and imaging, which was done in CASA, also using standard techniques. Examples of results from the first run for the project that was fully calibrated and imaged (8 AGNs) are presented here.

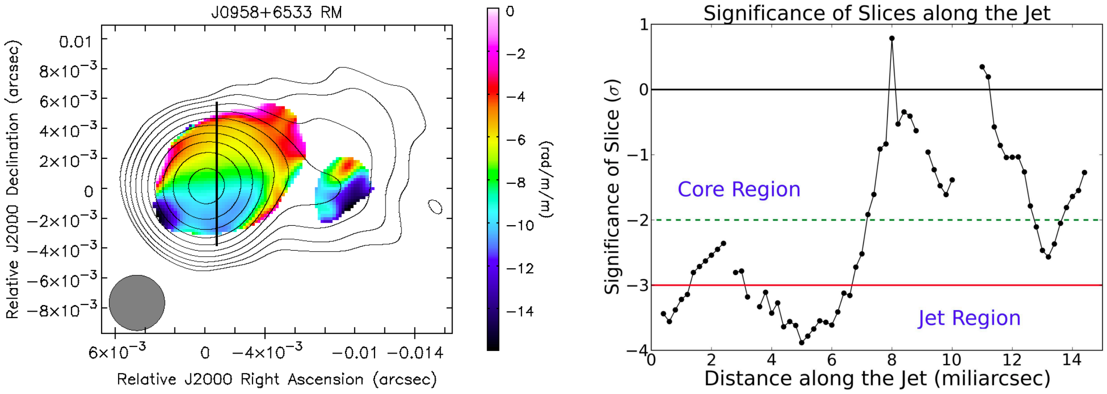

Figure 2: **Left:** RM map for J0958+6533 with 1.46-GHz intensity contours superposed. **Right:** Signifigances of RM gradients for a series of RM slices across the jet, as a function of distance along the core–jet structure. The dotted green and solid red lines show the 2σ and 3σ levels. The negative significances reflect the fact that the slices were taken downward across the RM distribution.

3. Results: Mapping of B Fields and Polarisation Structure.

J0909+0121. The left panel of Fig. 1 shows our RM map with 1.46 GHz intensity contours superposed. The RM is enhanced in the core region, and falls off to less than 5 rad/m^2 beyond about 5 mas from the core. For comparison, Faraday rotation could be measured only in the core in the high-frequency RM image of [3]. The right panel of Fig. 1 shows the 1.46 GHz polarisation angles as observed (blue) and corrected for the observed RM where possible (red). The corrected and uncorrected angles agree well in the jet, where the RM is low; correcting for the observed RM brings the polarizaton angles in the core into better agreement with the overall polarization structure, implying a **B** field that is aligned with the jet throughout the observed structure.

J0958+6533. The left panel of Fig. 2 shows our RM map, which shows a region of transverse RM gradients in the core and inner jet. The right panel shows a plot of the significances of monotonic transverse RM gradients detected by taking a series of RM slices across the jet, calculated as described by [4], at various distances along the observed core–jet structure. This shows a fairly extended region in the core and innermost jet where the significances of the transverse RM gradients exceed 3σ, providing firm evidence of a helical jet **B** field.

J0948+4039. The left panel of Fig. 3 shows our RM map, which shows transverse RM gradients in opposite directions in the core region and in much of the jet. The right panel shows a plot of the significances of a series of RM slices with distance along the core–jet structure, again calculated as described by [4]. This indicates the presence of statistically significant transverse RM gradients in both the core region and jet; the opposite directions of the gradients in different regions are reflected by the different signs of the calculated significances. The toroidal fields that generate these oppositely directed RM gradients could be associated with a “nested” helical magnetic field structure similar to a coaxial cable [5].

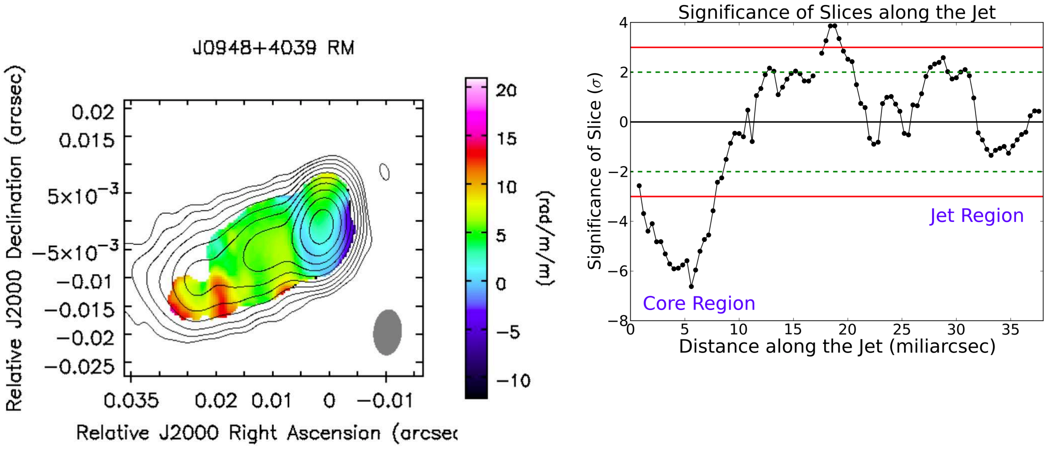

Figure 3: **Left:** RM map for J0948+4039 with 1.46-GHz intensity contours superposed. **Right:** Signifigances of RM gradients for a series of RM slices across the jet, as a function of distance along the core–jet structure. The dotted green and solid red lines refer to the 2σ and 3σ levels.

4. Conclusion

These first results from a new project to image the 191 AGNs of the MOJAVE-II sample at 1.4, 1.7, 2.3 and 4.8 GHz with the VLBA illustrate the potential of this project. We have highlighted here the enhanced sensitivity of these observations to Faraday rotation, but these observations are suitable for a wide range of studies of the morphology, kinematics, and magnetic-field structures of the jets as they propagate from the parsec scales sampled by the main MOJAVE observations at 15 GHz out to scales of tens or hundreds of parsecs, and on to the kiloparsec scales probed by VLA observations. These observations are already being used in a number of postgraduate and postdoctoral projects. We intend to make all the results publicly available in a timely fashion.

References

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