Linear polarization variability study of parsec-scale jets at 2 cm

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Main idea

We average single-epoch maps over epochs to reduce the noise level and get full cross-section of the AGN outflow. This produces the polarization maps reflected spatial variations of the magnetic field. Images of single-epoch changes around the mean values show B-field temporal variability. We search for connections between these two ways of evolution.

Sample

Our sample consists of 438 AGNs observed within the MOJAVE VLBA survey (Monitoring of Jets in AGN with VLBA Experiments). There are sources of three optical classes: quasars (60%), BL Lacs (30%) and radiogalaxies (4%). All sources have at least five epochs between 1996 January 19 and 2019 August 4 and non-zero polarization flux. Number of epochs and cadence distributions are shown in Fig. 1.

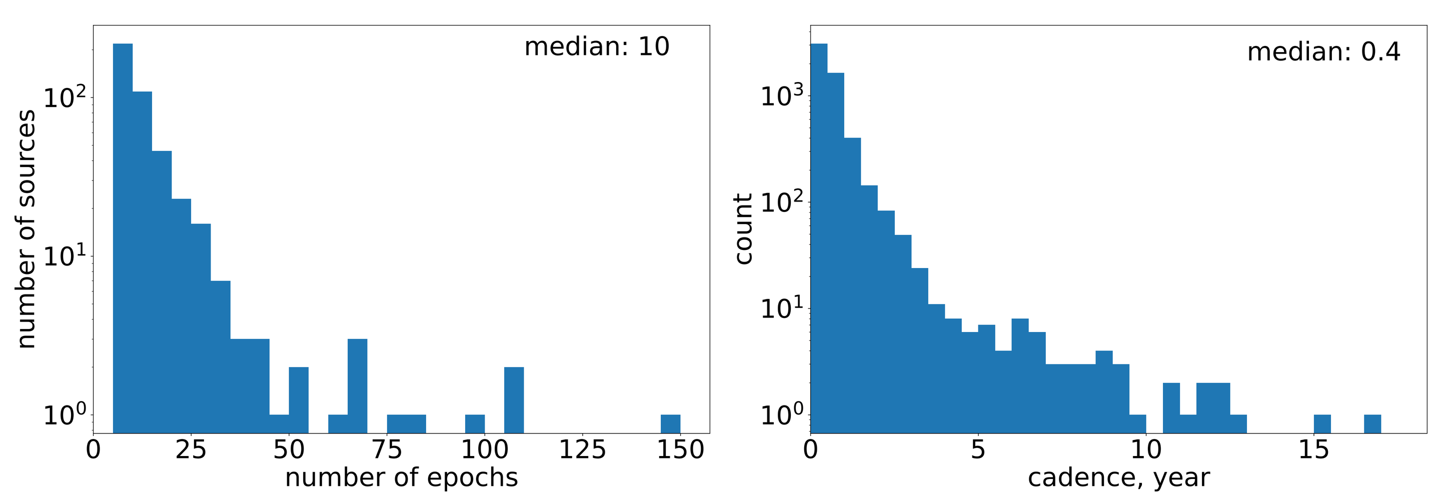

Fig. 1: Number of epochs (left) and cadence (right) distributions.

Stacking method and error estimation

The method procedure consists of the following steps:

1. single-epoch 2 cm maps of Stokes parameters I, Q, U are aligned according to the core position and convolve with circular beam which size is defined by source declination,
2. single-epoch polarization flux $P = \sqrt{Q^2 + U^2}$ maps are made and corrected for Rician bias using the approach of Wardle & Kronberg (1974, ApJ, 194, 249). This bias is due to non-Gaussian behaviour of P noise,
3. single-epoch maps of fractional polarization $m = \frac{P}{I}$ and electric vector position angle $EVPA = \frac{1}{2}\arctan\frac{U}{Q}$ are constructed,
4. maps of I_{stack} and m_{stack} as averaging over epochs, $EVPA$ variability as std $EVPA$ and relative fractional polarization variability ($\frac{\mathrm{std}\ m}{m_{\mathrm{stack}}}$) are made, total intensity ridgelines are constructed.

Errors were estimated by means of simulations (Pashchenko 2019, MNRAS, 482, 1955). 30 realisations of observations for each source were done. Each time thermal noise of the measured interferometric visibility function, residual instrumental polarization coefficients, residual uncertainty of the antenna gain amplitude scale, and absolute uncertainty of the positional angle of linear polarization were added to the observational data. Then stacked and variability maps were made for each realisation following the same procedure as for observations. The uncertainties were estimated as standard deviation between realisations. The example of m_{stack}, $\mathrm{std}\ EVPA$ and $\frac{\mathrm{std}\ m}{m_{\mathrm{stack}}}$ maps along with their errors for typical source 0420+417 are shown in Fig. 2.

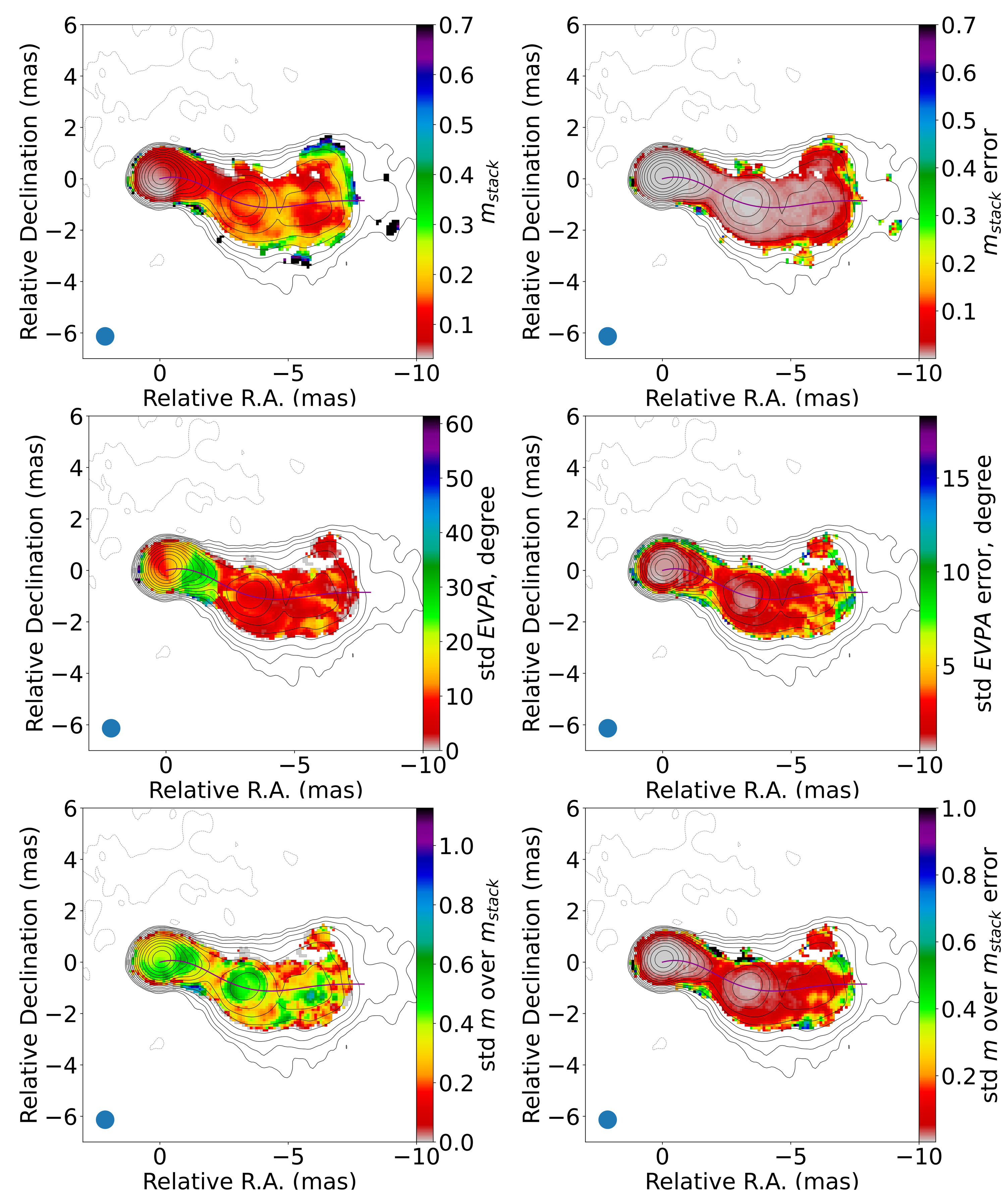

Fig. 2: Source 0420+417, 15 epochs in stack. Top: m_{stack} (left) and its error (right) maps. Centre: $\mathrm{std}\ EVPA$ (left) and its error (right) maps. Bottom: $\frac{\mathrm{std}\ m}{m_{\mathrm{stack}}}$ (left) and its error (right). In each plot the contours show I_{stack}. The lowest contour corresponds to 0.12 mJy/beam. The restoring beam is depicted in the lower left corner as a circle. The total intensity ridgeline is shown by violet line.

Polarization variability distribution along ridgeline

For correlation analysis of AGN jet polarization each source was divided into core and jet across the ridgeline at core component size from the core position. We chose objects with significant polarization detection and whose jet length is more than 1.5 beam size to have several independent points due to convolution with beam. The following significant correlations along the ridgeline were found

- positional angle variability std $EVPA$ decreases with the increase of m_{stack};
- relative fractional polarization variability $\frac{\mathrm{std}\ m}{m_{\mathrm{stack}}}$ decreases with the increase of m_{stack};
- stacked fractional polarization m_{stack} increases with the distance from the core.

These trends are seen, for example, in 0420+417 (Fig. 2). The distributions of the Kendall correlation coefficient for these dependencies for p-value < 0.05 are given in Fig. 3 The results can be interpreted in a jet model with the magnetic field becoming less variable and hence more ordered further downstream from the core. Indeed fractional polarization is higher for more stable magnetic field. According to our results increase of m_{stack} leads to lower std $EVPA$ and $\frac{\mathrm{std}\ m}{m_{\mathrm{stack}}}$ that are also the consequences of decreasing magnetic field variations.

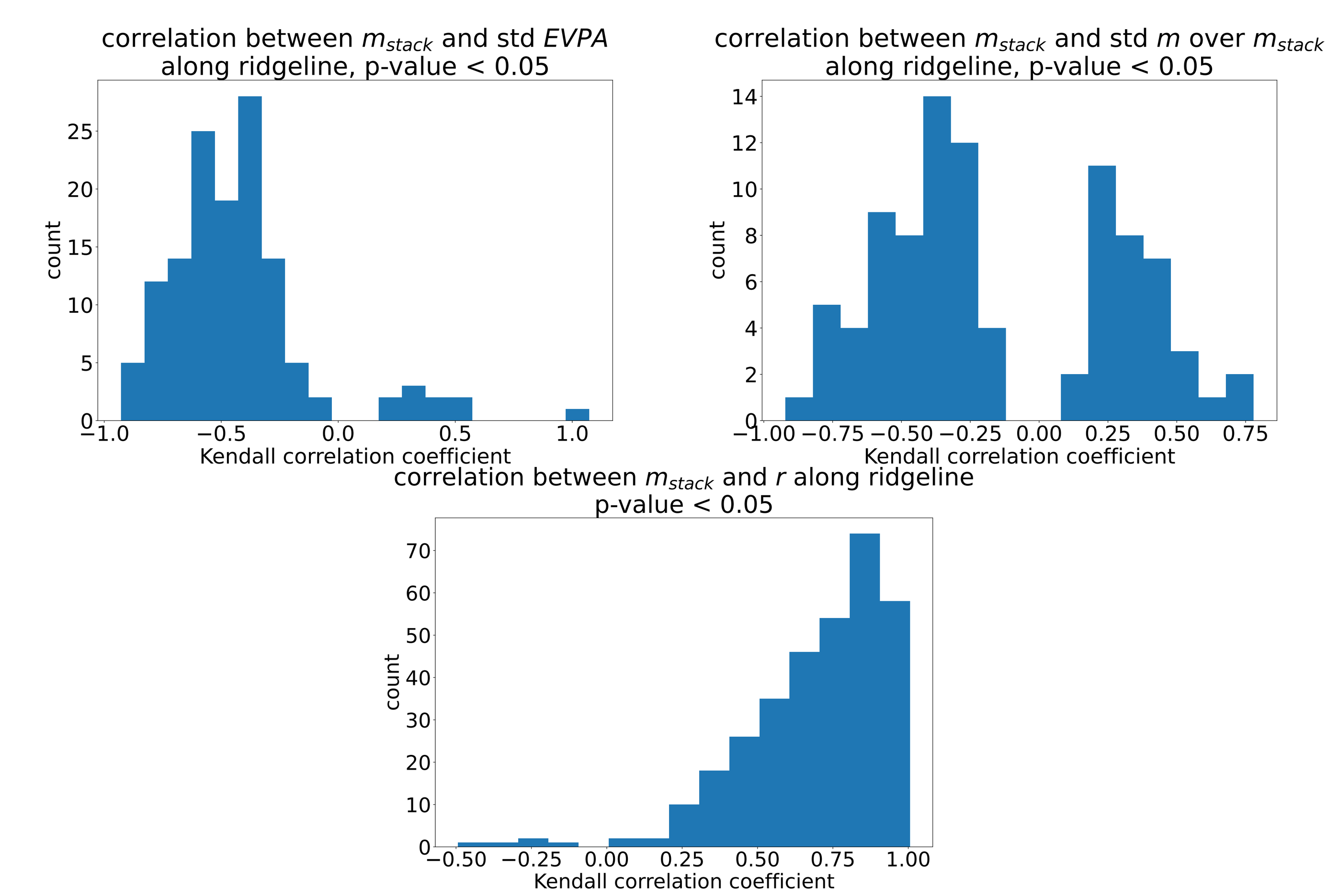

Fig. 3: Kendall correlation coefficient distribution for std $EVPA$ vs m_{stack} (top left), $\frac{\mathrm{std}\ m}{m_{\mathrm{stack}}}$ vs m_{stack} (top right) and m_{stack} vs distance from the core (bottom).

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