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Blazar Variability and Time Lags at Millimetre Wavelengths: Insights from Metsähovi and ALMA Monitoring

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Blazars, a class of active galactic nuclei with relativistic jets oriented close to our line of sight, dominate the extragalactic ɣ-ray sky and are well known for their strong variability across the electromagnetic spectrum. Millimetre observations are of particular interest because they probe emission regions near the jet base, where high-energy flares are likely originating.

In this work, we present a variability study of the blazar 3C 279 using long-term light curves from Metsähovi (37 GHz) and ALMA Bands 3, 6, and 7 (84 to 345 GHz). We applied multiple time-series methods, including Interpolated Cross-Correlation Function (ICCF), Discrete Correlation Function / Z-transformed Discrete Correlation Function (DCF/ZDCF), Python Reverberation-mapping of Active galactic nuclei (PyROA), and Just Another Vehicle for Estimating Lags In Nuclei (JAVELIN), to search for time lags between frequencies. In many cases, we find the expected trend of higher-frequency emission leading the lower frequencies, consistent with opacity-driven delays in the jet. However, we also identify cases where this trend does not hold, suggesting a more complex emission geometry or additional variability drivers.

We further quantified the amplitude of variability through the fractional variability parameter ($F_{\rm var}$). Our results show a clear increase in $F_{\rm var}$ with observing frequency, rising from ˜0.29 at 37 GHz to ˜0.38 at 345 GHz, with intermediate values at 90 and 230 GHz. This trend indicates that the highest-frequency emission is the most variable, consistent with its origin closer to the central engine.

These results highlight the importance of dense, multi-frequency millimetre monitoring in constraining the connection between jet dynamics and high-energy emission. They also set the stage for the Africa Millimetre Telescope (AMT) to establish long-term blazar monitoring from the southern hemisphere.

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