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Inferring Morphologies from Closure Invariants in VLBI using Machine Learning

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The Event Horizon Telescope (EHT) has released the first event horizon scale images of black holes residing at the centres of M87 [1] and our Milky Way [2]. Since then, attempts by various groups to independently infer the morphological features of these black holes have generated intense discussions and even a few controversies. The challenges to imaging from an extreme version of planet-scale Very Long Baseline Interferometry (VLBI) like the EHT primarily arise from a combination of various factors such as sparse aperture coverage, low signal-to-noise ratio, calibration, limitations in imaging algorithms, and any prior assumptions. While the EHT collaboration has reportedly taken extreme care in their analysis to avoid systematic effects from these factors, it is nevertheless important that such pathbreaking experiments require independent verification using orthogonal approaches not subject to such potential systematic biases.

For this reason, VLBI has historically relied on interferometric invariants like closure phases and closure amplitudes [3] which are invariant to antenna-based calibration and errors therein, and therefore contain true morphological information about the objects of interest. However, a direct correspondence between the closure invariants directly and detailed morphological features towards image reconstruction has not been established to date. I will describe recent work unifying different classes of closure invariants in interferometry under a single formalism yielding a complete and independent set [4, 5], and using a novel technique based on machine learning that successfully not only classifies the object morphology but also estimates the parameters of various morphological classes based on these invariants. Using the estimated parameters, our technique reconstructs images entirely using closure invariants alone without employing any prior assumptions unlike several imaging techniques. This technique, for the first time, has allowed us to map the closure invariants back on to morphological parameters. The orthogonality of our technique relative to existing methods promises to provide an independent insight into the morphological features of black holes on event horizon scales.

References

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