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Weak-value amplification and optimal parameter estimation in the presence of correlated noise.

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Weak-value amplification (WVA) is a technique that has been used in a variety of experimental settings to permit the precise measurement of small parameters. WVA is a special instance of a more general measurement strategy that involves sorting data into separate subsets based on the outcome of a second "partitioning" measurement. Whether or not WVA has an actual advantage in terms of the resulting measurement precision has been the subject of an ongoing debate over the past few years. In this paper we analytically and numerically investigate the performance of weak-value amplification (WVA) and related parameter estimation methods in the presence of temporally correlated noise. Using a simplified noise model that can be analyzed exactly we compare WVA to a conventional measurement method. We find that introducing WVA indeed yields a much lower variance of the parameter of interest than does the conventional technique, optimized in the absence of any partitioning measurements. In contrast, a statistically optimal analysis that employs partitioning measurements, incorporating all partitioned results and their known correlations, is found to yield an improvement – typically slight – over the noise reduction achieved by WVA. This is because the simple WVA technique is not tailored to a given noise environment and therefore does not make use of correlations between the different partitions. We also compare WVA to traditional background subtraction, a familiar technique where measurement outcomes are partitioned to eliminate unknown offsets or errors in calibration. Surprisingly, in our model background subtraction turns out to be a special case of the optimal partitioning approach in the balanced case, possessing a similar typically slight advantage over WVA. These results give deeper insight into the role of partitioning measurements, with or without post-selection, in enhancing measurement precision, which some have found puzzling. We finish by presenting numerical results to model a more realistic laboratory situation of time-decaying correlations, showing our conclusions hold for a wide range of statistical models.

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