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A fast and precise method to search for and analyze strongly lensed gravitational-wave events

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Like light, gravitational waves (GWs) can be lensed by massive astrophysical objects such as galaxies or galaxy clusters on their path. Strong gravitational lensing produces several "images" appearing as repeated GW signals in the detectors (doubles, triples, quadruplets), having the same frequency evolution and originating from the same sky position. With Advanced Virgo, Advanced LIGO, and KAGRA at design sensitivity, lensed GWs are forecasted at a rate of 1-2 per year. To search for them, at a minimum one needs to consider all the event pairs present in a gravitational-wave catalog. This leads to a rapidly increasing number of pairs to be looked at, reaching $O(10^5)$ for the detectors at design sensitivity. In order to make searches for lensed events feasible, we have developed a fast and precise methodology to uncover strongly lensed GWs, which relies on the efficient use of the posterior of one image to analyze a potential second image. We show how higher-order modes in the signal can be used for further corroboration of lensing. Finally, we point to applications, such as localizing the host galaxy of a binary black hole merger and probing dark matter around the galaxy acting as a lens.

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