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Rogue Waves and Large Deviations for the 2D Pure Gravity Deep Water Wave Problem

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Rogue waves are extreme ocean events characterized by the sudden formation of anomalously large crests. This phenomenon remains an important subject of investigation in oceanography and mathematics. A central problem is to quantify the probability of their formation under random Gaussian sea initial data. We rigorously justify the exponential large-tail law probability for the formation of rogue waves of the pure gravity water wave equations in deep water, up to the optimal timescales allowed by deterministic well-posedness theory. The proof shows that rogue waves most likely arise through "dispersive focusing", where phase synchronization produces constructive amplification of the water crest.
The main difficulty in justifying this mechanism is propagating statistical information over such long timescales, which we overcome by combining normal forms and probabilistic methods. Unlike previous results, this novel approach does not require approximate solutions to be Gaussian.
This is joint work with M. Berti, R. Grande and A. Maspero

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