Arcsine laws of light

V. G. Ramesh[1], K. J. H. Peters[1], S. R. K. Rodriguez[1]

[1]*Center for Nanophotonics, AMOLF, Science Park 104, 1098 XG Amsterdam, Netherlands*

Paul Lévy's arcsine laws are an example of emergent statistical structure in nature. They has been observed over the years in a large variety of unrelated physical systems. Yet, they have never been studied in the context of coherently driven resonators. In our experiment, we show that these laws arise asymptotically in the time-integrated transmitted intensity of an optical resonator. They apply arbitrarily far from resonance, when the system is far from equilibrium, and apply independent of driving speed. We find a convergence to the laws as a function of the integration time characterized by a power law with a universal exponent. Through numerical simulations we verify that the arcsine laws are also obeyed by the field quadratures and in a Kerr nonlinear resonator supporting non-Gaussian states of light. Our results are relevant to fundamental studies of optical resonators and are of consequence to technological applications like sensing. We demonstrate this via the concept of ergodicity-breaking that is implied by the arcsine laws and further corroborated by power-law tails in the first passage time distribution of the integrated intensity.

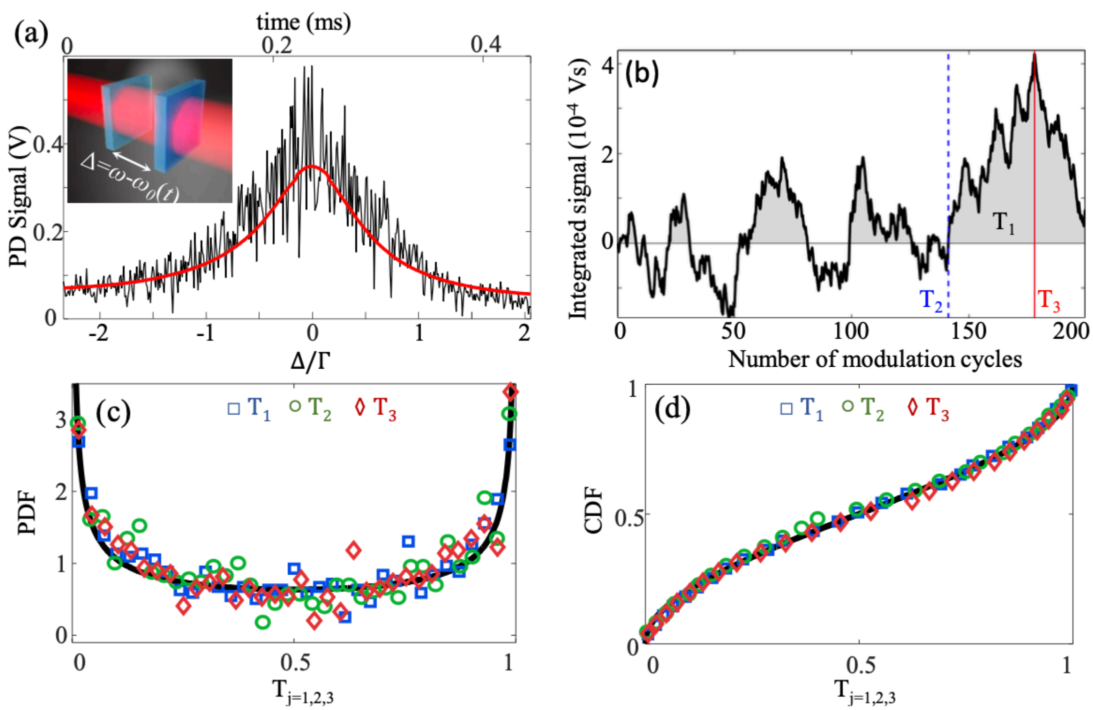

Fig. 1: (a) Inset: Laser-driven single-mode optical microcavity. Main: Single shot (black) and average (red) transmitted-intensity against detuning Δ. (b) Sample trajectory of the time- integrated intensity relative to its average, indicating the time spent above average (shaded area), time of last crossing of the average (dashed blue line), and time to attain maximum (solid red line), denoted $T_{j=1,2,3}$ respectively. (c) Probability distribution (PDF) and (d) cumulative distribution functions (CDF) plotted with blue, green and red markers for $T_{j=1,2,3}$ against the theoretical arcsine distribution (solid black line) corresponding to Paul Levv's arcsine laws.

References:

[1] V. G. Ramesh, K. J. H. Peters, and S. R. K. Rodroguez, arxiv:2208:07432