What happens to entropy production when conserved quantities fail to commute with each other

Nicole Yunger Halpern
(NIST + QuICS + University of Maryland)

We extend entropy production to a deeply quantum regime involving noncommuting conserved quantities. Consider a unitary transporting conserved quantities ("charges") between two systems initialized to thermal states. Three common formulae model the entropy produced. They respectively cast entropy as an extensive thermodynamic variable, as an information-theoretic uncertainty measure, and as a quantifier of irreversibility. Often, the charges are assumed to commute with each other (e.g., energy and particle number). Yet quantum charges can fail to commute. Noncommutation invites generalizations of the three formulae, which we posit and justify. Charges' noncommutation, we find, breaks the three formulae's equivalence. Furthermore, different formulae quantify different physical effects of charges' noncommutation on entropy production. For instance, entropy production can signal contextuality—true nonclassicality—by becoming nonreal. This work opens up stochastic thermodynamics to noncommuting charges—particularly quantum thermodynamics.

This soon-to-be-arXived work was performed with Twesh Upadhyaya; William F. Braasch, Jr.; and Gabriel Landi.