Representations, Probability, and Beyond: A Journey into Anatoly Vershik's World

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A Random Matrix Model for the Entanglement Entropy of Free Fermions

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Quantum entanglement, a special form of quantum correlation, is an important ingredient of modern quantum mechanics and related fields. Much of the extensive literature on entanglement considers quantum correlations between a particular subsystem (a block) and the rest of the system (environment), and uses the entanglement entropy as a quantifier of entanglement. It is assumed that the system size N is much larger than the block size L, which may also sufficiently large, i.e., heuristically, $1 \ll L \ll N$. A widely accepted mathematical version of this inequality is the regime of successive limits: first the macroscopic limit $N \longrightarrow \infty$, and then an asymptotic analysis of the entanglement entropy for $L \longrightarrow \infty$. We consider another version of the above heuristic inequality: the regime of asymptotically proportional L and N, i.e., simultaneous limits $N \longrightarrow \infty$, $L \longrightarrow \infty$, $L/N \longrightarrow c > 0$. Specifically, we deal with a quantum system of free fermions that are in their ground state and have a large random matrix as a one-body Hamiltonian. We show that the entanglement entropy obeys the volume law known for systems having a local one-body Hamiltonian but described either by a mixed state or by a pure but highly excited state.

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