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Random Matrices and Gauge Theory - Old and New

I will attempt to review some recent progress in probability concerning unitary random matrix models originating from gauge theory, and in particular from lattice gauge theory. From a probabilistic point of view, a graph is fixed—for instance, one associated with the regular d -dimensional lattice—and its edges are decorated with random unitary matrices whose joint distribution may take into account additional geometric structures of the graph.

From the 1980s onward, the large- N limit of lattice gauge theory attracted considerable attention from theoretical physicists, both as a significant simplification of gauge theory and as an initial attempt to relate gauge theory to string theory.

The case of two-dimensional lattices served as a paradigm for the more physically relevant four-dimensional setting, as it enjoys exact solvability properties, a direct connection to a continuous object (the now well-defined Yang–Mills measure), and, in some cases, an underlying symplectic structure. While substantial progress was made, many challenges remain unsolved, and numerous statements still await rigorous mathematical treatment.

I will focus here on some mathematical results concerning the so-called large- N limit of Wilson loops, originally investigated by theoretical physicists in the 1980s and 1990s. In two dimensions, I will highlight an argument based on a new exact formula expressed in terms of a particle system on the dual lattice.