Contribution ID: **249** Type: **not specified**

Second quantization of noncommutative spaces: emergence of the Standard Model minimally coupled to gravity

Tuesday, November 14, 2023 1:30 PM (1 hour)

We start with a gentle introduction to the spectral approach to (noncommutative) geometry. We insist on the presence of fermions, so that a central role is played by a Dirac operator, acting on a one-particle Hilbert space. The combination with a coordinate algebra then allows for a full reconstruction of the spacetime geometry from the spectral data. Moreover, when allowing for noncommutative spaces described by an algebra of matrix-valued coordinates, the Dirac operator gets minimally coupled to a gauge field, as well as to the Higgs field.

The dynamics of all of these fields will emerge from the second quantization of the system. After a careful exposition of the latter procedure in the present context, we will analyze the information theoretic von Neumann entropy of the unique equilibrium state. We show that this entropy is given by the spectral action for a specific universal function. In the case of a curved spacetime manifold one finds that there is an asymptotic expansion of this entropy yielding the Einstein-Hilbert action, plus higher-order gravitational terms. Finally, in the presence of gauge and Higgs fields, the very same procedure yields additionally the Yang-Mills action functional and the scalar terms describing a Higgs mechanism.

Based on joint work with Ali Chamseddine and Alain Connes.

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