Probabilistic Operator Algebra Seminar

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Title: *The emergence of time.*

Classically, one could imagine a completely static space, thus without time. As is known, this picture is unconceivable in quantum physics due to vacuum fluctuations. The fundamental difference between the two frameworks is that classical physics is commutative (simultaneous observables) while quantum physics is intrinsically noncommutative (Heisenberg uncertainty relations). In this sense, we may say that time is generated by noncommutativity; if this statement is correct, we should be able to derive time out of a noncommutative space. We know that a von Neumann algebra is a noncommutative space. About 50 years ago the Tomita-Takesaki modular theory revealed an intrinsic evolution associated with any given (faithful, normal) state of a von Neumann algebra, so a noncommutative space is intrinsically dynamical. This evolution is characterised by the Kubo-Martin-Schwinger thermal equilibrium condition in quantum statistical mechanics (Haag, Hugenholtz, Winnink), thus modular time is related to temperature. Indeed, positivity of temperature fixes a quantum-thermodynamical arrow of time. We shall sketch some aspects of our recent work extending the modular evolution to a quantum operation (completely positive map) level and how this gives a mathematically rigorous understanding of entropy bounds in physics and information theory. A key point is the relation with Jones' index of subfactors. In the last part, we outline further recent entropy computations in relativistic quantum field theory models by operator algebraic methods, that can be read also within classical information theory. The information contained in a classical wave packet is defined by the modular theory of standard subspaces and related to the quantum null energy inequality.