The Universality problem and the Renormalization Group

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Abstract: Even if the structure of matter is extremely complex and depending on an enormous number of parameters, certain macroscopic properties show a remarkable independence from the microscopic structure-a phenomenon known as universality. Understanding its origin, which in its simplest form is related to central limit theorems, is a fascinating mathematical problem.

The Renormalization Group provides a very powerful approach to universality, and in recent years important progress have been obtained. In these lectures we start introducing classical bidimensional statistical mechanics models like coupled Ising, Vertex and dimer models, whose critical exponents can be written in terms of convergent series.

Even if they depend on all the microscopic parameters, they verify universal relations due to certain emerging symmetries related to the scaling limit. Subsequently we consider quantum statistical mechanics models, in particular graphene, topological and spin Hall insulators, deriving universality results for transport coefficients, like the optical or Hall conductivity.

The mathematical analysis in classical or quantum systems show deep analogies another example of the universality phenomenon.