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Perturbative quantum field theory techniques applied to fluctuating elastic membranes.

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Quantum field theory (QFT) was developed in the 1940s as a theoretical framework for particle physics by combining classical field theory, special relativity and quantum mechanics. In the context of elementary particle physics, QFT provides various tools to accurately determine multiple physical quantities. The most used are essentially perturbative calculations via Feynman diagrams, as well as regularization and renormalization techniques, necessary to control the infinities encountered during the calculations. When used properly, this framework allows to theoretically calculate, with a very high accuracy, finite quantities called *probability amplitudes*, which provide answers to questions such as, for example, *"What is the probability of colliding particles A and B and getting particles X and Y as output?"* or, more famously, *"What is, very precisely, the value of the magnetic moment of an electron?"*.

Later in the 70's, it was discovered that QFT was also a very powerful framework to address many-body physics problems encountered in condensed matter and more generally in statistical physics systems. Thanks to the so-called renormalization group approach, the QFT framework now allows a systematic study of the critical properties of many-body systems near their phase transitions and provides a precise recipe for calculating with very high accuracy universal physical quantities called *critical exponents*. This has opened up the possibility of theoretically predicting the answer to a considerable number of new questions such as, *e.g.*, *"What happens to the magnetization of a magnet near its melting point?"* or *"How does the specific heat of a liquid diverge at one of its phase transitions" etc.*

In this talk, I will first briefly introduce the above topics. I shall then explain how we have recently successfully applied QFT techniques in the context of elastic degrees of freedom of fluctuating surfaces, which is an intuitive framework. Our goal was to predict the critical properties of a flat polymerized membrane in the vicinity of its critical (scale invariant) temperature, where it exhibits universal properties. Indeed, these surfaces are ubiquitous in physics, and are used to describe objects in various fields; from brane theory to cell membranes in biophysics or more recently, graphene and graphene-like materials. One could imagine a realization of this model as a free standing graphene sheet, globally flat in shape, close to a precise temperature such that its deformations are scale invariant, *i.e.* locally fractal. This thought experiment would show a universal behavior common to all membranes and would reveal very intriguing properties; anomalous rigidity, negative Poisson's ratio *etc.*

In the work [Metayer, Mouhanna, Teber. '22] we derive very high precision results (third order perturbative renormalization group equations) which describe such a flat membrane phase, following the pioneering first order calculation of [Aronovitz, Lubensky '88] and the more recent second order one [Coquand, Mouhanna, Teber '20]. These allow us to compute analytically, exactly order by order, three main quantities, namely the two mechanical Lamé coefficients μ and λ and an anomalous dimension η. The latter completely characterize the membrane, such that from this three quantities, one can calculate all the desired universal mechanical properties such as, for example, the Young's modulus, the Poisson's ratio, the speed of sound, the roughness properties etc.

Auteur principal: METAYER, Simon (LPTHE - Laboratoire de Physique Théorique et Hautes Energies)

Co-auteurs: Prof. MOUHANNA, Dominique (LPTMC); Dr TEBER, Sofian (LPTHE - Laboratoire de Physique Théorique et Hautes Energies)

Orateur: METAYER, Simon (LPTHE - Laboratoire de Physique Théorique et Hautes Energies)

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