

Soutenances de Thèses 2021

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Soutenance de thèse

Optimal measurement strategies for quantum state and quantum channel estimation

The rapid advance of quantum information technology requires precise control and manipulation of quantum systems; in particular, it is essential to certify that quantum processors truly work quantum mechanically, in order to validate experiments and their results. The problem of certification of quantum states and devices is a demanding one, thus many attempts have been put forward to find ways of efficiently testing their basic functionalities, such as their entanglement properties. The aim of the present thesis is to find optimal strategies for the estimation and characterization of quantum states and channels, with a special focus on entanglement correlations.

We consider in particular the certification of entanglement across a given partition of a multi-qubit system, when only partial information about the corresponding quantum state is available. We also discuss the problem of separability of quantum channels in terms of the Choi matrix representation, and we shall mention some preliminary results about quantum functional testing based on Bayesian adaptive strategies. As a separate issue, we also highlight the relevance of quantum information in the context of analogue gravity.

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Soutenance de thèse

Beyond-mean-field effects in ultracold gases

Ultracold gases are well controllable quantum systems that are described by a set of few parameters. The idea to look at systems with partially attractive and repulsive forces, fine-tuned to an approximate overall cancellation of the mean-field term, provide an interesting platform for studying various beyond-mean-field phenomena, remarkable recent examples being quantum droplets and dipolar supersolids. In this thesis, we take a step towards understanding the phase diagram of the 1D Bose-Bose mixture with attractive interspecies and repulsive intraspecies contact interactions. We

address the one-dimensional three-body problem with two- and three-body interactions that we solve analytically. Then, we develop the perturbation theory for systems with a weak two-body potential interaction, where the attractive and repulsive parts compensate each other. We calculate in every dimension the leading nonpairwise contribution, which represents an effective three-body interaction. We apply this result particularly to tilted dipoles in quasi-low-dimensional geometries. Interestingly, we show the consistency of this few-body perturbative approach with the Bogoliubov one.

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Soutenance de thèse

Elasticity of self assembling bio-materials

Self organization is crucial for the wealth of living systems, both at the molecular and cellular level. To correctly achieve their role a tight control over the shape and structure of protein for instance, is required. Any mistake can lead to various disease like Alzheimer, where proteins aggregate into fibrous structures. On a larger scale, cells need to probe the mechanical response of their environment -the extra cellular matrix- and to adapt their own rigidity to collectively orientate. In this thesis, we are looking at two different models. In the first part, we study protein aggregation beyond the microscopical details. By considering elastic assembling particles, we are able to derive generic law and understand the very persistent formation of fibers. In the second part, we model the dynamical response of a fashionable class of hydrogels for their bio-compatibility. Material engineers are now able to synthesize materials with more and more subtle behavior, although understanding certain emergent properties -such as non-exponential relaxation- can be a major challenge. We design a simple model for the dynamical response of hydrogels connected by large multivalent crosslinkers. We are able to account for experimental results, and rationalize their origin.

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Soutenance de thèse

Systèmes coulombiens en une et deux dimensions : résultats exacts

Soft matter often features charged units which interact through Coulomb forces, the treatment of which is difficult due to their long-range nature. This thesis gives results for three many-body systems where every long-range interaction is included, without approximations. First, we study exact results for a one-dimensional electroneutral salt-free suspension made of two fixed colloids and N neutralizing mobile counterions, with dielectric jumps at the colloids' position. This includes the partition function, density profile and pressure. We find that for any N counterions system there may be like-charge attraction, unlike when the dielectric is homogeneous in which case N must be even. Secondly, we consider the previous system out of equilibrium within a homogeneous dielectric space, as a model for the dynamics of two electrical double-layers. Using a combination of exact calculations where possible and Brownian dynamics simulations, we compute the relaxation time towards equilibrium (τ). The parity of N leads to distinctly different dynamics: for N even, thermal effects are detrimental to relaxation, increasing τ , while they accelerate relaxation for N odd. In the two 1D systems we show that in the limit $N \rightarrow \infty$ at fixed colloid's charge, the mean-field prediction is recovered. Finally, we analyse exactly the short-distance effective potential between two "guest" charges immersed in a two-dimensional two-component charge-asymmetric plasma composed of positively ($q_1 = +1$) and negatively ($q_2 = -1/2$) charged point particles. The result is valid in the collapse-free regime, where the Coulombic coupling (dimensionless inverse temperature) $\beta < 4$. At high Coulombic coupling $\beta > 2$, this model features like-charge attraction.

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