Contribution ID: **92**

Type: **poster**

Thermodynamic approach to non-relativistic quantum mechanics

In this contribution we explore the derivation of quantum mechanics from a classical field theory, or more precisely from a thermodynamic approach involving two field phases. This attempt is in line with the analysis of Laughlin and Pines on the emergent characters of physical laws, including quantum physics (PNAS, 97, 2000, 28).

The first part of the presentation analyzes in detail the stochastic interpretation of quantum physics grounded on the "Advective Quantum Gauge" (AQG for short), i.e., on the equivalence between the Schrodinger and the advection diffusion equations in a Wick-rotated time.

Albeit this connection have been addressed by a huge and extensive literature, several implications of the above equivalence are fairly novel and of physical interest. Specifically:

(i) The AQG approach provides for quantum system a kinematic equation of motion (complex Langevin equation) of the form $d\mathbf{x}(t) = i\,\mathbf{v}_q(\mathbf{x}(t))\,dt + \sqrt{i\,2\,D_h}\,d\mathbf{w}(t)$ where $d\mathbf{w}(t)$ the increments of a n-dimensional real-valued Wiener process. In the absence of stochastic fluctuations, from the above model one recovers the semiclassical limit of the Newton equations of motion.

(ii) The AQG furnishes an interesting interpretation of Bohmian quantum dynamics, as a mean field theory in which quantum fluctuations are accounted for by the quantum potential which depends on the modulus of the wavefunction.

(iii) The AQG provides a way to obtain the wavefunction or the quantum propagators in a simple and efficient way from random walk simulations. This is particularly relevant for quantum problems involving many degrees of freedom.

The stochastic interpretation of quantum mechanics, and specifically the AQG approach, is essentially a particle-based description of a physical system intrinsically subjected to fluctuations. This approach shows some limitations in the presence of time-dependent (and, a fortiori} stochastic) potentials.

The second part of the presentation provides a classical field-theoretical interpretation of the Schrodinger equation, in which quantum (field) fluctuations still play a leading role, but a quantum system is viewed as a statistical mechanical system in which two field-phases coexist.

In the present thermodynamic model we assume that a quantum system corresponds to a two-phase thermodynamic system in which

a “distributed” (radiating) field coexists with
a “condensed field phase”. Quantum equation
of motion emerges from the interaction between the two
phases by assuming a quasi steady-state approximation.
As regards the condensed phase, it is at present
described in a particle-like way via position and momentum.

As mentioned above, from a quasi-state approximation on the
statistical description of the condensed field phase, Schrodinger
equation is recovered.
More precisely, a system of hyperbolic first-order
equations analogous to the statistical description
of Generalized Poisson-Kac processes is derived.
The Kac limit of these equations provides the classical
Schrodinger model containing the Laplacian operator
accounting for the kinetic energy.

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