Hydrodynamics and the quantum butterfly effect in black holes and large N quantum field theories

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Stellingen

behorende bij het proefschrift

Hydrodynamics and the quantum butterfly effect in black holes and large N quantum field theories

1. For perturbative (quantum) field theories, the late-time-limit of the out-of-time ordered correlation function that measures (quantum) chaos is described by a Boltzmann-type kinetic equation that measures the total gross (instead of net) particle exchange between phase space cells.

   Chapter 2

2. Even close to a quantum critical point, quantum chaos seems to be described by a Boltzmann-type kinetic equation.

   Chapter 3

3. In theories with holographic duals, the retarded longitudinal two-point function of the stress-energy tensor has a hydrodynamic pole which contains all information about many-body chaos.

   Chapter 4

4. In a weakly-coupled ϕ^4 theory, a kinetic-theory argument indicates that the symmetric configuration of the time contour, namely the one for which the bound on chaos has been proven, has a proper interpretation in terms of dynamical chaos.

   Chapter 5

5. As stressed by Swingle, it will be possible, in the near future, to perform a coherent rewinding of time in more complex systems. This may not only shed light on the dynamics of quantum information, as Swingle suggests, but also may allow the study of very exotic objects such as wormholes.

   B. Swingle, Nature Physics **14**, 10 (2018).

6. The observable defined by Y. Gu and A. Kitaev is sensitive to the regularization on the thermal circle. Therefore, this observable should be *a priori* considered non-physical.

   Y. Gu and A. Kitaev: JHEP **1902**, 0755 (2019).

7. Approximating the perturbative expansion of the out-of-time ordered correlation function by replacing the commutator of fields by their expectation value, as done by D. Chowdhury and B. Swingle, is not fully justified even if it correctly allows to describe the bosonic $O(N)$ case.

   D. Chowdhury and B. Swingle: Phys.Rev. D **96**, 065005 (2017).

8. The effective hydrodynamical description of quantum chaos proposed by M. Blake, H. Lee and H. Liu appears to be mainly applicable to maximally chaotic systems. Nevertheless, connections between quantum chaos and hydrodynamic transport seem to persist also in non maximally-chaotic cases.
M. Blake, H. Lee and H. Liu: JHEP **1810**, 127 (2018).

9. Climate change, cyber security, the changes in the labour market and the increase of social and economic inequalities are the big challenges of our immediate future. The fact that they will jeopardize the respect for human rights is largely overlooked.

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