PhD proposal at Northumbria University:

THERMALISATION IN CLASSICAL AND QUANTUM FIELD THEORY: STUDYING A BILLIARD MODEL USING QUANTUM CHAOS TECHNIQUES

Scientific description of the project

Thermodynamics has been very successful in describing how a classical physical system reaches equilibrium. When the system is connected to a heat reservoir, this process is dubbed as thermalisation. In the recent years there has been a growing activity in mathematical physics to understand how a quantum isolated system can display the signatures of thermalisation. In particular, the integrability of the system or the Anderson localisation effects are known to prevent it. While the failure to thermalisation has been observed in a cold atom experiment, an analytically tractable model of this fundamental process is presently lacking, and developing such a model represents an important open problem. Billiard systems have been studied in detail from both mathematical and physical perspectives. A classical billiard consists of a moving particle that is trapped inside a closed domain and undergoes specular reflections at the boundary of the domain. Billiards are especially convenient to study a broad class of dynamics: changing the shape of the boundary can result in a transition from a regular to a fully chaotic motion. Studying the signatures of such dynamics in the corresponding quantum realm has been at the heart of quantum chaos. In the project the theoretical techniques of quantum chaos will be applied following [1] to the study of thermalisation in classical and quantum field theories, using a new model recently introduced in [2]. One goal of the project will be to develop the basic tools (both analytical and numerical) that would be applicable to higher dimensional systems, where the previous approaches have failed.

The initial steps of the project will be: (i) description of the classical phase space, distinguishing between ergodic and non-ergodic time evolution, (ii) application of quantisation schemes in order to understand the long time behaviour of the corresponding quantum systems. In particular you will learn about the celebrated KAM theory, the Fermi-Pasta-Ulam-Tsingou problem, as well as master elements of nonlinear field theory and spectral theory. You will use analytical techniques (Lax pairs, generalised hydrodynamics) as well as numerical tools (lattice field theory, Monte-Carlo,etc) using your favourite language (e.g. C++ or Python) in order to develop your own intuition and skills. At a later stage of the projects development those methods will be applied to a more challenging situation of higher dimensional space-time, or to understand more precisely the effects of integrability [3].

Applicants with a strong background in theoretical and/or mathematical physics (including field theory, quantum physics and nonlinear dynamics) are strongly encouraged. Besides, throughout the project, the applicant will interact with an international and multidisciplinary team. She/he will also attend international conferences, give seminars, and publish the results in international peer-reviewed journals to communicate on the progress. Such a timely subject, at the crossroads between physics and mathematics, is expected to provide the applicant with a broad set of skills, to understand the long time behaviour of possibly small quantum devices. Such a knowledge is to become crucial with the rapid advance in quantum technologies.

References

[1] R. Dubertrand, S. Müller, New J. Phys. **18**, 033009 (2016)

[2] D. Hahn, J.-D. Urbina, K. Richter, R. Dubertrand, S. L. Sondhi, `arXiv:2011.10637 [nlin.CD]`

[3] G. El, A. M. Kamchatnov, Phys. Rev. Lett. **95**, 204101 (2005)

Deadline and contact

The application's deadline is the **29th of January 2021**. The PhD project is assumed to start in September 2021. It is highly recommended to contact Dr Rémy Dubertrand (remy.dubertrand@northumbria.ac.uk) before the submission to make sure that all the criteria are met, *e.g.* for the administrative eligibility.