Conference Frontiers of Quantum and Mesoscopic Thermodynamics 2024

Public Lecture of Peter Hänggi

Main Hall of the Pyramida Hotel, Prague-Břevnov

Tuesday July 23, 2024, 15:30

https://fqmt.fzu.cz/24/

The ring of Brownian motion: Its beneficial use for physics and elsewhere

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Since the turn of the 20th century Brownian noise has continuously disclosed a rich variety of phenomena in and around physics. The understanding of this jittering motion of suspended microscopic particles has undoubtedly helped to reinforce and substantiate those pillars on which the basic modern physical theories are resting: Its formal description provided the key to great achievements in statistical mechanics, the foundations of quantum mechanics and also astrophysical phenomena, to name but a few. Recent progress of Brownian motion theory involves the description of relativistic Brownian motion and its impact for relativistic thermodynamics, or its role for fluctuation theorems and symmetry relations in recent developments for equilibrium and nonequilibrium thermodynamics/statistical mechanics.

Although noise commonly is hold as the enemy of order, it in fact also can be of constructive influence. The phenomena of Stochastic Resonance and Brownian motors present two such archetypes wherein random Brownian dynamics together with unbiased nonequilibrium forces beneficially cooperate in enhancing detection and/or in facilitating directed transmission of information. The applications range from information processing devices in physics, chemistry, and physical biology to new hardware for medical rehabilitation. Particularly, additional nonequilibrium disturbances enable the rectification of haphazard Brownian noise so that quantum and classical objects can be directed along on a priori designed routes (such as with Brownian motors). We conclude with an outlook for potential new applications and unsolved issues occurring with the theory of Quantum Brownian and Quantum Thermodynamics.

Peter Hänggi

Peter Hänggi is a theoretical physicist from Switzerland, Professor of Theoretical Physics at the University of Augsburg. He is best known for his original works on Brownian motion and the Brownian motor concept, stochastic resonance and dissipative systems (classical and quantum mechanical). Other topics include, driven quantum tunnelling, such as the discovery of coherent destruction of tunnelling, phononics, relativistic statistical mechanics and the foundations of classical and quantum thermodynamics.

Peter Hänggi is a recipient of a number of scientific awards, among them, Fellow of the American Physical Society in 1988 "for distinguished contributions to nonlinear statistical physics and reaction rate theory and for elucidating the influence of non-Markovian memory effects and dissipative tunneling in equilibrium and non equilibrium systems" and American Physical Society's 2023 Lars Onsager Prize, which recognizes outstanding research in theoretical statistical physics, "For development of Brownian motors and pioneering contributions to nonequilibrium statistical physics, relativistic and quantum thermodynamics." P. Hänggi has published over 700 original papers and has over 50,000 citations.