Energy transport processes in quantum systems coupled to thermal reservoirs

Interference is usually attributed to wave phenomena: electromagnetic waves or mechanical waves (sound, water, seismic ones). There are also quantum interference phenomena related to the quantum wave nature of matter and another one – to the superposition of states. A new area of quantum physics, *coherent caloritronic*, deals with control, measurements, storage, and conversion of heat in nanoscale devices. It was demonstrated by F. Giazotto i M. J. Martínez-Pérez in Nature 492, 401 (2012)), that for SQUID (Superconducting Quantum Interference Device) the heat flux carried by the electronic excitations is modulated by changing the superconducting phase difference between two superconductors. Thermal conduction through a Josephson junction involves both quasiparticle heat flow and the strange interference heat current that is influenced by the phase across the junction. It is now a unique playground for investigating phase coherent heat transport at the nanoscale. Our proposal fits into this new mainstream of research. It will be concentrated on analysis of energy transport in model *quantum systems* interacting with two thermal reservoirs of different temperatures and various spectral properties which, in turn, induce various mechanisms of energy dissipation.

The first class of problems will be devoted to energy (heat) transport in exactly solved systems which consist of two interacting subsystems and each of them is coupled to its independent thermal reservoir. Quantumness can result in new phenomena of energy transport which are absent in macro-world described by traditional statistical physics and thermodynamics. In particular, initial conditions can play an important role in dynamics of energy flow: at initial time two subsystems can be in entangled states or can be uncorrelated. Similarly, each subsystem can be entangled with its own thermostat or can be uncorrelated with the thermostat. Moreover, exactly solved models allow to analyze energy transport in the case of strong coupling to thermostats, the regime which cannot be studied by traditional statistical physics. We intend to consider both bosonic as well fermionic and spin thermal reservoirs. Can their different *quantum statistics* decide about specific features of transport? We want to answer this question.

The second class of problems is related to weak coupling regimes with thermostats. We will analyze energy transport through the rf- and dc-SQUIDs. A flux qubit based on a non–superconducting mesoscopic ring coupled to two split heat baths at different temperatures will also be studied in this part of the proposal. We hope that these systems could work as quantum heat interferometers in which the stationary heat flow can be controlled by the external magnetic field!

Current tendency toward miniaturization requires a better understanding of phenomena and processes in small space and time domain. In particular, one can notice an upsurge of interest in energy transport phenomena in micro- and nanostructures like molecular junctions, suspended nanotubes, quantum point contacts, nono-wires, phononic metamaterials, etc. Recent progress and rapid developments in technology will allow to convert research findings into potential applications of functional thermal devices such as quantum heat engines , thermal rectifiers, thermal transistors, controllers of local temperature , heat–voltage converters, thermal circuits, nano-refrigerators and last but not least hybrid thermal circuits and micro-electromechanical machines where energy transfer can be exploited to move microscopic devices.

Independently of the above motivation, we want to take up a major challenge to study *fundamental* problems of statistical physics of systems far from equilibrium and to study the influence of such pure quantum effects like quantum entanglement and quantum interference in heat transport processes.