Doing small systems: Concepts, Role of Ensembles, Thermalization and Fluctuation Theorems

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This talk is aimed at highlighting issues that relate of doing thermodynamics and statistical physics of finite size systems. This theme gained considerable importance in view of fascinating advances in nanotechnology and system biology. While the fathers of thermodynamics developed the famous 4 Laws of Thermodynamics, having in mind macroscopic systems these grand concepts need to be inspected anew in view of the fact that the fluctuations grow with decreasing size to a level where they even may play the dominant role. – The symposium touches upon several timely issues in designing, measuring and operating systems at the submicron scale, both **in** and also **far away** from thermal equilibrium.

With this presentation I discuss subtleties related to thermodynamics of small systems, such as (i) the role of finite size for quantities such as (in some cases negative-valued) canonical (!) heat capacitance [1], (ii) the role of entropy and temperature in these small systems, or (iii) the issue of thermalization [2]. Moreover, a key role in doing statistical physics of submicron systems relates to (iv) the choice of the ensemble description and the inter-relationships between the sizable fluctuations of measures like work, heat & heat flow and thermodynamic equilibrium quantifiers such as free energy changes or changes of entropy [3].

Some own pertinent literature that relates to this talk is:

[1] P. Hänggi and G. L. Ingold, *Quantum Brownian motion and the third law of thermodynamics* Acta Physica Polonica B **37**, 1537–1550 (2006); P. Hänggi, *et al.*, Finite quantum dissipation: the challenge of obtaining specific heat, New J. Phys. 10, 115008 (2008); see also in: G. Ingold, *et al.*, Phys. Rev. E 79, 061105 (2009).

[2] A. V. Ponomarev, S. Denisov, and P. Hänggi *Thermal equilibration between two quantum systems* Phys. Rev. Lett. **106**, 010405 (2011).

[3] M. Campisi, P. Hänggi, and P. Talkner *Quantum fluctuation relations: Foundations and applications* Rev. Mod. Phys. **83**, 771–791 (2011).