Classical and quantum chaos and understanding and control of heat flow

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The understanding of the underlying dynamical mechanisms which determines the macroscopic laws of heat conduction is a long standing task of non-equilibrium statistical mechanics. Recent years have witnessed some important progress in this direction even though a satisfactory understanding is, so far, unavailable. For example, after two decades of debates, it is now clear that exponential local instability is not a necessary condition for the validity of Fourier law.

A better understanding of the mechanism of heat conduction may also lead to potentially interesting applications based on the possibility to control the heat flow. Indeed, a model of thermal rectifier has been recently proposed in which heat can flow preferentially in one direction. Although this model is far away from a prototype realization, it is based on a mechanism of very general nature and, as such, is suitable of improvement and may eventually lead to real applications. More recently, a different thermal diode model has been proposed in which, even though the underlying physical mechanism is similar to the previous model, there is a new crucial element which allows to improve the efficiency by more than two orders of magnitude. Finally we briefly discuss the possibility to build a thermal transistor.

Of particular interest is the problem, almost completely unexplored, of the derivation of Fourier law from quantum dynamics. To this end we discuss heat transport in a model of a quantum interacting spin chain and we provide clear numerical evidence that Fourier law sets in above the transition to quantum chaos.

References

[1] M. Terraneo, M. Peyrard and G. Casati, "Controlling the energy flow in non-linear lattices: a model for a thermal rectifier'", Phys. Rev. Lett., 88, 094302 (2002).
[2] G. Casati and T. Prosen, "Anomalous heat conduction in a di-atomic one-dimensional ideal gas", Phys Rev E., 67, 015203 (2003)
[3] B. Li, G. Casati and J. Wang, "Heat conductivity in linear mixing systems", Phys Rev E. 67, 021204 (2003).
[4] B. Li, G. Casati, Jiao Wang and T. Prosen, "Fourier law in the alternate mass hard-core potential chain", Phys. Rev. Lett. 92, 254301 (2004).
[5] B. Li, L. Wang, and G. Casati, "Thermal diode: rectification of heat flux". Phys. Rev. Lett. 93, 184301 (2004).
[6] G. Casati, "Controlling the heat flow: now it is possible". Chaos, 15, 015120 (2005).
[7] C. Mejia-Monasterio, T. Prosen and G. Casati, "Fourier's law in a quantum spin chain and the onset of quantum chaos", Europhysics Letters, 72, 520 (2005)
[8] B. Li, L. Wang and G. Casati, "Negative differential thermal resistance and thermal transistor". Appl. Phys. Lett., 88, 143501 (2006).