Chaos, irreversibility and Hamiltonian hysteresis

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In thermodynamics, irreversibility is invariably linked to non-adiabatic evolution. Consider a piston moving out and then back into a cylinder filled with gas. The extreme case is an abrupt process that leads to "free expansion" of the gas. Due to lack of adiabaticity, the evolving state expands into a thicker energy shell in phase-space (increase of entropy). Chaos is conceived as an essential ingredient, leading to the second law of thermodynamics: the growth of the entropy implies that no Hamiltonian driving protocol can restore the system to its original state.

Is chaos really a necessary ingredient, as conjectured by Boltzmann, in order to witness irreversibility in the quasi-static limit? Somewhat surprisingly, the answer is "No". Irreversibility can be obtained even for an integrable (non-chaotic) one degree of freedom system through a "separatrix-crossing" mechanism. The question arises what is the role of Chaos in irreversibility [1-3], and whether it can be probed experimentally.

We highlight the role of chaos in the analysis of Bose-Hubbard circuits. Specifically, we address themes that are related to BEC metastability [4], and irreversibility of quasi-static sweep processes. For non-linear adiabatic passage [2,3] the failure of adiabaticity is related to chaotic spreading away from the followed stationary point. In hysteresis experiment [1,5], the irreversibility of the backward-sweep process can be due to separatrix crossing (non-chaotic scenario), or due to interplay between different mechanisms for adiabatic evolution (Landau vs Ott), or due to diffusion across the energy surface (Kubo dissipation).

We clarify what are the distinct experimental fingerprints of each mechanism.

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