THESIS DEFENSE: Information and thermodynamics

MATTEO SCANDI

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The modern understanding of physics is deeply linked with the concept of information. The revival of the study of quantum mechanics in the form of quantum information is just an example of a more general trend showing how the incorporation of ideas from information theory into the practice of physics is not simply a fertile opportunity to find new results, but it also offers a radically new understanding of what physics should be describing: emblematic of this paradigm shift is the transition from the infinite dimensional space associated to the wave functions appearing in the Schrodinger equation, to the extreme simplicity of the modern cornerstone of quantum mechanics, the qubit. A special place in this context is taken by thermodynamics: on the one hand, because it was one of the first branches of physics in which the role of information was explicitly recognised; on the other, as the formal correspondence between Shannon and Boltzmann entropy hints at a deep connection between the two. Ultimately, it almost feels like these two theories will end up coinciding, and one will speak about thermodynamics just as information theory with erasure. We are still far away from this claim, but the continuous appearance of information quantifiers in genuinely thermodynamics setting, especially when characterising the dissipation, cannot but corroborate this belief.

The aim of this thesis is to move further in the identification of the two theories, by focusing on some aspects of information geometry and showing how these naturally apply to the study of thermodynamic transformations. In particular, the main object of interest is the family of quantum Fisher information metrics, thoroughly studied in the first part of the thesis. In there we prove a fact that motivates the interest in this quantity: despite the statistical setting in which it was originally formulated, it has such a deep dynamical nature that all physical evolutions can actually be defined just in terms of their behaviour with respect to the Fisher information. In the second part of the thesis, we connect this discussion to the field of thermodynamics. In this context, we show that the Fisher information metrics naturally emerge in the description of the dissipation in near-isothermal transformations, that is whenever the driving is slow enough for the system to be close to equilibrium during the whole protocol. This shows another example of what seems to be a general rule: the naturality with which structures developed in the context of statistical inference and information theory apply to the study of entropy production.

Thesis Director: Prof Dr. Antonio Acin