

STOCHASTIC THERMODYNAMIC TREATMENT OF THERMAL ANISOTROPY

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ABSTRACT

Anisotropy in temperature fields, chemical potentials, and ion concentration gradients provide the fuel that feeds dynamical processes that sustain life. At the same time, anisotropy is a root cause of incurred losses manifested as entropy production. In this talk, we shed light on the delicate balance between energy extraction and entropic losses by considering an overdamped stochastic thermodynamic system in an anisotropic temperature heat bath. Specifically, we show that path lengths traversed in the manifold of thermodynamic states, measured in a suitable Riemannian metric (the Wasserstein-2 metric), represent dissipative energy losses, while area integrals of a work-density quantify work being extracted. Thus, the maximal amount of work that can be extracted relates to an isoperimetric problem in the Wasserstein space, trading off area against the length of an encircling path. Furthermore, we provide a geometric decomposition of entropy production, where dissipation is distinguished from seepage of energy between ambient anisotropic heat sources by way of the system dynamics. We show that, in the presence of anisotropy, minimization of entropy production can be expressed via a modified Optimal Mass Transport (OMT) problem. However, in contrast to the isotropic situation that leads to a classical OMT problem and Wasserstein length, entropy production may not be identically zero when the thermodynamic state remains unchanged, unless one has control over non-conservative forces.

REFERENCES

- [1] O. M. Miangolarra, *Stochastic Thermodynamic Treatment of Thermal Anisotropy*. Springer Nature, 2024.