

## Reply to 'The role of fluctuations in thermodynamics'

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## COMMENT

### Reply to 'The role of fluctuations in thermodynamics'

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**Abstract.** An answer to Paladin and Vulpiani's objections to some of the statements in a previous paper of the author is given.

In their article [1] Paladin and Vulpiani argue 'that energy fluctuations, and thus the higher-order moments of energy, contain essential information and cannot be neglected even in the thermodynamical limit'. They claim that what they show is in contradiction with some statements of my recent paper [2]. It appears to me that their comments concerning my work result entirely from a misunderstanding of its scope, purpose and conclusions. Confusion can also arise from ambiguous meaning of the term 'essential information', or even of the whole sentence quoted above. The authors seem not to realise that the term 'essential information' has a different meaning in their comment [1] and in my own paper [2].

My paper is concerned with the Jaynes principle of maximum entropy and addresses the general question: what kind of information is essential for the maximum entropy inference and what is superfluous. From the point of view of the thermodynamic limit I investigated the effect of including higher-order moments of energy among constraints used in the maximum entropy procedure. The generalised canonical distribution maximises the Shannon-Jaynes entropy subject to such constraints. I showed that in the thermodynamic limit the entropy density resulting from this distribution becomes indistinguishable from the canonical (or microcanonical) entropy density. In consequence, it is independent of the energy fluctuations (higher-order moments of energy). This proves that the generalised canonical distribution yields the same thermodynamic equations as the canonical one. These distributions are thermodynamically equivalent (i.e. from the point of view of the thermodynamic limit). Thus the derivation of thermodynamic equations based on the Jaynes principle of maximum entropy gives the same results when information about higher-order moments of energy is used, and when it is neglected. This is the exact meaning of the strongly contested statement that information corresponding to the higher-order moments of energy is non-essential from the thermodynamic point of view and can be neglected in the maximum entropy inference. I think this meaning should be clear from a careful reading of §§ 1 and 5 of my paper. Nowhere do I claim that fluctuations contain no physical information at all, or that they can always be neglected. This would be, of course, a nonsense.

Paladin and Vulpiani's quotation from my paper appearing in the sentence 'Jaworski then claims that the information contained in the moments is not essential from the thermodynamic point of view and can be neglected in a maximal entropy inference of the statistical weight because "it would be difficult to agree that . . . all thermodynamic

*properties depend in some essential way on energy fluctuations*'' is highly misleading since the quoted phrase appears on p 925 of my article in an entirely different context and has nothing to do with justification of the thesis that the information is not essential.

It is well known that thermodynamic equilibrium can be realised both in a completely isolated system (microcanonical distribution) and in a system freely exchanging energy with its surroundings (canonical distribution). This indicates that Paladin and Vulpiani's arguments in favour of the canonical distribution, although tenable, cannot be accepted without some qualifications. The same concerns the concluding sentence of their comment: 'In terms of the maximum entropy formalism, one has to conclude that there is only a relevant parameter, the mean energy, and that fluctuations are not negligible details since they are fully determined by it.' It is not true that fluctuations are fully determined by the mean energy since one should know in addition whether the system is isolated or free to energy exchange. The quoted sentence is confusing also for another reason. It seems self-contradictory for it implies that from the point of view of the maximum entropy inference the information about fluctuations is, after all, not essential since 'they are fully determined by (the mean energy)'.

## References

- [1] Paladin G and Vulpiani A 1988 *J. Phys. A: Math. Gen.* **21** 843
- [2] Jaworski W 1987 *J. Phys. A: Math. Gen.* **20** 915