Review of: "On the Statistical Arrow of Time"

Grzegorz Plewa[1]

1 National Centre for Nuclear Research

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The paper is written clearly and good. The Author's proposal is to supplement standard statistical arrow of time and second law of thermodynamic by the idea of ignorant observer, which has only partial access and knowledge about the system. Despite the argumentation is interesting, I cannot agree with the conclusion. But let me share my concerns.

The Autor starts claiming that entropy is subjective in the nature, being related with the observes ignorance or, alternatively, incomplete knowledge of a complicated system. One of the examples supporting this thesis is the stack of cards on the table. The initial state of the system is an ordered set of carts. Throwing the set up, we get another state, a random distribution of cards on a table. It was suggested that it would be difficult to the observer to determine any change in the system. Hence, the entropy should be related with uncertainty, or observer's ignorance.

The problem is that defining the entropy we do not need to consider any potential measurement effects or observer's knowledge about microstates. Classical observer is wise, by definition, and knows everything. The system is fully deterministic.

Now, considering the ignorant observer is something different because already on a theoretical level, we incorporate some sort of measurement. It is claimed than once the system is more complicated, the observer losses information about it because the access will be harder. In my opinion it is not a good idea, at least from perspective of entropy definition. This is for two reasons.

First, accepting something like this we are trying to hide fully deterministic classical physics, adding some aspects of uncertainty and complexity of the system. It is true that it would be impossible to trace all the molecules of the gas, measuring their positions and momenta with arbitrary accuracy. But for statistical mechanics or thermodynamics this is not needed. Instead, we describe the system in terms of global notions – like entropy, ignoring the details of microscopic interactions. The fact that the observer is wise or ignorant is meaningless. The only what matters for Boltzmann's entropy is the number of microstates, while for Gibbs entropy also the corresponding probabilities. Nothing else.

Second, if we really want to consider observer's ignorance, we cannot completely ignore quantum effects. In particular, as described in the paper, the ignorant observer finds a minimal, finite volume in the phase space. This is based on his inability of examining smaller volumes. But quantum mechanically, this is not surprising. In fact, from the uncertainty principle, one finds the same without referring to any experiment. What is more, the volume can be even estimated to be of order of Planck constant. No mentioning that quantum mechanically the state, observables and the observer are of special importance, and every microscopic interaction of constituent elements in the system is quantum in fact.

In my opinion, it is worth distinguishing between the practical ability of performing a measurement or collecting the information, and theoretical nature of underlying physical laws. The perfect knowledge is impossible from practical point of view, yet the mathematical description on the classical level does not require any additional uncertainty and information loss. This is just a mathematical model, nothing else. Measurement difficulties and tracing single molecules is another story and has nothing to do with classical thermodynamics and classical entropy.

Similarly, I see no reason to change anything in the standard definition of statistical arrow of time. The natural tendency for the system is to reach the state of more microstates, increasing the entropy. Imagine a system of molecules evolving from a state with small number of microstates to the state of higher entropy. Macroscopically, the wise observer and the ignorant one will observe *exactly the same.* This is because the evolution is governed by microscopic interactions rather than observer's knowledge. If the number of microstates is increasing and the system becomes more and more complicated, the ignorant observer will lose the information about it in the sense, it will be harder and harder to examine the microstates. Still, this does not affect the classical evolution. The measurement and so observer's action affects the state in quantum, but not in classical mechanics.

Similarly, I disagree that for a (perfect) wise observer there is no arrow of time. The fact that the evolution is deterministic and reversible in time is not an objection, because we can always check the number of available microstates in the initial and final state and, based on that, find the entropy and arrow of time: from smaller to larger entropy. The tendency to increase disorder will be present regardless of the observer's knowledge.

To some extent I agree with the Autor's statement that*Any given observer, whose knowledge about the initial conditions of any given system is limited, tend to lose information about the system at an exponential rate until there is none left*. The only I would change is replacing *system* by *isolated system* and removing *until there is none left*. However, I wouldn't take this as the form of second law of thermodynamic.

Summing up, I would suggest changing the thesis or making it much weaker. Also, discussing things like uncertainty or wise/ignorant observer, I think it would be good to say something about quantum physics, give a short comment at least (for instance, what is similar, what is different).