Further on the Black Hole War, or To Make the World Deep, Precise and Large Enough for Physics

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Dedicated to Marie-Louise Nykamp

Abstract

Two somewhat long overdue arguments presented here may help in further clarifying the so called "Black Whole War" and beyond that, may be useful in Physics at large.

1. Information and Physics

Concepts such as mass, motion and velocity have from times immemorial been in a form or other in human awareness, and thus one may say, also in Physics, whatever stage in the empirical or theoretical development of the latter one may refer to. Contrary to that, however, the concepts of acceleration, energy, entropy, and even more so information, are quite recent. In this regard, it is amusing to recall, for instance, that Aristotle believed velocity to be proportional to the force exerted upon an object. And it took until Newton's Second Law to realize that, in fact, it is acceleration, that is, the velocity of veloc-

ity, which has that proportionality property.
As for energy conservation, nearly another two centuries passed after Newton until it was introduced in Physics, not long before the concept of entropy.
Information, and the principle of information conservation, [9], came to Physics around the middle of the 20-th century. No wonder, therefore, that - contrary to what many may believe - information is still a less than sufficiently clarified subject, and suffers from being subjected to various insufficiently supported, or in fact, unsubstantiated claims, such as for instance that "information is physical" ...

As it turns out, the insufficient clarity surrounding the concept of information has further consequences in Physics. And as suggested in the sequel, one such consequence is a rather simple *misunderstanding* which happens to underlie the three decades old so called "black hole war", in which the main protagonists have been Stephen Hawking, and on the opposite side, Gerard t' Hooft and Leonard Susskind.

It is indeed important to keep in mind the following, formulated so clearly in [11], namely :

"The main problem with thermodynamical arguments is that the laws of thermodynamics are usually formulated in a natural language and have a common sense character. To apply them to some subtle problems one needs more rigorous formulations, than those found in most textbooks. This is particularly important in quantum theory, which often seems to be far from a 'common sense'..."

In this regard, in view of [1] for instance, it may be noted the need for a considerable care which should be exhibited whenever the concept of information is used in Physics. Indeed, as it turns out, the whole of Quantum Mechanics can be reconstructed from no more than three axioms with clear physical motivation, the first of which is called

- *Information Capacity* : All systems with information carrying capacity of one bit are equivalent.

But before we turn to a further clarification of the concept of information as such, it may be useful to note the following, related to the mentioned reductionist slogan "information is physical", a slogan no doubt expressing a certain tendency towards possessiveness, if not in fact, a good amount of wishful thinking when advocated and supported by physicists. In this regard, the often cited [3,4] papers are typical in their rather loose verbose presentation which ends up being more about intent, the intent to impose the reductionist view that "information is physical", than about achieving a satisfactory clarity, let alone, persuasiveness in its argumentation.

Obviously, whenever the statement "A is B" is made, such a statement has no meaning, unless the entity "B" is well defined, and defined so *a priori*. Thus, in the case of the above reductionist slogan related to information, what is meant by "physical" must be clearly defined in advance, in order for that slogan to have a chance to avoid being a mere trivial nonsense.

Here however, one faces a manifestly serious problem. Indeed, the term "physical" has even during recent times proved to have a significantly changing and expanding meaning. Just consider how since Newton it got enlarged by incorporating electro-magnetism, relativity, atoms, quanta, particle physics, and so on.

And then, the question arises : is the reductionist slogan "information is physical" a latest definition of Physics, one that chooses to further expand Physics by incorporating phenomena related to information, or on the contrary, that slogan is a mere claim in which the concepts of "physical" and "information" are only assumed to be defined in some vague and tacitly accepted ways ?

If that reductionist slogan is a new expansion in the definition of Physics, then everything is all right, provided of course that the concept of "information" is well defined, and defined before that slogan is launched upon the world.
Otherwise, as seen above, that slogan is quite nonsensical ...

Regarding the nuanced, varied and deeper role of information and entropy in Physics, recent literature, such as in [10-31], can be relevant.

Apart, however, from the above arguments, and of a surprisingly more fundamental relevance is the recent major discovery in [2]. According to it, if one is indeed to fall for any kind of reductionist sloganeering, then a far more appropriate one would be "Physics is but a mere subrealm of Information".
Indeed, as B. Roy Frieden shows it in convincing and rigorous detail in [2], major theories of Physics, both Classical and Quantum, can rather directly be obtained from an optimization of suitable applications of the well known statistical concept of *Fisher Information*.

Consequently, instead of diverging into slogans such as "information is physical", or worse yet, indulging in "black hole" and other "wars", it may be far more appropriate to take cognisance of such recent major breakthroughs as in [1], and above all, in [2], and realize at last that the concept of information has only been with us for a relatively short time, and thus quite likely, we do not yet understand its more true relevance properly enough ...

Let us now return to the issue of a more clear definition of the concept of information. In this regard a few preliminary considerations are useful, as presented next.

2. Simultaneous Presence and Total Involvement of Physical Entities

We can note a distinction between, on one hand, concepts such as mass, motion, velocity, acceleration, force, energy, electric charge, or say, magnetism, and on the other hand, entropy and information. And for convenience, let us start with a Classical Non-Relativistic setup.

Concepts of the first kind can not only be measured, and thus be associated with appropriate unique numbers, but their effective physical instances, that is, the given physical entities which instantiate such concepts, can be brought into a variety of physical interactions with other effective physical entities. Indeed, measurements of such entities corresponding to concepts of the first kind are themselves nothing else but results of particular cases of such physical interactions.

Now, an essential feature of such physical interactions, a feature without which the very possibility of measurements would cease to exist, is the following. Given a specific physical entity E instantiating one of such concepts, say C, like mass, motion, velocity, acceleration, force, energy, electric charge, or say, magnetism in a large variety of physical interactions with other physical entities, the entity E will in its various physical interactions exhibit the very same uniquely determined amount of what is described by the concept C.
For instance, a mass of 1 kg will in a large variety of physical interactions manifest itself with all of its mass of 1 kg, and thus, with nothing less or more than 1 kg. Certainly, in terms of Newton's Law of Universal Attraction, for instance, that mass will attract every other mass, say, m, with the force $f = Gm/r^2$, where G is the gravitational constant and r is the distance between the two masses.
After all, measurement in Classical Physics is essentially based on that feature of physical interactions. And this is precisely why in Classical Physics one does not face a "measurement problem", unlike it happens in Quantum Physics.

Let us call by *total involvement* the above phenomenon typical for effective physical entities which instantiate concepts such as for instance mass, motion, velocity, acceleration, force, energy, electric charge, or say, magnetism.

A second phenomenon related to various effective physical entities is the possibility of the *simultaneous presence* of several instantiations of physical concepts within the same given effective physical entity. Indeed, a given effective physical entity can at the same time instantiate, for instance, both mass and motion.

Clearly, in the case of such simultaneous presence there may, even within a Classical Non-Relativistic setup, be a certain relation between the concepts instantiated, such as for instance between mass, velocity and energy. However, such a relationship is obviously not always compulsory.

Within a Relativistic setup in Classical Physics, both total involvement and simultaneous presence apply. What may change is the result of measurements which, of course, will depend on the frame of reference of the observers.

3. Entropy and Information

Coming to the concepts of entropy and information and its various effective physical instantiations, however, the situation changes significantly.

For instance, the smallest possible amount of information, namely, one single *bit*, can be registered on a physical entity given by, say, a mass of 1 trillion kg, or on the contrary, it can be conveyed by one single photon. Also, the same bit can be registered on two physical entities which are at rest with respect to one another, or move with considerable velocity. Similarly, the energy of a physical entity upon which a single bit may be registered can range within very large limits. And so on.

Consequently, the instantiation of information by an effective physical entity need *not* necessarily occur with a total involvement of that entity.

Let us note in this regard several facts pertinent to the instantiation of information by an effective physical entity.

First, presently it is not known how small it may in the limit be the effective physical entity capable to convey one single bit of information. Of course, Quantum Physics can suggest some lower limit which is related to the Planck scale. Yet it would be a highly unsafe bet to consider that the present state of Quantum Physics is indeed the ... Final Theory of Physics ...

Second, when an effective physical entity conveying one single bit of information is larger than the mentioned assumed to exist lower limit, then typically a part of that physical entity is redundant in the process of conveying that bit. On the other hand, and as noted, a similar redundancy does not happen when a mass interacts with another mass, or some other interaction takes place between effective physical entities corresponding to concepts of the above first kind.

Third, given a physical record on an effective physical entity of a certain amount of information, that information can be interpreted in more than one way. Namely, the very existence of that record as a piece of information depends on an a priori convention about the way it is recorded and about the way it is read. On the other hand, in the case, for instance, of a mass interacting with another mass, there is neither a need, nor a possibility to interpret that mass in any other but a unique way, since there is one and only one way which exists as relevant, namely that mass being a mass. Consequently, there is neither the need, nor the possibility to make any a priori convention about that mass, other than being a mass prior, during, and following that respective interaction process.
Or to put it simply : when, for instance, a human messenger delivers a certain information, the race, sex, age, or for that matter, say, religion of that person is irrelevant, as long as the message itself is conveyed precisely.
On the other hand, when by some accident, that human messenger happens to fall off a cliff, all of his or her mass, that is, nothing less and nothing more, will be involved in the process.

Fourth, two different amounts of mass cannot be instantiated, thus be simultaneously present as a total involvement, in the same given effective physical entity. And the same goes for the other concepts in the first above category.
On the other hand, a given effective physical entity can simultaneously instantiate more than one information, and obviously can do so without total involvement in at least one of the cases.

Fifth, as seen in [1], the information carrying capacity of an effective physical entity is of a fundamental nature since it can be involved in one of the three physically motivated axioms which reconstruct the whole of Quantum Mechanics. Therefore, one should not disregard the above issues of total involvement and simultaneous presence when dealing with the information instantiated by effective physical entities.

As for the kind and the amount of entropy in a specific effective physical entity, they clearly depend on an a priori concept of information with which the respective concept of entropy is to be uniquely associated. For instance, if we have a meeting hall capable to seat, say, 100 people, then we can, among other situations, have the following two different entropies : first, we are only interested in how many people are in the hall, or second, we are also interested in the sex of the people in the hall. Needless to say, if we consider the age of the people, or any other possible features, then we are led to corresponding different entropies.

It follows that the above phenomena mentioned related to effective physical instantiations of information have an inevitable bearing upon the effective physical instantiation of entropy as well.

In conclusion, when speaking about entropy and information, we *cannot* automatically assume

- the total involvement of the effective physical entity which may instantiate them, or
- the existence of one and only one kind, and even less so, of a unique amount of information or entropy in that effective physical entity.

4. And How about the Black Hole War ?

Two arguments will be presented in order to help to clarify the Black Hole War. The first one shows the insufficiently well-founded use of the concept of information in the arguments of both sides in that controversy. The second one shows that whole new realms of possibilities regarding a deeper mathematical modelling of a large class of physical concepts, among them black hole singularities, information and entropy can be achieved by abandoning the more than two millennia old tacit and unfounded acceptance in Physics of the Archimedean Axiom on the structure of space-time.

In the case of the Black Hole War, the second argument tends to support the first one. Certainly, the considerably more rich self-similar structure of space-time which becomes possible with the setting aside of the Archimedean Axiom opens up wholly new ways information and entropy can manifest themselves in physical processes.

Let us start by considering the issue of *information conservation*. In [9, p. 87], it is declared as being identical with the *reversibility* of a large variety of physical processes, including under suitable conditions, quantum ones. In particular, information is considered *lost*, [9, p.180], whenever the future loses track of the past.

A few related instances may be instructive.

We can note that information conservation can happen in irreversible physical processes as well.

Indeed, let us consider the simple dynamical system in [9, p. 180] which has three states H, T and F, and evolves according to

$$(4.1) \quad H \longrightarrow T, \quad T \longrightarrow H, \quad F \longrightarrow T$$

Clearly, this dynamics is irreversible since the sate T can be obtained from both H and F.

Let us now associate the information bit 0 to both H and F, while to T we associate the information bit 1. Obviously, there will not be any information loss regarding these two bits when the system is run in reverse.

More involved irreversible physical processes without loss of information are possible due to the fact mentioned at the end of section 3, namely that, the total involvement of the effective physical entity which instantiates a given information is not always necessary.

A slight variation on the above example illustrates that fact as follows. Let us assume that the state F has the composite structure

(4.2) $\quad F = (F_1, F_2)$

and F_1 has the information bit 0 associate with it, while F_2 does not have associated with it either the information bit 0, or the information bit 1.

Then the dynamics (4.1) is again irreversible, yet no information loss regarding these two bits happens, when the system is run in reverse.

Let us now turn to the first step in Bekenstein's argument in the estimation of the entropy of a black hole, [9, p. 148]. Namely, one throws a container full of hot gas beyond the horizon of a black hole, and assumes that the high amount of entropy in the container will simply disappear completely from the universe observable outside of that horizon.

What one can assume here, based on a widespread enough agreement, is that the *mass* of the respective gas will indeed disappear from the observable universe.

From here, however, to jump to the conclusion that the same will happen with the entropy of that gas means to disregard the first of the two conclusions at the end of section 3.
Obviously, the same goes for the conclusion that the information corresponding to that entropy will also disappear.
So much, therefore, for Hawking's position ...

Regarding the position of t'Hooft and Susskind, which claims that no information disappears, the problem, of course, is that it is not experimentally testable according to our present understanding of black holes.

And if we reach the presently untestable physical realms, then we may as well venture the second argument mentioned at the beginning of this section. Namely, non-Archimedean space-time allows both *infinitesimals* and *infinitely large* domains in space and in time, with a consequent rich self-similar space-time structure, [5].

And then the possibility arises for Bekenstein's entropy, and the corresponding information, simply to shift to infinitesimal and/or infinitely large space time domains. Such a shift may, of course, correspond to some appropriate transformations of entropy and information, transformations which can be facilitated by the second conclusion at the end of section 3. And needless to say, such transformations may, or may not occur under certain conservation laws.

As for the evaporation of black holes, [9, pp. 161, 251], the poor self-similar structure of the usual space-time - built upon the more than two millennia old tacit and physically unmotivated acceptance of the Archimedean Axiom - only allows for limited alternatives in the dynamics of black holes. On the other hand, once non-Archimedean space-time structures are considered with their rich self-similar structures containing infinitesimals and infinitely large space-time domains, [5], the possible dynamics of black holes is considerably enriched.

In particular, black hole evaporation can possibly take a large variety of new forms and meanings.
In this regard, among the three alternative solutions to the Black Hole War mentioned in [9, p.252], and specifically, concerning the fate of information in a black hole, the last one, namely that, 'the information eventually resides in some sort of tiny black hole remnant that remains after evaporation', could clearly benefit from its expression in non-Archimedean space-time structures, structures that allow the presence of infinitesimals.

It is indeed hard to overestimate the severity of the limitations which have been imposed on thinking in Physics due to the more than two millennia old tacit and physically unmotivated acceptance of the Archimedean Axiom. Consequently, it is equally hard to overestimate the wealth of new opportunities opened up to thinking in Physics once non-Archimedean space-time structures may enter such thinking.
In this regard, a few first attempts to show that non-Archimedean space-time structures are fully and easily compatible with some basic physical phenomena in Relativity, Quantum Mechanics and Quantum Computation have recently been presented in [5-8].

In summary, the controversy known as the Black Hole War suffers from two limitations which may at present preclude its proper resolution, namely

- it disregards the two conclusions at the end of section 3,
- it has a poor view of space-time, a view subjected to the two millennia old tacit and unfounded acceptance in Physics of the Archimedean Axiom on the structure of space-time, a view that does not allow a sophisticated enough modelling of black hole singularities, entropy and information.

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