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Foreword

Since the advent of the theory of relativity at the beginning of the 20th century, a relativistic thermodynamics has developed. We can quote the pioneering works of Tolman, Einstein, Planck, de Broglie (e.g. [1]). More recently, physicists like Liu, Van, Sohrab, etc., have proposed developments (e.g. [2]). In this context, can we announce really new propositions? To this question, we answer yes: in the works mentioned just now, *the concepts of space and time are taken for granted without any special discussion*. But it seems to us that a good physical theory must construct itself the parameters of space and time (i.e. be background independent) and not be satisfied with receiving them from the outside.

Objective

Our objective is to take up the question of the relations between thermodynamics and relativity by being concerned with the very construction of space and time. We propose some tracks in this direction: they are for the moment *very general and based on intuitions which will deserve to be assured and completed by an adequate mathematical formalism*.

Mathematical tools

From the mathematical point of view, we are led to define, for each physical quantity, a pair of quantities $\{f, g\}$, *a priori* each a 3-vector, associated in basic elementary laws of the type

$$\frac{\partial f_i}{\partial t_j} = \frac{\partial g_j}{\partial x_i}$$

relating the four vectors f, g, r and t , of respective coordinates f_i, g_i, r_i and t_i ($i = 1$ to 3). Within a relational approach, this is the only thing we can do, relating coupled variations of quantities with respect to space and time, without being able to define any quantity by itself. We use a three-dimensional pre-temporal parameter t_i , from which we define scalar time t . Such are the pairs {electric field, magnetic field}, {energy, momentum}; in thermodynamics we will also need consider a pair such as {entropy, entropy flow}. We can see in the previous equation a conservation equation; it can be seen as a law linking a conservation and an evolution, or constraints on the flow of time and the measurement of space, as founded on the physical phenomena. These are two sides of the same coin. Note that some authors (e.g. [4]) expressed Maxwell's laws in the previous "conservative" form.

Lorentz invariance is at the heart of this mathematical approach. It incorporates the convention of defining a phenomenon of constant velocity (definition of time) in a spatial reference frame; it expresses the conservation of a metric used to define geodesics (extremal principle); the conservation / evolution equations of the type defined above are Lorentz invariant [5].

Uniting both conservation / evolution laws in relativity and in thermodynamics

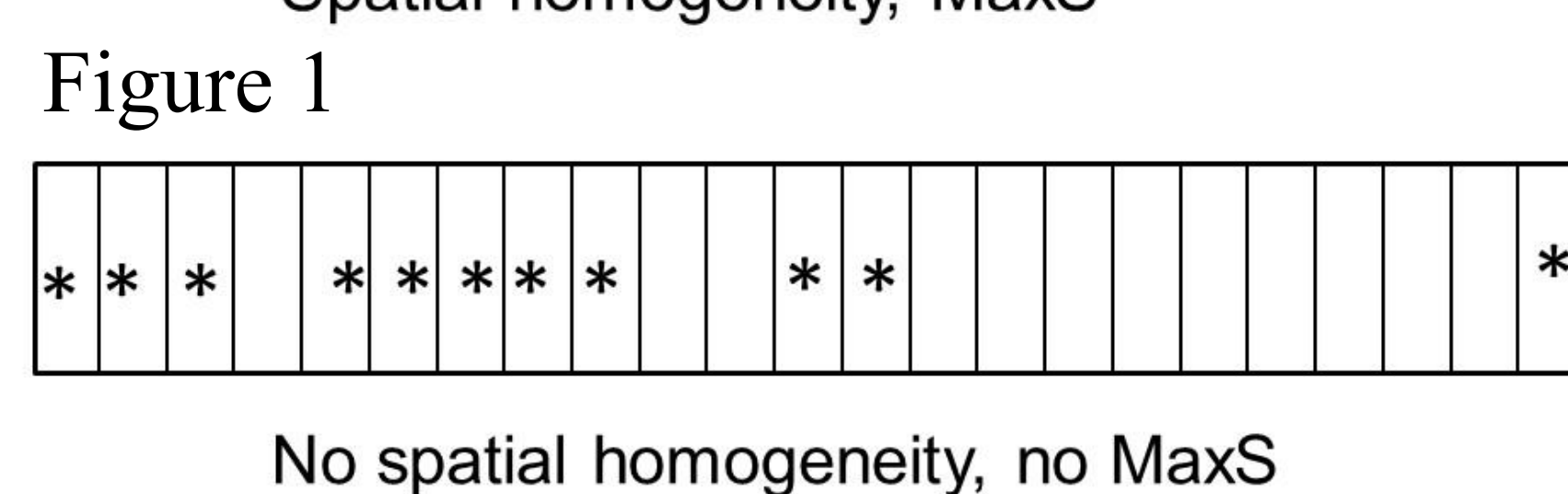
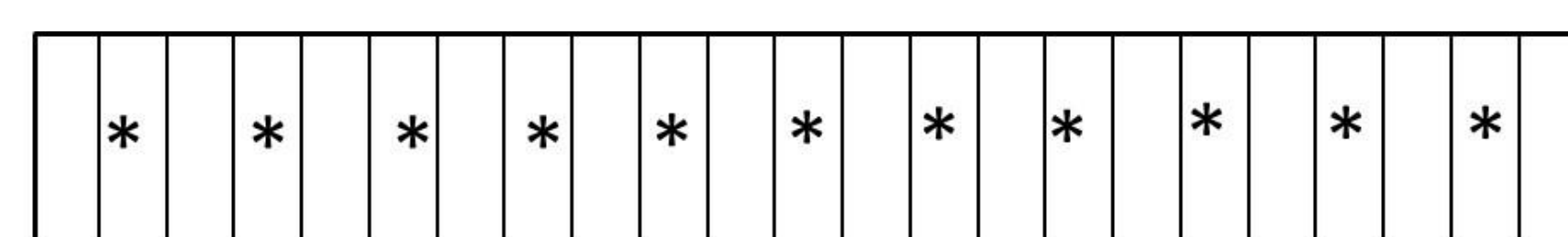
On the basis of the previous reflections, we are led to propose, within each of the domains (relativity, thermodynamics), a unification of the two principles that can be read there: both express in their own way a conservation principle and an evolution principle. This unification allows the joint definition of space and time within each theory. A conservation of something needs the permanence of a spatial frame which is itself gauged by the constancy of the speed of a mobile defining time (how can we speak of the conservation of energy if the spatial container shrinks or expands?) In relativity, we have noticed the conservation "character" of the basic physical laws (1st postulate); the 2nd postulate expresses the constancy of the temporal flow. On different bases, many authors have proposed to unify the first and second postulates of relativity (e.g. [6]).

In thermodynamics, the first law expresses the conservation of energy; the second tells us about the production of entropy: in the absence of any external and independent clock, entropy production can be taken as a clock (for example the product by a chemical reaction at a constant postulated rate). The production of entropy respects a principle of economy (minimum production) (e.g. [7]).

Relational thinking and the duality permanence / change

Our understanding of space and time refers to a fundamental process of thought: it opposes the stable to the fluctuating, conservation to evolution, permanence to change. It is the basis of a *relational thought*, the only one possible for an observer inside the world. Space and time are constructed in opposition/composition with each other by comparing phenomena, and the movements associated with them [3]. The boundary between space and time is subject to convention: *in one and the same step* one constructs a spatial frame (material points linked together in a constant immobility) and a time standard (a mobile declared of constant mobility). (Constant) immobility and (constant) mobility are decided together by the observer, according to what he is capable of, or interested in, studying.

Connecting relativity postulates with thermodynamic laws



The second law of thermodynamics expresses that, in an isolated system, spatial heterogeneities, whether of temperature or other parameters, tend to decrease (Fig. 1). Second postulate of relativity theory: a ruler, allowing to measure lengths, is constructed by marking regular graduations delimiting segments of supposedly equal sizes (Fig. 2). The space (and time) standards are derived from the standard of movement, supported by the assumption of constancy of the "speed" of light. The increments i of the ruler correspond to pieces of space travelled during equal times to the speed of the standard motion (equivalence between space and time)..

Figure 2

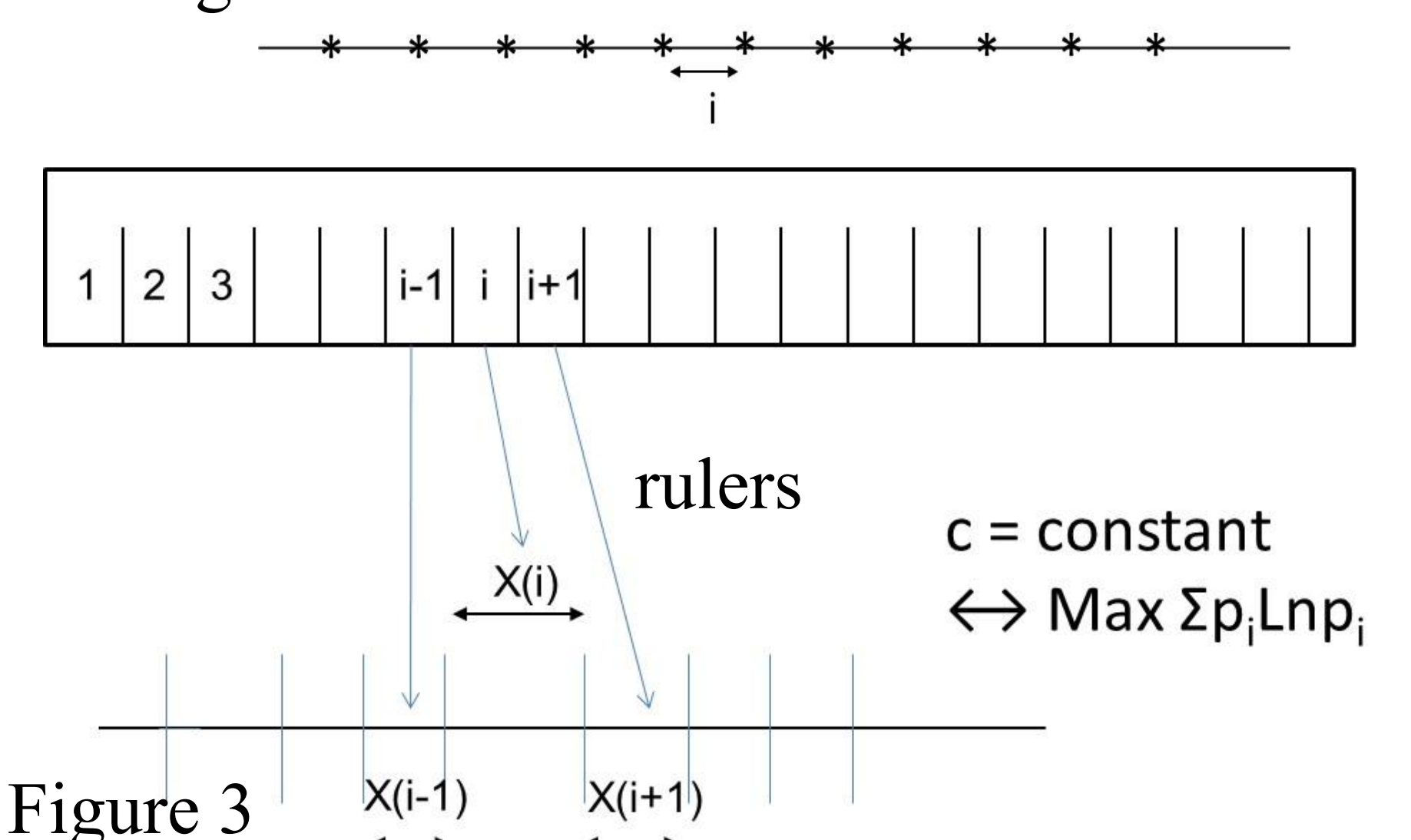


Figure 3

Giving the same weight /size to the «spatial pixels» is another way of talking about the constancy of the speed of light. We can consider the size of the different increments i of the spatial axis as values $X(i)$ of a discrete random variable X of probabilities p_i ; to say that they all have the same value is to proclaim the uniformity of the variable (Fig. 3). Another way is to require the maximum of the associated entropy $\sum p_i \ln p_i$. So thermodynamics is already present in the theory of relativity, seeing an entropy in the coordinate axes that this theory manipulates [8].



Further lines of research

It will be necessary to extend the preceding spatial view to the inseparable temporal aspect. Other questions will have to be examined, such as - that of taking into account, in a theory, in a distinct and/or associated way, what concerns the scene and its graduations on the one hand, and that of the phenomenon which unfolds there on the other hand (case of background independence), - that of linking what concerns the extremum of entropy production to what concerns the extremum of entropy flux divergence (in our understanding, it is the same problem); cf. also the constructal law [9] or the maximum caliber [10]. Etc

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