TIME, CAUSILY, ARROW OF TIME: WHAT LINKS BETWEEN THEM?

Abstract

One hundred and thirty years after the work of Ludwig Boltzmann on the interpretation of irreversibility of physical phenomena, and that one century after Einstein's formulation of Special Relativity, we are still not sure what we mean when we talk of "time", "course of time", "arrow of time". We shall try to show that one source of this difficulty is our tendency to confuse, at least verbally, time and becoming, i.e. the course of time and the arrow of time, two concepts that the formalisms of modern physics are careful to distinguish.

The course of time is represented by the time line on which it is customary to place a small arrow which, ironically, must not be confused with the "arrow of time". This small arrow is only there to indicate that the course of time has a direction and that travelling through time is impossible. In other words, it expresses the submission of time to the causality principle.

The arrow of time, on the other hand, indicates the possibility for physical systems to experience changes or transformations over the course of time that prevent them forever from returning to their initial state. It is therefore a property not of time itself but of certain physical phenomena the dynamic of which is irreversible. By its very definition, the arrow of time presupposes the existence of a well-established course of time within which – in addition – certain phenomena have their own temporal orientation.

The fact that the irreversibility of time and the irreversibility of phenomena involve two different levels of explanation inside physics formalisms indicates that, for modern physics at least, the course of time and arrow of time are two different concepts : to

assert that the entropy change for any spontaneous transformation of an isolated system is a non decreasing function of time implicitly assumes that the considered transformation occurs along the direction of time that bears us from our "past" to our "future" and not the reverse. This means that becoming cannot be thought without presupposing the course of time.

However it is not excluded that the flow of time and the arrow of time come from the same source, more profound than they both; that they are by-products of underlying phenomena that a "new physics" might reveal. Moreover, some progress has recently been made in that direction, in characterizing causality independently of any concept of time and deriving both time and becoming from an ordering relation on sets of events taken as primitives. It may thus appear that causality cannot be understood as a feature of the world that would exist independently of any phenomenon. Causality would be intrinsically shaped by the phenomena. As the principle of causality underlies our representation of time in physics, this would give some formal foundation to a close connection between time and becoming. But for the time being, it would be wiser to formally distinguish them in order to make the arguments clearer.

Key Words: Time, time's arrow, temporal asymmetry, causality principle, irreversibility.