Minkowski Space-time and Thermodynamics

Abstract

I. The purpose of this paper is twofold: **a)** to explore the compatibility of Minkowski's space-time representation of the Special theory of relativity with a dynamic conception of space-time; **b)** to locate its roots in the thermodynamic and entropic features of the propagation of signals in space-time. From its very beginning Minkowski's four-dimensional space-time was associated with a static view of reality, e.g. a block universe. Einstein added his influential voice to this conception when he wrote: 'From a "happening" in three-dimensional space, physics becomes (...) an "existence" in the four-dimensional "world".' (Einstein, *Relativity* 1920, 122) Yet it is by no means clear that Minkowski himself was a believer in the block universe. In his 1908 Cologne lecture on 'Space and Time' he speaks of a four-dimensional physics but concedes that a 'necessary' time order can be established at every world point. Although the conception of the block universe has gained much currency, an alternative view has been in circulation since the 1910s according to which the trajectories of particles constitute histories in space-time. (Robb 1914, Cunningham 1915, Carathéodorys 1924, Schlick 1917, Reichenbach 1924)

II. What does it mean that space-time trajectories have a history? As Minkowski had already indicated, the Here-Now separates events at a space-time point, *P*, into a basic 'before-after' relation. Events belonging to the past light cone necessarily occur earlier than events at Here-Now. But even if the 'before-after' relation between two events is an asymmetric relation, how does this linear order lead to the above-mentioned dynamic view of space-time? Are we in danger of re-introducing a metaphysical flow of time, leading to statements like: the world line at space-time point *P* represents the 'flow of time' at *P*, and 'world lines exhibit most clearly the singular character of time'? In order to avoid this danger, A. A. Robb, amongst others, based his account on the idea of histories in space-time. Instead of starting from Minkowski's 'absolute world postulate', Robb starts from a fundamental 'before-after' relation between null-like and time-like related events, on the

basis of which he constructs an axiomatic account of space-time. Although these events are represented in geometric terms, they are crucially based on optical facts, like the emission and absorption of photons. The propagation of these signals constitutes an invariant conical under the Lorentz transformations. The null-like and time-like trajectories between space-time events form the Minkowski world lines of light signals and material particles, respectively. The propagation of these signals constitutes a history of space-time relations, in which we may include both kinematic and dynamic aspects.

III. Let space-time diagrams be models of physical space-time, which represent histories of particle trajectories. But these models fail to represent two important dynamic and physical aspects of signal propagation through physical space-time: **a)** they are subject to thermodynamic processes, which lead to an increase in entropy; **b)** entropic processes are frame-invariant in the STR. These physical features suggest that the arrow of time can be based on entropic considerations, despite Popper's objection that the arrow of time does not seem to display a stochastic character. For to establish the arrow of time it is not necessary to stipulate a unidirectional evolution of all thermodynamic systems in the universe. It is sufficient to base the arrow of time on the thermodynamic behaviour of a 'majority of branch systems'. In this way the asymmetric relation between space-time events gains a physical grounding, which suggests that four-dimensionality does not necessarily imply a static view of space-time.