Reply to referee report #3

(SZABO: On the meaning of Lorentz covariance)

Taking into account of the referee reports, I have made important changes in the manuscript. However, there is no change in the main message of the paper. In this reply, I am reflecting to all of the referee's remarks and criticism, even if the corresponding passages have been rewritten or removed from the text.

1. Let me reflect first the referee's second point. (S)he writes the following: "in my opinion the relativity principle stated as 'the laws of physics (including Maxwell's) must be valid in the same form in all IRF's"' (Note, that three referees gave three different—conflicting—lessons about how relativity principle should be understood.) Let us try to unpack this (third) formulation of the principle. If the laws of physics have the same form in all IRF's then one can think that the same physical phenomenon must be described by the same solutions of the same equations in all IRF's. This is however obviously not the case. The motion of the plasma of the same solar flare is described differently by two observers in two different IRF's. Thus, the opposite must be true: *Different* physical phenomena are described by the same solutions of the same equations in the different IRF's. Namely, the behavior of the system co-moving as a whole with K', expressed in terms of the results of measurements obtainable by means of measuring-rods and clocks co-moving with K' is the same as the behavior of the original system, expressed in terms of the measurements with the devices at rest in K—as I formulated it in the paper, by "quoting" one of the more precise textbook formulations. Of course, this formulation is vague—that was my main concern. For what exactly does "the system co-moving as a whole with K'" mean? There are different typical reflections to such a question, which all I find unsatisfactory. Let me briefly sketch a few of them:

1. It definitely doesn't mean a system which was accelerated from one IFR to the other. (Referee#2)
2. It means a system which is an "identical copy" of the one "being at rest in K", but which is in a "uniform motion" together with IRF K' from eternity. (Referee#2)
3. It means the original system gently accelerated from K to K'. (Bell, Einstein)
4. It means the Lorentz boosted system, i.e., a system described by the solution of the same (covariant) equations, belonging to the condition$\Lambda_v^{-1}(\psi'_0)$ (see the notations in the rewritten new manuscript). (Referee#1)

5. It means the "original system" in a state when it is "at rest as a whole" relative to (the simultaneity in) K'. (Referee#3)

One can raise the following problems with respect to these views:

- The usual Einsteinian derivation of the Lorentz transformation, simultaneity in K', etc., starts with the declaration of the relativity principle. Therefore, all these things must be logically preceded by the concept of "a physical object in a uniform motion relative to K". (in contradiction with 4, 5, and partly 2)
- To know what the "identical copy", the "original system when ...", mean and, first of all, for the operational definition of the space and time tags in K' we need the concept/description of "the system gently accelerated from K into K'". (against 1 and 2)
- As Bell points out, "the laws of physics in any one reference frame account for all physical phenomena, including the observations of moving observers". (against 1, 2, 4 and 5)
- The concept of "gentle acceleration" as well as the concept of a "system which is in rest in K' from eternity" are meaningful only for a dissipative system being in equilibrium. (against 3 and 2)

2. The referee rightly points out that one of the reasons why the original initial conditions (29) and (30) [according to the numbering of the original manuscript] are mixed in (32) and (33) is that simultaneity in K and K' are meant differently. This observation does not solve, however, the above problem. The reason is, again, that the laws of physics in any one reference frame must account for all physical phenomena, including the observations of moving observers.

3. Because of the same reason I cannot agree the referee's last remark that "there is always the problem of trying to understand accelerated systems within the context of the principle of special relativity. By definition, such reference frames fall outside this principle". Accelerated reference frames fall outside this principle, indeed, but not accelerated physical objects. Note, that an accelerated reference frame falls outside of the scope of the (special, restricted) relativity principle only as the *subject* of the principle, but not as its *object*. Since the principle itself is about how the descriptions in different inertial (non-accelerated) reference frames are related to each other. But, in any inertial reference frame K the laws of physics must account for how the things look like in an arbitrary accelerated frame G. Imagine now another inertial frame K'. The laws of physics in K' must also account for what an observer observes in G. The relativity principle relates two such descriptions in the following sense: Let the described phenomenon be <how the things look like in G>. Let things$_v$ symbolically denote the same things when they are in collective motion at velocity v relative to K, and similarly let G_v be a frame which performs the same accelerating motion as G in superposition with a translation at velocity v relative to K. (Of course, these all are vague concepts, as usual.) Now, according to the relativity principle the <how the

things$_v$ look like in G_v> expressed in the terms of the results of measurements obtained by means of measuring-rods and clocks co-moving with K' is the same (has the same form) as the <how the things look like in G>, expressed in terms of the measurements with the devices at rest in K.

4. Finally I would like to reflect to the referee's following views:

> ...the relativity principle ...and Lorentz covariance, "transform from one IRF to another by the usual Lorentz transformations" are not in any way affected by such practical considerations. Both are *formal* conditions: the *form* of the Maxwell equations and relativistic mechanics *is* preserved by the Lorentz transformations, so Lorentz covariance does lead to the POR. The converse is true, by the usual arguments (adding homogeneity and flat geometry, of course).

What the referee calls "practical considerations" are nothing but the most fundamental questions of the theory, namely, the questions of how the theoretical concepts and theoretical statements are related to the empirical facts. Without such considerations our theory would be a nice mathematical game, but not an experimentally confirmed scientific theory. Without such considerations, the mere recognition that the Maxwell equations are symmetric with respect to the variable-transformation

$$x_1' = x_1 \quad x_2' = x_2 \quad x_3' = \frac{x_3 - vt}{\sqrt{1-\frac{v^2}{c^2}}} \quad t' = \frac{t - \frac{vx_3}{c^2}}{\sqrt{1-\frac{v^2}{c^2}}} \quad \cdots \tag{1}$$

and that one can use this symmetry for generating new solutions from a known one, would be nice mathematical facts without any significance for physics. In Einstein's words:

> A Priori it is quite clear that we must be able to learn something about the physical behaviour of measuring-rods and clocks from the equations of transformation, for the magnitudes z, y, x, t, are nothing more nor less than the results of measurements obtainable by means of measuring-rods and clocks.[1]

So, the physical significance of the Lorentz transformation and the Lorentz covariance of the equations consists in those "considerations" which relate these things to the empirical terms: It is a contingent fact of nature that the primed variables in (1) are nothing but the space and time tags obtainable by means of measuring-rods and clocks co-moving with K', and the new solution obtained through the Lorentz covariance of the equations is the one describing—again, roughly—the same system in the same state corresponding to the original solution but in a collective motion together with K'. And the aim of my paper is to understand this second statement more precisely.

I hope that this reply made my position more clear and acceptable for publication—even if there have remained several points where the referee has different views.

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[1]Einstein, A. (1920): Relativity: The Special and General Theory, H. Holt and Company, New York, p. 35.