Einstein-Bergson debate on special relativity

Author: Èric Gómez Bertomeu
Facultat de Física, Universitat de Barcelona, Diagonal 645, 08028 Barcelona, Spain.

Advisor: Enric Pérez Canals

Abstract: This paper deals with the debate between Albert Einstein and Henri Bergson that revolved around their corresponding interpretations of the theory of relativity. We will analyze the origins and evolution of each one of the multiple debate's positions as well as the persons and events that promoted and catalysed the debate. We will end our work with the study of the debate in itself. By this means, we are able to achieve the main goal of this work which is none other than understanding an historical debate that marked a turning point in the physical and philosophical fields in respect of the interpretations of the theory of relativity.

I. INTRODUCTION

Through this work we will be discussing the basis and the main implications of an historical debate that involved both the scientific and the philosophical communities. That is why we can classify our study as a historical work in the philosophical and physical fields for which we will use both direct sources, where we find both transcribed interventions [1] [2] and scientific and philosophical publications [3] [4]; and indirect sources that explain the origin and evolution of the various positions in the debate and its interpretations such as [5] [6]. We can take Einstein's work "On the electrodynamics of moving bodies" (1905) [3] as the origin of the debate; we will analyze the theoretical basis of the publication but also its interpretations and consequences. Next, we will study one of the most important persons and events in terms of promoting and catalysing the debate which is Paul Langevin and his talk *The Evolution of Space and Time* (1911) [1] not only for making Einstein's work on the theory of relativity known to Bergson but also for the way in which he did it. We will go on with our study with the analysis of the debate in itslef that took place after Einstein's talk *La théorie de la relativité* [2] during the meeting of *la Société française de philosophie* in the *Collège de France* the 5th of april of 1922. Our work ends with the summary of the fundamental pieces of the debate and its main implications by way of conclusion.

II. BEFORE THE DEBATE

A. A. Einstein: "On the electrodynamics of moving bodies" (1905)

Einstein's motivation for working on the electrodynamics of moving bodies comes from his aspiration of developing a theory based on the kinematics of the rigid body that avoids the asymmetries originated from the application of Maxwell's electrodynamics. We will base our analysis of this publication on the various aspects that collided with the classical physics and that will trigger the subsequent debate.

1. *Definition of Simultaneity*

Einstein starts this section by setting out the meaning of the concept of *time*. For that purpose, Einstein states that all our judgments in which time plays a part are always judgments of simultaneous events. In order to define concepts such as *time* or *simultaneity* Einstein proposes the following problem:

If at the point A of space we set a clock, an observer at point A can determine the time values of the events at the immediate entourage of A just by checking the position of the clock hands simultaneous with the events. We can define this analogously for a point B of space. That said, it should also be noted that it is not possible to compare the time values of events at the immediate entourages of points A and B; since we have only defined an *A time* and *B time* (valids for the entourage of A and B respectively). One thing we can know for sure is if this two clocks run synchronously just by checking the following equation:

$$t_B - t_A = t'_A - t_B \tag{1}$$

Where t_A is the instant (A time) when a ray of light starts moving from point A towards point B, t_B the instant (B time) when the ray of light is reflected at point B in the direction of point A, and t'_A the instant (A time) when the ray of light arrives again at point A. This allows Einstein to define the *time* of an event as that which is given simultaneously with the event by a stationary clock located at the place of the event, this clock being synchronous, and indeed synchronous for all time determinations, with a specified stationary clock.

From there, we can also define the following magnitude as an universal constant: the velocity of light in empty space. Where $\overline{AB}$ denotes the distance between the point A and the point B:

$$\frac{2 \cdot \overline{AB}}{t'_A - t_A} = V \tag{2}$$

2. On the Relativity of Lengths and Times

In this section, Einstein presents two principles that will become the grounding of his work and, combined, will explain the majority of the phenomenona and derivations that will appear from now on:

a. The principle of relativity: The laws by which the states of physical systems undergo change are not affected, whether these changes of state be referred to the one or the other of two systems of co-ordinates in uniform translatory motion.

b. The principle of the constancy of the velocity of light: Any ray of light moves in the *stationary* system of co-ordinates with the determined velocity c, whether the ray be emitted by a stationary or by a moving body.

In order to capture the concept of relativity of length based on this two principles Einstein states the following situation: Let there be given a stationary rigid rod, and let its length be l as measured by a measuring-rod which is also stationary. Consider the axis of the rod lying along the axis of x of the stationary system of coordinates and imagine we impart to the rod a uniform motion of parallel translation with velocity v along the axis of x in the direction of increasing x. We can now consider the measurement of the rigid rod length following the two operations below:

a) The observer moves together with the given measuring-rod and the rod to be measured, and measures the length of the rod directly by superposing the measuring-rod, in just the same way as if all three were at rest.

b) By means of stationary clocks set up in the stationary system and synchronizing in accordance with (1), the observer ascertains at what points of the stationary system the two ends of the rod to be measured are located at a definite time. The distance between these two points, measured by the measuring-rod, is also a length which may be designated the *length of the moving rod in the stationary system.*

According to the principle of relativity, the length of the rod obtained by a) (length of the rod in the moving system) should be equal to length l of the stationary rod. That said, the rod length obtained by b) (length of the moving rod in the stationary system) that can be determined combining the two principles stated before, is not equal to l.

In order to capture the concept of relativity of times, Einstein adds up: Let's imagine that at the two ends A and B of the rod, clocks are placed which synchronize with the clocks of the stationary system. We imagine further that with each clock there is a moving observer, and that these observers apply to both clocks the criterion established in (1) for the synchronization of two clocks. Let a ray of light depart from point A at the time t_A that is reflected at point B at the time t_B and comes back to point A at the time t'_A. Taking into consideration the principle of the constancy of the velocity of light we find that:

$$t_B - t_A = \frac{\tau_{AB}}{V - v} \qquad \textit{and} \qquad t'_A - t_B = \frac{\tau_{AB}}{V + v} \tag{3}$$

Where r_{AB} denotes the length of the moving rod measured in the stationary system. Therefore, in view of the above, we can conclude that observers moving with the moving rod will thus find that the two clocks are not synchronous, while observers in the stationary system will declare the clocks to be synchronous. So we conclude that we cannot assign any absolute meaning to the concept of simultaneity.

3. Theory of the Transformation of Coordinates and Times

In this section, Einstein derives the transformation equations of coordinates and times from a stationary system to a moving system. To that end let's consider two system of co-ordinates in stationary space. Now to the origin of one of the two systems k let a constant velocity v be imparted in the direction of the increasing x of the other stationary system K; so that to any value of time t of the stationary system K there then will correspond a definite position of the axes of the moving system k. Let's define (x, y, z) and (ξ, η, ζ) as the co-ordinates that measure the space from the stationary system K and the moving system k respectively; t and τ as the times of the stationary and the moving system respectively for all points thereof at which there are clocks. Einstein finds out that the transformation equations are:

$$\begin{aligned} \tau &= \beta \cdot \left(t - \frac{v \cdot x}{V^2}\right), \\ \xi &= \beta \cdot (x - v \cdot t), \\ \eta &= y, \\ \zeta &= z, \end{aligned}$$

$$\textit{where} \qquad \beta = \frac{1}{\sqrt{1 - \left(\frac{v}{V}\right)^2}} \tag{4}$$

4. Physical Meaning of the Equations Obtained in Respect to Moving Rigid Bodies and Moving Clocks

In order to understand the physical meaning of the transformation equations previously obtained (4), Einstein considers a rigid sphere of radius R, at rest relatively to the moving system k, and with its centre at the origin of co-ordinates of k. The equation of the surface of this sphere moving relatively to the system K with velocity v is:

$$\xi^2 + \eta^2 + \zeta^2 = R^2 \tag{5}$$

The equation of this surface expressed in (x, y, z) at the time $t = 0$ is:

$$\frac{x^2}{\left(\sqrt{1-\left(\frac{v}{V}\right)^2}\right)^2} + y^2 + x^2 = R^2 \tag{6}$$

A rigid body which, measured at rest, has the form of a sphere, therefore has in a state of motion (viewed from the stationary system) the form of an ellipsoid of revolution with the axes:

$$R \cdot \sqrt{1-\left(\frac{v}{V}\right)^2},\ R,\ R. \tag{7}$$

Therefore, the X dimension of our moving sphere will appear shortened in the ratio $\sqrt{1-(v/V)^2}$.

Consider now one of the clocks that mark the time t when at rest relatively to the stationary system, and the time τ when at rest relatively to the moving system, to be located at the origin of the coordinates of k, and so adjusted that it marks the time τ. Taking into account the following equations:

$$\tau = \frac{1}{\sqrt{1-\left(\frac{v}{V}\right)^2}} \cdot \left(t - \frac{v}{V^2} \cdot x\right) \qquad ; \qquad x = v \cdot t \tag{8}$$

We can state that the rate of this clock, when viewed from the stationary system is:

$$\tau = t \cdot \sqrt{1-\left(\frac{v}{V}\right)^2} = t - \left(1 - \sqrt{1-\left(\frac{v}{V}\right)^2}\right) \cdot t \tag{9}$$

B. P. Langevin: "The Evolution of Space and Time" (1911): The twin paradox

For the "Fourth International Congress of Philosophy" (Bologna, Spring 1911) Paul Langevin prepared a talk [1] dedicated to a *paradoxical fact* of the Einstein's work on the theory of relativity. Among many other philosophers we find Henri Bergson as one of the talk guests. Langevin would make Einstein's work known to Bergson by means of his analysis and the philosopher would start working on his own interpretation of the theory of relativity by coming up with some objections and propositions on which he will base his own time theory. Let us now first consider the *paradoxical fact* that appeared in Einstein's work:

1. *The Clock Paradox*

After Einstein's work "On the electrodynamics of moving bodies" (1905) the idea of the theory of relativity colliding with classical physics in the following fundamental aspects quickly became popular:

- Redefined the concepts of *time* and *space* advocating that those were no longer universal.
- Showed that concepts of *time* and *space* were closely connected.
- Eradicate the concept of *Ether* (a substance that presumably filled empty space and that scientists hoped would provide a stable environment for both the universe and their theories of classical mechanics).

These three new approaches contributed to popularize a new concept called *time dilation* and that can be derived directly from Einstein's work itself (9). Einstein himself tried to reflect the concept of *time dilation* through the paradox known as "Clock paradox" [6]:

If at the points A and B of K there are clocks at rest which, considered from the system at rest, are running synchronously, and if the clock at A is moved with the velocity v along the line connecting B, then upon arrival of this clock at B the two clocks no longer synchronize, but the clock that moved from A to B lags behind the other which has remained at B by $\frac{1}{2}\frac{tv^2}{c^2}$ *seconds. Where t is the time required by the clock to travel from A to B.*

2. *The Twin Paradox*

Let us now see how Paul Langevin interprets and spreads this *paradoxical fact* through his talk "Evolution of Space and Time talk" (1911) by formulating a new one adopting a didactic approach by including concepts such as human observers or the aging effect. This new paradox will be known as "The twin paradox"[6]:

For any of us, who is willing to devote two years of his life, of knowing how the Earth will be in two hundred years time. It is sufficient for this that our traveler agrees to shut himself up in a projectile, sent away from the Earth, with a speed sufficiently close to that of light; after one year in the life of the traveler, that sends the spaceship back towards the Earth with the same speed. Returning to Earth, having aged by two years, he will climb out of his vehicle and find our globe aged by at least two hundred years, if his speed had stayed within an interval of less than twenty-thousandth of the speed of light.

Langevin's new formulation of the "Clock paradox", which includes human observers and biological concepts such as the aging effect, would reveal the main differences between the multiple schools of thought about the interpretation of the theory of relativity by alluding to the relevance of the theory real implications. This talk, and especially the paradox stated by Paul Langevin, would go down in history as a turning point by triggering and catalyzing the debate between Einstein and Bergson on the interpretation of the theory of relativity.

III. THE DEBATE

As an initiative of the philosopher Xavier León, Einstein prepares an intervention about the theory of relativity and his interpretation in the context of the meeting of the *Société française de philosophie* in the *Collège de France* the 5th of April of 1922. This presentation [2] ends up turning into the perfect context for an historical debate about the interpretation of the theory of relativity. When Eintein's intervention about the theory of relativity came to an end, Bergson, pushed by the rest of guests and organizers, initiated the debate as such by laying out his own interpretation of the theory of relativity and, therefore, his time theory [4].

A. Bergson

Although Bergson's intervention was lengthy and wide, we will split up his statement in two sections: his objections to Einstein's interpretation of the theory of relativity, and his propositions in order to reconcile the theory of relativity with his time theory.

a. Objections: Bergson was persistent in conveying the idea that he did not have any objection with Einstein's interpretation of the theory of relativity in an analytical way and he did not intend to dispute none of his scientific assumptions. Despite this, he emphasizes that not everything ends with Einstein's theory of relativity and his interpretation. Bergson's main objection to Einstein's interpretation of the theory of relativity was the simple and dualist concept of time that the scientist advocated. A concept of time that could never encompass aspects of the universe that, in his opinion, should be included in the definition of time. Bergson stated that, in terms of a time theory, there was nothing more abhorrent than confusing the clock time and the general concept of time; just like using ones criteria for judging the other one. Bergson stated frankly that he fully accept, under certain conditions, the relativistic effects such as *time dilation.* However, he insisted, for example, on the need for knowing exactly what type of reality should we grant to each observer in case they deffer about time measurements. Bergson, therefore accepts every single result derived from Einstein's theory of relativity, he just refuses to assign the same real value to each one. The criteria for assigning or not assigning reality to certain effects had historically been fundamental ideas of Bergson's philosophy [4]. Extrapolating this to Einstein's theory of relativity interpretation we get to the dilemma of the real implications of the effects derived from the theory: Bergson, for example, wonders why or under what circumstances shall we consider clock's slowness derived from time dilation a real change in the general concept of time. Bergson contends that these time discrepancies measured by the clocks do not necessarily imply changes in the time in itself and that should not indispensably be understood the way Einstein proposed. The main question therefore was the way roles should be assigned to the real and the conventional effects, the importance that should be attributed to the different times that appear in Einstein's theory equations and the way in which they interact with our common notion of time. Bergson therefore objects to Einstein's theory the authority to equalize all systems (as real systems) and to declare all times equally valid.

Unsurprisingly, Bergson also differed from Einstein's interpretation of the theory of relativity [5] with everything related to the measurement of time. The philosopher stated that measuring time destroys parts of it and therefore scientists do not really measure time, but instead cut it into pieces and assume they are equal so that their equations are as simple as possible. Bergson advocated time measuring being such a complex and difficult operation that went much further than reading a number and that it was of fundamental importance understanding and analysing the general meaning of the operation. The philosopher defended the need to finding a more primitive definition for the concept of simultaneity that did not have its basis in the concept of clock and its measurements but rather explain why they *work*, *are used* or *are produced.* Bergson states that *knowing what time is it* by looking at the clock implies a previous correlation between the clock and the event, therefore, clocks were actually insufficient for explaining phenomenon such as the simultaneity or the general concept of time.

b. Propositions: In order to reconcile the theoretical and experimental results of the Einstein's theory of relativity, to which he had no objection, with his own philosophy; Bergson developed a time theory that had its basis in the definition of two different concepts: the time, and the Time. Which, at the same time, would allow him to accomplish his main objective: to reinterpret all the scientific concepts derived from the theory of relativity. Bergson thus defines a concept of Time [5] that was understood as a continual flow of duration and that was unique and universal. This concept differed with the concept of time which Bergson defined as an artificial fictional construction. The philosopher would therefore attribute the scientific concepts and its effects derived from Einstein's theory of relativity to this fictional time which, in turn, would allow him not to assign to such effects the same real value. This new concept of Time that Bergson defines implies, in turn, a new definition of the concept of simultaneity inherent to the event in itself, which is absolute, unique and universal; and that differs from the fictional simultaneity associated with Einstein's concept of time, which is not other than the one that prints an external observer to the event and that is, therefore, relative. Bergson concludes his intervention laying down the basis of his interpretation of the theory of relativity and the following conclusion: Einstein's theory does not add anything new to the classical conception of time in physics: Multiple times are nothing more than symbolic expressions referring to Time; which is unique and can be directly measured by the observer. This confirms the Bergsonian thesis which states that the time of physics is an artificial and symbolic construction.

B. Einstein

After Bergson's intervention, Einstein argued point by point the philosopher objections and propositions about his interpretation of the theory of relativity. Einstein begins his intervention with his famous phrase, which summarizes his stance on one of the basis of Bergson's interpretation of the theory of relativity which is: *Il n'y a donc pas un temps des philosophes* (the time of the philosophers does not exist); alluding to the concept of Time (unique and universal) that the philosopher previously exposed. For Einstein there were only two ways to understand the concept of time: the physical time and the philosophical time. The first one was the real one and, therefore, it made reference to the magnitude measured by an instrument; while the second on was nothing but the subjective perception of the first one. For Einstein, time was either what clocks measured or it was nothing at all. This is why, for example, questions like *why do clocks work* or *why clocks are produced*, which were essential reflections for Bergson and on which he would base his own time theory, did not make sense or arouse any interest for Einstein [5]. With this simply refusal to accept Bergson's definition of Time, Einstein gets to bringing down great part of the philosopher's argumentation and, therefore Bergson's time theory. With this achieved, Einstein started focusing his efforts on refuting those theories that granted to Einstein's interpretation of the theory of relativity a merely formal or mathematical relevance. Likewise, the scientist argued against those schools of thought that, from a conventionalist perspective, defined his interpretation of the theory of relativity as *one more* among all the possible ones. These arguments were enough for both Einstein and his supporters to reduce, from a simplistic perspective, much of the debate in itself to the fact that Bergson just did not understand Einstein's theory of relativity in a theoretical way as well as his interpretation.

IV. CONCLUSIONS

With regard to Einstein and Bergson positions and the popular opinion during and after the debate we can state that:

- Neither of them presented important changes in terms of the interpretation of the theory of relativity. Although the debate led both of them to develop and delve into their own theories.

- The idea that Bergson just did not understand Einstein's theory of relativity in a theoretical way transcended in public opinion. So, in the first instance, Einstein was perceived as the winner of the debate and, consequently, Bergson figure did not draw strength from the debate. Personally I think that, although we cannot assure that Bergson fully understood Einstein's theory of relativity, his argumentation and interpretation of Einstein's theory does not necessarily imply that he did not understand the theory.

- Although Einstein is, in the first instance, perceived as the winner of the debate; the idea of his interpretation of the theory of relativity being just one more interpretation among all the possible ones also transcended. Leading to Einstein adopting a radical stance against conventionalism.

- Personally, I think that, although we have clearly laid the basis of the debate during the course of this work, this could also be the starting point of a work that delves into the consequences and implications of the debate both in the physical and the philosophical fields.

Acknowledgments

I would like to thank my advisor Enric Perez introducing me to the historical context of the debate, recommending helpful bibliography that allowed us to develop the study of the debate and especially for his confidence.

[1] Paul Langevin, *Le temps, l'espace et la casualité dans la physique moderne*, (Bologna 1911)
[2] Albert Einstein, *Bulletin société française de philosophie: "La théorie de la relativité"*, (Paris 1922)
[3] Albert Einstein, *Zur Elektrodynamik bewegter Körper*, (Annalen der Physik 17, 1, 1905, pp. 891-921, p. 904)
[4] Henri Bergson, *Durée et simultanéité, a propos de la théorie d'Einstein*, (Presses universitaires de France, Paris 1922)
[5] Jimena Canales, *El físico y el filósofo*, (Arpa, Barcelona 2020)
[6] Galina Weinstein, *Einstein's clocks and Langevin's twins*, (Cornell University, New York 2012)