



# Arrow of time: A physical concept with philosophical roots

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## ABSTRACT

The notion of “time” is one of the key concepts in physics and philosophy and it “occupies a key role to bridge domains of experience belonging to the spiritual and physical sides of our nature” as says Sir Arthur Eddington. This essay has for subject, historical and philosophical origins of “arrow of time” as a physical notion. It is a case in which we can clearly see the close interplay between physics and philosophy.

**Keywords:** Time, Philosophy of Physics, Bergson, Eddington

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## INTRODUCTION

What is time? This is a question that fascinates generations of philosophers, scholars and scientists, since many centuries ago. Is it an entity that has an independent existence, as Isaak Newton defined it, or a physical quantity that depends on the phenomena? Well, after Einstein’s theories of Relativity (special & general) we know that the measurement of space-time is absolutely related to the velocity of observer and / or the gravitational field in which he / she is located. As Einstein said, by using clocks, the subjective sense of a flow of time which makes us able to arrange our impressions, to judge if one event has taken place before or after another one, becomes objective. We notice that for Einstein, the sense of “flow of

time” is subjective and perhaps it is an illusion generated by our brain. Also, it is known that Einstein was profoundly influenced by Ernst Mach who believed that the “Newtonian time” was a “pointless metaphysical entity”, because it cannot be “measured” independently from the phenomena. Ludwig Wittgenstein too, probably convinced by the idea of Mach, writes in his Tractatus that: " We cannot compare a process with 'the passage of time'-there is no such thing-but only with another process (such as the working of a chronometer" (Wittgenstein, 1994). This conception of time, which is based on the act of measurement and very operational, led to the idea according to which time is an illusory invention of classical physicists. But this point of view has its adversaries who tried to challenge physics on this particular question, namely Henri

Bergson, and I will try to discuss that his critics and remarks as a “philosopher”, had an effective result in the “scientific practice of physicists”. Sir Arthur Eddington, physicist and astronomer who baptized the “arrow of time”, under the impression of Bergson’s ideas about the nature of time, tried to build a bridge between inside and outside, mind and physical world and finally finds his answer in thermodynamics and Ludwig Boltzmann’s vision.

## BERGSON AND DURATION

Henri Bergson was one of the greatest philosophers whose major preoccupation was “time” and its nature. Unlike Einstein who believed that “the subjective sense of flow of time” is “primitive”, Bergson found it “fundamental”. This sense that Bergson calls the “Duration” is one of the “immediate data of consciousness”: “Pure duration is the form which the succession of our conscious states assumes when our ego lets itself *live*, when it refrains from separating its present state from its former states.” (Bergson, 2014). For him, the inner duration, perceived by consciousness, is totally different from the time of physicists: “Time, as dealt with by the astronomer and the physicist, does indeed seem to be measurable and therefore homogeneous.” (Bergson, 2014, p. 107).

Well, we know that, according to the Relativity, time of physicists or time measured by clocks, does not flow similarly for different observers, but we can notice the difference that Bergson considers between two concepts of time : “When I follow with my eyes on the dial of a clock the movement of the hand which corresponds to the oscillations of the pendulum, I do not measure duration, as seems to be thought; I merely count simultaneities, which is very different. Outside of me, in space, there is never more than a single position of the hand and the pendulum, for nothing is left of the past positions. Within myself, a process of organization or interpenetration of conscious states is going on, which constitutes true duration. It is because I endure in this way that I picture to myself what I call the past oscillations of the pendulum at the same time as I perceive the present oscillation.” (Bergson, 2014, p. 108).

So, in Bergson’s view, there are two types of time; time of “science” and that of “consciousness”. Time of science, in his opinion is an abstract result of parallelism between events in time and simultaneity in space. While, time of consciousness is continues flow, which flow inside and could be the conscious life itself; it does not depend on things: “There is no doubt but that for us time is at first identical to the continuity of our inner life. That of a flow or a passage, but a self-sufficient flow or passage, the flow not implying a thing that flows, and the passing not presupposing states through which we pass; the thing and the state are only artificially taken snapshots of the transition; and this transition, all that is naturally experienced, is duration itself.” (Bergson, 1999, p. 44).

Contrary to Einstein, Bergson thought that the real time is that of consciousness, the Duration, whereas the time of physicists is a “spatialized” time, which is not capable to describe the inner time: “... we cannot conceive a time without imagining it as perceived and lived. Duration therefore implies consciousness; and we place consciousness at the heart of things for the very reason that we credit them with a time that endures.” (Bergson, 1999, p. 49). And this philosophical preference or choice leads Bergson to the idea according to

which, there is a universal time: “How do we pass from this inner time to the time of things? We perceive the physical world and this perception appears, rightly or wrongly, to be inside and outside us at one and the same time; in one way it is a state of consciousness; in another, a surface film of matter in which perceiver and perceived coincide. To each moment of our inner life there thus corresponds a moment of our body and of all environing matter that is “simultaneous” with it; this matter then seems to participate in our conscious duration. Gradually, we extend this duration to the whole physical world, because we see no reason to limit it to the immediate vicinity of our body. The universe seems to us to form a single whole; and if the part that is around us endures in our manner, the same must hold, we think, for that part by which it, in turn, is surrounded, and so on indefinitely. Thus is born the idea of a duration of the universe, that is to say, of an impersonal consciousness that is the link between all individual consciousnesses, as between these consciousnesses and the rest of nature.” (Bergson, 1999, p. 45).

It is true that this particular conception of time is not acceptable for physics, but this disagreement does not mean that Bergson’s ideas had no effect on physicists; in fact, I will discuss that Sir Arthur Eddington was inspired by those thoughts. I will highlight three principle elements of Bergsonian time based on which, in my view, Eddington created a new concept in physics that englobes them all, namely “arrow of time”.

## I-MEMORY

we have seen that for Bergson, the real time is very close to continuity of our inner life; it is a flow, a transition: “...and this transition, all that is naturally experienced, is duration itself. It is memory, but not personal memory, external to what it retains, distinct from a past whose preservation it assures; it is a memory within change itself, a memory that prolongs the before into the after, keeping them from being mere snapshots appearing and disappearing in a present ceaselessly reborn. A melody to which we listen with our eyes closed, heeding it alone, comes close to coinciding with this time which is the very fluidity of our inner life.” (Bergson, 1999, p. 44).

The importance of “memory” in Bergson’s view for understanding “time”, relies in the fact that it is necessary in order to connect and distinguish the before and the after: “Without an elementary memory that connects the two moments, there will be only one or the other, consequently a single instant, no before and after, no succession, no time.” (Bergson, 1999, p. 48). So, memory is what constructs time by connecting the moments: “To tell the truth, it is impossible to distinguish between the duration, however short it may be, that separates two instants and a memory that connects them, because duration is essentially a continuation of what no longer exists into what does exist. This is real time, perceived and lived.” (Bergson, 1999, p. 49).

But for him, it is impossible too, to imagine a memory, without consciousness: “Everyone will surely agree that time is not conceived without a before and an after – time in succession. Now we have just shown that where there is not some memory, some consciousness, real or virtual, established or imagined, actually present or ideally introduced, there cannot be a before and an after; there is one or the other, not both; and both are needed to constitute time.” (Bergson, 1999, p. 65).

## 2-OPENNESS OF THE FUTURE TO POSSIBILITIES

Memory is all about the past, but it has nothing to do with the future. For Bergson, “the free will” like Duration, is one of “immediate data of consciousness”. In addition, this impression of freedom within us-which is real-shows that the future is open to “unforeseeable novelty”. That is why he criticizes the “mathematical time of physicists” which is not compatible with this impression: “...we cannot convert into space the time already elapsed without treating all of time the same way. The act by which we usher the past and present into space spreads out the future there without consulting us. To be sure, this future remains concealed from us by a screen; but now we have it there, all complete, given along with the rest. [...] Yes, it is we who are passing when we say time passes; it is the motion before our eyes which, moment by moment, actualizes a complete history given virtually. Such is the metaphysic immanent in the spatial representation of time.” (Bergson, 1999, p. 61). Bergson explains that in his view, in Duration he sees “the very stuff of our existence and of all things” and that is the reason why he thinks, “the universe is a continuity of creation.”

## 3-DURATION AS A TEMPORAL FLOW

Duration is a continuous flow and this fluidity means dynamism and mobility that we can feel regarding time. For him, the block universe of Minkowski and Einstein is unable to represent this truth about time: “We will never derive the idea of a temporal flow from Minkowski’s schema.” (Bergson, 1999, p. 63). At this stage, we need to notice that all these essential elements that Bergson considers as crucial in order to define the duration, are based on “consciousness”: “Duration therefore implies consciousness.” (Bergson, 1999, p. 49). And also: “...we cannot speak of reality that endures without inserting consciousness into it.” (Bergson, 1999, p. 48). But the notion of “consciousness” in particular, and all that is “subjective” in general, is considered as suspicious for physics. Therefore, normally, physicists try to get rid of it. But what is really interesting in the very fabrication of “arrow of time” is that the subjective aspects of time, discussed by Bergson, have been taken seriously and redefined in a way which is compatible to “objective” approach of physics.

## EDDINGTON; PHYSICIST WHO WORRIES ABOUT THE IMMEDIATE DATA OF CONSCIOUSNESS

Sir Arthur Eddington seems to be the first, who baptized the term “arrow of time” in his famous book (Eddington, 1928), although, the idea of a “directional time” had been introduced before him by Ludwig Boltzmann. But the particularity of Eddington’s contribution is that he reconciles the physical time and the subjective time by introducing a new physical concept. In this part, we shall concentrate on his preoccupations and arguments about time and its dual nature: *Time’s arrow. The great thing about time is that it goes on. But this is an aspect of it which the physicist sometimes inclined to neglect. In the four-dimensional world ... the events past and future lie spread out before us as in a map. The events are there in their proper spatial and temporal relation; but there is no indication that they undergo what has been described as ‘the formality of taking place’, and the question of their doing or undoing does not arise. We see in the map the path from past to future or from future to past; but there is no signboard to indicate that*

*it is a one-way street. Something must be added to the geometrical comprised in Minkowski’s world before it becomes a complete picture of the world as we know* (Eddington, 1928, p. 68).

The interesting thing in the passage above is that Eddington takes seriously “the world as we know” and thinks that we need to add something to “Minkowski’s world” in order to complete the picture. The picture in which, our “subjectivity” is taken into account. Well, in the world as we know, “becoming” is an essential element; it “goes on”. And we remember Bergson that could not accept Minkowski’s picture of the world because: “We will never derive the idea of a temporal flow from Minkowski’s schema.” (Eddington, 1928, p. 63). But in the “objective” discourse of physics, as long as it is about the physical reality, we should not appeal to the consciousness. So Eddington tries to explain the “immediate data of consciousness”, by searching a physical measurable element that represents the subjective impression of passage of time: *I shall use the phrase « time’s arrow » to express this one-way property of time which has no analogue in space... We must note that (i) It is vividly recognized by consciousness. (ii) It is equally insisted on by our reasoning faculty, which tells us that a reversal of the arrow of time would render the external world nonsensical. (iii) It makes no appearance in physical science except in the study of organization of number of individuals. Here the arrow indicates the random element* (Eddington, 1928, p. 69).

So, for this physicist, the subjective time is an undeniable truth for which there has to be a counterpart. In his opinion, entropy is that quantity which always grows: *The law that entropy always increases-the second law of thermodynamics-holds, I think, the supreme position among the laws of Nature. If someone points out to you that your pet theory of the universe is in disagreement with Maxwell’s equations-then so much the worse for Maxwell’s equations. If it is found to be contradicted by observation-well, these experimentalists do bungle things sometimes. But if your theory is found to be against the second law of thermodynamics I can give you no hope; there is nothing for it but to collapse in deepest humiliation* (Eddington, 1928, p. 74). And as we know thanks to Boltzmann, this law is not about impossibility, but improbability: *Some things never happen in the physical world because they are impossible; others because they are too improbable. The laws which forbid the first are the primary laws; the laws which forbid the second are the secondary laws* (Eddington, 1928, p. 75).

Since the deterministic laws cannot serve as a basis for “passage of time without return”, given their reversibility, we need a physical measurable which distinguishes *before* and *after* in the chain of events, with no dependence on consciousness: *...we cannot mean ‘later’ as judged by consciousness; its obviousness is not bound up with any speculation as the behavior of consciousness* (Eddington, 1928, p. 93). Entropy increasing is the only physical element that can do that, as says Eddington: *Entropy-gradient is then the direct equivalent of the time of consciousness...* (Eddington, 1928, p. 101). This is how Eddington constructs an objective memory and builds a bridge between “inside” and “outside”: *It is so welded into our consciousness that a moving on of time is a condition of consciousness. We have direct insight into ‘becoming’ which sweeps aside all symbolic knowledge as an inferior plane. If I grasp the notion of existence because I myself exist, I grasp the notion of becoming*

because I myself become. It is the innermost Ego of all which 'is' and 'becomes' (Eddington, 1928, p. 97).

## BOLTZMANN

Rudolf Clausius (1822-1888) German physicist, in 1850, introduced the concept of entropy (which means a transformation). His works were largely based on that of French Physicist Sadi Carnot (1796-1832). For Clausius the notion of entropy is mostly related to "order" and "disorder" in physical and chemical processes; systems evolve towards disorder and entropy is the quantity, which increases, unlike energy that is always conserved. But Ludwig Boltzmann tried to explain this tendency of physical systems towards disorder, by introducing a probabilistic interpretation of entropy. We know that he remained loyal to the mechanics, and having believed in existence of atoms, he introduced the idea according to which physical systems evolve from a less probable state to a more probable one. He related the irreversibility of evolutions to a mechanical quantity, which always increases. According to Boltzmann, the trajectory of every particle is "reversible" in the view of Newtonian mechanics, but the irreversibility of macroscopic phenomena is due to the very large number of atoms constituting those systems: *Only in those periods of time during which the system passes from a very improbable initial state to a more probable later state do the states change in the positive time direction differently than in the negative* (Boltzmann, 1995, p. 443). Therefore, decrease of entropy is not impossible, but it is highly improbable. And he claims what this hypothesis implies: *In the entire universe, the aggregate of all individual worlds, there will however in fact occur processes going in the opposite direction* (Boltzmann, 1995, p. 447). However, it seems legitimate to ask if Boltzmann makes a good use of language when he relates time to irreversibility of phenomena, given the fact that he believes in Newtonian mechanics and in Newtonian paradigm, time is independent from phenomena. When he writes his remarks about time, the theory of Relativity did not exist; the theory according to which there is no time independent from phenomena. Specially, the fact that he was against Ernst Mach about existence of atoms and Mach was the physicist who inspired Einstein makes us think that Boltzmann was a believer in absolute time, the Newtonian

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time. But, we know that Eddington was profoundly influenced by Boltzmann ideas about the direction of time.

## EDDINGTON AND BERGSON

There are several passages in Eddington's work in which we can notice the influence of Bergson's ideas on him. However, in the following one, he talks about the Bergsonian challenge: *Astronomer Royal's Time. I have sometimes thought it would be very entertaining to hear a discussion between the Astronomer Royal, and let us say, Prof. Bergson on the nature of time. Prof. Bergson's authority on the subject is well known; and I may remind you that the Astronomer Royal is entrusted with the duty of finding out time for every they use, so presumably he has some idea of what he has to find. I must date the discussion some twenty years back, before the spread of Einstein's ideas brought about a rapprochement. There would then probably have been a keen disagreement, and I rather think that the philosopher would have had the best of the verbal argument. After showing that the Astronomer Royal's idea of time was quite non-sensual, Prof. Bergson would probably end the discussion by looking at his watch and rushing off to catch a train, which was starting by Astronomer Royal's time* (Eddington, 1928, p. 36). What this passage implies, in my opinion, is that Eddington, knew enough about Bergson's ideas to be concerned by them in his thinking process. Thus, by retaking Boltzmann's ideas, Eddington applied them to the "timeless" representation of Minkowski from the universe, and reacted to Bergson's notices. By doing so, he tried to "put a sense into the world".

## CONCLUSION

Even if many would say or may think that science and philosophy have nothing to do with each other, especially in the era of modern science, the case that we saw here shows somehow that a philosophical analysis of physical concepts, based on our deep and human experiences can meaningfully influence the way those concepts are being formed and shaped during the "evolution" of science. Therefore, what can be learnt is that we would do better if we continue and preserve the dialogue between these two fields of thought and exploration.

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